Prepared for
MidCoast Council
ABN: 44 961 208 161

DRAFT

Water Yield Assessment Report

29-Jun-2023
Integrated Water Management Strategy

D R A F T

Water Yield Assessment Report

Client: MidCoast Council

ABN: 44 961 208 161

Prepared by

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29-Jun-2023

Job No.: 60696228

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Quality Information

Document Water Yield Assessment Report

Ref 60696228

https://aecomaus.sharepoint.com/sites/midcoastiwcmoptionsandscenarios/shared documents/general/deliverables/options scenarios report/water yield assessment report/water yield assessment report rev1.docx

Date 29-Jun-2023

Originator Mark de Jong

Checker/s Janice Moody

Verifier/s Wesley Bailey

Revision History

Rev	Revision Date	Details	Approved	
			Name/Position	Signature
0	8-May-2022	Draft	Zena Smith-White Project Manager	
1	29-Jun-2023	Draft	Zena Smith-White Project Manager	

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1.0 Introduction

This report provides a summary of the water balance yield assessments for the Manning, Gloucester, Bulahdelah and Stroud water supply headworks systems. The primary purpose of this report was to inform the development of the MidCoast Council Integrated Water Cycle Management (IWCM) Strategy in accordance with DPIE Water recommended procedures.

2.0 Available Data

Table 1 provides a list of the available data used for the WBM.

Table 1 List of Available Data

Item	Data
Previous Reports	• *MidCoast Council Secure Yield Study* completed by NSW Urban Water Services Pty Ltd in October 2015 • *MidCoast Council Urban Water Supplies Secure Yield Study Stage 1* report completed by NSW Urban Water Services Pty Ltd in October 2021. • *Bulahdelah Weir Leakage Inspections Report* (Report no. DC13178) completed by MidCoast Water in October 2013 • *Manning District Water Supply Augmentation - Desk-Top Groundwater Resources Study* completed by PPK Environment & Infrastructure Pty Ltd for DPIE in 1999 • *Gloucester Off-River Water Storage Preliminary Investigations and Concept Design* completed by SMEC for MidCoast Council in September 2014 • *Stroud Water Supply Augmentation Concept Design Report* completed by the NSW Public Works in 1993 • *Stroud WS Off Stream Storage (drawings)* developed by Water Technologies, Dams and Civil Technologies for the NSW Department of Commerce in 2008 • *A Drought Like No Other - Managing Water Supply For The Midcoast Community During The 2019-2020 Drought* completed by MidCoast Council • *Stroud Water Supply Scheme Servicing Strategy* completed by MidCoast in 2017 • Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources 2009
Operating Procedures and Schematics	• *Standard Operating Procedure (SOP) – Karuah river cease to pump* Version 1, adopted 8 March 2019 • Manning Water Supply Scheme schematic dated 2021
Historical Operational Data	• Bulahdelah Water Treatment Plant (WTP) operational record: 2006 to 2022 • Gloucester WTP operational record: 2011 to 2022 • Manning WTP operational record: 2011 to 2022 • Stroud WTP operational record: 2013 to 2022
River Gauge Data	• DPIE stream gauging records available from the WaterNSW Real Time Water Monitoring Portal. The location and period of record of the river gauges selected for this study is provided in **Table 2**.
Topographic Data	• 1 metre Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) data captured for the NSW Foundation Spatial Data Framework (FSDF) in 2012 available from Geoscience Australia's Elvis portal. • Hydrologically enforced Shuttle Radar Topography Mission (SRTM) derived 1 Arc-second (~30 m) captured by the National Aeronautics and Space Administration (NASA) in 2000
Aerial Photography	Google Earth © 2022
Climate Data	• Rainfall and evaporation data from the SILO database were used for this investigation. SILO is a database of historical Australian climate data dating back from 1889 to present and is hosted online by the Queensland Department of Environment

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Item	Data
	and Science (DES) (DES, 2021). Data from SILO is available on a daily timestep. Table 3 provides a list of coordinates for the SILO grid points used by this study. • Climate change predictions (Representative Concentration Pathway 8.5) - - Rainfall change predictions from the NSW and Australian Regional Climate Modelling (NARCliM) climate dataset provided by AdaptNSW - Evaporation and evapotranspiration change predictions from CMIP5 datasets from the ACCESS1.3 coupled climate model developed by the Centre for Australian Weather and Climate Research

Table 2 Available River Gauges

Gauge Name	Gauge Location	Period of Record
208004	Manning River at Killawarra	01/06/1945 to Present (~77 years)
208005	Nowendoc River at Rocks Crossing	09/06/1945 to Present (~77 years)
208006	Barrington River at U/S Rocky Crossing	08/11/1945 to Present (~77 years)
208011	Barnard River at Mackay	02/08/1962 to Present (~60 years)
209002	Mammy Johnsons River at Pikes Crossing	19/12/1967 to Present (~55 years)
209003	Karuah River at Booral	30/10/1968 to Present (~54 years)
209006	Wang Wauk River at Willina	22/04/1969 to present (~53 years)
209018	Karuah River at Dam Site	18/12/1979 to Present (~46 years)

Table 3 SILO Grid Sample Locations

Study Catchment		
Myall River Catchment	Manning River Catchment	Karah River Catchment
• -32.40, 152.20 • -32.35, 152.20 • -32.40, 151.85 • -32.15, 152.25 • -32.20, 152.20 • -32.15, 152.20 • -32.45, 152.15 • -32.25, 152.15	• -31.70, 152.25 • -31.95, 152.00 • -31.80, 152.00 • -31.50, 152.05 • -31.50, 151.85 • -31.95, 151.60 • -31.65, 151.55 • -31.95, 152.40	• -32.35, 152.00 • -32.20, 151.95 • -32.25, 151.90 • -32.15, 151.75 • -32.35, 151.90

3.0 Hydrology

3.1 Approach

The Australian Water Balance Model (AWBM) was used to simulate catchment runoff from daily rainfall and evapotranspiration data for the WBM. The AWBM was also used by NUWS 2021 for the previous MidCoast secure yield assessment. The usage of the AWBM in both studies facilitates the comparison secure yield assessment results between the studies. Furthermore, GoldSim has developed a AWBM module for use in its software. **Figure 1** demonstrates the process the AWBM uses to convert rainfall and potential evapotranspiration data into runoff.

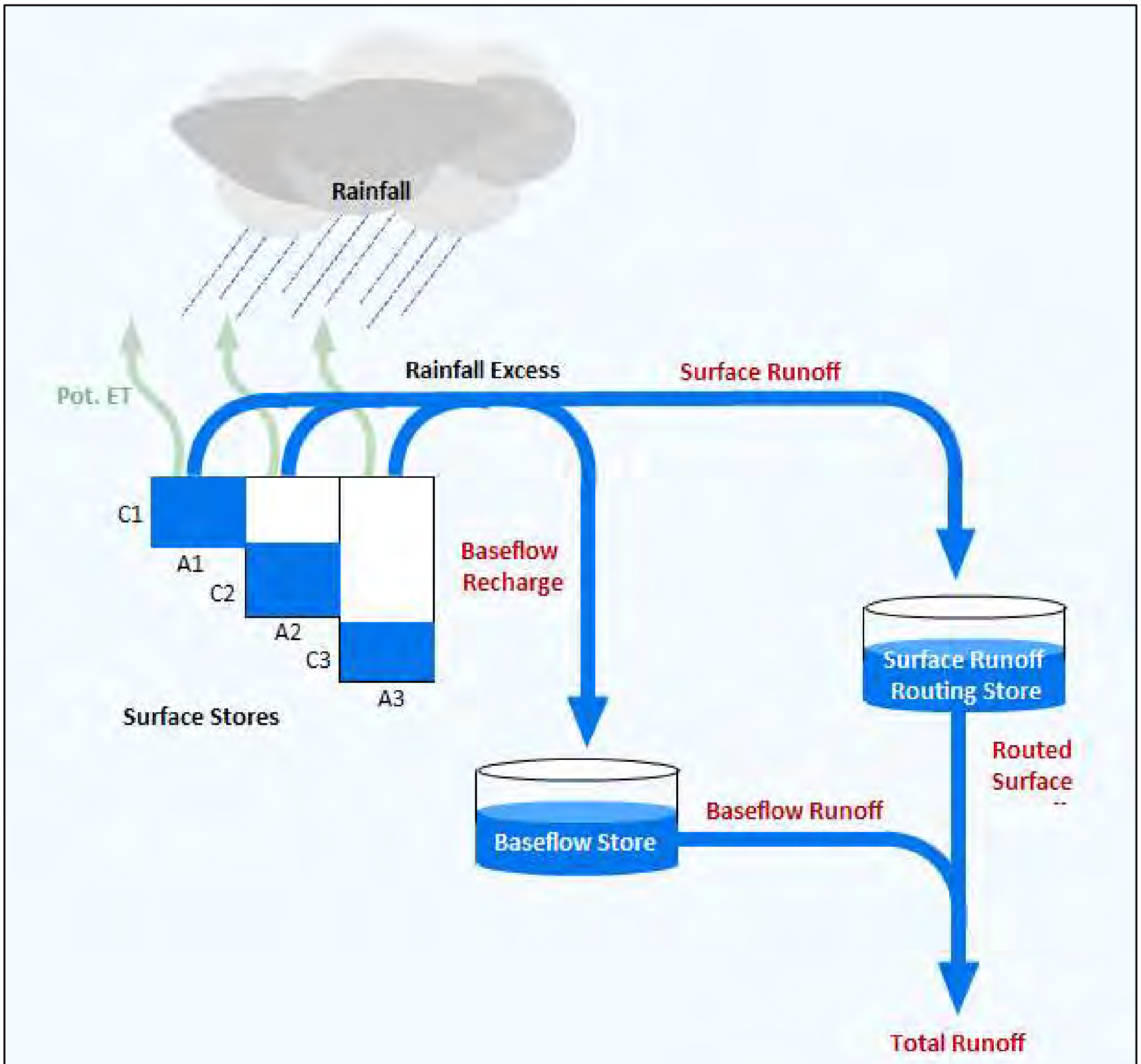

Figure 1 AWBM Process Flow Diagram

To determine representative parameters for the AWBMs used in the GoldSim WBMs, calibrated AWBMs were developed using eWater Source (Source) described in **Section 3.2**.

3.2 Model Calibration

This section provides a summary of the Source models used to determine the AWBM parameters for the GoldSim WBM. Source was selected for the determination of the AWBM parameters as it allows for:

- spatial variation of land uses across catchments
- spatial variation of climate data (rainfall and evapotranspiration) across catchments
- simulated calibration flow calibration to recorded flows at several river gauges across catchments.

3.2.1 Myall River Catchment

The layout of the Source model for the Myall River catchment is illustrated in **Figure 3**. The subcatchment contributing to Crawford Weir where WTP offtake is highlighted also in **Figure 3**. **Table 4** provides a summary of the Myall River Source model.

Table 4 Myall River Source Model Calibration

Parameter	Value	
River Gauge	DPIE Wang Wauk River at Willina (209006) gauge	
Stream Gauge Operation Period	22/04/1969 to present (~53 years)	
Gauge Catchment Area	150 km^2	
Distance Crawford Weir	29 km	
Calibration Period	22/04/1969 – 24/11/2022 (~53 years)	
Rainfall and Evapotranspiration Data	Spatially Varying – Data extracted from SILO data drill at catchment centroids	
Comparative Statistics for Runoff (Observed vs. Simulated)	Nash-Sutcliffe Log Daily Pearson's Correlation (r)	0.557 0.822
Calibrated AWBM Parameters (Applied Globally)	Partial Area Fractions: A1: 0.253 A2: 0.343 A3: 0.404 Surface Storage Capacities: C1: 50.0 mm C2: 88.8 mm C3: 159.4 mm Initial surface storage: 0% Base Flow Index (BFI): 0.890 Baseflow Recession Constant: 0.534 Initial baseflow runoff: 0 mm Surface Runoff Recession Constant: 0.966	
Duration Curve – Modelled vs observed	**Figure 2**	

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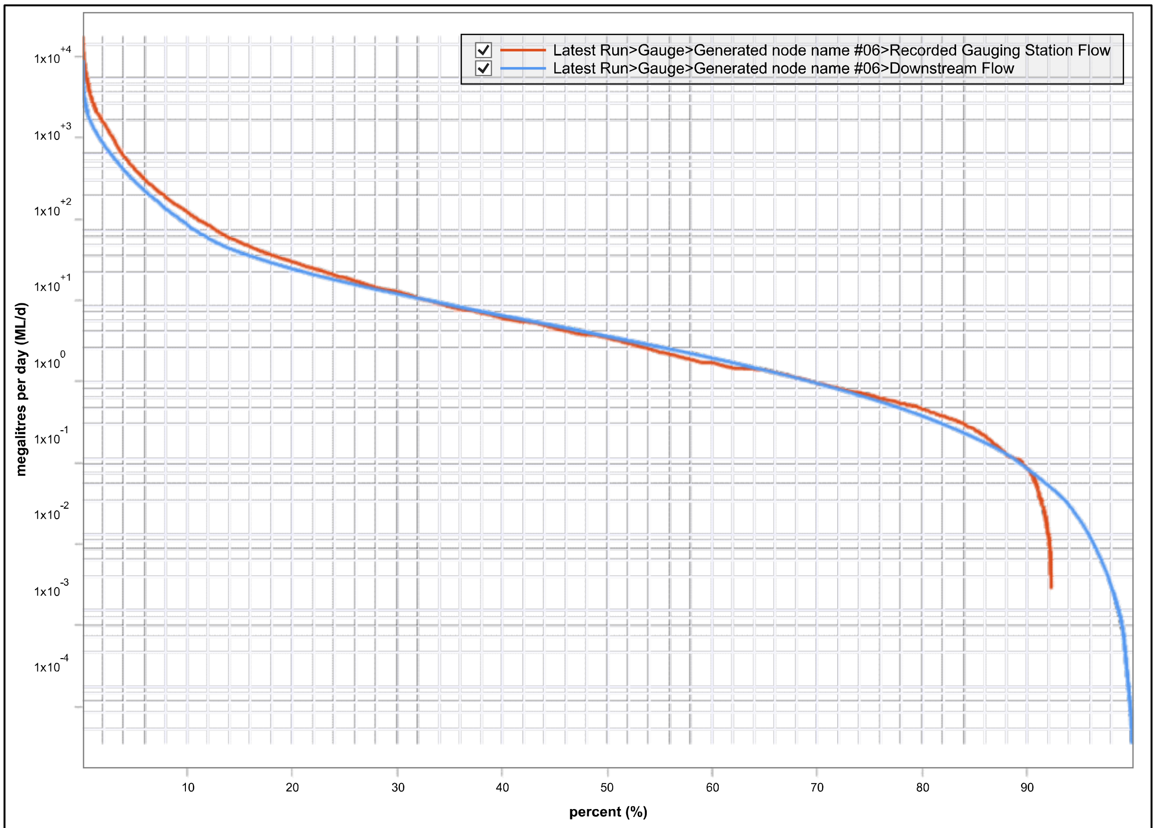


Figure 2 Duration Curve comparison between the Observed and Simulated Runoff at 209006

