

Hydrologic analysis of options for the Gwydir Regional Water Strategy

Regional Water Strategies Program

June 2022





Acknowledgement of Country

The NSW Government acknowledges Aboriginal people as Australia's first people and the traditional owners and custodians of the country's lands and water. Aboriginal people have lived in NSW for over 60,000 years and have formed significant spiritual, cultural, and economic connections with its lands and waters. Today, they practise the oldest living cultures on earth.

The NSW Government acknowledges the Gomeroi people as having an intrinsic connection with the lands and waters of Gwydir Regional Water Strategy area. The landscape and its waters provide the Gomeroi people with essential links to their history and help them to maintain and practice their Traditional culture and lifestyle.

The NSW Government recognises that the Traditional Owners were the first managers of Country and that incorporating their culture and knowledge into management of water in the region is a significant step for closing the gap.

Published by NSW Department of Planning and Environment

dpie.nsw.gov.au

Hydrologic analysis of options for the Gwydir Regional Water Strategy

First published: June 2022

Department reference number: PUB22/781

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Executive Summary

The NSW Government is developing 12 regional water strategies that bring together the best and latest climate evidence, with a wide range of tools and solutions to plan and manage each region's water needs over the next 20 to 40 years.

The draft Gwydir Regional Water Strategy, including a long list of options, was released in September 2020.¹

This report provides the outcomes of hydrological assessment that was undertaken to understand the impact of options that influence the supply or demand of water in the catchment, as well as to feed into the economic and environmental assessment of options.

Assessment of water security and changes in flows regime in the Gwydir valley were undertaken for three climatic regimes:

- Instrumental climate – this data includes the period of available instrumental meteorological recordings for the catchment (1889–2020)
- long-term historic climate projections (stochastic data) — these assume that our future climate is similar to what the science is indicating our long-term paleoclimate was like and are based on a 10,000-year dataset
- a dry climate change scenario (NARClIM modelling) — this assumes that there is a dry worst-case climate change scenario in the future and is also based on a 10,000-year dataset.

Four options and a base case were modelled. Three options were assessed by modelling alternate scenarios (Table 1). All hydrologic and water supply assessment modelling was undertaken using the Integrated Quantity and Quality Model (IQQM). The IQQM model was developed as a tool for planning and evaluating water resource management policies at the river basin scale. This model can be applied to regulated and unregulated streams and can address water quality and environmental issues, as well as water quantity issues.

¹ The draft Gwydir Regional Water Strategy and long list of options can be viewed at, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies/upcoming-public-exhibition/gwydir-regional-water-strategy

Table 1. Options assessed using hydrologic modelling for the Gwydir Regional Water Strategy

Category	Description
Base case	Scenario 1 — Current conditions with Held Environmental Water used for the environment
Option 1. Enlargement of Tareelaroi Weir	Scenario 2 — Enlarge Tareelaroi Weir without a growth-in-use response Scenario 3 — Enlarge Tareelaroi Weir, raise and maintain diversions at base case total diversions by reducing supplementary shares by 10%
Option 2. New Lower Gravesend Dam on the Gwydir River downstream of Warialda Creek	Scenario 4 — 175 GL dam at Lower Gravesend without a growth-in-use response Scenario 5 — 175 GL dam at Lower Gravesend and reducing supplementary shares by 60% as a growth-in-use response.
Option 18. Increase the storage reserve in Copeton Dam	Scenario 6 — Reserve increased from two to three years (166.5 GL)
Option 29, Investigation of licence conversions	Scenario 7 — General security shares reduced by 100% (407.76 GL) and 178.85 GL of high security shares created at Moree
a. Bulk licence conversion	Scenario 8 — General security shares reduced by 10% (40.78GL) and 17.89 GL of high security shares created at Moree
b. Partial licence conversion	

1. Introduction

This report outlines the hydrologic modelling undertaken to understand the how infrastructure and policy options that change the supply, demand or sharing of water will impact on different water users, licence holders and flows in the Gwydir catchment. Water security modelling for the Gwydir regulated river system was undertaken using the Gwydir Integrated Quantity and Quality Model (IQQM).

Hydrological modelling is a key input to the development of the final Gwydir Regional Water Strategy. The modelling provides part of the evidence for options being included in the proposed shortlist of actions identified in the *Gwydir Regional Water Strategy: Short-listed actions for the Gwydir region: Consultation Paper*.

Four options and a base case were modelled. Three options were assessed by modelling several scenarios (Table 2). Modelling results for each option and scenario are presented in Sections 4 to 8 of this report.

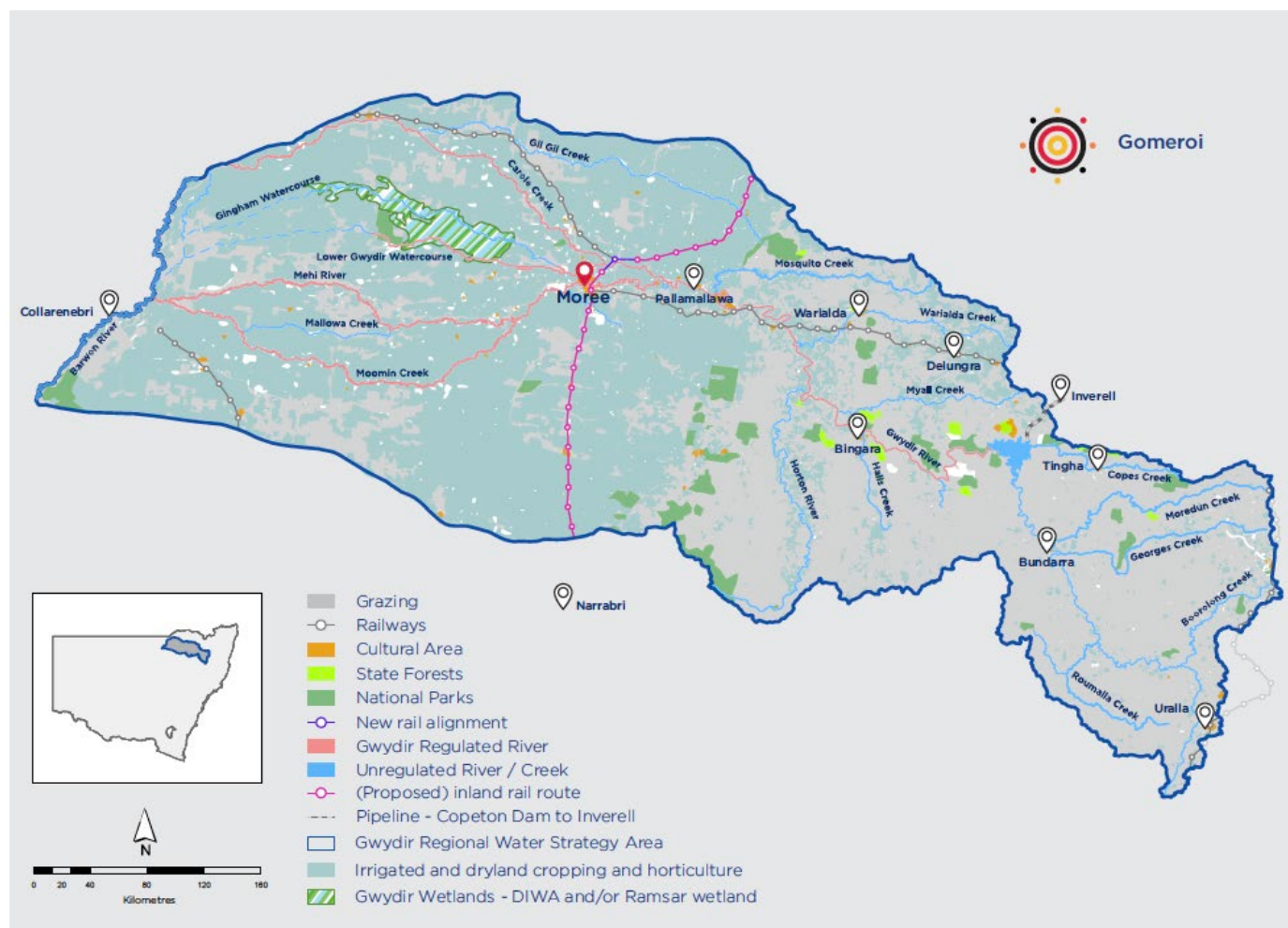
2. Background

Gwydir region

The Gwydir region is located in northern NSW. It covers more than 26,000 km². The region is bounded by the Border Rivers region to the north, the western slopes of the Great Dividing Range to the east, the Namoi catchment to the south and the Barwon River to the west.

The region's population is around 25,000. Moree is the largest town and an important employment and services hub for outlying areas. There are also smaller towns in the region with populations ranging from around 300 to 2,500 people, including Uralla, Bingara, Warialda, Tingha and Delungra.

Figure 1. Map of the Gwydir region



Water resources in the region

Water is a significant feature of the Gwydir region's environment, with its interconnected systems of rivers, creeks, groundwater aquifers and wetlands. The region has one main river, the Gwydir River, which begins northwest of Uralla and flows west for 480 km, joined by over 30 tributaries. The river spreads out into various smaller rivers and creeks as it reaches the Gwydir floodplain, which stretches west from Moree. Near Moree, the river branches out into three separate systems: the Mehi River, Lower Gwydir River and Carole Creek.

The region's towns, communities and industries use water from multiple sources:

- the regulated Gwydir River, supplied from Copeton Dam
- a system of unregulated rivers and creeks
- groundwater sources
- floodplain harvesting
- recycled water from local water utilities
- local runoff from rainfall captured in farm dams.

Copeton Dam, the region's main public water storage, is located on the Gwydir River in the upper reaches of the valley. The dam has a relatively small catchment area and needs large rainfall events to significantly increase the amount of water in storage. Many water users in the region, including towns, industry and environmental water holders, rely on surface water delivered from Copeton Dam. Most water is extracted below Biniguy, facilitated by a network of weirs and regulators on the Gwydir River and its effluent systems.

Unregulated rivers and groundwater from alluvial, artesian, and fractured and porous rock aquifers are also important water resources for towns, industry and water-dependent ecosystems in the region. Floodplain harvesting is also significant in the Gwydir region.

Managing water in the Gwydir region

Water in NSW is managed and shared under the *Water Management Act 2000*, with specific water sharing rules set out in water sharing plans.

The Murray-Darling Basin Plan sets the limit on the amount of water that can be extracted from water sources in the Gwydir region, based on long-term models of the river system. The current draft estimated sustainable diversion limits for the Gwydir are 381 GL per year for surface water and 33.72 GL per year for groundwater.

Extractions in the Gwydir region are managed so that they remain within these limits, irrespective of the licensed entitlement volume. These limits are implemented through water sharing plans for the *Gwydir Regulated River Water Source 2016*, the *Gwydir Unregulated Water Sources 2012* and the *Gwydir Alluvial Groundwater Sources 2020*.

The following plans also operate in the Gwydir Region:

- NSW Great Artesian Basin Groundwater Sources (2020)
- NSW Great Artesian Basin Shallow Groundwater Sources (2020)
- NSW Murray-Darling Basin Porous Rock Groundwater Sources (2020)

- NSW Murray-Darling Basin Fractured Rock Groundwater Sources (2020).

The Water Management Act sets out how we prioritise water sharing during normal operations, with the highest priority being for the environment, followed by basic landholder rights. During extreme events, such as prolonged droughts, the priority changes. Basic landholder rights and essential town water services (authorised by an access licence) become the highest priority in the Murray-Darling Basin, followed by the environment. This change in priorities is triggered when a water sharing plan (or part of a plan) is suspended. The aim is to operate within the plan rules for as long as possible, as they provide clarity for all users of these water sources.

3. Assessment framework

Modelled options

Table 2 lists the options and scenarios modelled for the draft Gwydir Regional Water Strategy.

Each of the options in Table 2 were modelled using the instrumental climate datasets. The options that passed the rapid cost-benefit analysis underwent additional hydrologic assessment using the long-term (stochastic) and climate change (NARClIM) datasets (Options 1, 18 and 29).

Table 2. Options assessed using hydrologic modelling for the draft Gwydir Regional Water Strategy

Category	Description
Base case	Scenario 1 — Current conditions with Held Environmental Water used for the environment
Option 1. Enlargement of Tareelaro Weir	Scenario 2 — Enlarge Tareelaro Weir without a growth-in-use response Scenario 3 — Enlarge Tareelaro Weir, raise and maintain diversions at base case total diversions by reducing supplementary shares by 10%
Option 2. New Lower Gravesend Dam on the Gwydir River downstream of Warialda Creek	Scenario 4 — 175 GL dam at Lower Gravesend without a growth-in-use response Scenario 5 — 175 GL dam at Lower Gravesend and reducing supplementary shares by 60% as a growth-in-use response.
Option 18. Increase the storage reserve in Copeton Dam	Scenario 6 — Reserve increased from two to three years (166.5 GL)
Option 29. Investigation of licence conversions	Scenario 7 — General security shares reduced by 100% (407.76 GL) and 178.85 GL of high security shares created at Moree
a. Bulk licence conversion	Scenario 8 — General security shares reduced by 10% (40.78GL) and 17.89 GL of high security shares created at Moree
b. Partial licence conversion	

Climate datasets

Instrumental climate

The instrumental climate refers to the period of available instrumental meteorological recordings (1889–2020) that are used as input into the rainfall–runoff models, required to generate runoff for river system models and as direct climate input to river system model simulations. For options assessment, fourteen replicates of 40-year periods were sampled from this data to provide a preliminary basis to evaluate options for shortlisting for portfolios.

This climate data is referred to as ‘instrumental’ throughout this report. It is the building block for incorporating long-term and climate change data. This dataset was used for all of the hydrologic options in this report.

Long-term historic climate projections (stochastic data)

The long-term historic climate projections (stochastic data) refers to the 10,000 years of stochastic-generated climate (developed using paleo climatic information by The University of Adelaide, Australia) that are used to evaluate the final viability of portfolios as well as define the base case. For option assessment, a thousand replicates of 40-year periods were sampled from this data to provide a comprehensive assessment of outcomes across many possible climate realisations.

This climate data set is referred to as ‘stochastic’ throughout this report.

Dry climate change scenario (NARCLiM modelling)

The ‘dry climate change scenario (NARCLiM modelling)’ refers to the stochastic climate data generated by multiplying the stochastic time-series of 10,000 years with average monthly scaling factors derived from NSW and Australian Regional Climate Modelling (NARCLiM) climate projections for 2060–2079 compared to the baseline period of 1990–2009 for each climate timeseries for every climate station used in the modelling. The average monthly scaling factors represent the mean of three regional climate models of CSIRO-MK3 GCM used in NARCLiM 1.0.

This set of stochastic data with climate projections are used in conjunction with the stochastic data to evaluate the final viability of options, as well as to define future base cases. For options assessment, 1,000 replicates of 40-year periods were sampled from this data to provide a comprehensive assessment of outcomes across many possible climate realisations.

This source of data is referred to as ‘stochastic+NARCLiM’ throughout the report.

Outputs for option assessment

The performance metrics presented in Table 3 were used to interpret the performance of each option. Streamflow locations were selected to represent the point of maximum flow (Gravesend), inflows to the Gwydir Wetlands (upstream of Tyreel regulator) and the end of the system (remaining stations).

Table 3. Performance metrics

Category	Component
Mean annual diversions	General security
	Supplementary
	High security
	Floodplain harvesting
	Rainfall harvesting
	Local water utilities
Allocations	General security average effective allocation 1 July
	General security average effective allocation 30 June
	90th percentile 30 June
	95th percentile 30 June
Storage behaviour	% of time below 25%
	% of time below 20%
	% of time below 15%
	% of time below 10%
Mean annual streamflow	Gwydir River upstream of Tyreel regulator
	Gwydir River at Gravesend (418013)
	Gwydir River at Collymongle (418031)
	Mehi River near Collarenebri (418055)
	Gil Gil Creek at Galloway (416052)

4. Enlargement of Tareelaroi Weir

Option description

Tareelaroi Weir and the Mehi regulator are located along the Gwydir River (Figure 2). The structures act as regulating water storages that assist with water diversions to the Mehi River system.

