Department of Planning and Environment

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Hydrologic analysis of options for the North Coast Regional Water Strategy

Regional Water Strategies Program

January 2023

Acknowledgement of Country

The NSW Government acknowledges **First Nations people as its first Australian people** and the traditional owners and custodians of the country's lands and water. **We have recognised that First Nations 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 practice the oldest living culture on earth.

The NSW Government acknowledges the **First Nations people/Traditional Owners** from the Far North Coast Region as having an intrinsic connection with the lands and waters of the Far North Coast Regional Water Strategy area. The landscape and its waters provide the **First Nations people** with essential links to their history and help them to maintain and practice their **Traditional** culture and lifestyle.

We recognise the **Traditional Owners** were the first managers of Country and by incorporating their culture and knowledge into management of water in the region is a significant step for closing the gap.

Under this regional water strategy, we seek to establish meaningful and collaborative relationships with **First Nations people**. We will seek to shift our focus to a Country-centred approach, respecting, recognising and empowering **Cultural and Traditional Aboriginal** knowledge in water management processes at a strategic level.

We show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places where **First Nations people** are included socially, culturally and economically.

As we refine and implement the regional water strategy, we commit to helping support the health and wellbeing of waterways and Country by valuing, respecting and being guided by **Traditional Owners/First Nations people**, who know that if we care for Country, it will care for us.

We acknowledge that further work is required under this regional water strategy to inform how we care for Country and ensure **Traditional Owners/First Nations people** hold a strong voice in shaping the future for **Indigenous/Aboriginal** and non-Aboriginal communities.

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Introduction

What are regional water strategies?

Across NSW, valuable and essential water resources are under pressure. A more variable climate, as well as changing industries and populations, mean we face difficult decisions and choices about how to balance the different demands for this vital resource and manage water efficiently and sustainably into the future.

The North Coast Regional Water Strategy is one of a suite of catchment-based strategies across the state. The strategies identify critical challenges that we need to tackle over the coming decades and outline the priorities and actions that we will undertake to respond to those challenges. The best and latest climate evidence, along with a wide range of tools and solutions, has been used to chart a progressive implementation of actions for the region's water needs over the next 20 years and beyond.

Purpose of this options modelling report

The North Coast regional water strategy aims to have a comprehensive, balanced package of options that delivers on five key objectives:

- deliver and manage water for local communities
- enable economic prosperity
- recognise and protect Aboriginal water rights, interests and access to water
- protect and enhance the environment
- affordability

The strategy actions aim to deliver benefits and complementary actions across all stakeholder groups. To support the regional water strategies, we have developed hydrologic models for each major catchment in a region. We have used these models to:

- improve our understanding of the water systems in the region
- understand the effects that different water management options could have on the environment and on the supply, demand and allocation of water.

This report outlines how the different management options were conceptualised and built in the model. It also discusses the assumptions we needed to make and presents a summary of the hydrologic results. More detailed discussion on the implications of the results for the economic and environmental assessments is presented in the detailed economic and ecological analysis for the North Coast.[1]

Methodology

The assessment approach aims to define risks to essential water supplies and the regional economy from climate variability and drought in the Clarence River catchment. This considered existing infrastructure and the potential for mitigating risks by augmenting water supply infrastructure or making operational changes. The hydrological assessment was a key tool for understanding the effects that options may have on existing water supply risks, on water users and on the environment in the Clarence River catchment.

All hydrologic and water supply assessment modelling was completed using the eWater Source modelling platform. The model was developed as a tool for planning and evaluating water resource management policies at the river basin scale. In addition to assessing water quantity, this model can be applied to regulated and unregulated streams to understand water quality and environmental issues.

For the North Coast, only a single infrastructure option from the long-list of options[2] met the criteria for hydrological modelling. The option modelled (as outlined in this report) is Option 1: Expand the Clarence- Coffs Harbour Regional Water Supply Scheme.

The modelling was completed using the eWater Source River System Model. Hydrological modelling is a key input to the development of the final North Coast Regional Water Strategy.

We used 3 climatic datasets to test the resilience of the system and proposed options. The hydrologic modelling in the North Coast region is based on:

- historical data from the instrumental record (130 years): this provided initial insight into current water supply performance and risks, potential improvements under augmentation options and relative benefits between defined options
- 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.

We also performed stochastic hydro-economic assessment by splitting the 10,000-year datasets into 1,000 40-year segments. This allowed us to assess the impact to each major water user using 1,000 40-year realisations or 'windows'. The 40-year time horizon reflects NSW Treasury guidelines for a long period of time to measure the consequence of an option.

[1] Department of Planning and Environment 2022, *North Coast Regional Water Strategy: Detailed economic and ecological analysis*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies, accessed 9 December 2022.

[2] Department of Planning, Industry and Environment 2020, *Draft Regional Water Strategy — North Coast: Long list of options*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies, accessed 9 December 2022.

The configuration, assumptions and results summaries of the options modelling are presented in detail in the sections below. Discussions on the implications of these results for water supply, economics and the environment are presented in the detailed economic and ecological analysis for the North Coast.[3]

[3] Department of Planning and Environment 2022, *North Coast Regional Water Strategy: Detailed economic and ecological analysis*, www.dpie.nsw.gov.au/water/plans-and-programs/regional-water-strategies, accessed 9 December 2022.

2. Background

2.1 Clarence River catchment

The Clarence River catchment is on the north coast of NSW. It is the largest river on the east coast of NSW, with a catchment area of 22,716 km^2. The catchment rises in the McPherson Range on the NSW–Queensland state border, and flows south through an extensive coastal floodplain to Yamba, where it meets the Pacific Ocean. Major tributaries include the Mann, Nymboida and Orara rivers (**Error! Reference source not found.**). The river mouth is located between the towns of Yamba and I luka and the estuary reaches 108 km inland to Copmanhurst. The towns of Grafton, Maclean, Yamba and Iluka are the main centres of population along the estuary, with Tenterfield and Dorrigo also located within the catchment.

