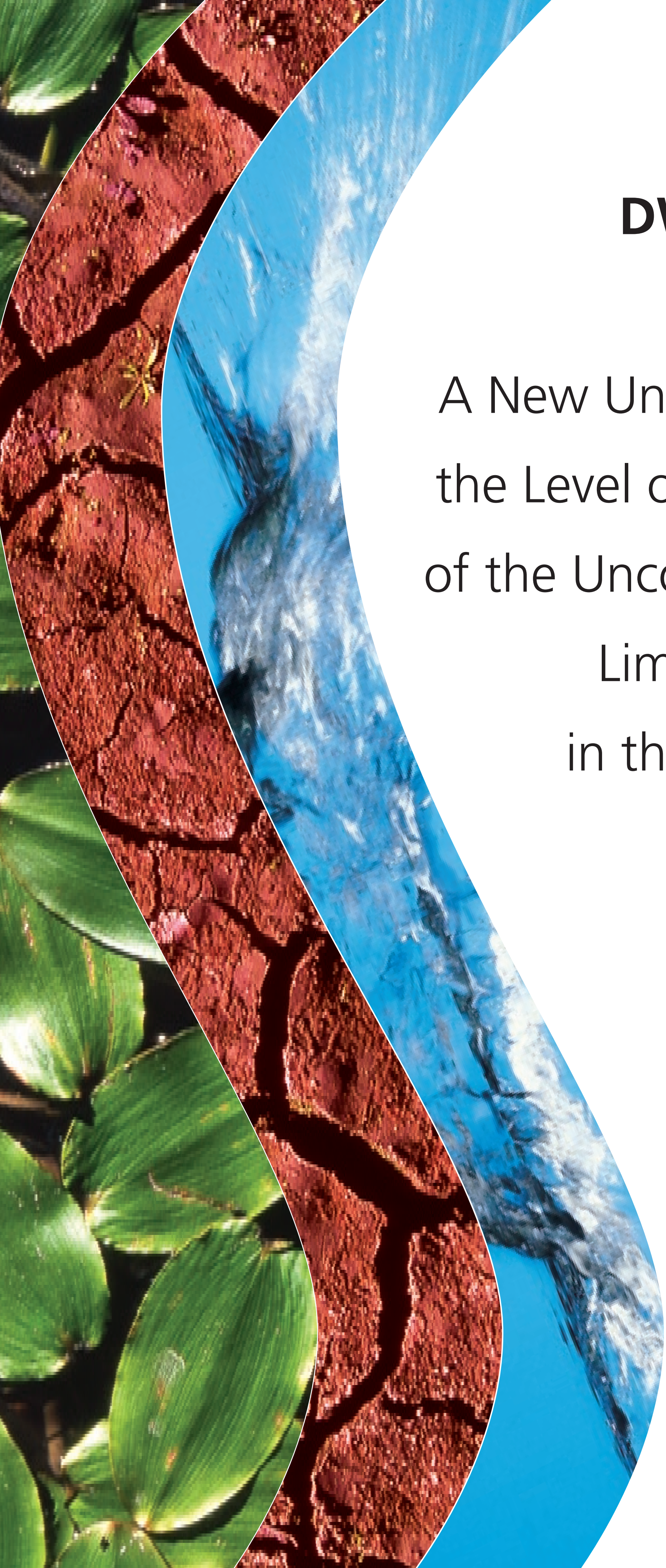

DWLBC REPORT

A New Understanding on the Level of Development of the Unconfined Tertiary Limestone Aquifer in the South East of South Australia

2007/11

Government of South Australia
Department of Water, Land and Biodiversity Conservation

A New Understanding on the Level of Development of the Unconfined Tertiary Limestone Aquifer in the South East of South Australia

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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EXECUTIVE SUMMARY

The purpose of this report is to combine the results of two significant bodies of work undertaken in the South East over the last five years, namely the Volumetric Conversion Project and the Review of Groundwater Resource Condition and Management Principles for the Tertiary Limestone Aquifer in the South East. Since the completion of these projects in late 2005 the South East Natural Resources Management Board, during their review of the 2001 Water Allocation Plans, have made revisions to the proposed Volumetric Conversion model and ran a stakeholder facilitated process to develop policy options for managing impacts of plantation forests on water resources. The revised volumetric conversion model and refined estimates of potential forestry impacts obtained through stakeholder discussions have resulted in substantial changes to the water balance calculations initially derived by Brown et al. (2006).

This report incorporates the new water balance calculations to facilitate future water allocation planning for the region. In addition, new methodologies have been developed for estimating both indicative volumetric allocation and indicative extraction at a management area scale, and the volume of water returned as drainage to the aquifer beneath surface (i.e. flood) irrigation. The methodology provides management area scale estimates for drainage based on both indicative allocation and indicative extraction from two irrigation seasons (2003–04 and 2004–05). The values of drainage are added to the Total Available Recharge term for each management area to produce a new variable called TARd.

A comparison of total inputs (TARd) against total outputs by indicative allocation (indicative licensed water allocation plus forestry, stock and domestic) and total outputs by indicative volumes extracted (indicative volumes extracted plus forestry, stock and domestic) has been made using delta V (Brown et al., 2006) as the comparison indicator. Of the 74 unconfined groundwater management areas, 40 management areas have either a negative delta V (based on allocation) or a groundwater resource condition trigger being exceeded. A further analysis of these 40 areas has been undertaken to assist in the development of resource management priorities.

1. INTRODUCTION

The Department of Water, Land & Biodiversity Conservation (DWLBC), in collaboration with the South East Natural Resources Management Board (SENRMB), has spent the last five years conducting two major water resource management projects: one on Volumetric Conversion and the other a review of resource condition and Permissible Annual Volumes (PAVs) for the unconfined aquifer (Brown et al., 2006). These two projects were planned to run in parallel until their completion dates, then have their results combined to assist with the review and amendment of the 2001 Water Allocation Plans. This report provides (i) an overview of the results of the two projects, (ii) a methodology for incorporating estimates of volumetric allocations and actual extractions into the water balance, and (iii) an indication of which areas in the South East (specifically the Lower Limestone Coast, Padthaway and Tatiara Prescribed Wells Areas) require greatest attention for future groundwater resource management.

Since the completion of these two major projects in late 2005, the South East Natural Resources Management Board, during their review of the 2001 Water Allocation Plans, have made revisions to the proposed Volumetric Conversion model and ran a stakeholder facilitated process to develop policy options for managing impacts of plantation forests on water resources. The revised volumetric conversion model and refined estimates of potential forestry impacts obtained through stakeholder discussions have resulted in substantial changes to the water balance calculations initially derived by Brown et al. (2006). This report incorporates the revised information.

2. BACKGROUND

2.1 PREVIOUS MANAGEMENT ARRANGEMENTS

The Irrigation Equivalent (IE) area-based water allocation system was developed for use in Prescribed Wells Areas in South Australia where non-metered groundwater supplies are used for irrigation. The unit of allocation is the Irrigation Equivalent (IE), defined as the Irrigation Requirement for 1 ha of Reference Crop (IR_0). Irrigators currently hold water licences specifying the number of IEs they can irrigate.

Crop Area Ratios (CAR) have been determined as the ratio of Irrigation Requirement for the Reference Crop (IR_0) to Irrigation Requirement for the range of crops being irrigated. The total area of each crop irrigated divided by the relevant CARs cannot exceed the value of IEs held on the licence.

This allocation system manages irrigation extraction by controlling the area of crops grown, rather than the amount of water applied. Irrigators may apply as much or as little irrigation as they choose, as long as they don't apply water to an area of crops greater than the equivalent value of the Irrigation Equivalents endorsed on their water licence.

The total volume allocated for each management area is calculated by multiplying the number of IEs allocated by the IR_0. This is then compared to the Volume for Licensed Allocation (VLA) to determine the level of over or under allocation.

To determine the annual water use within a management area under the area-based system, Annual Water Use Returns compiled by licensees are assessed to determine the area of each crop type irrigated. This data is then used to calculate the total number of IEs used. Total (theoretical) crop water use for the management area can then be compared to the VLA to determine the level of use (over use or under use).

Under the area-based allocation system a number of assumptions are made including:

- That all irrigation results in maximum crop water use according to the Irrigation Requirement of the crop.
- That water extracted in excess of Irrigation Requirements returns to the aquifer with no losses to evaporation.

The existing area-based water allocation system has been effective in regulating the maximum equivalent area of crop irrigated. However under this allocation system it is difficult to accurately determine levels of extraction from the resource and to identify and manage areas with sustainability problems.

2.2 REVIEW OF PERMISSIBLE ANNUAL VOLUMES

A comprehensive review of the groundwater resource condition and management framework for the Tertiary Limestone (unconfined) Aquifer (Brown et al., 2006) involved the development of a transparent and consistent methodology for estimating sustainable groundwater extraction rates in all 74 unconfined groundwater management areas.

Vertical groundwater recharge rates have been reviewed and updated to reflect new understandings of this component of the water balance for the region. Impacts of plantation forestry on natural recharge rates are no longer considered on the input side of the water balance ledger (see below). A nominal 10% of the mean annual vertical recharge to each management area (assuming dryland agriculture) has been set aside for environmental water requirements, including maintenance of groundwater dependent ecosystems and a component of lateral groundwater throughflow to mitigate possible adverse salinity impacts. The resulting volume available for extraction is now termed Total Available Recharge (TAR) to avoid confusion with the previous Permissible Annual Volume (PAV) terminology.

TAR = [Total Area – (Area of Native Vegetation + Lakes)] x Recharge Rate x 90%

The review then compared TAR with outputs to the groundwater balance, which are (i) licensed allocations, (ii) potential forestry impacts and (iii) unlicensed stock and domestic use. At the time of preparing the Brown et al. (2006) report, models for converting area-based allocations into volumetric allocations were incomplete. This meant that licensed allocations had to be estimated using the current irrigation equivalents (IE) system (see Section 2.1 above). However, these models are now complete (see Section 2.3 below) which allows more realistic representation of the true level of development of the groundwater resources in the region (Section 5).

Potential forestry impacts were divided into two components: recharge interception (termed recharge debits) and direct extraction. The following values were adopted by Brown et al. (2006) to estimate these components based on recent scientific investigations conducted in the region (e.g., Benyon & Doody, 2004):

- Recharge debits, calculated over threshold areas, with:
    - 83% of the recharge rate for the management area applied to softwood
    - 77% of the recharge rate for the management area applied to hardwood.
- Direct extraction, calculated over current forested estate areas where the seasonal greatest depth to groundwater is less than 7 m, with:
    - 2.6 ML/ha/yr for softwood
    - 2.3 ML/ha/yr for hardwood.

Total Outputs = Licensed allocations + Forestry impacts + Stock and domestic use

where Licensed allocations = irrigation, industry + public water supply
Forestry impacts = recharge debits + direct extraction

These groundwater management area-scale water balances provided insight to the current level of development of the resource, including which areas are over-allocated and under-allocated based upon the area-based irrigation allocation system (see Brown et al., 2006 for further details).

It should be noted that the concept of sustainable development of groundwater resources in the South East has historically assumed that allocating a portion of mean annual recharge (MAR) is sustainable. Whilst this assumption may be valid for some parts of the resource, particularly if significantly less than 100% of MAR is allocated, there are many parts of the region where this approach may be inappropriate. Future groundwater management in the

South East will move towards “adaptive management”, where the allocation system is flexible to change as resource condition and availability vary.

