Surface water modelling to support the Eastern Mount Lofty Ranges Water Resource Plan

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1 Introduction

1.1 Objectives

The objective of this report is to describe the hydrological modelling used to support South Australia's requirements under the Basin Plan (MDBA 2012) in the Eastern Mount Lofty Ranges (EMLR) Water Resource Plan (WRP) area. Specifically it describes the surface water models used to determine the modelled component of take for both annual permitted take and annual actual take in a manner that meets the requirements of Chapter 10 of the Basin Plan and further details outlined in *Position Statement 3C Method for Determining Take* (MDBA, 2015).

The modelled catchments are part of the EMLR WRP area defined under the Basin Plan (Figure 1). The EMLR WRP area is divided into two surface water Sustainable Diversion Limit (SDL) resource units:

- Eastern Mount Lofty Ranges (SS13), which equates to the boundary of the state EMLR Prescribed Water Resources Area (PWRA)
- Marne Saunders (SS12), which equates to the boundary of the state Marne Saunders PWRA.

The following surface water catchments within the EMLR WRP area have surface water models:

- Eastern Mount Lofty Ranges surface water SDL resource unit
    - Angas River
    - Bremer River
    - Currency Creek
    - Finniss River
    - Tookayerta Creek
- Marne Saunders surface water SDL resource unit
    - Marne River
    - Saunders Creek.

Key characteristics of these catchments are given in Table 1.

Table 1. Key characteristics of modelled catchments in the EMLR WRP area

Catchment	Area (km^2)	Mean annual adjusted runoff volume (ML)	Number of dams	Estimated total dam capacity (ML)
Angas River	197	8407	1052	3239
Bremer River	583	17925	1895	4846
Currency Creek	89	8060	546	1400
Finniss river	371	40094	2063	5464
Tookayerta Creek	100	23097	543	1273
Marne River	506	8406	827	3225
Saunders Creek	237	1003	133	553

Table notes: Data for Marne River and Saunders Creek are taken from SAMDB NRMB 2010 and Alcorn 2005 (mean annual adjusted runoff volume is for 1974–2003). Data for the other catchments are taken from SAMDB NRMB 2013 (mean annual adjusted runoff volume is for 1974-2006). See section 2.2.1 for a definition of adjusted runoff.

1.2 Outline

This document includes:

- background information on historical model development for each of the individual catchments in the WRP area (section 2)
- an overview of the surface water modelling approach adopted including model structure, platform, calibration, assumptions and limitations (section 3)
- a description of the model updates undertaken to enable actual and permitted take to be calculated for the WRP area (section 4)
- a description of model input data (section 5)
- a detailed description of individual catchment models (sections 6 to 12)
- documentation of the procedure to run the models (section 13)
- a summary of results of model runs (section 14).

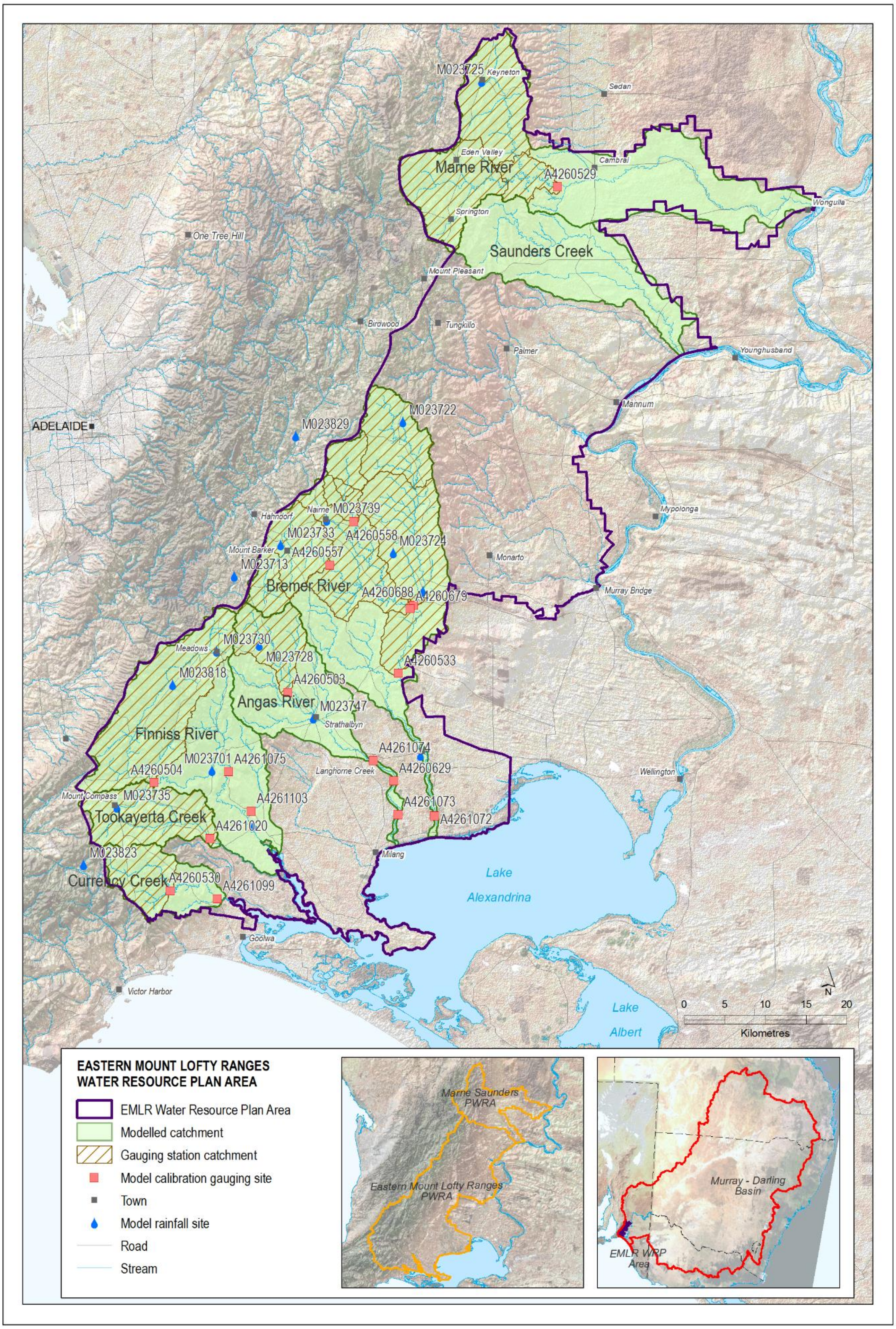


Figure 1. Eastern Mount Lofty Ranges Water Resource Plan Area and modelled catchments

2 Background

2.1 Basin Plan requirements

Under the Basin Plan, each surface water SDL resource unit in the Murray Darling Basin (MDB) has a sustainable diversion limit, which is a long-term average annual diversion volume that represents an environmentally sustainable level of take for the unit. The SDL for each surface water SDL resource unit is given in Schedule 2 of the Basin Plan.

Maintaining compliance with the SDL is a key requirement of the Basin Plan. Compliance with the SDL is determined on the basis of annual permitted take and annual actual take for each SDL resource unit, paraphrased from section 6.09–6.12 of the Basin Plan as follows:

1. determine annual permitted take and annual actual take each year
2. record the difference between permitted take and actual take on the take register as a credit (actual < permitted) or debit (actual > permitted)
3. non-compliance occurs if the cumulative balance is a debit equal to 20% or more of the SDL (once the cumulative balance is adjusted for disposal or acquisition of held environmental water) and there is no reasonable excuse for the excess.

2.1.1 Annual permitted take

Annual permitted take is the maximum quantity of water permitted to be taken for consumptive use during a water accounting period (generally a water-use year), for each form of take. Section 10.10 of the Basin Plan requires the WRP for each area to set out the method to determine annual permitted take after the end of each water accounting period. The method may include modelling, must have regard to the water resources available during the water accounting period (s10.10 (2)) and must take account of the matters set out in section 10.12.

The methods for determining annual permitted take in the EMLR WRP area are set out in the EMLR WRP, and include the use of the surface water models described in this report for the EMLR and Marne Saunders surface water SDL units.

2.1.2 Annual actual take

Annual actual take for a SDL resource unit is the sum of the quantity of water actually taken by each form of take for consumptive use during a water accounting period. The WRP for an area must set out how annual actual take will be determined after each water accounting period, for each form of take, using the best available information at the time (Basin Plan section 10.15 (1)). This may be determined by measuring or estimating the quantity of water actually taken. Where the quantity of water taken is estimated, then the estimation needs to be done consistently with the method for determining annual permitted take.

2.2 Hydrological model development for the EMLR WRP area

Surface water models in the EMLR WRP area have been developed in three stages, as described below:

1. initial model development for state water planning purposes (discussed in section 2.2.1)
2. major model review and recalibration to incorporate updated demand and flow data in 2010 for state water planning purposes (excluding Marne and Saunders catchments) (discussed in section 2.2.2)

3. model updates to support calculation of annual permitted take and annual actual take as per the Basin Plan requirements (discussed in section 4).

It is acknowledged that large sections of this document are direct extracts from previous (peer reviewed) modelling reports that were published during the state water planning process for the Eastern Mount Lofty Ranges and Marne Saunders Prescribed Water Resource Areas. This report is a collation of the appropriate information from those modelling reports and as such, not all extracts have been explicitly referenced. The main reports where direct extracts were taken in compiling this report were:

- Surface water assessment of the Upper Angas sub-catchment (Savadamuthu 2006)
- Surface water assessment of the Bremer River Catchment (Alcorn 2008)
- Surface water assessment of the Currency Creek Catchment (Alcorn 2006)
- Surface Water Assessment of the Upper Finniss Catchment (Savadamuthu 2003)
- Surface Water Assessment of the Tookayerta Catchment (Savadamuthu 2004)
- Impact of farm dams on streamflow in the Upper Marne Catchment South Australia (Savadamuthu 2002)
- Surface Water Assessment of the Upper Saunders Creek Catchment (Alcorn 2005 unpublished)
- Capacity of the surface water resource of the Eastern Mount Lofty Ranges (Alcorn, Savadamuthu & Murdoch 2008)
- Updates to the Capacity of the Surface Water Resource of the Eastern Mount Lofty Ranges (Alcorn 2010)
- Hydrological Modelling of the Eastern Mount Lofty Ranges: Demand and Low Flow Bypass scenarios (Alcorn 2011)

2.2.1 Initial hydrological model development to assess the impact of runoff dam development

Surface water models were used to assist the investigation to determine the capacity of the surface water resource of the EMLR Prescribed Water Resources Area (PWRA). The investigation, summarised in Alcorn et al. (2008), was done as part of the Water Allocation Planning process undertaken by the South Australian Murray-Darling Basin Natural Resources Management Board.

The main aim of all technical investigations discussed in the above catchment model reports was to quantify the effect of runoff dams on the surface water resources of the various catchments in the EMLR PWRA. Runoff dams are thought to be one of the main contributing factors to reductions in streamflow for the predominantly rural catchments that exist in the region (Alcorn et al. 2008).

The most up to date climate and runoff dam data were obtained for each catchment and applied to existing EMLR hydrological models in 2008. The models were recalibrated where required, and then run for a defined reference period, 1974–2003, and the results analysed. This process facilitated a better understanding of the state of the surface water resources across the extent of the region (Alcorn et al. 2008).

The main output of this investigation was to define the 'capacity of the surface water resource' or 'adjusted runoff' in the EMLR WRP area. This describes the mean annual runoff[1], with the impact of runoff dams removed from the catchment. Note that the impacts of watercourse diversions, urban runoff and plantation forestry have also been removed to calculate surface water resource capacity in the catchments of the EMLR SDL resource unit as part of the major model review described in the following section.

[1] Or mean winter runoff (May–November inclusive) for the Marne and Saunders catchments

Hydrological models were also built to assess the impact of runoff dams in the Marne River (Savadamuthu 2002) and Saunders Creek (Alcorn 2005 unpublished) catchments.

2.2.2 Major review of hydrological models

A major review of the hydrological models for the EMLR PWRA was undertaken to include data estimates on direct watercourse extractions not included in the first round of modelling. It also extended and revisited two of the five models — the Angas River catchment model and the Bremer River catchment model — to include previously excluded stream reaches in the lower plains region of the Angas-Bremer Irrigation Management Zone (ABIMZ).

The process to include more recent information relating to water resource development and streamflow monitoring that had become available for the EMLR PWRA models is summarised in Alcorn (2010). The models were reviewed and recalibrated where necessary, in light of either a change in the assumed water balance of the catchment due to extractions or losses, or as a result of new or improved streamflow calibration data.

Runoff dam data from Alcorn et al. (2008) were not changed as part of this amendment process.

The models were set-up to include current estimated use from runoff dams and watercourse extractions, but do not model the impacts of plantation forestry. Note that the impacts of existing plantation forestry on runoff have been accounted for when determining adjusted runoff for the modelled catchments in the EMLR SDL resource unit, which is discussed in Alcorn (2010). That is, one of the adjustments made when calculating adjusted runoff was to increase runoff by the volume estimated to be intercepted by existing plantation forestry for these catchments. However, for the modelled catchments in the Marne Saunders SDL resource unit, existing plantation forestry is negligible and has not been accounted for when determining adjusted runoff.

3 Surface water modelling approach

This section provides an overview of the approach that has been adopted for hydrological modelling in the EMLR WRP area. Further details on model construction, calibration and use for individual catchments are provided in the later sections of this report.

3.1 Modelling overview

Surface water models or catchment rainfall-runoff models or hydrological models (as referred to in this report) are conceptual models that represent interaction processes between the various surface water components of the hydrologic cycle (rainfall, interception, evaporation, infiltration, surface runoff, groundwater recharge, streamflow and baseflow), at a catchment scale. The interaction processes are represented by mathematical functions that are built into a model by using computer programming languages. Models are built to simulate catchment conditions, to generate long-term data and to enhance further understanding of the hydrological processes within catchments. They are further used for assessment of the impacts of various changes and management activities on the hydrological processes.

Hydrological models built for catchments in the EMLR PWRA and Marne Saunders PWRA are catchment scale rainfall-runoff water balance models. Individual catchment scale models for the Angas River (Savadamuthu 2006), Bremer River (Alcorn 2008), Currency Creek (Alcorn 2006), Finniss River (Savadamuthu 2003), Tookayerta Creek (Savadamuthu 2004), Marne River (Savadamuthu 2002) and Saunders Creek (Alcorn 2005 unpublished) were constructed as part of the state's water planning process.

3.2 Modelling framework and platform

WaterCress (Cresswell 2002), a PC-based water balance modelling platform, was used for construction of the hydrological models summarised in this model report. This modelling platform incorporates some of the most widely used models in Australia (AWBM, Simhyd, HYDROLOG and WC-1). WC-1 is the water balance model used to construct and calibrate catchment models in the EMLR PWRA (Appendix A). AWBM (Australian Water Balance Model) is the water balance model used for the Marne River and Saunders Creek catchments (Appendix B). WaterCress includes the following components:

- demand – includes town and rural demand
- catchment characteristics – includes rural and urban catchments
- storage – includes reservoir, aquifer, tank, and dam (on-stream and off-stream), including functionality to represent baseflow to pass
- treatment processes – includes sewage treatment works and wetlands
- transfer infrastructure – includes weir and routing components.

A model is then constructed as a series of 'nodes', each node being one of the components mentioned above. Nodes are then linked, based on the drainage direction to form one major catchment and parameterised with hydrological data such as rainfall and evaporation, among others.

All models have been based on the best available information and are consistent with the provisions of the relevant Water Allocation Plan (WAP).

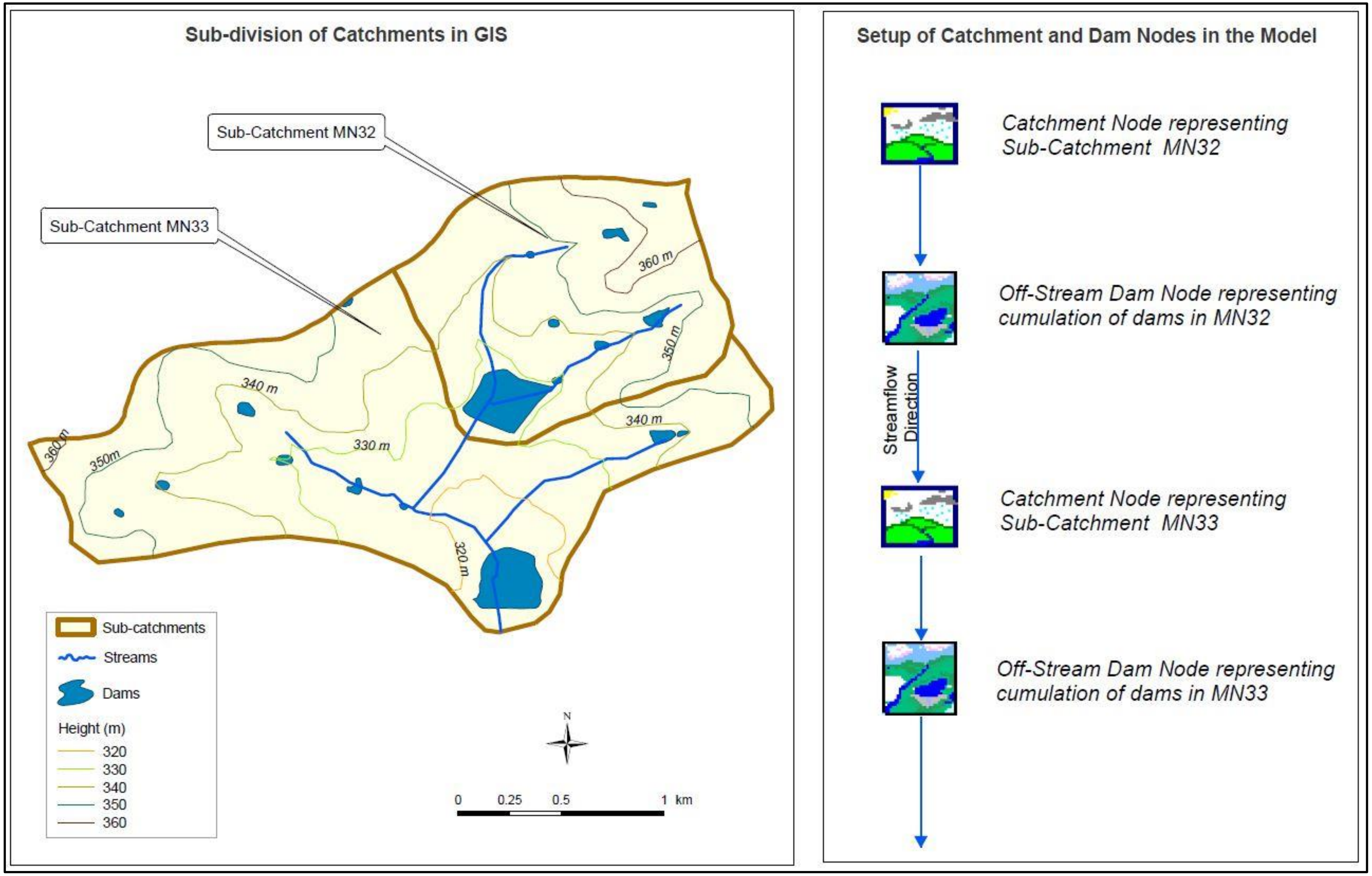


Figure 2. Model construction – Representation of catchment components as model nodes

3.3 Model build (node-link structure)

Prior to building a catchment model, extensive pre-processing work involved using Geographic Information System (GIS) tools to delineate the catchment into numerous sub-catchments that drain to the various runoff dams and watercourse extractions. Model construction then involved the process of representing these sub-catchments, in the WaterCress platform, as a series of rural or urban catchment nodes that drain to a dam node or a watercourse extraction node, with a routing node at the end of each sub-catchment. Stream loss nodes were incorporated at appropriate locations to represent loses and gains, to and from, groundwater along sections of the rivers.

A discrete node representing the relative location of the streamflow gauging station (or stations, where applicable) within the catchment was included, and the models were calibrated to observed streamflow records at this node. A typical layout of the spatial representation of the different components of a catchment as nodes in a model is illustrated in Figure 2.

The structures of the models built are considered to be partially distributed, from a perspective of spatial representation of the variability of hydrological parameters within a catchment. The models include explicit representation of: (i) spatial variability of rainfall across the catchment, (ii) location of major blocking dams (and the type of use, for irrigation or for stock and domestic purposes) relative to their contributing catchment areas, (iii) watercourse extractions at a surface water management zone (SWMZ) scale, (iv) urban catchment parameters and (v) catchment parameters that provide the best fit to observed streamflow in the catchment.

Spatial clusters of smaller dams were lumped into single dams and included in the model as a single dam, and at a location relative to other dams within a catchment. A single set of catchment parameters was used for all rural catchment nodes within a catchment except for the Bremer River model.

3.4 Model calibration

The models were calibrated to daily observed streamflow records from streamflow gauging sites that were included in the calibration node (gauge node) in the models. Calibration was undertaken twice, the first time when the models were built, and later when they were recalibrated in 2010 (Alcorn 2010). Recalibration in 2010 involved updating the initial models to include new and additional data sets, including: climate data, streamflow data available from additional sites, runoff dams, watercourse extractions and stream losses.

The calibration process for the initial models aimed at achieving the best fit between observed and modelled flow data at three time scales (annual, monthly and daily) using the primary statistics: (i) Percentage difference from observed mean and median, (ii) Coefficient of Determination (R^2) and (iii) Coefficient of Efficiency (CE). Furthermore, given the ephemeral nature of the rivers in the region, in addition to testing the primary statistics, a high level of emphasis was placed on aiming to achieve a close fit of the relevant flow percentiles of the daily flow exceedance curves, during the calibration process. For example, higher emphasis was placed for flows between the 10^{th} percentile and 80^{th} percentile daily flow exceedances, with lesser emphasis on very high flows (up to 10^{th} percentile exceedance) and very low or base flows (greater than 80^{th} or 90^{th} percentile exceedance).

With more models built progressively for catchments across the region, and with the advent of advanced modelling tools, the calibration of the Bremer River model, which was built later, included a slightly more sophisticated process involving a combination of methods (Alcorn, 2008):

1. initially, regional catchment parameter estimates were gathered from hydrologic models developed in the same region. Using these parameters gave an initial starting point for the calibration process
2. using a genetic algorithm (GA) calibration tool built into the WaterCress platform, various parameters were coupled and optimised until suitable calibration statistics were found
3. finally, fine adjustment of parameters was applied in order to achieve the best calibration possible.

Using the GA tool to optimise the parameters was initially helpful, but did not fully account for some of the requirements of the modelling process. For example, while it is possible within the GA to optimise to different objective functions and use several error models, it was necessary to visually fit some aspects of the calibration output, such as the difference in relevant daily flow exceedance percentiles. Optimisation of low flows was an imperative part of the modelling requirement, and as such these were assigned more weight than, for example, monthly flow totals. Overall, the model parameters were fitted using both automated and visual fitting methods to ensure best optimisation for the expected use of the model and model output.

Further information on the methodology and data sets used to recalibrate the models in 2010, the calibration statistics for each catchment model, the assumed initial conditions (like initial storage levels in the runoff dams), the sensitivity of the models in generating the different flow regimes and other assumptions and limitations of the models are provided in the individual modelling reports and summarised in Alcorn 2010.

4 Model updates to support determination of actual and permitted take

4.1.1 Annual permitted take

The methods for determining annual permitted take are set out in the EMLR WRP, and include the use of the surface water models described in this report for the EMLR and Marne Saunders surface water SDL units. This section describes the overall approach to updating the surface water models such that they may be used to contribute to calculating annual permitted take. Specific model updates are described in the subsequent sections.

The forms of take identified in the Basin Plan that are included in the EMLR WRP area surface water models are:

- take from a watercourse (including flood diversion)
- take by runoff dams (including use and loss from dams).

Take under basic rights is not included as a form of take in the EMLR WRP. Instead, take for the purposes of basic rights (stock and domestic use) is included as a class of water access right for the forms of take listed above, as discussed in the EMLR WRP. Take for the purposes of basic rights is represented in the models as take and loss from unlicensed dams.

The forms of take identified in the Basin Plan that are not included directly or indirectly in the EMLR WRP area surface water models are:

- take from a regulated river (as there are no regulated rivers in the EMLR WRP area)
- take by floodplain harvesting (does not occur in the EMLR WRP area)
- net take by commercial plantations (accounted for separately under the annual permitted and actual take methodologies, as described in the EMLR WRP)
- take from groundwater (not relevant for surface water SDL units).

As noted above, the surface water models do not account for take by commercial plantations. However it is noted that the effect of commercial plantations on runoff has been considered when determining resource capacity in the EMLR PWRA, as described in Alcorn 2010. Demand from commercial forestry was taken into consideration when creating the fully allocated models that contribute to calculating permitted take.

The EMLR WRP sets out how the annual permitted take method accounts for the requirements set out in Basin Plan sections 10.10 and 10.12, including: carryover, return flows, connected water resources, growth in use, trade of water access rights, disposal and acquisition of held environmental water, and water used for the purpose of managed aquifer recharge. Briefly, these requirements relate to the EMLR WRP area surface water models as follows:

- The models do not include carryover. Instead, the annual permitted take method accounts for carryover as a post-processing step outside the surface water models, as described in the EMLR WRP.
- The surface water models account for return flows in the lower Angas-Bremer area, the only part of the EMLR WRP area where return flows are expected, as described in sections 5.3.2.1 and 7.3.2.
- The surface water models incorporate interactions with connected water resources as described in section 5.3.2.1 and by being calibrated to measured stream flow data, which includes baseflow input from groundwater. The EMLR WRP area discharges to the River Murray and Lake Alexandrina, and does not receive inflow from other catchments.

- The models are based on full utilisation of water allocations, subject to the influence of climate and upstream demand, in a reasonable future scenario of a fully allocated system termed the permitted take scenario (see section 4.3.1). That is, there is no growth in use expected under the permitted take scenario. Trade, held environmental water within the consumptive use limits and use of surface water for managed aquifer recharge must all occur within the maximum volumes permitted under the fully allocated system. These processes do not change the amount of water that can be taken under the fully allocated system, and so are incorporated within the permitted take scenario and the associated surface water models.

The modelling platform is sufficiently flexible such that if the SDL is adjusted, then water demand could be added or removed from the permitted take models to represent a different permitted take value (e.g. by adding or removing runoff dams, or by adjusting volumes taken by runoff dams or watercourse extractions).

Sections 4.2 and 4.3 describes how the EMLR WRP area surface water models have been updated so that they can be used to support calculation of annual permitted take. Section 4.2 describes how the models used for state water planning purposes (as per section 2.2) have been updated to reflect information on current water demand. Section 4.3 describes how these updated models have been extended to create ‘permitted take’ models that are a component of a permitted take scenario that represent a reasonable future scenario of a fully allocated system.

As shown in Figure 1, some EMLR catchments do not have surface water models, and annual permitted take from those catchments are not directly determined using the models described in this report. As set out in the EMLR WRP, climate adjustment factors calculated from the ‘permitted take’ models are used to simulate the effects of climate and upstream water taking on water demand in those catchments under the permitted take scenario.

4.1.2 Annual actual take

The methods for determining annual actual take are set out the EMLR WRP. The models described in this report are not used to directly estimate annual actual take. However, values from the ‘permitted take’ models are used to calculate ‘climate adjustment factors’ that are used as part of the method to determine annual actual take. These climate adjustment factors are applied to estimates of maximum demand for unmeasured take (e.g. unmetered licensed use from watercourses and dams, take for basic rights or loss from dams) for the assessment year. Applying the climate adjustment factors simulates the effects of climate and upstream water use on estimated actual take volumes.

The first step in developing the permitted take models was to update the models used for state water planning purposes to reflect current water demand (as set out in section 4.2). These models have been named ‘actual take’ models, but are not used for the annual actual take method and are referred to in this report as current take models.

4.2 Updating models to reflect current demand

All models were updated to incorporate the best available estimate of current demand (2016–17). The current take models output take from watercourses and by runoff dams (including loss from dams). Current take models have been updated for the Angas, Bremer, Currency, Finniss, Tookayerta, Marne and Saunders catchments within the EMLR WRP area, as highlighted in Figure 1.

4.2.1 Changes to create updated ‘current take’ Eastern Mount Lofty Ranges models

Existing watercourse demand in the Angas, Bremer, Currency, Finniss and Tookayerta models was updated to match current licensed allocation volumes as outlined in Table 2. The purpose of this was to create newly updated current take models, including updates to Angas-Bremer flood diversions.

In most cases, this update required changing the watercourse demand volume at the existing watercourse diversion node at the end of the relevant zone in the models.

Table 2. Previous and updated licensed watercourse allocation volumes for updating current take models

Catchment	SWMZ	Previous WC Demand (ML)	Updated WC Demand (ML)
Angas River	426AR005	41.9	38.3
Angas River	426AR009	158.9	170.1
Angas River	426AR014	12.3	19.2
Angas River	426AR019	1.3	2.5
Angas River	426AR025	174.4	130.8
Angas River	426AR026	0	564.6
Bremer River	426BR008	16.1	17.0
Bremer River	426BR025	34.0	31.7
Bremer River	426BR029	32.6	33.1
Bremer River	426BR035	172.3	72.0
Bremer River	426BR039	123.4	46.6
Bremer River	426BR041	123.4	46.6
Bremer River	426BR043	11.3	10.0
Bremer River	426BR048	127.1	109.4
Bremer River	426BR049	193.2	229.9
Bremer River	426BR054	4.2	2.1
Bremer River	426BR062	0	1729.6
Currency Creek	426CC004	18.2	9.2
Currency Creek	426CC008	137.5	68.2
Currency Creek	426CC010	134.6	53.3
Finniss River	426FR001	29.5	68.7
Finniss River	426FR003	13.2	2.8
Finniss River	426FR007	15.1	6.4
Finniss River	426FR008	90.6	37.2
Finniss River	426FR009	31.5	21.1
Finniss River	426FR012	20.5	12.6
Finniss River	426FR013	163.7	69.5
Finniss River	426FR016	3.0	3.0
Finniss River	426FR018	0.4	0.4
Finniss River	426FR022	129.5	131.4
Finniss River	426FR027	134.4	182.5
Tookayerta Creek	426TC001	225.7	168.8
Tookayerta Creek	426TC002	46.7	23.8
Tookayerta Creek	426TC003	538.4	452.9
Tookayerta Creek	426TC004	95.4	64.8
Tookayerta Creek	426TC005	738.0	722.9
Tookayerta Creek	426TC006	70.4	41.9
Tookayerta Creek	426TC007	213.3	288.4
Tookayerta Creek	426TC008	142.5	134.8
Tookayerta Creek	426TC009	283.7	93.2

4.2.2 Changes to create updated 'current take' Marne Saunders models

Runoff dam demand was updated and watercourse demand was added to the Marne Saunders models to create newly updated current take models. Tasks undertaken for updating runoff dam demand and adding watercourse demand included:

1. Maximum demand (from dams and watercourses, not including evaporation) for existing models was detrermined.
    - It was found that maximum demand from the models slightly exceeded allowable take under the Marne Saunders WAP existing user licensing outcomes, so maximum demand in the models was reduced to within WAP take limits.
    - Maximum dam demand from the existing models was calculated as 1821.1 ML (dam capacity x usage factor per dam node) and included both licensed and stock and domestic demand.
    - Maximum allowable dam demand under the Marne Saunders WAP existing user licensing outcomes was found to be 1773.1 ML (surface water allocation volume of 1277.5 ML (from the state water licencing system) + estimated stock and domestic demand of 495.6 ML (30% of unlicensed dam capacity of 1652 ML from Table 17 of the Marne Saunders WAP)).
    - This resulted in dam demand in the models needing to be reduced by 48 ML (1821.1 – 1773.1).
2. Maximum dam demand in the models was reduced by reducing the usage factor in selected dam nodes until dam demand in the model was the same as the target value of 1773.1 ML.
    - Usage factors in the Saunders model nodes varied between 0.003-0.374, but for the Marne was 0.5 for all nodes. So a reasonably realistic approach was to reduce the usage factor in some nodes in the Marne model to 0.3 (30% stock and domestic use) for nodes with stock and domestic dams only, as set out in Table 3.

Table 3. Changes to usage factors in the Marne River model nodes

Sub-zone	Dam volume (ML)	Original usage factor	Updated usage factor	Original model dam demand (ML)	Updated model dam demand (ML)
M201	14.25	0.5	0.3	7.1	4.3
M202	15.948	0.5	0.3	8.0	4.8
M203	12.44	0.5	0.3	6.2	3.7
M207	7.31	0.5	0.3	3.7	2.2
M208	11.106	0.5	0.3	5.6	3.3
M209	9.11	0.5	0.3	4.6	2.7
M211	19.7	0.5	0.3	9.9	5.9
M212	37.5	0.5	0.3	18.8	11.3
M213	13.78	0.5	0.3	6.9	4.1
M214	51.47	0.5	0.3	25.7	15.4
M215	47.5	0.5	0.3	23.8	14.3
Total				120.1	72.0
		Difference between current and revised			48.0

There was 182.7 ML of watercourse allocation across the Marne Saunders SDL resource unit that also needed to be added to the models. This was added using a diversion node, routing node and demand node and the volumes per WAP sub-zone are listed in Table 4 below.

Table 4. Watercourse allocations per Marne Saunders WAP sub-zone as added to the models

Sub-zone	Watercourse allocation volume (ML)
M1-02	21.9
M1-03	3.4
M1-07	12.2
M1-10	2.0
Main watercourse between M1-05 and M1-09	3.7
Main watercourse in M3	27.8
Main watercourse in M5	71.6
S1-01	39.9
Main watercourse in S3	0.2
Total	182.7

Screen shots of all node changes made to the above mentioned current take models can be seen in Appendix J.

4.3 Permitted take models

Permitted take is defined as the sum of the maximum quantity of water permitted to be taken by each form of take for consumptive use from the SDL resource unit, and must be determined having regard to the water resources available during the period.

The method for determining annual permitted take set out in the EMLR WRP approaches these requirements as follows:

- Water resources available during the period – the surface water models described in this report are used to simulate the effects of climate and upstream water taking on water availability from year to year.
- Maximum quantity of water permitted to be taken – the volume of water demand in the surface water models has been adjusted to reflect a permitted take scenario where the maximum allowable demand for water equates to the WAP take limits (see section 4.3.1). The maximum allowable demand for water is what could be taken within WAP take limits if there were no impacts from climate or upstream use.

4.3.1 Permitted take scenario

To support determination of annual permitted take, a permitted take scenario was created that reflects a reasonable future scenario of full allocation under WAP take limits.

The Marne Saunders PWRA is currently fully allocated, so current demand already reflects the maximum quantity of water permitted to be taken, following the updates and adjustments made to the 'current take' models as detailed in section 4.2.2. Further work was undertaken to define the proportion of take from licensed dams and from stock and domestic dams, and to calculate average annual dam loss, as set out in section 4.3.2. These parameters are required for determining annual permitted take as set out in the EMLR WRP.

In the Eastern Mount Lofty Ranges PWRA, current demand is less than the WAP take limits, so work was undertaken to create a reasonable future scenario of full allocation across the area (i.e. maximum demand across modelled and unmodelled catchments = WAP take limit). The steps to develop this permitted take scenario are set out below.

1. Calculate current maximum demand across all relevant forms of take for modelled and unmodelled catchments (section 4.3.2).
2. Identify the volume of currently unassigned water (section 4.3.3).
3. Assign unallocated water to areas and forms of take to create a reasonable future scenario of full allocation (section 4.3.4).

4.3.2 Calculation of current maximum demand across all relevant forms of take for modelled and unmodelled catchments

4.3.2.1 Eastern Mount Lofty Ranges SDL resource unit

The following types of water demand are accounted for against the EMLR WAP take limits (called the 'evaporation and consumptive use limit' in the EMLR PWRA):

- allocation volume from watercourses (licences are bundled in the EMLR PWRA, and the allocation is a fixed maximum annual volume that can be taken, that does not change from year to year)
- allocation volume from dams (as for allocations from watercourses above)
- basic rights (estimated as 30% of unlicensed dam capacity, as per EMLR WAP section 1.6.2.3)
- loss from dams (estimated as average annual net evaporation from dams, calculated as volume of dam capacity in a management zone multiplied by the estimated evaporation factor for that zone given in Table 4.5 of the EMLR WAP – see EMLR WAP section 4.2.2.2, heading 'Evaporation' and also Appendix L in this report)
- interception by commercial plantations (estimated as 85% of annual adjusted runoff volume from the forest area, calculated in accordance with EMLR WAP principle 267 (a) – see section 1.6.3 of EMLR WAP)

The evaporation and consumptive use limit applies at a range of spatial scales, and the largest is at the scale of the entire PWRA. There are no specific limits on individual forms of water demand — instead the total volume across all forms of demand must be within the limit.

The current volume for each type of demand was determined for each catchment, as set out in Table 5.

Table 5. Method for determining current volume for each type of demand in the EMLR PWRA

Form of demand	Modelled catchments	Unmodelled catchments
Watercourse allocations	Watercourse allocation volume from 'current take' models as per section 4.2.1 of this report	Current watercourse allocation volume in the state water licensing system as of February 2017
Dam allocations	Licensed dam capacity in the model x 0.5	Current dam allocation volume in water licensing system as of February 2017
Basic rights	Unlicensed dam capacity in the model x 0.3	30% of unlicensed dam capacity from updated WAP dam dataset
Dam loss	Dam capacity per management zone from current take model x estimated evaporation factor for that zone; summed across all management zones in modelled catchments	Dam capacity per management zone from updated WAP dam dataset x estimated evaporation factor for that zone; summed across all management zones in unmodelled catchments
Commercial plantations	85% of annual adjusted runoff volume from forest area as of WAP adoption (see Table 1.8 of EMLR WAP)	As for modelled catchments

The licensed and unlicensed dam capacity in the current take models referred to in Table 5 was determined based on the internal annual usage fraction. As discussed in section 5.3.1.1, the models assume that maximum usage from licensed (irrigation) dams is 50% of dam capacity, and for basic rights (stock and domestic) dams it is 30% of dam capacity. This is represented in the model via the usage fraction for each dam node. A dam node with only licensed dams will have a usage fraction of 0.5; a dam node with only basic rights dams will have a usage fraction of 0.3; and a lumped dam node which includes both licensed and basic rights dams will have a usage fraction between 0.3–0.5 that represents the proportional split of dam capacity across the different purposes (see Appendix C-I).

The capacity of licensed dams in a dam node is calculated as:
Licensed dam capacity (ML) = [(5 x usage fraction for node) – 1.5] x dam capacity for node (ML)

The capacity of basic rights dams in a dam node is calculated as total dam capacity minus licensed dam capacity as calculated above. These values are then summed across dam nodes in a model to give total licensed and basic rights dam capacity per current take model. Note that these volumes of dam allocation are as per the model assumptions (licensed dams in the model x 0.5 dam capacity), rather than the specific allocation volumes currently on licence.

The 'updated WAP dam dataset' referred to in Table 5 is the dams dataset used for investigations underpinning the EMLR WAP (e.g. see Table 1.2 of the EMLR WAP), updated to reflect the final outcomes of the existing user licensing process and dams constructed since this dataset was generated, until February 2017.

4.3.2.2 Marne Saunders SDL resource unit

The methods for determining permitted take in the EMLR WRP require information on the proportion of take from licensed dams and from unlicensed dams, and also average loss from dams. These parameters were defined for the Marne and Saunders models as follows.

The approach used for determining licensed and unlicensed dam capacity described above for models in the EMLR SDL resource unit model could not be used for the Marne Saunders SDL resource unit. The Marne catchment has a usage fraction of 0.5 for all dam nodes, except for those adjusted as discussed in section 4.2.2. Instead the proportion of licensed dams and stock and domestic dams in the Marne and Saunders models was assumed based on the dams dataset used for the Marne Saunders WAP and existing user licensing process. According to Table 17 in the Marne Saunders WAP, there is 1,356 ML of unlicensed (stock and domestic) dam capacity in the Marne catchment and 296 ML in the Saunders catchment. Following the assumption above that basic rights maximum demand is 30% of unlicensed dam capacity, this means basic rights maximum demand is 406.8 ML for the Marne catchment and 88.8 ML for the Saunders catchment. The remaining dam capacity and maximum modelled dam demand is assumed to be from licensed dams.

Average loss from dams was calculated in the same way as for the EMLR SDL resource unit above (dam capacity x estimated evaporation factor by management sub-zone). Stated another way, estimated evaporation factor equals average net annual evaporation as a proportion of dam capacity. The Marne Saunders WAP does not include estimated evaporation factors, so these were calculated for each surface water management sub-zone using the same relationship between rainfall and modelled mean net annual evaporation used for the EMLR WAP (see EMLR WAP section 4.2.2.2, heading 'Evaporation' and Appendix L in this report). The resulting estimated evaporation factor per surface water management sub-zone in the Marne Saunders PWRA is given in Table 6.

Table 6. Estimated evaporation factor for management sub-zones in the Marne Saunders PWRA

Sub-zone	Est. evap. factor	Sub-zone	Est. evap. factor	Sub-zone	Est. evap. factor	Sub-zone	Est. evap. factor
M1-01	0.15	M2-03	0.30	M3	0.45	S2-05	0.35
M1-02	0.15	M2-04	0.33	M4	0.45	S2-06	0.35
M1-03	0.20	M2-05	0.35	M5	0.50	S2-07	0.40
M1-04	0.25	M2-06	0.35	S1-01	0.33	S2-08	0.40
M1-05	0.30	M2-07	0.35	S1-02	0.33	S2-09	0.40
M1-06	0.33	M2-08	0.35	S1-03	0.35	S2-10	0.40
M1-07	0.20	M2-09	0.35	S1-04	0.40	S2-11	0.35
M1-08	0.25	M2-10	0.35	S1-05	0.40	S3	0.45
M1-09	0.25	M2-11	0.40	S1-06	0.40	S4	0.45
M1-10	0.33	M2-12	0.40	S2-01	0.33	S5	0.50
M1-11	0.40	M2-13	0.40	S2-02	0.35	S6	0.50
M2-01	0.35	M2-14	0.40	S2-03	0.35		
M2-02	0.33	M2-15	0.40	S2-04	0.35		

4.3.3 Identification of volume of currently unassigned water

The current volume of demand for the modelled and unmodelled catchments for different components of demand determined as per section 4.3.2 is given in Table 7, together with the evaporation and consumptive use limit for each catchment and across the EMLR PWRA (summed across all unmodelled catchments). It can be seen that the currently unassigned volume of water is 2,961.9 ML, when demand is calculated in accordance with section 4.3.2.

