Hydrological model of the Onkaparinga Catchment, South Australia: Calibration report

DEWNR Technical report 2015/02

Government of South Australia
Department of Environment, Water and Natural Resources

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Foreword

The Department of Environment, Water and Natural Resources (DEWNR) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEWNR's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

Sandy Pitcher
CHIEF EXECUTIVE
DEPARTMENT OF ENVIRONMENT, WATER AND NATURAL RESOURCES

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Summary

This report describes the build and calibration of a hydrological model of the Onkaparinga Catchment in the Mount Lofty Ranges of South Australia.

It was completed for and supported by the Goyder Institute for Water Research, arising from a commitment by the Department of Environment, Water and Natural Resources to the Australian Council of Government's National Hydrological Modelling Strategy.

The Goyder Institute project "Integrated catchment water planning support for Adelaide Mount Lofty Ranges Water Allocation project" comprises four major tasks of which this project was a component of Task 2: Integrated Catchment Water Planning Support System.

Whilst the department has previously built models to describe the hydrology and water sharing of the Onkaparinga Catchment, this was the first time it had been attempted in the new eWater Source IMS modelling platform.

The model platform was able to incorporate existing methodologies for rainfall-runoff generation and stream routing, as well as new plugins and extended capabilities, in particular the use of a farm dam plugin.

The model was successfully built and populated before being calibrated using an inbuilt calibration routine. Results from the calibration compared favourably with previous models developed by the department for this catchment.

The future use of this model will be as an input to a Risk Assessment methodology currently being developed alongside this project, which will utilise the concept of workflows to streamline and more easily inform the process of water allocation planning.

Additional uses for the model will include supporting the development of robust environmental water requirements metrics currently being investigated also under Task 4 of this Goyder project.

1 Introduction

This project falls under Task 2 of the Goyder Institute[1] "Integrated catchment water planning support for Adelaide Mount Lofty Ranges Water Allocation Planning" research project.

The overall objective of Task 2 was to develop an integrated catchment water planning support system.

The main outcomes include building a rainfall-runoff catchment model in the eWater Source IMS[2] modelling platform for a trial catchment in the Mount Lofty Ranges by incorporating existing (and developing and integrating additional) software plug-ins that represent demand and supply functionalities (farm dams and watercourse extractions), land cover and/or soil variability. This report describes the build and calibration of this catchment model.

The model described in this report will support the development of an integrated catchment water planning support system using best-practice modelling; to enable water managers/planners/researchers to model, evaluate and plan for the risks of water extractions and/or climate change/variability/non-stationarity on catchment water resources including water dependent ecosystems.

The development of a workflow that demonstrates how risk based assessments could be implemented in a workflow tool is the main expected use of this model, although it will also support the development and verification of Environmental Water Requirements (EWRs), or ecological response models being investigated in Task 4 of this Goyder Project.

It is recognised that during this process additional issues and complexity may arise and that these issues would need to be addressed prior to developing a useful system for an end-user. These issues will be captured and tabled in a final report with recommendations on ways forward. The system will be primarily designed to run on a single computer but will be capable of running on high-performance computer clusters if appropriate equipment is available. Some prototyping on CSIRO's cluster system will be undertaken to test this capability.

[1] http://www.goyderinstitute.org

[2] http://www.ewater.com.au

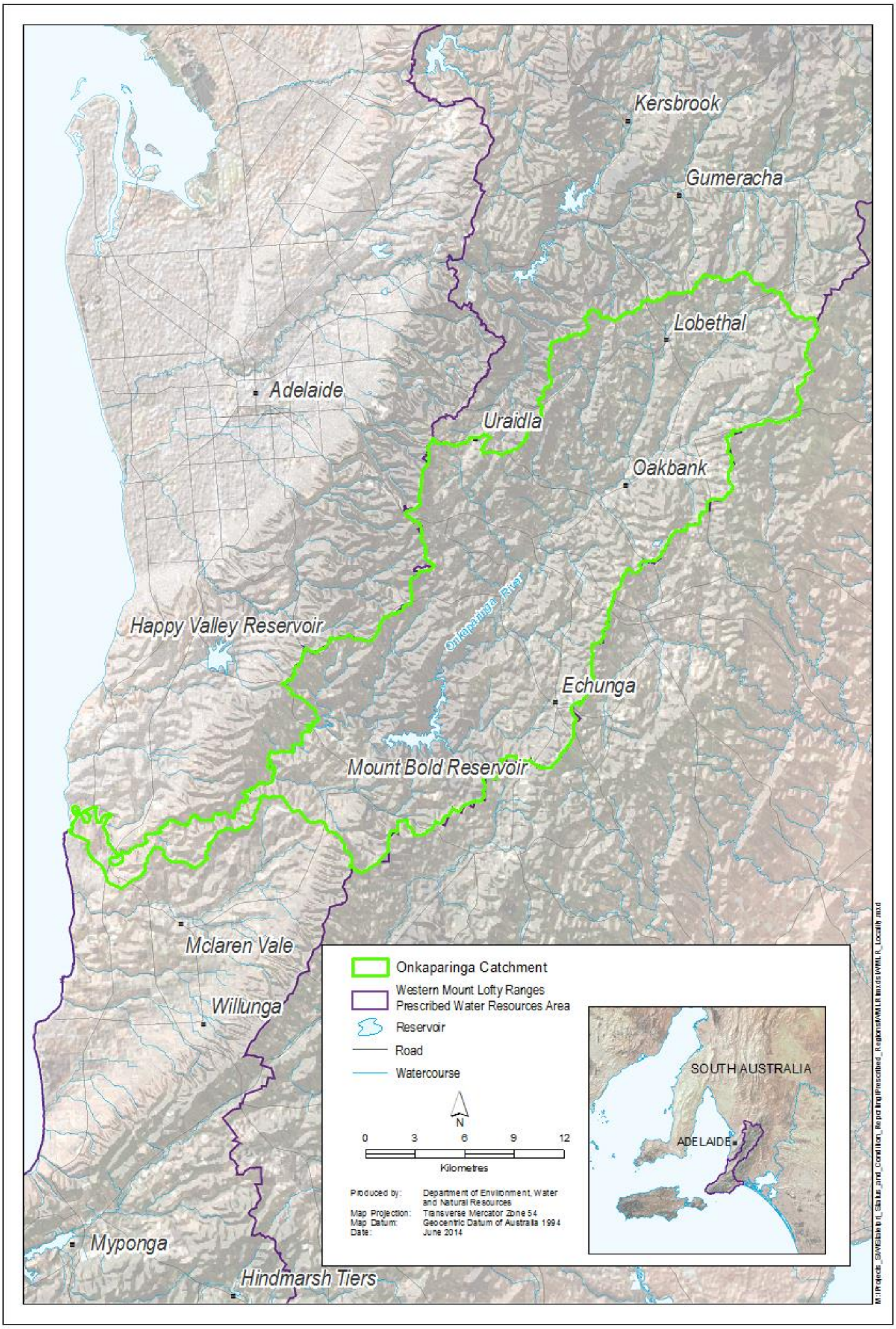


Figure 1. Location of the Onkaparinga Catchment in the Mount Lofty Ranges, South Australia

2 Methodology

2.1 Model selection

Selection of a hydrological modelling platform to represent the changes in flow regime and water balance due to different levels of low flow releases and consumptive water use was based on the following requirements:

1. The ability to represent the flow regime on a daily time step
2. The ability to bypass a specified flow rate (Low Flow Release)
3. The ability to represent the water balance of individual dams within a catchment or sub-catchment, including the following elements:
   a. Rainfall and evaporation
   b. Catchment inflows
   c. Dam outflows
   d. Internal water demand.

Previous studies by the Department of Environment, Water and Natural Resources (DEWNR) (Alcorn, 2008; Savadamuthu, 2006; Teoh, 2008) have used the WaterCRESS modelling framework (Creswell, 2010) with success. However under the National Hydrological Modelling Programme[3], there is an ongoing transition to a more standardised and nationally accepted model platform. For catchment and river system modelling, this platform is currently the eWater Source modelling platform (Welsh et al., 2012; Carr, R, Podger, G, 2012), which is a comprehensive and extensible modelling environment that supports water resource planning and management in complex regulated and unregulated river systems. A river system can be configured as a node-link network where flow and constituents are routed through the system. Upstream catchments can be spatially configured to enable processes such as rainfall-runoff and constituent generation to deliver flow and loads to the river network (for more details refer to Welsh et al., 2012).

Fundamental to this design is the flexibility which makes Source readily customisable as new science and information becomes available. New capabilities can be incorporated via plug-ins developed to suit particular needs. Whilst the currently available beta version of Source IMS does not have the ability to model an explicit, spatial representation of farm dams, work conducted jointly between Sinclair Knight Merz (SKM) and Western Australia's Department of Water has resulted in the development of the Farm Dam Analysis Tool plug-in (Fowler, et al., 2012). The plug-in meets all the requirements to model the spatial representation of farm dams configured with low flow releases and the effects these dams will have on catchment outflows. The advantage of using Source with the Farm Dam Analysis Tool plug-in is the ability to collaborate with interstate peers on this project, and also the ease with which the model itself can be set up, parameterised and shared.

Given that this model has two purposes: input to a Risk Assessment workflow, and assessment of environmental metrics at a daily time scale, it had to be fit for both purposes.

For use with the Risk Assessment workflow, the objective was to build and calibrate a model that can reproduce mean annual flows over a period of time relevant for long term planning purposes. For example, water allocation plan consumptive use limits and environmental water requirements have been previously determined using 33 years of model data for assessment.

Additionally, it was required to be able to set various management and water allocation mechanisms such as low flow releases from farm dams and variable water extraction rates from dams and to be able to access these outputs on a daily time scale to assess various environmental metrics.

[3] http://archive.nwc.gov.au/media/ministerial/source

The eWater Source modelling platform (Welsh et al., 2012; Carr, R, Podger, G, 2012) was selected as the platform in which to model these requirements. Source is adopted nationally as the National Hydrological Modelling Platform[3] and developed to be a multi-purpose platform able to model rivers, catchments, groundwater interactions as well as various management options.

2.2 Model domain and sub-catchment definition

The model sub-catchment definition was designed to match with the spatial scale of management of surface water in the Mount Lofty Ranges. Within the Onkaparinga catchment there are 100 surface water management zones as specified in the WMLR Water Allocation Plan (WAP) (Figure 2). The existing surface water model used by DEWNR for the preparation of the WAP (Teoh, 2002) was built at a similar scale with 114 sub-catchments to represent the catchment and its water resource development.

To build the new model, sub-catchments were derived using terrain analysis tools within the ArcGIS® platform, in the ArcHydro plugin tool. Whereas there are 100 existing surface water management zones within the Onkaparinga catchment, it was necessary for additional sub-catchments to be inserted to be able to interrogate model outputs at streamflow gauges. Thus the model structure is made up of 114 sub-catchments. Whilst some surface water management zones are split into two where there exists a gauge, many of the sub-catchments represent a nearly identical version of the management zone.