Figure 2. Location of Tareelaroi Weir and Mehi regulator



This option assesses enlarging Tareelaroi Weir and modifying the adjoining Mehi regulator to form an increased mid-system water storage. By raising the full supply level from 219.3 m Australian Height Datum (AHD) to 222 m AHD (a 2.7 m rise), an estimated 4 GL increase in storage volume can be achieved. The current weir pool at full supply level has a volume of approximately 2.5 GL, resulting in a total storage after raising of 6.5 GL. This new full supply level governs the height of

the proposed weir and regulator, which will both need to be reconstructed with increased height to accommodate the higher full supply level.²

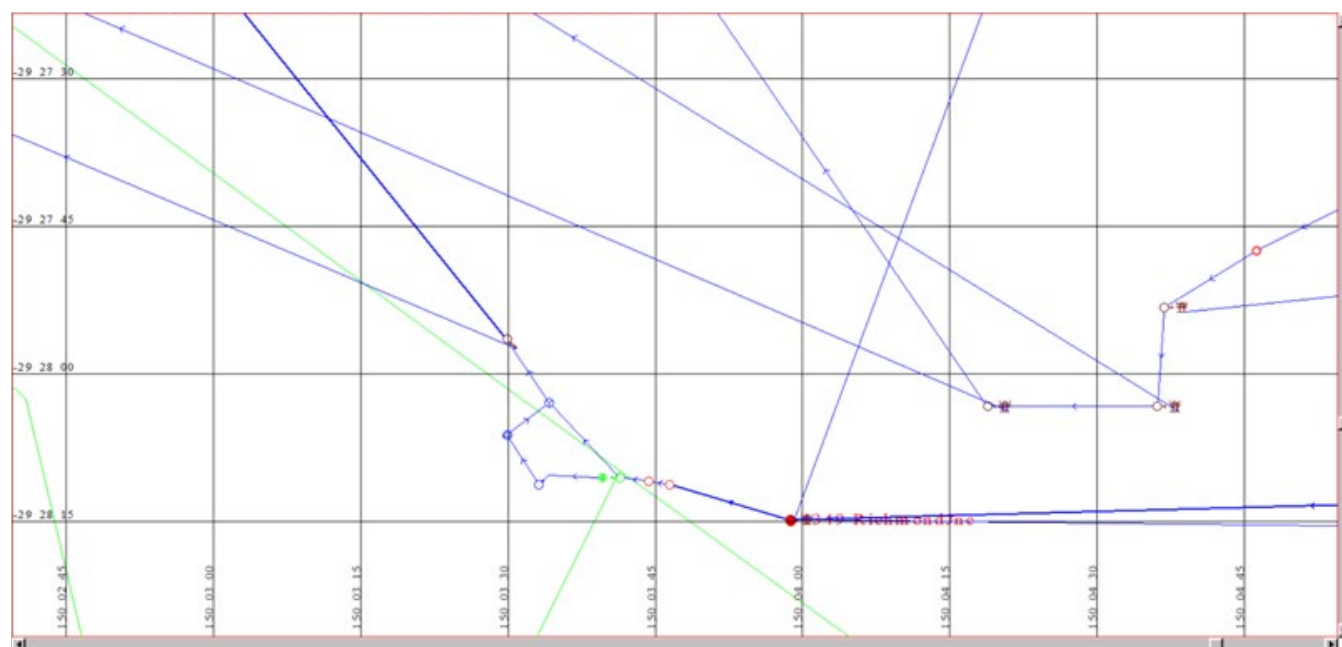
Two scenarios (Scenario 1 is the base case) were assessed:

- Scenario 2 – Enlargement of Tareelaroi Weir without a growth-in-use response
- Scenario 3 – Enlargement of Tareelaroi Weir with a growth-in-use response to maintain diversions at base case total diversions by reducing supplementary shares by 10%

Model configuration and assumptions

Enlarging Tareelaroi Weir was conceptualised as an off-river storage (Figure 3). It was assumed that only flows above 3 T (tributary) and 50:50 sharing of supplementary requirements are available for capture, and that water orders up to the volume held in the re-regulating storage are assumed to be delivered from the re-regulating storage, and that remaining orders are met from Copeton Dam.

Figure 3. Enlargement of Tareelaroi Weir schematic model



Storage characteristics

Assumed storage and outlet characteristics for Tareelaroi Weir are in Table 4 to Table 6.

² Note the draft Gwydir Regional Water Strategy states an increase in volume of 3.65 GL with a full supply volume of 6 GL can be achieved. Modelling has assumed a slightly higher volume based on storage geometry information provided by WaterNSW.

Table 4. Storage dimensions

Volume (ML)	Area (ha)	Level (m)	Comment
0	0	0	No dead storage
2,500	0	4.3	
6,500	2.1	7	Full supply level
7,000	2.5	8	

Table 5. Valve discharge relationship

Volume (ML)	Valve discharge (ML/day)
0	0
5,019	36,320
6,500	79,280

Table 6. Spillway discharge relationship

Volume (ML)	Spillway discharge (ML/day)
6,500	0
6,510	100
7,000	1,000,000
10,000	1.00 E+37

Modelling results

Modelling results are shown for the base case (Scenario 1) and Scenario 2 and Scenario 3 in Table 7.

Alterations in water diversions

Table 7 shows the average annual water diversions for existing water users under the base case (Scenario 1), enlarging Tareelaroi Weir (Scenario 2) and enlarging Tareelaroi Weir with a growth-in-use response (Scenario 3).

Table 7. Mean annual water diversions for the base case (Scenario 1), Scenario 2 and Scenario 3

Water diversions	Base case (GL/yr)	Scenario 2 (GL/yr) Enlarging Tareelaro Weir with no growth-in-use response	Scenario 3 (GL/yr) Enlarging Tareelaro Weir with a growth-in-use response
General security	195.70	203.31	204.16
Supplementary	87.37	83.63	79.34
High security	11.25	11.25	11.25
Floodplain harvesting	67.99	67.76	67.83
Rainfall harvesting	52.65	52.71	52.89
Total diversions	414.95	418.65	415.47

*Current conditions with Held Environmental Water represented.

Figure 4. General security annual diversions for the base case (Scenario 1) and Scenario 3

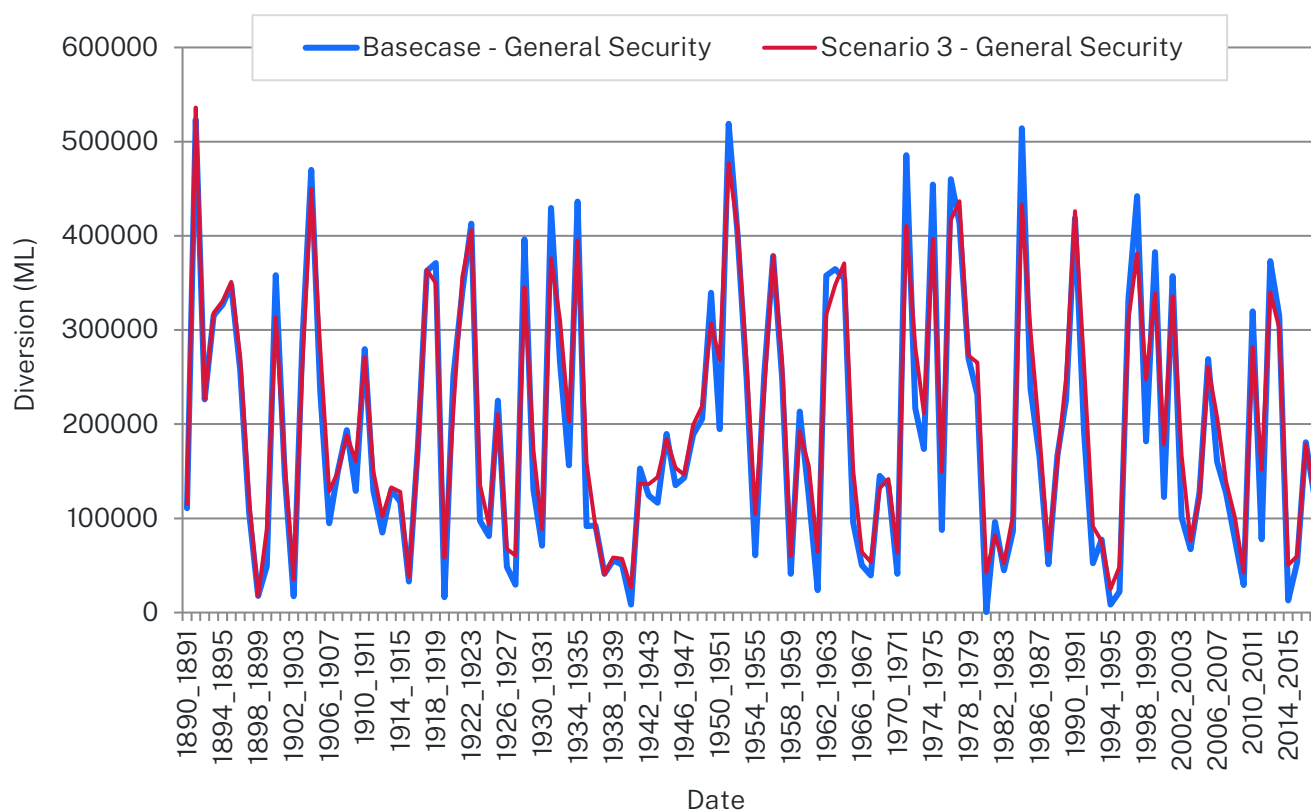
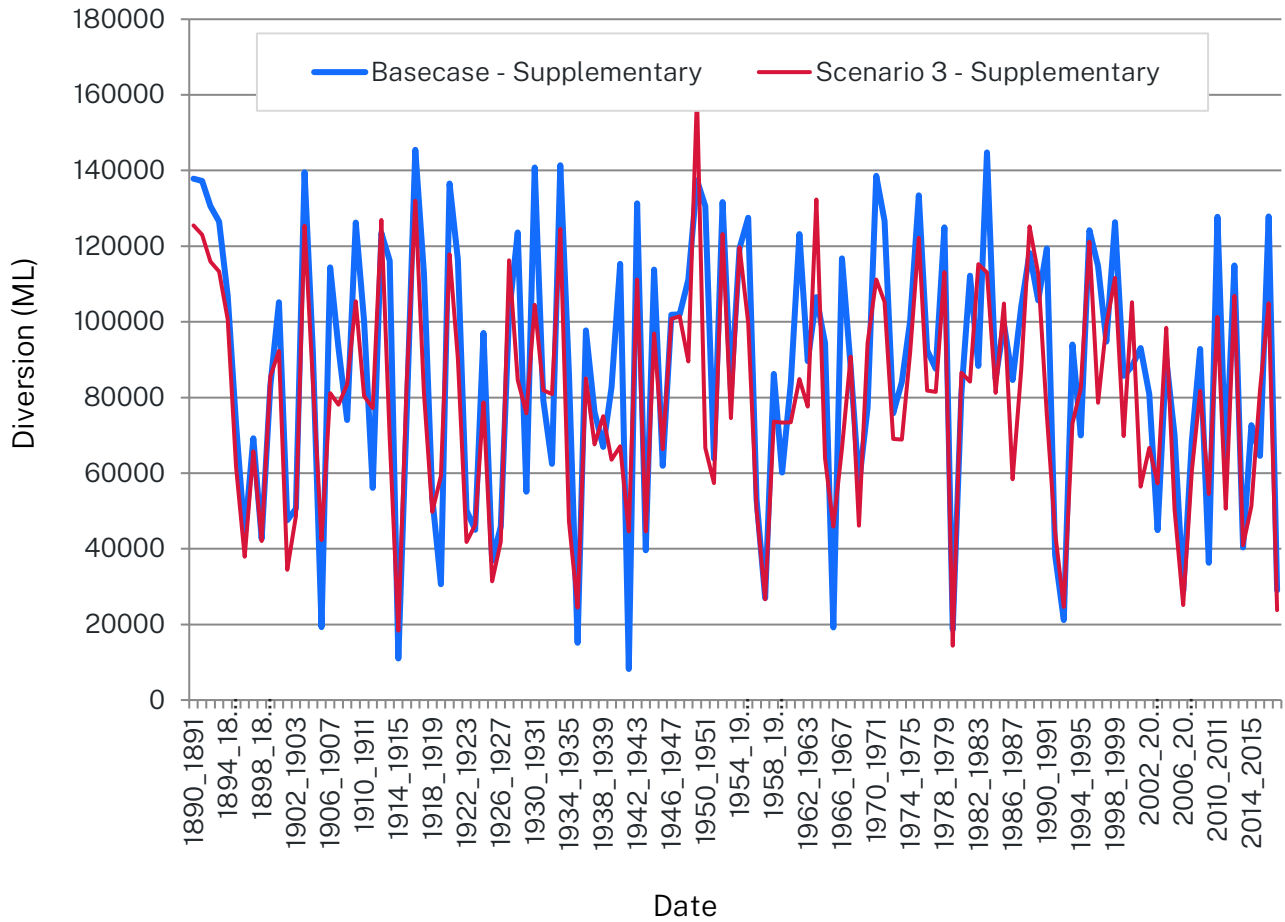


Figure 5. Supplementary diversions for the base case (Scenario 1) and Scenario 3



Alterations in allocation reliability

Changes in water allocation reliability at the start and end of the water year are shown in Table 8 for the base case (Scenario 1) and Scenarios 2 and 3.

The results show:

- construction of a re-regulating storage provides a small improvement in end-of-year general security allocations
- implementation of a growth-in-use response results in little change to general security allocation reliability
- improvements in allocation occur across the full range of allocations.

Table 8. General security effective allocation for the base case (Scenario 1) and Scenarios 2 and 3

	Base case*	Scenario 2	Scenario 3
Average effective allocation on 1 July	63.83	67.24	67.14
Average effective allocation on 30 June	103.99	108.27	108.26
90th percentile on 30 June	37.98	41.14	42.28
95th percentile on 30 June	24.59	28.97	28.55

*Current conditions with Held Environmental Water represented.

