9 REFERENCE PROJECT

CHAPTER SUMMARY AND CONCLUSIONS:

This chapter provides an overview of the NDMIP objectives, likely outcomes and implications of a 'do nothing' approach. Importantly, this chapter provides an overview of the scope, timing and cost of the identified Reference Project/s that are assessed against the defined base case (refer Chapter 8).

- The primary objective of the NDMIP is to support agricultural and industrial users in the short to medium term (10-20 years) and provide additional water security for urban users in the long-term (20- 50 years). This objective responds to the identified service need (refer Chapter 5)
- Reference Project 1 would deliver a new Nullinga Dam and required distribution infrastructure capable of supporting an allocation of 58,000 ML/a. Two sub-options have been considered as part of this DBC.
  - Reference Project 1A, Standalone Dam (58,000ML). Nullinga Dam would only supply new customers with new water allocations and have separate water sharing rules to the MDWSS. Distribution infrastructure would include two proposed pipelines, Cairns and A3 Walsh River.
  - Reference Project 1B, Conjunctive Dam (58,000ML). Nullinga Dam and Tinaroo Falls Dam would represent two water supply sources supplying customers within the MDWSS. Distribution infrastructure includes an upgrade of the Arriga Main Channel.
- Reference Project 2 would deliver a new Nullinga Dam and associated distribution infrastructure and upgrades capable of supporting an allocation of 74,000 ML/a. Three sub-options were considered as part of this DBC, including:
  - Reference Project 2A, Standalone Dam (74,000ML). Nullinga Dam would only supply new customers with new water allocations and have separate water sharing rules to the MDWSS. Distribution infrastructure would include two proposed pipelines, Cairns and A3 Walsh River.
  - Reference Project 2B, Partial Conjunctive Dam (74,000ML). Nullinga Dam to operate in conjunction with Tinaroo Falls Dam, noting not all customers could be supplied from both sources. Distribution works include an upgrade of Arriga Main Channel and a new A3 Walsh River Pipeline.
  - Reference Project 2C, Full Conjunctive Dam (74,000ML). As with 2B, Nullinga Dam and Tinaroo Falls Dam would be operated as the water supply sources for the MDWSS, though the distribution infrastructure would be constructed to allow water to be supplied from any storage to every customer at any time. Distribution works include upgrade of Arriga Main Channel and a new A3 West Barron Pipeline
- Upgraded channel works to be undertaken under the Reference Projects includes Arriga Channel system works, including duplication and replacement of pressurised and non-pressurised pipelines (for Reference Project 1B and 2B)

CHAPTER SUMMARY AND CONCLUSIONS:

- Dam infrastructure for the Reference Projects includes:

CharaCteristic	Reference Project 1	Reference Project 2
Description	New Nullinga Dam	New Nullinga Dam
FSL	545m AHD	556m AHD
Main Dam Crest Level	550.70m AHD	561.30m AHD
Capacity	256,262 ML at FSL	518,497 ML at FSL
Yield	58,000 ML MP	74,000 ML MP
Inundation Surface Area	1,996 ha at FSL	2,797 ha at FSL
Dam Height (Max)	54.7m	65.3m
Wall Length	635m	703m
Concrete Volume	375,000m^3	586,968m^3
Outlet Works Pipe Size	2 No. DN2200	4 No. DN2200
Outlet Works Flow (Max at FSL)	2 x 40 m3/s	4 x 40 m3/s
Design Life	100 years	100 years
Saddle Dam - Type - Height (Max) - Width (widest point) - Length (Max) - Material Volume	 - Zoned earth and rockfill - 10.2m - 49m - 1,035.7m - 140,252 m3	 - Zoned earth and rockfill - 19.8m - 109m - 1,631.4m - 609,556 m3
Fishway	A fish lock for downstream migration and a fish lift for upstream migration	A fish lock for downstream migration and a fish lift for upstream migration

- New distribution infrastructure includes new pipelines for several Reference Projects, as identified below.

Element	Cairns Pipeline	A3 Walsh River Pipeline	A3 West Barron Pipeline
Reference Project (Sub-option)	1A and 2A	1A and 1B, 2A and 2B	2C only
Length	9,018m	7,638m	6,240m
Material	High density polyethylene	High density polyethylene	High density polyethylene
Pipeline Diameter	1,400mm (all PN4.0 pressure pipe)	800mm (all PN4.0 pressure pipe)	Range of 800 mm to 1,200 mm (and range from PN4.0 to PN6.4 pressure pipe)
Pump head	32m	9m	Gravity
Pump station location	At Nullinga Dam	At Nullinga Dam	Not Applicable
Pipeline discharge location	West Barron Main Channel	Arriga	Arriga
Nullinga Dam Outlet Level	EL515m	EL515m	Not Applicable

CHAPTER SUMMARY AND CONCLUSIONS:

- Capital costs for the Reference Projects are presented below, in addition to the average annual real operating cost.

Reference Project	Real Upfront Capital Cost $M 2018-19	Nominal Upfront Capital Cost $M	Real average annual OPEX* $M
1A	755.8	1070.9	4.1
1B	713.7	1009.5	2.0
2A	1068.0	1493.4	5.1
2B	1022.8	1429.3	2.5
2C	999.1	1395.7	2.2

*NB. The average annual operating costs presented here include provision of major refurbishment works throughout the 30 years of operations. These costs are treated as capital in the financial and commercial analysis in the DBC.

- Milestone dated for the Reference Projects are presented below.

Reference Project	Planning Start Date	Construction Start Date	Operations Start Date	Water Sales Start Date
1A	July 2020	June 2027	July 2030	July 2034
1B	July 2020	June 2027	Jan 2031	Jan 2035
2A	July 2020	June 2027	Jan 2031	Jan 2035
2B	July 2020	June 2027	Jan 2031	Jan 2035
2C	July 2020	June 2027	Jan 2031	Jan 2035

9.1 Purpose

This Chapter provides an overview of the scope, timing and cost of the identified Reference Project/s that are assessed against the defined base case (refer Chapter 8). It also provides an overview of the adopted project objectives, likely outcomes and implications of a ‘do nothing’ approach.

9.2 Project objectives and outcomes

The primary objective of the NDMIP is to support agricultural and industrial users in the short to medium term (10-20 years) and provide additional water security for urban users in the long-term (20- 50 years). This objective responds to the identified service need (refer Chapter 5).

In the short-term, it is recognised that the service need is an opportunity, rather than a problem, with no user group forecast to catastrophically run out of water supply in this timeframe. However, there will be a point in time when CRC and MSC, having exhausted more cost-effective water supply options, will either need to develop an urban focused dam (potentially at the Nullinga Dam site) or other climate dependent or independent (such as desalination) facility to meet urban and industrial water demand.

Successfully meeting the primary objective would result in the outcomes and benefits identified in Table 9-1.

Table 9-1 Anticipated outcomes and benefits from meeting the primary objective

OUTCOME	DESCRIPTION
Supporting new / expanded agricultural production	Associated benefit - Additional water available for customers in the study area - Increase in regional employment from increased agricultural production - Enhanced usage of water delivery infrastructure for agricultural production - Enhanced confidence to invest in long term business operations and succession opportunities
Improved resource allocation	Associated benefit - Improved use of existing resources through changing water business practices - Increase in value and flexibility of existing water allocations
Supporting economic growth	Associated benefit - Change in land use to higher value per hectare crops in suitable areas. Monetised in the CBA

9.3 Implications of not proceeding

Limited ability to respond to short- and long-term future demands for water resources will result if the NDMIP is not progressed in preparedness for future demands from existing and new customers, drought and meeting the required reliability of supply for the CRC in the long term.