Discussion

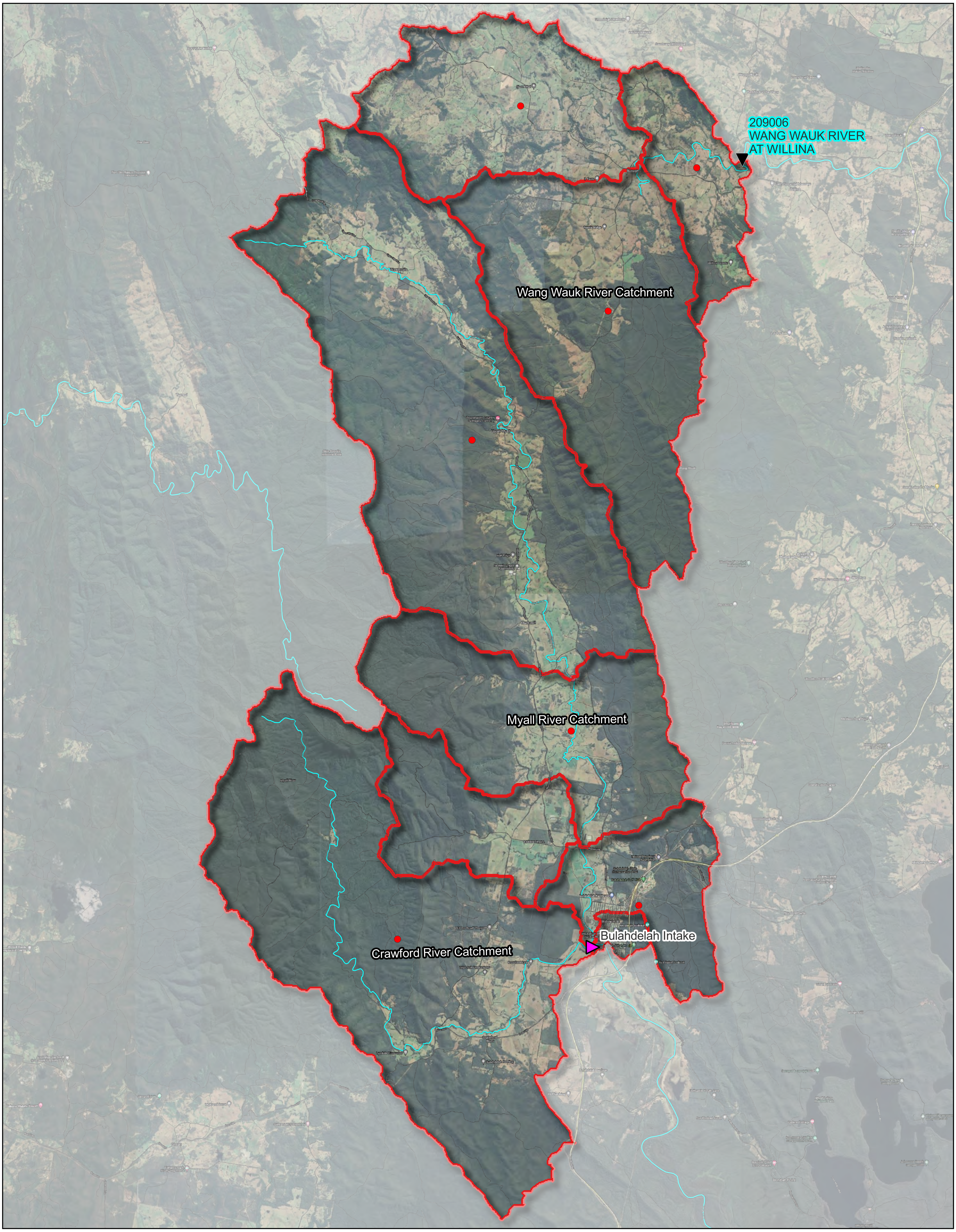
The closest river gauge with flow data available for the Source model calibration is the DPI Wang Wauk River at Willina (209006) gauge. The Wang Wauk River catchment borders the Myall River catchment on north-eastern side. The following gauges are also operational in the Myall River catchment, but Council indicated that rating curves were not available for this project:

- Myall River at Upper Markwell (560056) - Council
- Myall River at Markwell (561104) - Council
- Myall River at Bulahdelah (209460) - DPIE
- Crawford River U/S Bulahdelah (560058) - Council

It is noted DPIE used to also operate a river gauge at Myall River at Upper Markwell (209007) which closed in 1979. Gauge 209007 was used for the calibration of the AWBM parameters by **NUWS 2021**.

The Source model calibration focussed on discharges with an exceedance of 70% which have a similar magnitude to the WTP flow offtakes. **Figure 2** shows that the simulated streamflow overestimates the daily peak discharges compared to the recorded streamflow record for flows smaller than the 90% exceedance. This is associated with the greater number of sub-daily peak flows in the recorded streamflow record compared to the simulated streamflow sequence.

The sub-daily peak flows associated with the relatively small size of the Wang Wauk River catchment to 209006 was a challenge for AWBM calibration which calculations are at a daily timescale. The same challenge of sub-daily peak flows is also applicable for the Crawford River catchment to Crawford Weir. The calibration of Crawford Weir in the GoldSim WBM in **Section 4.2** provided an opportunity to compensate for the AWBM daily timestep calculation limitation through the adjustment of the WBM rules.



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DATUM GDA 2020, PROJECTION MGA ZONE 56

0 2.5 5 km

1:120,000 (when printed at A3)

Legend

- ▼ 209 - Karuah River Basin Gauging
- ▶ Intake_Location
- ● SILO Datapoint
- Streams
- Catchment Boundary

Integrated Water Cycle Managament Strategy

Bulahdelah Catchments

PROJECT ID	60565866
CREATED BY	deJong, Mark
LAST MODIFIED	2023-05-04
VERSION	1

Figure 3

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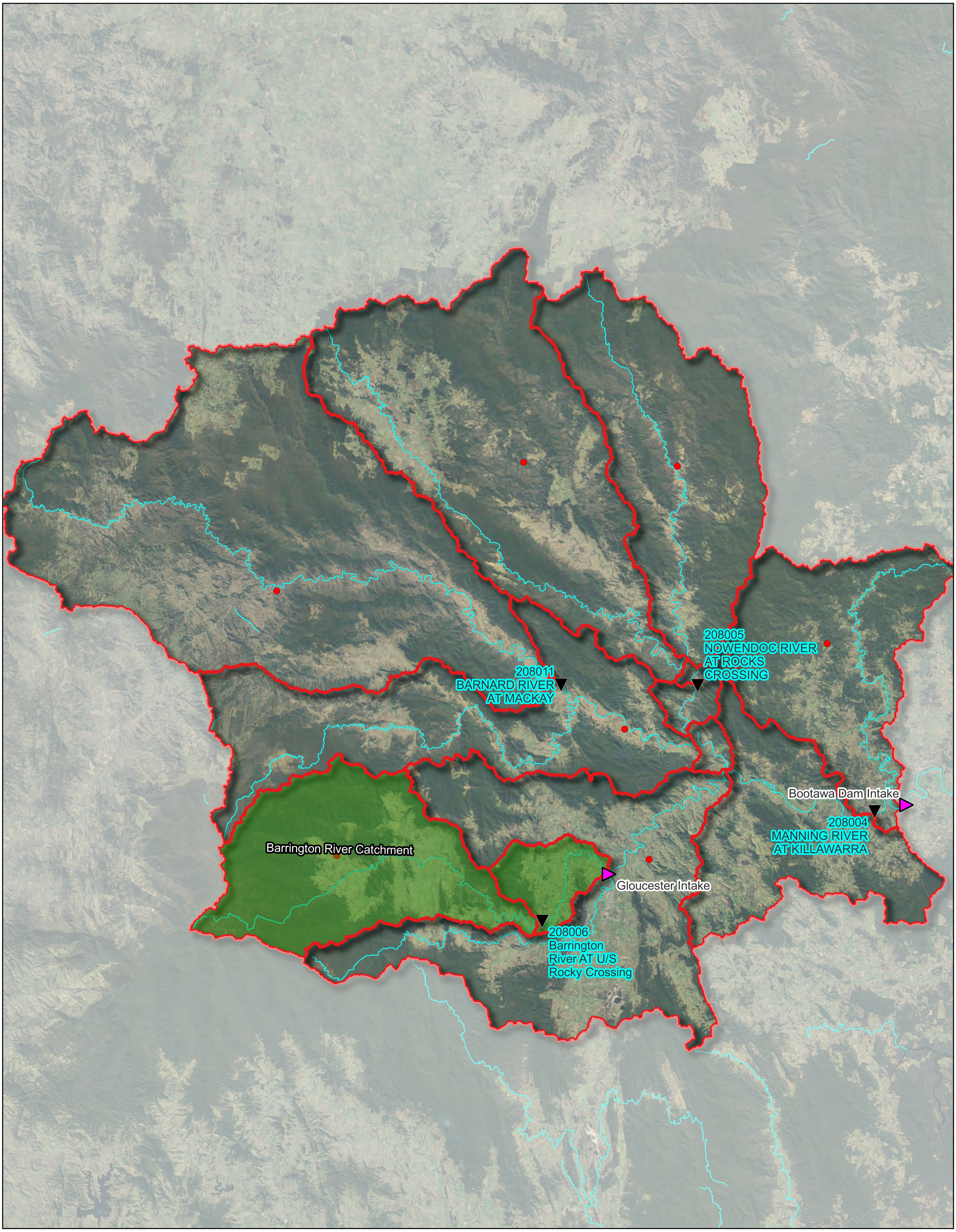
A3 size

3.2.2 Manning River Catchment

The layout of the Source model for the Manning River catchment is illustrated in **Figure 4**. The subcatchment contributing to Bulahdelah WTP offtake is highlighted also in **Figure 4**. **Table 6** provides a summary of the Karuah River Source model.

Table 5 Manning River Source Model Calibration

<table>
<tr><th>Parameter</th><th colspan="4">Value</th></tr>
<tr><td>River Gauges</td><td colspan="4">Barrington River at U/S Rocky Crossing (208006)
Barnard River at Mackay (208011)
Nowendoc River at Rocks Crossing (208005)
Manning River at Killawarra (208004)</td></tr>
<tr><td>Stream Gauge Operation Period</td><td colspan="4">208006: 08/11/1945 – Present (~77 years)
208011: 02/08/1962– Present (~60 years)
208005: 09/06/1945 – Present (~77 years)
208004: 01/06/1945 – Present (~77 years)</td></tr>
<tr><td>Gauged Catchment Area</td><td colspan="4">208006: 630km^2
208011: 1,790 km^2
208005: 1,870 km^2
208004: 6,560 km^2</td></tr>
<tr><td>Distance to WTP Intake</td><td colspan="4">Gloucester Intake -
• 208006: 10 km
Bootawa Dam Intake -
• 208011: 46 km
• 208005: 30 km
• 208004: 4 km</td></tr>
<tr><td>Calibration Period</td><td colspan="4">19/12/1967 – Present (~55 years)</td></tr>
<tr><td>Rainfall and Evapotranspiration Data</td><td colspan="4">Spatially Varying – Data extracted from SILO data drill at catchment centroids</td></tr>
<tr><td rowspan="2">Comparative Statistics for Runoff (Observed vs. Simulated)</td><td></td><td>209002</td><td>209018</td><td>209003</td></tr>
<tr><td>Nash-Sutcliffe Log Daily
Pearson’s Correlation (r)</td><td>0.399
0.753</td><td>0.725
0.805</td><td>0.647
0.797</td></tr>
<tr><td>Calibrated AWBM Parameters (Applied Globally)</td><td colspan="4">Partial Area Fractions:
A1: 0.433
A2: 0.433
A3: 0.134
Surface Storage Capacities:
C1: 45.3mm
C2: 123.1 mm
C3: 394.1 mm
Initial surface storage: 0%
Base Flow Index (BFI): 0.686
Baseflow Recession Constant: 0.272
Initial baseflow runoff: 0 mm
Surface Runoff Recession Constant: 0.974</td></tr>
<tr><td>Duration Curve – Modelled vs observed</td><td colspan="4">209002: Figure 9
209018: Figure 10
209003: Figure 11</td></tr>
</table>



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DATUM GDA 2020, PROJECTION MGA ZONE 56

0 7.5 15 km

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Legend

- 208 - Manning River Gauging
- Intake_Location
- SILO Datapoint
- Streams
- Catchment Boundary

Integrated Water Cycle Managament Strategy

Manning River Catchments

PROJECT ID 60565866
CREATED BY deJong, Mark
LAST MODIFIED 2023-05-04
VERSION 1

Figure 4

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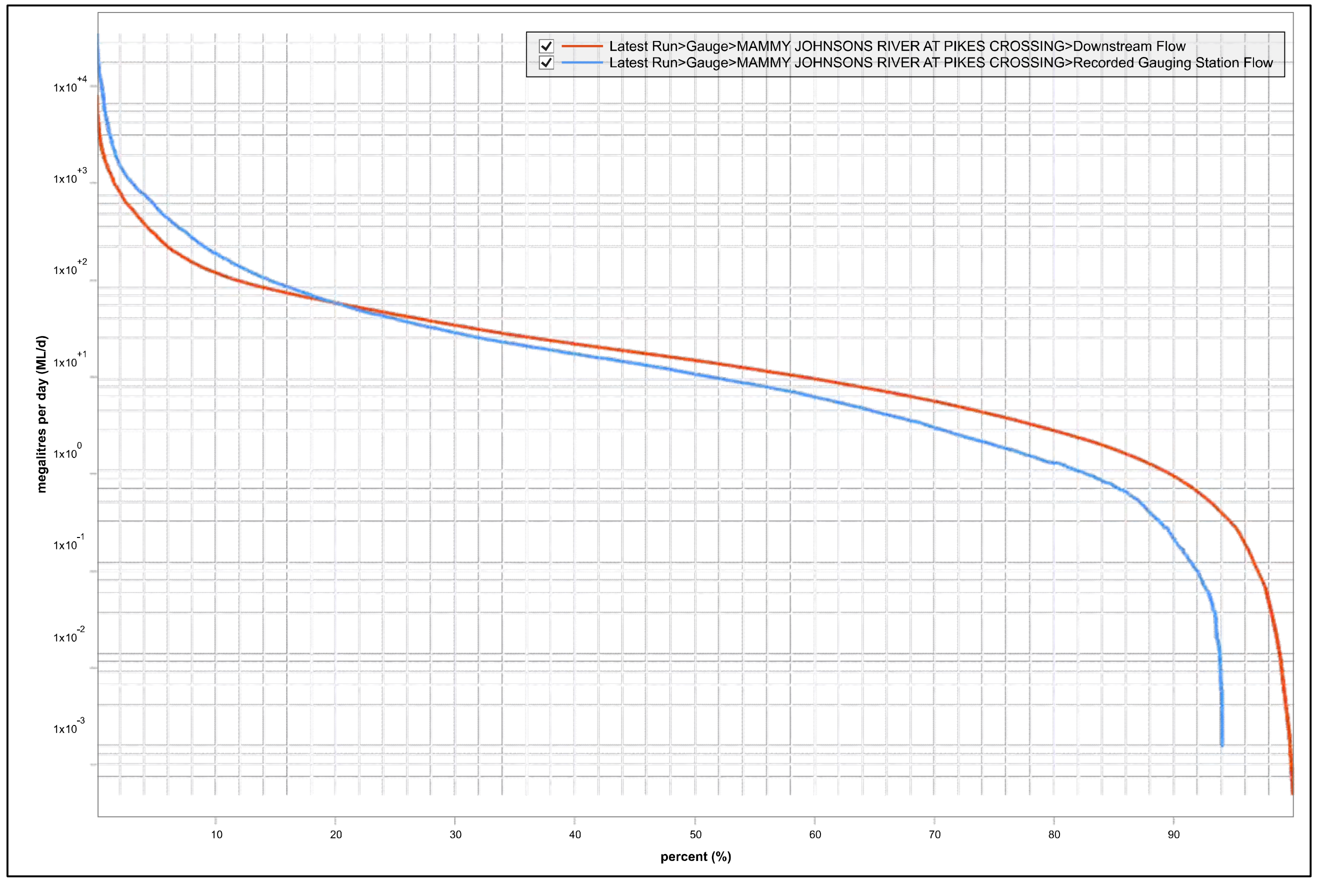

Figure 5 Duration Curve comparison between the Observed and Simulated Runoff at 209002