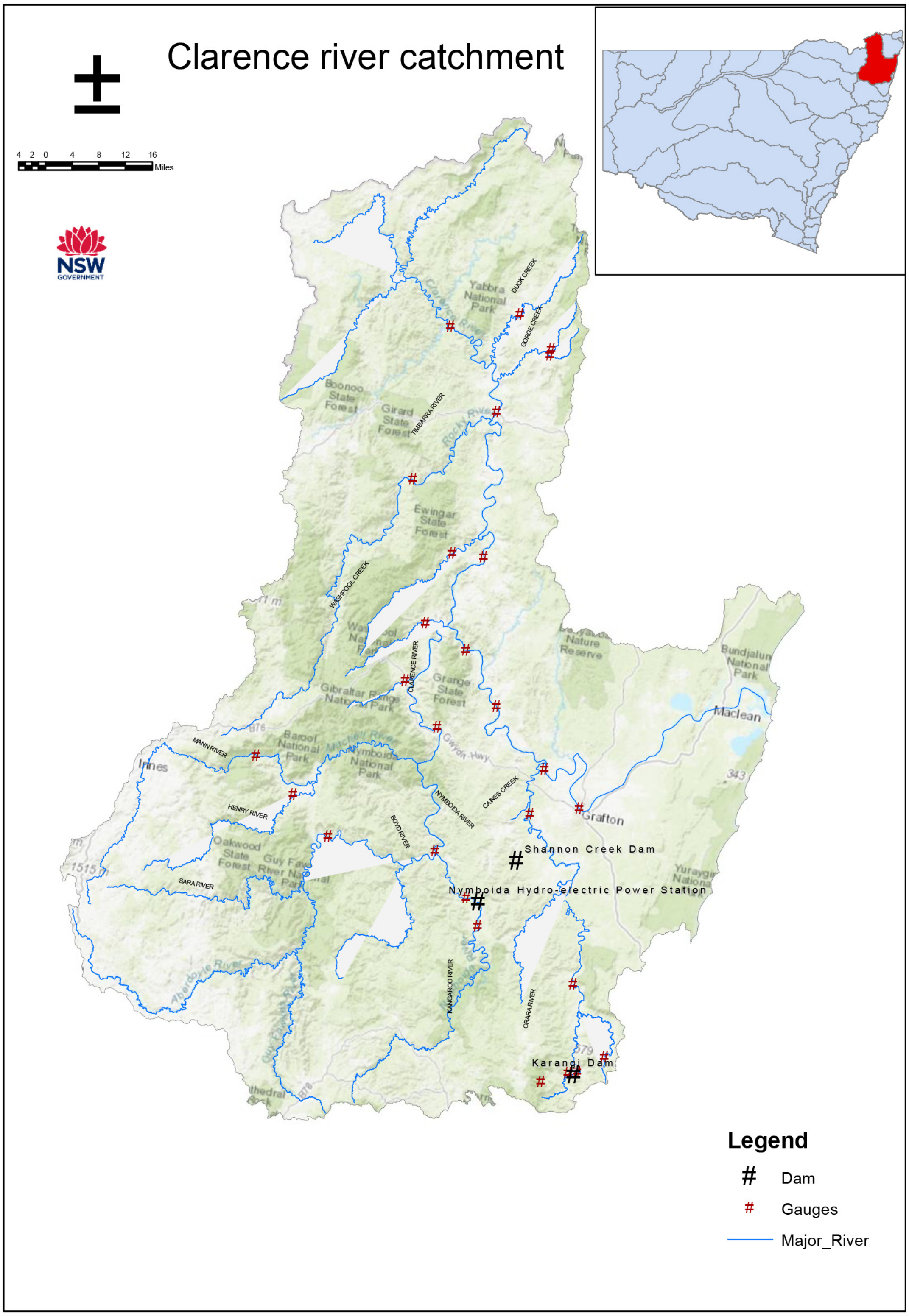

Figure 1. Clarence River catchment

2.2 Regulation

Most of the rivers and creeks in the Clarence River catchment are unregulated. Water users rely on natural flows or small structures, such as weirs, for their water supplies. As in most unregulated rivers, flows are affected the greatest during relatively dry times, when water availability is low and demand is high.

The only significant water management structure in the catchment is the Nymboida River Water System (referred to in this report as the Clarence – Coffs Harbour Regional Water Supply Scheme. This scheme was developed in 2009 to secure town water supplies for the rapidly growing populations of Grafton and Coffs Harbour and to address current town water security concerns. It involved the construction of Shannon Creek Dam and a bi-directional pipeline that allows transfer of water between Shannon Creek and Karangi Dam (built in 1980). Shannon Creek Dam is owned and operated by Clarence Valley Council, and Karangi Dam is owned and operated by Coffs Harbour City Council. The Nymboida weir is a legacy of a decommissioned mine. Ownership of the weir has recently been transferred to council. Water is diverted at the Nymboida weir to each dam during high flows in the Nymboida River (as well as from the Orara River for Karangi Dam) and is taken only when flows in the rivers are too low to allow extraction for town water use.

Water take in the catchment is regulated through the rules set in the *Water Sharing Plan for the Clarence River Unregulated and Alluvial Water Sources 2016.*[4]

Water sharing plans set the limits on the amount of water that can be extracted from surface water and groundwater sources in the North Coast region. The annual sharing of water is managed through long-term average annual extraction limits (LTAAELs), while daily sharing is managed through cease-to-take rules,[5] which can vary for different categories of licence.