It is acknowledged that if the NDMIP does not proceed:

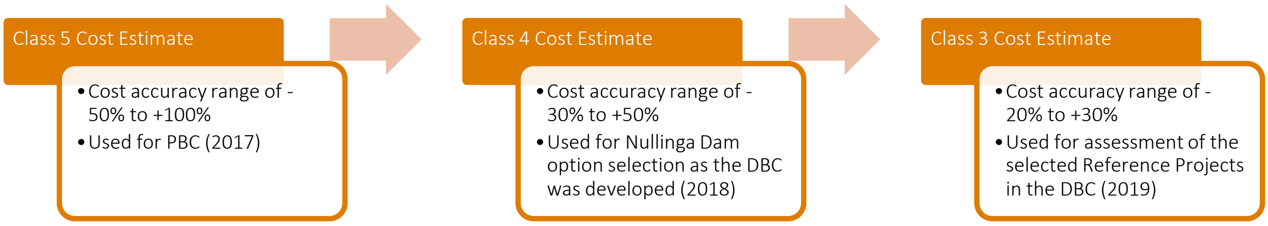
- no additional water allocations, above that which will be delivered under the base case, will be available for agriculture use in the Study Area, foregoing the potential for the growth of the regional agriculture sector in the region, both through the provision of additional and more certain water allocation
- continued reliance on Behana Creek and Copperlode Falls Dam as the primary sources of supply for urban water users, could leave CRC exposed to a water supply security risk from the early 2060 onwards.

A detailed assessment of each user group under the Base Case is provided in Chapter 8.

9.4 Cost development

The cost estimation development process, from the PBC to the finalisation of the DBC is shown below.

Figure 9-1 Cost estimation development process



The capital cost estimate for the PBC was based on a Sunwater report completed in 2008. The high-level capital cost estimate in the PBC was based on a 540 m AHD dam with a 168,000 ML capacity, which yields 44,000 ML/a after losses. Based on the preliminary level of design documentation, the PBC estimates typically comply with a Class 5 estimate[99], with an expected accuracy range of up to +100 per cent.

Since the PBC, there has been an increase in identified demand for water to meet agricultural (at a prescribed price) and future urban requirements. In addition to an increase in identified demand, the relevant design guidelines have been updated, the design status including hydrological analysis and time until first water is available from a Nullinga Dam has further developed in the ten years since the completion of the initial capital cost estimate, resulting in the following major changes from the PBC including:

- extension of hydrologic model data to capture the federation and millennium droughts has reduced the yield from the catchment, requiring a larger dam to deliver the increased yield
- Australian National Committee on Large Dams (ANCOLD) design guidelines for Concrete Gravity Dams have been revised since the Concept Investigation report were released, increasing the structural requirements of the dam.

In addition, these key drivers have resulted in the following major changes to project development and delivery timeframes from the PBC including:

- increased understanding of pre-construction activities including consideration by Queensland Government, conclusion of commercially binding agreements with future customers, and continuation and further development of design and procurement activities resulting in additional time and costs
- increased understanding of the risks, resources and timeframes required to develop an approved Environmental Impact Statement (EIS) has increased, resulting in additional time and costs
- increased understanding of risks of construction of Nullinga Dam options.

The DBC presents a selection of larger dam solutions (than that identified within the PBC) that will take longer to implement to meet the identified service need, resulting in an increase in the capital cost estimates for the Reference Projects. The DBC includes an increase in capital costs from $323 million (P50, Real $2017) in the PBC to $703 million (P90, Real $2019) for the smaller Reference Project 1B (excluding $11 million of delivery infrastructure) identified within the DBC.

Concept engineering designs and cost estimates, in addition to hydrological analysis, were developed for a range of different sized Nullinga Dam options, to inform a comparative CBA, resulting in larger dam options identified in the DBC to service the increased demand. These concept designs were further progressed and developed to preliminary design level and included updated hydrology, and interpretation of available

[99] Ibid

information on the geology and geotechnical conditions and published seismicity of the area. The dam options included within the DBC include:

- Reference Project 1: 256,000 ML capacity / 58,000 ML/a yield
- Reference project 2: 518,000 ML capacity / 74,000 ML/a yield

This increase in project definition from the PBC to DBC stage, results in the subsequent increase in costs from the PBC:

- increase in costs due to correction for contingency allowed from the PBC P50 capital cost estimate to DBC P90 capital cost estimate, including allowance for:
  - supply of a portion of quarry materials from external off-site quarry[100], if not available from within site boundary
  - demobilising during expected wet weather events during wet weather season in North Queensland
- increase in direct costs due to increase in size of Reference Project from:
  - 540 m AHD to 545 m AHD dam, for Reference Project 1, which includes a main dam which is 2 m higher and 60 m longer than the PBC dam solution, and 42,000 m^3 (13 per cent) larger, and the associated saddle dam is 5 m higher and over 300 m longer and 84,000 m^3 (250 per cent) larger than the saddle dam identified within the PBC
  - 540 m AHD to 556 m AHD dam, for Reference Project 2, includes a main dam which is 12 m higher and 130 m longer than the PBC dam solution, and 354,000 m^3 (100 per cent) larger, and the associated saddle dam is 16 m higher and over 900 m longer and 553,000 m^3 (1,000 per cent) larger than the saddle dam identified within the PBC
- increase in time related costs due to increase in overall project development and implementation duration from four to eleven years, to accommodate the detailed planning approval, design and procurement processes for a more complex dam option than envisioned under the PBC, and to include an increase in anticipated construction duration from two to three and a half years
- increase in costs due to provision for:
  - increase in size for various dam components, including stilling basin, fish lock and clearing for inundation areas
  - increase in allowance for project planning and approval related activities including EIS development and land acquisition costs
  - required distribution infrastructure including pipelines
- allowance for working in remote location including camp development and facilities operations and fly-In fly- out workforce.

As discussed in Section 3.2, Class 4[101] estimates were prepared early in the development of design documentation for the DBC and were utilised in the identification and selection of preferred Nullinga Dam options (refer Section 7.2.4).

The capital costs presented in this Chapter, and utilised in the economic, financial, commercial and affordability analysis (Chapters 15, 18 and 19) are based on Class 3[102] cost estimates, which has an expected accuracy range of between –20% and +30%, and reflect the preliminary engineering design, including greater project definition, particularly as relates to topography, ground conditions, construction schedule, and hydrology.

