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

Reviewing the allocation limits for the South West groundwater areas

Looking after all our water needs.

Department of Water

Water resource allocation planning series

Report no. 33

December 2008

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone   +61 8 6364 7600
Facsimile   +61 8 6364 7601
www.water.wa.gov.au

December 2008

ISSN 1327-8428 (Print)
ISSN 1834-2620 (On line)

ISBN 978-1-921508-35-6 (Print)
ISBN 978-1-921508-36-3 (On line)

Acknowledgements

This report was prepared by Rebecca Palandri.

The author acknowledges the assistance of Department of Water staff of the South West region, Water Allocation Planning Branch and Water Resource Assessment Branch who provided expert advice and comment in the completing this document.

For more information about this report, contact
Susan Worley
Department of Water
Branch Manager, Water Allocation Planning
168 St Georges Terrace
Perth WA 6000
Tel: 08 6364 7600
Fax: 08 6364 7601

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Preface

The *Review of allocation limits for the South West groundwater areas* report is based on the outcomes of a series of workshops held in November 2007 and September 2008. The following people from the Department of Water were involved in the process of reviewing and setting the allocation limits:

Mr Mick Owens, Program Manager Licensing and Water Use, South West Region

Ms Annaleisha Sullivan, A/Manager Policy and Planning, South West Region

Mrs Natasha Del Borrello, Senior Environmental Officer, Environmental Water Planning

Mr Adrian Goodreid, Senior Environmental Officer, Environmental Water Planning

Mr Phil Commander, Principal Hydrogeologist

Ms Penny Wallace-Bell, Hydrogeologist, Groundwater Assessment

Mr Travis Cattlin, Hydrogeologist, Groundwater Assessment

Mrs Rebecca Palandri, Water Allocation officer, Water Allocation Planning

Mr Patrick Seares, Program Manager, Water Allocation Planning section

Ms Susan Worley, Manager Water Allocation Planning Branch

Mr Wayne Tingey, A/Director Water Resource Use and Regional Manager, South West Region

This report was endorsed by the South West groundwater areas allocation plan Project Board in its meeting on 20 December 2007. The members present were:

Mr Robert Hammond, A/Director General

Mr Wayne Tingey, A/Director Water Resource Use and Regional Manager, South West Region

Ms Susan Worley, Manager Water Allocation Planning Branch

Mr John Ruprecht, Director Water Resource Management

Mr Patrick Seares, Program Manager, Water Allocation Planning section

Summary

The allocation limits for the South West groundwater areas were last set in the South West Coastal (1989), Bunbury (1994), and Busselton–Capel groundwater management plans (1995). A review of the allocation limits, in 2007, was necessary to incorporate the recent investigations into the groundwater resources and essential in defining the available water for allocation, now and into the future, while protecting the *in situ* water values.

The review process sets the allocation limits for the *South West groundwater areas allocation plan, 2008* for the aquifers and groundwater subareas across the plan area (Figure 1). This document describes the information and process used to determine the allocation limits, sets out the department's position on water allocation, and provides the methodology and justifications for the allocation limits.

The department has allocated water in the context of groundwater recharge in a changing climate. The allocation limits are based on scientific data and modelling information (South West Aquifer Modelling System (SWAMS)), while providing for existing use, future public water supply to support regional growth, and the environment. As a result of the review the allocation limits have generally decreased when compared to the previous limits (Summary table).

Allocation limits for the South West groundwater areas (GL/yr)

Aquifer	Allocation limits (to 2007)	Allocation limits (2008)
Yarragadee	120.0	87.5
Leederville	39.3	40.35
Superficial	96.2	66.48
*Other**	*9.7*	*18.15*
Total	**265.2**	**214.4**

*Other refers to the grouped aquifers of fractured rock, Lesueur Sandstone, Cattamarra and Sue Coal Measures.

The modelling scenarios provided the basis for determining the allocation limits of the Yarragadee and Leederville aquifers. The Superficial Aquifer was based on recharge and throughflow calculations. Where the model was unable to provide local scale information with a high level of confidence a greater emphasis was placed on the collected information, licensing data and departmental knowledge in determining the limits. Where modelling was used in the decision-making process it was balanced with local information and updated licensing and monitoring data, before a decision was reached.

1 Introduction

The Department of Water is responsible for setting how much water should be available for consumptive use and how much should remain in the environment. Consumptive use includes water for licensing, stock and domestic use, and public water supply. Water for the environment includes maintaining ecological, cultural and social sites of significance dependent on water.

The department sets the allocation limits through a comprehensive review process. The process considers the sustainable yield of the groundwater resource and sets the amount of water available, to ensure that the annual abstraction regime does not have unacceptable impacts on the water quantity and quality, and groundwater-dependent systems.

1.1 Background

To prepare the *South West groundwater areas allocation plan* the Department of Water reviewed the allocation limits set in the previous groundwater allocation plans. The allocation limits had not been formally reviewed and updated since the original limits were set in the existing management plans.

The original allocation limits for the groundwater areas of the South West Coastal, Bunbury and Busselton–Capel are defined in the *South West Coastal groundwater area management review (1989)*, *Bunbury groundwater area management plan (1994)* and the *Busselton–Capel groundwater management plan (1995)* produced by the Water Authority of Western Australia. The methodology used in these plans was applied to set allocation limits for the Blackwood groundwater area in 1997. The *Kemerton groundwater subareas water management plan* (DoW 2007) updated several subareas in the South West Coastal and Bunbury groundwater areas in early 2007.

The allocation limit review was necessary to incorporate the last five years of groundwater modelling, investigations and other work undertaken by the department to develop our understanding of the groundwater resources and their dependent systems. The review incorporates all work undertaken by the Water Corporation associated with the South West Yarragadee 45 GL/yr water supply proposal (SWY proposal).

The SWY proposal triggered extensive hydrogeological and ecological investigations and enabled the development of a regional scale groundwater model (South West aquifer modelling system – SWAMS). As a result of this work it became evident that the allocation limits associated with each of the aquifers in the South West groundwater areas were less conservative than previously thought. The investigation and assessment that was carried out for the SWY proposal, by both the department and the Water Corporation, has substantially improved our ability to understand how much water can be sustainably abstracted from the South West groundwater aquifers.

The confined and unconfined aquifers located in the plan area (Figure 1) were reviewed. They include the Yarragadee, Leederville and the Superficial aquifers and other confined aquifers (Lesueur Sandstone, Cattamarra and Sue Coal Measures) and fractured rock formations on the coastal plains and the Leeuwin–Naturaliste Ridge.

1.2 Allocation limits

An allocation limit is the amount of water assigned for consumptive use for a given water resource, after the needs of the supported systems are met. The systems' needs include maintaining aquifer integrity, throughflow, water quality, groundwater-dependent ecosystems, connected surface water systems, and meeting the ecological, social and cultural water requirements.

Allocation limits are the key mechanism used by the department to manage abstraction within reasonable environmental constraints. Water is allocated through the licensing process up to the allocation limit. Complementary mechanisms (monitoring, investigations, and compliance) enhance the effectiveness of the allocation limits and minimise the impacts of water abstraction on the environment and other users.

The allocation limits have been set to minimise the potential impacts to wetlands and rivers in the future, while sustaining reasonable growth in the region. As the allocation limits have been generally reduced for all aquifers, water users will need to become more efficient, use alternative supplies, or trade. Water has been reserved within the allocation limits to ensure that sufficient clean, safe drinking water supplies are available for local towns to expand provided this water is used efficiently.

Information for each aquifer, including from the SWAMS model, was used throughout the decision-making process in the context of a drying climate (reduced rainfall recharge), water level declines and increased demand for water. Water is not available in areas where it could lead to an increased risk of restrictions to existing licensees and the environment.

Figure 1 The South West groundwater areas – plan area.

2 Reviewing the allocation limits

2.1 Aim

> Revise the allocation limits for the South West groundwater areas for all subareas and aquifers, using a process that considers yield methodologies, water availability, monitoring data, licensed entitlement information, ecological, social and cultural information, modelling and regional knowledge.

The intent is to make a reasonable volume of water available for consumptive use while avoiding the possibility of over-allocation and impacts on existing water user's rights. The allocation limits for each groundwater area and subarea (Figure A1 and Figure A2 in Appendix A) were reviewed by aquifer (where present):

- Superficial (including surficial and fractured rock)
- Leederville
- Sue Coal and Cattamarra Coal Measures
- Lesueur Sandstone
- Yarragadee.

While climate projections are built into the supporting information, the allocation limits are precautionary in areas where information is limited.

2.2 Framework

The context for developing allocation limits is shown in Figure 2. The process used to make the decisions on the allocation limits is detailed in Chapter 4. The information provided for the decision-making is listed in Chapter 3 and detailed in Appendix A for all aquifers and subareas. Allocation limits and the associated management approach are set in the *South West groundwater areas allocation plan*. The plan feeds back into the decision-making as new information becomes available.

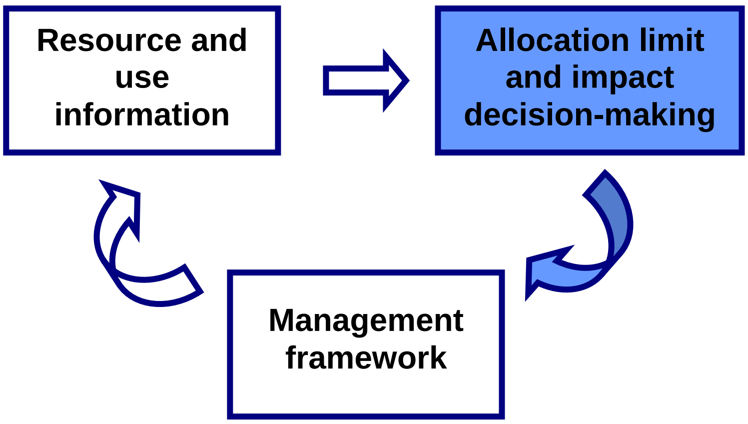

Figure 2 Framework for developing allocation limits.

The information phase of the review began in 2002 with the submission of the SWY proposal. The investigations into the hydrogeology (particularly the Yarragadee Aquifer), detailed social, cultural and ecological work, drilling investigations and modelling were undertaken over a five year period. This information was also used in developing modelling scenarios to predict the potential drawdown impacts on key ecological sites associated with varying amounts of water abstracted (including location of draw points) from the Yarragadee Aquifer over a 30-year period.

2.3 Post draft plan allocation limit changes

Following release of the *South West groundwater areas water management plan: Plan for public comment* in May 2008 the department has revised several allocation limits stated in this plan. The changes are based on completion of the Cowaramup drilling and modelling, results from the farm dams survey, and submissions. The process for updating and amending the limits was the same as for setting the earlier allocation limits. The new limits are used in the final *South West groundwater areas allocation plan*.

The changes affect the Leederville Aquifer in the Cowaramup and Blackwood Plateau North and South subareas; the Superficial Aquifer in the Rosa, Scott and Jasper subareas; and the surficial aquifer on the Cape to Capes North and South subareas, Cowaramup subarea and Blackwood Plateau North and South subareas. Chapter 5 and 6 have been updated including Tables 3–8 and Appendix A in light of the changes.

The changes to the Leederville Aquifer limits were an increase in the allocation limit for the Cowaramup subarea by 0.3 GL/yr. The small changes to the Blackwood Plateau North and South are to account for the Surficial Aquifer in this area.

The changes to the Superficial Aquifer in the Cape to Capes North and South, Rosa, Scott and Jasper subareas were in response to revised estimations of stock and domestic use. The Whicher area surface water allocation plan farm dams survey showed that there were several small off stream dams across these subareas that are largely groundwater fed, so these were accounted for in revised estimations.

The changes to the allocation limits Cape to Cape North and South subareas are for water accounting purposes and these areas will be managed according to the policies and rules in the final plan on an impact management basis. The limits for the Cape to Cape North and South subareas will be reviewed annually to ensure minimal impacts and identification of existing historical use.

3 Information

The information used in the decision-making process was accumulated (knowledge and data) over the last five years. There were key decision points during this time. They include the model development and allocation scenarios, Environmental Protection Authority (EPA) assessment of the SWY proposal, government decision on the SWY proposal and the allocation-decision exercise.

Information was provided through the technical and local knowledge collected, together with the modelling scenarios, EPA and government decisions on the SWY proposal. The timeline of information collection and key decision points is as follows:

- Water Corporation SWY proposal submitted (2002)
- collection of information and investigations (ongoing)
- model development (2003–2005)
- allocation scenarios and multi-criteria analysis with south west stakeholders (May 2006)
- EPA assessment of the Environmental Resource Management Plan (ERMP) on the SWY proposal (December 2006)
- government decision on the SWY proposal (May 2007)
- allocation scenario option post SWY proposal (September 2007).

This information was used in the allocation-decision exercise in November 2007. The allocation limit decisions made and their justifications are detailed in Chapter 5.

3.1 Model development and allocation scenarios

Investigations were triggered by the Water Corporation's SWY proposal. The proposal could not be assessed without an adequate groundwater model to predict the impact the proposal could have on the groundwater resources (including the environment and other users) over such a large and interconnected area.

To create a model with sufficient predictive capacity, the Water Corporation undertook a large investigation program, including drilling, geophysical surveys and hydrological studies. The results of these investigations were used to produce a regional scale numerical groundwater model of the Southern Perth Basin, where the Yarragadee Aquifer is present.

The model (SWAMS) was peer reviewed and updated before it was used as a predictive tool. The model will be reviewed again and updated in three years time with the addition of further local area modelling (Eastern Scott coastal plain, Cowaramup and Swan coastal plain local area models). The SWAMS model domain does not include the Leeuwin–Naturaliste Ridge area or the area covered by the *Kemerton groundwater subareas water management plan*.

The modelling scenarios were developed in the context of the SWY proposal, as a large proportion of the sustainable yield of the Yarragadee Aquifer would have been taken up by one proposal. Along with the development of the model as a predictive tool, groundwater allocation scenarios were developed to predict the potential impacts on groundwater-dependent systems associated with varying levels of abstraction (including the location of draw points) from the Yarragadee Aquifer.

The SWY proposal could not be assessed in isolation and had to be considered in the context of current and licensed use and future demand. The department's position was that reasonable regional needs should be met before water was transferred out of a region (*State water plan*, DPC 2007) so it was important that these needs be determined. The likelihood of a drying climate and a diminishing groundwater resource in the future also needed to be considered.

The SWY proposal was assessed by using SWAMS to test a series of allocation scenarios to predict the impact of various levels of allocation over a 30-year period. In developing these options it was important to ensure that they:

- were realistic
- encompassed a range of management objectives e.g. meeting environmental requirements, meeting regional demand for water
- covered the range of potential groundwater use options in the future (from lower to higher levels of use)
- were few in number so as to simplify the ability to compare between them.

Five alternative allocation options were developed by the Department of Water (Table 1). The impacts on the groundwater resource of each option were measured against a base case of the estimated current groundwater use (64 GL/yr as at October 2004). All scenarios were also run with a reduced recharge component to represent further drying of the climate in the future. The allocation options could then be compared with one another against a range of objectives (Table 2).

Table 1 Allocation options developed for the stage one process

Option*	Description
A: Meeting the environmental needs 100 GL/yr	In this scenario, the ecological water requirements of groundwater-dependent ecosystems would be fully met. In a modelling context this meant setting limits of acceptable drawdown on identified representative groundwater-dependent ecosystems (GDE) across the model domain. The model was then run over a 30 year modelling period to ascertain approximately how much water could be abstracted each year from each aquifer without exceeding the drawdown limits at the GDE. Several iterations of modelling were done in an attempt to optimise the allocation amount, which was finally estimated at 100 GL/yr from all aquifers within the Bunbury, Busselton–Capel and Blackwood groundwater areas. Under this allocation option, the 100 GL/yr would only be available for use within the region and inter-regional transfer of water would not occur.
B: meeting all existing licensed entitlements 112 GL/yr	In this scenario, all existing licensed water entitlements to the groundwater resource within the Blackwood, Busselton–Capel and Bunbury groundwater areas (as at October 2004) would be met. The entitlements exceed actual groundwater use because some entitlements were not fully utilised at the time. This scenario assumes no transfer of water outside the region. The ecological water requirements of GDE would not be fully met i.e. there would be some risk to some GDE.
C: partly meeting future regional demands (120 GL/yr) and 25 GL/yr of the Water Corporation's application (total 140 GL/yr)	In this scenario, 120 GL/yr would be allocated to meet current licensed entitlements with some allowance for future growth in regional demand and 25 GL/yr would be made available for transfer out of the region. Ecological water requirements of GDEs would be met to a lesser extent than in Option B.
D: meeting future regional demands (160GL/yr)	In this scenario, 160 GL/yr of groundwater would be allocated to meet future regional demands. No water would be made available for transfer outside of the region. Ecological water requirements of GDEs would be met to a lesser extent than in Option C.
E: meeting future regional demands (160 GL/yr) and 45 GL/yr for the Water Corporation's application (total 205 GL/yr)	In this scenario, 160 GL/yr of groundwater would be allocated to meet future regional demands. 45 GL/yr would be made available for transfer outside of the region. Ecological water requirements of GDEs would be met to a lesser extent than in Option D.

*The allocation options were for the combined allocation limits for the Yarragadee, Leederville and Superficial aquifers across the model domain.

Table 2 Objectives for each of the allocation options (stage one)

Objective	Description
Ecosystems	To maintain the ecological values of groundwater dependent ecosystems
Non-consumptive social values	To maintain the non-consumptive social values of groundwater dependent ecosystems. Examples include: • recreation values • cultural/heritage values • landscape and aesthetic values • education and scientific values
Regional community and economic development	To support the community/region in achieving its social and economic development objectives
State economic and social benefit	To provide economic and social benefits to the state.
Fairness	To develop a plan that is fair in its allocation of groundwater resources
Uncertainty	To develop an allocation plan that appropriately addresses uncertainties (e.g. climate change, future economic conditions, population growth)

The department carried out an assessment of the allocation scenarios using a multi-criteria analysis (MCA) process involving key stakeholders in May 2006. The stakeholder MCA process helped inform the department's groundwater allocation planning process and to provide community input into the licence assessment process for the SWY proposal. The stakeholder MCA process was a key part of the department's review of the allocation limits. Many of the final products of the investigation phase were presented and discussed at this forum and the stakeholders represented a large range of interest groups across the South West.

