Department of Planning and Environment

dpie.nsw.gov.au

Economic Base Case

Far North Coast Region

November 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 people of the Bunjalung and Githabul nations 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 people of the Bunjalung and Githabul nations with essential links to their history and help them to maintain and practise their 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

Title: Economic Base Case

Sub-title: Far North Coast region

First published: November 2022

Department reference number: PUB22/1059

More information water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies

Contents

Figures

Tables

Executive summary

This report details the economic base case that was used for the hydrological and economic modelling undertaken to support the assessment of the long list of options for the draft Far North Coast Regional Water Strategy.

The first step in any economic analysis is to understand what the future could look like, and the potential consequences if we do nothing. This is known as the base case.

For the purpose of the regional water strategies, we have looked at three different plausible futures.

1. Historical data: the future based on what would happen if our future climate is similar to the last 130 years.
2. Stochastic data — long term historic climate projections: this assumes that our future climate is similar to what the science is indicating our long-term paleo climate was like and is based on a 10,000-year data set.
3. NARCliM data — a dry climate change scenario: 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.

Historically we have only ever assessed water infrastructure and policy changes against the historic data. The long-term historic climate projection and the dry climate change scenario give us a much better understanding of the water risks that could be faced by the region.

To understand the consequences of doing nothing, we have modelled the three most significant water user groups within the region:

- towns (as water shortfall) — Tweed Heads, Murwillumbah, Uki, Bangalow, Lismore, Ballina, Byron Bay, Woodburn, Casino, Mullumbimby, Nimbin, Wardell, and Kyogle
- annual crop producers (as water supplied) — assumed to be lucerne pasture
- permanent crop producers (as water supplied) — assumed to be blueberries
- stock and domestic producers.

The first step in the base case is to understand how water availability changes for these water users (hydrological modelling). The hydrologic results suggest that towns and agricultural producers are, on average, likely to experience a very slight decrease in water supply reliability under the dry climate change scenario. Table 1 shows a summary of the average water shortfall or usage impact on each aggregated water user..

Table 1. Average yearly water provided to different water user groups

Water user group	(a) Long-term historical climate projections (stochastic)	(b) Dry climate change scenario (NARCliM)	Difference between (a) and (b)	Difference (%) between (a) and (b)
Towns (shortfall, ML/year)	29.2	38.9	9.8	33.5
Annual Crops (supplied, GL/year)	11.52	12.87	1.35	11.7
Permanent Crops (supplied, GL/year)	0.1	0.1	0.0	4.45
Stock and domestic (supplied, GL/year)	0.0	0.0	0.0	0.0

The second step is undertaking an economic analysis to understand how this change in water availability translates into dollar values and impacts on the economy. Economic analysis was undertaken in accordance with the framework set out in *Regional Water Value Functions.*[1] The evaluation period for each analysis was 40 years with a discount rate of 7 per cent. Economic valuations per megalitre of water for each water user group were:

- towns: escalating cost dependant on (a) the size of the town, and (b) the length of the shortfall. Note this value is applied to the volume of water not supplied (the shortfall).
- annual crops: lucerne ($175/ML)
- permanent crops: blueberries ($7,500/ML, $15,000/ML in shortfall).

The economic impacts on average are higher under the climate change scenario than under the stochastic scenario, reflecting the lower availability of water. However, the economic impacts are not as significant in the Far North Coast region as they are in other regions. Table 2 below shows the average economic outcomes per water user group.

[1] Marsdon Jacob Associates 2022, *Regional water value functions: Values for inclusion in the cost-benefit analysis to support NSW Regional Water Strategies*, Department of Planning and Environment, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/rhs-cta/regional-water-value-functions, accessed 8 November 2022.

Table 2. Average total (40 years) economic outcomes per water user group

Water user group	(a) Long-term historical climate projections (stochastic)	(b) Dry climate change scenario (NARCliM)	Difference between (a) and (b)	Difference (%) between (a) and (b)
Towns ($, mil)	-1.31	-1.72	-0.41	31.3
Annual crops ($, mil)	11.52	12.87	1.35	11.7
Permanent crops ($, mil)	0.1	0.1	0.0	4.45
Stock and domestic ($, mil)	0.0	0.0	0.0	0.0

Introduction

Economic base case context

This report details the economic base case that was used for the hydrological and economic modelling undertaken to support the assessment of the long list of options in the draft Far North Coast Regional Water Strategy. This report has been prepared to document the process used and support decision-making on the options that have an impact on the supply, demand or allocation of water and should be progressed as part of a portfolio in the Far North Coast Regional Water Strategy.

The economic base case has been prepared in accordance with the requirements of the:

- TPP18-06 — NSW Treasury, NSW Government Business Case Guidelines
- TPP17-03 — NSW Treasury, NSW Guide to Cost-benefit Analysis.

What is the economic base case and why is it important?

The economic base case represents what the future could look like for towns and water-based industries if we do nothing over the next four decades. The economic base case is generated by combining the value that different extractive water users place on water against water availability forecasts for the region. It assumes the current infrastructure and water policy settings but does include projected changes to population. The water demands of user groups are generally set as fixed, with some exceptions where town population growth is predicted to occur. This allows all potential options to be compared consistently and any benefits, costs or other impacts from an option can be assessed against its impact to the economic base case. The economic base case will be used as the central scenario in the cost-benefit analysis for the hydrologic modelling of portfolios.

Valuing the amount of water forecast to be available using the Regional Water Value Function

The Regional Water Value Function[2] is used to value the amount of water that is forecast to be available. The forecasts are developed through hydrologic modelling.

[2] Marsdon Jacob Associates 2022, *Regional water value functions: Values for inclusion in the cost-benefit analysis to support NSW Regional Water Strategies*, Department of Planning and Environment, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/rhs-cta/regional-water-value-functions, accessed 8 November 2022.

Two key features of the values estimated is that they:

- **focus on key water user groups** — not every water user in a region is analysed, as the hydrological modelling only captures changes in water availability for key water users in each region
- **reflect how users make decisions** and how they use water in practice — this water user behaviour has been studied and included in the department's water models over decades.

The values produced in the regional water value function are for key water users, which in the Far North Coast region include:

- town water supply
- irrigators of annual crops — assumed to be lucerne
- irrigators of permanent crops — assumed to be blueberries.

The regional water value function values reflect how water is utilised in practice by the key water user groups. For example, irrigators of annual crops scale their operations each year depending on water availability, whereas irrigators of permanent crops change their operations following a sustained change in high-reliability water. Irrigators with permanent plantings are therefore more vulnerable in periods of supply shortfalls. This reflects how the economic value of water adjusts as forecast availability changes.

We recognise that this approach will not necessarily capture every detail, or every individual water user in the region. More detail is appropriate when preparing a detailed business case. However, the approach does provide a robust and high-level strategic assessment of the impacts of major infrastructure or policy changes across the region.

Using climate change modelling to create expectations of amount of water available

The NSW Government has invested in new climate datasets and improved hydrologic modelling that provide a more sophisticated understanding of historic climate variability as well as likely future climate risks. The regional water strategies reliability assessments for towns and communities in the Far North Coast region are based on this new climate data, scaled down to the regional level and used in the modelling of surface water. This data and modelling include consideration of long-term historical paleoclimate data (where available) and climate change impacts to develop scenarios of plausible extreme climate events.

Using the eWater Source streamflow modelling platform, the rainfall-runoff (recorded at gauging stations across the catchment) is calibrated with historical streamflow data. The calibrated hydrologic model is then used to generate two series of streamflow sequences, one incorporating historical paleoclimate and the other adding climate change scenario impacts. These two climate scenarios are referred to as the stochastic and the NARCliM models respectively.

The stochastic and NARCliM models are used to create expectations on the amount of water available in the future. The hydrologic modelling creates 1,000 replicates of 40-year duration daily climate inputs (sampled with a moving window of 10 years from the 10,000-year estimates) to create a broad range of feasible possibilities for the next four decades.[3]

Translating hydrologic modelling to user group outcomes

The hydrologic modelling estimates surface water availability for towns over the next 40 years. Town water demand is estimated based on climate variability, town population and population growth (in the case of the Far North Coast, fixed demand is based on population only). The water availability for towns depends on the levels of storage in major dams of water supply systems. Extraction volume is estimated on the basis of demand and restriction curves associated with these storage volumes. For towns that do not have local storages, the water availability highly depends on natural flows in the rivers. The extraction is estimated by demand and cease-to-flow and water sharing plan rules at that water source.

The unregulated systems will overestimate town supply shortfalls, because the models do not include local water storages (i.e. water tanks/towers etc.). To address this, a filter has been applied so that shortfalls have to occur for two days before being counted as shortfalls for the purpose of calculating the economic cost.

The amount of water supplied to high security water entitlements and allocation shortfalls were calculated with restriction curves (similar to town and community water supply) to infer shortfalls in water supplied to those licences. This provides the data for the economic analysis. The relevant assumptions are detailed below.

General security entitlements are estimated according to the amount of water that is supplied to users based on the level of modelled water availability in the region. It is assumed that general security entitlement holders decide on an annual basis how they will use the water and what crops they will grow.[4]

There is no significant mining or other industrial activities that are reliant on substantial water supplies in the Far North Coast region.

The economic base case does not capture every user of water in a region given the regional water strategies are region wide, strategic-level studies. It also does not include quantitative analysis of groundwater. Rather, it provides an indication of surface water risks. Future business cases and studies will further analyse how far groundwater or other alternative water sources can go to fill the gaps identified in this analysis. It represents a robust estimate of future surface water availability and the economic value of that availability.

[3] Department of Planning, Industry and Environment 2020, *New climate analysis informs NSW's regional water strategies*, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/climate-data-and-modelling, accessed 8 November 2022.

[4] Marsdon Jacob Associates 2022, *Regional water value functions: Values for inclusion in the cost-benefit analysis to support NSW Regional Water Strategies*, Department of Planning and Environment, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/rhs-cta/regional-water-value-functions, accessed 8 November 2022.

Alternative base case method

An alternative base case was also examined. The alternative base case changed the way in which hydrologic uncertainty was addressed in the regional water value function. This identifies critical elements of the decision to augment or not augment a water supply system for town and community water security.

Far North Coast key details

The Far North Coast region (Figure 1) covers approximately 8,620 km^2 in the north-eastern part of NSW. The area includes the three catchments of the Richmond River (7,026 km^2), the Tweed River (1,080 km^2) and the Brunswick River (512 km^2) and is located within the traditional lands of the Bundjalung and Githabul Nations.

The Far North Coast region supports an exceptionally diverse economy. Its coastal, riverine and hinterland amenity, access to South-East Queensland and generally excellent quality infrastructure support a multitude of industry sectors, such as tourism, agriculture, fishing, and food manufacturing. The region's population is around 240,000. The main centres of Tweed Heads, Lismore, Ballina, Casino and Murwillumbah serve as important employment and services hubs for the region. There are also many smaller towns in the region with populations ranging from around 200 to 3,000 people, including Byron Bay, Mullumbimby, Nimbin and Kyogle. The region neighbours South-East Queensland and is closely connected economically to the more densely populated hubs of the Gold Coast and Brisbane.

The region encompasses six local government areas — Ballina Shire, Byron Shire, Kyogle, Lismore City, Richmond Valley and Tweed Shire. One county council — Rous County Council — is responsible for bulk water supply, weed biosecurity and flood mitigation over a large part of the region.

