NCEconomics

Paradise Dam Improvement Project Options Evaluation Report

November 2021

Proposal summary

Item	Description
Name of proposal	Paradise Dam Improvement Project – Stage 1 DBC Options Evaluation Report
Location of proposal	Paradise Dam, Burnett River, Queensland
Proposal owner	Sunwater
Proposal description	Improvements to Paradise Dam and associated infrastructure to meet dam safety and water supply and demand service needs

About this document

Natural Capital Economics Pty Ltd prepared the Paradise Dam Improvement Project Options Evaluation Report for the Department of Regional Development, Manufacturing, and Water (DRDMW). The core elements of the report are presented in this document. This document has been publicly released to ensure that stakeholders and community members are aware of the information that supported the Queensland Government decision. However, in making this report publicly available, information relating to names of stakeholder bodies, individuals, consultants, advisors and data sources have been removed. Additionally, financial information has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions. This information has been clearly marked.

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Citation

Natural Capital Economics (2021). Paradise Dam Improvement Project Options Evaluation Report.

Report Authors

The Options Evaluation Report was prepared and reviewed by Sunwater, the PDIP Project Development Team (comprising the Business Case Director, Business Case Management Services Team, technical and peer review advisors) with integral assistance from DRDMW.

Glossary

Abbreviations

Acronym	Description
AACE	Association for the Advancement of Cost Engineering
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AFC	Acceptable Flood Capacity
ALARP	As low as reasonably practicable
AMTD	Adopted Middle Thread Distance
ANCOLD	Australian National Committee for Large Dams
BCR	Benefit Cost Ratio
BCDF	Business Case Development Framework
BCMS	Business case management services
BQ	Building Queensland
BWPL	Burnett Water Pty Ltd
BWSS	Bundaberg Water Supply Scheme
CBA	Cost Benefit Analysis
CRA	Comprehensive risk assessment
CSSL	Costs to save a statistical life
DAF	Department of Agriculture and Fisheries
DBC	Detailed business case
DNRME	Department of Natural Resources, Mines and Energy
DPC	Department of the Premier and Cabinet
DRDMW	Department of Regional Development, Manufacturing and Water
DSDILGP	Department of State Development, Infrastructure, Local Government and Planning
DSR	Dam Safety Review
EOI	Expression of Interest
EPBC Act	Environmental Protection and Biodiversity Conservation Act
FAO	Food and Agriculture Organisation for the United Nations
FIA	Failure Impact Analysis
FID	Financial Investment Decision
FEAT	Farm Economic Analysis Tool
FSL	Full Supply Level
ha	Hectare
HP	High Priority
IBCR	Incremental benefit cost ratio
ILUA	Indigenous Land Use Agreement
INPV	Incremental net present value
LoT	Limit of Tolerability
IRR	Internal rate of return
MNES	Matters of National Environmental Significance

MP	Medium Priority
ML	Megalitres – one million litres
NCE	Natural Capital Economics Pty Ltd
NPV	Net present value
OA	Options Assessment
OE	The PDIP Options Evaluation
PAF	Project Assessment Framework
PAR	Population at risk
PBC	Preliminary business case
PDIF	Paradise Dam Industry Forum
PDIF WG3	Paradise Dam Industry Forum Working Group 3
PDIP	Paradise Dam Improvement Project
PLL	Potential loss of life
PMF	Probably Maximum Flood
PPP	Public private partnership
PSC	Project Steering Committee
PWG	Project Working Group
QCA	Queensland Competition Authority
RCC	Roller compacted concrete
RCP	Representative Concentration Pathway
SW	Sunwater
SASR	Strategic Assessment of Service Requirements
SRO	Senior Responsible Officer
SWOT	Strengths, weaknesses, opportunities, threats
TRP	Technical review panel
WTST	White-throated Snapping Turtle

Terminology

Term	Description
Alternative supply option	An alternative water supply to supplement the yield from the dam options so that the projected demand may be met.
Base case	The current Paradise Dam configuration following the Essential Works. The base case scenario is not an acceptable long-term solution, as further works are required to reduce dam risks to an acceptable level. As a result, the base case provides a counter-factual option against which proposal options are assessed.
Benefit cost ratio (BCR)	The benefits divided by the costs with a positive ratio indicating that benefits are greater than costs.
Central Case	The case used within the CBA modelling which represents the most likely scenario.
Dam option	An improvement option for Paradise Dam which meets dam safety requirements.
Distribution system upgrades	Upgrades to the water supply network to address constraints within the existing distribution system that have the potential to affect the capability of delivering the required yield to meet the projected demand.
Essential Works	Works to improve safety of Paradise Dam, in particular lowering of the primary spillway crest of Paradise Dam by five (5) metres.

Evaluation period	The period over which the evaluation for the preferred option is undertaken. For the Options Evaluation, this is a 30-year period up to 2050.
High Priority allocation	High Priority (HP) water allocations with a high reliability of supply. The HP product is typically purchased by urban, commercial, and industrial customers who require a consistent and very reliable supply of water.
Incremental Net Present Value (INPV)	An INPV enables analysis of the incremental differences between proposal options or even sub-options, for example, the additional net benefit of an alternative supply option, or the upgrade of the distribution system at a later date to ensure any emerging supply and distribution constraints are overcome.
Medium Priority allocation	Medium Priority (MP) water allocations with a medium reliability of supply. The MP product is typically purchased by irrigation customers who are comfortable with a potentially lower reliability of supply.
Medium Priority equivalent	The approach used in the demand analysis to present total demand or yield in similar units. MP equivalent total demand is based on total MP demands plus HP demands converted to MP equivalents.
Most likely	The case used within the CBA modelling which represents the central case (most likely scenario).
Net Present Value (NPV)	The NPV is a present value (all values discounted to present day terms) of the benefits less the present value of the costs. A proposal option with a high positive NPV has benefits that exceed the costs and would be preferred over a lower value. However, given the model limitations related to dam safety outlined above, a negative NPV is possible, where the economic estimate of benefits may be lower than the costs. When evaluating the proposal options under these circumstances, the option with the smallest negative NPV would be preferred.
Paradise Dam Options Assessment Report	The report issued in February 2020 analysing options for Paradise Dam. It concluded that a long-term recommendation was unable to be made due to the preliminary level of design and other technical and supporting information available at the time.
Projected demand	The estimated future demand (irrigation, urban and industrial) across the Burnett River subscheme to 2050.
Proposal option	An improvement option that will yield sufficient water and meet projected demand within the Burnett River subscheme, and includes a combination of a dam option, alternative supply options (if needed), and distribution system upgrades.
Scenario analysis	An analysis undertaken to determine the potential impact of variables on the evaluation results, for example a scenario analysis has been undertaken to identify the impact of climate change on yield.
Sensitivity analysis	An analysis undertaken to test the impact of changes to the input data in the economic model, for example, varying demand values.
Stage 1 DBC Options Evaluation	The work undertaken to identify a preferred option/s to progress to the Stage 2 DBC. This report sets out the approach, findings and recommendations of the Stage 1 DBC Options Evaluation.
Stage 2 DBC	The work following on from the Stage 1 DBC, to develop a full DBC for the preferred option/s.

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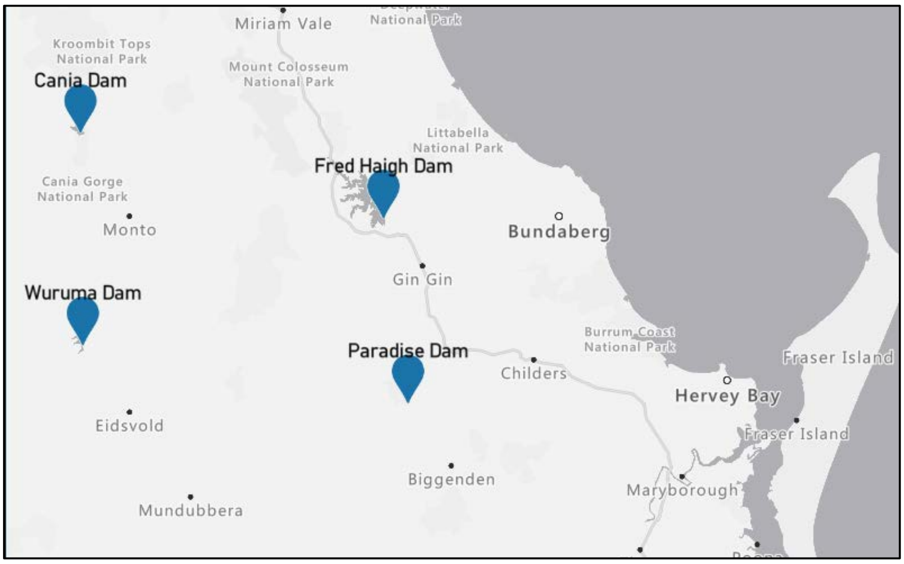
EXECUTIVE SUMMARY

Problem

Flood events in 2010, 2011 and 2013 caused extensive and unexpected scour damage to Paradise Dam, a roller compacted concrete structure on the Burnett River, approximately 80 kilometres southwest of Bundaberg.

Figure 1 Map of Paradise Dam



Source: Sunwater, 2021

Figure 2 Scour damage at Paradise Dam

Source: Sunwater 2021

These floods resulted in damage to the primary spillway apron and the area immediately downstream of the apron, and potential for further scour and undercutting of the dam. These flood events were substantially smaller than the maximum flows the dam had been designed to withstand.

Flood repairs were carried out in 2013. Investigations following these flood events identified structural concerns with the dam and subsequently led to early phase improvement works (2015 to 2017), and the establishment of the Paradise Dam Improvement Project (PDIP) in 2017 (the current project).

Further technical investigations, dam safety assessments and a Preliminary Business Case (PBC) led Sunwater to undertake additional sampling and testing in 2019 of the roller compacted concrete (the material in the dam wall). This confirmed a significantly increased risk of dam failure and led Sunwater to recommend to Government in September 2019 to undertake an immediate Essential Works project as early-stage improvement works, in advance of the broader PDIP which would take much longer to complete based on the likely full scope of works.

The Essential Works commenced in September 2019. Major construction was conducted over the period May 2020 to January 2021 to lower the primary spillway by 5.8m and temporarily strengthen the dam wall with 600 steel anchors. The seriousness of the dam safety concerns also triggered the 2019 Paradise Dam Preparedness Review by the Office of the Inspector-General Emergency Management and the Commission of Inquiry into Paradise Dam.

Following an Options Assessment (February 2020), Government directed that the Detailed Business Case (DBC) be progressed in two stages:

- Stage 1 DBC (this stage) – a detailed Options Evaluation of the three options highlighted in the Options Assessment. This would include a detailed demand assessment and economic analysis to identify a preferred long-term option that meets dam safety requirements and provides water security for the long-term future of the region.
- Stage 2 DBC – development of the DBC, and associated activities, for the preferred long-term option, recommending a final investment decision.

Service need

The two primary service needs for PDIP are dam safety and water supply and demand (water security).

Dam safety - Following completion of the Essential Works, which has significantly reduced the risk of dam failure, the dam does not currently meet the ANCOLD Guideline acceptable Limit of Tolerability, and requires further significant improvement works to reduce risks to an acceptable level in the long-term. Several detailed investigations were completed to inform the dam safety service need including:

- a comprehensive roller compacted concrete (RCC) sampling & testing program
- post-tensioned anchor trials
- development of a 3D geological model
- dam safety risk assessments
- concept design and options development.

Water supply and demand - There is a need to meet projected, long-term water requirements as and when required. Two key investigations were completed to inform the water supply and demand service need including:

- A detailed demand assessment of projected customer demands to 2050 including research on land use patterns, detailed consultations with customers and stakeholders, a regional survey, and development of a demand model.

- A yield assessment informed by detailed hydrological modelling to determine the volumes of water that can reliably be supplied each year to meet the projected demands. The assessment looked at yield from potential infrastructure options including Paradise Dam and alternative supply options within the Bundaberg Water Supply Scheme (BWSS) area, and more specifically the Burnett River subscheme area within the BWSS. The yield assessment also included an assessment of the potential impacts on yields from climate change.

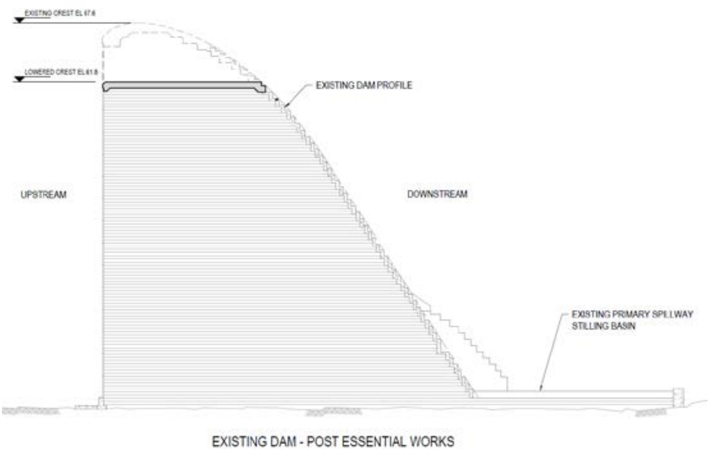
Two secondary service needs, environmental and social impacts, were also considered from a qualitative perspective.

Option development

Base case

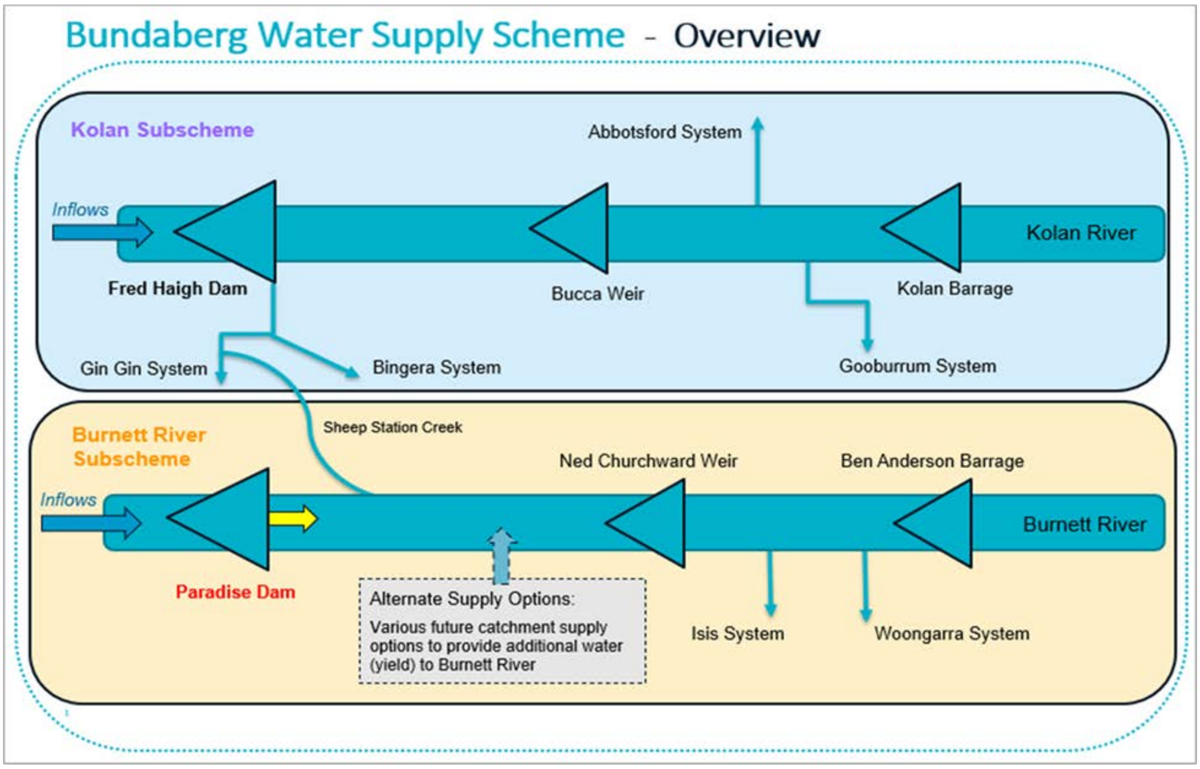
A base case was developed over a 30-year evaluation period to reflect the state of the dam at the completion of the Essential Works. It should be noted that while the base case is presented as a reference case for comparative purposes, it is not a viable long-term option as it does not meet the dam safety service need criteria.

Figure 3 Base case (current situation post essential works)



The geographical scope of the base case study area is principally the Burnett River subscheme (refer Figure 4) downstream of Paradise Dam, including other water supply sources, demand and customer areas along and adjacent (i.e., within 1 – 2 km) to the lower Burnett River. This includes Isis and Woongarra irrigation areas, and associated channel and water distribution infrastructure.

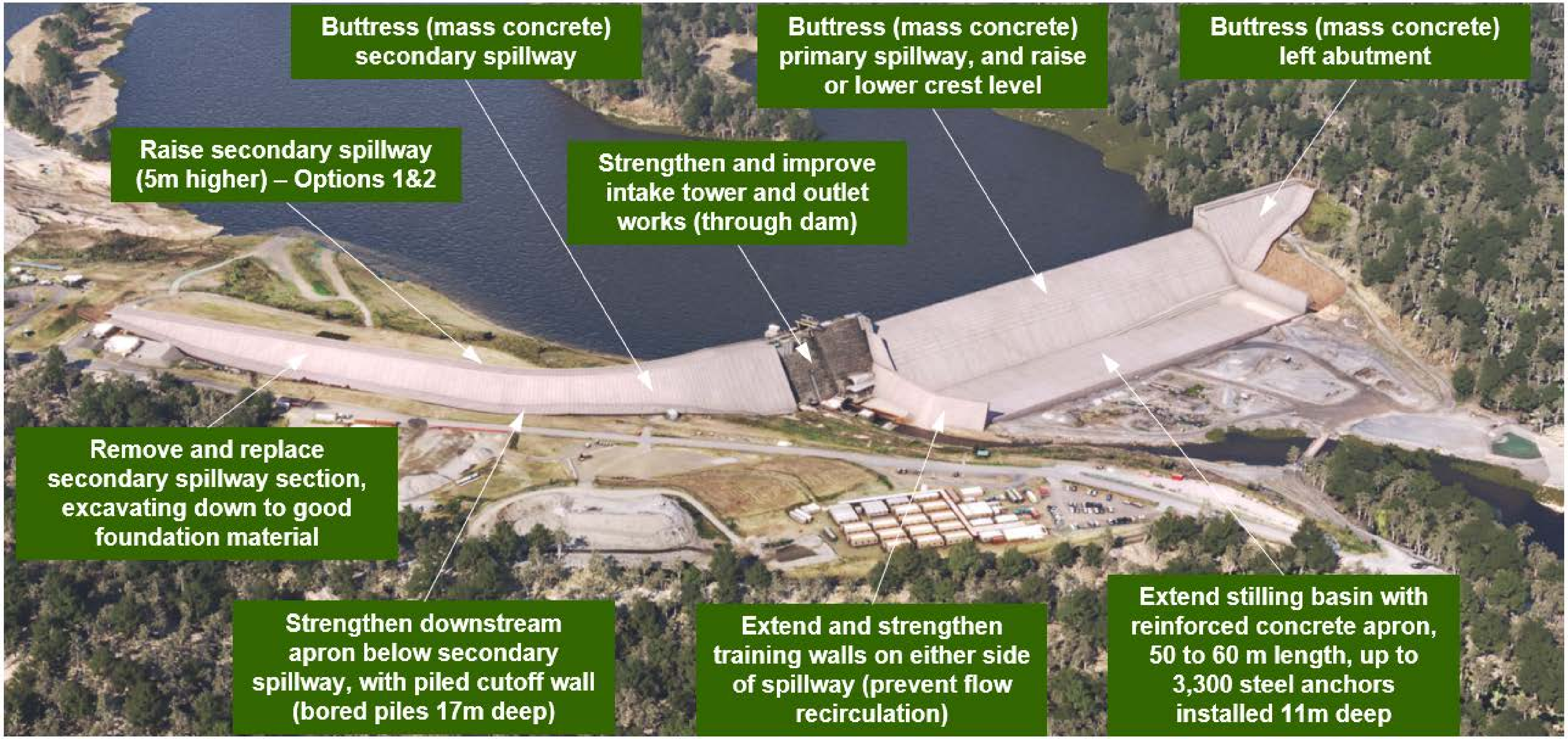
Figure 4 Burnett River subscheme



Addressing the dam safety service need

To meet the dam safety service need, remediation works are required on several elements of the dam, as shown in Figure 5. These remediation works are largely similar regardless of final height of the dam's primary spillway, as outlined below.

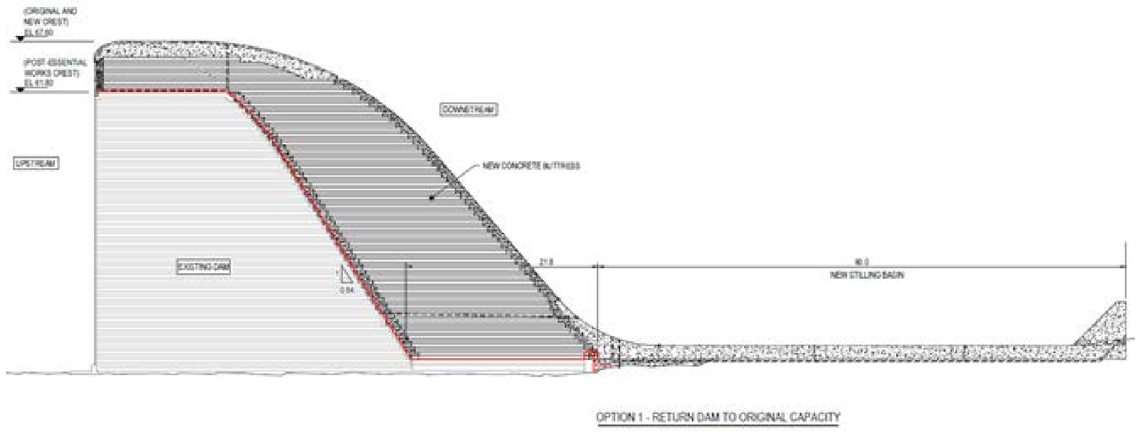
Figure 5 Summary of remediation and improvement works required to meet dam safety requirements



The three dam options analysed in this Options Evaluation are listed below and shown schematically in Figure 6, Figure 7 and Figure 8. These options are defined in terms of the primary spillway height as compared to the base case (i.e., the state of Paradise Dam following the Essential Works).

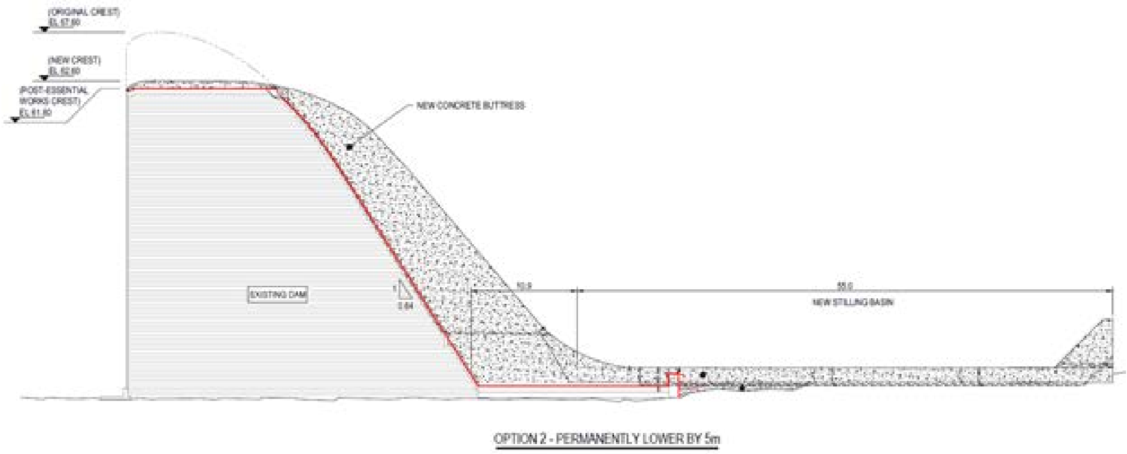
1. **Dam Option 1** – return the primary spillway back to its original height (Full Supply Level, FSL) (raising 5.8m above current temporary Essential Works level) plus associated improvement works

Figure 6 Dam Option 1 (return to Full Supply Level)



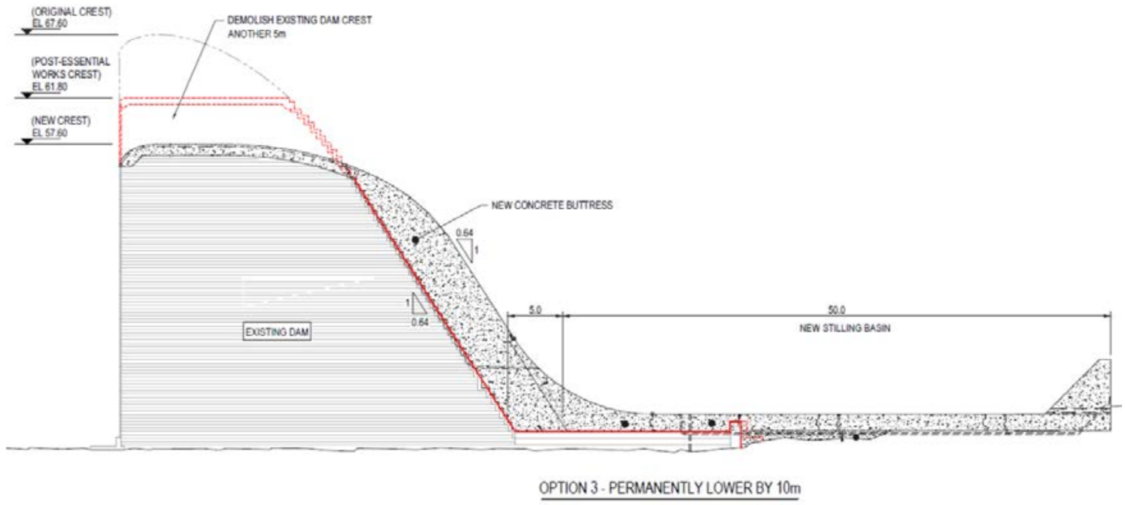
2. **Dam Option 2** – permanent lowering of the primary spillway level at 5m below the original height (raising 0.8m above Essential Works level) plus associated improvement works

Figure 7 Dam Option 2 (5m below original spillway level)



3. **Dam Option 3** – permanent lowering of the primary spillway to 10m below the original height (further lowering of 4.2m below Essential Works level) plus associated improvement works.

Figure 8 Dam Option 3 (10m below original spillway level)



Each of the dam options were assessed against the dam safety service need criteria (ANCOLD Guideline acceptable Limit of Tolerability for existing dams). The assessment determined that Dam Options 1, 2 and 3 satisfied this limit and were progressed for further assessment in the Options Evaluation.

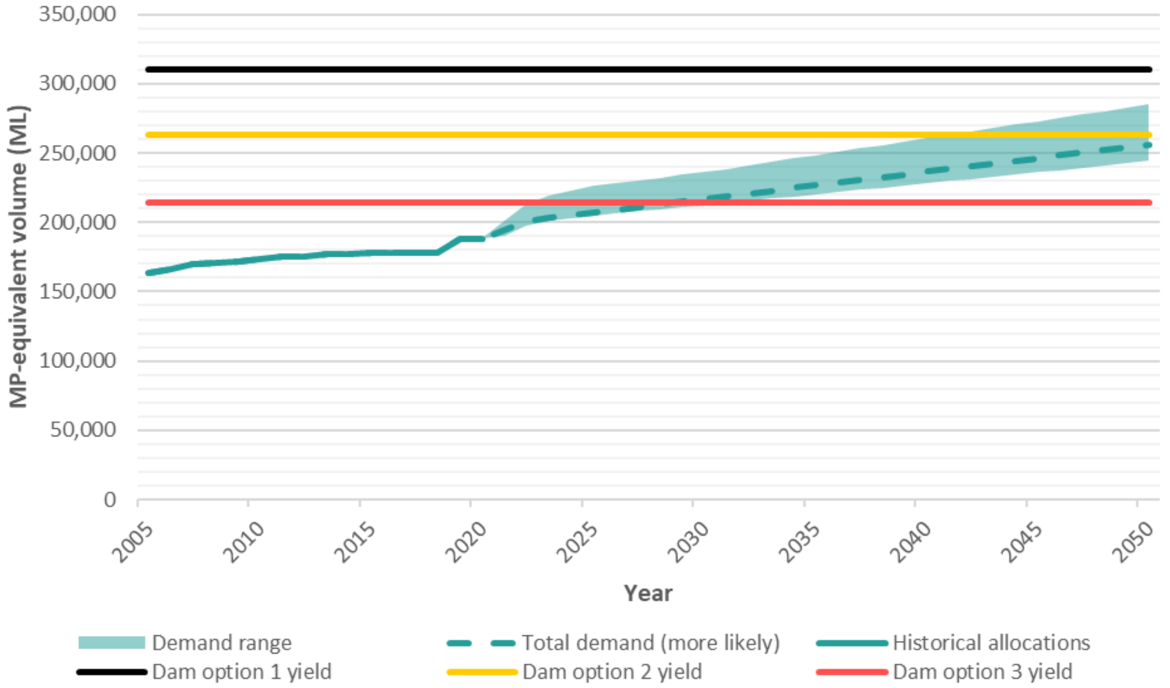
Addressing the water supply and demand service need

A detailed demand assessment was undertaken to establish the projected demands from urban, industrial and agricultural customers within the scope area. The assessment included a comprehensive stakeholder consultation process to define the water supply and projected demand to be met through the PDIP for the evaluation period up to 2050. The demand assessment identified:

- a significant structural shift in the irrigation industry in the Bundaberg region, involving the transfer of existing irrigated land use from sugar cane to perennial tree crops
- changed demand patterns and volumes and an unprecedented acceleration of demand growth in the region compared to historical growth trends
- the projected most likely increase in demand (from 2020 to 2050) was 68,100ML. This is the P50 of a probabilistic range of projected demands based on Monte Carlo simulations across the full range of inputs to the modelling.

Each of the three dam options were assessed against the increase in demand of 68,100ML. The results of the demand assessment compared to the water that would likely be available from the three dam options are presented in Figure 9. This shows Dam Option 1 meets the full range of projected demand. Dam Option 2 meets the most likely demand but does not meet scenarios above the most likely demand (P50) within the range, nor does it meet projected demand beyond 2053. Dam Option 3 does not meet the most likely demand. Dam Option 2 and 3 both require additional capital investment for alternative supply options to meet the service need and to be comparable to Dam Option 1.

Figure 9 Projected demand to 2050 with historical allocations and sub-scheme yields excluding alternative supply options



Notes:

- Total demand (more likely) represents the most likely projected demand from the demand assessment
- Historical allocations represent water sold from commissioning of the dam to 2020
- Dam option yields represent the totals available in the Burnett River subscheme under each dam option excluding alternative supply options.

Distribution system constraints

The demand assessment also identified capacity constraints in the distribution system impacting the ability to meet projected demand in the Isis and Woongarra irrigation areas. To resolve these constraints, upgrades of the distribution system infrastructure are required. The assessment grouped the upgrades into two tranches as follows:

- Tranche 1 is required to facilitate the distribution of water to meet short to medium-term demand growth. The scale, location and timing of these investment requirements is relatively certain (required by 2028) but requires detailed assessment to finalise scope for investment.
- Tranche 2, which are much larger upgrades, have been developed based on existing information and assumptions on longer-term demands. The requirement for these upgrades is certain, to meet the projected demand in the future. However, the type of augmentation, scale, location, and timing of much of Tranche 2 is uncertain as it ultimately needs to respond to future development and investment decisions of hundreds of irrigators. Detailed assessment of Tranche 2 will need to be performed at an appropriate time when development progresses in the region.

It is considered prudent and efficient to address distribution system constraints, regardless of selection of dam option, when the scale, location and timing can be more accurately estimated. As a result, distribution system upgrades are recommended to be the subject of separate assessment and investment consideration, with the assessment of Tranche 1 being the priority.

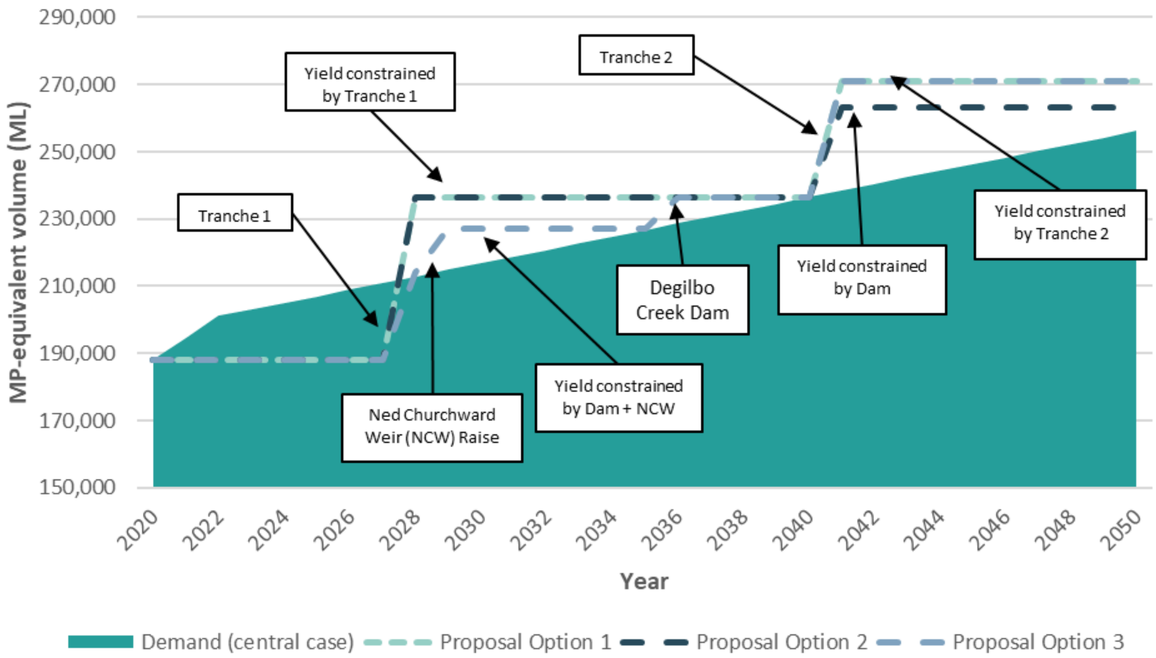
Proposal options

Where dam options alone were not capable of meeting the service need (assuming the most likely projected demand), alternative supply options were added to meet the projected demand. These are defined as proposal options.

- **Proposal Option 1**: Dam Option 1 plus upgrades to the distribution system (Tranches 1 and 2). This meets the most likely projected demand to 2050 and does not require alternative supply.
- **Proposal Option 2**: Dam Option 2 plus upgrades to the distribution system (Tranches 1 and 2). This meets the most likely projected demand to 2050 but requires alternative supply (raising the existing Ned Churchward Weir) by 2053. To meet this date, works for the proposed alternative supply need to commence within the evaluation period by 2046.
- **Proposal Option 3**: Dam Option 3 plus upgrades to the distribution system (Tranches 1 and 2). This requires two alternative supplies (raising the existing Ned Churchward Weir and building a new dam, Degilbo Creek Dam) to meet the most likely projected demand to 2050.

Figure 10 below shows the most likely projected demand, deliverable yields for each dam option, alternative supply required and upgrades to the distribution system (Tranches 1 and 2).

Figure 10 Proposal options deliverable yields to meet projected demand



Notes:

- Deliverable yield is a combination of dam option yield, alternative supply option yields, and distribution system capacity to deliver.
- At the time of writing the timing and sequencing of construction works for the PDIP and the Tranche 1 upgrade are not yet finalised. For simplicity and consistency in comparing dam options it has been assumed the works are completed and commissioned in the short term. The tranche 1 upgrades are also identical for each option and will not have any bearing on the comparative assessment of options.
- Proposal Option 3 is generally limited by the yield available from supply sources, more so than distribution system capacity. Proposal Options 1 and 2 are initially limited by distribution system capacity until 2040 and are then only limited by the yield available from supply sources.

Analysis – most likely projected demand

The following analyses were conducted on Proposal Options 1 and 2 to provide a comparison against the base case and against each other.

- Pricing
- Financial analysis
- Cost Benefit Analysis
- Qualitative assessment of environmental, social impacts and approvals required

Proposal Option 3 was identified as being cost-prohibitive due to its requirement for expensive alternative supply options, particularly the construction of a new Degilbo Creek Dam. Proposal Option 3 was filtered from further analysis.

Pricing (most likely projected demand)

Under Australian and Queensland government policy, water prices should seek to recover the full cost of water supply, including infrastructure costs.

As part of a decision on irrigation pricing in 2020, the Queensland Government has put in place a policy to fund the irrigators' share of dam safety upgrade costs, (i.e., these costs will not be recovered from irrigators). While this decision was made in relation to regulated irrigation schemes (where the Queensland Competition Authority recommends prices), for consistency it has been assumed that the same policy will apply to Paradise Dam safety upgrade costs.

Given this, the options evaluation has assumed current prices for Medium Priority (MP) and High Priority (HP) water (which do not include the recovery of any dam safety costs) for estimating revenue in the modelling, as outlined in section 8.3.13.

Financial Analysis (most likely projected demand)

A Class 4 cost estimate was prepared on the concept level designs for Proposal Options 1 and 2. As such costs should be considered preliminary in nature. Probabilistic risk modelling was performed in relation to the capital costs and operating and maintenance costs associated with each of the base case and proposal options to produce risk-adjusted project costs.

Table 1 below presents P90 (a 90 percent probability that the total project costs over the evaluation period will not be exceeded) capital expenditure (Capex) for Proposal Options 1 and 2 assuming the most likely projected demand.

Table 1 Capital expenditure outputs (most likely demand)

P90 Nominal, $'M	Proposal Option 1 P90	Proposal Option 2 P90
Dam Improvement Capex	CIC[1]	CIC[2]
Ned Churchward Weir Raising	-	CIC
Degilbo Creek Dam	-	-
Tranche 1 Distribution System Upgrade	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC
Other Capex	CIC	CIC
TOTAL CAPEX	**CIC**	**CIC**

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

[1] Dam Option 1
[2] Dam Option 2

The following key observations were made:

1. Dam Improvement Capex is similar between Dam Options 1 and 2 as they have common items of scope (as shown in Figure 5) including:
    a. Secondary spillway and left abutment buttress (addition of mass concrete strengthening)
    b. Secondary spillway raising by 5m in height (reduce overtopping frequency in this area)
    c. Demolition of half of the secondary spillway and excavation down to good foundation material, and reconstruction of this section of wall
    d. Temporary coffer dam to support item c. above
    e. Downstream scour protection below the secondary spillway and left abutment
    f. Extension of the existing apron below the primary spillway (significant scour protection)
    g. Construction and extension of training walls either side of the primary spillway and apron
    h. Improvement and modifications to the intake tower and outlet works
2. Proposal Option 2 includes capex for alternative supply (Ned Churchward Weir raising required by 2053), which requires work to commence across the period 2046-52, however only costs up to 2050 are included.
3. Upgrades to the distribution system are common to both Proposal Options 1 and 2
4. Other Capex consists of minor improvement works anticipated for Ned Churchward Weir in the medium term, irrespective of any weir raising.

After taking into consideration capital expenditure, operational expenditure and revenue, assuming the most likely projected demand, the project Financial Net Present Values (NPV)[3] are presented in Table 2 below.

Table 2 Financial Project outcomes (most likely projected demand)

Project outcome	Unit	Proposal Option 1 P90	Proposal Option 2 P90
Cost (Capex + Opex)	Nominal	CIC	CIC
Revenue	Nominal	CIC	CIC
Surplus/(Deficit)	**Nominal**	CIC	CIC
Discounting @ 1.95%	Nominal	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The NPV for both Proposal Options 1 and 2 is negative, as the costs for both options are greater than revenue derived from the sale of water. Whilst Proposal Option 2 has a greater cost than Proposal Option 1, its NPV is slightly better as the requirement for the alternative supply (Ned Churchward Weir raising) occurs across the end of the evaluation period (2046-2052). The small NPV difference between Proposal Options 1 and 2, assuming the most likely projected demand, is due to scope commonality of dam improvement works. Note that only costs to 2050 have been captured in Table 2 above.

[3] Financial Net Present Value is calculated by the present value (all values discounted to present day terms) of the revenues less the present value of the costs.

Cost Benefit Analysis (most likely projected demand)

The Benefit Cost Ratios (BCR)[4] calculated, assuming most likely demand over a thirty (30) year evaluation period, were Proposal Option 1: **0.137**, and Proposal Option 2: **0.152**. The outcomes from the cost benefit analysis were less than 1.0, indicating that both proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.

It is noted that the safety improvements already achieved through the Essential Works are not captured in this economic analysis.

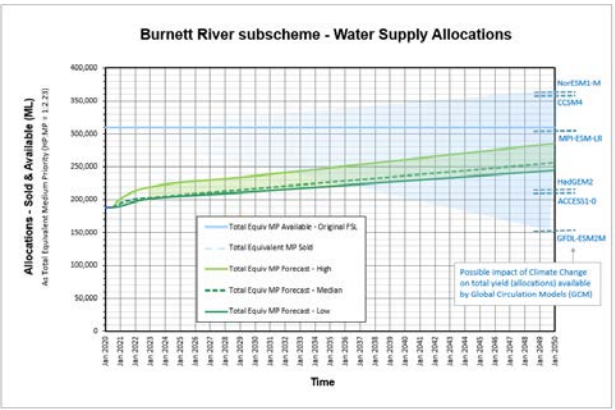
Analysis – climate change scenario

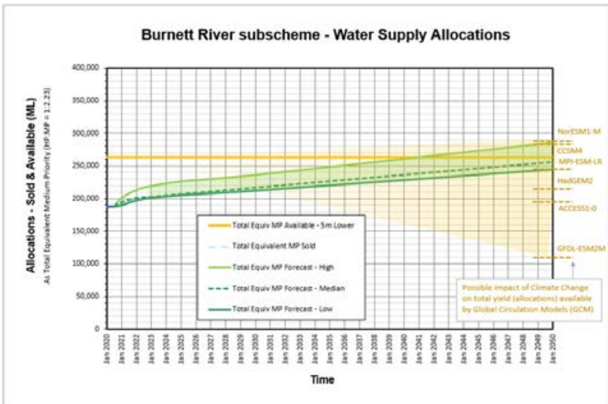
Financial analysis (climate change scenario – impact on yield)

There is acknowledgement across academia, industry and governments that climate change will have an environmental impact in the future. This impact may affect the performance of Paradise Dam throughout the evaluation period. The nature of this impact has been estimated through climate change modelling, which is a developing field that indicates potential negative and positive impacts through changes to rainfall, runoff and evapotranspiration. Due to the developing nature of the field, its outputs should be treated with caution.

A scenario on the impact of climate change on yield (reliable supply from storages from catchment inflows) was assessed using the outputs from six different climate change models, using emission scenario Representative Concentration Pathway RCP 8.5 (recommended as discussed with government representatives and consistent with the advice of the hydrology consultant and peer reviewer). The outputs of this assessment are presented in Figure 11.

Figure 11 Potential Climate Change Impacts on Yield of Dam Options 1 (left) and 2 (right)





As shown in Figure 11, the model outputs indicate that climate change may have a positive or negative impact on the available yield of dam options. Climate change sensitivity analysis further indicates that there is generally a greater potential negative impact to water security than a potential positive impact. In the event where negative impacts predicted from the models are realised, alternative supply options are more likely to be required, and required earlier, within the evaluation period.

Yield estimates for four out of the six assessed global circulation models (GCMs) indicated negative impacts and two out of the six indicated positive impacts. Four outcomes (excluding the extreme highest and lowest results) provided a range of outputs to inform the scenario analysis.

[4] Benefit Cost Ratio (BCR) divides the present value of estimated benefits by the present value of estimated costs. A ratio of one or more indicates economic viability where the assessed benefits to society are greater than the assessed costs.

Based on this yield scenario, Proposal Option 1 will still meet projected demands. Proposal Option 2 will require amendment to meet projected demand, as the original infrastructure configuration of this option no longer meets the service need. The construction of Degilbo Creek Dam may be required (to replace the raising of Ned Churchward Weir) in this scenario, significantly increasing capital expenditure to this option. This outcome is based on the yield scenario, while other yield scenarios may result in different infrastructure requirements.

Capital expenditure for each updated proposal option assuming climate change is provided in Table 3. Proposal Option 3 has been excluded from consideration in this scenario analysis as it cannot meet projected demand in this analysis.

Table 3 Capital expenditure outputs (impact of climate change)

P90 Nominal, $'M	Proposal Option 1 P90	Proposal Option 2 P90
Dam Improvement Capex	CIC	CIC
Ned Churchward Weir Raising	-	-
Degilbo Creek Dam	-	CIC
Tranche 1 Distribution System Upgrade	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC
Other Capex	CIC	CIC
TOTAL CAPEX	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

After taking into consideration capital expenditure, operational expenditure, and revenue, assuming the impact of climate change, the Project Net Present Values (NPV) are presented in Table 4 below.

Table 4 Financial Project outcomes (impact of climate change)

		Proposal Option 1 – Climate Change	Proposal Option 2 – Climate Change
Project outcome	**Unit**	**P90**	**P90**
Cost	Nominal	CIC	CIC
Revenue	Nominal	CIC	CIC
Surplus/Deficit	**Nominal**	CIC	CIC
Discounting @ 1.95%	Nominal	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The worsening of the NPV for Proposal Option 2 compared to Proposal Option 1 is due to the requirement of alternative supply for Proposal Option 2 within the evaluation period.

Cost Benefit Analysis (climate change scenario)

The Benefit Cost Ratios (BCR) calculated for this scenario, assuming most likely demand over a thirty (30) year evaluation period, were Proposal Option 1: **0.137** (no change), and Proposal Option 2: **0.112** (reduced from 0.152 assuming no climate change impact). The outcomes from the cost benefit analysis were less than 1.0, indicating that both proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.

Analysis – other scenarios

Cost Benefit Analysis (other scenarios)

A range of other scenarios, selected in consultation with key project stakeholders, were analysed to investigate the impact of alternative futures and different combinations of inputs on the outcomes of the options evaluation. The scenarios selected and the outcomes of the analyses are described below:

- Under the accelerated tree crop growth scenario, Proposal Option 1 performs well but Proposal Option 2 requires alternative supply options, at significant cost, earlier in the evaluation period.
- Under the delayed dam fill period scenario, the impacts are applied equally across all proposal options and as such, has no effect on the ranking of options.
- Under the extended evaluation period of 40 years (and two separate scenarios where demand either continues to increase or plateaus beyond the original 30-year evaluation period), additional alternative supply is required for Proposal Option 2 to meet projected demand for both scenarios, resulting in more favourable performance for Proposal Option 1.
- A staged approach to Proposal Option 1 (based on timing of the construction works to ensure yields meet projected demands), was considered. While detailed costs for this scenario have not been developed, the incremental cost of future raising works required (expected around 2042, based on probabilistic demand modelling) would need to be less than CIC (undiscounted), or CIC in present value terms (using a 7% real discount rate), to provide the same or better net present value outcomes as Proposal Option 1 (initial analysis suggests this is unlikely).

Analysis – social and environmental

Environmental and social impacts attributable to each of the proposal options were assessed at high level through a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. These impacts were defined as secondary service needs for PDIP and if material, may impact the assessment of which option/s should be progressed to the Stage 2 DBC.

The SWOT analysis found:

- Proposal Option 2 is likely to require a new Commonwealth referral for environmental approval process for PDIP, as the scope of works are different to those covered under existing approvals, which may lead to delays in obtaining approvals. Proposal Option 1 however, is likely to require only a minor variation to existing Commonwealth approvals (for Paradise Dam) as the original structure and full supply volume is reinstated.
- The alternative supply options required for Proposal Option 2 will impact upon greenfield areas and therefore require detailed impact assessments before works can commence. Proposal Option 1 avoids this requirement as no alternative supply options are required.

Given the largely desktop nature of the social and environmental analysis, specific climate change impacts in relation to these areas were not undertaken. Further work on the potential social and environmental impacts will be conducted in the Stage 2 DBC.

Analysis – approvals

A range of environmental and planning approvals are required for the delivery of PDIP under both Commonwealth and State legislation. At the State level, there are two overarching approvals processes available to permit the PDIP options to proceed – a Ministerial Infrastructure Designation or a Coordinated Project process. Each process has its own pros and cons however both are established, business-as-usual government procedures applicable to projects the size of PDIP and, as such, are known and well understood. The main factor in determining which of these processes Sunwater, as project proponent, will follow relies upon the Commonwealth Government approvals pathway.

Under Proposal Option 1, (that reinstates the dam to its originally approved state and that does not require new alternative supply options), it may be possible to proceed through a variation to the existing EPBC Act approval. In this case, due to the simpler approvals regime likely to be required by the State, Sunwater would apply to amend the existing Ministerial Infrastructure Designation.

Proposal Options 2 and 3 however, have more complex approvals requirements. New referrals for a 'controlled action' (and possibly preparation of Environmental Impact Statements for new development) would be required for changes to the dam to the extent that the original approval would no longer apply, as well as elements of greenfield development. Under the latter scenario, due to the extra level of assessment and coordination that would be required, at the State level, application for a Coordinated Project designation through the Office of the Coordinator-General, would be likely.

Findings

Dam Safety

- Despite completion of the Essential Works, which has significantly reduced the risk of dam failure, the dam does not currently meet the ANCOLD Guideline acceptable Limit of Tolerability and requires significant improvement works to reduce risks to an acceptable level in the long-term.
- Dam Options 1, 2 and 3 all satisfied this limit of tolerability.

Water Supply and Demand

- Dam Option 1 meets the full range of projected demands.
- Dam Option 2 meets the most likely projected demand but does not meet projected demands above P50, nor does it meet projected demand beyond 2053.
- Dam Option 3 does not meet the most likely projected demand.
- Dam Option 2 and 3 both require expensive alternative supply options to meet the service need and to be comparable to Dam Option 1.
- The demand assessment also identified constraints in the distribution system. Whilst the impact of these constraints has been considered in this analysis, it is considered prudent and efficient to address the distribution system requirements when the scale, location and timing can be more accurately estimated. The current assessment noted:
    - Tranche 1 is required to facilitate the distribution of water to meet short to medium-term demand growth. The scale, location and timing of these investment requirements is relatively certain (required by 2028) but requires detailed assessment to finalise scope for investment.
    - Tranche 2, which are much larger upgrades, have been developed based on existing information and assumptions on longer-term demands. The requirement for these upgrades is certain, to meet the projected demand in the future. However, the type of

augmentation, scale, location, and timing of much of Tranche 2 is uncertain as it ultimately needs to respond to future development and investment decisions of hundreds of irrigators. Detailed assessment of Tranche 2 will need to be performed at an appropriate time when development progresses in the region.

Proposal Options

- Proposal Option 1 meets the most likely projected demand to 2050 and does not require alternative supply. Proposal Option 1 includes: Dam Option 1 plus upgrades to the distribution system (Tranches 1 and 2).
- Proposal Option 2 includes: Dam Option 2 plus upgrades to the distribution system (Tranches 1 and 2 as above). Proposal Option 2 meets the most likely projected demand to 2050 but requires alternative supply (raising of existing Ned Churchward Weir selected as a minimum) by 2053. This will require the proposed alternative supply works to commence by 2046.
- The ability of Proposal Option 3 to meet demand was determined to be cost prohibitive due to the need for expensive alternative supply (raising of existing Ned Churchward Weir and the new Degilbo Creek Dam). Proposal Option 3 was filtered from further analysis.

Financial and Cost Benefit Analysis

Table 5 Outcomes of Financial and Cost Benefit Analysis

	Proposal Option 1 P90 $'M Nominal	Proposal Option 2 P90 $'M Nominal	Proposal Option 2 (climate change) P90 $'M Nominal
Dam Improvement Capex	CIC	CIC	CIC
Ned Churchward Weir Raising	-	CIC	-
Degilbo Creek Dam	-	-	CIC
Tranche 1 Distribution System Upgrade	CIC	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC	CIC
Other Capex	CIC	CIC	CIC
Total Capex	CIC	CIC	CIC
Total Opex	CIC	CIC	CIC
Total Proposal Option Cost	CIC	CIC	CIC
Total Proposal Option Revenue	CIC	CIC	CIC
Discounting @ 1.95%	CIC	CIC	CIC
Project Financial NPV (P90 $'M)	CIC	CIC	CIC
Benefit Cost Ratio (BCR)	**0.137**	**0.152**	**0.112**

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Note: Benefit Cost Ratio is calculated using an economic discount rate of 7%

- Capital expenditure for Proposal Option 2 was comparatively higher due to the requirement of alternative supply (i.e., Ned Churchward Weir Raise) which occurs across the end of the evaluation period (2046 – 2052).

- Dam improvement capital expenditure is similar between Proposal Options 1 and 2 as they have common items of scope.
- The BCR outcomes from the cost benefit analysis were less than 1.0, indicating that both proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.
- Consideration of the impact of climate change, through analysis of the yield scenario, results in a change in infrastructure required for Proposal Option 2, with the impact on P90 cost, NPV and BCR shown. Regardless of yield scenario chosen, Proposal Option 2 is more sensitive to the reduction in yield that may arise based on the various climate change models, which may impact the alternative supply options selected.

Environmental, Social and Approvals

- Proposal Option 2 is likely to require a new Commonwealth referral for environmental approval process for PDIP, as the scope of works are different to those covered under existing approvals. Proposal Option 1 however, is likely to require only a minor variation to existing Commonwealth approvals (for Paradise Dam) as the original structure and full supply volume is reinstated.
- The alternative supply options required for Proposal Option 2 will also impact upon greenfield areas and therefore require detailed impact assessments before works can commence. Proposal Option 1 avoids this requirement as no alternative supply options are required.
- Proposal Option 1 may be able to proceed through a variation to the existing EPBC Act approval. However, Proposal Option 2 will have more complex approval requirements (change to the original dam) new referrals for a 'controlled action' (and possibly preparation of Environmental Impact Statements for new development) would be required. Application for a Coordinated Project designation through the Office of the Coordinator-General, would be likely, and result in a risk of delay.

Summary Findings

- Table 6 below provides a summary of options evaluation outcomes:

Table 6 Summary of Options Evaluation outcomes

Assessment category	Proposal Option 1	Proposal Option 2
Design meets safety requirements – ANCOLD / ALARP	✓	✓
Meets most likely projected demand	✓	✓
Meets projected demand under impacts of climate change	✓	×
Total cost of all works	CIC	CIC

Assessment category	Proposal Option 1	Proposal Option 2
Cost of dam improvement only (P90, $'Nominal)	CIC	CIC
Timing of alternative supply (if required), and additional environmental risk / approval	✓ Not required	× FY46 to FY52
Cost of alternative supply (P90, $'Nominal)	✓ Nil	× CIC (+ post FY50 costs)
Cost of distribution system upgrade for infill development (Tranche 1) (P90, $'Nominal)	Same for both options	
Cost of distribution system upgrade for new development (Tranche 2) (P90, $'Nominal)	Same for both options	
Other costs (minor capex, operations and maintenance, etc)	Same for both options	
Commonwealth environmental approvals[5] (for Paradise Dam scope only, not alternative supply)	✓ variation	× new Referral
Proposal option NPV (P90 $'Nominal, most likely projected demand, no climate change impacts)	× (CIC)	✓ (CIC)
Proposal option NPV (P90 $'Nominal, most likely projected demand, with climate change impacts)	✓ (CIC)	× (CIC)
BCR (most likely projected demand)	× 0.137	× 0.152
BCR (most likely projected demand, climate change impacts)	× 0.137	× 0.112

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

[5] It should be noted that approvals processes cannot be pre-empted, however this depiction aims to describe the relative prospects of a favourable approval.

Conclusions

- It is considered prudent and efficient to address distribution system constraints, regardless of selection of dam option, when the scale, location and timing can be more accurately estimated. As a result, distribution system upgrades (Tranches 1 and 2) are recommended to be the subject of separate assessment and investment consideration, with the assessment of Tranche 1 being the priority.
- The BCR and NPV analysis indicates that there is a marginal difference between Proposal Option 1 and Proposal Option 2, with Proposal Option 2 slightly more favorable. However, investment preference towards Option 1 becomes more favorable when the following additional factors are considered:
    - Proposal Option 1 is the only option that meets the most likely projected demand to 2050 without the need for alternative supply.
    - Under a climate change scenario (using a range of climate change models), Option 1 is the only option that meets most likely projected demand to 2050, even with a decreased yield attributable to climate change, without the need for alternative supply.
    - The BCR and NPV analysis indicates that Option 1 becomes more favourable under a climate change scenario due to the Capex increase resulting from the need to shift the alternative supply from Ned Churchward Weir Raise to Degilbo Creek Dam to address climate change impacts on yield and capacity to meet longer term demand.
        - There is a high degree of uncertainty in climate change modelling and impacts on yield is variable. As such, scenario modelling outcomes should be treated with caution, Nevertheless, modelling outcomes indicate that the larger the capacity of the supply option (dam option or alternative supply option), the more resilient the infrastructure is to downside climate change impacts on dam inflows.
    - CBA sensitivity analysis further indicates that:
        - Option 1 is more favourable where demand is materially higher than the most likely projected demand as alternative supplies may be required to complement Option 2.
        - Option 1 is more favourable where the evaluation period is extended to 40 years to account for longer term demand.
    - Proposal Option 1 will cost less than Proposal Option 2 and 3 over the evaluation period as it does not require additional investment in new alternative supply.
    - Proposal Option 1 may be able to proceed through a variation to the existing EPBC Act approval and avoid the need to apply for a Coordinated Project designation as it this option returns the dam to the full supply level and avoids the need for alternative supply.
- A range of specific elements including detailed design, further development of the cost estimate, environmental and legal approvals, water supply during construction, affordability and constructability require further consideration as part of the next stage of considering the project (DBC stage 2).
- As a result of addressing distribution system constraints within a separate assessment, the total capital expenditure relating to Proposal Option 1 includes the cost of the dam improvement plus Other Capital Expenditure.

- The total estimated capital expenditure for Proposal Option 1 is based on a concept level of design and subject to a number of uncertainties, including global production and supply volatility as a result of the Covid-19 pandemic.
- Whilst the next stage of project development (DBC stage 2) will increase design definition, increase the accuracy of cost estimation and potentially identify innovation and efficiencies, there is also the possibility of uncovering costs unforeseen as a result of engaging with the market for more firm pricing.

Recommendations

It is recommended that Proposal Option 1 proceeds as follows:

- Sunwater to lead the next stage of project development (Detailed Business Case Stage 2) for returning Paradise Dam to its original full supply level (Dam Option 1).
- Separately, Sunwater to further investigate and assess relevant distribution system capacity constraints.

1 BACKGROUND AND SCOPE

1.1 Purpose

This document describes the process and findings of the Paradise Dam Improvement Project (PDIP) Stage 1 Detailed Business Case (DBC) Options Evaluation (OE). The OE was undertaken to determine the recommended spillway crest level in association with improvement options for the long-term remediation of Paradise Dam, delivered through the PDIP. The PDIP was identified as a high priority project for Sunwater after extreme flooding events in 2010/11 and 2013 led to the identification of critical dam safety issues.

Queensland Government provided a clear direction for the OE to assess options against their ability to meet dam safety requirements and provide water security for the long-term future of the Wide Bay-Burnett region, and more specifically to the Burnett River subscheme irrigation area located downstream of Paradise Dam. The outcomes of the OE will facilitate government decision making about the long-term option to remediate Paradise Dam.

This OE is aligned with the guidance provided in the Business Case Development Framework (BCDF). It sets out the technical, financial, commercial and affordability impacts of a series of options while also considering high-level social and environmental impacts.

This first chapter of the OE sets out the project history for PDIP and the scope of the options evaluation.

1.2 Project history

1.2.1 Bundaberg Water Supply Scheme

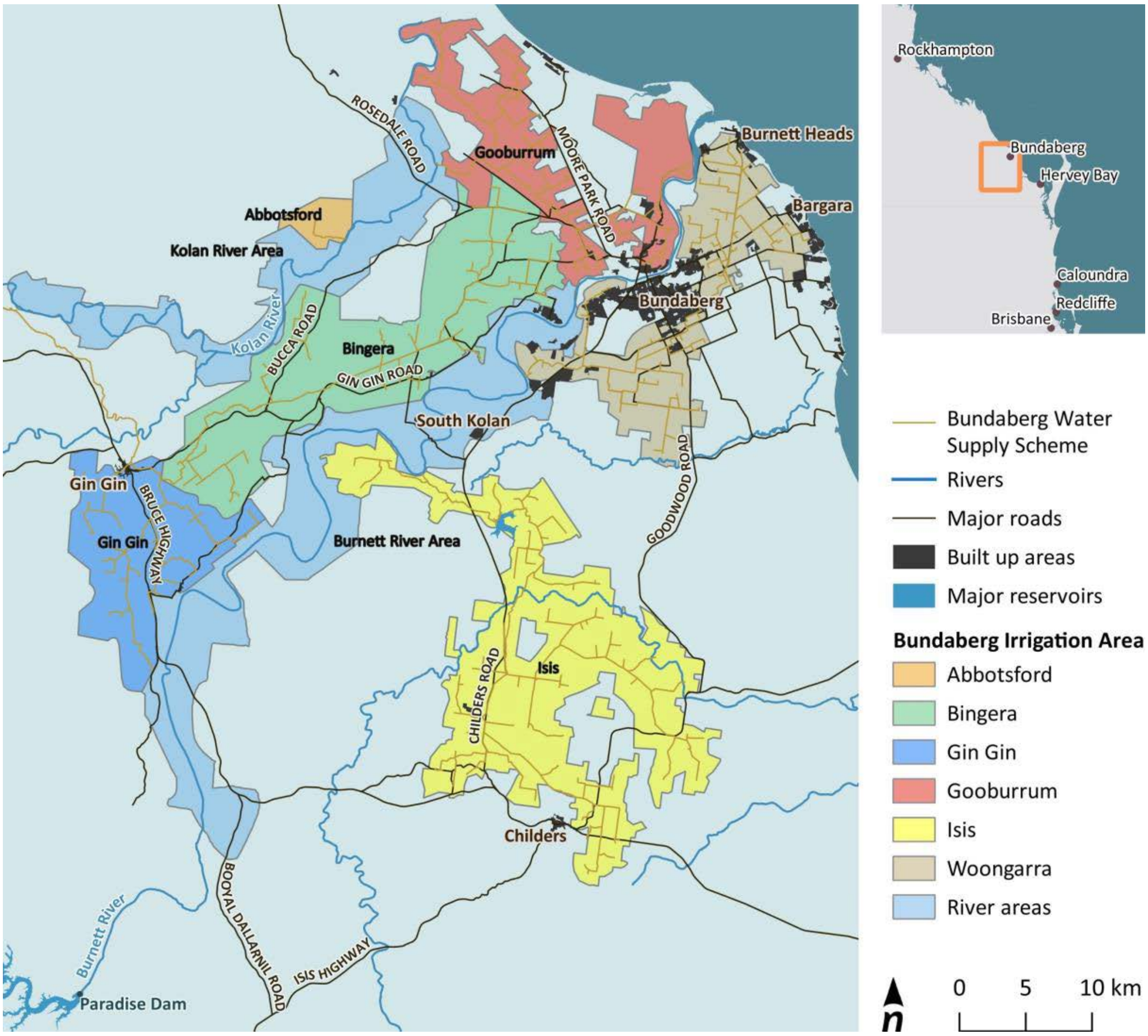
In 1970 the Queensland Government adopted a proposal for a two-phase water supply scheme for the Bundaberg district. Construction of the Bundaberg Water Supply Scheme (BWSS) began that year, with the second phase completed in 1993. Ned Churchward Weir was added to the scheme in 1998. As one of the driest sugar-producing areas in Queensland, the scheme was constructed to supplement natural rainfall and provide surface water irrigation to established sugar cane farming areas around Bundaberg, which were facing salinity issues associated with seawater ingress into groundwater supplies that until the early 1970s were used to irrigate crops.

Through the scheme, water is supplied to farmlands and communities in the Burnett, Kolan and Isis Shires as well as Bundaberg city. The scheme sources water from Fred Haigh and Paradise dams, Ned Churchward and Bucca weirs, and two barrages to service more than 1,100 farms, the city of Bundaberg, and several other communities in the Burnett, Kolan and Isis shires. The scheme consists of seven distinct channel systems, featuring 600 kilometres of channels and pipelines that supplement or replace demand for groundwater throughout the district.

The BWSS was designed primarily with sugar cane production in mind. This formed the basis of the design and sizing of the infrastructure within the scheme and allowed for delivery of 4.5 megalitres (ML) of water per hectare to supplement rainfall. Original water allocations and assigned flow rates were based upon land area under cane consignment in 1970. Channel/pipeline networks were sized to enable water to be delivered in line with the traditional 90 to 120-day active growing season for cane. This was delivered to farmers via a rostered flow applied to each metered outlet within a 15-day roster cycle based on land under production at the time.

Sunwater still operates the scheme with water user allocations consistent with the original assigned flow rates for individual metered outlets. The scheme is illustrated in Figure 12.