The information presented and considered by the stakeholders included:

- overview of regional hydrogeology and regional water balance
- current groundwater use and its impact on the groundwater resource and environment
- overview of groundwater level trends for all aquifers
- the potential for abstraction to activate acid sulphate soils and an understanding of where risk areas are located
- location of potential groundwater-dependent ecosystems and an overview of ecological values
- understanding of ecological values at most risk of impact due to increased levels of abstraction
- understanding of groundwater-dependent social and cultural values in the region and potential risk to these from increased abstraction
- overview of the five allocation options and comparison of their relative impact on the groundwater resource and potential risk to environmental values
- projected regional growth and increase in groundwater demand

- assessment of the economic value of water use in the region vs. transferring water to Integrated Water Supply Scheme (IWSS)
- economic evaluation of the five allocation options.

Stakeholders were asked to compare the *relative* importance of the six objectives (Table 2) when choosing a preferred allocation scenario. Overall, ecosystem health was viewed as the most important objective, followed by uncertainty. Economic and social benefits to the state were given the least relative importance by the participants.

Stakeholders were also asked to choose their preferred allocation option from the five presented (Table 1). Overall, Option A (100 GL/yr – Environmental needs met) was strongly preferred by the participants, followed by Option B (112 GL/yr – Existing licensed entitlements met). Option E (205 GL/yr – Meeting regional demands + 45 GL/yr for inter-regional transfer) was the least preferred of all options presented.

Concern over the uncertainty of the science behind the investigation, planning and decision-making process; external factors such as climate change; and the government's ability to reverse decisions to allocate water, was factors in the selection of Option A as the preferred option, as it appeared to be the scenario that held the lowest risk to the environment, social values and existing water users.

Full details of the MCA stakeholder workshops are provided in the report by Beckwith Environmental Planning (2006). The information gathered from the workshops was fed into the department's groundwater allocation planning process.

3.2 EPA assessment of the SWY proposal

In December 2006 the EPA released its report and recommendations on the ERMP for the SWY proposal. The EPA approved the proposal with strict environmental conditions including:

- no impact from the proposal on the Blackwood River, St John Brook, Milyeannup Brook, Poison Gully and the Reedia wetlands
- comprehensive baseline monitoring program for the Blackwood River, site-specific mitigation and management plans for the Blackwood River, Milyeannup Brook, St John Brook, Poison Gully and Rosa Brook
- an adaptive management plan to protect the values of GDEs on the Blackwood Plateau, Swan and Scott coastal plains
- establishment of an independent review group who would report to the EPA and the Ministers for the Environment and Water Resources on the Water Corporation's development and implementation of its management program.

The Department of Water considered the advice presented in Bulletin 1245 (EPA 2006) by the EPA on the SWY proposal in the decision-making process on the Yarragadee and other aquifers.

3.3 Government decision

On the 15 May 2007 the state government announced that the SWY proposal would not proceed, however the government still recognised the aquifer as a potential source of public water supply in the future and indicated a desire to reserve water from the Yarragadee Aquifer for future public water supply purposes. To implement this decision the department investigated the regional requirements for public water supply (Brennan 2007) for the next 30-years and reserved water from the Yarragadee and Leederville Aquifers. This lead to the development of the final allocation scenario (Option F) using the SWAMS model for the allocation limit decision-making process.

3.4 Final allocation scenario

The state government's decision prompted the development of a new allocation scenario (Option F) based on the additional information collected from the previous allocation scenarios (listed in Table 1) and the new regional public water supply requirements. This involved revising the priorities for water allocation and taking into account the department's requirements for sustainable water resource management, including:

- reserving sufficient Yarragadee Aquifer water for regional public water supply purposes
- the high quality of Yarragadee Aquifer water and low risk of contamination
- the high level of population growth and associated drinking water demand in the South West
- protection of existing users' entitlements (subject to compliance with licence conditions and water use efficiency requirements) before additional water was allocated to new users
- the results of numerical modelling of allocation scenarios (described above), which showed progressively higher levels of risk to some environmental assets at larger volumes of abstraction
- the results of community consultation and the stakeholder MCA process
- the lack of long-term monitoring datasets, limiting the ability to understand how the aquifers had responded to abstraction pressures to date, and therefore limiting the ability to predict how they might respond to significantly higher levels of use in the future
- the potential for a reduction in the available resource due to future reductions in rainfall and the need to take a precautionary approach to prevent an unintentional over-allocation of groundwater.

The PWS reserves were determined through an economic based approach undertaken in Brennan, 2007. The figures were used to predict the groundwater volumes, aquifers and predicted bore locations used in the final allocation scenario. The allocations to be reserved were based on population growth, urban expansion and most suitable aquifer and location for draw to meet demand. However it assumed that the PWS needs of Dunsborough and Quindalup would eventually be met from the existing PWS entitlements in the Busselton–Capel groundwater area, either through expansion of the Busselton Water Boards operating area or recouping and redistribution of licensed PWS.

Option F included 112 GL/yr of groundwater to cater for existing licensed entitlements (as per Option B, Table 1) plus a further 9 GL/yr of groundwater reserved for future public water supply purposes. In this scenario, all existing licensed water entitlements for the groundwater resources in the model domain would be met. In addition, enough water is reserved from the Yarragadee Aquifer to meet demand for future public water supply to 2030.

Within the existing entitlements, a significant volume of water had already been licensed for future town water supply purposes in the Bunbury and Busselton–Capel groundwater areas, currently over and above what would be required for public drinking water supply in this area. This unused water will be reviewed, and the current excess placed in the reserve to be re-issued when demand exceeds supply. This scenario assumes no transfer of water outside the south west region. Ecological water requirements of GDEs would be met to a lesser extent than in Option B, with most areas at a low level of risk.

The total groundwater volume modelled for Option F:

Superficial: 9.5 GL	Leederville: 24.7 GL
Yarragadee: 86.5 GL	(77.42 Option B + 9.08 PWS reserve)
TOTAL = 120.7 GL	

Option F was modelled using SWAMS to ascertain what the predicted water table draw downs would be in comparison to the other allocation scenarios from Table 1, and what level of risk might be assigned to the selection of representative (high value) GDEs. Option F was also modelled with a reduced recharge component (5 per cent reduction), representing the rainfall declines predicted by the CSIRO under a drying climate scenario.

Results showed that most representative GDEs remained under a low level of risk under Option F. However, some parts of the Swan coastal plain (around Bunbury town site and along the scarp), lower Blackwood River area (Yarragadee discharge zone) and small areas on the eastern parts of the Scott coastal plain showed slightly higher levels of risk at a few sites.

The department considered that these risks were acceptable and manageable for the following reasons:

1. The SWAMS model is considered to be a conservative model (regional scale), particularly on the coastal plains. This is mainly due to the fact that the model does not deal well with the rejected recharge aspect of these areas. Rejected recharge is the additional recharge that will be induced when the groundwater is drawn down by abstraction, creating more room for the water that would otherwise have run off (drainage) because the Superficial Aquifer was full and the soil profile saturated.
2. Some systems, particularly those located along the Whicher Scarp (such as some ironstone communities) may be perched systems and therefore protected from drawdown caused by abstraction from the confined aquifers. Further drilling investigation will be necessary at these sites to confirm this.
3. The new allocation plan contains strict policies associated with the allocation and use of groundwater which will prevent the inappropriate allocation of water in areas where environmental impacts may occur to GDEs.
4. Existing licensees will be audited to ensure they are meeting licence conditions and water use efficiency requirements. This will ensure existing licensees are not having an excessive impact on GDEs.
5. Regular monitoring of water levels has been increased across the region, and regular biological monitoring is now occurring at nearly forty GDEs sites across the area, ensuring closer scrutiny of trends and improving the department’s capacity to detect ecological impacts to GDEs.
6. Triggers have been identified at several representative GDEs across the South West groundwater areas, which will generate specified management responses if they are reached. Monitoring results and any management actions generated will be publicly reported each year as part of an annual evaluation statement for the allocation plan.
7. Hydrogeological and ecological investigations are continuing in the South West groundwater areas and this work will enable revision of the conceptual and numerical groundwater models of the region and improved definition of the ecological water requirements of important GDEs. This will create a better understanding of the level of risk that high value GDEs may be exposed to due to groundwater abstraction.
8. The current groundwater allocation plan will be revised within the next three years and a new statutory groundwater allocation plan prepared. This will provide another opportunity in the short term to review the allocation limits, policies and management frameworks of the South West groundwater areas in light of any new information collected.

Option F provided the basis for the model outputs presented in Appendix A, Tables A1–5, and was used in determining the final allocation limits (Chapter 4).

3.5 Technical information

The investigations into the hydrogeology and environmental water requirements are ongoing, however all available information at the time of the decision-making process was used. The technical knowledge from the following reports was utilised in preparing the subarea information tables (Appendix A) and the justifications for amending the allocation limits (section 4.2). For a complete reference list please see the *South West groundwater areas allocation plan*.

The collective knowledge and technical expertise of the members who participated in the allocation decision-making exercise also provided valuable information throughout the decision-making process.

- *Brennan D 2007, Public water supply and irrigation water demand projections to 2030 in the South West water management region* provided the department with future water demand and public water supply reserves required for the next 30 years.
- *Beckwith Environmental Planning Pty Ltd, 2006, Groundwater management in the South West: Bunbury, Busselton–Capel and Blackwood groundwater areas – Findings of stakeholder workshops* was used in the first stage of the modelling and the allocation limit decision-making process and determined the community's views on water allocation for the Yarragadee Aquifer.
- *Commander DP & Palandri RE 2006, Groundwater Level Trends Review of the aquifers in the Bunbury, Busselton – Capel and Blackwood groundwater area 2005, Hydrogeology Report No. 259* draft report gave an indication of areas of groundwater decline and areas of concern with increased abstraction and rainfall affected sites. November 2007 water level monitoring hydrographs were also used in conjunction with this report to provide up to date information.
- *Degens B P & Wallace-Bell P 2006, Acid sulphate soil survey of shallow regolith on the Scott coastal plain* assessment, and previous survey's undertaken on the Swan Coastal plain, provided information on the potential high risk areas for acid sulphate soils. This was particularly important in areas where groundwater levels were declining. Maps developed from these surveys were used in the workshops.
- *Department of Water 2006, Surface hydrology of the Cape to Cape Region. Surface water hydrology series report no 21* showed where surface water systems may be connected to groundwater and areas of rainfall affected surface water flows.
- *Department of Water 2007, Local area management plan for the groundwater resources of the Kemerton subareas* provided the allocation limits for the Kemerton subareas.
- *Economic Consultancy Services 2003, South West Yarragadee – Blackwood groundwater area: Economic value study* provided information on future water demand.

- *Goode B 2003, Aboriginal cultural values study report for the South West Yarragadee – Blackwood groundwater area* identified cultural sites that may be dependent on groundwater were discussed as part of this process. By aiming to meet the ecological requirements for water the majority of these sites would be protected by the amount of water left in the system following the allocation limit process.
- *Goodreid A 2007, Social water requirements for the Blackwood groundwater area, EWR 2* was important in understanding the social requirements of the Blackwood River.
- *Hyde NL 2006, A summary of investigations into ecological water requirements of groundwater-dependent ecosystems in the South West groundwater areas, EWR 3* was used, in both map form and as technical information, to provide an understanding of where water level declines were likely to impact on important ecological sites.
- *Indian Ocean Climate Initiative Panel 2002, Climate variability and change in south west Western Australia,* was used in applying a conservative decreased recharge factor to all decision making to account for the unknown risk of reduced rainfall. The rainfall changes and climate uncertainty play a large part in understanding groundwater recharge and changes to water levels.
- *Irwin R 2007, Hydrogeology of the eastern Scott coastal plain, Hydrogeology record series no. 19*, provided an understanding of the geology and hydrogeology of the eastern Scott coastal plain.
- *Johnson S 2000, Assessment of groundwater resources in the Busselton–Capel groundwater area, Hydrogeology report 164*, provided an understanding of the geology and hydrogeology of the Busselton–Capel groundwater area.
- *Schafer D, Kern A, & Johnson S 2007, Cowaramup groundwater investigation, Hydrogeology report 262*, provided an understanding of the geology and hydrogeology of the Cowaramup area.
- *Water Authority 1994, Bunbury groundwater area management plan*, provided the methodology for the previous allocation limits and information general information on the Bunbury groundwater area.
- *Water Authority 1995, Busselton–Capel groundwater area management plan,* provided the methodology for the previous allocation limits and information general information on the Busselton–Capel groundwater area.
- *Water Corporation 2005, South West Yarragadee hydrogeological investigations and evaluation – Southern Perth Basin*, provided an understanding of the geology and hydrogeology of the Southern Perth Basin.

The following data and tools were also used:

- Water resource licensing (WRL) reports from November 2007 and February 2008. These reports provided data on current allocation limits, licensed entitlements, existing public water supply reserves and requested unprocessed allocations.
- SWAMS groundwater model for the Bunbury, Busselton–Capel and Blackwood groundwater areas (minus the Leeuwin Naturaliste ridge). The information presented from the model was a 3D water balance for the major aquifers of the superficial, Leederville and Yarragadee Aquifers across the model domain.
- Water level monitoring data from November 2007. The water information network (WIN) database was investigated for water level monitoring data current to November 2007 for all monitoring bores in the department's regional network. The information was used to verify the model and provide information on where summer and winter declines in water levels were evident.
- Maps generated for the workshop included: environmental water requirement (EWR) sites, modelling information, subareas, potential acid sulphate soil (PASS) risk areas, land use and cadastre, monitoring bore sites, seawater interface and soil type maps.
- A list of the key EWR sites and their corresponding potential risk level (@ 30 years) through the modelling scenario was also used.
- Regional estimated use of licensed and exempt stock, domestic and garden bores in the plan area.
- Cowaramup local area hydrogeological model
- Farm dams survey (Sinclair Knight Merz 2007).

4 Process and methodology

4.1 Decision-making process

The information collected and discussed in Chapter 3 and presented in Appendix A formed the basis for the allocation limits review process (Figure 2). This information was brought together and used in the allocation decision-making exercise held in November 2007. Each participant had significant involvement in aspects of the South West groundwater area project, and brought their particular technical, policy or process expertise to the exercise. As preparation, the group was presented with the summarised information (Appendix A) and briefed on the previous methodology for the allocation limits (Appendix B). The model outputs from the final allocation scenario were presented during the meeting.

The exercise was held over two days, covering the Bunbury and Busselton–Capel groundwater areas on day one, and the Blackwood and South West Coastal groundwater areas on day two. The participants in the exercise reviewed the information for each subarea and aquifer and discussed the calculations and justifications before making a determination on the new allocation limit. Throughout the decision-making process the information was weighed and balanced against the department’s positions on management and allocation, and against the outputs of the model. A consensus was reached for each aquifer and subarea before proceeding.

The explanations for each of the new allocation limits and the department’s position on water resource management against these limits are presented in section 5.1 and 5.2. Through the plan implementation the allocation limits will be assessed against on ground use, monitoring and updated information over the next three years and adjusted accordingly through the next plan in 2011.

Where there was uncertainty in the knowledge or information presented, the decision on the allocation limits was precautionary. The less information available the more precautionary the allocation limits. As new investigations are undertaken over the next few years the allocation limits will be revised and updated.

Each aquifer used different types of information and methodology to reach the final decision. The methodology varied depending on the level of information and uncertainty for each aquifer.

4.2 Departmental positions for allocating water

In completing the decision-making process, taking into account all of the information presented, the department applied several of its key water resource management positions to the working limits (Appendix A, Table A1–5), before finalising the numbers (section 5.2 and Table 3).

These positions were used in justifying and finalising the allocation limits:

Position 1. The department recognises existing water users' rights and has accounted for this when the SWAMS model was run to show the likely effect of existing licensed abstraction would be over time. The model is used as a predictive risk management tool on water levels and through flow (to maintain sea water interfaces). The model also identified the possible impact risk to identified ecological water requirement (EWR) criteria sites some wetlands and discharge rivers.

Position 2. The department determined that climate change must be accounted for to protect existing users' rights and the environment from over-allocation. This has been considered by applying a further 5% reduction in recharge across all subareas and aquifers in the model outputs from the 1975–2003 average rainfall for this region. While some climate change modelling indicates a greater reduction than this for the south west, the department will adaptively manage to account for future variation from the 5% reduction.

Position 3. The department determined that it would accept greater than low level of risk to some ecological sites. This decision was made recognising the capacity for local management through monitoring and licence conditions. This decision was also made recognising that the model is predictive and that climate change and abstraction patterns are likely to vary into the future requiring adaptive management of allocation limits and policy. This decision still means that areas where there is clear evidence of over abstraction will still be identified as over-allocated.

Position 4. The department made the policy decision, in light of the government's direction, to ensure sufficient water was reserved for public water supplies to 2036 for the South West region.

4.3 Methodology

Yarragadee

The allocation scenario, Option F, provided the basis for the decision-making on the allocation limits for each groundwater area for the Yarragadee Aquifer. The model numbers presented were amended depending upon the updated licensing data (including unlicensed or exempt use) and current water level hydrographs. The amended numbers were reviewed in context with the department's positions on allocating the Yarragadee Aquifer and updated accordingly.

Leederville

The Leederville Aquifer allocation limits were generally based on the outputs of the model (Option F), except in areas where the SWAMS model was unreliable. The Cowaramup model was used for the Cowaramup and Dunsborough–Vasse subareas. In all cases model numbers presented were weighed against the information, local knowledge, and water licensing data — which were considered carefully, to ensure that the department's positions on water allocation were met.

In areas where the model numbers were less than the existing allocation limits the new limits were set at current licensed entitlements (including exempt use). In areas where the SWAMS and Cowaramup models were unreliable (subareas of Rosa and Beenup) other information carried more weight. As such the limits are precautionary and are supported by the allocation plan.

