Hughenden Irrigation Project detailed business case – Water strategy report

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This report has been prepared for Jacobs and HIPCo. This report provides high-level strategic advice regarding strategic and policy issues only. Badu Advisory does not provide legal advice, financial advice, engineering design or tax advice.

Key Points

Jacobs engaged Badu Advisory to provide it with strategic water advice for consideration in the development of a detailed business case for the Hughenden Irrigation Project which is being funded by the North Queensland Water Infrastructure Authority.

This report provides a summary of the findings in relation to Badu's review of surface water and groundwater planning requirements, constraints and opportunities relevant to the project, outcomes of surface water hydrologic modelling (undertaken separately for Jacobs by Barma Water Resources), and the potential use of groundwater to supplement the project's surface water products.

The previous versions of this report have been updated to include the results of further modelling of:

- the medium and high priority hydrologic yields for the updated water infrastructure details and refined project design that have emerged during the preparation of the detailed business case
- the estimated volume of water that might need to be acquired either from unallocated water reserves and/or purchases of existing water entitlements to offset the additional demands placed on the Flinders by the project infrastructure and water allocations and to achieve the downstream EFOs
- the sensitivity of the hydrologic performance of the scheme's water allocations to potential climate-related changes and
- the relationship between hydrologic yield and performance for a situation where a water allocation holder voluntarily reduces the volume of water that they take each year (i.e. less than their nominal volume and annual entitlement to take water under continuous sharing rules) as a means of saving water for future years and improving their individual monthly reliability.

This version of the report has also been updated in response to feedback from DRDMW on an earlier version.

Surface water

Hydrologic modelling has been undertaken by Barma Water Resources of a range of possible project scenarios and configurations that are variations and refinements of the reference cases previously developed in the Preliminary Business Case.

Multiple dam configurations with full supply volumes up to 237 GL were tested and found to be fully compliant with the Gulf water plan environmental flow objectives. Modelling of the project configuration and size that has developed during the detailed business case has found that, subject to a suite of modelling assumptions listed in this report, a hydrologic yield of up to either 74 GL (medium priority at 80% monthly reliability) of medium priority supplemented water allocations (at 80% monthly reliability) or up to 32 GL of high priority supplemented water allocations (at 95% monthly reliability) is possible from a dam with a total storage capacity of 160.9 GL at the Saego site.

Analysis also found that the hydrologic yield of the project is:

- Very sensitive to the size of the bypass flow volume assumed at the diversion weir – i.e. yield increases as maximum bypass flow volumes decrease
- Strongly correlated to the overall full supply volume available to the project and
- Only moderately increased for alternatives that target reductions in evaporation by reducing the storage's surface area
- Dependent on being able to capture flows from the Flinders River compared with options on smaller tributaries which were found to yield lower or zero volumes of reliable water.

The model was used to quantify the potential implications for existing unsupplemented water entitlements that are located downstream of the project. Modelling indicates that the total potential impact on downstream water entitlements from the project might be between approximately 5,000 and 6,000 ML/a when measured in terms of modelled mean annual flows. Such impacts might be mitigated by a range of operational strategies (that might be examined post-DBC as part of a future environmental impact assessment process and development of operational instruments for the project). These might include, for example, optimising the timing and volumes that bypass flows are released from the diversion weir downstream and/or purchasing a portion of the potentially impacted water entitlements.

All model runs reported in the previous version of this report included provision for water acquisitions made up of unallocated water plus purchases of existing water entitlements as assumed in post-PBC reference case. This volume has been optimised using the updated model of the DBC project configuration and found able to be reduced to a total of approximately 83 GL. This volume is effectively removed from the Source model to offset the additional demands placed on the Flinders by the project infrastructure and water allocations and achieve the downstream EFOs.

The volumes of unallocated water reserves remaining in the Flinders River catchment at the end of March 2021 are 8,500 ML/a as indigenous unallocated reserve, 15,700 ML/a of strategic unallocated water and 139,650 ML/a of general unallocated water.

Alternative approaches (involving different combinations of unallocated water and water entitlement acquisitions than that which are assumed in the model) to securing sufficient water to accommodate this project within the context of the water plan requirements are possible. However, the preferred and simplest approach would be to secure 83GL from the general unallocated reserve "… to service the scheme and to meet objectives of the Gulf Water Plan. Another approach might involve securing a volume of general unallocated water equivalent to the maximum volume of medium priority water allocations for the DBC project configuration (i.e. 74 GL) with the additional volume made up of a combination of water entitlements purchased from existing water entitlement holders and/or securing (through appropriate negotiation) a volume of unallocated water from the indigenous unallocated reserve. However, any alternative which involves the cancelling of existing water entitlements purchased by the project from other water licence holders would require support from DRDMW to expedite such cancellations through the water planning framework such as is currently the case with the Granite Belt Irrigation Project.