Figure 1. The Far North Coast region: water sources and infrastructure

Extractive users of water

The hydrologic outcomes and subsequent economic impacts have been considered in the context of the major extractive user groups. The key water user groups considered within this economic assessment are:

- town water supply
- agricultural users, considered as producers of:
  - annual crops
  - permanent crops
  - stock and domestic producers.

The approach taken in each case is to quantify the economic benefit or cost of water supplied or not supplied in $/ML for each user.[5]

Towns and communities

The economic base case for towns and communities is developed according to the systems where they draw their surface water supply. In the Far North Coast all town water supply is drawn from unregulated systems and there are several locally-operated storages. Several water supply systems that deliver to towns are represented in the hydrologic models:

- Tweed catchment
  - Tweed Heads and Murwillumbah
  - Uki
- Richmond catchment
  - Rous County Council bulk water supply, which supplies to the local government areas of Richmond Valley; Ballina Shire; Byron Shire; Lismore City.
  - Kyogle
  - Casino
  - Nimbin
  - Mullumbimby.

Two population forecasts have been used in the economic base case, generating a total of four separate outcomes. The first is based on the NSW Common Planning Assumptions.[6] These forecasts are consistent with the recommendation of NSW Treasury for estimating future population and will be referred to as the Common Planning Assumption outcomes. The second set of population forecasts are from the local governments of the Far North Coast and predict higher population growth than the Common Planning Assumptions. Table 3 compares the Common Planning Assumptions and local government population projections. Towns and communities forecast to experience declining populations by the Common Planning Assumptions, such as Uki, Kyogle,

[5] Detailed information on the development of the value of water for different extractive users can be found in *Regional Water Value Functions* (Marsden Jacob Associates, 2022).

[6] More information is available at https://www.treasury.nsw.gov.au/information-public-entities/nsw-common-planning-assumptions (accessed 8 November 2022)

Casino and Nimbin, have been included using static demands. This provides a conservative estimate of their future demand. Their actual demand is likely to be less.

Table 3. Far North Coast population projections — Common Planning Assumptions and local government forecast growth 2020–2060

LGA	Common planning assumptions forecast increase	Local Government forecast increase
Rous (Richmond Valley, Ballina, Byron and Lismore)	8%	31%
Tweed and Murwillumbah	24%	83%

The economic base case assigns different values for the replacement costs of surface water for towns and communities when surface water supply shortfalls are modelled. The cost of a shortfall is dependent on the size of the town or community and the length of shortfall being experienced. For example, for small towns it is assumed local water utilities can manage brief periods of shortfalls through water carting. The management response to longer shortfall periods is assumed to require a more permanent, expensive solution. For larger towns, carting may not be a feasible option. Details of towns considered within this document and their associated shortfall costs is shown in Table 4.

The concept of town water shortfall in the context of the regional water strategies differs from that referenced in the water security/secure yield analysis completed through local councils' integrated water cycle management strategy planning. Shortfalls for towns within the regional water strategy consider the availability of licensed extracted surface water only. Due to the different considerations between the two metrics, town water shortfalls considered within this document should not be viewed as a replacement for a water security/secure yield analysis. It provides insights into surface water availability risks for towns and may be considered in future revisions of integrated water cycle management strategies.[7]

[7] For more details on how the IWCM and RWS relate refer to *Regional Water Strategies — Frequently asked questions*

Table 4. Far North Coast towns water supply shortage economic costs

Time in water shortage	Hydrologic network (and relevant town)						
	Bray Park Weir*	Uki	Kyogle	Rous**	Casino	Nimbin	Mullumbimby
Population* **	70,731	183	2,811	78,449	10,192	465	3,414
System type	Regulated	Regulated	Unregulated	Regulated	Unregulated	Unregulated	Unregulated
0–6 months (restrictions)	$1,500/ML	$1,500/ML	$1,500/ML	$1,500/ML	$1,500/ML	$1,500/ML	$1,500/ML
6 to 12 months (restrictions)	$3,500/ML	$3,500/ML	$3,500/ML	$3,500/ML	$3,500/ML	$3,500/ML	$3,500/ML
Greater than 12 months	$16,000/ML (alternative water source)	$10,000/ML (carting)	$10,000/ML (carting)	$16,000/ML (alternative water source)	$16,000/ML (alternative water source)	$10,000/ML (carting)	$10,000/ML (carting)
Continued shortages (greater than 24 months)	$16,000/ML (alternative water source)	$10,000/ML (carting)	$10,000/ML (carting)	$16,000/ML (alternative water source)	$16,000/ML (alternative water source)	$10,000/ML (carting)	$10,000/ML (carting)

Table notes

* Tweed Heads and Murwillumbah

** Richmond Valley, Ballina, Byron, Woodburn and Lismore

*** 2016 populations, sourced from Australian Statistical Geography Standard 2019 local government area projections and Australian Bureau of Statistics census data. These are different that the future population forecasts based on the NSW Governments Common Planning Assumptions.

Within the Far North Coast, water supply restrictions are based on cease-to-pump rules or local independent water supply sources where they exist.

Agricultural users

The economic benefit of water for agriculture varies depending on the crop produced. The marginal economic benefit per megalitre of water supplied for an annual crop will not change with a shortfall in supply as the area cropped is adjusted to match the amount of water available. For permanent crops, a shortfall in supply will increase the marginal economic benefit per megalitre of water, recognising the replacement cost of establishing the crop. Table 5 highlights the most significant agricultural crops grown in the Far North Coast region, water licenses and their economic values.

Table 5. Far North Coast agricultural water supply economic benefit[8]

Crop/Stock	Cropping	Marginal economic benefit (of water) ($/ML)
Lucerne (hay)	Annual	$175/ML
Sorghum	Annual	150
Blueberries	Permanent	$7,500 ($15,000 during shortfall)
Avocados	Permanent	$3,000/ML ($4,100/ML during shortfall)
Macadamias	Permanent	$2,700 / ML ($4,700 /ML during shortfall)
Dairy cattle*	Permanent	$200 / ML (during shortfall only)

* We note that water is typically underutilised in this region, so water availability is usually not a limiting factor for herd size.

The highest economic value for annual and permanent crops in the Far North Coast region are:

- annual crop — lucerne ($175/ML)
- permanent crops — blueberries ($7,500/ML, $15,000/ML in shortfall).

Both of these crops have sensitivities associated with their producer surplus, estimated as the long run profitability derived from a megalitre of water as detailed in the Regional Water Value Functions report.[9] Annual crops grown in the region include cotton, wheat, sorghum and barley with a producer surplus of $75–$275/ML. The permanent crops generate long run average producer surpluses of $5,000–$10,500/ML for blueberries, $2,100–$3,600/ML for macadamias, and $2,650–$3,300/ML for avocados. In addition, the variability in the value of water when shortfalls occur is $13,500–$17,000/ML for blueberries, $3,800–$5,800/ML for macadamias, and $3,800–$4,500/ML for avocados.

[8] Derived from Marsdon Jacob Associates 2022, *Regional water value functions: Values for inclusion in the cost-benefit analysis to support NSW Regional Water Strategies*, Department of Planning and Environment, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/rhs-cta/regional-water-value-functions

[9] *Regional Water Value Functions* (MJA, 2022)

Hydrologic and economic base case outcomes

The estimated hydrologic and economic outcomes are given for the key extractive industries. All economic calculations use a discount rate of 7% as recommended by the NSW Treasury.[10]

Town and community hydrologic base case outcomes

The hydrologic modelling indicates towns within the region are likely to experience low levels of surface water supply shortfalls, with a moderate increase in magnitude predicted due to climate change. The average length and magnitude of the expected annual shortfalls for each town of the 1,000 realisations[11] of the two hydrological modelling methodologies (stochastic and NARCliM) are given in Table 6 and Table 7. Table 8 provides a summary of the difference between the stochastic and NARCliM modelling results.

Average water supply shortfalls as a percentage of unrestricted demand are very low (typically less than 1%) under the stochastic climatic conditions. This measure does not significantly change under NARCliM (climate change) conditions.

The amount of time that towns are expected to spend within a period of shortfalls is closely linked to the magnitude of shortfalls. Under both stochastic and NARCliM conditions this is likely to be less than 1% of the time, with the length of time increasing slightly for some towns under climate change conditions.

[10] NSW Treasury 2017, *NSW Government Guide to Cost-Benefit Analysis* (TPP17-03), https://www.treasury.nsw.gov.au/finance-resource/guidelines-cost-benefit-analysis, accessed 8 November 2022.

[11] Realisation refers to a single 40-year hydrologic simulation. There are 1,000 realisations for each of the stochastic and NARCliM datasets. The realisations are drawn from 40-year rolling windows out of the 10,000-year generated climatic datasets, with an approximate 9-year overlap between windows. More information on the stochastic and NARCliM datasets is available in the Regional Water Strategies guide to new climate data and modelling.

Table 6. Town water supply hydrologic outcomes — stochastic model Common Planning Assumptions

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Bray Park Weir	0.0	11379.6	0.0	0.0	0.0
Uki	0.0	55.5	0.0	0.0	0.0
Kyogle	0.0	323	0.0	0.0	0.0
Rous Bulk LWU	6.5	12678.2	0.1	0.0	0.1
Casino	0.0	2114.2	0.0	0.0	0.0
Nimbin	0.0	180.2	0.0	0.0	0.1
Mullumbimby	1.0	390.3	0.3	0.1	0.4

Table 7. Town water supply hydrologic outcomes–NARCliM model Common Planning Assumptions

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Bray Park Weir	0.3	11579.4	0.0	0.0	0.0
Uki	0.0	56.9	0.0	0.0	0.0
Kyogle	0.0	332.7	0.0	0.0	0.0
Rous Bulk LWU	10.0	12774.7	0.1	0.1	0.1
Casino	0.3	2191.1	0.0	0.0	0.0
Nimbin	0.0	184.4	0.0	0.0	0.2
Mullumbimby	1.3	397.9	0.3	0.3	0.6

The difference between the average annual demand in the stochastic and NARCliM model is due to the higher levels of evaporation forecast in the NARCliM model. The estimate for how demand for town water increases under NARCliM (due to their experiencing more evaporation when watering gardens and using water generally) is done in accordance with the Allen, Pereira, Raes, and Smith, 1998 estimates.[12]

Table 8. Town water supply hydrologic outcomes-difference in the Common Planning Assumptions (NARCliM–stochastic)

Town	Average Annual Shortfall (ML)	Average Annual Demand (ML)	Shortfall as % of Demand	Average Months per Year with Shortfall	Average % of the year with shortfall
Bray Park Weir	0.3	199.8	0.0	0.0	0.0
Uki	0.0	1.4	0.0	0.0	0.0
Kyogle	0.0	9.7	0.0	0.0	0.0
Rous Bulk LWU	3.5	96.5	0.0	0.0	0.0
Casino	0.3	76.9	0.0	0.0	0.0
Nimbin	0.0	4.2	0.0	0.0	0.1
Mullumbimby	0.3	7.6	0.0	0.0	0.2

The results shown in Table 9 contrast with the NARCliM and stochastic models under the Common Planning Assumptions in Table 8. It shows that the NARCliM model has higher shortfalls at Bray Park Weir, Casino, Mullumbimby and more significantly, the Rous Bulk local water utility. It should be noted that the additional difference is not a significant proportion of the annual demand, with none of the increases reaching 0.1% of annual demand.

The expected town shortfalls for the local government population projections are described in the following tables.

[12] Allen, R. G., *et al.* 1998, *Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56*, Food and Agriculture Organization of the United Nations, https://www.fao.org/3/x0490e/x0490e00.htm, accessed 8 November 2022.