[100] This is based on findings from preliminary site investigations undertaken as part of the preliminary design development process
[101] Ibid
[102] Ibid

9.5 Reference Project 1 – Nullinga Dam (58,000ML)

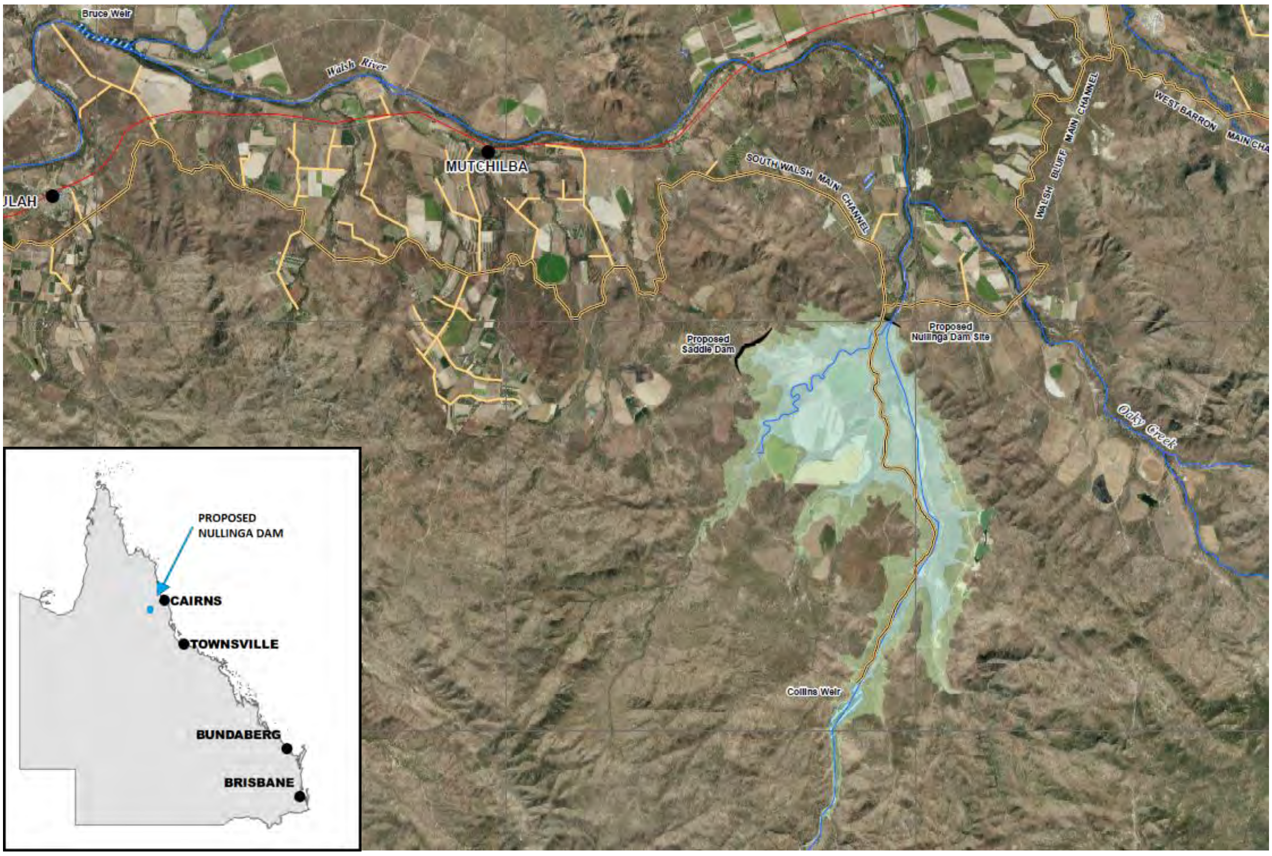
9.5.1 Overview and location

Reference Project 1 would deliver a new Nullinga Dam and required distribution infrastructure capable of supporting an allocation of 58,000 ML/a. Two sub-options have been considered as part of this DBC.

- Reference Project 1A, Standalone Dam (58,000ML)
  - Nullinga Dam would only supply new customers and would represent a new source of supply with new water products/water allocations and separate water sharing rules to the MDWSS
  - Distribution infrastructure would include two proposed pipelines, Cairns and A3 Walsh
- Reference Project 1B, Conjunctive Dam (58,000ML)
  - Nullinga Dam and Tinaroo Falls Dam would represent two water supply sources supplying customers within a single water supply scheme
  - Distribution infrastructure includes an upgrade of the Arriga Main Channel

The proposed Nullinga Dam site is located at AMTD 259.6 km on the Walsh River, and is approximately 55 km southwest of Cairns and 24 km south south-west of Mareeba. Figure 9-2 identifies the proposed Nullinga Dam site, and the anticipated scale of the dam under Reference Project 1 and Reference Project 2.

Figure 9-2 Location of Nullinga Dam site



The Walsh River and its sub-basin form a major part (8,958.1 km²) of the Mitchell drainage basin. Headwaters are situated on the Atherton tablelands west of the Great-dividing range flowing westward to meet the Mitchell River before extending to the Gulf of Carpentaria. The dam site is approximately 480 km upstream of the mouth of the Mitchell River.

9.5.2 Scope of Reference Project 1A and 1B

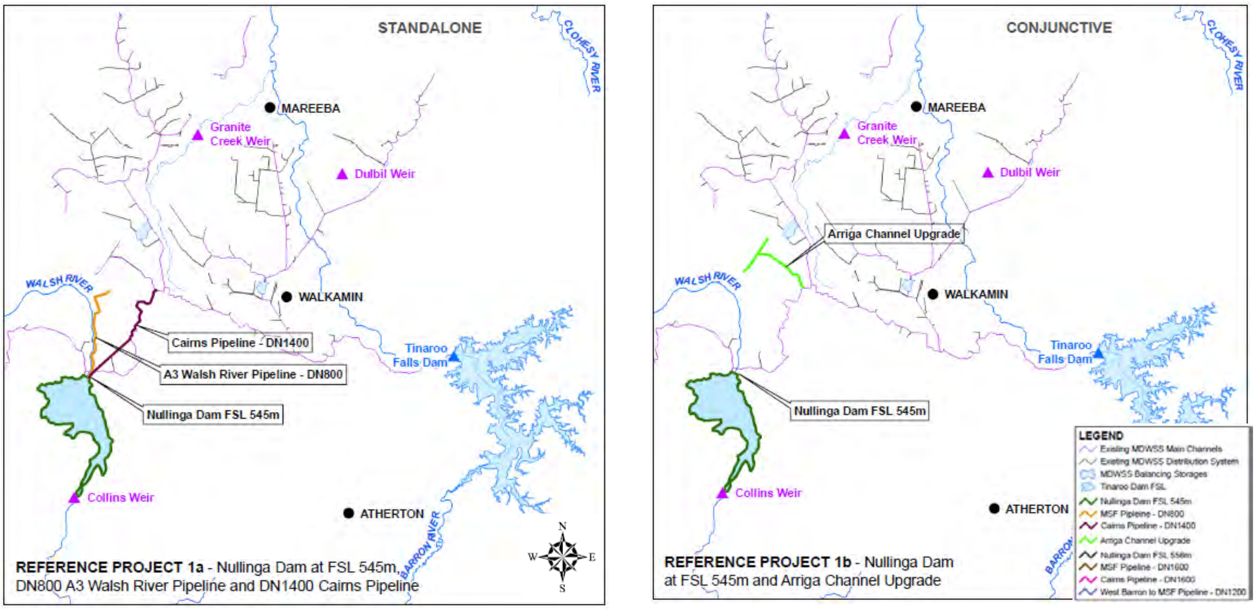
This section provides a summary of the preliminary design components for Reference Project 1A and 1B, including:

- dam infrastructure (refer Section 9.5.2.1)
- supporting infrastructure (refer Section 9.5.2.2)
- constructability considerations (refer Section 9.5.2.3)

Figure 9-3 provides a snapshot of the proposed works to be undertaken under the two sub-options, with detail on these elements provided further below.

