Department of Planning and Environment

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Economic base case

North Coast Region

June 2022

Acknowledgement of Country

The NSW Government acknowledges Aboriginal people as Australia's first people, practicing the oldest living culture on Earth and as the Traditional Owners and Custodians of the lands and waters.

We acknowledge that the people of the Anaiwan, Biripi, Bundjalung, Dunghutti, Githabul, Gumbaynggirr and Yaegl nations hold a significant connection to the lands upon which the North Coast Regional Water Strategy falls.

The North Coast region holds areas of great spiritual, cultural and economic importance to Aboriginal people and the NSW Government recognises the connection of water to the people of these nations.

We recognise the intrinsic connection of Traditional Owners to Country and acknowledge their contribution to the management of the North Coast Regional Water Strategy area landscape and natural resources. Published by NSW Department of Planning and Environment

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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 options in the Draft North Coast Regional Water Strategy.

The base case assumes existing infrastructure and policy settings but includes central planning assumptions on projections of future population in each region.

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

- towns (as water shortfall) — Clarence Valley, Coffs Harbour, Telegraph Point, Long Flat, Port Macquarie, Comboyne, Armidale and Guyra all unregulated where shortfall refers to a town unable to meet its unrestricted demand from surface water supply.
- annual crop producers (as water supplied) — sorghum assumed as the primary annual crop grown in the region.

Note towns are modelled based on those whose water supply is included in the hydrologic models. The hydrologic results indicate that the towns are on average likely to experience a significant decrease in how often they have access to water (known as water supply reliability) under the dry climate change scenario of 1,243%, but the outright shortage is fairly small at 255 ML. The agricultural producers will experience an 11% reduction. A summary of the average amount of water available on each aggregated water user can be seen in Table 1. Average yearly water provided to different water user groups.

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

Water user group	(b) Long-term historical climate projections (stochastic)	(c) Dry climate change scenario (NARCliM)	Difference between (b) and (c)	Difference (%) between (b) and (c)
Towns (shortfall, ML/year)	21	275	255	1,243
Annual crops (supplied, GL/year)	8	9	1	11

The second step is then to undertake 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* (MJA, 2020). The evaluation period for each analysis was 40 years with a discount rate of 7%. Economic valuations per megalitre of water for each water user group were:

- towns — escalating cost dependant on the size of the town and the length of the shortfall. Note this value is applied on the volume of water not supplied (i.e. shortfall). For more details refer to Table 6.
- annual crop producers (sorghum) — $175/ML.

The economic impacts on average are higher under the climate change scenario than under the stochastic scenario, reflecting the lower availability of water between the two estimates. The costs to towns and communities is estimated at approximately $18 million in social and economic costs on average while the amount of annual crop production would decline by $27 million on average. Average economic outcomes per water user group can be seen in Table 2.

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

Water user group	(b) Long-term historical climate projections (stochastic)	(c) Dry climate change scenario (NARCliM)	Difference between (b) and (c)	Differe betwee
Towns, cost to ($, mil)	-2	-20	18	964
Annual crops ($, mil)	558	531	27	5

The majority of the economic losses for towns will be experienced in Armidale (including Guyra) as seen in
Table 3.

Table 3. Shortfall Net Present Costs ($, Mil)

Town	Stochastic	NARCliM	Difference	Difference (%)
Clarence Valley	0	0	0	0
Coffs Harbour	0	0	0	0
Telegraph Point	0	0	0	0
Long Flat	0	0	0	0
Port Macquarie	0	0	0	0
Comboyne	0	0	0	0
Armidale	0	-15	-14	Much larger
Guyra	0	-3	-3	Much larger
Total	-1	-18	-17	Much larger

The drier climate scenario has important findings for the region. There is a significant increase in the number of shortfalls that occur across these towns with Armidale's large population base potentially impacted the most. This indicates that they will become more vulnerable to shortfalls and the resilience of the systems will be challenged. While the absolute shortfalls are relatively low in the smaller towns, the frequency of their occurrences are significantly higher. This suggests that water reliability will also become a more relevant issue for these towns and communities in a drier climate.

The regional water strategy analysis is not a business case and is not intended to provide the detail of a business case. Rather, it is the first step in undertaking a strategic analysis of alternate options. The analysis does however need to be robust and region-specific enough to be able to compare the merits of different options. The approach set out in this document aims to strike this balance between a high level, strategic assessment and region-specific information.

Introduction

Economic base case – context

This report details the economic base case that has been used for the hydrological and economic modelling undertaken to support the assessment of the long list options in the Draft North Coast Regional Water Strategy.

This report has been prepared to support decision-making on the North Coast Regional Water Strategy for options and portfolios that may impact the supply, demand, or allocation of water and are able to be adequately represented within catchment-level hydrologic modelling. There are a range of other options in the regional water strategy that do not impact on the supply, demand or allocation of water in the region.

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 changes to population projections. The water demands of user groups are generally set as fixed, with some exceptions with regards to town population growth where it 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 that hydrologically modelled portfolios will be assessed against in cost benefit analysis.

What is the Regional Water Value function?

The Regional Water Value function[1] is used to value the amount of water that is forecast to be available. The forecasts are developed through hydrologic modelling. A key feature of the values estimated is that they:

[1] *Regional Water Value Function* (Marsden Jacob Associates, 2020)

- **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 North Coast region include:

- town water supply
- irrigators of annual crops — which has been assumed to be sorghum given it is the primary crop grown in the region
- irrigators of permanent crops — there is no high security entitlements in the region, it is all general security. Consequently, the economic base case does not include permanent crops.

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 more vulnerable in periods of supply shortfalls as a result. 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. This level of detail is more appropriate to be considered in a detailed business case. 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 the 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 strategy reliability assessments for towns and communities in the 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 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 paleo-climate and the other adding climate change scenario impacts.[2] These two climate scenarios are referred to as the Stochastic and the NARCliM models respectively.