2.3 Water users

Water users include town water utilities, irrigators, basic landholder rights, and water for stock and domestic supplies.

Local council has the largest entitlement to water in the catchment. Agricultural land and water use is dominated by beef cattle production. Sugar cane is grown intensively on the lower Clarence, especially around Maclean, Harwood Island and Palmers Island. Horticulture (such as blueberries, tomatoes and cucumbers) are increasingly being grown in the area.

Other industries dependent on water include aquaculture, prawn trawling, fishing and tourism.

[4] NSW Government 2016, *Water Sharing Plan for the Clarence River Unregulated and Alluvial Water Sources 2016*, legislation.nsw.gov.au, accessed 19 December 2022.

[5] Water sharing plans for unregulated rivers require licence holders to stop pumping when the river flow falls below a certain volume or salinity levels in tidal pool or estuary water sources increase above certain thresholds. These rules are referred to as cease-to-take rules. Cease-to-take rules apply to surface water licences in all unregulated water sources, excluding licences held by local water utilities, licensed stock and domestic users, and licences used for food safety and essential dairy care.

3. Assessment framework

3.1 Modelled options

Only one option described in the long list of options for the Draft North Coast Regional Water Strategy passed the rapid cost-benefit analysis. This was Option 1: Expand the Clarence–Coffs Harbour Regional Water Supply Scheme.

The options that passed the rapid cost-benefit analysis underwent additional hydrologic assessment. The hydrological assessment was completed using three sources of data.

3.2 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. Further, it provided a faster way of testing the operational details of the options.

3.3 Long-term historic climate projections (stochastic data)

The long-term historic climate projection (stochastic data) refers to the 10,000 years of stochastic-generated climate[6] that are used to evaluate the feasibility of portfolios as well as define the base case. For portfolio 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.

3.4 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

[6] Leonard, M., *et al.* 2020, *Methodology Report for Multisite Rainfall and Evaporation Data Generation of the Northern Basins — Far North Coast Region Stochastic Evaluation*, University of Adelaide

three regional climate models of CSIRO-MK3 GCM used in NARCliM 1.0. These were the driest of the NARCliM 1.0 ensemble of models, chosen with the intent of stress-testing the system. This set of stochastic data with climate projections are used in conjunction with the stochastic data to evaluate the final viability of portfolios, 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 'NARCliM' throughout the report.

3.5 Outputs for option assessment

The outputs for all model runs used for economic assessment are shown in 1. The 'ordered' category refers to the demand generated for the output type; The 'supplied' category refers to the ordered water that was successfully supplied; and the 'shortfall' category refers to the difference between the water that was ordered and the water that was supplied. For all other outputs, a description is provided. These outputs are given at a daily timestep under instrumental, stochastic and NARCliM scenarios for all options.

Table 1. Modelled outputs generated for economic assessment

Category	Component
Ordered	Bellinger new town water supply (TWS) node
	CHCC TWS
	CVC TWS
Supplied	Bellinger new node TWS
	CHCC TWS
	CVC TWS
	unregulated
Shortfall	Bellinger new node TWS
	CHCC TWS
	CVC TWS
Rainfall harvesting	The amount of water absorbed into the soil moisture store of a crop due to direct rainfall on the crop
Idealised irrigation requirement	The required irrigation for the Clarence River catchment under a no-rainfall climate with unlimited access to irrigation
Total crop area	Total irrigated area over the catchment recorded on the day that has the most crop area within a year (1 April)

4. Clarence River hydrological baseline model

The hydrological computer models used by the NSW Department of Planning and Environment to underpin water management in NSW are quantitative simulation models. Simulation models are widely used in water resources management to improve understanding of how a system works and could behave under different conditions. The department, along with other Australian water agencies, uses or is migrating to use the eWater Source software platform, which has been adopted as Australia's National Hydrological Modelling Platform.

The Clarence River baseline hydrological model was developed in 2020 by the Department of Planning and Environment — Water to include the full range of runoff conditions, as well as the operational rules of the current water sharing plan and subsequent irrigator behaviour.

One of the key objectives of new model development is to build a high-quality, robust and fit-for-purpose model to run a range of scenarios to inform decisions related to policy, planning and strategies, including regional water strategies.

A systematic approach (as outline in **Error! Reference source not found.**) was used to develop the m odel, which included the following key steps:

1. conceptualisation
2. data collation and review for flow modelling
3. flow model calibration
4. collation and review of data for demand modelling and demand model calibration
5. implementing management rules and ordering calibration
6. full model calibration and validation.

The demand estimates are a series of demand models for town water supplies (TWS), basic landholder rights and irrigation. The town water supply demand model includes the Clarence - Coffs Harbour Regional Water Supply Scheme, which consists of town supplies and demands for:

- Clarence Valley Council (CVC)
- Coffs Harbour City Council (CHCC).

The CCHRWS Scheme includes two off-stream storages and a weir:

- Shannon Creek Dam
- Karangi Dam
- Nymboida River Weir

The technical details of the Clarence River baseline hydrological model are documented in a series of technical reports on model development. A schematic of the model is given in Appendix 1.