Table 7. Current maximum demand volumes for different components in the EMLR PWRA

EMLR catchment	Volume (ML)						
	Watercourse*	Dam take**	Dam loss**	Forestry	Total	Limit	Unassigned
Angas	925.6	1161.2	535.9	0.0	2622.6	1682.0	0.0
Bremer	2328.0	1900.6	844.2	51.4	5124.2	3583.0	0.0
Currency	130.7	523.1	156.2	28.1	838.1	1612.0	773.9
Finniss	535.5	1954.9	555.4	2519.2	5565.0	8021.0	2456.0
Tookayerta	1991.5	414.4	123.5	557.3	3086.8	4620.0	1533.2
Unmodelled	4.9	687.2	625.3	35.0	1352.4	2033.0	1052.0
Total	5916.2	6641.5	2840.5	3191	18,589.1	21,551.0	2961.9

* Watercourse demand excludes lower Angas-Bremer flood diversions, as these are not counted against the evaporation and consumptive use limit.

** Dam take and loss volumes include licensed as well as basic rights.

4.3.4 Changes to create updated 'permitted take' models

The next step in developing the permitted take scenario was to add water demand to catchments until maximum demand reached the EMLR WAP's regional evaporation and consumptive use limit.

It was decided to add the unassigned volume to the Finniss River and Tookayerta Creek catchment models. These two catchments have the highest demand as a proportion of their limit, for the under-allocated catchments under current conditions (69% for Finniss, 67% for Tookayerta). It was considered reasonable to assume future demand for water would occur in catchments where there is already significant water demand (e.g. in those with higher rainfall, suitable landscape for water using enterprises, access to markets etc.).

In the Finniss catchment, dams are the largest component of current modelled demand, so it was considered reasonable to add unassigned water to this model in the form of new licensed dams. Dam capacity was added to each management zone until total maximum demand reached the evaporation and consumptive use limit for the zone or any downstream zones (or the dam capacity limit if reached first). Maximum demand from the new dam capacity was calculated as take (50% of dam capacity) + loss (average annual net evaporation, calculated in the same way as dam loss in Table 5). Water was first added to the management zone with the highest current demand compared to the limit, working sequentially down towards the least developed zone, until the catchment-scale evaporation and consumptive use limit was reached.

In the Tookayerta catchment, watercourse diversions are the largest component of current modelled demand, so it was considered reasonable to add unassigned water to this model in the form of licensed watercourse diversions. The volume of unassigned water remaining once the Finniss catchment was fully allocated was added to each management zone until total demand reached the evaporation and consumptive use limit for the zone or any downstream zone. Water was first added to the management zone with the highest current demand compared to the limit, and then to the next most developed zone until there was no unassigned water remaining.

Specific detail of the addition of water demand to zones is given below.

The resulting permitted take scenario is as follows:

- Marne Saunders PWRA – Marne and Saunders 'permitted take' models are the same as the updated 'current take' models as described in section 4.2.2.
- EMLR PWRA – Angas, Bremer, Currency, Finniss and Tookayerta 'permitted take' models; and maximum demand values for unmodelled catchments are shown in Table 7. 'Permitted take' models for Finniss and Tookayerta catchments are the models as described below with the unassigned water added to them. 'Permitted take' models for Angas, Bremer and Currency are the same as the updated 'current take' models described in section 4.2.1.

4.3.4.1 Updates to Finniss and Tookayerta models to create permitted take models

Tasks undertaken to add unassigned water to the Finniss model to create the permitted take model for this catchment included:

- creating a new Finniss River catchment model, using the updated current model, as described in section 4.2.1 above, as a starting point
- adding new dam nodes to the downstream end of SWMZs and assigning the dam volume as given in the table below. The assumed use fraction was set to 50% of dam capacity for the added dam capacity (see section 5.3.1.1).

Table 8. New dam capacity added at the end of SWMZs in the Finniss River catchment

SWMZ	New dam capacity (ML)
426FR001	200.5
426FR005	264.5
426FR006	348.4
426FR007	235.2
426FR008	8
426FR009	164.8
426FR010	189.6
426FR011	107.5
426FR012	26.8
426FR013	576.1
426FR014	277.2
426FR015	31
426FR016	53.2
426FR017	140.8
426FR018	320.3
426FR019	65.8
426FR021	137.3
426FR022	311.6
426FR023	29.2
426FR024	31.3
426FR025	53.4
426FR026	92.3
426FR027	195.5

Tasks undertaken to add unassigned water to the Tookayerta model to create the permitted take model for this catchment included:

- creating a new Tookayerta Creek catchment model, using the updated current model, as described in section 4.2.1 above, as a starting point
- adding watercourse diversion volumes as given in the table below at the existing watercourse diversion node at the end of the relevant zone in the model, following the same process as set out in section 4.2.1.

Table 9. New watercourse diversion volume added at the end of SWMZs in the Tookayerta Creek catchment

SWMZ	New watercourse diversion (ML)
426TC001	401.1
426TC006	106.2

Screen shots and details of all node changes made to the above mentioned permitted take model can be seen in Appendix K.

4.4 Improvements to models over time

The updated permitted take models described above are considered to be fit-for-purpose for Basin Plan requirements.

Optional improvements could be made to the models over time to incorporate updated data and knowledge as it becomes available, and reflect future development and changes in climate. Such improvements are likely to be considered at the time of major water planning reviews (e.g. reviewing and updating water allocation plans or water resource plans).

5 Model data

This section provides general information on input data that applies to all the surface water models in the EMLR WRP area. The data used is considered the best available in each case. Specific information for each catchment model is provided in sections 6-12.

5.1 Climate data

Rainfall and evaporation data are obtained from the Queensland Government's enhanced climate database SILO (Scientific Information for Land Owners) and are available from 1889 to the day before the data is downloaded. The data are part of the Patched Point Dataset (PPD), which has been disaggregated and infilled using the methods described in Jeffrey et al. (2001), meaning that it is a complete data set with no missing days. Using the SILO dataset helps maintain consistency of data time scales and currency (Alcorn et al. 2008).

The spatial distribution of rainfall across catchments is represented in the models by applying a scaling factor to each modelled sub-catchment, which have been determined through the use of rainfall isohyets. Rainfall data from 1895-2016 is used for modelling purposes.

5.2 Runoff dam data

5.2.1 Runoff dam volumes

The total volumes of all runoff dams, as represented in each current take catchment model, are summarised in the table below. Runoff dam volumes were calculated using the dam surface area-volume relationship developed by McMurray (2004).

Table 10. Modelled runoff dam volumes

Model catchment	Total model runoff dam volume (ML)
Angas River	3133
Bremer River	5065
Currency Creek	1283
Finniss River	5009 (8869 ML permitted take model)
Tookayerta Creek	1103
Marne River	3290
Saunders Creek	621

5.2.2 Runoff dam losses

The following information on evaporation from runoff dams was largely taken from Alcorn (2011). The WaterCress model calculates both evaporation from and rain falling on the dam surface. When combined, the difference between evaporation loss and rain on the water surface is termed the net evaporative loss. At each time-step the WaterCress model calculates a water balance on the dam which is explained in the steps below:

1. Calculate the surface area from the volume at the previous time step

2. Calculate the evaporative loss, inflows, demand, and rainfall based on the surface area calculated at (1).
3. Calculate the change in storage, and if storage is greater than the full supply level, spill the remaining water downstream e.g.

$$S_t = S_{t-1} + (I - O - E + P - D)\ dt$$

Where:

S_t = storage to be calculated at current time step (m^3)

S_{t-1} = storage at previous time step (m^3)

I = inflow rate at current time step (m^3/s)

O = outflow rate at the end of the current time step (m^3/s)

E = evaporation loss at current time-step (m^3/s)

P = rain falling at current time-step (m^3/s)

D = water extraction rate (m^3/s)

dt = the model time step (s).

Terms E and P are calculated from the current estimate of surface area based on the storage volume at the previous time step.

Runoff dams, as digitised from aerial photography of the region in 2005, are initially calculated a maximum surface area at the level at which the dam ceases to flow. This is usually at the point of the dam spillway. The surface area of the dam at less than full supply level is calculated using the estimate described by McMurray (2004):

$$A = Amax\left(\frac{V}{Vmax}\right)^{0.6}$$

Where:

A = Surface area (m^2) at volume V

A_{max} = surface area (m^2) at maximum volume

V = volume (ML)

V_{max} = Volume at maximum capacity.

5.3 Water use data

Water use across the modelled catchments is currently represented in the hydrological models by:

- runoff dam extractions
- watercourse diversions and extractions
- flood irrigation.

The following information on water use from runoff dams was largely taken from Alcorn (2011).

5.3.1 Runoff dam extractions

In the WaterCress model, simulated water use from runoff dams is defined by two settings; the internal annual use fraction and the monthly usage distribution.

5.3.1.1 Internal annual usage fraction

The internal annual usage fraction sets the proportion of a dam's maximum capacity that will be removed from the dam for external use, and be lost from the system. The models assume stock and domestic dams (non-licensed) demand a maximum 30% of the dam capacity in each year and irrigation dams (licensed) demand a maximum 50% of the dam capacity in each year (Alcorn 2008, McMurray 2004). Irrigation dams require a licence to extract water and thus their location is identified during the water licensing process. The monthly usage distribution defines the proportion of the total demand from the dam that will be extracted in each month.

For modelled sub-catchments with a runoff dam node that is lumped — that is, contains a representation of several dams — and that lumping comprises dams of different types, the initial usage fraction is calculated using the ratio of the total irrigation dam capacity to the total dam capacity. This is termed here, the Irrigation Proportion. The Irrigation Proportion (IP) is defined as the total capacity of identified irrigation (licensed) dams divided by the total capacity of all dams for the modelled sub-catchment.

Thus the internal annual usage fraction for a mixed use dam node will be between 30-50% with a 30% usage fraction for a sub-catchment denoting a lumped sub-catchment with only non-licensed dams. Likewise a 50% usage fraction for a sub-catchment would denote only licensed dam(s) are represented. The IP is then used as the defining factor in assigning initial and variable demand from lumped runoff dam nodes.

5.3.1.2 Definition of monthly usage distribution patterns

For irrigation dams, the monthly pattern is summer dominated with extraction only occurring during the months of October-March and defined by the Pattern Number 1, as assigned in the WaterCress model. Stock and domestic dams are assigned a distribution pattern (Number 0) that follows the evaporation distribution of the Mount Lofty Ranges region. For lumped, mixed irrigation and stock and domestic dam nodes, there are three more patterns given, based on the IP. These can be seen in the table and figure below, taken from Alcorn (2011).

Table 11. Runoff dam Irrigation Proportion range and monthly usage proportions

	Irrigation Proportion range				
	0–0.2	0.8–1.0	0.4–0.6	0.2–0.4	0.6–0.8
	Pattern number				
	0 (S&D only)	1 (Irrigation only)	2	3	4
	Monthly usage proportions (% of annual demand)				
Jan	0.15	0.24	0.20	0.17	0.22
Feb	0.13	0.195	0.16	0.14	0.18
Mar	0.10	0.126	0.11	0.11	0.12
Apr	0.06	0	0.03	0.05	0.02
May	0.04	0	0.02	0.03	0.01
Jun	0.03	0	0.01	0.02	0.01
Jul	0.03	0	0.02	0.02	0.01
Aug	0.05	0	0.02	0.03	0.01
Sep	0.06	0	0.03	0.05	0.02
Oct	0.09	0.066	0.08	0.08	0.07
Nov	0.12	0.166	0.14	0.13	0.15
Dec	0.14	0.207	0.17	0.16	0.19

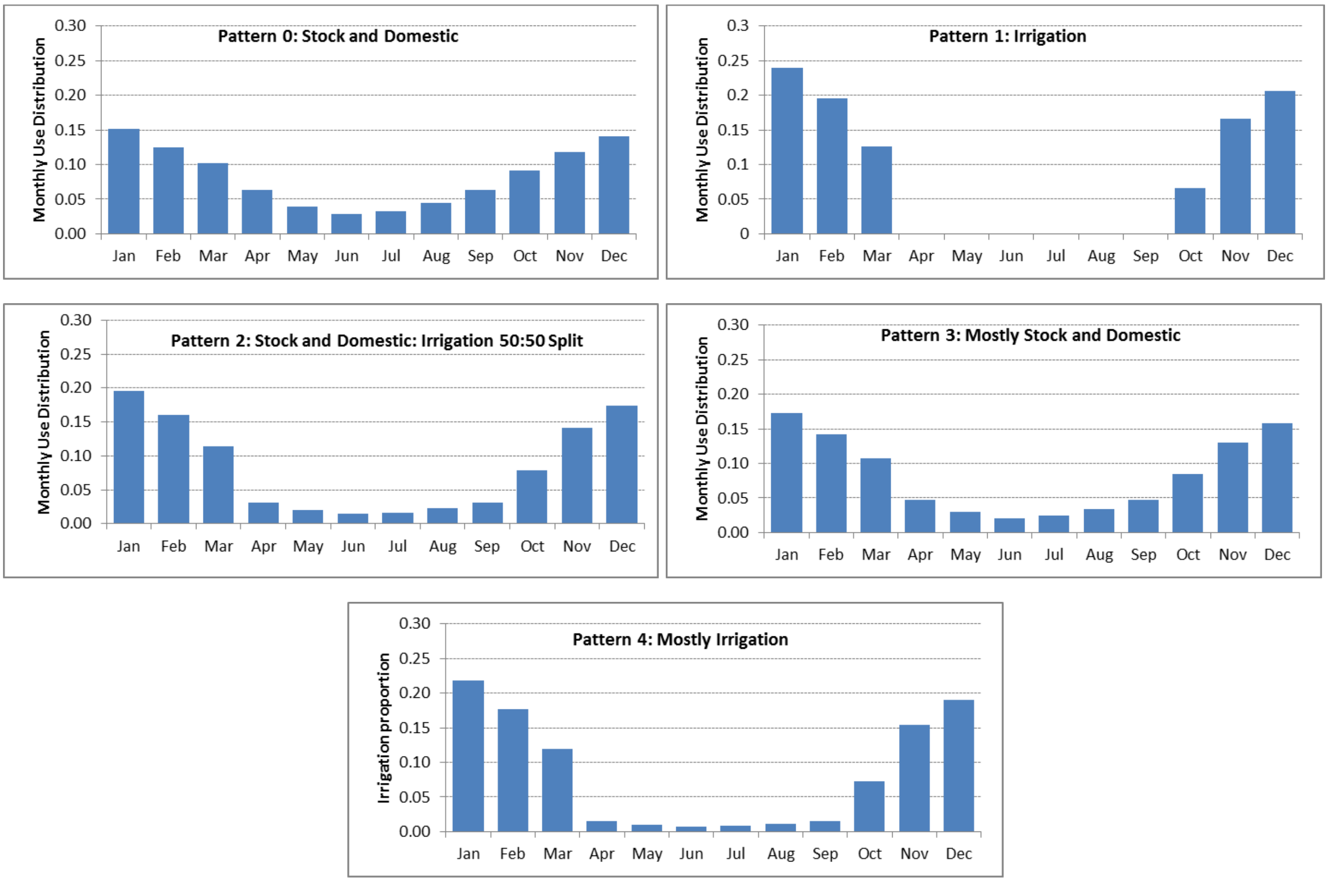


Figure 3. Monthly runoff dam usage proportions

5.3.2 Watercourse diversions and extractions

Watercourse diversions and extractions refer only to direct pumping from watercourses, and excludes extractions, diversions and flooding in the lower Angas and Bremer River catchments in the ABIMZ. Watercourse extractions, diversions and flooding in the ABIMZ are discussed in section 7.3.2 of this report.

Estimates of known watercourse extractions were obtained from the ongoing process of water allocation planning and were incorporated in the runoff dam catchment models as a demand node. The estimates were aggregated at the scale of the SWMZs in the EMLR WAP and the sub-zones in the Marne Saunders WAP, and are assumed to be extracted from the end of the relevant zones.

Direct watercourse extraction estimates were based on a number of factors including:

- a theoretical crop requirement – taking into account assumed crop type and climate
- the ability to take i.e. what water infrastructure is used to extract and a possible maximum rate
- other water sources available such as other runoff dams, or groundwater extractions.

As limited information on the timing of extractions was available, it was assumed that extractions were related to crop evapo-transpiration patterns, i.e., followed a summer dominant pattern with only minor winter extractions. The monthly extraction distributions were designed to mimic the monthly evaporation distribution in the region. Whilst some industries may extract strictly over the summer irrigation period, the chosen method also allows for those water users who may extract during winter to fill off-stream dams or flood irrigate during times when flow is actually available in the winter dominated streamflow of the Mount Lofty Ranges.

The implication of including a new factor in the water budget was that some of the models required recalibration to account for the extra water extractions, as discussed in Alcorn (2010). This is particularly the case where the extraction is large and above a previously calibrated streamflow gauge. Where the extraction is above a gauge and was only small relative to the streamflow, the model is generally not recalibrated. This is due to the fact that the calibration of streamflow is generally accurate only within 5-10% of the gauged flow at best.

The locations of the watercourse extractions were matched as closely as possible to the downstream end of a zone. Where necessary, a streamflow routing node was added to the model to create storage within the river reach to thus allow for direct extraction from the stream.

For each zone containing a known watercourse extraction or diversion, a separate daily water demand file was generated using a monthly distribution pattern. The total annual watercourse demand per modelled catchment in the updated current take models is summarised in the table below.

Table 12. Annual watercourse demand for modelled catchments

Model catchment	Annual watercourse demand (ML)
Angas River	1561*
Bremer River	2328**
Currency Creek	131
Finniss River	536
Tookayerta Creek	1991 (2499 ML permitted take model)
Marne River	143
Saunders Creek	40

*Annual watercourse demand for the Angas River catchment is inclusive of both standard watercourse demand and also flood diversions.

** Annual watercourse demand for the Bremer River catchment in this table only includes ‘standard’ watercourse demand and does not include flood diversions. Flood diversions in the Bremer River model are represented as demand from the main watercourse that varies in response to flow, and so the volume taken varies from year to year, as discussed in sections 5.3.2.1 and 7.3.2.

5.3.2.1 Stream losses

The modelling of EMLR PWRA catchments previously undertaken took into account flows leaving only the ‘Hills’ region of the Angas and Bremer River catchments. This was primarily due to lack of sufficient streamflow records for the plains section and watercourse extraction data. However, there is known to be an extensive system of diversions for flood irrigation with a complex system of flood pumps, flood gates and levy banks to direct the water in the Angas-Bremer Plains region. Unfortunately, the combined effects of streamflow losses and watercourse diversions and extractions has made the interpretation of more recently collected water level and streamflow data difficult to analyse. Actual water diversions from the two rivers are not measured directly, and thus these have been inferred from a combination of published areal flooding extents; theoretical estimates of likely water use and stream inflows to the plains indicated by upstream gauges measuring outflows from the hills. Estimation is further complicated by the diversification of water sources in the region. Irrigators within the ABIMZ have access to water from River Murray licences and groundwater pumping, and surface water from the Angas and Bremer Rivers. Landholders also regularly store surface water through the process of managed aquifer recharge. Further explanation of the modelling process to account for stream losses and high flow diversion in this area is provided in Section 7.3.2.

Streamflow losses in general were simulated by the use of a seepage rate applied to a stream routing node in the WaterCress model platform. As the flow is routed through this node, the storage in the reach increases, as does the seepage rate.

Watercourse diversions from the Lower Bremer River were simulated by applying a diversion rate from the stream and routing the flow through an off-stream storage. The stored floodplain water was then allowed to either infiltrate into the floodplain, and hence be lost to the river system, or allowed to return to the stream at high flows, such as may occur in a natural flood.

6 Angas River catchment model

6.1 Overview

The Angas River catchment is located approximately 50 km southeast of Adelaide (Figure 4). The headwaters of the main river are located near the township of Flaxley and the river flows in a south-easterly direction through the towns of Macclesfield and Strathalbyn to its confluence with Lake Alexandrina near Milang. The major tributaries feeding the river include Doctors, Paris, Burslem, Middle, Dawson and Burnside Creeks. Detailed catchment description and hydrology of the Angas River catchment are included in Savadamuthu (2006) and have been used to populate the descriptions below.

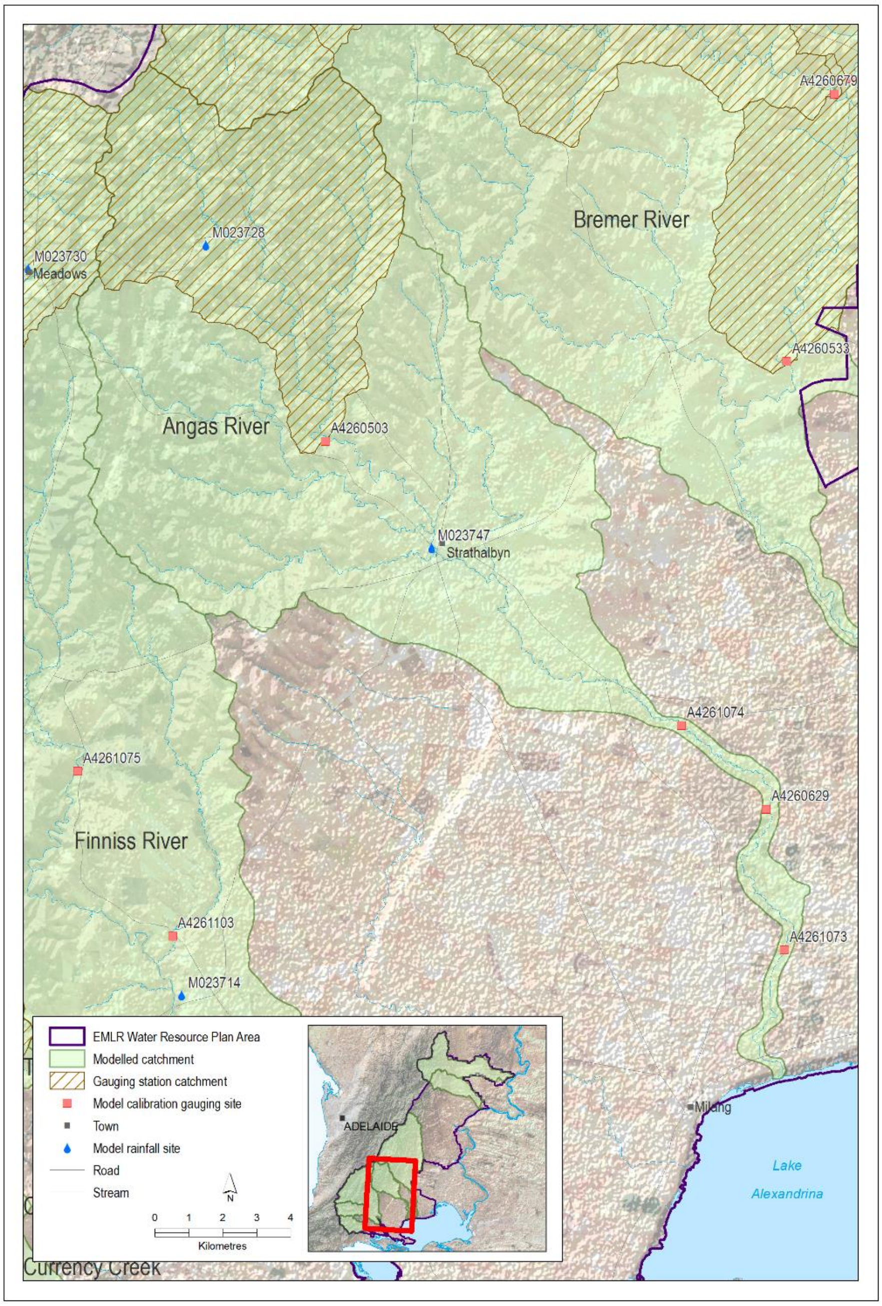


Figure 4. Angas River catchment location map

6.2 Model construction

6.2.1 Model nodes

The Angas River catchment was divided into 177 rural sub-catchments, set-up as a series of rural catchment nodes followed by off-stream dam nodes. Each rural catchment node in the model represents a sub-catchment within the whole of the Angas River catchment. Each off-stream dam node in the model represents an individual dam or accumulation of dams within that runoff dam sub-catchment. A demand node is used in the model to represent watercourse extractions and an urban node is used to represent a developed area with an impervious catchment area.

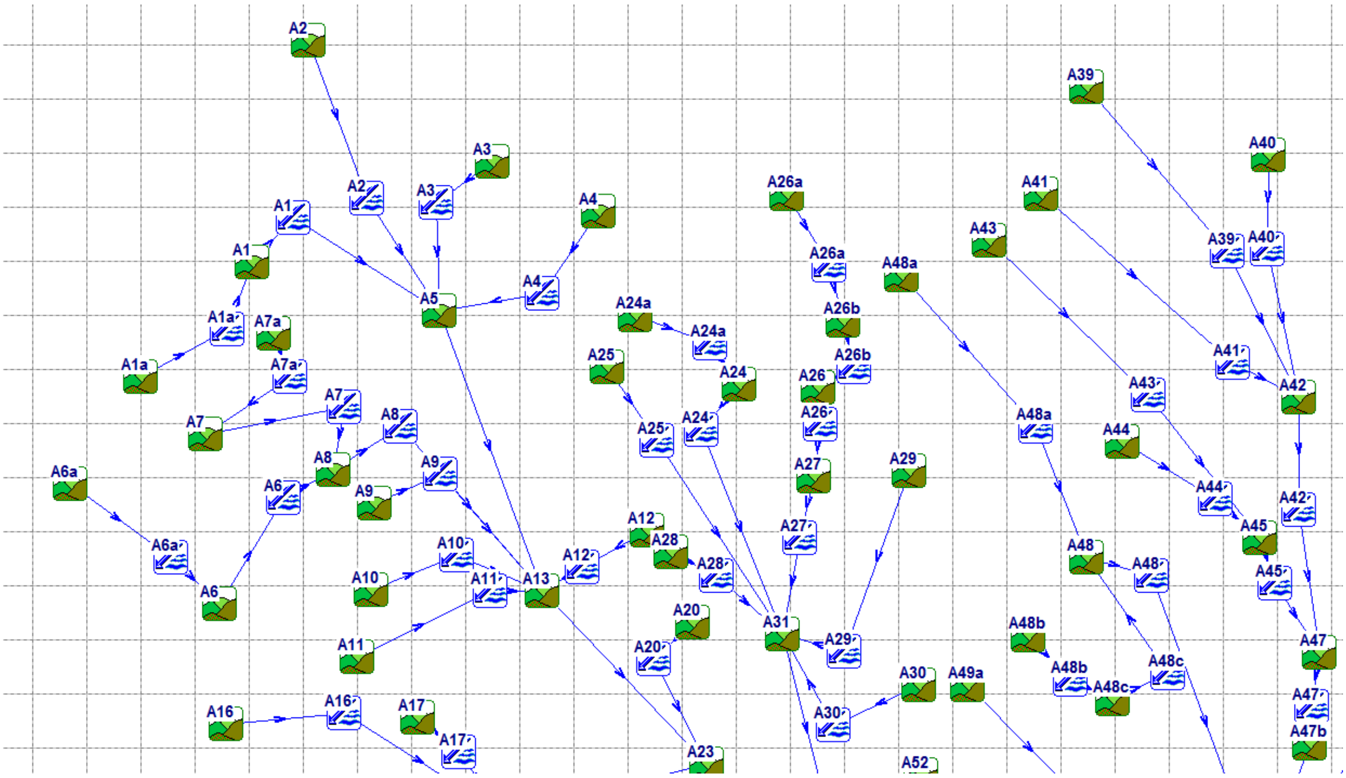
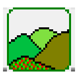


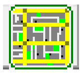
Figure 5. Model layout for a section of the Angas River catchment model

6.2.2 Catchment node inputs

The input data for rural catchment nodes  includes:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall data set, rainfall factor and monthly evaporation data set
- model to be used, which was WC-1 in this case, and the initial estimated values for the catchment parameter set (median soil moisture content, interception storage, catchment distribution, ground water discharge, soil moisture discharge, pan factor, fraction ground water loss, storage reduction coefficient, ground water loss and creek loss) (see Section 6.3.3)
- calibration file, which contains the observed daily rainfall data set and corresponding observed streamflow data set for the nodes that have a gauging station.

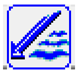
6.2.3 Urban node inputs

An urban node  representing the town of Strathalbyn is included in the model. Urban areas are calculated by digitising in GIS the extent of the towns and their surrounding impervious areas. Based on visual inspection, an impervious fraction coefficient is determined and multiplied by the area derived. This defines the actual impervious area, as the digitisation process does not differentiate between, for example, the backyard of a house and its driveway. The size of the coefficient is dependent on the scale and detail of digitisation, and the density of the urban or industrial development. This provides WaterCress an impervious area on which to run the urban model.

The urban model used within WaterCress is an Initial Loss – Continuing Loss (ILCL) model. It assumes that some amount of initial loss in the event of rainfall will first occur (e.g. when a small amount of rain falls on a roof, most will evaporate before becoming roof runoff to stormwater or a rainwater tank). Typical values for initial loss are 1 mm for roof runoff and 2 mm for pavement and roads. These values may be altered but remain fixed in this model.

Continuing loss is determined by means of a loss coefficient (between 0 and 1), which determines the fraction of water that is removed. What is left is the effective rainfall which is available as runoff to the catchment.

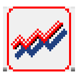
6.2.4 Dam node inputs

Each catchment node with runoff dams was linked to an off-stream dam node. The input data for each off-stream dam node  includes:

- dam storage volume, which in this case was the cumulative storage capacity of all the dams in the runoff dam sub-catchment
- corresponding measured daily rainfall data set, rainfall factor and monthly evaporation data set
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; this is dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). For example, this fraction was 1.0 if there was a large on-stream dam located on the downstream end of the catchment, as it would be a controlling dam that is deemed to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream
- water usage factors from the dams, which vary between 30-50% as discussed in Section 5.3.1.

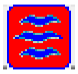
Key input data for each catchment and dam node in the Angas River catchment model are given in Appendix C.

6.2.5 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node. The input data for each demand node  includes:

- the daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system.

6.2.6 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

6.2.7 Rainfall spatial variability

Since rainfall varies spatially within a catchment, its variability has to be accounted for in the input data of each node. Spatial variability of rainfall in the Angas River catchment was accounted for by using a rainfall factor for each node derived from a daily rainfall data set from the Bureau of Meteorology (BoM) station at Macclesfield and the average annual rainfall for each runoff dam catchment calculated using GIS (Savadamuthu 2006). The rainfall factor for each node was calculated as the ratio of the average annual rainfall for each runoff dam catchment representing that node to the average annual rainfall at the Macclesfield BoM station.

6.3 Model calibration

Details of the initial model calibration can be found in Savadamuthu (2006). The following details of model recalibration are from Alcorn (2010). Calibration statistics for stations that are common to both calibration processes are shown in Table 13 below.

Table 13. Calibration statistics for the Angas River model for two calibration periods

Time step	**Difference in volume (%)**	**R^2**	**CE**
	Period 1 (Period 2)	Period 1 (Period 2)	Period 1 (Period 2)
Annual	8.8 (-11.9)	0.98 (0.763)	0.77 (0.895)
Monthly	8.8 (-11.9)	0.90 (0.80)	0.75 (0.83)
Daily	9.2 (-11.9)	0.78 (0.546)	0.61 (0.509)

Period 1: 1996 to 1999, Period 2: 1995 to 2002 (Gauging site: Angas River at Angas Weir, A4260503)

The initial Angas River catchment model was extended at the same time as model recalibration to include the 15 km of stream reach below the town of Strathalbyn that drains to Lake Alexandrina. Streamflow losses were modelled in this section, as well as the inclusion of plains watercourse extractions.

6.3.1 Watercourse extractions upstream of primary calibration gauges

Only a small volume of additional watercourse extractions were identified above the primary gauge location of the Angas Weir (station number A4260503), with the remaining being extracted below the main gauge and above the town of Strathalbyn.

6.3.2 Calibration notes

An addition of only 40 ML of extractions modelled above the upstream gauge would not normally indicate the need to recalibrate the model. However, when the calibration was reviewed, it was decided that the previous calibration was likely to be overestimating flows.

Flow records have been kept at the Angas Weir since 1969. However, until 1996 the weir was also used to divert water to the Strathalbyn reservoir. During this period only rudimentary records were kept of the amount of water diverted, and thus the records of flow over the weir were also approximate only and subject to random and systematic errors. Calibration after 1996 was made potentially more accurate since the reservoir officially ceased to operate and the weir has been measuring the true flow.

The previous calibration at the Angas Weir gauging station (as per Savadamuthu 2006) used only the record for the years between 1996 and 1999. One of the largest flow years recorded was 1996, whilst the following three years were all below average. It was found that when calibration was reworked over the longer period of the record, the calibration during the earlier shorter period was biased towards the large event in 1996, thereby overestimating flows in average or below average years.

The recalibration using data to 2002 at Angas Weir was carried out in conjunction with data over a similar period collected from the downstream site A4260629 (Angas River) at Angas Plains. The catchment area upstream of the Angas Plains site is 3.2 times greater than that of the Angas Weir site. However, the flow at the downstream site is, on average, only 1.2 times the flow leaving the Angas Weir for the concurrent period of record. This would indicate that there are considerable losses occurring in the plains downstream of Strathalbyn. Additional gauging stations downstream of Strathalbyn were also used to calibrate the losses, although over a different time period. The stations A4261073 (Angas River at Ballandown Road) and A4261074 (Angas River at Cheriton Road) were included as supplementary calibration stations for the period covering 2004 to 2010.

With respect to the recent records at Angas Weir, several notes on the station’s history file have indicated that unrecorded extractions have taken place in recent years, from 2002 onwards. These extractions appear to have taken place via direct pumping from the weir pool, or by the opening of the weir off-take valve. This is significant as there is known to be a strong summer baseflow of around 1 ML/d draining to the gauge from the upper catchment. When the record is used for calibration, the recorded flows below 1 ML/d have been assigned a bad quality code so that they are removed over this period in the calibration routine.

When good corrected-flow data is used in the calibrations, the model performs similarly well for both the upstream and downstream stations. While the calibrations at both stations for the three years 1997–99, both overestimate the flows by comparable amounts, the overall model performance, with introduced losses on the plains, is reasonably consistent over the longer timeframe. The calibration of the Angas Plains station could be improved by replacing the modelled flow at Angas Weir with the gauged flow.

6.3.3 Rainfall-runoff parameters

Figure 6 shows WC-1 rainfall-runoff parameter values used for the Angas River catchment model. An explanation of these parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

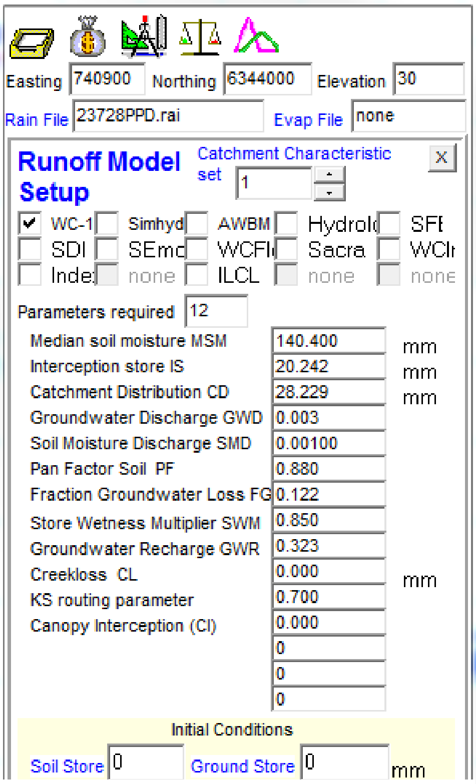


Figure 6. Model catchment characteristic set for the Angas River catchment

Medium soil moisture (MSM) – represents the median field capacity of the soil, usually in the range 150–300 mm. Increasing this value delays the early season initiation of runoff, decreases surface runoff by providing greater opportunity for evapotranspiration, but assists (to a lesser extent) in maintaining late season groundwater flows.

Interception store (IS) – represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10–25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) – sets the range of soil moisture values about MSM. The usual values are 25–60 mm. A larger value will initiate runoff earlier and more often.

Ground Water Discharge (GWD) – is the proportion of the groundwater store that discharges as baseflow to the stream. This is a simple linear function: Baseflow = groundwater store x GWD. Usual values are small, from 0.001 to 0.0001.

Soil moisture discharge (SMD) – As soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small, around 0.0001.

Pan factor for soil (PF) – This factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6 to 1.0. The higher the value the less the runoff. The higher the value, the earlier runoff ceases after winter.

Fraction Groundwater Loss (FGL) – The removal of groundwater store due to irrigation (or just assumed loss) is a multiplying factor for all recharge. For example a value of 0.6 here means only 40% of the calculated recharge actually occurs. The remainder is lost to the system.

Store Wetness multiplier (SWM) – This value determines the rate that water from the interception store moves to the soil store. The depletion of the interception store is calculated as the maximum of the loss based on the soil wetness multiplier and evaporation, whichever is the greater. The transfer rate can therefore be independent of season (if required) and ensures that the amount of water retained in the interception store follows a similar power recession curve to the Antecedent Precipitation Index (API). Usual values are around 0.9. Making this value close to 1 means that depletion of the interception store is controlled by the evaporation rate (which follows a more seasonal pattern).

Groundwater Recharge (GWR) – is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05 to 0.3, indicating that 5% to 30% of the flow running off the catchment is entering the groundwater system.

Creek Loss (CL) – is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates take-up of water from riparian vegetation and the reduction of baseflow in summer months.

6.4 Model assumptions and limitations

- Runoff dam data is based on a 2005 data set, obtained from aerial imagery captured between 2003 and 2005; locations of irrigation dams were gradually updated as they were identified as part of the water licensing process.
- Runoff dam volumes were calculated using the dam surface area-volume relationship developed by McMurray (2004).
- Runoff dams within a sub-catchment have been lumped to represent the total runoff dam volume of each sub-catchment and is represented in the model as one runoff dam node per sub-catchment.
- The proportion of the dam capacity used as an extraction limit varies from 0.3 for all stock and domestic dams to 0.5 for irrigation dams; it is variable between 0.3–0.5 for lumped runoff dam nodes consisting of stock and domestic and irrigation dams (discussed in Section 5.3.1).
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 0.7 fraction of maximum evaporation per month.
- Watercourse demand is based on allocation data obtained from the state water licensing system and for the Angas River catchment, total watercourse and floodplain demand is estimated to be 1561 ML at the time of writing.
- Refer to Savadamuthu (2006) for more detailed information.

7 Bremer River catchment model

7.1 Overview

The Bremer River catchment is located approximately 30 km south-east of Adelaide (Figure 7). The height above sea level of the upper catchment ranges from around 450 m in the north-west to 50 m at the confluence of the Bremer River and Rodwell Creek. Below this confluence, the Bremer River flows out onto the Angas–Bremer Plains, where it travels 20 km past the township of Langhorne Creek, to an elevation of less than 1 m, and into Lake Alexandrina. Detailed catchment description and hydrology of the Bremer River are included in Alcorn (2008) and have been used to populate the descriptions below.

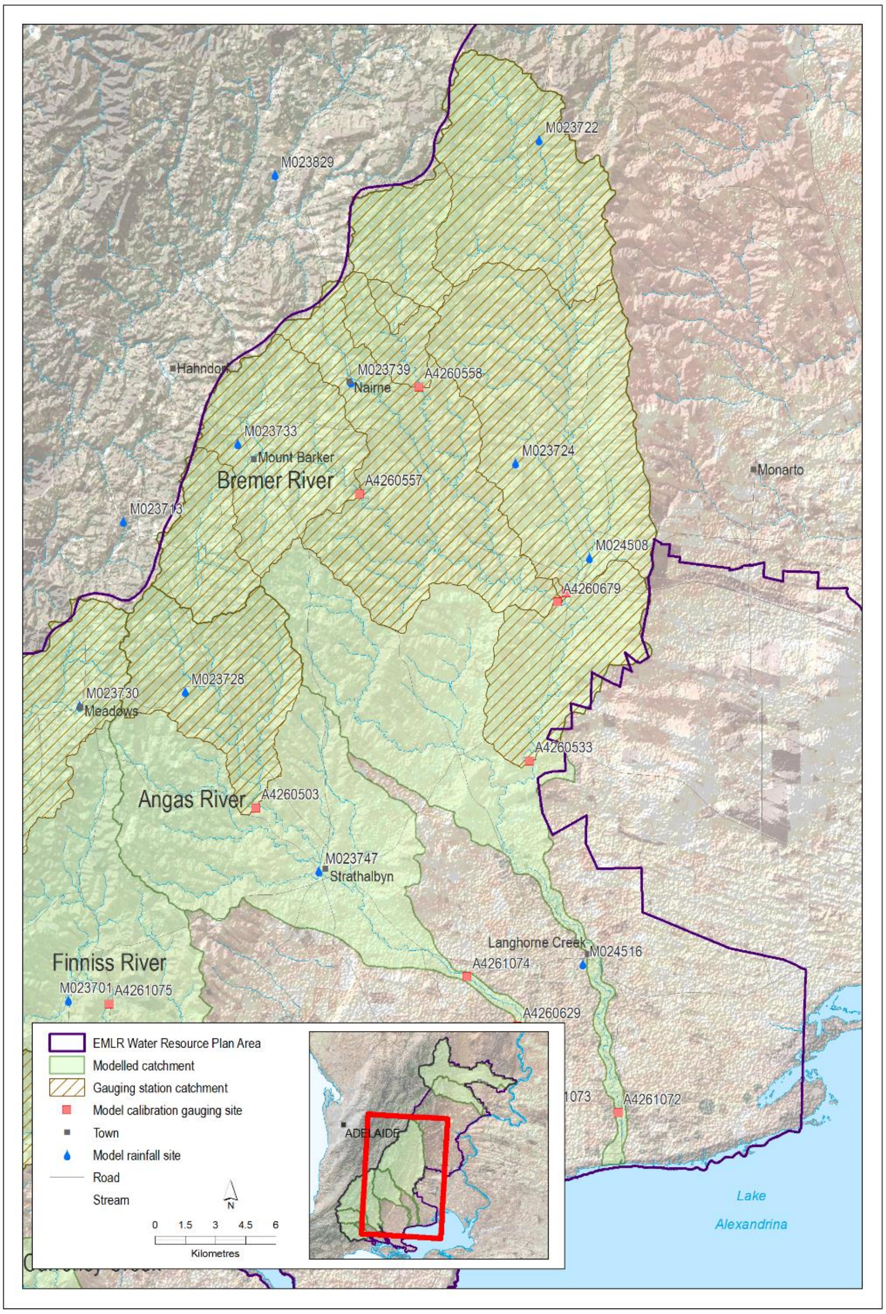


Figure 7. Bremer River catchment location map

7.2 Model construction

7.2.1 Model nodes

The Bremer River catchment was divided into 280 rural sub-catchments. The model chosen for this analysis was WC-1, due to its suitability for modelling ephemeral streams, such as those found in the Mount Lofty Ranges, and its use in previous technical investigations in this series. Each rural catchment node in the model represents a sub-catchment within the whole of the Bremer River catchment. Each off-stream dam node in the model represents an individual dam or accumulation of dams within that runoff dam sub-catchment. A demand node is used in the model to represent watercourse extractions and an urban node is used to represent a developed area with impervious catchment area.