[2] For more details on the setup of the hydrologic modelling report for the North Coast.

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 town surface water availability over the 40 years. Town water availability is estimated by simulating extraction volumes and restrictions curves associated with the levels of storage in the North Coast.

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 North Coast region.

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

[3] See *New climate analysis informs NSW's regional water strategies* (DPIE, 2020)

[4] *Regional Water Value Functions* (MJA, 2020)

North Coast key details

The North Coast region

The North Coast region (Figure 1) covers approximately 42,000 km^2 and comprises the catchments of six major rivers — the Clarence River, the Macleay River, the Bellinger River, the Nambucca River, the Hastings River and the Wilsons River, the waterways of the Coffs Harbour area and 13 underlying groundwater sources.[5] The region neighbours the Northern Rivers area of the Far North Coast, the Greater Hunter Region to the south and the Gwydir, Namoi and North Coast regions to the west. It incorporates seven local government areas — Clarence Valley Council, Coffs Harbour City Council, Kempsey Shire Council, Armidale Regional Council, Bellingen Shire Council, Port Macquarie-Hastings Council and Nambucca Valley Council.[6]

The North Coast region is renowned for its spectacular and diverse natural environment. The landscape transitions from the expansive New England Tablelands at its western periphery, descending sharply through rugged gorge country to undulating foothills, lowlands and floodplains before reaching the coast and its plethora of coastal lagoons, wetlands and estuaries. Almost 40% of the region is classified as national park, declared wilderness area or nature reserve,[7] including the Gondwana Rainforest World Heritage Area and Oxley Wild Rivers National Park. Large sections of the coast contain nationally important wetlands and estuaries, the most extensive being contained within Limeburners Creek Nature Reserve.

The lands and water resources of the North Coast region are of great importance to the Anaiwan, Biripi, Bundjalung, Dunghutti, Githabul, Gumbaynggirr and Yaegl Nations. Water is important to Aboriginal people and supports the wellbeing of communities and ensures connection to Country.

The region is home to around 300,000 people and the main towns of Grafton, Port Macquarie, Coffs Harbour, Armidale and Kempsey, which serve as important employment and service hubs. There are several smaller towns in the region with populations ranging from around 3,000 to 7,000[8] including Bellingen, Nambucca Heads and Yamba.[9]

The region's riverine and coastal environment, as well as its rural landscape, support one of the state's strongest economies (third in size following Greater Metropolitan Sydney and the Greater

[5] The boundary for the North Coast region is based on surface water catchments. It has been separated from the catchments of the Far North Coast Regional Water Strategy due to previous work by Infrastructure NSW on the State Infrastructure Strategies (2014 and 2018), which considered regulated surface water catchments only. It is noted that the boundaries for the North Coast region do not align with the North Coast region declared under the provisions of s.3.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

[6] The boundaries of the North Coast Regional Water Strategy also include parts of Tenterfield Shire Council, Kyogle Shire Council, Glen Innes Severn Shire Council and Walcha Shire Council. These local government areas source their main town water supplies from neighbouring regions. Options to address future water security for these councils are discussed in the North Coast, Gwydir, Namoi or Far North Coast Regional Water Strategies respectively.

[7] Data compiled by the Department of Planning, Industry and Environment

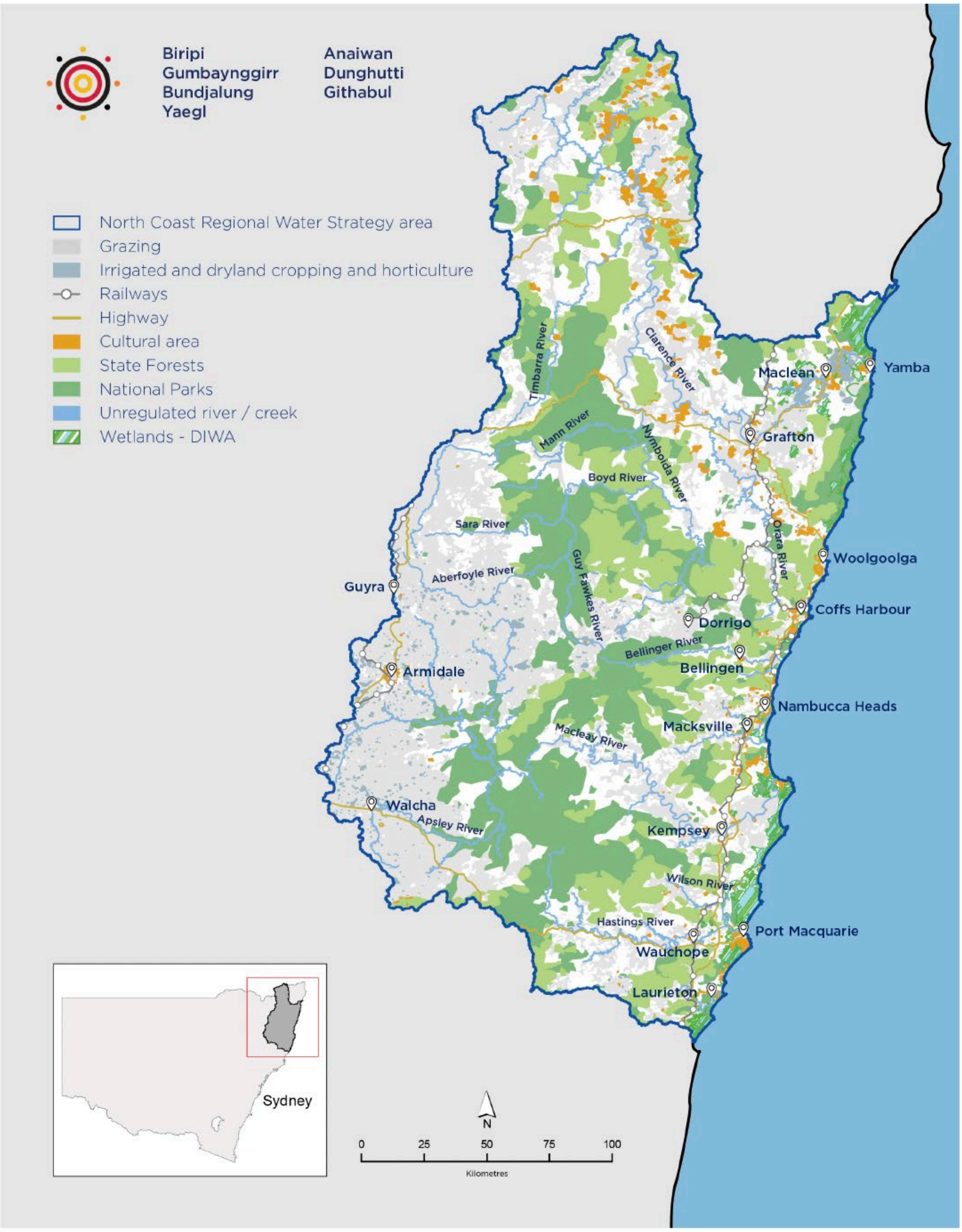
[8] https://www.planning.nsw.gov.au/Research-and-Demography/Population-projections/Projections (last accessed 28 June 2021).