Superficial

The allocation limits for the Superficial aquifers (Superficial and Surficial) were based on a combination of the older methodologies (throughflow and recharge calculations; Appendix B) and the SWAMS and Cowaramup models. The reason for using both types of calculations was the inherent limitations of models. The models are restricted in their capacity to accurately account for drainage, surface water recharge, and expression of surface water and its hydrogeological connection to the Superficial Aquifer. The numbers were weighed up against the information presented, local area knowledge of water use and current water levels. The amount of water allocated depended upon the level of protection required (water quality, ecology, exempt use, salt water interface, etc.) to manage the system on a local scale. This included taking into account locations of plantations, forested catchments and drainage issues.

Other confined aquifers

The SWAMS model was not used for the remaining confined aquifers (Sue Coal Measures and Lesueur Sandstone) as there is limited hydrogeological information available on each of these aquifers. The information presented in Appendix A was used to determine the allocation limits. The allocation limits are precautionary due to the lack of available knowledge on these aquifers.

In all cases the allocation plan provides the structure and tools for licensing to actively manage water use against the new allocation limits and protect the water resource and its dependent systems.

5 Allocation decisions

The allocation limits were finalised during the decision-making exercise held in November 2007 and again in September 2008 following completion of the Cowaramup model runs. The participants used the information and decision-making methodology described in Chapter 4, and the department's collective knowledge on groundwater resources and management in the South West.

5.1 Yarragadee and other confined aquifers

The addition of 45 GL/yr (or part thereof) on top of meeting existing licensed groundwater use and the environment's needs did not meet the department's positions on sustainable water resource management. The additional 45 GL/yr could not be taken from the Yarragadee Aquifer if the location of the draw points (from the Blackwood Plateau) was shifted toward the coastal plains (where existing abstraction is concentrated) without causing wider spread impacts on important ecological sites.

Yarragadee Aquifer

The final decision for the Yarragadee Aquifer allocation limit was 87.5 GL/yr across the plan area. This is the allocation required to meet current entitlements in most areas and the predicted demand for future public water supply. The 87.5 GL/yr was distributed based on groundwater area break downs (Bunbury 26.5 GL, Busselton–Capel 45.5 GL and Blackwood 15.5 GL), taking into account the north and south groundwater flow lines for the aquifer.

Following release of the plan and implementation of trading these groundwater area limits may change, so long as the 87.5 GL/yr is maintained, and any movement of draw points is managed on an impact assessment basis through the allocation plan.

As the licensed water use data from the model (October 2004) was not up to date the modelling scenario did not entirely meet the November 2007 licensed entitlements, as the licensing process continued to operate since the model development. Therefore the numbers from the final allocation decisions included both the model information and the updated licensing data.

Bunbury—Yarragadee

The 24.9 GL from the model currently meets the environmental and climate uncertainty requirements, but does not entirely meet existing licensed entitlements, the new PWS reserve or accounts for unlicensed or exempt use in the south of Bunbury. As the department aims to protect existing licensed entitlements and account for any unlicensed use the limit was set using the 5.7 GL for PWS, 20.2 GL licensed entitlements, 0.4 GL of estimated exempt and unlicensed use (total of 26.3 GL/yr). To meet any small pending licence applications in the Bunbury groundwater area the limit was set to 26.5 GL. This was considered acceptable, given the modelled draw of 24.9 GL is over the next 30 years. While the final limit is slightly higher than the modelled draw over 30 years, the department will adaptively manage, through monitoring and the policies in the plan.

Busselton–Yarragadee

The 41.27 GL from the model currently meets the environmental and climate uncertainty requirements, but does not entirely meet existing licensed entitlements, the new PWS reserve or accounts for unlicensed or exempt use. As the department aims to protect existing licensed entitlements and account for any unlicensed use the limit was set using the 0.35 GL for PWS, 44.7 GL licensed entitlements and a small amount of exempt use (total of 45.0 GL/yr).

To meet any small pending licence applications in the Busselton–Capel groundwater area the limit was set to 45.5 GL. It is expected that the pending applications will use the remaining 0.5 GL available. This was considered acceptable, given the modelled draw of 41.3 GL is over the next 30 years. While the final limit is slightly higher than the modelled draw over 30 years, the department will adaptively manage, through monitoring and the policies in the plan.

Blackwood–Yarragadee

The 11.25 GL from the model currently meets the environmental and climate uncertainty requirements, but does not entirely meet existing licensed entitlements, the new PWS reserve or accounts for unlicensed or exempt use. As the department aims to protect existing licensed entitlements and account for any unlicensed use the limit was set using the 3.0 GL for PWS, 8.9 GL licensed entitlements (total of 11.9 GL/yr). To meet some of the pending licence applications in the Blackwood groundwater area the limit was set to 15.5 GL. It is expected that the pending applications will use the remaining 3.6 GL available; however this will not meet all of the pending licence applications in this area.

This was considered acceptable, given the modelled draw of 11.3 GL is over the next 30 years and the 3 GL/yr for PWS is north of the Blackwood River and part of the northern flow line for the Yarragadee Aquifer. This means that existing use on the Scott coastal plain and the recharge/discharge areas of Blackwood River will be protected. While the final limit is slightly higher than the modelled draw over 30 years, the department will adaptively manage, through monitoring and the policies in the plan.

Sue Coal Measures

Cowaramup–Vasse subarea

The Sue Coal Measures is unlikely to be used for abstraction in the future due to the nature of its hydrogeology. There is limited current use and the aquifer does not support any known groundwater-dependent systems.

No new information is available on this aquifer and its characteristics since the original drilling and the completion of the *Busselton–Capel groundwater management plan* in 1995. Although there are water level changes in this aquifer it is due to localised impacts from abstraction and this will be managed through the licensing process. As we have insufficient information on this aquifer we have not altered the original allocation limit.

Lesueur Sandstone Aquifer

Rosa—Beenup subarea

Current information on the Lesueur Sandstone aquifer is limited. There is limited current use; however there may be demand for future abstraction when more information becomes available. It is currently unknown if this aquifer supports any groundwater-dependent systems but it is likely in the recharge area close to the Blackwood River in the north of the subarea. The water levels in this aquifer are also responding to abstraction, with declining water levels observed in monitoring bores near abstraction points.

The aquifer is now hydraulically connected to the Leederville Aquifer in the Beenup area, and as such abstraction in this area will be limited through the policies and rules in the allocation plan. Due to the risks associated with allocating more water from this resource without additional information on the hydrogeology and connectivity of this aquifer the allocation limit will be decreased to the current licensed entitlements plus the reserve (1 GL/yr) for Augusta's public water supply. The decrease in the allocation limit will be an issue for licensing in this area and has been identified through the department's licensing process and is supported by the plan.

This aquifer has been identified for drilling investigations by the department in 2014/2015 (Department of Water 2005). This information will be used to review the allocation limits when the drilling is completed.

5.2 Leederville and Superficial aquifers

Leederville Aquifer

The model outputs are generally used; however there are some areas where the model is unreliable at a local scale. In these instances the information on the aquifer, use and its dependent systems were used define the limits. In many areas this was simply capping the allocation limit at November 2007 licensed entitlements. In the case of Cowaramup and Dunsborough–Vasse the Cowaramup model was used. The justifications for each of the allocation limits requiring review and decision-making for the Leederville Aquifer are detailed in Table 3. The allocation limits for Kemerton North and South subareas are defined in the *Kemerton groundwater subareas water management plan, Department of Water, 2007*. The Lake Preston subarea was modified through recent amendments; however the numbers were reviewed again and found to be consistent with this process.

Superficial and surficial aquifers

The justifications for each of the allocation limits requiring review and decision-making for the Superficial aquifers (superficial and surficial) are detailed in Table 4. The allocation limits for the Australind, Myalup, Wellesley, Kemerton North, Kemerton South, Kemerton Industrial Park North and Kemerton Industrial Park South subareas are defined in the *Kemerton groundwater subareas water management plan,* Department of Water 2007. The allocation limits for the subareas of Lake Preston North and Lake Preston South were amended recently; however the numbers were reviewed again to ensure consistency with this process. The portion of Coastal subarea present in the plan area was not reviewed as this area extends outside the boundary of the plan area and will be updated and amended when the water allocation plan for the South West Coastal groundwater area is completed.

The model information was generally not used for the Superficial and Surficial aquifers and this is being addressed with the development of local area models for the Swan and Scott coastal plains and further investigations over the next three years. When this information becomes available the limits will be reviewed and updated.

Fractured rock

Cape to Cape North and Cape to Cape South subareas

The very limited groundwater resource in the granitic bedrock cannot be easily assessed, and a notional allocation limit is assigned. Conditions vary widely from solid bedrock with no groundwater, to areas where small quantities of fresh to saline groundwater may be obtained either from fractures, or from the clayey sand weathering profile. It is unlikely that these small yields, generally obtained from successful bores, would interfere with surface flows or cause significant water table reduction. However, with declines in rainfall recharge this may occur. The aquifer will be managed through the policies in the plan.

Table 3 Allocation limits and their justification for the Leederville Aquifer

Groundwater area	Subarea	Allocation limit (kL/yr)	Justification
South West Coastal	Lake Preston	500 000	The existing allocation limit, previously reviewed, was accepted as the new allocation limit for this subarea. The Leederville Aquifer is not readily accessible in this area for licensed use, there are no public water supply (PWS) reserve commitments or unlicensed/exempt use. The water levels are relatively stable in this area. This aquifer will be reviewed again when the limits reach 70% allocated.
Bunbury	Bunbury East	2 000 000	The basalt protects the majority of ecological water requirement (EWR) sites, so the majority of the EWR criteria sites in this subarea are at a low risk to the environment if more water was allocated for use. The model, existing use, future demand and the environmental risk were taken into account in deciding the new allocation limit. The location of the draw is also likely to be in the southern portion of the subarea where more water can be abstracted. As the water levels were relatively stable in this area, it was decided to allocate more than the model predicted and manage the impacts through licensing and monitoring.
	Dardanup	3 500 000	Set at current entitlements, allowing for stock and domestic use, as the model and the current water levels both indicate that the sustainable allocation has been reached.
Busselton–Capel	Donnybrook	2 400 000	The limit is set at the existing allocation limit, as the model and the current water levels both indicate that the sustainable allocation has been reached. This means that the aquifer is currently over allocated (monitoring shows water level declines and this area is a recharge zone) and there also is a need for a public water supply reserve (137 000 kL/yr).
	Busselton–Capel	10 500 000	The model suggested that the aquifer yield in this subarea was 10.4 GL (2.3 GL for maintaining through flow and the seawater interface at the 0 mAHD contour plus licensed entitlements and unlicensed/exempt use at 8.1 GL). The limit was set at 10.5 GL as this is relatively easy to manage, with low risk to the environment. The policies and management zones will ensure that any more water allocated will be in areas of low impact. The limit also protects existing use.
	Dunsborough–Vasse	5 400 000	Evidence suggests the model is not accurate in this subarea. As such the information from the Cowaramup local area model was used to amend the allocation limits. This aquifer is currently fully allocated (with trading already occurring) in this subarea with monitoring showing water level declines and that the seawater interface has moved inland.
	Cowaramup	1 800 000	The SWAMS model is not accurate in this subarea. As such the information from the Cowaramup local area model was used to amend the allocation limits.

Groundwater area	Subarea	Allocation limit (kL/yr)	Justification
Busselton–Capel and Blackwood	Blackwood Plateau North and Blackwood Plateau South	250 000 (both subareas)	The allocation limit was set low in this subarea to protect the through flow (north and west) into other subareas and the existing public water supply. These areas have extremely high *in situ* values (ecological, social, hydrogeological: Blackwood Plateau is a recharge area and supplies the coastal plains with through flow) so the amount of water available for abstraction has been restricted. The licensing policies in the plan will limit future water use in this area to domestic supply. Any future large proposals (e.g. PWS) that are submitted following the completion of the plan will be required to model and predict impacts before the allocation limit can be changed. There may be more water available but it requires strict management so the allocations the limit is set to ensure that this area is protected while allowing for future stock and domestic allocations.
Blackwood	Beenup	1 000 000	The model predicted that up to 3 GL could be abstracted from this aquifer over the subarea, provided that the leakage and through flow to the ocean were maintained. As there is now an artificial connection between the superficial and the Leederville near the old Beenup mine site and there are high *in situ* values the limit was reduced below the modelled yield (1 GL) to ensure that the acid sulphate soil management and environmental sites were protected. The aquifer will be controlled through the management zones and policies in the plan.
	Rosa	1 000 000	The model predicted that up to 1.3 GL could be abstracted from this aquifer over the subarea, provided that the leakage and through flow to neighbouring subareas and the Blackwood River were maintained. The high *in situ* values, current impacts associated with use aquifer in this area (acid sulphate soil (ASS) issues, declining water levels and EWR critical assets) and the lack of available information decreased the limit to below the modelled yield (1 GL). This will be an issue for licensing and refusals and will be supported in the plan through the policies and management zones.
	Scott	3 200 000	The model showed that 17 000 kL/yr could be abstracted from the subarea without impacting on groundwater throughflow to the ocean. However, it was decided that it was an acceptable risk to allocate the through flow from the area for consumptive use, as the risk of impacts was low for the *in situ* values (mostly dependent on superficial) and the seawater interface is several kilometres offshore (3.2 GL flows out to the ocean to the south). This means that some of the demand for the Yarragadee Aquifer can be met through the Leederville Aquifer where practical.
	Jasper	50 000	A notional number of 50 000 kL/yr was decided, as it the Leederville Aquifer is largely absent in this subarea.

Table 4 Allocation limits and their justification for the Superficial aquifers

Groundwater area	Subarea	Allocation limit (kL/yr)	Justification
South West Coastal	Harvey	11 500 000	As the model does not cover this area the old allocation limit methodology was used, updating it for climate change. This was then reviewed in light of current knowledge. The allocation limit was decreased from the previous limit due to the uncertainty regarding use, ecology, social/cultural requirements and groundwater throughflow to Lake Preston.
	Lake Preston South	10 500 000	The model does not cover this subarea. The allocation limits had previously been reviewed, and through the stage three processes these changes were accepted. Essentially water levels and quality are declining in this area, so the allocation limits were capped at use.
	Lake Preston North	9 300 000	The model does not cover this subarea. The allocation limits had previously been reviewed, and through the stage three processes these changes were accepted.
Bunbury	Bunbury West	2 000 000	The model information was not used for decision-making in this subarea as it is heavily modified by drainage and urban development. The calculated limit accounted for 70% of recharge for through flow maintenance, ASS and the environment. The resource in this area is relatively easy to manage through licensing given demand is for small entitlements. As the licensed entitlements and the estimation of stock and domestic use were already 1.2 GL/yr, and more domestic and stock requirements are likely, it was decided that the limit should be 2.0 GL/yr.
	Bunbury East	700 000	The modelled information was used in this area with the yield at 100% of recharge (1.27 GL). Approximately 30% was left in the system to maintain through flow to subareas in the north and the seawater interface. As this area is relatively low risk for management and the demand is small (due to the nature of the resource) it was decided to allow for the majority of this available for licensing.
	Dardanup	290 000	The modelled information was used in this area with the yield at 100% of recharge (0.41 GL). 30% was left in the system to maintain through flow to subareas in the north and the seawater interface (0.29 GL/yr). As this area is relatively low risk for management and the demand is small (due to the nature of the resource) so it was decided to allow the majority of this to be available for licensing.
Busselton–Capel	Donnybrook	500 000	This area is surficial deposits, and not readily available except in areas along river beds. It was decided to leave the allocation limit as the existing 0.5 GL. A review of the bore logs for existing entitlements is required to determine if any of these licenses are actually in the shallower part of the Leederville Aquifer. Stock and domestic use is likely to increase and the existing licensed use is already over the 100% recharge determined through the model. This aquifer requires investigations and further assessment to determine location and impacts as monitoring in this area is predominantly for the Leederville Aquifer.

Groundwater area	Subarea	Allocation limit (kL/yr)	Justification
Busselton–Capel	Busselton–Capel	8 000 000	The model information was not used for decision-making in this subarea as it is heavily modified by drainage and urban development. This aquifer is relatively easy to manage in this area, provided that the seawater interface is monitored. The model suggested that 5.5 GL supplies 100% to the identified EWR sites. However, as it does not take into account the complex drainage, rejected recharge, and demand is likely to increase as other aquifers became fully allocated, it was decided to set the limit to 8.0 GL. The potential impacts of allocating this water will be managed through licensing, trigger and responses and monitoring management in place on the coastal plain.
	Dunsborough–Vasse	4 500 000	This aquifer is capped at use, with only a small amount for future stock and domestic use. This is because the water table is declining (with possible water quality issues) and that the Cowaramup model showed that there is limited water availability in this area above what is already licensed. However, as the system is heavily modified through drainage, cleared land and urbanisation it was decided that the impacts of the 4.0 GL could be managed through licensing and the additional requirements in the management zones.
	Cowaramup	900 000	This area is surficial deposits only. It is thin to absent and abstraction in this area is most likely from the top of the Leederville Aquifer (unconfined). The SWAMS model is not accurate in this subarea. As such the information from the Cowaramup local area model was used to amend the allocation limits.
Busselton–Capel and Blackwood	Blackwood Plateau North and South	50 000 (both subareas)	Notional allocation limit has been attached to the surficial deposits in this areas as it is absent for the majority of the subarea and any bores drilled are likely to be accessing the unconfined shallow Leederville Aquifer.
	Cape to Cape North and Cape to Cape South	900 000 (N) 600 000(S)	These areas are surficial deposits only. The issue of domestic bore use and unknown interactions with surface water are a concern for groundwater management in this area. Many bores have had to be redrilled in the last few years as water levels have dropped by as much as 5m (decline in rainfall recharge). The aquifer will be managed through the policies and rules in the plan and the hydrogeological information submitted as part of the licence application. This area will be licensed on an impact management basis.
Blackwood	Beenup	1 400 000	The model is not reliable in this area as it does not account for surface water interaction and drainage. The 2.8 GL calculated value was used as the basis for decision-making. It already accounts for the cleared land, reduced rainfall and through flow to the ocean. However, there are high ecological *in situ* values and it is relatively difficult to manage the ASS issues in this area. This coupled with the low demand for water from this aquifer; the limit was set at 1.4 GL, provided any further abstraction is managed through the policies in the plan and controlled in the management zone around the ASS risk area.