Figure 12 Bundaberg Water Supply Scheme (BWSS) map

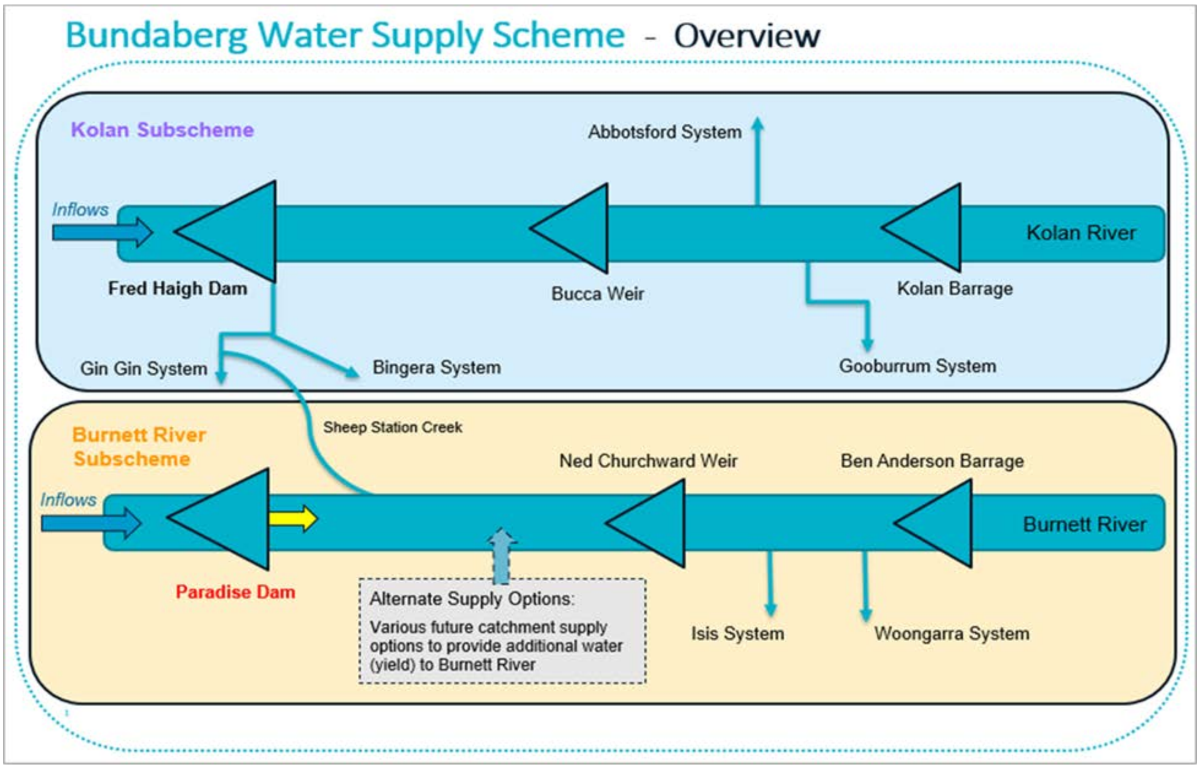


Source: Sunwater

The BWSS comprises two subschemes within its area. One is the Kolan River subscheme, which is primarily supplied by Fred Haigh Dam with a secondary supply from the Kolan River. This subscheme services the Abbotsford, Gooburrum, Bingera and Gin Gin irrigation areas. The other subscheme is the Burnett River subscheme, primarily supplied by Paradise Dam, with a secondary supply from the Burnett River. This subscheme services the Woongarra and Isis irrigation areas. Water can be supplied to a limited extent from the Kolan River subscheme to the Burnett River subscheme, though not in reverse, and in general the two subschemes operate relatively independently from each other. A schematic model of the subschemes is shown in Figure 13.

While the demand assessment undertaken to inform this evaluation considers water supply needs across the overall BWSS, the OE itself focuses on the assessment and analysis results of options located within the Burnett River subscheme only. Refer to section 1.4.2 for further details on the geographical scope of the OE.

Figure 13 Schematic model of the Kolan and Burnett River subschemes within the BWSS



Source: Sunwater

1.2.2 Construction of Paradise Dam

Paradise Dam (formerly known as the Burnett River Dam) was designed and built between 2003–2005 to provide much needed water infrastructure to the Wide Bay-Burnett region. The dam was constructed upstream of Bundaberg on the Burnett River to provide additional water supply for irrigation and urban areas around Bundaberg. Limited upgrades to the distribution system were implemented at the time.

The project was sponsored by the state government, which established Burnett Water Pty Ltd (BWPL) in 2001 specifically to act as project developer. BWPL commissioned the Burnett Dam Alliance as main contractor for construction of the dam. BWPL subsequently became a subsidiary of Sunwater in December 2005.

Located approximately 80-kilometres southwest of Bundaberg on the Burnett River (refer Figure 14), Paradise Dam was constructed as a 52m high gravity dam, with a 315-metre-wide spillway across the river channel. The dam was constructed with roller compacted concrete (RCC) with a low cementitious ('lean mix' or 'low paste') concrete laid down in approximately 300-millimetre-thick layers, also known as lifts. Paradise Dam is the largest volume RCC dam in Australia.

Key features of the original infrastructure include primary and secondary stepped spillways, a 20-metre long RCC spillway apron, a fishlock to allow fish movement past the dam structure and an intake/outlet structure located on the right abutment to allow selective withdrawal from the storage at a range of depths. The dam creates a 45-kilometre-long narrow reservoir with a surface area of 3,000 hectares, and at its original full supply volume, holds a total of 300,000 ML. An aerial view of the dam is shown in Figure 15 below. A period of dry weather conditions and below average inflows to the dam delayed wet commissioning of much of the infrastructure until March 2010.

Figure 14 Paradise Dam locality map

Source: QGlobe

Figure 15 Paradise Dam aerial view (2008)

Source: Sunwater

1.2.3 Origin of the PDIP

In December 2010, January 2011 and again in January 2013, the dam experienced a series of significant flooding events. Following the 2013 flood, extensive and unexpected scour damage occurred to the riverbed immediately downstream of the primary spillway apron, resulting in significant damage to the apron, and potential for further scour and undercutting of the dam (refer Figure 16). The three flood events were all smaller than the maximum flows the dam had been designed to withstand. The January 2013 flood was assessed as a 1 in 200 Annual Exceedance Probability flood event (a 0.5% likelihood of a flood event being exceeded in any one year), while the dam was originally designed to safely pass up to a 1 in 30,000 Annual Exceedance Probability flood event.

Following the January 2013 flood event, Sunwater undertook emergency dam repair works, and subsequently completed a detailed dam safety review, comprehensive risk assessment and associated studies which identified the need for longer term improvements to the dam. By 2015, a program of further improvement works was identified, and this resulted in the establishment of the PDIP. By 2017, initial improvement works were completed however further works were needed to ensure the dam could continue to hold and safely pass excess volumes of water during periods of extreme rainfall, and to satisfy design standards and dam safety guidelines. A preliminary business case (PBC), completed in June 2018, determined a series of options to take forward to DBC.

Figure 16 Scour damage at Paradise Dam

Source: Sunwater 2021

1.2.4 Timeline of key events for PDIP

Table 7 below provides a chronology of events, assessments and works undertaken on Paradise Dam since construction was completed in 2005.

Table 7 Key events, assessments and works undertaken on Paradise Dam since 2005

Date	Event
November 2005	Paradise Dam completed by Burnett Water Alliance and subsequently acquired by Sunwater bringing the dam into Sunwater's portfolio. Whilst initial allocations for the dam were progressively sold from commissioning, available water in the dam increased slowly over the period to March 2010.

Date	Event
December 2010 January 2011	Significant flood events experienced which caused operational issues.
January 2013	Flood event from Tropical Cyclone Oswald caused extensive scour downstream of the primary spillway compounding issues experienced in the 2010/11 flood event.
2013	Emergency flood repairs were carried out in 2013 and completed by December 2013, following the major flood events in 2010/11 and 2013 (cost of $35 million). These repairs were predominantly related to significant scour downstream of the dam, and repair and strengthening of the existing 20m length of apron below the primary spillway (315m wide).
2014 - 2015	Various investigations and studies undertaken, including a risk assessment which identified the primary dam safety risks as a) limited or inadequate downstream protection, below the primary and secondary spillways; and b) increased risks related to geological defects and weaknesses through the foundation and rock below and downstream of the dam. The latter risk was compounded by the limited geological modelling and geotechnical testing and data available from the original design and construction. The risk assessment informed the dam's elevated priority as part of Sunwater's portfolio-wide Dam Improvement Program and resulted in the initiation of the Paradise Dam Improvement Project (PDIP).
2014 - 2016	A Comprehensive Risk Assessment (CRA), a 20-year Dam Safety Review, and corresponding assessment of dam safety risks and related structural issues were undertaken, initially by 2014 – 2015 (in conjunction with studies above), and then revised by 2016. The CRA placed the dam outside the Australian National Committee on Large Dams (ANCOLD) Guideline acceptable Limit of Tolerability (LoT) for failure risks. This was predominantly due to the risk of downstream scouring undermining the integrity of the primary spillway structure, as well as foundation (poor strength) and other risks. This confirmed the need for the PDIP.
2015 - 2017	Initial improvement works were carried out and completed to protect two areas of the primary spillway, where there was a risk of undermining during flood events. Works were completed at total cost of $31 million, including strengthening the base of the primary spillway on the left and right sides, to protect against scour and undercutting at the toe of the dam.
June 2018	A PBC for further improvement works was completed. The study assessed factors including life cycle costs, current and future water demand, and environmental considerations to determine the best engineering design options to take forward for assessment in a DBC. Two key dam design options were identified: • Full upgrade of the existing dam – strengthening and anchoring of the primary and secondary spillways and enhancing downstream protection of the spillway apron. These proposed works ensured the original primary spillway height was retained. • Reduce the spillway height – reducing the height of the primary spillway, strengthening and anchoring of the primary and secondary spillways, and enhancing downstream protection by incorporating an extended spillway apron. The proposed height reduction was to be modelled at several levels.
October 2018	A water allocation Expression of Interest (EOI) completed. This tested the demand and increased the water allocations sold (from Paradise Dam) by an additional 12,000ML.
December 2018	A revised dam stability assessment was undertaken by Sunwater's design consultant that considered the stability of the dam's monoliths under flood loading, and highlighted a potential increased dam safety risk. The elevated risk to the dam was attributed to potentially low shear strength of the RCC lift joints. As a result, Sunwater commissioned further geological and geotechnical investigations.
February 2019 - April 2019	Formal approval was given to proceed with the DBC, led by Building Queensland (BQ), and cross-agency working group meetings commenced. The DBC was to progress preliminary designs for the two options identified in the PBC. Sunwater progressed a program of geological and geotechnical investigations of various elements of the dam including: • drilling, logging, and sampling of geotechnical boreholes

Date	Event
	• drilling, sampling, and testing at monolith locations and along the RCC lift joints at the toe of the secondary spillway and non-overflow section adjacent to the left abutment • engineering surveys and seismic profiles at drilling locations to further develop engineering design parameters • review and relogging of previous drilling campaigns • factual reporting of geotechnical investigation methodology and results.
April 2019 - September 2019	Ongoing laboratory test results, and analysis of results from geotechnical investigations, and progression of DBC studies.
August - September 2019	Following the latest results and testing from geological and geotechnical investigations, a Technical Review Panel (TRP) review and an updated dam stability assessment was undertaken in late August and early September 2019. These assessments confirmed an increase in dam safety risks, and in particular increased risk associated with shear / sliding failure through the RCC lift joints. The stability of the dam was assessed as marginal for a flood close to a 1-in-200 year flood event (similar to the peak of the 2013 flood), with consequential risk of failure resulting in potential loss of life and property. In response, Sunwater recommended to Government in September 2019 to undertake an immediate Essential Works project as early-stage improvement works, in advance of the broader PDIP which would take much longer to complete based on the likely full scope of works. The Essential Works project was initiated in September 2019, to reduce risks as soon as reasonably practicable, in advance of the longer term PDIP project. On 27 September 2019, Sunwater commenced lowering water levels in the dam for safety and to facilitate works to temporarily lower the primary spillway (the Essential Works).
October 2019	The Paradise Dam Community Reference Group (PDCRG) was established to facilitate information sharing and discussion of matters relating to the Paradise Dam Essential Works and the Dam Improvement Project. This included communicating to, and consultation with, the broader communities and stakeholders with an interest in Paradise Dam. The PDCRG is independently chaired.
October - December 2019	Water releases from Paradise Dam continued for a 10-week period, ending 3 December 2019 with the water level progressively lowered to 42% of the original full supply volume. The water released was made available, free of charge, to water users that could take it. Sunwater continued with design and technical investigations of the long-term options to assist the Options Assessment.
December 2019	The Inspector-General Emergency Management completed an independent Paradise Dam preparedness review into the effectiveness of emergency response during possible future floods. The Queensland Government accepted or endorsed all 17 recommendations.
December 2019 - April 2020	The Commission of Inquiry Paradise Dam commenced on 6 December 2019 with its purpose being to conduct a full and independent Inquiry of the structural and stability issues identified by engineering and technical studies on Paradise Dam conducted between 30 January 2013 and 30 November 2019. The activities being undertaken as part of the Options Assessment and DBC (technical investigations and considerations with regards to the proposed delivery model) were consistent with the recommendations of the Commission of Inquiry.
January 2020	Lowering options for the Essential Works were presented to the Sunwater Board for consideration. The Board granted approval for a nominal 5.8m lowering. The new temporary capacity of the dam once lowered would be 57% of the original capacity.
January 2020 - April 2020	The alternative options supply assessment commenced following engagement with the Paradise Dam Industry Forum (PDIF). The intent of the assessment was to assist Sunwater with the identification of alternative supply options for the catchment region. Specifically, the assessment focused on identifying options within the Burnett River subscheme and did not extend to reviewing options within the Kolan subscheme.

Date	Event
	Draft infrastructure options identified were used in the Options Assessment as potential alternative supply options to assist in meeting water security requirements. A series of community workshops were held in April 2020 to seek feedback on options identified and next stage plans.
February 2020	The Paradise Dam Options Assessment report was issued. It concluded that a long-term recommendation was unable to be made due to the concept level of design and other technical and supporting information available at the time. The Options Assessment recommended that further investigative works be carried out before the selection of a preferred option, noting that a number of these investigations works had already been commenced by Sunwater. Decommissioning of the dam was not recommended and was removed from consideration. Legislative amendments for the Essential Works received royal assent on 13 February 2020. On 13 February 2020, Sunwater commenced a further release of water from Paradise Dam to bring the storage level down to 42% to facilitate the Essential Works. Water releases continued for a 16-week period, ending 8 June 2020. Again, Sunwater made releases available free of charge to water users that could take it. The Paradise Dam Industry Forum (PDIF) (originally called Burnett Catchment Industry Forum until an agreed name change in July 2020) was established to facilitate information sharing and ideas between local industry groups and Sunwater in relation to water security in the Burnett Catchment. The group's first meeting was held on 20 February, prior to commencement of the Essential Works. The group continues to meet regularly and is independently chaired.
March 2020	Queensland Government consideration of the outcomes of the Options Assessment report (issued February 2020) led to a direction that Building Queensland and Sunwater work together to progress the DBC in two stages: • Stage 1 DBC – a detailed Options Evaluation (this report) of the three options highlighted in the Options Assessment. This would include a detailed demand assessment and economic analysis to identify a preferred long-term option that meets dam safety requirements and provides water security for the long-term future of the region. • Stage 2 DBC – development of the DBC, and associated activities, for the preferred long-term option, recommending a final investment decision. Concurrently, Sunwater's program of works (consistent with the recommendations of the Paradise Dam Options Assessment report) was continued with a focus of extending geological modelling of the dam and foundations, undertaking further RCC sampling and testing to confirm design parameters, and undertaking the testing of post-tensioned anchors suitable to provide long-term strengthening for the dam. Sunwater awarded a construction contract for the Essential Works.
April 2020 - January 2021	Sunwater's geological and geotechnical program of investigations and reviews for the Essential Works was completed and delivered in April 2020. Preparation activities and site mobilisation for the Essential Works construction commenced in April 2020, and lowering of the primary spillway commenced in May 2020. The lowering activity was completed in September 2020, temporary strengthening works completed in November 2020 (installation of 600 steel anchors) and final works for the temporary concrete crest were completed at the end of January 2021. As of January 2021, some ancillary Essential Works activities remained ongoing, (for example a new fishway installation) but the major dam safety scope of works was completed. The spillway lowering provided a short-term reduction in the failure potential of Paradise Dam (refer section 1.3), however substantially more work is required to ensure the long-term safety of the dam.
March 2021	The Paradise Dam Emergency Action Plan was updated noting the new full supply level at the completion of the Essential Works and revised dam safety triggers.

1.3 Risk reduction from Essential Works

As of January 2021, the dam safety aspects of the Essential Works project were completed. The risk reduction achieved through the Essential Works has been described based on the changed probability (the Annual Exceedance Probability (AEP)) attributed to the flood event that may likely result in dam failure occurring at its peak.

The dam failure risk has reduced for the dam as it was just prior to the Essential Works, from a probability of a 1 in 200 AEP flood event (i.e., 0.5% annual probability, and similar to the 2013 flood event) at which dam stability was assessed as marginal, to a 1 in 5,000 AEP flood event (0.02% annual probability) for the current dam post Essential Works.

This has led to a corresponding reduction in both the risk to human health and the economic risks of a dam failure. Because the dam is only likely to fail during a major flood event, the benefits of the dam improvements are essentially limited to the incremental reduction in damages and losses. Approximate economic consequences of a dam failure were estimated by HARC. Depending on the dam failure scenario used, the estimated incremental consequences of a failure (including indirect) range from $1.8 billion (PMF event with a secondary spillway failure) to $2.8 billion (1 in 1,860 AEP failure of the primary spillway).

Note that the dam failure risk is further reduced following completion of the recommended Paradise Dam Improvement Project works. For comparison, the original design basis for Paradise Dam was to safety pass flows over the dam up to a 1 in 30,000 AEP flood event. The Paradise Dam Improvement Project will achieve a similar dam safety and flood immunity.

1.4 Scope of the Options Evaluation

1.4.1 Overview

The scope of this OE is to deliver a recommended option/s to Government for endorsement and subsequent analysis in the Stage 2 DBC. The scope includes:

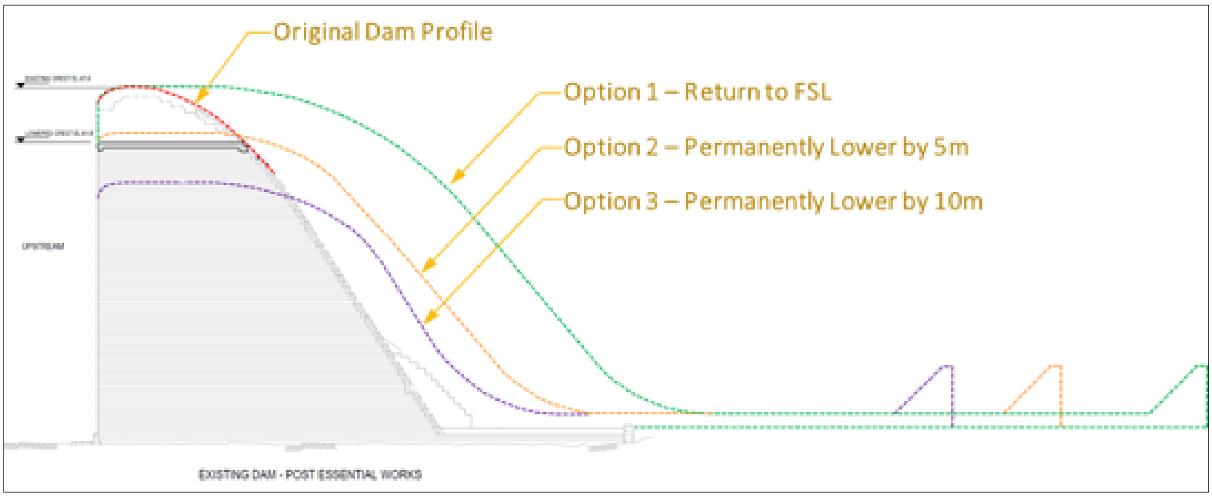
- completion of a sufficient level of technical investigation to support the current concept-level design, risk, and cost assessments of the recommended option/s
- completion of a detailed demand assessment to assess the requirements for water in the region
- assessment of potential alternative supply options for the region
- comprehensive evaluation of recommended options including a detailed assessment of costs and benefits.

The dam options under assessment in this OE are the three options identified in the Paradise Dam Options Assessment report from February 2020 and subsequent Ministerial statements. The options are summarised below and illustrated Figure 17.

- **Dam Option 1:** Returning the primary spillway back to its original height (raising 5.8m above current temporary Essential Works level)
- **Dam Option 2:** Permanent lowering of the primary spillway to 5m below the original height (raising 0.8m above current temporary Essential Works level)
- **Dam Option 3:** Permanent lowering of the primary spillway to 10m below the original height (further lowering of 4.2m below current temporary Essential Works level)

This report provides a summary of works completed to inform Stage 1, the evaluation process undertaken to assess and differentiate between options, and provides recommendations regarding the selection of a long-term option for Paradise Dam.

Figure 17 Schematic of dam options compared to original dam profile and profile post Essential Works



Source: Sunwater

1.4.2 Geographical scope

While the demand assessment carried out for this OE has considered the overall BWSS, the results and assessment for this OE are focused on the Burnett River subscheme. This relates more specifically to the recommended scope and spillway level for Paradise Dam. Hence the OE considers:

- the impact of total yield (water supply allocations) available from Paradise Dam for various improvement options (spillway levels)
- other existing supply sources
- long-term water supply demand to be serviced in the area downstream of Paradise Dam
- possible alternative supply options that may be required to meet long-term demand (for different dam level options), potential climate change impacts
- the impact on the existing channel system and distribution network to be able to meet long-term customer demand – all within the Burnett River subscheme.

Refer to section 1.2.1 for further details on the BWSS service area and Burnett River subscheme.

1.4.3 Key inputs to the OE

The works completed to inform the OE were those recommended in the Paradise Dam Options Assessment report and are outlined below:

- Geotechnical assessment of the dam foundations and further development of a 3D geological model to confirm the capacity of the dam's foundations.
- RCC sampling and testing to confirm the structural parameters of the RCC.
- Post-tensioned anchor trial to determine site specific design parameters for post tension anchors within the various ground conditions at Paradise Dam.
- Refinement of options designs, dam safety assessments and cost ranges using updated information determined through the testing program and supporting studies.
- Assessment of alternative supply options to potentially augment supply from Paradise Dam, including consideration of yield and cost impacts.

- Water resources assessment to determine the yield of Paradise Dam, including consideration of the impacts of climate change over the evaluation period.
- Detailed demand assessment to determine the level of supply required to service the region over the evaluation period.
- Distribution system assessment to determine potential limitations with servicing the projected demand over the evaluation period.
- Options evaluation to determine the option that best meets the service needs. This will include consideration of financial, commercial and affordability impacts of the options under evaluation.
- Assurance activities including internal and external peer review activities to meet the requirements of the PDIP DBC Assurance Plan.

These inputs are further described within the chapters and appendices of this report.

2 SERVICE NEED

2.1 Purpose

The purpose of this chapter is to define the service need for the PDIP Stage 1 DBC Options Evaluation, using outcomes from the PBC completed in June 2018 and subsequent Ministerial statements regarding the long-term objectives for the PDIP. In this chapter, two primary service need criteria are defined: dam safety, and water supply and demand (water security), along with two secondary service need criteria: environmental and social impacts. The service needs are briefly introduced here with details provided in chapters 5, 6 and 10.

2.2 Service need statement summary

In developing the PDIP (refer section 1.2.3), a problem statement was defined following a series of dam risk assessments undertaken between 2015 and 2016. These assessments identified dam safety risks of:

- inadequate scour protection downstream of the primary and secondary spillways
- poor foundation material below the secondary spillway
- structural problems with the outlet works

Following further review at the end of 2018, a further potential risk was raised relating to structural problems with the RCC that makes up most of the dam. This initiated a program of geotechnical investigations, testing and analysis in 2019, through which the additional dam safety risk was confirmed. The revised major dam safety risk was therefore identified as:

- structural problems within the RCC material making up the dam wall

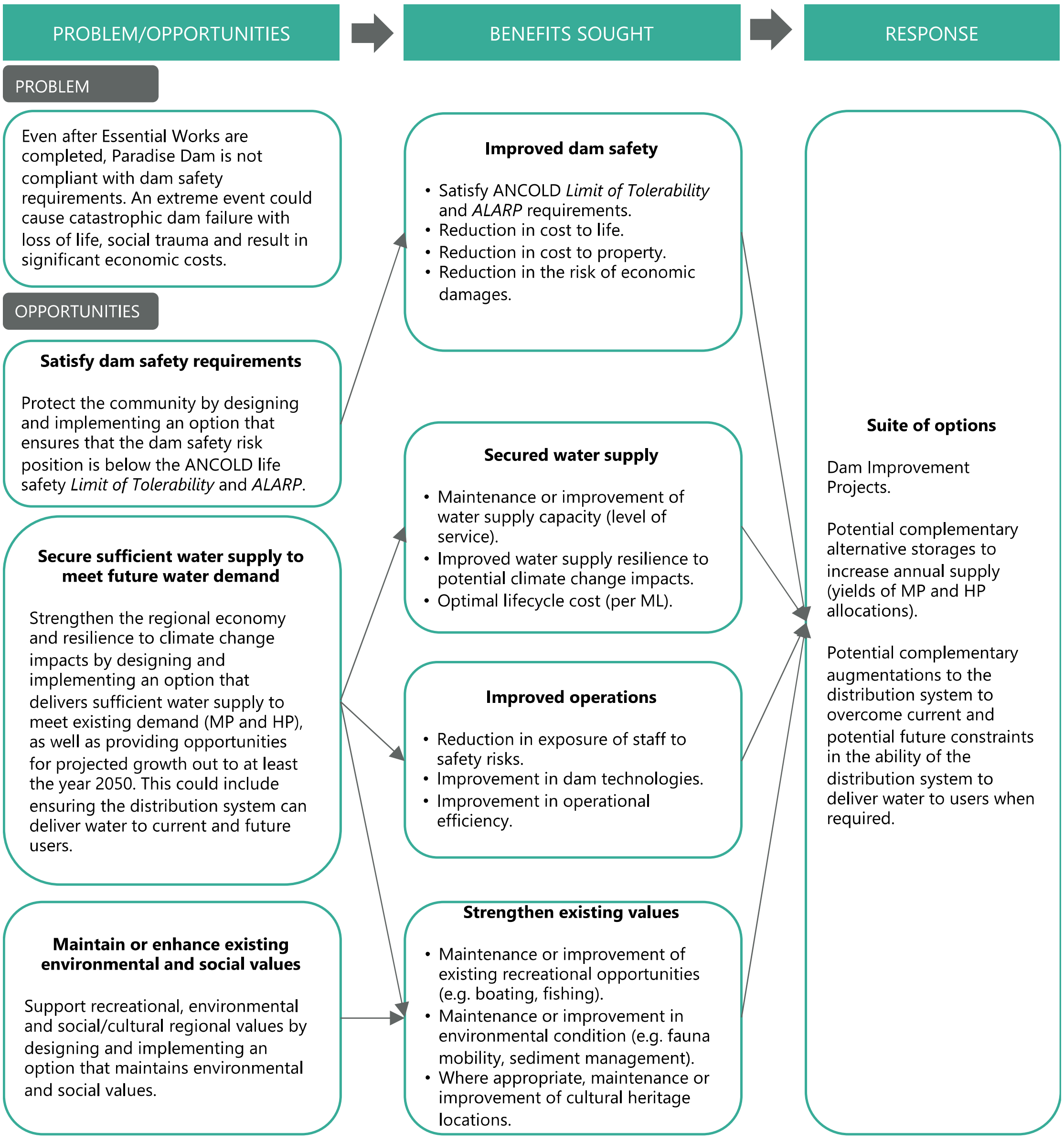
The PBC for PDIP completed in June 2018, included a brief strategic assessment of problems and opportunities defined in an ILM (Investment Logic Map) style process. Three core problem statements were identified through the ILM, these being unacceptable dam safety risks, lower than expected demand for water, and higher than expected whole-of-life costs. The corresponding service needs identified through this work included dam safety improvements and the need to meet existing and future demand for water.

The PDIP problems and opportunities identified in the PBC were updated in this OE based on the following (refer chapter 1):

- the outcomes of investigations and strategic assessments undertaken since the PBC was prepared
- the risk reductions achieved through the Essential Works.

The outcomes of this update are presented in Figure 18, along with the benefits sought and the proposed response.

Figure 18 Identification of problems, opportunities, benefits and responses



2.3 Service need overview

A summary of the service need is outlined in Table 8 below:

Table 8. Summary of the PDIP service need

Service need	Problem being addressed	Benefits of PDIP	Criteria
Primary service need criteria			
Dam safety	Paradise Dam is not compliant with dam safety requirements.	Address and rectify dam safety risks in accordance with regulated requirements	An option will satisfy the dam safety service need once the required dam safety guidelines are met (refer chapter 5).
Water supply and demand	There may be shortfalls in water supply for agricultural, community and commercial use with existing infrastructure.	Meet projected, long-term water requirements at the location/s where water is required. Increased system resilience to potential impacts of climate change	An option will satisfy the water supply and demand service need where long-term projected water demands are met (refer chapter 6) including testing under agreed sensitivity and scenario analyses.
Secondary service need criteria			
Environmental impacts	There is a potential for the PDIP to lead to environmental impacts not previously included under existing project approvals.	Identify, quantify and, if required manage and/or mitigate potential environmental impacts and maintain / enhance existing values	Does the analysis identify any material environmental issues that cannot be remedied / mitigated and/or identify opportunities that can improve existing values (refer section 10.3)
Social impacts	There is the potential for the PDIP to lead to social impacts not previously assessed.	Identify, quantify and, if required, manage and/or mitigate potential social impacts and maintain / enhance existing values	Does the analysis identify any material social issues that cannot be remedied / mitigated and/or identify opportunities that can improve existing values (refer section 10.4).

3 BASE CASE

3.1 Purpose

This chapter defines the base case against which options shall be compared. The base case is the business-as-usual (BAU) situation which pre-exists the proposed project case, inclusive of projected demand, demographic growth, policy, and operational settings.

3.2 Scope

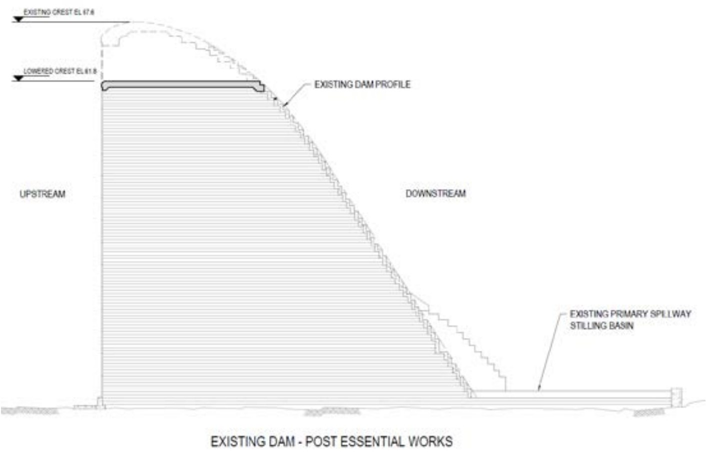
It should be noted from the outset that the base case defined for PDIP differs from a typical base case used in business cases. This base case is presented for comparative reference purposes and is not a viable option as it does not meet the dam safety service need criteria. Rather, it is prepared as a reference case against which the other options can be compared.

The geographical scope of the base case study area is principally the Burnett River subscheme that is downstream of Paradise Dam, including other water supply sources, demand and customer areas along and adjacent (e.g., within 1 – 2 km) to the lower Burnett River (including Isis and Woongarra irrigation areas), and associated channel and water distribution infrastructure.

The evaluation period for this base case is 30 years (to 2050). While this is typical for business cases, it is noted that the key components of the PDIP (major civil assets) have an expected asset life (and related economic life) that far exceeds the evaluation period.

The key parameters established in the base case represent the key parameters used in the economic analysis, also referred to as the central or most likely case. The dam cross section for the base case (the current situation post Essential Works) is shown in Figure 21.

Figure 19 Base case (current situation post Essential Works)



3.3 Current operating and economic environment

Paradise Dam is operated by Sunwater as a major storage facility located within the BWSS, and in conjunction with Fred Haigh Dam provides water services to agricultural, urban and industrial customers. This includes Part A and C tariffs designed to cover Sunwater's fixed costs attributable to dam and distribution system infrastructure, and variable charges (Part B and D tariffs) to cover variable costs. Service charges are regulated and do not provide a rate of return to Sunwater.

While the Burnett River subscheme has been supplying supplemented irrigation services since the 1970s, the establishment of Paradise Dam has significantly improved regional storages and yield to irrigators. Following construction of Paradise Dam in 2005, additional water allocations were created, totalling 124,000 ML of Medium Priority (MP) and 20,000 ML of High Priority (HP) "new" water allocations. Most of these allocations are assigned to the Burnett River subscheme, though 21,700 ML of the MP allocation (out of the 124,000 ML of MP total) is available within the Kolan River subscheme. Considering these new water allocations, total sales are currently equivalent to 20% and 15% of total MP and HP "new" allocations respectively.

This does not however account for the "old" water allocations available in the scheme prior to the construction of Paradise Dam. Within the Burnett River subscheme area, there are a total of 125,200 ML of MP and 17,000 ML of HP "old" allocations, attributed to supply available from Ned Churchward Weir and Ben Anderson Barrage. All these old water allocations were effectively sold / committed (including allowances for system losses) by the time Paradise Dam was constructed.

Hence in total in the Burnett River subscheme, there are 227,500 ML of MP and 37,000 ML of HP of "old" and "new" allocations (excluding allocations in the Kolan River subscheme). Including sales pre-Paradise Dam construction, total water allocation sales / commitments within the Burnett River subscheme are 63% and 54% of total MP and HP allocations available respectively.

The relatively slow pace of allocation sales since the dam was commissioned is attributable to multiple factors including a challenging economic environment for sugar (the dominant crop in the region by area and aggregate water use) and perceived constraints in the distribution system.

Recent years have seen significant structural change in the region with respect to irrigated crops. There are now a greater proportion of irrigated areas under higher-value horticulture cropping than even 10 years ago. This includes both annual fruit and vegetables and perennial tree crops (particularly macadamia and avocado) as the region's competitive advantages are realised and investment in intensification of irrigated agriculture occurs. The prospects for major crops can generally be very positive for higher value crops such as macadamia, avocado and annual fruit and vegetable crops (including emerging export opportunities) and relatively neutral for most other crops. The exception is sugar, that while able to cover costs, is at risk of conversion to higher-value crops by existing irrigators. This trend is expected to continue in the absence of a material and sustained improvement in the commercial prospects for the sugar industry.

To date, this major adjustment in crop mix is only partially reflected in water allocation sales and water use as the bulk of the developments have been occurring on former cane production areas (i.e., a substitution of water use is occurring).

Just prior to the announcement of the Essential Works, allocation sales were significant as irrigators that had already established perennial tree crops sought to purchase water for areas established in recent years. In effect, there is a lag between crop establishment and purchasing additional allocation. Given the areas established under tree crops in the past five years, there is a significant degree of latent demand for allocations that could be realised almost immediately once permanent allocations again become available. In the interim period, water trading (temporary and permanent) has increased in volume and traded prices have more than doubled.

3.4 Dam safety

Undertaking the Essential Works improved the dam safety risk profile considerably by reducing the probability of failure during extreme flood events. This risk reduction was achieved by temporarily lowering the primary spillway height by 5.8m, and installation of 600 steel anchors grouted into the primary spillway RCC wall across its width. This came at the cost of reduced water yield at Paradise Dam, estimated at approximately 55,000 ML of yield (and 130,000 ML of reduced storage volume, or 57% capacity of the original full supply volume).

Following completion of the interim dam safety risk reduction measures for the Essential Works, the flood event which may result in dam failure has changed from a 1 in 200 AEP to a 1 in 5,000 AEP flood. For comparison, the original design basis for Paradise Dam was to safety pass flows over the dam up to a 1 in 30,000 AEP flood event.

Despite completion of the Essential Works, which has achieved significant risk reduction outcomes, the dam does not currently meet the ANCOLD Guideline acceptable Limit of Tolerability, and requires further significant improvement works to reduce risks to an acceptable level in the long-term

The risk reduction is shown in Figure 20 below, with the top purple line indicating the risk associated with the dam prior to the Essential Works, and the lower red line indicates the resulting risks post Essential Works (the base case). The black line indicates the ANCOLD Guideline acceptable Limit of Tolerability, which is the key dam safety service need criteria.

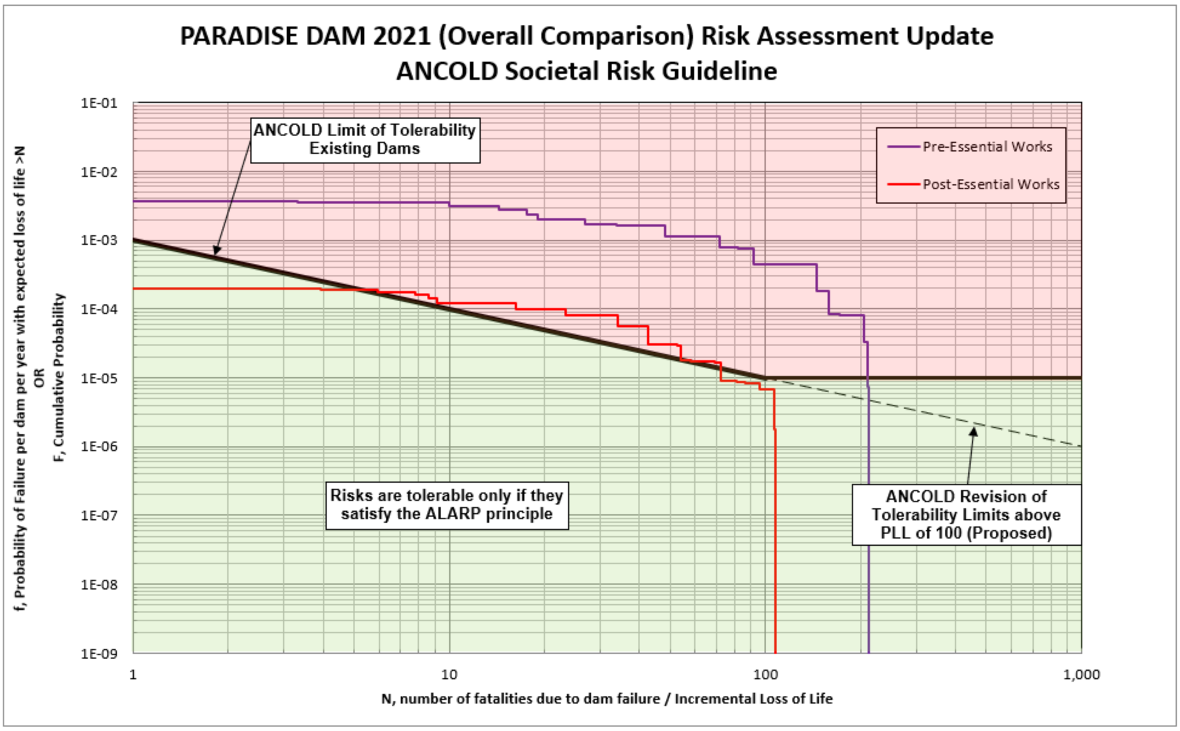
If the risk assessment outcomes for a dam plot above the applicable Limit of Tolerability, then the dam does not satisfy the ANCOLD Guideline and will require improvement works to reduce risks until it falls below the Limit of Tolerability. If the risk profile falls below the Limit of Tolerability, then dam owners still need to consider dam safety guideline approaches to ALARP, to assess if the costs involved to implement further improvements would be grossly disproportionate to the benefit gained. Dam owners will then also practically consider sensitivity scenarios for various dam safety and engineering inputs to the risk assessment process, to ensure confidence that the dam will remain below the Limit of Tolerability in the longer-term, or if further improvement works may be prudent.

The risk assessment process that underpins the dam safety analysis and risk profile to plot against the Limit of Tolerability calculates two key outputs:

1. The probability of dam failure (as shown on the vertical axis) – considering different failure modes, across different areas of the dam, with corresponding failure event paths and probabilities, for a range of different flood sizes or other conditions that the dam may experience (e.g. seismic events);
2. The consequence of dam failure (as shown on the horizontal axis) – considering the incremental potential loss of life resulting from the different dam failure events (compared to loss of life that may otherwise occur for the same flood event or scenario, without dam failure occurring).

The risk profile for the existing dam is above the Limit of Tolerability and therefore, without intervention, presents an unacceptable risk that the dam could fail with resultant probable impacts on life and property in the communities downstream of the dam, as well as ongoing impacts for water supply.

Figure 20 Dam Safety Risk Assessment Performance – Base Case (post Essential Works)



Source: Sunwater

The base case does not meet the key dam safety service need criteria and is therefore not an acceptable option for further consideration. This is discussed in detail in Chapter 5.

It should also be noted that for the purposes of this business case, the $100M expenditure on the Essential Works is treated as a sunk cost.

3.5 Storage yield

A yield assessment for the base case was not specifically modelled however, for the analysis it is assumed to be like that for Dam Option 2, at approximately 121,600 ML (MP equivalent). It is noted that the base case has a primary spillway height slightly lower (5.8 metres below original FSL) compared to Dam Option 2.

The assumed yield of the base case is shown in Table 9 below. No impacts of climate change have been included in these yield results.

Table 9 Key modelling input parameters

Parameter	Base case value	Comment
Total subscheme supply allocations (ML/a) as MP equivalent	Assumed as per Dam Option 2 263,000	Yields are Medium Priority equivalent, for the Burnett River subscheme, including Paradise Dam options (levels) and other existing scheme allocations, but excluding additional supply options. Note that there are also 16,500ML of MP allocations assigned to Paradise Dam in the Kolan subscheme.
Total subscheme allocations sold / committed (ML/a) as at 1 July 2021	188,200	Includes existing customer allocations, and allowance for system losses, expressed as Medium Priority equivalent

Source: Sunwater

3.6 Water demand

Water demand under the Base Case is a derived demand, where growth in demand is a function of the commercial viability of the use of water. The key drivers included population growth, market prospects, crop water requirements, and the impacts of climate change.

3.6.1 Urban demand

Urban demand growth is a function of population growth and an assumed average level of consumption of 174 litres/person/day (l/p/d). Commercial demand is anticipated to grow at the same rate as urban demand. HP demand for residential, commercial, and industrial use is estimated to increase to around 3,060 ML by 2050 (with a lower and upper range of 2,800 – 3,320 ML).

3.6.2 Irrigation demand

The major source of future demand growth is irrigated agriculture. This is a function of changes in investment, changes in land use, water use by crop type etc.

Key parameters and their values underpinning the base case are shown below, including assumed changes in land use, over the evaluation period. Note that this is based on development growth patterns that are unconstrained by factors including dam yield and the capacity of the distribution system to deliver supply.

Table 10 Key modelling input parameters (annual land use change)

Parameter	Base case value	Comment
Proportion of high value crop growth established on current cane production area over the evaluation period.	72%	This assumption is based on recent land use change trends and the outcomes of the consultation and landholder survey.
Land use change rate – cane (ha/annum)	-449	Land use change assumptions based on historical trends, survey data, and consultation.
Land use change rate – macadamia (ha/annum)	309	
Land use change rate – avocado (ha/annum)	74	
Land use change rate – other horticulture (ha/annum)	224	
Land use change rate – hay and silage (ha/annum)	17	

Table 11 below shows the breakdown of the base case demand assessments for 2020 and 2050. All figures are in MP equivalent volumes to enable aggregation.

The decision to invest in new cropping areas or change crops is a decision faced by hundreds of irrigators and is based on commercial investment opportunities and expected returns. It is therefore assumed that no investment will occur if it is not commercially viable for irrigators.

A summary of commercially viable projected changes in demand by 2050 is shown in Table 11 below. This represents the figures achievable under two situations, firstly where no constraints in the distribution system exist, and secondly, where existing constraints in the system are not programmed to be addressed.

Table 11 Projected demand profile to 2050 (MP equivalent volumes)

Projected demand profile to 2050	Projected 2050 unconstrained (ML)	Projected 2050 constrained (ML)
Land use change triggering change in usage (ML)		
Sugar cane	-66,873	-97,237
Macadamia (greenfield)	16,352	11,651
Macadamia (brownfield)	42,049	29,230
Avocado (greenfield)	4,911	3,499
Avocado (brownfield)	12,627	8,778
Other horticulture (greenfield)	13,143	9,364
Other horticulture (brownfield)	33,797	23,493
Hay and silage (greenfield)	657	468
Hay and silage (brownfield)	1,689	-2,123
Other agricultural considerations (ML)		
Tree crop maturation (current trees utilising their full requirement)	11,367	11,367
Climate change (net impact of changes in rainfall and peak temperatures)	7,864	4,215
Interrow watering for tree crops (emerging environmental requirement)	5,174	5,174
Urban use (ML)		
Urban use	1,596	1,596
Total additional demand (ML)		***9,475***

3.7 Economic value of water use

The economic value of water incorporated into the base case is based on the economic margins from water users, including current and potential future users, from Paradise Dam supplying to the Burnett River subscheme.

The economic value of water use is calculated as the present value of the economic margin from using the water by type of use (e.g., different crop). For each year, this will change as both the aggregate demand changes and the mix of water uses changes (e.g., due to changes in cropping patterns). A detailed outline of this approach is provided in chapter 9.

The use of water is determined by short-term climatic conditions, crop requirements, commodity process, and variable costs of utilising water (including Part B and Part D Sunwater tariffs). Furthermore, the use of water is not attributed to specific crops, which would enable an accurate estimate of the value of water to users. Therefore, to estimate the annual margins from current water use, it is assumed that:

- 50% of the irrigation water use is for sugar cane and the applicable margin is consistent with brownfield cane growing.
- 50% of the irrigation use is spread across horticulture uses with an average margin of $722/ML (the average margin for brownfield avocado, macadamia and annual horticulture crops).

- Margins for urban use are $726/ML.

Using these assumptions, the estimated value of annual water use from Paradise Dam is therefore calculated at $14.3 million. Within the base case, this value is included for each year of the evaluation period.

Table 12 Estimated annual value of current water use from Paradise Dam

Demand profile	2020 demand (ML)	Value ($/ML)	Estimated value ($ million)
Sugar estimate	11,299	$205	$2.3
Horticulture crops	11,299	$722	$8.2
Urban	5,238	$726	$3.8
Total	**27,835**	**N/A**	**$14.3**

For future water use, economic margins from water use were estimated based on available industry data and through the use of existing economic models (see chapter 9 for further details on this approach). Through this process, average margins ($/ML) were established and are shown in Table 13 below.

Table 13 Key modelling input parameters – average margins for water use

Parameter	Value ($/ML)	Comment
Sugar gross margin	$205	Refer section 9.4.4 for detailed comments on the derivation of each of these estimates.
Macadamia brownfield net margin	$763	
Avocado brownfield net margin	$757	
Other horticulture brownfield net margin	$645	
Hay and silage brownfield net margin	$46	
Macadamia greenfield net margin	$717	
Avocado greenfield net margin	$651	
Other horticulture greenfield net margin	$524	
Hay and silage greenfield net margin	$20	
Urban value (willingness to pay to avoid restrictions)	$726	

Based on the projected demand and margins for water use, annual estimates of benefits from water use can be established and discounted to estimate an NPV of benefits as shown in Table 14 below. The estimate benefits have been calculated using the constrained demands in Table 11 above.

Table 14 Estimated present value of base case – growth in crop specific water use ($ million)

Demand profile	Present value ($ million) Constrained demand
Sugar gross margin	CIC
Macadamia brownfield net margin	CIC
Avocado brownfield net margin	CIC
Other horticulture brownfield net margin	CIC
Hay and silage brownfield net margin	CIC
Macadamia greenfield net margin	CIC
Avocado greenfield net margin	CIC
Other horticulture greenfield net margin	CIC

Demand profile	Present value ($ million) Constrained demand
Hay and silage greenfield net margin	CIC
Urban	CIC
Existing use	CIC
Total net benefits for base case	CIC

3.8 Conclusions

The base case has been established as a comparative reference point for the evaluation of options. The key characteristics of the base case include:

- The base case does not meet the dam safety service need criteria.
- The economic value of water use is estimated from the value of margins from water use. This was based on an analysis of demand, margins per ML of water use, and considering dam yield and distribution system constraints.
- The present value of the net benefits from water use for the base case is CIC.

4 APPROACH

4.1 Purpose

This purpose of this chapter is to describe the approach taken for the Stage 1 DBC Options Evaluation. The chapter outlines the governance and assurance process, inputs used in the evaluation model, and provides an overview of the method used for the OE.

4.2 Governance and Assurance

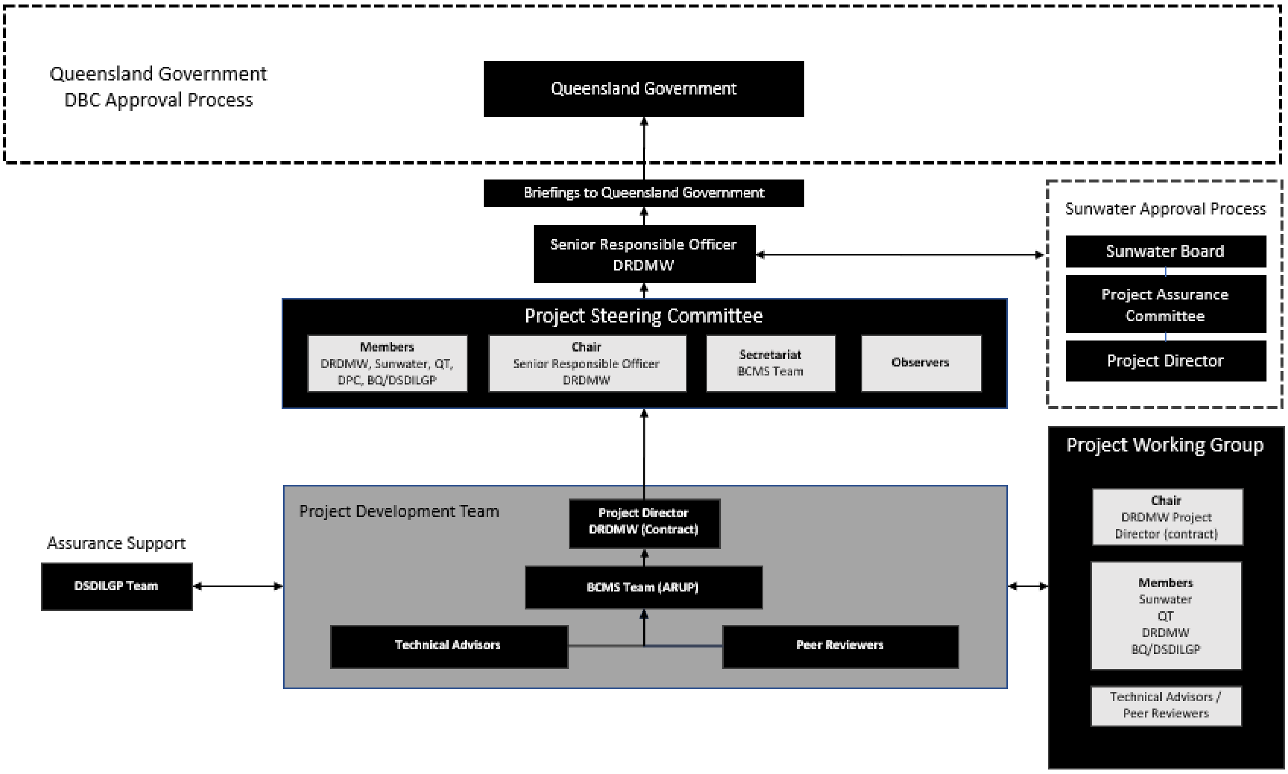
4.2.1 Project governance

Being a project with a total expected cost exceeding $100m, the PDIP DBC was required to be led by the former Building Queensland in accordance with the *Building Queensland Act 2015 (Qld)* (now repealed). Building Queensland commenced work for the DBC in early 2019 working with Sunwater and the former Department of Natural Resources Mines and Energy (DNRME).

In 2021, the Queensland Government announced the incorporation of Building Queensland into the Department of State Development, Infrastructure, Local Government and Planning (DSDILGP). With this, and other machinery of government changes, the responsibility for completion of the Stage 1 DBC OE was transitioned from Building Queensland to the Department of Regional Development, Manufacturing and Water (DRDMW) (the former DNRME).

The governance structure for delivery of the OE is illustrated in Figure 21 and the key roles and responsibilities for delivery are outlined in Table 15.

Figure 21 PDIP Stage 1 DBC Options Evaluation - Project Governance Structure



Notes: Governance structure applicable as at October 2021

Table 15 PDIP Stage 1 DBC Options Evaluation - roles and responsibilities

Team	Representatives	Roles and responsibilities
Project Development Team	Project Director-DRDMW	Overall responsibility for the finalisation of the OE including providing guidance to the BCMS team and reporting project progress to key stakeholders.
	Business case management services (BCMS) team	Responsible for the strategic and day to day leadership, management, and coordination of the business case.
	Technical advisors	Preparation of the demand assessment and options evaluation
	Peer review advisors	Undertake peer review of demand assessment and options evaluation, water resources/yield
Project Working Group (PWG)	Project Director-DRDMW DRDMW Sunwater DSDILGP Treasury BCMS team Advisors	The purpose of the PWG is to allow officer-level and subject matter expert input during the development of the DBC including the review and approval of draft documentation prior to submission to the PSC. The PWG is made up of officers from key departments involved in providing technical input to the business case. The PWG refers issues and outcomes to the PSC for resolution, guidance, or decision as appropriate.
Project Steering Committee (PSC)	DRDMW Sunwater DSDILGP Treasury DPC	The PSC provides direction, overall guidance, and leadership in the development of the business case. It is responsible for making decisions and/or endorsing recommendations, considering and approving the business case prior to progressing through further approval processes, including final submission to the State. It considers and confirms the position on policy or management for the project. DRDMW chairs the Project Steering Committee in its role as Senior Responsible Officer (SRO) for Stage 1.
Senior Responsible Officer (SRO)	DRDMW	The SRO is responsible for Chairing the PSC providing leadership of agenda items and managing meetings and member discussions. The SRO is also the senior person responsible for the delivery of the project and ensuring that the project meets broader Government requirements.
Sunwater Project Team	Project Director Project Manager Design Manager	Sunwater's project team represents Sunwater as the project proponent, managing the DBC process by overseeing the technical investigation program, materials testing, engineering design, alternative supply option and distribution system considerations and construction.
Sunwater Technical Review Panel (TRP)	External Subject Matter Experts Panel members Panel observers	The TRP comprises interdisciplinary external independent technical experts engaged by Sunwater to provide assurance through peer review of design, constructability, operability, maintenance, and dam safety considerations for the project. For PDIP, the TRP performs an assurance function for Sunwater as asset owner, the Sunwater Board and Queensland Government's Dam Safety Regulator.

4.2.2 Assurance activities

A three-tiered program of assurance activities was undertaken to support the OE process:

1. Internal reviews of reports submitted by advisors were undertaken by the BCMS team.
2. Assurance reviews were undertaken through the TRP, PWG, PSC, and SRO / DRDMW prior to Ministerial consideration.
3. Business case assurance reviews were undertaken by peer review advisors and through the Gateway Review process.

Table 16 outlines key assurance activities undertaken for each of these assurance tiers.

Table 16 Key assurance activities undertaken for the OE

Assurance Level	Activity	Responsibility	Description of Review
1	BCMS internal reviews	BCMS/Project Director-DRDMW	Review of output reports from advisors which form appendices to the OE Review of draft OE report chapters
2	Technical Review Panel (TRP)	Sunwater	Expert panel peer review of technical investigation approaches and outcomes, dam safety assessments, hydrology, and concept designs on behalf of Sunwater as the project owner
3	Independent technical peer review		Independent technical peer review of evaluation method and outcomes, hydrology, dam safety risk assessments, concept designs and raw/risk adjusted cost estimates on behalf of the SRO for the purposes of the OE
3	Peer review – water resources / yield		Peer review of water resource assessments including yield assessment and climate change impacts assessment
3	Peer review – demand assessment and options evaluation		Peer review of demand assessment and options evaluation approach, method and outcomes
3	Peer review – financial, commercial and affordability		Peer review of financial and commercial modelling and affordability analysis undertaken for options and scenarios
3	Options evaluation peer review		

A Gateway 2 review, in accordance with Queensland Treasury Project Assessment Framework, is planned to be undertaken at the conclusion of the Stage 2 DBC to comply with the approved assurance plan.

4.3 Inputs

The OE is based on information summarised in Table 17 below for each of the service needs. This information builds on a major body of work summarised throughout sections of this report and its appendices. This has included technical analysis of the dam itself, detailed modelling and analysis of the alternative supply options and the distribution system, climate change scenario analysis, hydrological modelling, detailed demand assessments, detailed costings based on concept designs and economic analysis.

Table 17 Key information sources

Key tasks	Key inputs	Sources of information
Dam safety service need assessment	Dam Safety Risk Assessment	ANCOLD Guidelines Queensland Dam Safety Regulations

	Dam Concept Designs	Testing (RCC, geotechnical/geological) developed for Options Evaluation Concept designs
	Dam Cost Estimates and Risk	Comprehensive Risk Assessments Detailed costings
	Alternative Supply Options Concept Designs	Concept design and cost estimates
	Hydrology	Hydrology studies
Water supply and demand service needs assessment	Demand Assessment	Demand Assessment
	Yield Assessments (Dam and Alternative Supply Options)	Yield assessment
	Channel System Capacity	Hydraulic modelling study
Other issues (environmental, social)	Previous investigations on environmental and social considerations	

4.4 Options evaluation method

As outlined in Chapter 1, the OE is being undertaken to determine the preferred option/s for the long-term remediation of Paradise Dam, to be delivered through the PDIP.

The OE has been undertaken across an evaluation period of 30 years, from 2020 to 2050. The rationale for this evaluation period was based on:

- 30 years being typically the limit to which projected water demands can be made with a level of confidence acceptable for economic analysis, noting that there is still variability in the range of projected demand.
- 30 years being the typical standard period length for an economic analysis for water projects. It is noted however that water infrastructure typically has an economic life well over 30 years.

As part of the scenario analysis, an extended evaluation period of 40 years was assessed.

Overall, the evaluation of options was conducted against the following criteria:

- **Dam safety.** Each option for the Dam is assessed against regulated dam safety requirements, particularly the ANCOLD LoT. This is treated as a threshold assessment approach, and only options that meet these dam safety requirements are eligible for further assessment (refer Chapter 6).
- **Water supply and demand.** This analysis is based on the detailed demand assessment, assessment of the yields of dam options and alternative supply options, and potential augmentations of the distribution system. The ability of options to meet projected demands was assessed.
- **Environmental and social issues.** Environmental and social issues and impacts for each option were assessed using a SWOT analysis approach. This was specifically designed to identify any critical challenges that would impact on the assessment of options.

The options evaluation process comprised the following activities:

- Establish the background of the origin of the PDIP and the scope of the OE process and report, including technical investigations and initial identification of potential options for assessment (chapter 1).

- Establish the foundation for the OE, including the base case, strategic context, problem statements, benefits and resulting service need (refer chapters 2 and 3).
- Define the service need in detail, identifying options to meet both primary services need criteria (refer chapters 5 and 6) and secondary service need criteria (refer chapter 10).
- Define the options and their infrastructure components needed to meet service needs (refer chapter 7).
- Determine the financial and commercial attributes of the options that form the foundation of the economic analysis (refer chapter 8).
- Undertake the cost benefit analysis of options to determine the preferred option (refer chapter 9).
- Assess options against secondary service need criteria and other key considerations (refer chapter 10).
- Outline the key investment considerations for Government including affordability, potential funding, and delivery model for the preferred option/s (chapter 11).
- Present the conclusions, recommendations, and next stage plan to guide the decision-making process (chapter 12).

Figure 22 illustrates the OE approach, setting out the key questions to be answered in assessing each option through the OE and decision rules applied to assist in identifying the preferred option/s.

Figure 22 Options Evaluation approach - summary of key tasks

Background and base case

- Key question: What is the origin of the PDIP and the context of the Options Evaluation?
- Key question: What will options be compared against in the evaluation to define the incremental costs and benefits?

Dam safety service need

- Key question: Does the option meet the Limit of Tolerability?
- Decision rule: Only options that meet both requirements are eligible for consideration.

Water supply service need

- Key question: Which infrastructure options (dam plus any alternative supply) provide sufficient yield to meet the projected demand?
- Key question: Can the yields be delivered to customers through the distribution system?
- Decision rule: Progress the resulting combination of infrastructure and distribution system options that meet projected demand to CBA.

CBA evaluation

- Key question: What are the net economic benefits attributable to the options?
- Key question: What is the impact of certain scenarios on the relative benefits of the options?
- Decision rule: Option/s with highest net benefits (measured as NPV) are considered for progression to the DBC.

Environmental and social service need

- Key question: For the options, does the SWOT analysis identify material issues that cannot be remedied/mitigated and/or identify opportunities that can improve existing values?
- Decision rule: If material issues can be remedied or offset with improvements, option/s to proceed to DBC.

Conclusions and Next Steps

- Key question: What is the preferred option/s from the CBA outcomes?
- Key question: What key issues require consideration, including the climate change scenario?

5 DAM SAFETY

5.1 Purpose

This chapter explores the primary service need criteria of dam safety for Paradise Dam. It defines in detail the regulatory requirements for dam safety, the technical investigations undertaken and the identified dam structural issues that impact its safety. The chapter concludes with identifying the dam options to meet the dam safety service need criteria.

5.2 Approach

Sunwater has an obligation to ensure that the storages it owns and operates comply with the relevant regulatory and industry recognised standards and guidelines. Further, responsible dam portfolio management requires the asset owner to develop a comprehensive understanding of the likelihood of dam failure and the associated consequential impacts.

There are several established processes and guidelines to assist asset owners to prioritise and deliver the ongoing risk assessment and management process required for compliance. This includes the Australian National Committee On Large Dams (ANCOLD) '*Guidelines on Risk Assessment 2003*' (ANCOLD, 2003) and various Queensland Government specific guidelines. These processes and guidelines form the basis of, and define the specifics for, the dam safety service need identified in chapter 2.

Undertaking dam stability, risk assessments, and scoping improvement options to achieve dam safety compliance, are complex and iterative processes involving many variables. The following must be considered:

- Assessment of the likelihood of dam failure under different failure modes for a range of flood events (flows) and other load cases (seismic).
- Assessment of the consequences of dam failure, for example the incremental potential loss of life (i.e., additional loss of life that may occur as result of dam failure, compared to loss of life that may occur for that same flow or seismic event without dam failure).
- Hydraulic and hydrological assessment including potential sensitivity of inputs including climate change (e.g., changing flood frequency), downstream population, engineering parameters, dam performance, and various design assumptions.
- The reduced failure potential that upgrades have on the different failure modes.

These assessments were undertaken for the current dam configuration (the base case). The results showed that the dam requires further improvement works to meet the ANCOLD Guideline acceptable Limit of Tolerability, and to reduce risks to an acceptable level in the long-term (refer chapter 3).

Sensitivity analysis has been undertaken utilising the inputs that influence the risk assessment outcomes the most. Additionally, further sensitivity adjustments were made to provide confidence that the improvement works will achieve long-term dam safety compliance requirements, though noting this is based on best information currently available and potential future changes (to inputs such as hydrology, climate change, population growth and development, design standards, dam condition and performance) could exceed current sensitivity assumptions.

5.2.1 Dam safety regulatory requirements

ANCOLD limit of tolerability

Dam owners are required to make informed judgements about tolerable risks for their various dam assets. A key tool available to assist establishing the level of tolerable risk for a particular dam is the ANCOLD limit of tolerability (LoT) concept. Tolerable risks determined through this framework are used in conjunction with a range of other considerations to guide the process of identifying, examining, and judging the significance of dam safety risks.

Typically, tolerable risks under this framework are identified and modelled through undertaking a risk assessment in conjunction with a series of dam break simulations. The outputs from this exercise assist with estimating the probability of the dam failing, defining the manner in which the failure occurs, and calculating the potential impacts that might be expected from the modelled event. In a more formal sense, the LoT represents the threshold for tolerable risk, which is "*a risk within a range that society can live with so as to secure certain net benefits. It is a range of risk that we do not regard as negligible or as something we might ignore, but rather as something we need to keep under review and reduce still further if and as we can*" (ANCOLD, 2003). Risks that are above the LoT are unacceptable, while risks below the limit may be considered tolerable. The process of calculating tolerable risk is a core element of a dam safety Comprehensive Risk Assessment (CRA) and the outputs allow benchmarking of risk against the recommended LoT criteria set by ANCOLD.

The use of the ANCOLD approach is supported by the Queensland Government referenced in detail within the Guidelines for Acceptable Flood Capacity for Water Dams (DNRME, 2019) which state:

> …*the risk assessment study data on the annual probabilities of dam failure and estimated* [impacts] *to determine whether the risk profile is within ANCOLD's recommended limits of tolerability. These minimum limits of tolerability are reproduced below from the… ANCOLD Guidelines on Risk Assessment (ANCOLD, 2003):*
>
> *for existing dams, an individual risk to the person or group, which is most at risk, that is higher than [1 in 10,000] per annum is unacceptable, except in exceptional circumstances*
>
> *for existing dams, a societal risk that is higher than the limit curve, shown on Fig. 7.4 of the ANCOLD Guidelines on Risk Assessment (ANCOLD, 2003) is unacceptable, except in exceptional circumstances.*

For this Stage 1 DBC 1 Options Evaluation, the ANCOLD limits of tolerability have been applied as a threshold assessment for each option. Any option that does not meet the ANCOLD limits of tolerability has been excluded from further consideration.

Principle of 'as low as reasonably practicable' (ALARP)

Once a dam's overall safety risk rating has been established, a further assessment step is required to determine if residual dam safety risks are "as low as reasonably practicable" (ALARP) and if the costs involved to implement further improvements would be grossly disproportionate to the benefit gained. The ALARP process is undertaken to further test the acceptability or adequacy of potential dam safety improvements once the limit of tolerability criteria have been met.

While there are dam safety Guidelines (ANCOLD, and Queensland Government) outlining ALARP processes to follow, there is no set definition for exactly determining when the ALARP principle has been satisfied, and as such, dam owners are required to make an informed judgement regarding the appropriate balance point for when '*the incremental cost of undertaking a spillway upgrade project to reduce the risk below the specified limits of tolerability exceeds the benefits.*'[1]

Judging ALARP assessments is more ambiguous than the more measurable limits of tolerability. To assist dam owners, Robilliard and Sih identified four relevant factors typically used when making an informed judgement as to whether risks are ALARP. These are:

- The cost-effectiveness of safety improvement options. For existing structures, this involves assessing the justification for additional safety works based on the adjusted cost-to-save-a-statistical-life (CSSL).
- Comparing potential dam safety improvements to recognised good practice and precedent. In effect, this is a qualitative benchmarking exercise considering issues such as the dam's flood capacity, dam design, freeboard, the level of instrumentation, and other similar factors.
- The level of existing risk in relation to the limit of tolerability and the ability of options to reduce risk materially below the limit of tolerability (e.g. half to one order of magnitude below the limit of tolerability).
- Societal concerns, such as the population at risk, or downstream economic impacts.