Ultimately, the preferred approach is likely to be influenced by such factors as:

- the volume of unallocated water reserves that the state government is prepared to release to the project
- whether the project is eligible to secure water from the strategic and/or indigenous unallocated water reserves
- the extent to which existing private water entitlements are available (and affordable) for purchase by the project within the Flinders sub-catchment and
- the appetite for the department to expedite cancelling of water entitlements purchased by the project to enable EFOs to continue to be met in the long-term with the project in place.

With respect to future surface water investigations, the following future (post-DBC) steps are suggested:

- As part of the environmental impact assessment process and operations manual development process, quantify the potential local impacts on downstream unsupplemented water entitlements in more detail (taking into account mitigating factors such as access to local waterholes for example) and then refine, assess and optimise strategies for mitigating any impacts in consultation with DRDMW and water entitlement holders (as discussed in section 4.3.5)
- Liaise with DRDMW in relation to the water planning related process requirements and regulatory steps that might be required to facilitate the future implementation of the project in the context of

government's future decisions about the release of unallocated water for the project and release or reserve of unallocated water to other proposals in the Flinders Catchment

- Examine the implications of the matters that are listed in sections 3.1.4 and 3.1.9 as part of detailed assessment within a future Environmental Impact Study.

Groundwater

The potential for groundwater supplies to be utilised from the alluvium for the project was examined. Although there is some potential to establish water supply bores in the alluvium at the project site, the likelihood of success is not considered to be high. Future geotechnical investigations associated with dam site investigation may provide opportunity to further assess groundwater potential from the alluvium. However, it is concluded that even if productive bores from the alluvium could be found it would take some years to have confidence that the bores could provide a reliable drought supply for the project.

The potential for Great Artesian groundwater supplies to utilised for the project was also explored. There is a very high probability that water would be physically available from the Hutton and Hooray sandstone aquifers of the GAB and that it would be of suitable quality for irrigation. Further, there is a state reserve of 16,400 ML/a from which GAB groundwater can be allocated for extraction from the Hooray and/or Hutton sandstone. However, it could be expected that water would only be allocated from the reserve if alternative sources were not viable.

Volumetric GAB water licences are relocatable and therefore there is the potential to obtain water for the project through trading. Assisting the owners of uncontrolled bores to repair or replace the bores and convert open bore drains to piped systems would enable volumetric GAB water licences to be granted and relocated to other land.

However, there are two main constraints on obtaining GAB water using such mechanisms. The first relates to managing the net impact on water pressures at GAB groundwater dependent ecosystems. Meeting existing statutory requirements to manage such net impacts needs to be a central focus. The second relates to managing potential interference with and between existing and new water bores. This issue may be overcome by appropriately locating project bores to minimize such impacts and limiting the pumping rates of individual bores.

Analysis was undertaken to estimate how much groundwater entitlement from the GAB might be needed to enable high priority water allocations to be supplemented from groundwater with at least a portion of their monthly demands during the 5% of months where they could expect their demands not to be fully met from dam supplies. This analysis suggested that if GAB bores are used in such a way as to provide 50% of monthly high priority demands during periods of shortfall from the dam, then:

- a total GAB licence volume that is approximately equivalent to a quarter of the high priority water allocation volume is needed to meet 50% of high priority demand in dam shortfall months
- in 95% of all months in the simulation period the dam would supply 100% of monthly high priority demand
- in 0.625% of all months in the simulation period (i.e. about 1/8th of the 5% shortfall months) the dam might supply around 75% of monthly high priority demand
- in 4.375% of all months in the simulation period the GAB might supply 50% of the monthly high priority demand.

The combined performance of the two high priority products (i.e. the high priority dam water and the GAB back up supply) might then be estimated to be around 97.6%. Of course, water would need to be physically able to be extracted from an appropriate number of bores set out with appropriate set-back distances for this approach to be viable.

A potential option is to use the GAB not as a water source but rather as a place to store surface water during periods of high surface water availability for later recovery during periods of low availability. This type of managed aquifer recharge (MAR) scheme would avoid the need for an allocation from the state reserve and avoid impact on GAB groundwater dependent ecosystems. However, MAR schemes do present engineering and water chemistry challenges that would need to be addressed.