Table 9. Town water supply hydrologic outcomes–stochastic model local government population projections

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Bray Park Weir	4.5	15750.8	0.0	0.0	0.1
Uki	0.0	55.5	0.0	0.0	0.0
Kyogle	0.0	323	0.0	0.0	0.0
Rous Bulk LWU	20.8	14342.1	0.1	0.0	0.2
Casino	0.0	2114.2	0.0	0.0	0.0
Nimbin	0.0	180.2	0.0	0.0	0.1
Mullumbimby	1.0	390.3	0.3	0.1	0.4

The major differences between the Common Planning Assumptions population growth forecast scenarios and those based on the local government population forecasts are, unsurprisingly, focused in the Tweed Heads and Murwillumbah network, and the Rous Bulk local water utility network. These two networks are where the population growth forecasts differ. The local government population forecasts result in an additional 4.5 ML/year average shortfall for Tweed Heads and Murwillumbah. This is less than 0.1% of total demand for those towns. For the Rous Bulk local water utility, the shortfall increases by an average of around 14 ML/year. This is significantly higher than the 6.5 ML/year forecast shortfall under the Common Planning Assumptions population forecast, yet still only 0.1% of the average annual demand.

Table 10. Town water supply hydrologic outcomes–NARCliM local government population assumptions

Town	Average annual shortfall (ML)	Average annual demand (ML)	Shortfall as % of demand	Average months per year with shortfall	Average % of the year with shortfall
Bray Park Weir	9.3	16116	0.1	0.0	0.2
Uki	0.0	56.9	0.0	0.0	0.1
Kyogle	0.0	332.7	0.0	0.0	0.0
Rous Bulk LWU	29.8	14504.5	0.2	0.0	0.3
Casino	0.3	2191.1	0.0	0.0	0.0
Nimbin	0.0	184.4	0.0	0.0	0.2
Mullumbimby	1.3	397.9	0.3	0.1	0.6

The outcomes for the local government population forecast scenarios have significantly more shortfalls in the NARCliM model. For Tweed Heads and Murwillumbah network the anticipated average annual increases by 4.8 ML/year, but still less than 0.1% of annual demand. The Rous Bulk local water utility annual average shortfall will increase by 9 ML/year, or around 0.1% of annual demand.

Table 11. Town water supply hydrologic outcomes–difference in the Common Planning Assumptions (NARCliM–stochastic)

Town	**Average annual shortfall (ML)**	**Average annual demand (ML)**	**Shortfall as % of demand**	**Average months per year with shortfall**	**Average % of the year with shortfall**
Bray Park Weir	4.8	365.2	0.1	0.0	0.1
Uki	0.0	1.4	0.0	0.0	0.1
Kyogle	0.0	9.7	0.0	0.0	0.0
Rous Bulk LWU	9.0	162.4	0.1	0.0	0.1
Casino	0.3	76.9	0.0	0.0	0.0
Nimbin	0.0	4.2	0.0	0.0	0.1
Mullumbimby	0.3	7.6	0.0	0.0	0.2

Shortfalls occur more often under the NARCliM simulation than under the stochastic simulation with local government population forecasts, but these shortfalls are relatively small in terms of the overall demands for each town and community.

Figure 2 and Figure 3 illustrate seven key town water supply shortfalls scenarios of the 1,000 realisations for individual towns, and the combination of all towns, in both the stochastic and NARCliM models under the Common Planning Assumptions and the local government population forecasts. It gives these scenarios as cumulative totals over the 40-year simulation period. The key scenarios are:

- minimum — the best-case scenario
- median — the exact middle scenario
- maximum — the worst-case scenario.

These scenarios illustrate the spread of what could happen (the outcomes) over all 40-year periods simulated for the region and how towns might experience the predicted economic outcomes of the climate models over time, as they occur. In short, it shows that over the next 40 years, the number of times that a town could run out of surface water could be anywhere between the dotted lines. Note that in instances where there are no or very low shortfalls, lines may overlap.

Similar to the above tables, the graphs show that expected shortfalls for towns under the stochastic dataset are typically low for both population projections. This is evident by examining the solid yellow line that is fairly flat for the 40-year period for most towns. It is worth noting that for the maximum scenario, there is a significant spike in cumulative shortfalls after 25 years and they are almost as extreme as under the NARCliM dataset with the Common Planning Assumptions. This is also true for the Rous Bulk water supply, but not for the Tweed Heads and Murwillumbah network of Bray Park Weir, where the worst outcome under NARCliM is significantly higher under the climate change realisations.

The maximum scenarios for the NARCliM dataset follow a very similar trajectory to the stochastic dataset. It is only at approximately the 25th year that a significant differentiation from the median outcome occurs. At this point, the cumulative shortfalls grow by approximately 15 times, representing a significant and sustained period of low water availability.

The collection of graphs presented in Figure 2 and Figure 3 indicate that individual town water supplies appear to be relatively secure for the stochastic and NARCliM datasets under both population projections. However, in both data sets the risk of water supply shortfalls increases after approximately 25 years and is significantly worse under local government projections. For the town supply from Bray Park Weir, both the stochastic and NARCliM forecasts have very low cumulative shortfalls under the Common Planning Assumptions. It is only towards the end of the 40-year period that they accumulate at all, and that is just for the extreme scenarios that represent 0.1% chance of occurring. However, under the local government population forecasts, the maximum scenario is considerably greater even if they only appear towards the end of the 40-year period being examined. The town of Uki is very similar, with extremely low probabilities that any shortfalls occur for most forecasts.

The town of Kyogle does not experience any significant shortfalls in the median outcome. However, the worst outcome, representing a 0.01% probability of occurring, experiences shortfalls within the first few years in both the NARCliM and stochastic forecasts. This is true for both the Common

Planning Assumptions and the local government forecasts. The Rous Bulk supply is similar in that the median outcomes have zero cumulative shortfalls under the Common Planning Assumptions. However, under the local government population forecasts they occur relatively earlier and are much higher. In contrast, the worst outcomes for both the stochastic and NARCliM forecasts experience shortfalls around the 10-year mark under both population forecasts. These outcomes are effectively the same for the town of Mullumbimby.

The Nimbin median forecast experiences shortfalls in both the stochastic and NARCliM forecasts by the tenth year. The cumulative shortfalls remain at a relatively low level throughout the 40-year timeframe. However, the minimum forecasts have zero shortfalls. Nimbin does not have two population growth forecasts.

Casino is forecast to experience significant shortfalls throughout the 40-year timeframe. While the NARCliM forecast suggests larger and earlier shortfalls in both the maximum and median forecasts, the stochastic shortfalls are also significant. The maximum scenarios for the NARCliM and stochastic forecasts are very similar, with pronounced shortfalls occurring over the 40-year timeframe. These shortfalls are the same in the two different population forecasts.

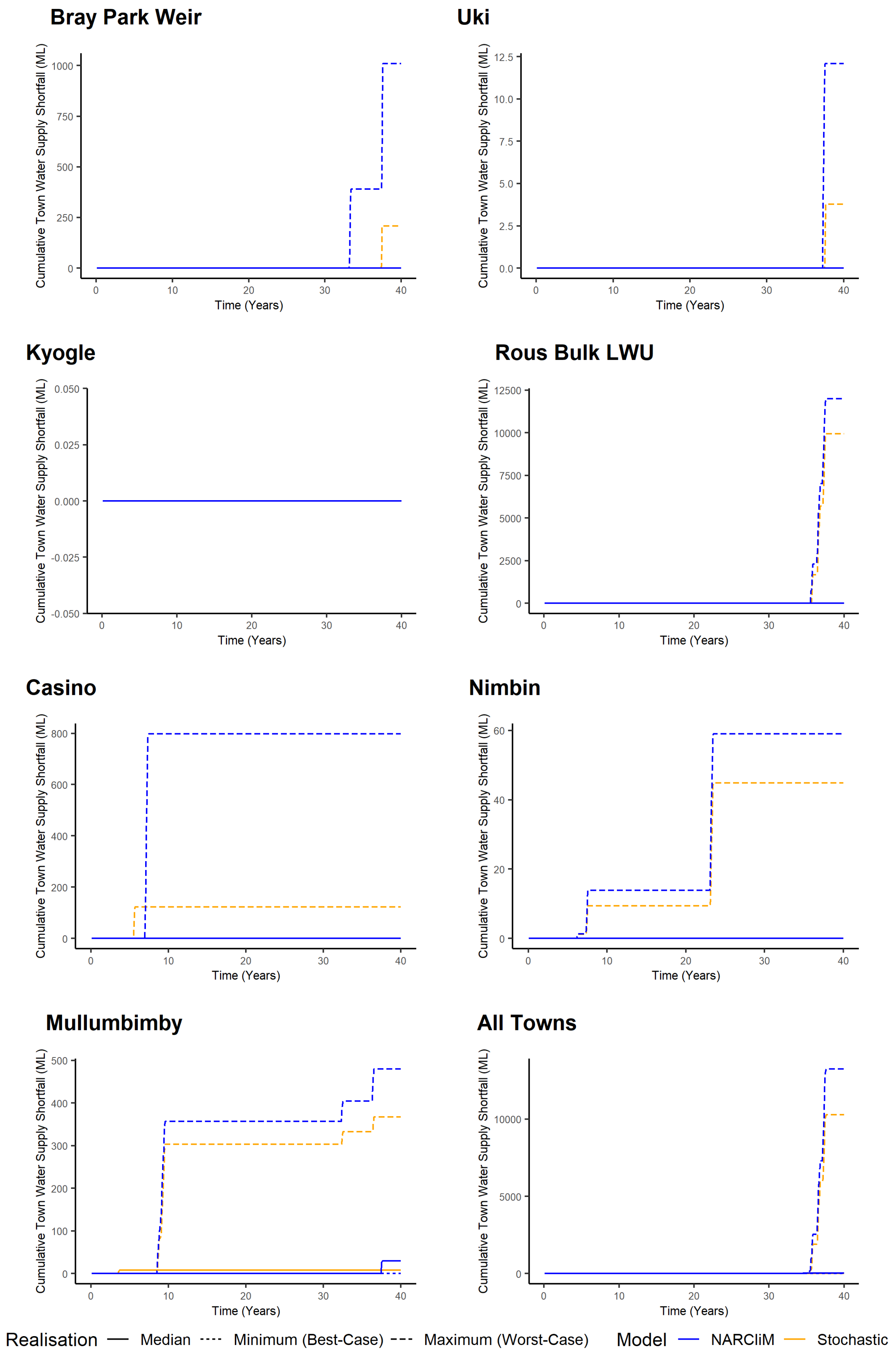

Figure 2. Town supply cumulative 40-year shortfall series (ML) under the Common Planning Assumptions