Figure 9-3 Scope of works for Reference Project 1

1A – Standalone | 1B - Conjunctive



9.5.2.1 Dam infrastructure

A preliminary design was prepared in support of this Reference Project. As shown in Table 9-2, this solution would deliver a new dam at the identified Nullinga site (refer Figure 9-2), with a FSL of 545m AHD, and total capacity of approximately 256,000ML.

The main dam would be constructed using Roller Compacted Concrete (RCC), and the saddle dam would be constructed using compacted earth and rockfill. Table 9-2 outlines the key design characteristics of the proposed dam infrastructure.

Table 9-2 Reference Project 1A: Nullinga Dam Characteristics

CHARACTERISTIC	DESCRIPTION
FSL	545m AHD
Main Dam Crest Level	550.70m AHD
Capacity	256,262 ML at FSL
Yield	58,000 ML MP
Inundation Surface Area	1,996 ha at FSL
Dam Height (Max)	54.7m
Wall Length	635m
Concrete Volume	375,000m3
Outlet Works Pipe Size	2 No. DN2200
Outlet Works Flow (Max at FSL)	2 x 40 m3/s
Design Life	100 years
Saddle Dam - Type - Height (Max) - Width (widest point) - Length (Max - Material Volume	 - Zoned earth and rockfill - 10.2m - 49m - 1,035.7m - 1,40,252 m3
Fishway	Fish lock for downstream migration, fish lift for upstream migration

For the main dam arrangement, a 122m wide spillway has been adopted, to pass the PMF flood event[103], along with a 55m long USBR Type 2 dissipator (see Figure 9-4).

Figure 9-4 Main Dam Spillway and Dissipator

Other design assumptions for the main dam arrangement include:

- concrete for main spillway and dissipator to be made of high cementitious content, assumed to be 150 kg of cementitious content per cubic metre of concrete
- placement of the RCC in 300 mm horizontal lift joints was adopted and, whenever possible, in continuous runs across the river valley
- on the downstream face of the spillway section a single bulb waterstop runs from foundation level, up to and around the perimeter of the ogee

[103] Tinaroo Falls Dam raising concept has been designed to pass the Possible Maximum Flood however this is not mandatory and subject to As Low As Reasonable Possible assessment

- upstream and downstream waterstops will be embedded (at least) 0.5 m into the foundation rock and grouted with low skink concrete.
- a waterstop will also be installed around the perimeter of the drainage gallery at the contraction joints
- external 0.6 m and 0.4 m thick GERV layers have been adopted for the upstream and downstream faces of the dam, respectively (to improve watertightness)
- a 3 m wide by 3.7 m high gallery was adopted, to collect drainage and seepage, for drilling and grouting of the foundation grout curtain, instrumentation access, inspection
- drainage holes drilled at 3 m centres were adopted to a minimum depth of 10 m
- non-overflow section of the dam has a 6 m wide crest, a vertical upstream slope, and a downstream slope of 0.75(V):1(V)
- an ogee crest shape was adopted in view of its hydraulics efficiency. The ogee cap would be constructed of reinforced conventional concrete (rather than RCC)

The proposed saddle dam for this Reference Project will comprise a relatively long, low height structure, which suggests an embankment type dam would be appropriate and would be located west (refer Figure 9-5) of the main dam and is an earth and rockfill design.

Figure 9-5 Saddle dam location

It is noted that the saddle 'is relatively broad, with a minimum ground level of approximately EL 543 m AHD', with a second low point on the reservoir rim, further south.

It is anticipated that infilling the saddle will require a 1 km dam length.

The proposed saddle dam would have a crest elevation of 551.7 m AHD and a maximum wall height of approximately 10.7 metres.

Figure 9-6 Saddle dam configuration

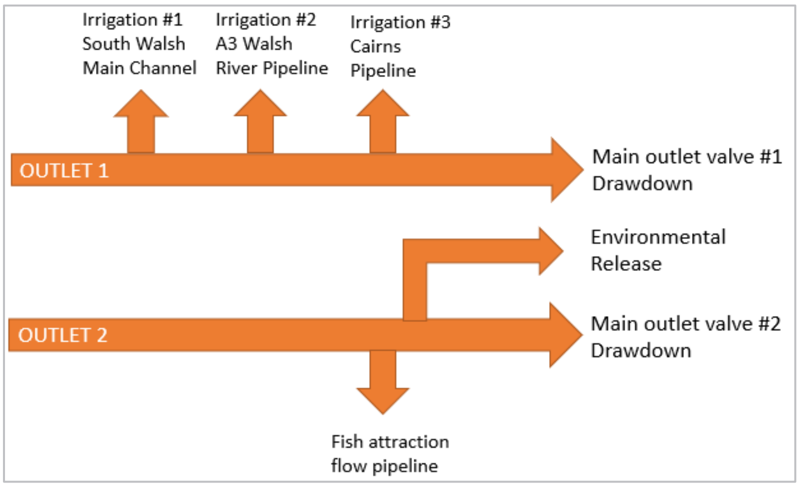
Other design elements and assumptions adopted for the saddle dam include:

- a 1-meter freeboard is included for the PMF flood event
- a traditional embankment section comprising central earthfill core, 2-stage downstream filters, upstream transition zone and rockfill shoulders
- zoned earthfilled embankment, incorporating downstream filter zones, riprap on the upstream face and an outer surface on the downstream dace to protect against weathering and erosion.
- rockfill and filter/transition materials from site to be utilised, and complement the expected quarrying and processing operations needed for the main dam
- foundation depth to be 2.5 m below the natural surface level along the full length and width of the saddle dam

While the preliminary design for the main dam and saddle dam are identical for Reference Project 1A and 1B, the outlet works are designed to cater specific supporting infrastructure. Overall, the proposed outlet works, adopted for either sub option, caters for irrigation supply, environmental flow supply, emergency drawdown of the reservoir and fishway attraction flow supply.

Figure 9-7 presents a diagram of the outlet works for Reference Project 1A.

Figure 9-7 Proposed outlet works for Reference Project 1A



The outlet works for 1A include:

- one combined intake structure on the upstream face of the main dam
- two outlet conduits
- one outlet valve pit and chamber on downstream of the dam
- two isolation and outlet regulating valves
- four irrigation and fishway attraction flow water supply offtakes and isolation valves
- one outlet work channel
- a fish lock for downstream migration

For Reference Project 1B, there are only two irrigation and fishway attraction flow water supply offtakes and isolation valves, as opposed to four for Reference Project 1A. Table 9-3 summarises key design considerations for the irrigation outlet works. Additional design information on the supporting water distribution infrastructure is provided in Section 9.5.2.2.