With respect to future groundwater investigations, the following future steps are suggested:

- Focus on the GAB water resources as a potential source of groundwater to support the project. The alluvium is unlikely to provide a suitable supply, however opportunities could be taken to further assess the potential of the alluvium during geotechnical testing associated with the project. The following recommendations relate to GAB water resources.
- Carry out a formal search of the water licence database and groundwater database to obtain details of:
    - volumetric water licences, associated water bores, and water use
    - stock bore licences that are uncontrolled and licenced to use bore drains
- For water licences and water bores on or near the project site assess the potential for acquisition and incorporation into the project, thus avoiding increased impact on GDEs and existing water bores. If necessary, assess how additional bores could be established without unacceptable impact on neighbouring bores.
- Carry out a formal search of the GAB GDE register to identify GDEs in the possible impact range from the project site, and the current cumulative impact of licensed water extraction at the site.
- Based on outcomes of the above searches, assess if there is a need for, and a potential benefit in carrying out, a hydrogeological study of any particular GDEs to reduce uncertainty about the connectivity to underlying aquifers and reduce sensitivity to increased extraction at the project site.
- Synthesize the search data to identify potential paths to securing different levels of water entitlement (including relocation of GAB licences) while avoiding unacceptable impacts on GDEs (e.g. springs) and water users. The order of preference being local licenses and associated bores, capping of suitably located uncontrolled stock bores, suitably located volumetric water licences and then the state reserve.
- Investigate the potential to implement a MAR scheme, using the GAB not as a source of water but as a place to store surface water during periods of high availability of surface water for later recovery during periods of low availability.

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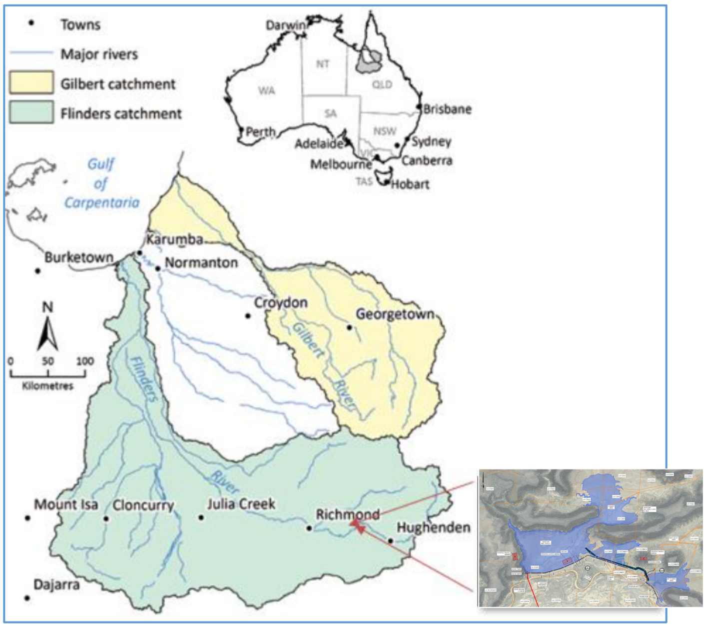
1 Introduction

1.1 Context

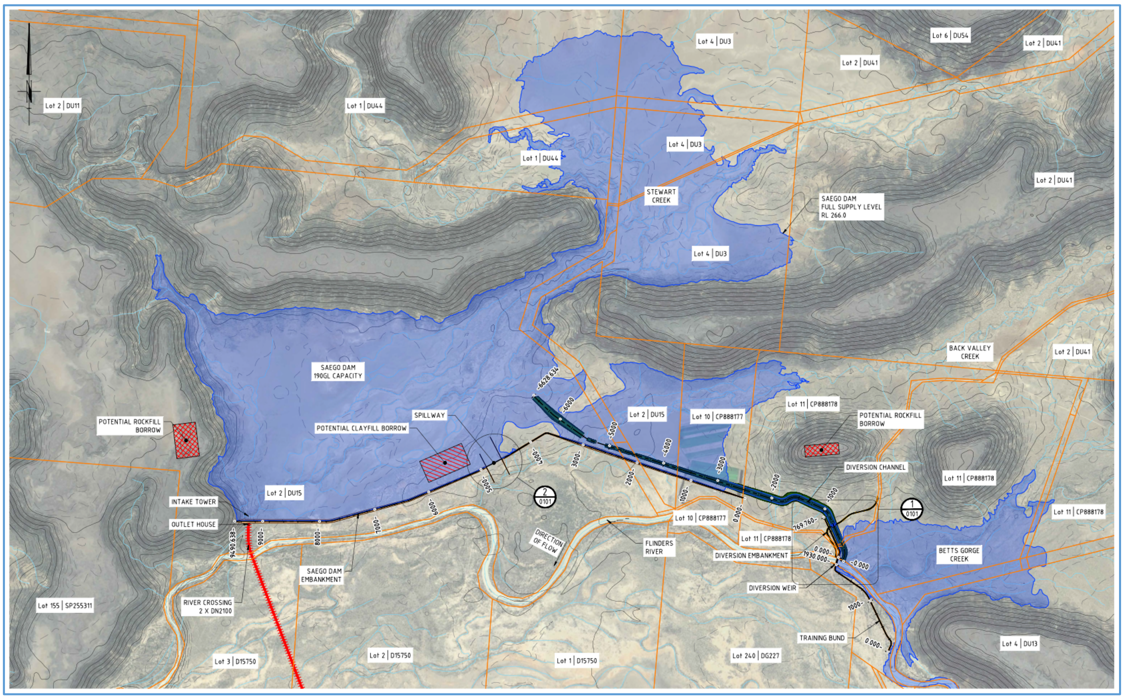
Jacobs was engaged by Hughenden Irrigation Project Corporation Pty Ltd ('HIPCo') to prepare a detailed business case (DBC) for the Hughenden Irrigation Project ('the project') which is located within the upper Flinders River catchment near Hughenden. Figure 1 shows the location of the proposed project.