For the PDIP, all of the dam improvement options have been assessed as satisfying the ALARP principal, as the cost of further risk improvements would be disproportionate to the benefits gained.

5.2.2 Dam safety guidelines and requirements

Dam safety risk assessment is a highly regulated activity that is guided by both statutory and best practice requirements that are detailed within government legislation and multiple industry body guidelines. As a dam owner and operator, Sunwater is responsible for ensuring its storages comply with government dam safety and relevant industry recognised standards. The Department of Regional Development, Manufacturing and Water (DRDMW) assists in this by regulating the safety of referable dams and by providing dam safety management guidance.

In particular, the Queensland Government's '*Dam Safety Management Guidelines'* (October 2020) set out the principles and framework for safe dam management. The guidelines are generally consistent with ANCOLD's '*Dam Safety Management Guidelines*' (2003) and have been developed with input from dam owners and industry leaders.

Any proposed PDIP works are also required to comply with the '*Guidelines on Acceptable Flood Capacity for Dams*' (DNRME, 2019) issued pursuant to the *Water Supply (Safety and Reliability) Act 2008* (Qld) and *Water Act 2000* (Qld). Because Sunwater has adopted a risk-based approach in determining the required dam safety mitigation measures, compliance with relevant procedures outlined within DNRME 2019 and the "*Dam Safety Improvement Decision Criteria Guidelines*" (Sunwater, 2018) is also required.

5.3 Dam safety technical investigations

5.3.1 Overview

The Paradise Dam Options Assessment Report (BQ, February 2020) recommended that additional technical investigations were required to develop the information required to allow a preferred option to be selected. In response to these recommendations and to inform further design development of potential dam safety options, Sunwater undertook a series of technical investigations and additional input studies, including:

- Roller Compacted Concrete (RCC) sampling and testing
- Post-tensioned anchor trials
- Geometry review (of strengthening approaches)
- Development of a 3D geological model
- Catchment hydrology review including extreme rainfall and paleohydrology assessments

- Impact assessment for potential dam failure scenarios

These detailed investigations are described in the following sections.

In summary however, the current risk profile for Paradise Dam following the Essential Works (the base case) remains above the ANCOLD limit of tolerability (i.e. non-compliant with dam safety Guidelines), and requires significant improvement works to reduce risks to an acceptable level, irrespective of which dam option is selected.

There are three key risks or structural issues identified for the existing dam, that influence the dam stability assessment and determine the improvement scope. While there are other dam safety risks and engineering aspects to be addressed (see Section 5.5 below), the key risks are:

- Low strength of the roller compacted concrete, including evidence of widespread debonding (no cohesion) between the layers, and potential sliding failure through the horizontal lift joints. This is not just limited to the Primary Spillway (on which the Essential Works scope was focused), but also the Secondary Spillway and Left Abutment.
- Poor extent of protection works at the base and downstream of the dam, and risk of scouring (as occurred during the 2013 flood event) and undermining of the dam wall. As above, this is not just limited to the Primary Spillway, but also the Secondary Spillway and Left Abutment.
- Poor foundation material under the Secondary Spillway, in particular for approximately 270 metre length on the right-hand side, and risk of failure through the foundation beneath the dam in this area.

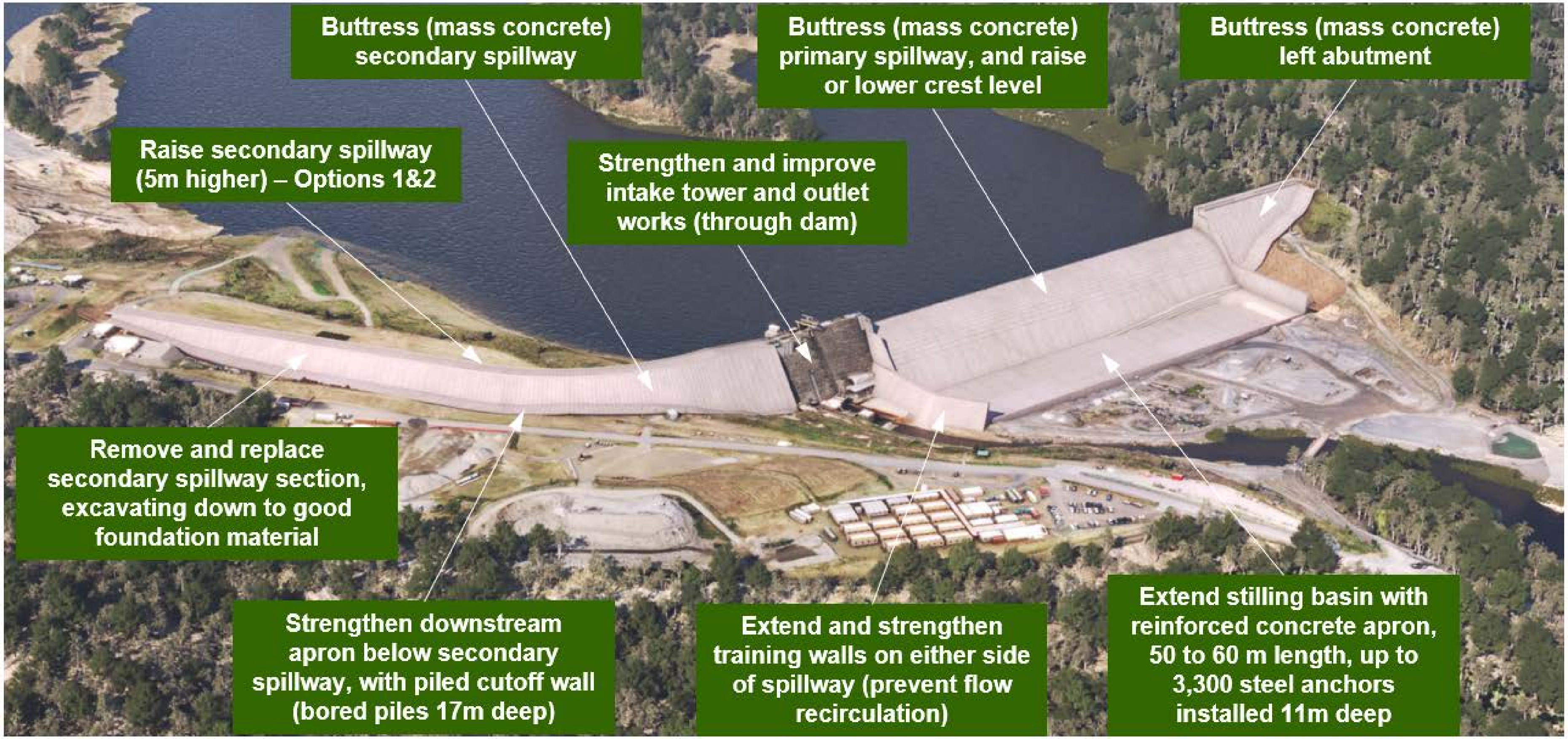
To meet the dam safety service need, remediation works are required on several elements of the dam, as shown in Figure 23. These remediation works are largely similar regardless of final height of the dam's primary spillway.

For Dam Options 1 and 2 (and to a lesser extent Dam Option 3), much of the required improvement scope is very similar, as assessed following the dam safety investigations detailed further below. While there is an obvious difference in spillway level (crest height) and buttress width (strengthening) for the primary spillway, the scope for other works required are the same or similar. This has resulted in relatively similar cost estimates between Dam Options 1 and 2.

Refer to Table 18 in Section 5.5 for further comparison of dam options. Common items of scope between Dam Options 1 and 2 include:

- Secondary spillway and left abutment buttress (addition of mass concrete strengthening)
- Secondary spillway raising by 5m in height (reduce overtopping frequency in this area)
- Demolition of half of the secondary spillway and excavation down to good foundation material, and reconstruction of this section of wall
- Temporary Coffer Dam to support item c. above
- Downstream scour protection below the secondary spillway and left abutment
- Extension of the existing apron below the primary spillway (significant scour protection)
- Construction and extension of training walls either side of the primary spillway and apron
- Improvement and modifications to the intake tower and outlet works

Figure 23 Summary of scope of work for dam improvement options

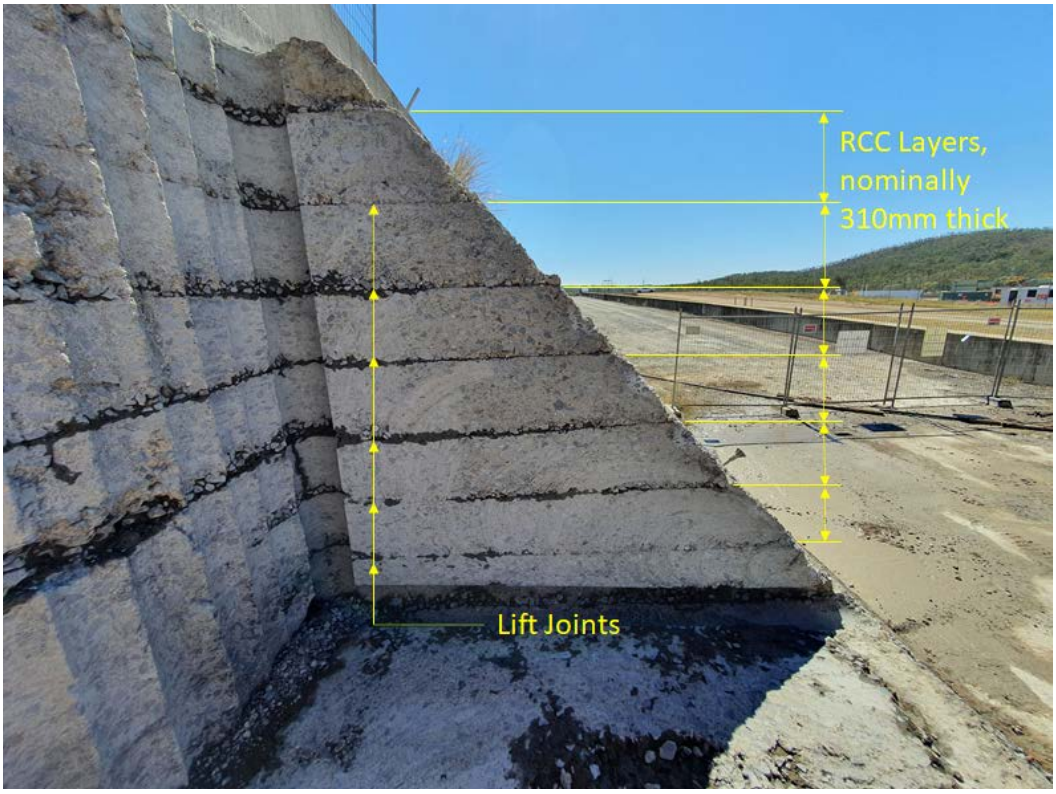


5.3.2 Roller Compacted Concrete (RCC) sampling and testing

Paradise Dam is the largest Roller Compacted Concrete (RCC) dam in Australia. RCC has the same ingredients as conventional concrete, however the mixture is dryer allowing placement by earthmoving equipment in horizontal layers typically around 300mm thick (refer Figure 1). RCC is typically a more economical method for constructing wide valley dams such as Paradise Dam (compared to conventional reinforced concrete), however the lift joint between each layer of RCC can be a point of weakness and a potential seepage path.

Paradise Dam was also constructed using a low proportion of cement in the mix of materials (also called a low cementitious mix or low paste mix). Combined with poor quality application of typical RCC construction methods, the lift joints for Paradise Dam were determined to be generally poor quality and major points of weakness.

Figure 24 Photo showing RCC layers and lift joints in Paradise Dam (August 2020)



Sunwater undertook a program of physical sampling and laboratory testing of the RCC throughout 2020-21 to better understand the lift joint shear strength. The results reaffirmed findings from 2019 that the lift joints are insufficiently bonded and present major lines of weakness throughout the structure. This significantly increases the likelihood that the spillway would not be able to withstand flood loading during significant rainfall events. As a result, the likelihood of the joints being a major contributor to dam failure is high.

The recent RCC sampling and testing activities follow a program of investigations that Sunwater had commenced in the wake of the flood events of 2010/11 and 2013. Initial sampling and testing to a lesser extent was undertaken from 2014 to 2015 (at this time, the failure of the dam through sliding along the RCC lift joints was not considered the primary failure mode). Further testing was undertaken in 2019, in conjunction with development of the Business Case. From this earlier program (2014 to 2019), a total of 21 sample RCC cores from various locations within the dam were extracted and tested. This testing, resulting in more detailed analysis and peer review in August and September 2019, identified a significant increased risk of dam failure due to lower RCC strength and potential failure through lift joints (compared to the original design basis), which triggered initiation of the Essential Works project in September 2019.

Dam stability assessments in 2019, based on the revised RCC strength, assessed that the dam was approaching marginal stability (likely failure) for a flood event equivalent to a 1 in 200 Annual Exceedance Probability (AEP) (a 0.5% likelihood of a flood event being exceeded in any one year), which is similar to the 2013 flood. This is compared to the original design basis, for which the dam was designed to safely pass up to a 1 in 30,000 AEP flood event (a 0.0033% likelihood of a flood event being exceeded in any one year). The dam's risk profile was assessed as being well above (not compliant with) the ANCOLD limit of tolerability. This required urgent and early-stage improvement works (the Essential Works), while further planning and design could be undertaken in parallel for much more significant improvement works proposed as the next stage, to meet the ANCOLD Guideline acceptable Limit of Tolerability, and reduce risks to an acceptable level in the long-term.

For the more recent sampling and testing activities (undertaken during 2020-21), a further 84 RCC blocks were removed from the primary and secondary spillways. These sampling and testing activities were consistent with the recommendations of the Commission of Inquiry in 2020. The samples were extracted by collecting twelve individual blocks of concrete at seven distinct locations across both the primary and secondary spillways: nine for testing and three spares in the event of sample damage. The blocks were carefully transported, and the lift joint (in the middle of the block sample) was subjected to direct shear testing in one of Australia's leading, independent rock and soil testing laboratories. An amount of untested material became available during the process and has been kept as spare material if initial samples were damaged during the extraction or transportation processes or if required for additional testing.

Through the laboratory process "well defined" residual shear strength parameters were determined (parameters with high statistical confidence from testing results in accordance with ANCOLD guidelines). This finding was important because it defines the point where the layers of the dam would likely start sliding past one another (a key dam failure mode). This information was used in stability calculations for the dam and compared against minimum acceptance criteria, for various flood loading cases that a structure of this nature is required to comply with.

The results from the 2020-21 RCC sampling and testing program were consistent with the 2019 testing program outputs and supported the 2019 dam stability assessment. Both sets of results represented a significant divergence to the values adopted in the original design of Paradise Dam. The original dam design required a cohesive bond between the lift joints which does not reflect the outcome of the construction process. The cohesive bond is a significant component when evaluating the sliding stability of a dam. Given that Paradise Dam has clear evidence of persistent unbonded lift joints, cohesion cannot be relied upon for the dam stability. The influence of this is that the current dam will never satisfy the required factors of safety for flood loading (that would typically be expected during the asset life of the dam) without significant improvement works.

In summary, in its current state, Paradise Dam *does not* meet ANCOLD's acceptance criteria for sliding stability for gravity dams and, therefore additional stabilisation and strengthening work is required.

5.3.3 Post-tensioned anchor trials

5.3.4 Overview

One method to compensate for the RCC lift joint shear strength being lower than design expectations is to install anchors vertically through the existing dam from the crest of the dam, passing through the body of the dam and into the underlying bedrock. The thick steel cables that make up the anchor are then tensioned after (post) installation, hence the label of post-tensioned (PT) anchors. Analysis indicated that Paradise Dam would require a significant number of these PT anchors at a relatively close spacing.

This solution however, carries with it an elevated technical risk, particularly as there is no precedent for such large and numerous PT anchor installations in large RCC dams like Paradise Dam. Sunwater determined that further investigations were required before confirming whether this remediation / strengthening measure would represent a preferred solution. The investigations would need to assess:

- the extent of variability in the foundation conditions, and from this, whether the foundations (the anchoring zone) had the appropriate strength to ensure the anchors could be relied upon
- the influence such large PT anchors, and the tensioning process (which would result in compression of the RCC layers), might have on the dam structure itself particularly given the existing issues identified with the RCC (refer section 5.4.2 above)
- the most appropriate drilling techniques and methods for installing the large and numerous PT anchors so the two processes did not damage the dam structure (particularly given the existing RCC issues, the required drilling accuracy, and the depth and diameter of drill holes required).

Sunwater undertook a full-scale PT anchor trial downstream of the dam structure and conducted an engineering assessment, known as a finite element analysis, to model the potential influence / impact the PT anchors may have on the dam structure itself. These two activities required Sunwater and its consultants to engage closely with industry to understand and assess the potential options available to undertake this work. Further details about the full-scale PT anchor trial and finite element analysis are outlined in the sections below.

5.3.5 Full-scale post-tensioned anchor trial

The full-scale PT anchor trial commenced concurrent to the Essential Works activities and involved installation of six (6) anchors downstream of the dam. Four (4) anchors were made up of 91 steel cable strands with the remaining two (2) anchors made up of 35 steel cable strands.

The 91-strand anchors were installed downstream of the primary spillway, with the anchoring zone of each targeted to reach, and be embedded within specific areas of interest in the foundations. The 35-strand anchors were installed downstream of the right abutment emergency spillway, with the intent of testing both the anchoring zone and the potential settlement of the foundation material.

A heavily reinforced, 2m thick concrete block was formed at each of the anchor sites. A large diameter hole was then drilled through the block, extending down to the foundation material that was to be tested. At each location, an anchor was inserted into the hole and concrete was subsequently poured into the same hole to form a bond at the bottom. This arrangement was left in place for 28 days, allowing the concrete to gain sufficient strength before the cables were tensioned. The stressing process was achieved using a high capacity hydraulic jack and was undertaken in line with timing specifications that incrementally added stress to the anchor.

The process continued until a force equal to 80% of the strand's strength was reached at which point it was 'locked off' into position and left in this state for a month. A second round of the stressing procedure was then completed. This second round testing was undertaken to check if the tension initially placed on the anchor had changed over the month that it had been left insitu. If measurements indicated that it had, some level of foundation failure was assumed to have occurred since the initial stressing process.

The key findings at the end of the trial on 26 February 2021 were that:

- Two of the 91-strand anchors successfully tested the ultimate capacity
- A third anchor had an 8.5% tension loss 51 days after the initial stressing process

These findings provided further data in relation to whether the use of PT anchoring as a potential remediation method was the most appropriate approach to strengthening the dam. Outcomes also provided input into the subsequent geometry review (refer section 5.3.7), undertaken to assess the use of anchoring as opposed to other strengthening approaches. By undertaking the full-scale anchor trials, engineering parameters for use within the concept and future design phases for the dam were able to be defined with a higher level of confidence.

Figure 25 Anchor cables being transported to installation location downstream of Paradise Dam (December 2020)

Figure 26 Anchors being stress-tested by 2,200t capacity jack at Paradise Dam (January 2021)

5.3.6 Finite Element Analysis

Finite element analysis (FEA) is a modelling approach used to understand how a structure will behave under a range of different forces including vibration, fluid flow and other physical effects. It helps engineers to identify potential problem areas within designs and predicts whether a proposed design element will perform as expected. Using specialised software, the modelling helps to predict the behaviour of each element under various load scenarios. The computer program then adds up the individual behaviours of each of these elements to predict the behaviour of the overall structure.

FEA modelling was undertaken for the dam options because there is no known precedent for installing the size, frequency, and arrangement of PT anchors within an RCC dam as would be required at Paradise Dam to improve its stability. The FEA models developed allowed the engineers to theoretically test various performance objectives without endangering the integrity of the dam structure.

As further information about the quality of the RCC and lift joints at Paradise Dam became known, the need to understand how inserting such a large number of PT anchors into the dam would affect the integrity of the structure became a key consideration. To answer these questions, four models were created, and using FEA software, analyses were undertaken to assess the feasibility of the proposed PT anchoring design.

The findings of the analysis concluded that several of the proposed arrangements were not feasible for use in the primary spillway because of the limited strength of the existing RCC and would likely result in significant cracking, additional load on already overloaded elements, uneven load distribution, and potential to interfere with the existing upstream waterproofing barrier.

5.3.7 Geometry review

The dam strengthening solutions considered prior to the Paradise Dam Options Assessment (Building Queensland, February 2020), relied on a significant extent of PT anchoring throughout the main dam structure to improve the dominant failure mode of shear sliding failure through the RCC lift joints.

The need to undertake the Essential Works project – in which a change to the profile of the primary spillway was required – meant that a re-evaluation of the geometric arrangement of the spillway was needed. This provided the opportunity to reassess the dam options to meet the requirements and the required level of strengthening to stabilise the dam. The three identified dam options (refer chapter 1) were evaluated to determine the preferred geometry and strengthening arrangement to be adopted within this OE.

The strengthening measures considered for the primary and secondary spillways are listed below:

- vertical post-tensioned anchoring (Figure 27)
- downstream buttressing (Figure 28)
- combined inclined post-tensioned anchoring with a *smaller* downstream buttress (Figure 29).

Figure 27 Strengthening option - vertical post-tensioned anchoring

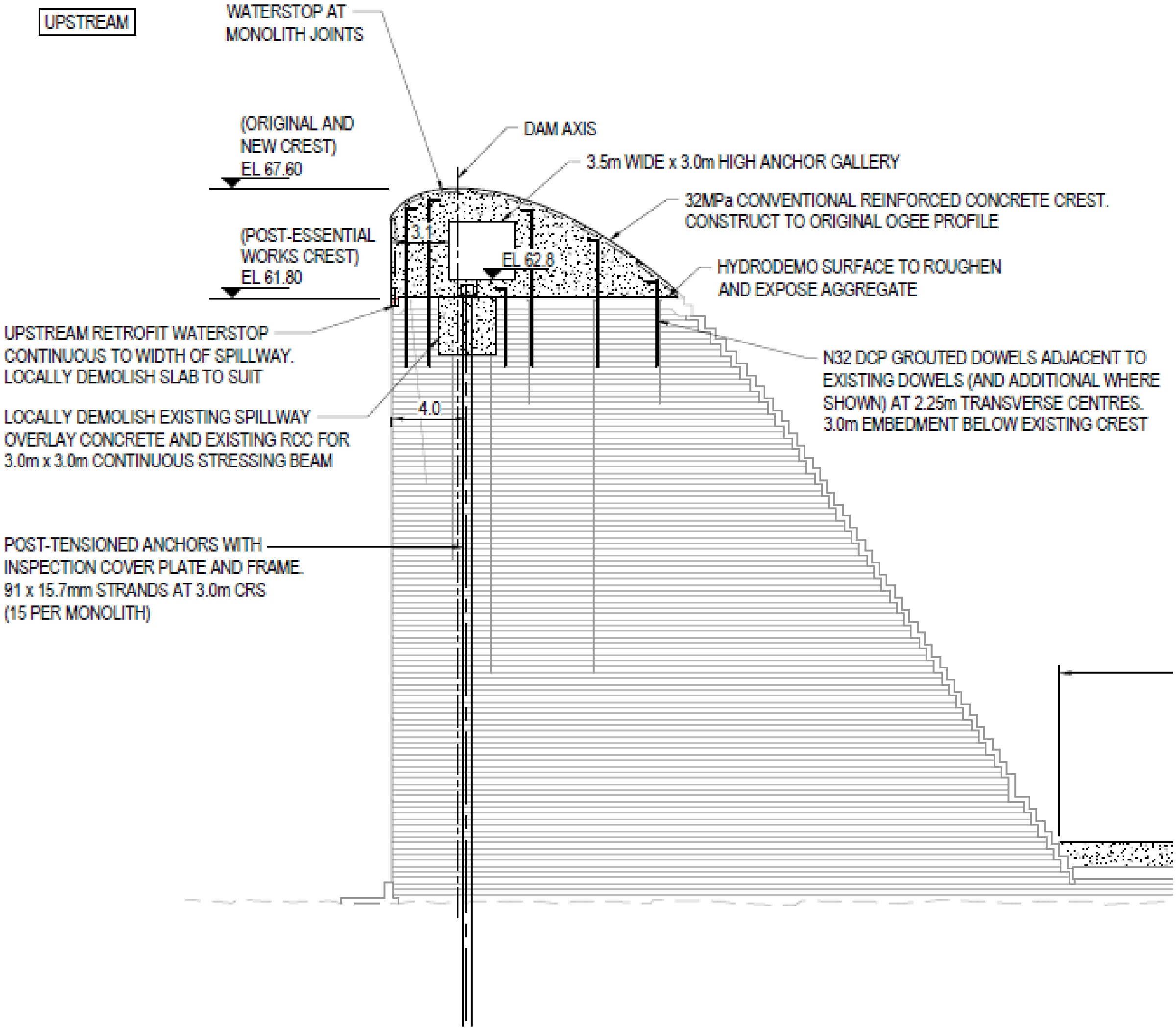


Figure 28 Strengthening option - Downstream buttressing

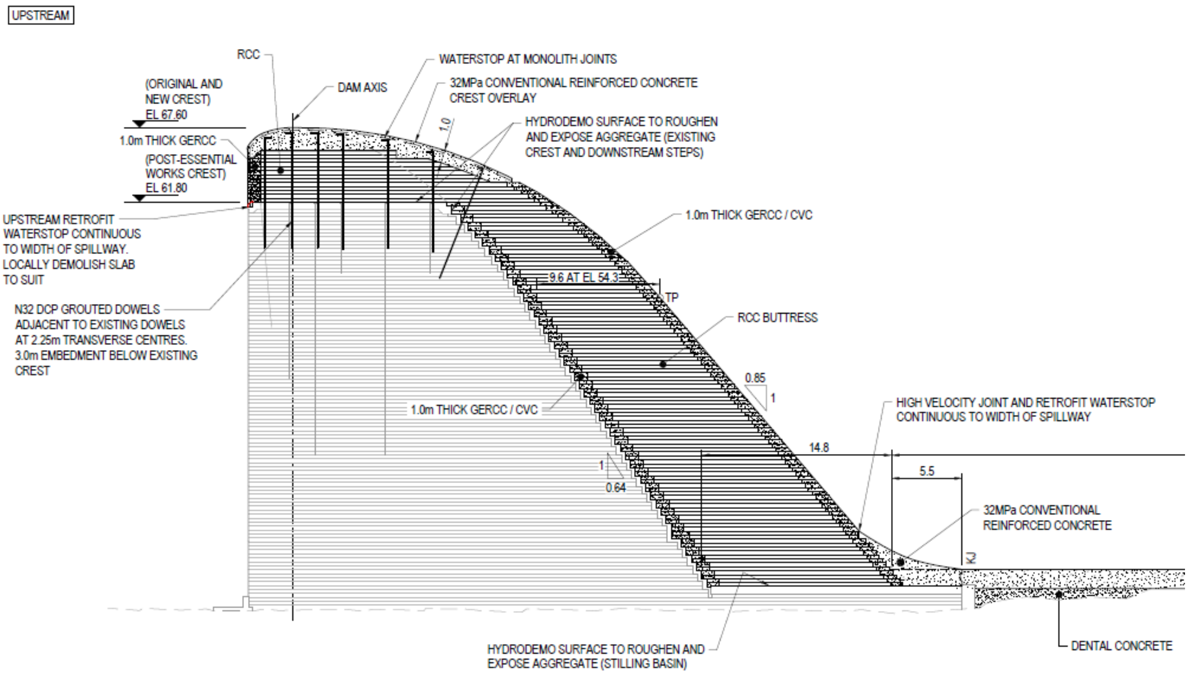
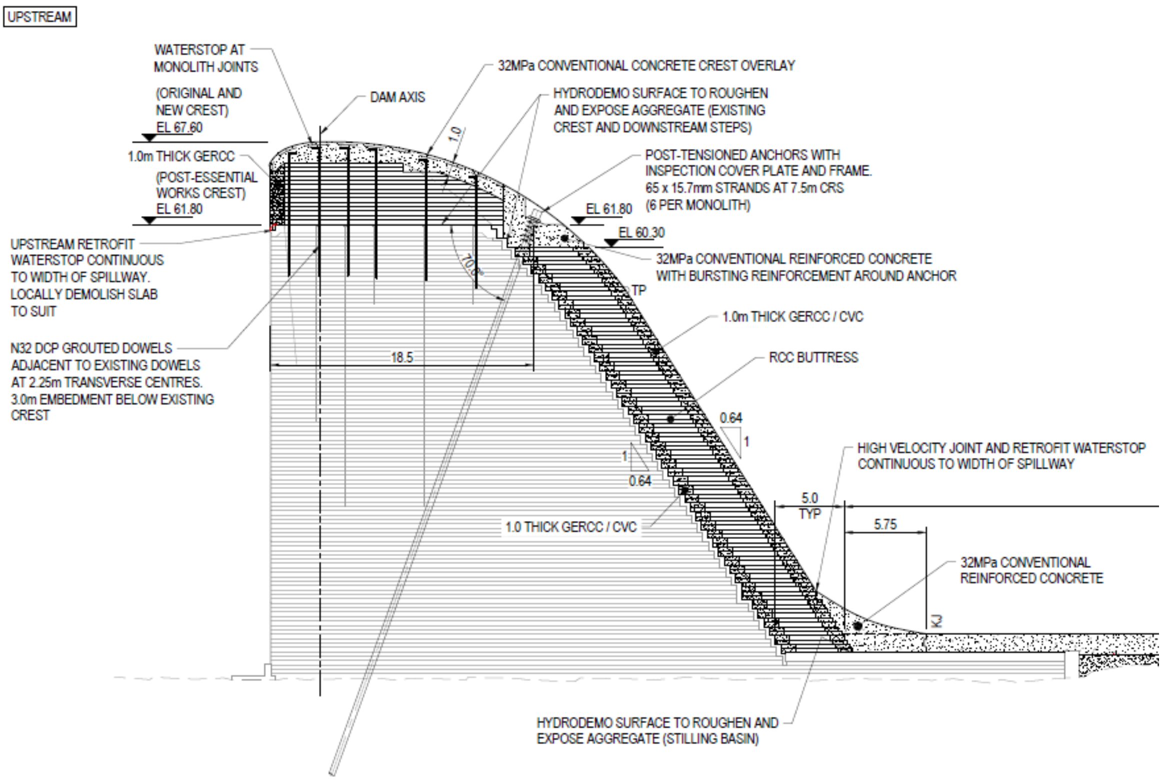


Figure 29 Strengthening option - combined inclined post-tensioned anchoring with a reduced downstream buttress



In assessing the geometry review and strengthening options, Sunwater undertook extensive consultation across the organisation, with the Technical Review Panel, and with key stakeholders. The consultation was used to review the risks and opportunities associated with each option and a consensus was reached that the preferred approach for increasing dam stability was a downstream buttressed solution. This consensus position was based on the following:

- There was no known precedent for PT anchoring of a low cementitious content (low-paste) RCC dam, let alone to the extent required to stabilise Paradise Dam.
- The Paradise Dam RCC has low compressive and tensile capacity, and variable lift consistency. The RCC is not an isotropic material, meaning material properties can vary across all directions at any given point. This makes results from computational analysis difficult to rely upon.
- Differential settlements are possible in areas of the primary spillway.
- Anchoring Option 1 has a high potential to disrupt the existing upstream drainage system as the construction activities of drilling anchor holes, water testing them, water-proof grouting, redrilling, retesting, and anchor grouting are very invasive and create significant vibration and additional pressure loads within the dam structure.
- There are still unknowns associated with the PT anchored options that require further investigation. This includes the potential for creating a longitudinal direct tension crack in the RCC under the stress distribution beam and edge effects at the upstream face.
- Downstream buttressing is a passive solution to strengthening the primary spillway and removes the requirement for ongoing maintenance and monitoring of PT anchors. The buttress geometry provides sufficient mass such that the stability of the dam meets the minimum ANCOLD criteria.
- Whilst the downstream buttressing solution is proposed to be largely RCC based, the characteristics of the RCC are different to that used in the original construction of Paradise Dam including the use of a high paste or high cementitious mix and industry practice construction techniques which directly respond to and resolve the key issues identified in the original construction of Paradise Dam.
- Whilst some high-level technical limitations for buttressing have been identified including sourcing sufficient aggregate, shear capacity of new/old concrete interface and draining seep water at the interface, these limitations are relatively simpler to solve than those presented by an extensive PT anchoring arrangement. These solutions are expected to be defined in the continuing design work leading into and throughout Stage 2 of the DBC.

5.3.8 Geological model

In 2018, Sunwater commissioned the collation, review and combination of all existing geological and geotechnical information relating to Paradise Dam and to develop a preliminary 3D geological model of the dam foundation, abutments, upstream and apron/downstream areas.

The purpose of the 2018 model was to:

- consolidate previous ground investigations
- identify and locate key geological features documented by historical information
- define geological boundaries.

The preliminary 3D model was also used to assess targets for proposed geotechnical investigations and assist in informing the future business case and design development. The expectation was that the model would require several revisions as additional information became available from further investigations and/or data review.

Since that time, several updates of the model have been completed primarily because of updated geotechnical information becoming available and a further review of borehole core, mapping data, construction photos, grouting information, and laboratory testing.

In early 2020, at the time the Paradise Dam Options Assessment report (February 2020) was published, data obtained from a 2019 program of on-site geotechnical investigations was in the process of being incorporated into the model. In early 2021, these updates were incorporated into the model and an interpretive geotechnical engineering assessment had been conducted. Combined, these two pieces of work have improved the level of technical knowledge and understanding of the distribution of geological units and structural features within the foundations of the dam and areas downstream of the spillway. This has allowed:

- the development of a structural (geology) foundation model
- a review / update of the geotechnical properties of the foundation
- the adoption of geotechnical parameters for use in future dam stability assessments, scour assessments and the next stage of design development.

The geological model was a useful tool to inform understanding of foundation conditions and geotechnical properties and the engineering design parameters for the PDIP and underpins the basis of engineering design. The model allowed engineering interpretation of how the dam foundation will perform under various load scenarios.

5.3.9 Hydrology review

With a catchment area of 33,000 km², Paradise Dam is in one of the largest river catchments in Queensland and therefore standard techniques for estimating the frequency of significant river flows have limitations.

The initiating events for most dam safety risks associated with Paradise Dam are flood related. Gaining a better understanding of the frequency at which unusual to extreme flood events occur helps to improve predictions for potential dam failure events. To inform the OE, Sunwater undertook two input studies to improve flood frequency estimates at Paradise Dam, including:

- a catchment specific extreme rainfall assessment
- paleoflood hydrology investigations.

Together, these assessments form what is considered best practice in the field of flood hydrology.

Flood frequency curves are an important design parameter and are based on a set of complex hydrological interactions to provide an estimate of the intensity of flood events. A new set of flood frequency curves for Paradise dam were derived through:

- bringing together the rainfall frequency curves from the extreme rainfall study
- calibrating data to include historical flood events
- incorporating this data into the catchment hydrological model
- checking the frequency of observed floods (including paleofloods).

This same approach was adopted for the Ord River, the Hume River and Burdekin River catchments, with the most recent Paradise Dam and Warragamba Dam assessments being undertaken concurrently by dam hydrologists HARC.

The outcomes of the extreme rainfall assessment and paleoflood hydrology study are discussed in the following sections.

5.3.10 Extreme rainfall assessment

A catchment-specific extreme rainfall study for Paradise Dam was undertaken throughout 2020-21 to provide a better understanding of the likelihood of extreme precipitation across the basin catchment area. This was based on a probabilistic distribution model that assimilates data from complex interactions between current hydrologic and meteorological knowledge. The findings of such studies inform parameters for the design of structures with high safety requirements and therefore, provide valuable information to consider as part of the long-term PDIP remediation solution.

The Paradise Dam extreme rainfall study focused on the application of two independent methods to estimate the probabilities of extreme rainfalls occurring across the extensive Paradise Dam catchment. The approach used historical storm events from the tropical coastal zone of Australia to simulate associated potential rainfall depths across the catchment. This was used to derive a set of catchment-average rainfall frequency curves for the dam catchment. These curves were used to underpin multiple scenarios in a software simulation to provide greater confidence in rainfall depth possibilities. This information was also used to update the overall catchment hydrological model for Paradise Dam, and allowed additional calibration as required for historical flood events. Verification of frequency of observed floods (including paleofloods) was undertaken to derive a new set of flood frequency curves for Paradise Dam.

By undertaking this assessment, it was determined that the frequency of storm events resulting in rainfall of catchment-average depths associated with probable maximum precipitation, are rarer than previous estimates.

5.3.11 Paleoflood hydrology

Paleoflood hydrology is the study of ancient floods that occurred prior to human observation. Paleoflood records provide evidence of past flood events and add to the systematic record. This is achieved by sampling preserved flood sedimentary deposits in areas within a river’s banks that are unaffected by currents (i.e. slackwater areas) and dating collected samples using Optically Stimulated Luminescence (OSL) techniques. OSL is a dating technique used to date the last time quartz sediment was exposed to light. The process exposes individual grains of quartz extracted from the samples to an external blue-green light stimulus. Based on a time-dependent increase in the number of trapped electrons induced in the quartz grains, a light is emitted. The level of luminescence emitted is related to an age and is the basis for paleoflood assessment.

The Burnett River is a bedrock-confined macrochannel. Field observation of exposed bedrock at numerous locations, provided confidence that the channel is laterally stable within 7km of Paradise Dam. The presence of bedrock provides a stable boundary condition and facilitates the reconstruction of discharges from previous floods with current surface elevations.

Findings from the Paradise Dam paleoflood assessment completed in 2021 found evidence of multiple significant level floods occurring over the last 1,000 years. Drawing on this data, it was identified that:

- The 2013 flood event was not the largest flood to occur within the last 200 years and larger floods have occurred within the study area in 1890, 1893 and 1942.
- The frequency of extreme flood events has not been consistent over the past 1,000 years, with a cluster of five extreme flood events in the last 200 years, and with only another five extreme flood events in the 800 years prior to that.

5.3.12 Climate change hydrology

Climate change has a potential longer-term impact on hydrology, which in turn may impact on dam safety and risk assessment processes. This is considering the potential change on flood frequency, and that the AEP of a given areal rainfall may be increased by climate change.

The assessment outcomes are that longer term, flood events for a given peak flow and peak flood level, may become more frequent, and this may be more evident for the more extreme flood events, leading up to the Probable Maximum Precipitation (PMP) Flood. The PMP has not changed in size, but rather the frequency of events leading up to this, reflecting an increase in the flood frequency curve (even though average annual rainfall may actually decrease longer-term).

This will result in an increased probability for dam failure within the 30 year evaluation period (considering the high level of uncertainty regarding climate change and other impacts beyond this time). This is in accordance with the risk assessment process for analysing dam safety against the ANCOLD Guideline acceptable Limit of Tolerability. This sensitivity assessment has been considered as part of various dam safety scenarios, but has not changed the recommended scope of works for each dam option – i.e. while the risk profile for the proposed improvement works increased longer-term due to potential climate change impacts on flood frequency, they remained below the ANCOLD Limit of Tolerability.

5.3.13 Failure impact assessment

Paradise Dam is a referable dam and is therefore subject to the provisions of the *Water Supply (Safety & Reliability) Act 2008* (WSSR Act) for dam safety purposes. As a result, dam safety conditions are applied, and the owner is required to establish a dam safety program to deliver appropriate design and operational management based on risks associated with any potential failure. Compliance is monitored and an emergency action plan is required to be in place and maintained to reflect any changes made at the dam.

The WSSR Act also mandates that a Failure Impact Analysis (FIA) must be undertaken for referable dams. An FIA determines what the potential impacts to the downstream community could be if a component of the dam was to fail during normal operational conditions or during a flood or seismic event (breach scenarios).

Sunwater has updated the Paradise Dam FIA for the current dam (post-Essential Works) and for the three proposed dam options to provide consequence information for the dam safety risk assessments. The FIA process involves:

- hydrologic modelling of the dam catchment and derivation of design flood frequency curves
- hydraulic modelling of the effects of dam breach outflows from Paradise Dam on the downstream reaches using 2D modelling
- detailed potential loss of life estimates including life loss simulation modelling (using HEC LifeSim software)
- direct and indirect costs to estimate the economic consequences of dam failure.

Comprehensive assessments of this nature are often undertaken as a dam safety measure on structures situated upstream of a population (such as Bundaberg), that is potentially vulnerable to inundation from the dam in the event of a dam breach. The FIA is a complex assessment that, using HEC LifeSim software, combines the outcomes from the extreme rainfall study, the paleoflood study, and hydrologic, dam break and consequence modelling to identify the population at risk (PAR) and potential loss of life (PLL). The PAR and PLL are the two main considerations used to assess the potential risk to life of dam failures. This information has been used to inform the design for each of the three dam options under consideration and is also required as critical input for improving and/or maintaining the effectiveness of emergency action planning and response.

5.4 Dam structural issues

5.4.1 Quality of Roller Compacted Concrete

A series of investigations into the quality of the RCC at Paradise Dam (refer chapter 1 and section 5.3.2) revealed the presence of unbonded lift joints, low strength, and voided concrete at the base of lift joints. This means that there are planes within the existing RCC that are weaker than originally designed and strengthening is required to reduce the risk of dam failure due to the forces it must withstand during flood events. The sampling and testing program results identified that these issues were extensive and persistent throughout the dam structure.

The engineering and technical studies were a topic of interest in the Commission of Inquiry into structural and stability issues at Paradise Dam. The technical investigations undertaken for the Options Assessment and this OE are consistent with the recommendations of the Commission of Inquiry.

5.4.2 Stilling basin

The existing stilling basin comprises an anchored, reinforced concrete apron slab that extends 20m downstream from the primary spillway. It terminates with an end sill, acting as an energy dissipator. The primary purpose of a dam's stilling basin is to protect the downstream riverbed and the dam's foundations from potentially being undermined by the erosive forces of water flowing over the spillway from the reservoir above.

In the wake of damage caused by the 2010-11 and 2013 flood events, it became evident the design of the stilling basin's apron and end sill were insufficient to provide controlled dissipation of energy and reduction in erosion and undermining (potential dam failure mechanisms). This was evidenced by the significant scouring that occurred immediately below the primary spillway and by the damage and commencement of undercutting to the existing apron (2013 event). Further, the 2020 Commission of Inquiry into Paradise Dam found that "*a root cause of the scour and erosion immediately downstream of the primary spillway apron was the apron's insufficient, 20 m width*".

The Essential Works has reduced the risk related to shear / sliding failure through the RCC lift joints as an interim measure but does not reduce the risk of dam failure related to erosion (i.e., scour) and undermining of the dam. The stilling basin therefore requires a major redesign.

A new stilling basin that extends significantly downstream is required to mitigate against this potential risk of failure. Using 2D Conceptual Fluid Dynamics (CFD) modelling it has been determined that the new stilling basin needs to extend downstream by 60m for Dam Option 1, 55m for Dam Option 2 and 50m for Dam Option 3. Final arrangements of the stilling basin require verification via 3D CFD and physical hydraulic modelling which will be undertaken in the next phase of design development.

Similarly, works are also proposed to provide improved protection against scour and undermining to the existing apron downstream of the secondary spillway in the event the secondary spillway overtops. The secondary spillway will also be raised to reduce the likelihood of flood events overtopping this section and by doing so, avoid the need for even further significant protection works in this area.

The RCC quality and lack of scour protection represent the most significant dam failure risks for Paradise Dam. Therefore, many of the improvement measures required to reduce the dam safety risks to an acceptable level relate to these two aspects.

5.4.3 Secondary spillway foundations

Paradise Dam's secondary spillway, located to the right side of the primary spillway (looking downsteam), has been designed to operate infrequently. As is typical of these dam structures, the secondary spillway was constructed at a level higher (RL78.0m) than the primary spillway (originally RL67.6m) and only starts to spill during rare to extreme flood events.

The peak of the 2013 flood, which was not a rare event, was only 1.5m from overtopping the secondary spillway crest. The Probable Maximum Design Flood (PMPDF) would overtop the secondary spillway by between 8-10m depending on the option being considered and up to 15m for the Probable Maximum Flood (PMF).

As well as being constructed of poor quality RCC, the secondary spillway requires remediation as the foundation material (upon which 270m, or approximately half of the spillway structure rests), consists of approximately 5-8m depth of poor strength, highly weathered soil-like material. In the event of overtopping there is a high potential that erosion of this loosely compacted material would occur and lead to failure of the secondary spillway.

The proposed approach to remediate this risk is to demolish the affected 270m upper portion of the secondary spillway, remove the poor foundation material down to a moderately weathered rock foundation then reconstruct and raise the secondary spillway by 5m to a crest elevation of RL83.0m in line with the left abutment height.

5.4.4 Training walls

Training walls are artificial embankments incorporated either side of a spillway structure to direct the course of water into the deeper, more stable river channel.

Paradise Dam features training walls located on either side of the primary spillway that extend along the length of the stilling basin to minimise erosion of the spillway abutments. They have been designed to guide the high velocity flows from the spillway downstream, diminishing flow velocity and reducing any consequent impact of recirculation on the dam abutments.

In its current arrangement, the left abutment training wall is ineffectual in protecting the riverbank/bed at this location. Without treatment, this leaves it vulnerable to scour from recirculation flow during high flow events. Exposure to scour here also has the potential to undermine the primary spillway monoliths due to potential erosion of foundation material. The vulnerability of the existing dam to this failure mechanism was clearly seen in the wake of the 2013 flood event. Once waters receded, a substantial scouring of the exposed riverbed was revealed.

Adding to the inadequacy of the existing training walls to protect the dam structure, both the right and left training walls were found to be unable to resist differential loads because they were designed to resist the range of hydraulic forces experienced during high flow events on both sides. To address this issue, the proposed remediation measure includes construction of new training walls to an elevation of RL51.5 m (approximately 20 – 25m high), for the full length of the stilling basin, to significantly reduce the potential for abutment scour. Strengthening of the existing training walls above this level through incorporating reinforced concrete thickening is also required. As noted in section 5.4.2, the new stilling basin and therefore the training walls, need to extend downstream by 60m for Dam Option 1, 55m for Dam Option 2, and 50m for Dam Option 3.

5.4.5 Outlet works

The outlet works at Paradise Dam are located on the right side of the primary spillway. An intake tower is located upstream of the dam which allows the controlled release of water for downstream customer use and environmental flows. The dam has separate outlets for irrigation and environmental releases. The existing outlet works have several known deficiencies that need to be rectified prior to the main PDIP construction activities within the river commencing. These deficiencies include:

- inadequate structural capacity of the irrigation and environmental conduits that pass water through the dam
- inability to inspect and maintain the 5.2m high x 3.6m wide environmental conduit guard gate. Without a reliable guard gate, releases through this outlet are heavily restricted.

- insufficient structural capacity within the base of the intake tower to meet seismic loading
- insufficient structural capacity within the walls and floor of the outlet works control room to withstand external hydrostatic loads
- insufficient protection of the environmental guard and regulating gate spindles from debris impact during flood events.
- The outlet works will be relied upon during the dam improvement works to divert river flows that would disrupt construction activities. The operational restrictions currently in place on the outlet works mean that this function would be severely hampered, therefore improvements must be made prior to commencing the main construction activities.

5.5 Dam options

The Options Assessment (February 2020) led to the definition of three dam options (refer chapter 1). Concept level engineering designs have been developed for each option, based on the following:

- Each option was required to meet the primary service need to meet dam safety requirements, as described in chapter 2.
- Designs were developed using the design parameters identified as part of the technical investigations set out in section 5.3.
- The design was further developed to address existing structural issues discussed in section 5.4.

The key design features for each dam option are presented Table 18 below. The improvement works for each dam option seek to rectify the same set of defects with the existing dam. In general, the extent of improvement required decreases as the spillway level reduces.

Concept design sketches for each option are included in chapter 7.

Table 18 Summary of works required for Dam Options

Zone	Dam Option 1	Dam Option 2	Dam Option 3
Primary Spillway	Construction of a 22m thick RCC buttress downstream of the dam and transitioning to a semi-ogee crest to reinstate the original full supply level of RL67.6m. Construction of an anchored reinforced concrete stilling basin with a total length of 60m from the toe of the new buttress. Construction of training walls at the left and right ends of the primary	Construction of an 11m thick mass concrete buttress downstream of the dam and transitioning to a semi-ogee crest 5m lower than the original crest level. Construction of an anchored reinforced concrete stilling basin with a total length of 55m from the toe of the new buttress. Construction of training walls at the left and right ends of the primary	Lowering the crest level by an additional 4.2m (10m lower than the original crest level). Construction of an anchored reinforced capping slab and 5m thick mass concrete buttress to the downstream face. Construction of an anchored reinforced concrete stilling basin with a total length of 50m from the toe of the new buttress. Construction of training walls at the left and right ends of the primary spillway to RL51.5m over a length of 50m.

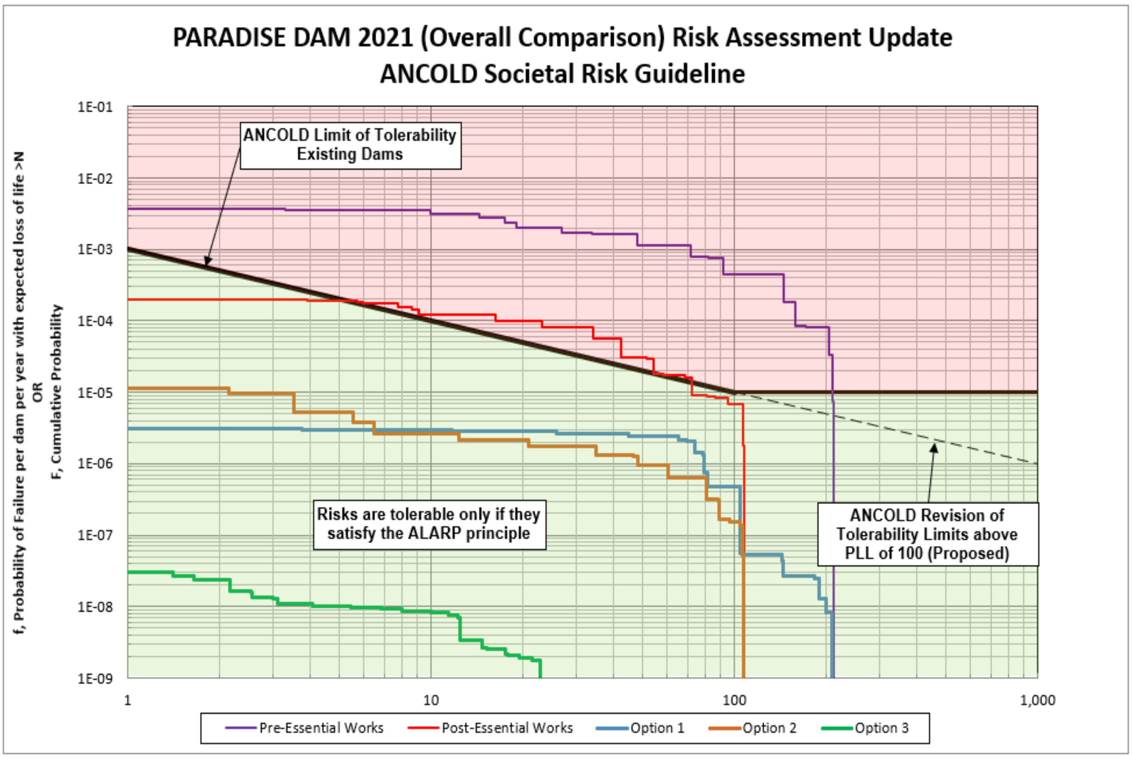
Zone	Dam Option 1	Dam Option 2	Dam Option 3
	spillway to RL51.5m over a length of 60m.	spillway to RL51.5m over a length of 55m.	
Secondary Spillway	Demolition of 270m of the secondary spillway, removal of 5-8m of poor foundation material, reconstruction and raising to RL83.0m (same level as Left Abutment).	As per option 1	Demolition of 270m of the secondary spillway, removal of 5-8m of poor foundation material, reconstruction to RL78.0m (same level as existing).
	Construction of an anchored reinforced concrete apron with a total length of 15m downstream of the dam toe, including a 17m deep contiguous piled cut-off wall.	As per option 1	As per option 1
Left Abutment	Construction of 5m wide RCC buttress to the full downstream face of the existing dam.	As per option 1	As per option 1
	Construction of an anchored reinforced concrete apron with a total length of 15m downstream of the dam toe, including a 17m deep contiguous piled cut-off wall.	As per option 1	As per option 1
Outlet Works	Lowering of the Environmental Intake sill by 5.8m to assist reservoir management during construction.	As per option 1	Lowering of the Environmental Intake sill by 10m to ensure serviceability with lower spillway level.
	Irrigation and environmental conduit strengthening.	As per option 1	As per option 1
	Protective covers for environmental conduit gate spindles.	As per option 1	As per option 1
			As per option 1

Zone	Dam Option 1	Dam Option 2	Dam Option 3
	Strengthening fine and coarse screens and support elements.	As per option 1	As per option 1
	Low Level outlet works wall strengthening.	As per option 1	
Other Works	Anchored reinforced concrete protection of the downstream face of the basalt outcrop known as "The Pimple" immediately downstream of Monolith L.	As per option 1	As per Option 1
	Removal of Mingo Crossing bridge (associated with condition of the original dam construction).	As per option 1	As per option 1
	Turtle Management	As per option 1	As per option 1
		Reservoir rim rehabilitation for reduced full supply level.	As per option 2
		Mingham Creek crossing upgrade for fish movement, for permanent lowering options.	As per option 2

5.6 Dam safety service need summary

Each of the three dam options indicate that the improvement works will improve the societal risk profile of Paradise Dam by approximately one order of magnitude better than the tolerable risk limit set out in ANCOLD 2003. This is shown in Figure 30 below which compares dam options against the ANCOLD societal risk guideline showing all three options meet the LoT, and therefore the threshold for further investigation in the OE.

Figure 30 Dam improvement options F-N curve



5.7 Limitations of the analysis

The dam safety risk assessments, engineering designs, and comparative cost estimates have been prepared in sufficient detail for the purposes of this OE. Further refinement of each of the input studies and the engineering design will be required as part of the Stage 2 DBC and once a preferred option has been determined.

There are several technical investigation elements that require further development to support a more detailed design process. These include:

- Geological and geotechnical model: Updating of the model to include information obtained from geological mapping completed prior to placement of dental concrete downstream of the primary spillway during the Essential Works project.
- CFD modelling: Hydraulic modelling of the preferred option with two- and three-dimensional CFD modelling.
- Physical hydraulic modelling: Construction of a scale model of the preferred option to confirm design assumptions and optimise design where possible.
- Finite element analysis: Further structural analysis focused on the buttressed dam monolith sections and focusing on the interface between the existing dam RCC and the new buttress; thermal modelling; the effects of buttress stiffness on load sharing; refinement of RCC/CVC breakdown within the buttress.
- Investigate construction of a drainage gallery within the existing dam.
- Crest stabilization: Review and refinement of crest stabilising dowel arrangements for the left abutment, primary spillway and secondary spillway following additional CFD modelling.
- Outlet conduit strengthening: Further consideration of the outlet conduit strengthening requirements based on results of additional structural assessment being undertaken.

- Geotechnical investigations: A range of further geotechnical investigations across the site to inform the following activities:
    - Onsite:
        - Extent of basalt on the right bank as this location presents as a possible concrete aggregate source.
        - Determination of whether a cut-off wall is required on the secondary spillway (upper section) to inform designer and contractor of relevant risk / cost and stability / scour analysis information.
        - Confirmation of possible coffer dam foundation materials to inform design and contractor risk
        - In-river cores – 1 x at left training wall and 3 x through downstream dental concrete to inform primary spillway buttress design.
    - Off-site:
        - Detailed site investigations for potential concrete aggregate sources.
        - Concrete mix design trials - to inform design and specification development.
        - Road Impact Assessment – considering local road network and to inform road upgrade requirements because of aggregate haulage.
        - Time of closure assessment - for Degilbo Creek bridge on Grills Road (main access road to site) to determine if upgrade is required.

  Investigations will continue as part of the Stage 2 DBC.

5.8 Key findings

- Despite completion of the Essential Works, which has significantly reduced the risk of dam failure, the dam does not currently meet the ANCOLD Guideline acceptable Limit of Tolerability and requires significant improvement works to reduce risks to an acceptable level in the long-term.
- Dam Options 1, 2 and 3 all satisfied this limit of tolerability.

6 WATER SUPPLY AND DEMAND

6.1 Purpose

The purpose of this chapter is to present the analysis of the primary service need of water supply and demand. This chapter outlines outcomes of the assessment of projected demand in the region, and an assessment of the alternative supply options available to meet this demand including consideration of yield, the delivery capacity of the existing distribution system and the impact of climate change on both water supply and demand through scenario analysis. These analyses lead to the identification of infrastructure option combinations that are best placed to meet projected demand for further consideration in the Options Evaluation.

6.2 Approach

The approach taken to assess a range of viable options to meet the water supply and demand service need involved:

- a detailed assessment of projected demand (agricultural, urban and industrial) across the Burnett River subscheme to 2050 to define the water supply and demand service need
- an assessment of the yield achievable from each of the dam options outlined in section 5.5
- identification and assessment of alternative supply options to supplement the yield from the dam options
- identification of constraints within the existing distribution system that have the potential to affect the capability of delivering the required yield to meet the projected demands across the Burnett River subscheme
- identification of distribution system improvements required over the evaluation period (i.e., to 2050)
- a scenario analysis to determine the potential impact of climate change on yield available from the dam options and the alternative supply options
- identification of the option combinations that provide sufficient yield to meet the projected demand (dam options plus alternative supply options). This step also included the identification of the combined options that provide sufficient yield under the climate change scenario.

6.2.1 Definition of allocations

A common approach is required to represent projected demand and enable a comparison of demands against the yields available from the supply options. Total demand is typically made up of two components, which represent the different water products available for sale allowing for different reliability of supply (as required depending on use).

The first component is High Priority (HP) (high reliability of supply) and is typically purchased by urban, commercial and industrial customers who require a consistent and very reliable supply of water. The second component is Medium Priority (MP) (medium reliability of supply) and is typically purchased by irrigation customers who are comfortable with a potentially lower reliability of supply. The demand analysis has presented the projected demand as medium priority equivalents, that is, total demand where the HP demands are converted to MP demands[6].

In a similar manner to, and to allow direct comparison to demand, yields in this analysis are also represented as MP equivalent allocations, with allocations representing a right to access water that can be purchased by customers. A customer purchasing a HP allocation is purchasing a right to access water in the future with a high average reliability (that is, a high probability that the water delivered under this allocation is the same volume as the allocation volume purchased). In contrast, a customer purchasing a MP allocation is purchasing a right to water which has a lower average reliability (that is, there is a much higher probability that the volume of water delivered is less than the volume of the allocation purchased. The price paid by the customer for HP and MP allocations differs to reflect this higher or lower reliability. The long-term average reliability of each HP and MP allocations is established legislatively in the region-wide Burnett Basin Water Plan while the specific reliability of allocations is announced by Sunwater annually.

Demand and water allocations may be considered in terms of water use by customers – for agricultural, urban, or industrial use. As identified above, and typical across the BWSS almost all water for urban and commercial use is purchased as HP allocations (to meet customer requirements for higher reliability), and almost all water for agricultural use is purchased as MP allocations (lower priced product).

6.3 Demand assessment

6.3.1 Summary

A detailed demand assessment was undertaken to establish the projected supply needs from agricultural, urban, and industrial customers within the scope area. This considered broader demand growth across the BWSS but focussed on supply that would be available from the Burnett River subscheme area. This included analysis of market prospects and key inputs available including developable land, potential yield from Paradise Dam, and the distribution footprint. The analysis was also remained consistent with the existing infrastructure constraints to delivering water from Paradise Dam outside the Burnett River subscheme.

The demand assessment included:

- detailed review and analysis of historical land and water use data, commodities data, and modelling of future drivers for demand such as population growth, commodity demand and climate change
- detailed stakeholder and customer consultation process (the detailed consultation process) via workshops and one-on-one discussions and a regional survey (electronic and paper-based) of current and prospective water users in the BWSS region. This detailed consultation process sought customers' views in relation to projected demand and key influences or drivers of demand. The survey received 255 responses (just over 58% of customers). An online engagement hub was also established to provide a central point for distributing information and collecting feedback. The engagement hub received over 1,000 visits while one-on-one discussions were held with key stakeholders.

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[6] Hydrologic modelling completed by Sunwater applied a conversion ratio of 2.23:1 for HP to MP.

- development and use of a probabilistic demand model that provided for a range of projected demands and allowed comparison to yield available from the water supply options.

The following sections detail the outcomes of the demand assessment for agricultural users, representing the largest proportion of the demand, and other users including urban, commercial, and industrial.

6.3.2 Agricultural demand

Agriculture and associated downstream processing and manufacturing are critical industries to the Bundaberg economy. Increases in water access entitlement sales have been slow but steady since 2005, when new allocations were made available to the scheme because of the construction of Paradise Dam. There was a sharper than average increase in sales in 2019 following Sunwater's Expression of Interest (EOI) - New Market Price - Paradise Dam Water Allocation sale process, released in September 2018. The EOI sought expressions of interest for the purchase of medium priority (MP) water allocations from Paradise Dam at a reduced market price, for existing or new customers in the downstream irrigation area, for a temporary timeframe only. This reduced the purchase price only for new MP allocations – not the ongoing water tariff (charges) – for a short period of time, to assess potential future market demand and sensitivity to pricing.

A demand analysis and the detailed consultation process about the projected water demand identified the following:

- Some crops/plants have undergone significant increase in the area planted over the last 10 years. The top three crops in terms of increased growth area are irrigated tree nuts (increase of approximately 3,800 ha), irrigated seasonal horticulture (increase of approximately 1,800 ha) and irrigated tree fruits (increase of approximately 700 ha).
- Expansion of these three crops has largely offset decreases in cane production area. This equates to an estimated 24% (over 10,000ha) reduction in production areas in the 10 years to 2019, with most cane production areas experiencing a structural change to the top three crops identified above. Market conditions for tree crops such as macadamia are extremely buoyant, and this trend is projected to continue at least to the end of the evaluation period.
- Other high value horticulture crops are also expanding, primarily in response to domestic market growth and the competitive advantages of the Bundaberg region including climate, quality soils, proximity to markets compared to North Queensland, water resource reliability, reliable logistics chains, and relatively good access to labour. This has been occurring on former cane production areas (crop conversions) and greenfield irrigation area development (formally dry land farming areas). These trends are projected to continue through the evaluation period but will likely be constrained by the rate of growth in the domestic market.
- The decreases in irrigated sugarcane land have resulted in the closure of the Bingera Sugar Mill. The shift in production away from cane reflects both recent history and future expectations (both a function of superior economic returns for other irrigated crops).
- Econometric analysis of historical water use found that usage is particularly susceptible to changes in climate (predominantly rainfall and temperature) but is not significantly impacted by short-term market trends (e.g., commodity prices).

- The region is projected to see continued growth in agricultural water demand largely due to tree crops (particularly macadamias), with smaller increases coming from a variety of other factors including climate change and farming practice change.

Analysis and the detailed consultation process also revealed several other factors with the potential to influence growth of areas under irrigation. These included:

- the ability of the distribution system to reliably deliver purchased allocations in a timely manner
- the long-term influence of climate change on future investment
- availability of good quality agricultural land
- the costs of land, establishment of high-value crops and water services and other business inputs
- availability of grafted trees (where relevant).

Agricultural projected demand (i.e., MP allocations) showed increasing demand across the full BWSS area from around 231,200 ML in 2020 to around 314,200 ML by 2050 an increase of approximately 83,000 ML. This projected increase is likely to be driven by:

- greenfield expansion of the total irrigation area (i.e., expansion of land not previously irrigated)
- net increases in projected demand as more irrigation areas previously under cane production are converted to perennial tree crops
- increased demand to offset the impacts of climate change (particularly peak temperatures)
- increased watering requirements to meet environmental policies and updated farming practices. These policies are largely driven by governmental policy to reduce diffuse runoff to the Great Barrier Reef. While best management practice is still under development for perennial tree crops, based on requirements for other horticultural crops, it will likely require inter-row watering to improve ground cover to mitigate sediment and nutrient runoff from crop plantations. This simple change to meet environmental requirements will increase water demand by approximately 0.5ML/ha for perennial tree crops.

A large proportion of the projected growth in demand is expected to come from the Isis irrigation area, and to a lesser extent, the Woongarra and Gooburrum irrigation areas. These locations have the largest areas of land available for agricultural development and, as revealed through the consultation process, also align with a high level of interest from agricultural users with an eye for future development.

6.3.3 Urban, commercial, and industrial demand

The actual urban, commercial, and industrial demand varies year-on-year, but over the five-year period to 2020, usage ranged between 2,350 – 2,550 ML per annum (based on data provided by Sunwater). In the future, projected urban demand will be influenced by population forecasts and per capita water use. Commercial and industrial water demand is typically expected to grow at the same rate as urban demand.

The projected demand across the full BWSS area indicates aggregate urban, commercial and industrial water use (i.e. HP allocations) increasing from around 17,100 ML in 2020 to around

17,820 ML by 2050, an increase of approximately 720 ML. This projected demand growth is relatively minor when compared to the projected demand increases for agriculture.

6.3.4 Total demand in the Burnett River subscheme

As identified in section 1.2.1, this OE is being undertaken at the Burnett River subscheme level. Considering demand at this level has several benefits including by allowing consideration of:

- total system yield (i.e., total water available represented as allocations available)
- impact on yield of different dam options (primary spillway levels)
- potential climate change impacts on yield related to rainfall and inflows from the upstream catchment
- alternative supply options that may supplement yield from the dam options
- projected demand in the lower Burnett River irrigation area
- potential constraints and upgrades required to the existing distribution system in the area (including Isis and Woongarra irrigation areas).