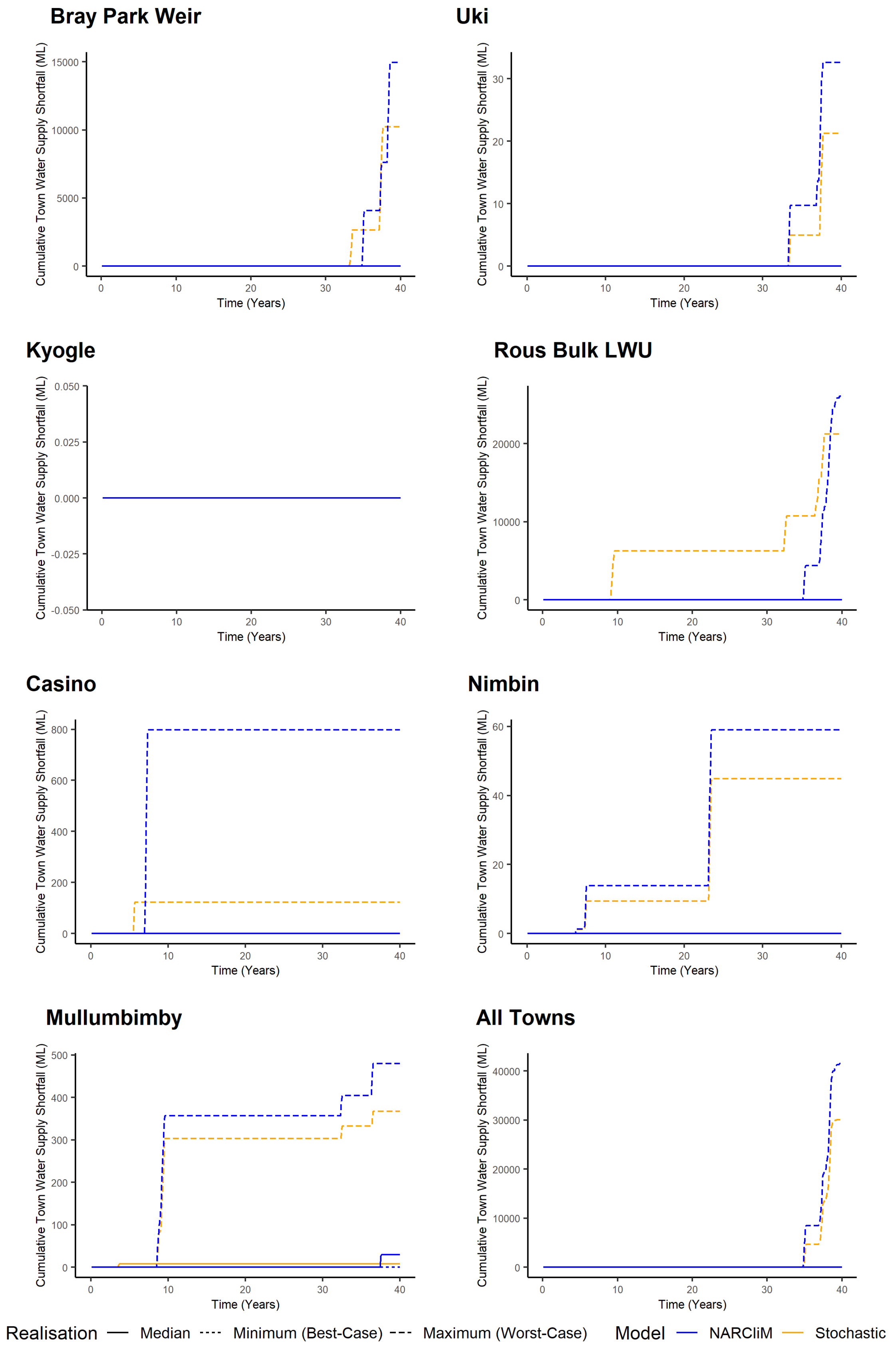

Figure 3. Town supply cumulative 40-year shortfall series (ML) under the local government population forecasts

Town and community economic base case outcomes

All economics impacts to towns have been assessed within the framework presented in Table 4. The estimated average economic impact of water supply shortfalls for towns within the Far North Coast over a 40-year period are provided in Table 12 and Table 13.

Table 12. Economic base case outcomes key user group–town water supply average 40-year shortfall net present costs ($, mil) under the Common Planning Assumptions

Town	Stochastic ($, mil)	NARCliM ($, mil)	Difference ($, mil)
Bray Park Weir	0.0	0.0	0.0
Uki	0.0	0.0	0.0
Kyogle	0.0	0.0	0.0
Rous Bulk LWU	-0.1	-0.2	-0.1
Casino	0.0	0.0	0.0
Nimbin	0.0	0.0	0.0
Mullumbimby	0.0	0.0	0.0
Total	-0.1	-0.2	-0.1

While there are differences in the economic outcomes of the stochastic and NARCliM realisations, these differences are relatively small in terms of total dollar value.

Table 13. Economic base case outcomes key user group–town water supply average 40-year shortfall net present costs ($, mil) under the local government population projections

Town	Stochastic ($, mil)	NARCliM ($, mil)	Difference ($, mil)
Bray Park Weir	0.0	-0.1	-0.1
Uki	0.0	0.0	0.0
Kyogle	0.0	0.0	0.0
Rous Bulk LWU	-0.3	-0.5	-0.2
Casino	0.0	0.0	0.0
Nimbin	0.0	0.0	0.0
Mullumbimby	0.0	0.0	0.0
Total	-0.4	-0.6	-0.3

The graphs in Figure 4 and Figure 5 indicates that most of the economic costs related to water supply shortfalls for the stochastic and NARCliM datasets were less than $1 million under both population forecasts. The results for the NARCliM outcomes are not significantly higher than those of the stochastic outcomes in either population forecast.

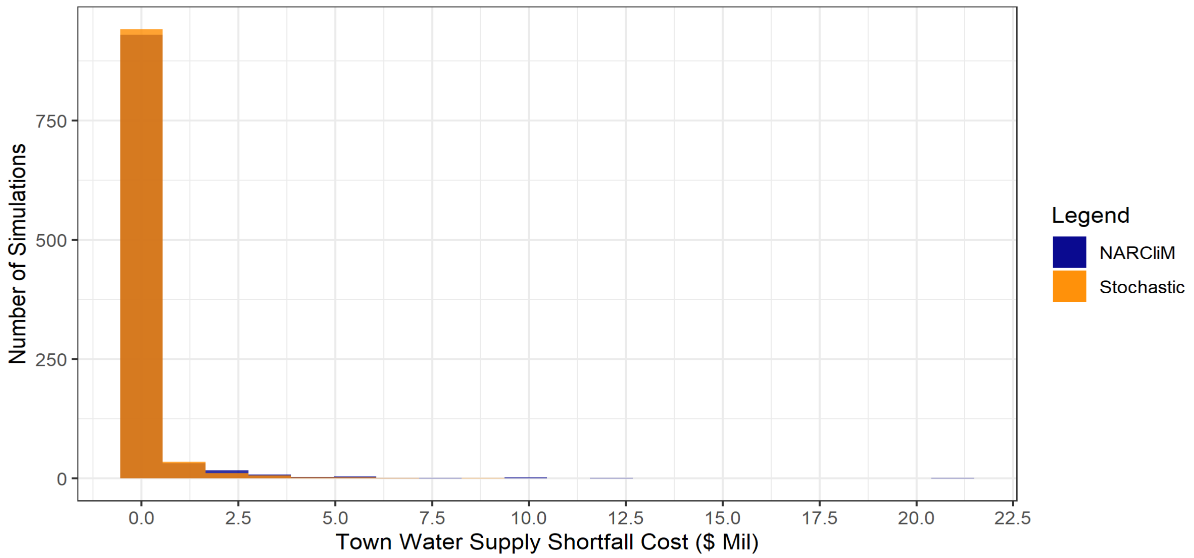

Figure 4. Total average towns water supply net present costs–Common Planning Assumptions

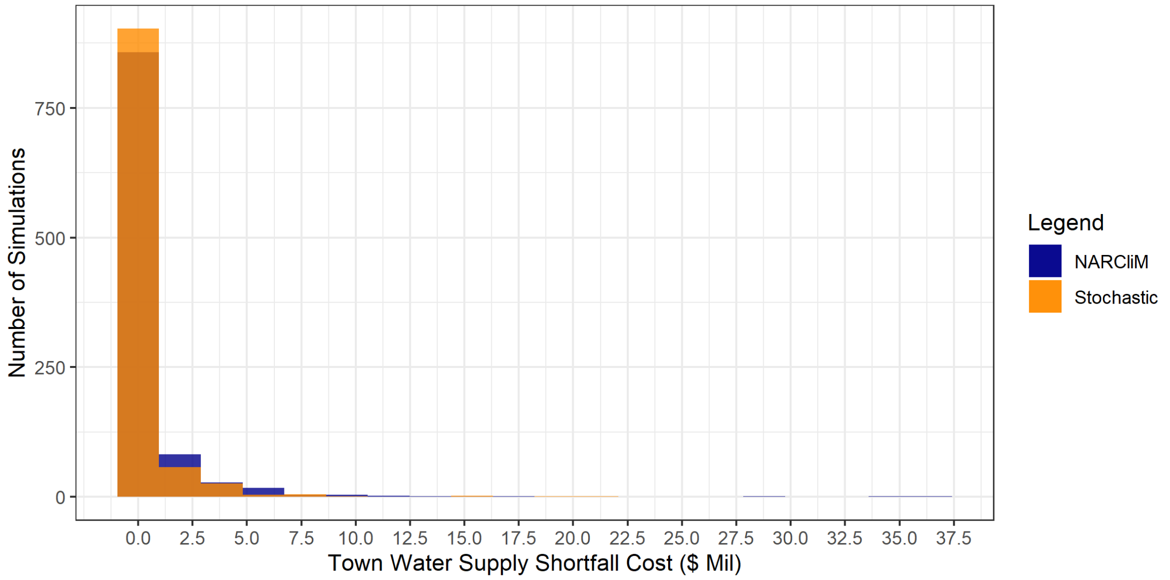

Figure 5. Total average towns water supply net present costs–local government population forecast

Table 14 to Table 16 provide additional information on the length of shortfalls and the percentage of time that each town spends under each restriction's regimes (when experiencing a shortfall) for the Common Planning Assumptions. It indicates that the average length, and therefore the average economic cost per megalitre, of shortfalls increase from the stochastic simulations to the NARCliM simulations. Typically, the length of time that towns continuously do not have access to surface water increases as the droughts lengthen slightly under the climate change scenario.

As an example, it can be seen that Casino experiences a decrease in shortfall durations lasting 0–6 months (incurring an economic cost of $1,500/ML) of 1% from stochastic to NARCliM climate models. This reduction is offset by the equivalent increase in longer droughts lasting 6–12 months and costing $3,500 /ML, by 1%. This shows that Casino is slightly likely to experience longer and more expensive droughts.

Table 14. Economic base case outcomes key user group–town water supply average share of restriction level–stochastic model Common Planning Assumptions

Town	Shortfall duration (% of time)			
	0–6 months	6–12 months	> 12 months	> 24 months
Bray Park Weir	100%	0%	0%	0%
Uki	100%	0%	0%	0%
Kyogle	NA	NA	NA	NA
Rous Bulk LWU	97%	3%	0%	0%
Casino	100%	0%	0%	0%
Nimbin	100%	0%	0%	0%
Mullumbimby	100%	0%	0%	0%

Table 15. Economic base case outcomes key user group–town water supply average share of restriction level–NARCliM model Common Planning Assumptions

Town	Shortfall duration (% of time)			
	0–6 months	6–12 months	> 12 months	> 24 months
Town	Shortfall duration (economic cost $/ML) (% of time)			
	0–6 months ($1,500/ML)	6–12 months ($3,500/ML)	> 12 months ($16,000/ML)	> 24 months ($10,000/ML)
Bray Park Weir	100%	0%	0%	0%
Uki	100%	0%	0%	0%
Kyogle	NA	NA	NA	NA
Rous Bulk LWU	95%	4%	1%	0%
Casino	100%	0%	0%	0%
Nimbin	100%	0%	0%	0%
Mullumbimby	99%	1%	0%	0%

Table 16. Economic base case outcomes key user group-town water supply average share of restriction level-difference (NARCliM–stochastic) Common Planning Assumptions

Town	Shortfall duration (% of time)			
	0–6 months	6–12 months	> 12 months	> 24 months
Town	Shortfall duration (economic cost $/ML)			
	0–6 months ($1,500/ML)	6–12 months ($3,500/ML)	> 12 months ($16,000/ML)	> 24 months ($10,000/ML)
Bray Park Weir	-2%	1%	1%	0%
Uki	0%	0%	0%	0%
Kyogle	0%	0%	0%	0%
Rous Bulk LWU	-1%	1%	0%	0%
Casino	-2%	1%	1%	0%
Nimbin	0%	0%	0%	0%
Mullumbimby	0%	0%	0%	0%

Similar to the previous three tables, Table 17 to Table 19 provide additional information on the length of shortfalls and the percentage of time that each town spends under each restrictions regimes but are based on the local government population projections. These tables indicate that the average length — and therefore the average economic cost per megalitre — of shortfalls increase from the stochastic simulations to the NARCliM simulations.