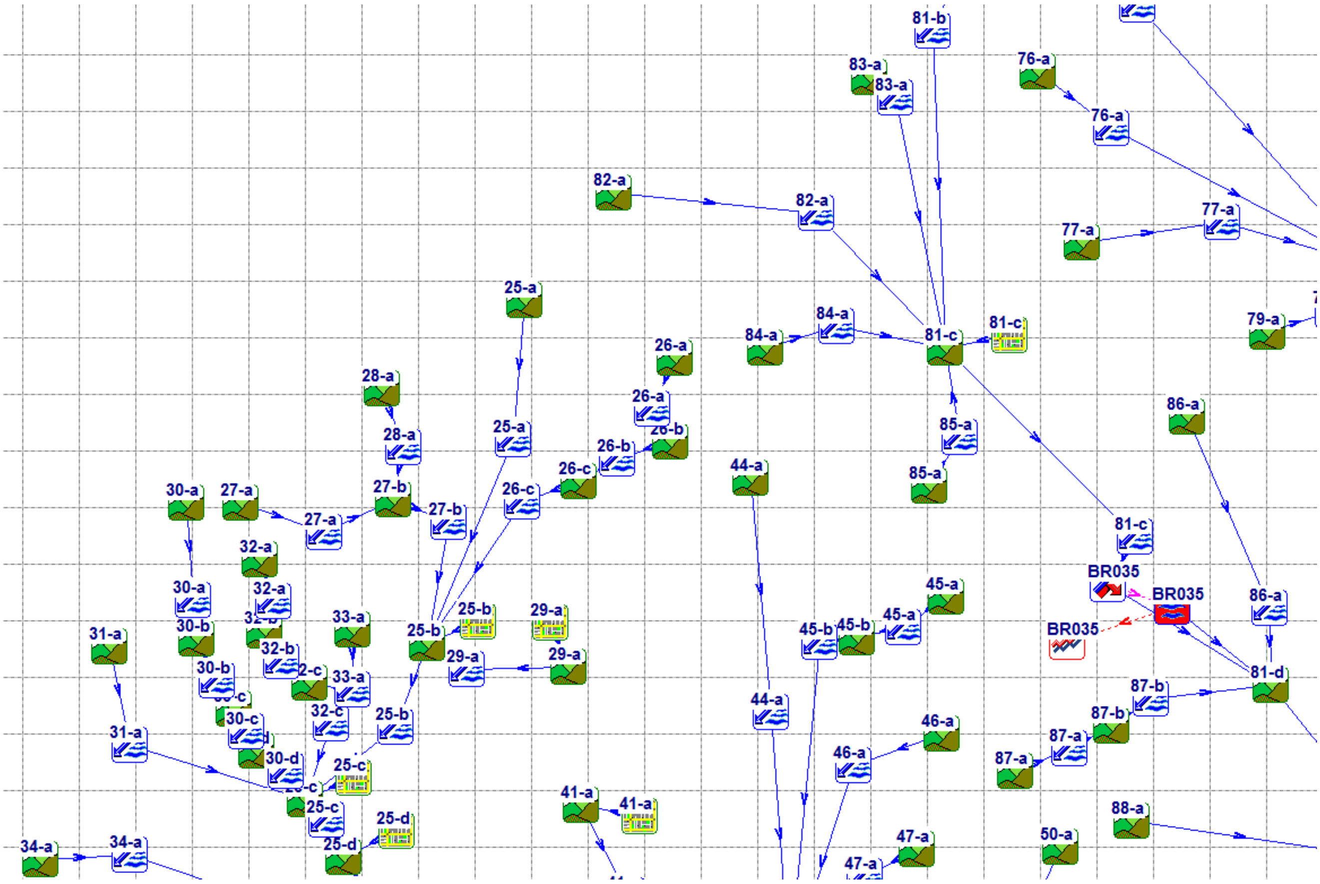
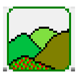


Figure 8. Model layout for a section of the Bremer River catchment model

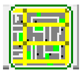
7.2.2 Catchment node inputs

The input data for rural catchment nodes  includes:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall data set, rainfall factor and monthly evaporation data set
- model to be used, which was WC-1 in this case, and the initial estimated values for the catchment parameter set (median soil moisture content, interception storage, catchment distribution, ground water discharge, soil moisture discharge, pan factor, fraction ground water loss, storage reduction coefficient, ground water loss and creek loss) (see Section 7.3.3)

- calibration file, which contains the observed daily rainfall data set and corresponding observed streamflow data set for the nodes that have a gauging station.

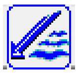
7.2.3 Urban node inputs

Urban nodes  representing the towns of Mount Barker, Littlehampton, Nairne and Brukunga are included in the model. Urban areas are calculated by digitising in GIS the extent of the towns and their surrounding impervious areas. Based on visual inspection, an impervious fraction coefficient is determined and multiplied by the area derived. This defines the actual impervious area, as the digitisation process does not differentiate between, for example, the backyard of a house and its driveway. The size of the coefficient is dependent on the scale and detail of digitisation, and the density of the urban or industrial development. This provides WaterCress an impervious area on which to run the urban model.

The urban model used within WaterCress is an Initial Loss – Continuing Loss (ILCL) model. It assumes that some amount of initial loss in the event of rainfall will first occur (e.g. when a small amount of rain falls on a roof, most will evaporate before becoming roof runoff to stormwater or a rainwater tank). Typical values for initial loss are 1 mm for roof runoff and 2 mm for pavement and roads. These values may be altered but remain fixed in this model.

Continuing loss is determined by means of a loss coefficient (between 0 and 1), which determines the fraction of water that is removed. What is left is the effective rainfall which is available as runoff to the catchment.

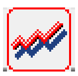
7.2.4 Dam node inputs

Each catchment node with runoff dams was linked to an off-stream dam node. The input data for each off-stream dam node  include:

- dam storage volume, which in this case was the cumulative storage capacity of all the dams in the minor sub-catchment
- nearest rainfall station and corresponding rainfall adjustment factor
- dam capacity to dam surface area relationship, for use in calculating surface evaporation at less than full supply level
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; the fraction of catchment runoff diverted to the dam was dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). For example, this fraction was 1.0 if there was a large on-stream dam located on the downstream end of the catchment as it would be considered a controlling dam to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream
- water usage factors from the dams, which vary between 30-50% as discussed in Section 5.3.1.

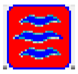
Key input data for each catchment and dam node in the Bremer River catchment model are given in Appendix D.

7.2.5 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node. The input data for each demand node  includes:

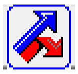
- daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system.

7.2.6 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

7.2.7 Stream loss

Upon inspection of the flow frequency curves for the gauging station at Hartley and other upstream stations (A4260679, A4260688, A4260557), it is apparent that between the confluence of the Bremer River and Mount Barker Creek and Hartley, there is a significant loss component through the stream bed. In order to compensate for this it is necessary to introduce a loss component into the model.

Stream losses were simulated using a weir node  to divert flows below a certain threshold at a specified rate. Derivation of the threshold and rate formed part of the calibration process and a trial and error method was used. Following model calibration at the gauging at Hartley, it was estimated that losses in that reach are on average 350 ML/y, but vary depending on upstream flow each year.

7.2.8 Rainfall spatial variability

Since rainfall varies spatially within a catchment, its variability has to be accounted for in the input data of each node. Spatial variability of rainfall in the catchment was accounted for by using a rainfall factor for each node. This was derived from a daily rainfall data set from a Bureau of Meteorology (BoM) rainfall station in the catchment, and the average annual rainfall for each runoff dam catchment calculated using GIS. The rainfall factor for each node was calculated as the ratio of the average annual rainfall for each runoff dam catchment representing the node to the average annual rainfall at the relevant BoM station, as given for each node in Appendix D.

7.3 Model calibration

Details of the initial model calibration can be found in Alcorn (2008). The following details of model recalibration are from Alcorn (2010). Calibration statistics for stations that are common to both calibration processes are shown in Table 14 below.

Table 14. Calibration statistics for the Bremer River model for two calibration periods

Time step	Difference in volume (%) Period 1 (Period 2)	R^2 Period 1 (Period 2)	CE Period 1 (Period 2)
Gauging site: Mt Barker Creek at downstream Mt Barker, A4260557. Period 1: 1979 to 2007 Period 2: 1979 to 2009			
Annual	2.26 (-3.3)	0.85 (0.87)	0.84 (0.85)
Monthly	2.15 (-3.3)	0.83 (0.84)	0.82 (0.84)
Daily	2.19 (-3.3)	0.76 (0.71)	0.75 (0.69)
Gauging site: Dawesley Creek at Dawesley, A4260558. Period 1: 1979 to 2007 Period 2: 1993 to 2006			
Annual	3.18 (-2.27)	0.74 (0.87)	0.72 (0.77)
Monthly	3.1 (-1.17)	0.77 (0.86)	0.77 (0.80)
Daily	3.1 (-1.15)	0.69 (0.79)	0.6 (0.49)
Gauging site: Bremer River at near Hartley, A4260533. Period 1: 1973 to 2007 Period 2: 1973 to 2009			
Annual	0.6 (10.17)	0.83 (0.877)	0.79 (0.864)
Monthly	1.21 (8.87)	0.81 (0.85)	0.82 (0.848)
Daily	1.21 (8.07)	0.74 (0.7)	0.67 (0.696)

Previously, the Bremer River catchment domain was established to as far south as the township of Woodchester, i.e. downstream of the confluence of the Bremer River and Red and Rodwell creeks, but not extending downstream to the ABIMZ. During the review by Alcorn (2010) the model was extended to the outflow of the Bremer River to Lake Alexandrina.

7.3.1 Watercourse extractions upstream of primary calibration gauges

Data indicated that approximately 840 ML of additional direct watercourse extractions were estimated to take place above the main streamflow gauges than previously estimated. This required minor recalibration of the model to account for this effect.

7.3.2 Estimation of streamflow diversion in the Angas-Bremer Plains from the Bremer River

This section describes the effort taken to estimate losses across the plains of the Bremer River catchment between downstream of the Rodwell Creek and Bremer River confluence and is taken from Alcorn (2010).

The extension of the model required recognition that the Lower Bremer River is an ephemeral stream with postulated stream losses and known watercourse diversions. Watercourse diversions occur via a range of mechanisms including direct pumping from the stream, lateral flood gates and flood diversion weirs, the largest of which (below Langhorne Creek) has the ability to completely divert the flow of the Bremer River for flood irrigation.

The information required to estimate losses came from a variety of sources including:

- streamflow gauges in place in the lower reaches since 2005

- reports on the Angas-Bremer Irrigations district (Cresswell and Herczeg 2004, Australian Water Environments (AWE) 2006)
- modelled and measured streamflow from the Bremer River hydrological model (Alcorn 2008).

As all of these sources provided variable estimates of stream recharge, floodplain inundation and water use extracted from the main stream for flood irrigation, the results will not be completely accurate. There will be considerable interplay, for example between the estimates made of water taken for flood irrigation via weirs and floodgates, and natural flooding over the plains in periods of high streamflow.

Flood irrigation in the area is known to happen annually, however no estimates of the actual volume diverted have been made. The irrigation annual reporting in the region affords some records of the areas inundated each irrigation year, and these can be used to estimate the diversion in each year.

The Angas-Bremer Floodplain Infiltration Final Report (AWE 2006) lists the areas inundated for the water years 1996-7 to 2003–4. These estimates have been used to develop a method for estimating possible volumes extracted.

The table below describes the areas inundated for those years, assuming a mean flood depth of 300 mm across the area flooded would yield the volumes in column 3.

Table 15. Angas-Bremer floodplain inundated area

Inundated Area 1997–2004 Year*	Total Inundated Area (ha)	Volume of Flooded Area at 300mm Depth (ML)
1997–98	330	990
1998–99	106	318
1999–2000	529	1587
2000–01	3474	10422
2001–02	1199	3597
2002–03	86	258
2003–04	587	1761

* (AWE 2006)

Using a diversion weir node and an off-stream storage node to represent the weir and the inundated area, the diversions in those years were modelled to try and match the evidence available.

The off-stream storage was given a maximum capacity of 4 GL and an infiltration rate of 50 ML/d to mimic infiltration over the entire area. The maximum storage chosen was designed to allow some return flows in extreme flow years. While water may actually return to the river it may also flow out via the disconnected Mosquito Creek to the east of Langhorne Creek.

Additional streamflow data from A4261072 (Bremer River at Ballandown Road) was also used to match the timing of streamflow events after losses and extractions have occurred upstream. The rating on this station is considered theoretical however, so the volume of flow passing may not be indicative of actual flows.

The estimates of the volume diverted to the floodplain made using the AWE (2006) data and the model agree in total, but differ in individual years. This annual difference is despite the gauged flow at the Hartley Gauging Station (A4265033) being used as the upstream input to the model in place of the modelled flows (which over-predict the flow during the period between 1997 and 2005). However, since the data is sparse, neither the AWE estimates nor the modelled estimates have great credibility in predicting individual annual diversions. Overall, the modelling approach used is considered fit-for-purpose for modelling high flow diversions for flood irrigation in the lower Bremer, using best available information for a complex system.

7.3.3 Rainfall-runoff parameters

Figure 9 shows the WC-1 rainfall-runoff parameter values used for the Bremer River catchment model. An explanation of these parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

Medium soil moisture (MSM) – represents the median field capacity of the soil. It is usually in the range 150–300 mm. Increasing this value delays the early season initiation of runoff, decreases surface runoff by providing greater opportunity for evapotranspiration, but assists (to a lesser extent) in maintaining late season groundwater flows.

Interception store (IS) – represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10-25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) – sets the range of soil moisture values about MSM. Usual values are 25-60 mm. A larger value will initiate runoff earlier and more often.

Ground Water Discharge (GWD) – is the proportion of the groundwater store that discharges as baseflow to the stream. This is a simple linear function: Baseflow = groundwater store x GWD. Usual values are small, from 0.001 to 0.0001.

Soil moisture discharge (SMD) – As soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small, around 0.0001.

Pan factor for soil (PF) – This factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6 to 1.0. The higher the value the less the runoff. The higher the value, the earlier runoff ceases after winter.

Fraction Groundwater Loss (FGL) – The removal of groundwater store due to irrigation (or just assumed loss) is a multiplying factor for all recharge. For example a value of 0.6 here means only 40% of the calculated recharge actually occurs. The remainder is lost to the system.

Store Wetness multiplier (SWM) – This value determines the rate that water from the interception store moves to the soil store. The depletion of the interception store is calculated as the maximum of the loss based on the soil wetness multiplier and evaporation, whichever is the greater. The transfer rate can therefore be independent of season (if required) and ensures that the amount of water retained in the interception store follows a similar power recession curve to the API. Usual values are around 0.9. Making this value close to 1 means that depletion of the interception store is controlled by the evaporation rate (which follows a more seasonal pattern).

Groundwater Recharge (GWR) – is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05 to 0.3 indicating that 5% to 30% of the flow running off the catchment is entering the groundwater system.

Creek Loss (CL) – is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates take up of water from riparian vegetation and the reduction of baseflow in summer months.

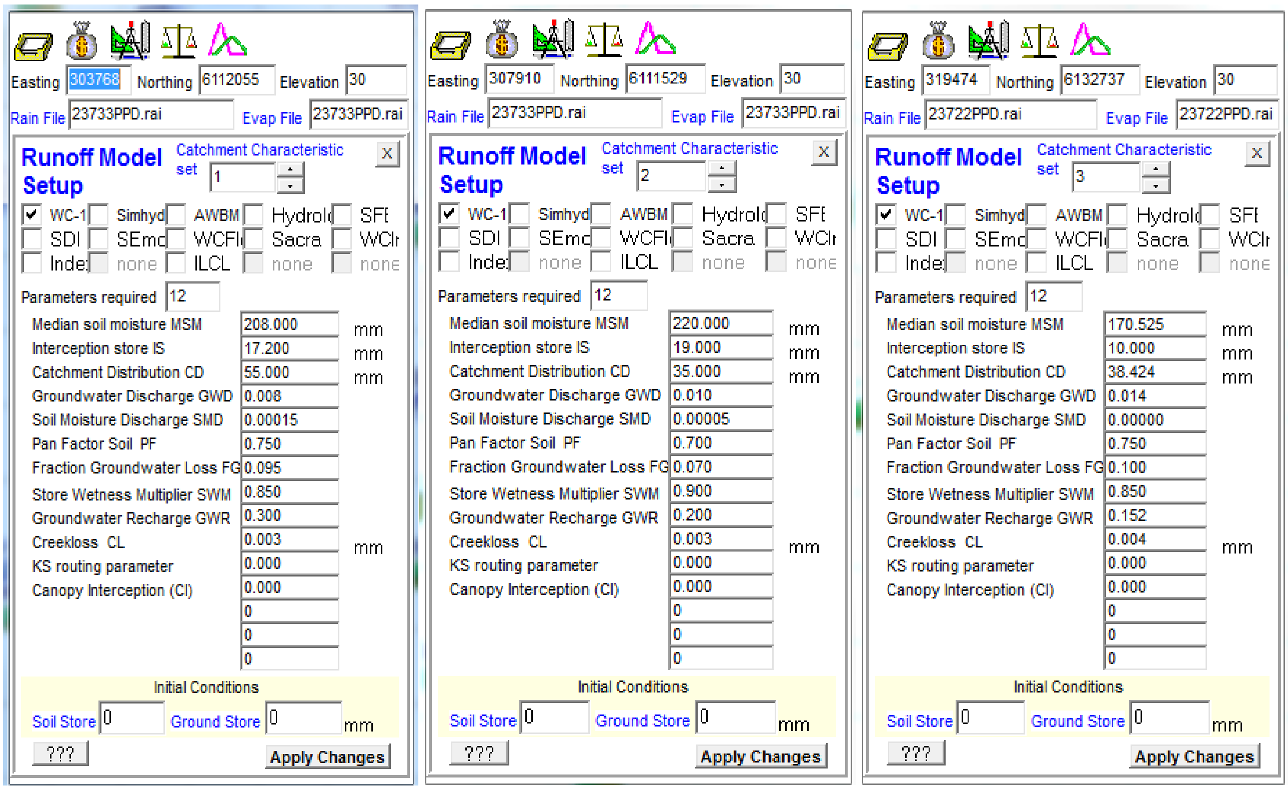


Figure 9. Model catchment characteristic sets for the Bremer River catchment

7.4 Model assumptions and limitations

- Runoff dam data is based on a 2005 data set, obtained from aerial imagery captured between 2003 and 2005; locations of irrigation dams were gradually updated as they were identified as part of the water licensing process.
- Runoff dam volumes were calculated using the dam surface area-volume relationship developed by McMurray (2004).
- Runoff dams within a sub catchment have been lumped to represent the total runoff dam volume of each sub catchment and is represented in the model as one runoff dam node per sub catchment.
- The proportion of the dam capacity used as an extraction limit varies from 0.3 for all stock and domestic dams to 0.5 for irrigation dams; it is variable between 0.3–0.5 for lumped runoff dam nodes consisting of stock and domestic and irrigation dams (discussed in Section 5.3.1).
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 0.7 fraction of maximum evaporation per month.
- Watercourse demand is based on allocation data obtained from the state water licensing system and for the Bremer River catchment, total watercourse demand is estimated to be 2328 ML at the time of writing (excluding lower Angas-Bremer allocations granted for flood diversions).
- Flood diversion estimates are based on estimates of inundated area from Irrigation Annual reporting.
- Refer to Alcorn (2008) for more detailed information.

8 Currency Creek catchment model

8.1 Overview

The Currency Creek catchment is located approximately 60 km from Adelaide, and occupies an area of 89.2 km^2 (Figure 10). The height above sea level ranges from around 380 m in the west, falling to below 50 m where the main creek flows into the lower River Murray. The catchment can be split into two major sub-catchments. The western side is characterised by higher elevations and relatively steeper slopes, ranging in heights from 380 m in the west to 200 m in the centre of the catchment. The eastern major sub-catchment is far flatter by comparison, ranging from 100 m to 30 m adjacent to the lower River Murray. Detailed catchment description and hydrology of the Currency Creek are included in Alcorn (2006) and have been used to populate the descriptions below.

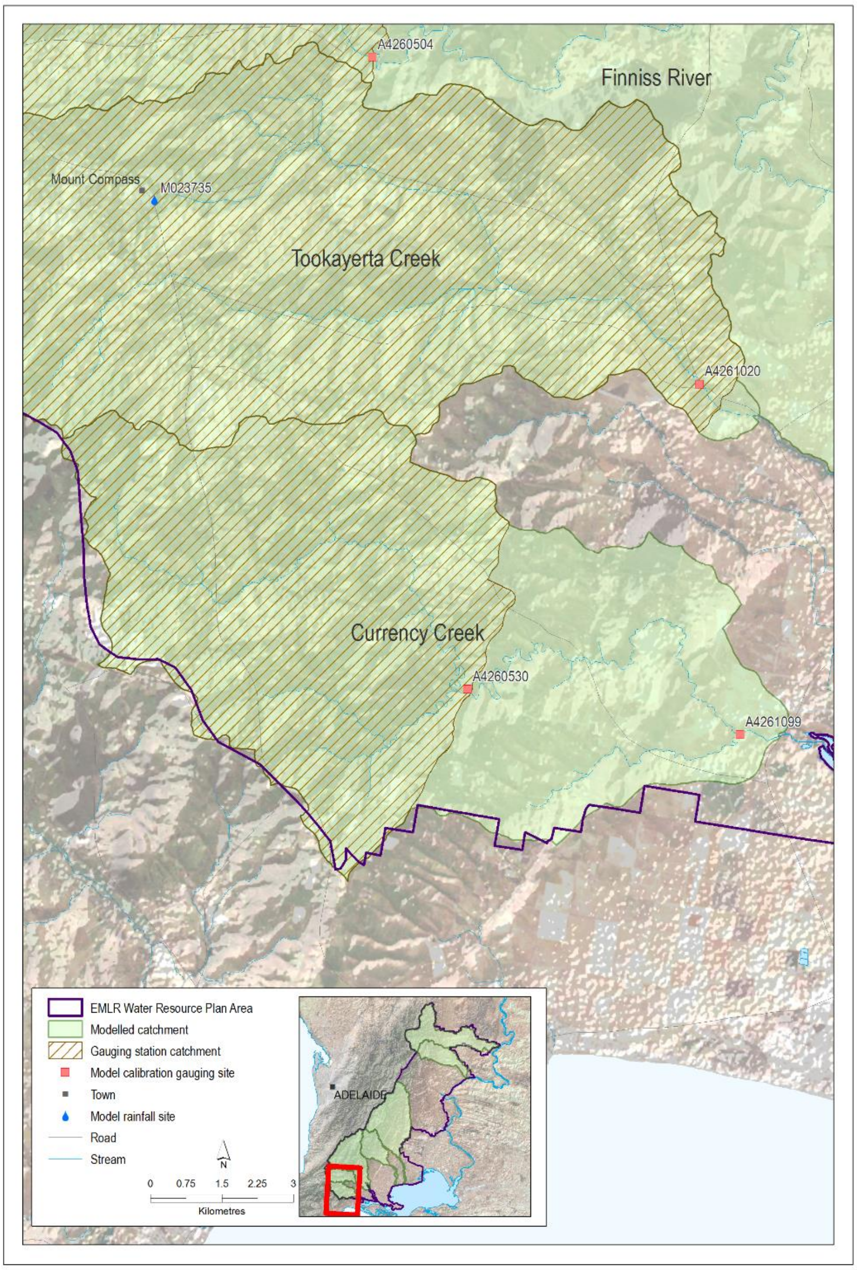


Figure 10. Currency Creek catchment location map

8.2 Model construction

8.2.1 Model nodes

The Currency Creek catchment is divided into 106 rural sub-catchments with a total of 95 dam nodes. Each rural catchment node in the model represents a sub-catchment within the whole of the Currency Creek catchment. Each off-stream dam node in the model represents an individual dam or accumulation of dams within that runoff dam sub-catchment. A demand node is used in the model to represent watercourse extractions. The model chosen for this analysis was WC-1 because it is thought to be well suited to modelling the ephemeral streams of the Mount Lofty Ranges.

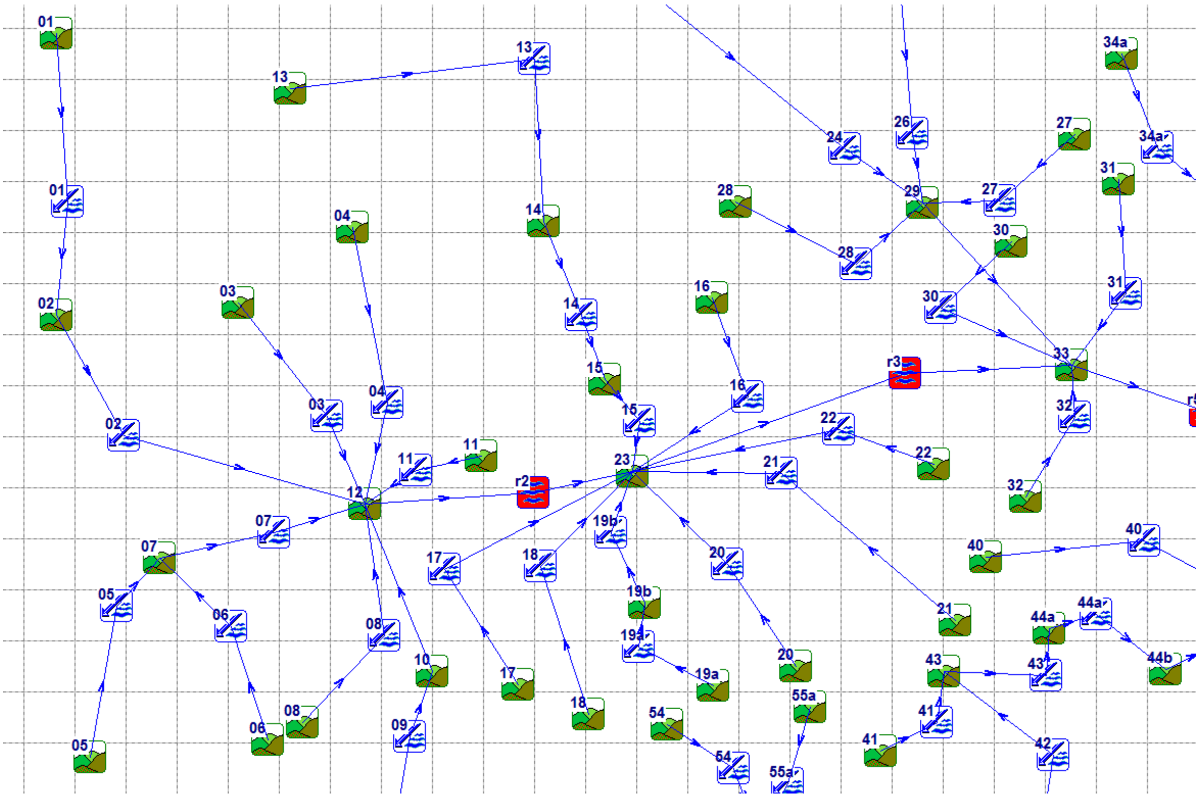
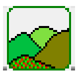


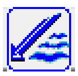
Figure 11. Model layout for a section of the Currency Creek catchment model

8.2.2 Catchment node inputs

The input data for each rural catchment node  include:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall dataset, rainfall factor and monthly evaporation dataset
- model to be used, which was WC-1, and the catchment parameters (discussed in Section 8.3.1).

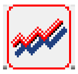
8.2.3 Dam node inputs

Each catchment node with runoff dams was linked to an off-stream dam node. The input data for each off-stream dam node  include:

- dam storage volume, which in this case was the cumulative storage capacity of all the dams in the minor sub-catchment
- corresponding measured daily rainfall and monthly evaporation dataset
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; the fraction of catchment runoff diverted to the dam was dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). For example, this fraction was 1.0 if there was a large on-stream dam located on the downstream end of the catchment, as it would be considered a controlling dam that is deemed to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream
- water usage factors from the dams, which vary between 30-50% as discussed in section 5.3.1.

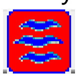
Key input data for each catchment and dam node in the Currency Creek catchment model are given in Appendix E.

8.2.4 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node. The input data for each demand node  includes:

- daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system.

8.2.5 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

8.2.6 Rainfall spatial variability

The spatial variability of rainfall within the catchment is accounted for by the use of a rainfall factor for each rural catchment node. The rainfall for each node is calculated using a spatial rainfall dataset provided by BoM (Fawcett et al. 2006). The dataset used describes mean annual rainfall at 1 km x 1 km intervals. Details of that process are described in Appendix H of Alcorn (2006).

8.3 Model calibration

Details of the initial model calibration can be found in Alcorn (2006). As the more recent data indicated only around 150 ML of new extractions needed to be added to the model upstream of the gauging station, the model did not require recalibration to remain within a reasonable bias (<5%) during the revisions in 2010. Calibration statistics for stations that are common to both calibration processes are shown in Table 16 below.

Table 16. Calibration statistics for the Currency Creek model for two calibration periods

Time step	Difference in volume (%)	R^2	CE
	Period 1 (Period 2)	Period 1 (Period 2)	Period 1 (Period 2)
Annual	3.64 (-2.02)	0.91 (0.87)	0.81 (0.863)
Monthly	3.64 (-3.23)	0.95 (0.878)	0.90 (0.874)
Daily	3.65 (-3.30)	0.89 (0.757)	0.76 (0.733)

Period 1: 1973 to 1992, Period 2: 1972 to 1993 (Gauging site: Currency Creek at near Higgins, A4260530)

8.3.1 Rainfall-runoff parameters

Figure 12 shows the WC-1 rainfall-runoff parameter values used for the Currency Creek catchment model. An explanation of these parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

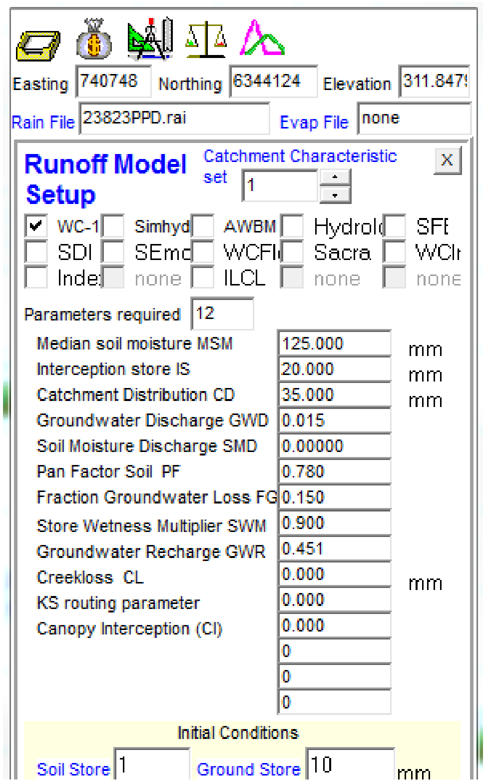


Figure 12. Model catchment characteristic set for the Currency Creek catchment

Medium soil moisture (MSM) – represents the median field capacity of the soil. Usually in the range 150-300 mm. Increasing this value delays the early season initiation of runoff, decreases surface runoff by providing greater opportunity for evapotranspiration, but assists (to a lesser extent) in maintaining late season groundwater flows.

Interception store (IS) – represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10-25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) – sets the range of soil moisture values about MSM. Usual values are 25-60 mm. A larger value will initiate runoff earlier and more often.

Ground Water Discharge (GWD) – is the proportion of the groundwater store that discharges as baseflow to the stream. This is a simple linear function: Baseflow = groundwater store x GWD. Usual values are small from 0.001 to 0.0001

Soil moisture discharge (SMD) – As soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small, around 0.0001.

Pan factor for soil (PF) – This factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6 to 1.0. The higher the value the less the runoff. The higher the value, the earlier runoff ceases after winter.

Fraction Groundwater Loss (FGL) – The removal of groundwater store due to irrigation (or just assumed loss) is a multiplying factor for all recharge. For example a value of 0.6 here means only 40% of the calculated recharge actually occurs. The remainder is lost to the system.

Store Wetness multiplier (SWM) – This value determines the rate that water from the interception store moves to the soil store. The depletion of the interception store is calculated as the maximum of the loss based on the soil wetness multiplier and evaporation, whichever is the greater. The transfer rate can therefore be independent of season (if required) and ensures that the amount of water retained in the interception store follows a similar power recession curve to the API. Usual values are around 0.9. Making this value close to 1 means that depletion of the interception store is controlled by the evaporation rate (which follows a more seasonal pattern).

Groundwater Recharge (GWR) – is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05 to 0.3 indicating that 5% to 30% of the flow running off the catchment is entering the groundwater system.

Creek Loss (CL) – is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates take up of water from riparian vegetation and the reduction of baseflow in summer months.

8.4 Model assumptions and limitations

- Runoff dam data is based on a 2005 data set, obtained from aerial imagery captured between 2003 and 2005; locations of irrigation dams were updated as information became available as part of the water licensing process.
- Runoff dam volumes were calculated using the dam surface area-volume relationship developed by McMurray (2004).
- Runoff dams within a sub catchment have been lumped to represent the total runoff dam volume of each sub catchment and is represented in the model as one runoff dam node per sub catchment.
- The proportion of the dam capacity used as an extraction limit varies from 0.3 for all stock and domestic dams to 0.5 for irrigation dams; it is variable between 0.3–0.5 for lumped runoff dam nodes consisting of stock and domestic and irrigation dams (discussed in Section 5.3.1).
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 0.7 fraction of maximum evaporation per month.
- Watercourse demand is based on allocation volumes obtained from the state water licensing system and for the Currency Creek catchment, total watercourse demand is estimated to be 131 ML at the time of writing.
- Refer to Alcorn (2006) for more detailed information.

9 Finniss River catchment model

9.1 Overview

The Finniss River catchment is located approximately 50 km south of Adelaide (Figure 13). Meadows, Ashbourne, Yundi and Finniss are the major towns in the catchment. The main river in this catchment is the Finniss River, which flows in a south-easterly direction. Meadows Creek, Blackfellows Creek, Bull Creek and Wattle Flat Creek are the major tributaries that feed into the Finniss River before it flows into Lake Alexandrina. Detailed catchment description and hydrology of the Finniss River are included in Savadamuthu (2003) and have been used to populate the descriptions below.

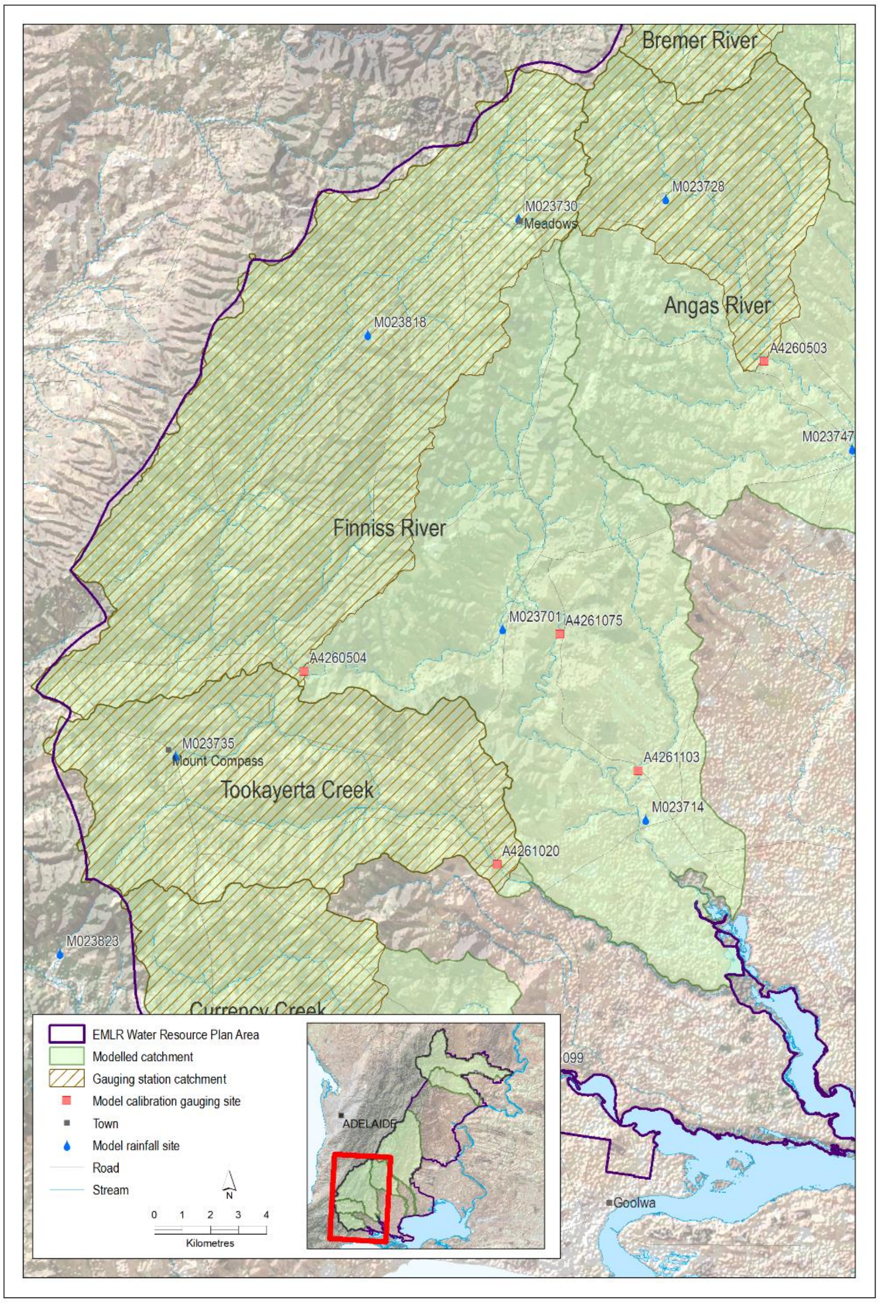


Figure 13. Finniss River catchment location map

9.2 Model construction

9.2.1 Model nodes

The Upper Finniss Catchment was subdivided into major and minor sub-catchments. The model was set-up as a series of rural catchment nodes followed by off-stream dam nodes, with a routing node added to the end of the catchment. Each rural catchment node in the model represents a minor sub-catchment within the whole of the Finniss River catchment. Each off-stream dam node in the model represents the accumulation of dams within that minor sub-catchment. A demand node is used in the model to represent watercourse extractions.