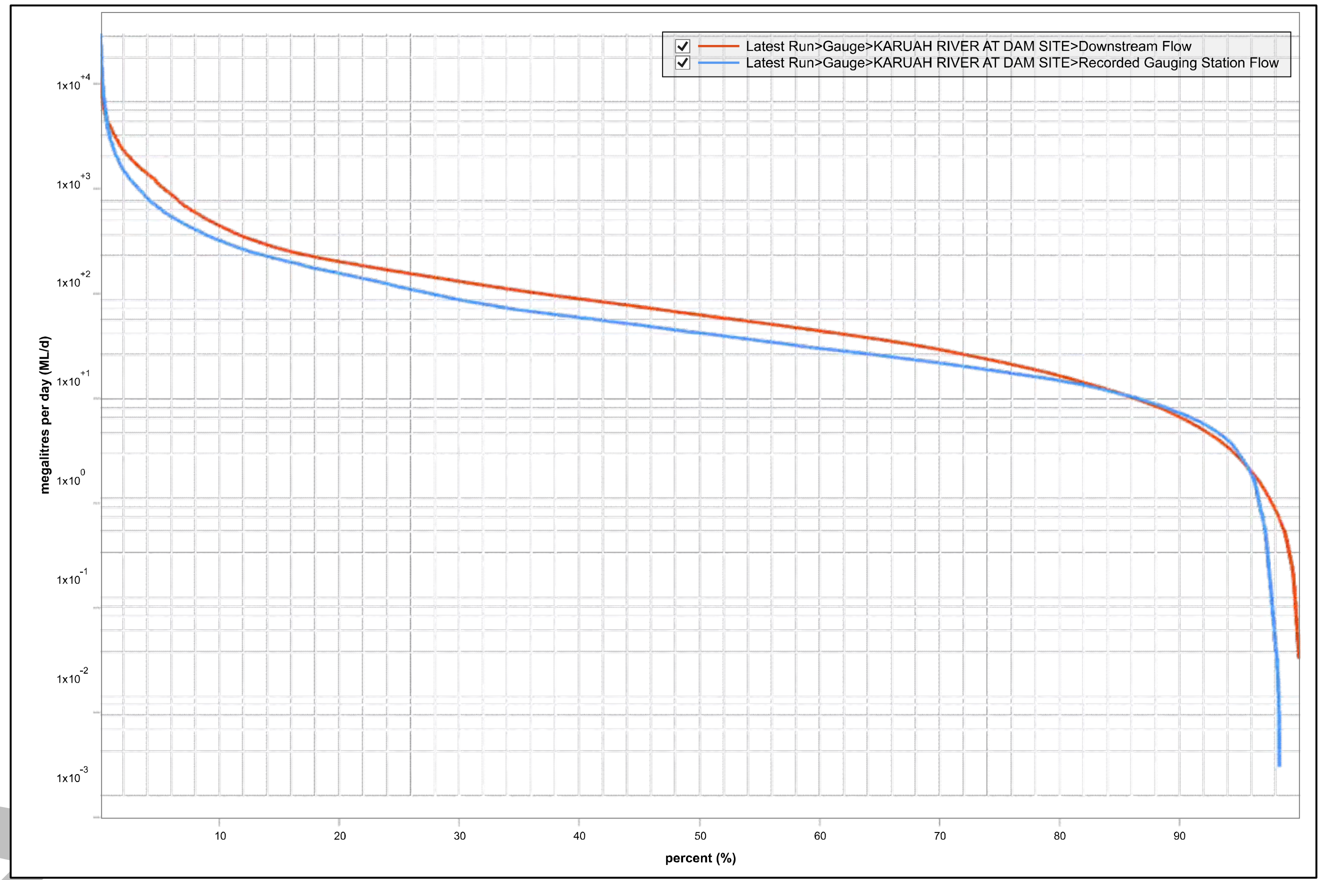

Figure 6 Duration Curve comparison between the Observed and Simulated Runoff at 209018

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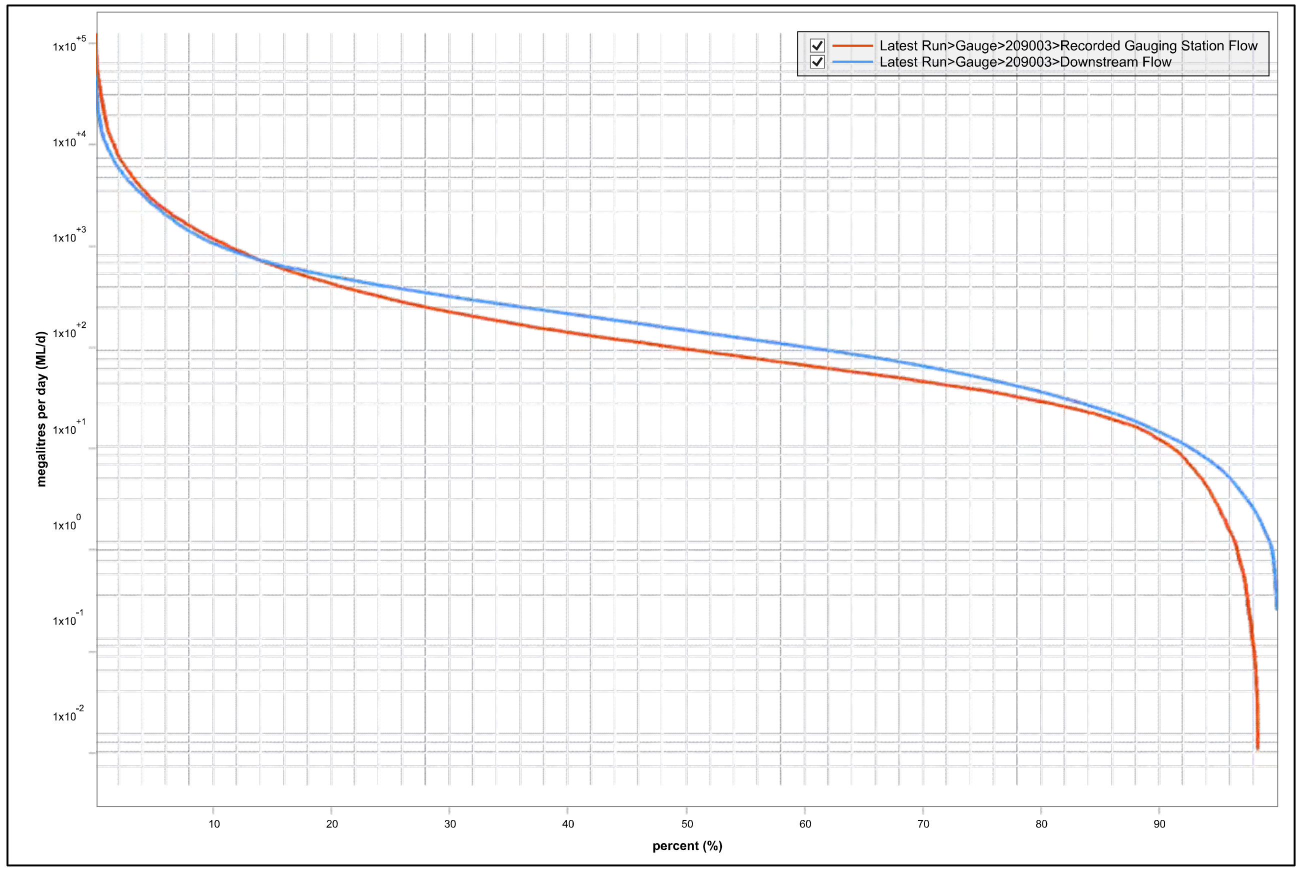

Figure 7 Duration Curve comparison between the Observed and Simulated Runoff at 209003

Discussion

The Source model calibration focussed on discharges with an exceedance of 70% which have a similar magnitude to the WTP flow offtakes. Initial Source model calibration efforts focused on the upstream gauges (209002 and 209018) before focussing on the downstream gauge 209003. A challenge with this initial approach was the individual calibrated AWBM parameter sets for the gauges 209002 and 209018 resulted in the poor calibration of gauge 209003 which has a higher priority for calibration given its use as a reference gauge for the Stroud WTP. A more acceptable calibration across all the gauges was achieved by only calibrating the Source model to gauge 209003 which is demonstrated in the figures above.

Figure 11 shows that the simulated streamflow overestimates the daily peak discharges compared to the recorded streamflow record for flows smaller than the 90% exceedance. Like the other study catchments, this is associated with the greater number of sub-daily peak flows in the recorded streamflow record compared to the AWBM daily timestep simulated streamflow sequence. The calibration of Stroud off stream storage in the GoldSim WBM in **Section 4.2** provided an opportunity to compensate for the AWBM daily timestep calculation limitation through the adjustment of the WBM rules.

3.2.3 Karuah River Catchment

The layout of the Source model for the Karuah River catchment is illustrated in **Figure 8**. The subcatchment contributing to Stroud WTP offtake is highlighted also in **Figure 8**. **Table 6** provides a summary of the Karuah River Source model.

Table 6 Karuah River Source Model Calibration

Parameter	Value			
River Gauges	Mammy Johnsons River at Pikes Crossing (209002) Karuah River at Dam Site (209018) Karuah River at Booral (209003)			
Stream Gauge Operation Period	209002: 19/12/1967 – Present (~55 years) 209018: 18/12/1979 – Present (~46 years) 209003: 30/10/1968 – Present (~54 years)			
Gauged Catchment Area	209002: 156 km^2 209018: 300 km^2 209003: 974 km^2			
Distance WTP Offtake	209002: 18 km 209018: 16 km 209003: 8 km			
Calibration Period	19/12/1967 – Present (~55 years)			
Rainfall and Evapotranspiration Data	Spatially Varying – Data extracted from SILO data drill at catchment centroids			
Comparative Statistics for Runoff (Observed vs. Simulated)		209002	209018	209003
	Nash-Sutcliffe Log Daily Pearson's Correlation (r)	0.399 0.753	0.725 0.805	0.647 0.797
Calibrated AWBM Parameters (Applied Globally)	Partial Area Fractions: A1: 0.433 A2: 0.433 A3: 0.134 Surface Storage Capacities: C1: 45.3mm C2: 123.1 mm C3: 394.1 mm Initial surface storage: 0% Base Flow Index (BFI): 0.686 Baseflow Recession Constant: 0.272 Initial baseflow runoff: 0 mm			

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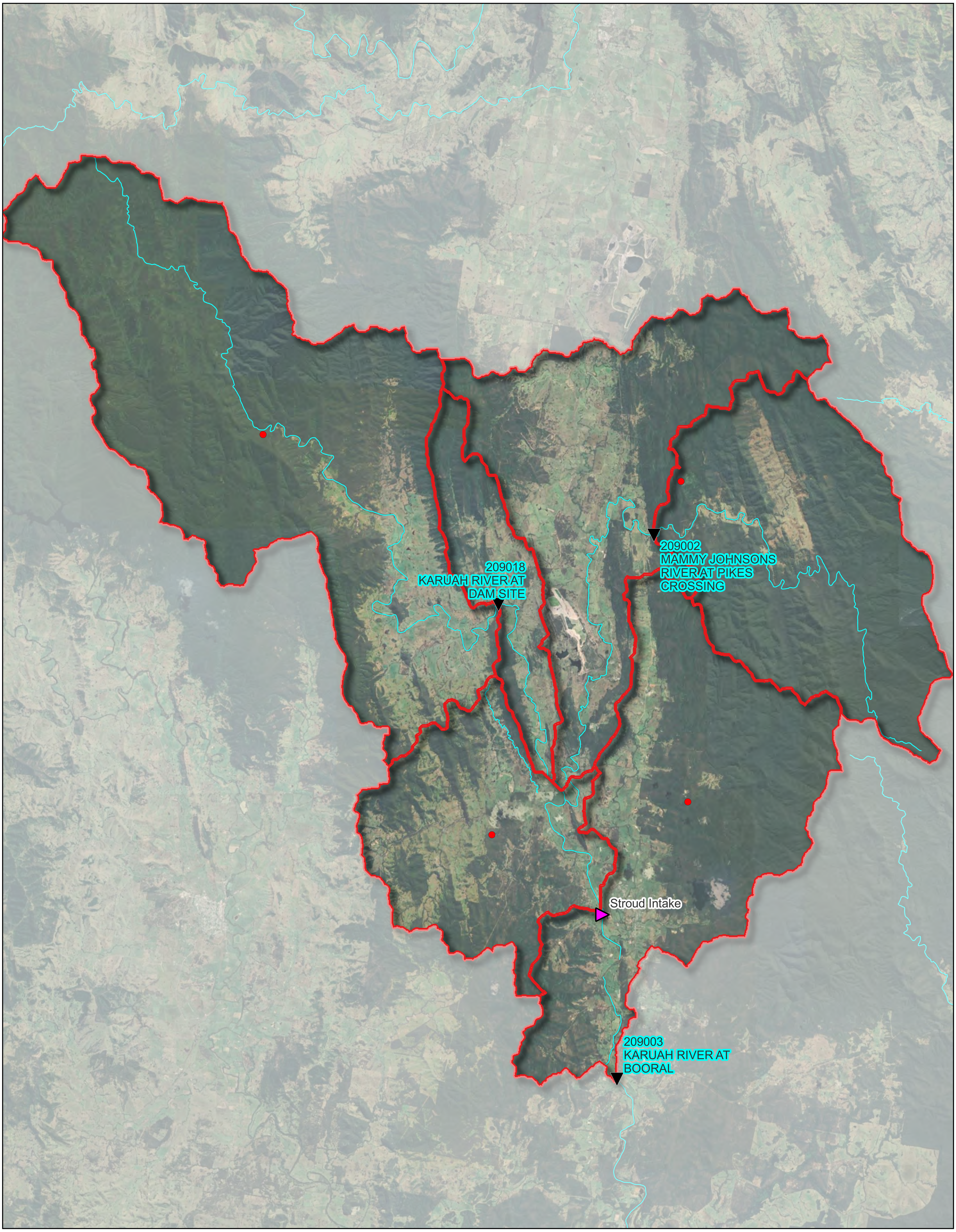
Parameter	Value
	Surface Runoff Recession Constant: 0.974
Duration Curve – Modelled vs observed	209002: **Figure 9** 209018: **Figure 10** 209003: **Figure 11**



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DATUM GDA 2020, PROJECTION MGA ZONE 56

0 2.5 5 km

1:160,000 (when printed at A3)

Legend

- 209 - Karuah River Basin Gauging
- Intake_Location
- SILO Datapoint
- Streams
- Catchment Boundary

Integrated Water Cycle Managament Strategy

Karuah River Catchments

PROJECT ID	60565866
CREATED BY	deJong, Mark
LAST MODIFIED	2023-05-04
VERSION	1

Figure
8

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A3 size

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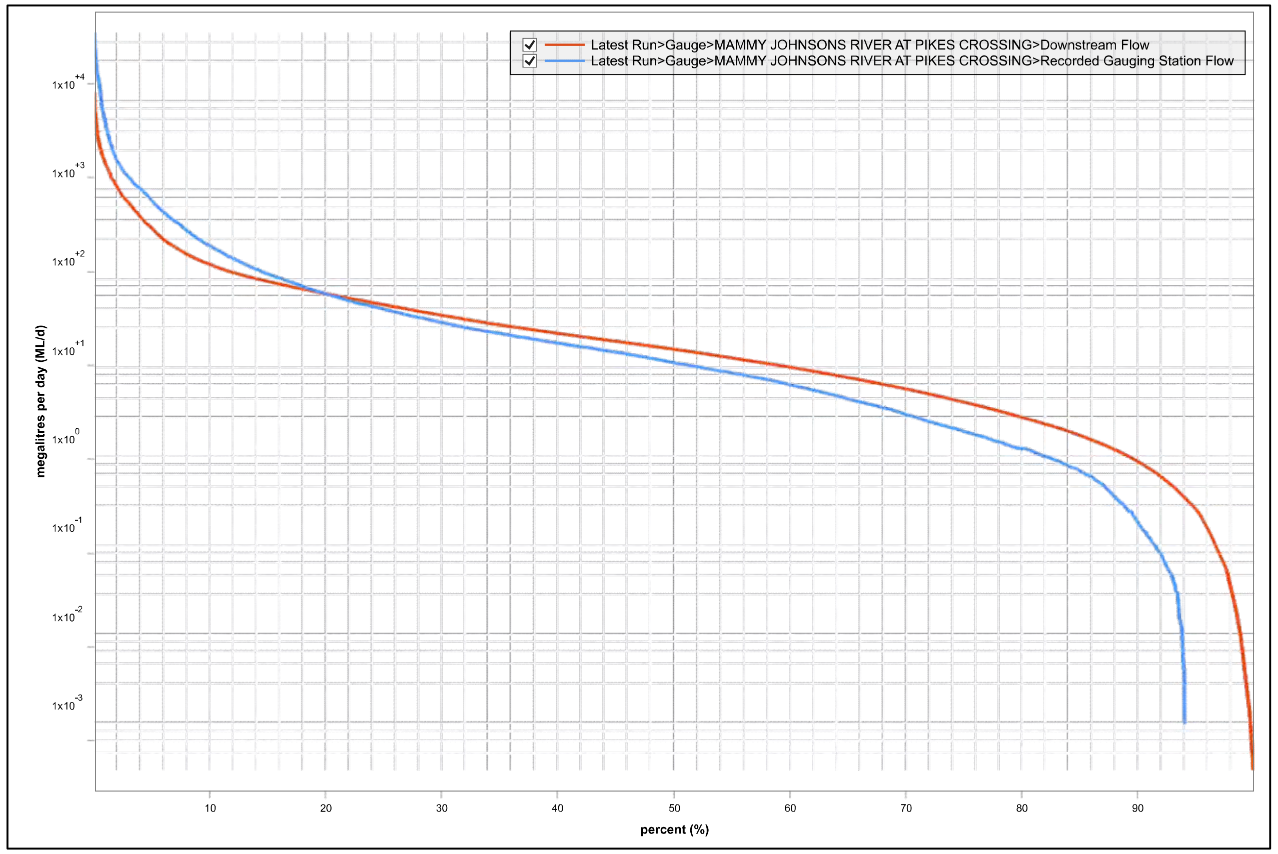