The demand assessment however was undertaken across the broader BWSS (including both the Burnett River and Kolan River subschemes). It was assessed however that the majority of this future demand (growth) would most likely occur in the Burnett River subscheme, and would be made available by utilising the larger volume of allocations available in this subscheme as a result of Paradise Dam.

There are a smaller volume of allocation remaining (for sale) in the Kolan River subscheme, though this is limited to the availability of approximately 16,500 ML MP. This is compared to 83,700 ML MP and 17,100 ML HP (or a total of 121,800 ML MP equivalent) allocations available for sale in the Burnett River subscheme, if Paradise Dam was returned to its original full supply level (Dam Option 1).

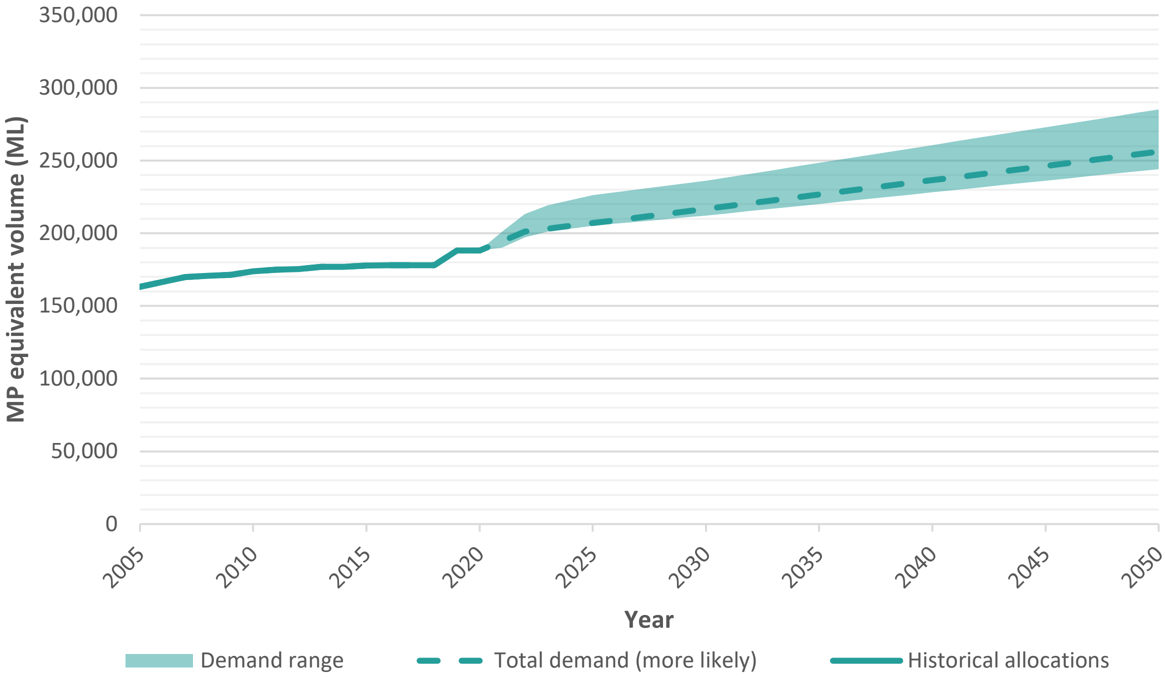
Consistent with the demand assessment findings and areas of likely growth, it is therefore assumed that of the 83,000 ML of additional MP demand for agricultural use over the period from 2020 to 2050 (Section 6.3.2 above), 16,500 ML will occur in the Kolan River subscheme utilising the remaining allocations available there, and the remaining 66,500 ML demand will occur in the Burnett River subscheme. For the small volume of 720 ML for additional HP demand over the same period (section 6.3.4), this is assumed to occur in the Burnett River subscheme.

Figure 31 shows the projected demand estimates for the Burnett River subscheme area up to the end of the evaluation period (2050). Using the central case outcome, the total projected demand is approximately 68,100 ML of additional MP equivalent by 2050. A range of higher and lower projected demands are also shown representing the variability in input assumptions in the modelling.

The figure shows that the actual demand profile increases steadily from 2005 to 2020 with a step increase in the short-term from 2021 to 2025. This step increase reflects the lag between low water requirements for tree crops established around 2015 and the significantly higher water use required for those crops as they reach maturity. This short-term growth rate is a function of the assumed current age of trees planted in recent years. This assumption is difficult to verify and to know with any level of certainty as GIS mapping of land use change is typically only undertaken by the State every 5 years. However, all trees currently planted will be at full maturity by around 2025. From 2025 onwards, projected demand is expected to increase steadily to the end of the evaluation period in 2050.

Note that the range was developed using Monte Carlo analysis (20,000 simulations across all model parameters). The outcome of the Monte Carlo analysis is very skewed with a lot more upside risk in the demand (P90 projections) than downside risk (P10 projections). This is a result of the increased water use for irrigated agriculture associated with a number of factors including: increased temperatures resulting from drivers including climate change; potentially higher growth rates for the development of high-value crops, and increase in water applications rates to optimise profitability. A range of projections was developed individually for the agricultural demand and the urban, commercial and industrial demands.

Figure 31 Projected demands from the Burnett River subscheme to 2050



Source: Adapted from NCEconomics (2021) Demand Assessment for Paradise Dam Improvement Project.

6.4 Yield assessment of supply options

6.4.1 Summary

A detailed yield assessment was undertaken to establish the projected water available from current and potential future water supply options within the scope area.

The yield assessment included three key tasks:

- developing a hydrological model of the existing water supply catchment area for Paradise Dam
- using the hydrological model to determine the potential yields available from various supply options including the dam options and a range of alternative supply options
- using the hydrological model to determine the impacts on potential yields available from each of the options under a climate change scenario.

6.4.2 Yield of dam options

Yields for each of the three dam options were calculated using hydrological models with each one being developed based on existing model information available from the Queensland Government's Department of Environment and Science (DES)(Queensland Water Modelling Network). The input parameters were based on the performance of the current Burnett River subscheme, including the target reliability of the different allocation levels set for the Burnett River subscheme in the Burnett Basin Water Plan.

The yield calculated for each dam option is based on multiple factors including:

- the volume of water available from the dam at each of the primary spillway height levels associated with the individual options. This is referred to as the Full Supply Volume (FSV).
- The balance between volumes of water flowing into the dam from upstream rivers and direct rainfall and the volumes of water flowing out of the dam (for example, as environmental flows)
- The reliability of supply (HP and MP as outlined in section 6.2.1 above) with the aggregate total supply represented as MP equivalent allocations.

The FSV and modelled MP equivalent allocations for the three dam options are outlined in Table 19 below.

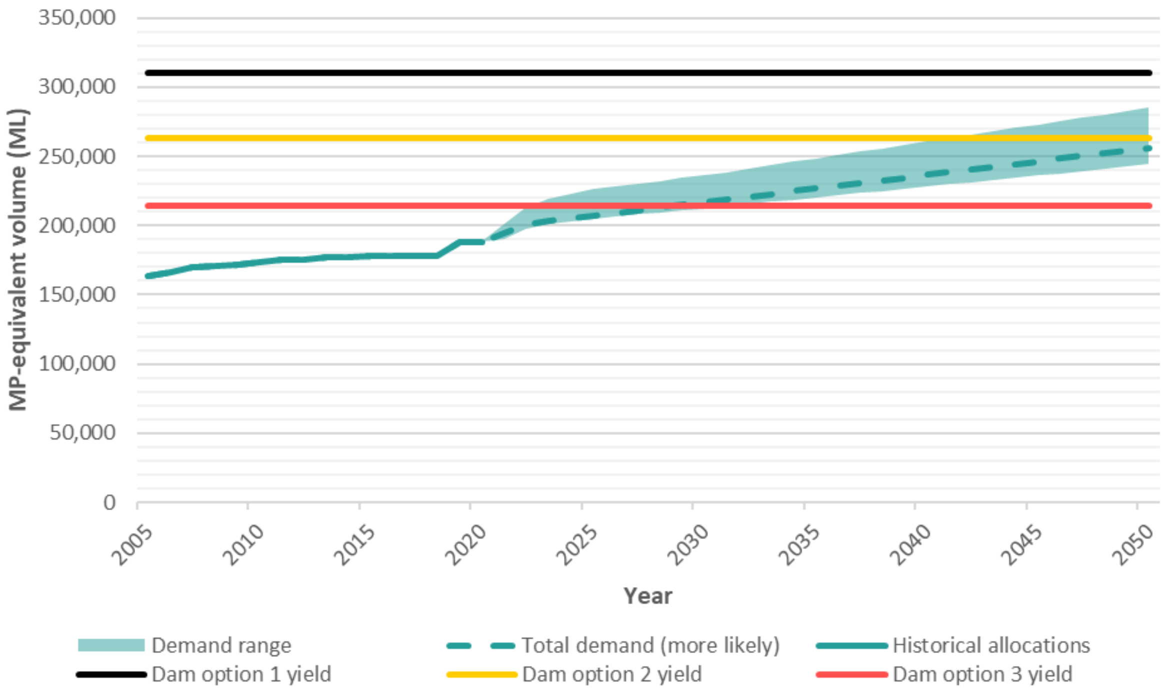
Table 19 Yields for each dam option

Dam option	Primary spillway level	Full supply volume (FSV)	Dam MP equivalent allocations (ML)	Burnett subscheme MP equivalent allocations (ML)
Dam Option 1	RL 67.6 m	300,000ML	168,600	310,180
Dam Option 2	RL 62.6 m	184,000ML	121,600	263,180
Dam Option 3	RL 56.7 m	114,000ML	72,600	214,180

Note: MP equivalent allocations represent the total yields from the Burnett River subscheme

Each of the three dam options were assessed against the increase in demand of 68,100ML. The results of the demand assessment compared to the water that would likely be available from the three dam options are presented in Figure 35. This shows Dam Option 1 meets the full range of projected demand. Dam Option 2 meets the most likely demand but does not meet scenarios above the most likely demand (P50) within the range, nor does it meet projected demand beyond 2053. Dam Option 3 does not meet the most likely demand. Dam Option 2 and 3 both require additional capital investment for alternative supply options to meet the service need and to be comparable to Dam Option 1.

Figure 32 Projected demand to 2050 with historical allocations and sub-scheme yields excluding alternative supply options



Notes:

- Total demand (more likely) represents the most likely projected demand from the demand assessment
- Historical allocations represent water sold from commissioning of the dam to 2020
- Dam option yields represent the totals available in the Burnett River subscheme under each dam option excluding alternative supply options.

6.4.3 Yield of alternative supply options

Where the yield available through one of the dam options does not meet the projected demand, alternative supply options may be required to supplement the dam supply. Several investigations into potential alternative supply options that may be required to enhance available yield from the PDIP have been undertaken. This includes development of such strategies as Sunwater's Burnett and Kolan Regional Blueprint, which though a process of global and regional trend analysis, scenario planning and early infrastructure identification assisted in identifying a longlist of high-level options to support the Paradise Dam Options Assessment (BQ, February 2020), as well as the detailed yield assessment and hydrological modelling process outlined in section 6.3.1.

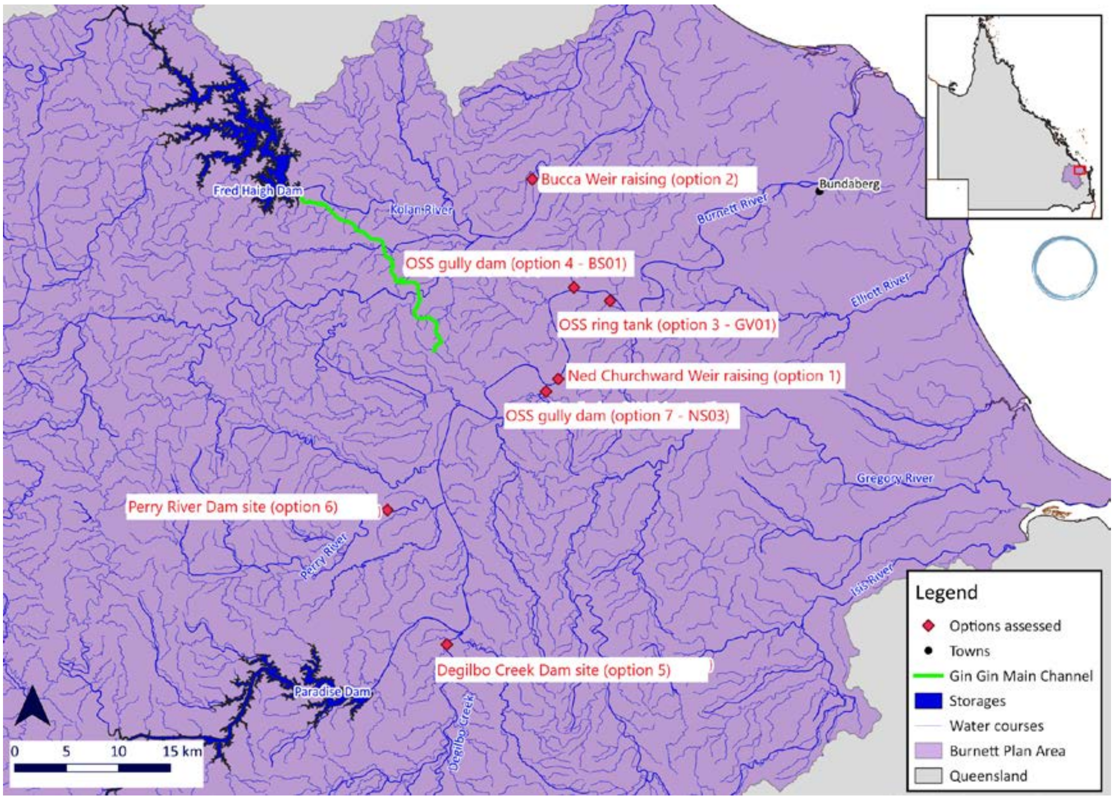
The long list of options identified in Table 20 included potential infrastructure solutions identified through the Regional Blueprint process.

Table 20 Alternative supply options long-list

Supply type	Description	Assessment findings
New dams and weirs	Kalliwa Dam	Due to proximity, the introduction of these dams would require a full decommissioning of Paradise Dam.
	Mingo Dam	
	Degilbo Creek Dam	Medium catchment size and medium yield
	Perry River Dam	Small catchment size and low yield
	Sunday Creek Dam	Very high cost compared to benefits – uneconomic
	Gregory River Dam	Very high cost compared to benefits – uneconomic
	Isis River Dam	Flow regime and associated conservation values impacts

Supply type	Description	Assessment findings
	Yandaran Creek Weir	Ruled out based on environmental impacts including estuarine impacts
Raising options	Ned Churchward Weir Raising	Large catchment size and medium yield
	Ben Anderson Barrage Raising	Ruled out based on environmental impacts including estuarine impacts
	Bucca Weir Raising	Medium catchment size and medium yield
	Kolan Barrage Raising	Upstream flooding impacts likely
Water harvesting and diversions	Granite Creek Diversion	Very high cost compared to benefits and environmental impacts (interbasin transfers)
	Offstream storages	Range of storage locations / sizes to be investigated.

Figure 33 Project locality plan showing alternative supply options assessed



The Paradise Dam Industry Forum Working Group 3 (PDIF WG3) was established at the commencement of the PDIP to provide a platform for irrigators to assist in the identification and assessment of options. The long list of options was workshopped through consultation with the PDIF WG3 and a total of six (6) alternative supply options of various storage types and volumes (generally located within the Burnett River subscheme except for Bucca Weir which is located within Kolan River subscheme) were shortlisted for further assessment (Refer Figure 25 above).

The initial six shortlisted options were assessed against multiple factors including:

- outcomes from hydrological modelling to determine yield
- technical complexity, concept designs and capital costs

- water planning implications
- potential environmental and social impacts.

Subsequent to the initial shortlisting, the working group specifically requested the inclusion of Perry River Dam as a potential secondary dam option (bringing the shortlist to a total of seven), with the assessment of this option limited to only the environmental and hydrological considerations. For comparative purposes, cost estimates from Degilbo Creek Dam were adopted for this option, given the similarities in dam type and sizing.

The outcomes of the hydrological assessment of alternative supply options are shown in Table 21 below. The results indicate that the yields available from each of the alternative supply options varies depending on which of the dam options is included in the modelling, and is a result of the variability of volume and regularity of flow passing over the dam at the different spillway heights. Concept designs and AACE Class 4 cost estimates were also prepared for each of the alternative supply options as shown in Table 21.

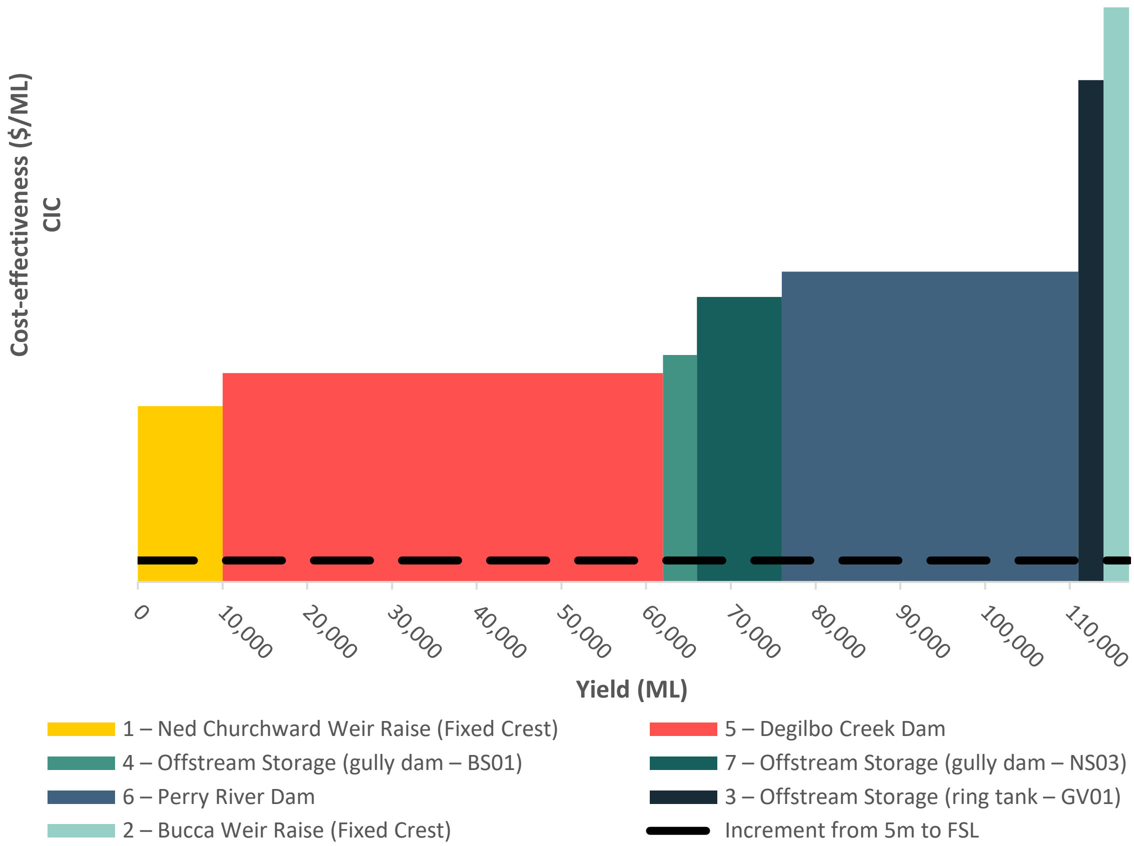
Table 21 Assessment of yields and associated costs for alternative supply options

Scenario	MP equivalent yield (ML) Dam Option 2	MP equivalent yield (ML) Dam Option 3	Base Cost Estimates ($M)	Rounded Cost per ML ($)
1 – Ned Churchward Weir Raise (Fixed Crest)	10,000	13,000	CIC	CIC
2 – Bucca Weir Raise (Fixed Crest)	3,000	6,000	CIC	CIC
3 – Offstream Storage (ring tank – GV01)	3,000	6,000	CIC	CIC
4 – Offstream Storage (gully dam – BS01)	4,000	5,000	CIC	CIC
5 – Degilbo Creek Dam	52,000	61,000	CIC	CIC
6 – Perry River Dam	35,000	41,000	CIC	CIC
7 – Offstream Storage (gully dam – NS03)	10,000	16,000	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

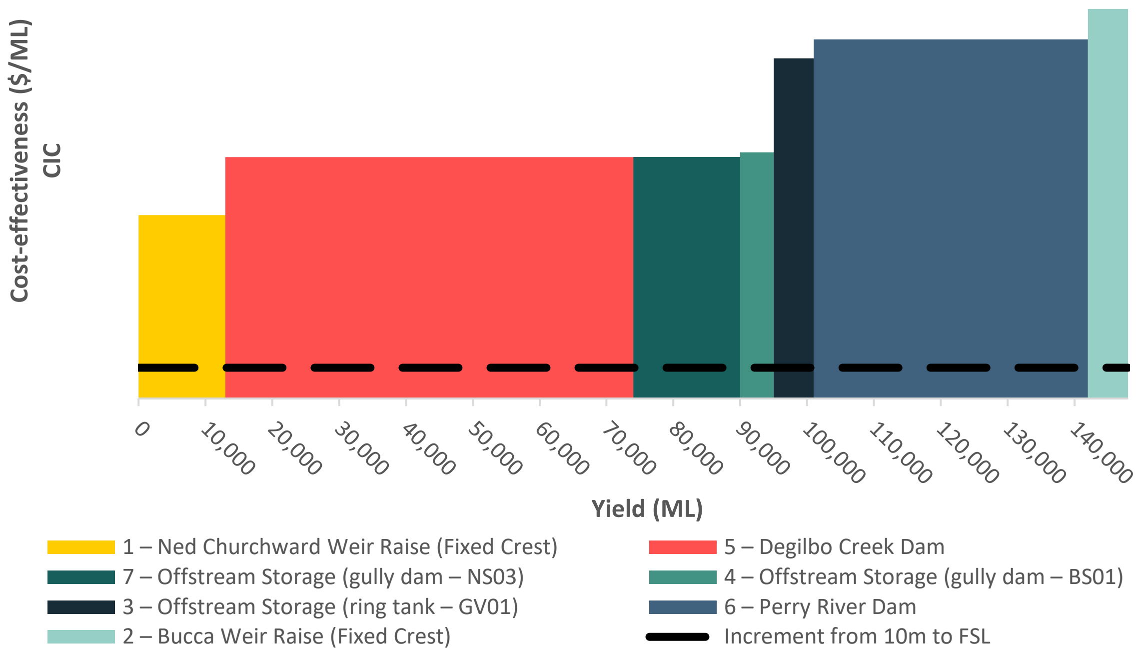
The yield and cost effectiveness of the alternative supply options are shown for Dam Option 2 in Figure 34 and for Dam Option 3 in Figure 35 below.

Figure 34 Yield and Cost-Effectiveness of Alternative Supply Options for Dam Option 2 (undiscounted)



Source: Adapted from Sunwater estimates

Figure 35 Yield and Cost-Effectiveness of Alternative Supply Options for Dam Option 3 (undiscounted)



Source: Adapted from Sunwater estimates

Additionally, desktop review of publicly available data was undertaken to understand the broad impact of each of the alternative supply options on surrounding environmental and social values specific to each location. The key findings from this assessment identified a number of similar environmental impacts common across all options, noting degree of impact more or less varying subject to the option size and inundation area, with no option excluded from further consideration on this basis. Initial investigations undertaken to inform this assessment included:

- Commonwealth, State and Local environmental and planning legislation approvals review including likely timing of approvals processes
- Assessment of terrestrial and aquatic offset requirements
- Cultural heritage assessments.

The evaluated alternative supply options were considered for selection in the infrastructure combinations, on the basis of their yield and cost effectiveness, as outlined in Section 6.6. The outcome of the environmental and social reviews of the selected options are incorporated into the evaluation analysis as outlined in distribution system (section 6.4.5)

6.4.4 Approach

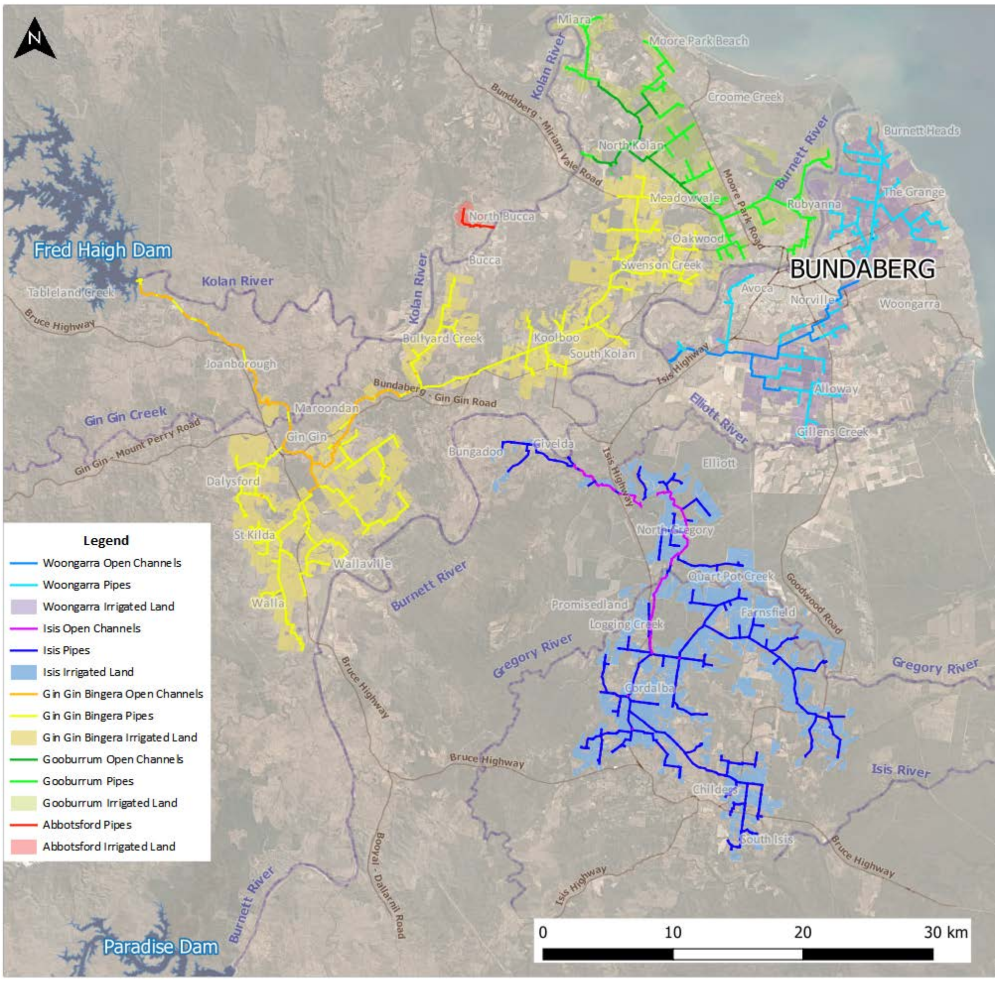
Water allocations purchased by customers of the Burnett River subscheme that come from Paradise Dam are delivered via an existing distribution system. As projected demand is set to increase, the existing network must also keep pace and have the capacity to deliver upon the water needs of users over the long term. This section provides an assessment of the current distribution system's capability to deliver available yields to meet the projected demands. To meet the service need, the distribution system must meet the peak irrigation requirements for projected 2050 demand in the central case.

The Bundaberg Irrigation Area (BIA) is comprised of five separate distribution systems including the Isis and Woongarra Systems in the south that extract water from the Burnett River; and the Gin Gin-Bingera, Abbotsford and Gooburrum systems that draw water from the Kolan River to the north of the Burnett. Figure 36 below shows the current distribution systems.

Investigations to date, operational feedback and the detailed consultation process conducted for the demand assessment revealed constraints in the existing distribution system that may result in an inability to deliver to customers, and as a result a potential constraining effect on demand. An assessment of the BIA distribution system in its current state was conducted to inform this OE and involved the construction of a hydraulic model of the southern system, identification of this system's constraints, and an assessment of required upgrades needed to increase capability of delivering the projected demands. The focus of the distribution system upgrade work assessments was on the Isis (in the south east) and Woongarra (in the east) irrigation systems as they were identified as having existing constraints and, in the demand assessment were identified as focus areas that would experience demand growth.

The hydraulic model of the Isis and Woongarra distribution systems considered a range of scenarios to assess whether the system has the capacity to meet the projected 2050 demand. The scenarios considered various demand volumes and staged infrastructure upgrades at 2021 and 2050 and informed the selection and prioritization of upgrade options.

Figure 36 Map of Bundaberg Irrigation Area distribution systems



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6.4.5 Distribution system assessment outcomes

The distribution system assessment process identified capacity constraints in the distribution system, impacting the ability to meet projected demand in the Isis and Woongarra irrigation areas. To resolve these constraints, upgrades of the distribution system infrastructure are required. The assessment grouped the upgrades into two tranches as follows:

- Tranche 1 is required to facilitate the distribution of water to meet short to medium-term demand growth. The scale, location and timing of these investment requirements is relatively certain (required by 2028) but requires detailed assessment to finalise scope for investment.
- Tranche 2, which are much larger upgrades, have been developed based on existing information and assumptions on longer-term demands. The requirement for these upgrades is certain, to meet the projected demand in the future. However, the type of augmentation, scale, location, and timing of much of Tranche 2 is uncertain as it ultimately needs to respond to future development and investment decisions of hundreds of irrigators. Detailed assessment of Tranche 2 will need to be performed at an appropriate time when development progresses in the region.

Because the uncertainty in tranche scale, location and timing is the same for each of the dam options, it does not impact on the relative differences in their overall assessment.

Based on the modelled date of implementation and criticality to the operation of the overall system, the potential scope for each tranche is summarised in Table 22 below

Table 22 Identified Distribution System Upgrades to meet service need

Area	Tranche 1 Upgrades (required by 2028)	Tranche 2 Upgrades (2036-2040)
Isis	• Upgrade Don Beattie Pump Station to 605ML/d • Quart Pot Creek Pump Station (Farnsfield side) and Rising Main to Farnsfield Storage increased to 341ML/d • Upgrade Farnsfield Main Channel at F8 reticulation channel • Telemetry monitoring for management of higher than design flow rates • Upgrade Isis Balancing Storage outlet structure	• South of Elliot River pipeline • Promised land pipeline • Farnsfield pipeline • Turpentine Road pipeline • Upgrade Siphons 1-7km Isis Main Channel (IMC) raise Hydraulic Grade Line (HGL) 3x • Upgrade Siphons 9-17km IMC raise HGL 2x • Upgrade Siphons 17-25.4km IMC 3x • Upgrade Crossings 19-25.4km IMC 4x • Upgrade DWB Pump Station 605-715ML/d and new RM
Woongarra	• Upgrade Woongarra Pump Station to 494ML/d • Additional siphon barrels and Childers Road and Price Street • Telemetry monitoring for management of higher than design flow rates	• Upgrade Woongarra Pump Station to 567ML/d • Three new pipelines to service expansion areas
Burnett River Area		• New pipeline and pump station to service new area

Distribution system upgrades required for the Isis and Woongarra irrigation areas are presented in Figure 37 and Figure 38.

Figure 37 Isis system performance and upgrades required under Scenario 4

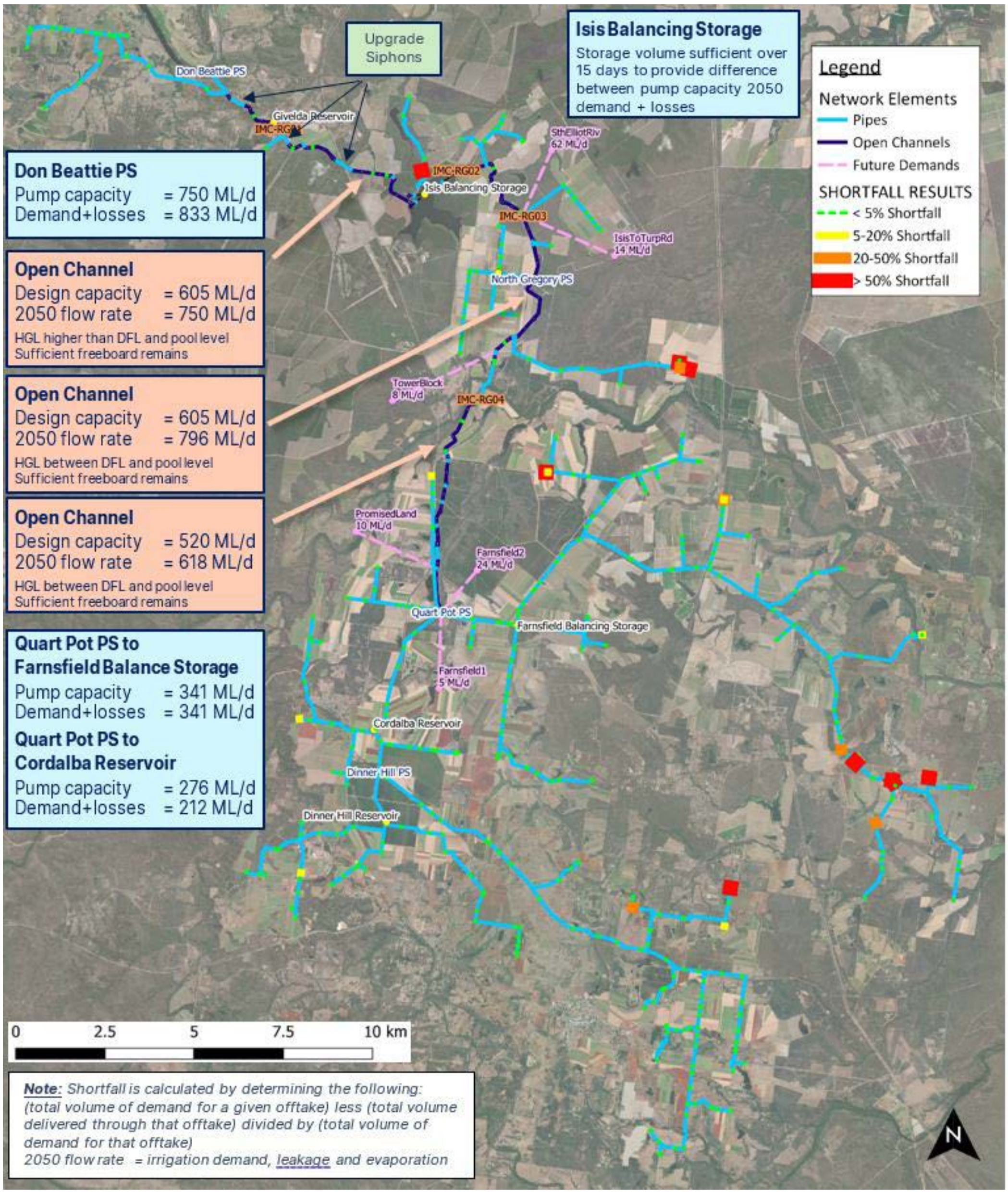
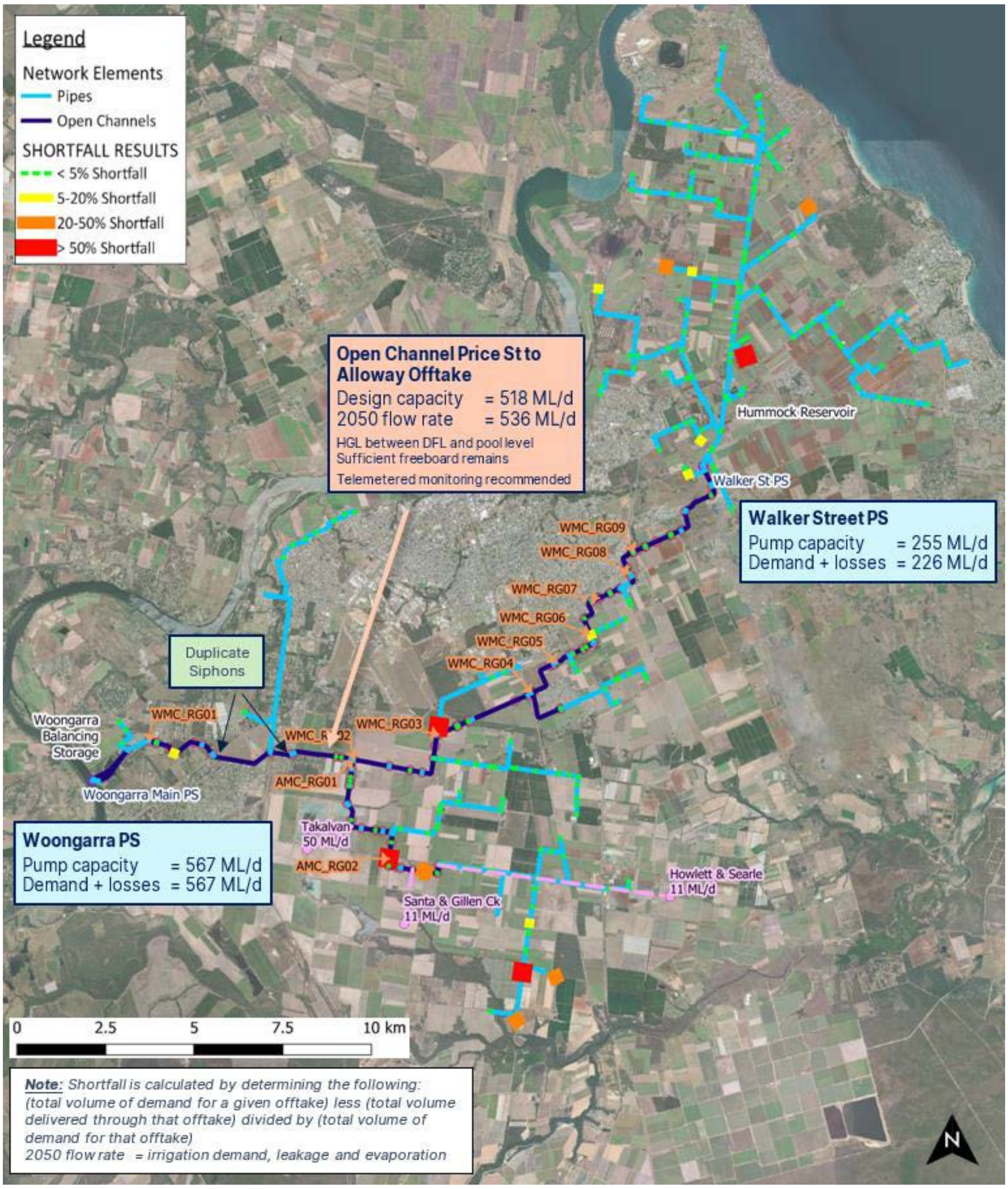


Figure 38 Woongarra system performance under Scenario 4



6.4.6 Summary

Tranche 1 is required to facilitate the distribution of water to meet short to medium-term demand growth. The scale, location and timing of these investment requirements is relatively certain (required by 2028) but requires detailed assessment to finalise scope for investment.

Tranche 2, which are much larger upgrades, have been developed based on existing information and assumptions on longer-term demands. The requirement for these upgrades is certain, to meet the projected demand in the future. However, the type of augmentation, scale, location, and timing of much of Tranche 2 is uncertain as it ultimately needs to respond to future development and investment decisions of hundreds of irrigators. Detailed assessment of Tranche 2 will need to be performed at an appropriate time when development progresses in the region.

It is considered prudent and efficient to address distribution system constraints, regardless of selection of dam option, when the scale, location and timing can be more accurately estimated. As a result, distribution system upgrades are recommended to be the subject of separate assessment and investment consideration, with the assessment of Tranche 1 being the priority.

The required distribution system upgrades are incorporated into the selection of options in Section 6.6.

6.5 Scenario analysis of impact of climate change on yield

To understand the impact of climate change on the dam option yields, hydrological modelling was undertaken as part of a scenario analysis. While undertaken on the basis of accepted industry-wide climate change approaches, as climate change science and its associated impacts continues to evolve, it should be noted that there remains considerable uncertainty and variation in scenario modelling outcomes. For this reason, while undertaking the OE process, a best endeavours approach has been adopted to address this modern issue, and the findings cannot be considered as confirming absolute certainty of the results. Based on these limitations therefore, scenarios were modelled and outcomes have been determined by modelling them through a range of climate models based on the commonly accepted Representative Concentration Pathway (RCP) 8.5 warming scenario which is a scenario increasingly used for water supply planning. The model runs were undertaken for Dam Option 1 and Dam Option 2 only and were undertaken to determine:

- The impact of the climate change on the average reliability of MP allocations if the existing yields are held constant. This was assessed across eleven different GCM, refer Table 23 below.
- The impact of climate change on the yields if the current average MP allocation reliability figures are held constant at the existing levels. This was assessed across six of the eleven GCMs, as representative ranges, excluding those models with the highest and lowest (extreme) results from above.

The key findings of the climate change assessment on yield were:

- There is a high level of uncertainty and a wide range of results, meaning that the selection of a central case (i.e., the most likely outcome) or aggregation of outcomes (e.g., selection of an average or median outcome) does not provide a meaningful input into the analysis. Therefore, the effect of each model outcome has been identified to provide a range of results that will inform the analysis.
- While some model outcomes showed a positive impact on yields (i.e., resulted in greater yield available), there was a larger number of models that showed a negative impact. Specifically:
    - Eight out of the eleven GCMs indicated reduced MP reliability performance compared with the historic benchmark of 92.3% (water security index, which is a measure of the probability that water security objectives can be met in any given month – being the ability to supply full allocation entitlements for that month – and is a different measure to the Announced Allocation calculation).
    - Yield estimates for four out of the six assessed GCMs indicated reduced outcomes (refer Table 23 below) and two out of the six indicated positive outcomes. Four outcomes (excluding the extreme highest and lowest results) provided a range of outputs to inform the scenario analysis.

- The larger the capacity of the alternative supply option, the more resilient the infrastructure is to downside climate change impacts on dam inflows. In effect, this is indicating that larger supplies provided a buffer against climate change risk and uncertainty.
- The analysis results consider potential climate change impacts on catchment inflows and supply reliability specifically at Paradise Dam, however the yield results are considered at the Burnett River subscheme level (related to the upstream catchment). For example, the size of the negative impact on yield for one model is similar to the total yield attributed to Paradise Dam however, the overall Burnett River subscheme (including Ned Churchward Weir and Ben Anderson Barrage) provides the best context for showing potential climate change impacts associated with the upstream catchment (upper Burnett River).

The results of the hydrological modelling have been presented in Table 23.

Table 23 Climate change influence on yield at 2050 for dam options 1 and 2

Climate Change Impacts			**Dam Option 1**		**Dam Option 2**
Global Circulation Model		Mean Annual Dam Inflows (ML/a)	Impact on reliability WSI (%)	Change in Yield to meet 92.3% WSI	Change in Yield to meet 92.3% WSI
Model ID	**Owner**				
CSIRO-Mk3.6	*(Australia – CSIRO-QCCCE)*	360,000	54.3		
GFDL-ESM2M	*(USA – NOAA, GFDL)*	530,000	72.9%	-160,000 ML	-153,000 ML
ACCESS1-3	*(Australia – CSIRO-BOM)*	700,000	79.9%		
GFDL-CM3	*(USA – NOAA, GFDL)*	720,000	81.9%		
ACCESS1-0	*(Australia, CSIRO-BOM)*	1,040,000	87.3%	-89,000 ML	-66,000 ML
HadGEM2	*(UK – MOHC)*	880,000	89.4%	-86,000 ML	-48,000 ML
CNRM-CM5	*(France – CNRM-CERFACS)*	1,050,000	91.5%		
MPI-ESM-LR	*(Germany – MPI-N)*	1,030,000	92.0%	-4,000 ML	-16,000 ML
CCSM4	*(USA – NCAR)*	1,440,000	94.2%	47,000 ML	20,000 ML

Climate Change Impacts				Dam Option 1	Dam Option 2
Global Circulation Model		Mean Annual Dam Inflows (ML/a)	Impact on reliability WSI (%)	Change in Yield to meet 92.3% WSI	Change in Yield to meet 92.3% WSI
Model ID	**Owner**				
NorESM1-M	*(Norway – NCC)*	1,160,000	94.9%	52,000 ML	26,000 ML
MIROC5	*(Japan, JAMSTEC)*	2,540,000	98.3%		

Graphical representation of potential climate change impacts for Dam Options 1 and 2 are as shown below, relative to the Burnett River subscheme. This is showing potential climate change impacts on yield as at 2050, based on the six GCMs as identified above (Table 235). This has been calculated by assuming that the historical performance for MP reliability is required to be maintained (water security index (WSI) as modelled in the integrated water quantity and quality simulation model (IQQM)) and identifying the corresponding impact on yield that can be provided by the system as assessed by each GCM.

Figure 39 Potential Climate Change Impacts on Yield (at 2050) for Dam Option 1

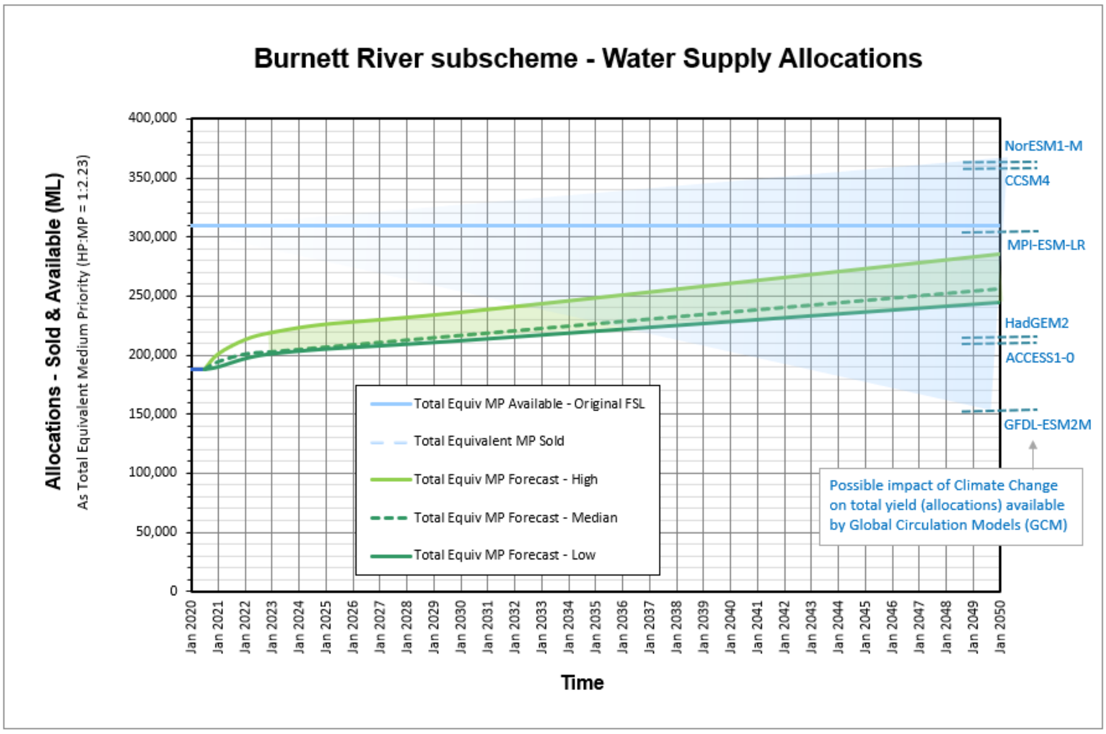
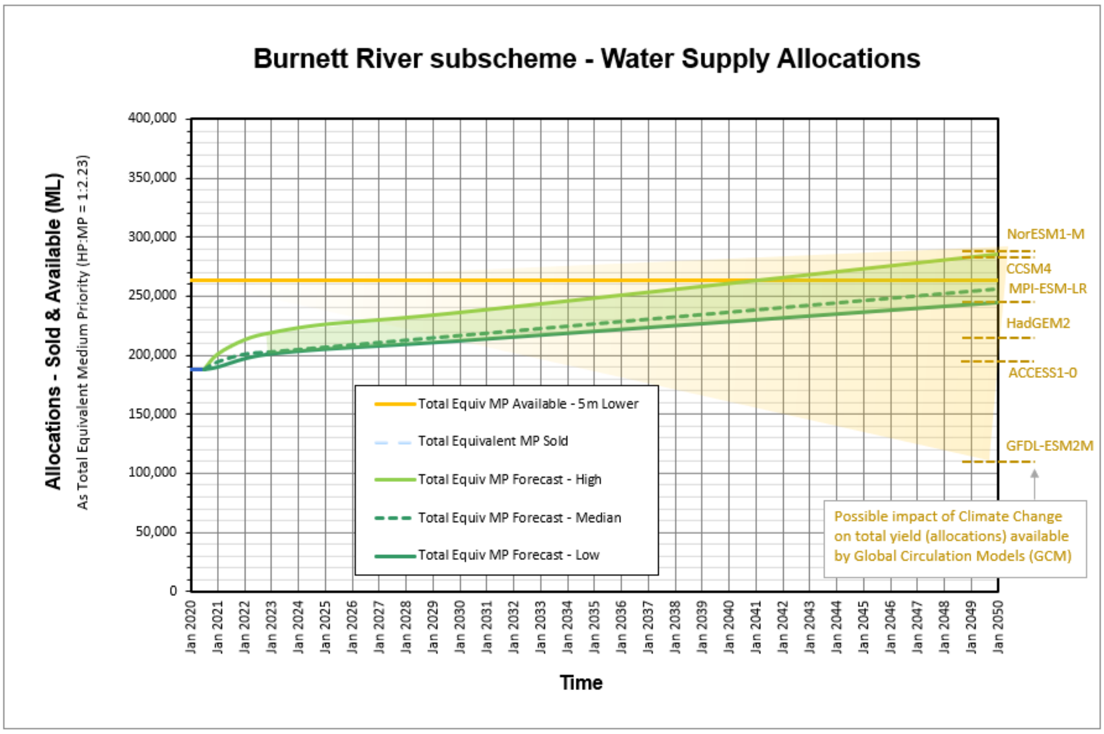


Figure 40 Potential Climate Change Impacts on Yield (at 2050) for Dam Option 2



In the event that the climate impacts predicted by the various models on the yield of Paradise Dam are realised, a different combination of dam and alternative supply options will be required to be selected in order to meet demand. The impact of these outcomes on the OE are described in section 6.6.2 below.

6.6 Options to meet demand

6.6.1 Summary

The outcomes of the earlier sections of this chapter have outlined the projected demand, as a key service need, and the range of supply options that can provide yield to contribute towards meeting this key service need.

Determining option combinations that meet the service need was undertaken based on the following methodology:

1. The yield of the dam options was compared to the projected central case demand as identified through the demand assessment.
2. Where the yield of the relevant dam option was insufficient to meet the projected demand, alternative supply options were selected to augment the yield using:
   a. The yield of the alternative supply option
   b. The cost effectiveness of the alternative supply option
3. The distribution system upgrades were evaluated based on their requirement to deliver the yield from the selected dam and alternative supply options to the demands in the region.

The outcome of this process identified the combined infrastructure options shown in Table 24 and presented in chapter 7.

Table 24 Combinations of options assessed against demand service need up to 2050 (central case)

Option (or combination of options) description	Sufficient yield?	Sufficient delivery capacity?
Dam Option 3	✗	✗
Dam Option 3 with alt. supply (Degilbo Creek Dam)	✓	✗
Dam Option 3 with distribution system upgrades	✗	✓
Dam Option 3 with distribution system upgrades and alt. supply (Ned Churchward Weir + Degilbo Creek Dam)	✓	✓
Dam Option 2	✓/✗	✗
Dam Option 2 with alt. supply (Ned Churchward Weir)	✓	✗
Dam Option 2 with distribution system upgrades	✓/✗	✓
Dam Option 2 with distribution system upgrades and alt. supply (Ned Churchward Weir)	✓	✓
Dam Option 1	✓	✗
Dam Option 1 with distribution system upgrades	✓	✓

6.6.2 Options to meet climate change scenario

To underpin the climate change scenario analysis, the above process was replicated utilizing the dam option yields incorporating the impact of climate change as described in Section 6.5. The resulting combined infrastructure options to be considered in the scenario analysis are summarized in Table 25. When climate change is incorporated into the analysis through a series of climate change scenarios on likely yield (and maintaining reliability), Dam Option 3 is highly unlikely to provide sufficient yield, even when combined with Degilbo Creek Dam. Therefore, detailed hydrological modelling for the climate change scenario was not undertaken for Dam Option 3. Dam Options 1 and 2 were assessed in detail using this hydrological modelling.

The analysis of Dam Option 1 and Dam Option 2 under climate change found that Option 1 is significantly more resilient to the downside risks of yield attributable to climate change and would still meet projected demand. For Dam Option 2, the need for Ned Churchward Weir Raise as the alternative supply option would be replaced by the need for Degilbo Creek Dam to meet projected demand, at a significantly greater cost. This outcome is dependent on the yield scenario. Other yield scenarios may result in different infrastructure requirements.

Table 25 Combinations of options assessed against demand service need up to 2050 (climate change scenario)

Option (or combination of options) description	Sufficient yield?	Sufficient delivery capacity?
Dam Option 2	✓/✗	✗
Dam Option 2 with alt. supply (Degilbo Creek Dam)	✓	✗
Dam Option 2 with distribution system upgrades	✓/✗	✓
Dam Option 2 with distribution system upgrades and alt. supply	✓	✓
Dam Option 1	✓	✗
Dam Option 1 with distribution system upgrades	✓	✓

6.6.3 Demand and supply beyond 2050

While the detailed demand assessment has only been undertaken out to 2050, the dam asset clearly has an economic life beyond 2050, and growth in water demand is likely to continue beyond the current evaluation period. In addition, the analysis of Dam Option 2 suggests that an alternative supply option is likely to be required around 2053 even under the more likely demand assessment. While the most efficient alternative supply option is the Ned Churchward Weir Raise, this solution only meets the requirements of around 4 years' growth, meaning that Degilbo Creek Dam may ultimately be required to meet demand under Dam Options 2 and 3.

To understand the potential demand and supply relationship beyond 2050, a scenario was established that extended the growth of water demand beyond 2050 for a further 20 years. The figure below shows the outcome of these scenarios, noting it is assumed that yields are not impacted by climate change. Scenarios that were established are based on:

- the more likely demand growth pattern up to 2050 (dashed line)
- the assumption that the more likely demand growth slows beyond 2050 to the same rate as the P10 demand growth from the demand assessment (dotted line)
- the range of growth (P10 to P90) is extended for 20 years (shaded wedge).

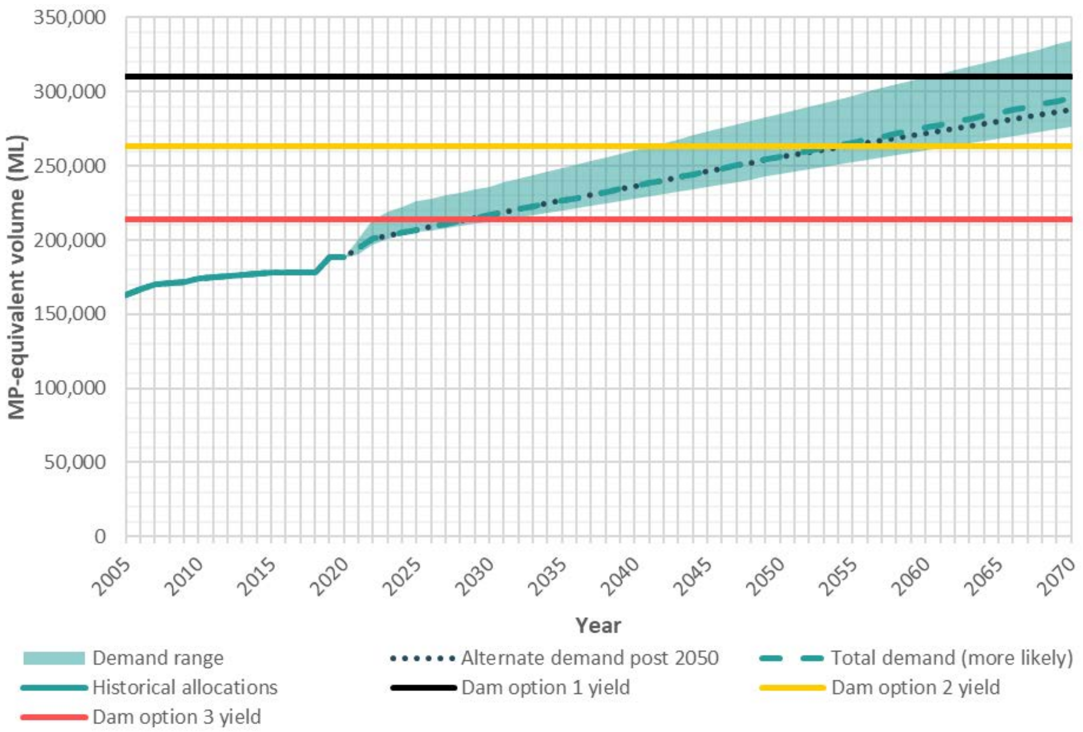
The key points to note are:

- Dam Option 1 provides sufficient yield for most potential demand scenarios. The exception is if the higher end of the range of demand scenarios eventuates (i.e., P90 demand), where an alternative supply may be required by around 2060.
- Dam Option 2 would require an additional supply by 2053 under the more likely demand growth, and the yield required by 2070 would far exceed the combination of Dam Option 2 plus Ned Churchward Weir Raise. This infers that Degilbo Creek Dam would be required by around 2060-2065. Even under the more pessimistic demand assessment (P10), an alternative supply would be required around 2060 and the yield requirement would exceed Ned Churchward Weir Raise before 2070. Again, this infers Degilbo Creek Dam would ultimately be required.
- Dam Option 3, consistent with the earlier analysis, provides insufficient yield even in the medium-term, and alternative supply options would be required.

This extension of the analysis is based upon limited information and the very long-term findings should be treated with caution. However, it does indicate that even a relatively short extension to the evaluation period materially changes the adequacy of the yield likely to be available from Dam Option 2.

In summary, even a relatively short extension of the evaluation period indicates that Dam Option 2 would also require major investment in Degilbo Creek Dam, while Dam Option 1 provides sufficient yield to meet all but the highest demand growth projections.

Figure 41 Demand and supply beyond 2050 scenarios



6.7 Key findings

- Dam Option 1 meets the full range of projected demands.
- Dam Option 2 meets the most likely projected demand but does not meet projected demands above P50, nor does it meet projected demand beyond 2053.
- Dam Option 3 does not meet the most likely projected demand.
- Dam Option 2 and 3 both require expensive alternative supply options to meet the service need and to be comparable to Dam Option 1.
- The demand assessment also identified constraints in the distribution system. Whilst the impact of these constraints has been considered in this analysis, it is considered prudent and efficient to address the distribution system requirements of tranches 1 and 2 when the scale, location and timing can be more accurately estimated.

7 PROPOSAL OPTIONS SUMMARY

7.1 Purpose

The purpose of this chapter is to document the combinations of infrastructure options identified in section 6.7 that are proposed to be assessed in the cost benefit analysis (the proposal options). The chapter also describes the potential infrastructure impacts on the proposal options that result from consideration of the scenario analyses, including the impact of climate change.

7.2 Overview

Three options were identified comprising of a combination of infrastructure elements to meet the service need. These options were required to meet the most likely projected demand within the Burnett River subscheme, through yielding sufficient water and delivering the yield through the distribution system. These three options incorporate a combination of:

- Paradise Dam upgrade options (dam options),
- alternative supply options, and
- distribution system upgrades (system upgrades provide additional delivery capacity for yields).

These options (the proposal options) are defined in Table 26 and outlined in Figure 42 below with further detail on each option provided in the following sections. These proposal options underwent further assessment through a cost benefit analysis (chapter 9) and were also considered in terms of the extent to which they each meet the secondary service needs of environmental and social impacts (chapter 10).

Table 26 Summary of proposal options for Paradise Dam

Proposal option	Option components	Summary of key design elements
1	a. Dam Option 1	a. Returning the primary spillway back to its original height plus associated improvement works
	b. No alternative supply option required	b. None required
	c. Distribution System Upgrades	c. Tranches 1 and 2 required
2	a. Dam Option 2	a. Permanent lowering of the primary spillway to 5m below the original height plus associated improvement works
	b. Alternative Supply Option 1	b. Ned Churchward Weir Raise[7]
	c. Distribution System Upgrades	c. Tranches 1 and 2 required
3	a. Dam Option 3	a. Permanent lowering of the primary spillway to 10m below the original height plus associated improvement works

[7] Works on Alternative Supply Option 1 need to be commenced during the evaluation period to ensure completion at the time required to meet demand (which is just outside the evaluation period).

	b. Alternative Supply Option 1 Alternative Supply Option 5 c. Distribution System Upgrades	b. Ned Churchward Weir Raise Degilbo Creek Dam c. Tranches 1 and 2 required

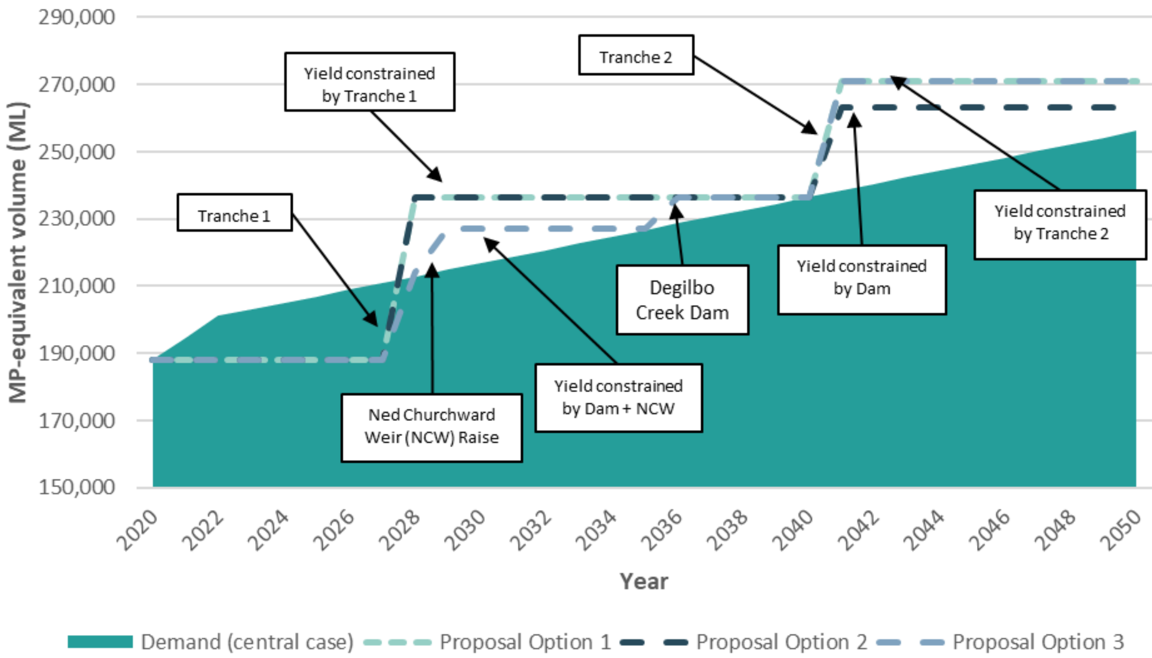
Figure 42 Summary of proposal options

	Dam Option	Alternative supply option	Distribution system upgrades
Proposal Option 1	**Dam Option 1** Return to FSL with strengthening works	Not required	Tranche 1,2
Proposal Option 2	**Dam Option 2** Permanent lowering of 5m with strengthening works	1.Ned Churchward Weir raise	Tranches 1,2
Proposal Option 3	**Dam Option 3** Permanent lowering of 10m with strengthening works	1.Ned Churchward Weir raise 5.Degilbo Dam	Tranches 1,2
Base Case	No further works	Nil	Nil

Note: For Proposal Option 2, works on Alternative Supply Option 1 need to be commenced during the evaluation period to ensure completion at the time required to meet demand (which is just outside the evaluation period).

Figure 43 below shows the most likely projected demand, deliverable yields for each option, alternative supply required and upgrades to the distribution system (Tranches 1 and 2).

Figure 43 Proposal options deliverable yields to meet projected demand



Notes:

- Deliverable yield is a combination of dam option yield, alternative supply option yields, and distribution system capacity to deliver.
- At the time of writing the timing and sequencing of construction works for the PDIP and the Tranche 1 upgrade are not yet finalised. For simplicity and consistency in comparing dam options it has been assumed the works are completed and commissioned in the short term. The tranche 1 upgrades are also identical for each option and will not have any bearing on the comparative assessment of options.
- Proposal Option 3 is generally limited by the yield available from supply sources, more so than distribution system capacity. Proposal Options 1 and 2 are initially limited by distribution system capacity until 2040 and are then only limited by the yield available from supply sources.