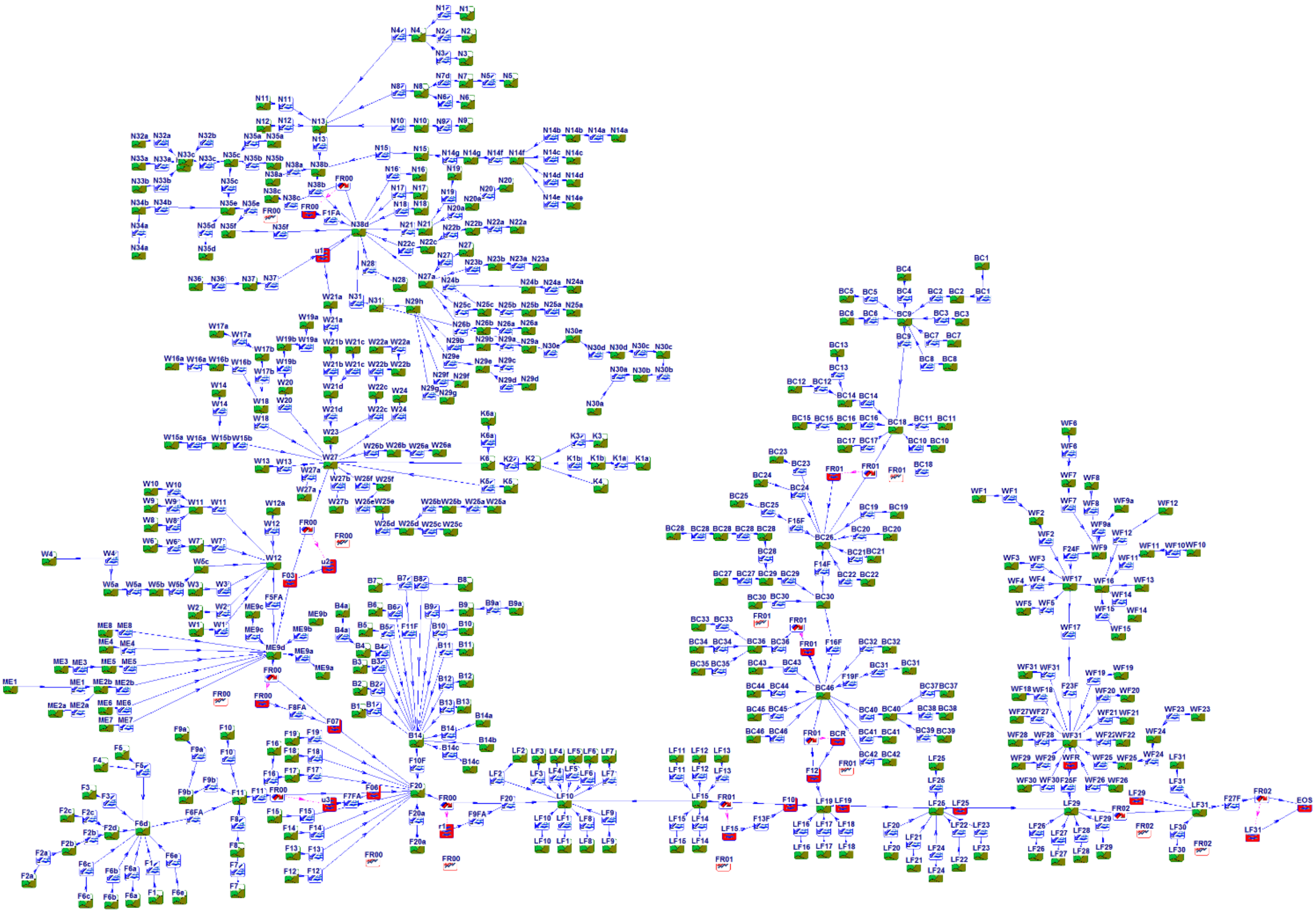
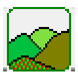


Figure 14. Model layout of the Finniss River catchment model

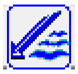
9.2.2 Catchment node inputs

The input data for each rural catchment node  include:

- area of the minor sub-catchment
- corresponding measured daily rainfall and monthly evaporation data files
- runoff model to be used, which was WC-1 in this case and initial estimated values for the catchment parameter set, viz., median soil moisture content, interception storage, catchment distribution, ground water discharge, soil moisture discharge, pan factor, fraction ground water loss, storage reduction coefficient, ground water loss and creek loss (see Section 9.3.1)

- calibration file, which is the set of measured daily rainfall and corresponding runoff data for the node that has the gauging station.

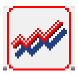
9.2.3 Dam node inputs

Each rural catchment node with runoff dams was linked to an off-stream dam node. The input data for each off-stream dam node  include:

- dam storage volume, which in this case, was the cumulative storage capacity of all the dams in the minor sub-catchment
- corresponding measured daily rainfall and monthly evaporation data files
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; this is dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). For example, this fraction was 1.0 if there were an on-stream dam located on the downstream end of the catchment, as it would be a controlling dam that is deemed to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream
- water usage factors from the dams, which vary between 30-50% as discussed in Section 5.3.1.

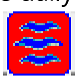
Key input data for each catchment and dam node in the Finniss River catchment model are given in Appendix F.

9.2.4 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node. The input data for each demand node  includes:

- daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system.

9.2.5 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

9.3 Model calibration

Details of the initial model calibration can be found in Savadamuthu (2003). The following details of model recalibration are from Alcorn (2010).

Calibration statistics for the Finniss River catchment model are provided in Table 17 for two calibration periods, for illustration purposes. The first calibration period (1969 to 2000) being when the model was initially set up in 2003 and the second calibration period (1969 to 2006) being when the models were recalibrated in 2010. As illustrated by the statistics, the calibration was considered to be a 'good fit' with regards to the model's ability to generate a flow regime very close to the observed flow regime. With the catchment parameters unchanged, the closeness of the statistics for the two calibration periods demonstrates the validation process and the model's ability to generate similar flow regimes for two sets of time periods.

Table 17. Calibration statistics for the Finniss River model for two calibration periods

Time step	Difference in volume (%) Period 1 (Period 2)	R^2 Period 1 (Period 2)	CE Period 1 (Period 2)
Annual	1.6 (-3.0)	0.96 (0.90)	0.90 (0.89)
Monthly	0.8 (-3.0)	0.97 (0.91)	0.92 (0.90)
Daily	0.67 (-3.1)	0.84 (0.72)	0.71 (0.71)

Period 1: 1969 to 2000, Period 2: 1969 to 2006 (Gauging site: Finniss River at 4 km East of Yundi)

There were minimal new extractions to be added to the Finniss River catchment model and the primary calibration at the Finniss River at 4 km East of Yundi gauging station is considered a good calibration in most years. No further recalibration of the model was therefore carried out.

In addition to the primary streamflow calibration site, two other gauges were considered as secondary calibration data – A4261075 Finniss River at Ford Road and A4261103 Finniss Giles Creek. Neither of these two sites have extensive streamflow gaugings carried out. However, the flows reported at these sites match reasonably well when compared to the modelled flow at the same locations.

9.3.1 Rainfall-runoff parameters

Figure 15 shows the WC-1 rainfall-runoff parameter values used for the Finniss River catchment model. An explanation of these parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

Medium soil moisture (MSM) – represents the median field capacity of the soil. Usually in the range 150-300 mm. Increasing this value delays the early season initiation of runoff, decreases surface runoff by providing greater opportunity for evapotranspiration, but assists (to a lesser extent) in maintaining late season groundwater flows.

Interception store (IS) – represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10-25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) – sets the range of soil moisture values about MSM. Usual values are 25-60 mm. A larger value will initiate runoff earlier and more often.

Ground Water Discharge (GWD) – is the proportion of the groundwater store that discharges as baseflow to the stream. This is a simple linear function: Baseflow = groundwater store x GWD. Usual values are small, from 0.001 to 0.0001.

Soil moisture discharge (SMD) – As soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small, around 0.0001.

Pan factor for soil (PF) – This factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6 to 1.0. The higher the value the less the runoff. The higher the value, the earlier runoff ceases after winter.

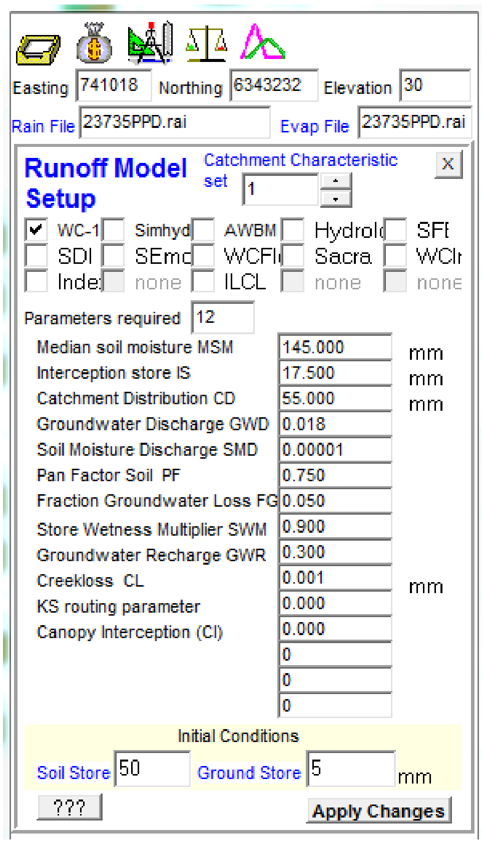


Figure 15. Model catchment characteristic set for the Finniss River catchment

Fraction Groundwater Loss (FGL) – The removal of groundwater store due to irrigation (or just assumed loss) is a multiplying factor for all recharge. For example a value of 0.6 here means only 40% of the calculated recharge actually occurs. The remainder is lost to the system.

Store Wetness multiplier (SWM) – This value determines the rate that water from the interception store moves to the soil store. The depletion of the interception store is calculated as the maximum of the loss based on the soil wetness multiplier and evaporation, whichever is the greater. The transfer rate can therefore be independent of season (if required) and ensures that the amount of water retained in the interception store follows a similar power recession curve to the API. Usual values are around 0.9. Making this value close to 1 means that depletion of the interception store is controlled by the evaporation rate (which follows a more seasonal pattern).

Groundwater Recharge (GWR) – is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05 to 0.3 indicating that 5% to 30% of the flow running off the catchment is entering the groundwater system.

Creek Loss (CL) – is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates take up of water from riparian vegetation and the reduction of baseflow in summer months.

9.4 Model assumptions and limitations

- Runoff dam data is based on a 2005 data set, obtained from aerial imagery captured between 2003 and 2005; locations of irrigation dams were gradually updated as these dams were identified as part of the water licensing process.
- Runoff dam volumes were calculated using the dam surface area-volume relationship developed by McMurray (2004).
- Runoff dams within a sub catchment have been lumped to represent the total runoff dam volume of each sub catchment and is represented in the model as one runoff dam node per sub catchment.
- The proportion of the dam capacity used as an extraction limit varies from 0.3 for all stock and domestic dams to 0.5 for irrigation dams; it is variable between 0.3–0.5 for lumped runoff dam nodes consisting of stock and domestic and irrigation dams (discussed in Section 5.3.1).
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 0.7 fraction of maximum evaporation per month.
- Watercourse demand is based on allocation volumes obtained from the state water licensing system and for the Finniss River catchment, total watercourse demand is estimated to be 536 ML at the time of writing.
- Refer to Savadamuthu (2003) for more detailed information.

10 Tookayerta Creek catchment model

10.1 Overview

The Tookayerta Creek catchment is located around 60 kilometres south of Adelaide (Figure 16). The catchment can be hydrological classified as a high rainfall catchment with permanently flowing streams. It is also hydro-geologically unique to the region due to the presence of extensive Permian sand aquifers with very good quality groundwater resources, which is a major contributor to the streamflow during summer months. It is one of the most ecologically diverse catchments in the EMLR, characterised by its swamps and wetlands that provide a variety of habitats inhabited by some rare and endangered species. Mount Compass, Nangkita and Tooperang are some of the towns in the catchment. Detailed catchment description and hydrology of the Tookayerta Creek catchment are included in Savadamuthu (2004) and have been used to populate the descriptions below.

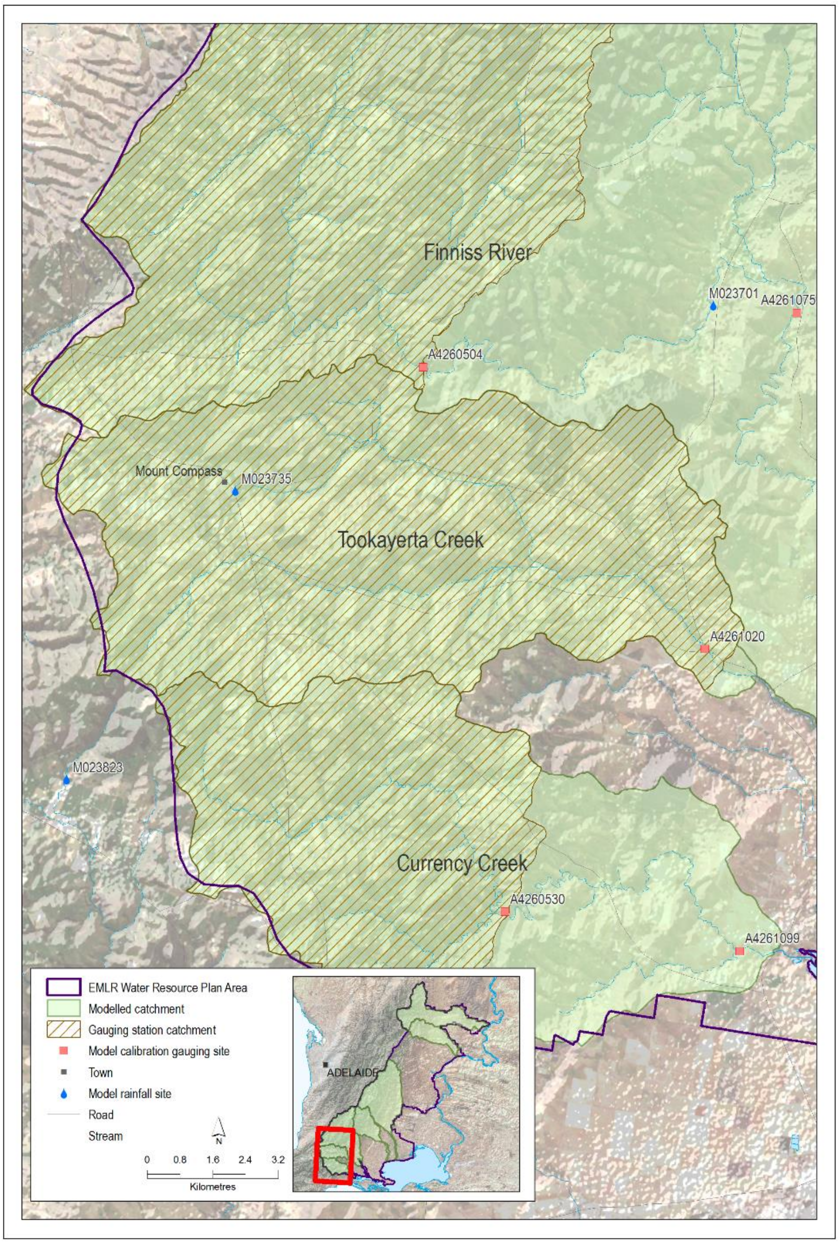


Figure 16. Tookayerta Creek catchment location map

10.2 Model construction

10.2.1 Model nodes

The Tookayerta Creek catchment was divided into 3 major sub-catchments that were further divided into 76 minor sub-catchments. The model was set up as a series of rural catchment nodes followed by off-stream dam nodes, with a routing node added to the end of the catchment. Each rural catchment node in the model represents a minor sub-catchment within the whole of Tookayerta Creek catchment. Each off-stream dam node in the model represents an individual dam or accumulation of dams within that minor sub-catchment. A demand node is used in the model to represent watercourse extractions.

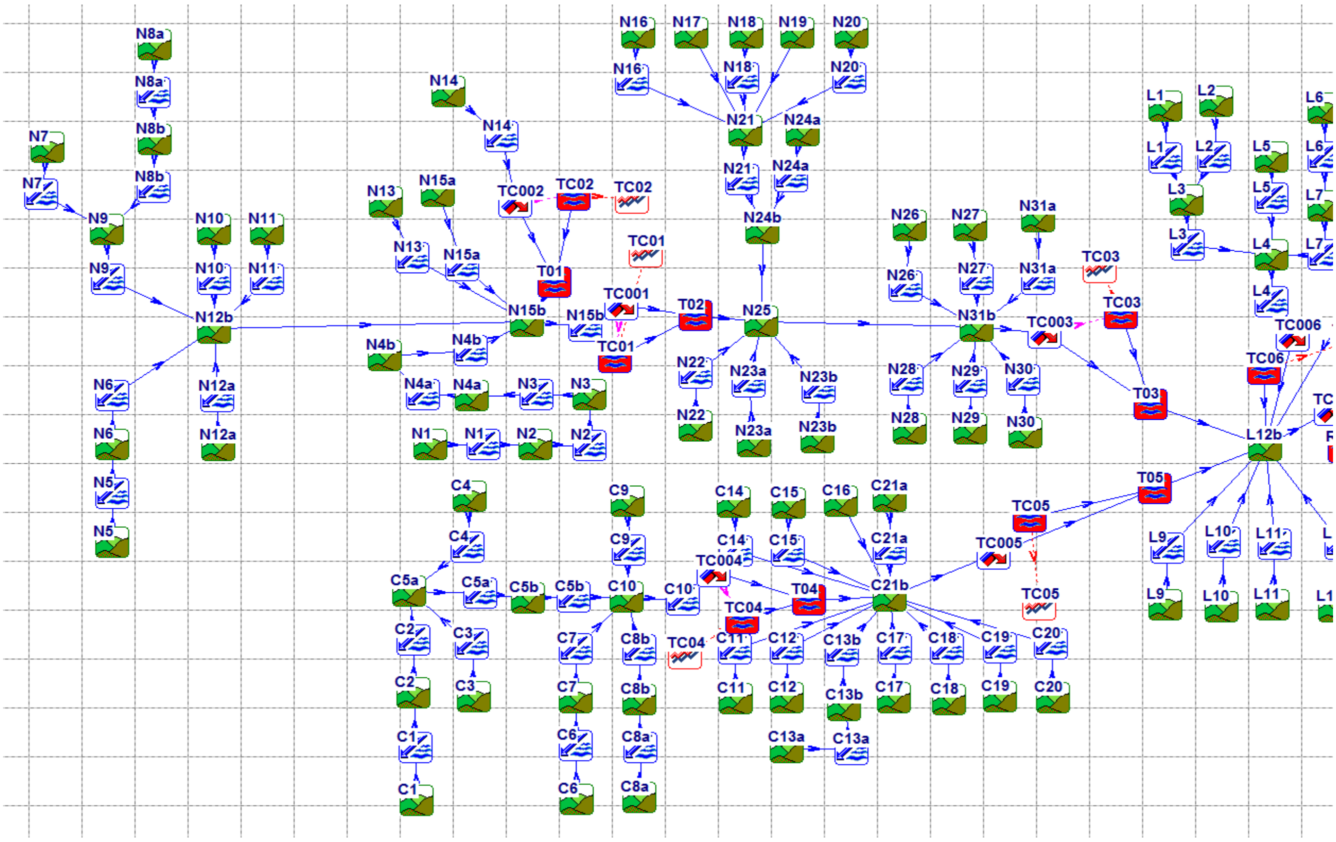
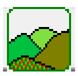


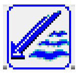
Figure 17. Model layout for a section of the Tookayerta Creek catchment model

10.2.2 Catchment node inputs

The input data for each rural catchment node  include:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall dataset, rainfall factor and monthly evaporation dataset
- model to be used, which was WC-1 in this case and the initial estimated values for the catchment parameter set viz., median soil moisture content, interception storage, catchment distribution, ground water discharge, soil moisture discharge, pan factor, fraction ground water loss, storage reduction coefficient, ground water loss and creek loss (see Section 10.3.1)
- calibration file, which contains observed daily rainfall dataset and corresponding observed streamflow dataset for the node that has the gauging station; since streamflow data from only one gauging site was used is this study, the calibration file was included in only one node in the catchment model.

10.2.3 Dam node inputs

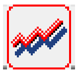
The input data for each off-stream dam node  include:

- dam storage volume, which in this case, was the cumulative storage capacity of all the dams in the minor sub-catchment
- corresponding measured daily rainfall dataset, rainfall factor and monthly evaporation dataset
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; this is dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). For example, this fraction was 1.0 if there were a large on-stream dam located on the downstream end of the catchment, as it would be a controlling dam that is deemed to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream
- water usage factors from the dams, which vary between 30-50% as discussed in Section 5.3.1.

Key input data for each catchment and dam node in the Tookayerta Creek catchment model are given in Appendix G.

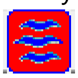
10.2.4 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node.

The input data for each demand node  includes:

- daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system.

10.2.5 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

10.2.6 Rainfall spatial variability

Since rainfall varies spatially within a catchment, its variability has to be accounted for in the input data of each node. Spatial variability of rainfall within the Tookayerta Creek catchment was accounted for by using a rainfall factor for each node derived from daily rainfall dataset from the BoM station at Mount Compass and the annual rainfall isohyets. The rainfall factor for each node was calculated as the ratio of value of the isohyet passing through the minor sub-catchment representing that node to the isohyet passing through the BoM station Mount Compass. Hence, the daily rainfall dataset for each node was obtained by multiplying the rainfall factor for that sub-catchment by the dataset from Mount Compass BoM station.

10.3 Model calibration

Details of the initial model calibration (Period 1) can be found in Savadamuthu (2004). The following details of model recalibration (Period 2) are from Alcorn (2010). Calibration statistics for stations that are common to both calibration processes are shown in Table 18 below.

Table 18. Calibration statistics for the Tookayerta River model for two calibration periods

Time step	Difference in volume (%)	R^2	CE
	Period 1 (Period 2)	Period 1 (Period 2)	Period 1 (Period 2)
Annual	3.8 (0.61)	0.99 (0.8)	0.87 (0.785)
Monthly	3.5 (-1.97)	0.96 (0.817)	0.91 (0.817)
Daily	3.2 (-2.12)	0.88 (0.695)	0.78 (0.69)

Period 1: 1997 to 2002, Period 2: 1997 to 2002 (Gauging site: Tookayerta Creek)

Of all the five daily flow models in the EMLR SDL resource unit, the Tookayerta Creek catchment model had the most significant potential change to its water budget by the inclusion of more recent watercourse diversion data during the 2010 review. A total of 1928 ML of diversions upstream of the calibration gauge had to be incorporated into the model, while a further 426 ML had to be incorporated below the gauge.

This need to incorporate additional diversions required that a recalibration of the model be undertaken in order to increase the runoff upstream of the diversion locations. The recalibration of the model centred mostly on redefining the value of the total soil store, but other adjustments were also made in regard to the groundwater recharge and baseflow recession rates to better fit the observed recession curve.

The resulting calibration was considered fair to good, but was not as good as the original model calibration. The daily time step calibration showed that the modelled baseflow was severely impacted by the additional extraction regime, while the observed streamflow data does not show such a marked impact. Further calibration attempts, in future, should be undertaken using the model feature that takes account of rainfall and soil moisture effects in setting demand rates and in seeking improved ways of modelling seepage returns to downstream channels from irrigation applications. Since no new streamflow data was available for this catchment, the model was recalibrated using data described in Savadamuthu (2004).

10.3.1 Rainfall-runoff parameters

Figure 18 shows the WC-1 rainfall-runoff parameter values used for the Tookayerta Creek catchment model. An explanation of these parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

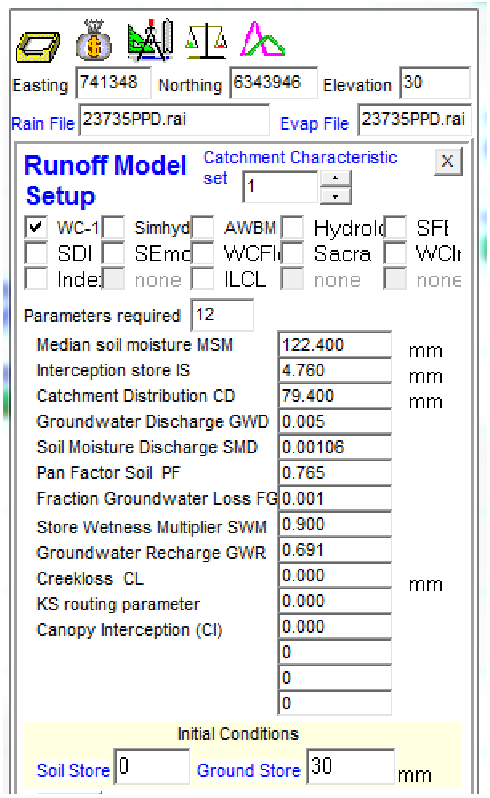


Figure 18. Model catchment characteristic set for the Tookayerta Creek catchment

Medium soil moisture (MSM) – represents the median field capacity of the soil. Usually in the range 150-300 mm. Increasing this value delays the early season initiation of runoff, decreases surface runoff by providing greater opportunity for evapotranspiration, but assists (to a lesser extent) in maintaining late season groundwater flows.

Interception store (IS) – represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10-25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) – sets the range of soil moisture values about MSM. Usual values are 25-60 mm. A larger value will initiate runoff earlier and more often.

Ground Water Discharge (GWD) – is the proportion of the groundwater store that discharges as baseflow to the stream. This is a simple linear function: Baseflow = groundwater store x GWD. Usual values are small, from 0.001 to 0.0001.

Soil moisture discharge (SMD) – As soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small, around 0.0001.

Pan factor for soil (PF) – This factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6 to 1.0. The higher the value the less the runoff. The higher the value, the earlier runoff ceases after winter.

Fraction Groundwater Loss (FGL) – The removal of groundwater store due to irrigation (or just assumed loss) is a multiplying factor for all recharge. For example a value of 0.6 here means only 40% of the calculated recharge actually occurs. The remainder is lost to the system.

Store Wetness multiplier (SWM) – This value determines the rate that water from the interception store moves to the soil store. The depletion of the interception store is calculated as the maximum of the loss based on the soil wetness multiplier and evaporation, whichever is the greater. The transfer rate can therefore be independent of season (if required) and ensures that the amount of water retained in the interception store follows a similar power recession curve to the API. Usual values are around 0.9. Making this value close to 1 means that depletion of the interception store is controlled by the evaporation rate (which follows a more seasonal pattern).

Groundwater Recharge (GWR) – is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05 to 0.3 indicating that 5% to 30% of the flow running off the catchment is entering the groundwater system.

Creek Loss (CL) – is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates take up of water from riparian vegetation and the reduction of baseflow in summer months.

10.4 Model assumptions and limitations

- Runoff dam data is based on a 2005 data set, obtained from aerial imagery captured between 2003 and 2005; locations of irrigation dams were gradually updated as information became available as part of the water licensing process.
- Runoff dam volumes were calculated using the dam surface area-volume relationship developed by McMurray (2004).
- Runoff dams within a sub-catchment have been lumped to represent the total runoff dam volume of each sub-catchment and is represented in the model as one runoff dam node per sub-catchment.
- The proportion of the dam capacity used as an extraction limit varies from 0.3 for all stock and domestic dams to 0.5 for irrigation dams; it is variable between 0.3–0.5 for lumped runoff dam nodes consisting of stock and domestic and irrigation dams (discussed in Section 5.3.1).
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 0.7 fraction of maximum evaporation per month.
- Watercourse demand is based on allocation volumes obtained from the state water licensing system and for the Tookayerta Creek catchment, total watercourse demand is estimated to be 1991 ML at the time of writing (2499 ML permitted take model).
- Refer to Savadamuthu (2004) for more detailed information.

11 Marne River catchment model

11.1 Overview

The Marne River catchment is located approximately 80 km north of Adelaide (Figure 19). The main river in this catchment is the Marne River, which flows eastwards. The other river is the Somme River (also known as the North Rhine), which originates from the northern section of the catchment and joins the Marne River just before the Marne Gorge. The river then flows eastwards onto the River Murray plains before joining the River Murray approximately 30 km downstream of the township of Swan Reach. Streamflow is measured at a gauging station downstream of the Marne Gorge at a location 5 km west of the township of Cambrai. Detailed catchment description and hydrology of the Marne River are included in Savadamuthu (2002) and have been used to populate the descriptions below.

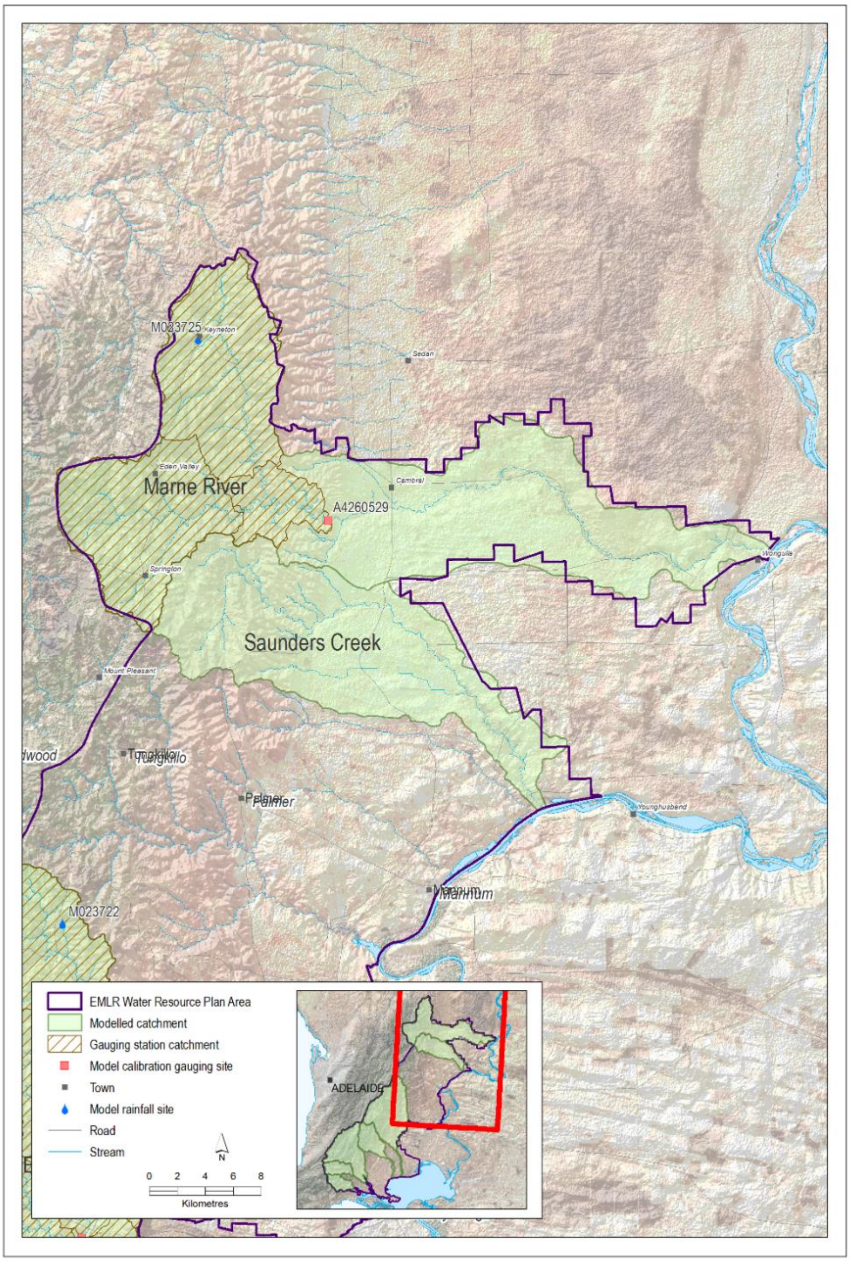


Figure 19. Marne River catchment location map

11.2 Model construction

The Marne River catchment was divided into 6 large sub-catchments (Western Slopes, Springton, Eden Valley, Marne, Keyneton and Somme) based on differing rainfall zones. The large sub-catchments were further subdivided into smaller sub-catchments. The major criteria for sub-division was the presence of a significant on-stream runoff dam (controlling dam), which is deemed to control or block the flow of the catchment area upstream. There may also be other smaller runoff dams present in the sub-catchment, which may not control the flow to the extent to which the major dam does. Confluence with adjacent tributaries was also a factor in the division factor. Based on these factors, each sub-catchment is either:

- a catchment area of a controlling dam with other smaller dams upstream, if any, or
- a catchment area of a series of controlling dams with other smaller dams upstream, if any, or
- in the absence of controlling dams, a catchment area of a stream with off-stream dams, or
- a similar catchment area of a stream to those above with no dams.

Each of these sub-catchments is represented in the model as a catchment node followed by an on-stream dam node (sub-catchments without runoff dams have no dam node). The on-stream dam node represents the accumulation of all the dams in the sub-catchment. The whole catchment is represented as a series of these nodes that are connected based on the drainage pattern. A demand node is used in the model to represent watercourse extractions.

11.2.1 Model nodes

The Marne River catchment was divided into 134 rural sub-catchments, set-up as a series of rural catchment nodes followed by off-stream dam nodes. Each rural catchment node in the model represents a sub-catchment within the whole of the Marne River catchment. Each off-stream dam node in the model represents an individual dam or accumulation of dams within that runoff dam sub-catchment. A demand node is used in the model to represent watercourse extractions.

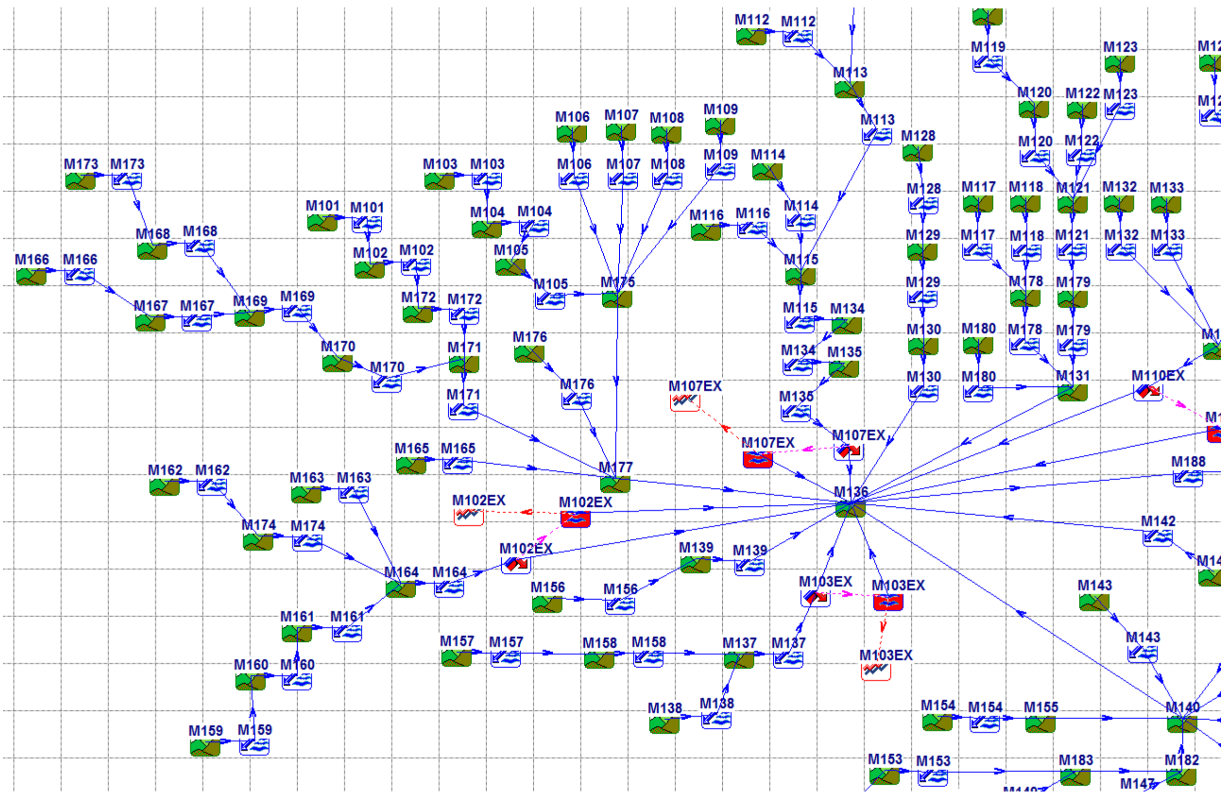


Figure 20. Model layout for a section of the Marne River catchment model

11.2.2 Catchment node inputs

The input data for rural catchment nodes includes:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall data set, rainfall factor and monthly evaporation data set
- model to be used, which was AWBM in this case, and the initial estimated values for the catchment parameter set (median soil moisture content, interception storage, catchment distribution, ground water discharge, soil moisture discharge, pan factor, fraction ground water loss, storage reduction coefficient, ground water loss and creek loss) (see Section 11.3.1)
- calibration file, which contains the observed daily rainfall data set and corresponding observed streamflow data set for the nodes that have a gauging station.

11.2.3 Dam node inputs

Each catchment node with runoff dams was linked to an off-stream dam node. The input data for each off-stream dam node includes:

- dam storage volume, which in this case was the cumulative storage capacity of all the dams in the runoff dam sub-catchment
- corresponding measured daily rainfall data set, rainfall factor and monthly evaporation data set
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; this is dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s), for example, this fraction was 1.0 if there was a large on-stream dam located on the downstream end of the catchment, as it would be a controlling dam that is deemed to control or block the runoff from the entire sub-catchment; this fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream
- water usage factors from the dams, which vary between 30-50% as discussed in Section 5.3.1.

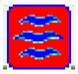
Key input data for each catchment and dam node in the Marne River catchment model are given in Appendix H.

11.2.4 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node. The input data for each demand node includes:

- daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system

11.2.5 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

11.3 Model calibration

Details of the model calibration can be found in Savadamuthu (2002). The model was calibrated using daily runoff data from Cambrai for 14 years starting from 1975. Rainfall data from Keyneton (for Keyneton sub-catchment), Mount Adam (for Western Slopes sub-catchment), Roesler (for Springton sub-catchment), Eichler (for Marne sub-catchment), Hillridge (for Eden Valley subcatchment) and Netherford (Somme sub-catchment) were used. The soil characteristics and land use were assumed to be uniform throughout the catchment. Due to lack of water usage information the annual water usage from the runoff dams was assumed to be 50% of the storage capacity. This rate of water use allows some carry over of storage to following years and is assumed to be the most appropriate option in this study as it provides for higher reliability of supply for permanent plantings.

The model was calibrated for an average rainfall year, which tends to underestimate the runoff during some wet years. Simulation of runoff from summer thunderstorms, and low flows, particularly during the end of a runoff event were also difficult.

11.3.1 Rainfall-runoff parameters

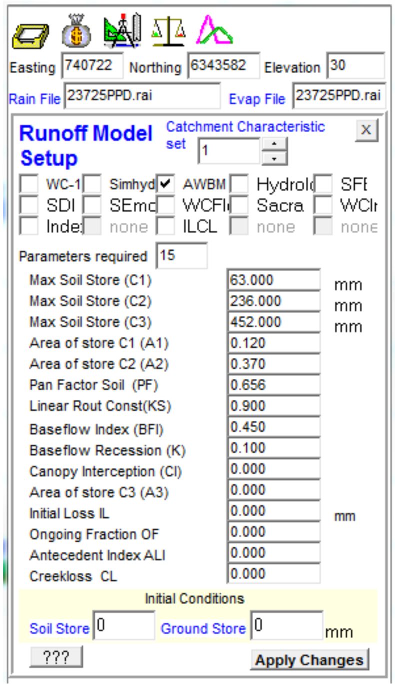


Figure 21. Model catchment characteristic set for the Marne River catchment

Figure 21 shows the AWBM rainfall-runoff parameter values used for the Marne River catchment model. An explanation of these parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

C1 – C3 are soil store capacities measured in depth units.

A1 – A3 are the proportions of area for each of the soil stores C1, C2 and C3. Note that A3 is not a standard input for AWBM. It is included here (when set less than 1–(A1+A2)) to allow for a fraction of the catchment that does not runoff. If A3 is set as zero, this value will be ignored and A3 will be calculated as 1–(A1+A2), as per the standard AWBM model.

Pan Factor (PF) multiplied by the evaporation rate gives the evapo-transpiration rate from the soil structure.

The linear Routing Coefficient (KS) determines how much water is retained in a routing store each day. Note this should be set to zero if other nodes are used in the project to perform system routing.

The Baseflow Index (BFI) determines how much water is directed to the groundwater store. In the case shown, a BFI of 0.45 means that after runoff is calculated, 45% will pass into the groundwater store.

Baseflow recession (K) defines the rate that the groundwater is redirected back to the surface. In the case shown a K = 0.1 means baseflow is calculated to be (1–0.1) x baseflow store.

The above parameters comprise the basic daily time-step AWBM model provided all data entries below K are set to zero.

Six additional parameters have been added to the basic AWBM model. The minor modification involving A3 has been described. Three additional parameters are related to sub-daily flow estimation to take account of high intensity rainfall on dry catchments: (initial loss (IL), ongoing fraction (OF) and antecedent index (ALI). The others are a creek loss factor and a canopy interception factor (CI).

Creek Loss (CL) is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates rapid (non-exponential) reduction in baseflow due to infiltration or riparian vegetation and will reduce the baseflow, particularly in summer months.

11.4 Model assumptions and limitations

- Runoff dams within a sub-catchment have been lumped to represent the total runoff dam volume of each sub-catchment and is represented in the model as one runoff dam node per sub-catchment.
- The proportion of the dam capacity used as an extraction limit was set to 0.5 for all stock and domestic, and irrigation dams (except those set to 0.3 as outlined in the updates to the current take models in section 4.2.2).
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 1.0 fraction of maximum evaporation per month.
- Watercourse demand is based on allocation volumes obtained from the state water licensing system and for the Marne River catchment, total watercourse demand is estimated to be 143 ML at the time of writing.
- Refer to Savadamuthu (2002) for more detailed information.

12 Saunders Creek catchment model

12.1 Overview

The Saunders Creek catchment is located approximately 80 km north of Adelaide (Figure 22). The catchment covers an area of 230 km^2. Two major tributaries provide the majority of streamflow, Saunders Creek and One Tree Hill Creek. The confluence of the streams is before a downstream gorge and they flow eastwards through the plains towards the River Murray. The catchment adjoins the southern boundary of the Marne catchment. Information below was taken from Alcorn (2005) (unpublished report) and has been used to populate the descriptions below.