Table 17. Economic base case outcomes key user group–town water supply average share of restriction level–stochastic model–local government population projections

Town	Shortfall duration			
	0–6 months	6–12 months	> 12 months	> 24 months
Bray Park Weir	100%	0%	0%	0%
Uki	100%	0%	0%	0%
Rous Bulk LWU	95%	4%	1%	0%
Casino	100%	0%	0%	0%
Nimbin	100%	0%	0%	0%
Mullumbimby	100%	0%	0%	0%

Table 18. Economic base case outcomes key user group–town water supply average share of restriction level–NARCliM model–local government population projections

Town	Shortfall duration			
	0–6 months	6–12 months	> 12 months	> 24 months
Bray Park Weir	100%	0%	0%	0%
Uki	100%	0%	0%	0%
Rous Bulk LWU	94%	5%	1%	0%
Casino	100%	0%	0%	0%
Nimbin	100%	0%	0%	0%
Mullumbimby	99%	1%	0%	0%

Table 19. Economic base case outcomes key user group–town water supply average share of restriction level–difference (NARCliM–stochastic)–local government population projections

Town	Shortfall duration			
	0–6 months	6–12 months	> 12 months	> 24 months
Bray Park Weir	0%	0%	0%	0%
Uki	0%	0%	0%	0%
Rous Bulk LWU	-1%	1%	0%	0%
Casino	-0.1%	0.1%	0%	0%
Nimbin	0%	0%	0%	0%
Mullumbimby	-1%	1%	0%	0%

Agricultural hydrologic base case outcomes

The following section describes the hydrologic impacts on the Far North Coast agricultural industry. Agriculture has been separated into the following groups:

- Tweed users:
  - annual agriculture (lucerne $175/ML)
- Richmond regulated users:
  - annual agriculture lucerne ($175/ml)
  - permanent agriculture (blueberries $7,500/ml, and $15,000 in shortfall)
  - stock and domestic ($7,000 in shortfall)
- Richmond unregulated users:
  - annual agriculture lucerne ($175/ML).

The estimated annual average volume of water that these producers use under both the stochastic and NARCliM scenarios are given in Table 20. The results show an increase in water use for perennial pasture from the river systems on average in the region in the dryer NARCliM climate region when compared with stochastic. This is due to increased evaporation and evapotranspiration rates due to increasing temperatures within the region. For the same crop production more water is now required, which leads to a greater reliance on the river systems.

The high security licence class in the region is assumed to be used solely for permanent agriculture. However, this licence class has not been explicitly included in the economic analysis because it comprises only a very small allocation (123 ML).

Table 20. Average annual agricultural water usage volumes–stochastic and NARCliM–GL/year

Water usage	Usage metric	Stochastic	NARCliM	Difference (NARCliM–stochastic)	Difference (%) (NARCliM–stochastic)
Annual crops (GL/year)	Average	11.1	12.2	1.1	9.5
	Maximum	12.9	13.7	0.7	5.6
	Median	11.1	12.2	1.1	9.5
	Minimum	8.8	9.9	1.1	12.8
	Standard deviation	0.7	0.6	0.0	-7.5
Permanent crops (GL/year)	Average	0.1	0.1	0.0	4.7
	Maximum	0.1	0.1	0.0	0.5
	Median	0.1	0.1	0.0	4.6
	Minimum	0.1	0.1	0.0	24.0
	Standard deviation	0.0	0.0	0.0	-24.7

Figure 6 and Figure 7 show the modelled annual agricultural water usage in the Far North Coast for annual and permanent crops respectively. The figures group the results of the realisations into 20 categories to provide an overview of the outcomes for 1,000 realisations of each model. They indicate that the amount of water used on average for both crop types is predicted to reduce under the climatic conditions present in the NARCliM model. The amount of variation is expected to remain roughly the same between the two data sets.

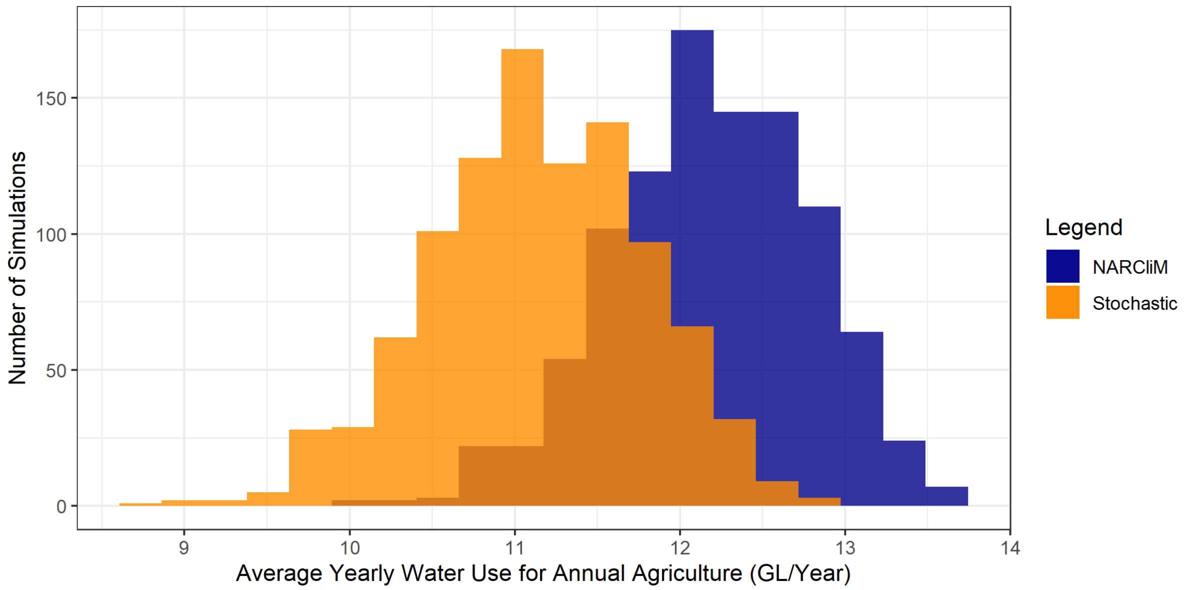

Figure 6. Stochastic and NARCliM annual crop water use

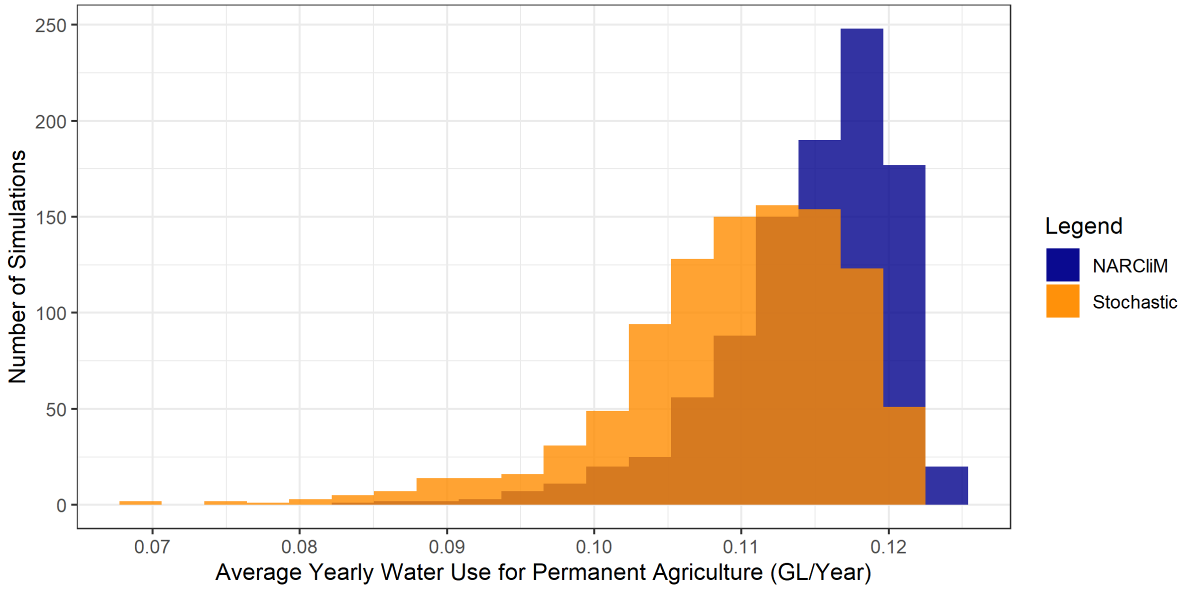

Figure 7. Stochastic and NARCliM permanent crop water use

Three scenarios of expected cumulative water usage for producers of annual and permanent crops are presented in Figure 8 and Figure 9 for both the stochastic and NARCliM hydrologic models. The scenarios are:

- minimum — the best-case scenario
- median — the exact middle scenario
- maximum — the worst-case scenario.

These results indicate that there will be more water available under the climate change predictions than under the stochastic predictions. However, that is because the hydrologic model also forecasts rainfall on farms. Under the NARCliM scenario, the modelling predicts less water availability for producing perennial pasture and permanent crops. The median cumulative expected water usage for perennial pasture in the climate change scenario is slightly above the minimum result for the stochastic climate conditions. This reflects the increased reliance on water from the river to maintain agricultural activity.