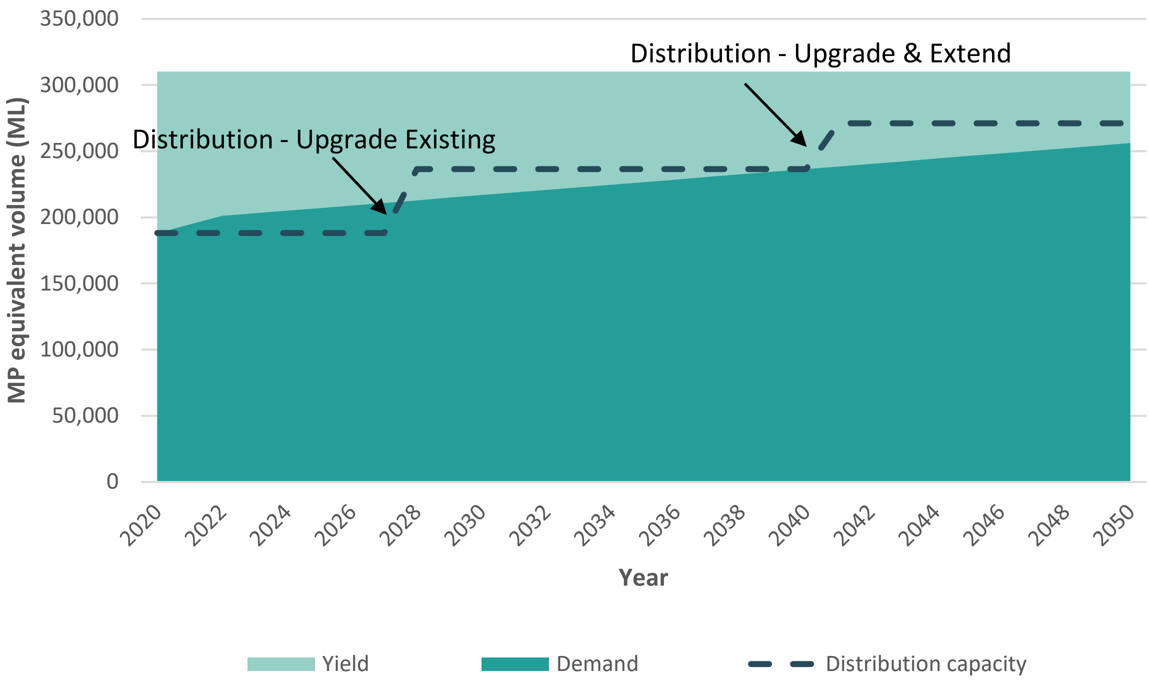
7.3 Proposal Option 1

Proposal Option 1 is presented in Figure 44 below, with the corresponding configuration of the primary spillway and strengthening works illustrated in Figure 46 below.

Figure 44 Overview of Proposal Option 1

Across the evaluation period, the dam provides more than sufficient yield to meet demand however, the deliverable yield is constrained by the existing distribution system capacity. As a result, distribution system upgrades are required at key points to ensure the yield can be delivered to customers. Figure 45 presents this graphically, with the step increases in deliverable yield representing the distribution system upgrades Tranches 1 and 2.

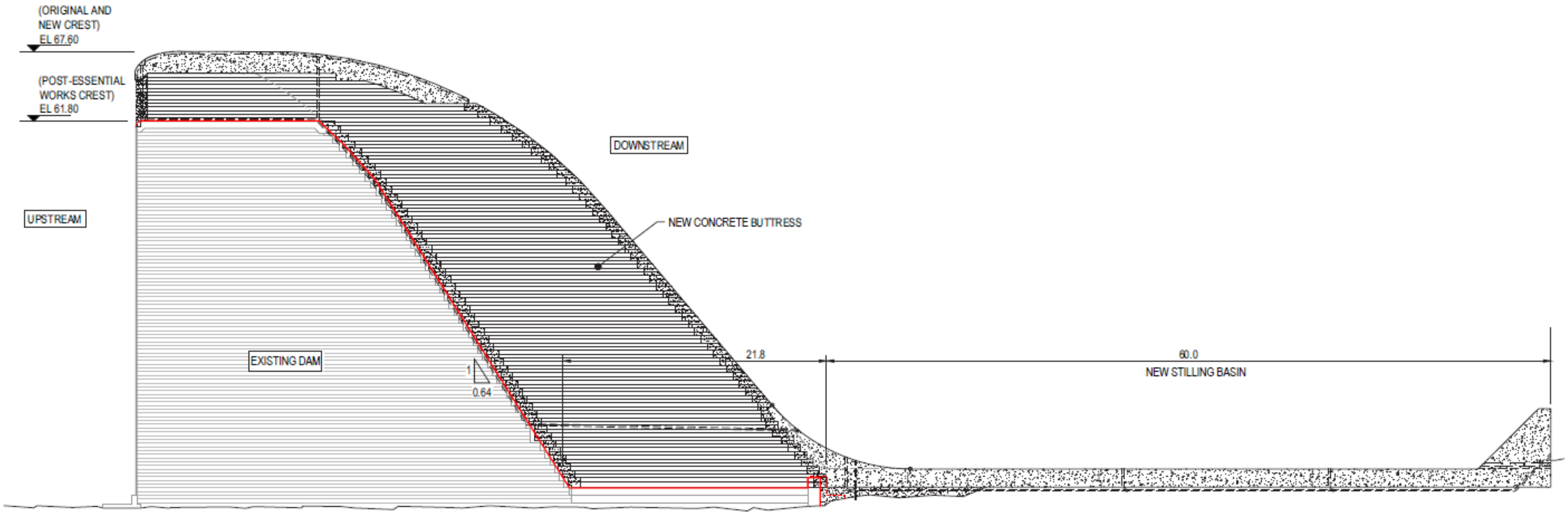
Figure 45 Deliverable yield and central case demand profiles for Proposal Option 1, showing impacts of distribution system upgrades over time



Note: Deliverable yield refers to yield from the Burnett River sub-scheme (including Paradise Dam).

Proposal Option 1 provides the greatest yield directly from Paradise Dam compared to other options (sufficient to meet the demand service need) but also involves the highest upfront investment. For this option, there is a large differential between yield and demand at 2050.

Figure 46 Proposal Option 1 – Configuration of Primary Spillway and Strengthening Works



Notes: Height levels in this figure are referred to as EL however this is equivalent to the RL designation used elsewhere in this report.

7.4 Proposal Option 2

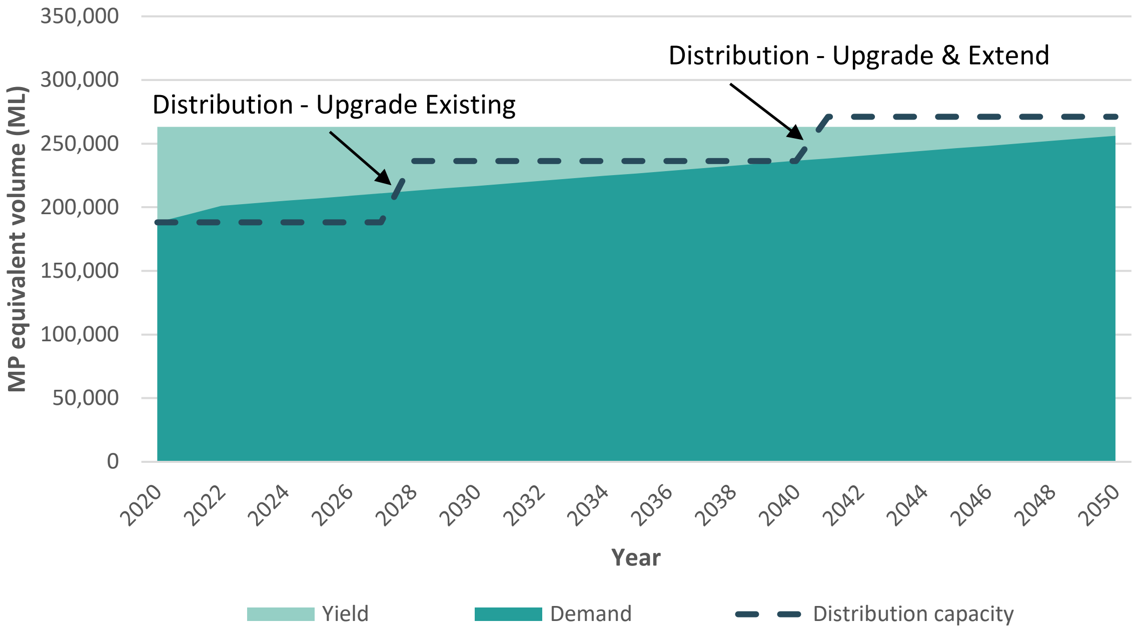
Proposal Option 2 is presented in Figure 47 below, with the corresponding configuration of the primary spillway and strengthening works illustrated in Figure 49.

Figure 47 Summary of Proposal Option 2

Like Proposal Option 1, the deliverable yield for Proposal Option 2 indicates that the dam provides sufficient yield to meet the demand service need within the evaluation period however, is constrained by the existing distribution system capacity. Under this scenario, some design and construction works required to deliver Alternative Supply Option 1 will need to commence during the evaluation period to ensure the yield provided by this proposal option is available at the required time to meet projected demand (which is just outside the evaluation period).

Figure 48 presents this graphically, with the step increases in deliverable yield representing the distribution system upgrades Tranches 1 and 2.

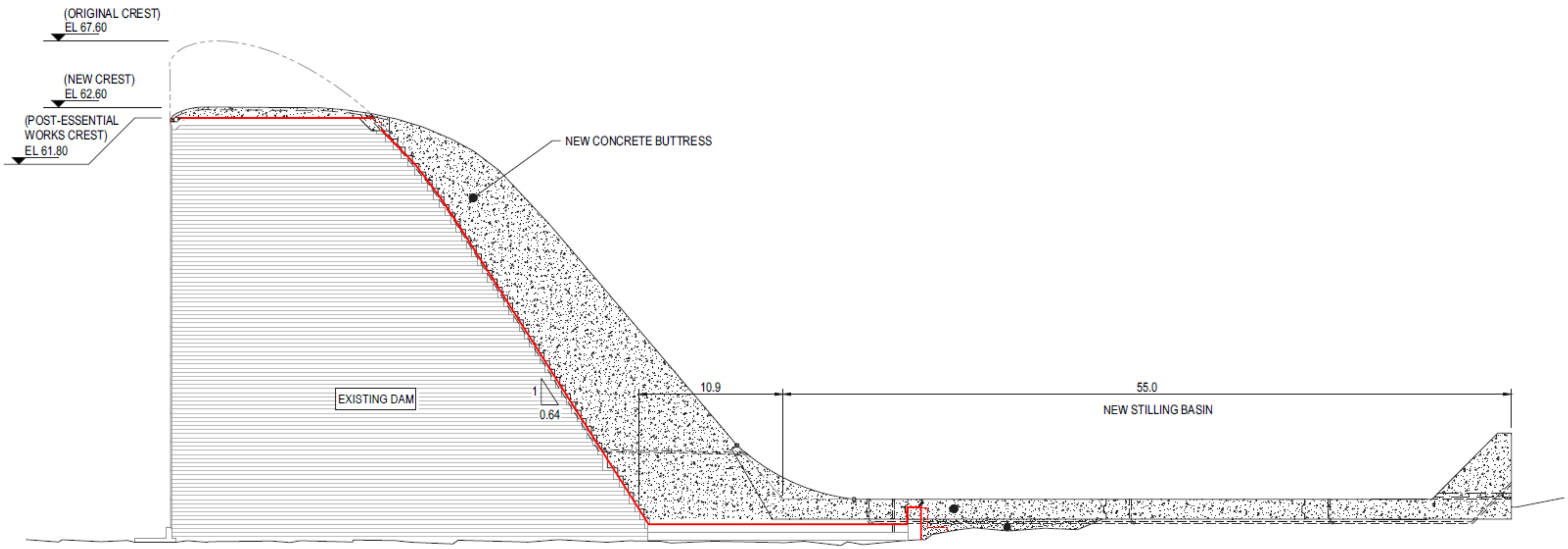
Figure 48 Deliverable yield and central case demand profiles for Proposal Option 2, showing impacts of distribution system upgrades over time



Note: Deliverable yield refers to yield from the Bundaberg Water Supply Scheme which includes the Burnett River subscheme (Paradise Dam) plus the Kolan River subscheme.

Proposal Option 2 also provides sufficient yield to meet the demand service need however the differential between yield and demand at 2050 is significantly smaller than for Proposal Option 1, meaning this option is particularly sensitive to any increases in demand over the central case.

Figure 49 Proposal Option 2 – Configuration of Primary Spillway and Strengthening Works



Notes: Height levels in this figure are referred to as EL however this is equivalent to the RL designation used elsewhere in this report.

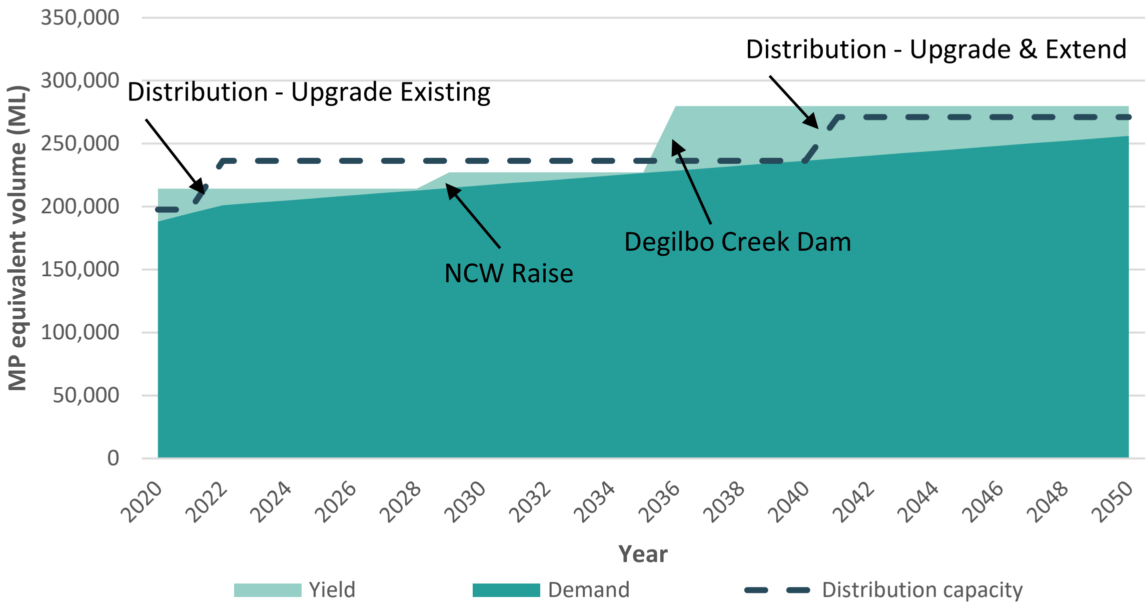
7.5 Proposal Option 3

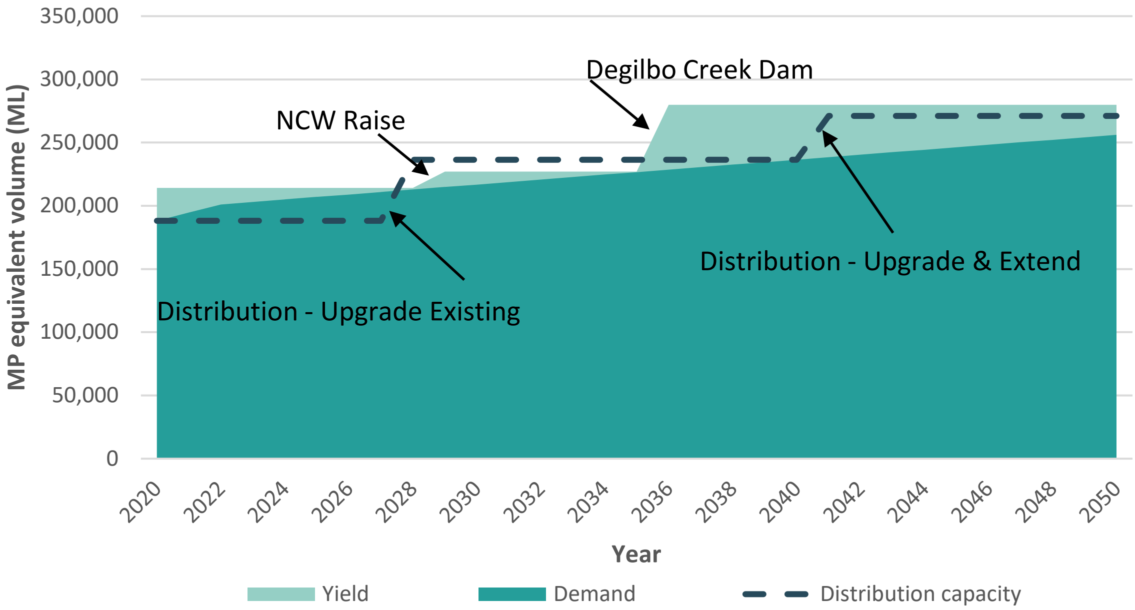
Proposal Option 3 is presented in Figure 50 below, with the corresponding configuration of the primary spillway and strengthening works illustrated in Figure 52.

Figure 50 Summary of Proposal Option 3

Unlike Proposal Options 1 and 2, the yield from the dam option cannot meet the demand service need. Additionally, the deliverable yield for Proposal Option 3 is constrained by the existing distribution system capacity. Figure 51 presents this graphically, with the step increases in deliverable yield representing the distribution system upgrades Tranches 1 and 2 and alternative supply options required from around 2030.

Figure 51 Deliverable yield and demand profiles for Proposal Option 3, showing impacts of distribution system upgrades over time and alternative supply options

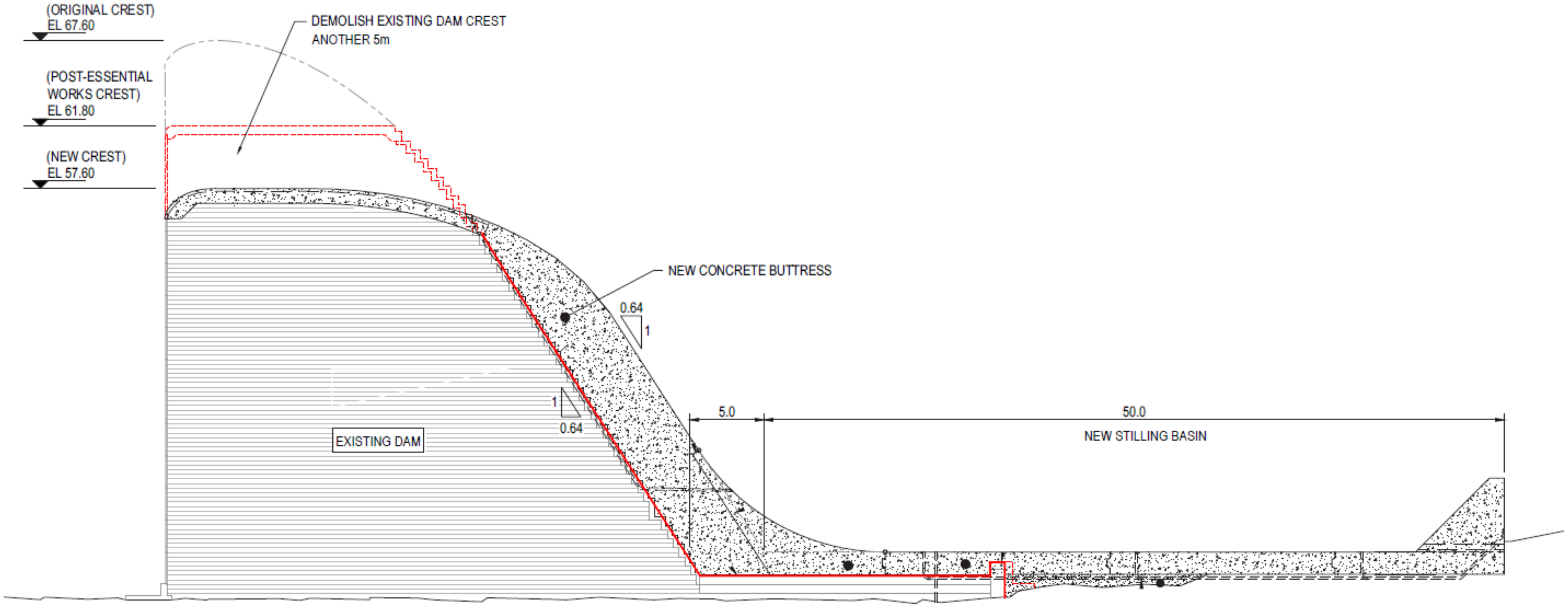




Note: Deliverable yield refers to yield from the Bundaberg Water Supply Scheme which includes the Burnett River sub-scheme (Paradise Dam) plus the Kolan River Sub-scheme.

Proposal Option 3 requires alternative supply options to provide sufficient yield to meet the demand service need. While the existing distribution system capacity is the constraining factor on delivering yield in early years, the total yield available is the primary constraint from around 2036 onwards. Figure 51 presented this graphically, with the major step increase from 2036 representing the additional yields from the alternative supply options (1. Ned Churchward Weir Raise and more significantly 5. Degilbo Creek Dam).

Figure 52 Proposal Option 3 – Configuration of Primary Spillway and Strengthening Works



Notes: Height levels in this figure are referred to as EL however this is equivalent to the RL designation used elsewhere in this report.

7.6 Options to meet climate change scenario

Section 6.5 highlighted that changes in climate, within the evaluation period, may significantly affect water yields from the dam options. Section 6.6 identified the climate change impacts on the options combinations to assess whether the water supply and demand service need could continue to be met under this climate change scenario and what supply options might be required to ensure the projected demands could continue to be met.

Similar to the proposal options presented above in sections 7.3, 7.4 and 7.5, the available supply sources incorporated a combination of:

- dam options,
- alternative supply options, and
- distribution system upgrades

The outcomes of the climate change scenario analysis in relation to the potential impacts on the three proposal options are summarised in the points below:

- Proposal Option 1 – for this option, there is a large differential between yield and projected demand at 2050. This differential means that Proposal Option 1 performed relatively well in the climate change scenario analysis and it is likely that no alternative supply options are required to ensure yields meet projected demands within the climate change scenario evaluation period.
- Proposal Option 2 – the differential between yield and projected demand at 2050 is significantly smaller than for Proposal Option 1. As a result, this option was particularly sensitive to the potential reductions in yield highlighted in the scenario analysis (refer section 6.6), and therefore relies heavily on larger alternative supply options being installed earlier to provide the additional yield needed to meet projected demand within the climate change scenario evaluation period.
- Proposal Option 3 – this option has the lowest yield available in the dam and already requires alternative supply options to provide sufficient yield to meet projected demand at 2050. This option therefore has the poorest performance in the climate change scenario analysis and relies even more heavily on alternative supply options to provide yield to meet the projected demand within climate change scenario evaluation period.

In summary, whilst the specific impacts of climate change on yields for the dam options are highly variable and highly uncertain, it is clear that the majority of the climate change scenario outcomes on yield impacts indicate that a lower yield is more likely to occur. In this situation, the analysis indicates that Proposal Option 1, with its larger storage capacity, can potentially provide a higher level of resilience to the potential impacts of climate change and may not need alternative supply options to continue to provide yields that meet projected demands. Proposal Options 2 and 3 on the other hand, are heavily reliant on alternative supply options to ensure that available yields can continue to meet projected demands.

7.7 Key findings

- Proposal Option 1 meets the most likely projected demand to 2050 and does not require alternative supply. Proposal Option 1 includes: Dam Option 1 plus upgrades to the distribution system (Tranches 1 and 2).
- Proposal Option 2 includes: Dam Option 2 plus upgrades to the distribution system (Tranches 1 and 2 as above). Proposal Option 2 meets the most likely projected demand to 2050 but requires alternative supply (raising of existing Ned Churchward Weir selected as a minimum) by 2053. This will require the proposed alternative supply works to commence by 2046.

- Proposal Option 3 may meet demand through the development of significant alternative supply (raising of existing Ned Churchward Weir and the new Degilbo Creek Dam).

8 FINANCIAL ANALYSIS

8.1 Purpose

The purpose of this chapter is to present the process and findings of the financial analysis for the base case and proposal options.

This section summarises the following information:

- the approach adopted for the financial analysis and modelling
- key inputs and assumptions underpinning the base case and the proposal options, including capital and operating expenditure, revenue, and risk adjustment
- financial outcomes for each of the base case and the proposal options, including risk-adjusted nominal and net present value (NPV) outcomes
- relevant sensitivity and scenario analyses.

8.2 Approach

The financial analysis in this chapter has been undertaken in accordance with the Queensland Government's Business Case Development Framework (BCDF) and Queensland Treasury's Project Assessment Framework (PAF).

8.2.1 Dam options cost estimates

8.2.2 Cost estimates approach

Given the concept level of design development reached at this stage of the options evaluation process, an Association for the Advancement of Cost Engineering (AACE) International, Class 4 concept level cost estimate has been prepared for each of the proposed dam options and alternative supply options. This consistent approach has been adopted to allow a like-for-like comparative assessment to be made between all options.

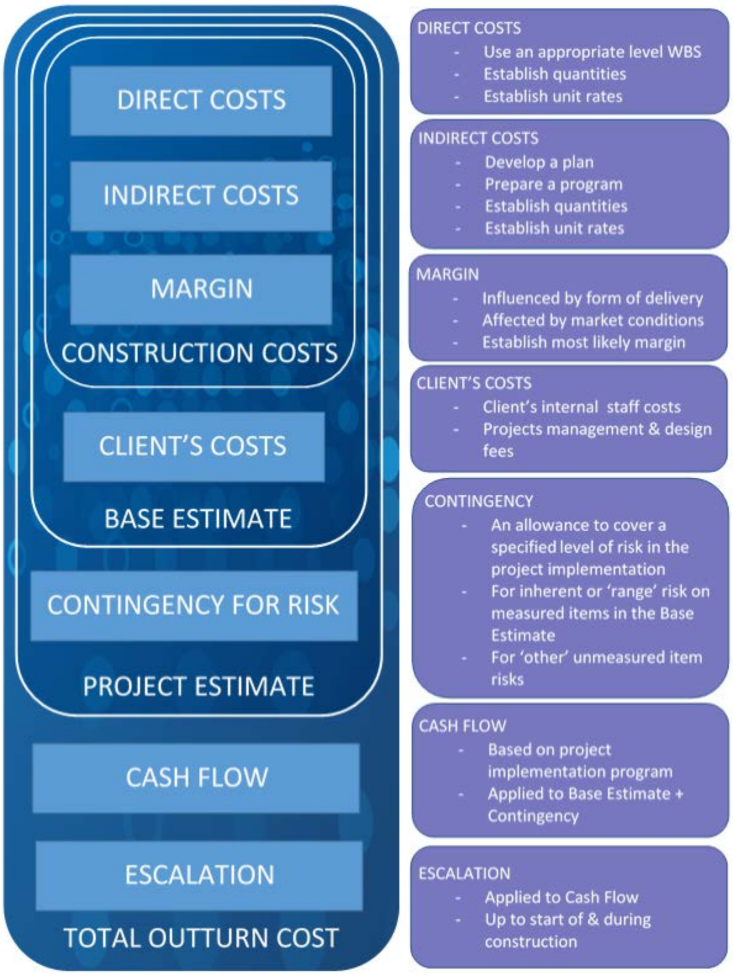
In accordance with the AACE guidelines, Class 4 estimates are most often prepared based on limited information (i.e. concept design). As such costs should be considered preliminary in nature. Typically, they are developed to assist with project screening activities including option evaluations and preliminary budget considerations. Typically, a Class 4 cost means that the associated level of project definition is between 1%-15% of the full project definition.

The key components of each of the cost estimates are detailed in Figure 53.

The methodology for developing the project cost estimate for each of the dam options involved four (4) steps as detailed in Table 27 below. Referenced in this table are the parties that provided input and a list of the estimate deliverables.

The construction cost estimates for the main dam package were prepared by contractors engaged by Sunwater (refer Figure 54). The contractors are international cost management consultants, quantity surveyors, sustainability consultants, PPP advisors and facilities managers. Their expertise covers the building, construction, and infrastructure sectors. The shadow estimate has been prepared by a construction contractor. As this Contractor has the experience and capability to tender for the future package of works, they have not been identified in this report.

Figure 53 Sunwater Cost Estimation Process



Source: Australian Government, Department of Infrastructure, Regional Development and Cities, *Cost Estimation Guidance Note Overview*, Queensland, 2018

Table 27 Cost estimate development steps

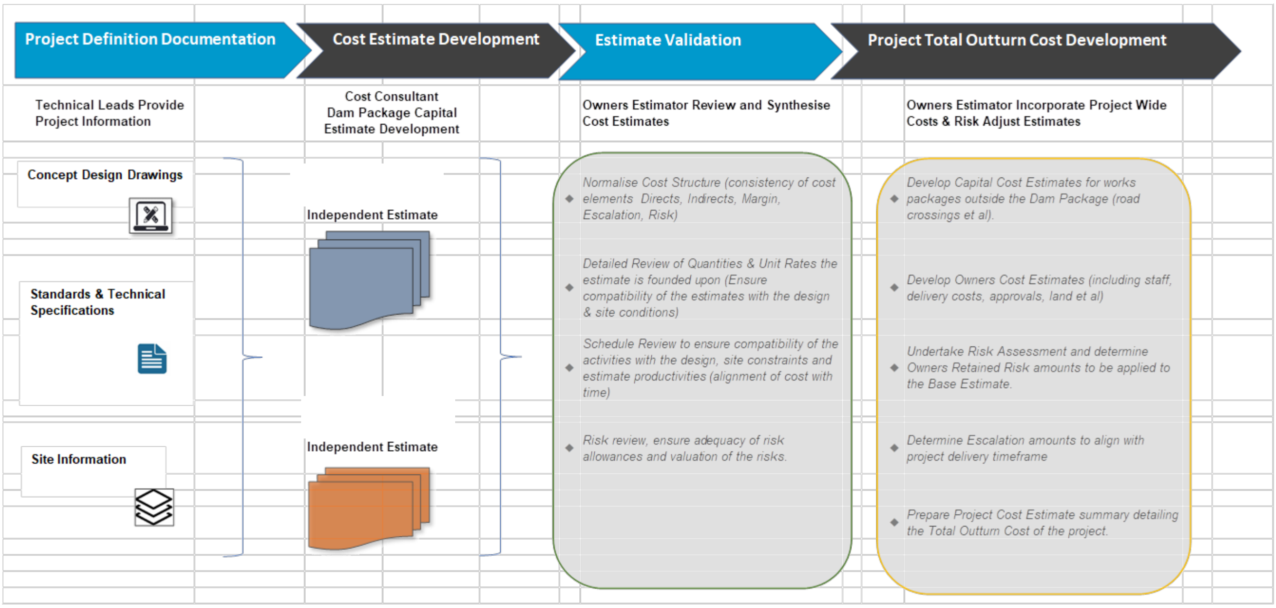
Estimate Development Step	Parties Involved	Key Deliverables
1. Source Project Definition Information	Sunwater and Design contractor	Concept Design Technical Standards / Specifications Site Investigation Reports
2. Cost Estimate Development	*Dam Package:* Financial contractor Tier 1 Contractor *Catchment Wide Packages:* Sunwater	Construction Cost Estimates Construction Schedule Risk / Contingency Assessment
3. Validation of Estimates	Sunwater	Detailed review of Contractor cost estimates Development of Project Schedule in P6 Cashflow and Escalation Calculation

Estimate Development Step	Parties Involved	Key Deliverables
		Risk Contingency Calculation for P90 value (Owner's Retained Risk allowances)
4. Project Outturn Cost Development	Sunwater	Project Cost Summary detailing the breakdown of the Total Outturn Cost of the Project

Figure 54 below provides more details on the activities undertaken at each phase of the estimate development process to generate the Total Outturn Cost for the Project

Figure 54 Overview of cost estimate development methodology, steps, and activities

Source: Sunwater



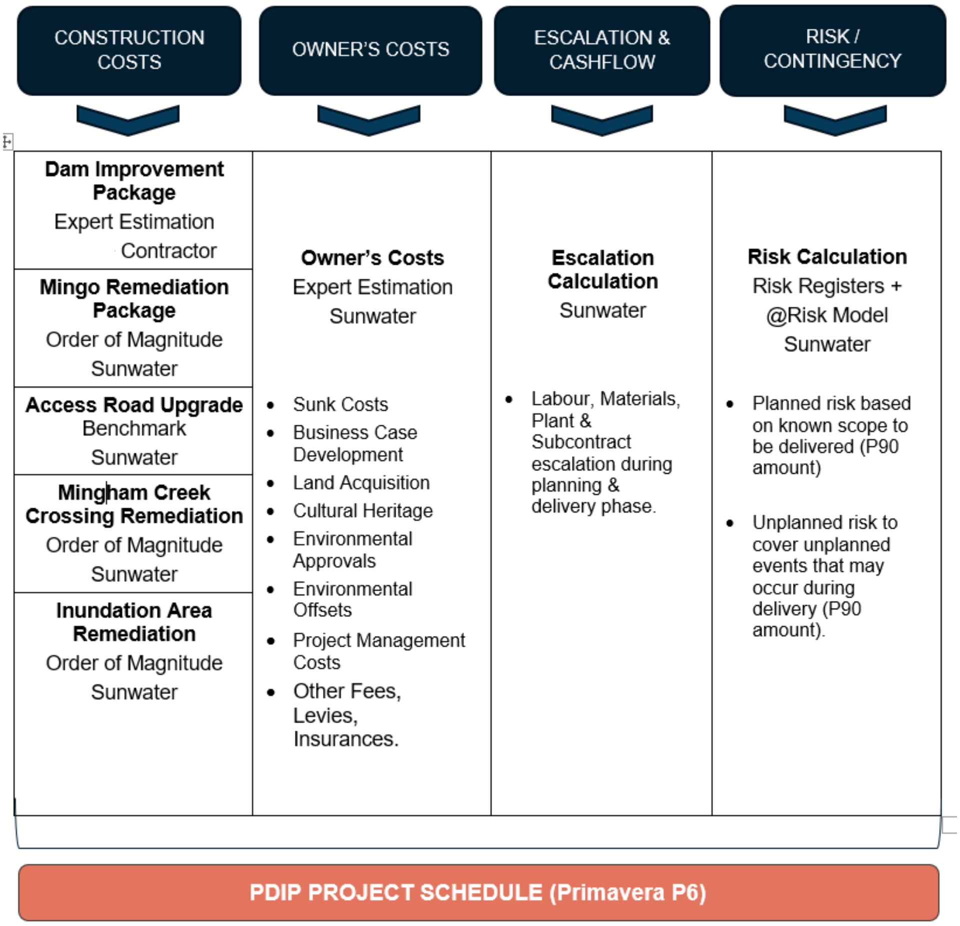
The methodology used to develop the estimates ensured rigorous interrogation of the outputs to ensure the:

- adequacy and robustness of the estimate approach
- compatibility of the estimates with the design and site conditions
- rates included in the estimates are commensurate with market conditions
- risk adjustments and contingency amounts are reasonable.

8.2.3 Summary of the cost estimate components

Figure 55 below details the components that makeup the project's Total Outturn Cost and outlines the parties involved, estimating approach, and estimating tools used.

Figure 55 Overview of Estimate Components, Estimating Approach & Parties Involved



Notes:

1. A cost contractor engaged by Sunwater.
1. Contractor means Tier 1 construction contractor.
2. @ Risk is a proprietary software platform used to undertake probabilistic risk estimation.
3. P90 value is the value of the contingency observed in the risk modelling to cover 90% of all observed project outturn costs.

The estimates have been developed based on the following inputs:

- Concept design drawings for the permanent works (20-30% detail)
- Preliminary estimates developed by the Contractor
- Benchmarking information
- Technical advice provided by the PDIP project team including:
- Construction methodology
- Regional quarry investigations
- Essential Works package actuals

8.2.4 Financial model

A financial model incorporating integrated capital and operational expenditure, revenue, and risk modelling was prepared for the OE, providing greater transparency and confidence in the determination of total project costs and outcomes.

8.2.5 Building block model

To streamline the financial analysis and modelling process, a building blocks approach has been adopted in which projects are considered in terms of relevant capital, operational, and revenue components (or blocks). The building blocks can broadly be described as the following:

- Paradise Dam Improvement
  - Dam Option 1, Return to Full Supply Level – return the primary spillway back to its original height (FSL) (raising 5.8m above current temporary Essential Works level) plus associated improvement works
  - Dam Option 2, 5m lowering of the primary spillway – permanent lowering of the primary spillway level at 5m below the original height (raising 0.8m above Essential Works level) plus associated improvement works
  - Dam Option 3, 10m lowering of the primary spillway – permanent lowering of the primary spillway to 10m below the original height (further lowering of 4.2m below Essential Works level) plus associated improvement works.
- Alternative supply options
  - Ned Churchward Weir Raise (NC Weir) – develop an alternative supply option in addition to Paradise Dam that is sourced from Ned Churchward Weir to meet future demand requirements
  - Degilbo Creek Dam - develop an alternative supply option in addition to Paradise Dam that is sourced from Degilbo Creek Dam to meet future demand requirements
- Distribution system upgrades
  - Tranche 1 - Complete upgrade/infill development work on distribution/channel system to meet short to medium-term demand growth
  - Tranche 2 - Complete upgrade/expansion development work on distribution/channel system to meet longer term demand growth.
- Other capital works
  - Improvements at Ned Churchward Weir with no additional supply - works are not yet confirmed but anticipated to include strengthening of the weir in the medium term.

Table 30 below outlines how the preceding elements form the distinct 'building blocks' included within the base case and proposal options.

Table 28 Project Building Blocks and Timing

Option:	BC	Proposal Option 1 (PO1)	Proposal Option 2 (PO2)	Proposal Option 3 (PO3)
Paradise Dam Improvement Project				
Return FSL		✓ (FY22 – FY28)		
5m Lowering			✓	

Option:	BC	Proposal Option 1 (PO1)	Proposal Option 2 (PO2)	Proposal Option 3 (PO3)
			(FY22 – FY28)	
10m Lowering				✓ (FY22 – FY28)
Alternative Supply Option/s				
Ned Churchward Weir Raise			✓ (FY46 – FY52)	✓ (FY23 – FY29)
Degilbo Creek Dam				✓ (FY27 – FY35)
Distribution System Upgrades				
Upgrade Existing (Tranche 1)		✓ (FY25 – FY27)	✓ (FY25 – FY27)	✓ (FY25 – FY27)
Upgrade & Extend (Tranche 2)		✓ (FY36 – FY40)	✓ (FY36 – FY40)	✓ (FY36 – FY40)
Other Capital Works				
Existing Bulk Water Improvement (Ned Churchward Weir)	✓ (FY26 – FY30)	✓ (FY26 – FY30)	✓ (FY26 – FY30)	✓ (FY26 – FY30)

8.2.6 Project cost and risk modelling

The modelling of the capital and operational expenditure and their associated risks were based on the following approach:

- Compile and process cost inputs received from the cost estimator
- Integrate and cash flow model the capital costs on an annual basis across the construction period
- Integrate and cash flow model the operational and maintenance costs on an annual basis
- Complete risk modelling and adjustment of cash flows.

8.2.7 Project revenue modelling

Project revenue was modelled having regard to the following approach:

- Compile projected demand including assessment of both sales and allocations drawn
- Compile relevant pricing assumptions for both allocations sales and charges
- Integrate and cash flow model revenues by priority type, including from new allocation sales, fixed allocation charges and water usage charges.

8.2.8 Consolidation and analysis

The process undertaken to consolidate and analyse the project results included:

- Applying financial treatments to cost and revenue cash flows, including escalation and discounting
- Completing sensitivity and scenario analyses on relevant inputs and assumptions
- Producing outputs and compiling results in tabular and chart format

8.3 Inputs and assumptions

A financial model was developed to estimate the risk-adjusted nominal and NPV outcomes for the base case and the proposal options.

The financial model incorporates a number of key inputs and assumptions including:

- General project inputs and assumptions
- Capital cost inputs
- Operation & maintenance cost inputs
- Revenue inputs (including pricing and demand)
- Project risk assumptions.

8.3.1 General assumptions

8.3.2 Project timing assumptions

For the purposes of completing the financial analysis, an evaluation period of 29 years has been adopted from 1 July 2021 to 30 June 2050 (FY22 to FY50), in alignment with the current limitations of the projected demand.

Table 31 below summarises the timing assumptions adopted for the projects.

Table 29 General timing assumptions

Element	Value
Evaluation period	29 years
Start of evaluation period	1 July 2021 (FY22)
End of evaluation period	30 June 2050 (FY50)
Base year (for financial inputs)	Year ending 30 June 2021 (FY21)

For each of the base case and proposal options, the 'building block' timings are displayed in Table 28.

8.3.3 Escalation and inflation assumptions

Cost inputs to the modelling were provided on a constant FY21 basis (abbreviated in tables and charts as 'Con'). As such, they were escalated by appropriate indices to reflect the nominal, or outturn, cost. All escalation rates were maintained at the following levels across the entire evaluation period.

Capital costs were escalated at 2.60%. This escalation rate is a weighted average of the following assumptions which are based on publicly available work agreements for construction contractors and assessment of market intelligence including recent competitive tender submissions for similar and comparable projects, and research:

- Labour cost escalation is 3.00% and comprises 40% of total capital costs
- Material cost escalation is 2.40% and comprises 40% of total capital costs
- Plant cost escalation is 1.50% and comprises 10% of total capital costs
- Subcontract cost escalation is 2.40% and comprises 10% of total capital costs.

Operation and maintenance costs were escalated at 2.40%. This escalation rate is a weighted average of the following assumptions:

- Labour cost escalation is 3.00% and comprises 40% of total operational costs

- Other cost escalation is 2.00% and comprises 60% of total operational costs.

Revenue was escalated at 2.00% as per Sunwater's portfolio financial model, which considers typical adjustments over time by the Queensland Competition Authority.

Real outputs, on an FY21 basis, were produced for use in the economic cost-benefit analysis. These real numbers were based on deflating the nominal, or outturn, figures by forecast inflation. Inflation was based on the Queensland Government's Queensland Budget 2021-22 Budget Paper No. 2 in the short term (forecast inflation ranging between 1.75% to 2.25%) and the Reserve Bank of Australia's inflation target of 2.50% in the long term.

8.3.4 Discount rate assumptions

A project net present value (NPV) has been produced to consider the impact of the time value of money on differently timed cash flows over the project. For the purposes of the financial analysis, the nominal cash flows for the project have been discounted to 1 July 2021, assuming mid-period cash flows.

Given Sunwater's classification as a Government-Owned Corporation (GOC), they are subject to the Queensland Government Owned Corporations Code of Practice for Financial Arrangement. Generally, the discount rate used for financial analysis and economic evaluation for GOC-developed projects is the respective GOC's weighted average cost of capital (WACC). For the purpose of the analysis it has been assumed that the majority of the project will need to be funded by Government. Accordingly, the Queensland Treasury Corporation (QTC) nominal discount rate, representing the Queensland Government's cost of financing the project, is considered the most appropriate discount rate to use for the analysis.

QTC has estimated an appropriate nominal discount rate for the project of 1.95% based on the average of QTC 10-year bonds for a period of 20 trading days (ending on 26 April 2021).

8.3.5 Capital expenditure

The following tables display the capital works components that have been identified in the following distinct scope packages:

- Paradise Dam Improvement works
- Alternative supply options
- Distribution system upgrades (Tranches 1 and 2)
- Ned Churchward Weir upgrades

8.3.6 Paradise Dam

The following table provides a summary of the costs incurred under each of the proposal options in relation to Paradise Dam improvement works. Sunk costs relating to the works are recognised in the owner's costs, and then reversed in the following table. The analysis and all further tables and charts are exclusive of these sunk costs.

Table 30 Capital Expenditure – Paradise Dam Improvement Project

Paradise Dam Improvement Project ($M)	Unit	Option 1 Return to original spillway level	Option 2 (5m Lowering)	Option 3 (10m Lowering)
Construction				
Direct Construction Costs	Con	CIC	CIC	CIC
Indirect Construction Costs	Con	CIC	CIC	CIC

Paradise Dam Improvement Project ($M)	Unit	Option 1 Return to original spillway level	Option 2 (5m Lowering)	Option 3 (10m Lowering)
Contractor's Margin	Con	CIC	CIC	CIC
Sub-Total Construction Costs	**Con**	CIC	CIC	CIC
Owner's Costs	Con	CIC	CIC	CIC
Total Cost	**Con**	CIC	CIC	CIC
Less Sunk Costs	Con	CIC	CIC	CIC
Total Remaining Costs	**Con**	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

8.3.7 Alternative supply options

The following table provides a summary of the alternative supply options' costs incurred in relation to Ned Churchward Weir Raise and Degilbo Creek Dam.

Table 31 Capital Expenditure – Alternative Supply

Alternative Supply ($M)	Unit	Ned Churchward Weir Raise	Degilbo Creek Dam
Construction			
Direct Construction Costs	Con	CIC	CIC
Indirect Construction Costs	Con	CIC	CIC
Contractor's Margin	Con	CIC	CIC
Sub-Total Construction Costs	**Con**	CIC	CIC
Owner's Costs	Con	CIC	CIC
Total Cost	**Con**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

8.3.8 Distribution System Upgrades

The following table provides a summary of the distribution system upgrade costs incurred in relation to distribution upgrades and distribution extension.

Table 32 Capital Expenditure – Channel/Distribution Works

Distribution System Upgrades ($M)	Unit	Tranche 1 (Infill / Upgrade)	Tranche 2 (Expand / Upgrade)
Direct Construction Costs	Con	CIC	CIC
Owner's Costs	Con	CIC	CIC
Total Cost	**Con**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

8.3.9 Ned Churchward Weir upgrades

The following table provides a summary of the capital costs incurred in relation to Ned Churchward Weir upgrades.

Table 33 Capital Expenditure – Channel/Distribution Works

Existing Bulk Water Improvement ($M)	Unit	NC Weir Upgrade
Construction	Con	
Direct Construction Costs	Con	CIC
Indirect Construction Costs	Con	CIC
Contractor's Margin	Con	CIC
Sub-Total Construction Costs	**Con**	CIC
Owner's Costs	Con	CIC
Total Cost	**Con**	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

8.3.10 Operating expenditure

The following operations and maintenance (O&M) costs have been identified for the existing assets and additional project components for the base case and proposal options:

- Existing Assets – Existing Paradise Dam and subscheme assets
- Additional Project Works - Paradise Dam Improvement works
- Additional Project Works - Alternative supply options
- Additional Project Works – Distribution system upgrades

The basis for O&M costs was as initially sourced from Sunwater's financial model, which provides actual O&M costs to date and forecasts future O&M costs for the existing infrastructure. This incorporates detailed asset planning and O&M for the bulk water infrastructure (headworks) and the irrigation scheme (distribution system costs for Woongarra and Isis irrigation areas). These costs are further detailed by Routine and Non-routine costs, including for example assessment of electricity, insurance, preventative maintenance, corrective maintenance, other operational costs, and refurbishment and enhancement costs as applicable.

Additional O&M costs were assessed for the associated improvement and upgrade works to Paradise Dam, Ned Churchward Weir raising, and the distribution system. O&M costs for Degilbo Creek dam were assessed as new infrastructure, though compared against costs for similar assets. All O&M costs were also compared against typical industry benchmarks (for example as a % of capital cost for civil and/or mechanical works).

The following table displays the O&M costs associated with the existing assets and the project works under the base case and proposal options. In relation to the following table, opex is the same for each of Proposal Option 1 and Proposal Option 2 as the timing of the completion of the alternative supply (Ned Churchward Weir Raise) and associated opex under Option 2 falls outside of the evaluation period.

Table 34 Operational Expenditure

Opex ($M)	Unit	BC	Proposal Option 1	Proposal Option 2	Proposal Option 3
Existing assets	Con	CIC	CIC	CIC	CIC
Project works	Con	-	CIC	CIC	CIC
Opex cost	**Con**	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

8.3.11 Users

Water customers of Paradise Dam have been considered in terms of key characteristics including priority (medium or high priority) and location of water supply (bulk or distribution).

Paradise Dam has two priority groups, namely medium priority, and high priority. The following is based on the broader Bundaberg Water Supply Scheme (BWSS) customer composition. It has been assumed that the Burnett River subscheme customer composition is like that of the BWSS.

Medium priority water allocations are primarily used by irrigators. They generally have lower reliability requirements than high priority meaning that during periods of sustained drier conditions, and when storage levels are low, medium priority water allocations are the first to be restricted. Given their relative lower reliability, medium priority water allocation holders pay lower water charges than high priority water allocation holders.

High priority water allocations are typically used by urban and industrial users. These water allocations are the most reliable and holders can usually access water more frequently with fewer restrictions than medium priority water allocation holders.

In relation to the location of water supply, the analysis assumes that all customers are distribution system customers.

8.3.12 Demand

Demand profiles have been developed in terms of allocations held and allocations drawn, for each priority type. Water allocations held relate to the entitlements that customers have purchased or otherwise have possession of, in a given year. Water allocations that have been drawn are those that have been used or partially used in that year by the customer.

Projected demand has been estimated at a BWSS level. The BWSS future demand is an aggregate of the projected demands of Burnett River subscheme and the Kolan subscheme. Using the projected demand at the BWSS level therefore, the Burnett River subscheme additional projected demand was determined to be 66,300 ML/a of MP allocations and 750 ML/a of HP allocations over the evaluation period. As such, the rate of additional demand for the Burnett River subscheme is:

- MP
    - From 1 June 2020 – 1 June 2022, increasing at 6,400 ML/a
    - From 1 June 2022 – 1 June 2050, increasing at 1,910 ML/a
- HP
    - From 1 June 2020 – 1 June 2050, increasing at 25 ML/a

The following diagrams show the demand profiles of water allocations held and water allocations drawn for each priority type.

Figure 56 Medium Priority Allocation Demand Profile*

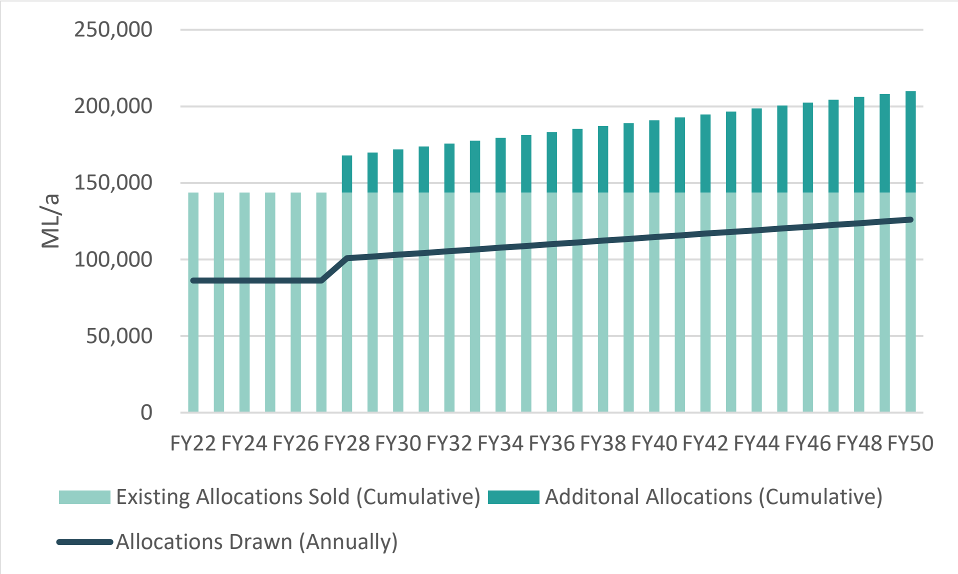
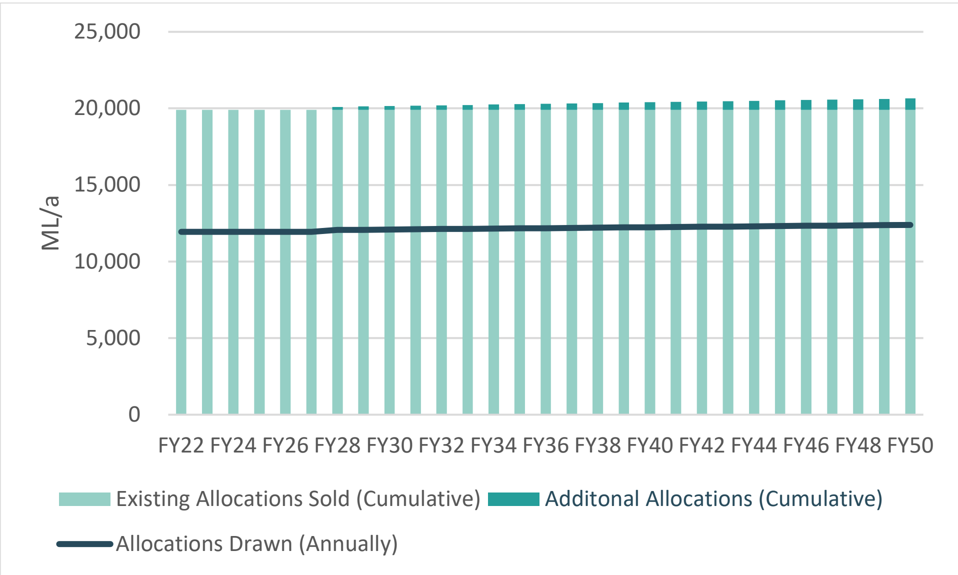


Figure 57 High Priority Allocation Demand Profile



It should be noted that, under the base case, allocation sales are recognised in FY22. This is based on the small amount of capacity remaining in the distribution system (9,000 ML pumped capacity only, split between MP and HP), which can accommodate a small amount of demand growth (fully taken up during FY22). Growth demand under the base case reflects the use of these allocations over the evaluation period.

No allocation sales are recognised under the proposal options until FY28, as it is assumed the Paradise Dam improvement works must be completed before new allocations can be sold (to ensure the reliability of the existing allocations that have been sold previously). In FY28, pent up demand for allocations is recognised in the form of a significant round of allocation sales. For clarity, this same restriction does not apply to the base case, as no dam improvement works are proposed under the base case which would necessitate this quarantining of water.

8.3.13 Pricing

Under Australian and Queensland government policy, water prices should seek to recover the full cost of water supply, including infrastructure costs.

As part of a decision on irrigation pricing in 2020, the Queensland Government has put in place a policy to fund the irrigators' share of dam safety upgrade costs, (i.e., these costs will not be recovered from irrigators). While this decision was made in relation to regulated irrigation schemes (where the Queensland Competition Authority recommends prices), for consistency it has been assumed that the same policy will apply to Paradise Dam safety upgrade costs.

In addition, the Government has recently introduced irrigation pricing discounts for the 2021-24 period, being a 15% discount to irrigators (for water supply schemes owned by Sunwater and Seqwater), and a further 35% rebate available (50% discount in total) for horticultural growers. For the purpose of the OE, a uniform average rate for water charges has been applied for the 30-year evaluation period, allowing for escalation as described below, but not including long term irrigation pricing discounts.

Pricing of water allocation, access and use is dependent on a range of factors including priority group and charge type. As previously mentioned, priority groups for Paradise Dam users are medium or high.

A one-off upfront charge is applicable to the sale of new allocations. The rates applicable on the sale of new allocations are as per FY19 rates for MP and HP water products, and allowing for 2% annual escalation for the 30-year evaluation period.

For each priority group (MP and HP), there are also four ongoing access/usage charges that are applicable depending on the source of the water access. The four types of charges and their magnitudes (based on 2% annual escalation on the FY19 charges from the Sunwater Fees and Charges Schedule 2018-2019 for Paradise Dam – Bundaberg WSS) are:

- Part A –a fixed price per megalitre of annual WAE, intended to recover the fixed costs associated with operating, maintaining, administering and renewing the bulk WSS.
- Part B – a price per megalitre of annual usage, intended to recover the bulk variable costs associated with the actual delivery (usage) of water.
- Part C – a fixed price per megalitre of annual WAE, intended to recover all distribution system fixed costs. In addition, the Part C charge is also adjusted depending on whether it is a "Peak" or "off Peak" service - this is an additional cost for users who source their water from the distribution system during peak supply periods, compared to a lower cost for those that don't require supply during peak periods.
- Part D – a price per megalitre of annual usage, intended to recover the distribution system variable costs associated with the actual delivery (usage) of water.

For the purposes of the OE only, the above pricing assumptions (adjusted for escalation) have been adopted for all existing and new projected demands under each of the base case and the proposal options. That is, it has been assumed that the capital expenditure incurred under each of the base case and the proposal options will not be passed through to end users, as may be expected under a typical cost reflective/recovery scenario. For the avoidance of doubt, Government may elect to pursue a different approach to pricing compared to what has been assumed for this analysis.

For costs associated with distribution system upgrades, this expenditure (and the resulting demand and revenues) should be considered on a commercial basis aligned with the Queensland Bulk Water Opportunities Statement (QBWOS). From a pricing perspective, this would involve an initial assumption of full cost recovery from customers, which is the same approach that applies in water supply schemes regulated by the QCA. Full cost recovery, rather than lower bound, would apply as the infrastructure is to be constructed post 2000. This may involve a transition period for pricing to reach cost recovery levels, for consistency with the approaches adopted in other schemes.

To reiterate, for the purposes of this analysis, no cost reflective pricing or other changes to pricing (aside from escalation) have been assumed or incorporated. Further analysis in relation to pricing is recommended as part of the Stage 2 Detailed Business Case. Government may elect to pursue a different approach to pricing compared to what has been assumed for this analysis.

8.3.14 Revenue

Paradise Dam revenue comprises existing allocation revenues and growth revenue.

Existing allocation revenue was obtained from Sunwater's business financial model. It was obtained at the BWSS level and was allocated against the relevant subschemes, - i.e., the Burnett River and Kolan subschemes. The Burnett River subscheme (the relevant subscheme for Paradise Dam) revenue is calculated by using the following proportions:

- MP – 62% of the existing MP allocations in the BWSS relate to the Burnett River subscheme
- HP – 73% of the existing HP allocations in the BWSS relate to the Burnett River subscheme.

Revenue derived from the sale of new allocations is calculated by the product of the future allocations demanded (per the demand section above) and the relevant upfront water purchase cost.

Revenue sourced from water charges for additional demand is calculated by the product of future allocations demand (per the demand section above) and the four charge types (for fixed and variable costs), as applicable. This additional revenue source includes MP and HP future water allocations.

8.3.15 Risk assessment and modelling

Risk assessment was conducted for all relevant cost items, including capital, and operating and maintenance costs, and processed for inclusion in the financial model and analysis. Risks considered are broadly classified based on the type of risk they relate to, namely inherent or contingent risks.

8.3.16 Inherent risks

Inherent risks, otherwise referred to as planned risks, reflect the uncertainty and potential variance in the estimates of the component cost items used in the cost estimate. This uncertainty and variance stems from potential changes in the quantities, productivity, and pricing used in deriving the cost estimates.

Inherent risks are modelled as the product of uncertainty in the quantities of items and uncertainty in the unit cost of items, and include an estimate of a lower, most likely, and upper values for the cost of the items. Inherent risks on operations and maintenance expenditure are modelled as an estimate of lower, most likely, and upper values for the cost of the items. Inherent risk inputs have been obtained from the respective capital and operational cost estimates.

Inherent risks have been modelled based on the probability distributions considered most appropriate by the relevant estimator for the specific cost item.

8.3.17 Contingent risks

Contingent risks, otherwise referred to as unplanned risks, are those derived from the process of assessing and making an allowance for unmeasured items. These represent events or outcomes that may occur with an associated impact on the cost of the project and have been sourced from the project risk registers integrated within the capital cost estimates.

Contingent risks are modelled through a risk event approach, in which the potential occurrence of the contingent risk is modelled as a binary outcome. In instances where the contingent risk is evaluated to have occurred, the magnitude of the impact is calculated and applied against the project.

Contingent risks have been modelled based on the probability distributions considered most appropriate by the relevant estimator for the specific risk, including the consideration of potential long-tail events in which extremely low probability events result in high consequence outcomes.

8.3.18 Risk modelling

Consistent with the approach outlined in Queensland Government's BCDF, probabilistic risk modelling was performed in relation to the capital costs and operating and maintenance costs associated with each of the base case and proposal options to produce risk-adjusted project costs.

Due to the forward looking, forecast nature of the financial modelling, uncertainty exists in relation to both inputs and outputs. Probabilistic risk modelling allows for the recognition and quantification of the uncertainty (where that uncertainty is sufficiently understood and able to be identified and estimated), providing a foundation for a forecast that incorporates a measure of that uncertainty.

The Microsoft Excel add-in @Risk, produced by Palisade, was used to conduct the probabilistic risk modelling via Latin Hypercube simulation. This process simulated ten thousand iterations of the project, sampling from input distributions for all relevant cost and risk inputs. Latin Hypercube simulation is similar to the well-known Monte Carlo simulation approach but addresses key limitations of the Monte Carlo approach through stratified sampling to more accurately recreate the underlying probability distributions through fewer iterations.

The use of probabilistic risk modelling allows the P50 and P90 risk adjustments to be determined. P50 and P90 risk adjustments are used to develop cost estimates and forecasts for which there is a 50 percent (P50) and 90 percent (P90) probability that the total project costs over the evaluation period will not be exceeded.

8.3.19 Risk inputs and cash flows

Risk inputs used in the modelling take the form of probability distributions. Probability distributions are mathematical models that describe the uncertainty associated with inputs, by explicitly establishing the range of potential values those inputs may take and the probabilities associated with each value in the range.

For the OE, extensive risk assessment has been completed, leading to the development of detailed cost and risk estimates and risk registers for the various project components. This has resulted in a significant number of risk inputs (~2,400 separate probability distributions). To streamline the financial modelling of these risks, the underlying source documents have been processed via risk modelling to enable the extraction of summarised risk outcomes for the various elements. These summarised risk elements have then been incorporated within the financial model and have been combined through risk modelling to enable the determination of total project costs and outcomes.

Figure 58 and Table 35 below provide details of these sources and process.

Figure 58 Risk Input Development and Flow

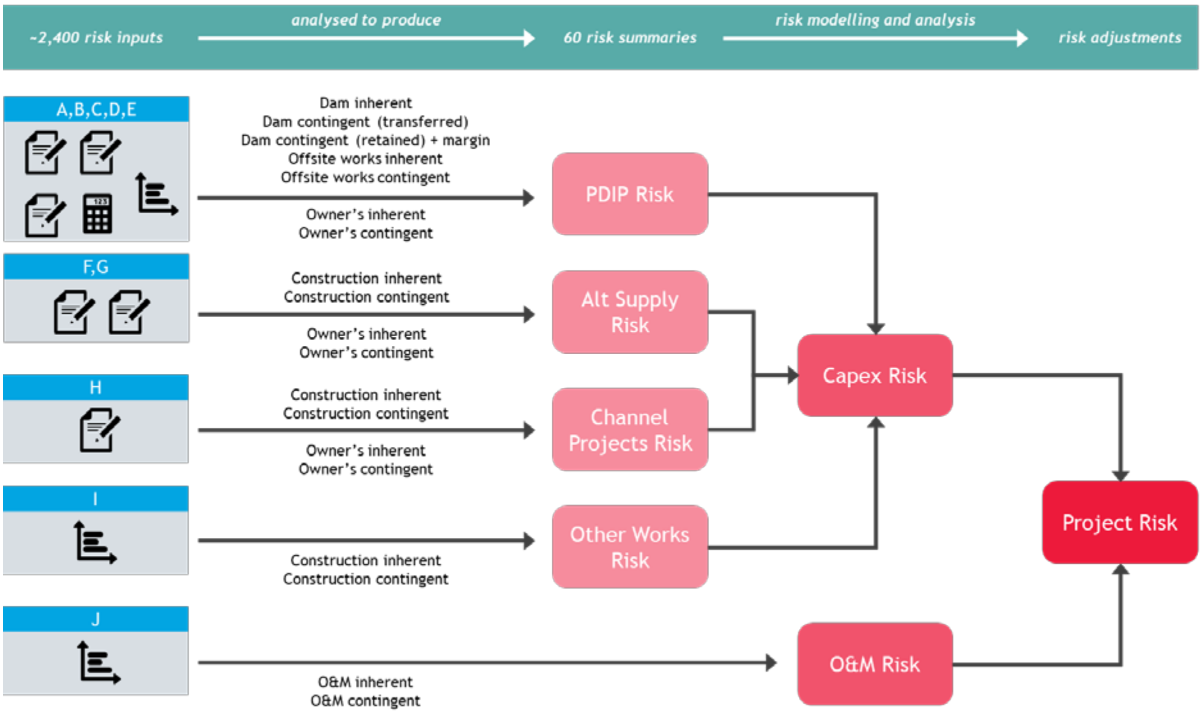


Table 35 Risk Input Sources

Item	Type	Source	Scope
A	First principles risk assessment	Copy of PDIP - Dam Package Contractors Risk Rev9.0 .xlsx	PDIP – Dam Package Contractor's Risk (Inherent and Contingent)
B	First principles risk assessment	PDIP - Owners Risk Assessment Rev8.5 (Planned Only).xlsx	PDIP – Owner's Risk (Inherent)
C	First principles risk assessment	PDIP - Owners Risk Assessment Rev9.7.4 (Unplanned Only).xlsx	PDIP – – Owner's Risk (Contingent)
D	Calculation input	Calculated locally based on margin assumptions for dam retained risk	PDIP – – Risk adjustment to margin
E	Benchmarks (converted to probabilistic)	PDIP - Summary of Offsite Works Packages Costs .xlsx	PDIP – Offsite Works Package Risk
F	First principles risk assessment	Alt Storage - Ned Churchward Risk Rev4.4 .xlsx	Alternative Supply – NC Weir – All Risks (Inherent and Contingent)
G	First principles risk assessment	Alt Storage - Degilbo Risk Rev3.3 .xlsx	Alternative Supply – DC Dam - All Risks (Inherent and Contingent)
H	First principles risk assessment	PDIP - Distribution Network Risk Assessment Rev3.1.xlsx	Channel Works – - All Risks (Inherent and Contingent)
I	Benchmarks (converted to probabilistic)	PDSI - DBC - Options Analysis St-1 - Financial Modelling - DET - SW - Capital & O&M & Revenue - 21 07 21.xlsb	Other Works – NC Weir DIP - All Risks (Inherent and Contingent)
J	Benchmarks (converted to probabilistic)	Comparable and contemporary water supply projects in Queensland	O&M – All Assets – All Risks (Inherent and Contingent)

Risks were profiled and cash flowed commensurate with the underlying component cash flow profile. This approach applies to both capital and operational costs and risks.

8.3.20 Correlation

Correlation allows for the explicit recognition of the relationship between the uncertainties of two or more input distributions. Noting the construction of the model, in which risk inputs were developed based on summaries of the risks of discrete components of the various projects (as set out in the preceding table), no correlation has been incorporated in the modelling.

8.3.21 Risk on pricing and demand

For the purposes of the OE, neither the price paths nor the demand profiles have been risk adjusted.

In relation to pricing, for the majority of the project capital components, the cost has been assumed not to be met by the customer base. As such, neither cost nor risk on cost would be expected to translate into changes to the Part A or Part C charges. In relation to operational cost components, although these have been modelled on a probabilistic basis and could be argued to be recoverable through the Part B and Part D charges (as applicable), this analysis has not been undertaken.