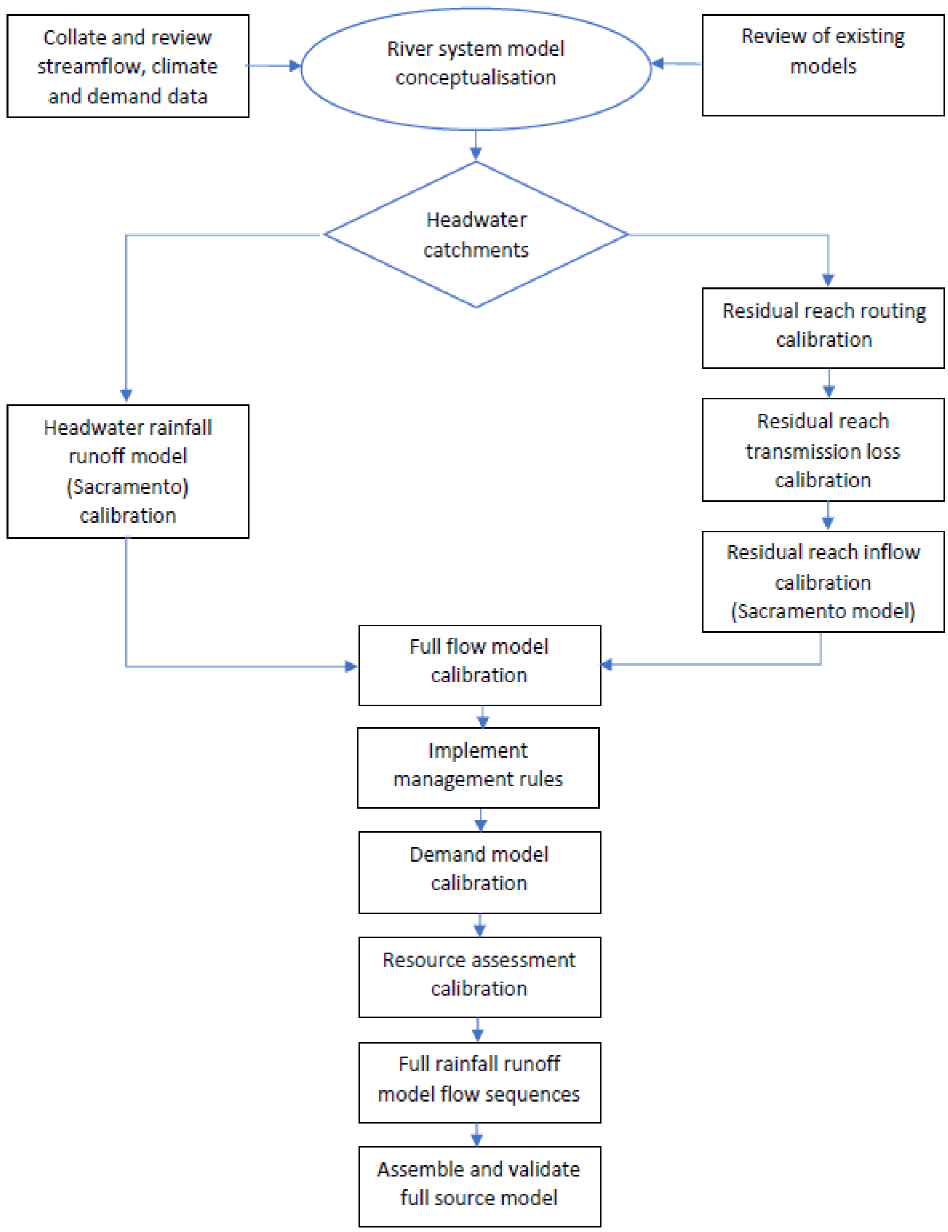

Figure 2. Key steps of model development

Table 2. Hydrologic data used in baseline model calibration

Gauge ID	Gauge name	Catchment area/residual reach area (km^2)	Headwater or reach
204001	Nymboida River at Nymboida	1,648	HW
204014	Mann River at Mitchell	883	HW
204015	Boyd River at Broadmeadows	2,637	HW
204034	Henry River at Newton Boyd	400	HW
204043	Peacock Creek at Bonalbo	47	HW
204044	Gorge Creek at Bonalbo	43	HW
204046	Timbarra River at Drake	1,716	HW
204048	Coombadjha Creek at Coombadjha	93	HW
204049	Duck Creek at Capeen	336	HW
204051	Clarence River at Paddys Flat	3,117	HW
204054	Washpool Creek at Lionsville	266	HW
204056	Dandahra Creek at Gibraltar Range	112	HW
204060	Bucca Creek at Central Bucca	21	HW
204068	Orara River at Orange Grove	125	HW
204069	Nymboida River D_S Nymboida Weir	5	Reach
204007	Clarence River at Lilydale (Newbold Crossing)	1,616	Reach
204025	Orara River at Karangi	8	Reach
204004	Mann River at Jackadgery	2,256	Reach
204041	Orara River at Bawden Bridge	1,376	Reach
204900	Clarence River at Baryulgil	1,000	Reach
204906	Orara River at Glenreagh	276	Reach
204002	Clarence River at Tabulam	999	Reach

5. Option 1: Expand the Clarence–Coffs Harbour Regional Water Supply Scheme

5.1 Description

The intent of Option 1 is to improve water security for Bellingen Shire Council during prolonged dry periods.

Bellingen Shire Council supply water to the towns of Bellingen, Fernmount, Yellow Rock, Newry Island, Urunga, Hungry Head, Mylestom, Repton and Raleigh. Raw water is drawn from an infiltration well and three bores in the Bellinger Alluvium Groundwater Source. The Bellinger Alluvium has a hydraulic connection with the Bellinger River in the vicinity of the Bellinger Borefield, and groundwater levels show a strong response to changes in river levels.

Bellingen Shire Council, as a result of the extended dry conditions experienced from 2018 to 2020, are looking at a range of options to improve their water security. One option being considered by Bellingen Shire Council that was identified in the Draft North Coast Regional Water Strategy is a pipeline allowing Bellingen Shire Council to access town water from the CCHRWS Scheme during drought. Specifically, the pipeline would link into Coffs Harbour City Council's treated water supply network in the suburb of Boambee East and connect into Bellingen Shire Council's town water system.