Figure 1 - Location of proposed project (Engeny, 2020a).



The development of the DBC includes analysing in detail water storage options and an associated irrigation area based on reference cases that were identified as a result of initial studies conducted as part of the Preliminary Business Case ('PBC') (Engeny, 2020a). Figure 2 shows the general arrangement of the diversion and storage infrastructure for the PBC reference cases.

Figure 2 – General arrangement of the PBC reference case (Engeny, 2020a).



1.2 Purpose of this report

Jacobs engaged Badu Advisory Pty Ltd ('Badu Advisory') to provide it with strategic water advice for consideration in the development of the DBC. Badu's key inputs include:

- reviewing surface water and groundwater planning requirements, constraints and opportunities relevant to the project
- providing strategic oversight of surface water hydrologic modelling undertaken separately for Jacobs by Barma Water Resources ('BWR')[1]
- developing strategies in relation to the potential use of groundwater to supplement the project's surface water products and in relation to any further groundwater studies or investigations that might be conducted either prior to and/or post the completion of the DBC
- providing strategic water planning advice to Jacobs, HIPCo and others during the course of the preparation of the DBC and
- engaging with the government agencies – including the Department of Regional Development, Manufacturing and Water ('DRDMW')[2], the Department of Environment and Science ('DES') and the North Queensland Water Infrastructure Authority ('NQWIA') – in relation to surface and groundwater planning requirements and considerations relating to the project.

This report provides an updated summary of the findings in relation to the above as at mid-October 2021.

2 Overview of Queensland's water planning framework

2.1 Introduction

The Water Act 2000 establishes the legislative framework for planning the sustainable allocation and management of Queensland's water resources (State of Queensland, 2021). The framework consists of:

- water plans (formerly referred to as water resource plans)
- water management protocols and operations manuals (which are progressively replacing resource operations plans)
- resource operations licences and distribution operations licences

The Water Act requires that all decisions about water allocation and management be consistent with this framework.

The Water Act also establishes water regulations that set out provisions relating to the administration of the Act including, for example, processes relating to the issuing of unallocated water reserves.

Figure 3 illustrates the relationships between the framework and other instruments that collectively govern how supplemented water supplies are allocated and governed. These are each discussed below.

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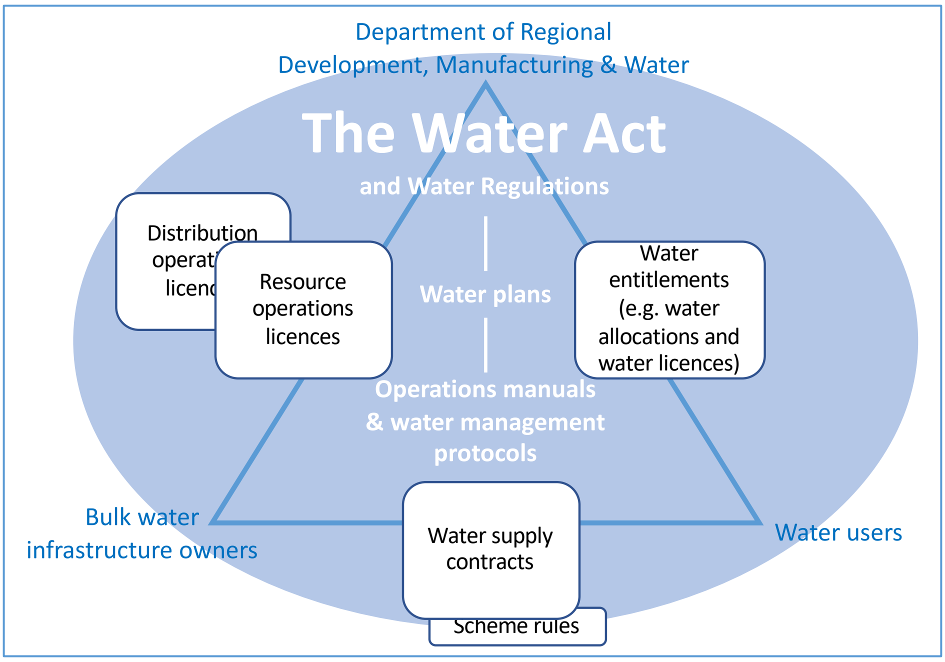
[1] BWR was engaged by Jacobs to review any hydrologic models developed and relied upon in previous phases of the project and update them to meet state department modelling standards, as well as to prepare and run hydrologic assessments (using the Source model) and produce summary results for a base (without project) case plus a suite of scenarios for developing, testing and refining project design and configurations (including water infrastructure, water allocation and management arrangements), demonstrating compliance with project objectives and water planning requirements, and testing sensitivity to climate change.