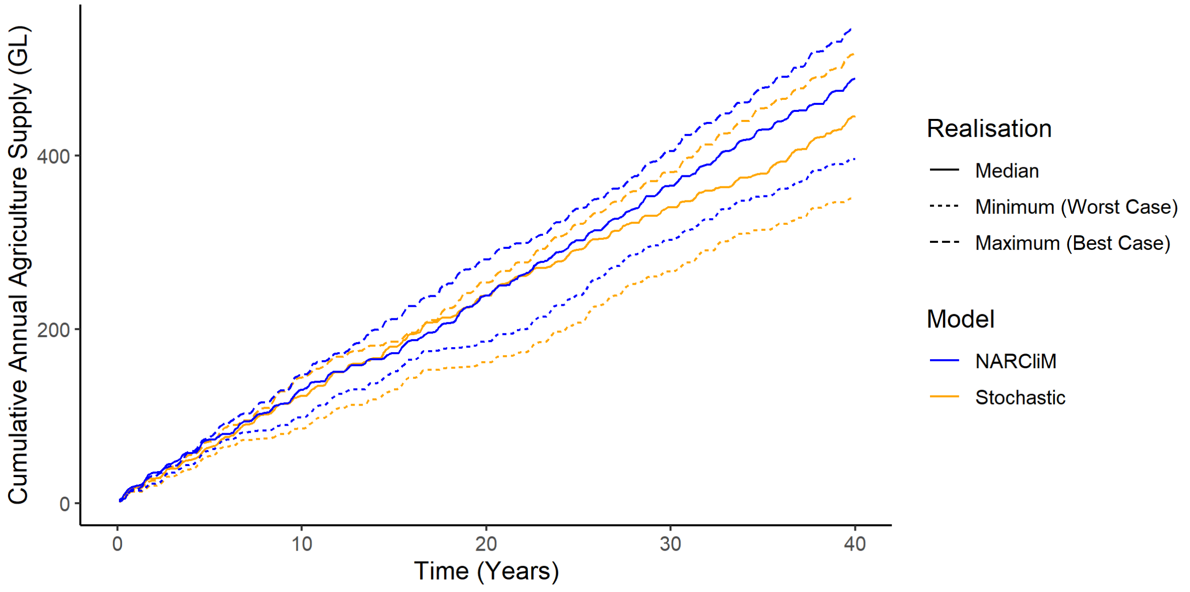

Figure 8. Stochastic and NARCliM cumulative annual crop agriculture water use

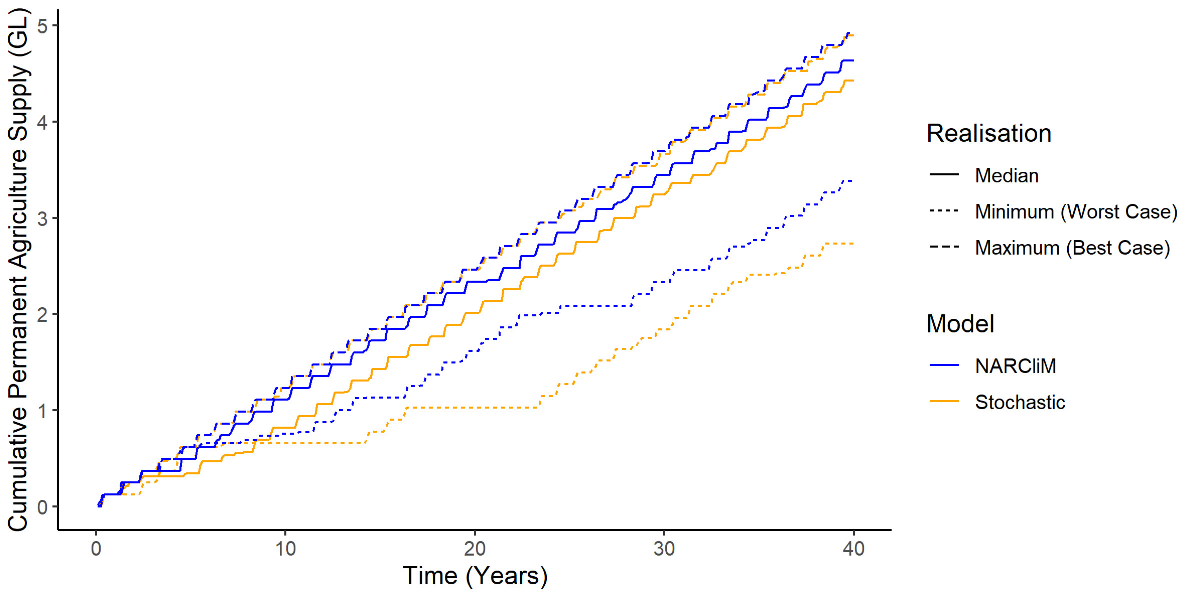

Figure 9. Stochastic and NARCliM cumulative permanent crop agriculture water use

Agricultural economic base case outcomes

Average economic values of water for agricultural producers within the Far North Coast region over the 40-year analysis period are given in Table 21.

Under the NARCliM scenario, there is a 2 per cent reduction in the average economic value for annual crop producers. This reflects the reduction of agricultural production due to decreased water supply under a climate change scenario.

Summaries of the distributions of possible outcomes for agricultural producers can be seen in Figure 10 for annual crops and Figure 11 for permanent crops. The figures illustrate the wide range of possible economic outcomes under both the NARCliM and stochastic scenarios. The predicted increase in economic activity due to irrigation for producers of annual crops ranges from approximately $460–$550 million, with an average value of $525 million under stochastic conditions over the forecast 40 years. For the NARCliM results the value of water for producers of annual crops is shifted with values ranging from $480–$560 million, with an average value of $535 million.

Table 21. Economic base case outcomes–key user group–agriculture net present producer surplus averages over 40 years ($, mil)

Usage	Stochastic	NARCliM	Difference (NARCliM–stochastic)	Difference (%) (NARCliM–stochastic)
Annual crops	533.42	522.32	-11.09	-2.1
Permanent crops	0	0	0	0
Stock and domestic	0	0	0	0
Total	533.42	522.32	-11.09	-2.1

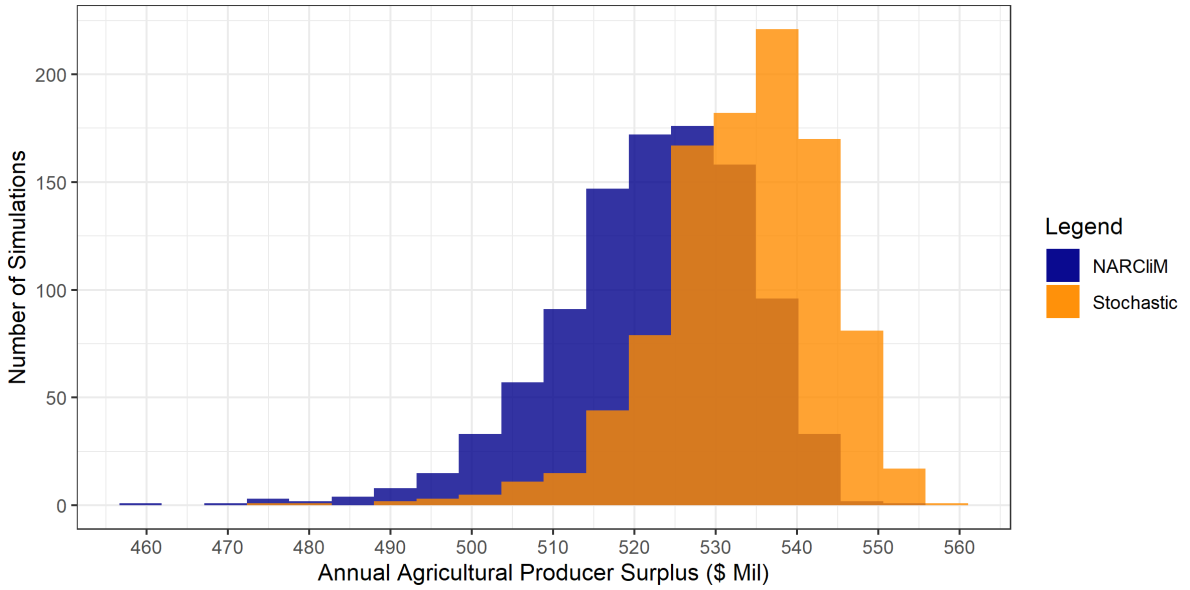

Figure 10. Annual agriculture net present producer surplus over 40 years

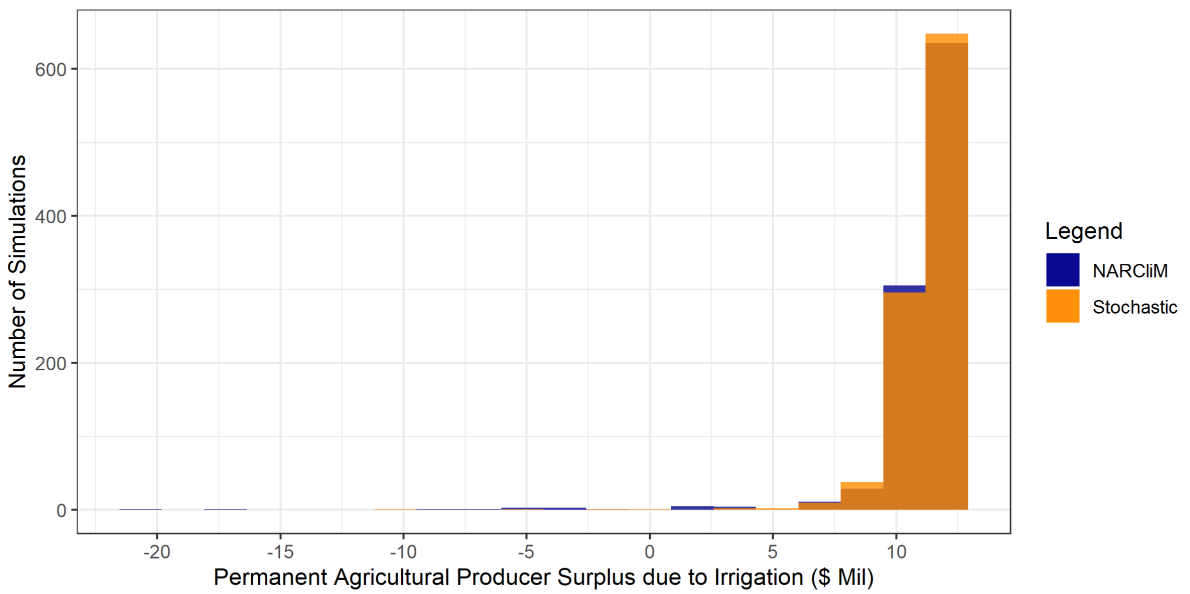

Figure 11. Permanent agriculture net present producer surplus over 40 years

Assumptions and uncertainties

The assumptions, uncertainties, and qualifications surrounding the results presented within this document are detailed below.

Assumptions adopted within this study include:

- Town shortfalls consider only modelled surface water availability and do not include any consideration of existing alternative supply sources such as groundwater or desalination plants.
- Population increases have been included in accordance with NSW Government Common Planning Assumptions medium population forecasts. It is noted that local government areas within the Far North Coast region are predicting population growth significantly in excess of what the Common Planning Assumptions suggest. Scenario analysis will be conducted on different population growth rates.
- It is assumed that the current use of water will be consistent over the 40 years examined. In practice it is likely technology and global demand for food and fibre will change the nature of the crops produced in the Far North Coast. Estimating these changes is beyond the regional water strategies project.

Uncertainties and qualifications relevant to this study include:

- Town shortfall analysis presented is not a replacement for secure yield analysis undertaken as part of the integrated water cycle management strategies.
- Economic outcomes are likely to be highly sensitive to the discount rate considered.
- The producer surpluses are based on long-run estimates. In practice, the profitability of each crop will vary year-by-year. Estimating these changes is beyond the scope of the regional water strategies project.

Attachment A: Alternative base case assessment method

Attachment A: Alternative base case assessment method

Introduction

A cost benefit analysis (CBA) can be a useful tool when trying to understand the effects of different approaches to mitigating drought risk.[1] A CBA assesses whether the benefits of a proposal or initiative are likely to exceed the costs. It can also help assess which option, among a range of options, is expected to result in the highest net social benefit. By quantifying the expected social outcomes of different drought mitigation options, the trade-offs between the expense of the option and the benefits it provides the community can be made explicit and assessed.

When conducting a CBA, the first step is to define the base case against which to assess options. One challenge in applying a CBA to critical water supply failures is that such failures are rare events. The low frequency of these extreme and rare events means that they may not significantly influence the CBA analysis, irrespective of how costly failures may be and even though it is these rare failures that the options are designed to address.