Table 9-3 Design considerations for irrigation outlets

Element	Annual Demand (ML/a)	Size	Flow rate for 6 hours a day (m^3/s)	Flow Velocity through offtake (m/s)
South Walsh Main Channel	32,400	DN1200	4.12	3.63
Cairns Pipeline	14,000	DN800	1.78	3.53
A3 Walsh River Pipeline	32,000	DN1200	4.06	0.59

A fishway has been included in the preliminary design to allow passage of fish both upstream and downstream of the main dam wall. The design elements are the same for both Reference Project 1A and 1B. A fish lock has been included for downstream migration and a fish lift has been included for upstream migration.

Table 9-4 outlines the design functionality of the fish lift and fish lock.

Table 9-4 Design criteria (functionality)

Feature	Fish Lift	Fish Lock
Type	Travelling hopper transfer over crest of dam to transfer migrating fish upstream	Fish lock with multilevel entrance from reservoir
Operation	Fully automated control with manual override	Fully automated control with manual override
Tailwater Operating Range - Min - Max	- EL 503.0 (estimated cease to flow level of river) - EL 506.0 (estimated 1 in 5-year post-dam flood level)	- EL 503.0 (estimated cease to flow level of river) - Estimated river level at maximum release from outlet works with no flow over spillway.
Reservoir Operating Range - Min - Max	- EL 523.0 - FSL +2m, i.e. 547m AHD	- 527m AHD - FSL + 2m, i.e. 547m AHD

9.5.2.2 Distribution infrastructure

Table 9-5 outlines the supporting water distribution infrastructure to be delivered for Reference Project 1A. This includes a Cairns and A3 Walsh River pipelines.

The Cairns Pipeline preliminary design allows for:

- water to be pumped from an outlet point at around EL515m at the downstream end of Nullinga Dam
- the discharge of water into the West Barron Main Channel at approximately chainage 29.3km (Water Level 540m)
- water to be conveyed along the West Barron Main Channel towards the West Barron Balancing Storage and discharged at chainage 32.9km into a small existing gully and then into Granite Creek (approximately 200m), which joins the Barron River on the northern outskirts of Mareeba.

The A3 Walsh River pipeline preliminary design allows for:

- allocation to be delivered during a peak flow time (Nov – mid March)
- a design flow rate of 7,000ML over 150 days, or alternatively it could also be used to deliver 14,000ML/a through on a consistent supply basis
- potential extension in the future to capture additional demand areas, noting this is not currently cost effective.

Table 9-5 Distribution infrastructure for Reference Project 1A

Element	Cairns Pipeline	A3 Walsh River Pipeline
Length	9,018m	7,638m
Material	High density polyethylene	High density polyethylene
Pipeline Diameter	1,400mm (all PN4.0 pressure pipe)	800mm (all PN4.0 pressure pipe)
Pump head	32m	9m
Pump station location	At Nullinga Dam	At Nullinga Dam
Pipeline discharge location	West Barron Main Channel	Arriga
Nullinga Dam Outlet Level	EL515m	EL515m

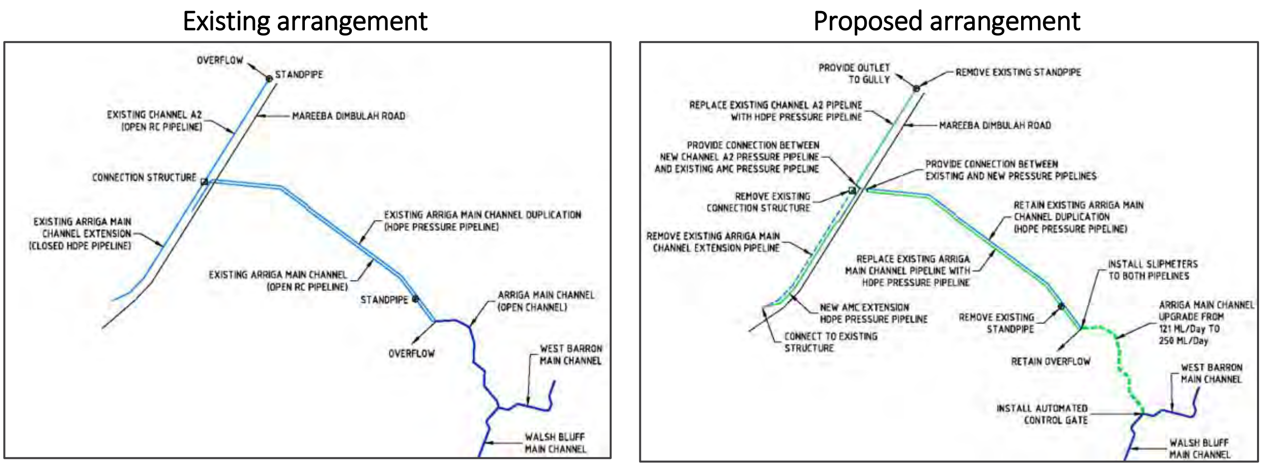
While these pipelines are not required for Reference Project 1B, an additional upgrade of the Arriga Channel would be required. Currently this channel is at capacity having already been upgraded in the past to deliver as much water to the large sugar cane landholdings in the area. The current Arriga system is a combination of:

- open earth channel (0m to 1442m)
- a non-pressure pipeline (1442m to 6240m)

- a parallel pressurised pipeline (1442m to 4950m)
- a non-pressurised lateral pipeline (1320m long)

The older non-pressure pipelines cannot be pressurised and replacement pressure pipelines and an upgrade of the open earth channel would be required, as shown in Figure 9-8.

Figure 9-8 Arriga Main Channel Upgrade Concept for Reference Project 1B



9.5.2.3 Constructability

Constructability issues considered in the preliminary design include diversion requirements and sequencing, road works and traffic management, material sourcing, power supply, environmental management and controls, and pre-construction and post-construction activities (refer Table 9-6).

Table 9-6 Constructability issues

Component	Key Issues / design elements / allowances
Diversion	▪ Walsh River to be diverted during construction through a channel ▪ diversion scheme to accommodate a 1 in 10-year flood (at a flood flow of 555 m3/s for Walsh River, based on hydrological assessments) ▪ Cofferdam – to be constructed, with an upstream crest of 514 m AHD and downstream crest of 510 m AHD. – have upstream and downstream slopes of 2.5(H):1(V) – construction methodology includes excavation of diversion channel, temporary bunds, clearing footprint, construction of embankment
Road works	Allowance in design for: ▪ for length of Collins Weir Road that is likely to be relocated ▪ upgrade of a number of major and minor creek crossings
Traffic management and local road access	Construction traffic would be greatest during the main earthworks and civil construction and includes: ▪ haulage of materials over a 24-month duration ▪ up to 200 daily heavy vehicle traffic movements would be attributable to the haulage of materials to the dam site ▪ two to three oversized vehicle loads per day during peak construction