2.3 VOLUMETRIC CONVERSION

The Volumetric Conversion Project was initiated in 2002 to facilitate the process of converting the existing area-based water licences in the South East to licences with a new volumetric basis for allocation. In the period 2002–06 the project has conducted comprehensive field investigations to determine the volumes of water required to grow irrigated crops in the South East. The project has worked in partnership with licensees to develop a volumetric conversion model that provides reasonably efficient irrigators with sufficient water to continue to irrigate. The conversion model includes a base allocation that provides for crop water requirements and a delivery component that allows for system losses including evaporation and deep drainage. Some cropping systems will also be eligible for a “specialised production requirements” (SPR) component that provides additional allocation for practices such as frost control for vines. Licensees (if eligible) may also be able to apply for a temporary bridging volume to provide time to adjust to the new system.

Preliminary conversion rates are now available (Carruthers 2006) to enable the calculation of draft volumetric allocations for each water licence. These conversion rates have been determined using the best available science and extensive field data. This data includes a dataset of more than 5000 volume extracted records collected from South East irrigation properties as well as comprehensive information on climatic conditions, soil variability and crop production systems.

The reissuing of existing area-based water licences as licences with volumetric allocations, will not begin until the new Water Allocation Plans have been adopted. However the proposed conversion model and associated conversion rates can now be used to determine indicative volumetric allocations for each groundwater management area in the region.

2.4 ESTIMATION OF DEEP DRAINAGE BENEATH FLOOD IRRIGATION

Deep drainage beneath flood irrigation has been shown to be an important component of the water balance in some management areas. A methodology to incorporate drainage estimates into calculated TAR values for each unconfined groundwater management area has been developed using data from the volumetric conversion dataset (Sections 4.3 and 4.4). TARd is defined as the total available recharge for allocation, plus the contribution from deep drainage beneath flood irrigation, determined for each unconfined groundwater management area.

3. AIMS

The main aims of this report are:

- To develop a methodology to determine indicative volumetric allocations for each unconfined groundwater management area.
- To develop a methodology to determine indicative volume extracted during an irrigation season for each unconfined groundwater management area.
- To develop a methodology for incorporating deep drainage beneath flood irrigation into TAR to enable the determination of TARd for each unconfined groundwater management area.
- To provide an update on refined estimates of the potential impacts of plantation forestry on water resources, incorporating changes to recharge interception and direct extraction calculations, and including separation of commercial and farm forestry areas.
- To compare indicative volumetric allocations and indicative volumes extracted (for the 2003–04 and 2004–05 irrigation seasons) with the maximum potential volume of water available for allocation (i.e., TARd) to provide a more realistic indication of the current level of allocation and use of the unconfined tertiary limestone aquifer in the region.
- To provide an update of resource condition in terms of recent groundwater level and salinity trends.

4. METHODOLOGY

4.1 INDICATIVE VOLUMETRIC ALLOCATIONS

The reissuing of existing area-based water licences as licences with volumetric allocations, will not begin until the new Water Allocation Plans have been adopted. However the proposed conversion model and associated conversion rates (Carruthers 2006) can now be used to determine indicative volumetric allocations for each groundwater management area in the region.

It should be noted that the indicative volumetric allocations calculated in this report are based on the best available information at this time. Final volumetric allocations will not be known until the Minister adopts the reviewed Water Allocation Plans and the process of reissuing existing licenses with new volumetric allocations is finalised.

The proposed conversion model is shown below (Fig. 1). All licensees will receive a Base Allocation and a Delivery Component. The base allocation provides for crop irrigation requirements (see Definition of Net Irrigation Requirements in the South East of South Australia, Skewes 2006 for more information). Some licensees may also be eligible for a Crop Adjustment Factor that provides additional base allocation where, due to initial calculation problems, the existing area-based allocation does not provide adequate allocation.

The delivery component is the volume of water needed in excess of the crop irrigation requirements to account for irrigation system losses (evaporation losses, deep drainage etc.). In certain crop production systems it is necessary to use water for other activities such as frost control for vines which is not provided by the base allocation and delivery component. This water will be provided through the Specialised Production Requirements model component.

The Bridging Volume is an additional temporary water allocation designed to give irrigators who are currently pumping in excess of their new volumetric allocation time to adjust to the new system. This report does not attempt to calculate a figure for indicative bridging volumes.

Additional details on the various components of the model are provided in Carruthers (2006), Carruthers et al (2006a, 2006b), Latcham et al (2006), Pudney (2006), Pudney et al (2006) and Skewes (2006).

4.2 DETAILED METHODOLOGY FOR CALCULATION OF INDICATIVE VOLUMETRIC ALLOCATIONS

The methodology that has been used to calculate indicative volumetric allocations in accordance with the volumetric conversion model is described below.

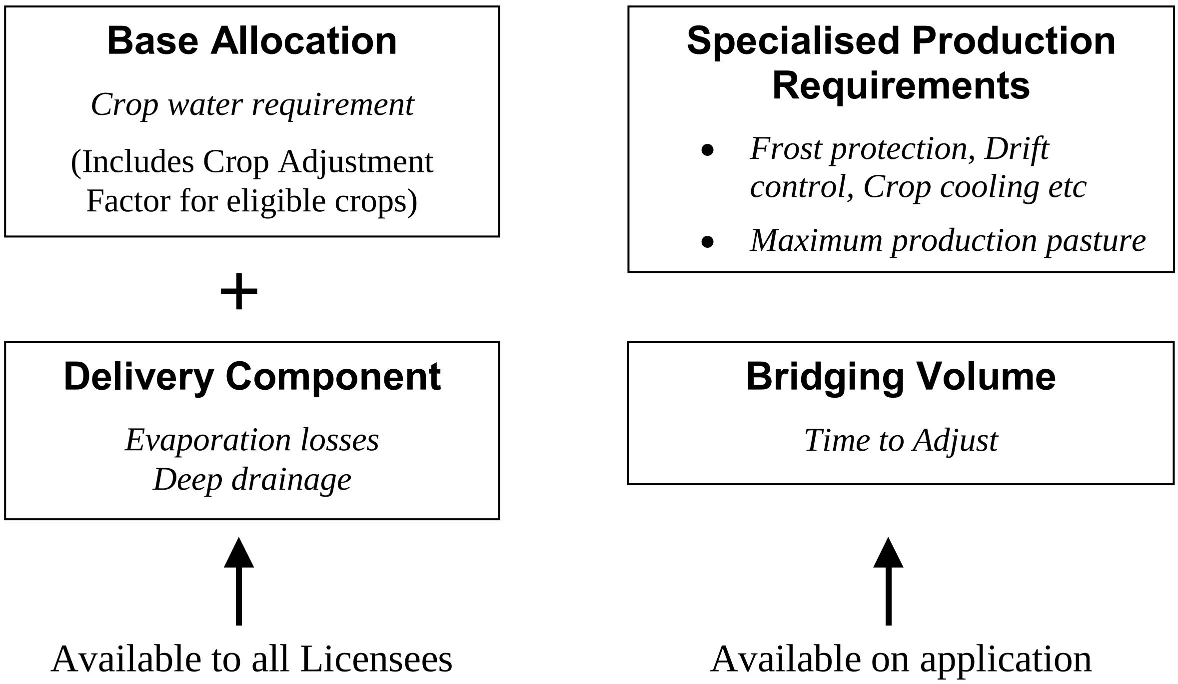


Figure 1. Proposed Volumetric Conversion Model

4.2.1 PROCESS FOR CALCULATING BASE ALLOCATION

$$V_{BA} = haIE_T \times NIRo$$

where V_{BA} is the total volume of Base Allocation, $haIE_T$ is the total number of hectares of irrigation equivalents allocated and NIRo is the Net Irrigation for Reference Crop for the climatic band associated with each management area.

4.2.2 PROCESS FOR CALCULATING DELIVERY COMPONENT

$$V_{DC} = [(V_{BA} \times P_D) \times D_{DC}] + [(V_{BA} \times P_F) \times F_{DC}] + [(V_{BA} \times P_S) \times S_{DC}]$$

where V_{DC} is the summed volume of all system Delivery Components, P_D P_F P_S are the relative proportions of drip, flood and spray irrigation based on current practices (2003–04) and D_{DC} F_{DC} and S_{DC} are the delivery component factors for drip, flood and spray irrigation.

4.2.3 PROCESS FOR CALCULATING CROP ADJUSTMENT FACTOR

$$CAF_{0304} = haIE_E \times NIRo$$

where CAF_{0304} is the total volume of Crop Adjustment Factor (CAF) allocations and $haIE_E$ is the extra number of irrigation equivalents required to account for all crops eligible for a CAF based on the area of these crops grown during the 2003–04 season.

4.2.4 PROCESS FOR CALCULATING SPECIALISED PRODUCTION REQUIREMENTS

$$SPR_{0304} = (A_{C1} \times R_{C1}) + (A_{C2} \times R_{C2})$$

where SPR_{0304} is the total volume of SPR allocations determined for all eligible crops based on the 2003–04 season, A_{C1} is the area of SPR Crop 1 (in ha) and R_{C1} is the additional water requirement for SPR Crop 1 (in ML/ha) etc.

Note: Areas for vine frost protection were provided by the viticulture industry and Maximum Production Pasture allocations calculated for the top 20% of the volume extracted data (for pasture sites only) in Delivery zones 10 and 11.

4.2.5 INDICATIVE ALLOCATION – CONVERSION OF IE'S

$$V_{IA} = V_{BA} + V_{DC} + CAF_{0304} + SPR_{0304}$$

where V_{IA} is the total volume of irrigation allocations converted from haIE licenses for each management area, V_{BA} is the total volume of Base Allocation, V_{DC} is the summed volume of all system Delivery Components, CAF_{0304} is the total volume of Crop Adjustment Factor allocations based on the 2003–04 season and SPR_{0304} is the total volume of SPR allocations determined for all eligible crops from the 2003–04 season.

NOTE: Calculations for Indicative Allocation – Conversion of IE's assumes full use of all haIE licenses. Any unused allocations have been issued delivery components based on the proportional split of irrigation system types for each management area based on the 2003–04 activities.

4.2.6 TOTAL INDICATIVE ALLOCATION

$$V_{LA} = V_{IA} + V_{EA} + V_{HA}$$

where V_{LA} is the total indicative volume of all licensed allocations, V_{EA} is the volume of existing volumetric allocations and V_{HA} is the total volume of holding allocations for each management area.

NOTE: No adjustments have been made to existing volumetric allocations currently used for either irrigation or aquaculture, which may be subject to adjustments post conversion.

4.3 INDICATIVE VOLUME EXTRACTED

Whilst meters are currently being installed on all irrigation wells in the South East, complete metered extraction data for each management area is not yet available. The dataset of volume-extracted data that has been compiled by the Volumetric Conversion Project enables the calculation of indicative volume extracted for each Management Area. The method for calculating indicative volume extracted uses the 2003–04 irrigation season as an example, however this methodology could be used for any irrigation season provided the data was available.

4.3.1 INDICATIVE IRRIGATION EXTRACTION

Step 1: Determine the total theoretical crop water use for 2003–04

$$CWU_{0304} = haIE_{Used} \times NIRo_{0304}$$

where CWU_{0304} is the total theoretical crop water use for the 2003–04 season, $haIE_{used}$ is the number of haIE's actually used and $NIRo_{0304}$ is the theoretical Net Irrigation Requirement for reference crop calculated for the 2003–04 season.

Step 2: Calculate the indicative volume extracted for the 2003–04 season using median volume extracted values for each irrigation system type and management area

$$V_{0304} = CWU_{0304} + \left[\left(CWU_{0304} \times P_D\right) \times D_M\right] + \left[\left(CWU_{0304} \times P_F\right) \times F_M\right] + \left[\left(CWU_{0304} \times P_S\right) \times S_M\right] + CAF_{0304} + SPR_{0304}$$

where V_{0304} is the total indicative volume extracted for the 2003–04 season, P_D P_F P_S are the relative proportions of drip, flood and spray irrigation for each management area for the season and D_M F_M and S_S are the median delivery factors for drip, flood and spray irrigation for the delivery zone associated with each management area, CAF_{0304} is the total volume of CAF allocations based on the 2003–04 season and SPR_{0304} is the total volume of SPR allocations determined for all eligible crops based on the 2003–04 season.