Based on feedback from Bellingen Shire Council, the modelled option assumed a daily demand of 2.5 ML during dry periods. A dry period was defined as any period when the cease-to-pump rules at the Bellinger River (Thora gauge, 205002) are in place.

5.2 Model setup

The Clarence River baseline hydrological model was modified to assess the hydrological impacts of the modelled option. The main modification is the inclusion of a new demand node from Karangi Dam. Supply from this node is activated when the cease to pump conditions at the Thora Gauge on the Bellinger River are in place. At these times, water is supplied at a rate of 2.5 ML/day, as described above.

The figure below illustrates how option 1 (and the new Bellinger River town water supply (TWS) node) has been incorporated into the Clarence River baseline hydrological model.

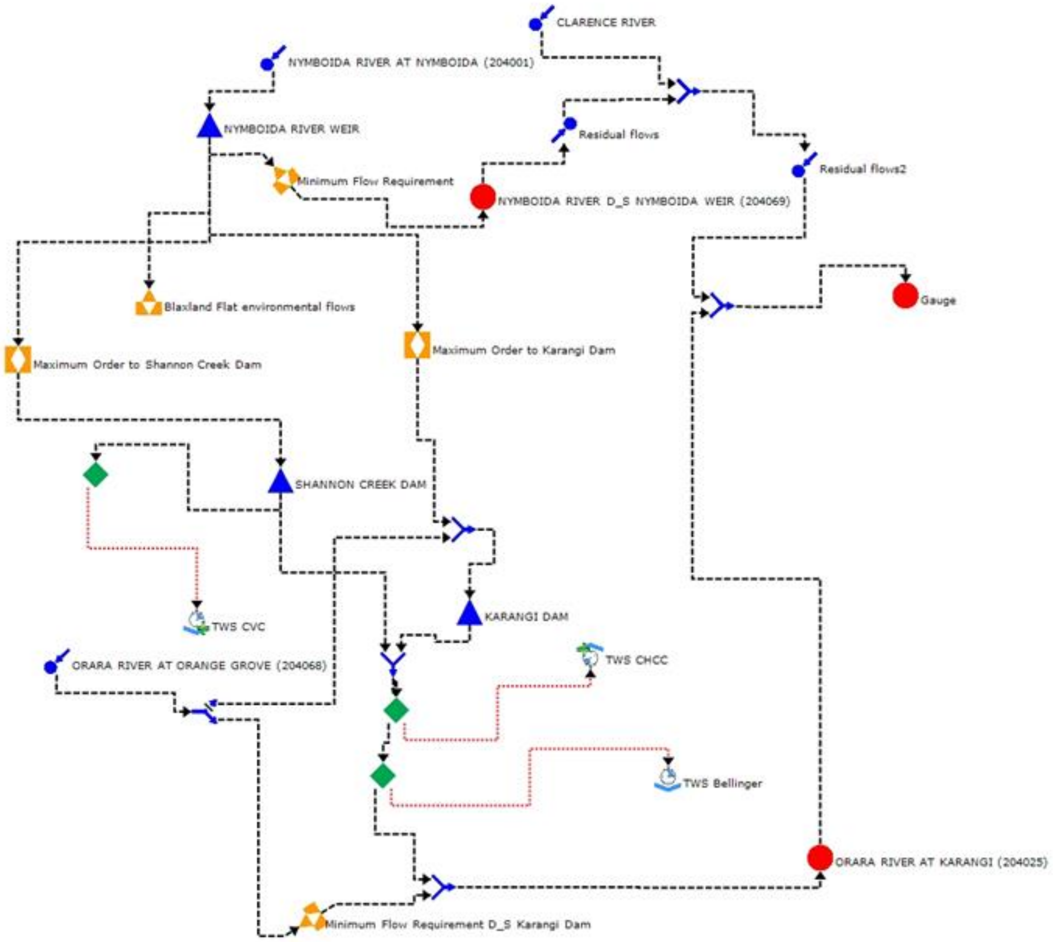

Figure 2. Proposed Bellinger River Town Water Supply demand model schematic

5.3 Key assumptions

The two key assumptions in modelling option 1 are when water is transferred to Bellingen Shire Council's treated water supply network and how much is transferred.

As discussed earlier, the model assumes a daily rate of 2.5 ML is transferred when cease to pump conditions at the Thora Gauge on the Bellinger River are activated. These rules are given in the *Water Sharing Plan for the Bellinger River Area Unregulated and Alluvial Water Sources 2020*[7] and are summarised in Table 3. The model also assumes there are no losses from the system and that water is only supplied if there is sufficient available from Karangi Dam.

[7] NSW Government 2020, *Water Sharing Plan for the Bellinger River Unregulated and Alluvial Water Sources 2020*, legislation.nsw.gov.au, accessed 19 December 2022.

Table 3. Cease-to-pump rules at Bellinger River at Thora gauge

Category	Component
Cease to take	Take of water must cease when flows at the reference point are equal to or less than 20 ML/ day (95th percentile). For high-flow licences, including Aboriginal community development licences, take of water must cease when flows at the reference point are equal to or less than 134 ML (50th percentile).
Commence to take	24 hours after reaching 20 ML/day after a cease-to-take event.
Daily take restrictions	Maximum of 8 hours/day when flows are between 20 ML and 4 ML/day (80th percentile). Take is unrestricted when flows are greater than 44 ML/day.
Reference point	Bellinger River at Thora gauge (205002)
Published daily flows	Access real-time flow data at Bellinger River at the Thora gauge at: realtimedate.waternsw.com.au/ > Access Real Time Data > Rivers and Streams > 205-Bellinger River Basin > 205002 Bellinger at Thora.