Figure 9 Duration Curve comparison between the Observed and Simulated Runoff at 209002

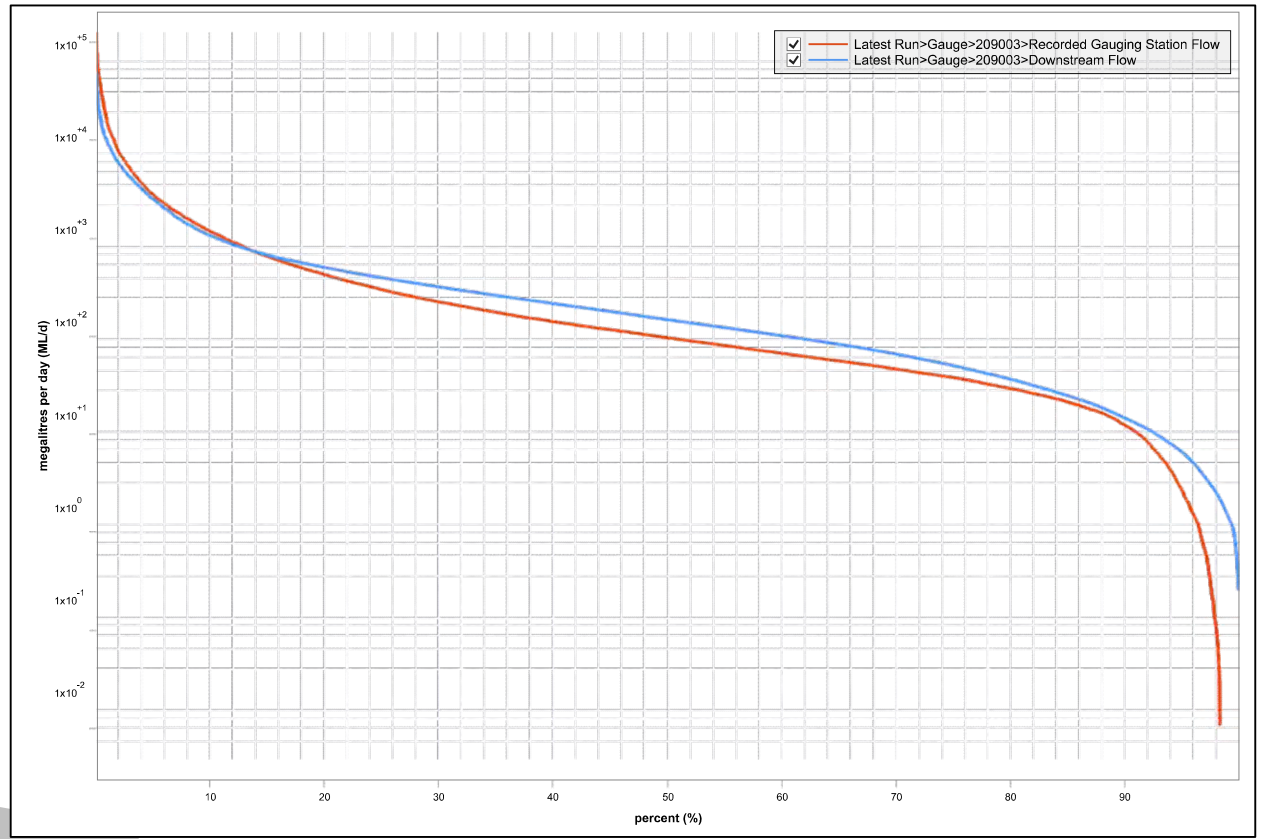

Figure 11 Duration Curve comparison between the Observed and Simulated Runoff at 209003

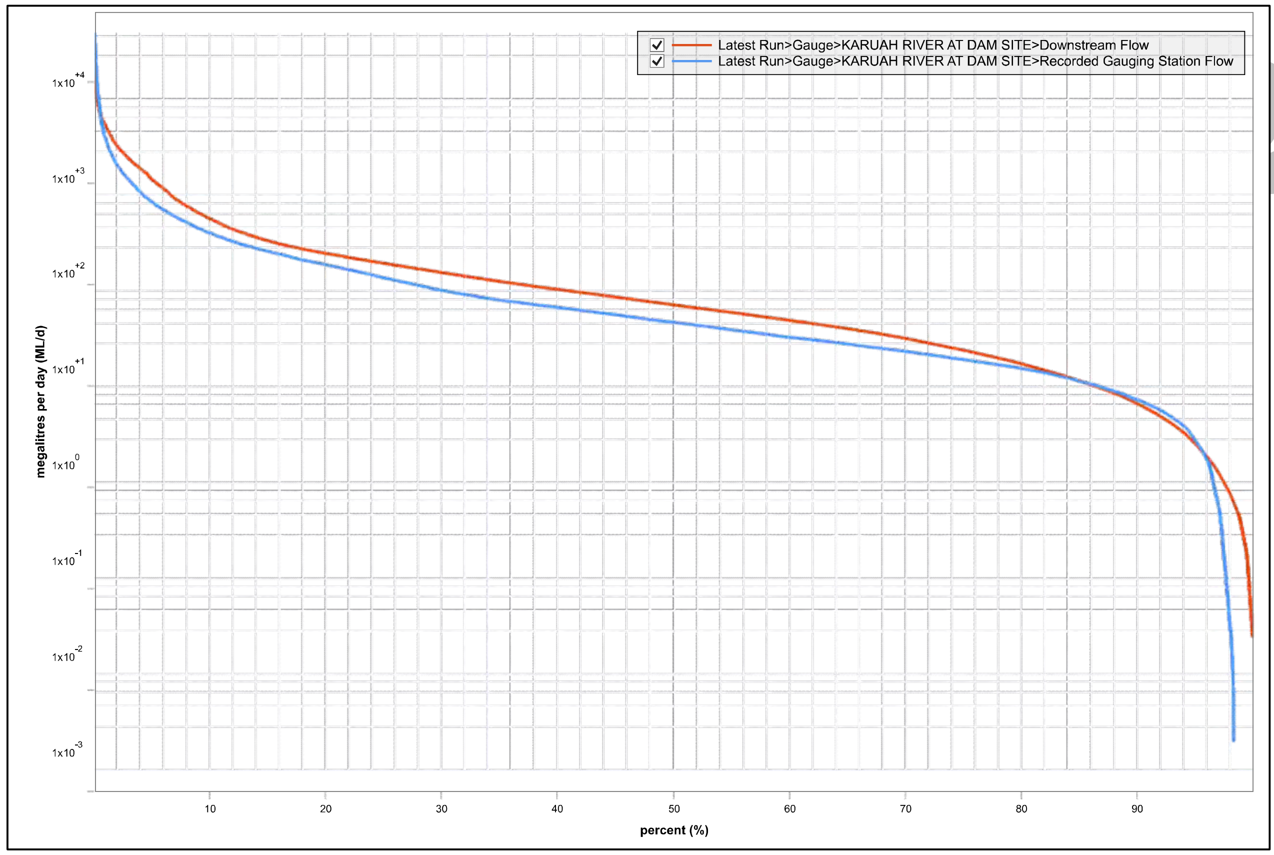

Figure 10 Duration Curve comparison between the Observed and Simulated Runoff at 209018

Discussion

The Source model calibration focussed on discharges with an exceedance of 70% which have a similar magnitude to the WTP flow offtakes. Initial Source model calibration efforts focused on the upstream gauges (209002 and 209018) before focussing on the downstream gauge 209003. A challenge with this initial approach was the individual calibrated AWBM parameter sets for the gauges 209002 and 209018 resulted in the poor calibration of gauge 209003 which has a higher priority for calibration given its use as a reference gauge for the Stroud WTP. A more acceptable calibration across all the gauges was achieved by only calibrating the Source model to gauge 209003 which is demonstrated in the figures above.

Figure 11 shows that the simulated streamflow overestimates the daily peak discharges compared to the recorded streamflow record for flows smaller than the 90% exceedance. Like the other study catchments, this is associated with the greater number of sub-daily peak flows in the recorded streamflow record compared to the AWBM daily timestep simulated streamflow sequence. The calibration of Stroud off stream storage in the GoldSim WBM in **Section 4.2** provided an opportunity to compensate for the AWBM daily timestep calculation limitation through the adjustment of the WBM rules.

3.3 Design Runoff Sequence

The design runoff sequence used for each water supply scheme was generated by combining the calibrated AWBM runoff sequence and historical streamflow record from the nearest stream gauge to the respective WTP raw water offtakes. This approach reduces the reliance on the AWBM runoff sequence where there is data accuracy concerns for low flows. The usage of more accurate recorded gauged data also facilitated the validation of the GoldSim WBMs to historical data in **Section 4.2**.

Table 7 provides the date ranges of the AWBM runoff sequence and historical streamflow record used to generate the design runoff sequence. **Table 7** shows that Bulahdelah is the only location where historical gauged data was not used as stream gauge data was not available for Crawford River.

Table 7 Design Runoff Sequence Data Periods

Water Supply Scheme	Data Source	
	AWBM (Source)	Historical (Gauged)
Bulahdelah	1/01/1889 – 29/11/2022	No gauged data available
Gloucester	1/01/1889 – 7/11/1945	Scaled streamflow record at Barrington River at U/S Rocky Crossing (209006): 8/11/1945 – 29/11/2022
Manning River	1/01/1889 – 1/06/1945	Scaled streamflow record at Manning River at Killawarra (209004): 2/06/1945 – 29/11/2022
Stroud	1/01/1889 – 26/10/1968	Scaled streamflow record at Karuah River at Booral (209003): 27/10/1968 – 29/11/2022

The historical streamflow period in **Table 7** was scaled to WTP raw water offtake by catchment area using the *Hydrological Recipes – Estimation techniques in Australian Hydrology (1963)* formula below:

$$F = (A_{candidate}/A_{Gauged})^{0.7}$$

Where:

- $A_{candidate} = catchment\ area\ to\ WTP\ (km^2)$
- $A_{Gauged} = catchment\ area\ of\ gauge\ (km^2)$

The catchment areas and scale factor for each water supply scheme except Bulahdelah is provided in **Table 8**.

Table 8 Catchment Flow Scale Factor

Water Supply Scheme	Candidate Catchment Area (km^2)	Gauged Catchment Area (km^2)	Scale Factor
Gloucester	708.2	602.1	1.12
Manning River	7,172	6,593	1.06
Stroud	815.4	917	0.92

4.0 GoldSim WBM Validation

4.1 Water Transfer Rules and Assumptions

The water transfer rules and assumptions for each of the water supply schemes is described below and were determined using the following process:

- The water transfer rules from the **NUWS 2021** report and Council supplied data were used to develop process flow diagrams for the water supply schemes.
- The newly developed process flow diagrams were then used to setup the GoldSim WBM for the water supply schemes.
- The newly developed GoldSim WBMs were then validated to available historical water level data of the key raw water storages in **Section 4.2**. The original water transfer rules were changed to facilitate the validation of the GoldSim WBM.
- The original process flow diagrams were then updated to reflect the water transfer rules and assumptions in the validated GoldSim WBMs.
- The updated process flow diagrams and outcomes from the GoldSim WBM validation were provided to Council for discussion. The water transfer rules in the GoldSim WBMs were then finalised following feedback from Council.

4.1.1 Bulahdelah

Figure 12 and **Table 9** demonstrate the water transfer rules and assumptions used in the GoldSim WBM for Bulahdelah.

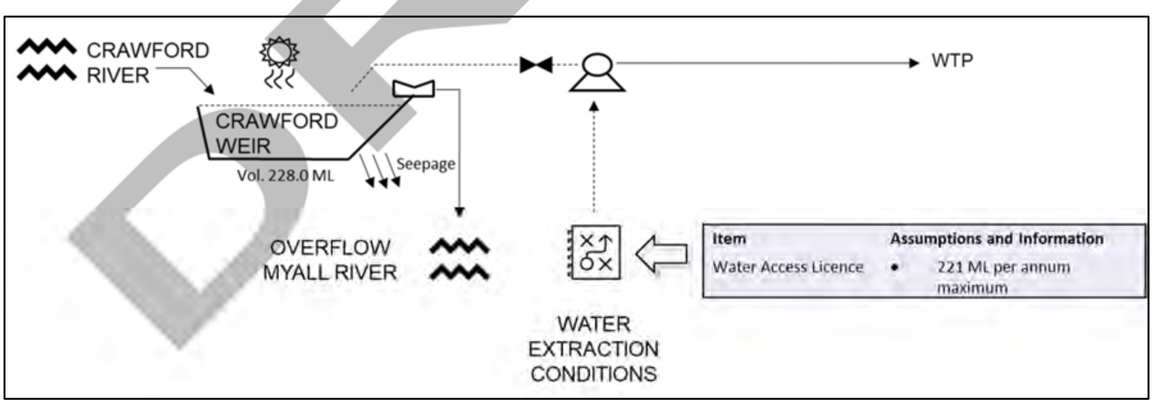

Figure 12 Bulahdelah WTP Raw Water Harvesting and Storage Process Flow Diagram

Table 9 Bulahdelah WBM Assumptions

Item	Assumptions and Information
Crawford Weir Storage	• Weir is directly recharged by Crawford River

Item	Assumptions and Information
	• Raw water is pumped directly to Bulahdelah WTP • Weir has a maximum capacity of 228 ML • Weir is subject to evaporation • Weir is subject to seepage of 0.1 mm/d

4.1.2 Gloucester

Figure 12 and **Table 9** demonstrate the water transfer rules and assumptions used in the GoldSim WBM for Gloucester.

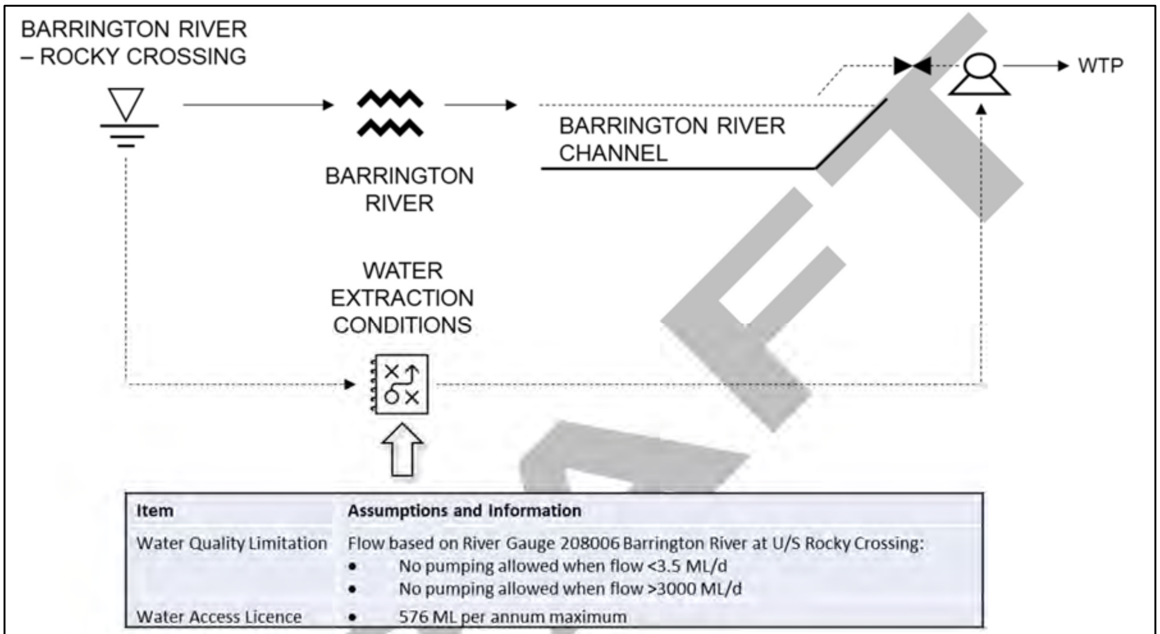

Figure 13 Bulahdelah WTP Raw Water Harvesting and Storage Process Flow Diagram

Table 10 Gloucester WBM Assumptions

Item	Assumptions and Information
Barrington River	• Raw water is pumped directly from the Barrington River channel to the Gloucester WTP

4.1.3 Manning River

Figure 12 and **Table 9** demonstrate the water transfer rules and assumptions used in the GoldSim WBM for Gloucester.