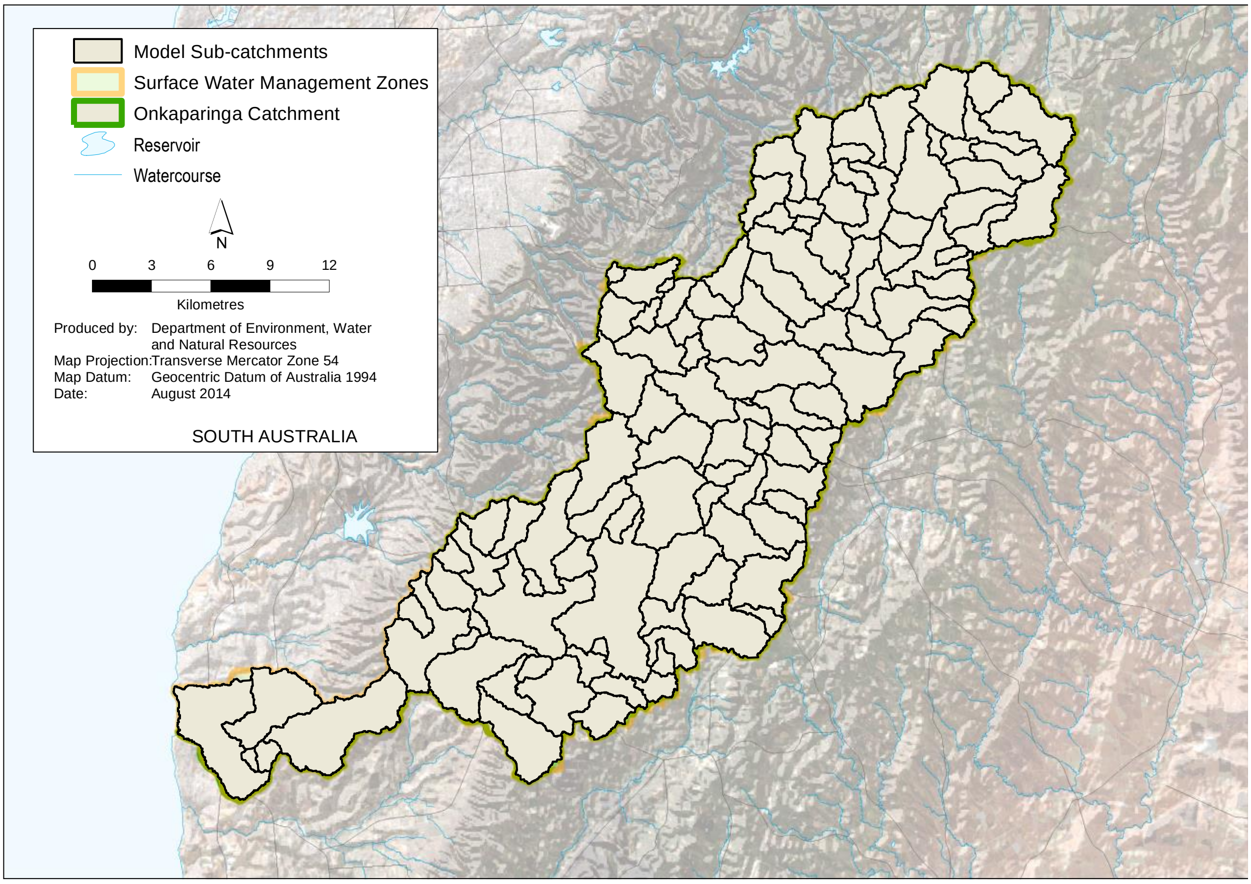


Figure 2. Surface Water Management Zones and modelled sub-catchment

2.3 Existing farm dam development

Inclusion of farm dams and their impacts on streamflow was essential in the framework for assessing the sustainable extraction yield and the determination of environmental water requirements. The management of farm dams is a key lever of the water allocation policy in the Mount Lofty Ranges, along with watercourse extractions.

Using the DEWNR database of farm dams captured by aerial photography in 2005, 3168 farm dams were identified in the Onkaparinga catchment (Figure 3). Farm dam surface areas are digitised on screen into a spatial database. Volumes of farm dams are inferred using the Area-Volume relationship derived by McMurray (2004).

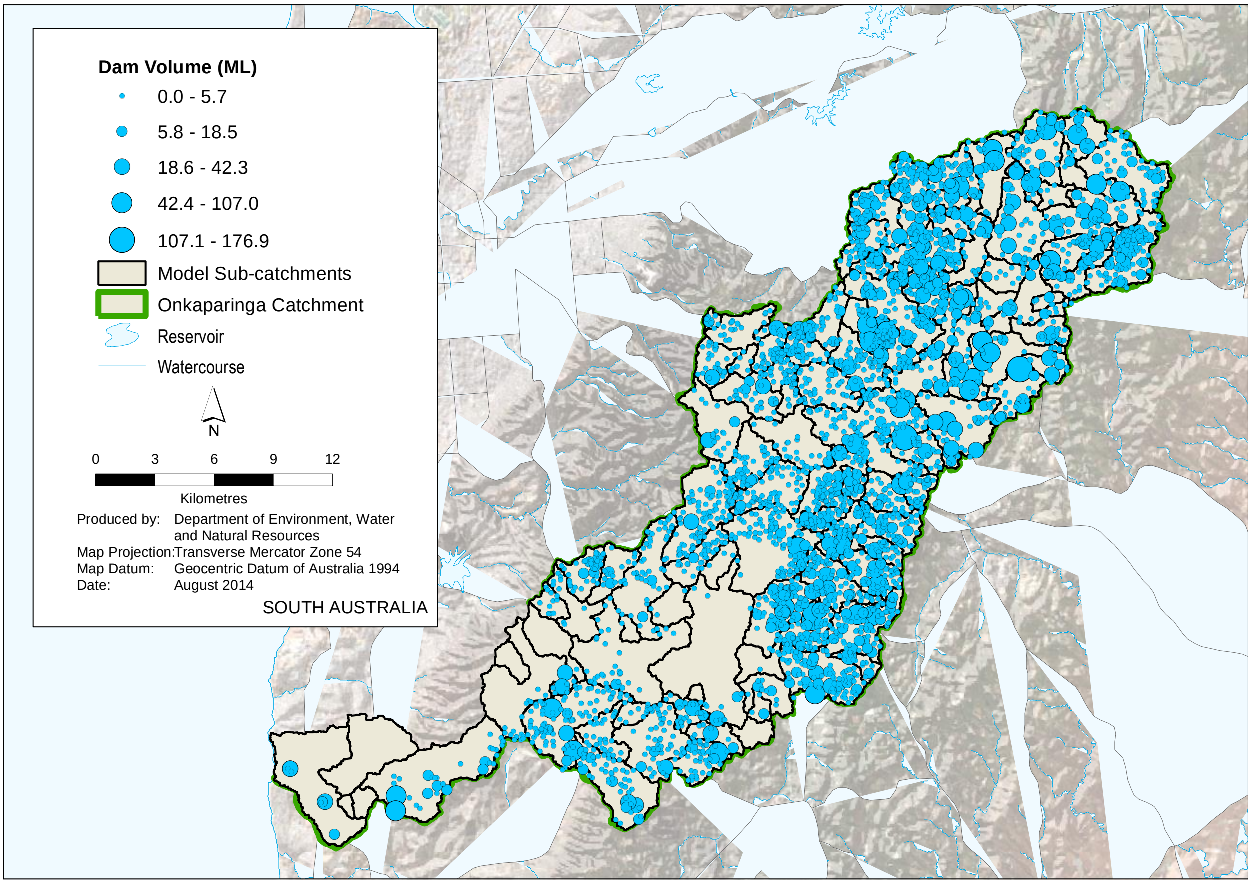


Figure 3. Location and relative capacity of farm dams in the Onkaparinga catchment

This resulted in an estimate of approximately 12,800 ML. Expressed as a spatial density, this equates to 23 ML/km^2.

When applied to sub-catchments in the model these dams are aggregated together to form one storage node at the outlet of each area. There are 114 sub-catchments in the model. The average volume of farm dams represented by each catchment is 28 ML with a minimum of 0 (no dams present) to a maximum of 462 ML. This results in an approximately uniform distribution of dam capacities, which is somewhat of a by-product of the process of management zone delineation in the first instance.

Due to farm dams being lumped at the end of a sub-catchment it was necessary to introduce a “diversion fraction” to the farm dam model plug-in. The concept of this is that if dams within the sub-catchment are spread out spatially and do not necessarily capture all of the flows within a sub-catchment then only a fraction of the flow generated within the sub-catchment is diverted to the farm dam node.

The appendix provides a list of farm dam input data including aggregated volume, surface area estimates and diversion fractions.

Figure 4 shows the frequency of different densities across the modelled sub-catchments.

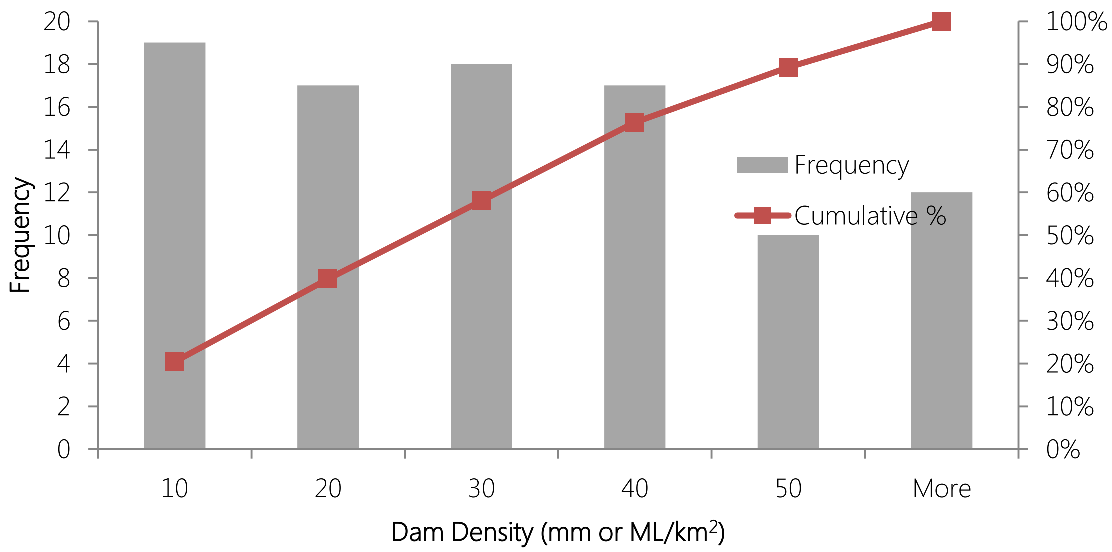


Figure 4. Histogram showing distribution of dam density by modelled sub-catchment

2.4 Functional Units and Land Use Classification

Functional Units (FUs) are classified within the Source model to group units of approximately similar hydrological response. This study employed two distinct FUs to describe the landscape of the Onkaparinga. This method was chosen for model parsimony as recent studies showing that two classifications, namely forested (F1) and non-forested (pasture, P1), produce a suitable representation of runoff in ungauged catchments (Vaze et al, 2011).