[9] The North Coast Plan 2036 describes towns as either a *regional city, strategic centre* or *centre*. Coffs Harbour and Port Macquarie are described as *strategic centres* and Grafton as a *regional city*. All other towns mentioned are described as important *centres*.

Hunter regions). The region (along with the Far North Coast[10]) is one of the most popular Australian tourist destinations, receiving an average of over five million visitors annually. Bananas have long been an iconic crop for the region and, more recently, blueberries and other berries have been growing in importance. Cattle and sheep grazing, and dairy farming continue to be mainstays of the regional economy. Other key sectors include health care and, in some parts of the region, education and construction.

Figure 1. The North Coast Regional Water Strategy area

[10] This refers to the area defined in the Far North Coast Regional Water Strategy: www.industry.nsw.gov.au/water/plans-programs/regional-water-strategies/public-exhibition/far-north-coast (last accessed 28 June 2021).



Biripi
Gumbaynggirr
Bundjalung
Yaegl
Anaiwan
Dunghutti
Githabul
North Coast Regional Water Strategy area
Grazing
Irrigated and dryland cropping and horticulture
Railways
Highway
Cultural area
State Forests
National Parks
Unregulated river / creek
Wetlands - DIWA
Maclean
Yamba
Grafton
Woolgoolga
Coffs Harbour
Dorrigo
Bellingen
Nambucca Heads
Macksville
Kempsey
Port Macquarie
Wauchope
Laurieton
Guyra
Armidale
Walcha
Timbarra River
Clarence River
Mann River
Nymboida River
Boyd River
Sara River
Aberfoyle River
Guy Fawkes River
Orara River
Bellinger River
Macleay River
Apsley River
Wilson River
Hastings River
Sydney
N
0
25
50
75
100
Kilometres

Extractive users of water

The hydrologic outcomes and the 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
    - 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.[11]

Towns and communities

The economic base case for towns and communities is developed according to the systems where they draw their surface water supply. They are the unregulated river catchments within the North Coast region — Bellingen, Clarence, Hastings and Macleay.

A range of towns were not included in the analysis. Tenterfield, while located on the border of the North Coast region has been included in the North Coast Regional Water Strategy. The town of Bellingen has also been excluded as the main town water supply comes from the Bellinger catchment.

There are also a range of townships and discrete communities not incorporated within the current hydrologic models of the region including Maclean, Yamba, Urunga, Wauchope and Nambucca Heads. Initial work indicates that the region-wide impacts will also be reflected to some extent in these communities. This assumption will need to be tested in any detailed business cases that are recommended to progress from the regional water strategy.

The economic base case assigns different values for the costs of replacing 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 under any circumstance. Details of towns considered within this document and their associated shortfall costs can be seen in Table 4.

Table 4. Economic cost of town water supply shortages in the North Coast

Time in water shortage	Clarence Valley	Coffs Harbour	Port Macquarie	Armidale	Guyra
Population*	50,671	25,752	73,131	25,752	2,027
System type	Unregulated	Unregulated	Unregulated	Unregulated	Unregulated

[11] 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, 2020).

Time in water shortage	Clarence Valley	Coffs Harbour	Port Macquarie	Armidale	Guyra
0 - 6 months (restrictions)	$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
Greater than 12 months	$16,000/ML (Carting)	$16,000/ML (Carting)	$16,000/ML (Carting)	$16,000/ML (Carting)	$16,000/ML (Carting)
Continued shortages (greater than 24 months)	$16,000/ML (Carting)	$16,000/ML (Carting)	$16,000/ML (Carting)	$16,000/ML (Carting)	$10,000/ML (Carting)

*2016 populations, sourced from Australian Statistical Geography Standard 2019 local government area projections (NSW, 2019) and Australian Bureau of Statistics census data

The population projections are based on the NSW Government's median common planning assumption population projections.

Water supply restrictions for unregulated systems are based on cease-to-pump rules or the management of local council town water supply storages, 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 majority of the agricultural crops grown in the North Coast region, water licenses and its economic value.