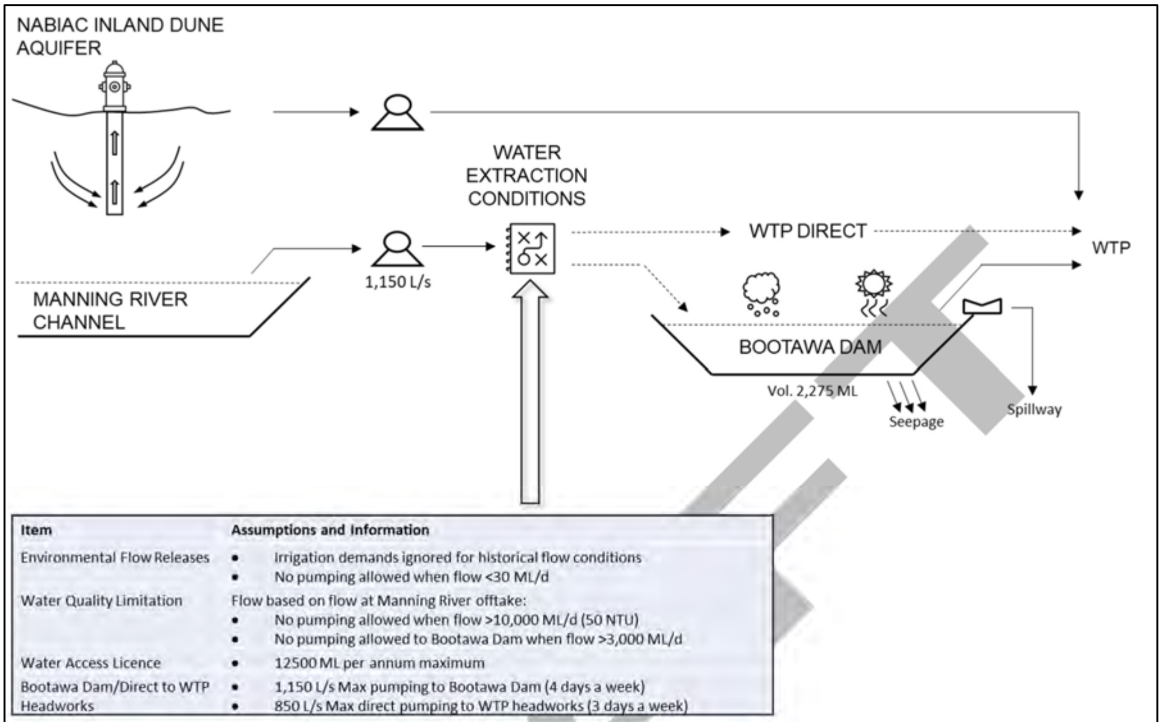

Figure 14 Manning WTP Raw Water Harvesting and Storage Process Flow Diagram

Table 11 Manning WBM Assumptions

Item	Assumptions and Information
Nabiac Inland Dune Aquifer (Aquifer)	• • • • Table 12 provides the maximum daily extraction to the WTP • Water from the Aquifer is used to meet the demand from the WTP first and then raw water from the Manning River (direct or Bootawa Dam) is used
Bootawa Dam	• Dam is recharged by pumping from the Manning River channel at a maximum rate of 1,150 L/s to keep storage as full as possible • Pumping to Dam during peak and shoulder electrical supply tariff periods • Dam is recharged from rainfall directly over the dam catchment • Dam maximum capacity of 2,275 ML • Dam dead storage capacity: - 637 ML for Gravity flow to WTP - 151 ML for Deep Recovery • Dam is subject to evaporation • Dam is subject to seepage of 2.0 mm/d
Direct to WTP headwork from Manning River	• Water is supplied directly to WTP from the Manning River channel at a maximum rate of 850 L/s • Pumping to WTP only during off peak (no electrical tariff) period over the weekend

Table 12 Nabiac Inland Dune Aquifer Supply Assumptions

Condition	WTP Rainfall over the past 6 months	Daily Extraction (ML/d)
Wet Period	>600 mm	10
Average Period	400 – 600 mm	9
Dry Period	<400 mm	6

4.1.4 Stroud

Figure 12 and **Table 9** demonstrate the water transfer rules and assumptions used in the GoldSim WBM for Stroud.

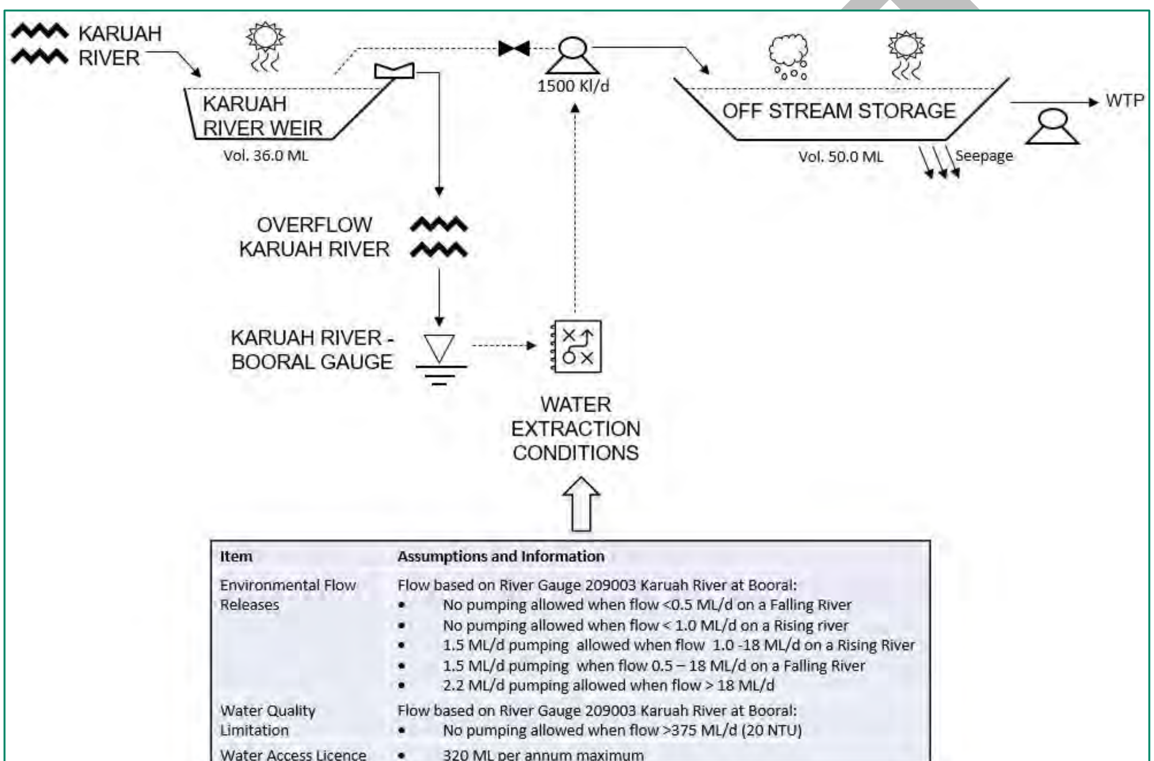

Figure 15 Stroud WTP Raw Water Harvesting and Storage Process Flow Diagram

Table 13 Stroud WBM Assumptions

Item	Assumptions and Information
Off stream Storage	• 1,500 KL/d max pumping to off stream storage • Water is pumped from Karah Weir to keep storage as full as possible • Storage is subject to evaporation • Storage is subject to seepage of 1.0 mm/day

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4.2 Model Validation

This section provides a summary of the validation of the GoldSim WBMs to historical data to confirm the water transfer rules in **Section 4.1**.

4.2.1 Bulahdelah

The Bulahdelah water supply scheme GoldSim WBM was validated to historical water level data at Crawford Weir. Details of the GoldSim WBM validation is provided in **Table 14** and **Figure 16**.

Table 14 GoldSim WBM Validation

Water Supply Scheme	Calibration Data
Bulahdelah	Calibration location: Crawford Weir Calibration metric: Water level Calibration period: 1/11/2016 – 24/04/2022

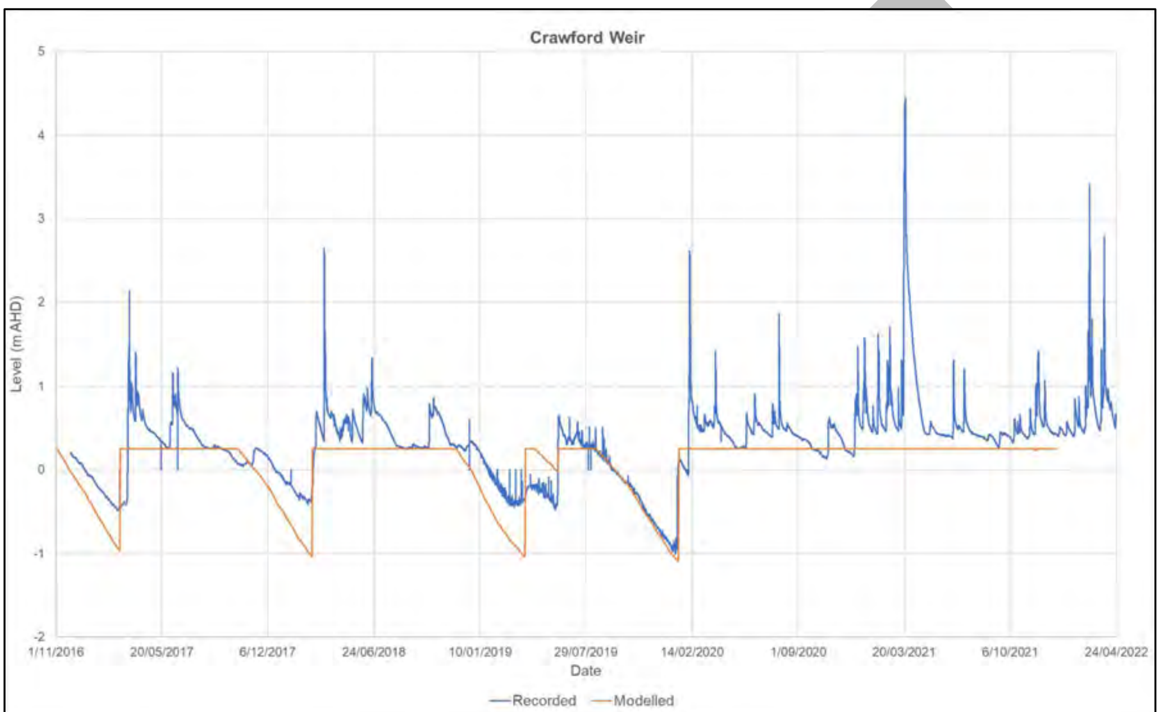

Figure 16 Calibration of the GoldSim WBM to the Historical Crawford Weir Storage Level Data

Discussion

Figure 16 shows that the recorded weir overflow levels are not represented in the GoldSim WBM results. This is associated with the availability of geometric data on Crawford Weir where data only the stage-storage details below the weir crest are available. The representation the weir overflow levels requires information on the stage-storage relationship above the weir crest level and on the stage-discharge relationship of the weir overflow.

A challenge of the GoldSim WBM validation was the accuracy of the generated AWBM stream inflow sequence (refer **Section 3.2.3**). Unlike the other water supply schemes in **Section 3.3**, there was no historical gauge information on Crawford River to supplement the generated AWBM sequence.

Figure 16 demonstrates that the recorded and modelled water levels are comparable for the 2019-2020 drought (October 2019 – February 2020). The accurate representation of the 2019-2020 drought was the key priority of the GoldSim WBM validation.

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4.2.2 Bootawa Dam

The Manning water supply scheme GoldSim WBM was validated to historical water level data at Bootawa Dam. Details of the GoldSim WBM validation is provided in **Table 15** and **Figure 17**.

Table 15 GoldSim WBM Validation

Water Supply Scheme	Calibration Data
Bootawa Dam	Calibration location: Bootawa Dam Calibration metric: Water level Calibration period: 1/10/2016 – 5/09/2021

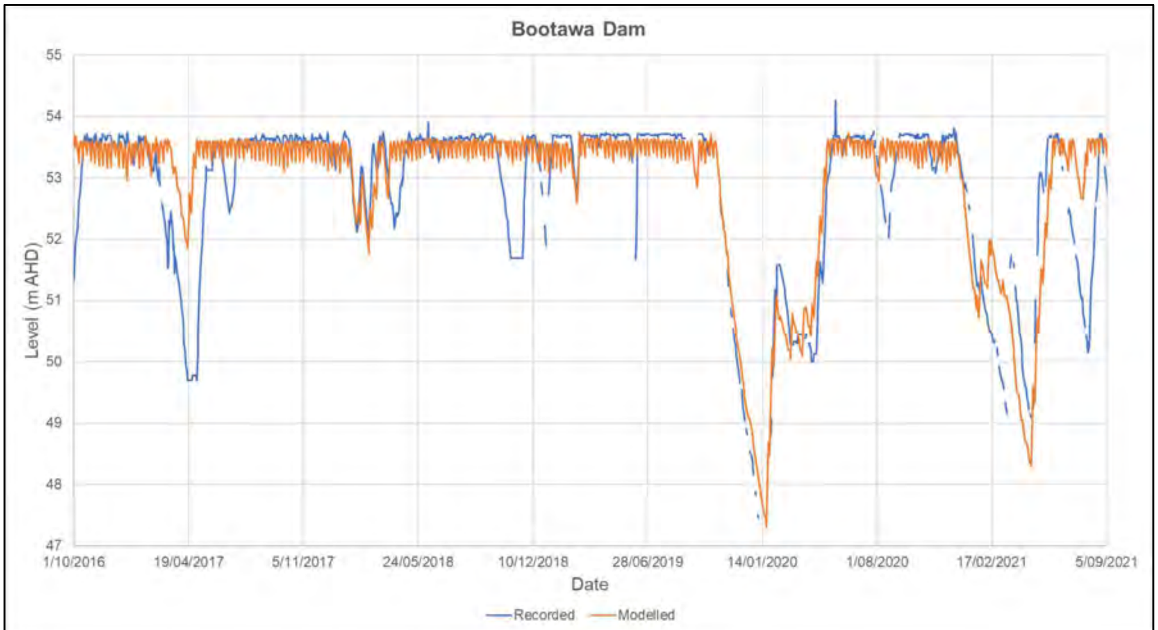

Figure 17 Calibration of the GoldSim WBM to the Historical Bootawa Dam Storage Level Data

Discussion

Figure 17 shows that the modelled water level cycles compared to the recorded water level data when Bootawa Dam is at fully supply level. The cycling in the GoldSim WBM is associated with the assumption that Bootawa Dam is only filled during the week where electrical tariffs apply to pumping. This assumption is based on the inspection of the supplied Bootawa Dam operational data and was required for an accurate representation of the 2019-2020 drought which was the key priority of the GoldSim WBM validation.

Figure 17 demonstrates that the recorded water level for the April 2017, October 2018 and August 2021 periods is not well represented in the GoldSim WBM results. Sensitivity testing of the water transfer rules indicate that this is associated with the adopted no raw water harvesting water quality threshold flow of 10,000 ML/d (50 NTU). GoldSim WBM uses the no pumping flow threshold of 10,000 ML/d to represent the cut-off water quality turbidity threshold of 50 NTU as the GoldSim WBM has not been developed for water quality modelling. The sensitivity testing indicated that the following water quality flow thresholds:

- April 2017 – ~3,000 ML/d (>15 NTU)
- October 2018 – ~1,000 ML/d (>3.2 NTU)
- August 2021 – ~2,200 ML/d (>10 NTU).

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4.2.3 Stroud

The Stroud water supply scheme GoldSim WBM was validated to historical water level data at the Stroud off stream storage. Details of the GoldSim WBM validation is provided in **Table 16** and **Figure 18**.