In calculating the social and economic consequences of drought events, the regional water strategies adopt a generic drought response plan that is based on the duration of surface water shortfalls. This allows comparison of shortfalls of naturally occurring hydrologic resources between regions throughout the state, as well as the options available to avoid or mitigate these shortfalls. However, it does not account for local water utilities' individual short-term risk preferences. This is because the regional water value function is tailored to the size of towns and communities but not to specific drought response plans. Using this generic base case methodology in the Far North Coast region can be challenging because the region has a large population and relatively small water storage compared to annual demand.

To address these limitations, the department has developed an alternative base case methodology to reflect the fact that local water utilities need to take action *before* an extreme event occurs. It uses a tailored drought response plan from an individual local water utility. It also uses an estimate of when an emergency augmentation would be needed based on the acceptable level of risk in the water supply system. The result is an alternative estimate of the expected costs of maintaining a water supply system when a decision on emergency augmentation needs to be made.

This appendix presents the alternative base case model, using Tweed Shire Council's water supply system as a test case. The results presented below are based on data and information provided by Tweed Shire Council.

The analysis showed that the costs incurred from the emergency supply will depend on short term risk preferences, expressed as the flow regime used as the basis for determining the emergency supply trigger. Tweed Shire Council advise was that an emergency augmentation would take two years to construct. When determining the emergency augmentation using the lowest annual inflows

[1] Drought in this context is defined as a critical failure of the water supply system due to low levels of water availability compared to demand.

to occur over the construction timeframe, major water supply deficits were observed. However, no supply deficits were observed when the analysis was based on the lowest biennial (2-year) inflows over the emergency augmentation timeframe. This suggests that the acceptable level of risk and the way in which it is calculated can be an important input to fully understanding the benefits and costs of augmenting the water supply.

Method

A critical step in undertaking a CBA is to define the base case against which options can be assessed. Defining the base case that underpins the CBA comprises two main parts. The first is hydrologic modelling, which provides data about the magnitude and probability of negative outcomes. The second is determining how the water supply system will be operated during extreme events. For the alternative base case, the hydrologic modelling is the same as the original base case. However, it examines a range of alternative methods to manage the water supply system and reduce the risk of critical water shortages.

Calculating water supply system vulnerability

The main factor that distinguishes the original regional water strategies base case assessment from the alternative method is the point at which emergency augmentation is triggered. While the original method uses the duration of surface water entitlement shortfalls, the alternative method uses 2 variables:

- the volume of inflows expected over the time it takes to construct the emergency supply
- the volume of water that is protected over the time it takes to construct the emergency supply.

The values used for both variables will depend on the risk preferences of the local water utility.

For the Tweed Shire Council water supply system, the analysis assumes that the emergency supply:

- is a 10 ML/day desalination plant
- takes 2 years to construct
- is operational by the time storages reach 45% capacity.

The 45% target is based on the emergency trigger currently used by Tweed Shire Council.

Costings for the emergency desalination plant were not available at the time this analysis was conducted. The capital and operating costs of the emergency augmentation were scaled in proportion with the costs of Option 11 used in the detailed economic and ecological analysis.[2]

The alternative base case is based on 14 realisations of a 40-year hydrologic simulation. The simulations are based on 40-year rolling windows of the 130-year instrumental climatic record. Because the Tweed Shire is expected to have considerable population growth over the 40-year period, a second emergency augmentation is also calculated. It is assumed that the second emergency augmentation cannot be triggered for four years after the first one is built. This

[2] Department of Planning and Environment 2022, *Far North Coast Regional Water Strategy: Detailed economic and ecological analysis*, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/what-we-heard/far-north-coast-regional-water-strategy, accessed 9 August 2023.

assumption ensures that the same drought event does not cause multiple augmentations to occur. The second emergency augmentation has the same characteristics as the first.

Volume of inflows

When defining the risk preferences of a local water utility, we need to identify the lowest level of expected inflows over the emergency augmentation construction period. If the local water utility has no tolerance for risk, then it will set the storage level that triggers an emergency augmentation assuming either:

- no inflows occur over the construction period; or
- the worst inflows on record occur over the construction period.

If using the worst inflows on record, the local water utility also needs to decide if the inflows considered are annual inflows or 2-year (biennial) inflows. Using 2-year inflows reflects the expected 2-year timeframe to construct an emergency augmentation.

In this test case, the analysis tests a range of the lowest 2-year inflows from the historical record (130-year hydrologic data). The lowest, third lowest, fifth lowest and 10th lowest inflows have been tested for both 12-month (annual) duration, where the inflows have been doubled, and 24-month (biennial) duration.

Setting the emergency augmentation trigger based on the annual or biennial inflows is a major decision. If annual inflows are selected (doubled to reflect the 2-year construction period), the model shows the possibility of large supply deficits. The worst annual inflow to Clarrie Hall Dam was about 2,400 ML. This is only 22% of Tweed Shire Council's 12-month water demand (Figure 1). However, the model shows the worst biennial inflows are 146% higher than the water demand over the same 2-year timeframe (Figure 2).

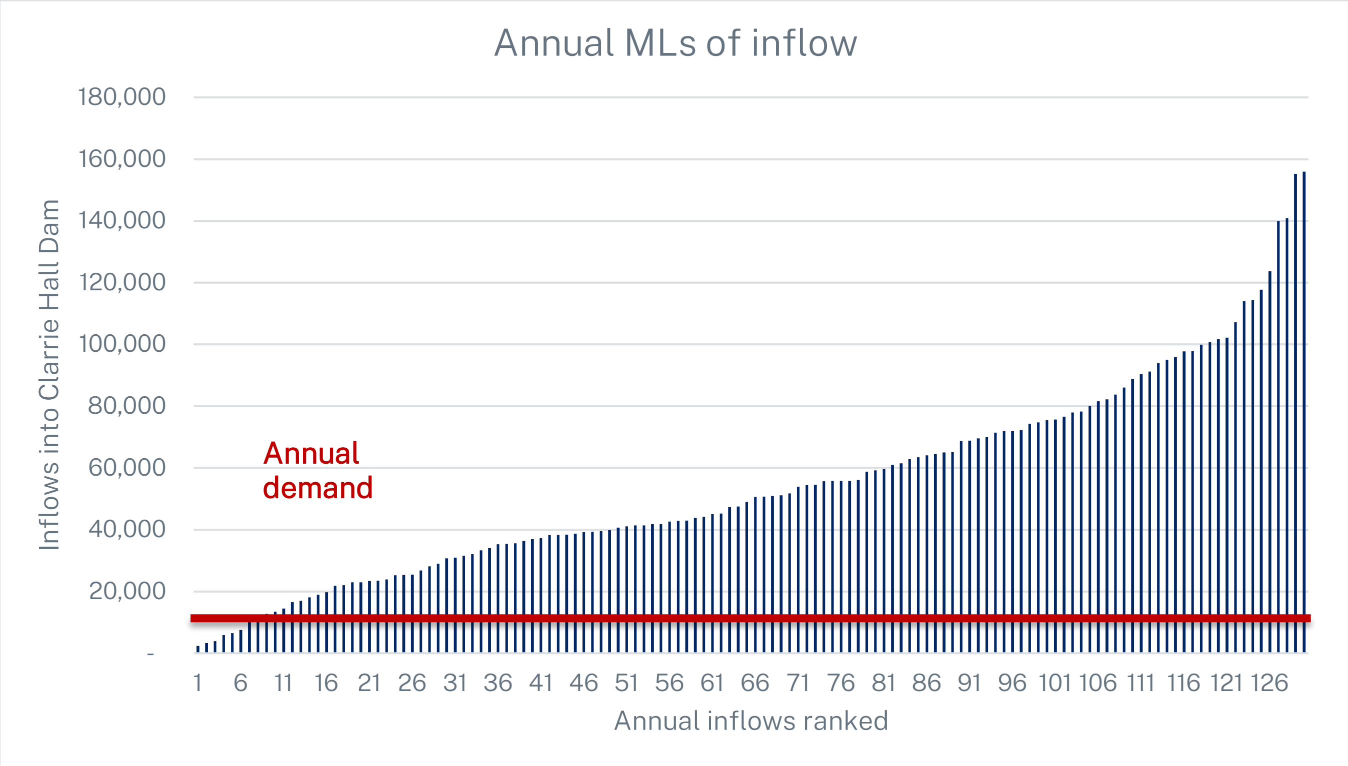

Figure 1. Clarrie Hall Dam annual inflows in the instrumental record (ranked from smallest to largest)

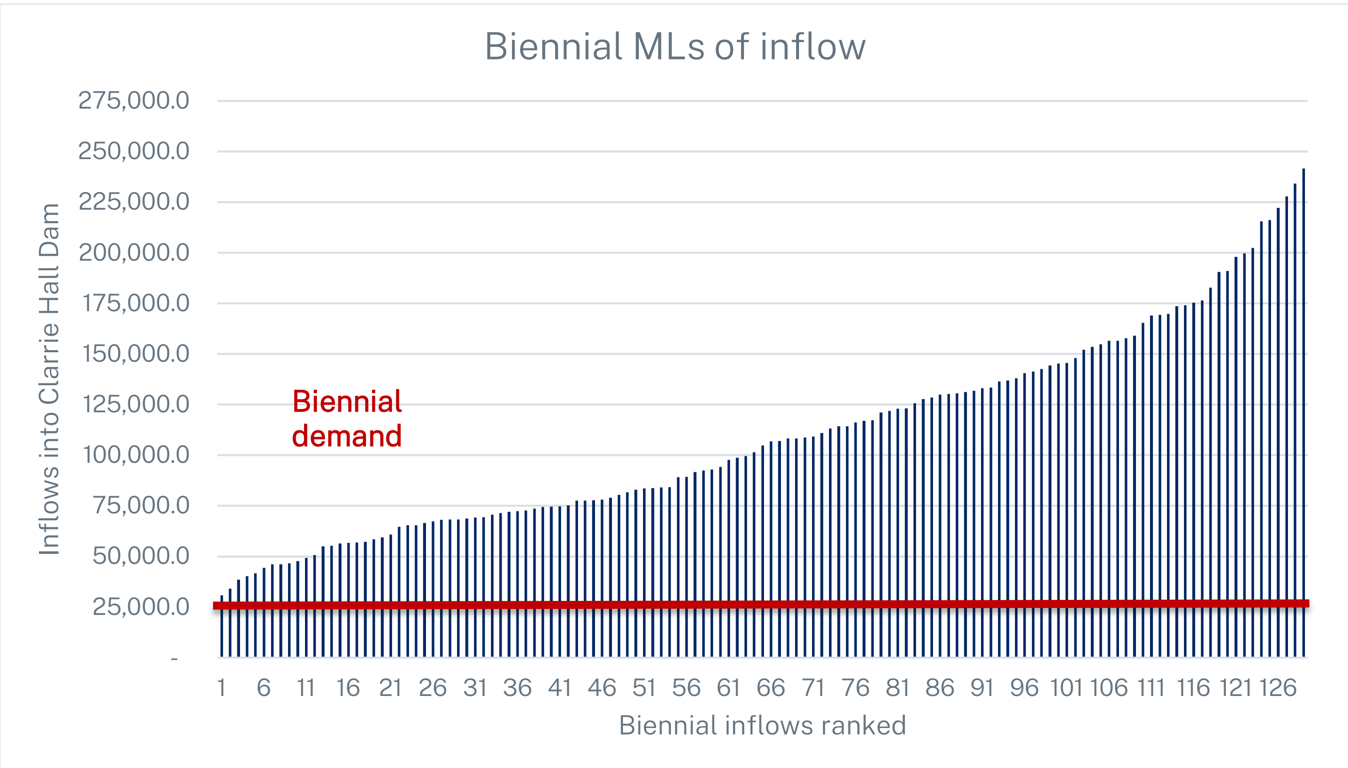

Figure 2. Clarrie Hall Dam biennial inflows in the instrumental record (ranked from smallest to largest)

The large difference leads to an important decision. The hydrologic record shows that there are individual years where inflows are not enough to meet the total demand for the Tweed Shire Council system. However, it also shows that the worst 2-year inflow sequence provides enough water to meet the total system demand over that period. The hydrologic record shows that a year of relatively high inflows has generally followed single years of low inflows. However, there is no guarantee this will always happen in the future. The alternative base case examines the consequence of using annual or biennial inflows as the basis of an economic base case.