4.3.2 INDICATIVE LICENSED EXTRACTION

$$V_{LE\,0304} = V_{0304} + V_{EA0304}$$

where VLE_{0304} is the indicative total volume extracted for licensed water use and VEA_{0304} represents the volume of existing volumetric allocations.

NOTE: Existing volumetric allocations are assumed to be fully utilised.

4.4 ESTIMATING DEEP DRAINAGE – BASED ON INDICATIVE ALLOCATIONS

Deep drainage beneath flood irrigation has been shown to be an important component of the water balance in some management areas, particularly those with large areas of flood irrigation. It should be noted however, that deep drainage may not return to the source aquifer.

4.4.1 TOTAL ESTIMATED DRAINAGE

$$V_{TD} = V_{UD} + V_{CD}$$

where V_{TD} is the total potential drainage volume from both the unconfined and confined aquifers based on maximum use of allocations at the current proportional split of flood irrigated areas, V_{UD} is the total potential drainage volume for the unconfined aquifer and V_{CD} is the total potential drainage volume from the confined aquifer that contributes to the unconfined aquifer water budget.

NOTE: Drainage calculations have been based on the current proportional split of flood irrigation per management area. The median volume extracted values for flood irrigation per management area were used. Where the median volume extracted was less than the theoretical (or maximum) crop water use, no drainage was calculated.

4.4.2 PROCESS FOR CALCULATING DRAINAGE FROM THE UNCONFINED AQUIFER

Step 1: Determine median flood volume extracted assuming full use of allocations at the current proportional split of flood irrigation for each management area

$$V_{FM} = \left[\left((haIE_T \times P_F) \times NIRo\right) \times \left(1 + F_M\right)\right] + CAF_{0304} + SPR_{0304}$$

where V_{FM} is the median flood volume extracted assuming full use of allocations using current proportional split, P_F is the relative proportion of flood irrigation based on current practices (2003–04) and F_M is the median delivery component factor for flood irrigation for the delivery zone associated with each management area.

Step 2: Subtract total losses (from the aquifer) from the volume extracted to determine surplus water (ie surplus water = drainage)

$$V_{UD} = V_{FM} - \left[\left(V_{FM} \times E_F\right) + \left((haIE_T \times P_F) \times NIRo\right)\right]$$

where V_{UD} is the total potential drainage volume due to pumping from the unconfined aquifer, and E_F is the evaporation from flood irrigation.

Note: $\left((haIE_T \times P_F) \times NIRo\right)$ *represents the theoretical (or maximum) crop water use component of the water budget. Evaporation estimates used were 2.5% of the volume extracted for flood irrigation on light / free draining soils and 5% for heavy soils.*

4.4.3 PROCESS FOR CALCULATING DRAINAGE FROM THE CONFINED AQUIFER

$$V_{CD} = V_{FM} - \left[\left(V_{FM} \times E_F\right) + \left((haIE_T \times P_F) \times NIRo\right)\right]$$

where V_{CD} is the total potential drainage volume due to pumping from the confined aquifer that contributes to the unconfined aquifer water budget. The total volume is proportioned amongst the relative unconfined management areas based on the location of each confined aquifer licence.

Note: $haIE_T$ and P_F are determined for the confined aquifer management areas and NIRo is based on the location of each confined aquifer licence with respect to the climatic bands.

4.5 ESTIMATING DEEP DRAINAGE – BASED ON INDICATIVE (SEASONAL) VOLUME EXTRACTED

4.5.1 2003–04 ESTIMATED DRAINAGE

$$V_{TD0304} = V_{UD0304} + V_{CD0304}$$

where V_{TD0304} is the total estimated drainage volume from both the unconfined and confined aquifers for the 2003–04 season based on the actual areas of flood irrigation and using median volume extracted values for the season, V_{UD0304} is the estimated drainage volume due to pumping from the unconfined aquifer and V_{CD0304} is the estimated drainage volume due to pumping from the confined aquifer that contributed to the 2003–04 unconfined aquifer water budget.

NOTE: Drainage calculations have been based on the area of flood irrigation per management area from the 2003–04 season. The median volume extracted values for flood irrigation per management area were used. Where the median volume extracted was less than the theoretical (or maximum) crop water use no drainage was calculated.

4.5.2 PROCESS FOR CALCULATING SEASONAL DRAINAGE FROM THE UNCONFINED AQUIFER

Step 1: Determine median flood volume extracted based on the haIE's used at the current proportional split for flood irrigation per management area.

$$V_{F0304} = \left[\left((haIE_{Used} \times P_F) \times NIRo_{0304}\right) \times \left(1 + F_M\right)\right] + CAF_{0304} + SPR_{0304}$$

where VF_{0304} is the median flood volume extracted for the 2003–04 area of flood irrigation, P_F is the relative proportion of flood irrigation based for the 2003–04 season and F_M is the median volume extracted value for flood irrigation for the relative delivery zone associated with each management area.

Step 2: Subtract total losses (to the aquifer) from the volume extracted to determine surplus water (i.e., surplus water = drainage)

$$V_{UD0304} = V_{F0304} - \left[\left(V_{F0304} \times E_F\right) + \left((haIE_{Used} \times P_F) \times NIRo_{0304}\right)\right]$$

where VUD_{0304} is the estimated drainage volume due to pumping from the unconfined aquifer, E_F is the total volume of evaporation from flood irrigation using 2.5% of the median volume extracted for flood irrigation (VF_{0304}) on light / free draining soils and 5% for heavy soils.

Note: $\left((haIE_{Used} \times P_F) \times NIRo_{0304}\right)$ *represents the theoretical crop water use component of the flood irrigation water budget for the 2003–04 season.*

4.5.3 PROCESS FOR CALCULATING SEASONAL DRAINAGE FROM THE CONFINED AQUIFER

$$V_{CD0304} = V_{F0304} - \left[\left(V_{F0304} \times E_F\right) + \left((haIE_{Used} \times P_F) \times NIRo_{0304}\right)\right]$$

where VCD_{0304} is the estimated drainage volume from the confined aquifer that contributed to the 2003–04 unconfined aquifer water budget. The total volume is proportioned amongst the relative unconfined management areas based on the location of confined aquifer licenses.

Note: $haIE_{Used}$ and P_F are determined for the confined aquifer management areas and $NIRo_{0304}$ is based on the location of each confined aquifer licence with respect to the climatic bands.

5. CHANGES TO THE VOLUMETRIC CONVERSION MODEL

5.1 VOLUMETRIC CONVERSION MODEL - DELIVERY COMPONENT FOR DRIP IRRIGATION

The delivery component of the volumetric conversion model is the volume of water needed in excess of the crop irrigation requirements to account for irrigation systems losses (Latcham 2006). It was originally recommended that the delivery factor for drip irrigation should be an additional 11% of the base allocation (Carruthers 2006).

Whilst the South East Natural Resources Management Board has adopted the model proposed by the Volumetric Conversion team, it has developed an alternative operating regime aimed at enabling tradeable components to be transferred between water holding, water taking, industrial and aquaculture allocations and offset against forestry in the Lower South East. Under these alternative arrangements, the tradeable component of the volumetric allocation is now the sum of the base allocation plus an additional 18% of the base allocation (representing 85% irrigation efficiency). This results in an additional volume of 7% of the base allocation now being required for drip irrigation. The indicative volumetric allocations that have been calculated are now based on the revised delivery factor for drip irrigation of 18%.

6. CHANGES TO THE ESTIMATES OF RECHARGE RATES AND THE POTENTIAL IMPACTS OF PLANTATION FORESTS

6.1 CHANGES TO ADOPTED RECHARGE RATES FOR ZONES 2A AND 3A

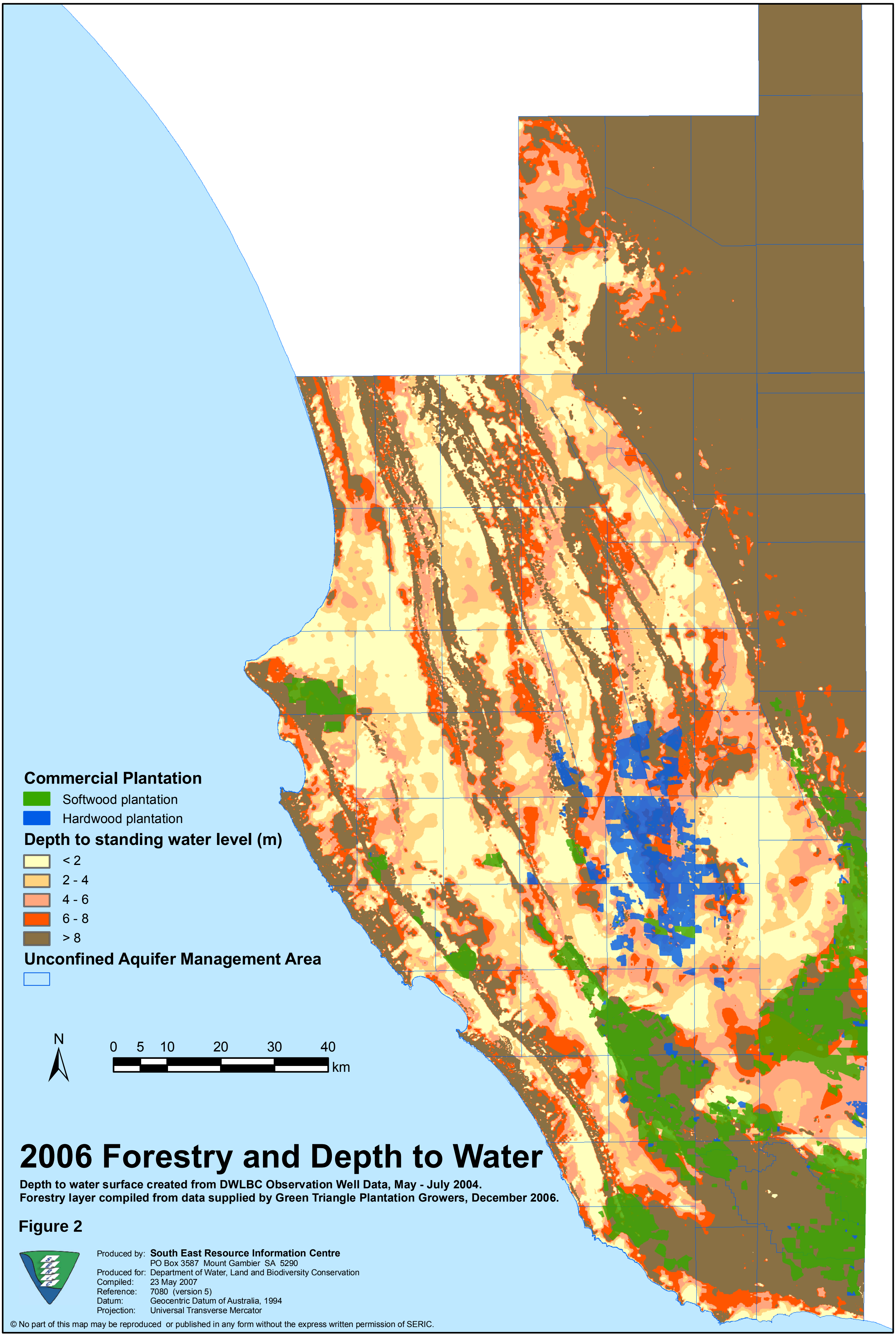
During the period July-September 2006 the South East Natural Resources Management Board (SENRMB) ran a facilitated negotiation process with forestry and non-forestry stakeholders to develop policy options for managing the impacts of plantation forests on groundwater resources. Following concerns by the forest industry that the work of Brown et al. (2006) had not updated the recharge rates for management areas in the Border Designated Area (BDA) (except for Zone 1A), a review of recharge was undertaken for Zones 2A, 3A and 4A. The review involved a comparison of recharge rates calculated by Brown et al. (2006) for similar soil types in adjacent management areas with those used originally for the BDA by Bradley et al. (1995). The result of the review is that the previously adopted recharge rates for Zone 2A and Zone 3A have been updated from 95 and 100 mm/yr to 140 and 120 mm/yr respectively. This has impacted on both the TAR and Forest Recharge Debit calculations (see App. 1). The adopted recharge rate for Zone 4A (actually four management areas within Zone 4A) was not changed from an area-weighted 66 mm/yr as the review produced a very similar value of ~70 mm/yr.