Table 16 GoldSim WBM Validation

Water Supply Scheme	Calibration Data
Stroud	Calibration location: Stroud off stream Storage Calibration metric: Water level Calibration period: 1/01/2016 – 5/11/2022

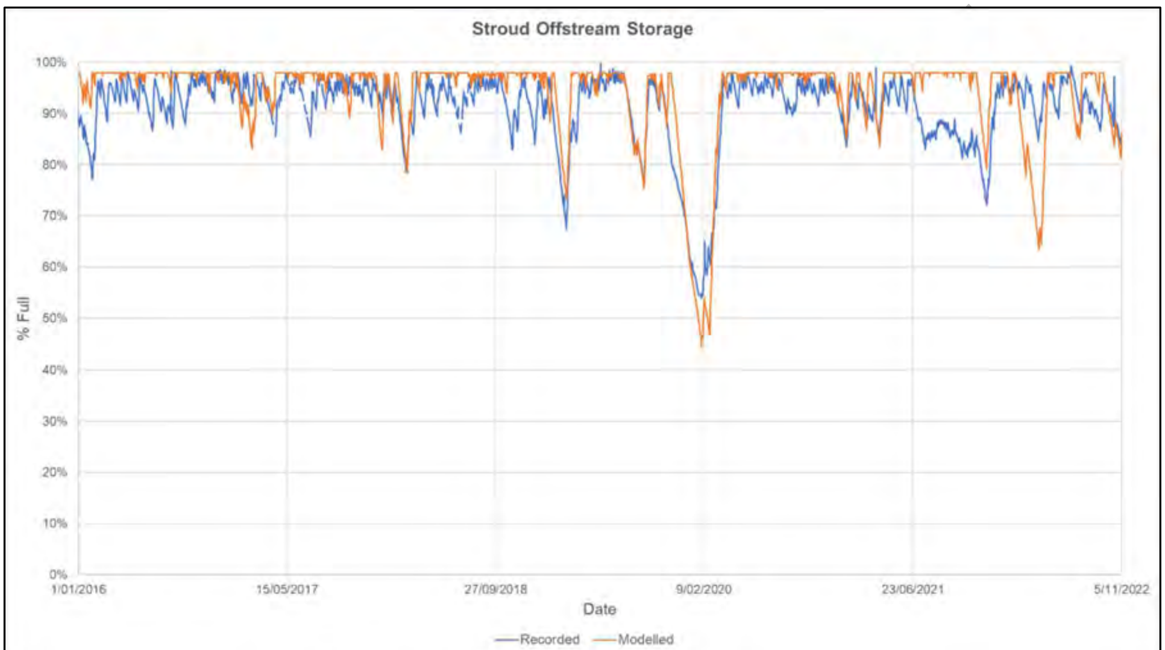

Figure 18 Calibration of the GoldSim WBM to the Historical Stroud off stream Storage Level Data

Discussion

Figure 18 demonstrates that the off-stream storage is generally closer to full capacity for the modelled storage level compared to the historical storage record. This is associated with the manual operation of the WTP which is challenging to represent in the GoldSim WBM which uses a fixed set of water transfer rules.

When determining the adopted WBM rules in **Section 4.1.4**, the key priority of the GoldSim WBM validation by Council was the accurate representation of the 2019-2020 drought. The adopted WBM rules from the GoldSim model validation to the 2019-2020 drought keep the off-stream storage nearer to full capacity for wet periods compared to historical operation of the WTP.

5.0 Climate Change

The DPIE *Guidance on strategic planning outcome -Understanding water security: Regulatory and assurance framework for local water utilities 2020* (**DPIE 2020**) requires that the potential influence of future climate change conditions are considered when understanding long-term water security. This is important for water long-term water strategies which look at the next 20 to 40 years.

The challenge for modelling climate change conditions for water yield assessments is the uncertainty of the seasonal variability of the climate variables such as rainfall, evaporation and evapotranspiration. The frequency and duration of wet and dry events determines how much water is available. To analyse to a reasonable standard the availability and reliability of access to water from a water source, **DPIE 2020** recommends using a combination of:

- historical streamflow data (SILO dataset)
- paleo-stochastic climate data
- Australian Regional Climate Modelling (NARCliM) climate projections.

The paleo-stochastic climate data is a standard reference dataset which is generated by running computer variations of the 500-year paleo-climatic dataset. The dataset covers a 10,000-year period of daily rainfall, evapotranspiration and temperature data representing the variability of the long-term climate at a reference climate station.

The paleo-stochastic climate dataset was not available for the Lower North Coast and Hunter region from the DPIE when the water yield assessment was completed in January 2023. In lieu of the paleo-stochastic climate, DPIE provided guidance that only using the generated historical streamflow and NARCliM climate projections for this study would be accepted. It has since been noted that the dataset is now available for the Lower North Coast and Hunter region. It is recommended that Council revise the water security assessment of climate change conditions in future studies using the paleo-stochastic climate dataset.

The water security uses factors to adjust each of the climate variables used to generate the historical climate sequence (**Section 0**) to the projected climate conditions for the far future (2060-2079) period. The climate models used for each climate variable is provided in **Table 17** and the monthly factors are provided in **Section 6.1**.

Table 17 Climate Models Used for Each Climate Variable

Climate Variable	Climate Model
Rainfall	NARCliM 1.0
Evaporation	CSIRO ACCESS 1.3 (RCP 8.5)
Evapotranspiration (FAO56)	CSIRO ACCESS 1.3 (RCP 8.5)

* RCP - Representative Concentration Pathway

It should be noted that the evaporation and evapotranspiration climate change factors were sourced from the Bureau of Meteorology (BOM) as these factors were not available from the NARCliM dataset available from the NSW Climate Data Portal.

6.0 GoldSim WBM Design Modelling

6.1 Design Modelling Approach

Table 18 provides a summary of the design case GoldSim WBM approach.

Table 18 Historical Climate Data

Item	Description		
Simulation Type	Deterministic simulation (all 133 years modelled as 1 simulation)		
Simulation Period	1/01/1889 – 15/11/2022 (133 years)		
Model Time Step	1 Day		
Data Source	SILO		
SILO Sample Location	Myall River Catchment: • -32.40, 152.20 • -32.35, 152.20 • -32.40, 151.85 • -32.15, 152.25 • -32.20, 152.20 • -32.15, 152.20 • -32.45, 152.15 • -32.25, 152.15	Manning River Catchment • -31.70, 152.25 • -31.95, 152.00 • -31.80, 152.00 • -31.50, 152.05 • -31.50, 151.85 • -31.95, 151.60 • -31.65, 151.55 • -31.95, 152.40	Karah River Catchment • -32.35, 152.00 • -32.20, 151.95 • -32.25, 151.90 • -32.15, 151.75 • -32.35, 151.90
SILO Data Type	• Daily Rainfall • Daily Evaporation (Class A Pan) • Daily Evapotranspiration (Morton's actual areal)		
SILO Length of Record	1/01/1889 – 15/11/2022 (133 years)		
Evaporation pan factor	0.85 or 85 % (applied to Class A Pan Evaporation)		
Climate Change	Climate change factors were applied to the historical climate variables for the far future period (2060-2079) and are provided in: • **Figure 19** for the Myall River catchment • **Figure 20** for the Manning River catchment • **Figure 21** for the Karah River catchment.		

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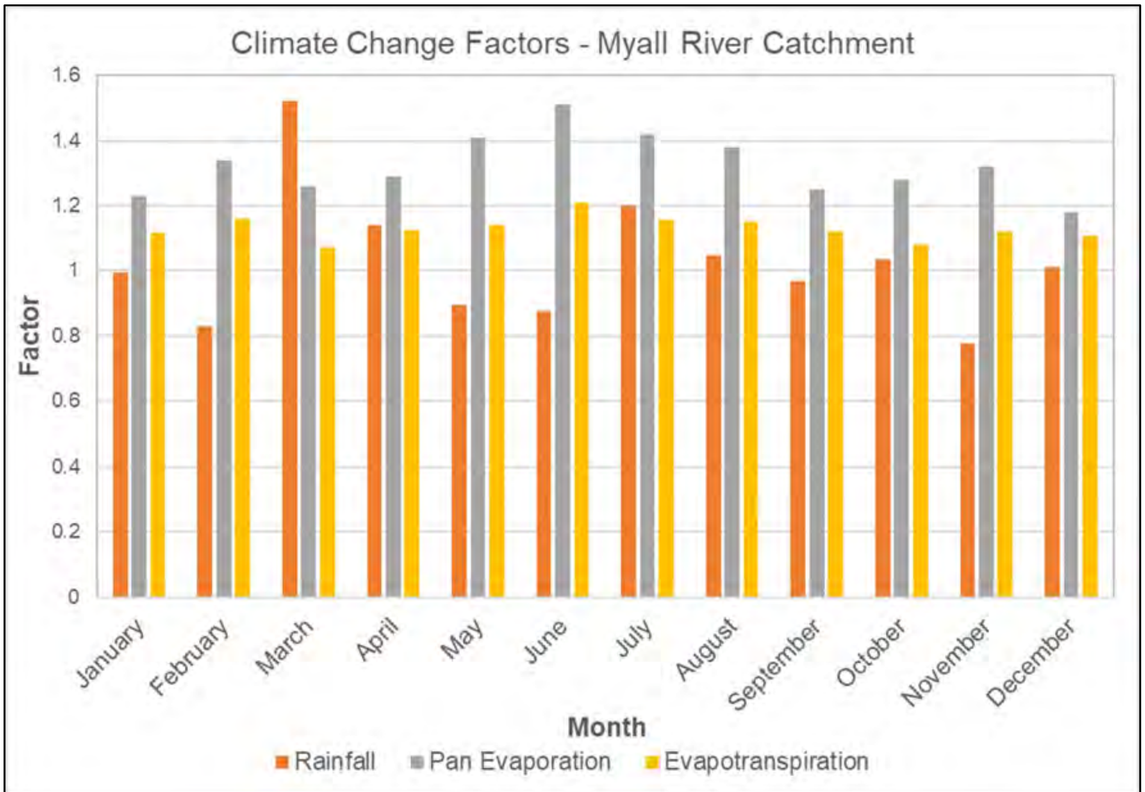

Figure 19 Climate Change Factors - Myall River Catchment

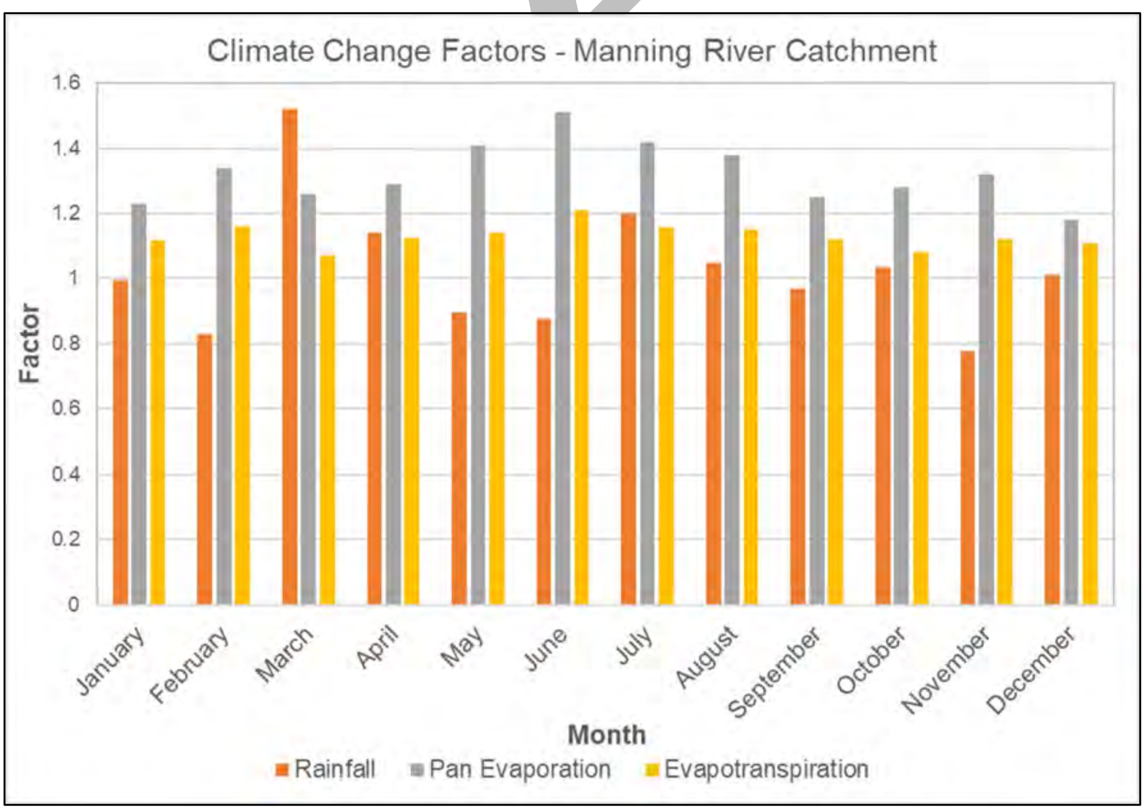

Figure 20 Climate Change Factors - Manning River Catchment

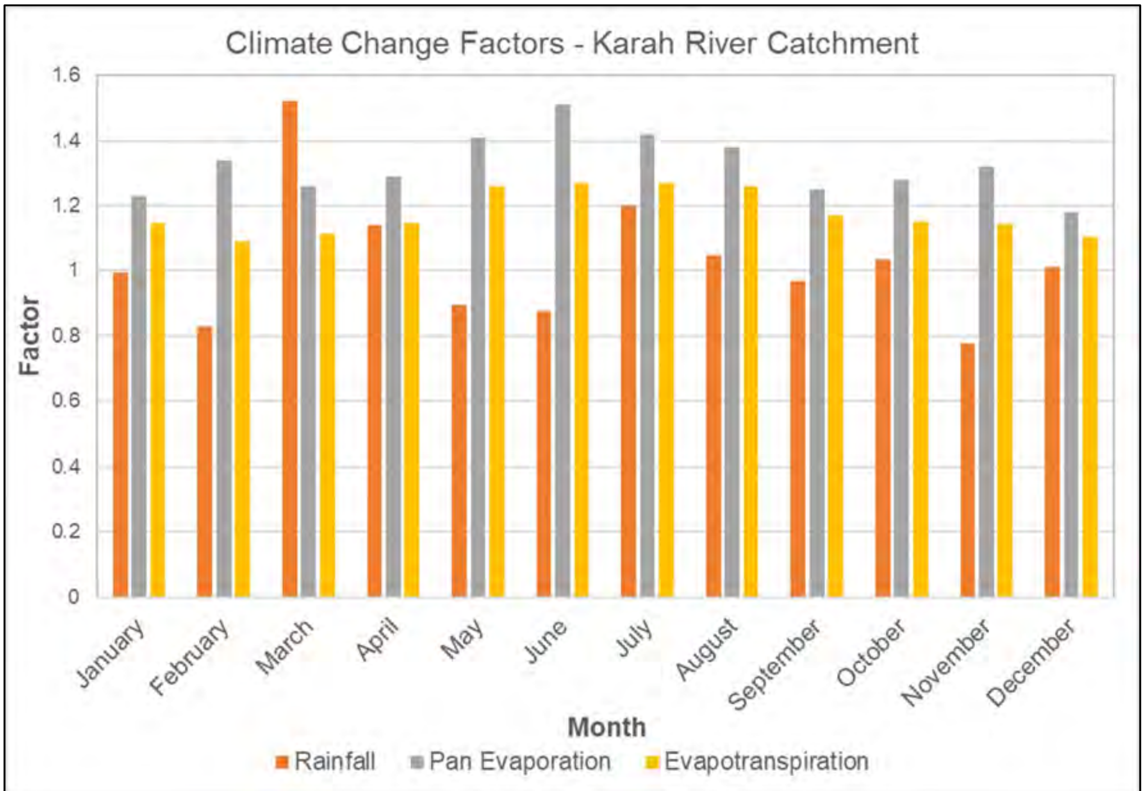

Figure 21 Climate Change Factors - Karah River Catchment

6.2 Demands

This section provides a summary of the demands considered in the GoldSim WBMs. It should be noted that the effect of water restrictions on demand is not included in this study.

6.2.1 Irrigation

Bulahdelah and Stroud

The effect of irrigation on daily flows was not explicitly modelled for Bulahdelah and Stroud. Like the **NUWS 2021** study, it has been assumed that upstream irrigation would be controlled by extraction licences and Water Sharing Plans.

Gloucester and Manning

The effect of irrigation demands in **Table 19** on daily flows was explicitly modelled for Gloucester and Manning. Irrigation demands were only considered for the calibrated AWBM runoff sequence and climate change AWBM runoff sequence. Irrigation was not considered for the historical gauged record used to generate the design runoff sequence (refer **Section 3.3**) as it nominally includes the effect of irrigation on daily peak flows.