Figure 6. Start of water year general security effective allocation for the base case (Scenario 1) and Scenario 3

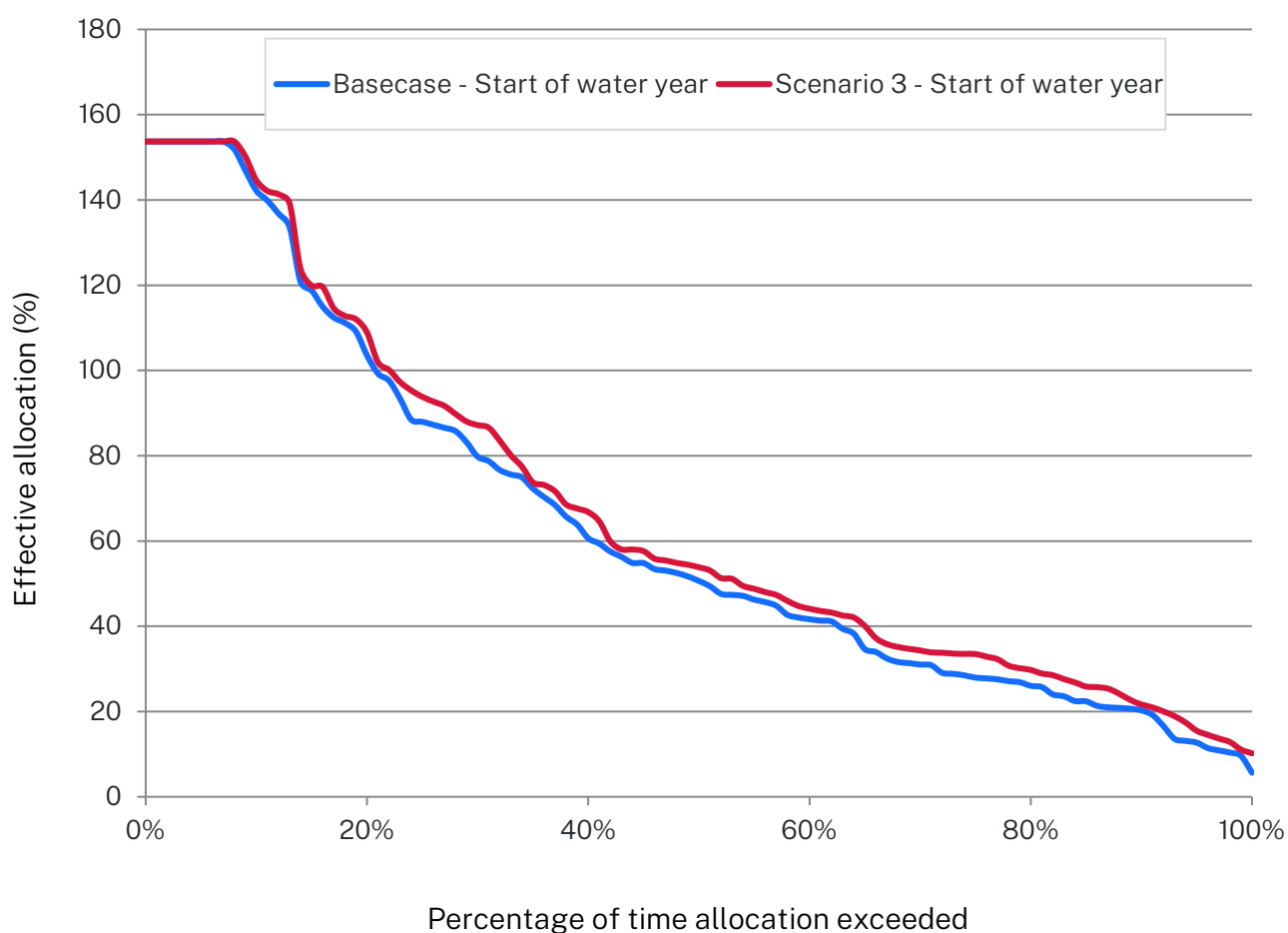
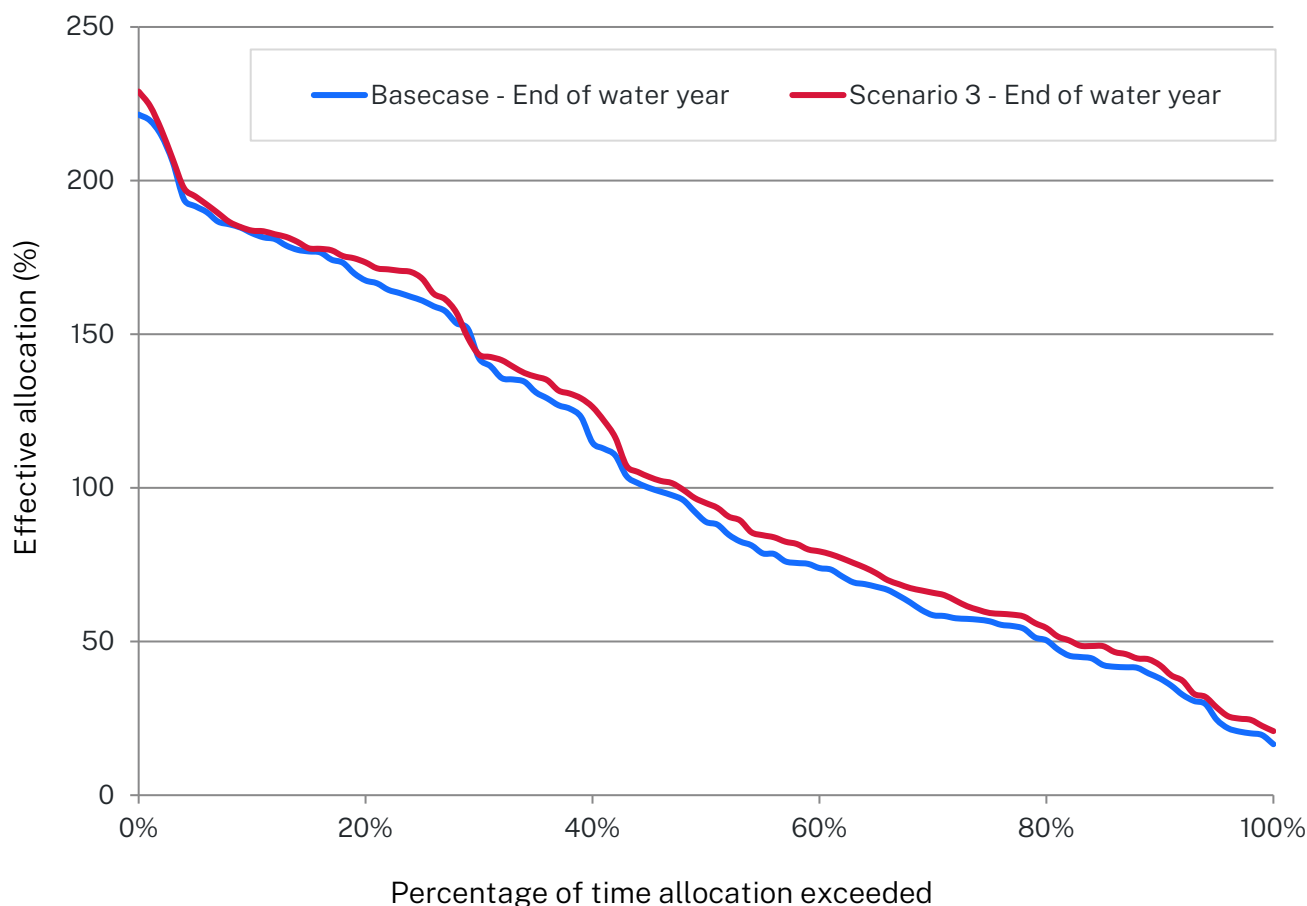


Figure 7. End of water year effective allocation for general security for the base case (Scenario 1) and Scenario 3



Alterations in storage behaviour

Alterations in Copeton Dam's storage behaviour are presented in Table 9, Figure 8 and Figure 9.

Modelling indicates that enlarging Tareelaroi Weir results in Copeton Dam drawing down slightly less frequently than in the base case.

Tareelaroi Weir is filled and drawn down to dead storage in a short timeframe and very frequently (see Figure 8). This is because water orders from Tareelaroi are prioritised over those from Copeton Dam.

Table 9. Copeton Dam's storage behaviour for the base case (Scenario 1) and Scenario 3

	Base case*	Scenario 3
% of time below 25%	25.29%	19.66%
% of time below 20%	11.91%	9.13%
% of time below 15%	3.37%	1.31%
% of time below 10%	0.00%	0.00%

*Current condition with Held Environmental Water represented.

Figure 8. Copeton Dam storage behaviour for the base case (Scenario 1) and Scenario 3

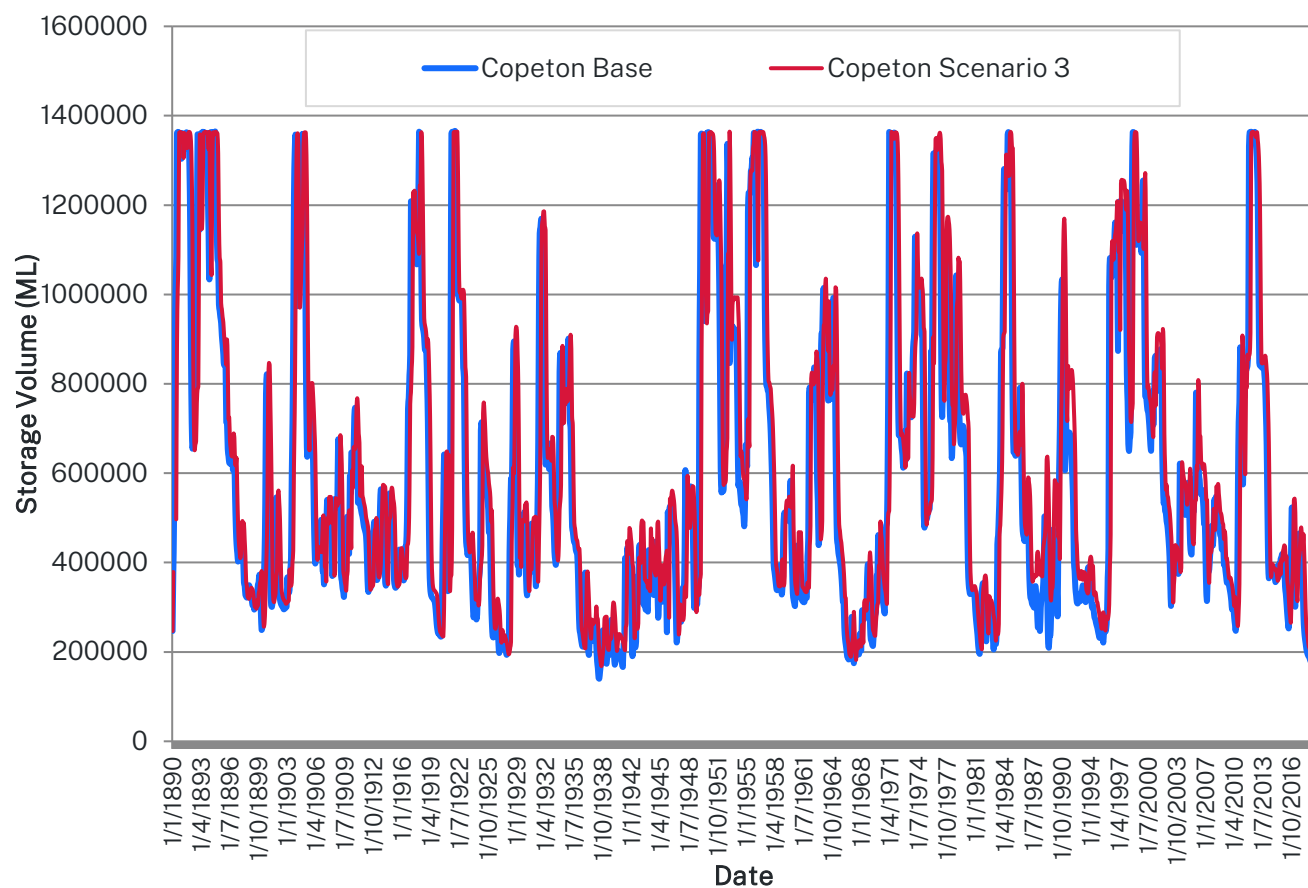
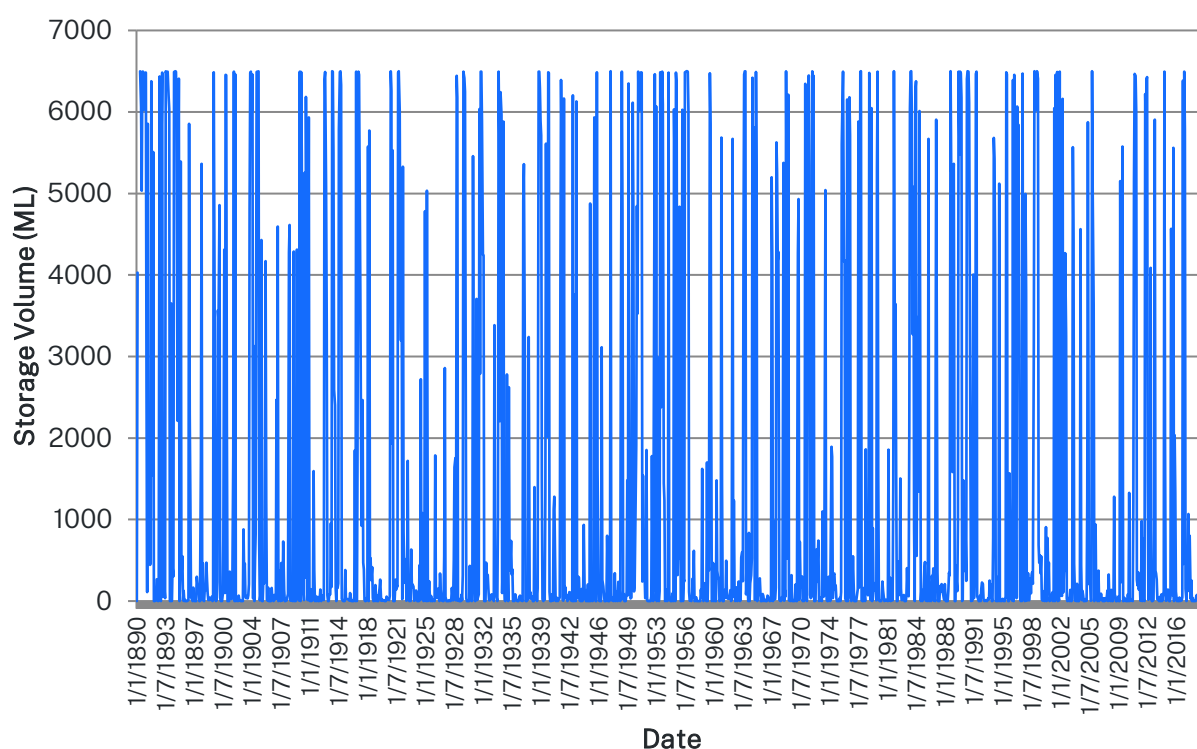


Figure 9. Tareelaro re-regulating storage behaviour for Scenario 3



Alterations in river flows

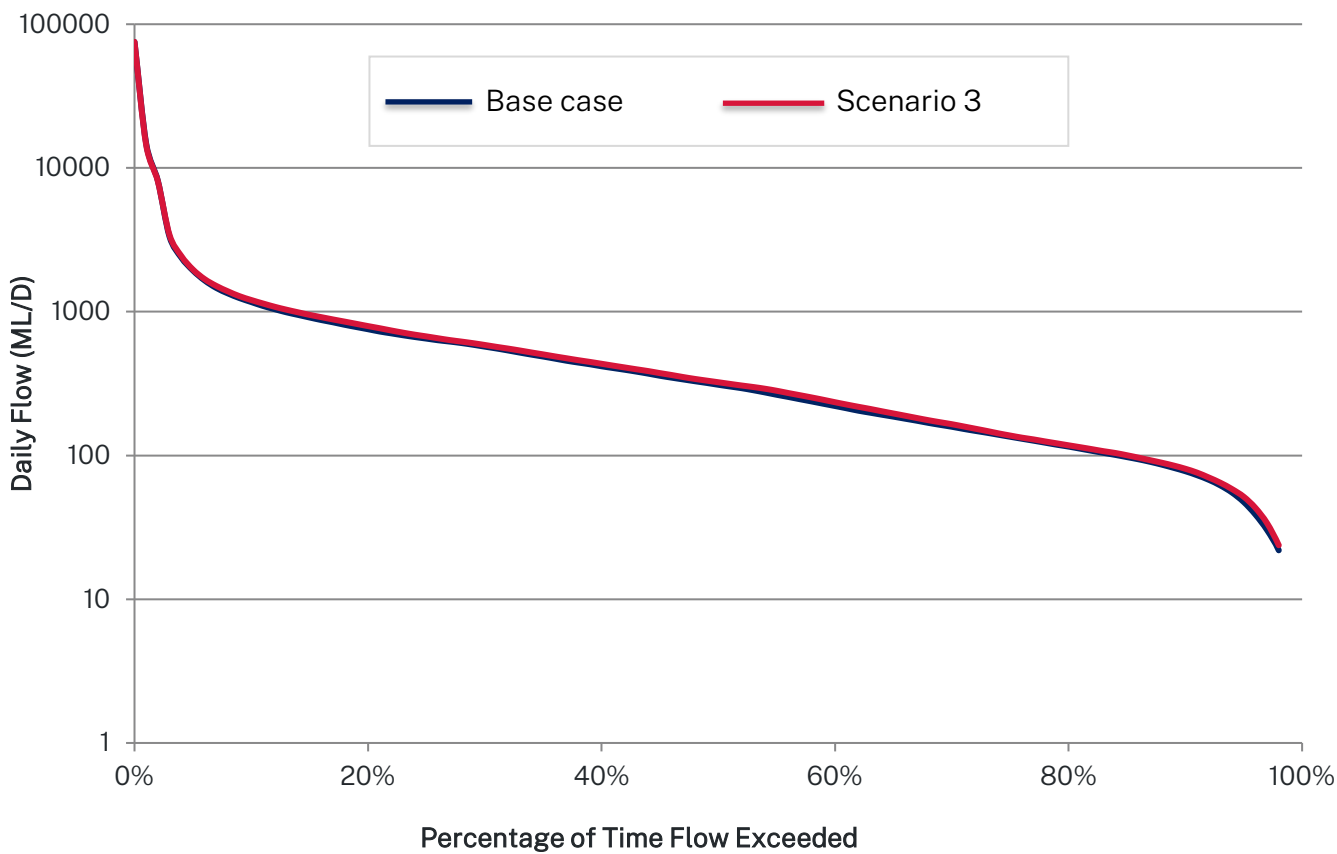
Changes in the flow regime resulting from enlarging Tareelaro Weir are shown for selected stream gauges in Table 10 and by a flow duration curve for the Gwydir River upstream of Tyreel regulator in Figure 10.