Table 5. Economic cost of agricultural users

Crop/Stock	Cropping	Water license	Marginal economic benefit (of water) ($/ML)
Sorghum	Annual	General security	175
Lucerne	Permanent	General security	150
Blueberries	Permanent	General security	5,500
Avocados	Permanent	General security	2,700

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

- annual crops: sorghum ($175/ML)
- permanent crops: blueberries ($5,500/ML, $14,000/ML in shortfall)

Both crops have sensitivities associated with their producer surplus, estimated at the long run profitability derived from a megalitre of water as detailed in the *Regional Water Value Functions* report.[12] Annual crops grown in the region are predominantly lucerne and sorghum with a producer surplus ranging from $75–$250/ML. Permanent crops grown in the region include blueberries and avocadoes. These crops generate producer surpluses of between $2,700/ML through to $5,500/ML for the water supplied but $3,900/ML to $15,000/ML when shortfalls occur. Dairy cattle have a producer surplus of $200/ML, during shortfall only.

For this analysis the annual crop of sorghum has only been considered, as there are no high security entitlements in the region.

[12] *Regional Water Value Functions* (MJA, 2020)

Hydrologic and economic base case outcomes

The estimated hydrologic and economic outcomes from the economic base case hydrologic modelling are given for the key extractive users in the North Coast region for both the observed historical, long-term paleoclimate (stochastic) and the climate change (NARCliM) model predictions in the following section.

We have 10,000 years of data in the stochastic and climate change data sets. This data has been split into 1,000 40-year segments. The analysis on each major water user is analysed using 1,000 40-year realisation or 'windows'.

All economic calculations use a discount rate of 7% as recommended by the NSW Treasury.[13]

The hydrological model that was developed for the Hastings catchment did not include the storages at Cowarra Dam (10,000 ML) and Port Macquarie Dam (2,500 ML). To compensate for this the economics modelling has assumed a conservative position and estimated that these two storages provide Port Macquarie with an additional 6 months of water (when its closer to 12 months) for all shortfall calculations.

Town and community hydrologic base case outcomes

The hydrologic modelling indicates the larger towns within the region are not likely to experience low levels of surface water supply shortfalls, with a small increase in magnitude predicted due to climate change. The average length and magnitude of the expected annual shortfalls for each town for the 1,000 realisations 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.

Table 6. Town water supply hydrologic outcomes–stochastic model

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
Clarence Valley	0	5,918	0	0	0
Coffs Harbour	0	6,445	0	0.0	0.2
Port Macquarie	1	6,806	0.1	0	0

[13] TPP17-03: NSW Treasury, NSW Guide to Cost-benefit Analysis

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
Comboyne	1	21	2.4	0.8	6.3
Armidale	9	3,482	0.2	0.1	0.4
Guyra	9	494	1.7	0.4	3.3

Table 7. Town water supply hydrologic base case outcomes–NARCliM model

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
Clarence Valley	0	6,095	0	0.0	0.0
Coffs Harbour	1	6,490	0	0.0	0.4
Port Macquarie	1	6,851	0.1	0.01	0
Comboyne	1	21	4.8	1.1	9.5
Armidale	223	3,482	6.4	1.0	8.3
Guyra	47	494	9.6	1.7	14.3

Table 8. Town water supply hydrologic base case outcomes – difference (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
Clarence Valley	0	177	0	0.0	0.0
Coffs Harbour	0	44	0	0.0	0.2
Port Macquarie	1	45	0.1	0.0	0
Comboyne	1	0	2.4	0.4	3.2
Armidale	214	-107	6.2	1.0	7.9
Guyra	38.5	-15	7.9	1.3	11

On average, surface water can provide the larger towns' — Clarence, Coffs Harbour and Port Macquarie — unrestricted demand for water in the stochastic climatic. Under the NARCliM (climate change) conditions we see a similar result for Clarence Valley and Coffs Harbour, with no major shortfalls experienced, indicating that the large towns have a secure supply of water under the drier climate scenario. Armidale is the main exception.

Armidale is significantly impacted under a drier climate with the shortfall as a percentage of demand increasing pointedly from 0.2 to 6.4% and shortfalls expected approximately 8% of the time. The Guyra Dam — which also feeds into the Armidale system — also experiences a significant reduction in water availability under a drier climate, with the average percentage of the year where it experiences a shortfall rising from 3.3 to 14.3 per cent. These two results indicate that if current infrastructure is maintained, Armidale is expected to experience significant risks to its water supply as we move into a drier climate.

For the smaller towns there is an increase in when towns cannot supply all their demand from surface water, with Telegraph Point seeing shortfalls of 3.7%, Comboyne 2.4% and Guyra 1.7% from the stochastic modelling. Under NARCliM (climate change) conditions these numbers increase to 4.7%, 4.8% and 9.6% respectively.

The amount of time that towns are expected to spend within a period of shortfalls is closely linked to the magnitude of shortfalls. In stochastic conditions this is likely to be less than 1% of the time for Coffs Harbour and Clarence Valley. Under the climate change scenario Coffs Harbour, Clarence Valley and Port Macquarie experience no real shortfalls across the year.

Across the smaller towns we see some larger jumps under the drying climate scenario compared to the stochastic with Telegraph Point rising from 6% to 8%, Comboyne rising to 9.5 from 6.3%. Long Flat remains the least impacted from the smaller towns rising from 2.2 to 3.4%.

The drier climate scenario has significant findings for the region. There is a significant increase in the number of shortfalls that occur across these towns with Armidale's large population base potentially impacted the most. This indicates they will become more vulnerable to shortfalls and the resilience of the systems will be challenged. While the absolute shortfalls are relatively low in the smaller towns, the frequency of their occurrences are significantly higher. This suggests that water reliability will become a more relevant issue for these towns and communities in a drier climate.