The preceding items should be considered for inclusion and analysis within the Stage 2 Detailed Business Case. Further, detailed consideration of key elements of the proposed projects, and whether these would be subject to cost reflective pricing as commercial projects, would likely be required to identify whether these would also be subject to a differing tariff structure.

In terms of demand risk, the demand profiles were developed through a probabilistic approach. The median result of this analysis has been incorporated into the financial model on a deterministic basis. Although high and low demand scenarios have not been assessed, a climate change scenario has been considered. In this scenario, anticipated decreases in supply yields have been addressed through the acceleration (bringing forward) of alternative supply options (as/if required).

8.3.22 Delivery model

A preliminary delivery model assessment was conducted, with a competitive alliance delivery model determined to be the most appropriate approach for the delivery of major capital elements of the projects. Other capital and operational and maintenance elements of the projects are anticipated to be delivered through separate traditional delivery models by Sunwater.

An alliance delivery model is a collaborative delivery model which features several unique commercial attributes. Of relevance to the financial analysis is the pain-share, gain-share mechanism that is a key characteristic and strength of alliance delivery models. Through this mechanism, cost overruns (or underruns) relative to an agreed target outturn cost are shared between the owner and the non-owner participants (i.e. the contractor and designer). This has the effect of transferring or sharing a portion of the financial risk and reward of the project.

Risk modelling of the alliance mechanism involves a complex process and requires significant work to determine which scope elements would be subject to the alliance arrangement, whether the various capital projects would be delivered through an alliance or traditional delivery model, and the commercial terms including the proportion of pain/gain shared, limitations on pain share, and the basis for determining contractor/designer margins.

For the purposes of completing the financial analysis for the OE, the pain-share, gain-share mechanism has not been modelled. As such, the potential financial benefits of this delivery model have not been reflected in the financial outcomes.

Noting that the risk sharing is based on the difference between the target outturn costs (typically based on a P50 value) and the risks as measured through the financial analysis (reported at a P50 and P90 level), and the relatively small differential between the P50 and P90 risk adjusted project costs (particularly when limiting the analysis to the likely scope of the alliances, namely the dam improvement projects), not incorporating the alliance mechanism within the financial analysis is understood to have had only a limited impact on the outcomes of the evaluation.

As elements of the Detailed Business Case, the delivery model analysis will be updated, and the status of the competitive alliance delivery model as preferred delivery model will be confirmed or amended. Likewise, the financial analysis will be enhanced to incorporate an alliance mechanism or mechanisms as appropriate. The inclusion of this mechanism would be anticipated to have a positive effect on the projects, through a decrease in costs, but are not anticipated to change the OE outcome. The Queensland Procurement Policy and Best Practice Procurement Principles will be taken into consideration in the Stage 2 Detailed Business Case.

8.3.23 Terminal value

No terminal values have been included in the financial analysis for the OE. The inclusion of terminal values would require detailed consideration of the magnitude and timing of capital and operational expenditure in the period immediately prior to and after the end of the evaluation period. It is understood that this is a period in which significant projects are (or may be) required, with resulting impacts on the cash flows and performance of the assets. Consideration of the terminal values for the proposal options may be appropriate in subsequent stages of the analysis.

8.4 Financial outcomes

Project financial outcomes in terms of expenditures, revenues, risks, and net present value are set out in the following sections, tables, and charts. Results are reported in constant terms ('Con' in subsequent tables), nominal terms for compatibility with the affordability analysis, and in net present value/cost ('NPV/NPC') terms for evaluation. Where appropriate, incremental outcomes have also been provided for enhanced clarity in terms of investment evaluation and decision making.

8.4.1 Project expenditure

Table 36 below provides a summarised build-up of the capital costs and associated risk for each of the scopes of work within the base case and proposal options. Further, it displays the escalation and discounting of the capital costs for the base case and proposal options.

Table 36 Capital Expenditure

		Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
Capex ($MM)	**Unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
Dam Improvement									
Capex	Con	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Risk	Con	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Sub-total DI		**-**	**-**	CIC	CIC	CIC	CIC	CIC	CIC
Alternative supply									
Capex	Con	-	-	-	-	CIC	CIC	CIC	CIC
Risk	Con	-	-	-	-	CIC	CIC	CIC	CIC
Sub-total AS		**-**	**-**	**-**	**-**	CIC	CIC	CIC	CIC
Distribution system									
Capex	Con	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Risk	Con			CIC	CIC	CIC	CIC	CIC	CIC
Sub-total CN				CIC	CIC	CIC	CIC	CIC	CIC

Capex ($MM)	Unit	Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
		P50	P90	P50	P90	P50	P90	P50	P90
Other									
Capex	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Risk	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Sub-total Other	**Con**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Capex cost	**Con**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Capex outturn cost	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Capex NPC	**NPC**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 37 provides a summarised build-up of the operational expenditure and risk for each of the scope of works within the base case and proposal options. Further, it displays the escalation and discounting of the operational expenditure for the base case and proposal options.

Table 37 Operational Expenditure

Opex ($M)	Unit	Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
		P50	P90	P50	P90	P50	P90	P50	P90
Existing assets	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Project works	Con	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Risk	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Opex cost	**Con**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Opex outturn cost	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Opex NPC	**NPC**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 38 provides a summarised build-up of the project costs for each of the scopes of work within the base case and proposal options.

Table 38 Project Costs

Project Costs ($M)	Unit	Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
		P50	P90	P50	P90	P50	P90	P50	P90
Capex (pre-RA)	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Project Costs ($M)	Unit	Base case P50	Base case P90	Proposal Option 1 P50	Proposal Option 1 P90	Proposal Option 2 P50	Proposal Option 2 P90	Proposal Option 3 P50	Proposal Option 3 P90
Opex cost (pre-RA)	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Risk on capex and opex	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Project cost	**Con**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Project outturn cost	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Project NPC	**NPC**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The following charts provide insight into the spectrum of potential risk adjusted project cost outcomes, and the key drivers.

Figures 59, 60 and 61 have been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions

Figure 59 Project Risk Curves and Key Drivers – Base case

Figure 60 **Project Risk Curves and Key Drivers – Proposal Option 1**

Figure 61 Project Risk Curves and Key Drivers – Proposal Option 2

In relation to both the preceding cost tables, and the preceding charts, it can be observed that the differential between P50 and P90 numbers is, while large in absolute terms, relatively small compared to the base project expenditure. This is attributable to the fact that the P50 risk adjustments are significant. This in turn is understood to be attributable to two key points:

- A significant proportion of the contingent risks noted in the project risk registers (and integrated within the capital cost estimates) are identified as having a relatively high probability of occurrence (20-50%) combined with significant cost impacts. Through the risk modelling, these would materialise to varying degrees at both the P50 and P90 levels (as opposed to lower probability risks, which would generally materialise only at the P90 level).
- The inherent risks are typically skewed towards higher cost outcomes, resulting in the recognition of risk against all costs even at a P50 level.

8.4.2 Project revenues

Table 39 below provides a summarised build-up of project revenues by priority type and water usage.

Table 39 Project Revenues

Project Revenues ($M)	Unit	Base Case P50	Base Case P90	Proposal Option 1 P50	Proposal Option 1 P90	Proposal Option 2 P50	Proposal Option 2 P90	Proposal Option 3 P50	Proposal Option 3 P90
MP									
Demand									

Project Revenues ($M)	Unit	Base Case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
		P50	P90	P50	P90	P50	P90	P50	P90
Allocations - existing	ML	143,770	143,770	143,770	143,770	143,770	143,770	143,770	143,770
Allocations - sold	ML	8,965	8,965	66,280	66,280	66,280	66,280	66,280	66,280
ML drawn	ML	2,657,589	2,657,589	3,126,324	3,126,324	3,126,324	3,126,324	3,126,324	3,126,324
Revenue									
Allocation sales	Con	9.1	9.1	67.0	67.0	67.0	67.0	67.0	67.0
Charges	Con	310.0	310.0	425.4	425.4	425.4	425.4	425.4	425.4
HP									
Demand									
Allocations - existing	ML	19,900	19,900	19,900	19,900	19,900	19,900	19,900	19,900
Allocations - sold	ML	35	35	750	750	750	750	750	750
ML drawn	ML	346,869	346,869	352,815	352,815	352,815	352,815	352,815	352,815
Revenue									
Allocation sales	Con	0.1	0.1	2.3	2.3	2.3	2.3	2.3	2.3
Charges	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	**Con**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Outturn revenue	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue NPV	**NPV**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Revenue across all project options is primarily derived from water charges from MP users (81% on a nominal basis) and allocation sales of MP allocations (12% on a nominal basis). The balance of the revenue is derived from HP charges and sales.

Base case revenue is lower than proposal options revenues as demand is capped at FY22 levels due to the capacity constraints of the existing distribution system. The increased yield available under the proposal options does not impact on revenues within the evaluation period (based on the projected median demand) but is understood to be a factor in meeting demand in the period immediately post the evaluation period.

8.4.3 Project outcomes

Table 40 provides a summary of project outcomes when revenues and expenditure over the 29-year evaluation period are considered.

Table 40 Project Outcomes

		Base Case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
Project Outcomes ($MM)	**Unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
Project cost	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Project outcome	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Project NPV	**NPV**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Proposal Option 3 was identified as being cost-prohibitive due to its requirement for expensive alternative supply options, particularly the construction of a new Degilbo Creek Dam, and has been excluded from further analysis.

The tables below summarise the project outcomes for Proposal Options 1 and 2. Table 41 presents P90 capital expenditure assuming the most likely projected demand.

Table 41 Capital expenditure outputs (most likely demand)

P90 Nominal, $'M	Proposal Option 1 P90	Proposal Option 2 P90
Dam Improvement Capex	CIC[8]	CIC[9]
Ned Churchward Weir Raising	-	CIC
Degilbo Creek Dam	-	-
Tranche 1 Distribution System Upgrade	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC
Other Capex	CIC	CIC
TOTAL CAPEX	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The following key observations were made:

1. Dam Improvement Capex is similar between Dam Options 1 and 2 as they have common items of scope (as shown in Figure 5) including:
    a. Secondary spillway and left abutment buttress (addition of mass concrete strengthening)
    b. Secondary spillway raising by 5m in height (reduce overtopping frequency in this area)
    c. Demolition of half of the secondary spillway and excavation down to good foundation material, and reconstruction of this section of wall
    d. Temporary coffer dam to support item c. above
    e. Downstream scour protection below the secondary spillway and left abutment

[8] Dam Option 1
[9] Dam Option 2

   f. Extension of the existing apron below the primary spillway (significant scour protection)
   g. Construction and extension of training walls either side of the primary spillway and apron
   h. Improvement and modifications to the intake tower and outlet works
2. Proposal Option 2 includes capex for alternative supply (Ned Churchward Weir raising required by 2053), which requires work to commence across the period 2046-52, however only costs up to 2050 are included.
3. Upgrades to the distribution system are common to both Proposal Options 1 and 2
4. Other Capex consists of minor improvement works anticipated for Ned Churchward Weir in the medium term, irrespective of any weir raising.
5. As a result of addressing distribution system constraints within a separate assessment, the total capital expenditure relating to Proposal Option 1 includes the cost of dam improvement plus Other Capital Expenditure.
6. The total estimated capital expenditure for Proposal Option 1 is based on a concept level of design and subject to a number of uncertainties, including global production and supply volatility as a result of the Covid-19 pandemic.
7. Whilst the next stage of project development (DBC stage 2) will increase design definition, increase the accuracy of cost estimation and potentially identify innovation and efficiencies, there is also the possibility of uncovering costs unforeseen as a result of engaging with the market for more firm pricing.

After taking into consideration capital expenditure, operational expenditure and revenue, assuming the most likely projected demand, the project Financial NPV are presented in Table 42 below.

Table 42 Financial Project outcomes (most likely projected demand)

Project outcome	Unit	Proposal Option 1 P90	Proposal Option 2 P90
Cost (Capex + Opex)	Nominal	CIC	CIC
Revenue	Nominal	CIC	CIC
Surplus/(Deficit)	**Nominal**	CIC	CIC
Discounting @ 1.95%	Nominal	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

8.4.4 Incremental analysis

The NPV for both Proposal Options 1 and 2 is negative, as the costs for both options are greater than revenue derived from the sale of water. Whilst Proposal Option 2 has a greater cost than Proposal Option 1, its NPV is slightly better as the requirement for the alternative supply (Ned Churchward Weir raising) occurs across the end of the evaluation period (2046-2052). The small NPV difference between Proposal Options 1 and 2, assuming the most likely projected demand, is due to scope commonality of dam improvement works. Note that only costs to 2050 have been captured in Table 42 above. Table 43 provides a summary of project outcomes of the proposal options over the 29-year evaluation period are compared incrementally to the base case.

Table 43 Incremental Analysis

		Base Case	Proposal Option 1	Proposal Option 2	Proposal Option 3

Incremental Analysis ($M)	Unit	P50	P90	P50	P90	P50	P90	P50	P90
Project cost	Nom	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	Nom	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Project Outcome	**Nom**	**-**	**-**	CIC	CIC	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	-	-	CIC	CIC	CIC	CIC	CIC	CIC
Project NPV	**NPV**	**-**	**-**	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

All options require significant capex at Paradise Dam and across the distribution system, while Proposal Options 2 and 3 also require significant capex to deliver alternative supply option projects (i.e., Ned Churchward Weir Raise and Degilbo Creek Dam).

The capital works and associated increases in operational and maintenance expenditure are significantly in excess of increases in revenue (which is based on pricing that is not cost reflective) resulting in projects that are not value accretive on an NPV basis. The negative financial impact of the projects is amplified when incremental NPV is considered, as the base case accrues significant revenues without the need for material capex.

In relation to the preceding, the increase in revenue is predominantly attributable to distribution system expansion (which enables access and supports growth in demand), rather than the dam improvement and alternative supply works (which support yield). This is demonstrated through Option 2, in which all demand is anticipated to be met notwithstanding the alternative supply works not being completed within the evaluation period. In contrast the full demand is not able to be met under the base case primarily due to the absence of distribution system upgrades.

8.4.5 Events outside of the evaluation period

The preceding analysis considers costs and revenues that occur within the evaluation period of FY22 to FY50. As noted in the inputs sunk costs ($20.6m in real FY21 terms) have been excluded from the results.

Due to the timing of alternative supply option works under Proposal Option 2 not all capex associated with the raising of the Ned Churchward Weir are captured in the preceding results. Additional capex for the raising of Ned Churchward Weir, not recognised in the preceding tables and figures, totals CIC on a P90 nominal basis.

8.5 Sensitivity and scenario analysis

Project financial outcomes for Proposal Options 1 and 2 were tested through a range of sensitivity and scenario analysis, in addition to the probabilistic modelling undertaken on costs and risks.

8.5.1 Scenario analysis

The scenarios analysed in the following sections include:

- Proposal Option 1 with climate change (Option 1 – CC). No change from the central (non-climate change case) required to meet demand, even with decreased yield attributable to climate change.
- Proposal Option 2 with climate change (Option 2 – CC). This scenario considers the need to both accelerate the alternative supply works and to increase the scale of the works (constructing

Degilbo Creek Dam rather than raising Ned Churchward Weir) due to decreased yield attributable to climate change.

- Proposal Option 2 with a delayed additional alternative supply option (Option 2 – D). This scenario considers the ability to defer the commencement of the raising of the Ned Churchward Weir to after the evaluation period.

The following table summarises the scope of works planned for each of the scenarios that were quantitatively analysed including the timing of these works.

Table 44 Scenario Analysis Summary

	Option 1 - CC	Option 2 - CC	Option 2 - D
Paradise Dam Improvement Project (DIP)			
Option 1 (Return to FSL)	✓ (FY22 – FY28)		
Option 2 – 5m lowering		✓ (FY22 – FY28)	✓ (FY22 – FY28)
Additional Alternative Supply Option/s			
Ned Churchward Weir Raise			Outside of the Evaluation Period
Degilbo Creek Dam		✓ (FY34 – FY42)	
Other			
Distribution System - Upgrade Existing (Tranche 1)	✓ (FY25 – FY27)	✓ (FY25 – FY27)	✓ (FY25 – FY27)
Distribution System - Upgrade & Extend (Tranche 2)	✓ (FY36 – FY40)	✓ (FY36 – FY40)	✓ (FY36 – FY40)
Existing Bulk Water Improvement (Ned Churchward Weir) - no additional supply	✓ (FY26 – FY30)	✓ (FY26 – FY30)	✓ (FY26 – FY30)

8.5.2 Option 1 and Option 2 – Climate Change Scenario

The following tables demonstrate the project outputs under the Proposal Options 1 and 2 under a climate change scenario.

Table 45 Capital Expenditure – Climate Change Scenarios

		Proposal Option 1-CC		Proposal Option 2-CC	
Capex ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**
Dam Improvement (DI)					
Capex	Con	CIC	CIC	CIC	CIC
Risk	Con	CIC	CIC	CIC	CIC
Sub-total DI		CIC	CIC	CIC	CIC
Alternative supply					
Capex	Con	-	-	CIC	CIC

		Proposal Option 1-CC		Proposal Option 2-CC	
Capex ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**
Risk	Con	-	-	CIC	CIC
Sub-total AS		**-**	**-**	CIC	CIC
Channel network					
Capex	Con	CIC	CIC	CIC	CIC
Risk	Con	CIC	CIC	CIC	CIC
Sub-total CN		CIC	CIC	CIC	CIC
Other					
Capex	Con	CIC	CIC	CIC	CIC
Risk	Con	CIC	CIC	CIC	CIC
Sub-total Other	**Con**	CIC	CIC	CIC	CIC
Capex cost	**Con**	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC
Capex outturn cost	**Nom**	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC
Capex NPC	**NPC**	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Capital expenditure for each updated proposal option assuming climate change is provided in Table 46.

Table 46 Capital expenditure outputs (impact of climate change)

P90 Nominal, $'M	Proposal Option 1-CC P90	Proposal Option 2-CC P90
Dam Improvement Capex	CIC	CIC
Ned Churchward Weir Raising	-	-
Degilbo Creek Dam	-	CIC
Tranche 1 Distribution System Upgrade	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC
Other Capex	CIC	CIC
TOTAL CAPEX	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 47 Operational Expenditure – Climate Change Scenarios

		Proposal Option 1-CC		Proposal Option 2-CC	
Opex ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**
Existing assets	Con	CIC	CIC	CIC	CIC
Project works	Con	CIC	CIC	CIC	CIC
Risk	Con	CIC	CIC	CIC	CIC
Opex cost	**Con**	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC
Opex outturn cost	**Nom**	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC
Opex NPC	**NPC**	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 48 Project Costs – Climate Change Scenarios

		Proposal Option 1-CC		Proposal Option 2-CC	
Project Costs ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**
Capex (pre-RA)	Con	CIC	CIC	CIC	CIC
Opex cost (pre-RA)	Con	CIC	CIC	CIC	CIC
Risk on capex and opex	Con	CIC	CIC	CIC	CIC
Project cost	**Con**	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC
Project outturn cost	**Nom**	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC
Project NPC	**NPC**	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 49 Project Revenues – Climate Change Scenarios

		Proposal Option 1-CC		Proposal Option 2-CC	
Project Revenues ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**
MP					
Demand					
Allocations - existing	ML	143,770	143,770	143,770	143,770
Allocations - sold	ML	66,280	66,280	66,280	66,280
ML drawn	ML	3,126,324	3,126,324	3,126,324	3,126,324
Revenue					
Allocation sales	Con	CIC	CIC	CIC	CIC
Charges	Con	CIC	CIC	CIC	CIC
HP					
Demand					
Allocations - existing	ML	19,900	19,900	19,900	19,900
Allocations - sold	ML	750	750	750	750

Project Revenues ($M)	Unit	Proposal Option 1-CC P50	Proposal Option 1-CC P90	Proposal Option 2-CC P50	Proposal Option 2-CC P90
ML drawn	ML	352,815	352,815	352,815	352,815
Revenue					
Allocation sales	Con	CIC	CIC	CIC	CIC
Charges	Con	CIC	CIC	CIC	CIC
Revenue	**Con**	CIC	CIC	CIC	CIC
Escalation	Con	CIC	CIC	CIC	CIC
Outturn revenue	**Nom**	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC
Revenue NPV	**NPV**	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 50 Project Outcomes – Climate Change Scenarios

Project Outcomes ($M)	Unit	Proposal Option 1-CC P50	Proposal Option 1-CC P90	Proposal Option 2-CC P50	Proposal Option 2-CC P90
Project cost	Nom	CIC	CIC	CIC	CIC
Revenue	Nom	CIC	CIC	CIC	CIC
Project outcome	**Nom**	CIC	CIC	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC	CIC	CIC
Project NPV	**NPV**	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

After taking into consideration capital expenditure, operational expenditure, and revenue, assuming the impact of climate change, the Project Net Present Values (NPV) are presented in Table 51 below. The worsening of the NPV for Option 2 compared to Option 1 is due to the requirement of alternative supply for Option 2 within the evaluation period.

Table 51 Financial Project outcomes (impact of climate change)

Project outcome	Unit	Proposal Option 1-CC P90	Proposal Option 2-CC P90
Cost	Nominal	CIC	CIC
Revenue	Nominal	CIC	CIC
Surplus/Deficit	**Nominal**	CIC	CIC
Discounting @ 1.95%	Nominal	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 52 Incremental Project Outcomes – Climate Change Scenarios Relative to Central Cases

		Proposal Option 1 / 1-CC		Proposal Option 2 / 2-CC	
Incremental Outcomes ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**
Central case	NPV	CIC	CIC	CIC	CIC
Scenario (CC)	NPV	CIC)	CIC	CIC	CIC
Incremental	**NPV**	**-**	**-**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Under the climate change scenario, Proposal Option 1 does not require additional capital expenditure to continue to meet projected demand over the evaluation period. Proposal Option 2 however, requires both an acceleration of the alternative supply option capex (otherwise scheduled for delivery over FY46 to FY52, brought forward to FY34 to FY42) and also an increase in the quantum of capex (shift from Ned Churchward Weir Raise to Degilbo Creek Dam), which both result in a worsening of the NPV position of the project, relative to the central case.

8.5.3 Proposal Option 2 – Delayed Alternative Supply Scenario

The following tables demonstrate the project outcomes achieved under the Proposal Option 2 with delay scenario. As set out in Table 44, the key difference between the central case and the delay scenario is that the alternative supply option (i.e., Ned Churchward Weir Raise) capex is deferred beyond the project evaluation period.

Table 53 Capital Expenditure – Delay Scenarios

			Proposal Option 2-Delay
Capex ($M)	**Unit**	**P50**	**P90**
Dam Improvement (DI)			
Capex	Con	CIC	CIC
Risk	Con	CIC	CIC
Sub-total DI		CIC	CIC
Alternative supply			
Capex	Con	-	-
Risk	Con	-	-
Sub-total AS		-	-
Distribution system			
Capex	Con	CIC	CIC
Risk	Con	CIC	CIC
Sub-total CN		CIC	CIC
Other			
Capex	Con	CIC	CIC
Risk	Con	CIC	CIC
Sub-total Other	**Con**	CIC	CIC
Capex cost	**Con**	CIC	CIC

Escalation	Con	CIC	CIC
Capex outturn cost	**Nom**	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC
Capex NPC	**NPC**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 54 Operational Expenditure – Delay Scenarios

			Proposal Option 2-Delay
Opex ($M)	**Unit**	**P50**	**P90**
Existing assets	Con	CIC	CIC
Project works	Con	CIC	CIC
Risk	Con	CIC	CIC
Opex cost	**Con**	CIC	CIC
Escalation	Con	CIC	CIC
Opex outturn cost	**Nom**	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC
Opex NPC	**NPC**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 55 Project Costs – Delay Scenarios

			Proposal Option 2-Delay
Project Costs ($M)	**Unit**	**P50**	**P90**
Capex (pre-RA)	Con	CIC	CIC
Opex cost (pre-RA)	Con	CIC	CIC
Risk on capex and opex	Con	CIC	CIC
Project cost	**Con**	CIC	CIC
Escalation	Con	CIC	CIC
Project outturn cost	**Nom**	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC
Project NPC	**NPC**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 56 Project Revenues – Delay Scenarios

			Proposal Option 2-Delay
Project Revenues ($M)	**Unit**	**P50**	**P90**
MP			
Demand			
Allocations - existing	ML	143,770	143,770
Allocations - sold	ML	66,280	66,280
ML drawn	ML	3,126,324	3,126,324
Revenue			

			Proposal Option 2-Delay
Project Revenues ($M)	**Unit**	**P50**	**P90**
Allocation sales	Con	CIC	CIC
Charges	Con	CIC	CIC
HP			
Demand			
Allocations - existing	ML	19,900	19,900
Allocations - sold	ML	750	750
ML drawn	ML	352,815	352,815
Revenue			
Allocation sales	Con	CIC	CIC
Charges	Con	CIC	CIC
Revenue	**Con**	CIC	CIC
Escalation	Con	CIC	CIC
Outturn revenue	**Nom**	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC
Revenue NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 57 Project Outcomes – Delay Scenarios

			Proposal Option 2-Delay
Project Outcomes ($M)	**Unit**	**P50**	**P90**
Project cost	Nom	CIC	CIC
Revenue	Nom	CIC	CIC
Project outcome	**Nom**	CIC	CIC
Discounting @ 1.95%	Nom	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 58 Incremental Project Outcomes – Delay Scenarios

			Proposal Option 2 / 2-D
Incremental Outcomes ($M)	**Unit**	**P50**	**P90**
Central case	NPV	CIC	CIC
Scenario (Delay)	NPV	CIC	CIC
Incremental	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Deferring the alternative supply option project does not have an observable impact on revenues within the project evaluation period while avoiding the need for capex associated with the Ned Churchward Weir Raise. This leads to an incremental improvement in NPV relative to the Proposal Option 2 central case. It should be noted however that the timing of the Ned Churchward Weir Raise capex in the Proposal Option 2 central case is based on completion of the works and filling time sufficient to meet projected median demand in FY53, which Proposal Option 2-Delay would be unable to satisfy (resulting in loss of revenue and economic outcomes). Mitigating the overall loss of revenue post FY50 under the Proposal Option 2-Delay scenario would require the commencement of significant capex in relation to the Ned Churchward Weir immediately subsequent to the evaluation period.

8.5.4 Sensitivity analysis

The following table and charts demonstrate the sensitivity of project outcomes only to changes in the escalation and discount rates applied.

Table 59 Sensitivity Analysis – Project Outcomes Under Sensitivity Testing

		Base Case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
Expenditure	**unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
Base	NPV	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Escalation - 1%	NPV	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Escalation + 1%	NPV	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discount Rate - 1%	NPV	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Discount Rate + 1%	NPV	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The following tornado charts display the variance of the P50 and P90 NPCs under the base case and Proposal Options when the respective sensitivities are applied.

Figures 63 and 64 have been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Figure 62 Escalation Rate Sensitivities (Tornado Charts)

Figure 63 Discount Rate Sensitivities (Tornado Charts)

As evidenced by the preceding table and charts, differences in escalation and discount rates can have material impacts on the magnitude of the NPV/NPC various proposal options. Noting that in the central case (with no sensitisation of escalation or discount rate) Options 1 and 2 are almost indistinguishable on an NPV/NPC basis, the impact of these changes in escalation and discount rate are most obvious. This is due to the timing of expenditure in these projects, with Option 1 having greater upfront capex while Option 2 has a portion of capex (associated with the alternative supply works) deferred until the end of the evaluation period. The implication of this is that movements in rates result in larger movements in Option 2, as the deferred capex is either increased (from an escalation rate increase, or discount rate decrease) or decreased (from an escalation rate decrease, or discount rate increase) in NPV terms. Although the differential between Option 1 and Option 2 remains moderate across all sensitivities, it should be noted that the relative ranking of the projects (in terms of NPV/NPC) does change under the various sensitivities considered.

9 COST-BENEFIT ANALYSIS

9.1 Purpose

This section sets out the cost-benefit analysis (CBA) undertaken for the Options Evaluation. It describes the CBA model, the financial costs of proposal options described in chapter 7, and the identified benefits included in the model. It summarises the results from the assessment of proposal options through the CBA to determine a preferred option.

This chapter also describes the sensitivity analysis undertaken within the modelling on an agreed set of key parameters, to assess any changes to the results. It also includes an overview of the separate modelling of a range of scenarios to understand the implications of specific uncertainties, including climate change, on the findings to determine a preferred option.

9.2 CBA model approach

9.2.1 Overview

CBA is a widely used tool for economic evaluation. It provides a logical approach for assessing the proposal options against the base case consistent with the requirements of the BCDF. The scope of the CBA is relatively narrow compared to the full economic analysis that will be undertaken for the Stage 2 DBC.

For the CBA, proposal options were assessed against the base case (as defined in chapter 3) and using the central case parameters (also defined in chapter 3) to show the incremental benefits and costs for each option, and to compare options. The evaluation of the water supply and demand service need for each proposal option incorporated a wide range of cost and benefit inputs. These inputs are summarised below, with detail provided in sections 9.3 and 9.4.

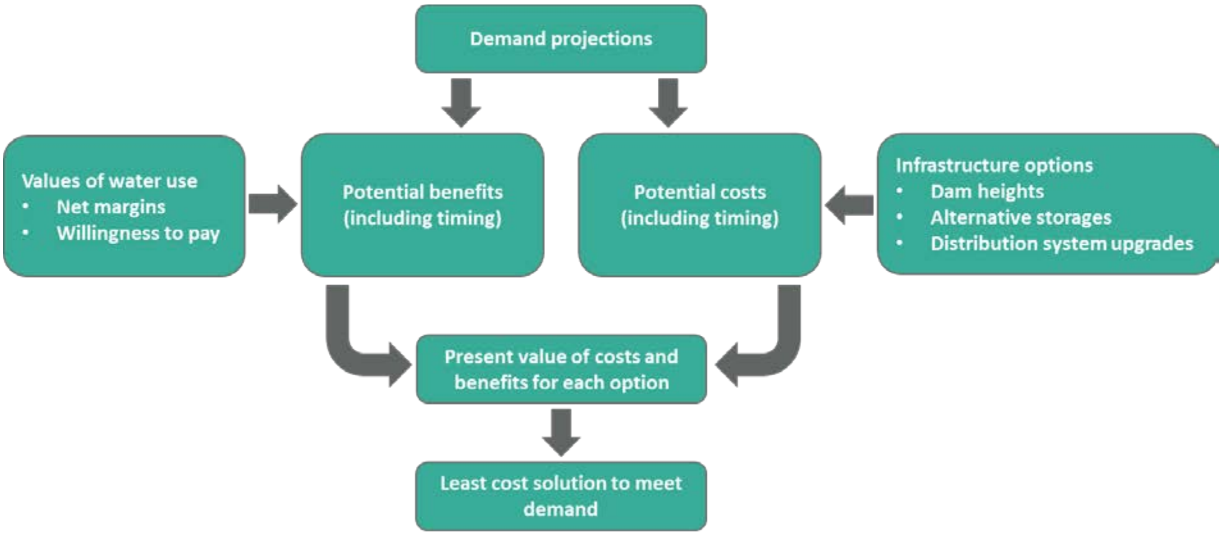
- **Cost inputs** – this includes the total cost of each proposal option including capital and operating costs (with options defined in chapter 7 and costs outlined in chapter 8).
- **Benefit inputs** – this includes the benefits associated with water supply and demand. Benefits are based on the estimated volumes of water required by customers from the demand assessment and estimated net margins of water use by end users (irrigators, urban users).

The CBA model considered costs and benefits over a 30-year evaluation period, with all costs and benefits discounted to present value terms. Benefits do not commence until the infrastructure within an option is fully commissioned and will then increase incrementally in line with water use over the 30-year evaluation period. A sensitivity analysis was undertaken to assess the impact of changes to key input variables on the outcome of the CBA.

A key feature of the model was the timing of alternative supply options and distribution system upgrades. The need for introducing alternative supply options is triggered by the projected demand exceeding the yields from the dam options, and the need for distribution system upgrades is triggered by limitations of the existing system's capacity to deliver the yields to customers. Capital expenditure in the model was timed to ensure infrastructure is completed just prior to the additional water being required. Where multiple alternative supply options were available, the economic model selected the least-cost combinations of options (in present value terms) that met the water supply and demand service need.

Figure 65 presents a flowchart showing how the various model inputs determined the least-cost combinations of options to meet the water supply and demand service need.

Figure 64 CBA model framework to determine the least cost options to meet demand



9.2.2 Limitations and constraints

There are limitations and constraints to the analysis as set out below:

- Positive and negative externalities have not been incorporated into the quantitative economic analysis. This includes, for example, the economic value of reduced damages and losses attributable to dam safety, the value of social impacts including recreation, and environmental impacts.
- Specifically, dam safety was not included in the quantitative analysis because all proposal options were required to meet the dam safety requirements as a threshold, and therefore no differences exist between the three proposal options.
- Social and environmental impacts were not included in the quantitative analysis because these potential impacts have not been developed to the degree of detail necessary for assessment within a CBA process (refer chapter 10). It is also anticipated that the values of social and environmental impacts will not differ significantly between proposal options as the options are largely variations of the brownfield redevelopment rather than a new greenfield project. The exception is likely to be the environmental impacts associated with any new alternative supply option, and further work is required to define these impacts. Detailed investigations, including a social impact evaluation and additional environmental impact assessments, will be conducted as part of the Stage 2 DBC.

9.2.3 Decision rules in the CBA

The CBA uses standard decision rules to assess proposal options and recommend a preferred option/s for consideration in the Stage 2 DBC. Each option is assessed against the base case and includes sensitivity analysis and scenario analysis to complement the economic analysis (consistent with the BCDF). The decision rules used are:

- **The net present value (NPV)** - The NPV is calculated by the present value (all values discounted to present day terms) of the benefits less the present value of the costs. A proposal options with a positive NPV has benefits that exceed the costs and would be preferred over an option with a lower NPV. Given the identified limitation related to dam safety outlined above, a negative NPV is possible, that is, where the economic estimate of benefits is lower than the costs. When evaluating the proposal options under these circumstances, the option with the smallest negative NPV would be preferred.

- **Incremental net present value (INPV)** – An INPV enables analysis of the incremental differences between proposal options or even sub-options, for example, the additional net benefit of an alternative supply option, or the upgrade of the distribution system at a later date to ensure any emerging supply and distribution constraints are overcome.
- **Benefit cost ratio (BCR) and incremental benefit cost ratio (IBCR)** – These are simply the benefits divided by the costs with a positive ratio indicating that benefits are greater than costs. These ratios have also been calculated for each proposal option.

The NPV, INPV, BCR and IBCR results have been presented in a format to enable decision makers to clearly identify the preferred proposal option for consideration in the Stage 2 DBC.[10]

9.2.4 Valuation of benefits and costs

The range of valuation techniques and input data for benefits and costs in the CBA are outlined in Table 60. The economic benefits from water use are based on margins from water use and derived from modelling undertaken for the analysis. Key points to note are:

- For irrigation areas where no land use change is indicated by the demand modelling, benefits have been measured as the range of gross margin estimates ($/ML) for key crops (e.g., sugar). This assumes capital investment costs are sunk.
- For irrigation areas where land use is indicated to change under the demand modelling (e.g., sugar to macadamias, or grazing to macadamias), simple net margins were used that also reflect the investment costs of converting to an alternative land use. Existing gross margin models[11] were enhanced to include capital investments (e.g., irrigation equipment), the opportunity cost of previous production margins foregone, and lags between investment and cashflow generation.

Table 60 Valuation approach for costs and benefits within the CBA

Cost or benefit	Valuation approach	Data sources
Cost of options		
Capital costs of each proposal option	Risk adjusted costs were provided by Sunwater and underwent a peer review process. Analysis included the profile of expenditure over the construction period.	Sunwater
Margins from water use - irrigation		
Crop revenues	Estimated crop yields multiplied by a range of farm-gate prices. Note: for perennial tree crops, revenues gradually build up over the period of tree maturation as per advice from industry and agronomists.	Qld Department of Agriculture and Fisheries (DAF), ABARES, industry forecasts and FAO

[10] Although BCRs have been calculated, in the case of mutually exclusive options, NPV should be used as the primary decision tool. See Pannell (2019) for further discussion.

[11] These are primarily crop-based economic models developed by Queensland Department of Agriculture and Fisheries (DAF) which have been updated to include data and additional parameters based on research and consultation already undertaken for this OE (see https://www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/sugar/farm-economic-analysis-tool, date accessed 1 July 2021)

Cost or benefit	Valuation approach	Data sources
Operational input costs	Derived from Qld DAF Farm Economic Analysis Tool (FEAT) input cost parameters, updated to reflect local parameters and 2021 costs where necessary.	Operational input costs DAF Farm Economic Analysis Tool (FEAT)
Crop establishment costs	Costs of clearing (if necessary), all pumps and irrigation distribution infrastructure, electricity connections, tree costs etc. This was included as a range of bundled capital costs for inclusion in the year of new crop establishment.	Industry sources and consultation already completed
Land cost / opportunity cost of previous land use	The land or opportunity cost was incorporated into the net margin analysis as a capital cost in year one for any land converting to high value crops. This provided a proxy value for land use foregone, irrespective of whether it is purchased or converted. This was estimated by capitalising the range of gross margins indicated for sugar and grazing. To be consistent with the land use scenarios used in the demand estimates, it was assumed 28% of future land use change is from grazing to high value crops, while 72% is from the conversion of sugar crops to high value crops.	Land cost / opportunity cost of previous land use
Allocation purchase prices	Based on historical allocation sales and statistical analysis of historical trade data.	Sunwater, DRDMW
Sunwater charges	Existing regulated price paths reported by the Queensland Competition Authority (QCA). In the absence of any contrary information, Sunwater charges at the end of the existing price path were maintained in real terms in perpetuity.	QCA
Margins from water use – urban and industrial		
Benefits of urban and commercial uses	Estimates of consumer surplus for general urban water supply were not available. Therefore, an estimated a range of values was used based on a benefit transfer study of consumers' willingness to pay to avoid major water restrictions.	Benefit transfer

9.2.5 Sensitivity analysis and scenario analysis

Sensitivity analysis of the CBA model was undertaken using Monte Carlo simulations for the following inputs:

- capital cost estimates for each proposal option
- variability in demand established through the sensitivity analysis (higher and lower projections as defined in section)
- benefits from water use, including revenues, costs, and subsequent margins
- supply yields attributable to each option, to determine the ability of an option to meet long-term requirements.

A number of agreed scenarios were modelled to understand the implication of specific drivers and uncertainties on the findings from the economic modelling. These were:

- a scenario testing the impacts of climate change on the proposal options,
- changes to the rates of land use change assumed, and
- changes in the proportion of high-value crops developed in greenfield areas.

9.3 Costs in the CBA

9.3.1 Dam option costs

The dam option costs include capital, remediation, and operating costs for the base case and the three dam options. These costs are defined as follows:

- Capital costs refer to the cost of the work required to alter the height of the dam wall (if necessary) and for the required strengthening and other improvement works.
- Remediation costs refer to the cost of the work required to manage the environmental impacts, including items such as water quality monitoring and erosion management.
- Operating costs refer to the cost of ongoing operation and maintenance of the dam.

The costs associated with the Essential Works are treated as sunk costs and are excluded from the CBA.

Table 61 presents the costs and yields of the dam options in present value terms, including incremental costs between options.

Table 61 Yields and costs in present value terms for dam options (7% discount rate)

Option	Capital costs ($million)	Remediation costs ($million)	Operating costs ($million)	P90 Risk adjustment ($million)	Total cost ($million)	Yield (ML)
Absolute						
Base case	CIC	CIC	CIC	CIC	CIC	121,600
Dam Option 3	CIC	CIC	CIC	CIC	CIC	72,600
Dam Option 2	CIC	CIC	CIC	CIC	CIC	121,600
Dam Option 1	CIC	CIC	CIC	CIC	CIC	168,600
Incremental						
Base case to Dam Option 2	CIC	CIC	CIC	CIC	CIC	0
Dam Option 3 to Dam Option 2	CIC	CIC	CIC	CIC	CIC	49,000
Dam Option 2 to Dam Option 1	CIC	CIC	CIC	CIC	CIC	47,000

Source: Sunwater

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The majority of costs associated with each of the options are capital costs, with relatively small amounts attributable to remediation and operating costs.

For the incremental costs, the bulk of the difference across options relates to capital costs, with minimal difference between options for remediation and operating costs.

9.3.2 Alternative supply options

Alternative supply options are defined in chapter 6 and Table 62 presents the costs (in present value), yields and cost-effectiveness for these options. Yields are interdependent and therefore the yield of a given alternative supply option varies depending on the height of Paradise Dam and any other alternative supply options it is combined with.

Table 62 Alternative supply options yields and P90 costs in present value terms (7% discount rate)

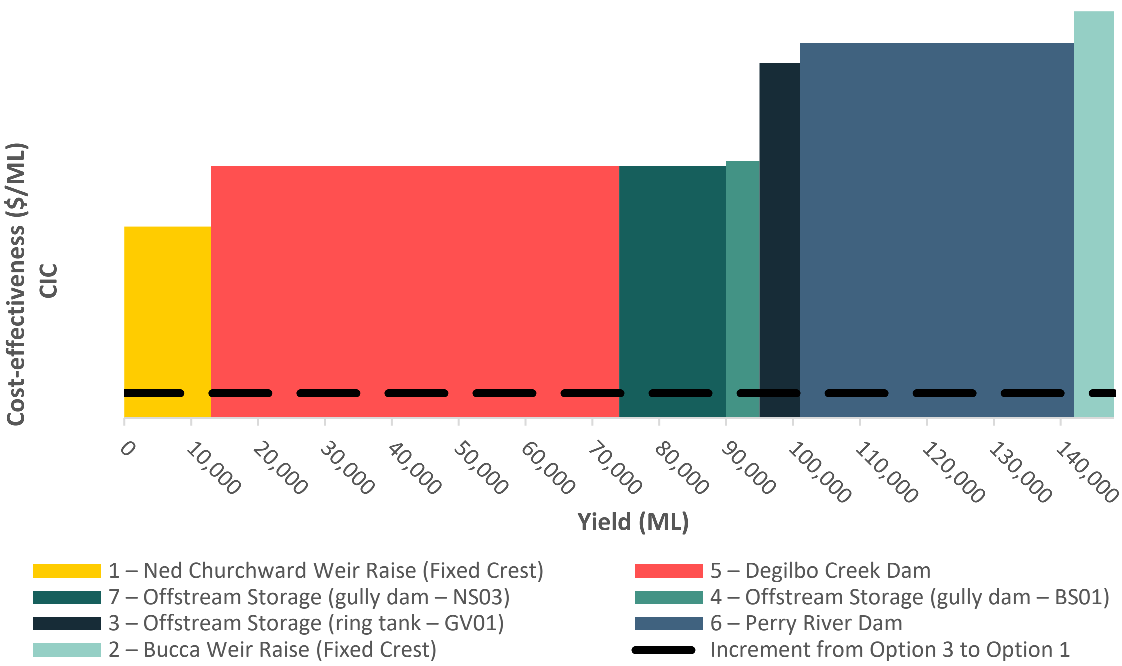
Alternative Supply Option	Cost ($million)	Yield (ML)	Cost-effectiveness ($/ML)
Dam Option 3			
1 – Ned Churchward Weir Raise (Fixed Crest)	CIC	13,000	CIC
2 – Bucca Weir Raise (Fixed Crest)	CIC	6,000	CIC
3 – Offstream Ring Dam Storage	CIC	6,000	CIC
4 – Birthamba Creek Dam	CIC	5,000	CIC
5 – Degilbo Creek Dam	CIC	61,000	CIC
6 – Oaky Creek Dam	CIC	16,000	CIC
Dam Option 2			
1 – Ned Churchward Weir Raise (Fixed Crest)	CIC	10,000	CIC
2 – Bucca Weir Raise (Fixed Crest)	CIC	3,000	CIC
3 – Offstream Ring Dam Storage	CIC	3,000	CIC
4 – Birthamba Creek Dam	CIC	4,000	CIC
5 – Degilbo Creek Dam	CIC	52,000	CIC
6 – Oaky Creek Dam	CIC	10,000	CIC

Source: Sunwater estimates

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

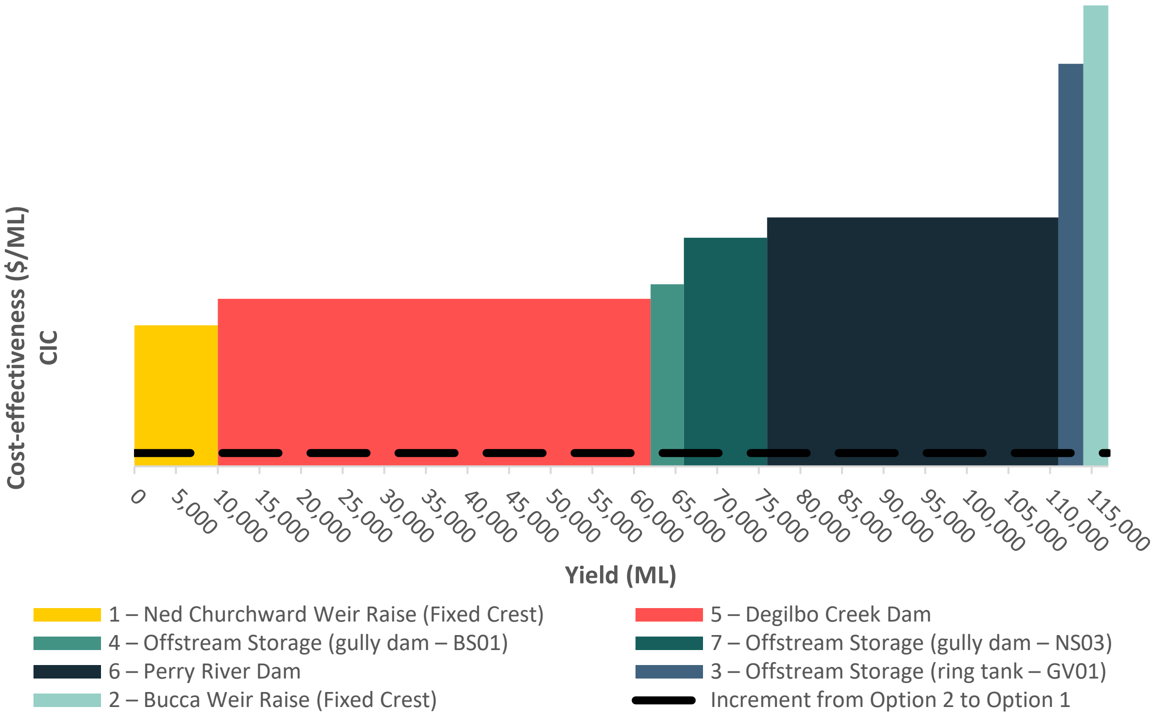
To determine the most cost-effective proposal option and the preferred sequencing of alternative supplies, the alternative supply options were ordered by cost-effectiveness, as outlined in Figure 66 and Figure 67 below, for the progressive increase in yields for Dam Option 3 and Dam Option 2 respectively. The incremental cost effectiveness of Dam Option 1 is shown on the charts for comparison.

Figure 65 Dam Option 3: Cost-effectiveness of alternative supply options for progressive increase in yields



Source: Adapted from Sunwater analysis

Figure 66 Dam Option 2: Cost-effectiveness of alternative supply options for progressive increase in yields



Source: Adapted from Sunwater analysis

The cost-effectiveness analysis identified the following:

- Returning Paradise Dam back to the original FSL (i.e., Dam Option 1) is significantly more cost effective than any alternative supply options.
- The Ned Churchward Weir Raise is the most cost-effective alternative supply option for both dam heights however, it only provides a relatively small additional 10,000ML – 13,000ML of yield. In comparison to the cost effectiveness of Dam Option 1, however, this option would require a cost reduction of over 80% to reach a similar level cost effectiveness.
- Degilbo Creek Dam provides a high yield (52,000ML – 61,000ML) and is only slightly less cost-effective than the Ned Churchward Weir Raise.
- Alternative supply option combinations involving both the Ned Churchward Weir Raise and Degilbo Creek Dam tended to be the most cost-effective.

The following configuration of alternative supply options have therefore been incorporated into the proposal options for consideration in the CBA. The timing of the construction has been deliberately chosen to ensure commissioning just prior to the projected demand requirements.

Table 63 Alternative supply options incorporated into each proposal option to meet central projected demand

Option	Cost ($million)	Yield (ML)	Construction Commence	Commissioning Complete
Proposal Option 1				
None Required				
Proposal Option 2				

Option	Cost ($million)	Yield (ML)	Construction Commence	Commissioning Complete
1 – Ned Churchward Weir Raise (Fixed Crest)	CIC	10,000	2045	2053
Proposal Option 3				
1 – Ned Churchward Weir Raise (Fixed Crest)	CIC	13,000	2021	2029
5 – Degilbo Creek Dam	CIC	61,000	2028	2036

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

9.3.3 Distribution system upgrades

Distribution system upgrades across two tranches were identified in chapter 6 and are presented in Table 64 below along with key characteristics required for assessment in the CBA. The Tranche 1 augmentation of the distribution system primarily involves upgrade of the distribution infrastructure within the existing scheme footprint (e.g., pump upgrades), while the Tranche 2 augmentations involve upgrades and extending the scheme footprint.

Table 64 Distribution system upgrades - delivery capacity, timing, and costs in present value terms (7% discount rate)

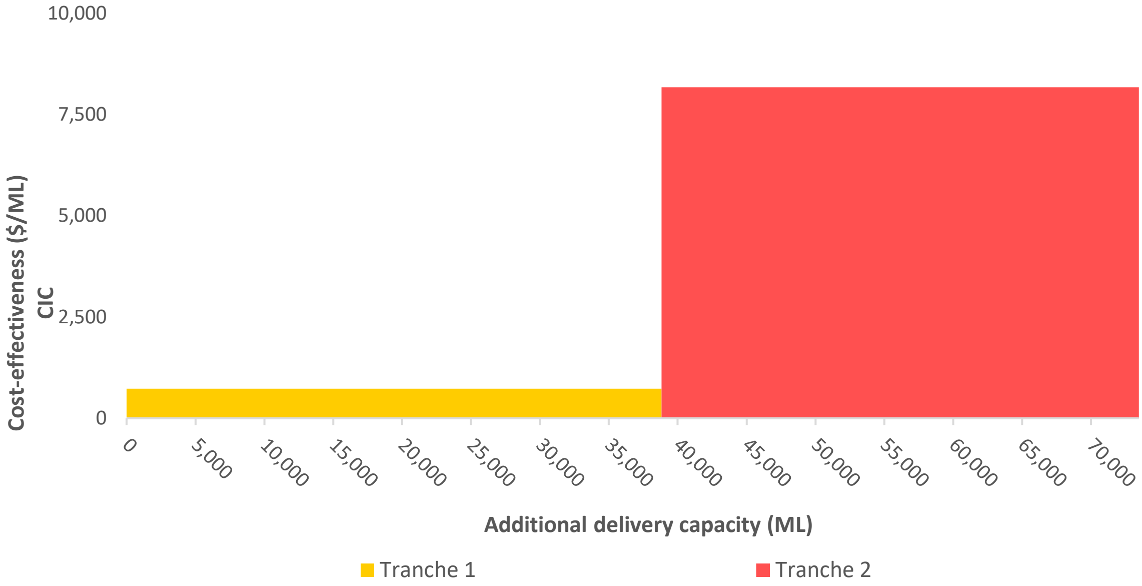
	Cost ($million)	Year required	Additional capacity (ML)	Cost-effectiveness ($/ML)
Current excess delivery capacity	$0	n/a	9,475	n/a
Distribution System Upgrades – Tranche 1	CIC	by 2028	38,830	CIC
Distribution System Upgrades – Tranche 2	CIC	2036-2040	34,644	CIC
Total additional deliverable capacity	CIC	n/a	73,474	CIC
Total excess delivery capacity	n/a	n/a	82,949	n/a

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The scale, location and timing of the first tranche of distribution system upgrades is relatively certain (estimated to be 2028) but requires detailed assessment to finalise the scope for investment. Tranche 1 is relatively cost-effective in terms of cost per megalitre of water.

The type, scale, location, and timing of much of the second tranche of upgrades is uncertain as it ultimately needs to respond to future development and investment decisions of hundreds of irrigators. Tranche 2 is not required until around 2036-2040 and is significantly less cost-effective (i.e., it costs more than ten times that of Tranche 1 upgrades in $/ML terms). This is presented visually in Figure 68 which compares the cost effectiveness for the two tranches of distribution system upgrade.

Figure 67 Cost-effectiveness of distribution system upgrades in present value terms (7% discount rate)*



*Timing based on the more likely demand profile.

Due to the vast difference in cost-effectiveness, the second tranche of distribution system upgrade was assessed in more detail in the CBA through incremental NPVs and BCRs. This determined whether the extension upgrades were likely to provide a positive net benefit on their own.

The selected approach (least lifecycle cost to meet demand requirements) for implementing distribution system upgrades has been applied to each proposal option.

9.4 Benefits in the CBA

There are considerable economic benefits to be derived from water use. The CBA model uses the demand profiles as a basis and applies unit benefit values to the demand volumes depending on how much water each proposal option can supply.

9.4.1 Demand

The demand model developed for the demand assessment, is a major input to the CBA model. It provides the probabilistic volumes of water use for each year that subsequently determines the economic benefits from that water use. The inputs into the demand model feed into the CBA and allow options to be compared on a like-for-like basis (i.e., the options are compared using the same demand scenarios).

Table 65 presents the unconstrained more likely projected demand for 2020 and 2050 in MP equivalent volumes, used in the CBA (i.e., demand that is not constrained by the distribution system constraints). Changes to demand volumes through land use change, are split between greenfield and brownfield developments[12] to align with the differing net margins.

The projected demand volumes (and therefore the benefits) to be supplied by each option was constrained in the CBA model by its delivery capacity and yield.

[12] Note: Brownfield development occurs through a change in land use from one irrigated crop to another. Greenfield development refers to changes in land use from dryland farming to irrigation.

Table 65 Unconstrained more likely projected demand for the CBA (MP equivalent volumes)*

Projected demand profile	2050 projected additional demand (ML)
Land use change and subsequent change in water demand	
Sugar cane	-66,873
Macadamia (greenfield)	16,352
Macadamia (brownfield)	42,049
Avocado (greenfield)	4,911
Avocado (brownfield)	12,627
Other horticulture (greenfield)	13,143
Other horticulture (brownfield)	33,797
Hay and silage (greenfield)	657
Hay and silage (brownfield)	1,689
Other agricultural considerations	
Tree crop maturation (current trees utilising their full requirement)	11,367
Climate change (net impact of changes in rainfall and peak temperatures)	7,864
Interrow watering for tree crops (emerging environmental requirement)	5,174
Urban use	
Urban use	1,596
Total	***84,353***

*It was assumed that 16,500 ML of this projected additional demand would be taken up in the Kolan subscheme.

9.4.2 Benefits – irrigation

The net margins for irrigators have been estimated as farm gate revenues less all relevant capital establishment and operating costs (fixed and variable), discounted over the 30-year evaluation period. This includes the opportunity cost of previous land use when growth in water demand is triggered by a land use change (e.g., sugar to macadamias). Benefits attributable to future water allocation sales would not accrue until the works are fully commissioned and water is available for use.

- For greenfield developments, net margins include the opportunity cost of previous land use (e.g., grazing to macadamias).
- The opportunity cost of sugar was not included in the brownfield net margins as it is accounted for separately in the model using the gross margin of sugar for the Bundaberg region (modelled as the impact of a decline on the area of sugar production).
- The net present values were then converted into $/ML to be applied to the demand volumes in each year.

An example of how net margins were derived for a greenfield macadamia development is provided below.

Net margin example: Macadamia development

Net margins were calculated for a greenfield macadamia development based on the AgBiz Whole Farm Budget (WFB) model for Macadamia (Qld Govt, 2018). Inputs from the WFB model were adjusted to reflect desktop research, consultation, and results from the survey of irrigators undertaken as part of the demand assessment. Where necessary, costs were also indexed to reflect price rises since the date of the data used. The cost inputs to calculate the net margin are shown in Table 66.

Table 66 Greenfield macadamia development net margin model inputs

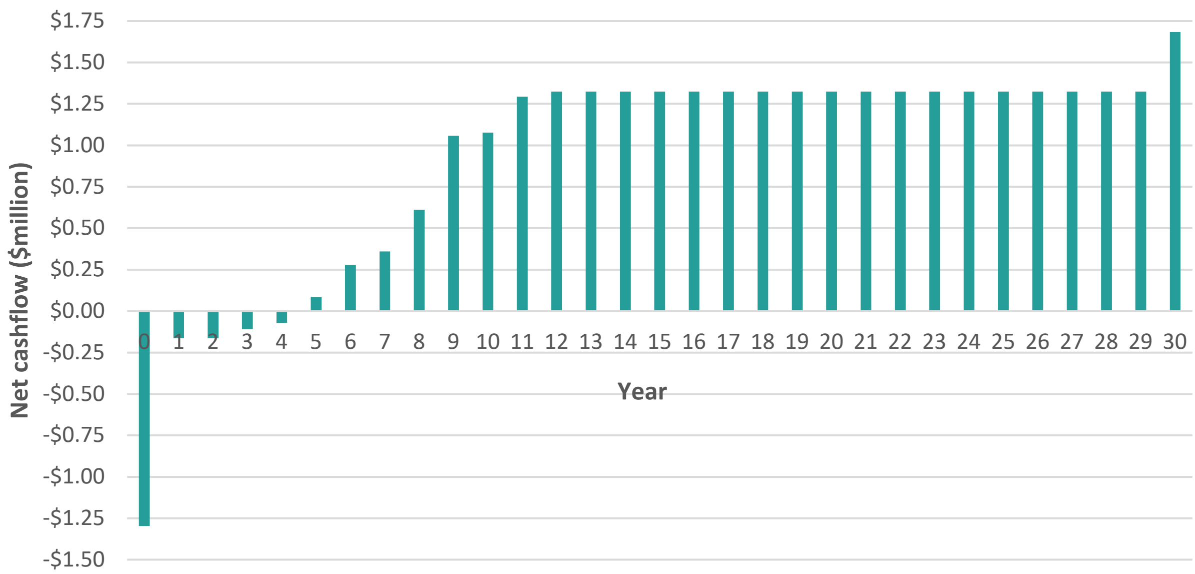
Input	Low	More likely	High	Comment
Capital costs				
Tractors & Vehicles ($/ha)	$1,404	$1,872	$2,340	Taken from AgBiz WFB model and inflation adjusted.
Implements ($/ha)	$1,326	$1,768	$2,210	
Irrigation ($/ha)	$3,463	$4,618	$5,772	
Shed Machinery ($/ha)	$780	$1,040	$1,300	
Buildings & Sheds ($/ha)	$1,365	$1,820	$2,275	
Trees – grafted ($/ha)	$2,340	$3,120	$3,900	
Harvesting Equipment ($/ha)	$140	$187	$234	
Land preparation ($/ha)	$892	$1,190	$1,487	
Water allocation ($/ha)	$4,275	$5,985	$9,500	Based on irrigation requirements and allocation price of $950/ML.
Total ($/ha)	$15,986	$21,599	$29,018	
Fixed costs				
Fixed costs – excl. water charges ($/ha)	$1,658	$2,210	$2,763	From AgBiz WFB model. Includes consideration of labour, administration, fuel, electricity, and maintenance.
Water charges ($/ML)	n/a	52.62	n/a	From Sunwater.
Variable costs at maturity*				
Variable costs – excl. water charges ($/ha)	$1,902	$2,537	$3,171	From AgBiz Macadamia WFB. Includes consideration of machinery operation, mulching, fertiliser, herbicide, insect and disease control, pumping, harvesting and freight costs.
Water charges ($/ML)	n/a	$55.36	n/a	From Sunwater.
Opportunity costs				
Gross margin of grazing ($/ha)	$7.94	$10.58	$13.23	From AgBiz Cattle GM model.
Revenue				
Price ($/tonne)	$5,000	$5,600	$6,200	Marquis prices paid across 2015 to 2020 (https://marquis.com/for-growers-australia/pricing-payments/). Similar prices are reported from SunCoast Gold (https://suncoastgold.com.au/nis-offer/).
Physical parameters				
Farm size (ha)	20	60	100	Based on Macadamia Benchmarking report.
Mature irrigation requirements (ML/ha) *	4.5	6.3	10.0	Survey, consultation, and desktop research.
Mature yield (t/ha)*				Consultation (Macadamia Benchmarking report suggests

Input	Low	More likely	High	Comment
				lower yields but include non-irrigated crops).
Financial parameters				
Discount rate	4%	7%	10%	Aligns with standard practice and BQ guidelines.
Evaluation period		30 years		

*Time profiles were also used to reflect the variation in costs, irrigation requirements, and yields over time.

The inputs were aggregated in each year to calculate the net cashflows over time. Figure 69 presents the estimated cashflows of a 60-hectare greenfield macadamia development using the more likely input values.

Figure 68 Greenfield macadamia development annual net cashflows (undiscounted)



The NPV across the 30-year evaluation period was calculated before dividing by the total water use to determine the NPV per ML used. Table 67 presents the results of this analysis.

Table 67 Net margin results for a 60-hectare greenfield macadamia development

	P10	Central case	P90
NPV ($)	$4,126,039	$7,269,927	$11,799,168
NPV ($/ML)	$458	$717	$1,091

Similar models were established and used for other major crops identified through the demand assessment. Table 68 shows net margins (benefits) for all the major crops.

9.4.3 Benefits – urban and industrial use

Estimates of consumer surplus for general water supply (urban use) are not available. The benefit of urban water supply was instead valued using consumer willingness to pay to avoid severe water restrictions.

Research conducted for water supply services in Canberra revealed a household willingness to pay $215/year to avoid level 4 water restrictions. This value was incorporated into the CBA using a benefit transfer approach by calculating the aggregate of this value across all residential users divided by the aggregate residential use, to estimate a value per ML of water used to avoid level 4 restrictions. This equated to $726/ML. For the purposes of the central case (defined in chapter 3), and in the absence of additional information on the value of consumer surplus, $726/ML has been adopted for each ML used and a range was used across this value ($693/ML to $758/ML).

9.4.4 Benefits – summary

Table 68 presents a summary of the benefit values used for water use in the CBA model including details on each margin the model considers. The benefit values are expressed as $/ML used, enabling benefits to be calculated directly from projected demand and the incorporation of any constraints in supply (attributable to insufficient storage yield and/or constraints in the distribution system).

Table 68 Benefit values used for water use ($/ML used) *

Water use**	Low	Central case	High	Comment
Sugar gross margin	$142	$205	$266	Based on FEATOnline's Bundaberg Scenario.
Macadamia brownfield net margin	$501	$763	$1,141	Net margin model for macadamia developments on former sugar farms. Based on AgBiz Whole Farm Budget model for macadamias with inputs updated for Bundaberg in present day.
Avocado brownfield net margin	$497	$757	$1,131	Net margin model for avocado developments on former sugar farms. Based on AgBiz Whole Farm Budget model for avocados with inputs updated for Bundaberg in present day.
Other horticulture brownfield net margin	$545	$645	$746	Net margin model for horticulture developments on former sugar farms. Based on AgBiz Gross Margin models for tomatoes and sweet potatoes, with inputs updated for Bundaberg in present day. Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Hay and silage brownfield net margin	$-	$46	$93	Net margin model for broadacre developments on former sugar farms. Based on AgBiz gross margin models for lucerne, maize, and sorghum, with inputs updated for Bundaberg in present day. Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Macadamia greenfield net margin	$458	$717	$1,091	Net margin model for macadamia developments on grazing lands. Based on AgBiz Whole Farm Budget model for macadamias with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production.
Avocado greenfield net margin	$416	$651	$991	Net margin model for avocado developments on grazing lands. Based on AgBiz Whole Farm Budget model for avocados with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production.
Other horticulture greenfield net margin	$424	$524	$625	Net margin model for horticulture developments on grazing lands. Based on AgBiz Gross Margin models for tomatoes and sweet potatoes, with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production.

Water use**	Low	Central case	High	Comment
				Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Hay and silage greenfield net margin	$-	$20	$40	Net margin model for broadacre developments on grazing lands. Based on AgBiz gross margin models for lucerne, maize, and sorghum, with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production. Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Urban value (willingness to pay to avoid restrictions)	$693	$726	$758	Based on estimates, adjusted for Bundaberg using urban water use data from Bundaberg Regional Council.
Sunwater allocation value	n/a	$950	n/a	This value is a transfer; however, it is included as a cost in the net margin calculations and therefore is balanced out by the revenue for Sunwater.

Notes: *Some demand profiles show scenarios where additional water use provides no additional benefit (e.g. water use increases to compensate for increased demand attributable due climate change).
**Brownfield net margins do not include the opportunity cost of sugar production as this is accounted for separately in the CBA model using the sugar demand profile and sugar gross margin.

9.5 Summary of CBA results

This section provides a summary of the CBA results based on the central case inputs and parameters.

9.5.1 Overview

As described in Section 9.2, the costs and benefits were used to calculate the NPVs and BCRs for each proposal option and incremental results of interest. Table 69 presents an overview of the core CBA results for each option, including indications as to whether they provide sufficient yield and/or delivery capacity to meet demand. This is based on the central case projected demand.

The BCRs calculated, assuming most likely demand over a thirty (30) year evaluation period, were Proposal Option 1: **0.137**, Proposal Option 2: **0.152**, and Proposal Option 3: **0.092**. The outcomes from the cost benefit analysis were less than 1.0, indicating that all proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.