Enlargement of Tareelaro Weir results in an alteration to the distribution of flows throughout the lower Gwydir. There appears to be an increase of flows into the Gwydir Wetlands at the expense of flows into the Mehi River system.

Table 10. Comparison of the mean annual flow for the base case (Scenario 1) and Scenario 3

Gauging sites	Base case (GL/yr)	Scenario 3 (GL/yr)
Gwydir River upstream of Tyreel regulator	322.10	328.00
Gwydir River at Gravesend (418013)	734.01	733.48
Gwydir River at Collymongle (418031)	0.64	0.66
Mehi River near Collarenebri (418055)	104.92	99.82
Gil Gil Creek at Galloway (416052)	47.80	47.80

Figure 10. Flow behaviour at Gwydir River upstream of Tyreel regulator for the base case (Scenario 1) and Scenario 3



5. Lower Gravesend Dam

Option description

This option would involve constructing a new 175 GL dam on the Gwydir River, approximately 200 m downstream of the confluence of Warialda Creek and seven kilometres south-east of the town of Gravesend (Figure 11).

The following two scenarios have been assessed:

- Scenario 4 – 175 GL dam at Lower Gravesend without a growth-in-use response
- Scenario 5 – 175 GL dam at Lower Gravesend with a growth-in-use response to maintain diversions at base case total diversions by reducing supplementary shares by 60%.

Figure 11. Location of Gravesend Dam

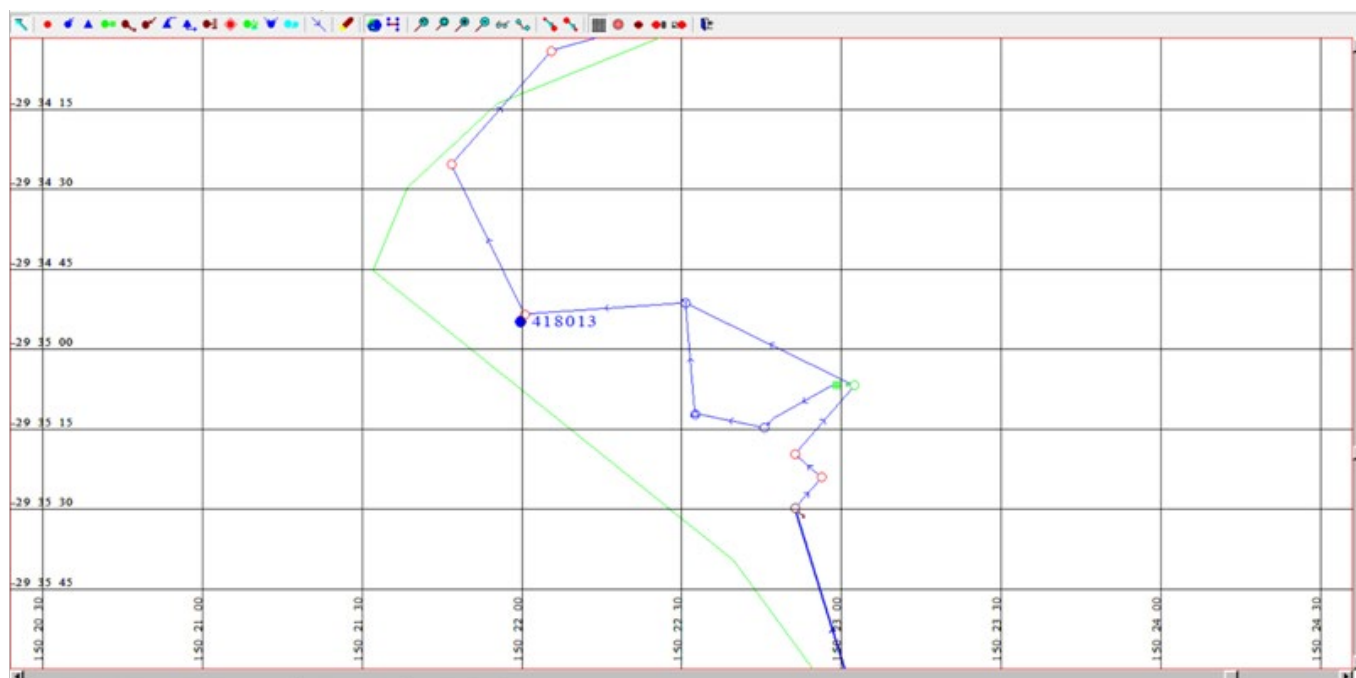


Model configuration and assumptions

An instream water storage near Gravesend was conceptualised as an off-river storage (Figure 12). The following key assumptions have been made to model the option:

- only surplus flows above water orders, 3T (tributary) and 50:50 sharing supplementary requirements are available for capture
- water orders up to the volume held in the storage are assumed to be delivered from storage
- no environmental releases occur from the storage
- remaining orders are met from Copeton Dam
- 16 GL of dead storage and zero losses to seepage
- valve capacity was set not to be a constraint in the delivery of orders.

Figure 12. Lower Gravesend Dam schematic model



Storage characteristics

Assumed storage characteristics used in the model are in Table 11 to Table 13.

Table 11. Spillway discharge relationship (175 GL)

Volume (ML)	Spillway discharge (ML/day)
175,000	0
176,000	78,000
180,000	92,638
184,400	92,638
200,020	119,971
200,240	119,971

Volume (ML)	Spillway discharge (ML/day)
202,000	119,971
246,000	184,708
250,004	184,708
250,048	184,708
290,000	258,137
334,000	339,330

Table 12. Storage dimensions

Volume (ML)	Area (Ha)	Level (m)	Comment
0	0	0.0	
15,000	515	265.0	
16,000	528	265.1	Dead storage
80,000	1,370	270.0	
175,000	2,728.5	274.8	(full supply level – 175 GL option)
180,000	2,800	275.0	
400,000	5,000	280.0	
500,000	5,890	281.7	(full supply level – 500 GL option)
700,000	7,670	285.0	
1,100,000	11,000	290.0	

Table 13. Valve discharge relationship

Volume (ML)	Valve discharge (ML/D)
16,000	0.00
16,300	11,300.00
1,100,000	11,300.00

Modelling results

In this section, modelling results are shown for Scenario 4 and Scenario 5 as listed in Table 14.

Alterations in water diversions

Locating an additional storage on the Gwydir River downstream of Warialda Creek increases average annual general security diversions. Under Scenario 4, this increase is not offset by reductions in other categories of diversions and, therefore, total diversions substantially exceed the base case.

Under Scenario 5, supplementary shares have been reduced by 60% to reinstate diversions to the base case. The impact occurs in all but the lowest water use years (see Figure 13). The supplementary share reduction also has the effect of further increasing general security diversions beyond those under the base case (Scenario 1). These increases occur in most years, including low allocation years (see Figure 13).

Table 14. Mean annual water diversions for the base case (Scenarios 1) and Scenarios 4 and 5

	Base case*	Scenario 4 175 GL dam at Lower Gravesend without a growth-in- use response	Scenario 5 175 GL dam at Lower Gravesend with a growth-in-use response to maintain diversions at base case total diversions by reducing supplementary shares by 60%.
General security	195.70	225.20	232.06
Supplementary	87.37	84.44	48.44
High security	11.25	11.25	11.25
Floodplain harvesting	67.99	66.38	67.06
Rainfall harvesting	52.65	53.31	54.08
Total diversions	414.95	440.58	412.89

*Current conditions with Held Environmental Water represented.

Figure 13. General security annual diversions for the base case (Scenario 1) and Scenario 5

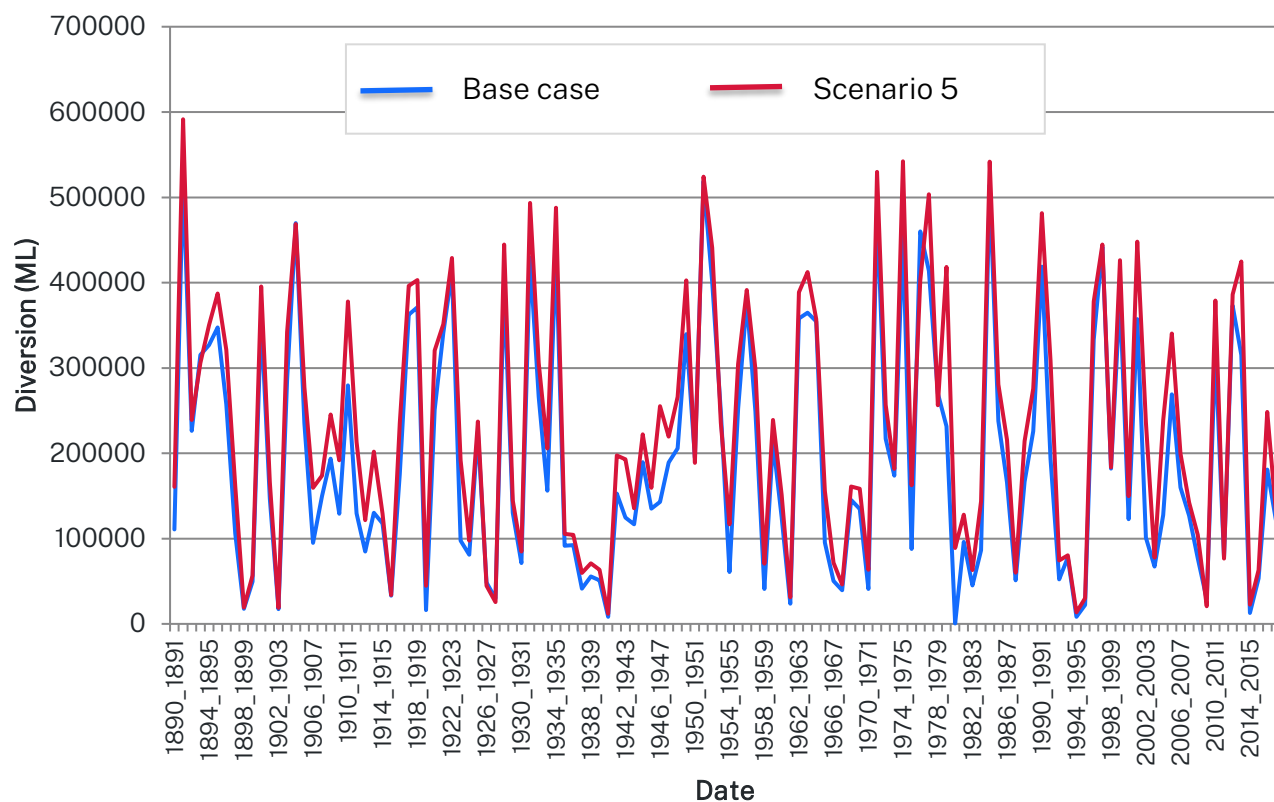
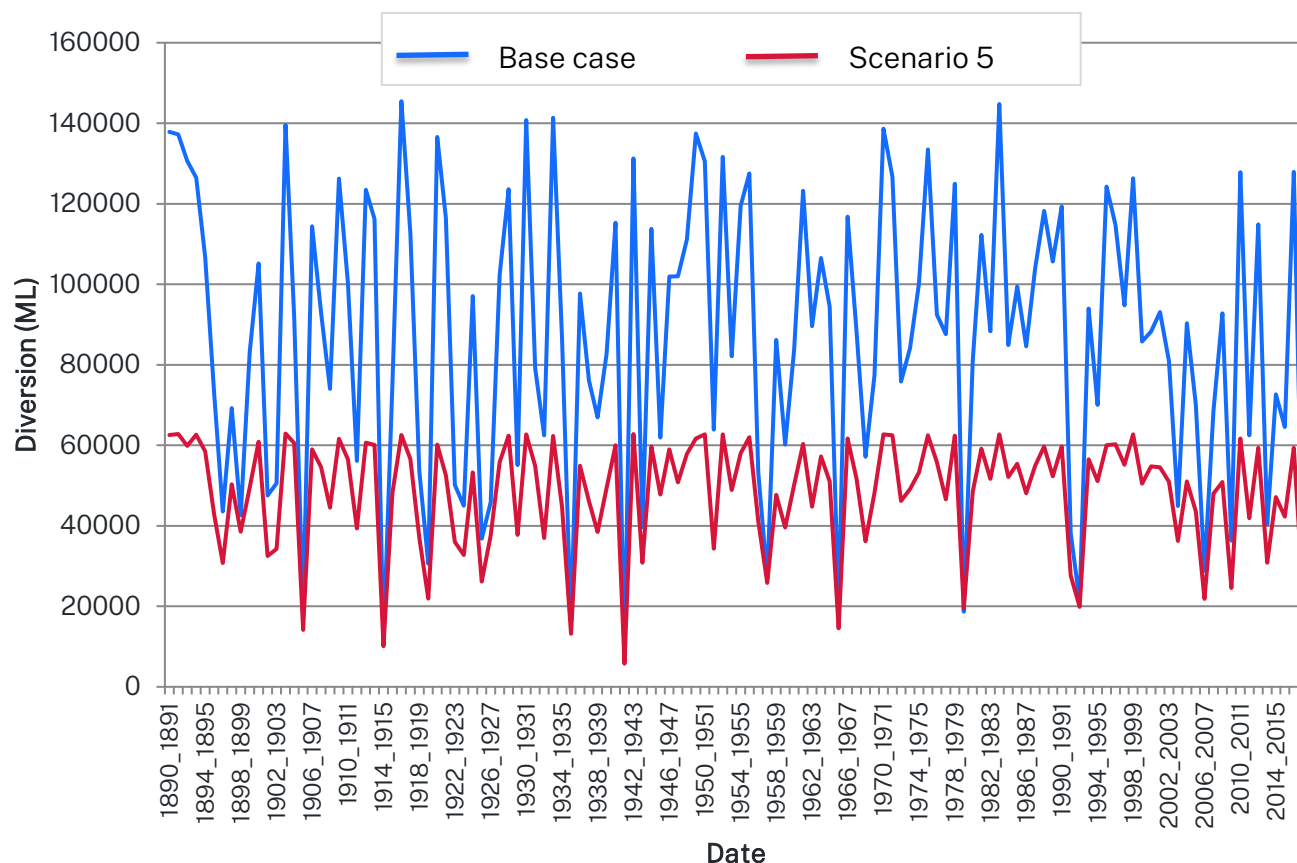


Figure 14. Supplementary diversions for the base case (Scenario 1) and Scenario 5



Alterations in allocation reliability

Changes in allocation reliability at the start and end of the water year are shown in Table 15 for the base case (Scenario 1) and Scenarios 4 and 5.

The results show:

- constructing a dam at Lower Gravesend provides significant improvement in end-of-year general security allocations
- implementing a growth-in-use response results in little change to general security allocation reliability.
- improvements in allocation occur across the full range of allocations.