[2] Formerly the Department of Natural Resources, Mines and Energy ('DNRME').

Figure 3: Queensland's water resource allocation and management framework.



2.2 Water plans

Water plans define the long-term availability of water for different purposes including environmental and consumptive water uses. Water plans have been developed and implemented in each river basin in Queensland as well as for certain groundwater aquifers including the Great Artesian Basin ('GAB').

Provisions in water plans include:

- outcomes or aspirational targets that represent what government and the community want to achieve over time
- strategies and requirements to guide the management of environmental flows
- environmental flow objectives ('EFOs'), water allocation security objectives ('WASOs') and associated performance indicators to be considered when making water allocation and management decisions
- strategies that specify the groups, types and volumes of water allocations (authorities to take water) that may exist within the plan area
- strategic, general, indigenous and other types of unallocated water reserves that establish volumes, locations and allowable uses of unallocated water available in the plan area and which may be issued as new water allocations through processes specified in the water plan and/or Water Regulations.

Water plans and underlying instruments are in most cases organised around surface water catchments. Any groundwater resources within a catchment, such as the alluvium associated with a watercourse or local volcanic aquifers, are managed under the water plan for the catchment.

However, management of the Great Artesian Basin (GAB) required a departure from this basic approach. The GAB exists as several of connected sub-basins underlying most of Queensland and operates largely independently of overlying watercourses and local aquifers. As a result, a separate water plan, the Great Artesian Basin and Other Regional Aquifer (GABORA) water plan provides the basis for management of the GAB together with some other deep aquifers underlying the GAB.

2.3 Water licences

The Water Act provides for water licences to be issued by the department which grant holders the authority to take water (e.g. from surface water, groundwater or overland flows etc.). They are generally tied to a specific land title, subject to a range of conditions and limited in tenure. They may be transferable subject to any conditions and/or prohibitions specified in a water plan, resource operations plan or water management protocol.

Because water licences are attached to land, its means that they are not an asset separate to land – i.e. they cannot be held in separate ownership to land ownership. Any value associated with a water licence is therefore to found in the value of the land to which it attaches. When land is transferred to a new owner, the water licence is transferred the new landowner.

A water license to take groundwater is basically the same as a licence to take surface water from a watercourse. However where a licence to take surface water specifies the watercourse, a water licence to take groundwater specifies an aquifer from which water may be taken. At any one geographic location multiple aquifers may exist at different depths.

Water allocation security objectives ('WASOs') – which are discussed below – do not typically apply to water licences although other water planning provisions usually require that potential impacts on water entitlements arising from proposed water resource allocation and management decisions be assessed and considered.

Groups of water licences may be converted to water allocations through a water planning review process.

2.4 Water allocations

The framework establishes water allocations which grant holders the authority to take water. Unlike water licences, water allocations are property rights that are separate from land, tradeable, perpetual in tenure and subject to the requirements of the water planning framework.

Water allocations are established through a water planning process. This generally involves a water plan including provisions to enable the conversion of pre-existing water entitlements (e.g. water licences) to water allocations. The details of how each water entitlement is to be converted are set out in a water entitlement notice that accompanies a water plan.

"Supplemented water" refers to water that is supplied under a resource operations licence. A resource operations licence is required to allow the owner of water infrastructure (such as a dam or weir) to interfere with the flow of water in a watercourse. Supplemented water allocations are specified in terms of:

- a nominal volume
- the location from which water may be taken (generally described in terms of zones)
- the purpose for which water may be taken
- the water plan and resource operations plan under which it is managed
- the priority group (e.g. high or medium priority) to which it belongs and
- other conditions or matters.