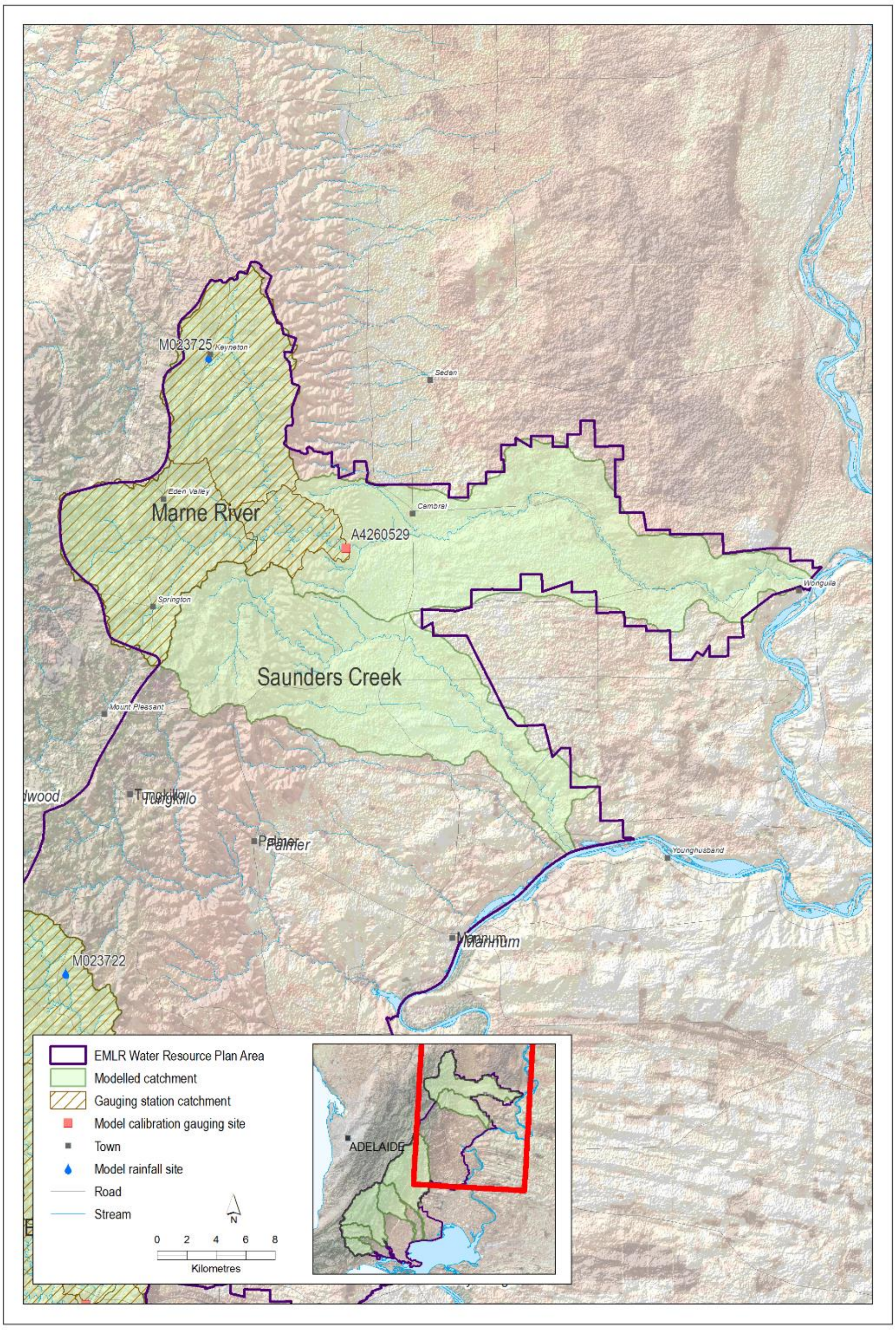


Figure 22. Saunders Creek catchment location map

12.2 Model construction

12.2.1 Model nodes

The Saunders Creek catchment was subdivided into 3 major sub-catchments, based on the 2 major streams feeding into the Saunders Gorge. These major sub-catchments were further subdivided into 64 minor sub-catchments. As such, each sub-catchment consists of a rural catchment node that then feeds into a dam node and so on. A demand node is used in the model to represent watercourse extractions.

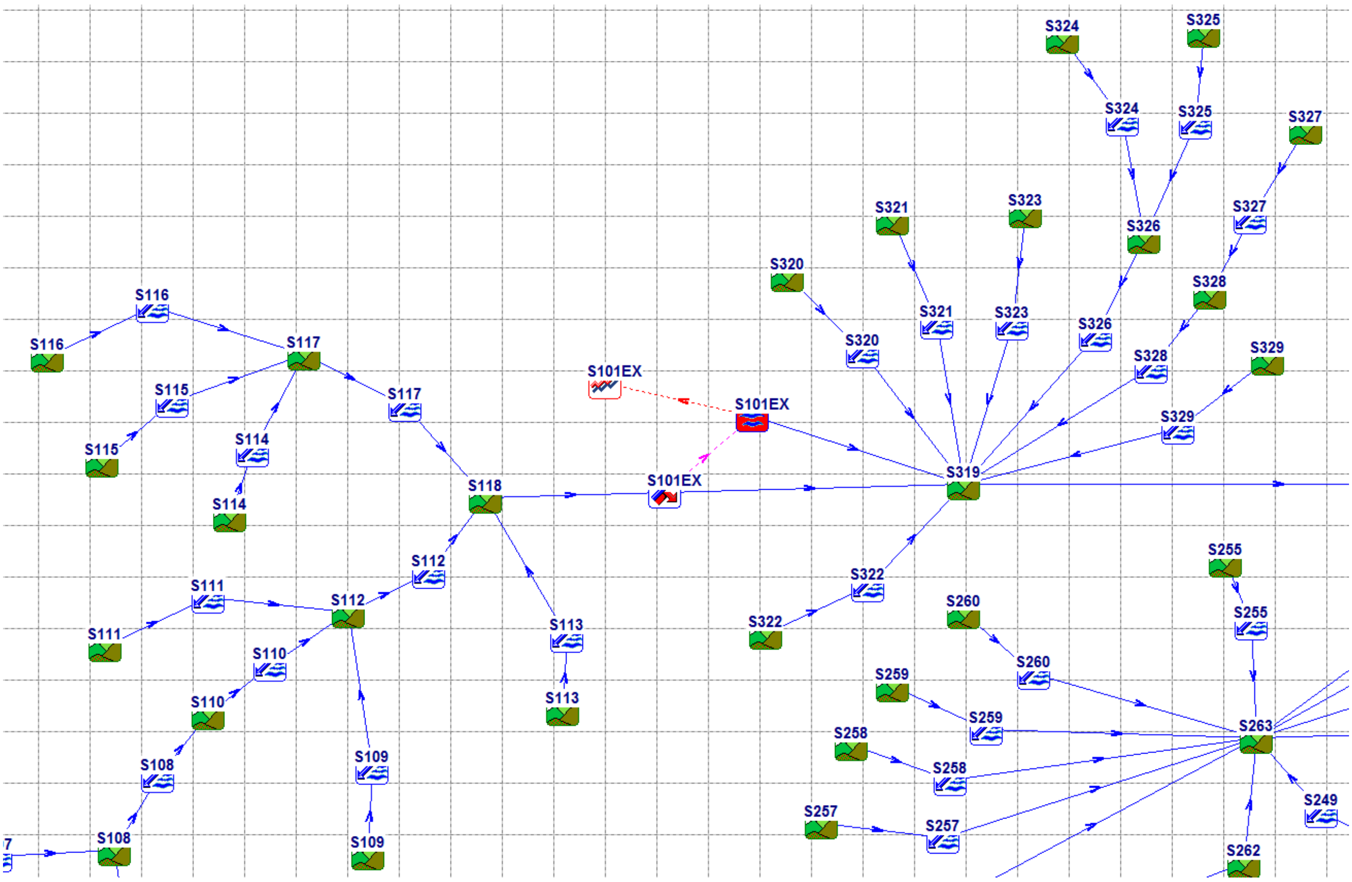
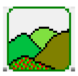


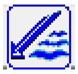
Figure 23. Model layout for a section of the Saunders Creek catchment model

12.2.2 Catchment node inputs

The input data for each rural catchment node  include:

- area of the minor sub-catchment representing that node
- corresponding observed daily rainfall dataset, rainfall factor and monthly evaporation dataset
- model to be used, which was AWBM in this case, and the catchment parameters.

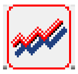
12.2.3 Dam node inputs

Each rural catchment node with runoff dams was linked to an off-stream dam node. The input data for each off-stream dam node  includes:

- dam storage volume, which in this case, was the cumulative storage capacity of all the dams in the minor sub-catchment
- corresponding measured daily rainfall dataset and monthly evaporation dataset
- dam capacity to dam surface area relationship
- maximum daily diversion to the dam, which in this case was the maximum capacity of the dam
- fraction of total catchment runoff diverted to the dam; this is dependent on the location of the dam(s) and the probable catchment runoff captured by the dam(s). , For example, this fraction was 1.0 if there were a large on-stream dam located on the downstream end of the catchment, as it would be considered a controlling dam that is deemed to control or block the runoff from the entire sub-catchment. This fraction was reduced when the total catchment storage was made up of numerous smaller dams spread throughout the catchment or when the dams were truly off-stream.

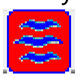
Key input data for each catchment and dam node in the Saunders Creek catchment model are given in Appendix I.

12.2.4 Watercourse demand node inputs

Watercourse extractions within the catchment (lumped to the end of a SWMZ) are represented as a demand node. The input data for each demand node  includes:

- daily demand file; when the daily demand volume passing the demand node for a given day is available, that daily volume of water is extracted and essentially lost from the system.

12.2.5 Routing node inputs

Due to the nature of the daily time step model used in this investigation, it is necessary to route flows through the system. Routing nodes  have been used in this model in areas where representation of the catchment was limited to only the use of a rural catchment node (i.e. where there are long stream lengths with no intercepting features) or to provide a pool of water for watercourse extractions. Addition of routing nodes can enable flows to be delayed where necessary, to achieve a better representation of the daily observed record.

12.2.6 Rainfall spatial variability

The spatial variability of rainfall within the catchment is accounted for by the use of a rainfall factor for each rural catchment and dam node.

12.3 Model calibration

As no long-term stream gauging data is available for the Saunders Creek catchment, the AWBM model was set up with the same set of parameters as the previously calibrated Marne River model. This assumes that the Saunders Creek catchment will respond in the same way as the Marne River catchment. This is a reasonable assumption given the similar geology and rainfall of the neighbouring catchments.

12.3.1 Rainfall-runoff parameters

Figure 24 shows the AWBM rainfall-runoff parameter values used for the Saunders Creek catchment model. An explanation of parameters and a typical range of values are given below, taken from the WaterCress User Manual (2011).

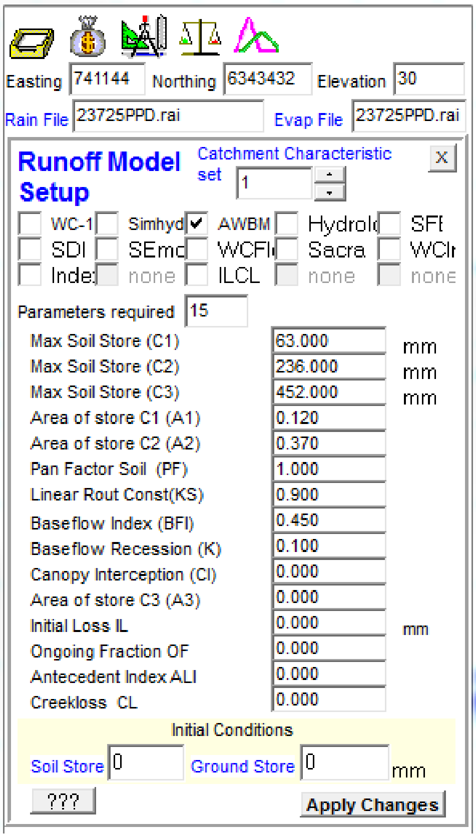


Figure 24. Model catchment characteristic set for the Saunders Creek catchment

C1 – C3 are soil store capacities measured in depth units.

A1 – A3 are the proportions of area for each of the soil stores C1, C2 and C3. Note that A3 is not a standard input for AWBM. It is included here (when set less than 1–(A1+A2)) to allow a fraction of the catchment that does not runoff. If A3 is set to zero, this value will be ignored and A3 will be calculated as 1–(A1+A2), as per the standard AWBM model.

Pan Factor (PF) multiplied by the evaporation rate gives the evapo-transpiration rate from the soil structure.

The linear Routing Coefficient (KS) determines how much water is retained in a routing store each day. Note this should be set to zero if other nodes are used in the project to perform system routing.

The Baseflow Index (BFI) determines how much water is directed to the groundwater store. In the case shown, a BFI of 0.45 means that after runoff is calculated 45% will pass into the groundwater store.

Baseflow recession (K) defines the rate that the groundwater is redirected back to the surface. In the case shown a K = 0.1 means baseflow is calculated to be (1–0.1) x baseflow store.

The above parameters comprise the basic daily time-step AWBM model provided all data entries below K are set to zero.

Six additional parameters are added to the basic AWBM model. The minor modification involving A3 has been described. Three additional parameters are related to sub-daily flow estimation to take account of high intensity rainfall on dry catchments: (initial loss (IL), ongoing fraction (OF) and antecedent index (ALI). The others are a creek loss factor and a canopy interception factor (CI).

Creek Loss (CL) is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates rapid (non-exponential) reduction in baseflow due to infiltration or riparian vegetation and will reduce the baseflow, particularly in summer months.

12.4 Model assumptions and limitations

- Runoff dams within a sub-catchment have been lumped to represent the total runoff dam volume of each sub-catchment and is represented in the model as one runoff dam node per sub-catchment.
- The proportion of the dam capacity used as an extraction limit varies for stock and domestic, irrigation and lumped runoff dams.
- Rainfall and evaporation data used is SILO patched point data.
- Pan evaporation factors for runoff dam nodes have been set at a constant 1.0 fraction of maximum evaporation per month.

- Watercourse demand is based on allocation volumes obtained from the state water licensing system and for the Saunders Creek catchment, total watercourse demand is estimated to be 40 ML at the time of writing.

13 Procedure to run models

13.1 Method to run 'current take' and 'permitted take' models

1. Install the model files for WaterCress (copy the wc2000 folder) onto the computer C:\ drive.
2. Current take models (named Actual take models) for modelled catchments contain the suffix 'ATake2017'.
3. Permitted take models for modelled catchments contain the suffix 'PTake2017'.
4. Open WaterCress.
    a. To select and open a model: *File>Existing Project>select a model>Accept>To Project Layout*
    b. To run the model: *To Output>Run>Run Information>Selection Preset '1'>Start run at 1/1895>over 122 years>daily data commences 1895>for 122 years>update>Run>Run*
    c. Filter through Daily, Monthly or Annual results by selecting the namesake header.
    d. To output results: *File>Save Results to file*>Annual/Monthly or Daily.csv options
5. Undertake to following steps to update models with the most recent data in future years. Obtain the latest rainfall files for each model (rainfall files are located in the 'raindata' subfolder within wc2000 and are .rai files).
    a. Internally, this patched point data is located at Q:\Corporate Science Information\Shared\SILO_PPD_DATA
    b. Externally, this patched point data can be downloaded from the SILO climate data website https://legacy.longpaddock.qld.gov.au/silo/.
6. Append manually only the last year's rainfall and evaporation data. Do not replace the entire rain data set as SILO may have changed some data in subsequent downloads.
7. Reset the model running period to cover the new period required for analysis.
8. If necessary, some input files like watercourse demand (located in the 'raindata' subfolder and ending in the suffix _Demand.txt) may need to be extended. This can be done using the named excel file DemandFileExtractionPattern2.xlsm within the wc2000 folder. This spreadsheet contains a macro to update all daily watercourse demand files.
9. For this to be effective, the date data in columns A, B and C of the spreadsheet need to be extended. Also open 'monthdist' macro in the same spreadsheet and ensure date range is extended to include new dates.
10. Once all input files have been updated, run each of the models and save the monthly output files (model outputs are already specified in the models at Output option 1).

13.2 WaterCress model output options

For watercourse extraction, select each demand node in the model and select the 'supply to' output option. This process needs to be repeated for all demand nodes within the model.

For runoff dam extraction, select any '1' O/S (offstream) dam node in the model and select the 'zone use' output option. Unlike the demand node output option, this process needs to be undertaken only once to obtain total runoff dam extractions from all O/S dam nodes within the model.

For runoff dam loss, select any '1' O/S dam node in the model and select the 'zone loss' output option. As with the runoff dam extraction output, this process needs to be undertaken only once to obtain total runoff dam loss from all O/S dam nodes within the model.

14 Results

14.1 Eastern Mount Lofty Ranges SDL resource unit

14.1.1 Modelled current take 1895-2016

Results for the 'current take' models in the EMLR SDL resource unit over 1895–2016 are summarized in Table 19 below.

Note that runoff dam loss values are average annual net evaporation volumes. The values provided in Table 19 – Table 22 include years with a negative value (where rainfall exceeded gross evaporation for the year).

Table 19. Average annual 'current take' (1895-2016) for modelled catchments for the EMLR SDL resource unit

Model catchment	Standard watercourse extraction (ML)	Flood watercourse extraction (ML)	Runoff dam extraction (ML)	Runoff dam loss (ML)	TOTAL
Angas River	513.2	260.5	1138.9	350.5	2263.1
Bremer River	1270.7	4503.2	1615.5	500.9	7890.4
Currency Creek	116.3	-	519.2	48.6	684.1
Finniss River	470.7	-	1939.0	319.2	2728.9
Tookayerta Creek	1986.3	-	411.4	112.0	2509.7
MODELLED CURRENT TAKE (ML)	4357.2	4763.7	5624.0	1331.3	16076.3
MODELLED CURRENT TAKE (GL)	**9.1**		**7.0**		**16.1**

14.1.2 Modelled permitted take 1895-2009

Results for the 'permitted take' in the modelled catchments in the EMLR SDL resource unit over 1895-2009 are summarized in Table 20. This period reflects the historical climate period used for SDL assessment purposes in the Basin Plan.

Table 20. Average annual 'permitted take' (1895-2009) for modelled catchments for the EMLR SDL resource unit

Model catchment	Standard watercourse extraction (ML)	Flood watercourse extraction (ML)	Runoff dam extraction (ML)	Runoff dam loss (ML)	TOTAL
Angas River	512.5	261.1	1138.2	344.1	2256.0
Bremer River	1275.7	4473.9	1612.0	489.2	7850.8
Currency Creek	116.8	-	519.1	43.3	679.2
Finniss River	385.9	-	3858.8	427.9	4672.5
Tookayerta Creek	2488.2	-	411.4	108.7	3008.3
MODELLED PERMITTED TAKE (ML)	4779.2	4735.0	7539.6	1413.2	18466.9
MODELLED PERMITTED TAKE (GL)		**9.5**		**9.0**	**18.5**

14.2 Marne Saunders SDL resource unit

14.2.1 Modelled current take 1895–2016

Results for the 'current take' modelled catchments in the Marne Saunders SDL resource unit over 1895-2016 are summarized in Table 21 below.

Table 21. Average annual 'current take' (1895-2016) for modelled catchments in the Marne Saunders SDL resource unit

Model catchment	Watercourse ext. (ML)	Runoff dam ext. (ML)	Runoff dam loss (ML)	TOTAL
Marne River	61.3	1266.4	710.7	2038.5
Saunders Creek	7.2	110.2	79.0	196.5
MODELLED CURRENT TAKE (ML)	68.6	1376.6	789.8	2235.0
MODELLED CURRENT TAKE (GL)	**0.07**	**1.38**	**0.79**	**2.2**

14.2.2 Modelled permitted take 1895-2009

Results for the 'permitted take' modelled catchments in the Marne Saunders SDL resource unit for 1895-2009 are summarized in Table 22 below. This period reflects the historical climate period used for SDL assessment purposes in the Basin Plan.

In the Marne Saunders SDL resource unit, the current take and permitted take models are the same, as the modelled catchments are already fully allocated. Note the only difference between Table 21 and Table 22 is that they cover a different time period.

Table 22. Average annual 'permitted take' (1895–2009) for modelled catchments in the Marne Saunders SDL resource unit

Model catchment	Watercourse ext. (ML)	Runoff dam ext. (ML)	Runoff dam loss (ML)	TOTAL
Marne River	61.3	1273.9	710.2	2045.4
Saunders Creek	7.3	112.2	81.2	200.8
MODELLED PERMITTED TAKE (ML)	68.6	1386.1	791.4	2246.2
MODELLED PERMITTED TAKE (GL)	**0.07**	**1.39**	**0.79**	**2.2**

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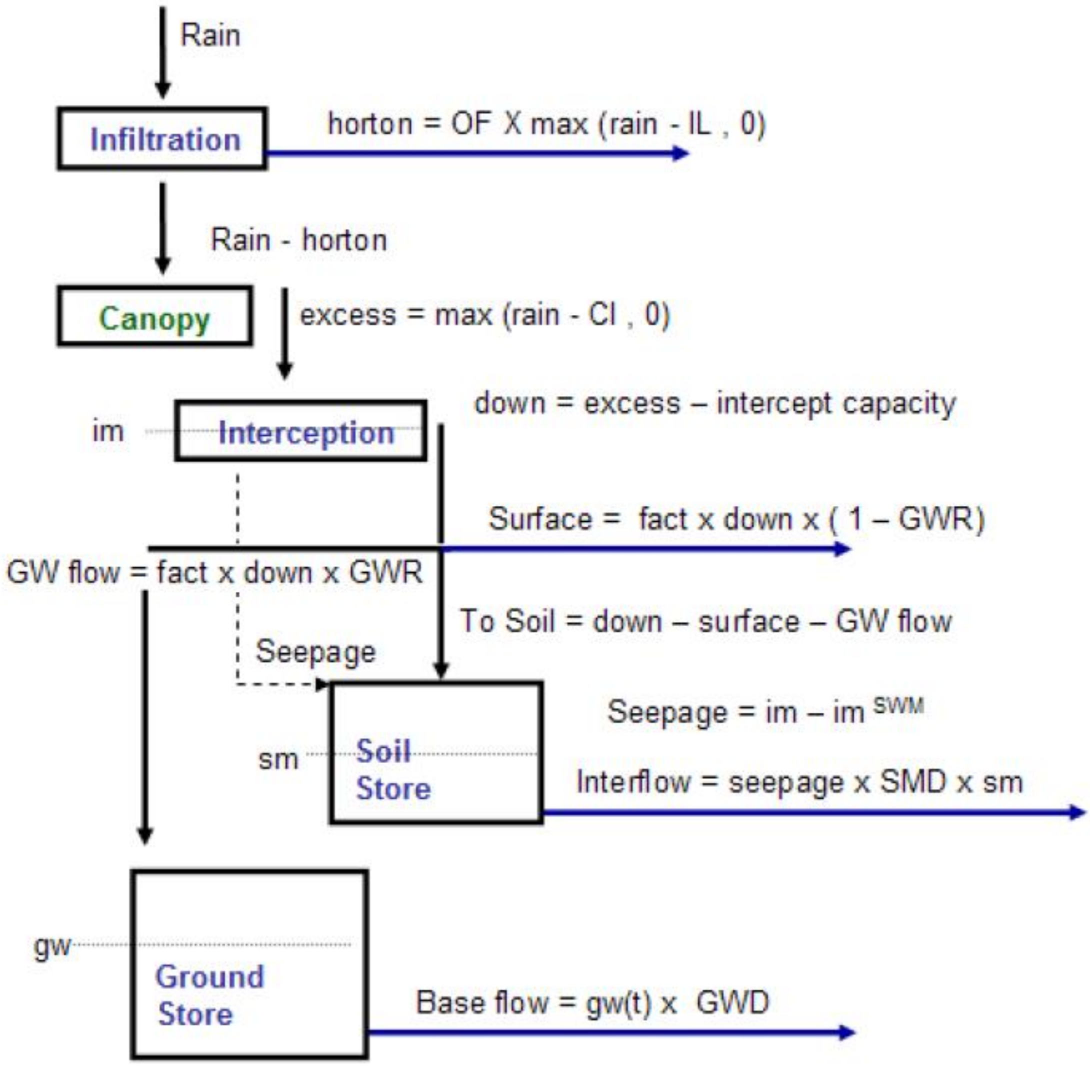
Appendix A: WC-1 model description

The following WC-1 model description and layout figure was taken from the WaterCress User Manual (2011).

The WC-1 model was developed for the South Australian Government following experience with South Australian rainfall to runoff model calibration in the Mount Lofty Ranges, Barossa Valley and Mid North. The program was developed in 1988 to estimate the impact of farm dams in the Barossa Valley when it was found most of the existing models were not able to reproduce the recorded runoff of South Australia's drier catchments with annual rainfall in the range 450 to 650 mm.

The WC-1 model uses three storages, as shown in the below figure, to track the notional vertical passage of rainfall by gravity through interception, soil moisture and groundwater. The soil store is generally the main runoff producing component, requiring only changes to four of the parameters to produce reasonable model calibration. Surface runoff is calculated with possible contributions generated via the calculations performed for the three layers of the model (as surface, interflow and groundwater contributions). For further information on the model and symbols in the figure below, see the WaterCress User Manual (2011).



Appendix B: AWBM model description

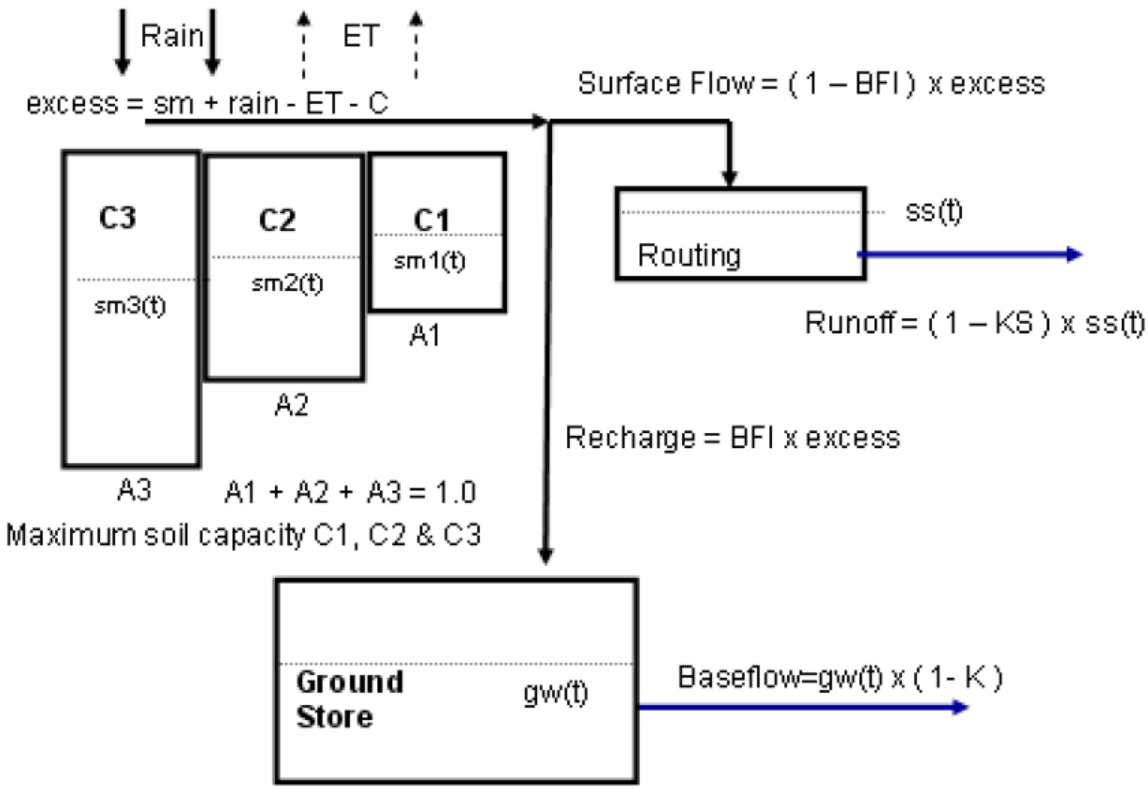
The following AWBM model description and layout figure was taken from the WaterCress User Manual (2011).

The original AWBM model was established as a daily rainfall runoff model only. The model uses five surface stores: three to simulate partial areas of runoff, one to simulate groundwater and one for routing (see figure below — for further information on symbols used in the figure, see WaterCress User Manual (2011). Runoff occurs if any of the three partial area stores exceeds their capacity. The sizes of the stores are selected to best simulate the catchments' non-linear response to rainfall as its wetness increases.

The WC models also adopt this concept of variable storage across the catchment but handle it in a different way to AWBM. The two models each offer advantages and disadvantages, which are discussed below, and it is considered that the concepts utilised by AWBM and WC-1 are likely to produce the best results for semi-arid catchments, where rainfall ranges from 400 to 700 mm.

The WC-1 model with its smooth relationship between rainfall and runoff produces more continuous runoff events than the three step function of AWBM. For example, no runoff will occur in AWBM until the smallest soil store is filled, whereas WC-1 will potentially provide runoff at low moisture stores. Different catchments may behave differently in this respect (e.g. runoff may be generated, even in summer, from relatively impervious areas close to a catchment outlet). In WC-1 this effect has to be overcome by introducing an interception store and/or creek loss.

Of interest is the similar way that the baseflow store is recharged, by taking a constant proportion of streamflow. Examination of streamflow in the Barossa Valley and the Wakefield River in South Australia has indicated that recharge (reflected as baseflow) is closely related to streamflow of the previous winter season. It appears in semi-arid catchments that the rainfall conditions that provide for streamflow also provide for recharge. This being said, the constant discharge rate adopted by both models is used by many others and is more an issue of simplicity rather than being the best function. For further information on the model and symbols in the figure below, see the WaterCress User Manual (2011).



Appendix C: Angas River – WaterCress sub-catchment and dam node details

Rainfall station: M – Macclesfield (M023728)

Angas River sub-catchment and dam node WaterCress details

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
B18	1	3.06						0.71M
B17	2	0.68						0.72M
B16	3	0.23	4	2.06	100%	0.3	9.0	0.73M
B15	5	1.84	6	4.84	90%	0.3	2.6	0.75M
B14	7	1.14	8	4.02	100%	0.3	3.5	0.75M
B13	9	1.26	10	44.27	100%	0.471	35.1	0.84M
B9	11	0.66	12	3.69	100%	0.3	5.6	0.86M
B8	13	0.74	14	3.78	90%	0.3	5.1	0.89M
B10	15	0.69	16	5.99	100%	0.3	8.7	0.89M
B12	17	0.47	18	0.73	100%	0.3	1.5	0.88M
B11	19	0.14	20	3.32	100%	0.3	23.7	0.88M
B6	21	0.57	22	0.44	100%	0.3	0.8	0.81M
B3	23	0.69	24	5.75	100%	0.3	8.3	0.83M
B2	25	0.39	26	4.56	100%	0.3	11.7	0.9M
B5	27	1.05	28	20.50	100%	0.3	19.5	0.76M
B1	29	1.83	30	35.63	100%	0.3	19.5	0.86M
B4	31	0.41	32	3.03	80%	0.3	7.4	0.85M
B7	33	0.17	34	0.00	0%	0.3	0.0	0.74M
D1	35	0.45	36	14.78	100%	0.402	32.8	1.09M
D2	37	0.98	38	7.57	100%	0.3	7.7	1.06M
D3	39	0.9	40	10.24	100%	0.3	11.4	1.08M
D4	41	0.25	42	6.79	100%	0.3	27.2	1.05M
D5	43	0.8	44	5.33	100%	0.3	6.7	1.01M
D6	45	0.53	46	1.16	30%	0.3	2.2	0.99M
D7	47	0.55	48	3.68	90%	0.3	6.7	0.97M
D8	49	1.12	50	27.29	100%	0.3	24.4	0.94M
D9	51	0.73	52	10.43	100%	0.3	14.3	0.9M
D12	53	0.32	54	2.27	100%	0.3	7.1	0.85M
D10	55	0.23	56	4.61	100%	0.3	20.0	0.91M
D11	57	0.89	58	9.88	80%	0.3	11.1	0.93M
D14	59	2.48						0.89M
D13	60	2.62	61	23.29	80%	0.3	8.9	0.96M
D15	62	0.68						0.91M
D16	63	1.1						0.89M
D17	64	0.27	65	2.28	100%	0.3	8.4	0.83M
D18	66	0.86						0.86M
D19	67	3.21	68	48.86	100%	0.481	15.2	0.78M
D1a	69	0.29	70	3.96	80%	0.3	13.6	1.1M
D1b	71	0.38	72	19.01	100%	0.481	50.0	1.09M
D4a	73	0.29	74	26.97	100%	0.491	93.0	1.07M
A1	232	1.3	75	12.59	100%	0.3	9.7	1.21M
A2	76	1.1	77	8.83	25%	0.3	8.0	1.21M
A3	78	0.47	79	21.75	75%	0.491	46.3	1.11M

Sub-cat.	WC cat. node	Cat. area (km²)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km²)	Rainfall station
A4	80	0.63	81	11.84	100%	0.3	18.8	1.11M
A5	82	1.83						1.12M
A6	83	2.1	84	72.64	100%	0.3	34.6	1.19M
A7	85	0.06	86	3.91	100%	0.3	65.2	1.14M
A8	87	0.79	88	5.16	100%	0.471	6.5	1.13M
A9	89	0.3	90	4.97	50%	0.3	16.6	1.1M
A10	91	0.48	92	41.95	100%	0.454	87.4	1.13M
A11	93	0.57	94	0.56	10%	0.3	1.0	1.13M
A12	95	0.52	96	14.56	80%	0.422	28.0	1.06M
A13	97	0.01						1.08M
A14	98	1.05	99	27.66	90%	0.3	26.3	1.2M
A15	100	1.88	101	20.46	80%	0.3	10.9	1.14M
A16	102	0.51	103	67.17	100%	0.3	131.7	1.22M
A17	104	0.54	105	4.09	90%	0.353	7.6	1.11M
A18	106	0.47	107	1.60	80%	0.3	3.4	1.06M
A19	108	1.03						1.08M
A20	109	0.25	110	3.30	100%	0.3	13.2	1M
A21	111	0.78	112	16.97	90%	0.3	21.8	1.05M
A22	113	1.05	114	13.29	60%	0.32	12.7	1.02M
A23	115	1.39						1.01M
A24	116	0.73	117	21.10	60%	0.3	28.9	1.07M
A25	118	0.28	119	8.54	100%	0.3	30.5	1.06M
A26	120	0.07	121	0.29	90%	0.3	4.2	1.03M
A27	122	0.51	123	5.68	90%	0.3	11.1	1.03M
A28	124	0.31	125	5.21	100%	0.3	16.8	1.03M
A29	126	0.9	127	11.84	100%	0.353	13.2	1.01M
A30	128	0.37	129	8.11	100%	0.3	21.9	0.98M
A31	130	1.65	131	5.92	10%	0.3	3.6	1.01M
A32	132	0.48	133	4.42	60%	0.3	9.2	0.99M
A33	134	0.28	135	4.71	100%	0.3	16.8	0.97M
A34	136	0.3	137	2.29	100%	0.471	7.6	0.98M
A35	138	0.41	139	3.71	90%	0.3	9.0	0.94M
A36	140	0.12	141	2.45	100%	0.3	20.4	0.94M
A37	142	0.36	143	18.67	100%	0.3	51.8	0.91M
A38	144	1.31						0.9M
A39	145	1.16	146	171.93	100%	0.481	148.2	1.04M
A40	147	0.58	148	5.60	90%	0.3	9.7	0.97M
A41	149	0.83	150	55.65	90%	0.444	67.0	1.02M
A42	151	1.18	152	22.09	100%	0.471	18.7	0.95M
A43	153	1.27	154	52.97	90%	0.382	41.7	1.02M
A44	155	0.18	156	3.35	100%	0.3	18.6	0.96M
A45	157	0.5	158	2.21	50%	0.3	4.4	0.94M
A47	159	0.98	160	34.85	100%	0.383	35.6	0.92M
A46	161	1.44	162	46.65	90%	0.353	32.4	0.91M
A48	163	3.03	164	161.05	100%	0.353	53.2	0.97M
A49	165	0.55	166	31.72	100%	0.3	57.7	0.93M
A50	167	2.04	168	111.20	100%	0.392	54.5	0.92M
A51	169	0.08	170	6.50	100%	0.3	81.3	0.88M
A52	171	0.84	172	32.99	100%	0.3	39.3	0.97M
A53	173	0.57	174	1.61	70%	0.3	2.8	0.9M
A54	175	0.69	176	7.52	90%	0.3	10.9	0.88M
A55	177	0.72	178	7.02	80%	0.3	9.7	0.88M
A56	179	0.3	180	3.17	100%	0.3	10.6	0.86M

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
A57	181	2.91	182	26.22	100%	0.3	9.0	0.87M
A58	183	1.62	184	2.74	100%	0.3	1.7	0.86M
A1a	186	0.4	187	3.81	100%	0.402	9.5	1.23M
A6a	188	0.3	189	42.84	100%	0.471	142.8	1.19M
A7a	190	0.23	191	38.77	100%	0.501	168.6	1.18M
A14a	192	0.26	193	10.17	100%	0.434	39.1	1.2M
A24a	194	0.09	195	4.82	100%	0.491	53.5	1.11M
A26a	196	0.15	197	22.10	100%	0.501	147.3	1.11M
A26b	198	0.18	199	18.20	100%	0.501	101.1	1.07M
A34b	200	0.1						0.98M
A34c	201	1.64	202	7.56	5%	0.3	4.6	0.96M
A35a	203	0.59	204	128.51	100%	0.33	217.8	1.04M
A35b	205	0.38	206	8.80	100%	0.501	23.2	1.01M
A35c	207	0.05	208	4.52	100%	0.3	90.3	0.98M
A35d	209	0.47	210	25.17	100%	0.491	53.5	0.99M
A35e	211	0.96	212	26.99	100%	0.392	28.1	0.98M
A35f	213	0.11	214	2.80	100%	0.3	25.5	0.97M
A35g	215	0.07	216	1.20	100%	0.3	17.2	0.94M
A36b	217	0.37	218	6.39	90%	0.3	17.3	0.94M
A38a	219	0.05	220	0.50	100%	0.501	10.0	0.91M
A47b	221	0.2						0.9M
A48a	222	1.7	223	53.37	100%	0.3	31.4	1.04M
A48b	224	0.1	225	1.84	100%	0.434	18.4	1.01M
A48c	226	0.2	227	11.41	100%	0.3	57.1	1.01M
A49a	228	1.1	229	44.17	100%	0.412	40.2	0.97M
A51a	230	0.6	231	25.07	100%	0.434	41.8	0.91M
MA1	233	0.88	234	63.94	100%	0.3	72.7	0.84M
MA2	235	0.43	236	7.61	5%	0.3	17.6	0.78M
MA3	237	0.21	238	24.21	50%	0.3	117.0	0.79M
MA4	239	0.3	240	15.42	50%	0.3	51.4	0.81M
MA5	241	0.87	242	77.54	100%	0.3	89.0	0.69M
MA6	243	2.78	244	23.02	10%	0.3	8.3	0.7M
P1	245	0.26	246	11.53	100%	0.491	44.3	1.18M
P2	247	0.08	248	0.47	100%	0.3	5.9	1.18M
P3	249	0.6	250	10.89	100%	0.31	18.1	1.14M
P4	251	0.34	252	0.32	10%	0.3	0.9	1.1M
P5	253	1.26	254	6.55	50%	0.3	5.2	1.12M
P6	255	0.53	256	17.79	100%	0.3	33.6	1.09M
P7	257	0.41	258	18.49	100%	0.3	45.1	1.06M
P8	259	1.48	260	24.38	90%	0.3	16.5	1.08M
P9	261	0.26	262	5.67	100%	0.3	21.8	1.03M
P10	263	0.78	264	31.07	100%	0.461	39.8	1.02M
P11	265	2.46	266	85.68	80%	0.3	34.8	0.95M
P12	267	0.58	268	57.98	100%	0.481	100.0	1.16M
P13	269	0.5	270	6.97	80%	0.3	13.9	1.16M
P14	271	0.49	272	5.62	50%	0.3	11.5	1.16M
P15	273	3.12	274	61.96	100%	0.363	19.9	1.11M
P16	275	1.18	276	44.45	100%	0.373	37.7	0.99M
P17	277	0.38	278	13.98	50%	0.3	36.8	0.95M
P18	279	0.92	280	1.35	50%	0.3	1.5	0.95M
P19	281	1						0.89M
P20	282	1.18	283	25.85	100%	0.3	21.9	1.02M
P19a	284	0.5	285	0.00	100%	0.3	0.0	0.9M

Sub-cat.	WC cat. node	Cat. area (km²)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km²)	Rainfall station
P21	286	0.38	287	10.76	100%	0.3	28.3	0.96M
P22	288	1.3						0.94M
P32	289	1.8	290	20.95	100%	0.3	11.6	0.92M
P31	291	1.35	292	8.19	100%	0.32	6.1	1.02M
P30	293	0.43	294	6.94	100%	0.3	16.1	1.02M
P29	295	0.3	296	3.59	100%	0.3	12.0	1.01M
P28	297	0.84						1.09M
P26	298	0.95	299	15.40	80%	0.32	16.2	1.08M
P27	300	0.93	301	21.23	100%	0.3	22.8	1.09M
P25	302	0.86	303	18.49	100%	0.3	21.5	1.12M
P24	304	0.56	305	1.72	100%	0.3	3.1	1.1M
P23	306	0.44	307	11.66	50%	0.3	26.5	1.11M
P35	308	3.27	309	7.00	100%	0.471	2.1	0.78M
P34	310	0.28	311	3.55	90%	0.3	12.7	0.81M
P33	312	0.38	313	1.16	70%	0.402	3.0	0.83M
P4a	314	0.43	315	4.75	100%	0.33	11.0	1.1M
P9a	316	0.57	317	21.20	100%	0.434	37.2	1.03M
P10a	318	0.04	319	0.60	100%	0.501	15.0	1.01M
P12a	320	0.07	321	1.90	100%	0.501	27.1	1.18M
P12b	322	0.07	323	2.00	100%	0.3	28.6	1.18M
P12c	324	0.7	325	7.46	90%	0.3	10.7	1.2M
P15a	326	0.48	327	9.83	100%	0.434	20.5	1.12M
P15f	328	0.8	329	51.93	100%	0.461	64.9	0.97M
P15e	330	0.96	331	79.91	100%	0.481	83.2	1.01M
P15d	332	0.74	333	47.73	100%	0.444	64.5	1.06M
P26b	334	0.09	335	5.01	100%	0.3	55.7	1.07M
P33a	336	0.67	337	17.28	100%	0.3	25.8	0.83M
P35a	338	0.97	339	6.40	20%	0.3	6.6	0.86M
TOTAL		**139**		**3133**			**22.5**	

Appendix D: Bremer River – WaterCress sub-catchment and dam node details

Rainfall stations: M – Macclesfield (M023728), H – Harrogate (M023722), E – Echunga Golf Course (M023713), K – Kanmantoo (M023724), MB – Mount Barker (M023733), N – Nairne (M023739), S – Strathalbyn (M023747), W – Woodside (M023829), C – Callington (M024508), L – Langhorne Creek (M024516)