Figure 6 illustrates key town water supply shortfalls scenarios of the 1,000 realisations[14] for individual towns, and the combination of all towns, in both the stochastic and NARCliM models. It gives these scenarios as cumulative totals over the 40-year simulation period. The key scenarios are:

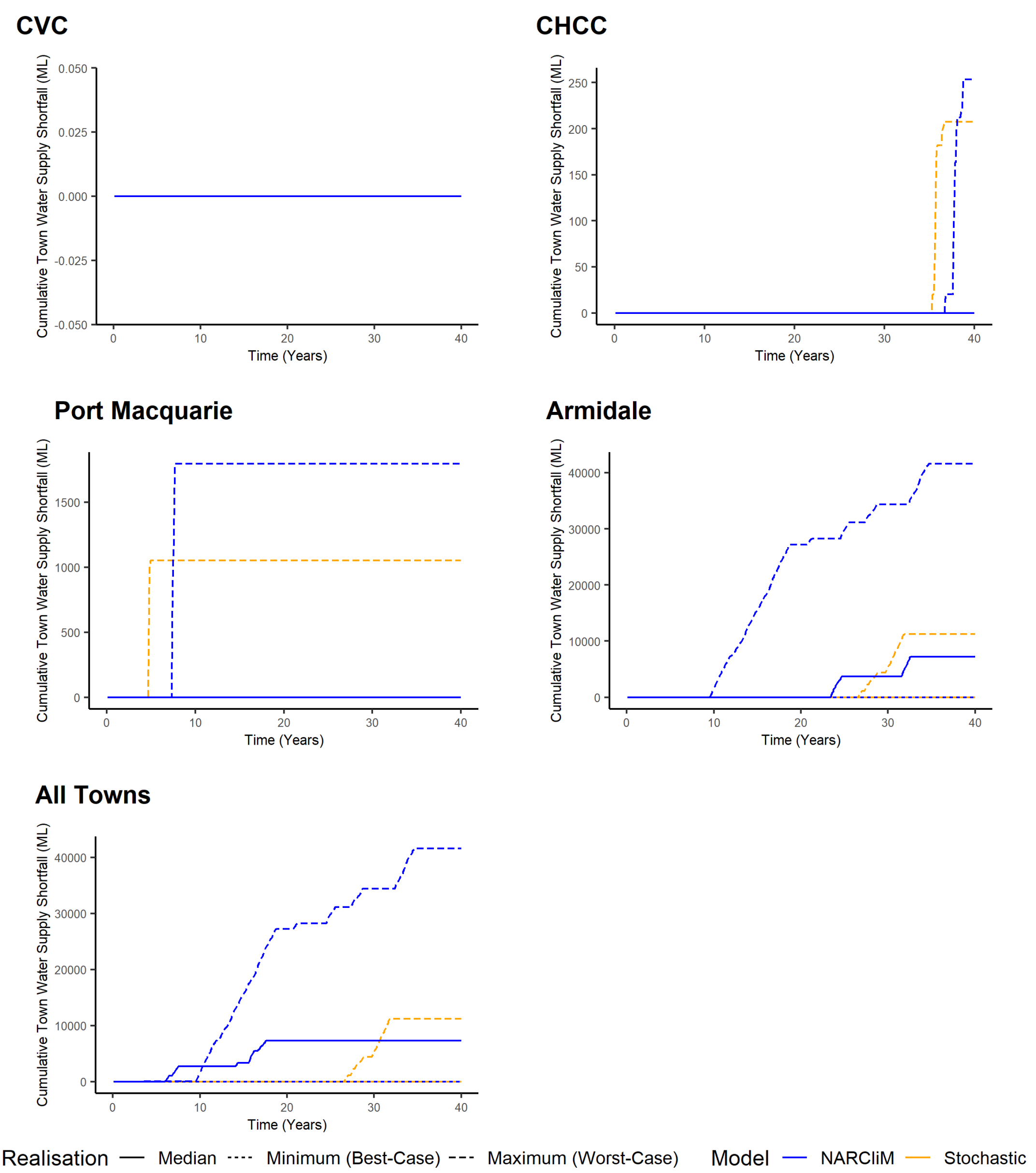
- minimum: the best-case scenario
- median: the exact middle scenario
- maximum: the worst-case scenario.

These scenarios allow for an understanding of the spread of what could happen (the outcomes) over all the 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

[14] Realisation refers to a single 40-year hydrologic simulation. There 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.

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.

Figure 2. Town supply cumulative 40-year shortfall series (ML)



Similar to Table 6-8 above, Figure 2 highlights that the expected shortfalls for towns under the stochastic dataset are typically low, with nearly half of all realisations producing minimal shortfalls for the towns across the region — except Armidale. This is evident by examining the relatively flat solid yellow line for the 40-year period in most graphs in the series, which shows for that key-realisation the town is not experiencing any water supply shortages. Where the line is not visible it is being obscured by the minimum or best-case scenario of the NARCliM dataset, which also indicates no town shortfalls for this key-realisation.

The worst-case (maximum) scenarios for the NARCliM dataset generally show a significant increase in expected town supply shortfalls when compared with the worst-case stochastic scenarios, depending on the town, except for Clarence Valley, where we see no impact. The most significant impacts can be seen in Armidale. Long periods of minimum impact under the average case scenario, followed by short, large bursts of poor water supply, will lead to dramatic shortfalls in cumulative shortfalls. In Armidale the difference in shortfall between the worst-case scenario (maximum) is approximately five times higher over a 40-year period.

The collection of graphs presented in Figure 2 indicate that individual town water supplies appear to be relatively secure for long periods of time under the stochastic dataset but are vulnerable to successive periods of low water leading to large shortfalls over time. These scenarios are even more pronounced under a drier climate, reinforcing our earlier point that these towns will become more vulnerable to shortfalls and the resilience of their systems will be challenged. This suggests that water reliability will become a more relevant issue for these towns and communities under a drier climate.