Groundwater area	Subarea	Allocation limit (kL/yr)	Justification
Blackwood	Rosa	100 000	To minimise the impacts on the underlying aquifers, EWRs and the thin nature of the surficial sediments in this area the allocation limit has been set low. This resource is difficult to manage and there is uncertainty with the connection to underlying aquifers and the surface water features in the area. With use already likely to increase the limit was restricted to 0.1 GL until further work is completed.
	Scott	2 000 000	The model is not reliable in this area (does not account for the surface water/groundwater expression or surface ponding and drainage of agricultural land). The calculated value of 7.1 GL was used as a basis for the decision-making. It already accounts for the cleared land, reduced rainfall and recharge to meet through flow to the ocean. There are high *in situ* values, associated with the ecology in this area so only 30% of the calculated available water was allocated for consumptive use. This was considered easy to manage as the demand was likely to be restricted to the cleared land and only used for stock supply and some small amounts of irrigation south of Scott River in the deeper dunal areas.
	Jasper	2 000 000	The model is not reliable in this area (does not account for the surface water/groundwater expression or surface ponding and drainage of agricultural land). The calculated value of 4.2 GL was used as a basis for the decision-making. It already accounts for the cleared land, reduced rainfall and recharge to meet through flow to the ocean. There are moderately high *in situ* values, associated with the ecology in this area so only 50% of the calculated available water was allocated for consumptive use. This was considered easy to manage as the demand was likely to be restricted to the cleared land and only used for stock supply and plantation use. This is also comparable and equitable with the Scott subarea.

6 Allocation limits

The new allocation limits for the South West groundwater areas are summarised in Table 5 and Table 6, and fully described in Table 7. The water available for licensing will change as licences are issued and the pending licence applications currently under assessment by the department are finalised.

It is anticipated that the water available for the Yarragadee Aquifer will be taken up by the pending applications currently with the department for assessment (Table 6). This is also true for the majority of the water available in the Leederville Aquifer on the Swan coastal plain. It is likely that the pending applications list will not all be met through the new allocation limits.

Following the review process the final allocation limit across the South West groundwater areas for the Yarragadee Aquifer is 87.5 GL/yr; the Leederville Aquifer north (Bunbury and Busselton–Capel groundwater areas) is 31 GL/yr and south (Blackwood groundwater area) is 6 GL/yr; and the superficial for the Swan coastal plain (Dunsborough to Bunbury) is 12 GL/yr and the Scott coastal plain is 6 GL/yr. The majority of the water available for allocation is north of Bunbury and on the Scott coastal plain.

The allocation limits set in this document are supported by the *South West groundwater areas allocation plan* policies and management framework. All licensing decisions regarding the allocation of water from a specific groundwater subarea or aquifer will be assessed against the *Rights in Water and Irrigation Act 1914* and the *South West groundwater areas allocation plan.* This means that even though there may be water available for licensing the allocation may not be granted because it does not meet the requirements of the plan or the *Rights in Water and Irrigation Act, 1914*.

Table 5 New and old allocation limits (kL/yr)

*The allocation limits in italics are notional, based on the existing allocation limit proportionally divided for each subarea to show the allocation limit distribution.

Groundwater area	Subarea	Aquifer	Allocation limit	
			2007*	2008
South West Coastal	Lake Preston South	Superficial	19 800 000	10 500 000
	Lake Preston North	Superficial		9 300 000
	Lake Preston	Leederville	500 000	500 000
	Kemerton Industrial Park North	Superficial	NA	790 000
	Kemerton North	Leederville	500 000	3 500 000
		Cattamarra	NA	6 000 000
	Myalup	Superficial	11 900 000	7 350 000
	Wellesley	Superficial	3 000 000	2 150 000
	Harvey	Superficial	15 700 000	11 500 000
Subtotal			**51 400 000**	**51 700 000**

Groundwater area	Subarea	Aquifer	Allocation limit	
			2007*	2008
Bunbury	Bunbury East	Superficial	900 000	700 000
		Leederville	4 000 000	2 000 000
	Dardanup	Superficial	700 000	300 000
		Leederville	4 000 000	3 500 000
	Australind	Superficial	900 000	690 000
	Kemerton Industrial Park South	Superficial		210 000
	Kemerton South	Leederville	5 000 000	5 000 000
		Cattamarra	1 000 000	4 000 000
	Bunbury West	Superficial	5 100 000	2 000 000
	Bunbury–Yarragadee	Yarragadee	33 000 000	26 500 000
Subtotal			**54 600 000**	**44 900 000**
Busselton–Capel	Cape to Cape North	Surficial	50 000	900 000
		Fractured Rock	150 000	100 000
	Dunsborough–Vasse	Superficial	8 800 000	4 500 000
		Leederville	6 100 000	5 400 000
	Cowaramup	Surficial	900 000	900 000
		Leederville	300 000	1 800 000
	Busselton–Capel	Superficial	27 000 000	8 000 000
		Leederville	12 800 000	10 500 000
	Donnybrook	Surficial	500 000	500 000
		Leederville	2 400 000	2 400 000
	Blackwood Plateau North	Surficial	0	50 000
		Leederville	300 000	250 000
	Cowaramup–Vasse	Sue Coal	4 000 000	4 000 000
	Busselton–Yarragadee	Yarragadee	67 000 000	45 500 000
Subtotal			**130 650 000**	**84 800 000**
Blackwood	Blackwood Plateau North	Surficial	0	50 000
		Leederville	*150 000*	250 000
	Cape to Cape South	Surficial	300 000	600 000
		Fractured Rock	50 000	50 000
	Scott	Superficial	*350 000*	2 000 000
		Leederville	*200 000*	3 200 000
	Jasper	Superficial	*100 000*	2 000 000
		Leederville	*50 000*	50 000
	Rosa	Superficial	*100 000*	100 000
		Leederville	*1 000 000*	1 000 000
	Beenup	Superficial	*50 000*	1 400 000
		Leederville	*500 000*	1 000 000
	Rosa-Beenup	Lesueur	4 550 000	4 000 000
	Blackwood–Yarragadee	Yarragadee	20 000 000	15 500 000
Subtotal			**27 400 000**	**30 950 000**
TOTAL			**263 700 000**	**212 430 000**

Table 6 Summary of available water (kL/yr) for the plan area, November 2008

Groundwater Area	Aquifer	Allocation limit	Licensed entitlements*	Estimated unlicensed use**	PWS reserve	Water available
South West Coastal	Superficial	41 590 000	21 794 890	65 000	0	Water available
	Leederville	4 000 000	570 000	10 000	3 000 000	Water available
	Cattamarra	6 000 000	0	0	0	Water available
Bunbury	Superficial	3 890 000	2 264 520	448 000	0	Water available
	Leederville	10 500 000	9 854 350	50 000	100 000	Limited availability
	Yarragadee	26 500 000	20 186 750	400 000	5 700 000	Fully allocated
	Cattamarra	4 000 000	992 000	0	0	Water available
Busselton – Capel	Superficial [b]	14 850 000	9 131 515	1 195 000	137 000	Water available
	Fractured Rock [a]	100 000	93 500	5 000	0	Not applicable
	Leederville	20 350 000	16 658 150	3 000	0	Limited availability
	Yarragadee	45 500 000	44 759 750	0	350 000	Fully allocated
	Sue Coal Measures	4 000 000	1 005 000	0	0	Water available
Blackwood	Superficial [b]	6 150 000	762 225	160 000	0	Water available
	Fractured Rock [a]	50 000	13 000	5 000	0	Not applicable
	Leederville	5 500 000	1 124 250	3 000	0	Water available
	Yarragadee	15 500 000	8 845 000	0	3 000 000	Limited availability
	Lesueur Sandstone	4 000 000	2 802 000	0	1 000 000	Fully allocated
TOTAL		**214 430 000**	**140 790 400**	**2 416 000**	**13 287 000**	

*Licensed entitlements are correct for November 2008 only.

**The estimates of exempt use are based on local knowledge, water user surveys and a desk top review of aquifer location, depth and number of lots with an average use of 100–300 kL/yr abstraction for domestic and garden use in small lots and 1500 kL/yr for larger lots with stock water.

a Fractured Rock is allocated based on abstraction impacts and actual water availability on a site by site basis. Allocation limits are notational and for accounting purposes only.

b Superficial includes both the superficial and surficial aquifers.

Table 7 Available water (including licensed, unlicensed and reserved water use) (kL/yr)

Groundwater area	Subarea	Aquifer	Allocation limit	Licensed entitlements**	Estimated exempt use	PWS reserve	Water available
South West Coastal (part in plan area)	Lake Preston	Leederville	500 000	420 000	10 000	0	Limited availability
	Lake Preston North	Superficial	9 300 000	1 195 200	10 000	0	Water available
	Lake Preston South	Superficial	10 500 000	11 386 740	10 000	0	Over-allocated
	Harvey	Superficial	11 500 000	1 733 800	10 000	0	Water available
	Kemerton North	Leederville	3 500 000	150 000	0	3 000 000	Limited availability
		Cattamarra	6 000 000	0	0	0	Water available
	Kemerton Industrial Park North	Superficial	790 000	18 900	20 000	0	Water available
	Myalup	Superficial	7 350 000	6 582 250	10 000	0	Limited availability
	Wellesley	Superficial	2 150 000	878 000	10 000	0	Water available
Bunbury	Australind	Superficial	690 000	652 410	181 000	0	Fully allocated
	Kemerton South	Leederville	5 000 000	4 873 750	50 000	0	Limited availability
		Cattamarra	4 000 000	992 000	0	0	Water available
	Kemerton Industrial Park South	Superficial	210 000	196 950	7 000	0	Fully allocated
	Bunbury West	Superficial	2 000 000	1 025 050	200 000	0	Water available
	Bunbury East	Superficial	650 000	347 310	50 000	0	Water available
		Leederville	2 000 000	1 874 800	0	0	Limited availability
	Dardanup	Superficial	290 000	42 800	10 000	0	Water available
		Leederville	3 500 000	3 105 800	0	100 000	Limited availability
	Bunbury–Yarragadee	Yarragadee	26 500 000	20 186 750	400 000	5 700 000	Fully allocated
Busselton–Capel	Busselton–Capel	Superficial	8 000 000	4 320 165	500 000	0	Water available
		Leederville	10 500 000	8 035 800	0	0	Water available
	Donnybrook	Surficial	500 000	372 040	50 000	0	Water available
		Leederville	2 400 000	2 484 475	0	137 000	Over allocated
	Dunsborough–Vasse	Superficial	4 500 000	3 447 610	500 000	0	Limited availability
		Leederville	5 400 000	5 413 075	0	0	Over allocated

Groundwater area	Subarea	Aquifer	Allocation limit	Licensed entitlements**	Estimated exempt use	PWS reserve	Water available
Busselton–Capel	Cowaramup	Surficial	900 000	615 700	25 000	0	Water available
		Leederville	1 800 000	724 800	25 000	0	Water available
	Cowaramup–Vasse	Sue Coal Measures	4 000 000	1 005 000	0	0	Water available
	Blackwood Plateau North	Surficial	50 000	0	0	0	Water available
		Leederville	250 000	0	50 000	0	Water available
	Cape to Cape North	Surficial#	900 000	376 000	120 000	0	Not applicable
		Fractured Rock#	100 000	93 500	5 000	0	Not applicable
	Busselton–Yarragadee	Yarragadee	45 500 000	44 759 750	0	350 000	Fully allocated
Blackwood	Blackwood Plateau South	Surficial	50 000	0	0	0	Water available
		Leederville	250 000	94 000	3 000	0	Water available
	Cape to Cape South	Surficial#	600 000	314 225	100 000	0	Not applicable
		Fractured Rock#	50 000	13 000	5 000	0	Not applicable
	Rosa	Superficial	100 000	75 600	15 000	0	Limited availability
		Leederville	1 000 000	605 100	0	0	Water available
	Beenup	Superficial	1 400 000	23 400	10 000	0	Water available
		Leederville	1 000 000	401 150	0	0	Water available
	Rosa–Beenup	Lesueur	4 000 000	2 802 000	0	1 000 000	Fully allocated
	Scott	Superficial	2 000 000	271 000	25 000	0	Water available
		Leederville	3 200 000	24 000	0	0	Water available
	Jasper	Superficial	2 000 000	78 000	10 000	0	Water available
		Leederville	50 000	0	0	0	Limited availability
	Blackwood–Yarragadee	Yarragadee	15 500 000	8 845 000	0	3 000 000	Limited availability
Total			**212 430 000**	**140 790 400**	**2 416 000**	**13 287 000**	

*Note that water available = allocation limit – licensed entitlements – public water supply reserve – estimated unlicensed use. It is important to note that the water available for many of the subareas and aquifers has already been applied for and is pending assessment. The water available is current as at November 2008. Any further allocations will reduce the amount of water available. Please refer to the department's licensing system or contact the department for an update on water availability.

**Licensed entitlements are current as of November 2008. The estimates of unlicensed use are based on local knowledge, water user surveys and a desk top review of aquifer location, depth and number of lots with an average use of 100–300 kL/yr abstraction for domestic and garden use in small lots and 1500 kL/yr for larger lots with stock water.

Fractured Rock and the Surficial aquifer is allocated based on abstraction impacts and actual water availability on a site by site basis. Allocation limits are notational and for accounting purposes only

6.1 Unproclaimed areas

There are subareas (Bunbury–Karri and Blackwood–Karri) that cover the unproclaimed areas of the plan area. These areas do not have allocation limits set as the area is unproclaimed. Only artesian groundwater can be licensed in this area under the *Rights in Water and Irrigation Act, 1914*. However, all licensing policies covering the artesian aquifers apply to these areas.

6.2 Actions for management

Through the development of the new allocation limits there were a number of actions (Table 8) that needed to be undertaken to enable the new limits to be managed appropriately. The actions will be met through the implementation of the plan, its associated monitoring program and the department's licensing processes (licensing, surveys, and compliance).

Table 8 Actions associated with managing the new allocation limits

Subarea	Action
Harvey and Lake Preston (North and South) subareas	• Review the water quality data for these subareas and amend the licence conditions to ensure there are minimal impacts. • Survey exempt stock and domestic water to gain a better understanding of the amount of water being used in each subarea.
Bunbury, Busselton and Blackwood–Yarragadee subareas	• Review the pending licence applications and finalise assessment. • Continue with survey and compliance, recouping any unused water entitlements where possible.
Donnybrook subarea	• Water use survey and recouping of unused licensed entitlements to be undertaken for the Leederville Aquifer. • Review of bore logs and information on surficial licenses to ensure that no entitlements are actually in the Leederville Aquifer. • Reserve the public water supply amount and review the public drinking water source protection plan.
Blackwood Plateau North and South subareas	• Maintain monitoring on the Blackwood Plateau (BP series of bores) to monitor the recharge area and the affects of climate. • Increase knowledge on connectivity of the systems with surface water (Blackwood River and tributaries).
Dunsborough–Vasse subarea	• Increase monitoring of the seawater interface.
Cowaramup subarea	• Divide the subarea for management in the next plan (north and south of the Margaret River) as the flow lines for the through flow change either side of the river.
Cape to Cape North and Cape to Cape South subareas	• Undertake investigations into groundwater/surface water interactions. • Investigate the impact of groundwater excavations at the top of catchments on surface water flow. • Increase understanding of springs in catchment areas and excavations into the shallow areas of the regionally confined Leederville Aquifer.

Subarea	Action
Rosa-Beenup subarea	• Support the drilling investigations for the Lesueur Sandstone in 2014. • Water use survey and recouping of unused licensed entitlements to be undertaken for the Lesueur Sandstone Aquifer.
Scott and Jasper subareas	• Understand the impacts associated with plantations and how this influences run-off, through flow, recharge and potential acid sulphate soils. • Understand the water balance (demand) of plantations. • Decrease the knowledge gap on drainage and its influence on water quality.

Appendices

Appendix A Information and considerations used in developing the allocation limits

Aquifer tables

The following tables describe the summarised information and considerations used in the allocation limit decision-making process. Each of the categories were considered and balanced against current scientific knowledge and the associated management risks in using the water resource. The tables provided the background and context for the decision-making regarding the new allocation limits for each aquifer and groundwater subarea. The information used included the current assessment of the department's hydrogeological, environmental, and water use information (current and estimated future demand).

The tables helped to set the department's direction for groundwater management in each area, including weighing up options for more, or less water to be allocated based on:

- high demand and low impacts
- water for the environment in areas where the water resource should be protected (recharge areas, sea water interface areas, sites with existing impacts)
- accounting for interception activities (drainage, dams and plantations)
- protecting current licensed use.

Throughout the process of developing the allocation limits various subareas required further actions to help manage the impacts associated with the changed limits. These actions are described in the text and will be followed up in the plan and through the department's licensing and monitoring programs.

The aquifer tables provide a brief synopsis for each aquifer by subarea. This includes information on what each aquifer is capable of producing (in terms of yield) and their limiting characteristics (environment, monitoring, ASS, climate, location and hydrogeological parameters) to give an understanding of what needs to remain in the system and what can be allocated for consumptive use. This included understanding current and future demand. The tables are based on the new subareas that have been developed through the planning process.

It is important to note that the social and cultural water requirements are currently met through maintaining the ecological water requirements, until further work is completed.

Allocation limit factors

The factors used in calculating the final allocation limits are presented Table A1–A5. The tables have various columns of information used in calculating the new limits. The first group of columns describe the groundwater area and subarea; the second group show the old allocation limit, model information and the calculated limits; the third group of columns are licensing data collected from WRL, estimations of stock and domestic use (including gardens); and the final column is the new allocation limit. The new limit has been reached considering the numbers presented and the information contained in the aquifer tables.

The old allocation limit was derived from the allocation limits set for the old subareas described in the 1994/1995 plans for the Bunbury and Busselton–Capel groundwater areas (Appendix B). This number was recalculated using the formulas described in the old management plans for the new subareas in the Blackwood groundwater area.

The calculated allocation limit was completed for each of the subareas for the Superficial Aquifer. This calculation was based on the previous formulas described in the old management plans with a through flow factor applied (70% to stay in the system to maintain through flow and environment). The calculations were based on estimated rainfall of 750 mm Bunbury, 850 mm Busselton–Capel, and 950 mm Blackwood. As SWAMS currently does not include modelling for drainage, surface water connectivity and ponding in all areas the final allocation limits were adjusted accordingly.