Table 15. General security effective allocation for the base case (Scenario 1) and Scenarios 4 and 5

	Base case*	Scenario 4 175 GL dam at Lower Gravesend without a growth-in-use response	Scenario 5 175 GL dam at Lower Gravesend with a growth- in-use response to maintain diversions at base case total diversions by reducing supplementary shares by 60%.
Average effective allocation on 1 July	63.83	75.08	75.19
Average effective allocation on 30 June	103.99	120.27	121.00
90th percentile on 30 June	37.98	44.62	45.32
95th percentile on 30 June	24.59	33.42	36.84

*Current conditions with Held Environmental Water represented

Figure 15. Start of water year general security effective allocation for the base case (Scenario 1) and Scenario 5

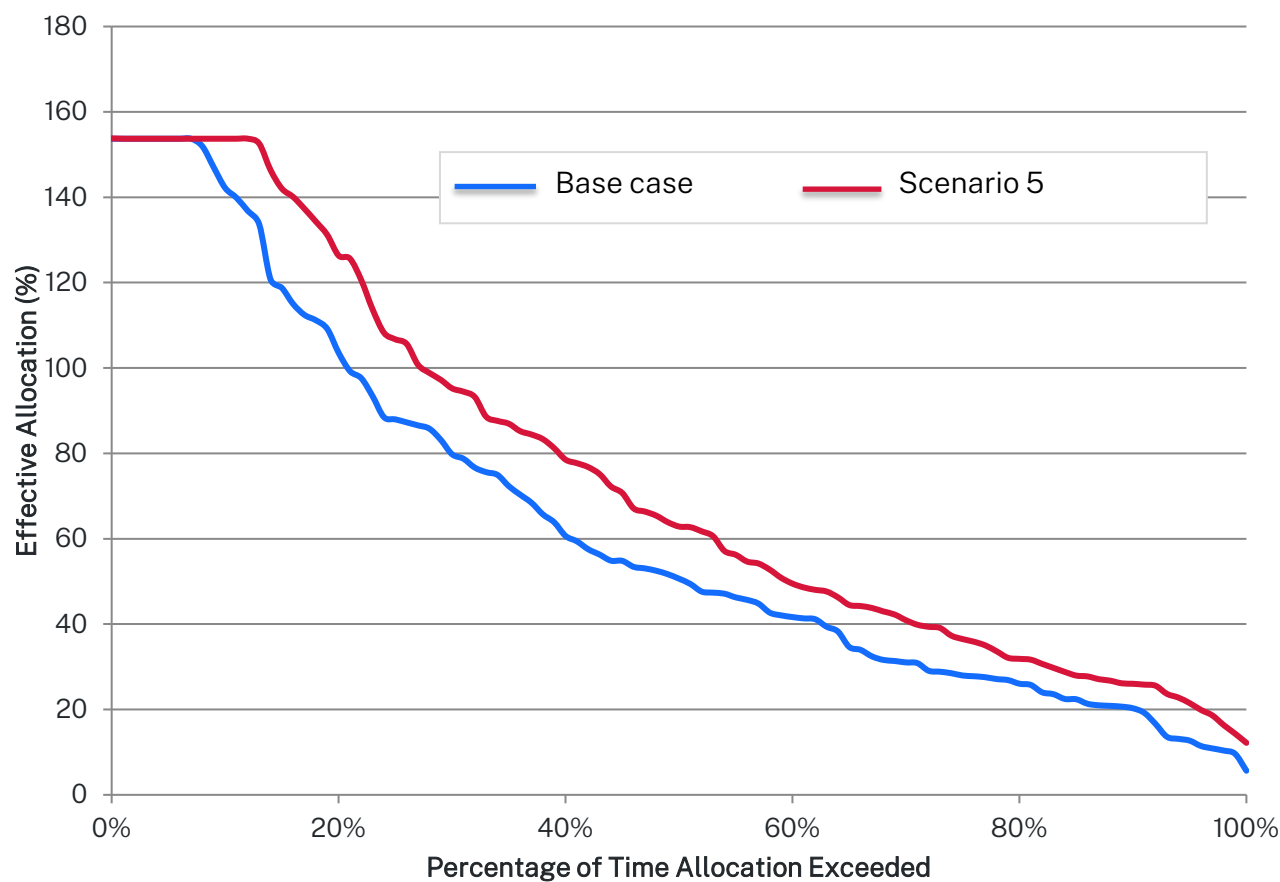
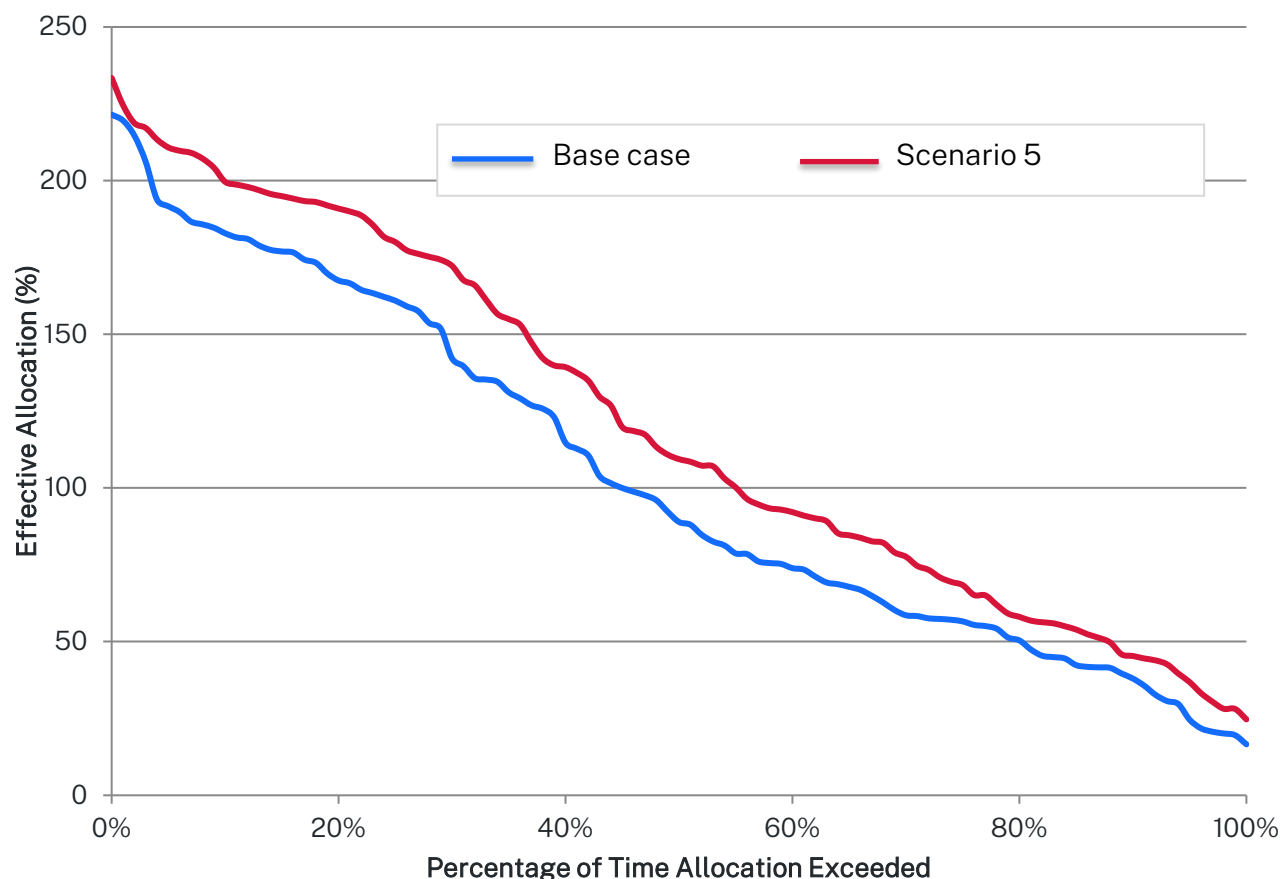


Figure 16. End of water year general security effective allocation for the base case and Scenario 5



Alterations in storage behaviour

Storage behaviour for the base case and Scenario 5 is in Table 16.

Monthly storage behaviour over the full model simulation period for Copeton Dam and the proposed dam at Lower Gravesend are also presented for the base case (Scenario 1) and Scenario 5 in Figure 17 and Figure 18.

The storage behaviour results indicate that the introduction of a storage at Gravesend reduces demand on Copeton Dam. The results also indicate that the dam at Gravesend is rarely full, and often below 25% of full supply volume. This is due to orders being met from the Gravesend storage first before the remainder of orders are passed to Copeton Dam.

Table 16. Storage behaviour for the base case (Scenario 1) and Scenario 5

	Base case	Scenario 5 175 GL dam at Lower Gravesend with a growth-in-use response to maintain diversions at base case total diversions by reducing supplementary shares by 60%	
	Copeton storage volume (full supply volume 1,364 GL)	Copeton storage volume (full supply volume 1,364 GL)	Gravesend storage volume (full supply volume 175 GL)
% of time below 25%	25.29%	16.39%	76.42%
% of time below 20%	11.91%	5.79%	73.56%
% of time below 15%	3.37%	0.53%	69.28%
% time below 10%	0.00%	0.00%	63.58%

*Current conditions with Held Environmental Water represented

Figure 17. Copeton Dam storage behaviour for the base case (Scenario 1) and Scenario 5

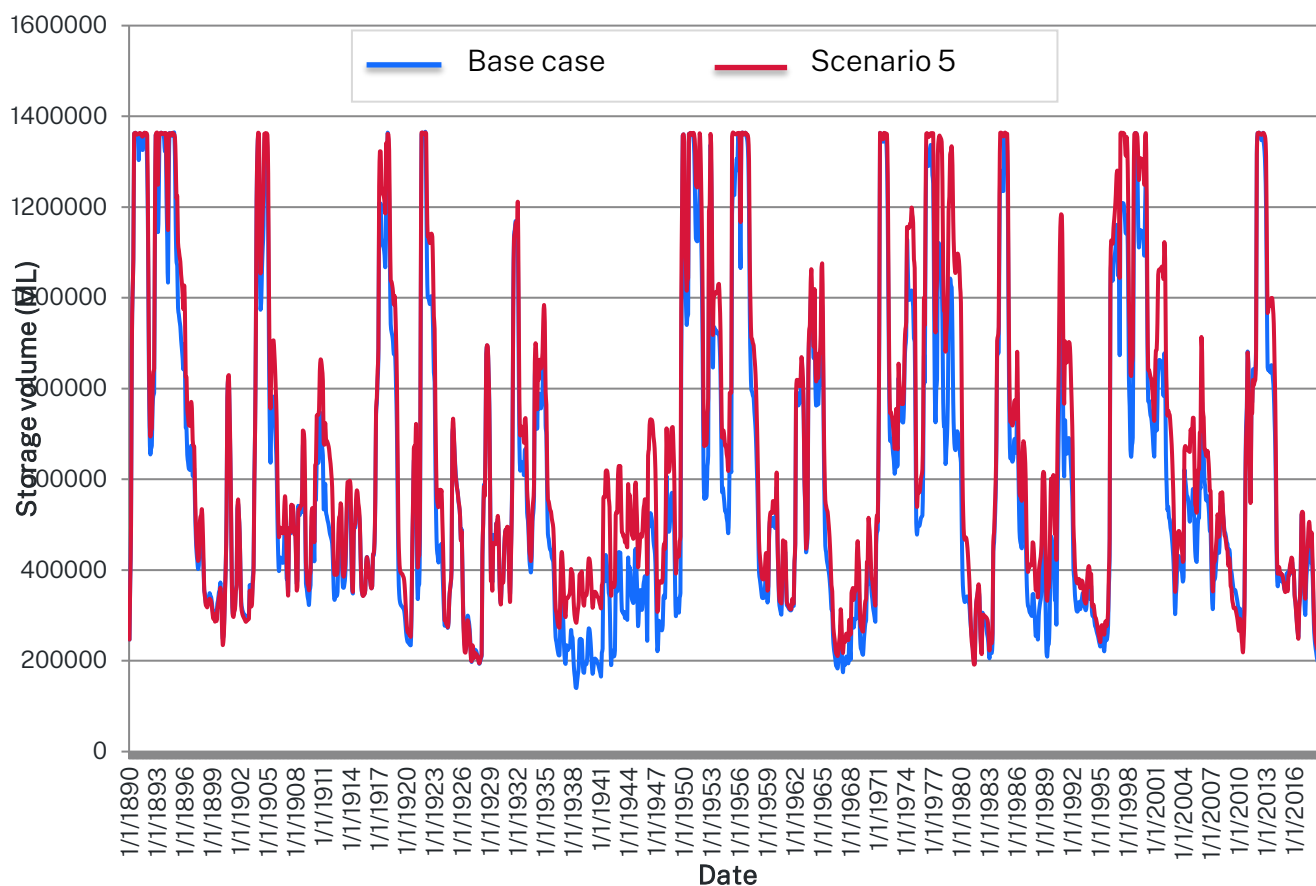
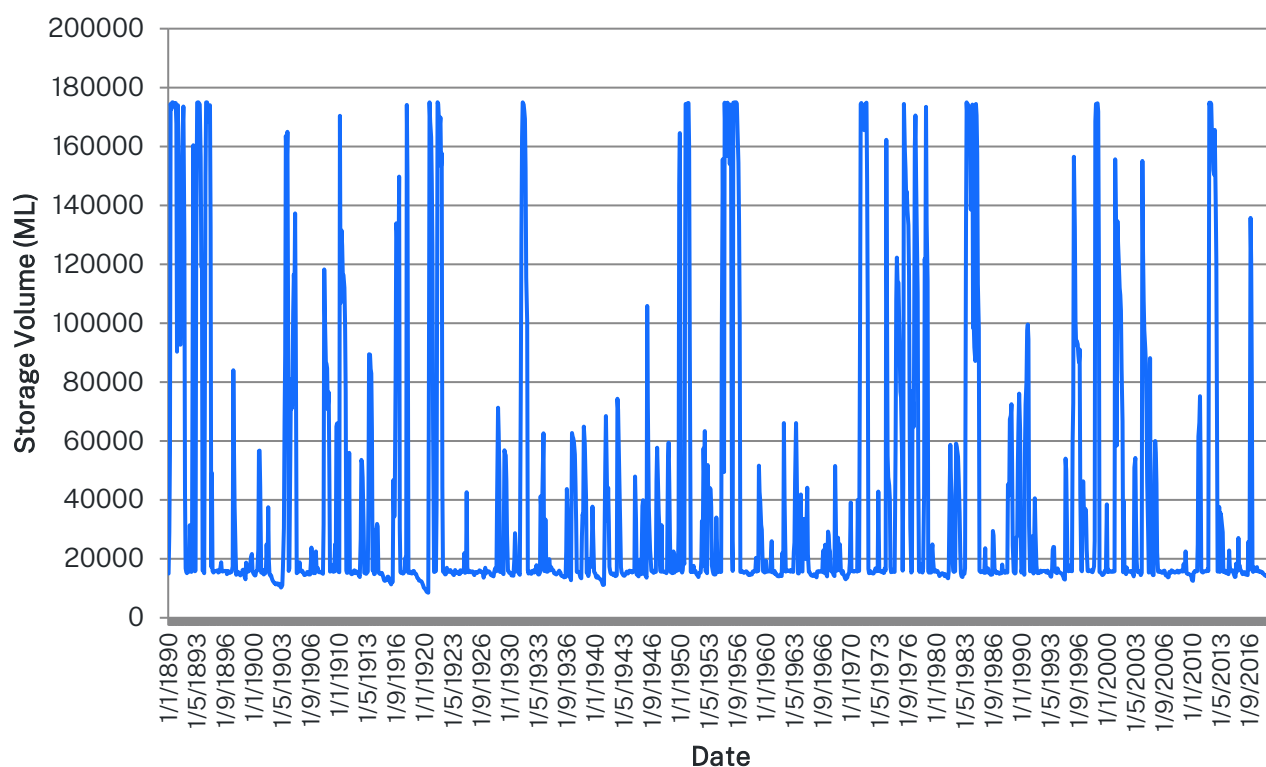