6.2 REFINED ESTIMATES OF POTENTIAL IMPACTS OF PLANTATION FORESTS

As a result of negotiations with the forest industry, the previously adopted recharge interception value for hardwood plantations (77%, section 2.2) was revised to 78%. This percentage applies to the mean annual recharge rate for non-irrigated pasture in each management area. The original direct extraction values adopted by Brown et al. (2006) for softwood and hardwood plantations (2.59 ML/ha/yr and 2.34 ML/ha/yr respectively) were also revised downwards (to 1.66 ML/ha/yr and 1.82 ML/ha/yr respectively) to better reflect current forest management practices.

During the SENRMB facilitated process, DWLBC in conjunction with the South East Resource Information Centre (SERIC) developed a sophisticated GIS model to derive a more accurate depth to water table map for the region, reflecting the topographic relief caused by the NW-SE trending dune ridges that transect the South East (Fig. 2). This new mapping approach has revealed that ~70% of the current blue gum estate (and ~20% of the current pine estate) overlies water tables with a median depth of less than 6 m.

Previous estimates of direct extraction by plantation forests at a management area scale have been based on 2005 (or earlier) plantation areas sourced from the major forest companies through SERIC. These calculations had inadvertently included areas of farm



2006 Forestry and Depth to Water

Depth to water surface created from DWLBC Observation Well Data, May - July 2004.
Forestry layer compiled from data supplied by Green Triangle Plantation Growers, December 2006.

Figure 2

Produced by: **South East Resource Information Centre**
PO Box 3587 Mount Gambier SA 5290
Produced for: Department of Water, Land and Biodiversity Conservation
Compiled: 23 May 2007
Reference: 7080 (version 5)
Datum: Geocentric Datum of Australia, 1994
Projection: Universal Transverse Mercator

forestry, which are exempt from any current legislation surrounding water use. In order to rectify this situation, DWLBC and ForestrySA worked with SERIC in May 2007 to firstly update the plantation areas to December 2006, and secondly separate areas of farm forestry from areas of commercial forestry.

The revised direct extraction rates, refined depth to water table map and updated (December 2006) commercial forest areas have been used to recalculate the impacts of plantation groundwater extraction at both regional and management area scales (App. 1). For the Lower Limestone Coast Prescribed Wells Area, which contains all of the current commercial plantation estates in the South East, direct extraction by plantation forests amounts to ~7% of the Total Available Recharge (compared with ~17% of the TAR that is intercepted by plantations). On a management area scale, direct extraction ranges from ~0–50% of the TAR, which equates to up to ~17 000 ML/yr.

7. REFINING THE GROUNDWATER BUDGET

7.1 COMPARING INPUTS AGAINST OUTPUTS BY INDICATIVE ALLOCATION

Outcomes from the indicative volumetric allocations and deep drainage estimates can now be combined with other components to the groundwater balance to obtain a more accurate assessment of the water balance at a groundwater management area scale. This can be achieved by comparing total inputs (TAR) plus drainage (TARd) against total outputs: (i) licensed allocations, (ii) potential forestry impacts, (iii) stock and domestic use along with (iv) the gazetted strategic reserve.

7.1.1 TARD BASED ON INDICATIVE ALLOCATION

$$TARd = TAR + V_{TD}$$

where TARd is the Total Available Rechage plus estimated maximum potential deep drainage from flood irrigation allocations.

7.1.2 TOTAL OUTPUTS BASED ON INDICATIVE ALLOCATION

$$V_{TO} = V_{LA} + (V_{ST} + V_{HT}) + (V_{SWU} + V_{HWU}) + V_{SD} + V_{SR}$$

where V_{TO} is the total volume of outputs (all indicative licensed water allocation plus forestry, stock and domestic and the strategic reserve) from the unconfined aquifer, V_{LA} is the total indicative volume of all licensed allocations, V_{ST} + V_{HT} is the total forestry recharge debits from softwood and hardwood respectively (based on Threshold Areas), V_{SWU} + V_{HWU} is the total volume of groundwater potentially used by softwood and hardwood respectively (based on current areas at November 2005), V_{SD} is the total (estimated) volume of stock and domestic use and VSR is the volume set aside as the strategic reserve.

7.1.3 DELTA V (INDICATIVE ALLOCATION)

$$\Delta V = \frac{(TARd - V_{TO})}{TARd}$$

where ΔV is the difference between the TARd and the total outputs (all licensed water allocations plus forestry, stock and domestic and the strategic reserve) from the unconfined aquifer, expressed as a percentage of the TARd.

NOTE: Delta V (Indicative Allocation), assumes full use of all converted haIE licences (based on the 2003–04 proportional split of irrigation system types per management area) and existing volumetric licences.

7.2 COMPARING INPUTS AGAINST OUTPUTS BY INDICATIVE SEASONAL EXTRACTION

The outcomes from estimating the regional water balance can be further refined by comparing indicative seasonal extraction against the TARd (Total Available Recharge plus estimated seasonal drainage).

7.2.1 TARD BASED ON INDICATIVE SEASONAL EXTRACTION

$$TARd_{0304} = TAR + V_{TD0304}$$

where $TARd_{0304}$ represents the TAR plus estimated drainage for the 2003–04 irrigation season.

7.2.2 TOTAL OUTPUTS BASED ON INDICATIVE VOLUME EXTRACTED

$$V_{TO0304} = V_{0304} + V_{EA} + \left(V_{ST} + V_{HT}\right) + \left(V_{SWU} + V_{HWU}\right) + V_{SD} + V_{SR}$$

where VTO_{0304} is the total volume accounted for (all indicative volumes extracted plus forestry, stock and domestic and the strategic reserve) from the unconfined aquifer for the 2003–04 season, V_{EA} is the volume of existing volumetric allocations, V_{ST} + V_{HT} is the total forestry recharge debits from softwood and hardwood respectively (based on Threshold Areas), V_{SWU} + V_{HWU} is the total volume of groundwater potentially used by softwood and hardwood respectively (based on current areas at November 2005), V_{SD} is the total (estimated) volume of stock and domestic use and V_{SR} is the volume set aside as the strategic reserve.

7.2.3 DELTA V (INDICATIVE VOLUME EXTRACTED)

$$\Delta V_{0304} = \frac{\left(TARd_{0304} - V_{TO0304}\right)}{TARd_{0304}}$$

where ΔV_{0304} is the difference between the volume available for the season ($TARd_{0304}$) and the indicative seasonal volume extracted (all licensed water allocations plus forestry, stock and domestic and the strategic reserve) from the unconfined aquifer, expressed as a percentage of the $TARd_{0304}$.

8. RESULTS AND DISCUSSION

Carruthers et al. (2006) documented a proposed volumetric conversion model and associated conversion rates for the conversion of the current area-based water allocations to volumetric allocations. The issuing of volumetric allocations for all water licenses in the South East will not occur until the current review of Water Allocation Plans is complete and the reviewed Water Allocation Plans adopted by the Minister. The methodology described in this report enables the calculation of indicative volumetric allocations and indicative volumes extracted (2003–04 and 2004–05 irrigation seasons) for each of the 73 unconfined groundwater management areas (Table 1).

Brown et al. (2006) detailed Total Available Recharge (TAR) calculations for each of the unconfined groundwater management areas. It has been established that deep drainage from flood irrigation forms an important component of the water balance for some management areas. Using the methodology described in this report and data collected through the Volumetric Conversion Project, deep drainage from flood irrigation has been estimated for each groundwater management area. This enables values for Total Available Recharge incorporating drainage (TARd) to be determined for each management area.

It has also been established that direct extraction of groundwater by forestry is an important component of the water balance. The original direct extraction values associated with the potential impacts of forestry on groundwater resources as described by Brown et al. (2006) have been refined through the South East Natural Resources Management Board facilitated process. Calculation of these impacts using the revised direct extraction values with refined depth to water table maps and updated (December 2006) commercial forest areas have now been completed for each of the unconfined groundwater management areas affected.

A comparison of total inputs (TARd) against total outputs by indicative allocation (indicative licensed water allocation plus forestry, stock and domestic and the strategic reserve) and total outputs by indicative volumes extracted (indicative volumes extracted plus forestry, stock and domestic) has been made using delta V as the comparison indicator. The outcomes of these comparisons are summarised in Table 2 for each of the unconfined groundwater management areas, combining all components of the water balance in a manner that wasn't possible before.

For water resource management, priority areas are those where the delta V Allocation is a negative value, indicating the total potential outputs (volume allocated) are greater than the inputs (TARd). There is particular concern for management areas where delta V Extraction is also negative. In these areas the estimated volume currently being extracted from the unconfined aquifer is greater than TARd.

Table 1. Indicative allocation and use per groundwater management area

Unconfined Management Area	**Indicative Taking Allocation Conversion of IEs** (ML)	**2004–05 Indicative Irrigation Extraction** (ML)	**2003–04 Indicative Irrigation Extraction** (ML)
Lower Limestone Coast PWA			
Bangham	6 042	2 410	2 738
Beeamma	8 389	2 533	2 535
Benara	8 143	4 697	2 018
Blanche Central	2 747	1 720	872
Bool	1 406	420	201
Bowaka	15 978	5 475	2 714
Bray	1 775	41	50
Coles	8 721	625	140
Comaum	2 672	608	988
Compton	236	382	90
Conmurra	13 643	5 550	4 014
Donovans	19 814	11 868	10 304
Duffield	0	0	0
Fox	8 497	3 846	3 480
Frances	5 878	3 659	2 229
Glenburnie	15 411	6 100	6 353
Glenroy	8 388	2 953	3 038
Grey	25 229	6 380	5 048
Hacks	7 079	1 984	1 295
Hindmarsh	7 759	2 744	1 488
Hynam East	6 863	3 296	2 747
Hynam West	9 023	3 674	3 305
Joanna	13 322	5 087	4 952
Joyce	12 316	3 139	2 121
Kennion	3 985	1 400	1 345
Killanoola	13 792	2 701	1 899
Kongorong	11 814	6 866	5 508
Lacepede	925	174	150
Lake George	1 168	263	484
Landseer	3 084	771	522
Lochaber	2 577	1 315	464
Macdonnell	22 456	17 553	13 289
Marcollat	1 142	0	822
Mayurra	1 526	2 620	247
Minecrow	5 582	677	0
Monbulla	13 975	4 210	2 687
Moorak	3 462	849	707
Mount Benson	3 981	887	413
Mount Muirhead	1 491	116	45
Moyhall	2 102	1 089	324
Murrabinna	525	242	256
Myora	4 362	2 157	2 347