Table 19 Irrigation Allowances

Month	Irrigation Release Requirement (ML/d)	
	Gloucester	Manning
January	23.39	53.5
February	20.04	49.6
March	21.42	42.3
April	12.97	29.6

Month	Irrigation Release Requirement (ML/d)	
	Gloucester	Manning
May	8.00	10.0
June	7.56	7.4
July	10.10	7.9
August	9.45	12.7
September	16.65	27.5
October	18.91	44.1
November	22.78	52.1
December	32.75	57.2

6.2.2 Water Treatment Plant

Table 20 provides the dry year average day demand projections used in the GoldSim WBMs for each of the WTPs considered by this investigation.

Table 20 Dry Year Average Day Demand Projections

Period	Demand Projections - Yield Average Year projections (ML/yr)			
	Bulahdelah WTP	Gloucester WTP	Manning WTP	Stroud WTP
2020	0.32	0.79	18.6	0.26
2026	0.36	1.03	22.5	0.32
2031	0.38	1.07	24.1	0.33
2036	0.41	1.12	25.8	0.35
2041	0.44	1.17	27.3	0.36
2046	0.46	1.22	29.0	0.37
2051	0.49	1.27	30.9	0.38

Past Demand

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7.0 Analysis and Results

7.1 Secure Yield Analysis: The 5/10/10 Level of Service Design Approach

This study uses the 'NSW Security of Supply' method, also known as the 5/10/10 level of service (LOS) design approach, for the secure yield assessment. This method is based on the draft NSW Guidelines for Assuring Future Urban Water Security, 2013. The method described in the excerpt below has been extracted from *DPIE Guidance on strategic planning outcome - Understanding water security, 2022.*

The NSW Security of Supply method was developed in the 1980s after lessons learnt from the severe 1978-83 drought. It aims to enable regional NSW water utilities to size their water supply headworks systems on a sound, robust, and cost-effective basis.

Commonly referred to as the '5/10/20 design approach', the '5/10/10 design approach' later replaced it due to the 53% reduction in average annual residential water supplied per property in the 20 years from 1991.

The 5/10/10 design approach aims to ensure full demand can be met in wet, average, and most dry years, with only water restrictions of moderate duration, frequency, and severity required to ensure continuity of the water supply during extended drought periods. See Figures 3 and 4.

As it can cope with effectively a '1-in-1,000 year' drought, it is sufficiently robust to maintain continuity of supply in significantly more severe future droughts than have occurred in the past 130 years, albeit with a higher level of drought water restrictions.

Under the 5/10/10 design approach, water supply headworks systems are normally sized so that:

a. time spent in restrictions does not exceed 5% of the time (5% duration – Figure 3)

b. there is no need to apply restrictions in more than 10% of years (10% frequency – Figure 3)

c. the severity of restrictions does not exceed 10%. Systems should meet 90% of the unrestricted dry year water demand (that is, 10% average reduction in consumption due to water restrictions) through simulation of the worst recorded drought (Figure 4) commencing at the time restrictions are introduced (with a commencing storage volume equal to the restriction volume C in Figures 3 and 4).

This enables utilities to operate their systems without restrictions until the volume of stored water approaches the restriction volume C, which is typically about 65% of the storage capacity (refer to Figure 3). If at this trigger volume, the utility imposes drought water restrictions that reduce demand by an average of 10%, the system would be able to cope with a repeat of the worst recorded drought, commencing at that time, without emptying the storage (as shown in Figure 4).

'Secure yield' is the highest annual water demand a headworks system can supply while meeting the 5/10/10 design rule.

Water security is achieved if the secure yield of a water supply is at least equal to the unrestricted dry year annual demand.

Figure 3 shows the results of simulating an example utility's storage behaviour for 120 years of observed historical daily streamflow, rainfall, and evaporation data. It shows:

- it is possible to supply unrestricted water demand for more than 95% of the time and more than 90% of years (that is, whenever the storage volume is above the restriction volume C). To satisfy the 5/10/10 design rule, a utility must impose restrictions whenever the volume of water in storage falls below the restriction volume C
- a 10% reduction in demand is applied when the storage falls below restriction volume C
- the (then) worst historical drought shown in Figure 3 is for approximately a 5-year period from January 1939 to December 1943
- the minimum simulated usable storage volume is approximately 30% of the full storage capacity.

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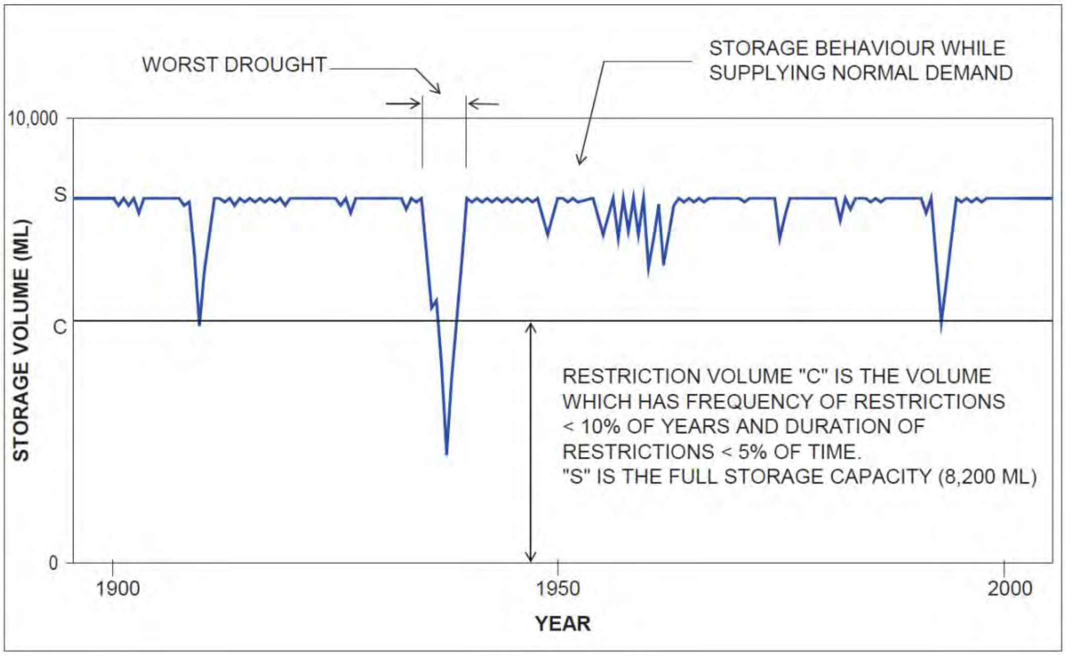

Figure 3 Duration and frequency of restrictions under 5/10/10 design approach

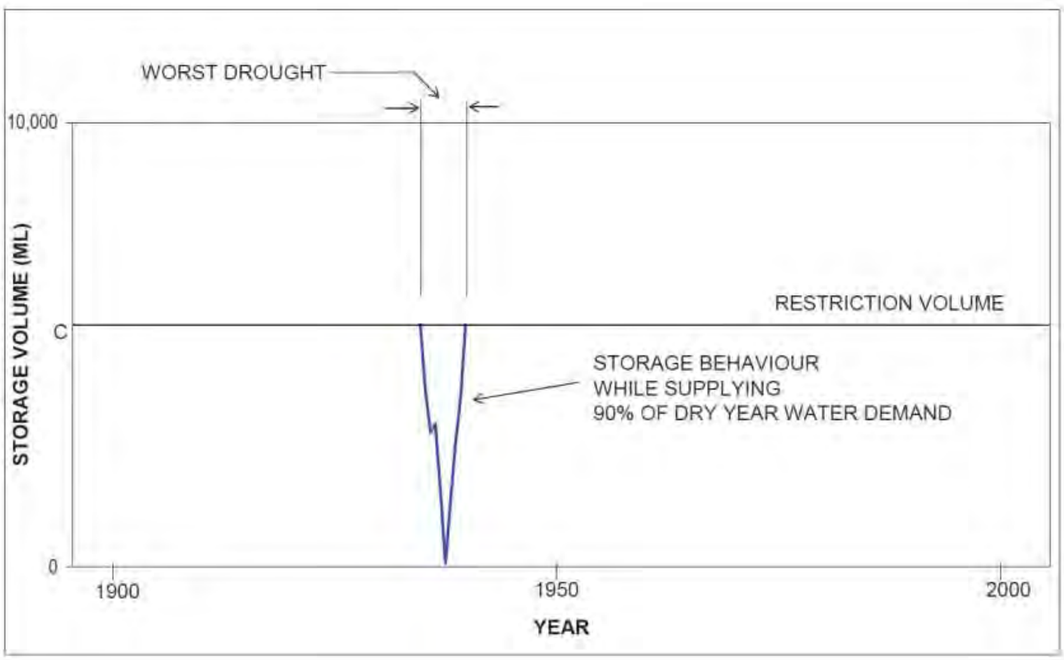

Figure 4 Duration and frequency of restrictions under 5/10/10 design approach

Figure 4 shows the results of simulating storage behaviour for the worst drought identified in Figure 3 (5-year drought from January 1939 to December 1943) on the following basis:

- a 10% reduction to the unrestricted dry year water demand for the full 5-year drought as the storage volume is below the restriction volume C
- the commencing storage volume for this simulation is the restriction volume C, and the resulting minimum simulated usable storage volume is approximately 2% of the full storage capacity.

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The requirements of the 5/10/10 design rule approximates the severity of a '1-in-1,000 year' drought and is necessary to enable a utility to manage its system in a drought of similar severity to the worst drought in the 130-year historical record, with only moderate water restrictions.

As Figure 3 and Figure 4 both simulate the first year of the worst drought for this example utility, the water supply system must be able to cope with effectively a 6-year drought, rather than the 5-year worst historical drought in Figure 3. It is important to note that the analytical process for the 5/10/10 design rule is iterative and only identifies a solution when all 3 requirements have been met.

7.2 Baseline Conditions

Table 21 and **Table 22** provide the security of supply (5/10/10 LOS design rule) for each water supply scheme using the water transfer rules in **Section 4.1** under historical climate conditions for 2020 demands and 2051 demands respectively. **Figure 22** provides exceedance charts for each water supply scheme for the restriction frequency (5%) and duration (10%) measures compared to the available storage volumes.

Table 21 Security of Supply – Historical Climate Conditions and 2020 Demands

2020 Demand					
Water Supply Scheme	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
		Applied at storage (% full)	Duration (%)	% of years	
Bulahdelah	139	67	0.9	9.8	03/10/1964 – 28/06/1965
Gloucester*	-	-	4.3	92.8	1/12/2019 - 18/01/2020 (48 d)
Manning	6,096	66	2.3	9.8	04/04/1950 – 09/06/1951
Stroud	47	24	1.1	9.7	02/09/1964 – 25/08/1965

* Metrics for Gloucester refer to the percentage of time where there is a supply deficit (supply<Demand)
- Gloucester Water Supply Scheme does not include a raw water storage

Table 22 Security of Supply – Historical Climate Conditions and 2051 Demands

2051 Demand					
Water Supply Scheme	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
		Applied at storage (% full)	Duration (%)	% of years	
Bulahdelah	139	58	0.9	9.8	04/02/1965 - 28/06/1965
Gloucester*	-	-	4.3	92.8	1/12/2019 - 18/01/2020 (48 d)
Manning	5,807	27.5	1.0	9.8	20/07/1949 – 01/11/1951
Stroud	46	15	2.2	23.1	09/02/1965 - 28/07/1965

* Metrics for Gloucester refer to the percentage of time where there is a supply deficit (supply<Demand)
- Gloucester Water Supply Scheme does not include a raw water storage

The following should be noted on **Table 21** and **Table 22**:

- Bulahdelah:
  - Water security is achieved for the water supply scheme under 2020 demands.
  - Water security is not achieved for the water supply scheme under 2051 demands. However, water restrictions may be an effective measure to improve the supply reliability given the low predicted demand profile of Bulahdelah.
- Gloucester:
  - The Gloucester Water Supply Scheme does not include a storage volume that supplies the water supply headworks. However, it is known from the 2019/2020 drought that the local water supply scheme could not reliably supply water to the town and supplementary water was trucked in by Council.
  - The supply reliability for Gloucester is 95.7% (number of days) under both 2020 and 2051 demands. However, it is noted that the critical supply deficit period of 48 days where the unrestricted demand is greater than the supply is relatively long.
  - The above dot points demonstrates that water security was not achieved for the water supply scheme under present day (2020) conditions. Without intervention, it is likely that water security would also not be achieved under future state conditions where the town's demands are predicted to increase and where climate change may case longer droughts.
- Manning:
  - The critical supply deficit period (13/11/1950 - 7/12/1950) for the Manning River water supply scheme is not caused by a drought (lack of water). Instead, the "critical drought" is a relatively wet period in the Manning River catchment where the modelled streamflow is high. The high modelled streamflow is higher than the maximum water quality offtake assumption for phosphate of 10,000 ML/d (50NTU). This means that water cannot be harvested from the Manning River during the "critical drought" period.
  - The water security is not achieved for the water supply scheme under 2020 demands even though the restriction volume (66%), duration (0.9%) and frequency (9.8%) are reasonable compared to the **DPIE 2022** guidance of around 65%.
  - The water security is not achieved for the water supply scheme under 2051 demands. Furthermore, the restriction volume of 27.5% is low compared to the typical restriction of volume of 65% described in the **DPIE 2022** guidance of around 65%. It should be noted that the restriction volume of 27.5% is equal to the dead storage volume of Bootawa Dam.
- Stroud:
  - The water security is not achieved for the water supply scheme under both 2020 and 2051 demand scenarios.
  - The restriction volume of 24% under 2020 demands and 14% under 2051 demands is low compared to the typical restriction of volume of around 65% described in the **DPIE 2022** guidance.

Table 23 provides a summary of the water security and potential actions that could be considered to improve the water security under the unrestricted dry year demand scenarios for each water supply scheme.

Table 23 Summary of Baseline Condition Assessment Results

Water Supply Scheme	Is Water Security Achieved?		Potential Actions to Improve Water Security
	2020 Demands	2051 Demands	
Bulahdelah	Y	N	• Provide a raw water supply storage • Provide a supplementary water supply
Gloucester	N	N	• Provide a raw water supply storage • Provide a supplementary water supply
Manning	N	N	• Provide a raw water supply storage

Water Supply Scheme	Is Water Security Achieved?		Potential Actions to Improve Water Security
	2020 Demands	2051 Demands	
			• Provide a supplementary water supply • Investigate whether there are opportunities for harvesting raw water with high phosphate levels
Stroud	N	N	• Provide a raw water supply storage • Provide a supplementary water supply

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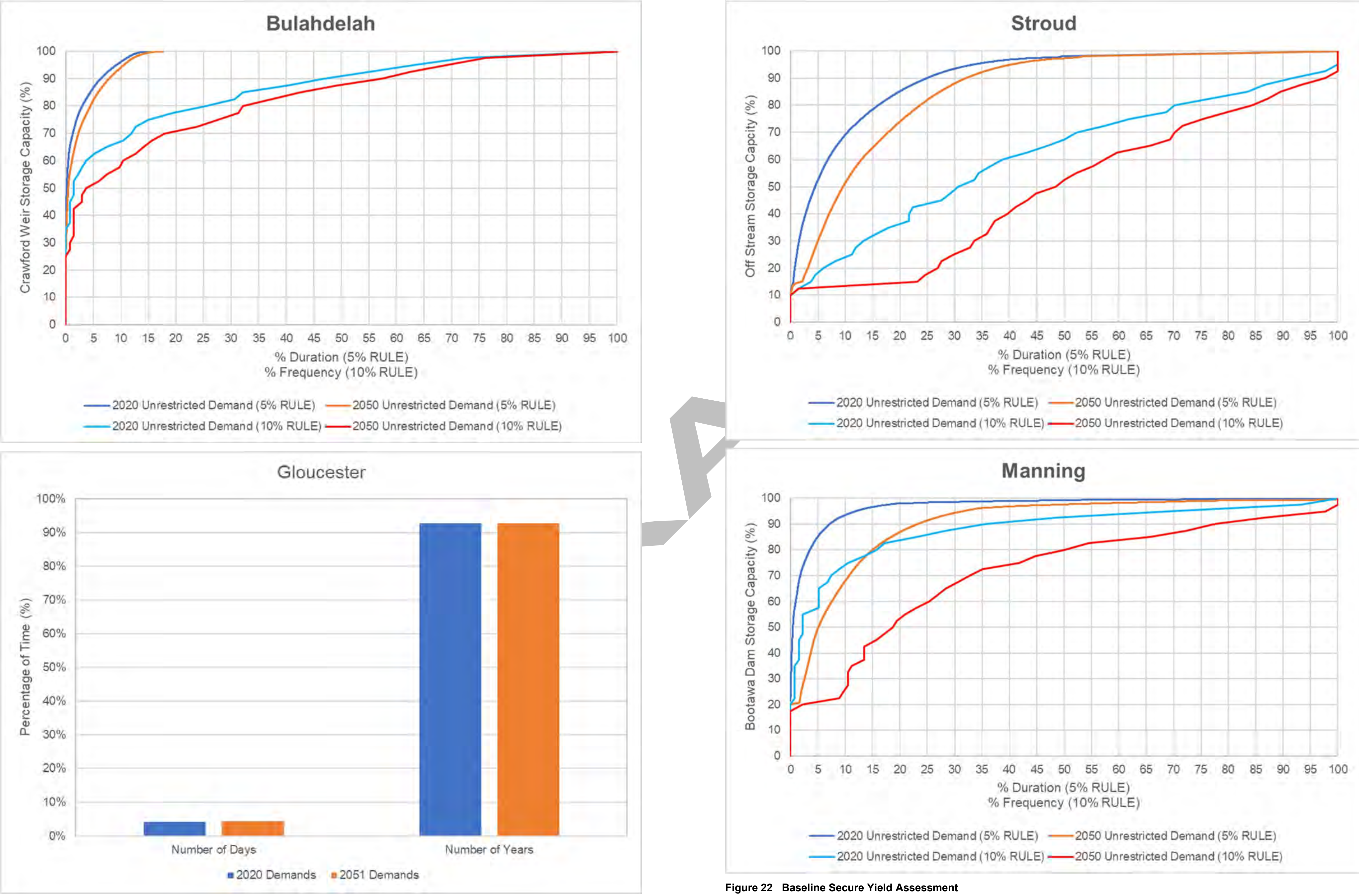

Figure 22 Baseline Secure Yield Assessment

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7.3 Climate Change Conditions

Table 24 provides the security of supply (5/10/10 design rule) for each water supply scheme using the water transfer rules in **Section 4.1** under climate change conditions for the projected 2051 demands.