Component	Key Issues / design elements / allowances
	Construction compounds to be accessed by heavy vehicles, including oversized vehicles transporting plant and other large items. These movements would be conducted in a controlled manner with all necessary safety and traffic management measures in place During construction traffic on Springmount Road and all other local roads in the vicinity of the dam would need to continue to operate, with appropriate detours or temporary roads put in place
Material sourcing	▪ rock material suitable for use in RCC and Conventional Concrete Mix is expected to be available on site. ▪ assumed blasting e required in the onsite quarries to enable excavation of rockfill. ▪ explosives would be placed within drill holes within the quarries. Following detonation, dozers would be used to rip and excavate quarry rock. ▪ assumed earthfill materials would be available in close proximity to the saddle dam locations, along with alluvial sands for the embankment filter materials
Power supply	▪ connection to existing 11kv (for construction and ongoing operations) ▪ allowance for temporary power generators for site facilities
Pre-construction activities	Activities to be undertaken: ▪ confirmation of property boundaries and locations of environmentally sensitive areas ▪ implementation of necessary safeguards in accordance with relevant conditions of approval to protect sensitive areas ▪ establishment of construction compounds, batch plants (as required) and access roads ▪ clearing of vegetation and processing (including recycling) of materials ▪ construction of storage access road and regrading of the catchment boundary roads for haulage and stripping of topsoil and placement into stockpiles for reuse services adjustments ▪ load, haul and placement of both natural materials (crushed rock) and manufactured materials, (concrete and asphalt) mix (if necessary) ▪ construct road pavement in practical lengths as the work is finished ▪ installation of roadside furniture including traffic barriers such as guard fencing, line marking and signposting ▪ Installation of fencing around the construction area to exclude fauna and for safety purposes. ▪ development of the construction environmental management plan (EMP) and supporting plans, controls and reporting templates ▪ implementing necessary traffic and access arrangements ▪ fencing of the catchment boundary to reduce the risk of livestock entering the construction site ▪ consultation and liaison with utility providers and road owners ▪ relocation of immediately affected utilities ▪ establish concrete batching plant
Environmental management and controls	▪ development of the construction EMP and supporting plans ▪ preparation of environmental performance reporting templates ▪ establishment of erosion and sedimentation controls included in the Erosion and Sediment Control Plan (ESCP), within the construction EMP

Component	Key Issues / design elements / allowances
	▪ All sedimentation detention basins would be sized in accordance with the requirements of Managing Urban Stormwater; 'Soils and Construction' Volume 1 4th Edition (Landcom, 2004) and Volume 2D – Main Road Construction (the Blue book) (DECC, 2008) ▪ Temporary surface drainage, erosion protection and ongoing water quality management across the site would be achieved through measures such as: – design of work areas to minimise exposure of unprotected soil to rainfall and minimise slopes on drains – temporary runoff barriers – sedimentation ponds – progressive rehabilitation as work stages are completed ▪ Vegetation clearing would be completed in a staged approach ▪ Tree and shrub vegetation would be cleared to the full supply level ▪ timber suited for milling would be sold and as much of the remaining suitable material as practicable would be mulched for use in construction site rehabilitation or made available for potential use in regional rehabilitation schemes
Post-construction (including demobilisation and rehabilitation	▪ commissioning of mechanical and electrical components would be undertaken include: – pressure testing of pipelines – full scale commissioning of fishlift and fishlock – full scale commissioning of storage outlet works ▪ wash down and removal of surplus construction equipment as stages of construction completed ▪ stabilisation of the landscape around the embankment, all roads, quarry areas and the pipeline route ▪ reuse of quality topsoil stockpiled (during site stripping activities) for landscaping, or repair of disturbed areas, or other identified opportunities ▪ rehabilitation / repair of damaged road pavement ▪ disposal of unsuitable materials

9.5.3 Timing

The overall delivery schedule for the main dam and saddle dam under Reference Project 1A and B are identical. As shown in Table 9-7, it is anticipated that Reference Project 1A would take longer to complete as a direct result of the time required to complete the identified pipelines.

Table 9-7 Reference Project 1A and 1B, delivery schedule

PHASE	REFERENCE PROJECT 1A: STANDALONE	REFERENCE PROJECT 1B: CONJUNCTIVE
EIS / PLANNING		
Start date	July 2020	
End date	June 2025	
DETAILED DESIGN		
Start Date	July 2025	
End Date	June 2027	
DAM CONSTRUCTION		
Start Date	July 2027	
End Date	June 2030	
SUPPORTING INFRASTRUCTRE		
Cairns Pipeline - Start Date - End Date	October 2029 June 2030	Not Applicable
A3 Walsh River Pipeline - Start Date - End Date	December 2029 June 2030	Not Applicable
Arriga Channel Upgrade - Start Date - End Date	Not Applicable	January 2022 Jul 2022

9.5.4 Costs

The estimated upfront real capital cost for the Reference Project 1A (standalone) is approximately $755.8M. This includes capital costs, implementation costs and risk cost provisions. In nominal terms, the total upfront costs are approximately $1,070.9M.

Table 9-8 Real and Nominal Cost Estimate for Reference Project 1A (50 years)

COMPONENT	COSTS $M Reference Project 1
Capital Expenditure	522.2
Implementation Costs	90.0
Risk Costs	143.6
Total Upfront Capital Costs – Real $M	**755.8**
Escalation	315.1
Total Upfront Capital Costs – Nominal $M	**1070.9**

Reference Project 1B is less expensive to deliver and maintain than 1A, with an estimated real upfront cost of approximately $713.7M. In nominal terms is equates to $1,009.5M.

Table 9-9 Real and Nominal Cost Estimate for Reference Project 1B (50 years)

COMPONENT	COSTS $M Reference Project 1
Capital Expenditure	500.6
Implementation Costs	78.0
Risk Costs	135.1
Total Upfront Capital Costs – Real $M	**713.7**
Escalation	295.8
Total Upfront Capital Costs – Nominal $M	**1009.5**

The average annual real operating costs for Reference Project 1A and 1B are $4.1m and $1.9m per annum respectively.[104]

[104] The average annual operating costs presented here include provision of major refurbishment works throughout the 30 years of operations. These costs are treated as capital in the financial and commercial analysis in the DBC (refer Chapter 18).

9.6 Reference Project 2 – Nullinga Dam (73,000ML)

Reference Project 2 would deliver a new Nullinga Dam and associated distribution infrastructure and upgrades capable of supporting an allocation of 74,000 ML/a. Notably, only Reference Project 2 can support potential expansion plans local producers.

Three sub-options were considered as part of this DBC, including:

- Reference Project 2A, Standalone Dam (74,000ML)
  - Nullinga Dam would only supply new customers and would represent a new source of supply with new water products/water allocations and separate water sharing rules to the MDWSS
  - Distribution infrastructure would include two proposed pipelines, Cairns and A3 Walsh River
- Reference Project 2B, Partial Conjunctive Dam (74,000ML)
  - Nullinga Dam and Tinaroo Falls Dam would represent two water supply sources supplying customers within a single water supply scheme, noting not all customers could be supplied from both sources
  - Distribution infrastructure includes an upgrade of Arriga Main Channel and a new A3 Walsh River Pipeline
- Reference Project 2C, Full Conjunctive Dam (74,000ML)
  - As with 2B, Nullinga Dam and Tinaroo Falls Dam would be operated as the water supply sources for the MDWSS, though the distribution infrastructure would be constructed to allow water to be supplied from any storage to every customer at any time
  - Distribution infrastructure, including upgrade of Arriga Main Channel and a new A3 West Barron Pipeline

This Reference Project places the dam at the same proposed site as Reference Project 1, on the Walsh River, approximately 55 km southwest of Cairns and 24 km south south-west of Mareeba. Figure 9-2, in Section 9.5.1 shows the proposed location of the dam and the anticipated footprint of the larger dam proposal, as compared with the smaller dam solution which would be delivered under Reference Project 1.