Unconfined Management Area	**Indicative Taking Allocation Conversion of IEs** (ML)	**2004–05 Indicative Irrigation Extraction** (ML)	**2003–04 Indicative Irrigation Extraction** (ML)
Ormerod	1 056	0	262
Peacock	0	0	0
Riddoch	12 897	3 799	2 070
Rivoli Bay	27	686	3
Ross	4 969	460	369
Short	21 306	6 452	4 327
Smith	3 333	5 411	967
Spence	5 644	2 389	1 697
Stewarts	44 115	19 532	19 990
Struan	6 886	3 057	2 973
Symon	2 674	1 046	1 191
Townsend	9 771	4 769	2 803
Waterhouse	6 854	2 039	1 625
Western Flat	1 391	254	347
Woolumbool	3 456	0	638
Young	2 475	3 287	838
Zone 2a	26 616	12 004	11 562
Zone 3a	39 931	13 403	12 391
Zone 5a	25 238	10 150	8 917
Total	**525 919**	**211 819**	**167 201**
Padthaway PWA			
Management Area 1	39 784	14 044	20 871
Management Area 2a	14 927	7 418	7 020
Management Area 2b	14 377	7 151	6 406
Management Area 3	7 479	4 063	3 511
Management Area 4	2 967	839	1 824
Total	**79 535**	**33 515**	**39 633**
Tatiara PWA			
Cannawigara	5 404	1 604	1 691
North Pendleton	11 375	6 540	5 790
Shaugh	10 012	1 803	697
Stirling	61 872	28 646	39 559
Tatiara	12 067	4 846	4 137
Willalooka	29 604	15 455	14 733
Wirrega	56 545	27 628	27 503
Zone 8a	6 391	602	759
Total	**193 272**	**87 124**	**94 869**
Grand total	**798 725**	**332 459**	**301 702**

Table 2. Summary of water account for the Lower Limestone Coast, Padthaway and Tatiara Prescribed Wells Areas, December 2006

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
	Unconfined Management Area	Total Available Recharge TAR (ML/yr)	Total Indicative Licensed Allocation *1 (ML/yr)	Estimated Flood Irrigation Drainage *2 (ML/yr)	TARd (Allocation) (ML/yr)	Commercial Forest Recharge Debits (Threshold & Excess) (ML/yr)	Commercial Forest Direct Extraction at December 2006 (ML/yr)	Farm Forestry Recharge Loss (ML/yr)	Stock & Domestic Use (ML/yr)	TOTAL ACCOUNT *3 (Allocation) (ML/yr)	Water Account Surplus/Deficit (ML/yr)	delta V Allocation	delta V 03/04 USE	delta V 04/05 Use	Water Level Trigger Exceeded	Salinity Trigger Exceeded
LOWER LIMESTONE COAST PWA	BANGHAM	5 408	6 076	271	5 679	0	0	149	155	6 380	-701	-12%	45%	50%		
	BEEAMMA	4 123	8 389	59	4 182	0	0	73	105	8 568	-4 386	-105%	34%	34%		
	BENARA	37 749	13 890	0	37 749	7 907	458	5	279	22 540	15 209	40%	60%	53%		
	BLANCHE CENTRAL	12 140	2 789	0	12 140	4 547	0	34	263	7 633	4 507	37%	53%	46%		
	BOOL	4 417	2 077	0	4 417	245	0	3	76	2 401	2 016	46%	71%	66%	Y	
	BOWAKA	16 107	18 479	8 596	24 703	224	0	21	238	18 962	5 741	23%	77%	72%		
	BRAY	17 118	7 432	0	17 118	1 677	30	0	219	9 358	7 760	45%	72%	72%		
	COLES	25 228	11 129	690	25 918	13 650	17 539	109	222	42 648	-16 730	-65%	-31%	-32%	Y	
	COMAUM	3 388	2 717	0	3 388	1 235	151	2	30	4 135	-747	-22%	28%	39%		
	COMPTON	5 921	889	0	5 921	1 153	0	0	191	2 233	3 688	62%	67%	62%		
	CONMURRA	29 764	22 446	4 986	34 750	1 623	673	513	400	25 656	9 094	26%	58%	57%		
	DONOVANS	34 394	20 235	0	34 394	5 600	0	151	645	26 631	7 762	23%	50%	46%		
	DUFFIELD	9 225	859	0	9 225	0	0	1	185	1 045	8 179	89%	96%	96%		
	FOX	20 370	16 394	1 350	21 720	4 574	1 095	139	249	22 451	-731	-3%	33%	31%		
	FRANCES	4 393	5 946	0	4 393	0	0	0	140	6 086	-1 693	-39%	44%	12%	Y	
	GLENBURNIE	36 789	20 812	0	36 789	11 178	0	417	2 530	34 937	1 852	5%	30%	30%	Y	
	GLENROY	7 357	8 401	0	7 357	0	0	0	65	8 466	-1 109	-15%	58%	59%	Y	
	GREY	25 044	25 609	1 153	26 197	258	282	80	286	26 515	-318	-1%	76%	70%	Y	
	HACKS	5 229	7 079	200	5 429	0	0	0	78	7 157	-1 728	-32%	74%	61%		
	HINDMARSH	31 276	8 616	0	31 276	14 505	2 452	201	492	42 919	-11 643	-37%	6%	2%		
	HYNAM EAST	3 576	6 863	0	3 576	0	0	4	140	7 007	-3 431	-96%	19%	4%		
	HYNAM WEST	5 725	9 023	2 279	8 004	0	0	0	70	9 093	-1 089	-14%	51%	46%		
	JOANNA	12 855	13 485	0	12 855	669	395	29	330	14 907	-2 052	-16%	49%	48%	Y	
	JOYCE	38 180	17 319	1 434	39 613	3 276	4 484	382	243	25 705	13 908	35%	68%	66%		
	KENNION	25 271	15 114	120	25 391	6 482	1 209	144	288	23 236	2 155	8%	46%	46%	Y	
	KILLANOOLA	22 340	16 344	1 202	23 542	2 018	1 512	42	209	20 126	3 416	15%	62%	59%	Y	
	KONGORONG	32 676	12 068	0	32 676	9 275	577	220	394	22 533	10 143	31%	50%	46%	Y	
	LACEPEDE	18 014	6 451	67	18 081	0	0	0	162	6 613	11 467	63%	94%	94%		
	LAKE GEORGE	7 975	4 730	129	8 104	388	19	5	166	5 308	2 796	35%	53%	57%		
	LANDSEER	7 626	4 255	889	8 514	0	0	0	14	4 269	4 245	50%	93%	90%		
	LOCHABER	18 916	8 476	0	18 916	0	0	49	84	8 609	10 307	54%	72%	68%		
	MACDONNELL	24 410	22 989	0	24 410	4	0	14	381	23 388	1 021	4%	42%	24%	Y	
	MARCOLLAT	13 262	2 461	419	13 681	0	0	27	36	2 524	11 157	82%	94%	100%		
	MAYURRA	19 430	8 308	0	19 430	757	0	19	234	10 965	8 465	44%	59%	47%		
	MINECROW	18 387	9 809	1 608	19 995	0	0	194	54	10 056	9 939	50%	96%	92%		
	MONBULLA	26 692	16 877	2 017	28 709	7 651	2 563	132	207	27 430	1 279	4%	44%	38%	Y	
	MOORAK	11 164	3 627	0	11 164	225	0	121	95	4 069	7 095	64%	89%	88%		
	MOUNT BENSON	12 940	8044	0	12 940	2 613	1 101	2	98	11 858	1 081	8%	60%	56%		
	MOUNT MUIRHEAD	25 066	13859	0	25 066	3 233	1 661	85	40	18 877	6 189	25%	62%	62%		
	MOYHALL	5 565	3419	382	5 947	0	0	1	83	3 503	2 444	41%	92%	79%		
	MURRABINNA	13 919	3859	142	14 061	0	0	0	40	3 899	10 162	72%	97%	97%		
	MYORA	20 655	5231	0	20 655	10 966	4 373	77	725	21 372	-718	-3%	10%	11%	Y	
	ORMEROD	8 901	1 056	359	9 260	0	0	0	85	1 141	8 119	88%	96%	99%		
	PEACOCK	19 666	2 186	0	19 666	0	0	3	240	2 429	17 237	88%	99%	99%		
	RIDDOCH	28 633	14 489	1 213	29 846	12 113	651	158	267	27 679	2 167	7%	41%	35%	Y	
	RIVOLI BAY	14 029	5 398	0	14 029	628	84	15	423	6 548	7 481	53%	78%	73%		
	ROSS	20 538	10 485	2 909	23 447	0	0	0	175	10 660	12 787	55%	90%	91%		
	SHORT	30 597	21 485	3 834	34 431	14 211	16 722	723	245	53 386	-18 955	-55%	-14%	-20%	Y	
	SMITH	17 154	12 337	1 835	18 989	551	707	2	213	13 810	5 180	27%	86%	66%		
	SPENCE	32 643	12 231	1 165	33 808	2 400	1 851	124	301	16 906	16 901	50%	69%	67%		
	STEWARTS	12 128	44 497	15 937	28 065	72	0	101	85	44 756	-16 691	-59%	7%	2%		
	STRUAN	6 147	6 886	138	6 285	0	0	0	70	6 956	-671	-11%	51%	50%	Y	
	SYMON	22 498	10 108	0	22 498	4 355	151	85	259	14 958	7 541	34%	59%	60%		
	TOWNSEND	20 970	14 115	2 609	23 579	572	0	86	294	15 067	8 512	36%	68%	60%		
	WATERHOUSE	16 102	10 562	47	16 149	566	71	9	466	11 674	4 475	28%	69%	66%		
	WESTERN FLAT	1 154	1 403	0	1 154	0	0	1	30	1 434	-280	-24%	66%	74%		
	WOOLUMBOOL	25 182	9 240	955	26 137	0	0	308	238	9 785	16 352	63%	95%	98%		
	YOUNG	30 273	6 091	0	30 273	9 808	2 469	210	355	18 933	11 339	37%	47%	39%	Y	
	ZONE 2A	66 015	28 116	0	66 015	29 040	7 674	391	857	66 079	-64	0%	21%	20%	Y	
	ZONE 3A	54 158	40 869	609	54 767	12 960	8 433	117	505	62 883	-8 116	-15%	35%	33%	Y	Y
	ZONE 5A	18 780	25 855	0	18 780	5	0	37	505	26 402	-7 622	-41%	46%	40%	Y	
	TOTAL	**1 165 650**	**700 285**	**59 602**	**1 225 252**	**203 214**	**79 385**	**5 818**	**16 554**	**1 023 557**	**201 696**					
PADTHAWAY PWA	MANAGEMENT AREA 1	15 157	39 784	12 742	27 899	0	0	4	461	40 249	-12 350	-44%	13%	30%	Y	Y
	MANAGEMENT AREA 2A	2 443	15 011	4 289	6 733	0	0	8	73	15 092	-8 359	-124%	-33%	-45%	Y	Y
	MANAGEMENT AREA 2B	3 279	14 427	372	3 651	0	0	0	99	14 526	-10 875	-298%	-84%	-91%	Y	Y
	MANAGEMENT AREA 3	3 556	7 479	1 429	4 985	0	0	0	107	7 586	-2 601	-52%	19%	10%	Y	Y
	MANAGEMENT AREA 4	5 935	2 997	433	6 368	0	0	95	196	3 288	3 080	48%	68%	81%		
	TOTAL	**30 370**	**79 698**	**19 265**	**49 635**	**0**	**0**	**106**	**936**	**80 740**	**-31 105**					
TATIARA PWA	CANNAWIGARA	3 399	5 434	20	3 419	0	0	3	285	5 722	-2 303	-67%	41%	44%		
	NORTH PENDLETON	6 699	11 398	188	6 886	0	0	2	170	11 571	-4 684	-68%	12%	2%		
	SHAUGH	3 597	10 012	0	3 597	0	0	0	170	10 182	-6 585	-183%	76%	45%		
	STIRLING	17 027	62 077	21 264	38 291	0	0	6	285	62 368	-24 076	-63%	-15%	-2%	Y	Y
	TATIARA	6 185	12 760	1 299	7 483	0	0	1	250	13 011	-5 528	-74%	26%	16%		
	WILLALOOKA	13 072	29 610	8 356	21 428	0	0	10	340	29 960	-8 532	-40%	21%	16%	Y	Y
	WIRREGA	24 442	57 792	5 483	29 925	0	0	16	590	58 397	-28 472	-95%	-2%	-4%	Y	Y
	ZONE 8A	7 211	6 451	0	7 211	0	0	0	280	6 731	480	7%	85%	87%		
	TOTAL	**81 632**	**195 535**	**36 610**	**118 242**	**0**	**0**	**37**	**2 370**	**197 942**	**-79 700**					

*1 Includes indicative volumetric allocations for irrigation, plus volumetric industrial, volumetric town water supply and volumetric water holding allocations

*2 Non-transferable temporary allowance

*3 Includes Total Indicative Licensed Allocation (C3), plus forest recharge debits (C6), forest direct extraction (C7), farm forestry recharge loss (C8), KCA allowance (16 653 ML in Hindmarsh, 1647 ML in Mayurra) and stock & domestic use (C9). Minister's Gazetted Reserve is excluded and considered as unallocated water

Use > TARd, Allocation > TARd, trigger exceeded

Use < TARd, Allocation > TARd, trigger exceeded

Use < TARd, Allocation > TARd, but no trigger exceeded

Only trigger exceeded

Brown et al. (2006) described areas where groundwater resource condition triggers for water levels and salinity had been exceeded. A recent review of groundwater level and salinity trends for the 5 years to December 2006 has revealed an additional 10 management areas where triggers are being exceeded, in addition to those identified by Brown et al. (2006). These areas are summarised in Table 2. Of the 74 unconfined groundwater management areas, 40 management areas have been highlighted. In these areas the delta V for Allocation is a negative value and/or a groundwater resource condition trigger has been exceeded. A further analysis of these 40 areas has been undertaken to assist in the development of future resource management priorities and solutions. A summary of this analysis is detailed in Table 3.