Unsupplemented water allocations are not supplied under a resource operations licence (and generally not associated with major instream water infrastructure located in a watercourse) and include overland flow, private water harvesting (i.e. opportunistic taking of water during periods of high flow) and area-based entitlements.

The minimum and/or target ranges of hydrologic performance of different groups of supplemented or unsupplemented water allocations are set out in water plans. Water plans require proposed operating rules, new water resource developments and/or other water allocation and management related decisions to be assessed in terms of their ability to meet the water plan's WASOs. WASOs are generally assessed using defined hydrologic performance indices and objectives, historical simulation periods and a hydrologic model that are all specified within a water plan.

2.5 Operations manuals

An operations manual is prepared under the Water Act where required as a condition of a resource operations licence or distribution operations licence. A manual may be developed or updated by the operator of a water supply scheme in consultation with stakeholders but must be approved by the chief executive of DRDMW. The provisions of an operations manual must comply with a water plan's WASOs and EFOs.

An operations manual includes the day to day operation rules for supplemented water schemes such as:

- water releases from dams to ensure that infrastructure is operated efficiently providing flows for industry, agriculture, town water supply whilst meeting with WASOs and EFOs.
- water sharing rules for supplemented water to provide equitable sharing of water between water users supplied by the scheme and
- seasonal (temporary) water assignment rules for supplemented water allocations to facilitate the efficient use of water within the scheme while ensuring trading complies with WASOs and EFOs.

2.6 Water management protocols

Water management protocols generally includes specific rules and requirements to achieve the outcomes stated in the water plan. A protocol is developed by DRDMW and approved by the department's chief executive. The provisions of water management protocol must comply with a water plan's WASOs and EFOs.

Key matters included within a water management protocol include:

- (where applicable) the processes for releasing specified water volumes of unallocated unsupplemented water for stated purposes and locations
- water sharing rules for unsupplemented water to provide equitable sharing of water between water users
- permanent water trading rules and limits for supplemented and unsupplemented water allocations and
- seasonal (temporary) water assignment rules for unsupplemented water allocations, and other water dealing rules, to facilitate the efficient use of water while ensuring trading does not adversely affect water allocation security or environmental flow objectives.

2.7 Resource operations licences and distribution operations licences

A distribution operations licence or a resource operations licence allows a holder to take, or interfere with the flow of, water to distribute it to water allocation holders (typically through systems of channels or pipelines). A resource operations licence also allows a holder to interfere with the flow of water to construct and operate water infrastructure (typically dams and weirs). The owner of an instream storage that supplies water to water allocation holders is therefore likely to require a resource operations licence.

A resource operations licence may only be held by owner of the water infrastructure (to which the licence relates) or the owner's parent company. A distribution operations licence, however, may be held by owner of the water infrastructure (to which the licence relates), the owner's parent company or by an entity nominated by the owner. Depending on the institutional, operational and supply arrangements that are adopted, there may be situations where both a resource operations licence and one or more distribution operations licences may be necessary[3].

An operations licence typically includes conditions related to operating arrangements and water supply requirements. A licence holder is also required to comply with the provisions of the relevant water plan and operations manual.

2.8 Water supply contracts and scheme rules

In the case of a supplemented water allocation (i.e. one managed under a resource operations licence), the Water Act 2000 requires there to be a water supply contract between the resource operations licence holder and the holder of the water allocation. A water supply contract sets out the arrangements by which water is to be stored and supplied as well as the financial obligations. A water supply contract may also set out detailed scheme rules such as service level targets, local supply constraints and water ordering arrangements etc.

3 Water planning requirements, constraints and opportunities relevant to the project

3.1 The Gulf water plan – surface water

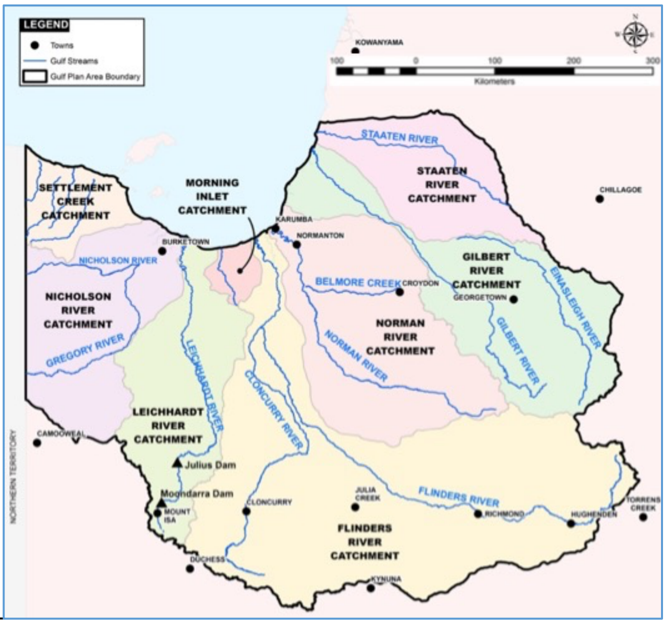
3.1.1 Introduction

Water in the Flinders River catchment is allocated and managed under the Water Plan (Gulf) 2007 (the 'Gulf water plan") (Queensland Government, 2017).