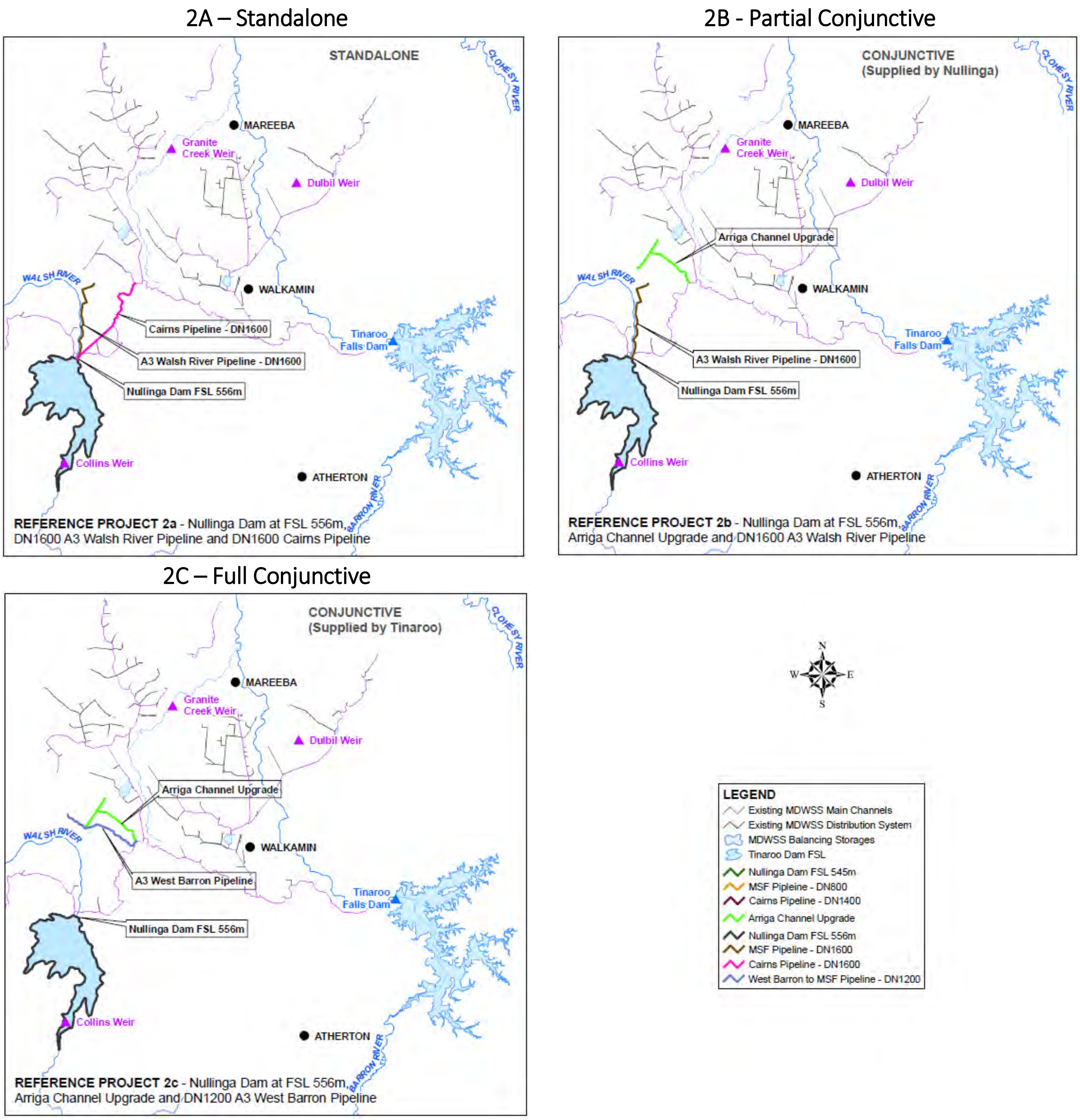
9.6.1 Scope of Reference Project 2A, 2B and 2C

This section provides a summary of the preliminary design components for Reference Project 2A, 2B and 2C, including:

- dam infrastructure (refer Section 9.6.1.1)
- supporting infrastructure (refer Section 9.6.1.2)
- constructability considerations (refer Section 9.6.1.3)

Figure 9-9 provides a snapshot of the proposed works to be undertaken under the two sub-options, with detail on these elements provided further below.

Figure 9-9 Scope of works for Reference Project 2



9.6.1.1 Dam infrastructure

This solution would deliver a new dam at the identified Nullinga site with a FSL of 556m AHD, and total capacity of approximately 518,497ML. The main dam would be constructed using RCC, and the saddle dam would be constructed using compacted earth and rockfill. Table 9-10 provides a summary of key metrics for this Reference Project.

Table 9-10 Reference Project 2A: Nullinga Dam Characteristics

CHARACTERISTIC	DESCRIPTION
FSL	556m AHD
Main Dam Crest Level	561.30m AHD
Capacity	518,497 ML at FSL
Yield	74,000 ML MP
Inundation Surface Area	2,797 ha at FSL
Dam Height (Max)	65.3m
Wall Length	703m
Concrete Volume	586,968m3
Outlet Works Pipe Size	4 No. DN2200
Outlet Works Flow (Max at FSL)	4 x 40 m3/s
Design Life	100 years
Saddle Dam - Type - Height (Max) - Width (widest point) - Length (Max - Material Volume	 Zoned earth and rockfill 19.8m 109m 1,631.4m 609,556 m3
Fishway	A fish lock for downstream migration and a fish lift for upstream migration

For the main dam arrangement, a 122m wide spillway has been adopted, to pass the PMF flood event, along with a 55m long USBR Type 2 dissipator (see Figure 9-4). This is the same arrangement as Reference Project 1, which was deemed appropriate based on hydrological modelling undertaken for the DBC.

Figure 9-10 Main Dam Spillway and Dissipator

Other design assumptions for the main dam arrangement that were the same for Reference Project 1 and 2 include:

- concrete for main spillway and dissipator to be made of high cementitious content, assumed to be 150 kg of cementitious content per cubic metre of concrete
- placement of the RCC in 300 mm horizontal lift joints was adopted and, whenever possible, in continuous runs across the river valley
- on the downstream face of the spillway section a single bulb waterstop runs from foundation level, up to and around the perimeter of the ogee
- upstream and downstream waterstops will be embedded (at least) 0.5 m into the foundation rock and grouted with low skink concrete.

- a waterstop will also be installed around the perimeter of the drainage gallery at the contraction joints
- external 0.6 m and 0.4 m thick GERV layers have been adopted for the upstream and downstream faces of the dam, respectively (to improve watertightness)
- a 3 m wide by 3.7 m high gallery was adopted, to collect drainage and seepage, for drilling and grouting of the foundation grout curtain, instrumentation access, inspection
- drainage holes drilled at 3 m centres were adopted to a minimum depth of 10 m
- non-overflow section of the dam has a 6 m wide crest, a vertical upstream slope, and a downstream slope of 0.75(V):1(V)
- an ogee crest shape was adopted in view of its hydraulics efficiency. The ogee cap would be constructed of reinforced conventional concrete (rather than RCC)

The proposed saddle dam for Reference Project 2 will be approximately 600 metres longer than for Reference Project 1. It would have a crest elevation of 562.3 m AHD and a maximum wall height of approximately 21.3 metres.