It is noted that the safety improvements already achieved through the Essential Works are not captured in this economic analysis

Table 69 CBA results

Option	PVC ($million)	PVB ($million)	NPV ($millions)	BCR
Compared to base case (essential works)				
Proposal Option 1	CIC	CIC	CIC	0.137
Proposal Option 2	CIC	CIC	CIC	0.152
Proposal Option 3	CIC	CIC	CIC	0.092
Incremental results of interest				
Proposal Option 2 to 1	CIC	$-	CIC	-
Proposal Option 3 to 2	CIC	$-	CIC	-

Option	PVC ($million)	PVB ($million)	NPV ($millions)	BCR
With / without distribution system upgrades	CIC	CIC	CIC	0.226

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

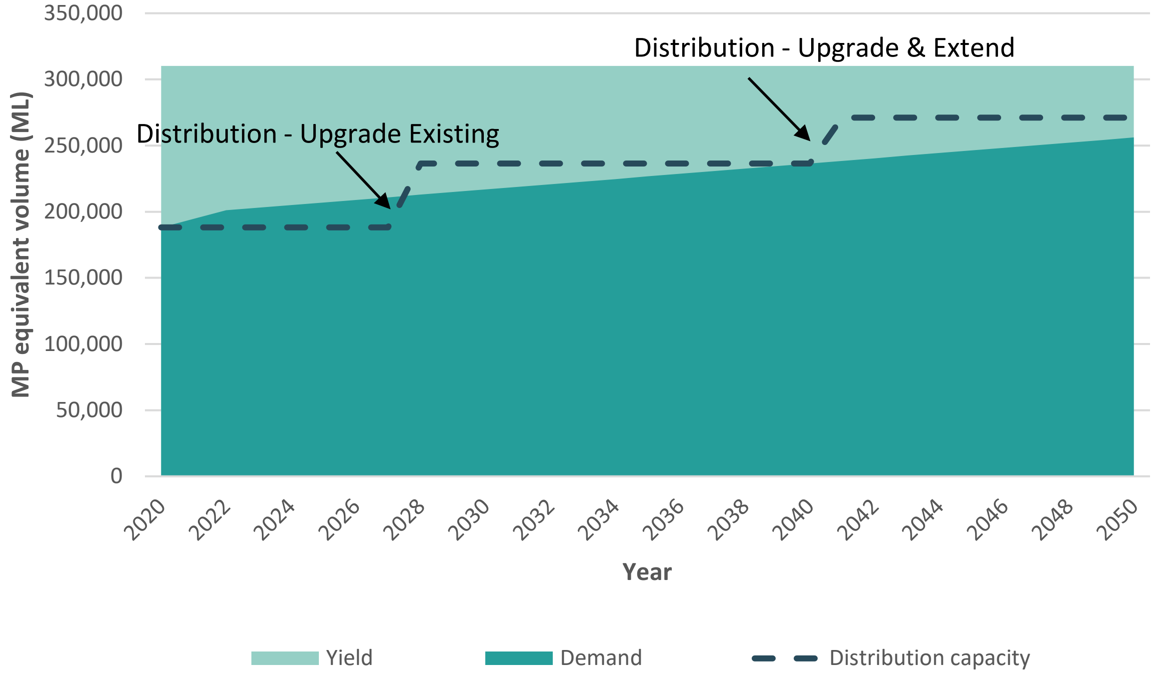
Key points to note from the results are:

- **Each proposal option has the same benefits:** This is because each proposal option is specifically designed to meet projected water demand needs including distribution. Yield beyond that, required by the projected demand, would not provide any economic benefit as it would not be used.
- **Negative NPVs:** All options result in negative NPVs as they include the cost of strengthening the dam wall which far outweighs any benefits derived from water use, particularly as the base case provides a yield equivalent to the 5m lowering (Proposal Option 2). The negative NPV is also influenced by the scope of the CBA, which does not include the benefits (avoided damages) of the dam safety works.
- **Incremental net benefit of distribution system upgrades:** As the second tranche of distribution system upgrades is considerably more expensive per ML of capacity than the first tranche, it does not provide a positive net benefit. The timing, location, and scale of these second tranche upgrades will be dependent on both market conditions (actual growth rates and location of growth) and related Sunwater decision making. With this, there may be an opportunity for Sunwater to have an important influence on land use development patterns through consultation with stakeholders to encourage development in areas of the scheme that still have excess capacity. This could improve the overall cost-benefit outcomes by optimising the timing, and size, of upgrades.

9.5.2 CBA results: Proposal Option 1

The development of Proposal Option 1 provides the greatest deliverable yield from the dam but also requires the greatest upfront investment. Over the evaluation period, the dam provides more than sufficient yield to meet projected demand, however distribution system upgrades must be timed to ensure yield is not constrained by the distribution system capacity. Figure 70 shows the relationship between the deliverable yield and increased delivery capacity due to distribution system upgrades, to meet the central case projected demand.

Figure 69 Deliverable yield and central case demand profiles for Proposal Option 1, showing impacts of distribution system upgrades over time

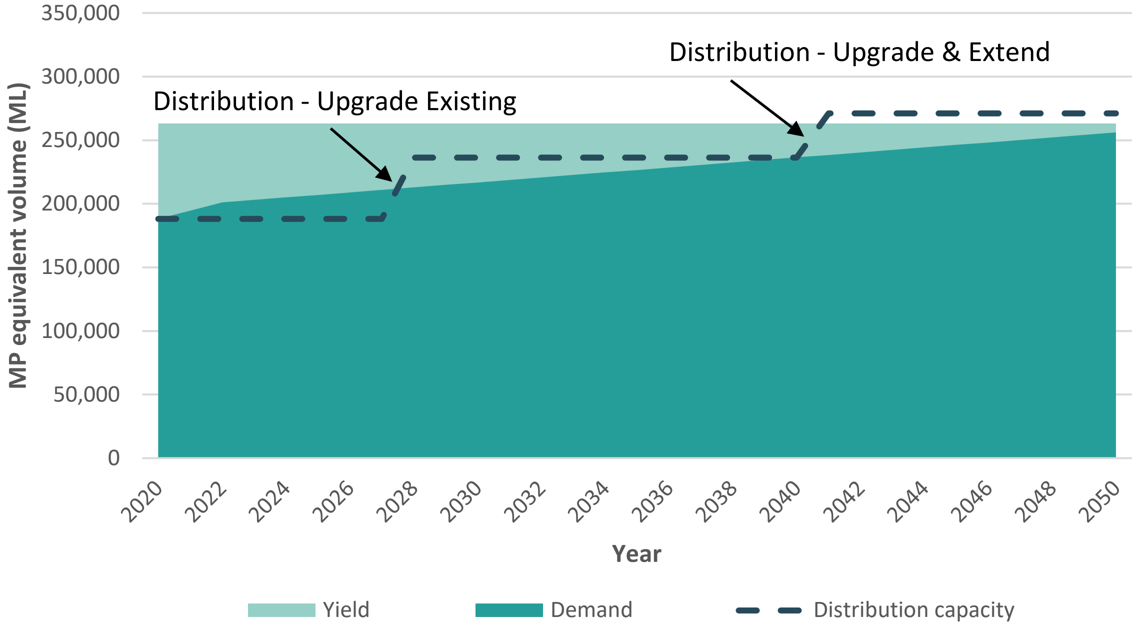


9.5.3 CBA results: Proposal Option 2

Proposal Option 2 is cheaper than Proposal Option 1 and still provides enough yield to meet the central case demand scenario, but not the P90 projected demand. Similar to Proposal Option 1, across the evaluation period the deliverable yield is constrained by the distribution system capacity, with the dam providing sufficient yield to meet projected demand. Figure 71 shows the relationship between the deliverable yield and increased delivery capacity due to distribution system upgrades. Here deliverable yield is constrained by the yield from Dam Option 2 – not the distribution system.

By 2050, the central case projected demand is almost equal to the deliverable yield, meaning that Dam Option 2 provides little opportunity for demand growth beyond 2050 without investment in alternative supply options. Furthermore, it constrains realisation of the higher end of the projected demand (e.g. the P90 projections).

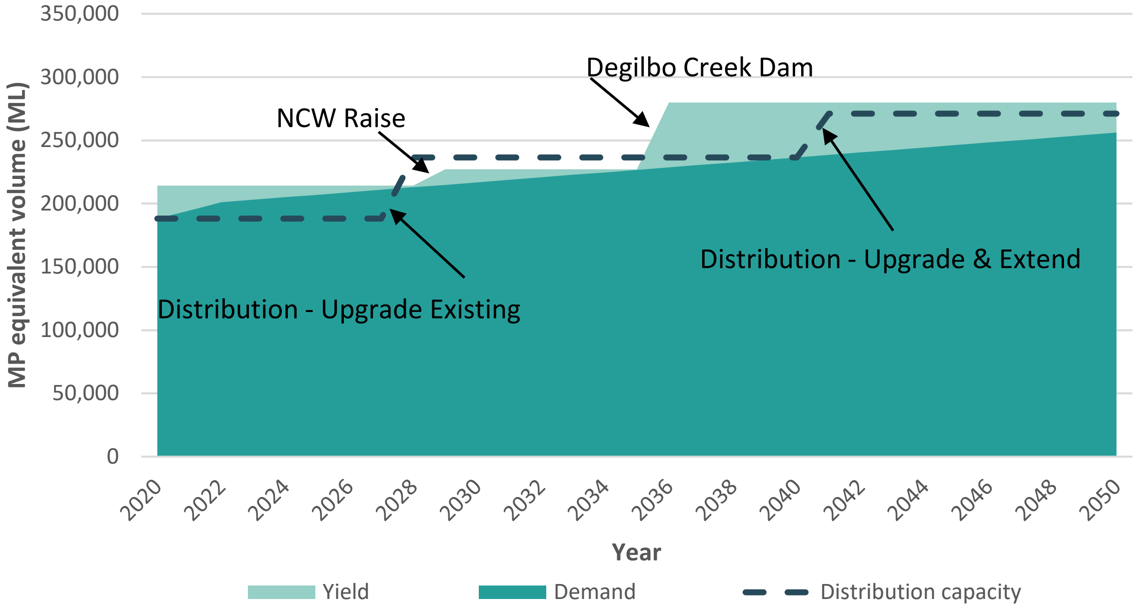
Figure 70 Deliverable yield and central case demand profiles for Proposal Option 2, showing impacts of distribution system upgrades over time



9.5.4 CBA results: Proposal Option 3

Proposal Option 3 is the most expensive of the three options when including alternative supplies and does not provide sufficient yield to meet projected demand on its own. While the distribution system is still the constraining factor initially, yield is the primary constraint from around 2022 until 2036 when Degilbo Creek Dam is commissioned. Figure 51 presents this graphically, with steps up in yield representing additions from the Ned Churchward Weir Raise and Degilbo Creek Dam as well as capacity increases associated with distribution system upgrades. If yield is provided through Degilbo Creek Dam, the second tranche of the distribution system upgrades will also be required.

Figure 71 Deliverable yield and demand profiles for Proposal Option 3, showing impacts of distribution system upgrades over time and alternative supplies



9.6 Sensitivity analysis

Monte Carlo simulations were performed with 50,000 iterations to help understand the variability in the results and the key drivers of that variability.[13] Table 70 presents the detailed summary of the CBA model parameters along with their sources and methods of incorporation into the model.

Data available for model inputs did not allow for a more sophisticated and/or statistically relevant assessment of the distribution for the range of each input variable (e.g. water use per hectare). Rather, the range reflects multiple sources of input data sourced from research and/or consultation. Rarely are these from the same source which would enable a formal distribution to be established.

Table 70 Model parameters sources and methods of incorporation

Model parameter	Low	More likely	High	Source	Incorporation
HP to MP conversion ratio		2.23		Water plan	Used to convert all volumes to MP equivalent.
Land use change trend sugar (ha/annum)	-339	-449	-567	Farmer survey, QLUMP, UNE Tree crop mapping	These parameters are a result of applying the greenfield brownfield ratio to the other land use change values.
Land use change trend macadamia (ha/annum)	259	309	376	Farmer survey, QLUMP, UNE Tree crop mapping	Annual land use change trends applied linearly across the 30-year period.
Land use change trend avocado (ha/annum)	37	74	104	Farmer survey, QLUMP, UNE Tree crop mapping	
Land use change trend seasonal horticulture (ha/annum)	143	179	215	Farmer survey, QLUMP	
Land use change trend seasonal vegetables and herbs (ha/annum)	31	38	46	Farmer survey, QLUMP	
Land use change trend citrus (ha/annum)	-	6	8	Farmer survey, QLUMP, UNE Tree crop mapping	
Land use change trend hay and silage (ha/annum)	-	17	38	Farmer survey, QLUMP	
Irrigation water requirement sugar (ML/ha)	4.0	5.0	6.8	Farmer survey, desktop research, consultation	Irrigation water requirements of each key crop type which is applied to the annual land use change estimates to calculate the change in aggregate water demand.
Irrigation water requirement macadamia (ML/ha)	4.5	6.3	10.0	Farmer survey, desktop research, consultation	
Irrigation water requirement avocado (ML/ha)	7.0	7.9	10.0	Farmer survey, desktop research, consultation	

[13] Low, more likely, and high estimates of inputs were used as the parameters for triangular distributions of each input, which take into account asymmetrically distributed inputs.

Model parameter	Low	More likely	High	Source	Incorporation
Irrigation water requirement seasonal horticulture (ML/ha)	4.5	7.0	9.5	Farmer survey, desktop research, consultation	
Irrigation water requirement seasonal vegetables and herbs (ML/ha)	3.0	7.0	8.0	Farmer survey, desktop research, consultation	
Irrigation water requirement citrus (ML/ha)	6.5	7.0	9.5	Farmer survey, desktop research, consultation	
Irrigation water requirement hay and silage (ML/ha)	2.0	4.6	5.5	Farmer survey, desktop research, consultation	
Estimated average age of macadamia (years)	6	7	8	Farmer survey, consultation	Used to calculate the lagged demand that is expected to occur due to the maturation of tree crops.
Estimated average age of avocado (years)	5	6	7	Farmer survey, consultation	
Estimated average age of citrus (years)	6	7	8	Farmer survey, consultation	
Estimated current area of macadamia (ha)		7,108		UNE Tree crop mapping	Current area of tree crops to which the additional maturation demand is applied based on average age.
Estimated current area of avocado (ha)		2,641		UNE Tree crop mapping	
Estimated current area of citrus (ha)		599		UNE Tree crop mapping	
Annual change in average annual rainfall due to climate change (ML/ha)	-0.05	-0.00	0.06	Queensland Future Climate Datasets	Used to calculate impacts of climate change on irrigation. Annual change in rainfall multiplied by farmer responsiveness and irrigation demand in each year.
Irrigator rainfall responsiveness coefficient (% change in irrigation)	-0.03	-0.04	-0.05	Econometric analysis	
Annual change in average maximum temperature due to climate change (^{0}C)	0.04	0.06	0.08	Queensland Future Climate Datasets	Used to calculate impacts of climate change on irrigation. Annual change in temperature multiplied by farmer responsiveness and irrigation demand in each year.
Irrigator temperature responsiveness coefficient (% change in irrigation)	0.06	0.07	0.07	Econometric analysis	
Irrigation increases for compliance - interrow watering (ML/ha)	0.25	0.50	0.75	Consultation	Multiplied by area of tree crops to determine additional demand for interrow watering. Uncertainty around timing so assumed linearly increasing over the 30-year period.
Irrigated area requiring interrow watering - sum of tree crop areas (ha)		10,348		UNE Tree crop mapping	Starting point for area of tree crops to apply additional interrow watering requirements.

Model parameter	Low	More likely	High	Source	Incorporation
Current urban demand from Paradise Dam (ML of HP)		2,349		Sunwater	Starting point for urban demand.
Population growth rate (% p.a.)	0.36%	0.89%	1.39%	Queensland Government Statistician's Office	Compound annual growth rate applied to urban demand.
Sugar gross margin	$142	$205	$266	FEATOnline, Farmer survey, desktop research, consultation	Based on FEATOnline's Bundaberg Scenario.
Macadamia brownfield net margin	$501	$763	$1,141	AgBiz, Farmer survey, desktop research, consultation	Net margin model for macadamia developments on former sugar farms. Based on AgBiz Whole Farm Budget model for macadamias with inputs updated for Bundaberg in present day.
Avocado brownfield net margin	$497	$757	$1,131	AgBiz, Farmer survey, desktop research, consultation	Net margin model for avocado developments on former sugar farms. Based on AgBiz Whole Farm Budget model for avocados with inputs updated for Bundaberg in present day.
Other horticulture brownfield net margin	$545	$645	$746	AgBiz, Farmer survey, desktop research, consultation	Net margin model for horticulture developments on former sugar farms. Based on AgBiz Gross Margin models for tomatoes and sweet potatoes, with inputs updated for Bundaberg in present day. Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Hay and silage brownfield net margin	$-	$46	$93	AgBiz, Farmer survey, desktop research, consultation	Net margin model for broadacre developments on former sugar farms. Based on AgBiz gross margin models for lucerne, maize, and sorghum, with inputs updated for Bundaberg in present day.

Model parameter	Low	More likely	High	Source	Incorporation
					Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Macadamia greenfield net margin	$458	$717	$1,091		Net margin model for macadamia developments on grazing lands. Based on AgBiz Whole Farm Budget model for macadamias with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production.
Avocado greenfield net margin	$416	$651	$991		Net margin model for avocado developments on grazing lands. Based on AgBiz Whole Farm Budget model for avocados with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production.
Other horticulture greenfield net margin	$424	$524	$625		Net margin model for horticulture developments on grazing lands. Based on AgBiz Gross Margin models for tomatoes and sweet potatoes, with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production. Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Hay and silage greenfield net margin	$-	$20	$40	AgBiz, Farmer survey, desktop	Net margin model for broadacre developments on grazing lands. Based

Model parameter	Low	More likely	High	Source	Incorporation
				research, consultation	on AgBiz gross margin models for lucerne, maize, and sorghum, with inputs updated for Bundaberg in present day. Includes opportunity cost of grazing from AgBiz gross margin model of beef production. Capital and fixed costs were added where necessary to develop the net margin model. It was assumed that these costs would be similar to those for sugar.
Urban value	$693	$726	$758		Adjusted for Bundaberg using urban water use data from Bundaberg Regional Council.
Brownfield proportion of development		72%		Survey	Proportion of crop development that occurs on former sugar cane land. No range was used however this variable was tested using scenario analysis.
Sunwater allocation value		$950		Sunwater	This value is a transfer; however, it is included as a cost in the net margin calculations and therefore is balanced out by the revenue for Sunwater.

The confidence intervals for the proposal options are presented in Table 71. The low (worst) estimates reflect the P10 estimates from the Monte Carlo simulations, while the highest represent the P90 estimates.

Table 71 CBA sensitivity analysis results (confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case (essential works)		
Proposal Option 1	CIC	0.137 (0.112, 0.249)
Proposal Option 2	CIC	0.152 (0.126, 0.209)
Proposal Option 3	CIC	0.092 (0.080, 0.144)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.226 (0.181, 0.392)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

While the NPV of each option remains negative across all simulations, the ranges give insight into the potential preferred options. Key points to note are:

- While the central estimate of NPV for Proposal Option 2 is superior, there is cross-over of the range of NPV estimates for Proposal Option 1 and Proposal Option 2 (due to simulations where costs could be higher). In effect, the modelling does not demonstrably show that Proposal Option 2 is superior.
- Proposal Option 3 consistently performs poorly relative to other options. This is due to the need to invest in Degilbo Creek Dam which is orders of magnitude more expensive than the incremental cost of Paradise Dam works.

Distribution and contribution to variance charts show the variability of the results in more detail. These are presented for the options which meet demand in Figure 73, Figure 74, and Figure 75.

For **Proposal Option 1**, the distribution is relatively normal in shape and the greatest influence on NPV variance is the choice of discount rate, with crop margins, water requirements, and assumed tree ages also contributing small amounts to the variance (refer to Table 70 above for variable ranges).

Figures 73, 74 and 75 have been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Figure 72 Proposal Option 1: Distribution and contribution to NPV variance

For **Proposal Option 2**, the distribution of NPV estimates is more skewed. This is due to the alternative supply options specifically as there are thresholds modelled where they are, or are not, actually needed. For example, with the 5m lowering the high frequencies for NPVs between CIC and CIC represent simulations where demand was low enough that no alternative supply option was needed (and the capital costs of alternative supply options can be avoided).

Figure 73 Proposal Option 2: Distribution and contribution to NPV variance

For **Proposal Option 3**, the distribution of NPV estimates is slightly skewed towards simulations that include Degilbo Creek Dam which is a very expensive source of yield.

Figure 74 Proposal Option 3: Distribution and contribution to NPV variance

The key parameters driving the variability of the results for Proposal Option 2 and Proposal Option 3 were the macadamia and sugar irrigation requirements and the discount rate across the three options (refer to Table 70 above for variable ranges). This is due to the irrigation requirements determining the timing of required augmentations, and the discount rate determining the marginal cost or benefit of moving costs forward or backward in time. In simpler terms, the timing of the considerable costs of alternative supply options and distribution system upgrades was an important factor.

9.7 Scenario analysis

Scenario analysis is an important component for any sensitivity analysis process and enables the examination of drivers, constraints and other areas of uncertainty that impact on the analysis.

9.7.1 Overview

A range of scenarios, selected in consultation with key project stakeholders, were analysed to investigate the impact of alternative futures and different combinations of inputs on the outcomes of the options evaluation. The scenarios considered included:

- A staged approach to Proposal Option 1 based on timing the construction works to ensure yields meet projected demands (i.e. yield equivalent to Proposal Option 2 immediately, with an augmentation to the former FSL to meet future demand).
- The potential impact of climate change on yields from Paradise Dam.
- Accelerated tree crop growth. This reflects feedback from the horticulture sector that development is likely to occur in the earlier part of the 30-year evaluation period if deliverable water supply is available.
- Extended dam fill period which delays the realisation of benefits (two years is assumed).
- Changes in the ratio of greenfield to brownfield development. This reflects uncertainty in the potential pattern of changes on land use over such a long period.
- Extending the evaluation period to 40 years to consider longer-term demand requirements.

An overview of the results and implications for each of these scenarios is set out in the following sections. This includes an explanation of the basis for each scenario, the changes in the physical attributes (e.g., impact on dam yield), and the subsequent NPV of each option.

9.7.2 A staged Proposal Option 1

Proposal Option 1 involves returning Paradise Dam back to FSL; however, the yield from this raising is not required immediately. A common approach to dam development is to undertake a staged approach. This would involve a modified approach to Dam Option 1 (i.e. providing a yield equivalent to Option 2 immediately, with an augmentation to the former FSL to meet future demand). This would essentially result in the deferred raising being used in place of alternative supplies.

Future raising works would need to be fully commissioned by 2042, based on probabilistic demand modelling, to provide the same level of resilience as Proposal Option 1 (which can provide the P90 projected demand out to 2050). While detailed costs for this scenario have not been developed, the incremental cost of future raising works would need to be less than CIC (undiscounted), or CIC in present value terms (using a 7% real discount rate), to provide the same or better net present value outcomes as Proposal Option 1. Initial analysis suggests this is unlikely.

It should be noted that no detailed technical feasibility analysis, design, costing, or economic analysis has been undertaken for a staged approach to Dam Option 1. However, while it may be technically feasible to stage the works between Option 1 and 2, there are issues associated with this, as well as cost inefficiencies, based on a preliminary analysis as follows.

As the primary spillway increases in height, the width of primary spillway buttress also thickens (which comprises the majority of the scope and cost difference between Dam Option 1 and 2). If thickening of the downstream face were to be undertaken in two stages this would introduce another plane of weakness into the dam (more so than with a single stage buttress solution).

Significant inefficiency in concrete placement would occur if delivered in two stages, as a large proportion of cost is associated with placement and relocation of formwork, surface preparation and curing activities. The increased width of the pour and additional concrete volume is of relatively smaller cost, for which a concrete batch plant will already be required and established for other common works for the first stage improvement scope (including the secondary spillway works and apron extension). Other efficiencies and shared support costs will apply for a single stage project, that would result in significant additional costs for a second stage project, including temporary works, access, accommodation camp, mobilisation, and other related indirect costs.

If the intention were to stage the primary spillway raise, it is more likely that the first stage would construct the buttress of sufficient width to accommodate a future raise (minimising technical issues) and defer only the spillway raising scope (which is more favourable to deferment). The raising scope only represents approximately 10% of this. Similar arguments as above would apply to inefficiencies associated with staging these works.

A different design option for a staged approach was previously investigated. This was for mechanical gates installed along the 315m spillway width, including 5m heigh flap gates, or alternatively fuse gates. This was discounted very early given the significant capital cost requirement associated with gates for this configuration, and ongoing operational costs, compared to the preferred passive concrete raise design.

A staged approach for Proposal Option 1 is therefore not recommended.

9.7.3 Climate change

Climate change was identified in the survey undertaken as part of the demand assessment, as being an important consideration in investment decision making by over 60% of respondents.

There is acknowledgement across academia, industry and governments that climate change will have an environmental impact in the future. This impact may affect the performance of Paradise Dam throughout the evaluation period, including impacts on demand as well as system yield. The nature of this impact has been estimated through climate change modelling, which is a developing field that indicates potential negative and positive impacts through changes to rainfall, runoff and evapotranspiration[14]. Due to the developing nature of the field, its outputs should be treated with caution.

An initial hydrological assessment using eleven Australian and international Global Circulation Models were identified as most relevant to analysing climate change impacts on system yield for this region. This was done to assess potential impact on supply reliability. The results from this were used to select six climate change models to further analyse potential impact on yield, considering a representative range of models and outputs, and excluding the two extreme models (positive and negative). All models adopted the RCP 8.5 greenhouse gas emission scenario, as recommended by the peer reviewer and Government agency representatives for climate change, to assess potential impacts by 2050.

Using the six different climate models, the hydrological assessment focused on maintaining current reliability for both Dam Options 1 and 2.[15] Table 72 presents the results from the assessment, showing considerable variation in results across the different climate models with both positive and negative outcomes. Of the six models used to analyse impacts, two models indicated a potential moderate increase in yield. Conversely however, four models indicated that yields are likely to decrease, and three significantly so. This was representative of the initial modelling outcomes, with eight of the eleven models indicating a negative impact on supply reliability by 2050, and several significantly so.

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[14] Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

[15] Yields under climate change were not estimated for Dam Option 3 or the alternative supply options. This is because, even in the absence of climate change, Dam Option 3 could not meet demand requirements.

Table 72 Climate change effects on yields (ML) at the Burnett sub-scheme level*

Option	Initial yield	Min yield in 2050	Average yield in 2050	Max yield in 2050
At the dam				
Dam Option 1	168,600	8,600	128,600	220,600
Dam Option 2	121,600	-31,400	82,100	147,600
Burnett River subscheme				
Dam Option 1	310,180	150,180	270,180	362,180
Dam Option 2	263,180	110,180	223,680	289,180

*Minimum, maximum, and average values across the 6 climate models considered in the hydrological assessment.

While the data on climate change yields is only provided at two different points in time, the path of climate change effects across time is likely to be non-linear. This can be better understood by using forecasts of 'radiative forcing' levels in 2020, 2030, 2040, and 2050 as a proxy for the path of climate impacts across time. This results in a slope increasing in magnitude across the 30-year evaluation period (i.e., climate change impacts on yield were very slightly concentrated towards the later years of the evaluation period). Based on that analysis, the non-linearity of climate change impacts emerging will not have a material impact on the timing of infrastructure augmentations.

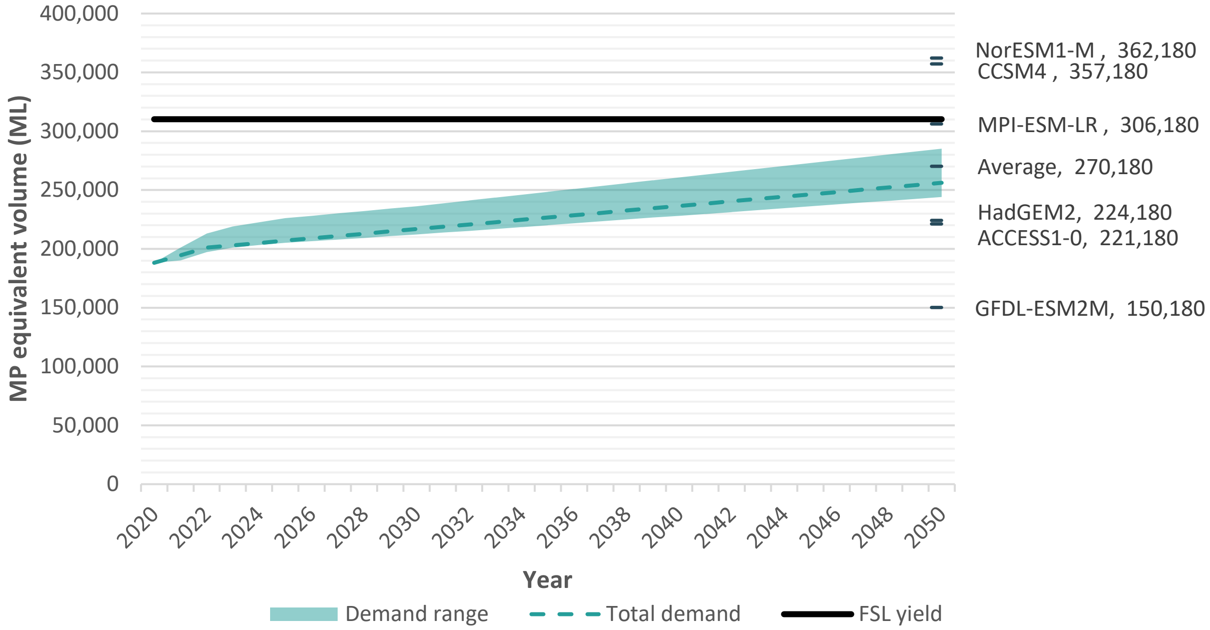
Climate scenarios were modelled using IQQM to assess the potential impacts on yields. The results of this modelling and the demand modelling are plotted together in Figure 76 and Figure 77 for Proposal Options 1 and 2 respectively.

For Proposal Option 1:

- Four of the six scenarios modelled indicate a decline in yield while maintaining current allocation reliability.
- Three of the six scenarios modelled are lower than the more likely projected demand.

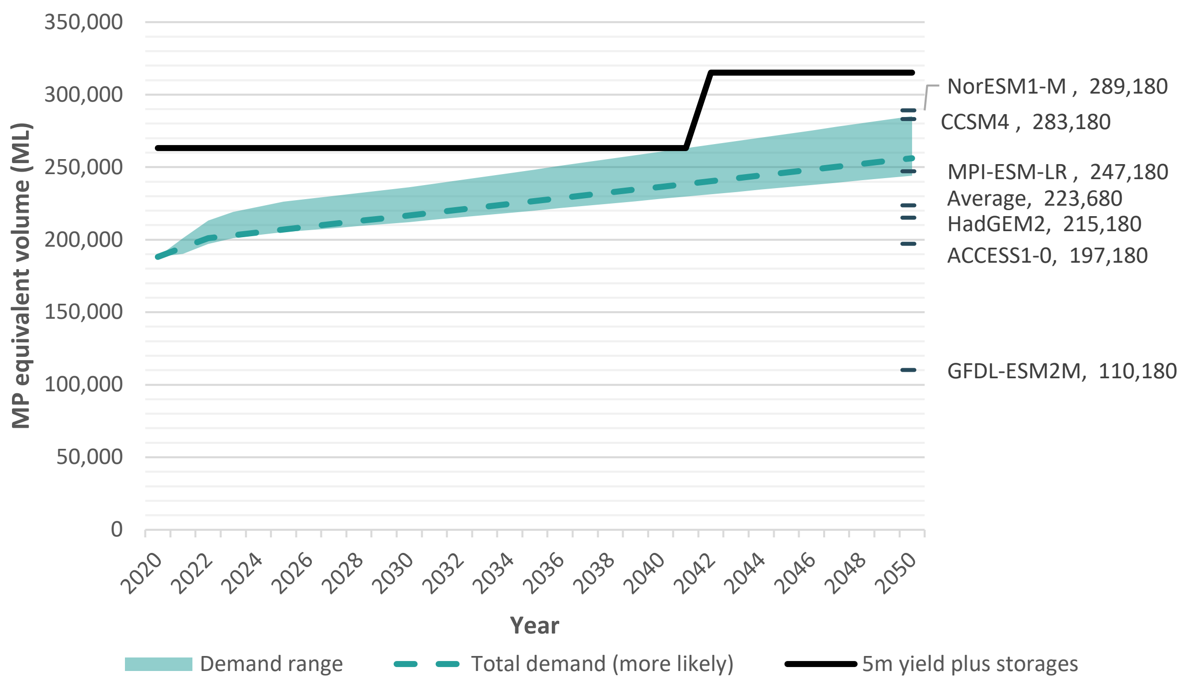
Given the concerns of irrigators raised during the demand assessment consultation focused on downside risks, it is reasonable to assume risks to current investments are of more concern than a foregone opportunity (i.e., respondents are more concerned about reductions in reliability to allocation already held, than the possibility that reliability might improve in the future).

Figure 75 Proposal Option 1: Climate change effects on yield compared to demand (80% confidence intervals shown)



The climate impacts are more profound for Proposal Option 2, where a significant proportion of the projected demand exceeds the yield of the dam even without any climate change impacts. Under these climate change scenarios, only two of the climate scenarios would provide enough yield to even meet the more likely projected demand, while no scenarios could meet the higher end of the projected demand. This significantly increases the likelihood that a large alternative supply option would be required to meet demand in the long term, and that Degilbo Creek Dam is the most likely (and very expensive) option.

Figure 76 Proposal Option 2: Climate change effects on yield compared to demand (80% confidence intervals shown)



It should be noted that the low yield scenarios are likely to be correlated with high demand scenarios. More specifically, if climate change results in lower rainfall and greater evapotranspiration, the yield is likely to decline but irrigation demand is likely to increase. The full CBA model was run with consideration of these climate change impacts on yield. Table 73 presents the results of this scenario, under which there is much greater variability than that of the central case.

Table 73 CBA results with climate change effects on yield (80% confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.137 (0.109, 0.238)
Proposal Option 2	CIC	0.112 (0.087, 0.180)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.226 (0.112, 0.354)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The results show that when climate change impacts are considered, Proposal Option 1 performs well due to its greater capacity to absorb those impacts. Under most climate change scenarios, Proposal Option 2 would require alternative supply to meet demand, significantly increasing cost. This results in Proposal Option 1 delivering greater net benefits across the entire 80% confidence interval.

The Benefit Cost Ratios calculated for this scenario, assuming most likely demand over a thirty (30) year evaluation period, were Proposal Option 1: **0.137** (no change), and Proposal Option 2: **0.112** (reduced from 0.152 assuming no climate change impact). The outcomes from the cost benefit analysis were less than 1.0, indicating that both proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.

9.7.4 Changes in tree crop growth rates

There may be scenarios where the growth rates of tree crop industries are greater or less than the growth modelled in the demand assessment. For example, consultation with the horticulture sector since the projected demands were finalised, indicated an expectation that short-term growth would be faster than the average rate assumed.

The tree crop growth rate scenarios were modelled in the CBA in two different ways:

1. Concentrating the transition to tree crops in the earlier half of the evaluation period
2. Testing higher and lower tree crop growth rates across the entire evaluation period, using a constant rate of growth.

In the **first scenario**, the transition to tree crops was concentrated in the earlier half of the evaluation period (i.e., a doubled growth rate in the first 15 years with no additional growth in the second 15 years). This approach does not result in greater demand in 2050 but affects the timing of investments into the distribution system and delivery of alternative supply options. The results of this scenario are presented in Table 74, with key findings being:

- distribution system upgrades are required earlier
- Proposal Option 3 alternative supply option was required earlier.
- for the central case projected demand profile, the impact on the overall NPV on Proposal Option 1 and Proposal Option 2 was similar, but Proposal Option 3 performed relatively worse

- when assessing a range of probabilistic demand profiles from the demand assessment, Proposal Option 1 performs even better, as for many Proposal Option 2 scenarios, the alternative supply options are required earlier in the evaluation period

The BCR improves compared to the central case (Table 10) for Proposal Option 2 as the development of higher value crops is faster (partially offset by reduction in areas of lower value crops), while the capital costs are lower than Proposal Option 1. This scenario results in the difference in NPVs for Proposal Options 1 and 2 increasing slightly.

Table 74 CBA results with tree crop growth concentrated in first 15 years (80% confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.208 (0.155, 0.311)
Proposal Option 2	CIC	0.214 (0.156, 0.239)
Proposal Option 3	CIC	0.119 (0.088, 0.180)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.268 (0.194, 0.441)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

In the **second scenario**, the tree crop growth rates were tested with higher and lower values across the entire evaluation period, with a constant growth rate applied. A growth rate range of 50% either side of the rates used for the central case was used to cover a wide selection of scenarios. The results of the 50% higher and 50% lower tree crop growth scenarios are presented in Table 75 and Table 76 respectively.

The results showed that a higher growth rate of tree crop development results in higher demand. This means that alternative supply and distribution system upgrades would be required earlier and there will be more benefits to be realised in early years of the evaluation period. Under this scenario, Proposal Option 1 performed relatively better, while Proposal Option 2 performed relatively worse.

For the lower tree crop growth rate, the opposite was true, with the smaller supply (Proposal Option 2) performing relatively well. Overall, these scenarios do not provide sufficient evidence to suggest that the preferred option would change based on the modelled changes to the rate of tree crop development.

Table 75 CBA results with 50% higher tree crop growth rates (80% confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.200 (0.160, 0.337)
Proposal Option 2	CIC	0.180 (0.165, 0.256)
Proposal Option 3	CIC	0.120 (0.102, 0.193)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.385 (0.272, 0.620)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 76 CBA results with 50% lower tree crop growth rates (80% confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.097 (0.081, 0.177)
Proposal Option 2	CIC	0.110 (0.092, 0.184)
Proposal Option 3	CIC	0.074 (0.068, 0.106)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.164 (0.000, 0.257)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

9.7.5 Extended dam fill period

There is the potential for a drought to occur during the period in which the dam is expected to fill. This scenario will mean the yield may remain relatively low for an additional couple of years, regardless of the dam height option. This would delay the benefits of water use by two years.

The benefit delay changes the net benefits slightly, however this affects all options in the same way. As a result, it has no implication for which option may be preferred to take forward to the DBC.

9.7.6 Greenfield versus brownfield development

The CBA model has assumed 28% of new tree crop developments are on greenfield sites (e.g., former grazing country) compared to brownfield sites (e.g., former sugar cane farms). This proportion was based on land use mapping and survey results and affects both the net irrigation requirements and the net margins of water use. As a result, it is important to consider scenarios with different ratios of greenfield to brownfield development. This was tested using greenfield ratios of 42% (high) and 14% (low), representing +/- 50% from the assumed 28% used in the CBA. The results of the high and low greenfield development ratios are presented in Table 77 and Table 78 respectively.

The high scenario (more tree crop development on greenfield sites), resulted in higher net demand. This means alternative supply options and distribution system upgrades would be required earlier and more benefits would be realised earlier in the evaluation period. This results in Proposal Option 1 performing relatively better than Proposal Option 2 (Table 775).

For the low scenario (less tree crop development on greenfield sites), the opposite is true, although the range of results is still skewed towards a preference for Proposal Option 1 (i.e., the high end of the NPV and BCR range is better).

Table 77 CBA results with 50% higher greenfield ratio (80% confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.151 (0.127, 0.260)
Proposal Option 2	CIC	0.141 (0.132, 0.204)
Proposal Option 3	CIC	0.095 (0.082, 0.149)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)

Option	NPV ($millions)	BCR
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.256 (0.210, 0.419)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Table 78 CBA results with 50% lower greenfield ratio (80% confidence intervals in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.120 (0.092, 0.237)
Proposal Option 2	CIC	0.136 (0.105, 0.221)
Proposal Option 3	CIC	0.088 (0.080, 0.139)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.177 (0.000, 0.377)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

9.7.7 Extending the analysis to 40 years

It is common practice to test the impact of using longer evaluation periods to evaluate the CBA. In this case, the projected demands were assumed to continue with the same growth rates out to 2060, and the CBA was evaluated with a 40-year evaluation period. The results of this analysis are presented in Table 79. The longer period captures more of the costs associated with alternative supply options for Proposal Option 2, which would require additional yield by 2054 (Ned Churchward Weir Raise), and again in 2058 (Degilbo Creek Dam). Therefore, this scenario also results in a greater preference for Proposal Option 1.

Table 79 CBA results with 40-year evaluation period and continued demand growth (80% confidence interval in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.186 (0.149, 0.330)
Proposal Option 2	CIC	0.183 (0.161, 0.272)
Proposal Option 3	CIC	0.125 (0.105, 0.192)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.009)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.454 (0.343, 0.633)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The bottom line from this analysis is that where the length of the evaluation period is extended, even by only 10 years, Proposal Option 1 becomes the superior option.

The assumption of continued demand growth may not necessarily be an accurate representation of longer-term demand however, with issues such as market saturation resulting in a tapering-off of demand. To test this assumption, a version of the CBA model was run with demand increases related to crop development flatlining post 2050. This leaves only incremental increases in crop irrigation demand due to climate change and incremental increases in urban demand due to population growth, resulting in annual demand increases of approximately 450 ML rather than 2,750 ML (MP equivalent volumes). Figure 78 presents the demand profiles using these reduced growth rates.

Figure 77. Demand profile with reduced growth rates post 2050

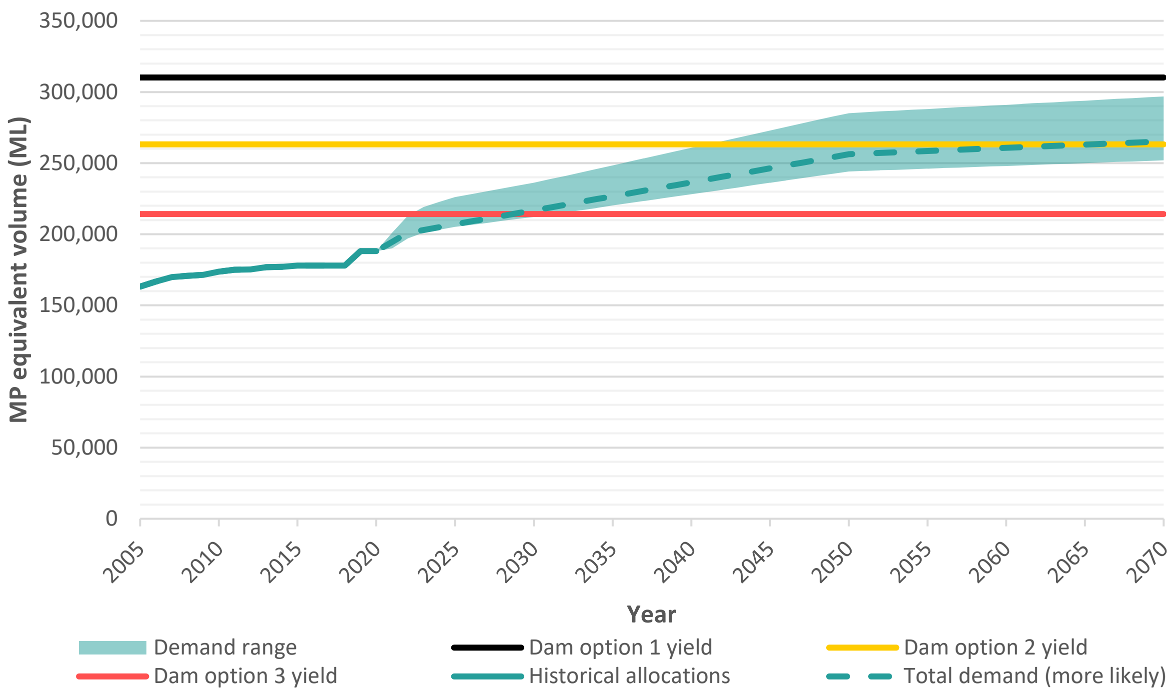


Table 80 presents the CBA results using this reduced demand and a 40-year evaluation period.

Table 80 CBA results with 40-year evaluation period and tapered demand growth (80% confidence interval in parentheses)

Option	NPV ($millions)	BCR
Compared to base case		
Proposal Option 1	CIC	0.170 (0.136, 0.308)
Proposal Option 2	CIC	0.189 (0.152, 0.256)
Proposal Option 3	CIC	0.115 (0.097, 0.180)
Incremental results of interest		
Proposal Option 2 to 1	CIC	0.000 (0.000, 0.000)
Proposal Option 3 to 2	CIC	0.000 (0.000, 0.000)
With versus without distribution system extension	CIC	0.310 (0.228, 0.538)

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

It is key to note that despite this reduced demand growth, the yield of Proposal Option 2 is still exceeded in 2066 based on the more likely projection, which would require the commencement of construction of an alternative supply option in 2059.

9.7.8 Key findings from sensitivity analysis and scenario analysis

The high-level results of the CBA presented in Section 9.5.1 are based entirely on the central case for demand and the central values for all input parameters. In addition, the analysis is based on a 30-year period only. That analysis found that Option 2 was marginally superior based in the NVP.

The sensitivity analysis and scenario analysis has tested the robustness of the findings outlined in Section 9.5.1. The key points to note are:

- The sensitivity analysis found that the differences in NPV between Options 1 and 2 are negligible, with significant cross-over of the ranges of NPV. The NPV estimates are highly unlikely to be statistically different. In effect, relying on the central case analysis outlined in Section 9.5.1 only could lead to poorly informed decision-making.
- The sensitivity analysis found that where demand is materially higher than the central projected demand (as irrigators have constantly stated), alternative supplies may be required to complement Option 2. Where this is the case, Option 1 would become superior.
- The scenario analysis of the potential impacts of climate change on storage yields found, for the bulk of the climate scenarios, yields would decline. Even assuming the central demand case and a 30-year evaluation period, there would be a need of alternative supplies to complement Option 2. Where this occurs, Option 1 becomes superior.
- The scenario analysis found that, even under the central demand case, small extensions of the evaluation period (beyond 30 years) indicate that Option 1 is superior. This finding holds even when the rate of growth in demand declined significantly in the long-term. Given the fact that the economic life of the asset is around 100 years, this would indicate that Option 1 is superior.

In summary, the sensitivity and scenario analysis found that the superiority of Option 2 indicated by the central case analysis is questionable. And any demand materially above the central case, or most climate change scenarios, or any extension of the assessment beyond 30 years, all indicate that Option 1 is more likely to be superior.

10 OTHER CONSIDERATIONS

10.1 Purpose

The purpose of this chapter is to provide a high-level overview of the range of additional matters that need to be considered to deliver the proposal options (refer Chapter 7) including:

- Evaluation of environmental and social impacts (i.e. the secondary service needs outlined in Chapter 2) through SWOT analysis as part of the Options Evaluation approach outlined in Chapter 4
- Public policy matters, covering water allocation approaches, alternative water products with different reliabilities, industry assessments for sugar and flood risk incremental value assessments
- Approvals processes, covering State and Commonwealth approvals processes, Native Title, environmental impact assessment requirements and other planning/development approvals likely to be required to facilitate project delivery.

10.2 Approach to assessing secondary service needs

10.2.1 Background

The Paradise Dam Options Assessment Report from February 2020 provided a preliminary analysis only of environmental and social impacts for the three dam options. This was completed at high-level through a desktop review of existing site investigation material. The analysis identified there would likely be some level of environmental and social impact associated with delivery of those options. Environmental and social impacts are identified as secondary service needs as outlined in section 2.3.

Recent work has expanded on the previous preliminary analysis, with further consideration of these secondary service needs as they relate to each proposal option. The analysis was undertaken through the following process:

- A further desktop review of historical project impact assessment material, this time considering not only the dam options individually but inclusive of potential alternative supply options.
- Review of findings from more recent site investigations to confirm existing environmental and social values were considered and incorporated to the analysis.
- A strengths, weaknesses, opportunities, and threats (SWOT) analysis for each proposal option, comparing it to the base case (as defined in chapter 3).
- Assessment of the likely timeframe of impacts (i.e., short- or long-term) was considered to assist identifying optimal timing of any interventions needed to manage/mitigate impacts and to flag whether issues are driven by internal or external origins.
- Impacts typically associated with a project the size and scope of the PDIP were also considered more generally, based on the current, high-level understanding of the project delivery and construction methodology.

10.2.2 SWOT analysis approach

Environmental and social impacts attributable to each of the proposal options were assessed at high level through a SWOT analysis. These impacts were defined as secondary service needs for PDIP and if material, may impact the assessment of which option/s should be progressed to the Stage 2 DBC.

The SWOT analysis considers what the potential strengths, weaknesses, opportunities, and threats associated with a project or proposal are. The analysis focuses on identifying any internal or external factors that might affect the project/proposal and each of the four factors considered, aims to evaluate the balance between internal benefits of the project and external possibilities or threats.

For the each of the SWOT analyses, the three proposal options have been assessed against the base case.

It should also be noted that, as demand increases over time, all options will require the staged upgrade of the existing distribution system. However, for the purposes of the environmental and social impact analyses, these future works have been considered as broadly similar and therefore, no assessment of the impact of these works has been conducted as all proposal options are equal in this regard.

10.2.3 Climate change

Climate change is likely to have a pervasive effect across the project area/s. This will lead to impacts on the natural environment, economic performance, social behaviour, infrastructure, and other aspects of human existence. For these reasons, integrating appropriate responses to potential climate change impacts on environmental and social factors is a critical consideration across all proposal options.

To date, detailed climate change impact assessments on environmental assets such as riparian habitat, water flow and species impacts, as well as social behaviour, have not been undertaken as part of this OE. The climate change modelling for other parts of the OE has determined additional alternative supply options to supplement yield under Proposal Options 2 and 3 (and the associated environmental and social impacts), will be required sooner rather than later.

Within this context therefore, the SWOT analyses below provide only a high-level assessment of the impact of each of the proposal options on surrounding environmental and social values specific to each location and remain silent on identification of specific climate change impacts. Instead, the analyses are focused on highlighting the relative advantages and disadvantages of each of the three options without further reference to specific climate change impacts.

10.3 Environmental impacts

10.3.1 Overview

Each of the three proposal options have several common environmental elements which are different from the base case:

- replacement of the existing stepped spillway with a smooth buttress to the full downstream face of the dam, and construction of a new, elongated stilling basin located downstream – both providing positive outcomes for aquatic fauna transfer, including fish and turtles
- potential to impact two Matters of National Environmental Significance (MNES) as listed under the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) which are:
    - White Throated Snapping Turtle (WTST) (Elseya albagula)
    - Australian Lungfish (Neoceratodus forsterii)
- increased risk associated with dewatering and lowering of the lake levels for construction
- majority of the dam works are being undertaken in already extensively modified environments (brownfield sites), and as a result many environmental assets and ecosystem functions have adapted to the changed storage and altered river flow regimes.

For more information in relation to areas where there likely to be significant differences in the level of environmental impact between the three proposal options, refer to Table 84 in section 10.3.5.

10.3.2 Proposal Option 1 findings

Proposal Option 1 appears to provide superior environmental outcomes when compared to the base case (refer Table 81). The key characteristics of Proposal Option 1 provide substantial environmental benefit as it involves the reinstatement of all aspects of the original dam while not requiring any alternative supply options to supplement supply. This means that habitat values will most likely revert to those in-situ prior to commencement of the base case construction activities. The long-term effects of implementing Proposal Option 1 will see a return to the system previously assessed and approved, negating the need to undertake extensive additional impact assessment, or seeking any new environmental approvals to address project-initiated environmental change.

Table 81 Environmental SWOT Analysis – Proposal Option 1

	Positive / helpful	Negative / harmful
Current / Internal origin	Strengths • Generally compliant with existing environment approvals – with works likely to require only minor variation. • Introduction of a smooth, buttressed spillway is beneficial to aquatic fauna transfer • Reinstatement of historic (i.e., pre–base case) environmental values	Weaknesses • This option requires placement of a large volume of concrete, with associated environmental issues arising from a large quantity of raw material and energy requirements for production • Additional State level approvals processes required relative to anticipated construction activities.
Future / External origin	Opportunities • The spillway height will result in fewer overtopping events than the base case – resulting in greater control of the downstream flow regime and river levels and fewer impacts on turtle nesting sites.	Threats • No obvious environmental threats

Source: Sunwater

10.3.3 Proposal Option 2 findings

Proposal Option 2 (refer Table 82) minimises the impact of the dam on aquatic species, including the identified MNES, compared to the previous arrangements at the dam (pre-base case) due to the smaller capacity and greater frequency of overtopping events producing a flood regime more analogous to natural, pre-dam conditions. However, this is negatively offset by, for example, having less ability to manage the downstream flow regime and river levels to enhance turtle nesting.

As the normal operating water level of the dam for this option is less than the original Paradise Dam, it will result in the return of some of the upstream lakeside habitat to riverine habitat. Reverting of this habitat to that which was present naturally prior to the dam being built is considered a positive outcome for the upstream environment, maximising ecological benefits.

When compared to the base case, the environmental impact of Proposal Option 2 is similar in many ways particularly regarding the upstream lake margins and the partial return of lakeside habitat to riverine characteristics. The added environmental benefit of the smooth, buttressed spillway and the extended stilling basin would also be realise under this option.

On the other hand, Proposal Option 2 also requires the raising of Ned Churchward Weir (approximately 25 km downstream from the dam) and this will result in the expected loss of riverine habitat, including nesting banks for the critically endangered WTST and spawning habitat for the vulnerable Australian Lungfish.

Under this option, extensive consultation with environmental regulators will need to be undertaken at both State and Commonwealth Government levels to address the long-term impact management requirements for the permanent implementation of the lowered spillway. At the Commonwealth Government level, it is likely that this option will require a referral for a 'controlled action' under Part 8 of the EPBC Act. This referral would be required as the dam option works represent changed conditions from the original environmental approvals granted for Paradise Dam. This may put at risk the construction commencement dates due to requirements for several statutory timeframes to be complied with as part of the approval process. Similarly, an impact assessment process and new environmental approvals will be required from both levels of government before works associated with the raising of Ned Churchward Weir could commence. In particular, due consideration will be required to be given to the two threatened species listed under both state and commonwealth legislation.

Table 82 Environmental SWOT Analysis – Proposal Option 2

	Positive / helpful	Negative / harmful

Current / Internal origin	Strengths
	• Introduction of a smooth, buttressed spillway and extended stilling basin at the dam is beneficial to aquatic fauna transfer
	• Partial return to pre-development flow regime
	• Return of some areas of lacustrine habitat to riverine habitat upstream of the dam
		Weaknesses
		• All works likely to require new/additional State and Commonwealth government environmental approvals leading to potential delay in commencement of project works pending project approval.
		• Proposal Option 2 overall project footprint includes multiple impact sites – i.e., dam and weir
		• Paradise Dam:
		  o requires placement of a large volume of concrete (though less than Dam Option 1) with associated environmental impacts arising from a large quantity of raw material and energy requirements for production (compared to base case)
		• Ned Churchward Weir Raise:
		  o Results in loss of riverine habitat, causing inundation of nesting banks for WTST and spawning habitat for the Lungfish
		  o Alteration and/or loss of existing riparian ecosystem balance
		  o Increased height of the waterway barrier will act as an additional hinderance to aquatic fauna passage

Future / External origin	Opportunities • No obvious environmental opportunities associated with Proposal Option 2	Threats • No obvious environmental threats associated with Proposal Option 2

Source: Sunwater

10.3.4 Proposal Option 3 findings

Findings from the assessment of Proposal Option 3 (refer Table 83) mirror those associated with Proposal Option 2 in terms of impacts and benefits associated with implementation of a lowered and smoothened spillway and an extended stilling basin.

Likewise, and for the same reasons as Proposal Option 2 and the base case, it is likely that this option will require consultation and referral to both State and Commonwealth environmental regulators, seeking approval of planned impact management and/or mitigation measures before the works can proceed.

The greatest point of difference associated with Proposal Option 3 is the requirement for two alternative supply options (i.e., raising of Ned Churchward Weir and construction of the new Degilbo Creek Dam), both involving impacts on greenfield sites – either wholly or to some degree – and as a result, requiring more intensive impact assessment due to each of them occurring or impacting upon previously undisturbed natural environment. The requirement to undertake these additional environmental approval processes (including the preparation of at least one Environmental Impact Statement) will introduce significant environmental approval risk to this suite of options when considered in their entirety.

Table 83 Environmental SWOT Analysis – Proposal Option 3

	Positive / helpful	Negative / harmful
Current / Internal origin	Strengths • Introduction of a smooth, buttressed spillway and extended stilling basin at Paradise Dam is beneficial to aquatic fauna transfer • Reduced dam height represents less of a barrier to aquatic fauna movement (e.g., naturally overtops more frequently) • Partial return to pre-development flow regime • Return of some areas of lacustrine habitat to riverine habitat upstream of the dam	Weaknesses • All works likely to require new/additional State and Commonwealth government environmental approvals leading to potential delay in commencement of project works pending project approval. • Proposal Option 3 overall project footprint includes multiple impact sites – i.e., two dam sites (one brownfield and one greenfield) and a weir • Paradise Dam: o Existing structure requires further demolition to lower the spillway an additional 5m (increased environmental impacts) o Other weaknesses as for Proposal Option 2 (refer Table 82 above) • Ned Churchward Weir Raise weaknesses as for Proposal Option 2 (refer Table 82 above) • Degilbo Creek Dam: o Results in loss of riverine habitat, causing potential inundation of nesting banks for WTST and spawning habitat for the Lungfish (to be confirmed by survey) o Alteration and/or loss of existing riparian ecosystem balance o Introduction of a new waterway barrier would represent a major risk to aquatic fauna passage
Future / External origin	Opportunities • No obvious environmental opportunities associated with Proposal Option 3	Threats • No obvious environmental threats associated with Proposal Option 3

Source: Sunwater

10.3.5 Comparison of findings

The environmental SWOT analyses in the preceding sections were made in relation to the base case. Table 84 below offers a comparison of significant environmental considerations between Proposal Options 1, 2 and 3.

Table 84 Comparison of significant environmental considerations across proposal options

Environmental Consideration	Proposal Option 1	Proposal Option 2	Proposal Option 3
Are alternative supply options required? (i.e., if so, cumulative impacts occur at multiple sites)	✓ No alternative supply options required	× Ned Churchward Weir Raise	×× Ned Churchward Weir Raise <u>and</u> Degilbo Creek Dam
Commonwealth's EPBC Act environmental approvals[16] (an associated difficulty in gaining approvals)	✓ Only minor variation to existing Paradise Dam approval	× EPBC Act referral for Paradise Dam with likely outcome as 'controlled action' New 'controlled action' referral required for Ned Churchward Weir Raise	×× EPBC Act referral for Paradise Dam with likely outcome as 'controlled action' New 'controlled action' referral required for Ned Churchward Weir Raise <u>and</u> Degilbo Creek Dam
State approval processes	-- Some approvals required for Paradise Dam e.g. update to Waterway Barrier Works approval, quarry permit, etc	× Similar for Paradise Dam Additional environmental assessment process (possibly EIS) for Ned Churchward Weir Raise	×× Similar for Paradise Dam Additional environmental assessment process (possibly EIS) for Ned Churchward Weir Raise <u>and</u> an EIS for Degilbo Creek Dam. Cumulative impacts of multiple projects.
Aquatic fauna passage (including threatened fish and turtle species)	✓ Smooth, buttressed spillway & extended stilling basin at Paradise Dam	✓ Smooth, buttressed spillway & extended stilling basin at Paradise Dam × Ned Churchward Weir Raise introduces a greater barrier to aquatic fauna movement	✓ Smooth, buttressed spillway & extended stilling basin at Paradise Dam ×× Ned Churchward Weir Raise <u>and</u> Degilbo Creek Dam both introduce new barriers to aquatic fauna movement
Impact on existing environmental values	-- Return to status quo with Paradise Dam as originally	✓ Long term benefit resulting from partial return of some areas of lake habitat to riverine habitat	✓ Long term benefit resulting from partial return of greater extent of lake habitat to riverine habitat

[16] It should be noted that approvals processes cannot be pre-empted, however this depiction aims to describe the relative prospects of a favourable approval.

Environmental Consideration	Proposal Option 1	Proposal Option 2	Proposal Option 3
	constructed (i.e., pre-base case)	upstream of Paradise Dam due to lowered spillway × Riverine habitat lost due to Ned Churchward Weir Raise	upstream of Paradise Dam due to further lowered spillway ×× Riverine habitat lost due to Ned Churchward Weir Raise and more extensive loss with new Degilbo Creek Dam

Symbol key is shown below

Symbol key

✓	Indicates an environmental benefit or positive outcome
×	Indicates a negative environmental impact or negative outcome (and its extent)
--	Neutral – neither positive or negative (e.g. a process to be followed, or insufficient data known)

10.4 Social impacts

10.4.1 Overview

Social impacts of the PDIP have been considered in the context of the primary service needs of dam safety and water supply and demand. High-level desktop social impact assessments to date have focused on the extent to which PDIP is likely to affect people's lives and have included matters ranging from the immediate, short-term impacts on adjacent landowners to long-term impacts affecting the broader region.

An initial understanding of social impacts has been developed by:

- **Engagement during the Essential Works** - a detailed project specific Stakeholder Management Plan was implemented by Sunwater for the Essential Works. This identified individual stakeholders and the key stakeholder groups which will be similar for PDIP. A Paradise Dam Community Reference Group (CRG) and Paradise Dam Industry Forum (PDIF) have been at the centre of engagement to date, with membership of these groups including downstream residents, grower groups, environmental groups, and local government.
- **A quantitative and qualitative community and stakeholder survey** – this was undertaken midway through the Essential Works project to provide insight into the effectiveness of the engagement and communications approach. It included two focus groups, a phone survey of 400 people across the region and 20 in-depth interviews with project stakeholders.
- **The future water demand survey** – this was rolled out with extensive regional engagement and received over 250 responses. Presentations on the findings of the survey provided further opportunity for engagement on the matters of importance to key stakeholders.

10.4.2 Approach

The social impact SWOT analysis has been developed on the basis that all three proposal options:

- meet the water supply and demand service need by supplying yield ahead of projected demand

- meet the dam safety service need
- include distribution system upgrade tranches 1 and 2, thus no assessment of the social impacts of that work has been conducted as all options are equal in that regard
- require a significant period of construction activity at Paradise Dam resulting in:
    - o the lake level needing to remain below original water levels up to and during construction and following project completion until inflows refill the storage
    - o amenity impacts including noise, dust, increased heavy vehicle traffic etc.
    - o disruptions to recreational use of the lake and associated amenities up to the construction period and for the duration of the construction period.

10.4.3 Proposal Option 1 findings

The social impacts associated with Proposal Option 1 (refer Table 85) include an extended construction phase (compared to other options) and impacts that are temporary in nature. These impacts appear manageable and upon implementation of the PDIP, will result in a largely positive outcome with all social assessment values returning to pre-Essential Works measures.

Table 85 Social SWOT Analysis – Proposal Option 1

	Positive / helpful	Negative / harmful
Current / Internal origin	Strengths • Provides greatest yield directly from Paradise Dam (more than sufficient yield to meet demand). • Returning to original FSL reinstates the water-related aesthetic, cultural and recreational values that were previously available (prior to the Essential Works) • Customer certainty that original dam yields are returned is provided in the shortest timeframe	Weaknesses • Community disruption (e.g., traffic/road impacts, noise, dust etc) – when compared to the base case – resulting from construction activities required to reinstate the primary spillway to its originally constructed height.
Future / External origin	Opportunities • As this option provides more than sufficient yield to meet demand, it also presents opportunities for: o Increased security for town water and irrigation supplies o Additional water available for population growth in regional towns and communities o Stakeholder support of outcome	Threats • No obvious social threats associated with Proposal Option 1

Source: Sunwater

10.4.4 Proposal Option 2 findings

The short-term social impacts for Proposal Option 2 (refer Table 86) will be generally similar to Proposal Option 1, however the long-term social outcomes are likely to be inferior compared to Proposal Option 1.

Table 86 Social SWOT Analysis – Proposal Option 2

	Positive / helpful	Negative / harmful
Current / Internal origin	Strengths • No strengths identified for Proposal Option 2.	Weaknesses • Paradise Dam weaknesses as for Proposal Option 1 (refer Table 85 above) • Customer and investor uncertainty that original dam yields will be returned, leading to delayed investment decisions. • Requires Ned Churchward Weir Raise to provide sufficient yield to meet the demand service need, thus additional social impacts including: o Additional lost amenity during the construction phase of the NCW raise • Permanent reduction in original recreational and amenity values at Paradise Dam due to lower lake levels.
Future / External origin	Opportunities • No significant opportunities identified for Proposal Option 2.	Threats • Ned Churchward Weir Raise: o Potential threats to cultural connections to significant sites due to increased inundation area and potential localised changes in flow regimes. • Higher risk of political / reputational / stakeholder challenge of outcome

Source: Sunwater

10.4.5 Proposal Option 3 findings

Proposal Option 3 (refer Table 87) is likely to provide the least desirable long-term social outcomes of the three options at both the local community level as well as across the region. This proposal option requires two alternative supply options to be delivered to meet the water supply and demand service need. Permanent lowering of the lake level will restrict the extent to which it will capably provide recreational opportunity (e.g. water sport, fishing), and will result in extensive loss of recreational and amenity values.

Table 87 Social SWOT Analysis – Proposal Option 3

	Positive / helpful	Negative / harmful
Current / Internal origin	Strengths • No strengths identified for Proposal Option 3.	Weaknesses • Requires two alternative supply options to provide sufficient yield to meet the demand service need, thus results in social impacts across a broader geographic footprint and across a longer timeframe. • Ned Churchward Weir Raise weaknesses as for Proposal Option 2 (refer Table 86 above) • Degilbo Creek Dam: o Requires land acquisition (unallocated state land and freehold land) and material change to land use at a greenfield site

	Positive / helpful	Negative / harmful
		• Customer and investor uncertainty that original dam yields will be returned, leading to delayed investment decisions. • Permanent reduction in original recreational and amenity values at Paradise Dam due to lower lake levels.
Future / External origin	Opportunities • May create additional/new water-related aesthetic, cultural and recreational values at Ned Churchward Weir and Degilbo Creek Dam	Threats • Very high risk of stakeholder challenge • Ned Churchward Weir Raise threats as for Proposal Option 2 (refer Table 86 above) • Degilbo Creek Dam: o Potential threats to cultural connections to significant sites due to new greenfield infrastructure and potential localised changes in flow regimes.

Source: Sunwater

10.5 Outcomes of secondary service needs assessment

Findings from the assessments generally indicate that while there are a number of potential environmental and social impacts likely to result from proceeding with the proposal options, they are not likely to be significant for activities that will occur in brownfield locations, previously disturbed through earlier construction activity. Many of the potential impacts are manageable and/or able to be mitigated through efficient design and the selection of appropriate project delivery methods.