The SWAMS model numbers show the amount of water available for licensing, where through flow is maintained to the ocean and/or neighbouring subareas, including taking into consideration downward leakage to other aquifers and areas of recharge. This is generally indicated in brackets next to the numbers. In each case this has been factored into the methodology.

The estimated stock and domestic use is based on our understanding of licensed and unlicensed/exempt bores. The estimation is of exempt stock and domestic use only and does not take into consideration licensed stock and domestic use, as this is accounted for in the licensed entitlements column. This number gives an understanding of what water is being used in each subarea, which has not previously been accounted for in decision-making. This number also shows where areas of high urban development are likely and if the exempt or unlicensed water requirements would be increasing.

Yarragadee and other confined aquifers

Figure A1 South West groundwater areas: subareas for the Yarragadee and other confined aquifers

Yarragadee Aquifer

The following table represents a summary of the available information for each subarea (Figure A1) in the Yarragadee Aquifer. Table A1 gives the numbers used to determine the new allocation limits.

Category	Information	Issue (impact risk and knowledge gap)
Bunbury–Yarragadee		
Hydrogeology	Shallow south of Bunbury (west) (unconfined). East of the Bunbury Basalt underlies the Leederville Aquifer (confined).	Salt wedges exist in the aquifer along the coast (Bunbury West) at varying depths in the different layers of the aquifer.
Monitoring		Declining up to 2 m. Goes below sea level at two monitoring bores on the Bunbury coast in summer.
Recharge	Recharged from Blackwood Plateau; downward leakage from superficial in unconfined area.	Declining rainfall on Blackwood Plateau.
Through flow	Flow lines north to discharge of Bunbury.	Seawater interface issue in the bores on the coast. Abstraction impacts.
Seawater interface		See above.
Acid Sulphate Soils (ASS)	ASS not investigated at depth however potential connection to overlaying aquifers is noted.	ASS risk in West Bunbury where it is unconfined.
Groundwater-dependent systems	Wellesley river is a potential groundwater-dependent ecosystem (GDE) and large allocations should not be licensed close to these systems.	Moderate risk to GDE under climate change scenarios. Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Predominantly cleared for urban and agriculture.	
Current use	Public water supply, industry and service sector.	Movement of the seawater wedges present in the aquifer have occurred already and are affecting current use – PWS for Bunbury on the coast.
Stock and domestic unlicensed	Increased urban development will likely increase the number of domestic backyard bores in south of Bunbury where the superficial overlies the unconfined Yarragadee.	Cumulative impacts from shallow system.
Public water supply (PWS) reserve	5.7 GL to be reserved for PWS	Capped over area with PWS issues.

Category	Information	Issue (impact risk and knowledge gap)
Busselton–Yarragadee		
Future demand	Public water supply, industrial development.	May be issues with domestic bores in the south of Bunbury in the expanding urban fringe.
Hydrogeology	Formation is predominantly sandstone. Usually 150m below ground level. Artesian flow in most areas.	Artesian head has declined at the coast.
Monitoring		Declining up to ~2 m over last 10 years on coastal plain. Abstraction impacts evident in local areas.
Recharge	Recharged on the Blackwood Plateau.	Declining rainfall on Blackwood Plateau.
Through flow	Flow lines north to discharge of the point near Bunbury and out into Geographe Bay.	If large abstractions occur in the Blackwood Plateau this will restrict the amount of water flowing through the system onto the Swan coastal plain.
Seawater interface	Sea water interface is off shore in this area.	
ASS		ASS not investigated at depth however potential connection to overlaying aquifers is noted.
Groundwater-dependent systems		Low risk to GDE on the coastal plain where Leederville is thinner. Model also shows greater draw downs along the scarp where the majority of threatened ecological communities (TEC) are.
Land use	Predominantly cleared for urban and agriculture on the coastal plain, forested on the Blackwood Plateau.	
Current use	PWS, pasture, dairy, horticulture and viticulture. Public water supply already existing (Busselton Water Board 17 GL).	Recouping or redistribution may be necessary, as this is sufficient water to supply drinking water for the next 30 years for the entire Busselton–Capel groundwater area based on the projections determined by Brennan, 2007.
Stock and domestic unlicensed	It is unlikely that there is any unlicensed stock and domestic bores in this aquifer due to the depth requirements.	The component listed in the table below is the licensed portion of existing entitlements.
PWS reserve	350 000 kL/yr	See above risk with BWB licence.
Future demand	PWS, pasture, dairy, horticulture.	

Category	Information	Issue (impact risk and knowledge gap)
Blackwood–Yarragadee		
Hydrogeology	Area covers the recharge and discharge areas of the Yarragadee and where the aquifer is both confined and unconfined.	The groundwater area has both the north and south flow line that cuts across the Blackwood Plateau.
Monitoring		Declining in recharge area (~2 m) and on Plateau. Localised declines on coastal plain (up to 2 m).
Recharge	Recharged on the Blackwood Plateau; possible downward leakage from surficial and Leederville Aquifers on the coastal plain.	Declining at the recharge area; possibly linked to climate
Through flow	South from below the Blackwood River out to Flinders Bay.	If large abstractions occur in the Blackwood Plateau this will restrict the amount of water flowing through the system onto the Scott coastal plain
Seawater interface	Offshore at present.	Increased abstraction may move the sea water interface north.
ASS	ASS not investigated at depth however potential connection to overlaying aquifers is noted.	May be ASS issues in the recharge area/Blackwood River tributaries if water levels decline.
Groundwater-dependent systems	Currently low risk, however, larger allocations along eastern end of lower Blackwood River pose a risk to St John Brook, local allocations may pose risk to wetlands on the Scott coastal plain–Blackwood Plateau border.	Allocations around Spearwood/Adelaide Creek may pose risk to Reedia wetlands. Currently high risk to Poison Gully area. Additional large allocations in close proximity could reduce summer stream length, dry organic soils; result in change in vegetation communities.
Land use	Predominantly cleared for urban and agriculture on the coastal plain, forested on the Blackwood Plateau.	
Current use	Dairy and pasture production with some horticulture.	Issue with irrigation efficiency (time of application and the need for irrigation).
Stock and domestic unlicensed	It is unlikely that there is any unlicensed stock and domestic bores in this aquifer due to the depth requirements.	The component listed in the table below is the licensed portion of existing entitlements.
PWS reserve	3 GL/yr for Margaret River – abstraction points on the Blackwood Plateau north of the Blackwood river (northern flow line for Yarragadee).	
Future demand	Public water supply and pasture irrigation.	Capped currently for licensing.

Table A1 Allocation limit factors for the Yarragadee Aquifer (kL/yr)

Groundwater area	Subarea	Old allocation limit	Model	Licensed entitlements	Estimated stock and domestic	New allocation limit
Bunbury	Bunbury – Yarragadee	33 000 000	24 900 000	20 186 750	400 000	26 500 000
Busselton–Capel	Busselton – Yarragadee	67 000 000	41 270 000	44 759 750	20 000	45 500 000
Blackwood	Blackwood – Yarragadee	20 000 000	11 250 000	8 845 000	11 000	13 000 000
Total		**120 000 000**	**77 420 000**	**73 791 500**	**431 000**	**87 500 000**

The following tables represent the summary of the available information for the Sue Coal Measures and Lesueur Sandstone groundwater resources. Table A2 gives the numbers used to determine the new allocation limits.

Sue Coal Measures

Category	Information	Issue (impact risk and knowledge gap)
Cowaramup–Vasse		
Hydrogeology	There are two distinct flow systems in the aquifer, which are separated by the Wirring Fault. The Sue Coal Measures is found at depths greater than 200–1800 m. The formation is predominantly sandstone, with minor areas of siltstone, shale and coal seams. The Sue Coal Measures is extensively faulted and eroded, with an irregular surface for deposition. It is considered an unreliable resource.	The formation has a limited capacity to produce flows required for large scale irrigation due to the dense nature of the lithography, and its unwillingness to give up water readily. The investigations in to groundwater resources from monitoring wells drilled in the area did not encounter large flows. Groundwater allocation in this aquifer is limited by the aquifer's ability to provide adequate water for certain types of activities.
Monitoring		Decline (up to 9 m) on the coast.
Recharge	From overlying aquifer systems.	
Through flow	Unknown	
Seawater interface and drainage	Unknown	
Climate	Unknown	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems		Lack of understanding of relationship between Sue Coal Measures and the water table

Category	Information	Issue (impact risk and knowledge gap)
Cowaramup–Vasse		
Land use	See Cowaramup and Dunsborough–Vasse subareas (Superficial Aquifer)	
Current use	PWS and service sector	
Future demand	Difficult to predict as resources is unreliable.	Unlikely to be used as a major water resource due to nature of formation

Lesueur Sandstone

Category	Information	Issue (impact risk and knowledge gap)
Rosa–Beenup		
Hydrogeology	Sabina and Lesueur Sandstone formation make up the Lesueur aquifer. The aquifer may be recharged in the north of the subarea with some Sue Coal Measures present.	Generally unknown. Drilling required.
Monitoring		Localised declines in area in 1999 returning to stable and then declining again in 2006.
Recharge	Overlying aquifers and rainfall on recharge area (Blackwood Plateau).	
Through flow	Unknown	
Seawater interface and drainage	Unknown	
Climate	1100–1400 mm rainfall. Wet areas into Sept/Oct. on surface.	Climate uncertain on declining rainfall 900–1100 mm.
ASS		PASS at depth not yet investigated.
Groundwater-dependent systems		Potential risk to Scott coastal plain ironstone TEC and Reedia sites. Not enough known about hydrogeological interactions to adequately measure risk.
Land use	Cleared for agriculture. Some areas of state forest and national park.	
Current use	Dairy, Pasture and Horticulture	
PWS	Currently supplies Augusta town site	Reserve required – 1 000 000 kL/yr
Future demand	Town water supply	EPA recommended cap on allocation limit for this area until investigations (drilling and EWR monitoring) are completed

Table A2 Allocation limit factors for the Sue Coal Measures and Lesueur Sandstone (kL/yr).

Groundwater area	Subarea	Aquifer	Old allocation limit	Model*	Licensed entitlements	Estimated stock and domestic**	New allocation limit
Busselton–Capel	Cowaramup–Vasse	Sue Coal Measures	4 000 000	N/A	1 005 000	0	4 000 000
Blackwood	Rosa–Beenup	Lesueur Sandstone	4 550 000	N/A	2 802 000	0	4 000 000
Total			**8 850 000**		**3 807 000**	**10 000**	**8 100 000**

*The model was not used in the determination of the new allocation limits for the confined aquifers (Sue Coal Measures and Lesueur Sandstone). The fractured rock area is outside of the model domain. **The estimated stock, domestic and garden for the confined aquifers is zero due to the nature of the resource (deep and costly to access).

Leederville and Superficial aquifers

Figure A2 South West groundwater areas: subareas for the Superficial and Leederville Aquifers.

Leederville Aquifer

The following table represents a summary of the available information for each subarea (Figure A2) in the Leederville Aquifer. Table A3 gives the numbers used to determine the new allocation limits.

Category	Information	Issue (impact risk and knowledge gap)
Lake Preston		
Hydrogeology	Deeper formation underlying superficial deposits (30 m+). Depth varies across the formation (100–300 m) and is generally >1000 mg/L.	Aquifer is not readily used so there is limited recent information available on the aquifer properties.
Monitoring	Limited monitoring bores in this area	Water levels are stable.
Recharge	Rainfall recharge west of the Harvey ridge (northward flow). Leakage from the Superficial Aquifer	
Through flow	Through flow to the north and west out to the ocean.	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	Unknown	Unknown interconnectivity with the Superficial Aquifer and potential areas where the superficial is thinner.
Land use	Cleared for horticulture and agriculture.	
Current use	Irrigation for horticulture.	
Stock and domestic unlicensed	Unlikely to be used (depth to aquifer).	
Future demand	Potentially used for irrigation if the water quality in the Superficial Aquifer changes (saline or acidic).	
Bunbury East		
Hydrogeology	Vasse member for majority of area. Shallow depth to top of the aquifer with flow lines north. Up to 250 m deep. Unconfined in many places.	Shallow nature and unconfined may increase risk of draw down impacts.
Monitoring		Sight decline in winter water levels (~1 m in last 10 years) to the north of the subarea. Increased amplitude in summer water levels. Decline result of abstraction.

Category	Information	Issue (impact risk and knowledge gap)
Bunbury East		
Recharge	Recharged on the Blackwood Plateau (Donnybrook area) – rainfall and connectivity with the Superficial Aquifer.	Changes to rainfall and recharge east and south of the subarea may change available water.
Through flow	Through flow to the north may be into Preston River.	Recharged in Donnybrook area – any changes to this area will limit the through flow.
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	Low risk to GDE reference sites, moderate risk under worst case climate change scenario. Many other Conservation category wetlands that could be affected by local pumping. Preston River is a potential GDE and large allocations should not be licensed close to these systems.	Not enough information on surface-groundwater relationships to make specific recommendations. Area underlain by Bunbury Basalt which may mitigate effects of pumping from deeper aquifers.
Land use	Cleared for agriculture. Irrigation of pasture and market gardens. Some mining and industry.	
Current use	PWS, pasture production, horticulture and service sector	
Stock and domestic unlicensed	Used for domestic supply where superficial is thin to absent.	Increased urban development may put pressure on shallow part of aquifer for domestic supply (cumulative impacts).
Future demand	Public water supply, industrial development.	
Dardanup		
Hydrogeology	Vasse member for majority of area, with Quindalup member to the north. Shallow depth to top of the aquifer with flow lines north. Up to 300 m deep.	
Monitoring		Declining winter and summer (increase in amplitude) in the eastern portion (~1 m in last 10 years) – abstraction impacts
Recharge	Recharged on the Blackwood Plateau (Donnybrook area) – rainfall and connectivity with the Superficial Aquifer.	Changes to rainfall and recharge east and south of the subarea may change available water.
Through flow	Through flow to the north may be into Preston River.	Recharged in Donnybrook area and north – any changes to this area will limit the through flow.
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	Low risk to GDE ref sites. Ferguson, Preston and Collier rivers have potential GDE and large allocations should not be licensed close to these systems.	Not enough information on surface-groundwater relationships to make specific recommendations

Category	Information	Issue (impact risk and knowledge gap)
Dardanup		
Land use	Cleared for agriculture. Mostly stock, domestic and some service and industry.	
Current use	PWS, pasture production, horticulture and service sector.	
Stock and domestic unlicensed	Used for domestic supply where superficial is thin to absent.	Increased urban development may put pressure on shallow part of aquifer for domestic supply (cumulative impacts).
Public water supply	Currently supplies town of Dardanup and Eaton.	Reserve required – 100 000 kL/yr
Future demand	Public water supply, industrial development.	
Donnybrook		
Hydrogeology	Recharge area along Darling fault. Mostly shallow unconfined Quindalup member 50–75 m, confined by Mowen member, with Vasse below to depth 180 m.	
Monitoring		Increase in amplitude (summer declines) areas close to abstraction show impact on water levels.
Recharge	Rainfall and potentially recharge from surface water in some places	Declining rainfall
Through flow	North and west providing other subareas with recharge.	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	No GDE reference sites in this subarea. However, watercourses such as the Capel and Preston rivers are potential GDE and large allocations should not be licensed close to these systems.	Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Domestic and horticulture. Mostly state forest.	
Current use	PWS, pasture, horticulture and viticulture	
Stock and domestic unlicensed	At least 80% of properties in Donnybrook have a domestic garden bore into the shallow (unconfined) Leederville Aquifer	Risk of cumulative drawdown. Risk to PWS. Risk of further over allocation.
Public water supply	Reserved water needed 137 000 kL/yr to allow for urban expansion	Health risk – including domestic bores in same resource.
Future demand	PWS and irrigated horticulture.	Trading will define following water use surveys and recouping.

Category	Information	Issue (impact risk and knowledge gap)
Blackwood Plateau North		
Hydrogeology	Three members of the formation exist in this area – Quindalup, Vasse and Mowen members. Leederville recharged on plateau. Discharges (and recharges) in various areas of the Blackwood River and tributaries. Absent in some areas where Yarragadee recharges (south eastern portion of the area). This area predominantly is Quindalup.	
Monitoring		Rainfall decline is evident in recharge area. Declines in both summer and winter water levels in some bores; others stable.
Recharge	Recharge area for Leederville Aquifer - rainfall	Reduction in rainfall and recharge may have cumulative impacts to the north and west of the subarea
Through flow	North and west providing other subareas with recharge.	
ASS	Risk of ASS unknown in majority of the Plateau - however there may be risks associated with the valley areas and river beds (Poison Gully)	PASS at depth not yet investigated
Groundwater-dependent systems	Wetlands and river pools of the upper Margaret River, and St John Brook may be affected by large allocations too close to these areas.	Risk of abstraction – impacts on SWR/CWR/EWR sites
Land use	National Park (95%) with some land cleared along St John Brook and odd patches in the National park mosaic. The cleared areas are semi-rural blocks with small hobby style production.	
Current use	Stock and domestic	
Stock and domestic unlicensed	May be some areas of unlicensed domestic use	
Future demand	Potentially PWS where impacts are not predicted. Increase in semi-rural blocks and demand for self supply domestic requirements.	