Using a spatial representation of catchments firstly allows the use of different climate files to be used across the landscape. Secondly, the splitting of the catchment into discrete hydrologic units allows differently defined areas to produce different runoff responses. It thus allows the model to produce a similar pattern of runoff in areas where no gauged data is available. This is essentially a form of sub-catchment grouping, or regionalisation.

The decision to use the rainfall-runoff model GR4J, having been chosen for its low number of parameters without compromising model performance, would be rendered ineffective by increasing the number of parameter sets (FUs). This model has also demonstrated good performance on Australian catchments (Coran et al., 2012). With two FUs the model effectively has 8 rainfall-runoff model parameters to calibrate.

The Land Use data set from the AMLR Region, mapped in 2007 (ALUM, 2007) was used to generate a map of FUs by assigning one of the two FU types (forest or pasture) to individual land use classifications (Table 1).

Table 1. Functional units assigned by land use class

Functional Unit	Land Use Description	Area km^2	% of Total Area
F1	Residual native cover	45.60	8%
F1	Managed resource protection	33.60	6%
F1	Nature conservation	29.51	5%
F1	Plantation forestry	13.69	2%
P1	Grazing modified pastures	203.36	36%
P1	Residential	69.92	12%
P1	Irrigated perennial horticulture	54.63	10%
P1	Transport and communication	22.42	4%
P1	Unmapped	19.15	3%
P1	Cropping	18.36	3%
P1	Irrigated modified pastures	14.04	3%
P1	Services	11.52	2%
P1	Reservoir/dam	7.00	1%
P1	Other	6.55	1%
P1	Irrigated seasonal horticulture	3.92	1%
P1	Irrigated cropping	1.71	0%
P1	Mining	1.29	0%
P1	Utilities	0.93	0%
P1	Waste treatment and disposal	0.70	0%
P1	Intensive animal production	0.62	0%
P1	Intensive horticulture	0.34	0%
P1	Manufacturing and industrial	0.31	0%
P1	Irrigated land in transition	0.27	0%
P1	Perennial horticulture	0.24	0%
P1	River	0.08	0%
P1	Irrigated plantation forestry	0.06	0%
P1	Estuary/coastal waters	0.01	0%
Total		***559.82***	***100%***

2.5 Climate data

2.5.1 Source

Climate data used in the model are the SILO Patched Point Dataset (Jeffrey et al., 2001) using all rainfall sites included in the Bureau of Meteorology Australian Data Archive for Meteorology (ADAM) database. There are 28 rainfall stations within and nearby the Onkaparinga Catchment.

Potential evaporation data is calculated using the FAO56 Method and is provided as part of the SILO database.

2.5.2 Processing steps

Climate data was assigned to sub-catchments using the Thiessen Polygons method. Figure 5 below shows the Thiessen Polygons used and the locations of the rainfall stations, including several outside of the watershed.

Where a sub-catchment overlaps more than one of these polygons, the station assigned to the sub-catchment is the one with the largest coinciding area. Most sub-catchments however are entirely covered by a single Thiessen polygon.

As climate data are assigned to just one climate station, no further data manipulation is required beyond the infilling and disaggregation of the original data which is completed in the SILO database. Assigning a single station to a sub-catchment also avoids the problem of "drizzle", an artefact often seen in spatially averaged rainfall data sets where consistently small portions of rainfall continue to be observed, caused by the interpolation process.

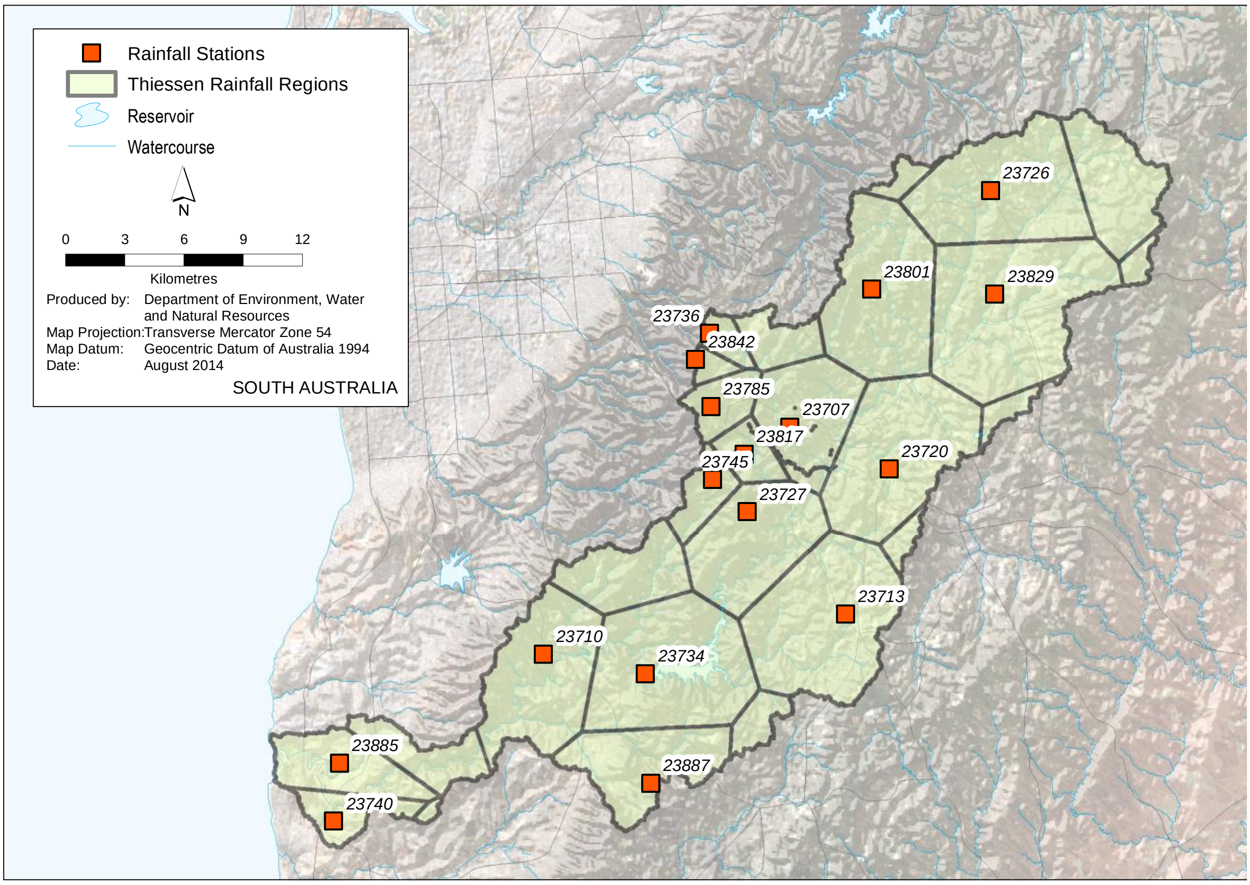


Figure 5. Location of rainfall stations and Thiessen polygons

2.6 Inflow from the River Murray at Hahndorf dissipator

Just downstream of Hahndorf Creek, between the gauging stations A5030504 and A5031001 exists the Hahndorf dissipator which delivers water from the Murray Bridge–Onkaparinga pipeline. Water is pumped into the Onkaparinga River main channel, normally during summer months, to supplement the supply to Mt Bold Reservoir.

To account for these inflows additional water is introduced into the model with an inflow node. Inflows here were calculated using an unaccounted difference approach with a maximum flow of 300 ML/day. The unaccounted difference refers to a method where the model is run with all upstream gauges turned on as inflow nodes and no inflows pumping in from the pipeline. This way the difference in modelled flows with gauged flows at Houlgraves weir represents the pumping from the River Murray and any additional small catchment flows between the upstream gauges and the pump.

The maximum inflow rate was determined by analysing the level of flows over summer months at Houlgraves weir (A5030504) that would generally be due to pumping. Any modelled inflows were also removed from the flow at Houlgraves to give an estimate of the additional inflows from the pipeline. Figure 6 shows a histogram of daily gauged flows at Houlgraves weir during January–March. Most flows (67%) are below 150 ML/d whilst 99% of these flows are less than 350 ML/d.

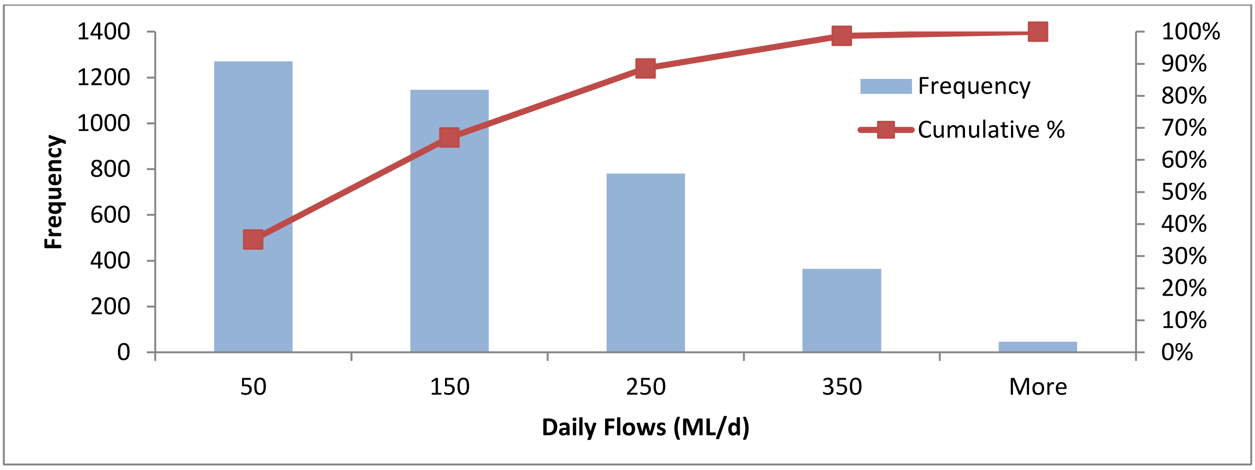


Figure 6. Distribution of gauged daily flows during the dry season, used to derive additional inflows

3 Results

Calibration of the GR4J rainfall runoff model was performed using the inbuilt calibration routine in the eWater Source platform using the Shuffled Complex Evolution method (SCE). The optimal set of rainfall-runoff parameters was determined by minimizing the difference between modelled and gauged flows. Stations used for model calibration are shown in Table 2 and Figure 7.

A combined objective function was used, made up of seven streamflow gauging stations with a combined Square Root Nash-Sutcliffe Efficiency and daily bias objective function. This objective function was found by Hughes et al. (2014) to create a reasonable balance between low flow calibration and overall bias. Each calibration gauge was given equal weighting.

The calibration period was 1986–2013 to match the period used for calibration by Teoh (2001) and extended to include more recent data. This 27-year period has been used to encapsulate a range of climatic conditions including extremely wet (early 1990s) and longer dry periods (2006–09).