Bremer River sub-catchment and dam node WaterCress details

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
100-a	1	3.07	279	60.76	100%	0.300	19.79	1H
101-a	2	0.06	280	10.04	100%	0.471	174.97	0.93H
102-a	3	1.22	281	7.76	100%	0.300	6.35	0.97H
103-a	4	5.37	282	10.58	100%	0.300	1.97	0.96H
104-a	5	0.29	283	12.70	100%	0.491	43.99	0.91H
105-a	6	0.60	284	2.14	5%	0.373	3.56	0.89H
105-b	7	0.16	285	2.06	90%	0.300	13.10	0.88H
106-a	8	0.07	286	0.00	0%	0.300	0.00	0.88H
107-a	9	17.38	287	26.49	60%	0.300	1.52	1H
107-b	10	1.05	288	0.40	1%	0.300	0.38	0.86H
108-a	11	1.91	289	12.64	5%	0.300	6.61	0.82H
109-a	12	1.05	290	0.84	1%	0.300	0.80	0.89H
10-a	13	0.54	291	18.05	100%	0.300	33.36	1.09MB
10-b	14	0.39	292	26.70	100%	0.501	67.99	1.06MB
10-c	15	0.22	293	30.98	100%	0.491	141.87	1E
10-d	16	0.10	294	15.00	100%	0.501	153.37	1E
110-a	17	13.01	295	22.31	5%	0.300	1.72	1.02K
111-a	18	7.56	296	6.09	5%	0.320	0.81	0.99H
112-a	19	12.45	297	34.82	5%	0.300	2.80	1.06K
113-a	20	9.29	298	4.46	1%	0.300	0.48	1.05K
114-a	21	0.84	299	0.00	1%	0.300	0.00	0.98K
115-a	22	25.13	300	24.26	5%	0.300	0.97	1.05K
116-a	23	2.88	301	0.00	1%	0.300	0.00	1.1C
117-a	24	2.64	302	0.00	1%	0.300	0.00	1.11C
118-a	25	1.92	303	0.00	1%	0.300	0.00	1.1C
119-a	26	4.07	304	4.22	5%	0.300	1.04	1.12C
11-a	27	0.20	305	18.38	100%	0.464	92.07	1.01E
11-b	28	0.55	306	33.98	100%	0.481	61.92	1E
11-c	29	0.25	307	3.91	100%	0.300	15.54	1E
120-a	30	0.39	308	7.43	100%	0.454	18.90	0.96MB
120-b	31	1.13	309	31.51	100%	0.363	27.94	0.95MB
120-c	32	1.40	310	16.95	100%	0.330	12.08	0.94MB
120-d	33	1.73	311	31.37	100%	0.444	18.10	0.88MB
120-e	34	1.74	312	12.58	100%	0.300	7.22	0.88M
120-f	35	1.05	313	7.54	100%	0.300	7.15	0.87M
120-g	36	2.74	314	37.58	100%	0.300	13.70	1.04K
120-h	37	2.52	315	10.51	80%	0.300	4.17	1.14S
120-i	38	3.11	316	12.55	25%	0.300	4.04	1.05S
120-j	39	2.45	317	2.48	1%	0.300	1.01	1.14S
120-k	40	0.94	318	4.37	5%	0.300	4.66	1.12S
120-l	41	4.57	319	9.42	10%	0.300	2.06	1.04S

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
120-m	42	2.25	320	0.00	1%	0.300	0.00	0.96S
120-n	43	14.70	321	4.41	1%	0.300	0.30	1S
121-a	44	0.56	322	2.18	15%	0.300	3.92	0.97MB
122-a	45	1.04	323	84.33	100%	0.471	81.37	1.02MB
122-b	46	1.24	324	31.05	100%	0.424	25.05	0.98MB
123-a	47	0.46	325	21.14	100%	0.300	45.86	0.94MB
124-a	48	0.90	326	7.74	80%	0.300	8.64	0.92MB
125-a	49	1.04	327	21.58	100%	0.353	20.78	0.97M
125-b	50	1.13	328	35.12	100%	0.300	31.17	0.94M
126-a	51	0.18	329	13.24	100%	0.300	72.21	0.93M
126-b	52	1.38	330	23.10	100%	0.300	16.77	0.91M
126-c	53	0.98	331	11.20	100%	0.300	11.49	0.82M
126-d	54	0.35	332	4.47	100%	0.300	12.86	0.93M
127-a	55	1.22	333	13.81	85%	0.300	11.35	0.9M
128-a	56	1.60	334	26.10	75%	0.300	16.36	0.94M
128-b	57	1.17	335	21.98	100%	0.300	18.71	0.92M
128-c	58	1.68	336	21.01	100%	0.382	12.54	0.88M
129-a	59	0.76	337	3.12	30%	0.300	4.11	1.15S
12-a	60	0.27	338	4.34	100%	0.300	16.17	1.03E
130-a	61	3.07	339	3.44	5%	0.300	1.12	1.02S
131-a	62	1.73	340	21.03	100%	0.471	12.16	1.15K
131-b	63	11.39	341	1.47	10%	0.300	0.13	1.18C
131-c	64	3.72	342	0.00	1%	0.300	0.00	1.15C
131-d	65	0.79	343	0.00	1%	0.300	0.00	0.94S
132-a	66	0.52	344	2.33	100%	0.300	4.48	1.21K
132-b	67	2.53	345	1.24	5%	0.300	0.49	1.17C
133-a	68	0.33	346	1.13	100%	0.300	3.46	1.23K
134-a	69	0.28	347	1.14	100%	0.300	4.03	1.18K
135-a	70	0.56	348	1.98	75%	0.300	3.52	1.21K
135-b	71	2.56	349	0.00	1%	0.300	0.00	1.21C
136-a	72	0.65	350	0.00	1%	0.300	0.00	1.12C
137-a	73	0.52	351	3.01	100%	0.300	5.83	1.12S
137-b	74	1.67	352	7.33	85%	0.300	4.39	1.07S
137-c	75	2.16	353	0.00	1%	0.300	0.00	1S
13-a	76	0.45	354	18.09	100%	0.471	40.54	1.09MB
13-b	77	0.17	355	11.13	100%	0.300	65.37	1.04E
14-a	78	0.26	356	12.64	100%	0.300	48.81	1.08MB
14-b	79	0.60	357	9.81	100%	0.434	16.27	1.07MB
14-c	80	0.37	358	14.09	100%	0.300	37.95	1.07MB
15-a	81	0.23	359	26.93	100%	0.300	117.86	1.09MB
16-a	82	0.42	360	16.07	100%	0.454	38.15	1.04E
17-a	83	0.16	361	5.83	100%	0.300	35.64	1.01E
17-b	84	0.16	362	6.07	100%	0.300	37.41	1.01E
18-a	85	0.15	363	8.03	100%	0.454	55.19	1.03MB
19-a	86	0.44	364	10.52	100%	0.434	23.71	1.07E
1-a	87	0.20	365	6.35	100%	0.363	32.04	1.11M
1-b	88	0.34	366	9.51	100%	0.300	27.76	1.09M
1-c	89	1.03	367	34.93	100%	0.300	33.90	1.09M
1-d	90	0.70	368	21.99	100%	0.300	31.23	1.08M
1-e	91	1.28	369	14.29	30%	0.300	11.20	1.02E
1-f	92	1.54	370	5.67	10%	0.320	3.68	1.01E
1-g	93	3.43	371	57.15	25%	0.340	16.64	1.04MB
1-h	94	0.69	372	13.90	70%	0.300	20.15	1.05MB

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
1-i	95	1.54	373	24.08	85%	0.300	15.66	1.01MB
1-j	96	2.74	374	23.71	25%	0.464	8.66	1.02MB
1-k	97	2.20	375	2.65	1%	0.300	1.21	1MB
1-l	98	0.63	376	12.16	5%	0.300	19.43	0.96MB
1-m	99	2.39	377	4.88	1%	0.300	2.04	0.95MB
1-n	100	2.78	378	5.65	1%	0.300	2.03	0.99N
1-o	101	9.61	379	32.84	80%	0.300	3.42	0.98N
1-p	102	7.80	380	0.29	1%	0.300	0.04	1.11K
1-q	103	5.32	381	0.00	1%	0.300	0.00	1.07C
1-r	104	35.93	382	0.26	1%	0.300	0.01	1.02C
1-s	105	4.96	383	0.00	1%	0.300	0.00	1.07L
1-t	106	11.10	384	0.00	1%	0.300	0.00	1.06L
20-a	107	0.81	385	75.58	100%	0.330	93.18	1.12MB
20-b	108	0.27	386	11.90	100%	0.501	44.42	1.05MB
21-a	109	0.04	387	1.43	100%	0.300	33.94	1.11MB
21-b	110	0.31	388	5.45	100%	0.300	17.81	1.13MB
22-a	111	0.28	389	16.18	100%	0.300	58.06	1.13MB
22-b	112	0.18	390	10.25	100%	0.471	56.72	1.1MB
23-a	113	0.81	391	4.40	100%	0.300	5.41	1.12MB
23-b	114	0.85	392	58.07	100%	0.454	68.20	1.04MB
23-c	115	0.20	393	21.86	100%	0.300	111.45	1.03MB
24-a	116	0.09	394	7.38	100%	0.300	80.51	1.03MB
24-b	117	0.21	395	13.86	100%	0.402	64.63	1.03MB
25-a	118	1.75	396	24.99	85%	0.353	14.31	1.14N
25-b	119	1.89	397	15.44	5%	0.454	8.17	1.06MB
25-c	120	1.38	398	1.27	1%	0.300	0.92	1.05MB
25-d	121	0.56	399	0.00	1%	0.300	0.00	1.02MB
26-a	122	0.32	400	1.30	100%	0.300	4.10	1.14N
26-b	123	0.64	401	11.28	100%	0.300	17.74	1.14N
26-c	124	0.69	402	3.04	15%	0.300	4.40	1.09N
27-a	125	0.47	403	12.60	100%	0.422	26.86	1.13MB
27-b	126	0.83	404	13.23	50%	0.300	15.89	1.1MB
28-a	127	0.40	405	15.72	100%	0.300	38.84	1.08MB
29-a	128	1.02	406	5.63	70%	0.300	5.51	1.02MB
2-a	129	0.56	407	32.53	100%	0.412	58.38	1.11M
2-b	130	0.33	408	11.49	100%	0.300	34.80	1.09M
30-a	131	0.75	409	10.20	100%	0.300	13.68	1.07MB
30-b	132	0.31	410	5.00	100%	0.501	16.08	1.1MB
30-c	133	0.18	411	2.90	100%	0.501	16.13	1.06MB
30-d	134	0.22	412	19.43	100%	0.300	87.96	1.04MB
31-a	135	0.84	413	19.02	100%	0.300	22.53	1.14MB
32-a	136	0.11	414	3.03	100%	0.300	27.98	1.1MB
32-b	137	0.33	415	3.62	100%	0.300	10.90	1.1MB
32-c	138	0.37	416	1.69	70%	0.300	4.55	1.06MB
33-a	139	0.08	417	1.67	100%	0.300	21.30	1.07MB
34-a	140	0.74	418	42.56	100%	0.353	57.57	1.12MB
35-a	141	0.31	419	3.09	85%	0.300	9.84	1.11MB
35-b	142	1.17	420	1.84	5%	0.300	1.56	1.05MB
36-a	143	0.28	421	14.26	100%	0.300	50.62	1.08MB
36-b	144	2.19	422	26.93	100%	0.300	12.32	1.04MB
36-c	145	1.88	423	15.05	50%	0.310	7.99	1.02MB
36-d	146	2.74	424	7.71	5%	0.320	2.81	1MB
37-a	147	0.41	425	20.86	100%	0.300	51.51	1.08MB

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
38-a	148	0.13	426	15.89	100%	0.300	121.91	1.1MB
39-a	149	0.67	427	53.05	100%	0.454	78.75	0.96MB
39-b	150	0.69	428	57.23	100%	0.481	82.73	0.98MB
3-a	151	0.39	429	39.42	100%	0.300	101.26	1.11M
3-b	152	0.30	430	31.29	100%	0.300	103.43	1.08M
40-a	153	0.07	431	1.11	100%	0.300	16.58	1.03MB
40-b	154	0.22	432	3.53	100%	0.300	15.70	1.04MB
41-a	155	1.21	433	1.71	1%	0.300	1.42	0.97MB
42-a	156	0.27	434	7.14	100%	0.300	26.23	0.98MB
42-b	157	1.45	435	19.84	100%	0.300	13.67	0.97MB
43-a	158	2.30	436	21.85	30%	0.300	9.51	1MB
44-a	159	0.41	437	4.01	100%	0.300	9.70	1.11N
44-b	160	5.75	438	31.09	10%	0.300	5.41	1.06N
45-a	161	0.45	439	12.90	100%	0.491	28.66	1.11N
45-b	162	1.97	440	27.05	100%	0.330	13.74	1.11N
46-a	163	0.31	441	10.33	100%	0.444	33.52	1.07N
47-a	164	0.25	442	82.90	100%	0.501	331.07	1.04N
48-a	165	0.31	443	5.29	100%	0.300	16.91	1.04N
49-a	166	0.37	444	8.93	100%	0.300	24.00	0.98MB
49-b	167	0.56	445	0.34	1%	0.300	0.61	0.97MB
4-a	168	0.18	446	13.24	100%	0.300	74.48	1.1M
4-b	169	0.19	447	169.21	100%	0.501	903.90	1.09M
50-a	170	2.25	448	9.34	15%	0.300	4.16	1.08N
50-b	171	1.14	449	9.74	100%	0.444	8.58	1.13N
51-a	172	0.06	450	0.16	80%	0.300	2.62	1.22N
52-a	173	0.49	451	10.36	100%	0.300	21.29	0.98MB
52-b	174	0.20	452	1.95	1%	0.300	9.77	1.01N
52-c	175	0.29	453	3.52	100%	0.412	12.32	0.99N
52-d	176	0.10	454	1.36	100%	0.300	13.93	0.97N
53-a	177	0.09	455	1.34	100%	0.300	14.93	0.97N
53-b	178	0.61	456	5.11	100%	0.434	8.38	0.97N
53-c	179	0.05	457	1.83	100%	0.300	33.68	0.97N
53-d	180	0.09	458	1.75	100%	0.300	18.58	0.97N
54-a	181	0.21	459	1.50	100%	0.300	7.08	1.18N
55-a	182	1.41	460	14.34	80%	0.300	10.14	1.01N
55-b	183	3.60	461	13.90	90%	0.300	3.86	0.97N
55-c	184	1.11	462	8.52	95%	0.300	7.64	1.15K
55-d	185	3.10	463	3.94	1%	0.300	1.27	1.11K
56-a	186	0.66	464	9.03	95%	0.300	13.59	1.05N
57-a	187	0.19	465	1.35	95%	0.434	7.29	0.93MB
57-b	188	2.44	466	17.11	100%	0.363	7.01	0.93MB
57-c	189	3.69	467	13.92	95%	0.300	3.77	0.93N
57-d	190	1.28	468	0.91	5%	0.300	0.71	1.21K
57-e	191	1.10	469	8.72	85%	0.300	7.91	1.18K
58-a	192	1.09	470	23.26	100%	0.300	21.40	0.95N
59-a	193	1.27	471	13.78	100%	0.392	10.85	0.9MB
59-b	194	1.50	472	11.61	70%	0.300	7.76	0.94N
59-c	195	1.03	473	2.03	40%	0.300	1.96	1.26K
59-d	196	3.44	474	36.38	75%	0.373	10.58	1.26K
5-a	197	0.35	475	1.82	100%	0.300	5.19	1.1M
60-a	198	0.45	476	1.90	100%	0.300	4.23	0.91N
61-a	199	0.35	477	11.13	100%	0.300	31.51	0.9MB
62-a	200	0.99	478	14.23	100%	0.300	14.37	0.93N

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
62-b	201	0.78	479	15.33	100%	0.320	19.72	1.24K
63-a	202	0.51	480	23.09	100%	0.444	45.12	1.12K
64-a	203	1.46	481	242.76	100%	0.491	165.80	1.27H
64-b	204	0.82	482	4.69	50%	0.363	5.73	1.24H
64-c	205	3.37	483	22.40	25%	0.300	6.64	1.11H
64-d	206	1.57	484	7.96	1%	0.300	5.06	1.06N
64-e	207	0.70	485	0.88	1%	0.300	1.25	1.08N
64-f	208	3.42	486	27.35	5%	0.300	8.00	1.04N
64-g	209	5.61	487	13.05	5%	0.300	2.33	0.99N
64-h	210	14.43	488	23.81	5%	0.300	1.65	1.07K
64-i	211	2.38	489	4.30	10%	0.300	1.80	1.11K
64-j	212	9.53	490	36.57	1%	0.471	3.84	1.07K
65-a	213	0.81	491	29.74	100%	0.444	36.63	1.31H
66-a	214	1.31	492	2.58	100%	0.300	1.97	1.12N
66-b	215	0.67	493	10.23	85%	0.300	15.19	1.15H
67-a	216	1.66	494	206.21	100%	0.300	124.27	1.06W
67-b	217	1.40	495	10.44	5%	0.353	7.46	1.04W
67-c	218	1.02	496	13.53	25%	0.434	13.27	1.1W
68-a	219	0.55	497	24.30	5%	0.501	44.55	1.04N
69-a	220	0.32	498	24.20	100%	0.501	74.55	1.1W
69-b	221	0.31	499	2.64	100%	0.300	8.52	1.03W
6-a	222	1.93	500	41.52	40%	0.330	21.56	1.09W
6-b	223	1.00	501	16.57	100%	0.330	16.53	1.01MB
70-a	224	0.32	502	14.25	25%	0.300	44.22	1.1W
70-b	225	0.93	503	5.91	100%	0.300	6.35	1.16N
71-a	226	1.88	504	8.38	100%	0.300	4.46	1.12N
72-a	227	0.31	505	8.69	95%	0.300	28.11	1.13N
72-b	228	0.82	506	5.04	100%	0.300	6.13	1.11N
73-a	229	0.54	507	21.32	4%	0.300	39.54	1.02N
74-a	230	2.81	508	41.65	100%	0.412	14.82	1N
75-a	231	2.03	509	95.38	100%	0.300	46.95	1.18N
76-a	232	0.54	510	19.64	100%	0.300	36.28	1.12N
77-a	233	0.89	511	6.86	95%	0.300	7.69	1.1N
78-a	234	0.61	512	10.62	95%	0.300	17.46	0.98N
78-b	235	1.29	513	1.50	100%	0.300	1.16	0.94N
79-a	236	1.89	514	23.44	5%	0.300	12.38	1.02N
7-a	237	0.61	515	30.38	100%	0.402	49.59	1.05E
7-b	238	0.19	516	41.52	100%	0.501	219.66	1.02E
7-c	239	0.58	517	1.31	100%	0.300	2.26	1.02E
7-d	240	0.13	518	10.89	100%	0.300	83.93	0.99E
80-a	241	0.77	519	8.64	100%	0.353	11.28	0.92E
81-a	242	0.17	520	30.69	75%	0.491	176.10	1.18N
81-b	243	1.32	521	108.21	100%	0.501	82.08	1.16N
81-c	244	7.75	522	13.45	100%	0.300	1.74	1.09N
81-d	245	1.94	523	38.70	1%	0.300	19.96	0.95N
81-e	246	3.71	524	7.17	50%	0.383	1.93	1N
82-a	247	2.40	525	82.50	10%	0.412	34.38	1.14N
83-a	248	0.38	526	56.90	100%	0.501	148.91	1.15N
84-a	249	0.66	527	16.43	80%	0.300	24.75	1.15N
85-a	250	0.12	528	5.06	100%	0.300	42.85	1N
86-a	251	2.33	529	8.44	100%	0.300	3.62	1.02N
87-a	252	0.42	530	20.64	5%	0.491	49.54	1.03N
87-b	253	0.49	531	6.94	100%	0.300	14.17	1.02N

Sub-cat.	WC cat. node	Cat. area (km²)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km²)	Rainfall station
88-a	254	1.76	532	11.93	100%	0.363	6.78	1.03N
89-a	255	2.07	533	27.25	85%	0.373	13.15	1.32H
89-b	256	7.29	534	65.79	60%	0.300	9.02	1.18H
89-c	257	18.12	535	81.68	100%	0.300	4.51	0.94H
89-d	258	1.37	536	0.98	10%	0.300	0.71	0.82H
89-e	259	5.55	537	0.56	15%	0.300	0.10	0.98H
89-f	260	0.00	538	0.00	5%	0.000	0.00	0.98K
89-g	261	12.70	539	13.83	1%	0.300	1.09	0.99K
89-h	262	23.80	540	0.00	1%	0.300	0.00	1.03C
89-i	263	6.00	541	2.60	1%	0.501	0.43	1.01C
8-a	264	0.16	542	11.61	100%	0.300	74.78	1.05E
8-b	265	0.70	543	80.38	100%	0.491	115.14	1.09E
90-a	266	0.21	544	30.80	100%	0.501	146.81	1.31H
90-b	267	0.98	545	82.36	100%	0.491	84.22	1.32H
91-a	268	0.03	546	3.00	100%	0.501	90.09	1.34H
92-a	269	0.03	547	2.70	100%	0.501	96.09	1.29H
93-a	270	3.11	548	63.24	100%	0.310	20.35	1.09H
94-a	271	4.10	549	85.82	80%	0.353	20.94	1.23H
95-a	272	4.91	550	25.00	15%	0.310	5.09	1.12H
96-a	273	3.24	551	33.53	70%	0.300	10.33	1.18H
97-a	274	0.64	552	20.76	80%	0.300	32.44	1.21H
98-a	275	0.27	553	8.82	100%	0.300	32.33	1.1H
99-a	276	0.35	554	7.55	100%	0.402	21.57	0.96H
9-a	277	0.64	555	7.65	100%	0.402	11.91	1.07E
9-b	278	0.41	556	10.80	100%	0.300	26.13	1.04E
68-b	597	0.79	598	7.19	50%	0.300	9.15	1.04N
MH22	625	6.30						0.95H
TOTAL		**584**		**5065**			**8.7**	

Appendix E: Currency Creek – WaterCress sub-catchment and dam node details

Rainfall station: HV – Hindmarsh Valley (M023823)

Currency Creek sub-catchment and dam node WaterCress details

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
1	10	3.39	11	187.50	100%	0.402	55.28	1.02HV
2	12	1.68	13	44.80	100%	0.471	26.72	1HV
3	25	0.49	26	1.95	85%	0.3	3.96	0.97HV
4	27	0.84	28	0.40	100%	0.3	0.47	0.98HV
5	16	1.21	17	11.00	90%	0.3	9.07	0.98HV
6	18	0.19	19	2.01	100%	0.3	10.37	0.99HV
7	14	1.30	15	1.72	90%	0.3	1.32	0.98HV
8	23	0.64	24	2.86	75%	0.33	4.45	0.97HV
9	20	1.82	21	39.36	100%	0.363	21.61	0.98HV
10	22	0.32						0.96HV
11	29	0.17	30	1.33	85%	0.3	7.67	0.95HV
12	1	1.34						0.96HV
13	31	1.37	32	147.85	50%	0.491	108.23	0.99HV
14	33	1.97	34	156.54	100%	0.491	79.43	0.97HV
15	35	0.55	36	29.58	100%	0.471	53.42	0.94HV
16	41	0.24	42	2.93	70%	0.3	12.36	0.91HV
17	37	0.11	38	2.01	100%	0.3	17.95	0.96HV
18	39	0.31	40	6.06	50%	0.491	19.40	0.96HV
20	43	0.42	45	5.83	90%	0.3	14.00	0.95HV
21	44	1.17	47	6.95	35%	0.3	5.92	0.93HV
22	48	0.13	46	1.91	100%	0.3	14.43	0.92HV
23	2	1.60						0.93HV
24	49	2.14	59	4.51	70%	0.3	2.10	0.95HV
25	50	1.31	56	4.54	50%	0.392	3.47	0.94HV
26	51	1.34	58	2.20	35%	0.3	1.64	0.94HV
27	54	0.24	57	2.44	100%	0.3	10.24	0.95HV
28	53	0.66	55	2.76	90%	0.32	4.19	0.93HV
29	52	0.54						0.92HV
30	60	0.21	61	1.00	85%	0.3	4.84	0.92HV
31	62	0.49	63	0.66	15%	0.3	1.33	0.92HV
32	64	0.35	65	4.10	100%	0.3	11.75	0.87HV
33	3	1.24						0.89HV
35	109	1.29	106	44.95	100%	0.471	34.81	0.88HV
36	110	0.48	107	4.14	100%	0.3	8.65	0.89HV
37	111	0.84	108	6.07	50%	0.3	7.20	0.87HV
38	105	0.68	101	30.68	75%	0.501	45.19	0.87HV
39	112	0.43	102	6.76	80%	0.3	15.87	0.87HV
40	97	0.56	98	2.57	40%	0.3	4.61	0.86HV
41	91	0.46	92	7.70	100%	0.373	16.75	0.91HV
42	93	0.88	94	7.42	85%	0.3	8.45	0.88HV
43	95	0.97	96	34.26	100%	0.454	35.38	0.88HV
45	99	0.23	100	0.90	45%	0.3	3.91	0.88HV
46	113	0.77	103	20.56	100%	0.3	26.61	0.82HV

Sub-cat.	WC cat. node	Cat. area (km²)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km²)	Rainfall station
47	114	0.67	104	7.79	45%	0.392	11.71	0.83HV
48	4	2.17						0.81HV
49	66	0.31	67	7.33	100%	0.3	23.43	0.95HV
50	68	0.85	69	3.97	55%	0.3	4.68	0.97HV
51	70	0.33	71	2.42	60%	0.3	7.34	0.96HV
52	72	0.19	73	2.92	100%	0.3	15.77	0.94HV
53	74	1.11	205	1.04	100%	0.3	0.93	0.95HV
54	75	0.32	76	21.65	100%	0.491	67.01	0.95HV
56	77	0.58	78	8.51	100%	0.3	14.79	0.91HV
57	89	0.26	90	3.66	100%	0.3	13.97	0.94HV
59	84	1.64	81	29.14	100%	0.444	17.72	0.92HV
60	85	0.30	82	19.14	100%	0.3	63.49	0.89HV
61	86	0.32	83	4.84	100%	0.3	15.27	0.91HV
62	79	1.03	80	9.85	100%	0.3	9.59	0.91HV
63	118	2.00	115	33.86	100%	0.3	16.96	0.9HV
64	121	0.64	120	7.92	100%	0.3	12.39	0.89HV
65	119	0.46	116	1.65	40%	0.3	3.55	0.87HV
66	122	0.39	117	2.11	70%	0.3	5.45	0.83HV
67	87	0.90	88	7.21	60%	0.3	8.05	0.83HV
68	9	1.39						0.84HV
69	161	0.64	162	7.29	50%	0.3	11.31	0.85HV
70	163	1.10	164	13.10	100%	0.3	11.93	0.77HV
71	170	0.12	169	2.13	100%	0.3	18.22	0.84HV
72	168	0.95	167	11.44	100%	0.392	12.06	0.81HV
73	166	0.68	165	5.13	100%	0.3	7.59	0.73HV
74	174	0.47	173	5.70	85%	0.3	12.02	0.82HV
75	172	1.34	171	13.89	75%	0.33	10.35	0.74HV
76	176	0.71	175	8.18	100%	0.353	11.56	0.72HV
77	160	0.75	159	3.53	80%	0.33	4.69	0.73HV
78	158	1.11						0.68HV
79	157	0.95	156	17.71	100%	0.444	18.56	0.68HV
80	155	1.90	154	14.17	100%	0.3	7.47	0.66HV
81	139	0.89	138	8.78	60%	0.33	9.87	0.87HV
82	137	1.44	136	19.79	100%	0.3	13.77	0.72HV
83	124	0.57	123	3.52	75%	0.3	6.21	0.82HV
84	135	0.33	134	6.47	100%	0.3	19.34	0.68HV
85	133	0.53	131	0.66	80%	0.3	1.24	0.66HV
86	5	2.83						0.74HV
87	140	0.43	132	7.78	100%	0.3	17.93	0.66HV
88	128	0.74	125	6.69	100%	0.3	9.05	0.74HV
89	129	0.45	126	4.95	100%	0.3	11.01	0.69HV
90	130	0.20	127	7.18	100%	0.3	36.27	0.68HV
91	6	0.91						0.65HV
92	150	0.68	149	3.30	85%	0.3	4.88	0.75HV
93	146	1.57	143	5.50	100%	0.461	3.51	0.67HV
94	147	1.83	144	3.92	50%	0.3	2.14	0.65HV
95	148	0.14	145	0.22	100%	0.3	1.53	0.61HV
96	142	0.53	141	0.97	60%	0.3	1.82	0.67HV
97	7	4.47						0.64HV
98	153	1.43						0.62HV
99	152	0.80	151	3.62	65%	0.3	4.51	0.59HV
100	8	1.15						0.58HV
19a	188	0.26	186	11.41	60%	0.501	44.49	0.96HV

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
19b	187	0.28	185	17.75	60%	0.3	62.65	0.96HV
34a	201	0.24	202	1.32	100%	0.501	5.61	0.95HV
34b	203	0.58	204	2.11	100%	0.3	3.65	0.91HV
44a	197	0.10	198	0.38	50%	0.501	3.89	0.82HV
44b	199	0.14	200	3.64	100%	0.3	25.19	0.82HV
44c	206	0.19	207	2.87	100%	0.3	15.24	0.83HV
55a	189	0.22	190	3.13	100%	0.491	14.49	0.93HV
55b	191	0.50	192	14.70	100%	0.461	29.56	0.93HV
58a	193	0.90	194	23.12	100%	0.471	25.81	0.92HV
58b	195	0.37	196	1.38	100%	0.3	3.74	0.9HV
TOTAL		**90**		**1283**			**14.3**	

Appendix F: Finniss River – WaterCress sub-catchment and dam node details

Rainfall stations: A – Ashbourne (M023701), F – Finniss (M023714), Me – Meadows (M023730), MC – Mount Compass (M023735), KF – Kuitpo Forest (M023818)

Finniss River sub-catchment and dam node WaterCress details

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
F5	1	0.66	2	31.89	100%	0.300	48.64	1.04MC
F7	3	0.51	4	8.37	90%	0.300	16.49	1.04MC
F8	5	1.47	6	5.34	100%	0.300	3.64	1.03MC
F10	7	0.57	8	0.52	20%	0.340	0.92	1.04MC
F11	9	1.53	165	17.14	80%	0.424	11.22	1.02MC
F12	10	0.32	11	25.03	70%	0.491	78.13	1.03MC
F13	12	0.44	13	4.55	100%	0.300	10.28	1.01MC
F14	14	0.43	15	0.14	100%	0.300	0.33	1.01MC
F15	16	0.32	17	3.77	100%	0.300	11.64	0.98MC
F16	18	0.31	19	0.46	100%	0.300	1.50	1MC
F17	20	0.57	21	0.94	20%	0.300	1.66	1.03MC
F18	22	0.49	23	8.71	90%	0.471	17.90	1.01MC
F19	24	0.44	25	11.68	100%	0.300	26.46	0.98MC
F20	26	1.16	27	27.10	100%	0.000	23.37	0.99MC
B1	28	0.92	29	30.34	90%	0.300	32.98	1.03KF
B2	30	0.41	31	17.08	90%	0.300	41.20	1.03KF
B3	32	1.05	33	23.13	100%	0.300	21.93	1.03KF
B4	34	1.19	35	3.98	90%	0.300	3.35	1.04KF
B5	36	0.69	37	0.81	30%	0.300	1.18	1.03KF
B6	38	0.94	39	58.60	60%	0.501	62.11	1.01KF
B7	40	0.39	41	0.53	50%	0.300	1.34	1.01KF
B8	42	0.21	43	0.40	20%	0.300	1.86	1.03KF
B9	44	0.41	45	6.97	100%	0.481	17.17	1.02KF
B10	46	0.82	47	1.26	90%	0.300	1.54	1.04KF
B11	48	2.72	49	51.81	100%	0.300	19.08	1.01KF
B12	50	1.28	51	19.64	60%	0.300	15.36	1.02KF
B13	52	0.50	53	17.57	100%	0.412	35.47	0.99KF
B14	54	8.00						1.02KF
ME1	56	0.40	57	73.88	100%	0.501	186.14	1.03KF
ME3	58	0.65	59	65.35	100%	0.300	101.17	1.04KF
ME4	60	0.56	61	110.88	100%	0.471	199.66	1.02KF
ME5	62	0.51	63	19.98	100%	0.300	39.19	1KF
ME6	64	0.88	65	5.03	80%	0.300	5.74	1KF
ME7	66	2.02	67	111.05	100%	0.481	55.10	1.03KF
ME8	68	0.77	69	16.10	100%	0.300	21.00	1.02KF
F20a	70	5.00	368	0.00	100%	0.310	0.00	0.99MC
B14a	71	0.20	55	16.69	100%	0.300	82.70	1.02KF
W1	72	1.89	73	68.09	100%	0.402	36.01	1.05KF
W2	74	0.96	75	32.24	100%	0.454	33.75	1.05KF
W4	76	0.30	77	29.25	100%	0.501	97.62	1.04KF
W6	78	0.52	79	68.65	100%	0.300	131.07	1.04KF
W7	80	0.84	81	10.59	100%	0.412	12.59	1.04KF
W8	82	0.23	83	12.70	100%	0.501	55.11	1.02KF

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
W9	84	0.92	85	24.24	100%	0.310	26.46	1.03KF
W10	86	1.02	87	38.59	100%	0.402	37.84	1.03KF
W11	88	1.04	89	11.39	100%	0.300	10.92	1.02KF
W12	90	0.47						1.03KF
W12a	92	5.00	91	60.49	100%	0.320	12.10	1.03KF
W13	93	1.75	94	30.09	100%	0.300	17.19	1.02KF
W14	95	0.69	96	56.45	100%	0.491	81.87	1.04KF
W18	97	2.37	98	16.71	50%	0.300	7.06	1.03KF
W20	99	1.37	100	50.70	90%	0.471	36.90	1.01KF
W24	101	0.66	102	4.85	90%	0.300	7.37	1KF
W27	103	2.44						1.02KF
K3	104	1.11	105	3.01	50%	0.300	2.71	1KF
K4	106	1.14						1.01KF
K2	107	1.24	108	25.07	90%	0.471	20.20	1KF
K6	109	1.65						1KF
K6a	111	13.00	110	0.00	100%	0.330	0.00	1KF
K5	112	2.44	113	23.85	100%	0.491	9.78	1.01KF
N1	114	0.41	115	2.96	100%	0.402	7.25	0.96Me
N2	116	0.25	117	7.45	100%	0.373	29.93	1.04Me
N3	118	0.32	119	7.44	80%	0.300	22.89	1.07Me
N4	120	1.60	121	73.76	100%	0.454	46.01	0.97Me
N5	122	0.65	123	22.64	100%	0.481	35.02	1.04Me
N7	124	0.58	125	0.00	60%	0.343	0.00	0.97Me
N8	126	0.32	127	4.70	100%	0.340	14.74	0.97Me
N9	128	0.49	129	23.34	100%	0.444	47.64	0.98Me
N10	130	1.37	131	11.10	90%	0.363	8.12	0.97Me
N11	132	0.38	133	18.37	100%	0.300	48.49	0.97Me
N12	134	0.25	135	8.55	100%	0.392	33.73	0.97Me
N13	136	1.89	137	92.68	100%	0.300	49.13	0.97Me
N15	138	1.04	139	44.31	80%	0.412	42.49	0.97Me
N16	140	1.00	141	9.25	40%	0.382	9.28	0.97Me
N17	142	0.41	143	16.01	70%	0.300	39.00	0.98Me
N18	144	0.59	145	5.96	100%	0.300	10.08	0.97Me
N19	146	2.11	147	30.92	80%	0.300	14.63	1.01Me
N20	148	0.21	149	0.00	100%	0.422	0.00	1Me
N20a	150	0.52	151	5.06	90%	0.300	9.72	0.98Me
N21	152	0.72	153	3.54	70%	0.300	4.95	0.98Me
N27	154	0.31	155	18.01	100%	0.373	58.10	0.97Me
N27a	156	0.70						0.97Me
N28	157	0.37	158	5.21	100%	0.340	14.15	0.97Me
N31	159	1.81	160	9.21	50%	0.300	5.08	0.98Me
N36	161	0.68	162	12.85	75%	0.300	18.81	1Me
N37	163	0.89	164	16.82	100%	0.353	18.80	0.98Me
F2a	167	0.14	168	1.94	100%	0.300	13.49	1.04MC
F2b	169	0.19	170	35.50	100%	0.501	183.01	1.05MC
F2c	171	0.33	172	12.88	100%	0.300	38.73	1.04MC
F2d	173	0.23						1.04MC
F3	174	0.69	370	9.82	100%	0.300	14.15	1.06MC
F6d	175	0.80						1.03MC
F1	176	1.72	187	1.93	20%	0.300	1.12	1.04MC
F6a	177	0.07	178	33.00	100%	0.300	442.73	1.05MC
F6b	179	0.11	180	6.05	100%	0.444	54.62	1.04MC
F6c	181	0.14	182	5.63	100%	0.454	40.89	1.04MC
F9a	183	0.21	184	6.32	100%	0.434	30.09	1.04MC

Sub-cat.	WC cat. node	Cat. area (km²)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km²)	Rainfall station
F9b	185	4.48	186	78.12	80%	0.330	17.44	1.04MC
B4a	188	0.30	189	5.55	100%	0.464	18.49	1KF
B9a	190	0.76	191	21.22	100%	0.300	27.95	1.03KF
B14b	192	0.47						1.02KF
N6	193	0.59	194	23.18	100%	0.464	39.55	0.98Me
N14a	195	0.07	196	2.27	100%	0.300	30.38	1.02Me
N14b	197	0.16	198	4.10	100%	0.501	25.14	1Me
N14c	199	0.07	200	1.54	90%	0.300	21.67	1.02Me
N14d	201	0.07	202	2.31	100%	0.300	32.81	1Me
N14e	203	0.10	204	6.50	100%	0.501	65.72	1.02Me
N14f	205	0.52	206	32.18	100%	0.300	62.24	1Me
N14g	207	1.12	208	25.85	100%	0.444	22.98	0.98Me
N22a	209	0.82	210	13.95	90%	0.300	17.11	0.97Me
N22b	211	0.30	212	4.95	100%	0.454	16.59	0.96Me
N22c	213	0.18	214	1.58	100%	0.300	8.90	0.96Me
N23a	215	1.71	216	36.62	100%	0.320	21.39	1Me
N23b	217	0.25	218	49.95	100%	0.471	198.15	0.96Me
N24a	219	0.03	220	0.90	100%	0.501	26.23	1.01Me
N24b	221	0.86	222	18.72	90%	0.412	21.69	1Me
N25a	223	0.35	224	14.84	100%	0.300	41.97	1Me
N25b	225	0.56	226	50.60	100%	0.491	90.14	1Me
N25c	227	0.45	228	13.27	100%	0.300	29.32	0.99Me
N26a	229	0.45	230	41.52	100%	0.464	93.03	0.99Me
N26b	231	0.37	232	2.11	30%	0.300	5.71	0.98Me
N29b	234	0.80	233	140.20	100%	0.434	175.16	1Me
N29e	236	0.51	235	8.19	100%	0.491	15.97	1Me
N29f	238	0.10	237	0.13	100%	0.300	1.31	0.99Me
N29h	239	0.43						0.99Me
N29g	241	0.02	240	0.24	100%	0.300	10.61	0.99Me
N29a	243	0.80	242	61.77	100%	0.481	77.17	1Me
N29c	244	0.29	245	8.12	100%	0.300	28.22	1Me
N29d	247	0.09	246	1.20	100%	0.501	12.87	1.01Me
N30e	249	1.16	248	27.10	70%	0.300	23.34	0.99Me
N30d	251	0.36	250	1.99	100%	0.300	5.49	0.99Me
N30c	253	0.05	252	40.60	100%	0.501	774.81	0.99Me
N30b	255	0.72	254	8.81	50%	0.300	12.25	1.01Me
N30a	257	0.02	256	1.04	100%	0.501	42.00	1Me
N32a	258	0.22	259	8.45	100%	0.300	38.83	0.98Me
N32b	260	1.00	261	189.96	100%	0.491	190.00	0.99Me
N33a	262	0.18	263	6.40	100%	0.501	36.26	0.97Me
N33b	264	0.50	265	12.89	90%	0.300	25.53	0.98Me
N33c	266	1.59	267	120.09	100%	0.501	75.71	0.99Me
N34a	268	0.51	269	13.14	100%	0.461	25.77	0.99Me
N34b	270	1.23	271	32.09	90%	0.300	26.05	0.98Me
N35a	272	0.59	273	7.48	30%	0.471	12.78	0.97Me
N35b	274	0.99	275	11.77	50%	0.300	11.85	0.97Me
N35c	276	0.55	277	3.20	100%	0.402	5.85	0.96Me
N35e	278	0.48	279	5.64	100%	0.300	11.65	0.96Me
N35d	280	0.93	281	8.69	70%	0.300	9.39	0.97Me
N35f	282	0.60	283	1.67	20%	0.300	2.79	0.97Me
N38b	284	0.46	286	0.00	100%	0.300	0.00	0.97Me
N38d	285	2.05						0.96Me
N38a	287	0.24	288	13.60	80%	0.481	57.72	0.98Me
N38c	289	7.05	290	149.80	100%	0.310	21.25	0.96Me