Category	Information	Issue (impact risk and knowledge gap)
Busselton–Capel		
Hydrogeology	Found at shallow depth, unconfined in places. Mostly Vasse member with salinity increasing towards the coast. Varying thickness – deeper to the west towards the Busselton fault.	Unconfined near the coast – impacts of abstraction and wetland connection.
Monitoring		Abstraction impact in summer. Small declines in winter water levels in some places. Lack of seawater interface monitoring
Recharge	Recharge area on northern section of Blackwood Plateau	Decreased rainfall and recharge on Blackwood Plateau may impact on available water
Through flow	From Blackwood plateau to coast (Geographe Bay).	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	Moderate risk to some reference GDE north-east of Vasse-Wonnerup estuary under all scenarios and severe risk to Tutunup TEC under low recharge scenarios.	Large allocations too close to GDE are likely to have an impact.
Land use	Land predominately cleared for agriculture. Pasture, dairy, horticulture and viticulture are all water users in this subarea. Urban land development is increasing.	
Current use	PWS, pasture, dairy, horticulture and viticulture	
Stock and domestic unlicensed	Unlicensed use in urban developments prevalent	Issue of unlicensed use and shallow bores
Future demand	Trading will define	
Dunsborough–Vasse		
Hydrogeology	Overlies Sue Coal Measures. Seawater interface at coast. Salinities increase towards coast. Various members present over area. Most used aquifer.	
Monitoring		Declining (~2–4 m) with localised large drops (up to 24 m) with some areas going below sea level. Declines result of abstraction (particularly through PWS). Lack of seawater interface monitoring
Through flow	From the Whicher Scarp (recharge area in Cowaramup subarea) to the ocean	
ASS		PASS at depth not yet investigated

Category	Information	Issue (impact risk and knowledge gap)
Dunsborough–Vasse		
Groundwater-dependent systems	Moderate risk to TEC on scarp and conservation category wetlands near coast under reduced recharge scenarios.	Large allocations (single or cumulative) close to high value GDE would be likely to cause impact.
Land use	Predominantly cleared for agriculture; increased urban development. Most areas for horticulture, viticulture and tourism.	Impact of changing land use as rural turns to semi-rural and urban areas.
Stock and domestic unlicensed	Unlicensed use in urban developments prevalent	Issue of unlicensed use and shallow bores
Future demand	Trading will define	
Climate	Recharged on Whicher Scarp (Cowaramup subarea)	Decrease in rainfall and recharge (including from abstraction) may impact available water
Cowaramup		
Hydrogeology	Major recharge area for aquifer, supports pools of the MR, larger proportion of shale (Quindalup, Mowen and Vasse members)	
Monitoring		Current monitoring limited – monitoring bores recently drilled
Recharge	Rainfall and surface water.	Decline in recharge area may lead to impacts in Dunsborough–Vasse subarea.
Through flow	Drainage into rivers and waterways (particularly Margaret River)	Changes to through flow may impact on pools in MR and water availability in Dunsborough–Vasse subarea. Risk setting allocation limit without Cowaramup drilling information.
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	Margaret River is a key dependent ecosystem in this subarea and will be affected by large allocations too close to the river. The upper Carbanup River may also be affected.	
Land use	Partially cleared for agriculture. Mostly horticulture and viticulture with some areas of urban development.	
Current use	PWS, horticulture, viticulture and general agriculture	
Stock and domestic unlicensed	Excavations into waterways and at the top of catchments may be intersection the Surficial or Leederville – for stock water and small irrigation	Impacts to waterways and interaction with surface water.
Future demand	Potentially PWS and increased viticulture	

Category	Information	Issue (impact risk and knowledge gap)
Blackwood Plateau South		
Hydrogeology	Three members of the formation exist in this area – Quindalup, Vasse and Mowen members. Leederville recharged on plateau. Discharges (and recharges) in various areas of the Blackwood River and tributaries. Absent in some areas where Yarragadee recharges (south eastern portion of the area). This area predominantly is Quindalup.	
Monitoring		Rainfall decline is evident in recharge area. Declines in both summer and winter water levels in some bores; others stable.
Recharge	Recharge area for Leederville Aquifer (rainfall and possibly surface water)	Reduction in rainfall and recharge may have cumulative impacts to the north and west of the subarea
Through flow	North and west providing other subareas with recharge.	
ASS	Risk of ASS unknown in majority of the plateau – however there may be risks associated with the valley areas and river beds (Poison Gully)	PASS at depth not yet investigated
Groundwater-dependent systems	Currently low risk, however, larger allocations along eastern end of lower Blackwood River pose a risk to St John Brook, local allocations may pose risk to wetlands on the Scott coastal plain–Blackwood Plateau border. Allocations around Spearwood/Adelaide Creek may pose risk to Reedia wetlands.	Risk of abstraction – impacts on sites with water requirements.
Land use	National park (95%) with some land cleared along St John Brook and odd patches in the National park mosaic. The cleared areas are semi-rural blocks with small hobby style production.	
Current use	Stock and domestic, small land holders' hobby farms.	
Stock and domestic unlicensed	May be some areas of unlicensed domestic use	
Future demand	Increase in semi-rural blocks and demand for self supply domestic requirements.	Potentially PWS where impacts are not predicted.

Category	Information	Issue (impact risk and knowledge gap)
Beenup		
Hydrogeology	Predominantly Vasse member (most accessible Formation for aquifer). Overlies the Sabina sandstone and Lesueur Sandstone formations.	May discharge into areas of the Blackwood river and tributaries in the northern section of the subarea.
Monitoring		Decline (~2 m). Impacts from mining
Recharge	Recharged from Blackwood Plateau; possible downward leakage from surficial.	
Through flow	Moves south; may discharge into lower reaches of the Blackwood River and tributaries, may recharge the Lesueur Sandstone.	Unknown.
ASS		PASS at depth not yet investigated. Exposed ASS at Beenup mine site – unknown risks in dissipation of plume and monitoring information.
Groundwater-dependent systems	SWAMS model indicates GDE reference sites in this subarea are at low risk under most recharge scenarios, though TEC adjacent to the Scott River are indicated as being at high to severe risk under the lower recharge scenarios. ASS risk area. Small allocations away from GDE may be appropriate.	
Land use	Small area of National Park – mostly cleared for agriculture.	
Current use	Mining (rehabilitation), dairy, pasture production, domestic supply.	
Stock and domestic unlicensed	Unlikely to be unlicensed (depth and construction requirements)	
Future demand	Increased demand for service sector, domestic supply, dairy and pasture production.	
Rosa		
Hydrogeology	Predominantly Mowen and Vasse member, with areas of recharge in the upper catchment areas and potentially support the Reedia wetlands. Monitoring data suggests declining in pressure heads.	
Monitoring		Declining summer water levels - winter stable. Increased pumping - change in amplitude.

Category	Information	Issue (impact risk and knowledge gap)
Rosa		
Recharge	Recharged from Blackwood Plateau; possible downward leakage from surficial.	
Through flow	Moves south; may discharge into lower reaches of the Blackwood River and tributaries, may recharge the Lesueur Sandstone.	
ASS		PASS at depth not yet investigate.
Groundwater-dependent systems		No GDE reference sites within this subarea, however, larger allocations close to Reedia wetlands may pose a risk to these systems. EPA recommended cap on allocation limit for this area until investigations (drilling and EWR monitoring) are completed.
Land use	Half national park – remainder cleared for agriculture.	
Current use	Horticulture and viticulture irrigation.	
Stock and domestic unlicensed	Unlikely to be unlicensed (depth and construction requirements)	
Future demand	Increased demand for service sector, domestic supply, viticulture and horticulture.	
Scott		
Hydrogeology	Mowen member present (unconformity) potential aquitard or aquiclude.	Unknown distribution of the formation. Monitoring bores present but lack of drilling information. Problems understanding connectivity.
Monitoring		Declining summer water levels – winter stable. Increased pumping – change in amplitude
Recharge	Recharged from Blackwood Plateau; possible downward leakage from superficial.	
Through flow	South to Flinders Bay.	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems	SWAMS model outputs show severe risk to Gingilup wetlands (and one other reference site) under all recharge scenarios while ESCP model indicates low risk.	Large-scale abstraction would be undesirable close to identified GDE (including Scott River). ASS risk area

Category	Information	Issue (impact risk and knowledge gap)
Scott		
Land use	Predominantly cleared for agriculture.	Issue of plantations and expansion or clearing of plantations.
Current use	Limited to domestic and other small uses (pasture production) at present.	
Stock and domestic unlicensed	Unlikely to be unlicensed (depth and construction requirements)	
Future demand		May be in demand following reductions in access to Yarragadee Aquifer for dairy, horticulture and pasture production.
Jasper		
Hydrogeology	Absent for most of the area with the Yarragadee underlying the superficial. Mowen member present in the eastern area and may be an aquiclude.	
Monitoring	Not applicable	
Recharge	Blackwood Plateau – recharge areas	
Through flow	South to Flinders Bay.	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems		Undesirable for large Leederville allocations to be granted close to GDEs.
Land use	Predominantly national park with areas cleared for agriculture	
Current use	Not used – aquifer not present for majority of the subarea.	
Stock and domestic unlicensed	Not applicable	
Future demand	Not applicable	

Table A3 Allocation limit factors for the Leederville Aquifer (kL/yr)

Groundwater area	Subarea	Old allocation limit*	Model	Licensed entitlements	Estimated stock and domestic	New allocation limit
South West Coastal	Lake Preston	500 000	Model domain does not extend past the Bunbury groundwater area.	420 000	10 000	500 000
Bunbury	Bunbury East	4 000 000	1 300 000 (maintain through flow for neighbouring subareas)	1 874 800	100 000	2 000 000
	Dardanup	4 000 000	3 000 000 (maintain through flow for neighbouring subareas and seawater interface @ 0 mAHD contour)	3 105 800	0	3 500 000
Busselton–Capel	Donnybrook	2 400 000	1 470 000 (maintain through flow for neighbouring subareas)	2 484 475	0	2 400 000
	Blackwood Plateau North	300 000	3 000 000 (all water needed to maintain throughflow to neighbouring subareas)	0	3000	250 000
	Busselton–Capel	12 800 000	10 000 000 (maintain through flow for neighbouring subareas and seawater interface @ 0 mAHD contour)	8 035 800	0	10 500 000
	Dunsborough–Vasse	6 100 000	5 700 000 (maintain through flow for neighbouring subareas and seawater interface @ 0 mAHD, currently inland from the coast)	5 413 075	0	5 400 000
	Cowaramup	300 000	Cowaramup model 1 800 000 kL/yr	724 800	25 000	1 800 000
Blackwood Blackwood	Blackwood Plateau South	150 000	100% to remain in ground to maintain Blackwood River tributaries.	94 000	3000	250 000
	Rosa	1 000 000	1 300 000 (maintain through flow for neighbouring subareas and to ocean)	605 100	0	1 000 000

Groundwater area	Subarea	Old allocation limit*	Model	Licensed entitlements	Estimated stock and domestic	New allocation limit
	Beenup	500 000	3 000 000 (assuming 4.2 GL leakage from the superficial and through flow maintained for neighbouring subareas and to ocean)	401 150	0	1 000 000
	Scott	200 000	17 000 (maintain through flow to ocean)	24 000	0	3 200 000
	Jasper	50 000	320 000 (maintain through flow to ocean)	0	0	50 000
Total		**32 300 000**		**23 183 000**	**141 000**	**31 850 000**

Fractured rock and Superficial aquifers

Estimating groundwater availability in the superficial formations (Superficial and Surficial aquifers) using through flow or recharge methods is difficult because of the nature of the aquifer system. The Superficial formation lacks a defined groundwater flow and has numerous rivers, drains and wetlands that are connected to the recharge and flow dynamics. The variable thickness of the formation, nature of the sediments (clays and sands) and its ability to recharge underlying formations make it difficult to estimate the storage capacity of the formation.

The following table represents a summary of the available information for each subarea (Figure A2) in the Superficial aquifers. Table A4 gives the numbers used to determine the new allocation limits.

The fractured rock system has a notional allocation limit (Table A5), and the resource is allocated based on the licence applicant's ability to show that the required yield is obtainable and that the impacts of abstraction are acceptable.

Superficial aquifers

Category	Information	Issue (impact risk and knowledge gap)
Harvey		
Hydrogeology	High sand content and deep nature of sediments (15–30 m). Low salinity and high recharge (sandy soils).	Issue of recycling of salts through continual irrigation.
Geology	Coastal plain dunal systems (Tamala limestone and Bassendean sands). Deep sands and sandy–gravels.	
Monitoring	The Superficial Aquifer has adequate monitoring of water levels and water quality. Water levels are generally stable in this area.	
Recharge	Rainfall and surface water.	
Through flow	Westward flow of groundwater within the Superficial Aquifer from the Yanget Mound (east of the subarea) towards Lake Preston. Through flow from the superficial also goes into the Leederville and is heavily drained.	
Seawater interface and drainage	Seawater interface at coast. Heavily drained through the coastal plains from the Darling scarp.	Changing drainage practices through the Harvey irrigation scheme may alter the amount of water moving through the system.
Climate	Decreasing rainfall over the last 10 years. Average rainfall 700–900 mm.	
ASS	Moderate risk over most of the area, with higher risks along wetland and river beds.	
Groundwater-dependent systems	Unknown	Numerous wetlands (north/south line) east of the highway.
Land use	Cleared for agriculture.	Increased urban development my be likely along the proposed Perth–Bunbury Hwy.
Current use	Pasture production, stock and domestic.	
Stock and domestic unlicensed	Potentially many sites (windmills and other shallow stock bores) for the beef and dairy production in this area.	Exempt stock water use needs to be surveyed.
Future demand		Potential for use in irrigating pasture production as a viable alternative option to the Harvey irrigation scheme.

Category	Information	Issue (impact risk and knowledge gap)
Lake Preston North		
Hydrogeology	High sand content and deep nature of sediments (15–30 m).	Issue of salinity increases and management/monitoring of groundwater abstraction and recycling. High risk of water becoming unusable for certain purposes if not managed appropriately.
Geology	Coastal plain dunal systems (Tamala limestone formations). Deep sands and sandy-gravels.	
Monitoring	The superficial has adequate monitoring of water levels and water quality. Water levels are generally stable in this area.	
Recharge	Rainfall and surface water seepage.	
Through flow	Westward flow of groundwater within the Superficial Aquifer from the Yanget Mound (east of the subarea) towards Lake Preston. Through flow from the superficial also goes into the Leederville and Lake Preston.	If the groundwater levels or water quality change this may impact on the water flowing into Lake Preston.
Seawater interface and drainage	Seawater interface at coast. Heavily drained.	
Climate	Decreasing rainfall over the last 10 years. Average rainfall 700–900mm.	
ASS	Moderate risk over most of the area, with higher risks along wetland and river beds.	
Groundwater-dependent systems	Wetland chains associated with Lake Preston and the north/south line of wetlands along the coastal strip.	May be impacted by water level declines or changes to water quality.
Land use	Cleared for agriculture.	
Current use	Irrigation of horticulture.	
Stock and domestic unlicensed	Potentially many sites (windmills and other shallow stock bores).	Exempt stock water use needs to be surveyed.
Future demand	Potential for increased demand for irrigation of horticulture now that the allocation limits for Lake Preston South have been capped.	Issue of salt water recycling and changes to water quality.

Category	Information	Issue (impact risk and knowledge gap)
Lake Preston South		
Hydrogeology	High sand content and deep nature of sediments (15–30 m)	Issue of salinity increases and management/monitoring of groundwater abstraction and recycling. High risk of water becoming unusable for certain purposes if not managed appropriately.
Geology	Coastal plain dunal systems (Tamala limestone formations). Deep sands and sandy-gravels.	
Monitoring	The superficial has adequate monitoring of water levels and water quality.	There has been a regional drawdown response to decreased rainfall conditions since the early 2000's. However there are no detrimental draw-down impacts apparent directly related to licensed abstractions.
Recharge	Rainfall and surface water seepage.	
Through flow	Westward flow of groundwater within the Superficial Aquifer from the Yanget Mound (east of the subarea) towards Lake Preston. Through flow from the superficial also goes into the Leederville and Lake Preston.	If the groundwater levels or water quality change this may impact on the water flowing into Lake Preston.
Seawater interface and drainage	Seawater interface at coast. Heavily drained.	
Climate	Decreasing rainfall over the last 10 years. Average rainfall 700–900 mm.	
ASS	Moderate risk over most of the area, with higher risks along wetland and river beds.	
Groundwater-dependent systems	Wetland chains associated with Lake Preston and the north/south line of wetlands along the coastal strip.	May be impacted by water level declines or changes to water quality.
Land use	Cleared for agriculture.	
Current use	Irrigation of horticulture.	
Stock and domestic unlicensed	Potentially many sites (windmills and other shallow stock bores).	Exempt stock water use needs to be surveyed.
Future demand	Licensing has been capped and recouping has been started. Unlikely to change in the short term.	Issue of salt water recycling and changes to water quality.

Category	Information	Issue (impact risk and knowledge gap)
Bunbury West		
Hydrogeology	Overlies Yarragadee Aquifer. In hydraulic connection with the Yarragadee (unconfined). Thin, with variable thickness over the area. Little fresh water with areas of clay, basalt and limestone.	Connectivity and drawdown in Yarragadee Aquifer may cause impacts to superficial.
Geology	Predominantly Bassendean sands with Tamala limestone formation and coastal dune deposits (Safety bay sands).	Some areas of Guildford formation (east) and Bunbury Basalt.
Monitoring		Increased amplitude in summer water levels – potential impacts on wetlands and PASS.
Recharge	Rainfall recharge – increased recharge over urban areas and cleared land	Issue of declining rainfall
Through flow	Superficial through flow from recharge – Bunbury Basalt confining, limestone formations sink for water.	
Seawater interface and drainage	Area drained to allow for urban development. Most into stormwater drains and some into wetland areas and local streams.	Issue of seawater interface at coast.
Climate	Average rainfall 700–900 mm.	Declining over last 10 years, may impact on water levels and recharge.
ASS	High risk of PASS, with dewatering issues present.	Some areas have begun to cause problems with suburban developments and dewatering. Investigation needed with regard to connection with Yarragadee and ASS.
Groundwater-dependent systems	Moderate to low risk to Muddy Lakes and Hay Park (TEC) under climate change scenarios.	Increased use may impact on wetlands.
Land use	Urban development and semi-rural lots. Mostly domestic with horse and hobby farms.	Nutrient application; salt recycling; increased urban development – induced recharge?
Current use	Stock and domestic, pasture production, public open space, small hobby farms	Increased urban development.
Stock and domestic unlicensed	60% of use is related to stock, domestic and garden.	Unlicensed stock and domestic may have cumulative impact on resource. Issue with connectivity with the Yarragadee
Future demand	Increase in urban development/semi-rural	

Category	Information	Issue (impact risk and knowledge gap)
Bunbury East		
Hydrogeology	Thin to absent in many areas overlying the Leederville Aquifer. Areas near rivers deeper (Preston River). Basalt to the west of the subarea. In hydraulic connection with Leederville Aquifer. Salinities vary.	Shallow nature may have impacts for any large scale use. Connection with the Leederville Aquifer.
Geology	Bassendean sands and alluvium deposits (coastal area mouth of the Preston River), some areas of eroded basalt (clay) [North]. Guildford sands and clays [South]	
Monitoring		Increased amplitude in summer water levels – potential impacts on wetlands and PASS.
Recharge	Rainfall recharge – increased recharge over urban areas and cleared land	Issue of declining rainfall
Through flow	Through flow north and into Preston river.	
Seawater interface and drainage	Numerous drains throughout area. Most drain into the Preston River and tributaries and out into the Leschenault Inlet and the ocean.	Seawater interface issue – monitoring bore on the coast drops below sea level.
Climate	Average rainfall 700–900 mm.	Declining over last 10 years – may impact on water levels and recharge.
ASS	Moderate risk over most of the area, with higher risks along wetland and river beds.	Increased drainage may expose PASS if water levels decline.
Groundwater-dependent systems	Low risk to GDE reference sites, moderate risk under worst case climate change scenario. Many other Conservation category wetlands that could be affected by local pumping. Preston River is a potential GDE and large allocations should not be licensed close to these systems.	Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Cleared for agriculture. Irrigation of pasture and market gardens. Some mining and industry.	Nutrient application; salt recycling; increased urban development may possibly lead to induced recharge
Current use	Stock and domestic, pasture production, public open space, small hobby farms	Increased urban development.
Stock and domestic unlicensed		Limited by location and aquifer presence. Salinity factor.
Future demand	Increase in urban development and semi-rural blocks.	