Table 2. Surface water gauging stations used in the calibration

Site Number	Site Name	Watershed Area (km^2)	Upstream Gauges
A5030502	Scott Creek	27	-
A5030503	Bakers Gully	48	-
A5030504 (M523726)	Houlgraves Weir	321	A5030507, A5031001, A5030509
A5030506	Echunga Creek	34	-
A5030507	Lenswood	17	-
A5030509	Aldgate Creek	8	-
A5031001	Onkaparinga River U/S Hahndorf dissipator	227	A5030507

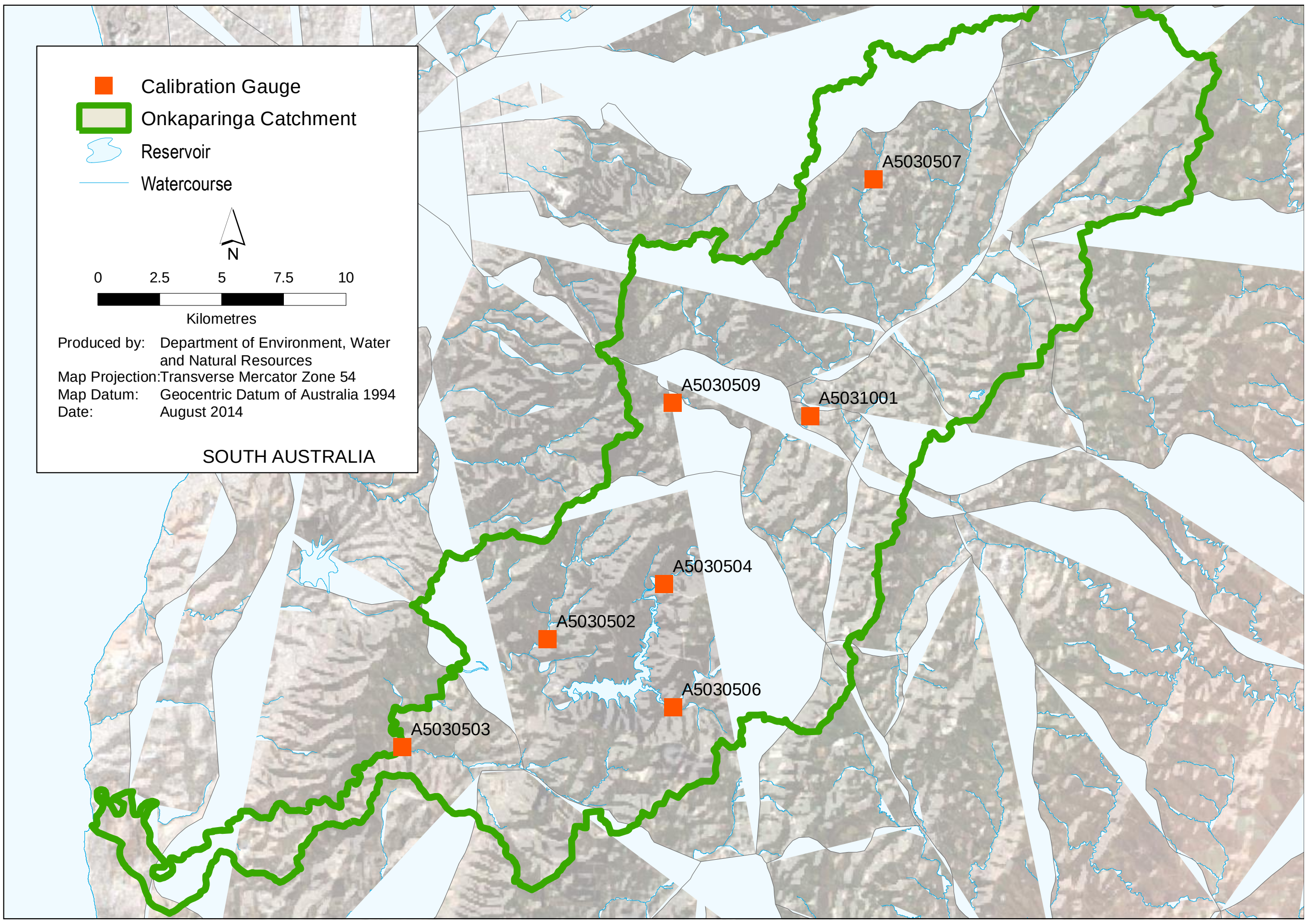


Figure 7. Location of gauging stations used in the calibration process

3.1 Calibration results

Results for the calibration of the combined objective function are described below.

Plots of results included are:

- Scatterplot of daily observed flows vs. modelled flows (ML/d)
- Total monthly observed and modelled flows (ML)
- Daily flow duration curve (ML/d)
- Total annual observed and modelled flow (ML)

The following statistics are also reported for each temporal period (daily, monthly and annual):

- %Bias: the percentage difference between observed and modelled flows.
- Pearson's R-Squared: A measure of model fit varying from 0–1 with 1 indicating a perfect fit.

$$R^2 = \left\{ \frac{\sum_{i=1}^{N} \left(O_i - \overline{O}\right)\left(P_i - \overline{P}\right)}{\left[\sum_{i=1}^{N} \left(O_i - \overline{O}\right)\right]^{0.5} \left[\sum_{i=1}^{N} \left(P_i - \overline{P}\right)\right]^{0.5}} \right\}^2$$

- Coefficient of efficiency (Nash-Sutcliffe efficiency): A measure of model fit which varies for –infinity to 1 with 1 indicating a perfect fit. Good results are generally 0.7 or higher.

$$E = \frac{\sum_{i=1}^{N} \left(O_i - P_i\right)^2}{\sum_{i=1}^{N} \left(O_i - \overline{O}\right)}$$

Where:

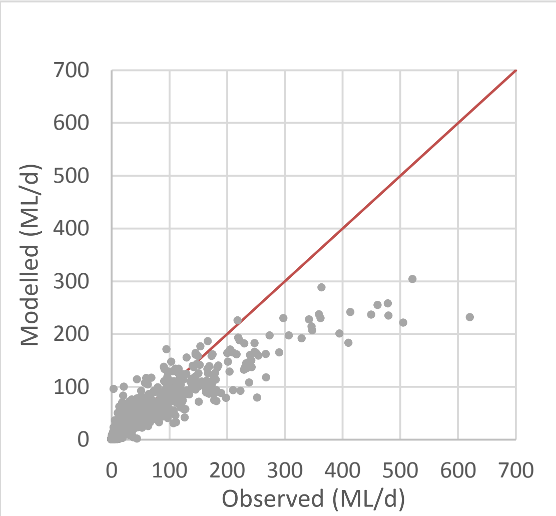
N = number of observations

O = Observed Runoff

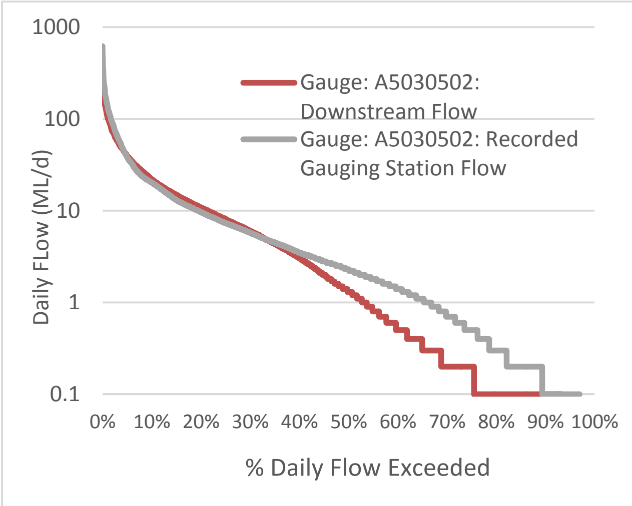
P = Predicted (modelled runoff)

3.1.1 A5030502: Scott Creek

Statistic	Daily	Monthly	Annual
R-Squared	0.86	0.96	0.95
CE	0.82	0.94	0.86
Bias	-13%	-13%	-13%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

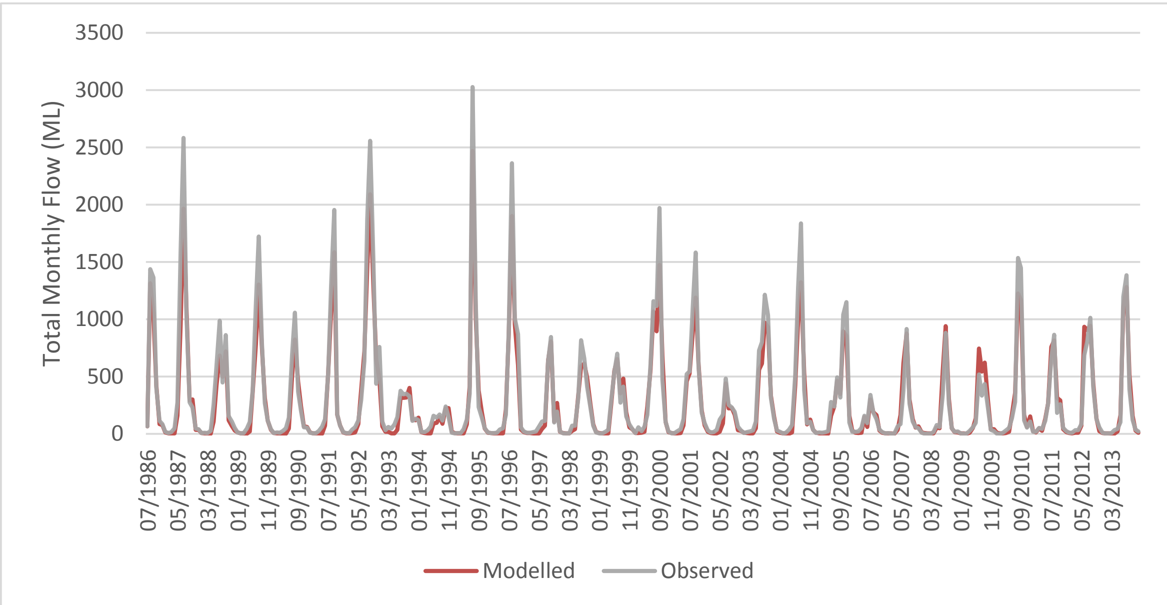
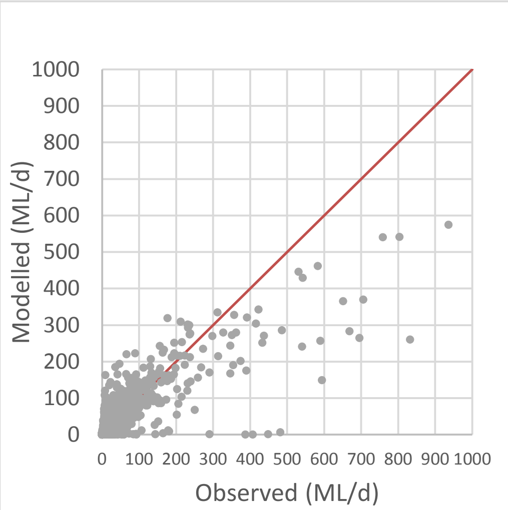