Source: DPIE, 2020

5.4 Modelling results

The simulated instrumental daily and annual extraction to meet the new town water supply demand described in Option 1 is illustrated in Figure and Figure .

The instrumental average annual extraction is 32.8 ML/annum ranging from 0 to 417.5 ML/annum. The extraction of this water results in a slight decrease in the volume of Karangi Dam (Figure) and a very small change in volume of Shannon Creek Dam (Figure) because the two dams are connected. The effect of the extraction on flows downstream of Karangi Dam is negligible (Figure). The modification also results in stable extractions for both Clarence Valley Council and Coffs-Harbour City Council.

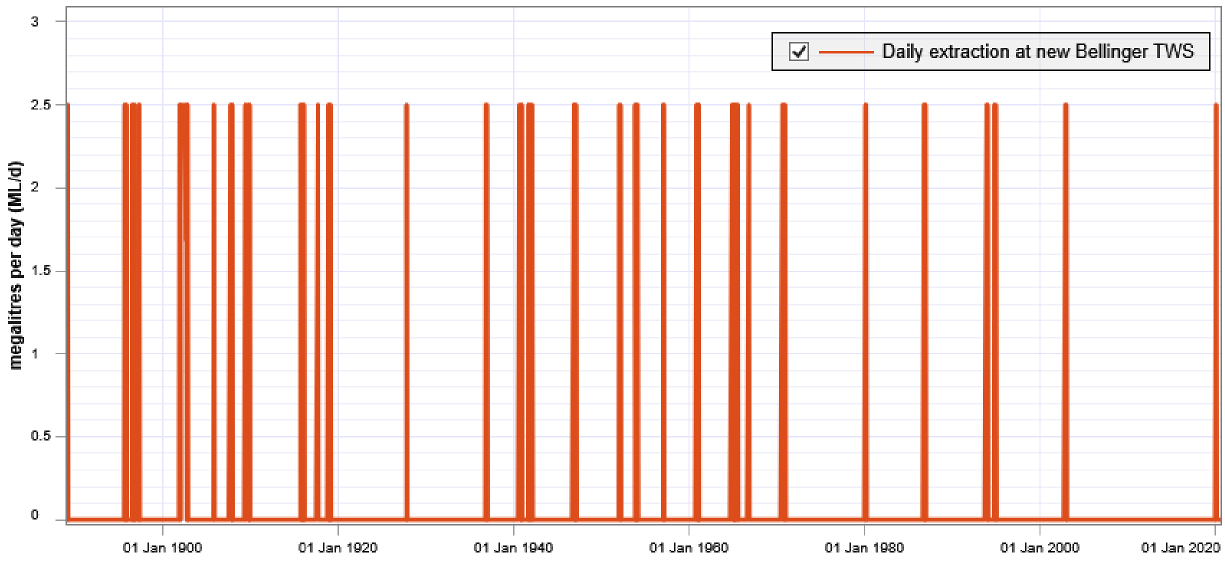

Figure 4. Daily extraction at new Bellinger TWS node under instrumental scenario

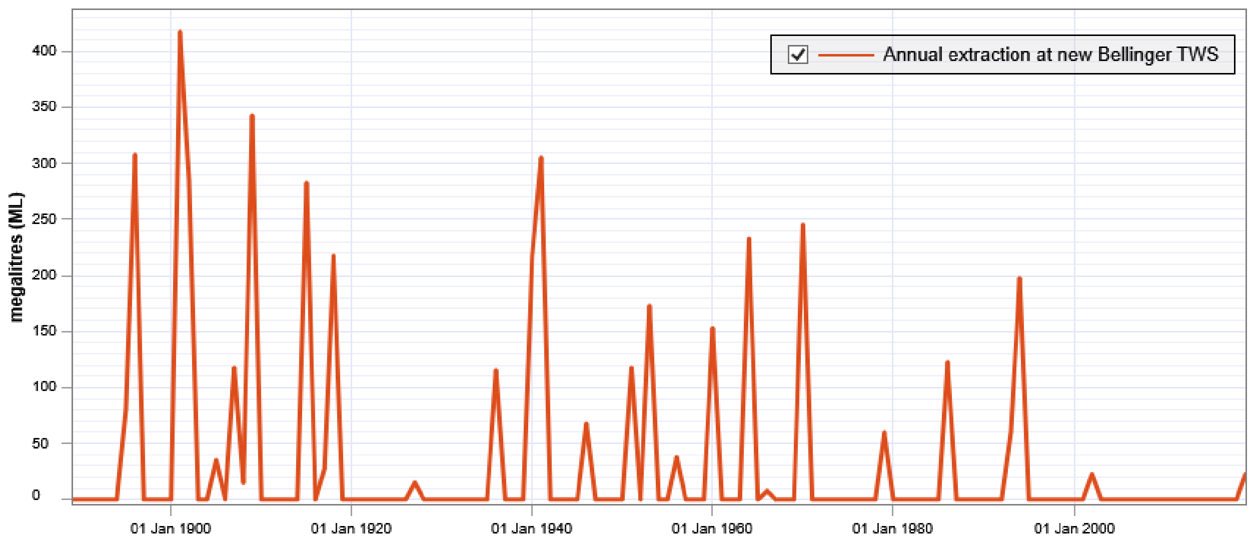

Figure 5. Annual extraction at new Bellinger TWS node under instrumental scenario