Figure 9-11 Saddle dam configuration for Reference Project 2

Other design elements and assumptions adopted for the saddle dam under Reference Project 2 are the same as for Reference Project 1, including:

- a 1-meter freeboard is included for the PMF flood event
- a traditional embankment section comprising central earthfill core, 2-stage downstream filters, upstream transition zone and rockfill shoulders
- zoned earthfilled embankment, incorporating downstream filter zones, riprap on the upstream face and an outer surface on the downstream dace to protect against weathering and erosion.

- rockfill and filter/transition materials from site to be utilised, and complement the expected quarrying and processing operations needed for the main dam
- foundation depth to be 2.5 m below the natural surface level along the full length and width of the saddle dam

Figure 9-7 presents a diagram of the outlet works for Reference Project 2A has the same outlet arrangement as Refence Project 1A (refer Figure 9-7, in Section 9.5.2.1). Table 9-11 outlines the outlet works for the three sub-options under Reference Project 2.

Table 9-11 Outlet works for Reference Project 2A, 2B and 2C

Component	Reference Project 2A	Reference Project 2B	Reference Project 2C
Intake structure	1	1	1
Outlet conduits	2	2	2
Isolation and outlet regulating valves	1	1	1
Irrigation and fishway offtakes	4	3	2
Fishlock for downstream migration	Yes	Yes	Yes

A fish lock has been included for downstream migration and a fish lift has been included for upstream migration. The design elements for these components is as per Reference Project 1 (refer Table 9-4, Section 9.5.2.1).

9.6.1.2 Distribution infrastructure

As previously identified, the required distribution works for under this Reference Project include:

- Reference Project 2A, two new pipelines for Cairns and A3 Walsh River
- Reference Project 2B, one new pipeline, A3 Walsh River and an upgrade of the Arriga Main Channel
- Reference Project 2C, one new pipeline, A3 West Barron and an upgrade of the Arriga Main Channel

Table 9-12 outlines the proposed new pipelines that are to be delivered under one or more of the above sub options.

Table 9-12 New distribution pipelines under Reference Project 2

Element	Cairns Pipeline	A3 Walsh River Pipeline	A3 West Barron Pipeline
Sub-option	2A only	2A and 2B	2C only
Length	9,018m	7,638m	6,240m
Material	High density polyethylene	High density polyethylene	High density polyethylene

Element	Cairns Pipeline	A3 Walsh River Pipeline	A3 West Barron Pipeline
Pipeline Diameter	1,400mm (all PN4.0 pressure pipe)	800mm (all PN4.0 pressure pipe)	Range of 800 mm to 1,200 mm (and range from PN4.0 to PN6.4 pressure pipe)
Pump head	32m	9m	Gravity
Pump station location	At Nullinga Dam	At Nullinga Dam	Not Applicable
Pipeline discharge location	West Barron Main Channel	Arriga	Arriga
Nullinga Dam Outlet Level	EL515m	EL515m	Not Applicable

The upgrade of the Arriga Main Channel under Reference Project 2B and 2C is as per the scope outlined for Reference Project 1B. This upgrade would replace older non-pressure pipelines, and pressure pipelines and an upgrade of the open earth channel.

9.6.1.3 Constructability

The same constructability issues are anticipated for Reference Project 2 as for Reference Project 1. These issues are captured in Table 9-6 (refer Section 9.5.2.3).

9.6.2 Timing

The overall delivery schedule for the main dam and saddle dam under Reference Project 2A, 2B and 2C are identical. As shown in Table 9-13, it is anticipated that construction of any of the sub-options of Reference Project 2, including distribution infrastructure would be finalised by the end of 2030.

Table 9-13 Reference Project 2A, 2B and 2C delivery schedule

PHASE	REFERENCE PROJECT 2A: STANDALONE	REFERENCE PROJECT 2B: PARTIAL CONJUNCTIVE	REFERENCE PROJECT 2C: FULL CONJUNCTIVE
EIS / PLANNING			
Start date	July 2020		
End date	June 2025		
DETAILED DESIGN			
Start Date	July 2025		
End Date	June 2027		
DAM CONSTRUCTION			
Start Date	July 2027		
End Date	June 2030		
SUPPORTING INFRASTRUCTRE			

PHASE	REFERENCE PROJECT 2A: STANDALONE	REFERENCE PROJECT 2B: PARTIAL CONJUNCTIVE	REFERENCE PROJECT 2C: FULL CONJUNCTIVE
Arriga Channel Upgrade - Start Date - End Date	Not Applicable	June 2030 December 2030	June 2030 December 2030
A3 West Barron Pipeline - Start Date - End Date	Not Applicable	Not Applicable	June 2030 December 2030
Cairns Pipeline - Start Date - End Date	April 2030 December 2030	Not Applicable	Not Applicable
A3 Walsh River Pipeline - Start Date - End Date	June 2030 December 2030	June 2030 December 2030	Not Applicable

9.6.3 Costs

The estimated real upfront cost for the Reference Project 2A (standalone) is approximately $1,068.0M. This includes capital costs, implementation costs and risk cost provisions. In nominal terms, the total upfront costs are approximately $1,493.4M.

Table 9-14 Real and Nominal Cost Estimate for Reference Project 2A (30 years)

PHASE	REAL COSTS REFERENCE PROJECT 2A
Capital Expenditure	748.3
Implementation Costs	129.9
Risk Costs	189.8
Total Upfront Capital Costs – Real $M	**1068.0**
Escalation	425.4
Total Upfront Capital Costs – Nominal $M	**1493.4**

Reference Project 2B has an estimated real upfront cost of approximately $1,022.8M. In nominal terms, this equates to approximately $1,429.3M.

Table 9-15 Real and Nominal Cost Estimate for Reference Project 2B (30 years)

PHASE	REAL COSTS REFERENCE PROJECT 2B
Capital Expenditure	724.8
Implementation Costs	116.8
Risk Costs	181.2
Total Upfront Capital Costs – Real $M	**1022.8**
Escalation	406.5
Total Upfront Capital Costs – Nominal $M	**1429.3**

Reference Project 2C is the least expensive large dam solution. It has an estimate real upfront cost of approximately $999.1M, or $1,395.7M.

Table 9-16 Real and Nominal Cost Estimate for Reference Project 2C (50 years)

PHASE	REAL COSTS REFERENCE PROJECT 2C
Capital Expenditure	711.8
Implementation Costs	110.1
Risk Costs	177.3
Total Upfront Capital Costs – Real $M	**999.1**
Escalation	396.6
Total Upfront Capital Costs – Nominal $M	**1395.7**

The average real operating costs for theses Reference Projects are estimated at:

- $5.1M per annum for Reference Project 2A
- $2.5M per annum for Reference Project 2B
- $2.2M per annum for Reference Project 2C.

These average annual operating costs include provision for major refurbishment works throughout the 30 years of operations considered in the evaluation period. It is acknowledged that these costs are treated as capital in the financial and commercial analysis (refer Chapter 18).