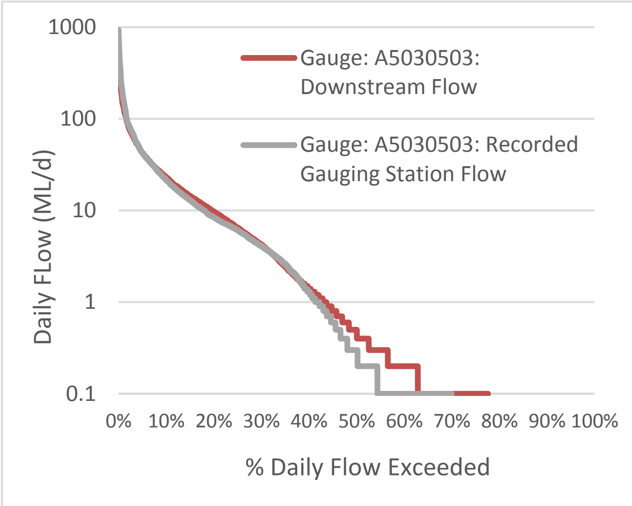
Figure 8. Calibration results for site A5030502 – Scott Creek

3.1.2 A5030503: Baker Gully

Statistic	Daily	Monthly	Annual
R-Squared	0.70	0.76	0.68
CE	0.69	0.76	0.67
Bias	-7%	-7%	-7%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

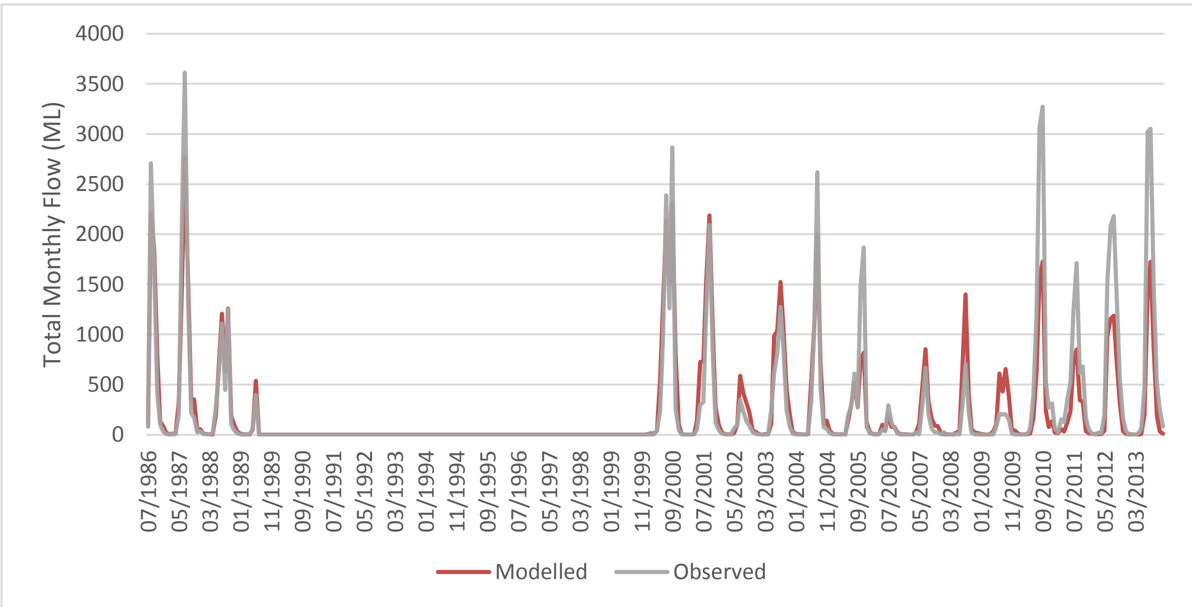
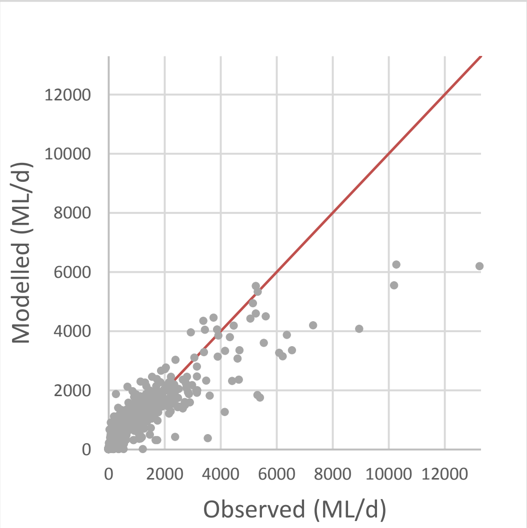


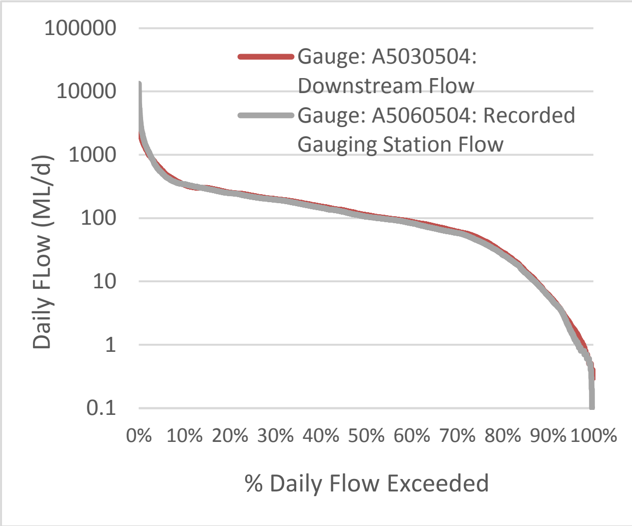
Figure 9. Calibration results for site A5030503 – Baker Gully

3.1.3 A5030504: Houlgraves Weir

Statistic	Daily	Monthly	Annual
R-Squared	0.84	0.94	0.89
CE	0.82	0.94	0.87
Bias	-1%	-1%	-1%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

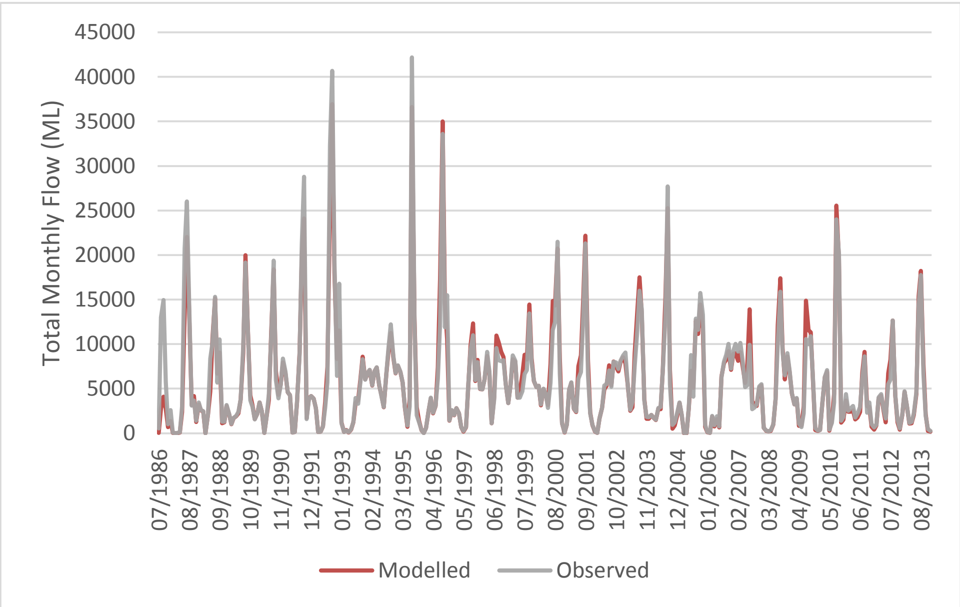
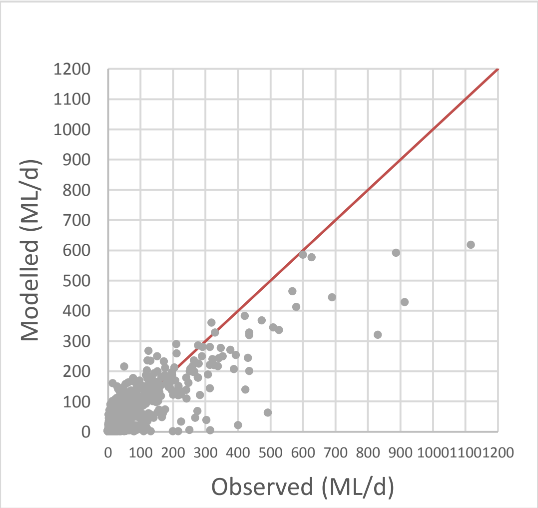


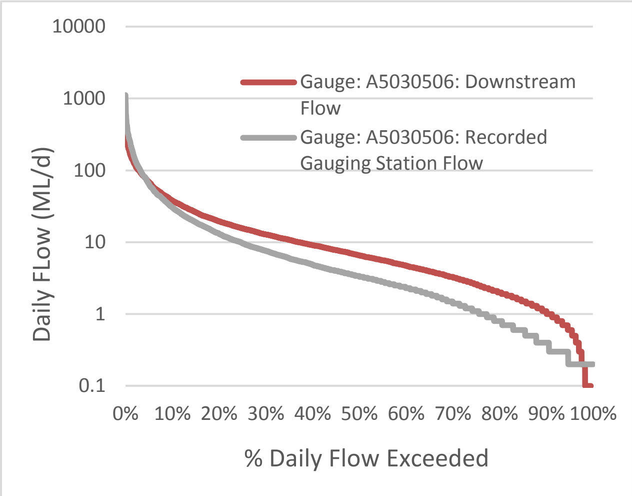
Figure 10. Calibration results for site A5030504 – Houlgraves Weir

3.1.4 A5030506: Echunga Creek

Statistic	Daily	Monthly	Annual
R-Squared	0.76	0.86	0.79
CE	0.75	0.86	0.78
Bias	6%	6%	6%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