Table 3. Categorisation of Management Areas. Colour codes also shown in Table 2.

Category	Code	Prescribed Wells Area	Groundwater Management Area/s
delta V Allocation is negative delta V Extraction is negative Trigger/s are exceeded	red	Lower Limestone Coast	Short, Coles
		Padthaway	Management Area 2A, Management Area 2B
		Tatiara	Stirling, Wirrega
delta V Allocation is negative delta V Extraction is positive Trigger/s are exceeded	green	Lower Limestone Coast	Frances, Glenroy, Joanna, Kennion, Monbulla, Myora, Struan, Zone 2A, Zone 3A, Zone 5A
		Padthaway	Management Area 1, Management Area 3
		Tatiara	Willalooka
delta V Allocation is negative delta V Extraction is positive No trigger/s exceeded	purple	Lower Limestone Coast	Beeamma, Hynam East, Stewarts, Hindmarsh, Hacks, Western Flat, Fox, Comaum, Hynam West, Bangham
		Padthaway	
		Tatiara	Shaugh, Tatiara, North Pendleton, Canniwigara
Only trigger/s exceeded	pink	Lower Limestone Coast	Bool, Glenburnie, Killanoola, Kongorong, Macdonnell, Riddoch, Young
		Padthaway	
		Tatiara	

Selected data from Table 2 and Appendix 1 has also been collated for the forest industry to assist them in planning future expansion opportunities in line with water balance considerations. This information is presented in Appendix 2.

9. CONCLUSION

This report merges the results of two major projects; one on Volumetric Conversion and the other a review of resource condition and Permissible Annual Volumes for the unconfined aquifer. Innovative methodologies have been developed to enable comparisons to be made between total inputs and total outputs of the groundwater balance for each of the 73 unconfined groundwater management areas. This data has been matched with resource condition data (water level/salinity triggers exceeded) for each management area, enabling management areas to be categorised according to the data profile. The outcomes from this report will provide key background information for the review of Water Allocation Plans that is currently underway and for the future management of the groundwater resources of the South East.

1. FOREST IMPACTS ON WATER RESOURCES FOR THE LOWER LIMESTONE COAST, PADTHAWAY AND TATIARA PRESCRIBED WELLS AREAS, DECEMBER 2006

Groundwater Management Area	Adopted Recharge Rate (mm/yr)	Softwood: Farm Forestry (ha)		Softwood: Commercial (ha)		Softwood: Commercial Direct Extraction (ML/yr)	Softwood: Threshold Area *1 (ha)	Softwood: 83% Recharge Debit (ML/yr)	Hardwood: Farm Forestry (ha)		Hardwood: Commercial (ha)		Hardwood: Commercial Direct Extraction (ML/yr)	Hardwood: Threshold Area *1 (ha)	Hardwood: 2002–04 Plantings (ha)	Hardwood: 78% Recharge Debits (ML/yr)	Hardwood: Volume of Offsetting Holding Allocations *2 (ML/yr)	Forestry Regulation Area: Yes or No	Forestry Regulation Area: Total Direct Extraction (ML/yr)	Forestry Regulation Area: Total Recharge Debits (ML/yr)	Forestry Regulation Area: Combined (ML/yr)
		<6 m	*>6 m*	*<6 m*	*>6 m*				*< 6 m*	*> 6 m*	*< 6 m*	*> 6 m*									
Bangham	20	0	704.1	0	0	0		0	0	39.1	0	0	0			0		N	0	0	0
Beeamma	20	0.2	319.4	0	0	0		0	0	47.6	0	0	0			0		N	0	0	0
Benara	170	1.4	0	276.2	3 555.1	458	5 430	7 662	1.6	0	0	30.9	0	185		245		Y	458	7 907	8 366
Blanche Central	175	0	19	0	2 439	0	2 842	4 128	0	0.4	0	20.9	0	307		419		Y	0	4 547	4 547
Bool	105			0	0	0		0	0.1	2.9	0	0	0	299		245		Y	0	245	245
Bowaka	85	2.3	0.6	0	0	0	318	224	0.1	21.4	0	0	0			0		Y	0	224	224
Bray	90	0	0	18.1	635.2	30	1 681	1 256	0	0	0	1.6	0	600		421		Y	30	1 677	1 707
Cannawigara	15	0	15	0	0	0		0	0	5	0	0	0			0		N	0	0	0
Coles	120	42.9	10.1	47.4	60.5	79	610	608	31.1	6.5	9541.3	4327	17 461	13 934		13 042	959	Y	17 539	13 650	31 189
Comaum	60	0	0.4	90.8	2 139.9	151	2 477	1 234	2.6	1.1	0	5	0	3		1		Y	151	1 235	1 386
Compton	175	0	0	0	698.1	0	794	1 153			0	0	0			0		Y	0	1 153	1 153
Conmurra	95	60.7	345.4	0	0	0	1 730	1 364	44.2	90.1	367.6	864.8	673	350		259		Y	673	1 623	2 296
Donovans	175	0	56.8	0	3 626.6	0	3 756	5 456	0	29.5	0	81.4	0	106		145		Y	0	5 600	5 600
Duffield	50	0	2.2	0	0	0		0			0	0	0			0		N	0	0	0
Fox	100	12.7	50.4	223.4	335	371	1 740	1 444	45.5	30.7	395.8	657.2	724	4012		3129		Y	1 095	4 574	5 669
Frances	30			0	0	0		0			0	0	0			0		N	0	0	0
Glenburnie	150	0	264.8	0	7 995.8	0	8 497	10 579	0	13.5	0	83.9	0	512		599		Y	0	11 178	11 178
Glenroy	100			0	0	0		0			0	0	0			0		N	0	0	0
Grey	150	30	0	0.3	71.6	0	86	107	23.4	0	153.7	75.5	281	129		151	135	Y	282	258	540
Hacks	125			0	0	0		0			0	0	0	63		61		N	0	0	0
Hindmarsh	150	6	127.1	1 440.4	8 872.2	2 391	11 241	13 995	0	1	33.3	148.3	61	436		510		Y	2 452	14 505	16 957
Hynam East	25	0	16.9	0	0	0		0			0	0	0			0		N	0	0	0
Hynam West	80			0	0	0		0			0	0	0			0		N	0	0	0
Joanna	50	3.7	47.2	237.9	1 381.2	395	1 611	669	0	7.4	0	0	0			0		Y	395	669	1 063
Joyce	120	26.3	213.6	0	0	0	533	531	56.4	22.2	2450.3	361.5	4 484	263	2 670	2 745		Y	4 484	3 276	7 760
Kennion	120	39	80.9	639.4	1 320.6	1 061	3 009	2 997	0	0	80.5	14	147	3 723		3 485		Y	1 209	6 482	7 690
Killanoola	145	3	0	0	0	0	366	440	26.3	0	826.4	211.9	1 512	1 395		1 578	560	Y	1 512	2 018	3 531
Kongorong	170	126.8	2.6	347.3	5 278.2	577	6 573	9 275			0	0	0			0		Y	577	9 275	9 851
Lacepede	100			0	0	0		0			0	0	0			0		N	0	0	0
Lake George	75	2.1	0	11.6	117.5	19	623	388	0	4.2	0	0	0			0		Y	19	388	407
Landseer	45			0	0	0		0			0	0	0			0		N	0	0	0
Lochaber	90	2.1	42.3	0	0	0		0	6.7	3.5	0	0	0			0		N	0	0	0
MacDonnell	150	0	2.7	0	0	0	3	4	0	6.8	0	0	0			0		Y	0	4	4
Management Area 1	75	0	4.8	0	0	0		0			0	0	0			0		N	0	0	0
Management Area 2	75	0	5.4	0	0	0		0	0	4.7	0	0	0			0		N	0	0	0
Management Area 3	75			0	0	0		0			0	0	0			0		N	0	0	0
Management Area 4	25	0.2	368.2	0	0	0		0	0	12.4	0	0	0			0		N	0	0	0
Marcollat	75	16.2	15.7	0	0	0		0	4.3	0.2	0	0	0			0		N	0	0	0
Mayurra	110	0	11.5	0	15.2	0	780	712	0.1	5.8	0	0	0	52		45		Y	0	757	757
Minecrow	75	9.4	240.5	0	0	0		0	2.2	6.2	0	0	0			0		N	0	0	0
Monbulla	180	4.2	26.1	4.1	44.6	7	828	1 237	42.9	0	1 396.8	310.4	2 556	45 68		6 413		Y	2 563	7 651	10 213
Moorak	175	0	68.3	0	52.8	0	141	205	0	1	0	0	0	15		20		Y	0	225	225
Mount Benson	60	1.3	0.5	663.1	4 264.4	1 101	5 247	2 613	0	2.2	0	0	0			0		Y	1 101	2 613	3 714
Mount Muirhead	110	10.6	59.3	975.2	996.6	1 619	2 946	2 690	0	7.5	22.8	12.7	42	633		543		Y	1 661	3 233	4 893
Moyhall	105			0	0	0		0	0	1	0	0	0			0		Y	0	0	0
Murrabinna	90			0	0	0		0			0	0	0			0		N	0	0	0
Myora	160	4.6	21.4	2 634.4	5 106.5	4 373	8 005	10 631	21.7	0.4	0	11.5	0	269		336		Y	4 373	10 966	15 339
North Pendleton	30	0	7.4	0	0	0		0			0	0	0			0		N	0	0	0
Ormerod	120			0	0	0		0			0	0	0			0		N	0	0	0
Peacock	70	3.8	0.1	0	0	0		0			0	0	0			0		N	0	0	0
Riddoch	130	7	86.8	213.8	6 354.9	355	7 895	8 519	4.8	22.7	162	253.6	296	3 545		3 595		Y	651	12 113	12 765
Rivoli Bay	100	0	7.8	50.7	156.4	84	757	628	6.7	0.1	0	0	0			0		Y	84	628	712
Ross	110			0	0	0	464	424			0	0	0	600		515		N	0	0	0
Shaugh	15			0	0	0		0			0	0	0			0		N	0	0	0
Short	150	1.9	0	810.6	72.8	1 346	627	781	374	106.3	8402.3	630.5	15376	11 479		13 430		Y	16 722	14 211	30 933
Smith	100	1.9	0	425.1	124.4	706	664	551	0	0	0.6	0	1			0		Y	707	551	1 258
Spence	115	34.5	53.1	0	0	0	548	523	5.8	14.1	1011.4	2 254.4	1851	1 998	94	1877	433	Y	1 851	2 400	4 250
Stewarts	145	3.6	66.1	0	0	0	60	72			0	0	0			0		Y	0	72	72
Stirling	50	8.8	3	0	0	0		0			0	0	0			0		N	0	0	0
Struan	95			0	0	0	59	47			0	0	0			0		N	0	0	0
Symon	110	32.4	19.7	90.4	1 659.2	150	3 155	2 881	6.2	18.8	0.3	37.8	1	1 719		1 475		Y	151	4 355	4 506
Tatiara	15	0	3.2	0	0	0		0	0	2	0	0	0			0		N	0	0	0
Townsend	85	17.4	84.2	0	0	0	552	389			0	0	0	275		182		Y	0	572	572
Waterhouse	80	0	9.7	42.8	381.7	71	852	566	2	0	0	0	0			0		Y	71	566	637
Western Flat	20	0	5.3	0	0	0		0			0	0	0			0		N	0	0	0
Willalooka	40			0	0	0		0	21.7	2.5	0	0	0			0		N	0	0	0
Wirrega	30	0	33.5	0	0	0		0	0	18.3	0	0	0			0		N	0	0	0
Woolumbool	90	56	285.8	0	0	0		0			0	0	0			0		N	0	0	0
Young	200	9.7	71.2	1373.9	2 498.8	2 281	4 670	7 752	0.7	23.6	102.7	111.4	188	1 318		2 056		Y	2 469	9 808	12 277
Zone 2A	140	53.2	32	4065	16 209.5	6 748	22 103	25 684	91	103.1	506.1	222.9	926	3 074		3 357		Y	7 674	29 040	36 715
Zone 3A	120	0.4	59.2	4902.3	6 688.4	8 138	12 839	12 788	36.8	0.7	161.1	124.6	295	184		172	13	Y	8 433	12 960	21 392
Zone 5A	40	0	27.9	0	0	0	15	5	0	65	0	0	0			0		Y	0	5	5
Zone 8A	15			0	0	0		0			0	0	0			0		N	0	0	0
Grand Total		**636**	**3 999**	**19 584**	**83 153**	**32 510**	**127 127**	**143 208**	**859**	**752**	**25 615**	**10 854**	**46 875**	**56 046**	**2 764**	**61 053**	**2 100**		**79 385**	**20 3214**	**282 599**