Town and community economic base case outcomes

The estimated average economic impact of water supply shortfalls for towns within the North Coast over a 40-year period is provided in Table 9.

Table 9. Economic base case outcomes key user group — town water supply average 40-year shortfall net present costs ($, Mil)

Town	Stochastic	NARCliM	Difference	Difference (%)
Clarence Valley	0	0	0	0
Coffs Harbour	0	0	0	0
Port Macquarie	-1	-2	-1	72
Comboyne	0	0	0	0
Armidale	0	-15	-14	5,884
Total	-2	-20	-18	964

Three quarters of all the towns are predicted to experience very minimal declines in costs associated with maintaining water supply under both climate datasets. This is especially the case for the three larger towns of Clarence Valley, Coffs Harbour and Port Macquarie, who provide the majority of the economic activity for the region. Under the NARCliM scenario the economic loss to the town of Armidale is significantly higher, rising to $15 million from almost zero under the stochastic scenario, a rise of almost 6,000%.

The distribution of the expected economic outcomes for each model can be seen in Figure 3. The histogram condenses town shortfall economic costs for all 1,000 realisations by grouping results into ranges of values (in this case 20 ranges per data series). The figure illustrates that both the magnitude and uncertainty (ie the spread) of the average cost of town shortfalls increases under the NARCliM forecasts. The increase in spread of the town water supply costs under a NARCliM scenario is reflective of the predicted increase in the number of, and severity of shortfalls where water supply is required to be supported via a more expensive alternative source.

The figure indicates that the worst economic outcomes with regards to town water supply shortfalls for the stochastic and NARCliM datasets were approximately $25 million and $175 million respectively. Like the hydrologic results, the worst case NARCliM outcomes are significantly higher than the worst-case stochastic outcomes.

Figure 3. Total average towns water supply net present costs

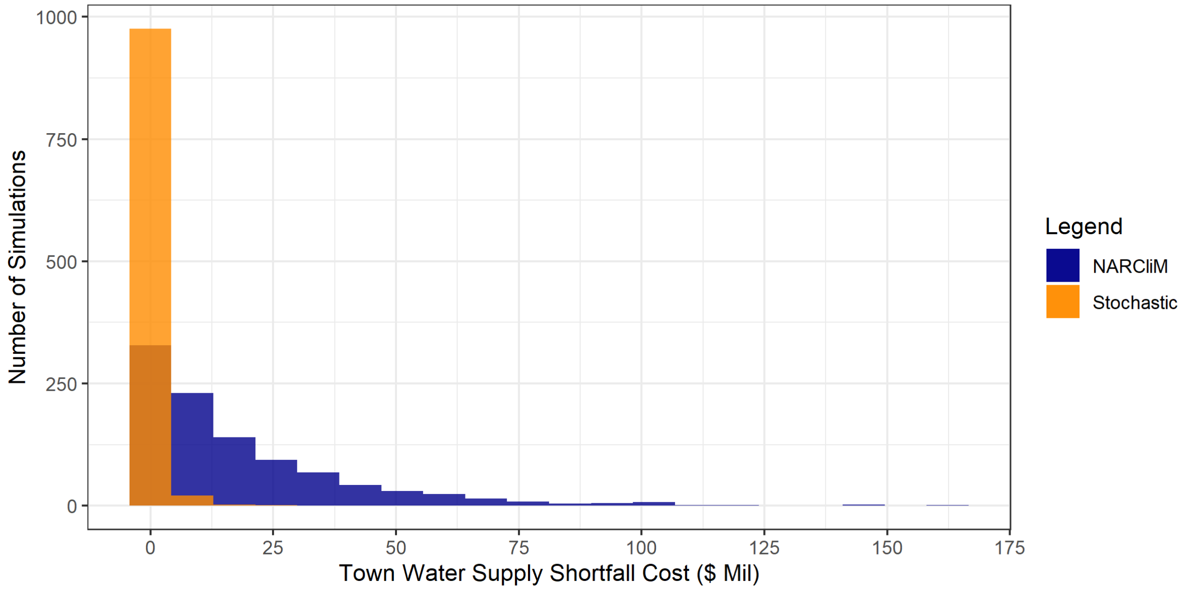


Table 10 to Table 12 provide additional information on the length of shortfalls and the percentage of time that each town spends under each restrictions regimes outlined in Table 4 (when experiencing a shortfall). For Clarence Valley, Coffs Harbour, Telegraph Point, Long Flat and Port Macquarie, there is no real change between the stochastic and NARCliM datasets, whilst Comboyne sees minimum impacts. For Armidale and Guyra the length of time that these towns continuously do not have access to surface water increases as droughts lengthen under the climate change scenario.

Table 10. Economic base case outcomes key user group — town water supply average share of restriction level — stochastic model

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)
Clarence Valley	100%	0	0	0
Coffs Harbour	99%	1%	0%	0%
Port Macquarie	100%	0%	0%	0%
Comboyne	96%	3%	0%	0%
Armidale	78%	17%	4%	0%

Table 11. Economic base case outcomes key user group–town water supply average share of restriction level — NARCliM model

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)
Clarence Valley	100%	0	0	0
Coffs Harbour	99%	1%	0%	0%
Port Macquarie	99%	1%	0%	0%
Comboyne	94%	5%	1%	0%
Armidale	52%	23%	18%	7%

Table 12. Economic base case outcomes key user group — town water supply average share of restriction level — difference (NARCliM–stochastic)

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)
Clarence Valley	0%	0%	0%	0%
Coffs Harbour	0%	0%	0%	0%
Port Macquarie	0%	0%	0%	0%
Comboyne	-2%	2%	0%	0%
Armidale	-26%	5%	14%	7%

To demonstrate: Armidale experiences a decrease in shortfall durations lasting 0-6 months, of 26% from stochastic to NARCliM climate models. This reduction is unfortunately offset by the equivalent increase in longer droughts. Those lasting 12–24 months (costing $16,000/ML) increase by 14% and those lasting more than 24 months (costing $10,000/ML) increase by 7%. This indicates that the average length (and therefore the average economic cost per megalitre) of shortfalls increases from the stochastic simulations to the NARCliM simulations once we go out past six months; therefore, Armidale is likely to experience longer and more expensive droughts as we move into a drier climate scenario.