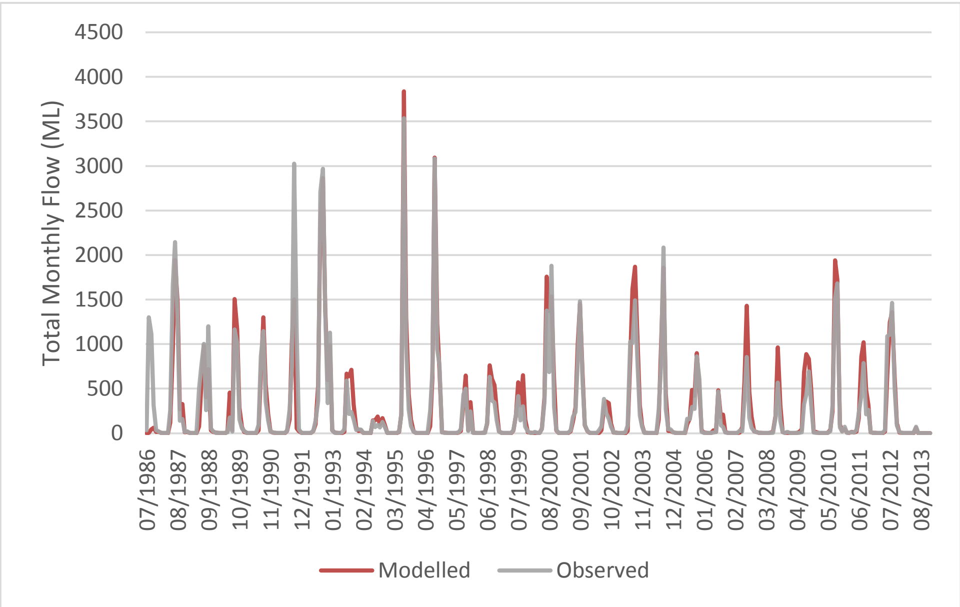
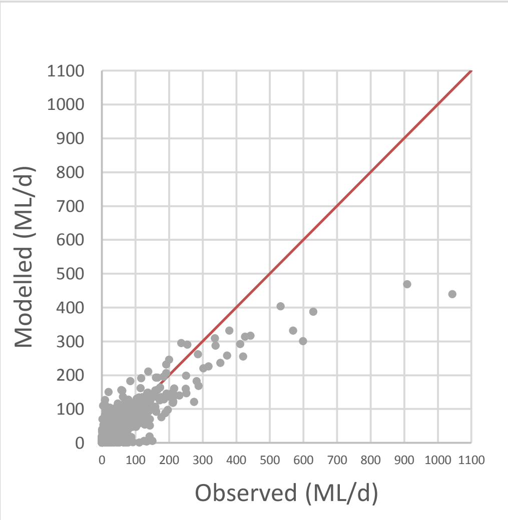


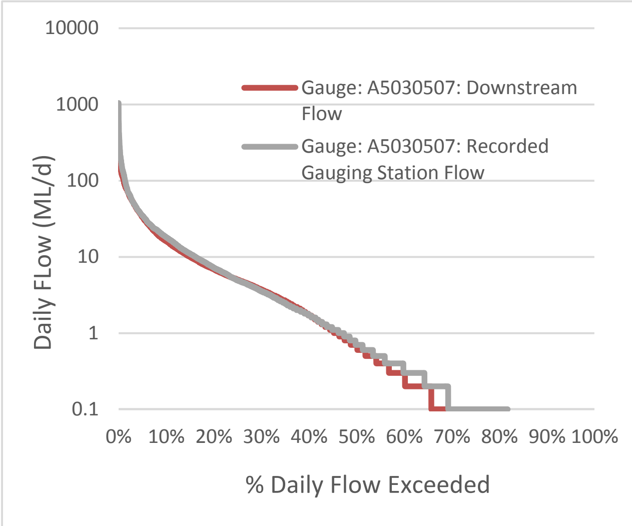
Figure 11. Calibration results for site A5030506 – Echunga Creek

3.1.5 A5030507 Aldgate Creek

Statistic	Daily	Monthly	Annual
R-Squared	0.81	0.88	0.78
CE	0.78	0.86	0.75
Bias	-17%	-17%	-17%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

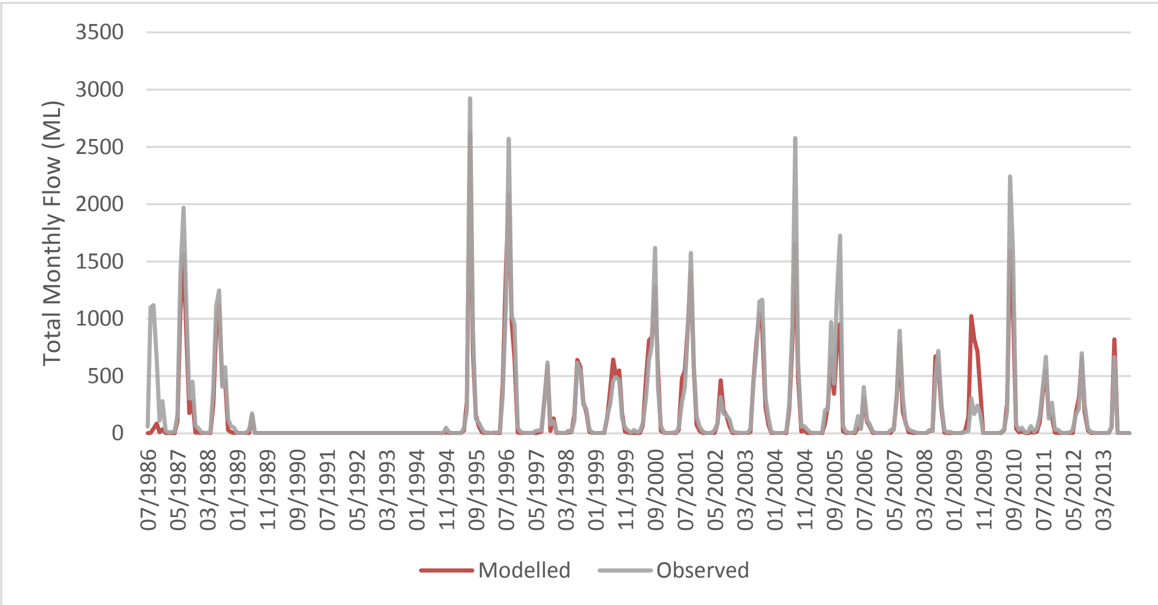
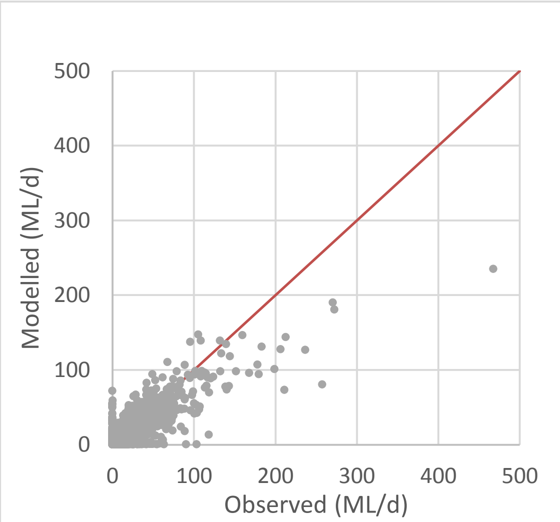


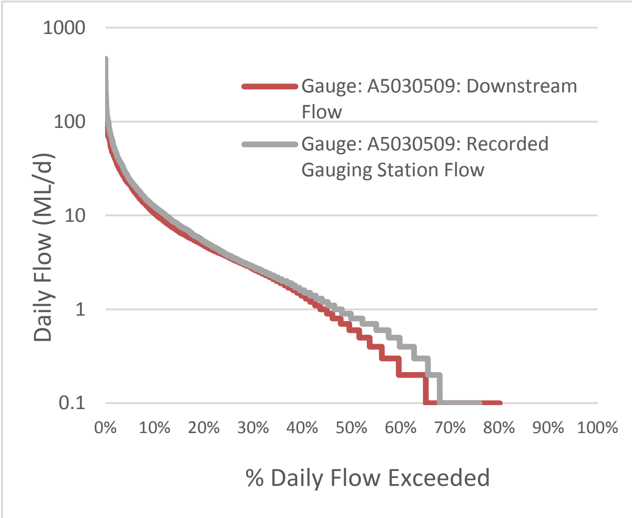
Figure 12. Calibration results for site A5030507 – Aldgate Creek

3.1.6 A5030509 Lenswood Creek

Statistic	Daily	Monthly	Annual
R-Squared	0.75	0.83	0.72
CE	0.74	0.83	0.70
Bias	-11%	-11%	-11%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

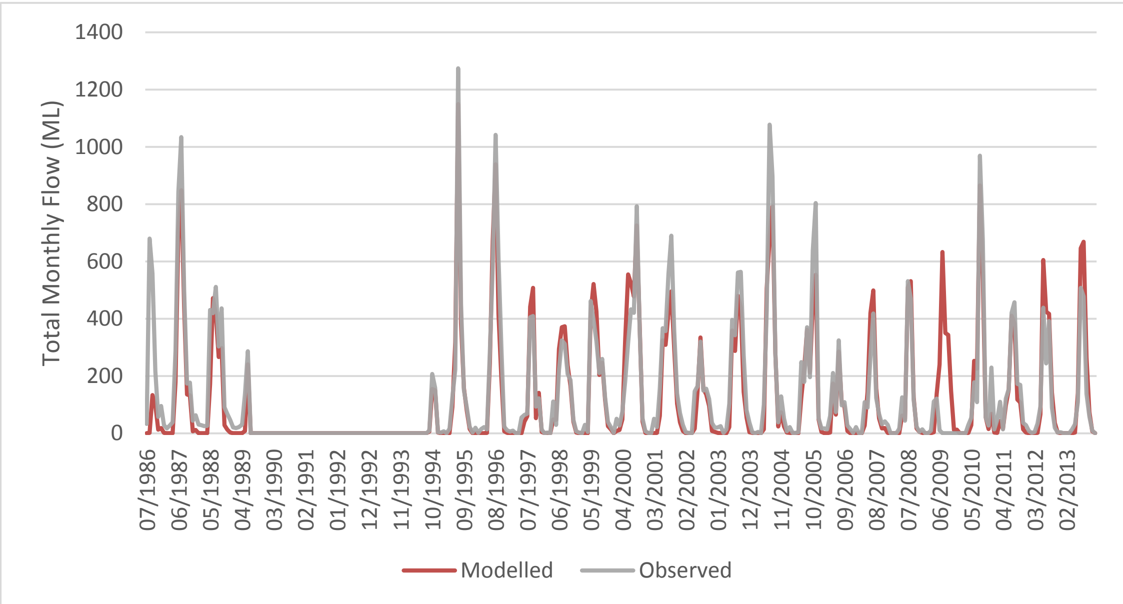
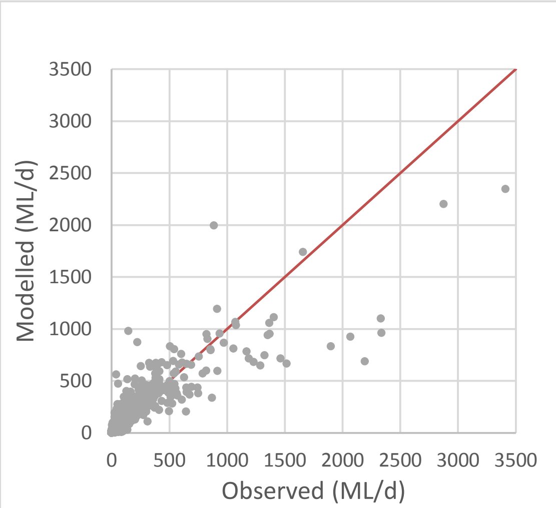