Category	Information	Issue (impact risk and knowledge gap)
Dardanup		
Hydrogeology	Thin to absent in many areas overlying the Leederville Aquifer. Areas near rivers deeper (Preston and Collie rivers). Basalt to the west of the subarea. In hydraulic connection with Leederville Aquifer	Shallow nature may have impacts for any large scale use. Connection with the Leederville Aquifer.
Geology	Bassendean sands and alluvium deposits (coastal area mouth of the Preston River), some areas of eroded basalt (clay) [West]. Guildford sands and clays [South and East].	
Monitoring		Increased amplitude in summer water levels
Recharge	Rainfall recharge – increased recharge over urban areas and cleared land	Issue of declining rainfall
Through flow	Through flow north and west – into Preston and Collie rivers.	
Seawater interface and drainage	Numerous drains throughout area. Most drain into the Preston or Collie rivers and tributaries and out into the Leschenault Inlet and the ocean.	Seawater interface issue
Climate	Average rainfall 700–900 mm.	Declining over last 10 years – may impact on water levels and recharge.
ASS	Moderate risk over most of the area, with higher risks along wetland and river beds.	Drainage may increase risk if water levels decline.
Groundwater-dependent systems	Low risk to GDE ref sites. Ferguson, Preston and Collier rivers are potential GDE and large allocations should not be licensed close to these systems.	Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Cleared for agriculture. Mostly stock, domestic and some service and industry.	Nutrient application; salt recycling; increased urban development – induced recharge?
Current use	Stock and domestic, pasture production, public open space, small hobby farms	
Stock and domestic unlicensed		Limited by location and aquifer presence. Salinity factor.
Future demand	Increase in urban development and semi-rural blocks.	

Category	Information	Issue (impact risk and knowledge gap)
Donnybrook		
Hydrogeology	Surficial sediments in river valleys. Limited by geology – sediments vary in depth and location.	
Geology	Lateritic materials with quazite, gravel, basalt and valley filled deposits of lateritic material (alluvium and colluvium deposits in valley areas)	
Monitoring		Monitoring of the shallow surficial sediments difficult due to location and hydrogeology.
Recharge	Rainfall recharge (possibly from surface water features)	Declining over last 10 years – may impact on water levels and recharge.
Through flow	Into rivers and waterways, may flow onto coastal plain.	
Seawater interface and drainage	Drainage into rivers and waterways	
Climate	Average rainfall 700–900 mm.	
ASS	Areas of PASS along alluvial deposits (bed and banks of water courses) in valleys.	
Groundwater-dependent systems	No GDE reference sites in this subarea. However, watercourses such as the Capel and Preston rivers are potential GDE and large allocations should not be licensed close to these systems.	Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Domestic and horticulture. Mostly state forest.	
Current use	Pasture, horticulture and viticulture	
Stock and domestic unlicensed		Impacts on unconfined Leederville Aquifer – where super does not exist and licenses have been allocated – risk to resource
Future demand		Limited demand other than for domestic supply – nature of aquifer

Category	Information	Issue (impact risk and knowledge gap)
Blackwood Plateau North		
Hydrogeology	Surficial sediments in areas of old valleys and river beds. Leederville is unconfined in areas under thin sediments. Superficial is not generally present	
Geology	Lateritic materials with quazite, gravel, basalt and valley filled deposits of lateritic material (alluvium and colluvium deposits in valley areas)	
Monitoring		Monitoring of the shallow surficial sediments difficult due to location and hydrogeology.
Recharge	Rainfall	Declining rainfall
Through flow	Limited to rivers and waterways.	
Seawater interface and drainage	Drainage into rivers and waterways	
Climate	High rainfall area – 1100 mm	Declining over last 10 years – may impact on water levels and recharge.
ASS	Risk of ASS unknown in majority of the Plateau – however there may be risks associated with the valley areas and river beds (Poison Gully)	
Groundwater-dependent systems		Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Mostly state forest.	
Current use	Limited use – stock and domestic	
Stock and domestic unlicensed	Most stock and domestic would likely be accessing the Leederville	
Future demand		Limited demand other than for domestic supply – nature of aquifer

Category	Information	Issue (impact risk and knowledge gap)
Busselton–Capel		
Hydrogeology	Supports wetlands. Sandy along coast, clayey along scarp. Thickness varies along the coastal plain. Salinity increases towards the coast.	
Geology	Predominantly Alluvium sediments sand/clay and Bassendean sands with Tamala limestone formation and coastal dune deposits (Safety bay sands). Some areas of Guildford formation and clay layers (north-east).	
Monitoring		Predominantly stable with localised areas of decline (summer)
Recharge	Rainfall and drainage.	Declining rainfall
Through flow	Whicher Scarp out to sea and into wetlands and waterways.	
Seawater interface and drainage	Drainage into rivers and waterways. Seawater interface at coast. Estuarine system and various cuts in coastline drain water out to sea	Increased use may move the seawater interface inland or increase salinities in coastal bores. Lack of seawater interface monitoring
Climate	Annual rainfall including 10–15% decline in rainfall ~750 mm/a	May impact on water levels and recharge.
ASS	High risk of PASS in 6 m depth of soil profile.	Concern with summer water levels declining and exposing soils (winter water levels rise taking acid with it). Issue of nutrient application and drainage (excavation) impacts, land use to be managed through plan and advice to Department of Agriculture and Food (DAF) and Local government authorities (LGA). All applications will need to follow ASS protocols and monitoring.
Groundwater-dependent systems	Moderate risk to some reference GDE north-east of Vasse-Wonnerup estuary under all scenarios and severe risk to Tutunup TEC under low recharge scenarios.	Large allocations too close to GDEs are likely to have an impact.
Land use	Land predominantly cleared for agriculture. Pasture, dairy, horticulture and viticulture are all water users in this subarea. Urban land development is increasing.	
Current use	Pasture, dairy, horticulture and viticulture	
Stock and domestic unlicensed	Superficial aquifer used for stock water (shallow wells, excavations) throughout the subarea.	Increased use may impact on recharge and through flow, and increase in summer declines may expose PASS.
Future demand	Small licenses and domestic use	

Category	Information	Issue (impact risk and knowledge gap)
Dunsborough–Vasse		
Hydrogeology	Supports wetlands. Sandy along coast, clayey along scarp. Thickness varies along the coastal plain. Salinity increases towards the coast.	
Geology	Lateritic materials with quazite, gravel and valley filled deposits of lateritic material (alluvium and colluvium deposits in valley areas) (north). South – alluvium depositions and coastal dune systems.	
Monitoring		Decline in summer water levels. Lack of seawater interface monitoring
Through flow	From the Whicher Scarp to the ocean	
Seawater interface and drainage	Drainage into rivers and waterways into wetlands and Toby Inlet (outlet to ocean).	Issue of seawater interface moving inland; increasing salinity in coastal bores
Climate		Declining over last 10 years – may impact on water levels and recharge.
ASS	High risk of PASS in 6 m depth of soil profile.	Concern with summer water levels declining and exposing soils (winter water levels rise taking acid with it). Issue of nutrient application and drainage (excavation) impacts - land use to be managed through plan and advice to DAF and LGA. All applications will need to follow ASS protocols and monitoring.
Groundwater-dependent systems	Moderate risk to TEC on scarp and CCW near coast under reduced recharge scenarios.	Large allocations (single or cumulative) close to high value GDEs would be likely to cause impact.
Land use	Predominantly cleared for agriculture; increased urban development. Most areas for horticulture, viticulture and tourism.	Impact of changing land use as rural turns to semi-rural and urban areas.
Stock and domestic unlicensed	Superficial aquifer used for stock water (shallow wells, excavations) throughout the subarea.	Increased use may impact on recharge and through flow, and increase in summer declines may expose PASS.
Future demand	Small licenses and domestic use	

Category	Information	Issue (impact risk and knowledge gap)
Cowaramup		
Hydrogeology	Limited by geology. Located along the ridge running parallel to the coastline – sediments vary in depth and location.	
Geology	Lateritic materials with quazite, gravel and valley filled deposits of lateritic material (alluvium and colluvium deposits in valley areas).	
Monitoring		Current monitoring limited
Recharge	Rainfall and possibly surface water.	
Through flow	Into waterways, valleys, wetlands and down onto coastal plain.	Risk setting allocation limit without Cowaramup drilling information
Seawater interface and drainage	Drainage into rivers and waterways	
Climate	Annual rainfall including 10–15% decline in rainfall ~750 mm/a	Declining over last 10 years – may impact on water levels and recharge.
ASS	Areas of PASS along alluvial deposits (bed and banks of water courses) in valleys.	
Groundwater-dependent systems	Margaret River is a key dependent ecosystem in this subarea and will be affected by large allocations too close to the river. The upper Carbanup River may also be affected.	
Land use	Partially cleared for agriculture. Mostly horticulture and viticulture with some areas of urban development.	
Current use	Viticulture and Horticulture	
Stock and domestic unlicensed	Excavations into waterways and at the top of catchments may be intersecting the surficial or Leederville – for stock water and small irrigation	Impacts to waterways and interaction with surface water.
Future demand	Small licenses – domestic and stock supply.	

Category	Information	Issue (impact risk and knowledge gap)
Cape to Cape North		
Hydrogeology	Limited by geology – located along the ridge running parallel to the coastline – sediments vary in depth and location.	
Geology	Leeuwin-Naturaliste Ridge. Leeuwin Block – fractured rock, Gneiss base, lateritic formation. Sandy ridge with surficial sediments. Limestone (Tamala) formations along coastline with granite outcrops.	
Monitoring		No monitoring of groundwater
Recharge	Rainfall and surface water seepage	
Through flow	Through the limestone to the coast, wetlands, waterways and cave systems	
Seawater interface and drainage	Drainage into rivers and waterways	
Climate	High rainfall ~ 1100 mm – decline over last 10 years.	Declining over last 10 years – may impact on water levels and recharge.
ASS	Areas of PASS along alluvial deposits (bed and banks of water courses) in valleys.	
Groundwater-dependent systems		Risk unknown. Would require investigation to assess risk. Potential impacts on cave streams/cave fauna as limestone areas occur all along western coastline. Knowledge gap with surface/groundwater interactions.
Land use	Predominantly cleared for agriculture and urban development.	
Current use	Stock and domestic, viticulture, service sector	
Stock and domestic unlicensed	Potentially many unlicensed domestic bores and excavations	Unknown amounts of excavations and domestic bores
Future demand	Domestic supply, small irrigation and service sector (tourism).	

Category	Information	Issue (impact risk and knowledge gap)
Cape to Cape South		
Hydrogeology	Limited by geology – located along the ridge running parallel to the coastline – sediments vary in depth and location.	
Geology	Leeuwin-Naturaliste Ridge. Leeuwin Block – fractured rock, Gneiss base, lateritic formation. Sandy ridge with surficial sediments. Limestone (Tamala) formations along coastline with granite outcrops.	
Monitoring		No monitoring of groundwater
Recharge	Rainfall and surface water seepage	
Through flow	Through the limestone to the coast, wetlands, waterways and cave systems	
Seawater interface and drainage	Drainage into rivers and waterways	
Climate	High rainfall ~ 1100 mm – decline over last 10 years.	Declining over last 10 years – may impact on water levels and recharge.
ASS	Areas of PASS along alluvial deposits (bed and banks of water courses) in valleys.	
Groundwater-dependent systems	Risk unknown.	Risk unknown. Would require investigation to assess risk. Potential impacts on cave streams/cave fauna as limestone areas occur all along western coastline. Knowledge gap with surface/groundwater interactions.
Land use	Predominantly cleared for agriculture and urban development.	
Current use	Stock and domestic, viticulture, service sector	
Stock and domestic unlicensed	Potentially many unlicensed domestic bores and excavations	Unknown amounts of excavations and domestic bores
Future demand	Domestic supply, small irrigation and service sector (tourism).	

Category	Information	Issue (impact risk and knowledge gap)
Blackwood Plateau South		
Hydrogeology	Surficial sediments in areas of old valleys and river beds. Leederville is unconfined in areas under thin sediments. Superficial is not generally present	
Geology	Lateritic materials with quazite, gravel, basalt and valley filled deposits of lateritic material (alluvium and colluvium deposits in valley areas)	
Monitoring		Monitoring of the shallow surficial sediments difficult due to location and hydrogeology.
Recharge	Rainfall and surface water	
Through flow	Limited to rivers and waterways.	
Seawater interface and drainage	Drainage into rivers and waterways	
Climate	High rainfall area – 1100 mm	Declining over last 10 years – may impact on water levels and recharge.
ASS	Risk of ASS unknown in majority of the Plateau – however there may be risks associated with the valley areas and river beds (Poison Gully)	
Groundwater-dependent systems	Currently high risk to Poison Gully area. Additional large allocations in close proximity could reduce summer stream length, dry organic soils; result in change in vegetation communities.	Not enough information on surface-groundwater relationships to make specific recommendations.
Land use	Mostly state forest.	
Current use	Stock and domestic, small land holders’ hobby farms.	
Stock and domestic unlicensed	Most stock and domestic would likely be accessing the Leederville	
Future demand		Limited demand other than for domestic supply – nature of aquifer

Category	Information	Issue (impact risk and knowledge gap)
Beenup		
Hydrogeology	Multiple wetland features and estuarine areas. Ponding of water on surface (dampland/sumpland) during winter (into Oct). Impacts from pumping during summer months – when water is used. Shallow system (6 m) on plains, deep system in dunal areas (south-west of Scott River). Deep sands.	May be connection in places with underlying Vasse member
Geology	Predominantly sandy dunal systems with areas of alluvium deposits in valley areas, river mouth (delta) and shorelines. Remainder is deep sand dunes and coastal deposits with Tamala limestone formation on coastline.	
Monitoring		Stable with small areas of increased amplitude. Areas with change are associated with mining.
Recharge	Rainfall recharge.	
Through flow	Moves south out to Flinders bay; Scott River and Hardy inlet.	
Seawater interface and drainage	Drainage issue – particularly with the Scott and Blackwood rivers and the Hardy inlet (increased pH and water quality issues).	Drainage influence in recharge and discharge into wetlands/Scott River need to be managed. ASS issue with new drains.
Climate	Wet are of State. 1100–1400 mm rainfall. Wet areas into Sept/Oct on surface.	Climate uncertain on declining rainfall 900–1100 mm – may impact on water levels and recharge.
ASS	High risk of PASS in 6 m depth of soil profile. Concern with summer water levels declining and exposing soils (winter water levels rise taking acid with it).	Issue of nutrient application and drainage (excavation) impacts – land use to be managed through plan and advice to the DAF and LGA. All applications will need to follow ASS protocols and monitoring.
Groundwater-dependent systems	SWAMS model indicates GDE reference sites in this subarea are at low risk under most recharge scenarios, though TEC adjacent to the Scott River are indicated as being at high to severe risk under the lower recharge scenarios. ASS risk area. Small allocations away from GDE may be appropriate.	
Land use	Small area of national park – mostly cleared for agriculture and mining.	
Current use	Domestic supply, small irrigation (horticulture) and service sector (tourism).	

Category	Information	Issue (impact risk and knowledge gap)
Beenup		
Stock and domestic unlicensed	Small areas of use close to Augusta town site and outlying properties.	
Future demand	Increased demand for service sector, domestic supply, viticulture and horticulture.	
Rosa		
Hydrogeology	Limited by sedimentation deposition in upper reaches of the Blackwood Plateau. Shallow system with thin depth. Overlies the Leederville (unconfined in some areas along watercourses and upper parts of catchments).	May be connection in places with underlying Vasse member.
Geology	Predominantly lateritic profile, with areas of alluvium deposits (valleys and paleochannels).	
Monitoring		Increased pumping – change in amplitude
Recharge	Rainfall recharge.	
Through flow	Moves south out to Flinders bay; Blackwood River and Hardy inlet.	
Seawater interface and drainage	Drainage into rivers and waterways	Issue of plantations changing drainage flow (overland).
Climate	Wet are of State. 1100–1400 mm rainfall. Wet areas into Sept/Oct on surface.	Climate uncertain on declining rainfall 900–1100 mm – may impact on water levels and recharge.
ASS	High risk of PASS in 6 m depth of soil profile. Concern with summer water levels declining and exposing soils (winter water levels rise taking acid with it).	Issue of nutrient application and drainage (excavation) impacts – land use to be managed through plan and advice to the DAF and LGA. All applications will need to follow ASS protocols and monitoring.
Groundwater-dependent systems		Not determined.
Land use	Half National Park – remainder cleared for agriculture.	
Current use	Small scale use – domestic and horticulture. Plantation developments are an issue, using groundwater and dewatering soil profile. Protection of the National park areas priority.	