*1 Threshold Area based on 2002 forest estate and formalised in 2004 *2 Offset Volume is outside of the Threshold Area and Volume

2. PLANTATION FOREST IMPACTS AND MANAGEMENT DATA, DECEMBER 2006, LOWER SOUTH EAST (PART OF LOWER LIMESTONE COAST PWA)

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25
Unconfined Management Area	plantation area, December 2006		plantation threshold area		plantation area in excess of threshold *1		recharge impact of plantation area, Dec 2006		plantation area, water table <6 metres, Dec 2006		extraction impact of plantation area, Dec 2006		total forest impact on water resource	total licensed water allocations	combined impacts of all licenses and forests	forest as a share of combined impacts	water account, surplus/ deficit	annual recharge rate	expansion available within threshold area at 20 Dec 2006 *2		volume required to offset recharge impact		volume required to offset extraction impact	
	hardwood	softwood	hardwood	softwood	hardwood	softwood	hardwood	softwood	hardwood	softwood	hardwood	softwood							hardwood	softwood	hardwood 78%	softwood 83%	hardwood	softwood
	ha	*ha*	*ha*	*ha*	*ha*	*ha*	*ML*	*ML*	*ha*	*ha*	*ML*	*ML*	*ML*	*ML*	*ML*	*%*	*ML*	*mm/yr*	*ha*	*ha*	*ML/ha*	*ML/ha*	*ML/ha*	*ML/ha*
BENARA	31	3 831	185	5 430			245	7 662	0	276	0	458	8 366	13 890	22 256	38%	15 209	170	153	1 872	1.33	1.41	1.82	1.66
BLANCHE CENTRAL	21	2 439	307	2 842			419	4 128	0	0	0	0	4 547	2 789	7 336	62%	4 507	175	286	429	1.37	1.45	1.82	1.66
BOOL	0	0	299				245	0	0	0	0	0	245	2 077	2 322	11%	2 016	105	296	0	0.82	0.87	1.82	1.66
BOWAKA	0	0		318			0	224	0	0	0	0	224	18 479	18 703	1%	5 741	85	0	243	0.66	0.71	1.82	1.66
BRAY	2	653	600	1 681			421	1 256	0	18	0	30	1 707	7 432	9 139	19%	7 760	90	600	982	0.70	0.75	1.82	1.66
COLES	13 868	108	13 934	610			13 042	608	9 541	47	17 461	79	31 189	11 129	42 318	74%	**-16 730**	120	0	420	0.94	1.00	1.82	1.66
COMAUM	5	2 231	3	2 477	2		1	1 234	0	91	0	151	1 386	2 717	4 103	34%	**-747**	60	0	246	0.47	0.50	1.82	1.66
COMPTON	0	698		794			0	1 153	0	0	0	0	1 153	889	2 042	56%	3 688	175	0	122	1.37	1.45	1.82	1.66
CONMURRA	1 232	0	350	1 730	882		259	1 364	368	0	673	0	2 296	22 446	24 742	9%	9 094	95	0	1 605	0.74	0.79	1.82	1.66
DONOVANS	81	3 627	106	3 756			145	5 456	0	0	0	0	5 600	20 235	25 835	22%	7 762	175	67	196	1.37	1.45	1.82	1.66
FOX	1 053	558	4 012	1 740			3 129	1 444	396	223	724	371	5 669	16 394	22 062	26%	**-731**	100	2 407	1 184	0.78	0.83	1.82	1.66
GLENBURNIE	84	7 996	512	8 497			599	10 579	0	0	0	0	11 178	20 812	31 989	35%	1 852	150	423	549	1.17	1.25	1.82	1.66
GLENROY	0	0					0	0	0	0	0	0	0	8 401	8 401	0%	-1 109	100	0	0	0.78	0.83	1.82	1.66
GREY	229	72	129	86	100		151	107	154	0	281	0	540	25 609	26 149	2%	-318	150	0	10	1.17	1.25	1.82	1.66
HACKS	0	0	63				61	0	0	0	0	0	61	7 079	7 141	1%	-1 728	125	63	0	0.98	1.04	1.82	1.66
HINDMARSH	182	10 313	436	11 241			510	13 995	33	1 440	61	2 391	16 957	8 616	25 573	66%	**-11 643**	150	289	1 037	1.17	1.25	1.82	1.66
JOANNA	0	1 619		1 611		8	0	669	0	238	0	395	1 063	13 485	14 548	7%	-2 052	50	0	194	0.39	0.42	1.82	1.66
JOYCE	2 812	0	263	533	2 549		2 745	531	2 450	0	4 484	0	7 760	17 319	25 080	31%	13 908	120	0	533	0.94	1.00	1.82	1.66
KENNION	95	1 960	3 723	3 009			3 485	2 997	81	639	147	1 061	7 690	15 114	22 804	34%	2 155	120	3 606	1 025	0.94	1.00	1.82	1.66
KILLANOOLA	1 038	0	1 395	366			1 578	440	826	0	1 512	0	3 531	16 344	19 875	18%	3 416	145	0	366	1.13	1.20	1.82	1.66
KONGORONG	0	5 626		6 573			0	9 275	0	347	0	577	9 851	12 068	21 919	45%	10 143	170	0	943	1.33	1.41	1.82	1.66
LAKE GEORGE	0	129		623			0	388	0	12	0	19	407	4 730	5 137	8%	2796	75	0	446	0.59	0.62	1.82	1.66
MACDONNELL	0	0		3			0	4	0	0	0	0	4	22 989	22 993	0%	1 021	150	0	3	1.17	1.25	1.82	1.66
MAYURRA	0	15	52	780			45	712	0	0	0	0	757	8 308	9 064	8%	8 465	110	46	765	0.86	0.91	1.82	1.66
MONBULLA	1 707	49	4 568	828			6 413	1 237	1 397	4	2 556	7	10 213	16 877	27 091	38%	1 279	180	2 569	828	1.40	1.49	1.82	1.66
MOORAK	0	53	15	141			20	205	0	0	0	0	225	3 627	3 852	6%	7 095	175	14	89	1.37	1.45	1.82	1.66
MOUNT BENSON	0	4 928		5 247			0	2 613	0	663	0	1 101	3 714	8 044	11 758	32%	1 081	60	0	184	0.47	0.50	1.82	1.66
MOUNT MUIRHEAD	36	1 972	633	2 946			543	2 690	23	975	42	1 619	4 893	13 859	18 752	26%	6 189	110	603	968	0.86	0.91	1.82	1.66
MOYHALL	0	0					0	0	0	0	0	0	0	3 419	3 419	0%	2 444	105	0	0	0.82	0.87	1.82	1.66
MYORA	12	7 741	269	8 005			336	10 631	0	2 634	0	4 373	15 339	5 231	20 570	75%	-718	160	3	177	1.25	1.33	1.82	1.66
RIDDOCH	416	6 569	3 545	7 895			3 595	8 519	162	214	296	355	12 765	14 489	27 254	47%	2 167	130	2 988	1 344	1.01	1.08	1.82	1.66
RIVOLI BAY	0	207		757			0	628	0	51	0	84	712	5 398	6 110	12%	7 481	100	0	550	0.78	0.83	1.82	1.66
ROSS	0	0	600	464			515	424	0	0	0	0	938	10 485	11 423	8%	12 787	110	600	464	0.86	0.91	1.82	1.66
SHORT	9 033	883	11 479	627			13 430	781	8 402	811	15 376	1 346	30 933	21 485	52 418	59%	**-18 955**	150	1 349	0	1.17	1.25	1.82	1.66
SMITH	1	550		664			0	551	1	425	1	706	1 258	12 337	13 595	9%	5 180	100	0	116	0.78	0.83	1.82	1.66
SPENCE	3 266	0	1 998	548	1 268		1 877	523	1 011	0	1 851	0	4 250	12 231	16 482	26%	16 901	115	0	548	0.90	0.95	1.82	1.66
STEWARTS	0	0		60			0	72	0	0	0	0	72	44 497	44 570	0%	-16 691	145	0	60	1.13	1.20	1.82	1.66
STRUAN	0	0		59			0	47	0	0	0	0	47	6 886	6 932	1%	-671	95	0	59	0.74	0.79	1.82	1.66
SYMON	38	1 750	1 719	3 155			1 475	2 881	0	90	1	150	4 506	10 108	14 614	31%	7 541	110	1 663	1 433	0.86	0.91	1.82	1.66
TOWNSEND	0	0	275	552			182	389	0	0	0	0	572	14 115	14 687	4%	8 512	85	275	552	0.66	0.71	1.82	1.66
WATERHOUSE	0	425		852			0	566	0	43	0	71	637	10 562	11 199	6%	4 475	80	0	429	0.62	0.66	1.82	1.66
YOUNG	214	3 873	1 318	4 670			2 056	7 752	103	1 374	188	2 281	12 277	6 091	18 368	67%	11 339	200	1 092	860	1.56	1.66	1.82	1.66
ZONE 2A	729	20 275	3 074	22 103			3 357	25 684	506	4 065	926	6 748	36 715	28 116	64 831	57%	**-64**	140	2 069	526	1.09	1.16	1.82	1.66
ZONE 3A	286	11 591	184	12 839	102		172	12 788	161	4 902	295	8 138	21 392	40 869	62 261	34%	**-8 116**	120	0	983	0.94	1.00	1.82	1.66
ZONE 5A	0	0		15			0	5	0	0	0	0	5	25 855	25 860	0%	-7 622	40	0	15	0.31	0.33	1.82	1.66
TOTAL	**36 469**	**102 737**	**56 046**	**127 127**	**4 903**	**8**	**61 053**	**143 208**	**25 615**	**19 584**	**46 875**	**32 510**	**283 646**	**614 988**	**898 634**	**32%**	**114 231**		**21 460**	**23 354**				

*1 Some of the area exceeding threshold area is offset with holding allocations (2100 ML). Balance planted between 2002 and 2004.