Although water plans are typically updated every ten years, the expiry of the Gulf water plan was postponed until 1 November 2027 based on a departmental review and public consultations. It was concluded that postponing the expiry of the water plan was not expected to impact adversely on water users or the environment (State of Queensland, 2018).

Figure 4 shows the plan area for the water plan including the location of the Flinders River catchment.

Figure 4 – Water plan area (Queensland Government, Undated)



[3] For example, if the owner of a distribution network (e.g. pipeline or channel) was a different entity to (and not a subsidiary of) the owner of the dam, and water allocations were to be supplied via that distribution network, then the distribution network owner would also need to separately hold a distribution operations licence.

3.1.2 Unallocated water provisions

The Gulf water plan sets out a number of unallocated surface water provisions. These provisions, and their potential implications for the project, are set out Table 1 below[4].

Table 1 – Key unallocated water provisions within the Gulf water plan

Topic and key water plan Section numbers	Key provisions within the Gulf water plan	Implications for the project
Coordinated projects and projects of regional significance (s.27, 34 and 37)	The Gulf water plan enables DRDMW to consider a particular project to be a project of regional significance subject to having regard to: • The outcomes of the Gulf water plan • the economic or social impact the project will have on the region • the public interest and the welfare of people in the region and • any other relevant consideration. Unallocated water granted from a strategic reserve for either a coordinated project[5] or a project of regional significance may only be granted for the life of the project. On conclusion of the project the volume of water must return to the strategic reserve. This suggests that this provision relates to the granting of water licences (which are limited in tenure) rather than water allocations.	As the project is likely to target the general unallocated water reserve rather than the strategic unallocated water reserve, this provision within the Gulf water plan is not considered to be an impediment to the project seeking to be considered as either a project of regional significance or a coordinated project.
Unallocated water reserves (s. 28, 32,	Sets out that unallocated water in the Flinders River catchment is held as: • an indigenous reserve • a strategic reserve or • a general reserve.	The three types of unallocated water reserves are discussed in turn below.
Indigenous reserves (s. 32, 33 and Schedule 6A)	Indigenous unallocated water may be granted for "helping indigenous communities", including in the Flinders River catchment area, "to achieve their economic and social aspirations". The total annual volumetric limit[6] of indigenous unallocated water in the Flinders River catchment area is 8,500 ML.	Discussions with DRDMW[7] suggest that this means that the project may be able to negotiate for a portion of the indigenous reserve to be granted to the project if the project delivers tangible outcomes to indigenous communities in ways that meet this test. Given the size and extent of the Flinders River catchment area, it might be appropriate for the project to consider strategies and project inclusions that target a portion of the indigenous reserve in the Flinders River catchment area.

[4] Note that the commentary in this report and table was compiled prior to the DRDMW's commencement of a process for releasing of unallocated from the general reserve water by competitive tender on 30 November 2021, and from the strategic reserve for the Saint Elmo Vanadium Project (a project of regional significance) on 29 November 2021.

[5] Defined in the Gulf water plan to mean a coordinated project under the State Development and Public Works Organisation Act 1971).

[6] Annual volumetric limit is defined by the water plan to mean: "for a water licence… the maximum volume of water that may be taken under the licence in the water year for the licence". For water allocations, the Water Act states that a 'volumetric limit' is an attribute of a water allocation and "is the maximum volume of water, in megalitres, that may be taken under the allocation during a water year". The Act also states that "if a condition on a water allocation or a water management protocol contains a water sharing rule about volumetric limits that applies to the water allocation, the volumetric limit stated on the water allocation is used to calculate, under the rule, the maximum volume that may be taken under the allocation during a particular period or in particular circumstances".

[7] As discussed between Badu Advisory and DRDMW on 3 February 2021.