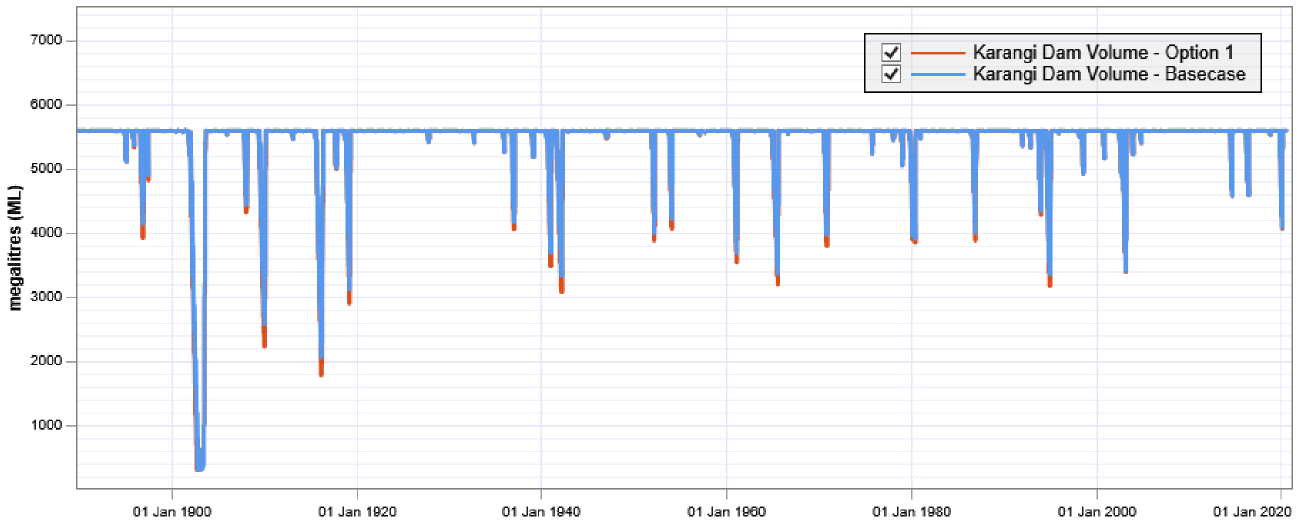

Figure 6. Karangi Dam volume under instrumental scenario for the base case and Option 1

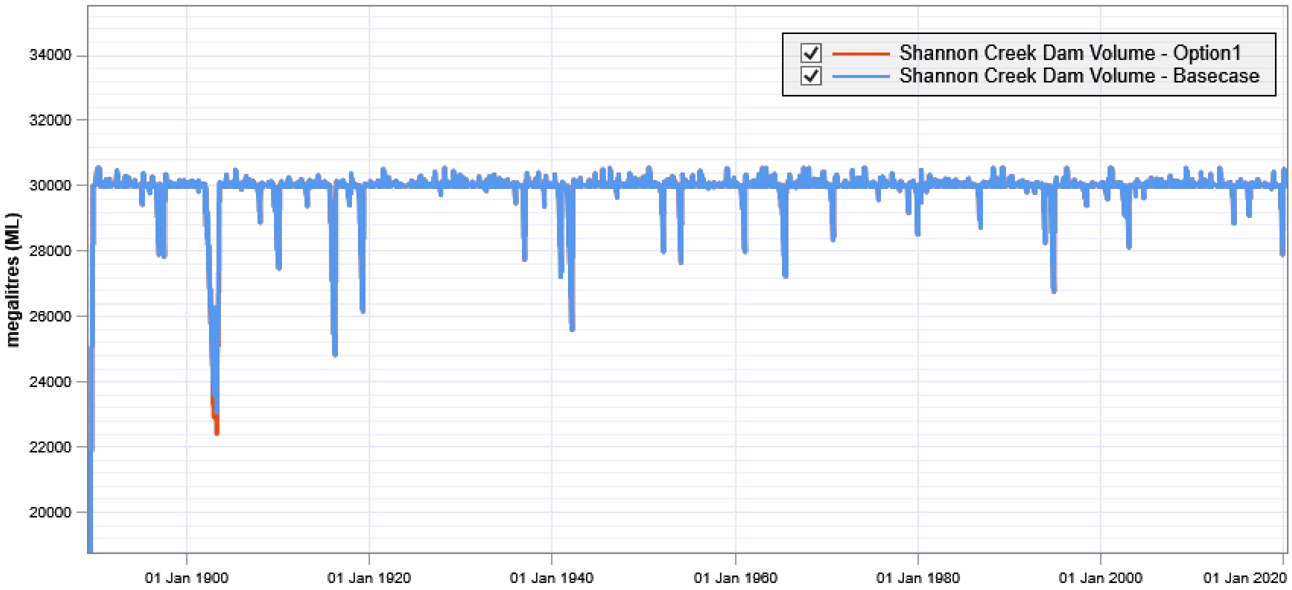

Figure 7. Shannon Creek Dam volume under instrumental scenario for base case and Option 1