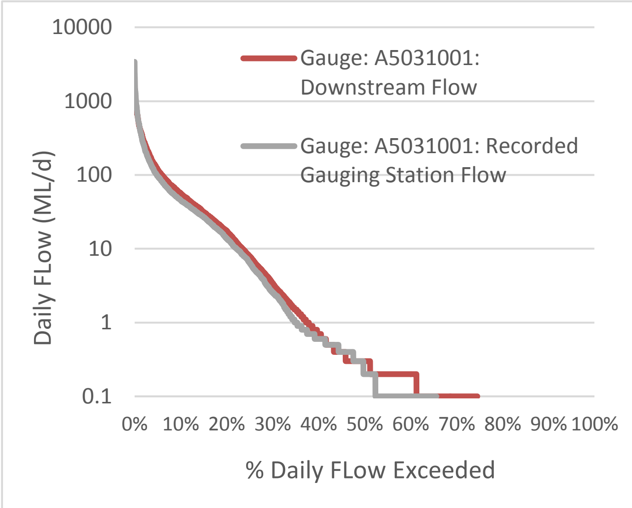
Figure 13. Calibration results for site A5030509 – Lenswood Creek

3.1.7 A5031001 Onkaparinga River upstream of Hahndorf dissipator

Statistic	Daily	Monthly	Annual
R-Squared	0.79	0.95	0.97
CE	0.78	0.95	0.97
Bias	4%	4%	4%



Scatterplot daily observed vs. modelled flow



Daily Flow Duration Curve

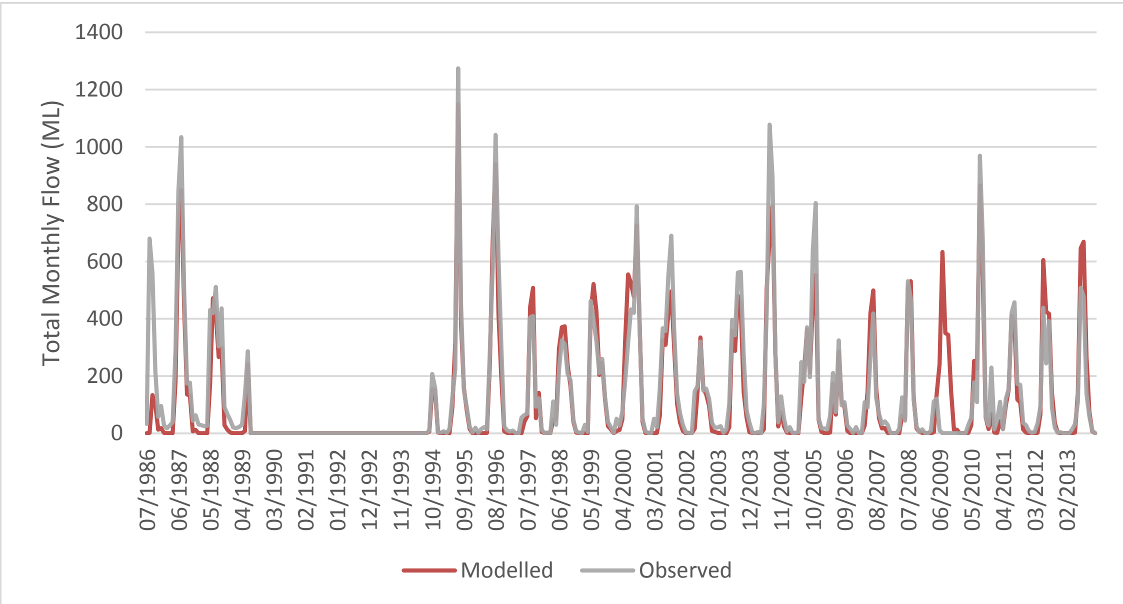


Figure 14. Calibration results for site A4261001 Onkaparinga River upstream of Hahndorf dissipator

3.2 Calibrated parameter values for each functional unit

Table 3 shows the calibrated parameter values for each FU.

Table 3. Functional unit calibrated parameters

GR4J parameter (units)	Functional unit F1	Functional unit P1
x1 (mm)	500.10	393.78
x2 (mm)	-9.99	-2.29
x3 (mm)	48.60	14.22
x4 (day)	2.30	1.21

The calibrated parameter values result in different runoff characteristics that represent the conceptually derived differences between runoff from forested or residual native cover and those that are pastured or otherwise not heavily covered by vegetation. Notionally it would be expected the forested (F1) FU to contribute less runoff than the pasture (P1) FU. This is indeed what was observed after calibration of these parameter sets.

Figure 15 below shows the rainfall-runoff curves for the two types of FU (forested and pasture) for sub-catchment SC #3478, located in the upper reaches of the Onkaparinga catchment, with a Tanh function fitted to each set. At the mean annual rainfall of 700 mm for this sub-catchment, the pasture (P1) FU produces approximately 56% more runoff than the forested (F1) FU.

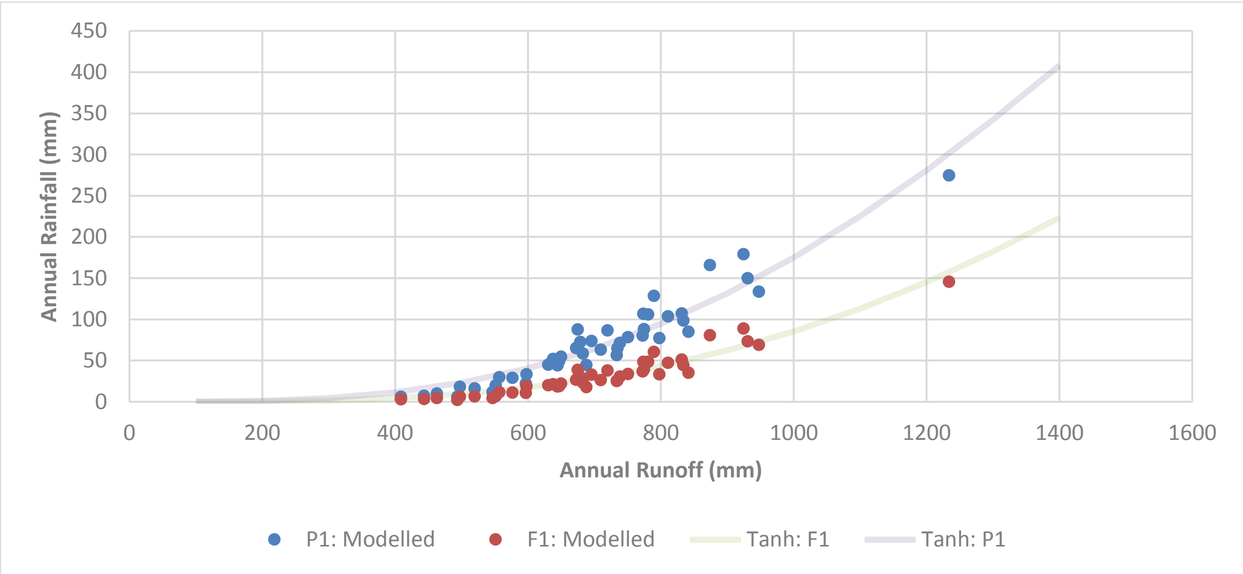


Figure 15. Rainfall-runoff curves for functional units pasture (P1) and forested (F1) for sub-catchment #3478

4 Discussion

Model performance is generally good (daily NSE 0.69-0.82), where typically 0.7 is accepted as good model performance. This result was achieved with a very parsimonious model with only 8 parameters across 2 functional units. In terms of runoff from the two defined hydrological units (functional units) of forested and pasture land, model results were logical with less runoff occurring from forestry compared to pasture.

Biases indicate overall modelled volumes are generally lower than observed (with the exception of Echunga and Onkaparinga US dissipator gauging stations). Related to this, the scatter plots indicate that higher flows are systematically underestimated.

Low flow results as indicated by the flow duration curve show good agreement at three of six gauges, namely gauges A5030504, A5030507, and A5030509, fair agreement at site A5030503, and relatively poor agreement for gauging stations A5030502 and A5030506. It is thought that the use of only two functional units and a combined objective function to calibrate the entire model may impact on the quality of low flow calibration at some gauges. The introduction of more classifications for FUs may improve this aspect, however at the expense of having a more complex model.

This model is primarily set up for use as a farm dam and water allocation impact tool. River operations aside from the inflows downstream of Hahndorf are not explicitly modelled, so flows modelled flows below Mt Bold and Clarendon Weir may not be used for analysis of environmental flows.

5 Conclusion

Using newly developed and improved plug-ins in the eWater Source modelling platform, this project was able to build and calibrate a rainfall runoff model of the Onkaparinga catchment located in the Mount Lofty Ranges of South Australia.

The model was able to satisfactorily model runoff volumes and timings using a functional unit approach to represent two different land cover categories over the catchment namely pasture and forest. This approach was different from the previously calibrated model of the catchment by Teoh (2001) which used individual parameter sets (or FUs) for each calibrated sub-catchment, combined with a nearest neighbour approach. Despite the difficulty in calibrating using a combined objective function using seven streamflow gauges, the results of the calibration are encouraging as a feasible approach to calibrating rainfall-runoff models in this way. This method could be particularly useful when modelling ungauged catchment areas. Whilst the Onkaparinga has a very good network of streamflow gauges, many other catchments in the Mount Lofty Ranges do not.

As previously stated the potential future uses of the model include:

1. Input of results into the risk assessment module for further water planning and management.
2. Outputs of future management scenarios to be used in environmental water requirements studies and ecological response models.
3. Assessment of alternate water management assumptions including low flow release studies and water allocation.