Category	Information	Issue (impact risk and knowledge gap)
Rosa		
Stock and domestic unlicensed	Small areas of use close to Witchcliffe and Rosa town sites and outlying properties.	
Future demand	Limited future demand. Uncertainty of supply.	
Scott		
Hydrogeology	Multiple wetland features. Ponding of water on surface (dampland / sumpland) during winter (into Oct). Impacts from pumping during summer months – when water is used. Shallow system (6 m) on plains, deep system in dunal areas (south of Scott River). Deep sands.	May be confined from Leederville (Mowen aquitard). May be connection in places.
Geology	Predominantly sandy dunal systems. Majority is underlain by ferringous laterite. Remainder is deep sand dunes and coastal deposits.	
Monitoring		Declining summer water levels – winter stable. Increased pumping – change in amplitude
Recharge	Rainfall recharge; may support wetlands and surface flow into Scott River.	
Through flow	Moves south into Scott River, Flinders Bay and wetlands.	Declining rainfall and use may impact on through flow reaching river and wetlands.
Seawater interface and drainage	Drainage issue – particularly with the Scott River (increased pH and water quality issues).	Drainage influence in recharge and discharge into wetlands/Scott River need to be managed. ASS issue with new drains.
Climate	Wet are of State. 1100–1400 mm rainfall. Wet areas into Sept/Oct on surface.	Declining over last 10 years – may impact on water levels and recharge. Climate uncertain on declining rainfall 900–1100 mm.
ASS	High risk of PASS in 6 m depth of soil profile. All applications will need to follow ASS protocols and monitoring.	Issue of nutrient application and drainage (excavation) impacts – land use to be managed through plan and advice to the DAF and LGA. All applications will need to follow ASS protocols and monitoring.
Groundwater-dependent systems	SWAMS model outputs show severe risk to Gingilup wetlands (and one other reference site) under all recharge scenarios while ESCP model indicates low risk.	Large-scale abstraction would be undesirable close to identified GDEs (including Scott River). ASS risk area

Category	Information	Issue (impact risk and knowledge gap)
Scott		
Land use	Predominantly cleared for agriculture.	Issue of plantations and expansion or clearing of plantations.
Current use	Small scale use – pumping and application rates issue. Protection of the National park areas priority. Mostly dairy and pasture use – deeper confined aquifers for irrigation.	Issue of land use and irrigation practices when soil profile is wet less than 1m from surface. Education required - through DAF. Plantation developments are an issue using groundwater and dewatering soil profile (ASS issue).
Stock and domestic unlicensed	Potential use for domestic and stock water supply for dairy farms.	
Future demand	Any future demand will likely replace deeper confined aquifer use. In order to minimise impacts on wetland and TEC features the impacts need to be spread.	Impacts need to be managed on a regional and local scale in this aquifer on the Scott coastal plain. ASS tests will be required for licensing.
Jasper		
Hydrogeology	Multiple wetland features. Ponding of water on surface (dampland/ sumpland) during winter (into Oct). Impacts from pumping during summer months – when water is used. Shallow system (6 m) on plains, deep system in dunal areas (south of Scott River). Deep sands. May be confined from Leederville (Mowen aquitard). May be connection in places.	Overlies Yarragadee – possible impacts with wetland areas; drainage issue and ASS
Geology	Predominantly sandy dunal systems underlain by ferringous laterite and granite derived material. Remainder is deep sand dunes and coastal deposits with Tamala limestone formation on coastline with granite outcrops.	
Monitoring		Declining summer water levels – winter stable. Increased pumping – change in amplitude
Recharge	Rainfall recharge; may support wetlands and surface flow into Scott River.	
Through flow	Moves south into Scott River, Flinders Bay and wetlands.	Declining rainfall and use may impact on through flow reaching river and wetlands.
Seawater interface and drainage	Drainage issue – particularly with the Scott River (increased pH and water quality issues).	Drainage influence in recharge and discharge into wetlands/Scott River need to be managed. ASS issue with new drains.

Category	Information	Issue (impact risk and knowledge gap)
Jasper		
Climate	Wet are of State. 1100–1400 mm rainfall. Wet areas into Sept/Oct on surface.	Climate uncertain on declining rainfall 900–1100 mm – may impact on water levels and recharge.
ASS	High risk of PASS in 6 m depth of soil profile. Concern with summer water levels declining and exposing soils (winter water levels rise taking acid with it).	Issue of nutrient application and drainage (excavation) impacts – land use to be managed through plan and advice to the DAF and LGA. All applications will need to follow ASS protocols and monitoring.
Groundwater-dependent systems	SWAMS model indicates moderate to severe risk at several sites (including Lake Jasper) under all recharge scenarios while ESCP indicates similar levels of risk under the low recharge scenarios.	Higher potential for impacts here than in most other areas of the Scott CP and Blackwood Plateau due to hydrogeology (superficial over Yarragadee), high ecological values and risk area for ASS.
Land use	Predominantly National Park with areas cleared for agriculture.	Issue of plantations and expansion or clearing of plantations.
Current use	Pasture and stock water – with limited use.	
Stock and domestic unlicensed	Potential use for domestic and stock water supply for dairy farms.	
Future demand	Any future demand will likely replace deeper confined aquifer use. In order to minimise impacts on wetland and TEC features the impacts need to be spread.	

Table A4 Allocation limit factors for the Superficial aquifers

Groundwater area	Subarea	Old allocation limit*	Calculated allocation limit**	Model*	Licensed entitlements	Estimated stock and domestic	New allocation limit
South West Coastal	Harvey	15 700 000	11 500 000	-	1 733 800	10 000	11 500 000
	Lake Preston North	19 800 000	7 000 000	-	1 195 200	10 000	9 300 000
	Lake Preston South		7 000 000	-	11 386 740	10 000	10 500 000
Bunbury	Bunbury West	5 100 000	1 540 000)	1 500 000 (100% of recharge)	1 025 050	61 000	2 000 000
	Bunbury East	900 000	720 000	1 270 000 (100% of recharge)	347 310	60 000	700 000
	Dardanup	700 000	210 000	410 000 (storage depletion)	42 800	10 000	290 000
Busselton–Capel	Donnybrook	500 000	-	230 000 (100% of recharge)	372 040	50 000	500 000
	Busselton–Capel	27 000 000	8 100 000	5 490 000 (100% of recharge)	4 320 165	500 000	8 000 000
	Dunsborough–Vasse	8 800 000	2 640 000	1 740 000 (100% of recharge. Licensed use may be causing storage depletion)	3 447 610	500 000	4 500 000
	Cowaramup	900 000	-	Cowaramup model 900 000kL/yr	615 700	25 000	900 000
	Cape to Cape North	50 000	-	-	376 000	120 000	900 000
Blackwood	Cape to Cape South	300 000	-	-	314 225	100 000	600 000

Groundwater area	Subarea	Old allocation limit*	Calculated allocation limit**	Model*	Licensed entitlements	Estimated stock and domestic	New allocation limit
Blackwood	Rosa	100 000	980 000	Assuming 1.4 GL leaks into the Leederville then there is 25 000 available for licensing	75 600	15 000	100 000
	Beenup	50 000	2 800 000	3 520 000 (potential for storage depletion)	23 400	10 000	1 400 000
	Scott	350 000	7 100 000	9 200 000 (100% of recharge)	271 000	25 000	2 000 000
	Jasper	100 000	4 200 000	28 200 000 (100% of recharge)	78 000	10 000	2 000 000
Total		**80 350 000**			**25 624 640**	**1 379 000**	**55 190 000**

*The model domain does not extend past the Bunbury groundwater area and does not cover the Leeuwin–Naturaliste ridge.

**Calculations using the previous methodology from 1994/95 plans and allowing for 70% to remain in the system. The formula does not apply on the Blackwood Plateau because of the change in geology and the nature of the aquifer.

Fractured rock

Category	Information	Issue (impact risk and knowledge gap)
Cape to Cape North and Cape to Cape south subareas		
Hydrogeology	Generally recharged through rainfall and potentially in some areas from stream flow.	Fractured rock (underground streams in some places) is unknown with regard to its hydrogeology. Likely to support surface water systems, caves and freshwater springs.
Monitoring	No monitoring at present.	Difficult to monitor due to nature of resource.
Recharge	Rainfall and surface water seepage; possibly through flow from surficial aquifer.	
Through flow	Through the limestone and fractured rock formations to the coast, wetlands, waterways and cave systems.	
ASS		PASS at depth not yet investigated
Groundwater-dependent systems		Not yet investigated
Land use	Predominantly cleared for agriculture, large areas of the coast protected by national park.	
Current use	Stock and domestic, viticulture, service sector	
Stock and domestic unlicensed	Potentially many unlicensed domestic bores and excavations	Unknown amounts of excavations and domestic bores
Future demand	Limited to domestic and other small uses at present.	

Table A5 Allocation limit factors for fractured rock

Groundwater area	Subarea	Aquifer	Old allocation limit	Model*	Licensed entitlements	Estimated stock and domestic**	New allocation limit
Busselton–Capel	Cape to Cape North	Fractured Rock	150 000	N/A	93 500	5000	100 000
Blackwood	Cape to Cape South	Fractured Rock	150 000	N/A	13 000	5000	50 000

Appendix B Previous methodology used for setting allocation limits

The previous methodology used for setting the allocation limits for the groundwater areas of Bunbury and Busselton–Capel are defined in the *Bunbury groundwater area management plan (1994)* and the *Busselton–Capel groundwater management plan (1995)* produced by the Water Authority of Western Australia. The methodology used in these plans was applied to the Blackwood groundwater area and other areas across the state.

The following descriptions and calculations have been summarised from the *Bunbury groundwater area management plan, (Water Authority 1994)* and the *Busselton–Capel groundwater management plan, (Water Authority 1995)*. This information is based on the old management subareas for each groundwater area (Figure B1). The subareas defined in these plans have been reviewed and updated through the development of the *South West groundwater areas allocation plan*.

The old methodology used was based on hydrogeological knowledge of the time and is limited in its understanding and accounting for groundwater-dependent systems, acid sulphate soils, water quality, seawater interface movement, groundwater level changes, aquifer connectivity and surface water interactions.

Superficial

The Superficial Aquifer supplies groundwater for both consumptive use and environmental features such as wetlands and native vegetation. Concerns associated with the retention of such environmental features and intrusion of the sea water wedge from the ocean, limits the quantity of groundwater that may be drawn.

Groundwater storage and availability on the coastal plains depends on the proportion of sand to clay, with high proportions of clay usually associated with poor-quality groundwater and low yields.

Generally the historical calculations show recharge to be 20% of the annual rainfall (depending on a number of factors). The limits were calculated using rough soil type distribution, area and rainfall of 850 mm/yr, with a 10% recharge rate for areas with sand/limestone and 3% for areas with mostly clay.

Generally 100% of this calculation became the allocation limit. In parts of subareas adjoining the coast, 25% of this recharge calculation was left for the environment, and 75% was made available for use.

Figure B1 Groundwater subareas from the original 1994 and 1995 groundwater management plans

The factors affecting the recharge rate and the calculation of the allocation limits were:

- vegetation cover
- rainfall and infiltration rates (average rainfall – 850 mm)
- depth to water table
- variable sediments e.g. clay, sand, limestone
- surface soil types and land use
- variable thickness of formation
- impacts from underlying formations
- presence of rivers, drains and wetlands
- lack of strongly defined regional flow system
- water quality.

The Superficial Aquifer is found on the Swan and Scott coastal plains and in the surficial sediments of the Leeuwin Naturaliste Ridge, river floodplains and alluvial/colluvial sediments in paleochannels.

Leederville Aquifer

The Leederville Aquifer is found across the Bunbury trough and the Vasse shelf, however it is absent on the Leeuwin Naturaliste Ridge, north of Australind and an area south of Bunbury town site. Recharge for the Leederville Aquifer occurs mainly above the Whicher Scarp on the Blackwood Plateau. A seawater interface exists along the coast, particularly along Geographe Bay and the Leschenault Inlet. The groundwater generally flows north from the Whicher Scarp to discharge offshore near Australind, and south of the Blackwood Plateau onto the Scott coastal plain and out to sea.

Box 1: Darcy's formula

$Q = K\ i\ b\ l$

Q = through flow (kL/day).

K = Hydraulic conductivity (m/day).

i = hydraulic gradient.

b = saturated thickness (m).

l = width of through flow section (m).

The hydraulic conductivity was calculated by Geological Society of Western Australia. Calculations for the recharge areas, based on cleared and forested land from 1991. The limits were calculated using through flow and recharge rates, taking into account water for seawater interface management. The division of the sustainable groundwater yield into the various management subareas was determined by taking into account estimated local demand, varying flow systems, local recharge potential, depth/thickness of the formation and hydrogeological factors (e.g. faults).

Through flow was used to estimate groundwater availability. This was calculated using Darcy's formula.

East of Darradup fault:

Originally calculated using k = 15 m/day, i = 0.0013, b = 100 m, l = 14.5 km = 11 GL/yr. As 27% of the recharge area had been cleared, it was assumed recharge increased by 2 to 3 times so groundwater availability was increased to 20 GL/yr. Of this 20 GL/yr:

3 GL/yr for seawater interface management

12 GL/yr allocated downstream to meet Bunbury groundwater area requirements

5 GL/yr distributed between Donnybrook, Elgin–Capel River and Jarrahwood subareas

Between Darradup and Busselton faults:

k=6 m/day, i = 0.0025, b = 100 m, l = 29 km = 16 GL/yr. Of this 16 GL/yr, 25% (4 GL/yr) allocated for seawater interface management. The remaining 12 GL/yr available for use in the Capel–Ludlow, Busselton-Jindong and Kingswood subareas (split between upper and lower Leederville).

Vasse Shelf:

k= 2 m/day, i = 0.003, b = 50 m, l = 14.5 km = 1.6 GL/yr. Taking into account induced recharge by pumping, this was increased to 6.4 GL/yr (distributed between Broadwater–Jindong, Quindalup–Vasse, and Cowaramup management subareas).

Yarragadee Aquifer

The Yarragadee Aquifer is only found in the Bunbury trough in the Southern Perth Basin, and is absent on the Vasse Shelf, Leeuwin Naturaliste Ridge and north of Australind. Recharge occurs mainly above the Whicher Scarp on the Blackwood Plateau. The groundwater generally flows north from the Whicher Scarp towards Bunbury, and south of the Blackwood River onto the Scott coastal plain, discharging off the coast (Geographe Bay and Flinders Bay).

Through flow was derived from aquifer slope, after estimating aquifer parameters using Darcy’s formula. Calculations of recharge areas were based on cleared and forested land from 1991. The limits were calculated using through flow and recharge rates. The calculated estimated through flow of 100 GL/yr was completely distributed between the subareas in the Bunbury and Busselton–Capel groundwater areas.

The reasoning behind this decision was based on the following:

- the proportion of recharge, which can safely be drawn, is dictated by factors such as the dependence of any environmental features on the aquifer, and the proximity of a seawater interface at the discharge boundary
- the discharge from the aquifer is entirely offshore

- due to the aquifers depth below the surface, the aquifer does not support any wetlands or vegetation
- by extracting large quantities of groundwater, the hydraulic gradient of the aquifer will increase, increasing the through flow and eventually inducing more recharge (Water Authority 1995).

Through flow was used to estimate groundwater availability. This was calculated using Darcy's formula Q = Kibl. For the Yarragadee, k= 25 m/day, i = 0.004, b = 600 m, l = 45 km. Through flow = 100 GL/yr

This was also applied to the calculation of the Yarragadee Aquifer allocation limits for the Blackwood groundwater area (20 GL/yr).

A later study estimated through flow at 37 GL/yr, but it was thought that pumping would induce more through flow, probably to around the 100 GL/yr calculated earlier. Of this 100 GL/yr, 40% was allocated east of the Darradup fault (Bunbury groundwater area and Jarrahwood, Elgin–Capel, Donnybrook subareas) and 60% allocated to Busselton–Chapman Hill, Capel–Ludlow and Kingswood subareas.

Sue Coal, Cockleshell Gully, Lesueur Sandstone and Fractured rock

Sue Coal Measures

The Sue Coal Measures is located on the Vasse Shelf. It is divided into two distinct flow systems by block faulting. The eastern flow is between the Wirring and Busselton faults, and the western flow is between the Wirring and Dunsborough faults. The formation has varying chemical and geological compositions between flows. The hydraulic conductivity varies between, and within the aquifer.

The calculations for the sustainable groundwater yield were based on permeability, hydraulic conductivity and the depth of the formation. Hydraulic conductivity has been estimated for each of the flow systems based on limited fieldwork. The calculations are estimates only and set at 75% of through flow. Until more data becomes available the groundwater availability of the aquifer and the allocation limits will remain conservative (WAWA, 1995).

Through flow was used to estimate availability.

- East of Wirring Fault: Through flow estimated at 2.3 GL/yr, but 25% of this was retained to maintain the seawater interface, so availability was 75% or 1.7 GL/yr (Broadwater–Jindong subareas)
- West of Wirring Fault: Through flow estimated at 25 GL/yr, but because it was thought this was probably overestimated; only 2.3 GL/yr was made available (Quindalup–Vasse and Cowaramup subareas).

Cockleshell Gully

The freshwater flow system of the Cockleshell Gully aquifer is considered to be part of the Yarragadee Aquifer. The Cockleshell Gully Formation in the Bunbury trough occurs at depth (below the Yarragadee Aquifer). The formation has not been extensively drilled and as such limited information was available. It has no true allocation limit. Availability is determined upon each application and considered on merit.

Lesueur Sandstone

The Lesueur Sandstone aquifer is present on the Scott coastal plain and Blackwood Plateau between Busselton and Dunsborough faults, on the Vasse shelf. The limit was determined using calculations based on permeability, hydraulic conductivity and the depth of the formation. The hydraulic conductivity has been estimated for each of the flow systems based on fieldwork. The calculations are estimates only and set at 75% of through flow.

Fractured rock

The Fractured rock system has a notional allocation limit, and the resource is allocated based on the licence applicant's ability to show that the required yield is obtainable and that the impacts of abstraction are acceptable.

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