Agricultural hydrologic base case outcomes

The following section describes the hydrologic impacts on the agricultural industry within the North Coast. The annual crop of sorghum has been considered, as there are no high security entitlements in the region.

The estimated annual average volume of water these producers use under both the stochastic and NARCliM (climate change) scenarios are given in Table 13.

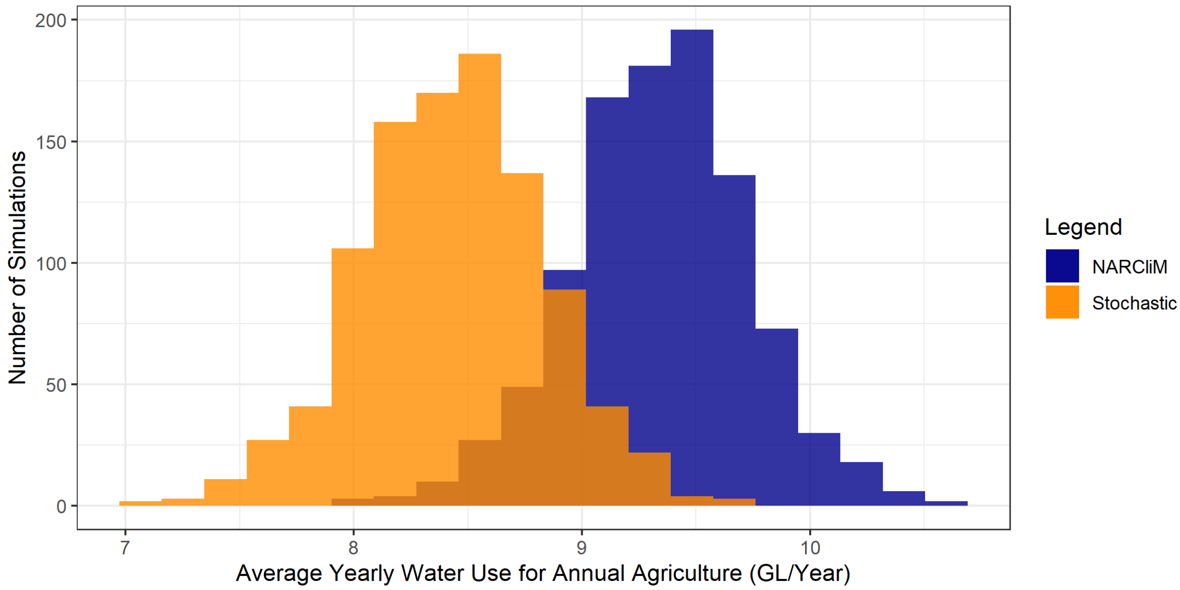
Agricultural water users are expected to receive less water under the climate change scenario than the stochastic scenario with an average usage difference of about 9 GL per year, amounting to a reduction of 11%. Water usage is sourced from general security for annual crops, and from general security access licenses shares or harvestable right dams for permanent crops.

Table 13. Average annual agricultural water usage volumes — stochastic and NARCliM

Crop classification	Water use metric	Stochastic	NARCliM	Difference	Difference (%)
Annual crops (GL/Year)	Average	8	9	1	11
	Maximum	10	11	1	9
	Median	8	9	1	11
	Minimum	7	8	1	12
	Standard Deviation	0	0	0	-3

Histograms of the modelled annual agricultural water usage for annual crops within the North Coast region can be seen in Figure 4. The figure groups 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 annual crop types is predicted to reduce marginally under the climatic conditions present in the NARCliM model. The amount of variation is expected to remain roughly the same between the two datasets.