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
W5a	291	0.91	292	27.08	100%	0.300	29.76	1.04KF
W5b	293	0.14	294	3.60	100%	0.501	26.07	1.03KF
W5c	295	0.08						1.01KF
W3	296	0.40	297	71.60	100%	0.491	177.01	1.04KF
W15a	298	0.49	299	13.21	100%	0.363	26.84	1.04KF
W15b	300	1.55	301	13.01	80%	0.310	8.41	1.04KF
W16a	302	0.43	303	6.76	100%	0.300	15.77	1.04KF
W16b	304	0.55	305	8.60	70%	0.501	15.63	1.04KF
W17b	307	0.27	306	8.68	90%	0.471	32.31	1.04KF
W17a	309	0.49	308	58.60	100%	0.501	119.94	1.04KF
W19b	311	0.34	310	31.13	100%	0.491	92.74	1.06KF
W19a	313	0.92	312	12.76	70%	0.300	13.89	1.04KF
W23	314	0.37						0.99KF
W21d	316	0.28	315	39.70	100%	0.300	141.04	1.06KF
W22c	318	0.09	317	10.10	100%	0.491	107.54	1.02KF
W21b	320	0.54	319	40.50	100%	0.501	75.34	1.04KF
W21c	322	0.81	321	17.40	100%	0.300	21.43	0.99KF
W21a	324	0.32	323	5.75	100%	0.300	17.84	1.05KF
W22b	326	0.87	325	36.59	100%	0.481	42.18	1.04KF
W22a	328	0.45	327	15.20	100%	0.501	33.70	0.99KF
W25f	330	1.80	329	13.82	100%	0.300	7.68	1.03KF
W25e	332	0.75	331	15.53	100%	0.424	20.73	1.04KF
W25d	334	0.92	333	13.35	100%	0.471	14.56	1.01KF
W25b	336	0.30	335	12.16	100%	0.392	40.51	1.07KF
W25a	338	0.18	337	8.50	100%	0.501	47.14	1.06KF
W25c	340	0.03	339	2.60	100%	0.501	90.18	1.03KF
W26b	342	1.38	341	31.04	70%	0.471	22.41	1.05KF
W26a	344	1.76	343	55.38	80%	0.422	31.53	1.01KF
W27b	346	10.00	345	0.00	100%	0.300	0.00	1.02KF
W27a	348	1.04	347	21.26	80%	0.330	20.51	1.02KF
ME2b	350	3.11	349	11.01	90%	0.300	3.54	1.03KF
ME2a	352	0.20	351	4.63	100%	0.300	22.92	1.04KF
ME9d	353	0.81						0KF
ME9a	355	0.18	354	1.01	100%	0.300	5.64	1.06KF
ME9b	357	5.00	356	79.24	100%	0.402	15.85	0.99KF
ME9c	359	0.19	358	3.02	100%	0.300	16.00	1.01KF
K1a	360	0.22	361	14.00	100%	0.501	64.59	1.01KF
K1b	362	2.52	363	35.56	50%	0.300	14.10	1.01KF
B14c	364	1.38	365	0.00	100%	0.300	0.00	1.02KF
F6e	366	4.00	367	0.00	100%	0.300	0.00	1.03MC
F4	369	0.39						1.04MC
LF10	371	1.81						1.21A
LF10a	372	6.00	373	0.00	100%	0.310	0.00	1.21A
LF1	374	0.81	375	21.55	100%	0.383	26.52	1.27A
LF2	376	0.40	377	2.56	70%	0.300	6.34	1.44A
LF3	378	0.56	379	4.79	30%	0.300	8.60	1.4A
LF4	380	1.46	381	9.22	20%	0.300	6.30	1.35A
LF5	382	1.40	383	6.65	30%	0.300	4.76	1.33A
LF6	384	0.59	385	31.92	60%	0.300	54.45	1.23A
LF7	386	1.35	387	5.96	50%	0.300	4.42	1.32A
LF8	388	0.86	389	3.97	50%	0.300	4.63	1.25A
LF9	390	2.09	391	163.61	50%	0.491	78.40	1.32A
LF15	392	1.00						1.08A
LF15a	393	1.49	394	0.00	100%	0.300	0.00	1.08A

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
LF14	395	3.31	396	25.09	50%	0.330	7.58	1.05A
LF11	397	1.60	398	11.67	50%	0.300	7.31	1.17A
LF12	399	3.77	400	43.59	70%	0.343	11.55	1.31A
LF13	401	4.05	402	48.80	80%	0.300	12.05	1.24A
LF19	403	5.19						0.99A
LF16	404	5.59	405	13.30	90%	0.300	2.38	1.03A
LF17	406	1.54	407	7.80	50%	0.300	5.06	1A
LF18	408	0.52	409	2.87	10%	0.300	5.49	1.01A
BC46	410	1.03						1.09A
BC40	411	0.26	412	10.88	100%	0.454	41.66	1.09A
BC41	413	0.41	414	0.00	0%	0.300	0.00	1.07A
BC42	415	1.98	416	7.68	20%	0.300	3.87	1.03A
BC43	417	1.23	418	3.65	20%	0.300	2.96	1.19A
BC44	419	0.86	420	2.62	30%	0.300	3.06	1.25A
BC45	421	0.71	422	10.00	70%	0.300	14.10	1.16A
BC46a	423	3.00	424	0.00	100%	0.300	0.00	1.09A
BC31	425	3.09	426	11.81	40%	0.300	3.83	1.24A
BC32	427	0.72	428	1.27	90%	0.300	1.77	1.14A
BC30	429	0.74						1.19A
BC30a	430	2.00	431	0.00	100%	0.320	0.00	1.19A
BC36	432	1.75	433	6.25	20%	0.300	3.57	1.25A
BC37	435	1.05	436	8.60	100%	0.300	8.18	1.16A
BC38	437	0.93	438	50.56	100%	0.300	54.48	1.08A
BC39	439	0.12	440	1.92	100%	0.300	16.23	1.09A
BC33	441	2.18	442	14.70	30%	0.300	6.75	1.33A
BC34	443	2.08	444	14.22	100%	0.300	6.83	1.39A
BC35	445	4.10	446	28.59	50%	0.300	6.97	1.37A
BC29	447	1.12	448	7.31	90%	0.300	6.54	1.28A
BC27	449	1.25	450	10.25	100%	0.300	8.22	1.26A
BC28c	451	1.96	452	4.01	10%	0.300	2.04	1.33A
BC28b	453	0.64	454	15.80	100%	0.340	24.69	1.41A
BC28a	455	0.08	456	2.88	100%	0.300	34.46	1.36A
BC26	457	1.08						1.27A
BC22	458	0.98	459	5.91	90%	0.330	6.06	1.3A
BC21	461	0.17	460	1.71	100%	0.300	10.25	1.3A
BC20	463	0.50	462	2.04	20%	0.300	4.09	1.32A
BC19	465	0.26	464	2.60	100%	0.300	9.86	1.28A
BC25	467	1.21	466	15.00	100%	0.300	12.42	1.33A
BC24	469	0.48	468	4.17	100%	0.330	8.64	1.29A
BC23	471	0.88	470	2.26	90%	0.300	2.56	1.34A
BC18	472	0.66						1.28A
BC11	475	0.75	474	9.20	100%	0.300	12.20	1.26A
BC10	477	0.39	476	8.02	100%	0.300	20.79	1.29A
BC17	479	1.20	478	1.78	10%	0.300	1.49	1.36A
BC16	481	0.32	480	0.00	0%	0.300	0.00	1.32A
BC14	483	0.96	482	1.72	50%	0.461	1.80	1.35A
BC15	485	0.09	484	0.40	30%	0.501	4.37	1.37A
BC9	487	1.29	486	3.18	90%	0.300	2.46	1.34A
BC8	489	0.29	488	5.75	100%	0.300	19.68	1.31A
BC7	491	0.26	490	2.13	50%	0.300	8.32	1.34A
BC3	493	0.29	492	5.10	100%	0.373	17.53	1.35A
BC2	495	0.24	494	1.34	100%	0.300	5.58	1.4A
BC4	497	0.10	496	1.68	100%	0.300	16.83	1.42A
BC5	499	0.11	498	3.75	100%	0.300	33.57	1.36A

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
BC6	501	0.18	500	2.73	100%	0.300	15.08	1.36A
BC1	502	0.15	503	5.14	100%	0.300	34.12	1.42A
BC13	505	0.39	504	3.00	90%	0.300	7.78	1.36A
BC12	507	0.43	506	13.30	100%	0.422	31.11	1.37A
LF25	508	0.88						1.03A
LF20	510	0.60	509	13.63	100%	0.481	22.71	0.92A
LF21	512	1.14	511	4.49	50%	0.454	3.92	1.11A
LF22	513	1.28	514	4.03	70%	0.300	3.15	1.14A
LF23	516	0.48	515	3.73	90%	0.300	7.77	1.2A
LF24	518	1.70	517	6.18	80%	0.300	3.65	1.02A
LF25a	520	3.00	519	0.00	20%	0.300	0.00	1.03A
LF29	521	1.09						0.89A
LF26	523	1.60	522	5.80	100%	0.300	3.62	0.97A
LF27	525	1.68	524	3.83	90%	0.300	2.28	0.92A
LF28	527	5.76	526	32.52	50%	0.300	5.65	0.95A
LF29a	529	5.00	528	0.00	10%	0.300	0.00	0.89A
WF31	530	1.32						0.91A
WF30	532	4.57	531	14.80	50%	0.412	3.24	0.92A
WF29	534	0.68	533	0.89	90%	0.300	1.30	0.97A
WF28	536	1.40	535	3.62	90%	0.300	2.59	0.97A
WF27	538	0.57	537	9.64	100%	0.300	16.92	1.05A
WF26	540	1.50	539	0.00	0%	0.300	0.00	0.94A
WF25	542	1.46	541	12.80	100%	0.300	8.78	0.99A
WF22	544	0.59	543	1.02	50%	0.300	1.72	0.97A
WF21	546	0.11	545	1.98	100%	0.300	18.80	0.96A
WF20	548	0.06	547	0.23	60%	0.300	4.16	1.06A
WF19	550	0.20	549	2.31	90%	0.300	11.48	1.06A
WF18	552	0.38	551	3.76	70%	0.300	9.96	1.05A
WF31a	554	6.00	553	0.00	100%	0.300	0.00	0.91A
WF17	556	1.53	557	7.38	100%	0.300	4.83	1.07A
WF5	559	0.25	558	1.03	100%	0.300	4.11	1.07A
WF4	561	0.40	560	1.83	90%	0.300	4.54	1.07A
WF3	563	0.62	562	8.71	70%	0.300	13.95	1.12A
WF16	564	0.52						1.06A
WF9	565	0.31						1.07A
WF2	567	0.30	566	20.08	100%	0.300	67.33	1.13A
WF15	569	0.40	568	4.05	100%	0.300	10.18	1.06A
WF14	571	0.22	570	1.77	90%	0.300	8.08	1.07A
WF13	572	0.29						1.08A
WF11	574	0.40	573	14.98	90%	0.481	37.86	1.07A
WF12	576	0.39	575	4.22	90%	0.300	10.92	1.08A
WF10	578	0.44	577	16.27	100%	0.300	36.63	1.09A
WF8	580	0.39	579	4.26	90%	0.300	10.97	1.08A
WF7	582	0.68	581	0.62	10%	0.300	0.91	1.12A
WF6	584	0.34	583	5.89	90%	0.300	17.41	1.14A
WF1	586	1.54	585	20.79	100%	0.300	13.51	1.2A
WF9a	588	0.50	587	0.00	100%	0.300	0.00	1.07A
LF31	589	1.16						1.01F
LF30	591	5.21	590	17.90	90%	0.300	3.43	1.08F
LF31a	593	30.00	592	0.00	100%	0.300	0.00	1.01F
WF24	600	0.68	599	11.98	100%	0.300	17.52	1.02A
WF23	602	0.56	601	15.60	100%	0.481	28.01	1.05A
			F1FAB*	200.50	100%	0.500		0.97Me
			F5FAB*	264.50	100%	0.500		1KF

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
			F6FAB*	348.40	100%	0.500		1.03MC
			F7FAB*	235.20	100%	0.500		1MC
			F8FAB*	8.00	100%	0.500		0.98MC
			F9FAB*	164.80	100%	0.500		0.99MC
			F10FAB*	216.4	100%	0.500		1.02KF
			F11FAB*	107.50	100%	0.500		1.01KF
			F13FAB*	576.10	100%	0.500		1.03A
			F14FAB*	277.20	100%	0.500		1.27A
			F15FAB*	31.00	100%	0.500		1.30A
			F16FAB*	53.20	100%	0.500		1.18A
			F17FAB*	140.8	100%	0.500		1.28A
			F18FAB*	320.3	100%	0.500		1.25A
			F19FAB*	65.80	100%	0.500		1.23A
			F21FAB*	137.3	100%	0.500		1.09A
			F22FAB*	311.6	100%	0.500		1.03A
			F23FAB*	29.20	100%	0.500		1.06A
			F24FAB*	31.30	100%	0.500		1.06A
			F25FAB*	145.7	100%	0.500		0.91A
			F27FAB*	195.5	100%	0.500		1F
TOTAL		**376**		**7775 (8869 ML fully allocated)**			**13.3**	

*Dams added to the Finniss River catchment fully allocated model representing the volume of unassigned water added to this catchment

Appendix G: Tookayerta Creek – WaterCress sub-catchment and dam node details

Rainfall station: MC – Mount Compass (M023735)

Tookayerta Creek sub-catchment and dam node WaterCress details

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
C1	1	0.48	2	26.04	100%	0.3	54.36	1.09MC
C2	3	2.25	4	55.84	100%	0.3	24.78	1.06MC
C3	5	0.90	6	25.33	100%	0.3	28.25	1.06MC
C4	7	0.41	8	52.42	50%	0.3	129.39	0.99MC
C6	9	0.56	10	6.65	100%	0.3	11.92	1.03MC
C7	11	6.03	12	136.78	100%	0.471	22.70	1.01MC
C9	13	0.79	14	6.50	20%	0.3	8.20	0.96MC
C10	15	2.05	16	2.83	60%	0.3	1.38	0.98MC
C11	17	1.83	18	5.30	80%	0.383	2.89	0.97MC
C12	19	1.11	20	5.68	20%	0.3	5.09	0.96MC
C14	21	0.51	22	0.38	90%	0.3	0.75	0.95MC
C15	23	0.64	24	0.73	10%	0.3	1.13	0.94MC
C16	25	0.15						0.91MC
C17	26	2.51	27	129.20	90%	0.434	51.42	0.91MC
C18	28	0.85	29	8.06	90%	0.373	9.47	0.88MC
C19	30	0.74	31	1.90	5%	0.32	2.55	0.86MC
C20	32	0.31	33	0.56	5%	0.422	1.79	0.83MC
C21a	34	0.29	35	4.32	100%	0.353	14.81	0.88MC
C21b	36	2.63						0.9MC
N1	37	0.76	38	19.27	100%	0.491	25.47	1.07MC
N2	39	3.00	40	36.54	90%	0.444	12.17	1.05MC
N3	41	2.50	42	43.01	90%	0.373	17.22	1.02MC
N5	43	2.26	44	152.78	100%	0.3	67.62	1.05MC
N6	45	1.20	46	4.23	80%	0.454	3.53	1.04MC
N7	47	0.50	48	12.15	90%	0.3	24.47	1.05MC
N9	49	0.31	50	0.39	100%	0.3	1.23	1.03MC
N10	51	0.37	52	3.36	40%	0.3	9.16	1.03MC
N11	53	1.72	54	15.46	90%	0.363	8.99	1.02MC
N12a	55	1.26	56	8.20	100%	0.3	6.53	1.01MC
N12b	57	0.31						1.01MC
N13	58	1.05	59	25.58	90%	0.481	24.44	1.04MC
N14	60	3.18	61	29.79	90%	0.392	9.37	1.02MC
N15a	62	2.37	63	6.29	50%	0.3	2.65	0.94MC
N15b	64	1.58	65	0.00	100%	0.3	0.00	0.94MC
N16	66	0.22	67	4.36	100%	0.3	19.37	0.99MC
N17	68	0.17						0.99MC
N18	69	0.19	70	13.31	70%	0.3	71.03	0.98MC
N19	71	0.20						0.95MC
N20	72	0.70	73	3.10	50%	0.3	4.42	0.95MC
N21	74	1.05	75	7.70	100%	0.3	7.36	0.95MC
N22	76	2.50	77	4.22	50%	0.32	1.69	0.95MC
N24a	78	0.20	79	3.51	100%	0.3	17.32	0.9MC
N24b	80	0.81						0.9MC

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
N25	81	1.17						0.9MC
N26	82	0.54	83	10.43	100%	0.3	19.45	0.93MC
N27	84	0.88	85	2.54	50%	0.3	2.89	0.87MC
N28	86	0.41	87	1.97	80%	0.3	4.86	0.91MC
N29	88	0.85	89	0.79	90%	0.3	0.93	0.94MC
N30	90	1.37	91	3.83	60%	0.3	2.81	0.84MC
N31a	92	0.03	93	1.58	100%	0.501	50.76	0.77MC
N31b	94	5.72						0.82MC
L1	95	7.24	96	25.87	80%	0.3	3.57	0.81MC
L2	97	2.89	98	11.02	100%	0.3	3.82	0.81MC
L3	99	1.50	100	4.27	50%	0.32	2.85	0.77MC
L4	101	0.86	102	5.47	75%	0.3	6.32	0.73MC
L5	103	1.21	104	2.45	100%	0.3	2.02	0.78MC
L6	105	1.88	106	25.31	90%	0.383	13.47	0.8MC
L7	107	0.62	108	0.71	10%	0.3	1.15	0.76MC
L8	109	0.83	110	5.48	90%	0.3	6.64	0.74MC
L9	111	0.61	112	1.99	80%	0.3	3.27	0.87MC
L10	113	0.35	114	8.74	100%	0.424	25.01	0.74MC
L11	115	2.89	116	7.90	70%	0.3	2.73	0.82MC
L12a	117	1.24	118	4.23	100%	0.34	3.41	0.72MC
L12b	119	4.96	121	0.39	100%	0	0.08	0.72MC
C5a	122	2.48	123	6.16	50%	0.31	2.48	1.02MC
C5b	124	0.68	125	12.92	50%	0.3	19.06	1MC
C8a	126	0.62	127	2.78	50%	0.471	4.49	0.96MC
C8b	128	1.72	129	1.39	50%	0.3	0.81	0.96MC
N23a	130	0.79	131	54.89	100%	0.501	69.79	0.98MC
N23b	132	0.56	133	2.81	10%	0.3	5.06	0.99MC
N8a	134	0.12	135	1.27	100%	0.422	10.69	1.03MC
N8b	136	0.16	137	1.43	50%	0.3	9.07	1.02MC
N4a	138	0.06	139	0.97	50%	0.501	15.23	0.98MC
N4b	140	1.00	141	1.44	50%	0.3	1.44	0.99MC
C13a	142	0.82	143	26.41	50%	0.481	32.35	0.95MC
C13b	144	0.48	145	3.70	50%	0.3	7.68	0.93MC
TOTAL		**101**		**1103**			**10.9**	

Appendix H: Marne River – WaterCress sub-catchment and dam node details

Rainfall station: Ke – Keyneton (M023725)

Marne River sub-catchment and dam node WaterCress details

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
M101	1	0.4	2	1.01	35%	0.501	2.52	1.51Ke
M102	3	0.8	4	193.60	50%	0.501	242.00	1.49Ke
M172	5	1.4	6	6.33	15%	0.501	4.52	1.46Ke
M171	7	1.4	8	12.11	45%	0.501	8.65	1.41Ke
M170	9	0.3	10	13.05	90%	0.501	43.50	1.41Ke
M169	11	1.4	12	94.18	90%	0.501	67.27	1.44Ke
M168	13	0.9	14	115.00	100%	0.501	127.78	1.47Ke
M173	15	1.3	16	6.51	90%	0.501	5.01	1.46Ke
M167	17	1.3	18	61.71	100%	0.501	47.47	1.46Ke
M166	19	0.5	20	53.88	80%	0.501	107.77	1.47Ke
M165	21	0.4	22	16.95	95%	0.501	42.37	1.38Ke
M164	23	2.4	24	7.35	100%	0.501	3.06	1.34Ke
M174	25	0.6	26	9.89	90%	0.501	16.48	1.34Ke
M162	27	0.2	28	26.74	95%	0.501	133.70	1.36Ke
M163	29	5.1	30	23.00	25%	0.501	4.51	1.41Ke
M161	32	0.8	31	44.27	100%	0.501	55.33	1.32Ke
M160	34	0.8	33	111.83	100%	0.501	139.78	1.33Ke
M159	36	0.9	35	9.03	90%	0.501	10.03	1.33Ke
M104	37	0.3	38	20.16	50%	0.501	67.21	1.43Ke
M103	39	0.3	40	4.17	80%	0.501	13.91	1.45Ke
M106	41	0.1	42	12.97	80%	0.501	129.65	1.35Ke
M107	43	0.1	44	27.25	100%	0.501	272.52	1.34Ke
M108	45	0.1	46	1.80	75%	0.501	18.00	1.35Ke
M109	47	0.2	48	4.50	60%	0.501	22.50	1.34Ke
M105	49	1.7	50	116.00	100%	0.501	68.24	1.37Ke
M175	51	1.7						1.37Ke
M177	52	0.8						1.37Ke
M176	53	2.5	54	28.29	80%	0.501	11.31	1.37Ke
M157	55	0.3	56	44.92	100%	0.501	149.73	1.29Ke
M158	57	5.2	58	86.00	90%	0.501	16.54	1.26Ke
M137	59	3.2	60	31.17	50%	0.501	9.74	1.22Ke
M138	61	0.3	62	10.25	100%	0.501	34.15	1.19Ke
M136	63	8.8	251	4.10	100%	0.501	0.47	1.08Ke
M156	64	0.5	65	9.38	100%	0.501	18.77	1.21Ke
M139	66	2.8	67	11.97	15%	0.501	4.28	1.15Ke
M135	68	0.6	69	2.20	100%	0.501	3.67	1.27Ke
M134	70	0.6	71	134.49	100%	0.501	224.15	1.3Ke
M115	72	1.5	73	47.26	90%	0.501	31.51	1.3Ke
M116	74	0	75	2.58	100%	0.501		1.27Ke
M114	77	0.1	76	7.10	100%	0.501	71.00	1.33Ke
M113	79	0.2	78	28.00	70%	0.501	139.98	1.31Ke
M112	81	0.2	80	1.67	50%	0.501	8.34	1.33Ke
M111	83	0.9	82	10.00	100%	0.501	11.11	1.3Ke

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
M110	85	0.2	84	28.00	75%	0.501	140.00	1.3Ke
M128	86	0.4	87	27.84	90%	0.501	69.59	1.24Ke
M129	88	0.3	89	36.13	100%	0.501	120.43	1.24Ke
M130	90	0.9	91	60.92	95%	0.501	67.69	1.22Ke
M131	92	1.8						1.15Ke
M178	94	1.6	93	4.97	30%	0.501	3.11	1.15Ke
M117	95	0.3	96	29.85	80%	0.501	99.50	1.26Ke
M118	97	0.2	98	4.66	50%	0.501	23.28	1.24Ke
M180	99	1.8	100	29.60	100%	0.501	16.44	1.15Ke
M179	101	1.3	102	11.51	80%	0.501	8.85	1.15Ke
M121	103	0.9	104	12.68	55%	0.501	14.09	1.19Ke
M120	106	0.3	105	30.05	100%	0.501	100.17	1.19Ke
M119	108	0.1	107	18.73	90%	0.501	187.26	1.23Ke
M122	109	0.2	110	1.19	90%	0.501	5.97	1.21Ke
M123	111	0.5	112	16.26	95%	0.501	32.52	1.18Ke
M181	113	6.7						1.02Ke
M132	115	2.2	114	58.00	100%	0.501	26.36	1.02Ke
M133	116	0.3	117	26.06	100%	0.501	86.88	1.08Ke
M124	118	1.7	119	61.09	100%	0.501	35.94	1.09Ke
M127	120	0.3	121	11.62	95%	0.501	38.74	1.14Ke
M125	122	0.7	123	7.70	50%	0.501	11.00	1.05Ke
M126	124	0.3	125	13.58	95%	0.501	45.27	1.05Ke
M140	126	3.8						1.08Ke
M143	128	0.2	127	4.60	95%	0.501	23.00	1.12Ke
M155	129	0.6						1.17Ke
M154	131	0.5	130	7.97	100%	0.501	15.93	1.2Ke
M147	133	2	132	11.22	100%	0.501	5.61	1.11Ke
M148	135	0.5	134	96.83	95%	0.501	193.66	1.12Ke
M182	136	3.1						1.11Ke
M183	137	2.6						1.18Ke
M149	139	1.1	138	29.34	100%	0.501	26.67	1.18Ke
M150	141	1.3	140	59.00	100%	0.501	45.38	1.22Ke
M153	143	1	142	4.22	50%	0.501	4.22	1.23Ke
M152	145	0.4	144	79.01	100%	0.501	197.54	1.25Ke
M151	147	0.3	146	4.84	80%	0.501	16.13	1.26Ke
M141	149	1.8	148	34.40	50%	0.501	19.11	1.03Ke
M144	151	1	150	4.65	50%	0.501	4.65	1.05Ke
M145	153	0.2	152	3.34	95%	0.501	16.70	1.09Ke
M146	155	0.7	154	5.25	25%	0.501	7.50	1.09Ke
M142	157	3.9	156	35.00	70%	0.501	8.97	0.96Ke
M301	158	8.4	255	1.00	50%	0.501	0.12	0.83Ke
M286	159	6						0.88Ke
M238	160	4.2	161	9.13	50%	0.501	2.17	0.84Ke
M240	162	4	163	8.56	45%	0.501	2.14	0.83Ke
M243	164	3.9	165	7.00	20%	0.501	1.79	0.89Ke
M244	166	2.9	167	9.64	60%	0.501	3.32	0.83Ke
M239	169	0.6	168	0.76	20%	0.501	1.26	0.95Ke
M241	171	1.5	170	2.85	40%	0.501	1.90	0.8Ke
M242	173	2.3	172	3.80	30%	0.501	1.65	0.92Ke
M285	174	3	254	24.33	95%	0.501	8.11	0.88Ke
M233	175	1.3	176	15.73	45%	0.501	12.10	1.09Ke
M221	178	9.2	177	62.00	60%	0.501	6.74	1.04Ke
M229	180	5	179	14.69	65%	0.501	2.94	1.13Ke

Sub-cat.	WC cat. node	Cat. area (km²)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km²)	Rainfall station
M226	182	9.4	181	69.00	90%	0.501	7.34	1.14Ke
M235	184	0.5	183	35.98	100%	0.501	71.96	1.11Ke
M237	186	0.5	185	16.02	90%	0.501	32.04	0.96Ke
M287	187	1.3						1.14Ke
M230	189	3.1	188	27.00	100%	0.501	8.71	1.14Ke
M234	191	0.2	190	36.21	100%	0.501	181.03	1.05Ke
M236	193	0.5	192	23.79	100%	0.501	47.58	1.07Ke
M231	195	0.2	194	8.10	80%	0.501	40.49	1.44Ke
M232	197	0.5	196	8.32	100%	0.501	16.63	0.83Ke
M284	198	3	253	15.07	30%	0.501	5.02	0.88Ke
M217	200	5.7	199	51.00	70%	0.501	8.95	1.11Ke
M216	202	0.2	201	65.10	100%	0.501	325.52	1.02Ke
M218	204	4.1	203	31.00	50%	0.501	7.56	0.97Ke
M222	206	0.1	205	2.00	90%	0.501	20.00	1.17Ke
M225	208	1.7	207	29.00	80%	0.501	17.06	1Ke
M228	210	0.5	209	13.54	100%	0.501	27.07	0.95Ke
M227	212	1	211	24.02	90%	0.501	24.02	1.1Ke
M224	214	0.1	213	3.76	80%	0.501	37.63	1.07Ke
M223	216	1	215	15.68	75%	0.501	15.68	1.15Ke
M215	218	6.1	217	47.50	95%	0.300	7.79	1.04Ke
M210	219	3	252	17.25	35%	0.501	5.75	0.88Ke
M212	221	5.8	220	37.50	90%	0.300	6.47	0.91Ke
M214	223	1.1	222	51.47	100%	0.300	46.79	0.86Ke
M209	225	1.2	224	9.11	35%	0.300	7.59	0.87Ke
M208	227	0.6	226	11.11	65%	0.300	18.51	0.97Ke
M204	229	1.2	228	14.00	45%	0.501	11.67	0.96Ke
M203	231	0.5	230	12.44	80%	0.300	24.88	0.97Ke
M206	233	0.3	232	25.88	90%	0.501	86.26	0.89Ke
M205	235	0	234	3.44	90%	0.501		0.95Ke
M201	237	1.5	236	14.25	50%	0.300	9.50	0.9Ke
M202	239	4.6	238	15.95	45%	0.300	3.47	0.99Ke
M207	241	1.6	240	7.31	85%	0.300	4.57	1Ke
M211	243	4.4	242	19.70	50%	0.300	4.48	1.02Ke
M213	245	2.9	244	13.78	30%	0.300	4.75	1.05Ke
M219	246	0.3	247	18.33	100%	0.501	61.09	0.96Ke
M220	248	1.6	249	14.38	60%	0.501	8.99	0.84Ke
trans1	263	10						1Ke
trans2	264	21						1Ke
TOTAL		**256**		**3290**			**12.9**	

Appendix I: Saunders Creek – WaterCress sub-catchment and dam node details

Rainfall station: Ke – Keyneton (M023725)

Saunders Creek sub-catchment and dam node WaterCress details

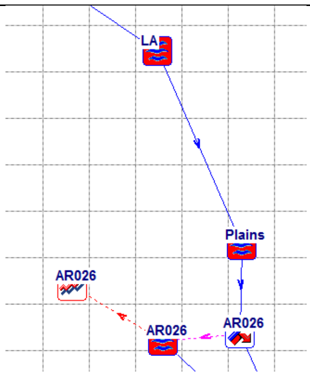
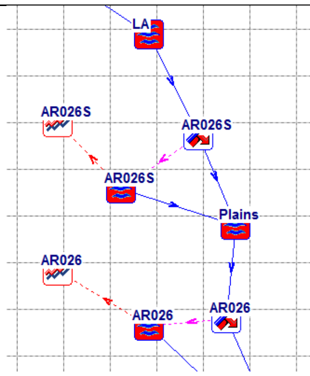
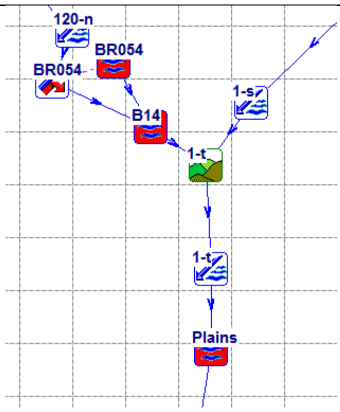
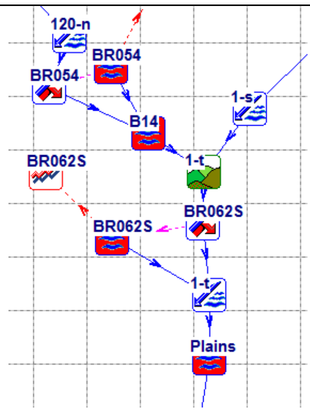
Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
S101	1	0.52	2	13.72	100%	0.344	26.48	1.07Ke
S102	3	0.48	4	33.07	100%	0.303	69.19	1.03Ke
S103	5	0.87	6	2.88	100%	0.303	3.32	1.04Ke
S105	7	1.64	8	111.09	100%	0.184	67.90	1.05Ke
S106	9	0.89	10	9.91	100%	0.303	11.19	1.01Ke
S107	11	0.71	12	7.88	100%	0.303	11.17	1.06Ke
S108	13	0.70	14	8.82	100%	0.303	12.59	1.01Ke
S109	15	0.26	16	3.56	100%	0.303	13.71	1.06Ke
S110	17	0.30	18	20.31	100%	0.374	66.82	1.01Ke
S111	19	0.28	20	11.12	100%	0.303	40.14	1.06Ke
S112	21	1.43	22	65.00	100%	0.364	45.55	1.02Ke
S113	23	0.42	24	8.82	80%	0.303	20.80	0.98Ke
S320	26	1.16	25	6.11	40%	0.303	5.27	0.98Ke
S321	28	1.21	27	1.84	10%	0.303	1.52	0.92Ke
S323	30	1.42	29	2.56	100%	0.303	1.81	0.81Ke
S326	32	3.17	31	5.45	100%	0.303	1.72	0.76Ke
S324	34	0.19	33	1.49	100%	0.303	7.91	0.72Ke
S325	36	0.26	35	2.42	100%	0.303	9.17	0.74Ke
S328	38	0.67	37	1.17	100%	0.303	1.75	0.74Ke
S327	40	0.17	39	1.38	100%	0.303	8.36	0.73Ke
S329	42	0.12	41	1.80	100%	0.303	14.60	0.77Ke
S322	44	0.07	43	0.96	70%	0.303	13.11	0.92Ke
S232	45	1.08	46	14.74	100%	0.303	13.62	0.91Ke
S233	47	0.30	48	1.51	100%	0.303	5.05	0.91Ke
S230	49	0.92	50	3.13	100%	0.303	3.41	1Ke
S231	51	3.06	52	7.11	100%	0.303	2.32	0.96Ke
S236	54	1.28	53	12.50	30%	0.303	9.81	0.97Ke
S235	56	0.31	55	25.00	100%	0.214	79.87	0.99Ke
S234	58	0.11	57	1.67	60%	0.303	15.80	0.89Ke
S238	59	2.06	97	3.39	100%	0.303	1.65	0.92Ke
S237	61	0.56	60	6.97	40%	0.303	12.50	0.94Ke
S260	62	1.58	63	3.41	10%	0.303	2.16	0.91Ke
S259	64	0.58	65	13.41	60%	0.303	23.03	0.94Ke
S258	66	0.71	67	10.13	60%	0.303	14.29	0.95Ke
S257	68	1.61	69	9.74	40%	0.303	6.05	0.94Ke
S256	70	2.23	71	14.33	40%	0.303	6.42	0.94Ke
S240	73	0.37	72	3.27	100%	0.303	8.88	0.84Ke
S239	75	0.31	74	2.33	100%	0.303	7.49	0.85Ke
S248	77	0.70	76	9.71	100%	0.303	13.79	0.83Ke
S245	79	0.60	78	5.84	100%	0.303	9.69	0.81Ke
S244	81	0.49	80	3.29	100%	0.303	6.66	0.8Ke
S246	83	0.15	82	7.30	100%	0.303	47.41	0.81Ke
S247	85	0.16	84	4.95	100%	0.303	31.97	0.81Ke

Sub-cat.	WC cat. node	Cat. area (km^2)	WC dam node	Dam vol. (ML)	Diversion rate	Usage factor	Dam density (ML/km^2)	Rainfall station
S249	87	3.62	86	6.16	20%	0.303	1.70	0.85Ke
S250	89	0.66	88	15.41	60%	0.303	23.42	0.83Ke
S252	91	0.42	90	11.53	100%	0.303	27.25	0.8Ke
S254	93	0.53	92	9.09	40%	0.303	17.15	0.84Ke
S255	95	0.31	94	5.80	70%	0.303	18.90	0.85Ke
S241	99	0.19	98	3.27	100%	0.303	16.88	0.88Ke
S243	102	0.45	101	6.40	70%	0.303	14.19	0.89Ke
S242	103	0.26	100	16.44	40%	0.303	63.24	0.88Ke
S251	105	0.32	104	8.58	100%	0.303	26.73	0.8Ke
S253	106	1.27	107	10.49	50%	0.303	8.28	0.81Ke
S104	108	0.26	109	25.00	100%	0.234	96.53	1.02Ke
S114	110	0.25	111	8.99	60%	0.303	35.68	1.04Ke
S115	112	0.25	113	3.84	100%	0.303	15.62	1.06Ke
S116	114	0.12	115	1.00	100%	0.374	8.06	1.06Ke
S117	116	0.37	117	3.94	100%	0.303	10.66	1.03Ke
S118	118	0.92						0.99Ke
S319	119	5.25	96	0.10	100%	0.003	0.02	0.88Ke
S263	120	5.17						0.86Ke
S262	121	0.90						0.87Ke
S261	122	0.95						0.9Ke
TOTAL		**59**		**621**			**10.5**	

Appendix J: Current take model changes

Angas River and Bremer River catchments

Screen shots of node changes made to the Angas River and Bremer River current take models are shown below. The changes included adding new watercourse demand nodes for standard watercourse allocations as discussed in Section 4.2.1.

SWMZ	Original model layout	Updated model layout
426AR026S		
426BR062S		

426AR026S additional node parameters

- diversion weir AR026S added to main watercourse between routstore nodes LA and Plains
  - baseflow to pass set at 0
  - constant diversion fraction set to 1 (same setting as next downstream weir node AR026)
  - maximum diversion rate set to 5000 ML (same setting as next downstream weir node AR026)
  - all other settings left as default
- routstore node AR026S added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23747PPD.rai (same setting as next downstream routstore node AR026)
  - maximum volume set to 50 ML (same setting as next downstream routstore node AR026)

- stream routing functions set to RF1 of 1.511 and RF2 of 0.7 (same setting as next downstream routstore node AR026)
- all other settings left as default

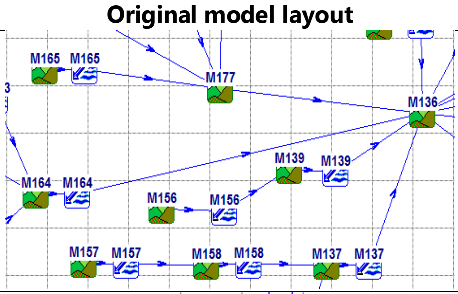
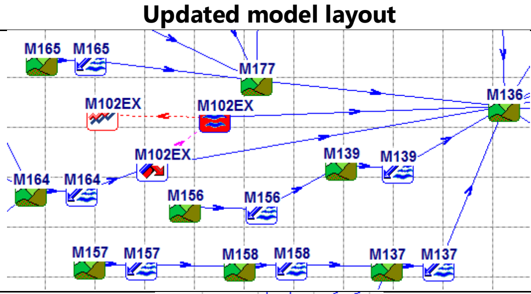
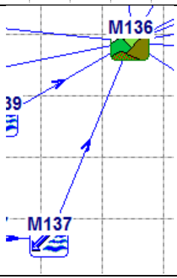
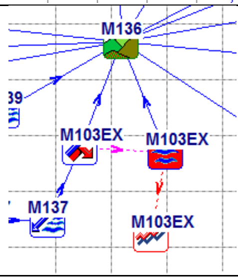
- demand node AR026S added after routstore node to draw the standard watercourse allocation of 564.58 ML from the system

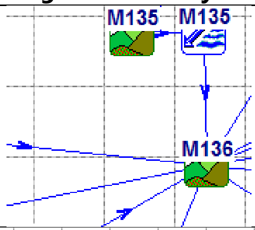
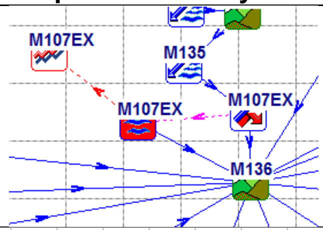
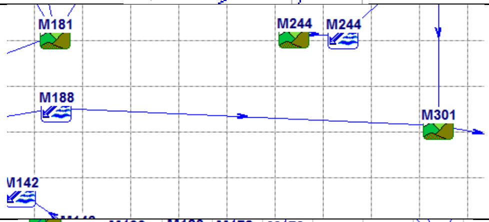
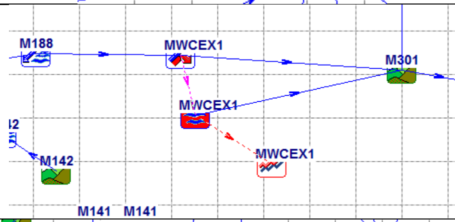
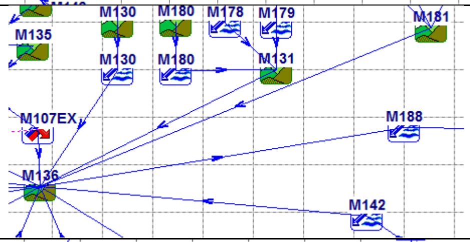
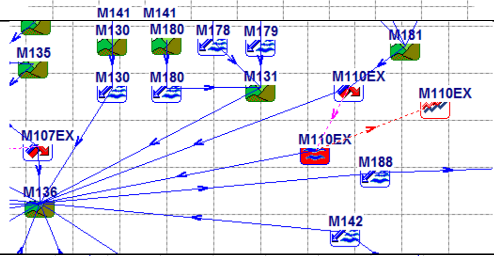
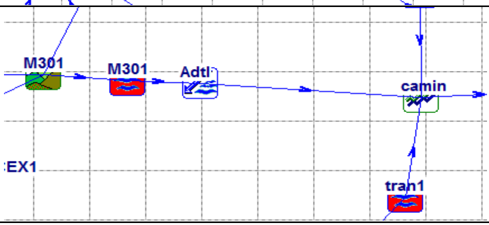
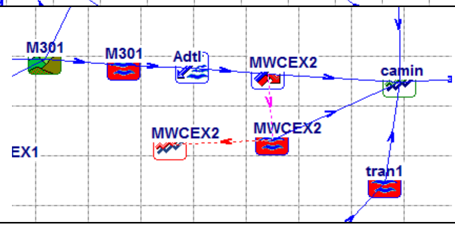
426BR062S additional node parameters

- diversion weir BR062S added to main watercourse between catchment node 1-t and dam node 1-t
  - baseflow to pass set at 0
  - constant diversion fraction set to 1 (same setting as upstream weir node BR054)
  - maximum diversion rate set to 5000 ML (same setting as next downstream weir node BR062)
  - all other settings left as default
- routstore node BR062S added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall file set to none (same setting as next downstream routstore node Plains)
  - maximum volume set to 50 ML
  - stream routing functions set to RF1 of 6.295 and RF2 of 0.7 (same setting as upstream routstore node BR054)
  - all other settings left as default
- demand node BR062S added after routstore node to draw the standard watercourse allocation of 1729.6 ML from the system

Marne River catchment

Screen shots of node changes made to the Marne River current take model are shown below. The changes included adding new watercourse demand nodes for standard watercourse allocations as discussed in Section 4.2.2.