6 Appendix

Hydro ID	*Surface water management zone (Gauge No.)*	*Zone*	*Sub-catchment name*	*Dam Node Name*	*Number of dams in sub-catchment*	*Dam capacity in sub-catchment (ML)*	*Total Dam Surface Area (Ha)*	*Diversion Fraction*	*Sub-catchment Area (km^2)*
3478	CH01	CH01	SC #3478	D3478	50	129.36	7.89	0.41	9.03
3479	CH02	CH02	SC #3479	D3479	14	122.40	5.26	0.69	3.87
3480	CH04	CH04	SC #3480	D3480	7	124.55	4.74	0.39	3.50
3481	CH03	CH03	SC #3481	D3481	35	211.78	10.37	0.58	7.12
3482	CH05	CH05	SC #3482	D3482	13	79.56	3.91	0.67	4.25
3483	CH07	CH07	SC #3483	D3483	28	156.57	7.99	0.76	4.69
3484	CH06	CH06	SC #3484	D3484	5	9.00	0.60	0.12	1.84
3485	CH08	CH08	SC #3485	D3485	35	183.01	9.02	0.74	10.12
3486	CH09	CH09	A5030903	D3486	11	38.72	2.21	0.49	3.24
3487	CH09	CH09	SC #3487	D3487	9	11.95	0.83	0.12	2.41
3488	IV03	IV03	SC #3488	D3488	17	95.26	4.97	0.26	5.62
3489	IV04	IV04	SC #3489	D3489	16	80.27	3.96	0.57	3.29
3490	IV03	IV03	A5030530	D3490	6	16.54	0.98	0.95	1.04
3491	IV01	IV01	SC #3491	D3491	21	60.11	3.55	0.87	3.46
3492	IV02	IV02	SC #3492	D3492	27	196.94	9.02	0.85	4.61
3493	MT03	MT03	SC #3493	D3493	18	251.21	9.85	0.85	6.54
3494	MT01	MT01	SC #3494	D3494	23	296.39	12.49	0.97	5.12
3495	MT02	MT02	SC #3495	D3495	8	61.00	2.77	0.62	2.47
3496	UP02	UP02	SC #3496	D3496	11	161.47	6.44	0.72	3.05
3497	UP01	UP01	SC #3497	D3497	15	72.89	3.71	0.14	3.24
3498	WB08	WB08	SC #3498	D3498	20	185.46	8.17	0.67	4.05
3499	UP03	UP03	SC #3499	D3499	23	59.48	3.54	0.40	4.68
3500	BH01	BH01	SC #3500	D3500	33	293.34	12.94	0.68	9.65
3501	UP08	UP08	SC #3501	-	-	-	-	-	0.15
3502	UP08	UP08	SC #3502	D3502	42	80.16	5.01	0.38	5.99
3503	UP09	UP09	SC #3503	D3503	86	389.52	19.30	0.66	11.04
3504	A5030537	HD04	SC #3504	D3504	31	97.60	5.20	0.93	4.30
3505	OM02	OM02	A5031001	D3505	1	0.38	0.04	0.01	0.14
3506	HD01	HD01	SC #3506	D3506	24	256.77	10.72	0.75	4.20
3507	HD02	HD02	SC #3507	D3507	27	139.53	6.80	0.86	2.58
3508	HD03	HD03	SC #3508	D3508	32	59.12	3.99	0.85	3.65
3509	BF02	BF02	SC #3509	D3509	30	64.85	3.97	1.00	2.20
3510	BF01	BF01	SC #3510	D3510	54	165.52	9.85	0.75	5.34
3511	BF03	BF03	SC #3511	D3511	45	195.78	10.30	0.98	4.79
3512	BF04	BF04	SC #3512	D3512	41	163.49	8.12	0.81	3.32
3513	BF05	BF05	SC #3513	D3513	63	249.85	13.58	0.93	6.20
3514	OM01	OM01	SC #3514	D3514	20	94.64	5.04	0.88	1.71
3515	OM03	OM03	SC #3515	D3515	29	103.11	5.88	0.86	1.94
3516	OM02	OM02	SC #3516	D3516	77	179.34	10.49	0.83	6.16
3517	AG03	AG03	SC #3517	D3517	72	136.53	8.83	0.54	6.76
3518	CX07	CX07	SC #3518	D3518	25	32.09	2.21	0.33	7.35
3519	CX03	CX03	SC #3519	D3519	29	94.41	5.36	0.77	5.35
3520	CX06	CX06	SC #3520	D3520	17	21.45	1.55	0.68	1.54

Hydro ID	Surface water management zone (Gauge No.)	Zone	Sub-catchment name	Dam Node Name	Number of dams in sub-catchment	Dam capacity in sub-catchment (ML)	Total Dam Surface Area (Ha)	Diversion Fraction	Sub-catchment Area (km^2)
3521	CX05	CX05	SC #3521	D3521	35	50.29	3.55	0.89	2.06
3522	CX03	CX03	A5031006	D3522	8	13.31	0.92	0.88	1.40
3523	CX04	CX04	SC #3523	D3523	33	81.81	4.83	0.95	2.56
3524	CX02	CX02	SC #3524	D3524	31	65.40	3.60	0.95	3.75
3525	CX01	CX01	SC #3525	D3525	21	21.85	1.67	0.38	4.39
3526	CX1	CX01	SC #3526	D3526	1	0.78	0.07	0.32	0.40
3527	CX01	CX01	A5030525	D3527	6	11.95	0.74	0.22	0.67
3528	BF06	BF06	SC #3528	D3528	14	126.87	5.58	0.88	1.83
3529	OM04	OM04	SC #3529	D3529	81	117.13	8.00	0.39	12.63
3530	OM06	OM06	SC #3530	D3530	14	41.77	2.35	0.03	22.49
3531	OM06	OM06	A5030529	-	-	-	-	-	0.57
3532	EC06	EC06	SC #3532	D3532	4	6.27	0.44	0.02	3.29
3533	EC08	EC08	SC #3533	D3533	9	20.66	1.30	0.46	3.55
3534	EC08	EC08	SC #3534	-	-	-	-	-	0.00
3535	OM11	OM11	SC #3535	-	-	-	-	-	0.64
3536	EC07	EC07	SC #3536	D3536	4	19.44	1.08	1.00	1.31
3537	EC01	EC01	SC #3537	D3537	12	46.77	2.38	0.83	1.60
3538	EC02	EC02	SC #3538	D3538	72	354.08	17.26	0.88	7.87
3539	EC03	EC03	SC #3539	D3539	82	311.50	16.75	0.62	8.70
3540	EC04	EC04	SC #3540	D3540	55	329.01	15.43	0.77	4.35
3541	EC05	EC05	SC #3541	D3541	62	358.73	17.32	0.73	8.00
3542	BK01	BK01	A5030505	-	-	-	-	-	2.19
3543	BK01	BK01	SC #3543	D3543	10	59.46	2.75	0.67	2.68
3544	BK02	BK02	SC #3544	D3544	25	81.12	4.26	0.84	2.34
3545	BK03	BK03	SC #3545	D3545	39	163.68	8.26	0.66	4.19
3546	BK04	BK04	SC #3546	D3546	52	79.92	5.22	0.69	9.01
3547	BK05	BK05	SC #3547	D3547	8	6.39	0.54	0.10	1.61
3548	BK06	BK06	SC #3548	D3548	29	33.87	2.59	0.55	3.71
3549	BK07	BK07	SC #3549	D3549	49	170.79	8.97	0.91	9.25
3550	BK08	BK08	SC #3550	D3550	83	282.97	14.31	0.66	11.59
3551	OM08	OM08	SC #3551	D3551	14	10.97	0.89	0.05	11.57
3552	OM11	OM11	A5030522	D3552	28	161.00	7.22	0.27	17.07
3553	OM11	OM11	A5031005	-	-	-	-	-	1.45
3554	OM12	OM12	SC #3554	D3554	7	104.83	4.64	0.09	15.18
3555	OM12U	OM12U	SC #3555	-	-	-	-	-	9.93
3556	OM09	OM09	SC #3556	D3556	6	31.83	1.47	0.81	0.90
3557	OM10	OM10	SC #3557	-	-	-	-	-	2.05
3558	OM08	OM08	A5031004	D3558	2	33.09	1.34	0.00	4.87
3559	OM06	OM06	A5030500	D3559	34	35.47	2.63	0.23	15.13
3560	AN04	AN04	SC #3560	D3560	9	6.58	0.55	0.23	4.50
3561	AN03	AN03	SC #3561	D3561	11	8.88	0.72	0.62	2.04
3562	AN02	AN02	SC #3562	D3562	36	90.60	5.61	0.86	3.87
3563	AN01	AN01	SC #3563	D3563	15	35.89	2.24	0.62	3.68
3564	SC03	SC03	A5030502	D3564	49	65.18	4.47	0.93	9.68
3565	SC03	SC03	SC #3565	-	-	-	-	-	0.98
3566	SC02	SC02	SC #3566	D3566	35	52.89	3.74	0.73	4.07
3567	SC01	SC01	SC #3567	D3567	98	148.75	10.07	0.77	10.45

Hydro ID	Surface water management zone (Gauge No.)	Zone	Sub-catchment name	Dam Node Name	Number of dams in sub-catchment	Dam capacity in sub-catchment (ML)	Total Dam Surface Area (Ha)	Diversion Fraction	Sub-catchment Area (km^2)
3568	OM05	OM05	SC #3568	D3568	3	5.24	0.38	0.03	2.26
3569	AG01	AG01	SC #3569	D3569	20	58.35	3.00	0.81	7.73
3570	AG02	AG02	SC #3570	D3570	45	74.24	4.89	0.51	4.99
3571	UP07	UP07	SC #3571	D3571	49	90.86	5.71	0.77	5.35
3572	UP05	UP05	SC #3572	D3572	37	88.67	5.45	0.93	4.25
3573	UP06	UP06	SC #3573	D3573	33	111.76	6.47	0.98	2.89
3574	UP04	UP04	SC #3574	D3574	67	461.96	20.12	0.97	6.64
3575	LW06	LW06	SC #3575	D3575	56	315.25	15.61	0.48	9.13
3576	WB07	WB07	SC #3576	D3576	39	379.92	16.63	0.93	4.59
3577	LW04	LW04	SC #3577	D3577	18	76.61	4.10	0.91	1.75
3578	LW05	LW05	SC #3578	D3578	4	27.69	1.45	0.28	0.78
3579	LW05	LW05	SC #3579	D3579	15	97.05	4.41	0.38	1.58
3580	LW01	LW01	SC #3580	D3580	69	280.96	15.62	1.00	6.45
3581	LW02	LW02	SC #3581	D3581	36	197.12	10.00	0.82	5.08
3582	LW03	LW03	SC #3582	D3582	34	101.63	5.92	0.67	3.81
3583	WB06	WB06	SC #3583	D3583	36	213.04	10.23	0.82	4.15
3584	WB05	WB05	SC #3584	D3584	28	116.70	6.07	0.45	4.97
3585	WB04	WB04	SC #3585	D3585	12	44.57	2.48	0.76	2.08
3586	WB01	WB01	SC #3586	D3586	22	139.35	6.12	0.58	6.18
3587	WB02	WB02	SC #3587	D3587	37	229.29	10.64	0.72	5.06
3588	WB03	WB03	SC #3588	D3588	13	61.47	3.13	0.59	1.74
3589	IV01	IV01	A5030508	D3589	80	400.90	19.97	1.00	8.32
3590	CH06	CH06	A5030531	D3590	6	59.10	2.30	0.29	1.04
3591	SC03	SC03	A5030545	D3591	3	3.72	0.29	0.02	3.19

7 Units of measurement

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

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

8 Glossary

BoM — Bureau of Meteorology, Australia

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

DEWNR — Department of Environment, Water and Natural Resources (Government of South Australia)

d/s — Downstream

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

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

Flow regime — The character of the timing and amount of flow in a stream

GIS — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

MLR — Mount Lofty Ranges

Model — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change

Percentile — A way of describing sets of data by ranking the dataset and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

Sub-catchment — The area of land determined by topographical features within which rainfall will contribute to run-off at a particular point

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

Tributary — A river or creek that flows into a larger river

u/s — Upstream

WAP — Water Allocation Plan; a plan prepared by a Natural Resources Management Board or water resources planning committee and adopted by the Minister in accordance with the Act

WMLR — Western Mount Lofty Ranges

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