Figure 18. Lower Gravesend Dam storage behaviour for Scenario 5



Alterations in river flows

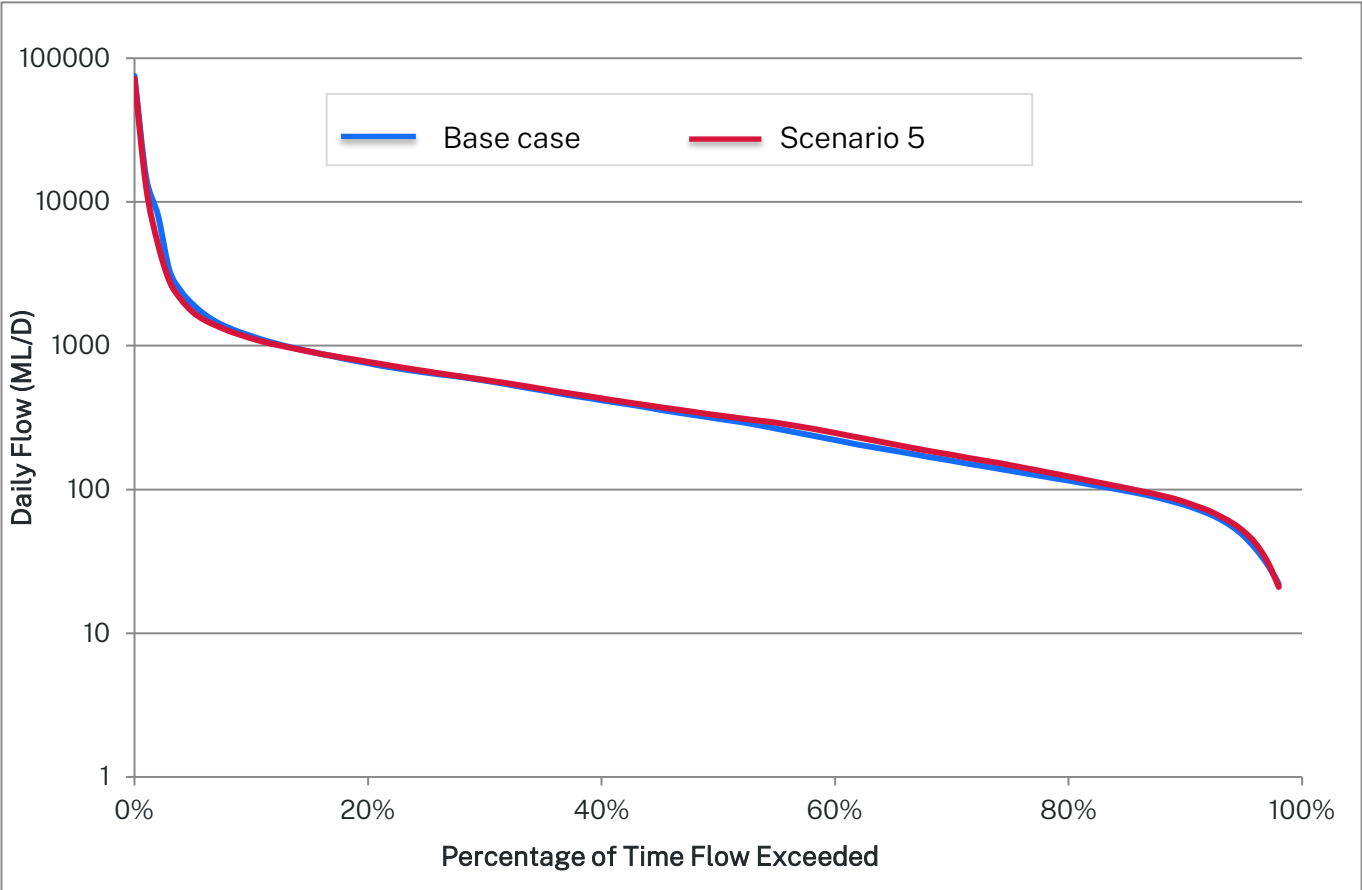
Changes in the flow regime at selected stream gauges as a result of a dam at Lower Gravesend are shown in Table 17 and by a flow duration curve for upstream of the Tyreel regulator in Figure 19 for Scenario 5.

Introduction of a storage at Gravesend results alters the distribution of flows throughout the lower Gwydir. Additionally, the Gravesend storage will reduce high flows and increase low flows.

Table 17. Mean annual flow changes for the base case (Scenario 1) and Scenario 5

River gauging sites	Base Case (GL/yr)	Scenario 5 (GL/yr) 175 GL dam at Lower Gravesend with a growth-in-use response to maintain diversions at base case total diversions by reducing supplementary shares by 60%
Gwydir River upstream of Tyreel regulator	322.10	297.80
Gwydir River at Gravesend (418013)	734.01	725.63
Gwydir River at Collymongle (418031)	0.64	0.60
Mehi River near Collarenebri (418055)	104.92	119.93
Gil Gil Creek at Galloway (416052)	47.80	49.55

Figure 19. Flow behaviour at the Gwydir River upstream of Tyreel regulator for the base case (Scenario 1) and Scenario 5



6. Increase the storage reserve in Copeton Dam

Option description

The 111 GL reserve set aside in the Gwydir model covers 2 years of water for essential supplies. Scenario 6 assessed an extra year of reserve (55.5 GL) to evaluate changes in water security. This results in the reserve increased from 2 to 3 years (165 GL)

Model configuration and assumptions

The components that make up the reserve are shown in Table 18.

Table 18. Essential water supply volumes

Essential supplies	Year 1	Year 2
Town water supplies	4.0	4.0
High security irrigation	15.0	15.0
Minimum Copeton Dam releases	5.0	5.0
Stock and domestic replenishments	21.5	21.5
End-of -system flows	0.0	0.0
Delivery losses	10.0	10.0
Total	55.5	55.5

The relationship between Copeton Dam's storage volume and the carryover reserve was adjusted within the model to reflect the additional increase in reserve to 3 years (Table 19).

Table 19. The storage volume and carryover reserve relationship used for assessment of Scenario 6

Month	Measure	Relationship between storage volume and carryover reserve		
Jan	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Feb	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Mar	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Apr	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
May	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Jun	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Jul	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Aug	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Sep	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Oct	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166,500	166,500
Nov	Storage volume (ML)	18,490	184,990	1,400,000

Month	Measure	Relationship between storage volume and carryover reserve		
	Carryover reserve (ML)	0	166500	166,500
Dec	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	166500	166,500

Modelling results

Alterations in water diversions

Results of diversion changes for existing entitlements and water users as a result of increasing the storage reserves are presented in Table 20. The reserve increase results in a 4 GL per year decrease in general security diversions.

Table 20. Diversions for the base case (Scenario 1) and Scenario 6

Water diversions	Base case (GL/yr)	Scenario 6 (GL/yr) Increase essential needs reserve by one year (55.5 GL)
General security	195.70	191.54
Supplementary	87.37	87.28
High security	11.25	11.25
Floodplain harvesting	67.99	68.06
Rainfall harvesting	52.65	52.56
Total diversions	414.95	410.69

Alterations in allocation reliability

Changes in allocation reliability at the start and end of the water year are shown in Table 21. Creation of an additional reserve amount results in a small decrease in both the start and the end of the water year general security effective allocation.

Table 21. General security effective allocation for the base case (Scenario 1) and Scenario 6

	Base case	Scenario 6 Increase essential needs reserve by one year (55.5 GL)
General security average effective allocation on 1 July	63.83	61.99
General security average effective allocation on 30 June	103.99	101.33
90th percentile on 30 June	37.98	36.26
95th percentile on 30 June	24.59	23.21

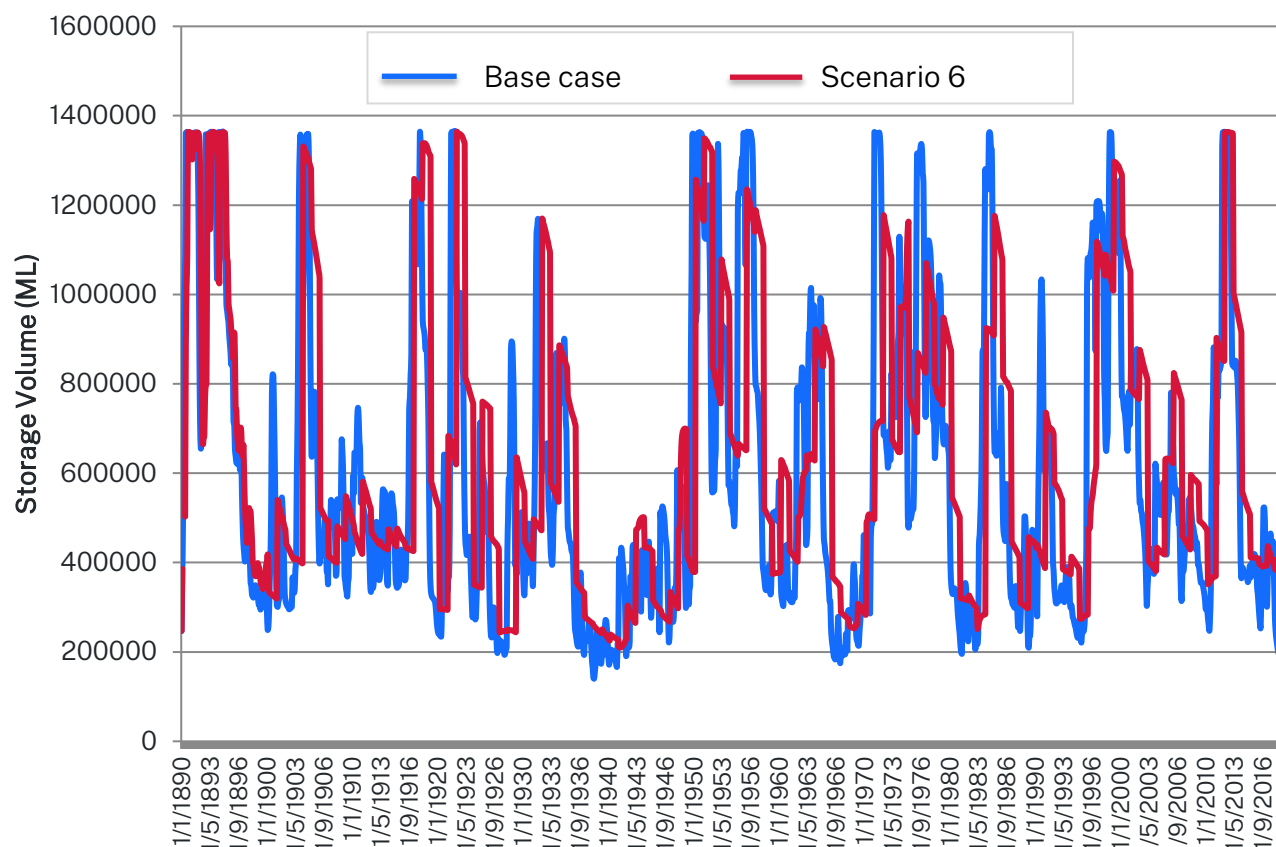
Alterations in storage behaviour

The increase in the reserve results in Copeton Dam spending less time below the 25% full supply volume (Table 23). This is mainly due to the increase reserve not being used during the historic simulation period (Figure 20).

Table 22. Copeton Dam storage behaviour for the base case (Scenario 1) and Scenario 6

	Base case	Scenario 6 Increase essential needs reserve by one year (55.5 GL)
% of time below 25%	25.29%	14.82%
% of time below 20%	11.91%	6.14%
% of time below 15%	3.37%	0.18%
% of time below 10%	0.00%	0.00%

Figure 20. Copeton Dam storage behaviour base case (Scenario 1) and Scenario 6



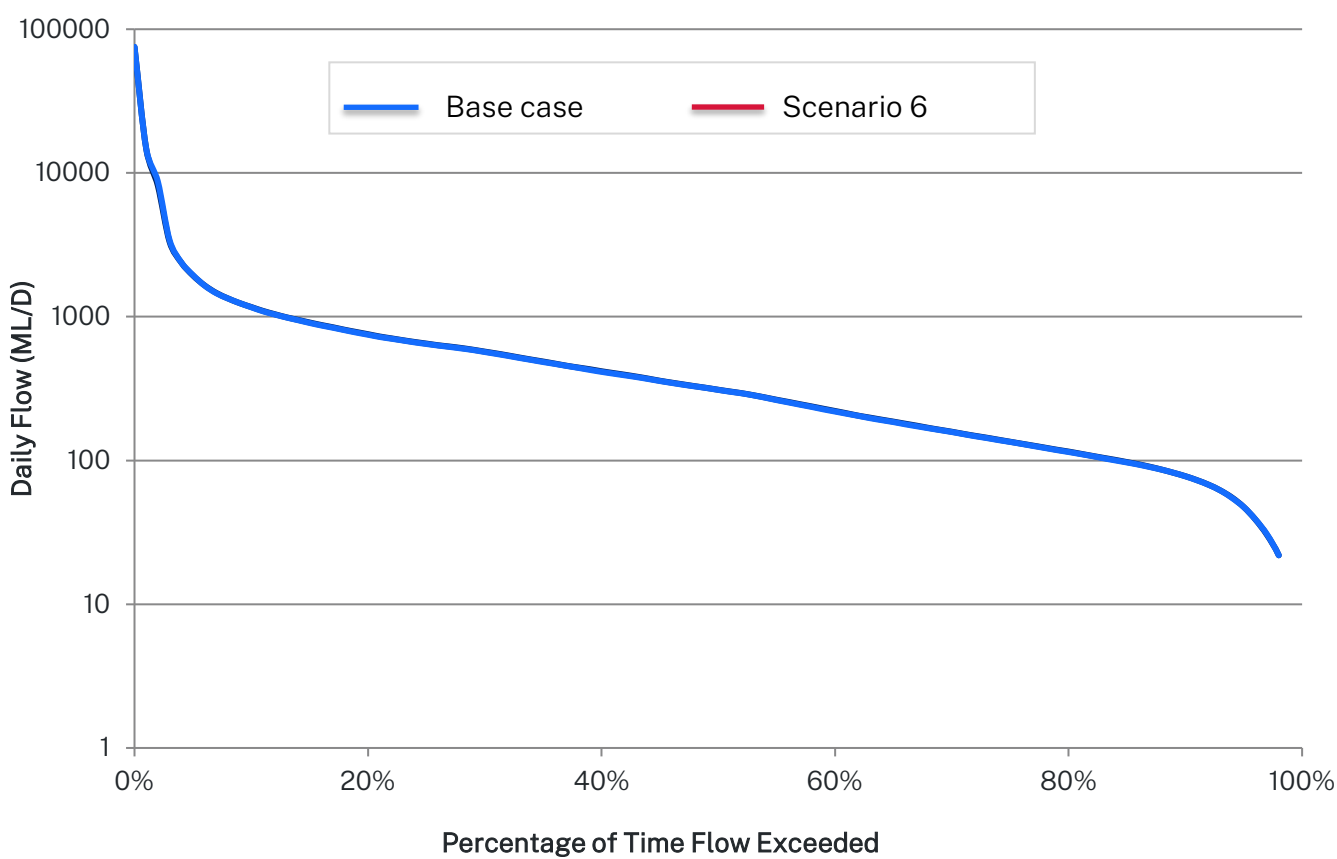
Alterations in river flows

Changes in the flow regime are shown in Table 24 and Figure 21. This option results in negligible alterations in flows at the selected gauges.

Table 23. Mean annual flow changes (GL/yr) for the base case (Scenarios 1) and Scenario 6

Mean annual stream flow (GL/yr)	Base case	Scenario 6 Increase essential needs reserve by one year (55.5 GL)
Gwydir River upstream of Tyreel Regulator	322.10	323.61
Gwydir River at Gravesend (418013)	734.01	732.37
Gwydir River at Collymongle (418031)	0.64	0.65
Mehi River near Collarenebri (418055)	104.92	104.90
Gil Gil Creek at Galloway (416052)	47.80	47.87

Figure 21. Upstream of Tyreel flow behaviour for base case (Scenario 1) and Scenario 6



7. Investigate licence conversions (Bulk licence conversion and Partial licence conversion)

Option description

Two scenarios for creating additional high security licences at the expense of other licence products were evaluated.

In Scenario 7, all general security licences are converted to 178.85 GL of high security licences. In Scenario 8, 40.7 GL of general security licence is converted to 17.8 GL of high security licence. The conversion rate applied in Scenario 8 is based on the value obtained in Scenario 7:

- Scenario 7 — Bulk conversion: General security shares reduced by 100% (407.76 GL) with 178.85 GL high security shares created at Moree
- Scenario 8 — Partial conversion: General security shares reduced by 10% (40.78GL) with 17.89 GL high security shares created at Moree.

Model configuration and assumptions

The following model configuration changes were required for analysis:

- general security shares reduced using an input set
- base case model system storage reserves increase by 1.33* (with Held Environmental Water represented) created entitlement volume
- new high security demand created at Moree
- high security demand spread uniformly across the year.