*2 Not equal to Plantation Threshold Area (C4 or C5) minus Plantation Area at December 2006 (C2 or C3). Includes planning approved.

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

GLOSSARY

Act (the). In this document, refers to The Natural Resources Management Act (South Australia) 2004.

Allowable Annual Volume (AAV). Allowable Annual Volume, defined in the South Australian – Victorian Borders Groundwaters Agreement Review Committee 20th Annual Report as "the allowable volume of extraction, which is specified, for each aquifer within a zone of the (Border) Designated Area, which is component of the Permissible Annual Volume for that zone".

Annual Water Use Returns (AWUR's). End of season reporting process whereby water license holders detail their water use activities for the given season. The details required include areas of crop types grown and assessments of volumes pumped.

Aquifer. An underground layer of rock or sediment which holds water and allows water to percolate through.

Aquifer, confined. Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer.

Aquifer, unconfined. Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Area-Based Licensing System (haIE). Existing water access entitlements to irrigate a given area of crop per annum, with no restrictions on the volume of water applied to the crop. Measured in terms of hectares of irrigation equivalents (haIE).

Base Allocation (BA). The crop water requirement component of the proposed volumetric licenses. Base Allocation (ML) = haIE x NIRo

Bore. *See well.*

Bridging Volume (BV). The Bridging volume is an additional temporary water allocation (granted on application) designed to give irrigators who are pumping in excess of their new volumetric allocation time to adjust to the new system.

Climatic Bands. 10 Climatic Bands across the South East that were developed to better represent the range of evapotranspiration and rainfall rates across the SE of SA. It is proposed that these Climatic Bands form the basis for determination of each irrigator's volumetric allocation.

Comparative Volume Pumped (CVP). The difference between the seasonal volume pumped for irrigation and the seasonal NIRc, expressed as a percentage of NIRc, i.e. CVP = (volume pumped – NIRc) / NIRc.

Crop Adjustment Factor (CAF). The Crop Adjustment Factor provides additional base allocation for licensees where, due to initial calculations problems, the existing area-based licensing system does not provide adequate allocation.

Crop Area Ratio (CAR). Used in the existing area-based licensing system to determine area of crops that may be grown in relation to the theoretical irrigation requirement.

Crop Water Requirement. Depth of water required by a crop…for evapotranspiration (ET_C) during a given period (Doorenbos and Pruitt, 1977).

Deep Drainage. Water that percolates past the crop root zone and is no longer available to the crop for transpiration.

Delta V (ΔV). The difference between TARd and;

1. *Indicative Allocation* – Total groundwater allocation, defined herein as the sum of (i) indicative licensed allocations for irrigation (haIE licenses converted to volumetric), (ii) existing volumetric allocations, (iii) potential forestry impacts (recharge interception and direct extraction) and (iv) estimated stock and domestic use.
2. *Indicative Volume Extracted* – Total groundwater extraction, defined herein as the sum of (i) indicative licensed extraction for irrigation (haIE system), (ii) existing volumetric allocations, (iii) potential forestry impacts (recharge interception and direct extraction) and (iv) estimated stock and domestic use.

Delivery Component (DC). The volume of water that a reasonably efficient irrigator needs to extract in excess of the crop water requirement to irrigate and grow the crop to account for application and distribution losses.

Delivery Zones (DZ). Areas of like characteristics within the SE. They were used to calculate delivery components and have been developed using soil mapping data, volume pumped data and other hydrogeological information sources (ie depth to water table, salinity).

Distribution Losses. Water pumped from the aquifer or from storage, which is lost during the delivery of water to the border of the field. May include evaporation and seepage from channel delivery systems, and leakage from piped delivery systems.

Domestic (use) purpose. The taking of water for ordinary household purposes and includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares.

Drip Irrigation. High precision irrigation where water is delivered via emitters (drip, trickle, micro-spray) spaced evenly along a supply line, usually located along each crop row.

DWLBC. Department of Water, Land and Biodiversity Conservation. Government of South Australia.

Environmental water requirements. The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.

Evapotranspiration (ET). The total loss of water as a result of transpiration from plants and evaporation from land, and surface waterbodies.

FAO 24. Food and Agriculture Organization of the United Nations. FAO Irrigation and Drainage Paper, 24 (1977) – *Crop Water Requirements.*

FAO 56. Food and Agriculture Organization of the United Nations. FAO Irrigation and Drainage Paper, 56 (1998) - *Crop Evapotranspiration; Guidelines for Computing Crop Water Requirements.*

Flood / Surface Irrigation. Non-pressurised gravity feed irrigation, whereby water is delivered from the pump via channels to fields constructed to form rectangular bays using parallel check banks. Water flows down the bay’s slope as a sheet guided by the check banks.

Frost Protection. Water applied to the crop canopy using fixed overhead sprinklers to prevent frost damage to the crop.

Groundwater. *See underground water.*

haIE. The number of hectares of irrigation equivalents endorsed on an existing area-based water licence.

Hydrogeology. The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See hydrology.)*

Hydrology. The study of the characteristics, occurrence, movement and utilisation of water on and below the earth’s surface and within its atmosphere. *(See hydrogeology.)*

Irrigation. Watering land by any means for the purpose of growing plants.

Irrigation Equivalents (IE’s). The current area-based water licensing system shown in hectares, where 1 haIE is equivalent to the evapotranspiration minus contribution by effective precipitation from one hectare of reference crop under the average climatic conditions for that region.

Irrigation Rate (ML/ha). The annual volume pumped for irrigation expressed in Megalitres (ML) divided by the area irrigated in hectares (ha).

Irrigation Requirement (IR). Depth of water required for meeting evapotranspiration minus the contribution by effective precipitation, groundwater, stored soil water, required for normal crop production systems, calculated according to the FAO 24 method (Doorenbos and Pruitt, 1977).

Irrigation Requirement – Reference Crop (IRo). Depth of water required for meeting reference crop evapotranspiration minus the contribution by effective precipitation, groundwater, stored soil water, required for normal crop production systems, calculated according to the FAO 24 method (Doorenbos and Pruitt, 1977).

Lake. A natural lake, pond, lagoon, wetland or spring (whether modified or not) and includes: part of a lake; and a body of water declared by regulation to be a lake; a reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

Land. Whether under water or not and includes an interest in land and any building or structure fixed to the land.

Licence. A licence to take water in accordance with the Water Resources Act 1997. *(See water licence.)*

Management Area (unconfined). Part of a Prescribed Wells Area used for groundwater management.

Maximum Production Pasture (MPP). A category of pasture that has been recognised as having increased NIRc due to significant changes in pasture management systems.

Mean Annual Recharge (MAR).

Median delivery factor. The median volume pumped in relation to seasonal NIRo for each irrigation system type and delivery zone. *(See Comparative Volume Pumped).*

Megalitre (ML). One ML equal one million litres or one thousand Kilolitres.

Net Irrigation Requirement – Crop (NIR_C). Net irrigation requirement for a specific crop, grown according to a defined crop calendar, calculated according to the FAO 56 method (Allen et al., 1998).

Net Irrigation Requirement – Reference Crop (NIR_0). Net irrigation requirement for the reference crop, reflecting the evapotranspiration demand at a certain location, according to climatic conditions in that location, calculated according to the FAO 56 method (Allen et al., 1998).

Net Irrigation Requirement (NIR). Depth of water required for meeting evapotranspiration minus contribution by effective precipitation, ground water, stored soil water; does not include operational losses and leaching requirements (Doorenbos and Pruitt, 1977).

Natural recharge. The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) *(See recharge area, artificial recharge.)*

Natural Resources. Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

Natural Resources Management (NRM). All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

PAV. Permissible Annual Volume, defined by the –

> 2001 Water Allocation Plans for the TLA as *"the volume of water that can be sustainably used or assigned from the unconfined aquifer on an annual basis, in a particular management area.*
>
> South Australia – Victorian Border Groundwaters Agreement Review Committee 20th Annual Peport as *"the permissible annual volume of extraction that is prescribed for each zone of the (Border) Designated Area. It is the maximum volume that may be authorized for extraction."* NB. PAV in the context comprises the sum of the AAV for the unconfined aquifer (TLA) and the AAV for the confined aquifer (TCSA).

PIRSA. (Department of) Primary Industries and Resources South Australia.

Prescribed Wells Area (PWA). A water resource declared by the Governor to be prescribed under the Water Resources Act 1997, and includes underground water to which access is obtained by prescribed wells.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

South East Natural Resource Management Board (SENRMB). Responsible for natural resources planning, public consultation and education and in advising the Minister for Environment and Conservation on various natural resource management issues and policies.

Specialised Production Requirements (SPR). (1) Water that is necessarily applied as a part of the crop production process that does not contribute to crop water use and is not included in the delivery component (e.g. to prevent soil drift or to protect against frost damage). (2) Water that is required in addition to base allocation due to significant changes in the crop production system (as recognised by FAO 56). For example Maximum Production Pasture.

Spray Irrigation. Pressurised irrigation systems with water applied through some form of sprinkler/s. Water is delivered from the pump to the sprinkler through pipe works. Includes centre pivots, fixed sprinklers and travelling irrigators.

Stock Use. The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act).

Surface water. (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Total Available Recharge (TAR). Total available recharge for allocation in each management area, calculated as the area not covered by native vegetation multipled by the adopted recharge rate for that area, less 10% for EWR.

TARd. Total available recharge for allocation, plus the contribution from deep drainage beneath flood irrigation, determined for each unconfined groundwater management area.

Tertiary Confined Sands Aquifer (TCSA). Tertiary Confined Sands Aquifer, existing as either the Dilwyn or Mepunga Formations in the Otway Basin, or the Renmark Group Aquifer in the Murray Basin.

Tertiary Limestone Aquifer (TLA). Tertiary Limestone Aquifer, existing as either the Gambier Limestone in the Otway Basin or the Murray Group Aquifer in the Murray Basin, or a younger geological unit in either province.

Transpiration. Rate of water loss through the plant which is regulated by physical and physiological processes (Doorenbos and Pruitt, 1977).

Underground water (groundwater). Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Volumetric allocation. An allocation of water expressed on a water licence as a volume (e.g. kilolitres) to be used over a specified period of time, usually per water use year (as distinct from any other sort of allocation).

Volumetric Conversion Model. Describes the components and methodologies for the conversion of existing area-based allocations to volumetric allocations.

Volumetric licensing system. Licensees are entitled to pump a certain volume of water per annum, but are not restricted by the area of crop/s grown.

Volume for Licensed Allocation (VLA). The total quantity of water (in megalitres) available for licensed extraction on an annual basis within each management area.

Water affecting activities. Activities referred to in Part 4, Division 1, s. 9 of the Act.

Water allocation. (a) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence; (b) in respect of water taken pursuant to an authorisation under s. 11 means the maximum quantity of water that can be taken and used pursuant to the authorisation.

Water allocation plan (WAP). A plan prepared by a SENRMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

Water licence. A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area. This grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water. A water licence confers a property right on the holder of the licence and this right is separate from land title.

Waterbody. Waterbodies include watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers.

Water-dependent ecosystems. Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

Well. (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

Wetlands. Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic/intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres.

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