Figure 4. Stochastic and NARCliM annual crop water use

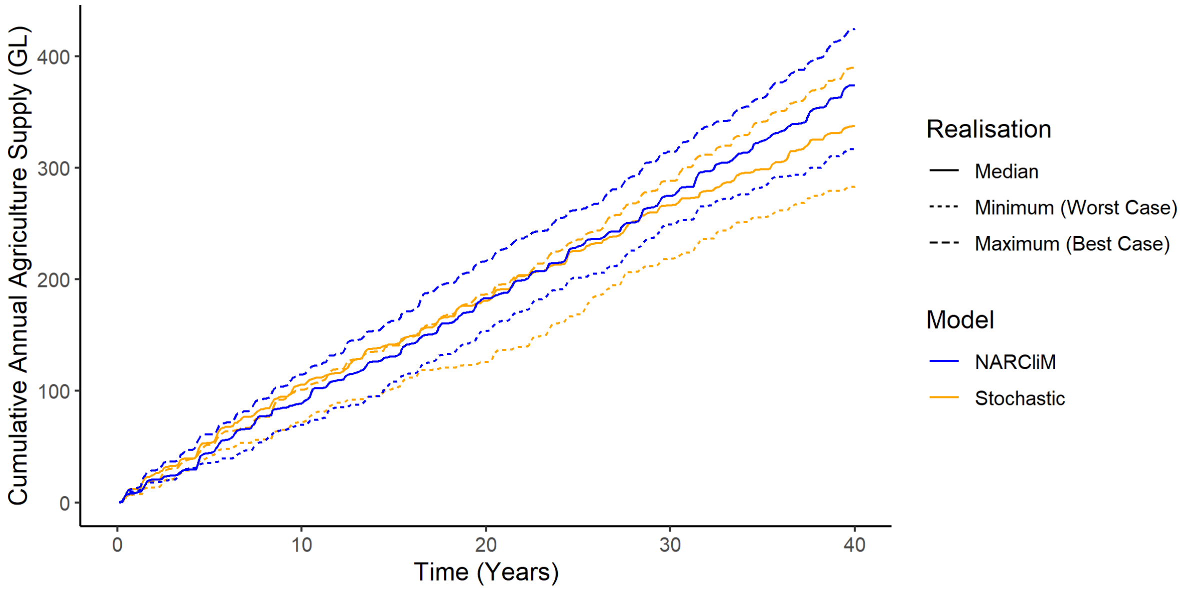


Three scenarios of expected cumulative water usage for producers of annual crops are presented in Figure 5 for both the stochastic and NARCliM hydrologic models. The scenarios are:

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

These results indicate that the impact of climate change on annual plantings is less visible, with the modelling indicating very similar outcomes under both scenarios.

Figure 5. Stochastic and NARCliM cumulative annual crop agriculture water use



Agricultural economic base case outcomes

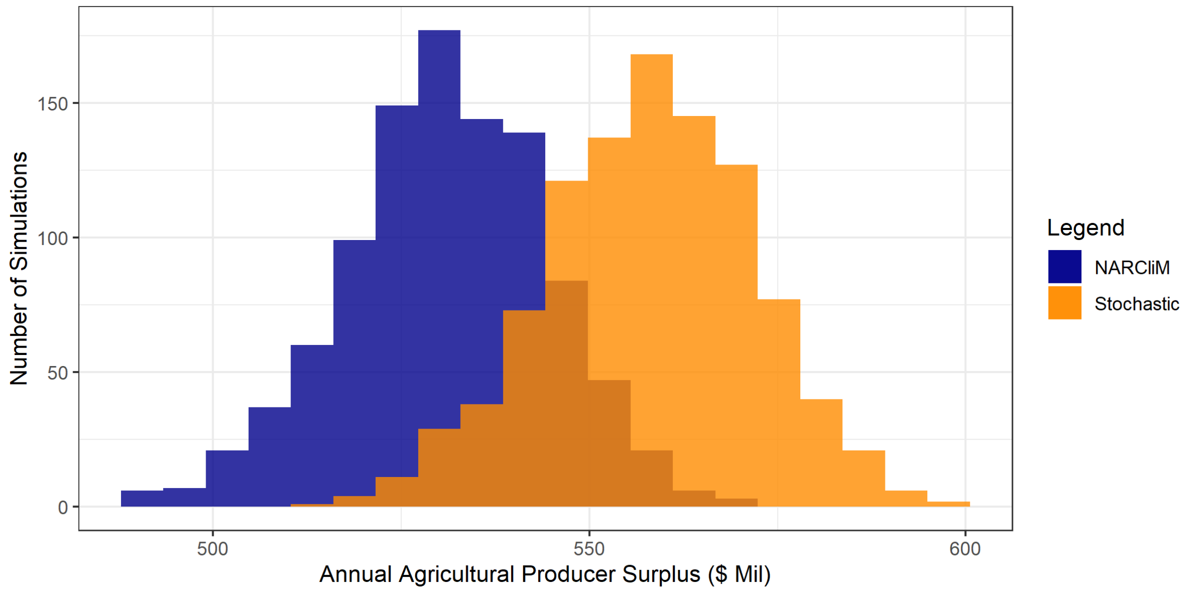
Average economic values of water for agricultural producers within the North Coast region over the 40-year analysis period are given in Table 14. The NARCliM dataset results in a 5% reduction in the average economic value for annual crop producers reflects the reduction in agricultural production due to a decreased water supply. We would expect to see a similar drop in economic output for producers specialising in more permanent types of crops such as higher-value horticulture crops currently grown in the region (blueberries and avocados).

Table 14. Economic base case outcomes for the key user group — agriculture, net present producer surplus averages over 40 years ($, Mil)

Crop classification	Stochastic	NARCliM	Difference	Difference (%)
Annual crops	558	531	-27	-5

A summary of the distribution of possible outcomes for annual agricultural producers can be seen in F9igure 6, illustrating the relatively narrow range of possible economic outcomes under both the NARCliM and stochastic scenarios.

Figure 6. Annual agriculture net present producer surplus over 40 years



The expected decrease in economic activity under stochastic conditions due to a reduction in water availability for producers of annual crops, ranges from approximately $510-$600 million, with an average value of $558 million over the forecast 40 years. For the NARCliM results the value of water for producers of annual crops shifts lower with values ranging from approximately $470–$600 million, with an average value of $531 million.

Assumptions and uncertainties

The analysis in the regional water strategies is based on the best available information at the time. As with all types of analyses; a range of assumptions, uncertainties and qualifications are necessary.

Assumptions adopted within this economic base case analysis include the following.

- 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. The purpose of the analysis is to identify how secure the surface water supply is for each town. Further analysis needs to be undertaken to understand how these risks can be met by existing alternative water sources that the towns already access.
- It is assumed that the current uses of water, in both general security and high security entitlements, are constant over the 40 years examined. In practice, it is likely that technology and global demand for food and fibre will change the nature of the crops produced in the North Coast and the amount of water used. Estimating these changes is beyond the regional water strategies project.

The following uncertainties and qualifications are relevant to this study.

- The town shortfall analysis presented is not a replacement for secure yield analysis undertaken by local water utilities as part of their integrated water cycle management strategies; however, it can be used as an input into determining the secure yield.
- 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.