Table 24. Essential supply volumes (Scenario 7)

Essential supplies	Year 1	Year 2
Town water supplies	4.0	4.0
High security irrigation	15.0	15.0
New high security licence	180.0	180.0
Minimum Copeton Dam releases	5.0	5.0
Stock and domestic replenishments	21.5	21.5

Essential supplies	Year 1	Year 2
End-of-system flows	0.0	0.0
Delivery losses	70.0	70.0
Total	295.5	295.5

Table 25. Essential supply volumes (Scenario 8)

Essential supplies	Year 1	Year 2
Town water supplies	4	4
High security irrigation	15	15
New high security licence	18	18
Minimum Copeton Dam releases	5	5
Stock and domestic replenishments	21.5	21.5
End-of-system flows	0	0
Delivery losses	16	16
Total	79.5	79.5

Table 26. The storage volume and carryover reserve relationship used for assessment of Scenario 7

Month	Measure	Relationship between storage volume and carryover reserve		
Jan	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Feb	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Mar	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Apr	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
May	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Jun	Storage volume (ML)	18,490	609,490	1,400,000

Month	Measure	Relationship between storage volume and carryover reserve		
	Carryover reserve (ML)	0	591,000	591,000
Jul	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Aug	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Sep	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Oct	Storage volume (ML)	18,490	609,490	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Nov	Storage volume (ML)	18490	184990	1,400,000
	Carryover reserve (ML)	0	591,000	591,000
Dec	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	591,000	591,000

Table 27. The storage volume and carryover reserve relationship used for assessment of Scenario 8

Month	Measure	Relationship between storage volume and carryover reserve		
Jan	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Feb	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159000	159,000
Mar	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Apr	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159000	159,000

Month	Measure	Relationship between storage volume and carryover reserve		
May	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Jun	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Jul	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Aug	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Sep	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Oct	Storage volume (ML)	18,490	177,490	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Nov	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	159,000	159,000
Dec	Storage volume (ML)	18,490	184,990	1,400,000
	Carryover reserve (ML)	0	159,000	159,000

New demands

Any new demands have been represented at 100% allocation utilisation, with demand distributed uniformly over the year. This implies that users will seek to use all of their allocation every year, either through trade or storage in on-farm infrastructure.

Constraints

Three constraints were considered when creating additional high security volumes:

- end-of-year allocation reliability for any remaining products must not decrease below the base case
- total diversions must not exceed the base case diversion limit
- end-of-system flows must not decrease below the base case.

Modelling results

Alterations in water diversions

Converting all general security shares to high security shares would result in a decrease in total diversions (see Table 28). Converting 10% of general security shares to 18 GL of high security shares increases total diversions above the base case due to the newly created high security product being fully utilised.

The annual performance of the new high security product is shown in Figure 23 and Figure 24. The modelling indicates that 98% of the entitlement is supplied and diverted in most years in the historic period for Scenario 7 (full conversion of general security to high security) and 100% for Scenario 8 (conversion of 10% of general security to high security).

Table 28. Water diversions for the base case (Scenario 1), Scenario 7 and Scenario 8

	Base case	Scenario 7 Bulk conversion of GS licences to HS licences	Scenario 8 Partial conversion of GS licences to HS licences
General security (ML)	195.70	0.00	182.90
Supplementary (ML)	87.37	88.39	87.14
High security (ML)	11.25	11.19	11.25
Floodplain harvesting (ML)	67.99	68.61	68.05
Rainfall harvesting (ML)	52.65	49.14	52.40
New high security (ML)	N/A	177.43	17.90
Total diversions (ML)	414.95	394.77	419.63

Figure 23. New high security annual diversion (Scenario 7)

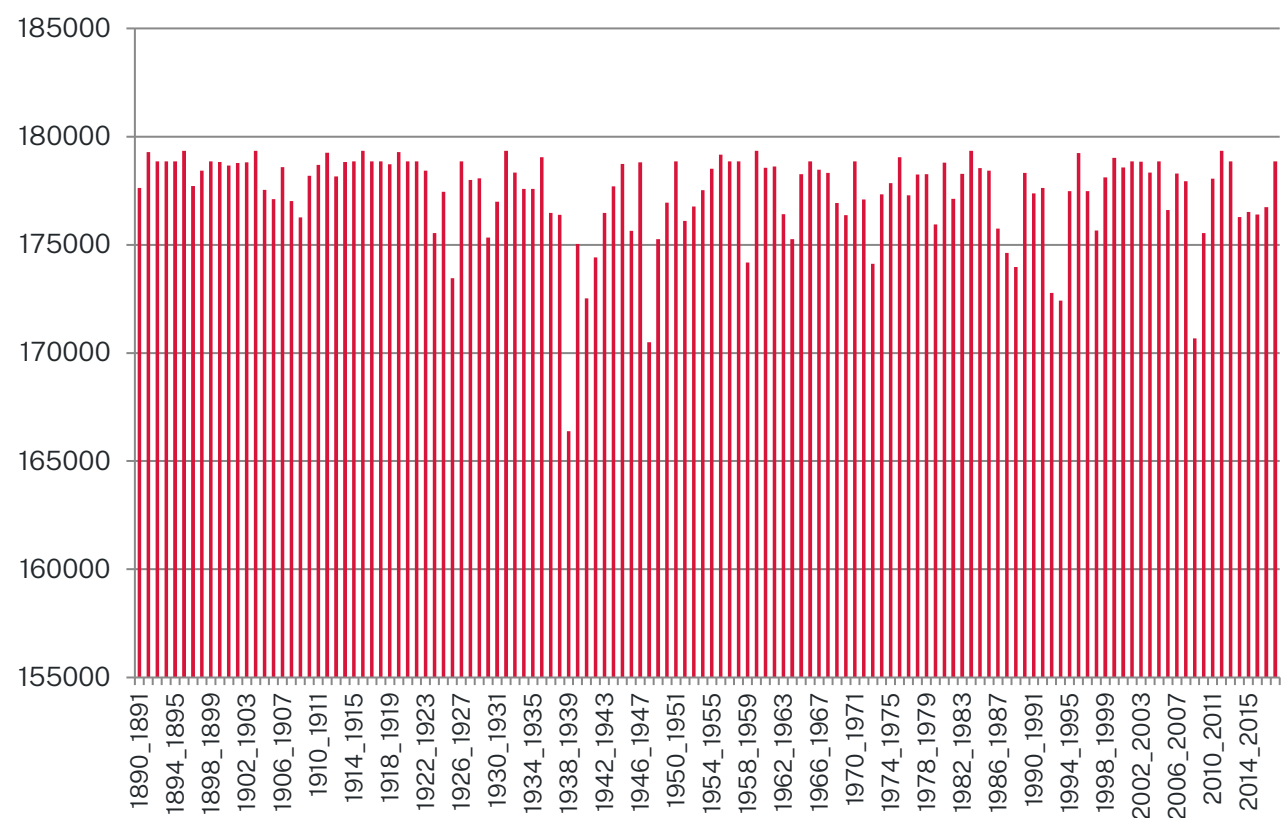
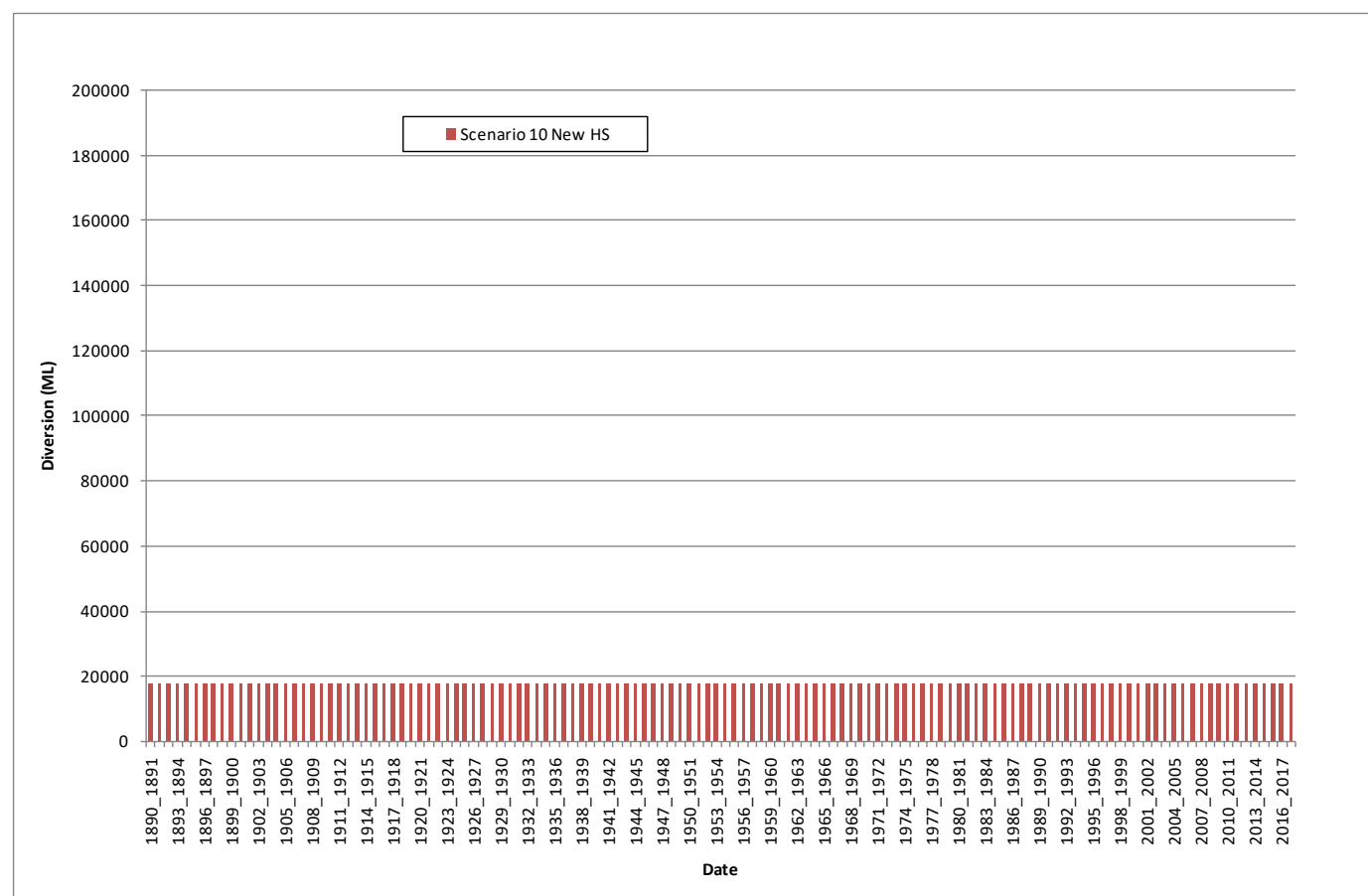


Figure 24. New high security annual diversion (Scenario 8)



Alterations in allocation reliability

IQQM does not explicitly calculate high security allocations. However, from the diversion results for newly created high security shares, allocations are sufficient to allow for 99% of the entitlement to be supplied on average under both Scenario 7 and Scenario 8.

Alterations in storage behaviour

Alterations in storage behaviour as a result of the conversion are in Table 29 and Figure 25. As can be seen from the results for Scenario 7, the large increase in the reserve results in the storage spending hardly any time at low levels below the 25% full supply volume. This is mainly due to the increase reserve not being utilised during the historic simulation period. Scenario 8 exhibits a reduction in time below the 25% full supply volume relative to the base case, but considerably less than for Scenario 7 due to the smaller reserve volume.

Table 29. Storage behaviour for the base case (Scenario 1), Scenario 7 and Scenario 8

	Base case	Scenario 7 Bulk conversion of GS licences to HS licences	Scenario 8 Partial conversion of GS licences to HS licences
% of time below 25%	25.29%	0.04%	19.38%
% of time below 20%	11.91%	0.03%	9.68%
% of time below 15%	3.37%	0.00%	0.98%
% of time below 10%	0.00%	0.00%	0.00%

Figure 25. Copeton Dam storage behaviour base case (Scenario 1) and Scenario 7

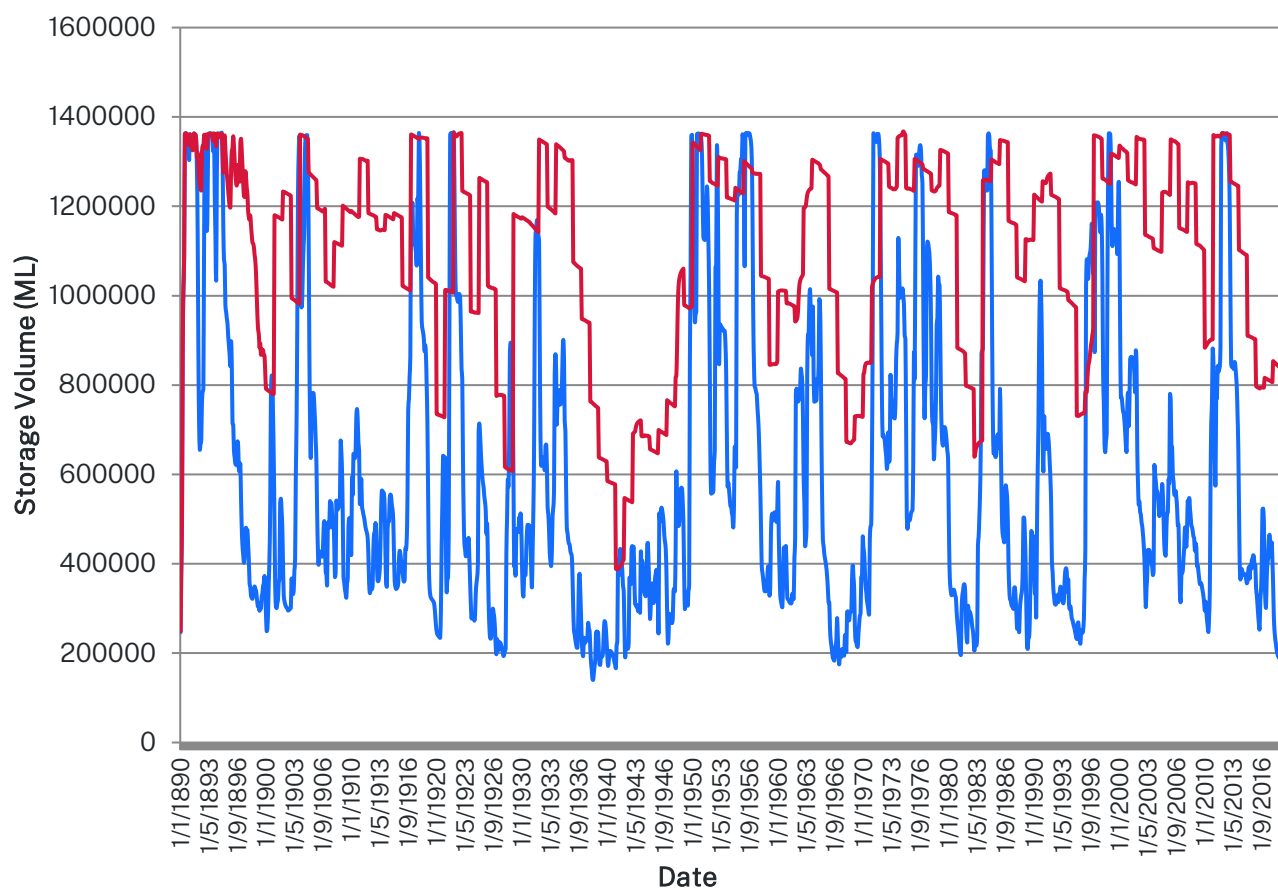
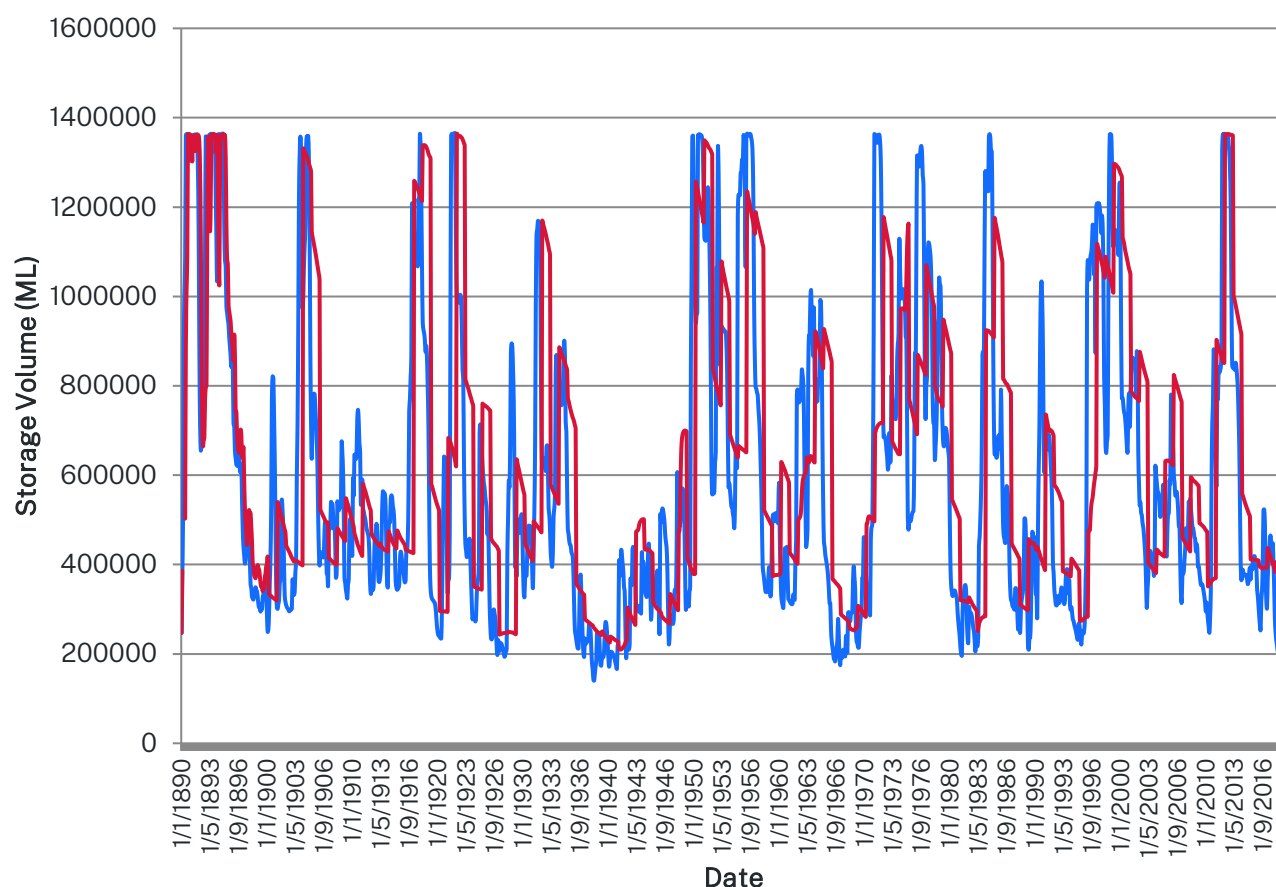