Table 24 Security of Supply – Climate Change Conditions and 2051 Demands

2051 Demand						
Water Supply Scheme	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
		Applied at storage (% full)	Duration (%)	% of years	
Bulahdelah	58	26.5	0.9	9.8	19/01/1965 - 29/06/1965
Gloucester	-	-	0.9	21	04/12/2019 - 09/01/2020
Manning	6,720	27.5	1.1	10.5	17/06/1950 – 24/05/1951
Stroud	36.5	15	4.3	42	14/01/1965 - 31/07/1965

* Metrics for Gloucester refer to the percentage of time where there is a supply deficit (supply<Demand)
- Gloucester Water Supply Scheme does not include a raw water storage

Table 24 demonstrates that except for Manning, the modelled security of supply for the 2051 demands is lower under climate change conditions compared to historical climate conditions. The modelled security of supply for the Manning scheme is higher reliability under climate change conditions as the critical deficit period is shorter compared to historical climate conditions.

7.4 Design Case

The sections below provide a summary of the design case assessments undertaken for the water supply schemes.

7.4.1 Design Case Modelling Approach

The following approach was used for the design case assessment:

- The design case assessments were only undertaken on the 2051 demands given that this project is focused on developing future water usage strategies.
- The simulated historical and climate change streamflow sequences were considered in the design case assessments.
- The required storage volumes for each design case option were determined using the 5/10/10 guidance in **DPIE 2022** using a twostep approach:
  - Step 1 (**Supply = Demand**): The storage volumes were calculated for a 100% reliability of supply design case where supply is equal to demand. If the calculated restriction volume (Volume C) for the 5/10/10 rule was greater than the typical 65% restriction volume described in the **DPIE 2022**, no further calculations were undertaken for the design case. If the restriction volume was smaller than the **DPIE 2022** guidance, Step 2 was followed.
  - Step 2 (**Restriction Volume = 65**%): Calculation of the required storage so that the 5/10/10 guidance in **DPIE 2022** is satisfied for a minimum restriction volume of 65%.
  - Selected volume – the greater of volumes determined through step 1 and 2 above
- The **DPIE 2022** secure yield assessment was not considered for the supplementary supply options. The aim of the supplementary supply options was to provide an indication of the volume required when supply is less than the demand.

7.4.2 Design Case Options

Table 25 provides a list of the design case water supply scheme augmentation scenarios evaluated by the water yield assessment.

Table 25 Water Yield Assessment Scenarios

Town	Demand Configuration	Option
Bulahdelah	• 2051 Demands	B1 – New Storage
		B2 – Supplementary Supply
Gloucester	• 2051 Demands	G1 – New Storage
		G2 – Supplementary Supply
Manning	• 2051 Demands + 1 ML/d truck fill allowance	M1 – New Storage (Peg Leg Dam)
		M2 – Supplementary Supply
	• Combined 2051 Demands: - Local Scheme - Bulahdelah - Gloucester + 1 ML/d truck fill allowance	M3 – New Storage (Peg Leg Dam)
		M4 – Supplementary Supply
	• 2051 Local Scheme Demands + 1 ML/d truck fill allowance • Bulahdelah Supplementary Supply (from B2) • Gloucester Supplementary Supply (from G2)	M5 – New Storage (Peg Leg Dam)
		M6 – Supplementary Supply
	• 2051 Demands + 1 ML/d truck fill allowance • 5.3 ML/d Purified Recycled Water (PRW) recovery	PRWM1 – New Storage (Peg Leg Dam)
		PRWM2 – Supplementary Supply
	• Combined 2051 Demands: - Local Scheme - Bulahdelah - Gloucester + 1 ML/d truck fill allowance • 5.3 ML/d PRW recovery	PRWM3 – New Storage (Peg Leg Dam)
		PRWM4 – Supplementary Supply
	• 2051 Local Scheme Demands + 1 ML/d truck fill allowance • Bulahdelah Supplementary Supply (from B2) • Gloucester Supplementary Supply (from G2) • 5.3 ML/d PRW recovery	PRWM5 – New Storage (Peg Leg Dam)
		PRWM6 – Supplementary Supply
Stroud	• 2051 Demands	S1 – New Storage
		S2 – Supplementary Supply

7.4.3 Design Case Results

7.4.3.1 Bulahdelah

A summary of the design case scenarios for Bulahdelah is provided in:

- **Table 26** for the new storage option (B1)
- **Table 27** for the supplementary supply option (B2).

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Table 26 Secure Yield Assessment Results for Storage Option B1

Streamflow Sequence	Design Case	Storage	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
				Applied at storage (% full)	Duration (%)	% of years	
Historic Climate	Supply = Demand	228 ML (Crawford Weir) + 190 ML	179	45	1.5	9.8	11/08/1964 – 21/11/1965
	Restriction Volume = 65%	228 ML (Crawford Weir) + 360 ML	329	65	1.9	9.8	09/08/1964 – 09/12/1965
Climate Change	Supply = Demand	228 ML (Crawford Weir) + 200 ML	179	43	1.3	9.0	09/08/1964 – 29/11/1965
	Restriction Volume = 65%	228 ML (Crawford Weir) + 390 ML	321	65	2.0	10.5	09/08/1964 – 05/05/1966

Table 27 Supplementary Supply Results for Option B2

Scenario	Streamflow Sequence	Deficit (ML)	Peak Daily Volume Deficit (ML/d)	Deficit Period
B2	Historic Climate	71	0.53	04/02/1965 - 28/06/1965
	Climate Change	80	0.57	19/01/1965 - 29/06/1965

7.4.3.2 Gloucester

A summary of the design case scenarios for Gloucester is provided in:

- **Table 28** for the new storage option (G1)
- **Table 29** for the supplementary supply option (G2).

Table 28 Secure Yield Assessment Results for Storage Option G1

Streamflow Sequence	Design Case	Storage	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
				Applied at storage (% full)	Duration (%)	% of years	
Historic Climate	Supply = Demand	120 ML	463	56	2.6	9.0	13/11/2019 - 28/09/2020
	Restriction Volume = 65%	180 ML	479	65	3.0	9.0	10/11/2019 - 06/10/2020
Climate Change	Supply = Demand	260 ML	463	32	5.0	8.3	01/12/2019– 15/11/2022
	Restriction Volume = 65%	260 ML	463	65	6.4	9.8	01/12/2019– 15/11/2022

Table 28 Notes:

- The 5/10/10 secure yield rule cannot be satisfied for a restriction volume of 65% under climate change conditions regardless of the maximum storage size. This is associated with the 3,000 ML/d maximum offtake flow threshold assumption for turbidity in the Barrington River. In the GoldSim WBM, the modelled wet periods under climate change conditions have larger peak discharges compared to the same periods under historical climate conditions. This means that there are longer periods under climate change conditions where the modelled streamflow in the Barrington River is greater than the maximum 3,000 ML/d turbidity flow threshold assumption during the wet season compared to historical climate conditions.

Table 29 Supplementary Supply Results for Option G2

Scenario	Streamflow Sequence	Deficit (ML)	Peak Daily Volume Deficit (ML/d)	Deficit Period
G2	Historic Climate	62	1.31	30/11/2019 - 18/01/2020
	Climate Change	46	1.31	03/12/2019 - 09/01/2020

7.4.3.3 Manning

A summary of the design case scenarios for Manning is provided in:

- **Table 30** for the new storage options (Peg Leg Dam)
- **Table 31** for the supplementary supply options.

Table 30 Secure Yield Assessment Results for Storage Options

Scenario	Streamflow Sequence	Design Case	Bootawa Dam (ML) [Peg Leg Storage ML]	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
					Applied at storage (% full)	Duration (%)	% of years	
M1	Historic Climate	Supply = Demand	2,275 [5,430]	12,571	70	1.1	10.5	19/04/2019 - 28/03/2020
	Climate Change	Supply = Demand	2,275 [2,851]	12,571	55	1.0	10.5	19/04/2019 - 08/03/2020
		Restriction Volume = 65%	2,275 [4,660]	17,853	65	0.8	9.0	20/10/2019 – 11/04/2020
M3	Historic Climate	Supply = Demand	2,275 [5,430]	13,258	68	1.2	9.8	30/12/2019 - 04/04/2020
	Climate Change	Supply = Demand	2,275 [3,209]	13,258	55	1.0	9.8	07/07/2019 - 14/04/2020
		Restriction Volume = 65%	2,275 [5,045]	18,302	65	0.9	9.8	20/10/2019 – 18/04/2019
M5	Historic Climate	Supply = Demand	2,275 [4,660]	12,571	67	1.1	9.8	20/07/2019 - 23/03/2020
	Climate Change	Supply = Demand	2,275 [2,851]	12,571	55	1.0	10.5	19/10/2019 - 09/03/2020
		Restriction Volume = 65%	2,275 [3,045]	16,396	65	1.0	9.8	19/10/2019 - 14/02/2020

Scenario	Streamflow Sequence	Design Case	Bootawa Dam (ML) [Peg Leg Storage ML]	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
					Applied at storage (% full)	Duration (%)	% of years	
PRW M1	Historic Climate	Supply = Demand	2,275 [3,542]	12,571	68	0.9	9.8	19/10/2019 – 09/03/2020
	Climate Change	Supply = Demand	2,275 [2,259]	12,571	54	0.8	9.8	19/10/2019 – 09/03/2020
		Restriction Volume = 65%	2,275 [3,045]	16,710	65	0.9	9.8	20/10/2019 – 24/02/2019
PRW M3	Historic Climate	Supply = Demand	2,275 [3,398]	13,258	67	0.8	9.8	20/07/2019 – 14/03/2020
	Climate Change	Supply = Demand	2,275 [2,470]	13,258	57	0.8	9.8	20/10/2019 - 01/03/2020
		Restriction Volume = 65%	2,275 [3,542]	17,111	65	0.9	9.8	20/10/2019 – 02/032020
PRW M5	Historic Climate	Supply = Demand	2,275 [3,542]	12,571	68	0.9	9.0	14/07/2019 - 09/03/2020
	Climate Change	Supply = Demand	2,275 [2,259]	12,571	59	0.8	9.8	17/08/2019 – 12/02/2020
		Restriction Volume = 65%	2,275 [2,265]	16,827	65	0.7	9.0	14/10/2019 – 30/01/2020

Table 30 notes:

- The minimum offtake flow threshold in the Manning River for raw water harvesting was increased from 30 ML/d to 225 ML/d for the Peg Leg Dam Storage option.
- The stage-storage and stage-surface area relationship for Bootawa Dam was applied for Peg Leg Dam Storage option in the modelling.

Table 31 Supplementary Supply Results for the Manning Water Supply Scheme

Scenario	Streamflow Sequence	Deficit (ML)	Peak Daily Volume Deficit (ML/d)	Deficit Period
M2	Historic Climate	1,693	28.4	20/11/2019 - 21/01/2020
	Climate Change	1,152	22.4	06/03/2022 - 29/04/2022
M4	Historic Climate	1,949	30.3	15/11/2019 - 21/01/2020
	Climate Change	1,294	24.1	27/02/2022 - 29/04/2022
M6	Historic Climate	1,612	28.4	20/11/2019 - 21/01/2020
	Climate Change	1,152	22.4	06/03/2022 - 29/04/2022
PRWM2	Historic Climate	921	22.7	09/12/2020 - 21/01/2020
	Climate Change	425	16.9	03/04/2022 - 29/04/2022
PRWM4	Historic Climate	1,171	24.6	02/12/2019 - 21/01/2020
	Climate Change	682	17.7	22/03/2022 - 29/04/2022

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Scenario	Streamflow Sequence	Deficit (ML)	Peak Daily Volume Deficit (ML/d)	Deficit Period
PRWM6	Historic Climate	833	22.7	11/12/2019 - 21/01/2020
	Climate Change	425	16.9	03/04/2022 - 29/04/2022

7.4.3.4 Stroud

A summary of the design case scenarios for Stroud is provided in:

- **Table 32** for the new storage option (S1)
- **Table 33** for the supplementary supply option (S2).

Table 32 Secure Yield Assessment Results for Storage Option S1

Streamflow Sequence	Design Case	Storage	Secure Yield (ML/a)	Restrictions			Critical Deficit Period
				Appliedat storage (% full)	Duration (%)	% of years	
Historic Climate	Supply = Demand	50 ML + 110 ML	139	56	2.9	9.7	05/04/1964 - 19/07/1966
	Restriction Volume = 65%	50 ML + 190 ML	237	65	3.6	9.7	03/09/1964 – 10/05/1966
Climate Change	Supply = Demand	50 ML + 130 ML	139	46	2.4	9.0	10/08/1964 - 05/05/1966
	Restriction Volume = 65%	50 ML + 400 ML	267	65	3.2	9.0	23/11/1900 - 05/12/1903

Table 33 Supplementary Supply Results for Option S2

Scenario	Streamflow Sequence	Deficit (ML)	Peak Daily Volume Deficit (ML/d)	Deficit Period
S2	Historic Climate	59	0.49	11/02/1965 - 26/07/1965
	Climate Change	72	0.49	16/01/1965 - 29/07/1965

8.0 Conclusions and Recommendations

This report provides a summary of the water balance yield assessments for the Manning, Gloucester, Bulahdelah and Stroud water supply headworks systems. The primary purpose of this report was to facilitate the development of the MidCoast Council Integrated Water Cycle Management (IWCM) strategy in accordance with DPIE Water recommended procedures.

The following approach was used for the WBM yield assessment:

- Runoff sequences were generated for each water supply scheme by the calibration of catchment specific AWBMs.
- GoldSim WBMs were developed using water transfer rules described in previous studies and provided by Council.
- The GoldSim WBMs were validated to recorded historical water level data for the available raw water storages.
- A baseline secure yield assessment was undertaken following the 5/10/10 rule provided by **DPIE 2022** for both historical and future climate change conditions.
- Different water supply scheme augmentation options were evaluated using the GoldSim WBMs.

The following recommendations have been noted from the WBM yield assessment:

- The calibration of the WBMs should be reviewed as more calibration data becomes available. Regular reviews of the WBM calibration will improve the accuracy of the WBM results and facilitate water security planning.
- A more detailed WBM assessment should be undertaken for any options that Council wishes to pursue to improve water security. This includes any investigations to improve the operational efficiency of the current water supply schemes.
- The climate change assessment in the WBM should be reviewed using the recently available paleo-stochastic climate data. The review should be undertaken before any detailed feasibility investigations are undertaken on any option that Council wishes to pursue.

9.0 References

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