Sub-zone	Original model layout	Updated model layout
M1-02		
M1-03		

Sub-zone	Original model layout	Updated model layout
M1-07		
Main WC		
M1-10		
Main WC (lumped extractions for WAP zones M3 and M5)		

M1-02 additional node parameters

- diversion weir M102EX added to watercourse between dam node M164 and rural node M136
    - baseflow to pass set at 0
    - constant diversion fraction set to 1
    - maximum diversion rate set to 5000 ML/day
    - all other settings left as default
- routstore node M102EX added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
    - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
    - maximum volume set to 5 ML (more than the maximum daily demand)
    - stream routing functions set to no routing
    - all other settings left as default
- demand node M102EX added after routstore node to draw the standard watercourse allocation of 21.87 ML from the system

M1-03 additional node parameters

- diversion weir M103EX added to watercourse between dam node M137 and rural node M136

  - baseflow to pass set at 0
  - constant diversion fraction set to 1
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node M103EX added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default
- demand node M103EX added after routstore node to draw the standard watercourse allocation of 3.43 ML from the system

M1-07 additional node parameters

- diversion weir M107EX added to watercourse between dam node M135 and rural node M136
  - baseflow to pass set at 0
  - constant diversion fraction set to 1
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node M107EX added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default
- demand node M107EX added after routstore node to draw the standard watercourse allocation of 12.18 ML from the system

M1-10 additional node parameters

- diversion weir M110EX added to watercourse between rural node M181 and rural node M136
  - baseflow to pass set at 0
  - constant diversion fraction set to 1
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node M110EX added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream

  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default
- demand node M110EX added after routstore node to draw the standard watercourse allocation of 2.02 ML from the system

MWCEX1 additional node parameters

- diversion weir MWCEX1 (for main watercourse diversions between M1-05 and M1-09) added to watercourse between dam node M188 and rural node M301
  - baseflow to pass set at 0
  - constant diversion fraction set to 1
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node MWCEX1 added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default
- demand node MWCEX1 added after routstore node to draw the standard watercourse allocation of 3.72 ML from the system

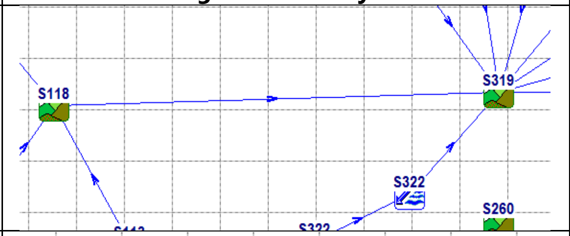
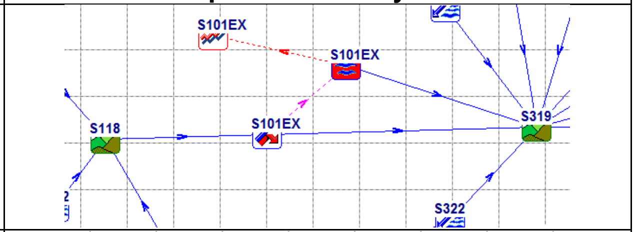
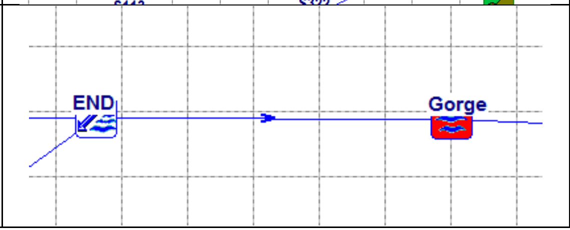
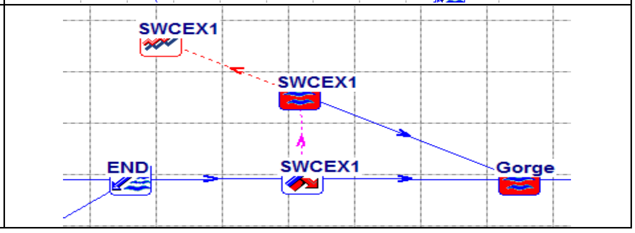
MWCEX2 additional node parameters

- diversion weir MWCEX2 (lumped for main watercourse diversions in WAP zones M3 and M5) added to watercourse between dam node Adtl and txt drain node camin
  - baseflow to pass set at 0
  - constant diversion fraction set to 1
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node MWCEX2 added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default

- demand node MWCEX2 added after routstore node to draw the standard watercourse allocation of 99.36 ML from the system

Saunders Creek catchment

Screen shots of node changes made to the Saunders Creek current take model are shown below. The changes included adding new watercourse demand nodes for standard watercourse allocations as discussed in Section 4.2.2.

Sub-zone	Original model layout	Updated model layout
S1-01		
Main WC		

S101EX additional node parameters

- diversion weir S101EX added to watercourse between rural node S118 and rural node M319
  - baseflow to pass set at 0
  - constant diversion fraction set to 1
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node S101EX added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default
- demand node S101EX added after routstore node to draw the standard watercourse allocation of 39.91 ML from the system

SWCEX1 additional node parameters

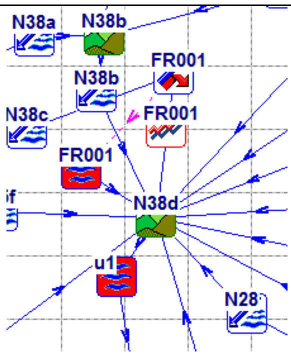
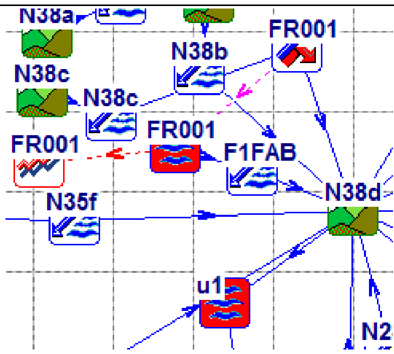
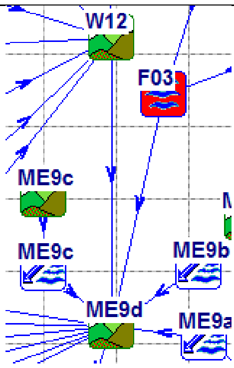
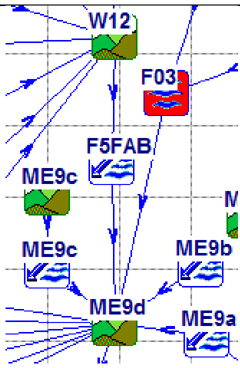
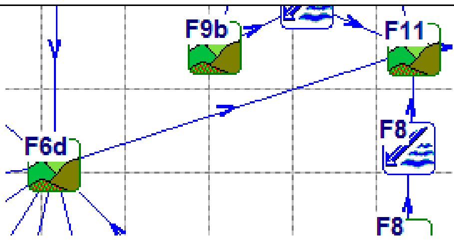
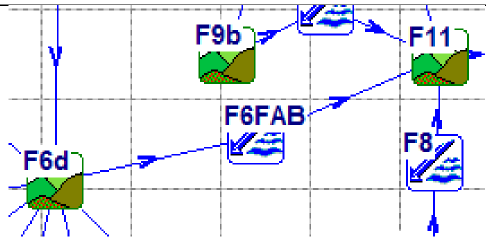
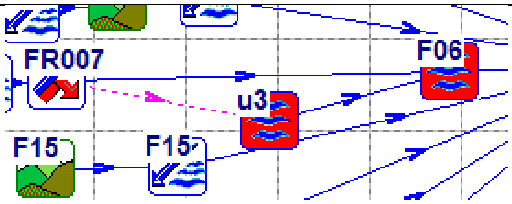
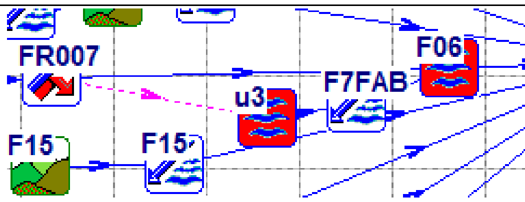
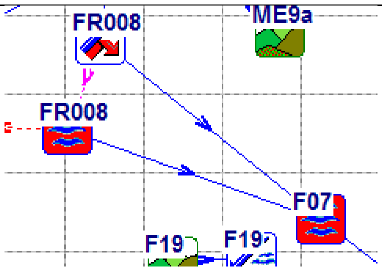
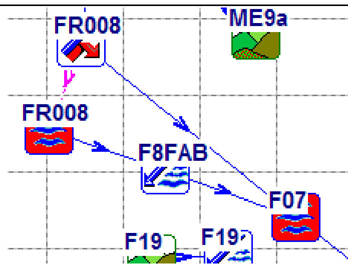
- diversion weir SWCEX1 (for main watercourse diversions in WAP zone S3) added to watercourse between dam node END and routstore node Gorge
  - baseflow to pass set at 0
  - constant diversion fraction set to 1

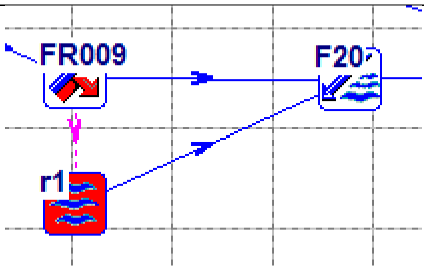
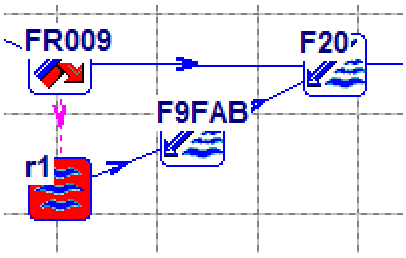
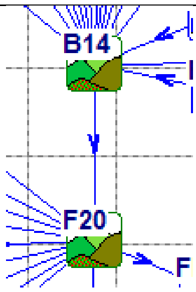
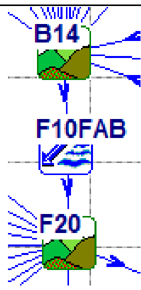
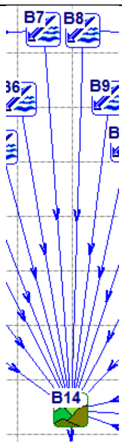
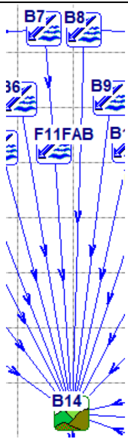
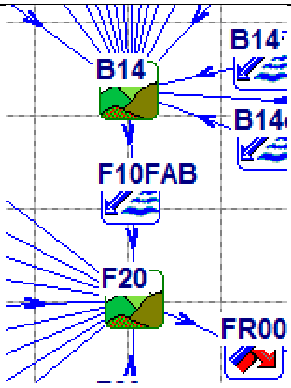
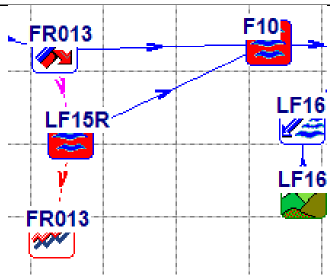
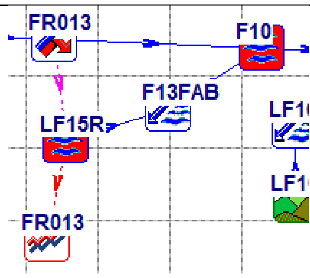
  - maximum diversion rate set to 5000 ML/day
  - all other settings left as default
- routstore node SWCEX1 added after the diversion weir node to create storage within the river reach to allow for direct extraction from the stream
  - rainfall and evaporation file set to 23725PPD.rai (only 1 rain file used throughout the model)
  - maximum volume set to 5 ML (more than the maximum daily demand)
  - stream routing functions set to no routing
  - all other settings left as default
- demand node SWCEX1 added after routstore node to draw the standard watercourse allocation of 0.21 ML from the system

Appendix K: Permitted take model changes

Finniss River catchment

Screen shots of node changes made to the Finniss River permitted take model are shown below. The changes included adding new runoff dam nodes as discussed in Section 4.3.4.

SWMZ	Original model layout	Updated model layout
426FR001		
426FR005		
426FR006		
426FR007		
426FR008		

SWMZ	Original model layout	Updated model layout
426FR009		
426FR010		
426FR011		
426FR012		n/a (added extra dam capacity to existing o/s dam node F10FAB)
426FR013		

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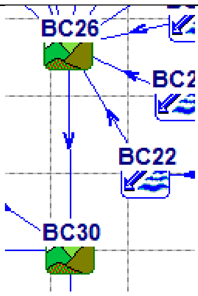
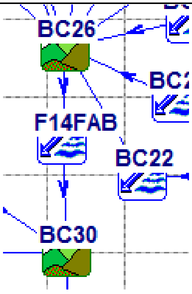
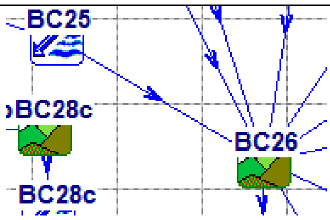
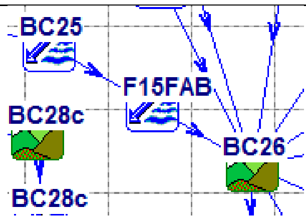
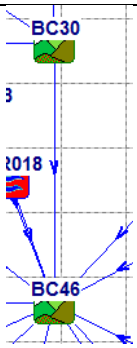
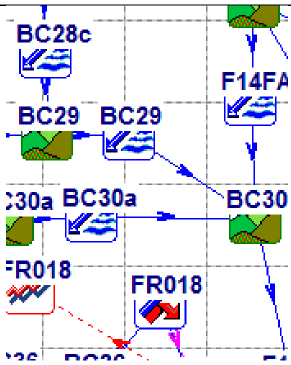
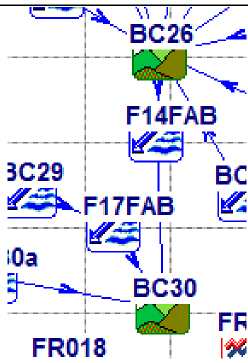
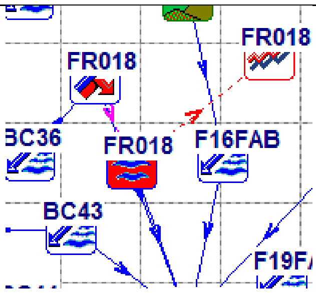
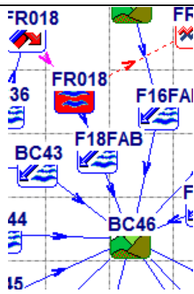
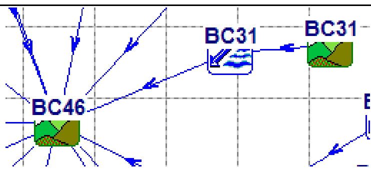
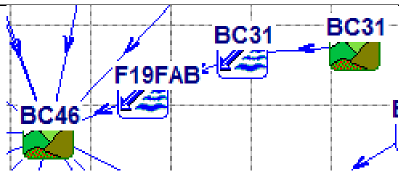
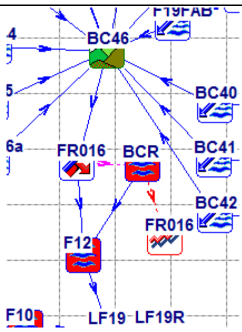
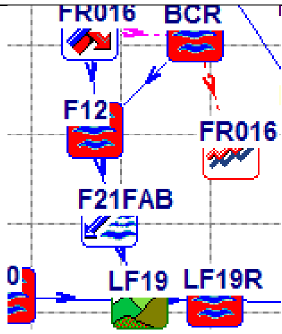
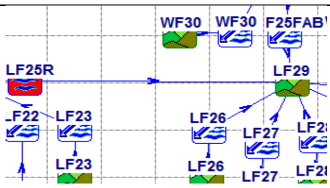
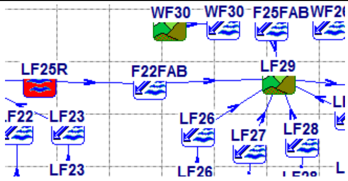
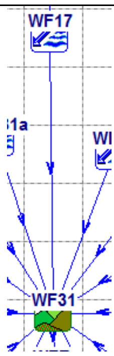
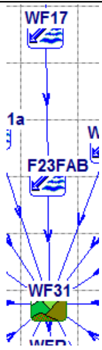
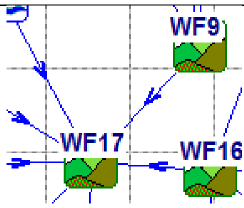
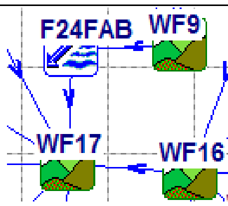
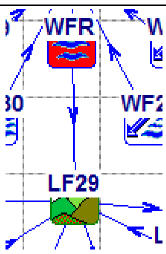
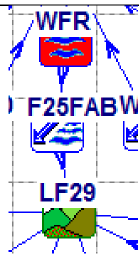
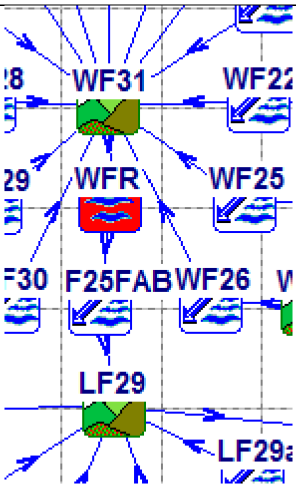
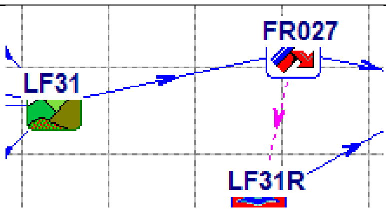
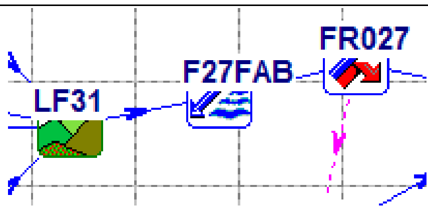
426FR014		
426FR015		
426FR016		
426FR017		
426FR018		
426FR019		

SWMZ	Original model layout	Updated model layout
426FR021		
426FR022		
426FR023		
426FR024		
426FR025		

SWMZ	Original model layout	Updated model layout
426FR026		n/a (added extra dam capacity to existing o/s dam node F25FAB)
426FR027		

Additional dam node parameters set for all new dam nodes

- zone set to 2 to match all existing dam nodes
- max filling rate set to 50 ML to match all existing dam nodes
- max accepted salinity set to 5000 mg/L to match all existing dam nodes (although we are not modelling quality)
- max Qcode set to 10 to match all existing dam nodes
- area factors left as default because dams are not actual dams in reality
- usage fraction set to 0.5 and demand pattern set to 1 (irrigation)
- baseflow to pass set to 0
- constant divert fraction set to 1
- supply sequence set to 1 to match all existing dam nodes
- maximum diversion rate set to the dam capacity to match all existing dam nodes

426FR001 additional dam node parameter

- dam node F1FAB added to watercourse between routing node FR001 and rural node N38d
  - rain and evaporation file set to 23730PPD.rai to match existing upstream dam node
  - rain factor set to 0.97 to match existing upstream dam node
  - dam volume set to 200.5 ML and initial volume 100.25 ML (50% of capacity)

426FR005 additional dam node parameter

- dam node F5FAB added to watercourse between rural node W12 and rural node ME9d

  - rain and evaporation file set to 23818PPD.rai to match nearby dam node
  - rain factor set to 1 to match nearby dam node
  - ram volume set to 264.5 ML and initial volume 132.25 ML (50% of capacity)

426FR006 additional dam node parameter

- dam node F6FAB added to watercourse between rural node F6d and rural node F11
  - rain and evaporation file set to 23735PPD.rai to match nearby dam node
  - rain factor set to 1.03 to match nearby dam node
  - dam volume set to 348.4 ML and initial volume 174.2 ML (50% of capacity)

426FR007 additional dam node parameter

- dam node F7FAB added to watercourse between routstore node u3 and routstore node F06
  - rain and evaporation file set to 23735PPD.rai to match nearby dam node
  - rain factor set to 1
  - dam volume set to 235.2 ML and initial volume 117.6 ML (50% of capacity)

426FR008 additional dam node parameter

- dam node F8FAB added to watercourse between routstore node FR008 and routstore node F07
  - rain and evaporation file set to 23735PPD.rai to match nearby dam node
  - rain factor set to 0.98 to match nearby dam node
  - dam volume set to 8 ML and initial volume 4 ML (50% of capacity)

426FR009 additional dam node parameter

- dam node F9FAB added to watercourse between routstore node r1 and dam node F20
  - rain and evaporation file set to 23735PPD.rai to match nearby dam node
  - rain factor set to 0.99 to match nearby dam node
  - dam volume set to 164.8 ML and initial volume 132.4 ML (50% of capacity)

426FR010 additional dam node parameter

- dam node F10FAB added to watercourse between rural node B14 and rural node F20
  - rain and evaporation file set to 23818PPD.rai to match upstream rural node
  - rain factor set to 1.02 to match upstream rural node
  - dam volume set to 189.6 ML and initial volume 94.8 ML (50% of capacity)

426FR011 additional dam node parameter

- dam node F11FAB added to watercourse between dam node B7 and rural node B14
  - rain and evaporation file set to 23818PPD.rai to match upstream rural node
  - rain factor set to 1.01 to match upstream dam node

  - dam volume set to 107.5 ML and initial volume 53.75 ML (50% of capacity)

426FR012

- additional volume (26.8 ML) added to existing o/s dam node F10FAB. Revised o/s dam node capacity 216.4 ML.

426FR013 additional dam node parameter

- dam node F13FAB added to watercourse between routstore node LF15R and routstore node F10
  - rain and evaporation file set to 23701PPD.rai to match nearby dam node
  - rain factor set to 1.03 to match nearby dam node
  - dam volume set to 576.1 ML and initial volume 288.05 ML (50% of capacity)

426FR014 additional dam node parameter

- dam node F14FAB added to watercourse between rural node BC26 and rural node BC30
  - rain and evaporation file set to 23701PPD.rai to match upstream rural node
  - rain factor set to 1.27 to match upstream rural node
  - dam volume set to 277.2 ML and initial volume 138.6 ML (50% of capacity)

426FR015 additional dam node parameter

- dam node F15FAB added to watercourse between dam node BC25 and rural node BC26
  - rain and evaporation file set to 23701PPD.rai to match upstream dam node
  - rain factor set to 1.3 to match upstream dam node
  - dam volume set to 31 ML and initial volume 15.5 ML (50% of capacity)

426FR016 additional dam node parameter

- dam node F16FAB added to watercourse between dam node BC25 and rural node BC26
  - rain and evaporation file set to 23701PPD.rai to match upstream rural node
  - rain factor set to 1.18 to match upstream rural node
  - dam volume set to 53.2 ML and initial volume 26.6 ML (50% of capacity)

426FR017 additional dam node parameter

- dam node F17FAB added to watercourse between o/s dam node BC29 and rural node BC30
  - rain and evaporation file set to 23701PPD.rai to match existing upstream node
  - rain factor set to 1.28 to match existing upstream node
  - dam volume set to 140.8 ML and initial volume 70.4 ML (50% of capacity)

426FR018 additional dam node parameter

- dam node F18FAB added to watercourse between routing node FR018 and rural node BC46
  - rain and evaporation file set to 23701PPD.rai to match existing upstream node
  - rain factor set to 1.25 to match existing upstream node

- dam volume set to 320.3 ML and initial volume 160.15 ML (50% of capacity)

426FR019 additional dam node parameter

- dam node F19FAB added to watercourse between dam node BC31 and rural node BC46
  - rain and evaporation file set to 23701PPD.rai to match upstream dam node
  - rain factor set to 1.23 to match upstream dam node
  - dam volume set to 65.8 ML and initial volume 32.9 ML (50% of capacity)

426FR021 additional dam node parameter

- dam node F21FAB added to watercourse between routing node F12 and rural node LF19
  - rain and evaporation file set to 23701PPD.rai to match existing upstream node
  - rain factor set to 1.09 to match existing upstream node
  - dam volume set to 137.3 ML and initial volume 68.65 ML (50% of capacity)

426FR022 additional dam node parameter

- dam node F22FAB added to watercourse between routing node LF25R and rural node LF29
  - rain and evaporation file set to 23701PPD.rai to match existing upstream node
  - rain factor set to 1.03 to match existing upstream node
  - dam volume set to 311.6 ML and initial volume 155.8 ML (50% of capacity)

426FR023 additional dam node parameter

- dam node F23FAB added to watercourse between dam node WF17 and rural node WF31
  - rain and evaporation file set to 23701PPD.rai to match upstream dam node
  - rain factor set to 1.06 to match upstream dam node
  - dam volume set to 29.2 ML and initial volume 14.6 ML (50% of capacity)

426FR024 additional dam node parameter

- dam node F24FAB added to watercourse between rural node WF9 and rural node WF17
  - rain and evaporation file set to 23701PPD.rai to match upstream rural node
  - rain factor set to 1.06 to match upstream rural node
  - dam volume set to 31.3 ML and initial volume 15.65 ML (50% of capacity)

426FR025 additional dam node parameter

- dam node F25FAB added to watercourse between routstore node WFR and rural node LF29
  - rain and evaporation file set to 23701PPD.rai to match upstream rural node
  - rain factor set to 0.91 to match upstream rural node
  - dam volume set to 53.4 ML and initial volume 26.7 ML (50% of capacity)

426FR026

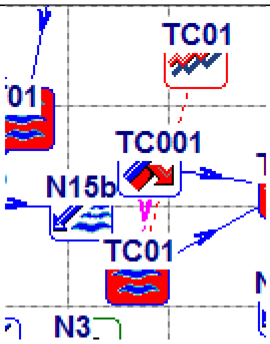
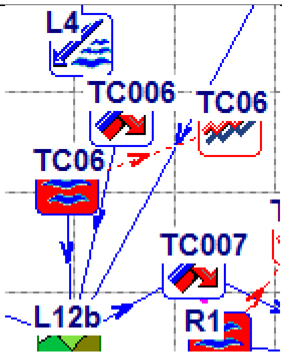
- additional volume (92.3 ML) added to existing o/s dam node F25FAB. Revised o/s dam node capacity 145.7 ML.

426FR027 additional dam node parameter

- dam node F27FAB added to watercourse between rural node LF31 and diversion node FR027
  - rain and evaporation file set to 23714PPD.rai to match upstream rural node
  - rain factor set to 1 to match upstream rural node
  - dam volume set to 195.5 ML and initial volume 97.8 ML (50% of capacity)

Tookayerta Creek catchment

Screen shots of node changes made to the Tookayerta Creek permitted take model are shown below. The changes included adding extra watercourse extraction volumes as discussed in Section 4.3.4.

SWMZ	Original model layout	Updated model layout
426TC001		n/a (added watercourse demand to existing node TC01)
426TC006		n/a (added watercourse demand to existing node TC06)

426TC001

- additional volume (401.05 ML) added to existing demand node TC01. Revised watercourse demand 569.9 ML.

426TC006

- additional volume (106.2 ML) added to existing demand node TC06. Revised watercourse demand 148.1 ML.

Appendix L: Calculation of average net annual evaporation

This appendix outlines how the average net annual evaporation rates for dams, expressed as a proportion of dam capacity, were determined for the EMLR water allocation plan. The relationships described in this appendix have also been used to calculate estimated evaporation factors for the surface water management sub-zones in the Marne Saunders PWRA, as per section 4.3.2.2 of this report.

Basis for determining average net annual evaporation rates

Surface water modelling has been carried out for the EMLR PWRA as described in Alcorn (2011) and references therein. These models have been used to generate data on average net annual evaporation rates from a number of dams in areas of different rainfall, as given on page 17 of Alcorn (2011). This average net annual evaporation rate is expressed as a percentage of dam capacity, and the average was calculated over the modelling period (1971–2006).

Net annual evaporation is the difference between gross annual evaporation and annual rainfall (i.e. net loss/gain from the dam in terms of evaporation and rainfall). In wetter areas, the evaporative loss over summer can be significantly offset by rainfall over winter and spring.

The data from Alcorn (2011) was used to generate a relationship between average annual rainfall (mm) and average net annual evaporation (as a % of dam capacity), as shown in Figure 25.

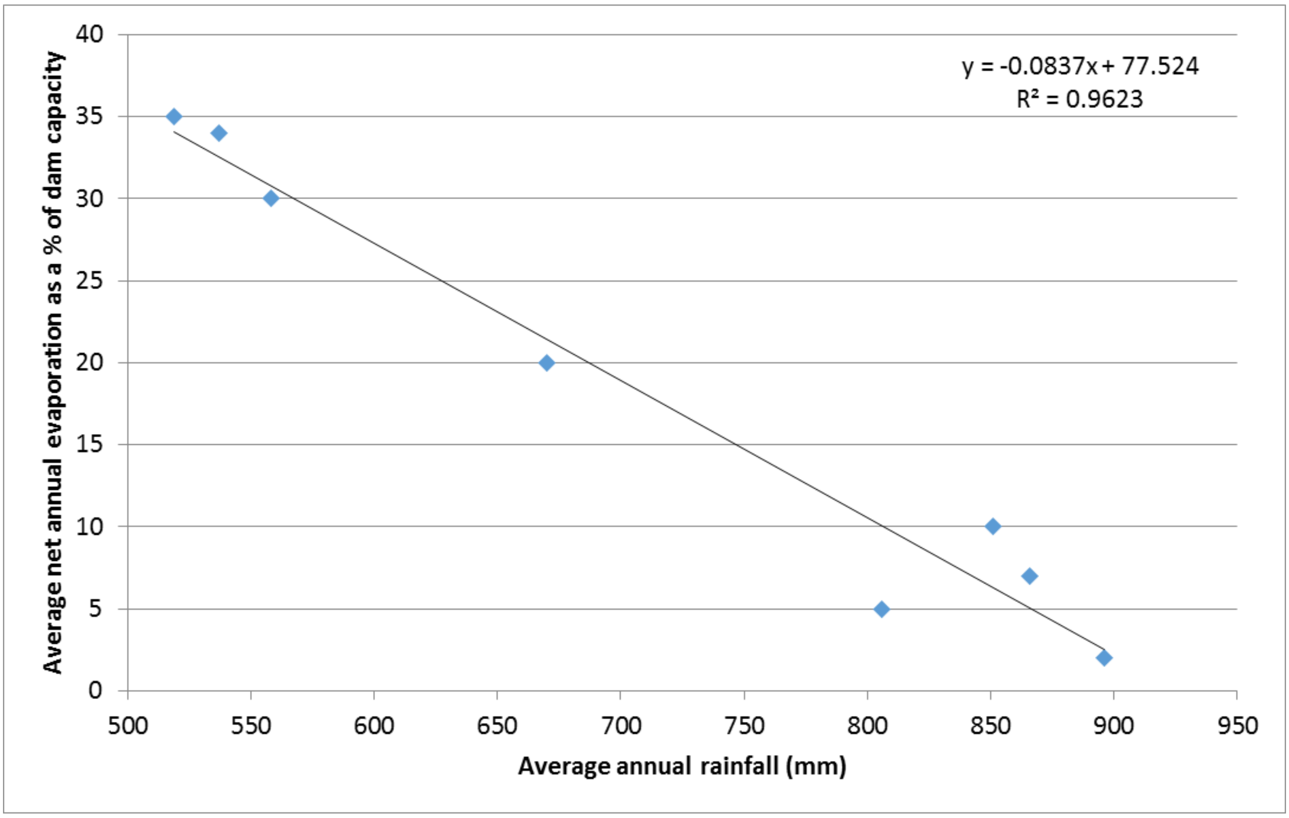


Figure 25. Relationship between average annual rainfall and average net annual evaporation rate (as percentage of dam capacity) for data from Alcorn 2011.

The relationship from Figure 25 was used to assign an estimated evaporation factor (average net annual evaporation as a proportion of dam capacity) to rainfall bands of 50 mm increments, as given in Table 23. The values in Table 23 are derived by calculating the average net annual evaporation rate for the rainfall at the top of each rainfall band using the relationship shown in Figure 25, and then rounding this value to the nearest increment of 5% (proportion of 0.05). Where the rounded value would have been more than 1% below the modelled value, the value has been rounded to the nearest increment of 2.5% instead (e.g. the 500 – 550 mm rainfall band was assigned an estimated evaporation factor of 0.33 (rounded up from 0.325)). A minimum factor of 0.10 has been used as a conservative measure to reduce the risk of over-allocation as a result of under-estimating evaporation, recognizing that the evaporation rates used come from a modelled relationship.

Estimated evaporation factors were then assigned to each management zone (or sub-zone) on the basis of average annual rainfall from the zone. So for example, a zone with an average rainfall of 672 mm would be assigned an estimated evaporation factor of 0.2 across the zone (i.e. average net annual evaporation rate of 20% of dam capacity).

Table 23. Estimated evaporation factor for rainfall bands

Average annual rainfall (mm) – min	Average annual rainfall (mm) – max	Estimated evaporation factor (proportion of dam capacity)
300	350	0.50
350	400	0.45
400	450	0.40
450	500	0.35
500	550	0.33
550	600	0.30
600	650	0.25
650	700	0.20
700	750	0.15
750	800	0.10
800	850	0.10
850	900	0.10

Appendix M: Method for determining take – SDL models 'guidance notes'

Guidance note #	Guidance notes	Refer to section
1. Documentation and model overview		
1.1	Has a complete model report been provided which documents all the matters necessary to allow peer review consistent with the Basin Plan and these evaluation criteria?	Yes (MDBA to determine)
1.2	Has sufficient effort been directed to documentation? (I.e. is the model report readable and clear?)	Yes (MDBA to determine)
1.3	Where previous reports, including any peer reviews, are essential to evaluation of the model, have copies of these reports been provided?	Refer Section 2
1.4	Is there a clear statement of objectives in the report? Do the objectives include use of the model to compute SDL(s) (and BDLs) consistent with Chapter 10 of the Basin Plan?	Refer Section 1
1.5	In the model report, has the definition of SDL in Schedule 2 of the Basin Plan been correctly interpreted and documented? Where interpretations or assumptions have been made concerning the application of Schedule 3, have these been documented and are they appropriate?	Refer Section 4 and EMLR WRP
1.6	Have the WRP area(s) and the SDL resource unit(s) to which the model has been applied been clearly and accurately defined? If the model is applied to only part of these area(s) or resource unit(s), have the areas of application been clearly defined?	Refer Figure 1
1.7	Is there a clear statement, in the model report, which specifies the 'forms of take' that are included in the model and those which are not? Should other forms of take have been included in the model, given its coverage and application within the WRP(s)?	Refer Section 4
1.8	Has the model report established that the model can be used to provide a practical and reliable method to determine the annual permitted take in a water accounting period (for the forms of take to which the model is applied)?	MDBA to determine
1.9	If these models were independently reviewed (e.g. when the model was applied as a cap model), have the recommendations of these reviews been considered in formulating the SDL model? If not, have the reasons been documented and are they appropriate?	Yes
1.10	Have the diversion results been individually reported for each form of take simulated in the model? Where the model covers more than one surface water SDL resource unit, have the diversion results been reported for each SDL unit, and for each form of take simulated in the model?	Refer Section 14
1.11	Are the model report's conclusions and recommendations reasonable and supported by evidence?	MDBA to determine
2. Data analysis		

Guidance note #	Guidance notes	Refer to section
2.1	Have all relevant data been collected and analysed? (Surface water, groundwater, land use, diversions, climate, etc.)	Refer Section 5
2.2	Has information on the spatial and temporal extent, together with the quality of the relevant data, been provided?	Refer Sections 3.3 Previous reports outlined in Section 2
2.3	Has the recorded diversion data (for the forms of take simulated in the model) been analysed and reported in sufficient detail to allow calibration/validation of the model? Are the accuracy and limitations of this diversion data adequately described?	If 'recorded' data refers to metered data, the process to collect this information has only commenced in recent years
2.4	In respect of the relevant surface water, groundwater and climatic data used in the model, has the process of infilling data gaps and extending data beyond the period of record been properly documented? Where these data extensions relied on separate modelling, has this modelling been documented and provided for review?	Refer to Section 5.1 and to previous reports outlined in Section 2
2.5	Has the process of infilling gaps and extending data been carried out appropriately?	Standard procedure for infilling data has been adopted
2.6	Have all locations been identified where recorded flow data already includes for upstream take (e.g. from runoff dams, groundwater usage or diversions from unregulated systems)? Have appropriate procedures been included to allow for this upstream take?	Assumed take from runoff dams and watercourses have been included in the models
3. Model structure		
3.1	Is there a clear description of the model structure and its spatial coverage? Is the model structure and coverage appropriate for SDL assessment?	Refer Section 3 and Figure 1
3.2	Has a complete link-node diagram or other representation been provided to identify all the components of the model within each reach?	Refer Figures 2, 5, 8, 11, 14, 17, 20, 23
3.3	Are all the system conceptualisations appropriate for a SDL model (and consistent with the WRP) when properly calibrated, including those required under Basin Plan s10.12? This includes, but is not limited to, conceptualisation of: • principle water inputs and outputs, flow routing, transmission losses/gains, storage operations, diversions for each form of take, permanent and temporary trade, water sharing rules, resource assessments, other management rules, procedures to manage HEW, carryover, return flows, water used for aquifer recharge and is the model time step(s) appropriate?	Refer Sections 5-12 and Section 4; and also the parts of the EMLR WRP responding to Basin Plan sections 10.10 and 10.12
3.4	Where there are water resources with a significant hydrological connection to adjacent systems (including groundwater systems), has the structure of the model been prepared appropriately? If this inter-connection has not been simulated, has the likely impact on model results been assessed?	Refer Section 3

Guidance note #	Guidance notes	Refer to section
	Is the model appropriately structured to interface with other SDL models (surface water and groundwater), both upstream and downstream? Where the model interfaces with other SDL models (upstream and/or downstream) are the linkages to these other models clearly described and appropriately established? Have the upstream models been independently reviewed and accredited?	
3.5	Has the conceptualisation of held environmental water (i.e. managed by CEWH, TLM, VEWH, OEH, Water for Rivers and others, if any) been sufficiently described? Is this conceptualisation appropriate for this SDL model, when properly calibrated?	No held environmental water at time of writing; if occurs in future then is treated like other allocations so no different model treatment required
3.6	Is the model flexible enough to demonstrate it will meet the SDL, including an adjusted SDL? Is a reason provided why, if this is not currently the case?	Refer Section 4
3.7	Is the model operated over historical climate conditions consistent with the requirements of the Basin Plan, for each form of take simulated in the model?	Yes
4. Calibration		
4.1	Every model has different components that can be calibrated. These usually involve some or all of the following: flow calibration, storage calibration, diversion calibration and planted area calibration. For each of model components requiring calibration, has the calibration period been specified? Are the climatic and resource conditions over each of these calibration periods, described? Is the selection of these periods appropriate?	Refer Sections 3.4, 6-12 and previous reports outlined in Section 2
4.2	Has sufficient effort been expended to obtain data for calibration of each model component?	
4.3	Has the calibration 'fit' been documented for each model component requiring calibration? Have an appropriate range of statistics of the 'fit' and time series plots of observed and predicted values been provided? Have the model parameters that were 'forced' during each component of the calibration been documented?	
4.4	Is each component of the model sufficiently calibrated against spatial and temporal observations? Are the calibrated values plausible and resultant 'fit' appropriate?	
4.5	If the calibration components share a sufficient common period, has the overall calibration been reported? What is the quality of the resultant 'fit'?	
4.6	Has the robustness of the model to operate outside the calibration period been considered? What is the robustness likely to be having regard to the variability of climatic and other factors during the calibration periods?	
5. Verification and testing		
5.1	Where appropriate, have all reasonable avenues for verifying and testing the model been undertaken and documented? Alternatively if verification or testing has not been undertaken, have the reasons been documented and are they appropriate?	Verification and testing was undertaken as part

Guidance note #	Guidance notes	Refer to section
5.2	Have the climatic and resource conditions over the validation period, been described? Is the selection of this period appropriate and has its duration been maximised?	of the model recalibration process. Refer Sections 3.4, 6-12 and previous reports outlined in Section 2
5.3	Have the initial conditions for the validation been documented and appropriately set? Has the extent of any other 'forcing' been described and justified? If present is such 'forcing' appropriate.	
5.4	Have an appropriate range of statistics of the 'fit' and time- series plots of observed and predicted values been provided for all relevant model parameters? What is quality of the resultant 'fit'?	
5.5	For periods when the development limits are sufficiently similar to the historical infrastructure and management rules, has the model been run to compare annual take with the recorded take? Have these results been compared statistically? What is quality of the resultant 'fit' and what confidence can be placed in the resultant SDL (and annual take) determined by the model?	
6. Prediction		
6.1	Has the procedure for establishing the initial conditions for a model run been described? Is this procedure appropriate?	Refer Sections 5-12
6.2	Where the model relies on outputs provided by other SDL models, have the appropriate data sets been used?	N/A
6.3	Has the BDL and SDL estimate (for each form of take) been compared with that estimated by the Authority when developing the Basin Plan in 2012? Are the reasons for the differences documented? Are the differences plausible?	
6.4	Has a water balance been provided which defines the magnitudes of all principal model inputs and outputs? Has a satisfactory water balance been achieved?	Refer Tables 13-16 of Alcorn (2011)
7. Sensitivity and uncertainty analyses		
7.1	Have the potential uncertainties in the model inputs been identified? Have the potential errors in the modelling processes been discussed?	Provided in the individual modelling reports
7.2	Have the potential uncertainties in the model outputs been estimated, and in particular, the simulated annual take and SDL?	
8. Model improvements		
8.1	Where model development has been constrained by limitations in the available data, have these been identified?	Refer Sections 4.4, 6.4, 7.4, 8.4, 9.4, 10.4, 11.4, 12.4
8.2	Have the model's limitations been considered and has a potential list of improvements been prepared? Are these limitations and improvements appropriate?	
8.3	Is it necessary to collect more data or obtain further information to improve the model? If so have these been documented and scheduled?	
8.4	Where any model improvements are considered essential within a specified timeframe, has this timeframe been documented?	
9. Quality assurance		

Guidance note #	Guidance notes	Refer to section
9.1	Has the model run number, the software version and all relevant model input been defined to enable the SDL model run to be repeated, at a later date, if required?	Refer Section 13
9.2	Where the model relies on input data generated by other models, have sufficient details been provided to uniquely define those other models and their operating assumptions. Has the source and date of supply of those other models' results been documented?	N/A