Figure 26. Copeton Dam storage behaviour base case (Scenario 1) and Scenario 8



Alterations in river flows

Changes in the flow regime at selected stream gauges are shown in Table 30 and Figure 27.

For Scenario 7, the introduction of an increased reserve results in increased variability in flows and a slight increase in mean wetland inflows. Higher flows have increased in frequency and low flows have decreased. For Scenario 8, low flows below 100 ML/d appear to have slightly decreased in frequency.

Table 30. Mean annual flow changes for the base case (Scenario 1), Scenario 7 and Scenario 8

Mean annual streamflow (GL/Yr)	Base case	Scenario 7 Bulk conversion of GS licences to HS licences	Scenario 8 Partial conversion of GS licences to HS licences
Gwydir River US Tyreel Regulator	322.10	326.21	318.87
Gwydir River at Gravesend (418013)	734.01	715.26	732.88
Gwydir River at Collymongle (418031)	0.64	0.87	0.64
Mehi River near Collarenebri (418055)	104.92	100.44	104.36
Gil Gil Creek at Galloway (416052)	47.80	48.71	47.67

Figure 27. Flow behaviour at Gwydir River upstream of Tyreel flow base case (Scenario 1) and Scenario 7

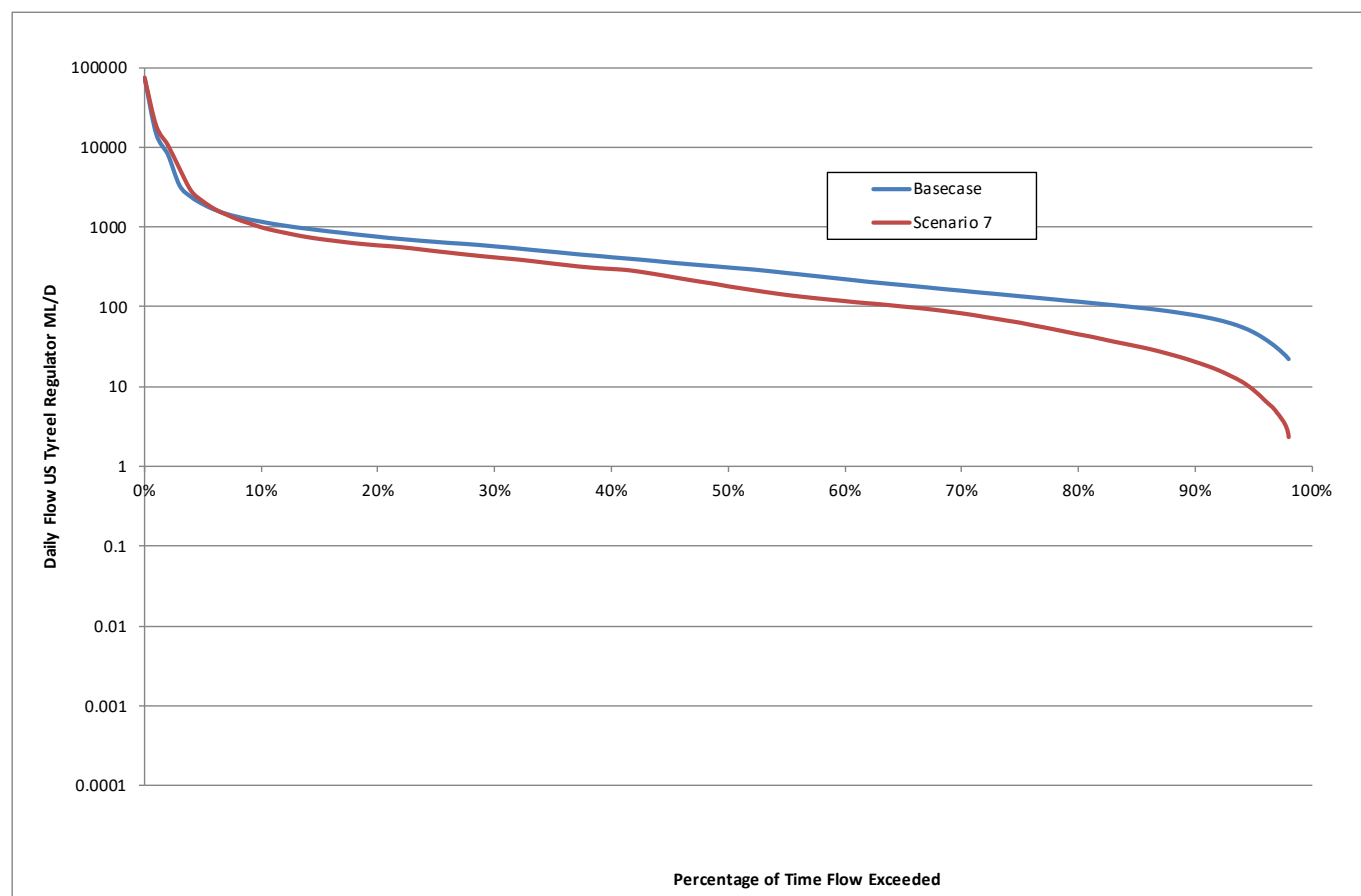
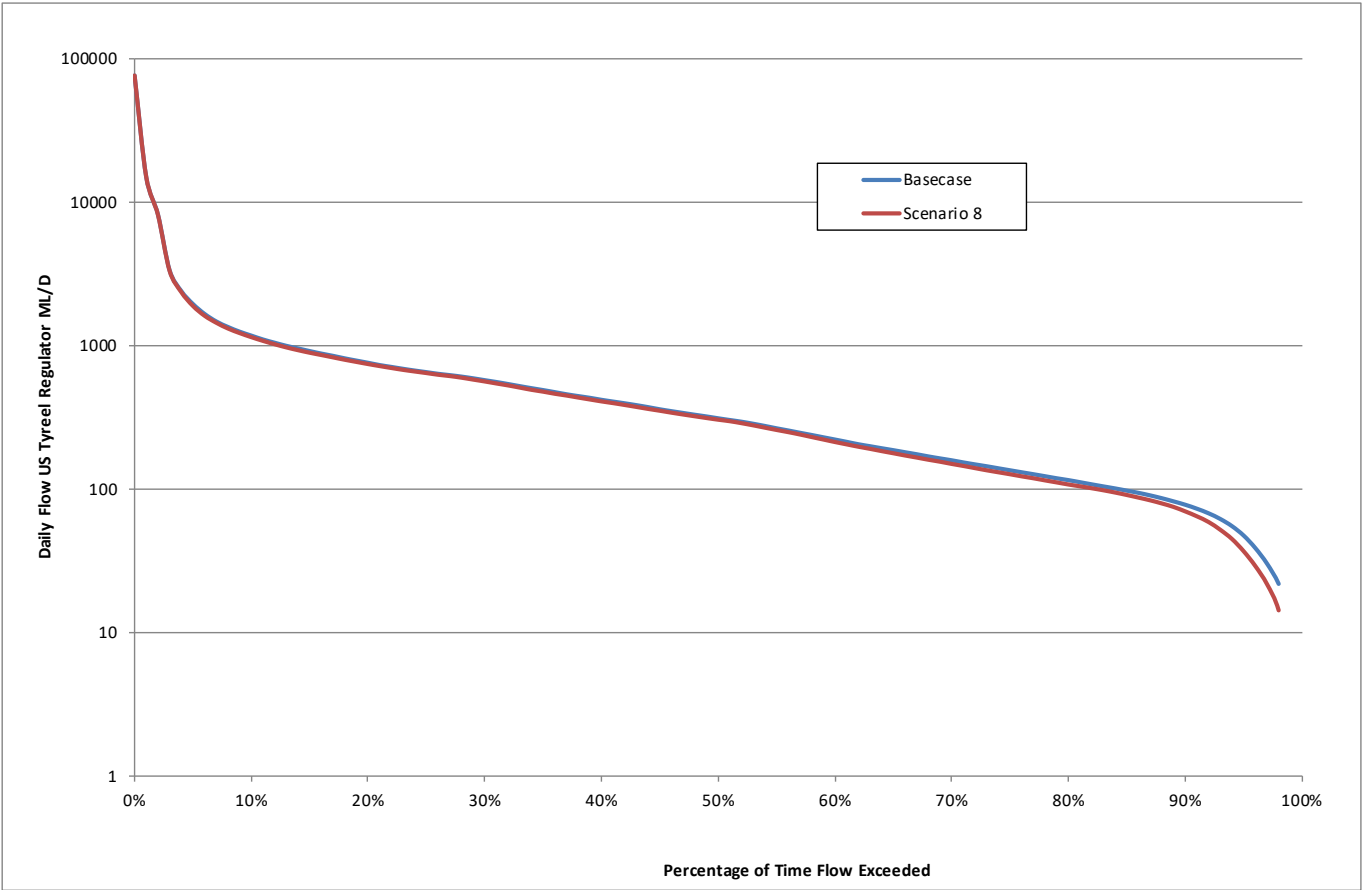


Figure 28. Flow behaviour at Gwydir River upstream of Tyreel flow base case (Scenario 1) and Scenario 8



8. Stochastic and NARClIM assessment

Description

The base case and three options (totalling four scenarios) were evaluated using the stochastic and NARClIM modelling (Table 31). Results of the analysis are presented in Table 32.

Table 31. Gwydir Regional Water Strategy portfolio options

RWS option	Number	Scenario description
Base case		
Option 1 – Enlargement of Tareelaroi Weir	Scenario 3	Enlarge Tareelaroi Weir, raise and maintain diversions at base case total diversions by reducing supplementary shares by 10%
Option 18 – Increase the storage reserve in Copeton Dam	Scenario 6	Reserve increased from two to three years (166.5 GL)
Option 29 – Investigate licence conversions (Bulk)	Scenario 7	General security shares reduced by 100% (407.76 GL) and 178.85 GL of high security shares created at Moree
Option 29 – Investigate licence conversions (Partial)	Scenario 8	General security shares reduced by 10% (40.78GL) and 17.89 GL of high security shares created at Moree

Modelling results

The results for each scenario are presented for three climatic periods:

- Instrumental record – the past 130 years with all inflows simulated
- Stochastic period – 10,000 years
- Stochastic with climate change projections (NARClIM) – 10,000 years.

Comparison of total diversions for these three periods indicate:

- Diversions for each scenario over the instrumental record are greater than over the stochastic period, indicating that the full extent of climatic variability has not been seen over the historical climate.
- Total diversions are reduced under a climate change NARClIM projection in the range of 20% for scenarios modelled, except Scenario 7, which is reduced by 12%. The lower reduction for Scenario 7 is due to the large reserves being set aside for high security supply.
- Performance of high security entitlements is largely unaffected over both the stochastic period and the climate change projection.

Table 32. Gwydir Regional Water Strategy scenario results (Instrumental, Stochastic and NARClIM)

Mean annual – Water Year					
Metrics	Base case	Scenario 3	Scenario 6	Scenario 7	Scenario 8
Instrumental dataset					
Town water supply - Bingara supplied (ML/y)	654	654	654	654	654
Town water supply - Gravesend supplied (ML/y)	118	118	118	118	118
Town water supply - Inverell supplied (ML/y)	3,046	3,046	3,046	3,042	3,046
General security supplied (ML/y)	192,995	201,254	189,009	N/A	180,199
High security supplied (ML/y)	11,292	11,292	11,292	11,203	11,290
High security new node supplied (ML/y)	N/A	N/A	N/A	176,886	17,895
Overbank harvesting (ML/y)	67,908	67,753	67,972	68,673	67,971
Rainfall harvesting (ML/y)	53,833	54,046	53,751	50,510	53,594
Supplementary (ML/y)	88,002	79,952	87,972	88,443	87,731
Total diversions	417,847	418,114	413,814	399,529	422,499
Effective allocation on 30 June (%)	100	104	97	163	102
Stochastic dataset					
Town water supply - Bingara supplied (ML/y)	654	654	654	654	654
Town water supply - Gravesend supplied (ML/y)	118	118	118	118	118

Town water supply - Inverell supplied (ML/y)	3,046	3,046	3,046	3,039	3,046
General security supplied (ML/y)	185,607	192,868	182,211	0	173,040
High security supplied (ML/y)	11,290	11,289	11,288	11,161	11,285
High security new node supplied (ML/y)	N/A	N/A	N/A	175,794	17,890
Overbank harvesting (ML/y)	66,029	65,932	66,042	66,357	66,009
Rainfall harvesting (ML/y)	52,778	53,048	52,719	48,457	52,516
Supplementary (ML/y)	86,710	78,797	86,752	87,963	86,544
Total diversions	406,232	405,753	402,829	393,542	411,102
Effective allocation on 30 June (%)	96	100	94	148	98
NARcliM dataset					
Town water supply - Bingara supplied (ML/y)	654	654	654	653	654
Town water supply - Gravesend supplied (ML/y)	118	118	118	118	118
Town water supply - Inverell supplied (ML/y)	3,046	3,046	3,046	2,995	3,046
General security supplied (ML/y)	135,668	141,204	133,171	-	124,742
High security supplied (ML/y)	11,352	11,351	11,351	10,825	11,337
High security new node supplied (ML/y)	N/A	N/A	N/A	170,665	17,882
Overbank harvesting (ML/y)	58,631	58,526	58,655	58,608	58,583
Rainfall harvesting (ML/y)	41,266	41,416	41,226	38,960	41,095
Supplementary (ML/y)	65,364	59,926	65,387	64,415	65,077
Total diversions	316,099	316,242	313,607	347,237	322,534
Effective allocation on 30 June (%)	71	74	69	96	71