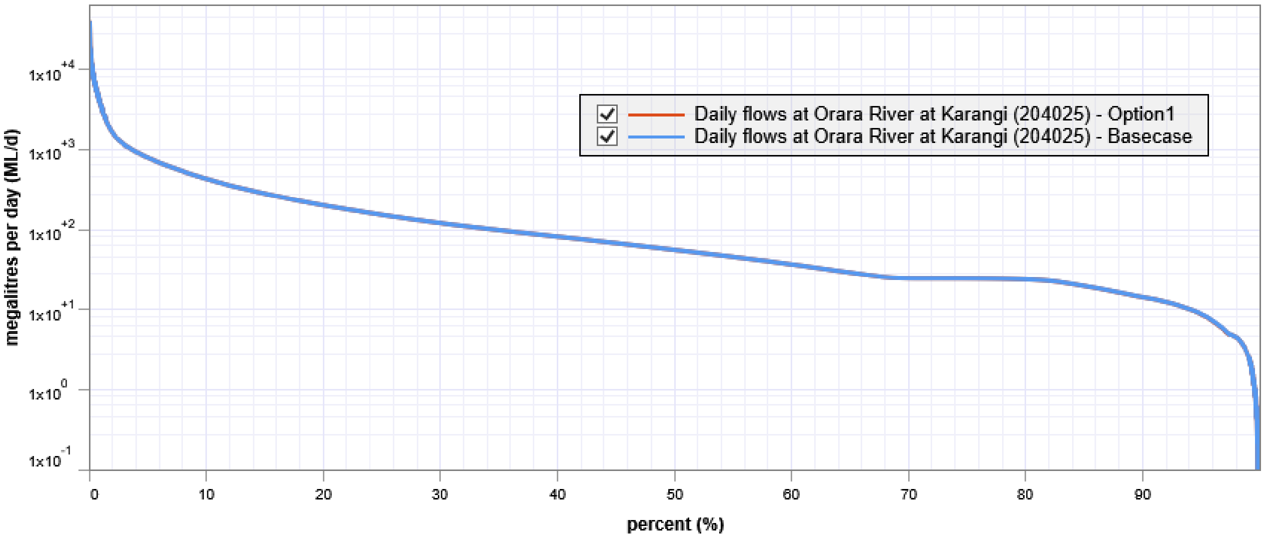

Figure 8. Flow duration curve at downstream of Karangi Dam (Orara River at Karangi (204025)) under instrumental scenario for base case and Option 1

5.5 Preferred portfolio — assessment with instrumental, stochastic and NARCliM climate data

Because only a single option was selected for modelling, it was decided to progress the option further as a 'preferred portfolio' for simulation using stochastic and NARCLiM climate scenarios.

The baseline model and the portfolio model (i.e., the baseline model with Option 1) were simulated using three sets of multiple replicates of climate data of 40-year duration for economic analysis:

- 14 replicates for instrumental climate
- 1,000 replicates for stochastic climate
- 1,000 replicates for NARCliM.

A summary of the key portfolio results for the unregulated system is shown in **Error! Reference source not found.**. Simulated extractions for these three periods indicate that the extraction meets the demand for all town water supply nodes of the CCHRWS Scheme. The simulations demonstrate that the scheme can support Bellingen Shire Council's town water supply needs during the defined dry period at a fixed rate of extraction of 2.5 ML/d for all the instrumental, stochastic and NARCliM climate scenarios.

Table 4. Regional water strategy preferred portfolio option results (instrumental, stochastic and NARCliM climate projections)

Climate inputs	Metrics	Annual average flow (ML/yr)	
		Base case	Option 1
Instrumental	Ordered new Bellinger TWS node	0	32
	Supplied new Bellinger TWS node	0	312
	Ordered CVC TWS	5,904	5,904
	Supplied CVC TWS	5,904	5,904
	Ordered CHCC TWS	6,452	6,452
	Supplied CHCC TWS	6,452	6,452
	Unregulated supplied	5,967	5,966
	Idealised irrigation requirement	21,920	21,920
	Rainfall harvesting	16,805	16,806
	Total crop area (hectares) at 1 April	2,553	2,553
Stochastic	Ordered new Bellinger TWS node	0	25
	Supplied new Bellinger TWS node	0	25
	Ordered CVC TWS	5,918	5,918
	Supplied CVC TWS	5,918	5,918
	Ordered CHCC TWS	6,446	6,446
	Supplied CHCC TWS	6,445	6,445
	Unregulated supplied	5,747	5,747
	Idealised irrigation requirement	21,972	21,972
	Rainfall harvesting	17,097	17,097
	Total crop area (hectares) at 1 April	2,554	2,554

Climate inputs	Metrics	Annual average flow (ML/yr)	
		Base case	Option 1
NARCLiM	Ordered new Bellinger TWS node	0	37
	Supplied new Bellinger TWS node	0	37
	Ordered CVC TWS	6,094	6,094
	Supplied CVC TWS	6,094	6,094
	Ordered CHCC TWS	6,490	6,490
	Supplied CHCC TWS	6,490	6,490
	Unregulated supplied	6,383	6,382
	Idealised irrigation requirement	22,965	22,965
	Rainfall harvesting	17,095	17,095
	Total crop area (ha) at 1 April	2,553	2,553

5.6 Outputs for ecological analysis of the preferred portfolio

The baseline model and the [portfolio model were simulated using two sets of single-sequence climate data for ecological analysis:

- 10,000-year stochastic climate
- 10,000-year NARCliM climate projection.

The ecological outputs for portfolios are supplied as a single 10,000-year daily time-series output modelled flow at the following gauges (Table 5):

Table 5. List of gauges for ecological outputs

Gauge ID	Gauge name
204001	Nymboida River at Nymboida
204002	Clarence River at Tabulam
204004	Mann River at Jackadgery
204007	Clarence River at Lilydale (Newbold Crossing)
204014	Mann River at Mitchell
204015	Boyd River at Broadmeadows
204025	Orara River at Karangi
204034	Henry River at Newton Boyd
204041	Orara River at Bawden Bridge
204043	Peacock Creek at Bonalbo
204044	Gorge Creek at Bonalbo
204046	Timbarra River At Drake
204048	Coombadjha Creek at Coombadjha
204049	Duck Creek at Capeen
204051	Clarence River at Paddys Flat
204054	Washpool Creek at Lionsville
204056	Dandahra Creek at Gibraltar Range
204060	Bucca Creek at Central Bucca
204068	Orara River At Orange Grove
204069	Nymboida River D_S Nymboida Weir
204900	Clarence River at Baryulgil
204906	Orara River at Glenreagh
204400	Clarence River at Grafton*
204460	Clarence River at Mylneford*

6. Appendix 1

Schematic of the Clarence River baseline hydrological model