The exception to this is the alternative supply options that form part of Proposal Options 2 and 3 – i.e., raising of Ned Churchward Weir and Degilbo Creek Dam. Building alternative supply option infrastructure, with the likelihood of impacting greenfield areas, will almost certainly require a greater level of impact assessment to be undertaken (e.g., preparation of an environmental impact statement) before works will be approved to commence.

In summary:

- Proposal Option 2 is likely to require a new Commonwealth referral for environmental approval process for PDIP, as the scope of works are different to those covered under existing approvals, which may lead to delays in obtaining approvals. Proposal Option 1 however, is likely to require only a minor variation to existing Commonwealth approvals (for Paradise Dam) as the original structure and full supply volume is reinstated.
- The alternative supply options required for Proposal Option 2 will impact upon greenfield areas and therefore require detailed impact assessments before works can commence. Proposal Option 1 avoids this requirement as no alternative supply options are required.

Given the largely desktop nature of the social and environmental analysis, specific climate change impacts in relation to these areas were not undertaken. Further work on the potential social and environmental impacts will be conducted in the Stage 2 DBC.

10.6 Approvals

10.6.1 Overview

A range of approvals may be required for the delivery of each of the proposal options under both Commonwealth and State Government legislation. This legislation is summarised in Table 88 below, with details of potential approvals and requirements provided in the following sections.

At the State level, there are two overarching approvals processes available to permit the PDIP options to proceed – a Ministerial Infrastructure Designation or a Coordinated Project process. Each process has its own pros and cons however both are established, business-as-usual government procedures applicable to projects the size of PDIP and, as such, are known and well understood. The main factor in determining which of these processes Sunwater, as project proponent, will follow relies upon the Commonwealth Government approvals pathway.

Under Proposal Option 1, (that reinstates the dam to its originally approved state and that does not require new alternative supply options), it may be possible to proceed through a variation to the existing EPBC Act approval. In this case, due to the simpler approvals regime likely to be required by the State, Sunwater would apply to amend the existing Ministerial Infrastructure Designation.

Proposal Options 2 and 3 however, have more complex approvals requirements. New referrals for a 'controlled action' (and possibly preparation of Environmental Impact Statements for new development) would be required for changes to the dam to the extent that the original approval would no longer apply, as well as elements of greenfield development. Under the latter scenario, due to the extra level of assessment and coordination that would be required, at the State level, application for a Coordinated Project designation through the Office of the Coordinator-General, would be likely.

Table 88 Summary of potential approvals/requirements and associated legislation

Government	Possible approval/requirement	Legislation
Commonwealth	Native Title	Native Title Act 1993 (Cmwlth)
State	Aboriginal Cultural Heritage	Aboriginal Cultural Heritage Act 2003 (Qld)
Commonwealth	EPBC Act Approval	Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Cmwlth)
State	Designation/development permits	Planning Act 2016 (Qld)
State	Coordinated project declaration	State Development and Public Works Organisation Act 1971 (Qld)
State	Dam safety conditions	Water Supply (Safety and Reliability) Act 2008 (Qld)
State	Water plans, water management protocols, resource operations licences and other instruments under the Act	Water Act 2000 (Qld)
State	Temporary permits, additional permanent land tenure	Land Act 1994 (Qld)
State	Environmental authority for any environmentally relevant activity	Environmental Protection Act 1994 (Qld)
State	Environmental offsets	Environmental Offsets Act 2014 (Qld)
State	Development permit for native vegetation removal	Vegetation Management Act 1999 (Qld)

Government	Possible approval/requirement	Legislation
State	Approvals such as damage mitigation permits and species management plans	Nature Conservation Act 1992 (Qld)
State	Authorisation or general fisheries permit	Fisheries Act 1994 (Qld)
State	Building work assessment	Building Act 1975 (Qld)
State	Management of any biosecurity risks	Biosecurity Act 2014 (Qld)
State	Permits or approvals for any work impacting a state-controlled road or railway	Transport Infrastructure Act 1994 (Qld)

Source: Sunwater

10.6.2 Commonwealth Government approvals

10.6.3 Native title

With reference to the *Native Title Act 1993* (Cmwlth), the existence of native title rights for the project area must be assessed and, in consultation and agreement with Traditional Owners, impacts must be managed and/or mitigated before on-site activities can commence. This requirement applies to any land and/or waters that fall within the project area. Neither the State or Commonwealth Governments will grant project approvals if it cannot be demonstrated conclusively that native title does not exist or, in the event that it does, that it is being properly managed.

While Aboriginal cultural heritage is not considered a significant risk for the PDIP, non-exclusive native title is held in several locations to the north of, and within, the Burnett River. Some of the identified project areas may be impacted by either Paradise Dam works, Ned Churchward Weir Raise works, or both.

To better understand the extent of impact on Native Title, further detailed review of requirements and actions as they relate to the proposal options will be undertaken as part of the Stage 2 DBC.

10.6.4 Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Cmwlth)

The EPBC Act enables the Commonwealth Environment Minister to regulate development which will, or is likely to, have a significant impact on a "matter of national environmental significance" (i.e., MNES). An approval is required under the EPBC Act where a development is a "controlled action" – that is, where it has been determined that the taking of an action will, or is likely to, have a significant impact on MNES.

To facilitate the original construction of Paradise Dam, a 'controlled action' approval was granted by the then Commonwealth Government on 25 January 2002. The approval granted authorisation for Paradise Dam to proceed based on agreed management/mitigation measures with respect to listed threatened species and communities and listed migratory species know to occur within the project area. The approval has subsequently been varied on several occasions over time.

To understand whether a new EPBC Act approval and further impact assessment work is required for the PDIP works to proceed, further assessment is required both at the dam site – with respect to the permanently lowered spillway options – and at the predominantly greenfield alternative supply option sites.

Sunwater has commenced early engagement with the Commonwealth Government regulator regarding approval requirements under the EPBC Act, with further activities to be undertaken during the Stage 2 DBC.

10.6.5 State Government approvals

10.6.6 Planning Act 2016

The *Planning Act 2016 (Qld)* (the Planning Act) sets out land use planning requirements to achieve ecological sustainability. Under the Planning Act, it is an offence to carry out assessable development unless all necessary development permits are in place.

PDIP works may be eligible for a designation by the Minister under Part 5 of the Planning Act. Under this legislation, development of infrastructure on premises subject to a Ministerial Infrastructure Designation is considered accepted development and therefore development permits are not required[17]. This is advantageous for the each of the proposal options as provides certainty in relation to schedule.

Paradise Dam was originally granted an equivalent Community Infrastructure Designation under the now repealed *Integrated Planning Act 1997* on 10 October 2002. Depending upon the final scope of the overall PDIP works, consideration will be given as to whether a new infrastructure designation will be required or if the existing CID (now MID) can be varied to suit the particular requirements unique to each proposal option. If a designation is not applied for, or not granted by the Minister, then new development permits may be required under the Planning Act and any applicable local planning scheme.

10.6.7 State Development and Public Works Organisation Act 1971

Under the *State Development and Public Works Organisation Act 1971* (Qld) (SDPWO Act) the Coordinator-General may declare a project to be 'coordinated project' under the Act. There are two assessment methods under the SDPWO Act, an Environmental Impact Statement (EIS) or an Impact Assessment Report (IAR). The SDPWO Act assessment process may be accredited for the purposes of the Commonwealth EPBC Act assessment process.

To be declared a coordinated project, an environmental impact assessment process is undertaken and a Coordinator- General's Evaluation Report (CG's Report) is issued.

The declaration of a project as a ‘coordinated project’ under the SDPWO Act can improve the timeliness and efficiency of the overall approval assessment process, with the increased certainty of approval conditions being stated, imposed, or recommended by the Coordinator-General. This includes efficiencies for any EPBC Act approvals that may be required in relation to Proposal Options 2 and 3.

10.6.8 Water Supply (Safety and Reliability) Act 2008

The purpose of the *Water Supply (Safety and Reliability) Act 2008* (Qld) (Water Supply Act) is to provide a safe and reliable water supply. Dam safety in Queensland is regulated under the Water Supply Act. This Act establishes the regulatory framework for dam safety regulation in Queensland and provides for the making of guidelines by the chief executive administering the Water Supply Act.

Under the Water Supply Act, the chief executive may apply safety conditions to a referable dam. Safety conditions are used to enforce the timeframe for a dam owner to provide an Acceptable Flood Capacity (AFC) report and any required dam safety upgrades. It is an offence for an owner to fail to comply with a safety condition.

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[17] This excludes building work classed as building assessment work under the Building Act 1975 (Qld). Most building work is declared as accepted development under the Building Act, for the purpose of the Planning Act, meaning a development permit is not required.

Each of the proposal options may necessitate a variation to the dam safety conditions for Paradise Dam and/or may require a set of new and/or amended conditions as applicable to Ned Churchward Weir Raise and Degilbo Creek Dam.

10.6.9 Water Act 2000

The *Water Act 2000* (Qld) (Water Act) provides a framework for the sustainable management of Queensland's water resources and quarry material. This includes water impoundments (e.g. dams and weirs) and water extraction through pumping for irrigation and other uses.

Key instruments under the Water Act are:

- water plans – which set out desired outcomes, measures, and strategies for achieving the water outcomes for the plan area
- water management protocols – which address matters such as water dealing/trading rules
- resource operations licences – which document the infrastructure used to operate the scheme and outline, for example, the roles and responsibilities of a dam operator to deliver against the water plan.

The specific instruments relevant to the PDIP, under the Water Act, are the:

- Water Plan (Burnett Basin) 2014
- Burnett Basin Water Management Protocol, February 2020 (amended September 2020)
- Bundaberg Water Supply Scheme Resource Operations Licence.

The overall PDIP may necessitate amendments to these specific instruments and other requirements under the Water Act. Specifically, if the PDIP works result in a change to the FSL of the dam, or increased volume within the supply scheme (i.e., through raising Ned Churchward Weir or introducing a new dam into the system), it can be expected that, at minimum, the resource operations licence will require amendment.

The activity of removing quarry material from a watercourse is also considered assessable development and a new approval may be required. In deciding an application for allocation of quarry material, the chief executive must consider the impact the removal of the quarry material will have on the long-term sustainable use of the watercourse. For quarry material removed under an allocation notice, a royalty may also be payable to the State. Each of the proposal options under consideration are likely to require the quarrying of material from a watercourse during the various construction phases.

10.6.10 Land Act 1994

The *Land Act 1994* (Qld) (Land Act) provides a framework for the allocation of state land as either leasehold, freehold or other tenure. Permits may be required under the Land Act for the occupation of a reserve, road, or unallocated state land. Sunwater will engage with the State for any temporary permits required for the overall PDIP works and any additional permanent tenure if required for the dam structure.

10.6.11 Aboriginal Cultural Heritage Act 1993

The existence of Aboriginal cultural heritage is to be managed under the *Aboriginal Cultural Heritage Act 2003* (Qld), to ensure effective recognition, protection and conservation of Aboriginal cultural heritage.

10.6.12 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (Qld) (EP Act) provides the primary legislative framework for environmental management and protection in Queensland. The objectives of the EP Act include protecting Queensland's environment while allowing for development that improves the total quality of life. It is an offence to undertake an environmentally relevant activity under the EP Act unless an environmental authority is held by the person undertaking the activity. At a minimum, activities across the proposal options that may require EAs include:

- extractive and screening activities
- chemical storage.

10.6.13 Other potential approvals

The following list of potential approvals provides a high-level summary of the other types of approval ordinarily required for a project the size and scale of the PDIP and associated infrastructure projects. This list is not exhaustive and will require further clarification and investigation during the Stage 2 DBC.

10.6.14 Environmental Offsets Act 2014

The primary purpose of the *Environmental Offsets Act 2014 (Qld)* (Offsets Act) is to counterbalance the significant residual impacts of activities on prescribed environmental matters using environmental offsets. The Act will only be relevant in relation to the delivery of offsets imposed as a condition of an approval if the project has a significant residual impact on prescribed environmental matters under the Act.

10.6.15 Vegetation Management Act 1999

The removal of native vegetation is regulated by the *Vegetation Management Act 1999 (Qld)*. Operational work for the clearing of native vegetation may require a development permit under the Planning Act.

10.6.16 Nature Conservation Act 1992

The *Nature Conservation Act 1992 (Qld)* (NC Act) provides the framework for creating and managing protected areas such as national parks, nature refuges and wilderness areas, and the protection of native flora and fauna. Under the NC Act it is unlawful to take, kill, injure or trap protected wildlife, or take protected plants unless authorised.

Approvals such as damage mitigation permits and species management plans under the NC Act may be required.

10.6.17 Fisheries Act 1994

The regulation of fisheries and fish habitat (among other things) is managed under the *Fisheries Act 1994 (Qld)* (Fisheries Act).

Any works that may impact on fish habitat and fish movement may require authorisation under the Fisheries Act. Such works include waterway barrier works, including work on existing waterway barriers such as dams and weirs. Under the *Fisheries Declaration 2019*, a person must not, in regulated waters, take any fish. The Burnett River is listed as regulated waters. Under the *Fisheries Regulation,* the chief executive can issue a general fisheries permit allowing the taking of fish in regulated waters where environmental protection is the sole or main purpose.

10.6.18 Building Act 1975

The *Building Act 1975 (Qld)* (Building Act) regulates building work in Queensland. Amongst other things, the Building Act provides what building work is assessable development or accepted development for the Planning Act.

10.6.19 Biosecurity Act 2014

The *Biosecurity Act 2014* (Qld) imposes a general obligation on all persons who deal with a biosecurity matter or a carrier, to take all reasonable and practical measures to prevent or minimise the biosecurity risk.

10.6.20 Transport Infrastructure Act 1994

The purpose of the *Transport Infrastructure Act 1994 (Qld)* (TIA) is to provide a regime that allows for and encourages effective integrated planning and efficient management of a system of transport infrastructure.

The TIA is administered by the Department of Transport and Main Roads. Under the TIA, permits or approvals are required to work in, or interfere with a state-controlled road or railway and for ancillary works and encroachments in a state-controlled road corridor.

10.7 Hydropower facility

Paradise Dam features an existing mini hydropower facility located on the right abutment of Paradise Dam and forms part of the outlet works arrangement. The hydro station and its associated control building are operated as a standalone facility, constructed to utilise the excess energy available from water discharged from Paradise Dam into the Burnett River. The facility consists of a turbine, generator, switchgear, hydraulic system, and control system and is connected to the irrigation discharge system. The turbine operates when water levels and flow rates are appropriate. The station does not supply the dam site. Instead the generated power is fed into the Ergon HV power distribution system.

Under original spillway height arrangements with the relatively low head level, the facility provided Sunwater with a cost neutral asset when the dam was at FSL and a generally reliable level of generation output. Under any of the proposal options featuring a lowered primary spillway, the power generation would likely reduce as well due to the lower-level driving head. This poses a risk to overall revenue to Sunwater.

11 AFFORDABILITY

11.1 Overview

Project affordability is a key consideration for all stakeholders. The affordability analysis draws upon the financial analysis to separately assess the affordability of the capital works and recurring budgetary considerations for Paradise Dam under the base case and proposal options. The discussion is aimed at assisting stakeholders and decision makers to make an informed decision regarding affordability and funding for both capital operation and maintenance expenditures.

This section sets out the following information:

- Revenue earned as a result of operations of Paradise Dam under the base case and the proposal options
- Potential alternative funding sources that could be used to supplement the revenue generation of Paradise Dam which would be used to finance the capital works and recurring operational and maintenance expenditure
- Funding uses under the base case and proposal options
- Assessment of the potential funding deficit, once revenue generation and potential funding sources are considered, as a result of any capital works and operation & maintenance costs under the base case and proposal options.

11.2 Project funding requirements

Project funding requirements are based on project expenditures less project revenues. The following section sets out details of project cash flows on an annual basis, and a summary of the residual funding requirements.

11.2.1 Project cash flows

The following charts provide details of the annual cash flows for each proposal option, including all identified revenues and expenditure.

Figures 79, 80, 81 and 82 have been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Figure 78 Base case (P90)

Figure 79 Proposal Option 1 (P90)

Figure 80 Proposal Option 2 (P90)

Figure 81 Proposal Option 3 (P90)

11.2.2 Project funding requirements

The following table summarises the funding requirements by proposal option, through consideration of total expenditure and revenues over the evaluation period.

Table 89 Project funding requirements

		Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
($M)	**Unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
Expenditure									
Capex	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Opex	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Risk	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Total expenditure	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Surplus/Deficit	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Due to the timing of alternative supply option requirements under Proposal Option 2, not all capex associated with the raising of the Ned Churchward Weir are captured in the preceding results. Additional capex and resultant funding requirement for the raising of Ned Churchward Weir not recognised in the preceding tables and figures totals CIC on a P90 nominal basis.

11.3 Project funding options

The affordability of a project is contingent on alternative funding sources that are available to meet the net costs involved. The BCDF sets out alternative funding sources potentially available including:

- User-pays mechanisms
- Value capture opportunities
- Developer contributions
- Government appropriations.

11.3.1 User-pays mechanism

User-pays mechanisms relate to revenue raised through water charges and through the sale of water allocations. Where available, this funding source has been included within the cash flow modelling and acts as a funding requirement offset.

As part of a decision on irrigation pricing in 2020, the Queensland Government has put in place a policy to fund the irrigators' share of dam safety upgrade costs, (i.e., these costs will not be recovered from irrigators). While this decision was made in relation to regulated irrigation schemes (where the Queensland Competition Authority recommends prices), for consistency it has been assumed that the same policy will apply to Paradise Dam safety upgrade costs.

On this basis, it is assumed that the cost of the PDIP capex will not be passed on to irrigators. For the purposes of this analysis, prices have not been adjusted for the expenditure associated with the dam improvement works for any customers in the scheme, and no costs have been assumed to be recovered through this mechanism.

Additionally, non-dam improvement works including distribution system upgrades would potentially be delivered under commercial arrangements in which prices would be based on a cost recovery basis pending an assessment of demand. However, for the purpose of this analysis, prices have not been adjusted for the expenditure associated with the non-dam improvement works for any customers in the scheme, and no costs have been assumed to be recovered through this mechanism.

The preceding points should be closely considered in subsequent analysis in the DBC as this may form a viable funding source.

The following table shows the total expected water charge revenue for each allocation priority type under the base case and proposal options, over the entire evaluation period.

Table 90 Water Charge Revenues

		Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
Water Charges ($M)	**Unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
MP charges	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
HP charges	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

As previously noted, the sale of water allocations has also been considered as a source of user-pays funding for the purpose of the analysis. The following table shows the total expected revenue derived from allocation sales for each priority type under the base case and proposal options, over the entire evaluation period.

Table 91 Allocation Sales Revenues

		Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
Charges $M	**$ unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
MP sales	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
HP sales	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

11.3.2 Government appropriations

To the extent any of the funding sources below can contribute to the costs it will reduce the funding deficit. Should alternate funding sources be unavailable, any remaining funding gap will be a matter for the Queensland government's consideration, in order for the proposal options to proceed

Additionally, there is an opportunity to apply for Commonwealth Government funding through the National Water Grid Fund (NWGF) water infrastructure initiatives.

The NWGF, replacing the National Water Infrastructure Development Fund (NWIDF) as per the 2021-22 Federal Budget announcement, is a 10-year rolling program that has a commitment of up to $3.5 billion in water infrastructure funding. There are currently 45 water infrastructure projects at different stages in development that have received funding from the NWGF. The funding is available for water infrastructure at each of the PBC, DBC, planning, and construction phases of a project.

In Queensland, there are nine water infrastructure projects which are currently receiving NWGF funding at stages ranging from PBC to construction.

11.3.3 Value capture opportunities

Value capture enables the recovery of some or all of the value that public infrastructure generates for beneficiaries of the infrastructure. Consideration was made in relation to value capture analysis guided by the process outlined in the BCDF including:

- Identification of beneficiaries and benefits
- Estimate of value uplift (where possible)
- Identification of relevant value-capture mechanisms
- Evaluation of mechanisms.

Beneficiaries of the project can be divided into two classes, the direct beneficiaries as users of Paradise Dam and indirect beneficiaries who receive advantage from the broader benefits of economic development. For the direct beneficiaries, value capture is best achieved through potential user-pay mechanisms discussed above. For the indirect beneficiaries, it is expected that it will be difficult to attribute the benefits to individual entities due to the dispersed impact of any such benefits throughout the community.

11.3.4 Developer contributions

Developer contributions are not a relevant potential funding source as private development is not considered as part of the project.

11.4 Funding analysis

The following sets out a compilation analysis in which funding requirements are compared with identified potential and committed funding, to enable the determination of the total residual project budget to enable the determination of the total residual project budget which will be a matter for the Queensland Government's consideration.

Table 92 Funding Analysis

		Base case		Proposal Option 1		Proposal Option 2		Proposal Option 3	
Charges $M	**Unit**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
Expenditure	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	Nom	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Surplus/deficit	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC
Identified funding	Nom	-	-	-	-	-	-	-	-
Funding deficit	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

11.5 Scenario analysis

As per the financial analysis, the affordability analysis considers alternative scenarios assessing the potential impacts of climate change and a delay to alternative supply option capital works. The impact on cash flows and funding requirements are set out in the following subsections.

11.5.1 Cash flows

11.5.2 Proposal Option 1 and 2 – climate change scenario

The following figures provide details of the forecast cash flows for each of Proposal Option 1 and Proposal Option 2under the delayed alternative supply option scenario.

Figures 83, 84 and 85 have been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Figure 82 Proposal Option 1 – Climate Change Scenario (P90)

Figure 83 Proposal Option 2 – Climate Change Scenario (P90)

11.5.3 Proposal Option 2 – Delayed Alternative Supply Scenario

The following figure provides details of the forecast cash flows for Proposal Option 2 under the delayed alternative supply option scenario.

Figure 84 Proposal Option 2 – Delayed Alternative Supply Option Scenario (P90)

11.5.4 Scenario funding analysis

The following table summarises the funding requirements, sources, and funding deficit by scenario.

Table 93 Project funding requirements

		Proposal Option 1-CC		Proposal Option 2-CC		Proposal Option 2-Delay	
	$ unit	P50	P90	P50	P90	P50	P90
Expenditure							
Capex	Nom	CIC	CIC	CIC	CIC	CIC	CIC
Opex	Nom	CIC	CIC	CIC	CIC	CIC	CIC
Risk	Nom	CIC	CIC	CIC	CIC	CIC	CIC
Total expenditure	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC
Revenue	Nom	CIC	CIC	CIC	CIC	CIC	CIC
Surplus/deficit	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC
Identified funding	Nom	-	-	-	-	-	-
Funding deficit	**Nom**	CIC	CIC	CIC	CIC	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

12 CONCLUSIONS, RECOMMENDATIONS, NEXT STAGE PLAN

12.1 Purpose

The purpose of this chapter is to summarise the key outcomes of the Options Evaluation, present recommendations, and set out the next steps for completion of the PDIP Stage 2 DBC.

12.2 Key findings

12.2.1 Dam safety service need criteria

Flood events in 2010, 2011 and 2013 caused extensive and unexpected scour damage to Paradise Dam. These flood events were substantially smaller than the maximum flows the dam had been designed to withstand. Extensive investigations and studies have been carried out since this time, although the full extent of the dam safety risks presented by the RCC was not confirmed until September 2019. Dam risk assessments identified key dam safety risks of:

- inadequate scour protection downstream of the primary and secondary spillways
- poor foundation material below the secondary spillway
- structural problems with the outlet works
- structural problems with the RCC that makes up most of the dam.

Initial dam safety repairs and early stage improvement works were completed (2013, and 2015 to 2017 respectively), however extensive studies revealed that further improvement works were needed to ensure the dam can safely pass excess volumes of water during periods of extreme rainfall; and for the dam to satisfy dam safety requirements.

Studies undertaken for the business case development, and sampling and testing of the RCC in 2019, identified a significant increased risk of dam failure (compared to that as previously assessed), leading to initiation of the Essential Works project in September 2019. This was an urgent staged project, required to reduce risks in the short term through interim strengthening works and lowering the spillway wall by 5.8m (reducing flood loading). The dam safety scope for the Essential Works stage was completed in early 2021 (representing the base case), reducing the dam risk profile, though further significant improvement works are required to reduce risks to an acceptable level in the long-term. In parallel, planning and design has been ongoing for the next stage improvement project, including assessment of the final spillway crest level.

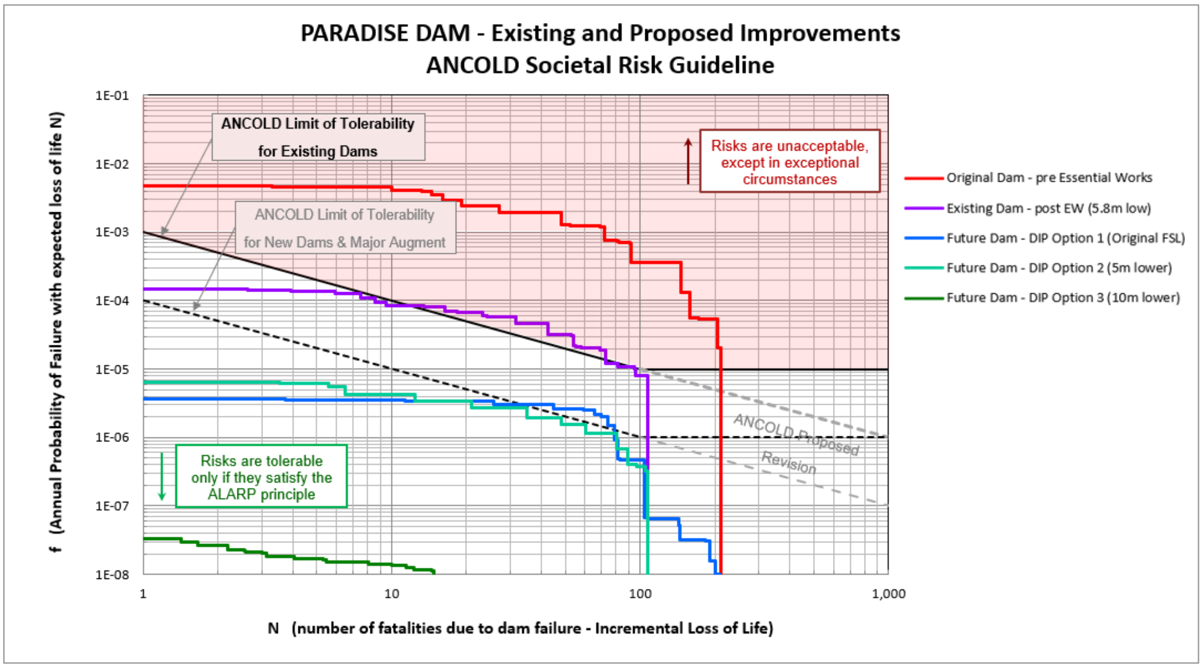
Three dam improvement options (Dam Options 1, 2 and 3) were identified and concept level designs prepared, which met the threshold criteria of LoT and ALARP within ANCOLD's dam safety guidelines as outlined in chapter 5. While a base case was developed to reflect the state of the dam at the completion of the Essential Works, it is only a reference case for comparative purposes as it is not a viable long-term option (does not meet the dam safety guideline).

This is illustrated in Figure 48, where the base case (existing dam-post Essential Works (EW)) exceeds the ANCOLD Limit of Tolerability for existing dams. Dam Options 1, 2 and 3 satisfied this limit as shown and were progressed for further assessment in the OE.

In summary:

- Despite completion of the Essential Works, which has significantly reduced the risk of dam failure, the dam does not currently meet the ANCOLD Guideline acceptable Limit of Tolerability and requires significant improvement works to reduce risks to an acceptable level in the long-term.
- Dam Options 1, 2 and 3 all satisfied this Limit of Tolerability.

Figure 85 Assessment of options against dam safety service need criteria



Notes: The base case is equivalent to the "Existing Dam – post EW (5.8m low)"

12.2.2 Water supply and demand service need criteria

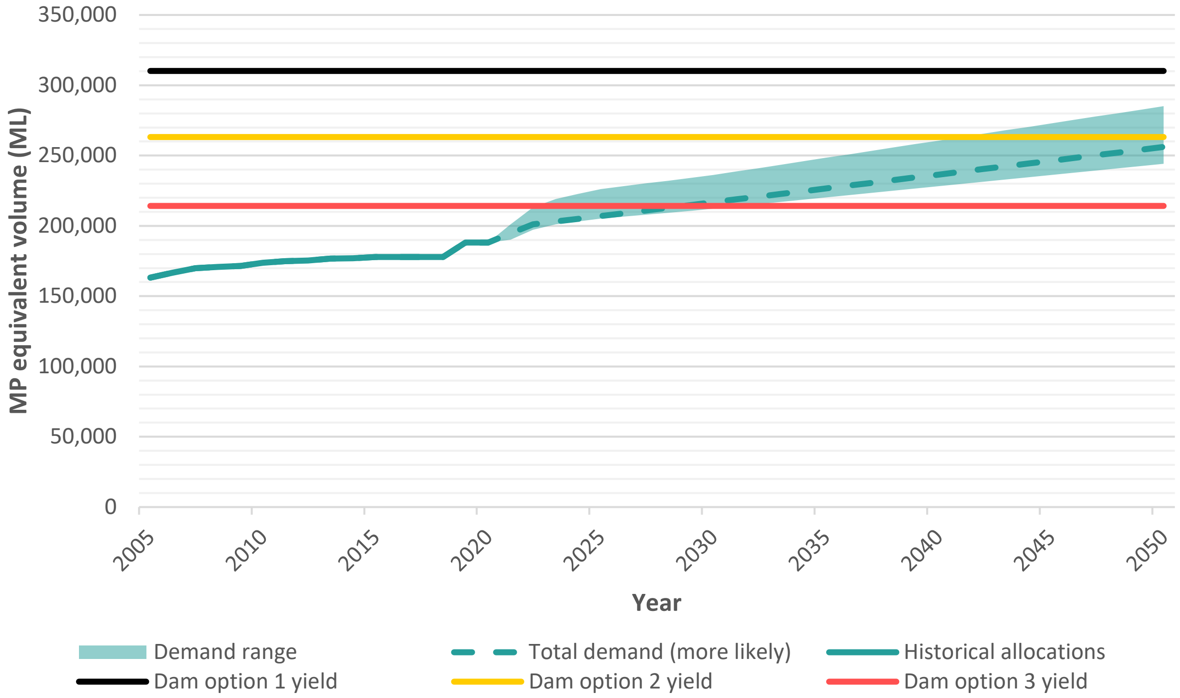
A detailed demand assessment was undertaken to establish the projected demands from urban, industrial and agricultural customers within the scope area. The assessment included a comprehensive stakeholder consultation process to define the water supply and projected demand to be met through the PDIP for the evaluation period up to 2050. The demand assessment identified:

- a significant structural shift in the irrigation industry in the Bundaberg region, involving the transfer of existing irrigated land use from sugar cane to perennial tree crops
- changed demand patterns and volumes and an unprecedented acceleration of demand growth in the region compared to historical growth trends
- the projected most likely increase in demand (from 2020 to 2050) was 68,100ML. This is the P50 of a probabilistic range of projected demands based on Monte Carlo simulations across the full range of inputs to the modelling.

Each of the three dam options were assessed against the increase in demand of 68,100ML. The results of the demand assessment compared to the water that would likely be available from the three dam options are presented in Figure 87. This shows:

- Dam Option 1 meets the full range of projected demands.
- Dam Option 2 meets the most likely projected demand but does not meet projected demands above P50, nor does it meet projected demand beyond 2053.
- Dam Option 3 does not meet the most likely projected demand.
- Dam Option 2 and 3 both require expensive alternative supply options to meet the service need and to be comparable to Dam Option 1.

Figure 86: Projected demand to 2050 with historical allocations and subscheme yields (excluding alternative supply options)



Notes:

- Total demand (more likely) represents the most likely projected demand from the demand assessment
- Historical allocations represent water sold from commissioning of the dam to 2020
- Dam option yields represent the totals available in the Burnett River subscheme under each dam option excluding alternative supply options.

Distribution system constraints

The demand assessment also identified capacity constraints in the distribution system impacting the ability to meet projected demand in the Isis and Woongarra irrigation areas. To resolve these constraints, upgrades of the distribution system infrastructure are required. The assessment grouped the upgrades into two tranches as follows:

- Tranche 1 is required to facilitate the distribution of water to meet short to medium-term demand growth. The scale, location and timing of these investment requirements is relatively certain (required by 2028) but requires detailed assessment to finalise scope for investment.
- Tranche 2, which are much larger upgrades, have been developed based on existing information and assumptions on longer-term demands. The requirement for these upgrades is certain, to meet the projected demand in the future. However, the type of augmentation, scale, location, and timing of much of Tranche 2 is uncertain as it ultimately needs to respond to future development and investment decisions of hundreds of irrigators. Detailed assessment of Tranche 2 will need to be performed at an appropriate time when development progresses in the region.

It is considered prudent and efficient to address distribution system constraints, regardless of selection of dam option, when the scale, location and timing can be more accurately estimated. As a result, distribution system upgrades are recommended to be the subject of separate assessment and investment consideration, with the assessment of Tranche 1 being the priority.

Proposal options

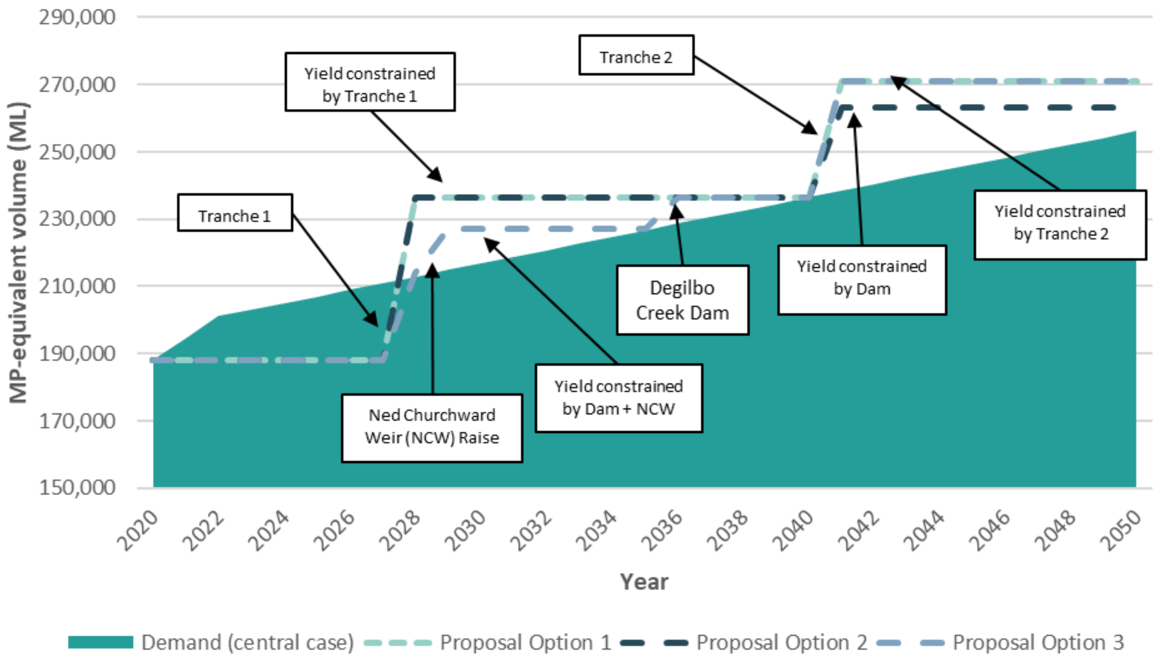
Where dam options alone were not capable of meeting the service need (assuming the most likely projected demand), alternative supply options were added to meet the projected demand. These are defined as proposal options.

- **Proposal Option 1**: Dam Option 1 plus upgrades to the distribution system (Tranches 1 and 2). This meets the most likely projected demand to 2050 and does not require alternative supply.
- **Proposal Option 2**: Dam Option 2 plus upgrades to the distribution system (Tranches 1 and 2). This meets the most likely projected demand to 2050 but requires alternative supply (raising the existing Ned Churchward Weir) by 2053. To meet this date, works for the proposed alternative supply need to commence within the evaluation period by 2046.
- **Proposal Option 3**: Dam Option 3 plus upgrades to the distribution system (Tranches 1 and 2). This requires two alternative supplies (raising the existing Ned Churchward Weir and building a new dam, Degilbo Creek Dam) to meet the most likely projected demand to 2050.

Figure 88 below shows the most likely projected demand, deliverable yields for each dam option, alternative supply required and upgrades to the distribution system (Tranches 1 and 2).

The ability of Proposal Option 3 to meet demand was determined to be cost prohibitive due to the need for expensive alternative supply (raising of existing Ned Churchward Weir and the new Degilbo Creek Dam). Proposal Option 3 was filtered from further analysis.

Figure 87 Proposal options deliverable yields to meet projected demand



Notes:

- Deliverable yield is a combination of dam option yield, alternative supply option yields, and distribution system capacity to deliver.
- At the time of writing the timing and sequencing of construction works for the PDIP and the Tranche 1 upgrade are not yet finalised. For simplicity and consistency in comparing dam options it has been assumed the works are completed and commissioned in the short term. The tranche 1 upgrades are also identical for each option and will not have any bearing on the comparative assessment of options.
- Proposal Option 3 is generally limited by the yield available from supply sources, more so than distribution system capacity. Proposal Options 1 and 2 are initially limited by distribution system capacity until 2040 and are then only limited by the yield available from supply sources.

12.2.3 Analysis – most likely projected demand

The following analyses were conducted on Proposal Options 1 and 2 to provide a comparison against the base case and against each other.

- Pricing
- Financial analysis
- Cost Benefit Analysis
- Qualitative assessment of environmental, social impacts and approvals required

Pricing (most likely projected demand)

Under Australian and Queensland government policy, water prices should seek to recover the full cost of water supply, including infrastructure costs.

As part of a decision on irrigation pricing in 2020, the Queensland Government has put in place a policy to fund the irrigators' share of dam safety upgrade costs, (i.e., these costs will not be recovered from irrigators). While this decision was made in relation to regulated irrigation schemes (where the Queensland Competition Authority recommends prices), for consistency it has been assumed that the same policy will apply to Paradise Dam safety upgrade costs.

Given this, the options evaluation has assumed current prices for Medium Priority (MP) and High Priority (HP) water (which do not include the recovery of any dam safety costs) for estimating revenue in the modelling, as outlined in section 8.3.13.

Financial Analysis (most likely projected demand)

A Class 4 cost estimate was prepared on the concept level designs for Proposal Options 1 and 2. As such costs should be considered preliminary in nature. Probabilistic risk modelling was performed in relation to the capital costs and operating and maintenance costs associated with each of the base case and proposal options to produce risk-adjusted project costs.

Table 94 below presents P90 (a 90 percent probability that the total project costs over the evaluation period will not be exceeded) capital expenditure (Capex) for Proposal Options 1 and 2 assuming the most likely projected demand.

Table 94 Capital expenditure outputs (most likely demand)

P90 Nominal, $'M	Proposal Option 1 P90	Proposal Option 2 P90
Dam Improvement Capex	CIC[18]	CIC [19]
Ned Churchward Weir Raising	-	CIC
Degilbo Creek Dam	-	-
Tranche 1 Distribution System Upgrade	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC
Other Capex	CIC	CIC
TOTAL CAPEX	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

[18] Dam Option 1
[19] Dam Option 2

The following key observations were made:

1. Dam Improvement Capex is similar between Dam Options 1 and 2 as they have common items of scope (as shown in Figure 5) including:
    a. Secondary spillway and left abutment buttress (addition of mass concrete strengthening)
    b. Secondary spillway raising by 5m in height (reduce overtopping frequency in this area)
    c. Demolition of half of the secondary spillway and excavation down to good foundation material, and reconstruction of this section of wall
    d. Temporary coffer dam to support item c. above
    e. Downstream scour protection below the secondary spillway and left abutment
    f. Extension of the existing apron below the primary spillway (significant scour protection)
    g. Construction and extension of training walls either side of the primary spillway and apron
    h. Improvement and modifications to the intake tower and outlet works
2. Proposal Option 2 includes capex for alternative supply (Ned Churchward Weir raising required by 2053), which requires work to commence across the period 2046-52, however only costs up to 2050 are included.
3. Upgrades to the distribution system are common to both Proposal Options 1 and 2
4. Other Capex consists of minor improvement works anticipated for Ned Churchward Weir in the medium term, irrespective of any weir raising.

After taking into consideration capital expenditure, operational expenditure and revenue, assuming the most likely projected demand, the project Financial Net Present Values (NPV)[20] are presented in Table 95 below.

Table 95 Financial project outcomes (most likely projected demand)

Project outcome	Unit	Proposal Option 1 P90	Proposal Option 2 P90
Cost (Capex + Opex)	Nominal	CIC	CIC
Revenue	Nominal	CIC	CIC
Surplus/(deficit)	**Nominal**	CIC	CIC
Discounting @ 1.95%	Nominal	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The NPV for both Proposal Options 1 and 2 is negative, as the costs for both options are greater than revenue derived from the sale of water. Whilst Proposal Option 2 has a greater cost than Proposal Option 1, its NPV is slightly better as the requirement for the alternative supply (Ned Churchward Weir raising) occurs across the end of the evaluation period (2046-2052). The small NPV difference between Proposal Options 1 and 2, assuming the most likely projected demand, is due to scope commonality of dam improvement works. Note that only costs to 2050 have been captured in Table 95 above.

Cost Benefit Analysis (most likely projected demand)

The Benefit Cost Ratios (BCR)[21] calculated, assuming most likely demand over a thirty (30) year evaluation period, were Proposal Option 1: **0.137**, and Proposal Option 2: **0.152**. The outcomes from

[20] Financial Net Present Value is calculated by the present value (all values discounted to present day terms) of the revenues less the present value of the costs.

[21] Benefit Cost Ratio (BCR) divides the present value of estimated benefits by the present value of estimated costs. A ratio of one or more indicates economic viability where the assessed benefits to society are greater than the assessed costs.

the cost benefit analysis were less than 1.0, indicating that both proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.

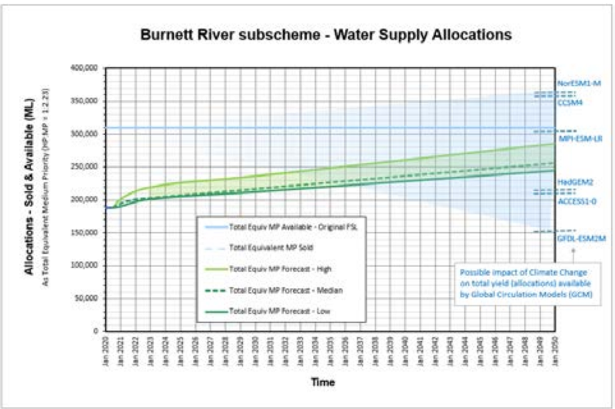
It is noted that the safety improvements already achieved through the Essential Works are not captured in this economic analysis.

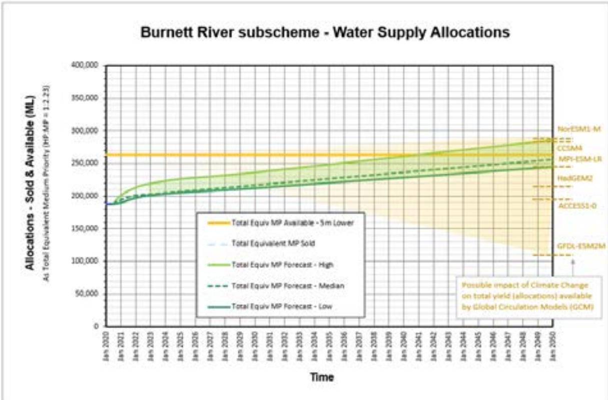
12.2.4 Analysis – climate change scenario

Financial analysis (climate change scenario – impact on yield)

A scenario on the impact of climate change on yield (reliable supply from storages from catchment inflows) was assessed using the outputs from 11 different climate change models, using emission scenario Representative Concentration Pathway RCP 8.5 (recommended as discussed with government representatives and consistent with the advice of the hydrology consultant and peer reviewer). The outputs of this assessment are presented in Figure 89.

Figure 88 Potential Climate Change Impacts on Yield of Dam Options 1 (left) and 2 (right)





As shown in Figure 89, the model outputs indicates that climate change may have a positive or negative impact on the available yield of dam options. Climate change sensitivity analysis further indicates that there is generally a greater potential negative impact to water security than a potential positive impact. In the event where negative impacts predicted from the models are realised, alternative supply options are more likely to be required, and required earlier, within the evaluation period.

Based on this yield scenario, Proposal Option 1 will still meet projected demands. Proposal Option 2 will require amendment to meet projected demand, as the original infrastructure configuration of this option no longer meets the service need. The construction of Degilbo Creek Dam is required (to replace the raising of Ned Churchward Weir) in this scenario, adding capital expenditure to this option. This outcome is based on the yield scenario, while other yield scenarios may result in different infrastructure requirements.

Capital expenditure for each updated proposal option assuming climate change is provided in Table 96. Proposal Option 3 has been excluded from consideration in this scenario analysis as it cannot meet projected demand in this analysis.

Table 96 Capital expenditure outputs (impact of climate change)

P90 Nominal, $'M	Proposal Option 1 P90	Proposal Option 2 P90
Dam Improvement Capex	CIC	CIC
Ned Churchward Weir Raising	-	-
Degilbo Creek Dam	-	CIC

P90 Nominal, $'M	Proposal Option 1 P90	Proposal Option 2 P90
Tranche 1 Distribution System Upgrade	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC
Other Capex	CIC	CIC
TOTAL CAPEX	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

After taking into consideration capital expenditure, operational expenditure, and revenue, assuming the impact of climate change, the Project Net Present Values (NPV) are presented in Table 97 below.

Table 97 Financial Project outcomes (impact of climate change)

		Proposal Option 1 – Climate Change	Proposal Option 2 – Climate Change
Project outcome	**Unit**	**P90**	**P90**
Cost	Nominal	CIC	CIC
Revenue	Nominal	CIC	CIC
Surplus/Deficit	**Nominal**	CIC	CIC
Discounting @ 1.95%	Nominal	CIC	CIC
Project NPV	**NPV**	CIC	CIC

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

The worsening of the NPV for Option 2 compared to Option 1 is due to the requirement of alternative supply for Option 2 within the evaluation period.

Cost Benefit Analysis (climate change scenario)

The Benefit Cost Ratios (BCR) calculated for this scenario, assuming most likely demand over a thirty (30) year evaluation period, were Proposal Option 1: **0.137** (no change), and Proposal Option 2: **0.112** (reduced from 0.152 assuming no climate change impact). As shown in Table 98:

- The outcomes from the cost benefit analysis were less than 1.0, indicating that both proposals were not economically viable as the assessed costs to society were greater than the assessed benefits.
- Capital expenditure for Proposal Option 2 was comparatively higher due to the requirement of alternative supply (i.e., Ned Churchward Weir Raise) which occurs across the end of the evaluation period (2046 – 2052).
- Dam improvement capital expenditure is similar between Proposal Options 1 and 2 as they have common items of scope.
- Consideration of the impact of climate change, through analysis of the yield scenario, results in a change in infrastructure required for Proposal Option 2, with the impact on P90 cost, NPV and BCR shown. Regardless of yield scenario chosen, Proposal Option 2 is more sensitive to the reduction in yield that may arise based on the various climate change models, which may impact the alternative supply options selected.

Table 98 Outcomes of Financial and Cost Benefit Analysis

	Proposal Option 1 P90 $'M Nominal	Proposal Option 2 P90 $'M Nominal	Proposal Option 2 (climate change) P90 $'M Nominal
Dam Improvement Capex	CIC	CIC	CIC
Ned Churchward Weir Raising	-	CIC	-
Degilbo Creek Dam	-	-	CIC
Tranche 1 Distribution System Upgrade	CIC	CIC	CIC
Tranche 2 Distribution System Upgrade	CIC	CIC	CIC
Other Capex	CIC	CIC	CIC
Total Capex	CIC	CIC	CIC
Total Opex	CIC	CIC	CIC
Total Proposal Option Cost	CIC	CIC	CIC
Total Proposal Option Revenue	CIC	CIC	CIC
Discounting @ 1.95%	CIC	CIC	CIC
Project Financial NPV (P90 $'M)	CIC	CIC	CIC
Benefit Cost Ratio (BCR)	**0.137**	**0.152**	**0.112**

Note: Information in the table has been identified as commercial in confidence (CIC) to allow the State to achieve value for money on future commercial and negotiation decisions.

Note: Benefit Cost Ratio is calculated using an economic discount rate of 7%

12.2.5 Analysis – other scenarios

Cost Benefit Analysis (other scenarios)

A range of other scenarios, selected in consultation with key project stakeholders, were analysed to investigate the impact of alternative futures and different combinations of inputs on the outcomes of the options evaluation. The scenarios selected and the outcomes of the analyses are described below:

- Under the accelerated tree crop growth scenario, Proposal Option 1 performs well but Proposal Option 2 requires alternative supply options, at significant cost, earlier in the evaluation period.
- Under the delayed dam fill period scenario, the impacts are applied equally across all Proposal Options and as such, has no effect on the ranking of options.
- Under the extended evaluation period of 40 years (and two separate scenarios where demand either continues to increase or plateaus beyond the original 30-year evaluation period), additional alternative supply is required for Proposal Option 2 to meet projected demand for both scenarios, resulting in more favourable performance for Option 1.
- A staged approach to Proposal Option 1 (based on timing of the construction works to ensure yields meet projected demands), was considered. While detailed costs for this scenario have not been developed, the incremental cost of future raising works required (expected around 2042, based on probabilistic demand modelling) would need to be less than CIC (undiscounted), or CIC

in present value terms (using a 7% real discount rate), to provide the same or better net present value outcomes as Proposal Option 1 (initial analysis suggests this is unlikely).

12.2.6 Analysis - social and environmental

Environmental and social impacts attributable to each of the proposal options were assessed at high level through a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis. These impacts were defined as secondary service needs for PDIP and if material, may impact the assessment of which option/s should be progressed to the Stage 2 DBC.

The SWOT analysis found:

- Proposal Option 2 (and Proposal Option 3) is likely to require a new Commonwealth referral for environmental approval process for PDIP, as the scope of works are different to those covered under existing approvals. Proposal Option 1 however, is likely to require only a minor variation to existing Commonwealth approvals (for Paradise Dam) as the original structure and full supply volume is reinstated.
- The alternative supply options required for Proposal Option 2 and 3 will also impact upon greenfield areas and therefore require detailed impact assessments before works can commence. Proposal Option 1 avoids this requirement as no alternative supply options are required.
- Proposal Option 1 may be able to proceed through a variation to the existing EPBC Act approval. However, Proposal Option 2 and 3 will have more complex approval requirements (change to the original dam) new referrals for a 'controlled action' (and possibly preparation of Environmental Impact Statements for new development) would be required. Application for a Coordinated Project designation through the Office of the Coordinator-General, would be likely, and result in a risk of delay.

Given the largely desktop nature of the social and environmental analysis, specific climate change impacts in relation to these areas were not undertaken. Further work on the potential social and environmental impacts will be conducted in the Stage 2 DBC.

12.2.7 Analysis – approvals

A range of approvals may be required for the delivery of PDIP under both Commonwealth and State legislation. This legislation is summarised in Table 99 below.

At the State level, there are two overarching approvals processes available to permit the PDIP options to proceed – a Ministerial Infrastructure Designation or a Coordinated Project process. Each process has its own pros and cons however both are established, business-as-usual government procedures applicable to projects the size of PDIP and, as such, are known and well understood. The main factor in determining which of these processes Sunwater, as project proponent, will follow relies upon the Commonwealth Government approvals pathway.

Under Proposal Option 1, (that reinstates the dam to its originally approved state and that does not require new alternative supply options), it may be possible to proceed through a variation to the existing EPBC Act approval. In this case, due to the simpler approvals regime likely to be required by the State, Sunwater would apply to amend the existing Ministerial Infrastructure Designation.

Proposal Options 2 and 3 however, have more complex approvals requirements. New referrals for a 'controlled action' (and possibly preparation of Environmental Impact Statements for new development) would be required for changes to the dam to the extent that the original approval would no longer apply, as well as elements of greenfield development. Under the latter scenario, due to the extra level of assessment and coordination that would be required, at the State level, application for a Coordinated Project designation through the Office of the Coordinator-General, would be likely.

Table 99 Summary of potential approvals/requirements and associated legislation

Government	Possible approval/requirement	Legislation
Commonwealth	Native Title	Native Title Act 1993 (Cmwlth)
State	Aboriginal Cultural Heritage	Aboriginal Cultural Heritage Act 2003 (Qld)
Commonwealth	EPBC Act Approval	Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Cmwlth)
State	Designation/development permits	Planning Act 2016 (Qld)
State	Coordinated project declaration	State Development and Public Works Organisation Act 1971 (Qld)
State	Dam safety conditions	Water Supply (Safety and Reliability) Act 2008 (Qld)
State	Water plans, water management protocols, resource operations licences and other instruments under the Act including the consideration of climate change	Water Act 2000 (Qld)
State	Temporary permits, additional permanent land tenure	The Land Act 1994 (Qld)
State	Environmental authority for any environmentally relevant activity	Environmental Protection Act 1994 (Qld)
State	Environmental offsets	Environmental Offsets Act 2014 (Qld)
State	Development permit for native vegetation removal	Vegetation Management Act 1999 (Qld)
State	Approvals such as damage mitigation permits and species management plans	Nature Conservation Act 1992 (Qld)
State	Authorisation or general fisheries permit	Fisheries Act 1994 (Qld)
State	Building work assessment	Building Act 1975 (Qld)
State	Management of any biosecurity risks	Biosecurity Act 2014 (Qld)
State	Permits or approvals for any work impacting a state-controlled road or railway	Transport Infrastructure Act 1994 (Qld)

Source: Sunwater

12.3 Summary of findings

Table 100 provides a summary of the options evaluation findings and outcomes:

Table 100 Summary of Options Evaluation outcomes

Assessment category	Proposal Option 1	Proposal Option 2
Design meets safety requirements – ANCOLD / ALARP	✓	✓
Meets most likely projected demand	✓	✓
Meets projected demand under impacts of climate change	✓	×
Total cost of all works	CIC	CIC
Cost of dam improvement only (P90, $'Nominal)	CIC	CIC
Timing of alternative supply (if required), and additional environmental risk / approval	✓ Not required	× FY46 to FY52
Cost of alternative supply (P90, $'Nominal)	✓ Nil	× CIC (+ post FY50 costs)
Cost of distribution system upgrade for infill development (Tranche 1) (P90, $'Nominal)	Same for both options	
Cost of distribution system upgrade for new development (Tranche 2) (P90, $'Nominal)	Same for both options	
Other costs (minor capex, operations and maintenance, etc)	Same for both options	
Commonwealth environmental approvals[22] (for Paradise Dam scope only, not alternative supply)	✓ variation	× new Referral
Proposal option NPV (P90 $'Nominal, most likely projected demand, no climate change impacts)	× (CIC)	✓ (CIC)

[22] It should be noted that approvals processes cannot be pre-empted, however this depiction aims to describe the relative prospects of a favourable approval.

Assessment category	Proposal Option 1	Proposal Option 2
Proposal option NPV (P90 $'Nominal, most likely projected demand, with climate change impacts)	✓ (CIC)	× (CIC)
BCR (most likely projected demand)	× 0.137	× 0.152
BCR (most likely projected demand, climate change impacts)	× 0.137	× 0.112

12.4 Conclusions

The following conclusions have been drawn from the options evaluation:

- It is considered prudent and efficient to address distribution system constraints, regardless of selection of dam option, when the scale, location and timing can be more accurately estimated. As a result, distribution system upgrades (Tranches 1 and 2) are recommended to be the subject of separate assessment and investment consideration, with the assessment of Tranche 1 being the priority.
- The BCR and NPV analysis indicates that there is a marginal difference between Option 1 and Option 2, with Option 2 slightly more favorable. However, investment preference towards Option 1 becomes more favorable when the following additional factors are considered:
    - Proposal Option 1 is the only option that meets the most likely projected demand to 2050 without the need for alternative supply.
    - Under a climate change scenario (using a range of climate change models), Option 1 is the only option that meets most likely projected demand to 2050, even with a decreased yield attributable to climate change, without the need for alternative supply.
    - The BCR and NPV analysis indicates that Option 1 becomes more favourable under a climate change scenario due to the Capex increase resulting from the need to shift the alternative supply from Ned Churchward Weir Raise to Degilbo Creek Dam to address climate change impacts on yield and capacity to meet longer term demand.
        - There is a high degree of uncertainty in climate change modelling and impacts on yield is variable. As such, scenario modelling outcomes should be treated with caution, Nevertheless, modelling outcomes indicate that the larger the capacity of the supply option (dam option or alternative supply option), the more resilient the infrastructure is to downside climate change impacts on dam inflows.
    - CBA sensitivity analysis further indicates that:
        - Option 1 is more favourable where demand is materially higher than the most likely projected demand as alternative supplies may be required to complement Option 2.
        - Option 1 is more favourable where the evaluation period is extended to 40 years to account for longer term demand.

    - Proposal Option 1 will cost less than Proposal Option 2 and 3 over the evaluation period as it does not require additional investment in new alternative supply.
    - Proposal Option 1 may be able to proceed through a variation to the existing EPBC Act approval and avoid the need to apply for a Coordinated Project designation as it this option returns the dam to the full supply level and avoids the need for alternative supply.
- A range of specific elements including detailed design, further development of the cost estimate, environmental and legal approvals, water supply during construction, affordability and constructability require further consideration as part of the next stage of considering the project (DBC stage 2).

12.5 Limitations

This section sets out:

- Elements that were not considered during the course of the OE
- Further actions that may be required in future to address known limitations

12.5.1 Dam safety

Whilst extensive technical investigations have been undertaken to inform this OE (consistent with the recommendations of the Paradise Dam Options Assessment from February 2020), further investigations remain ongoing and are required to improve the understanding of key technical design parameters. The outcomes of this OE have been based on the best available information at the time of analysis. As such, all conclusions drawn, and recommendations made have been done so on this basis.

The key elements of technical investigation requiring further development to support the detailed design process as part of the Stage 2 DBC, include:

- Geological and geotechnical modelling: Updating of the existing geological model to include information obtained from additional mapping completed prior to placement of dental concrete downstream of the primary spillway during the Essential Works project.
- CFD modelling: Hydraulic modelling of the preferred dam option with two- and three-dimensional CFD modelling.
- Physical hydraulic modelling: Construction of a scale model of the preferred dam option to confirm design assumptions and optimise design where possible.
- Finite element analysis: Further structural analysis focused on the buttressed dam monolith sections and focusing on the interface between the existing dam RCC and the new buttress; thermal modelling; the effects of buttress stiffness on load sharing; refinement of RCC/CVC breakdown within the buttress.
- Crest stabilization: Review and refinement of crest stabilising dowel arrangements for the left abutment, primary spillway and secondary spillway following additional CFD modelling.
- Outlet conduit strengthening: Further consideration of the outlet conduit strengthening requirements based on results of additional structural assessment being undertaken by GHD.
- Geotechnical investigations: A range of further geotechnical investigations across the site to inform the following activities:
    - Onsite:

    - Extent of basalt on the right bank as this location presents as a possible concrete aggregate source.
    - Determination of whether a cut-off wall is required on the secondary spillway (upper section) to inform designer and contractor of relevant risk / cost and stability / scour analysis information.
    - Confirmation of possible coffer dam foundation materials to inform design and contractor risk
    - In-river cores – 1 x at left training wall and 3 x through downstream dental concrete to inform primary spillway buttress design.
  - Off-site:
    - Detailed site investigations for potential concrete aggregate sources.
    - Concrete mix design trials - to inform design and specification development.
    - Road Impact Assessment – considering local road network and to inform road upgrade requirements because of aggregate haulage.
    - Time of closure assessment - for Degilbo Creek bridge on Grills Road (main access road to site) to determine if upgrade is required.

12.5.2 Water supply and demand

- While a detailed demand assessment was conducted, the projections were made consistent with an agreed evaluation period to 2050. The structural shift in land use identified is likely to continue, even at a reduced rate, beyond the evaluation period (at 2050 around half of the land potentially available to experience the structural shift has been converted).
- The outcomes of the climate change scenario work demonstrated significant variations with no statistically robust average or median result able to be used. This introduces significant uncertainty into the likely impacts and potential options required to meet the anticipated impacts.

12.5.3 Cost Benefit Analysis

- Positive and negative externalities have not been incorporated into the quantitative economic analysis including the economic value of reduced dam safety related damages, and the value of social and environmental impacts.
- The evaluation period of the CBA was set at 30 years (from 2020 to 2050) as this is typical of economic analyses. For Proposal Option 2, some significant investments are likely required just outside the evaluation period. These have only been considered in scenario analysis outcomes.
- Specific limitations on scenario analysis are qualitative in nature only.
- Estimates for growth in demand beyond 2050 are highly uncertain and have been extrapolated or assumed based on previous trends.

12.5.4 Pricing

- It has been assumed that the cost of the PDIP capex will not be passed on to irrigators, consistent with the Queensland Government's decision not to recover irrigator's share of dam safety upgrade costs through prices in regulated schemes. Non-dam improvement works including distribution system upgrades should be considered on a full cost recovery basis, consistent with Australian and Queensland government policy. Pricing will be considered further as part of Sunwater's separate investigation and assessment of relevant distribution system capacity constraints.

12.6 Next stage plan

12.6.1 Overview

It has been recommended that the preferred option progresses to a Stage 2 DBC. The plan to deliver this next stage of the business case is summarised below, including the key governance, scope, and program requirements.

12.6.2 Governance

12.6.3 Project owner

Sunwater will continue to be the project owner for PDIP. For the Stage 2 DBC, the ownership for preparing the DBC shall transfer from DRDMW to Sunwater. Sunwater is well placed to deliver this role as it has a wealth of experience and expertise in the planning, design, and delivery of dam improvement projects.

12.6.4 Sunwater project team

It is proposed that the project team be comprised of Sunwater personnel, supported by key State government departments, Sunwater's Technical Review Panel and other technical advisors as required. Refer to Table 101 for the proposed governance structure for the Stage 2 DBC.

The planning and delivery of major water resource remedial works is a substantial task that requires the establishment of a dedicated and experienced project team. A Project Director has been assigned to progress Stage 2 and has responsibility for the delivery of the project. The Project Director will be supported by technical managers delivering various aspects of the project. The Project Director will report to a Project Steering Group (PSG) who in turn reports to the Sunwater Board and Shareholding Ministers as required.

The majority of the Sunwater project team has recently delivered and/or are currently participating in similar works for the Paradise Dam Essential Works, Fairbairn Dam Improvement projects and the Rookwood Weir project.

12.6.5 Advisors

As described in chapter 4, Sunwater's Technical Review Panel (TRP) will provide the key review and advisory role for Stage 2. Sunwater will engage an engineering company to progress the detailed design of the preferred Proposal Option for the Stage 2 DBC. Independent advisors will also be engaged by Sunwater as described in Table 101.

12.6.6 Project Steering Committee

Similar to the Stage 1 DBC, there will be a Project Steering committee (PSC) for Stage 2, however membership will change slightly. The PSG will be ultimately accountable for the successful delivery of the project, providing project leadership, direction, and oversight to the project. The chair of the PSC will be Sunwater's Project Director (currently DRDMW). The PSC will include representatives from the Shareholding Ministers' departments, namely Department of Regional Development, Manufacturing and Water (DRDMW), Queensland Treasury and the Department of State Development, Infrastructure, Local Government and Planning (DSDILGP).

Table 101 Stage 2 DBC proposed governance structure

Team	Representatives	Roles and responsibilities
Chief Development Officer	Sunwater	The CDO will be responsible for Chairing the PSC, providing leadership of agenda items and managing meetings and member discussions.

Team	Representatives	Roles and responsibilities
Project Director	Sunwater	The PD is the senior person responsible for the delivery of the project and ensuring that the project meets broader Sunwater and Government requirements.
Project Steering Committee (PSC)	Sunwater DRDMW DSDILGP Treasury DPC	The PSC will provide direction, overall guidance, and leadership in the development of the Stage 2 DBC. It is responsible for making decisions and/or endorsing recommendations, considering and approving the business case prior to progressing through further approval processes, including final submission to the State. It considers and confirms the position on policy or management for the project. Sunwater will chair the PSC.
Sunwater Technical Review Panel (TRP)	External Subject Matter Experts	The TRP comprises interdisciplinary external independent technical experts engaged by Sunwater to provide assurance through peer review of design, constructability, operability, maintenance, dam safety considerations for the project. For PDIP, the TRP performs an assurance function for Sunwater as asset owner, the Sunwater Board and the Queensland Government's Dam Safety Regulator.
Sunwater Project Team	Project Manager Design Manager	Sunwater's project team represents Sunwater as the project proponent, managing the DBC process by overseeing the engineering design, input studies and finalisation of the detailed business case.
Technical advisors	To be confirmed	Preliminary engineering design of preferred proposal option. Undertake environmental, social impact and sustainability assessments. Develop a risk adjusted delivery estimate, schedule delivery model analysis and implementation plan. Prepare the financial and commercial analysis

Source: Sunwater

12.6.7 Scope

The scope, program and budget for Stage 2 of the DBC is to be determined by DRDMW and Sunwater and may include (but is not limited to) the following:

1. Hydrology and flood frequency review
2. Preliminary design and scope definition
3. Constructability review
4. Revised dam safety risk assessment
5. Delivery model analysis
6. Hydraulic and computational fluid dynamics (CFD) modelling
7. Project costing and constructability review
8. Queensland and Commonwealth Government environmental and planning approvals
9. Cultural heritage and Native Title considerations.
10. Legal and regulatory considerations
11. Socio-economic assessment
12. Sustainability assessment
13. Financial assessment

The delivery of the Stage 2 DBC will align with the BCDF.

12.7 Recommendations

It is recommended that Proposal Option 1 proceeds as follows:

- Sunwater to lead the next stage of project development (Detailed Business Case Stage 2) for returning Paradise Dam to its original full supply level (Dam Option 1).
- Separately, Sunwater to further investigate and assess relevant distribution system capacity constraints.