Volume of protected water

Protected water is the volume of water that needs to be provided over the emergency construction timeframe. One way to estimate this is to use historic depletion rates. However, this has 2 main limitations: the depletion records need to represent the worst drought on record, and the records need to be at least as long as the timeframe to construct the emergency augmentation.

An alternative method that does not have these limitations is to estimate the volume of water to be provided before the emergency augmentation is available. This could be by using full unrestricted demand or it could be calculated using some level of water restrictions. Examining the cost of protecting different amounts of water demand allows a better understanding of the trade-offs between reliability and the acceptable level of risk.

Emergency augmentation trigger points

Table 1 shows the different storage trigger points for Tweed Shire Council's decision to construct an emergency augmentation. It shows that the point at which a decision is made depends heavily on the volume of anticipated inflows and the volume of assumed protected water. As a result, the trigger point selected for use will depend on the level of risk that a local water utility is willing to tolerate.

For the Tweed Shire Council system, the choice of acceptable level of inflows is the variable with the most significant implications for the alternative base case. If biennial inflows are used there is enough water to meet two years of full demand and an augmentation is not triggered. However, if annual inflows are used, assuming that the lowest inflows on record can occur in 2 consecutive years, then the emergency augmentation may be triggered when storages are completely full.

Table 1. Emergency augmentation storage triggers for different levels of acceptable inflows and protected demands

Protected demand (restriction level)	Annual inflows				Biennial inflows
	Lowest inflow	3rd lowest inflow	5th lowest inflow	10th lowest inflow	All inflows
Full demand	100%	100%	100%	88%	N/A
Level 1	100%	100%	85%	77%	N/A
Level 2	100%	96%	82%	77%	N/A
Level 3	100%	90%	78%	69%	N/A
Level 4	100%	86%	77%	40%	N/A

Calculating the costs of maintaining the water supply

The alternative base case is based on 14, 40-year hydrologic simulations (see *Calculating water supply system vulnerability* above). The calculated costs to maintain the water supply system are the average costs across the 14 realisations. These costs include the social costs of restrictions, and the costs of building and operating the emergency augmentation. The capital and operating costs of the emergency augmentation are incurred if the storage levels fall below the emergency augmentation trigger. It is assumed that the emergency augmentation is operated when storages are at or below the level 2 restrictions zone of the storages.

As described in *Calculating water supply system vulnerability* above, the assessment considers the possibility that a second augmentation is required over the 40-year timeframe. The storage level that triggers construction of the second emergency augmentation is determined by the following rule:

$$S_2 = S_1 + Q_{protected} - \left(Q_{inflows} + Q_{emergency}\right)$$

where:

S_2 is the trigger level (volumetric) of the second emergency augmentation

S_1 is the trigger level (volumetric) of the first emergency augmentation

$Q_{protected}$ is the volume of protected water over the construction timeframe of the second emergency augmentation

$Q_{inflows}$ is the acceptable volume of inflows over the construction timeframe of the second emergency augmentation

$Q_{emergency}$ is the volume of water produced by the first emergency augmentation of the construction timeframe of the second emergency augmentation.

The expected costs of maintaining the desired level of water supply security are calculated based on these triggers. They comprise the social costs of restrictions[3] and the capital and operating costs of the emergency augmentation.

Although a desalination plant has been used to estimate the cost of an emergency augmentation, this approach does not advocate using desalinated water as the emergency augmentation option. Rather, it is used as an anchor point for supplying an emergency water supply because it is a climate-independent water supply.

Results

When using the Tweed Shire Council system as an example, the costs of the emergency supply depend on the flow regime used to determine the emergency supply trigger. That is, the costs depend on the level of risk that the water provider can tolerate. Figure 3 shows the additional costs for maintaining the water supply system based on different levels of risk. If annual inflows are used, then the costs reflect both the social costs of restrictions and the costs to construct and operate

[3] Detailed in Marsdon Jacob Associates 2022, *Regional water value functions: Values for inclusion in the cost-benefit analysis to support NSW Regional Water Strategies*, Department of Planning and Environment, https://water.dpie.nsw.gov.au/plans-and-programs/regional-water-strategies/identifying-and-assessing, accessed 10 August 2023.

the emergency supply. If biennial flows are used, then the emergency supply is not triggered, and the costs only comprise the social costs of restrictions.

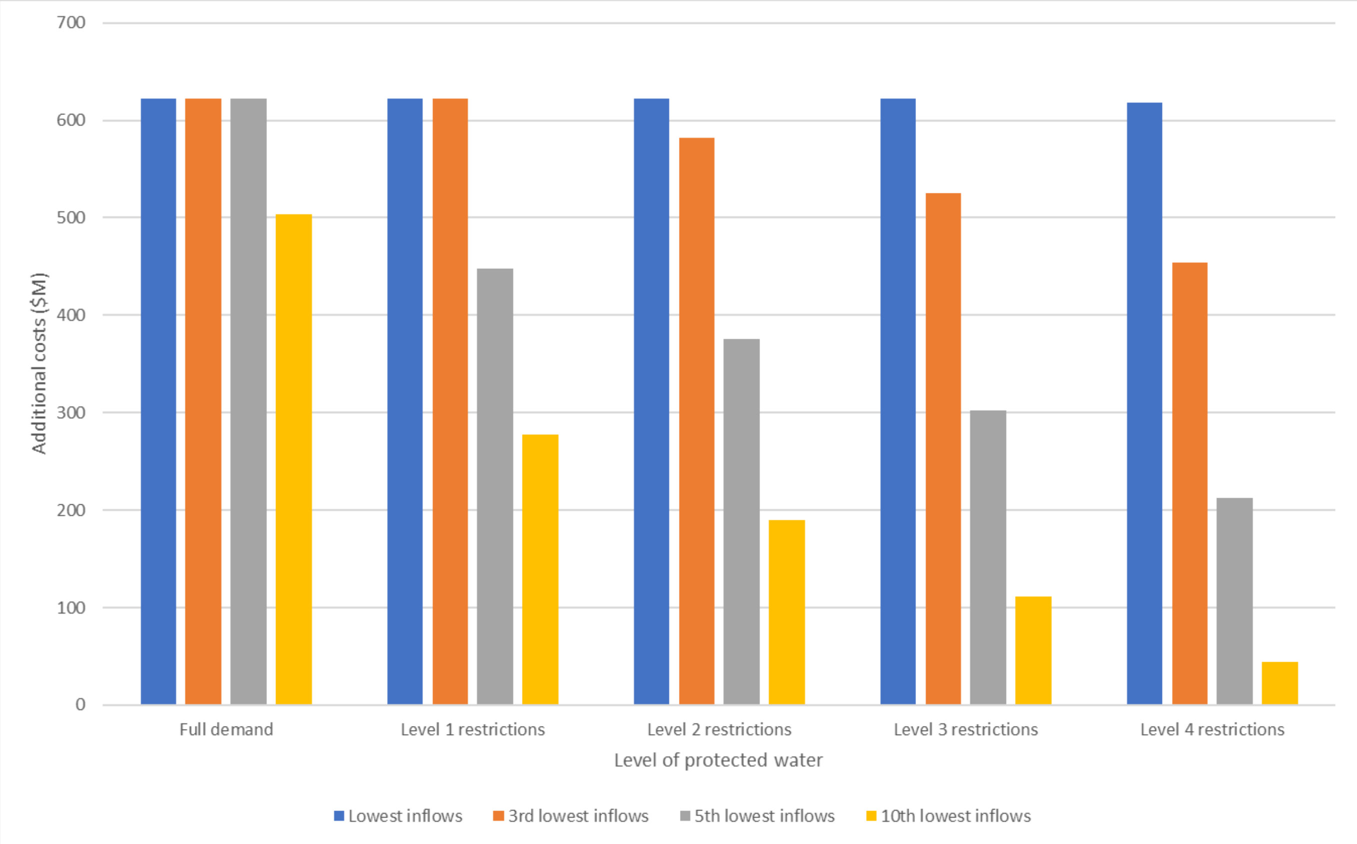

Figure 3. Expected discounted costs of maintaining the water supply system

When the worst annual inflows are used as inflows over the emergency augmentation construction timeframe to determine the emergency augmentation storage trigger, the emergency augmentation is triggered when storages are full. The amount of protected water has little effect on the cost of maintaining the water supply. Total expected discounted costs are $622 million or $618 million if basing the trigger on level 4 restrictions. Expected costs decrease further when the trigger is based on different severity of inflows (Table 2).

Table 2. Expected discounted costs of maintaining the water supply system

Level of protected water	Lowest inflows	3rd lowest inflows	5th lowest inflows	10th lowest inflows
Full demand	622.0	622.0	622.0	503.6
Level 1 restrictions	622.0	622.0	447.6	277.3
Level 2 restrictions	622.0	582.1	375.4	190.1
Level 3 restrictions	622.0	525.2	302.3	111.6
Level 4 restrictions	618.3	453.7	212.1	44.6

Using the fifth worst annual inflows shows a wide range of total expected costs for maintaining the water supply system. The most expensive option (trying to protect full demand) is almost 300 per cent more expensive than the least expensive option. When basing the alternative base case on the tenth worst annual inflows the total expected costs are between $504 million and $45 million (Table 2). This is a large range of potential costs for the water supply system. The actual costs incurred would depend on the risk preferences of the Tweed Shire Council.

When the emergency augmentation trigger is based on biennial inflows, the total expected discounted cost is always $31 million. This is because even the lowest 2-year inflows provide enough water to supply the full demand over that period.

These different costs provide an alternative basis for evaluating an option in a cost-benefit analysis. The cost-benefit analysis for an augmentation option will decrease as the LWU risk tolerance increases. This shows that the acceptable level of risk can be an important input to fully understanding the benefits and costs of augmenting the water supply.

Conclusions

In the Far North Coast, the standard regional water strategies economic assessment methodology estimated very low levels of expected costs associated with maintaining the water supply system over the 40-year strategy horizon. The alternative base case method gives greater consideration to the risk tolerance of local water utilities. It highlights that the assessment is affected by 2 important variables:

1. the hydrologic inflow used to determine the emergency augmentation storage trigger
2. the amount of water to be supplied while the emergency augmentation is being constructed.

This alternative base case showed that if annual inflows are used to determine the emergency augmentation storage trigger, there are major decisions to be made about the level of risk to be tolerated, and the planned level of demand to be met over the construction timeframe.

For this alternative base case, the type of hydrologic inflow to consider has the most significant influence on the emergency augmentation storage level. As a result, it also has the most significant influence on the cost of maintaining the water supply system.