Topic and key water plan Section numbers	Key provisions within the Gulf water plan	Implications for the project
		None of the 8,500 ML of indigenous unallocated water had been granted from the Flinders River catchment as at the end of March 2021 (Department of Natural Resources Mines and Energy, 2021).
Strategic reserves (s. 34, 36, 37 and Schedule 7)	Strategic unallocated water may be granted for a "state purpose". The water plan defines a state purpose as meaning: • a coordinated project • a project of regional significance • town water supply or • ecotourism (in specific areas that are outside of the Flinders River catchment area). The total annual volumetric limit[6] of strategic unallocated water for a state purpose in the Flinders River catchment area is 17,850 ML.	If the project was to provide a volume of water for town water supply, this volume might be considered to meet the definition of a state purpose. A state purpose that is for town water supply is not subject to the same tenure limitations as a water entitlement that is granted from the strategic reserve for a coordinated project or a project of regional significance. This suggests that the project may be eligible to be granted a portion of the strategic reserve equivalent to the volume of water allocation being made available from the project for town water supplies. 15,700 ML of strategic unallocated water remained held as reserve in the Flinders River catchment as at the end of March 2021 (Department of Natural Resources Mines and Energy, 2021).
General reserves (s. 38, 39 and schedule 8)	General unallocated water may be granted for any purpose. The total annual volumetric limit[6] of general unallocated water in the Flinders River catchment area is 239,650 ML.	Discussions with DRDMW[7] indicated that a significant volume of the general unallocated water has been issued as water licences to landholders in the Gulf water plan area. Only 139,650 ML of general unallocated water remained held as reserve in the Flinders River catchment as at the end of March 2021 (Department of Natural Resources Mines and Energy, 2021).
Conditions applying to general unallocated water (s. 39A)	Water entitlements granted from the general reserve in the Flinders River catchment area must include at least 1 pass flow condition and a condition stating the transfer of water under the entitlement must be done in accordance with "group B water transfer rules". Group B water transfer rules are not defined in the water plan. They are mentioned within the Gulf Resources Operations Plan in the context of water licence transfer and seasonal assignment rules (Department of Natural Resources Mines, 2015).	Discussions with DRDMW[7] indicated that the provisions in the Gulf water plan and Resource Operations Plan are generally focussed on, and relate to, the specification and management of water licences rather than supplemented water allocations[8]. This includes the way that the provisions relating to the conditions attaching to water entitlements granted from the general unallocated water reserve are couched in the water plan. Importantly, the water allocations associated with the proposed project would be supplemented water allocations. It is noted that the Gulf water management protocol, two resources operations licences and one distribution operations licence and associated operations manuals are currently in preparation (Business Queensland, 2020b) which will mean that parts of the current water plan will be moved to the new instruments. DRDMW have indicated that a targeted amendment to the water plan could be considered to facilitate the administrative changes required to establish a new supplemented water supply scheme in the Flinders catchment. This is similar to the recent targeted water plan amendment process for the water plan in the Fitzroy Basin where changes are being made to "bring the Rookwood Weir into the water planning process". Unlike a full water plan review, the targeted amendment of the Fitzroy water plan has not contemplated changes to plan's EFOs or to WASOs for existing water allocations (Business Queensland, 2020a).

[8] This is also consistent with previous discussions with DNRME on 2 July 2019 in relation to the Gilbert River system also indicated that the provisions relating to the group B water transfer rules were intended to apply to new unsupplemented water entitlements rather than supplemented water allocations.

3.1.3 Process for granting unallocated surface water

Section 29 of the Gulf water plan (State of Queensland, 2017b) states that the process for granting unallocated water is a process stated in part 2, division 2, subdivision 2 of the Water Regulation 2016 ('the Regulation') (State of Queensland, 2020).

Section 16 of the Regulation prescribes processes for releasing unallocated water by:

- public auction
- tender
- fixed price sale or
- a grant for a particular purpose.

Section 17 of the Regulation states that the chief executive must publish a notice about the availability of water released by auction or tender. However a public notice is optional for water released by fixed price sale and not mentioned as being required for water released as a grant.

Further discussions will be required between HIPCo and the state government – probably after the completion of the DBC – in relation to the chief executive's preference as to the process for releasing unallocated water for the project.

3.1.4 Matters that must be considered by chief executive when preparing and implementing a process for granting unallocated water

Sections 23 and 30 of the Gulf water plans set out the matters that the chief executive must consider in preparing and implementing such a process (State of Queensland, 2017b). These include:

- the purpose for which the water is required
- the efficiency of existing and proposed water use practices
- the extent to which water in the plan area is being taken under authorisations
- the availability of an alternative water supply for the purpose for which the water is required
- the impact the proposed taking of, or interfering with, the water may have on existing water users in the plan area
- whether the proposed taking or interfering is likely to have a direct adverse effect on groundwater flows
- the matters mentioned in Section 23(1)(a) i.e. streamflows required to maintain:
  - the longitudinal connectivity of low flow habitats throughout river systems in the plan area
  - the wetted habitats at riffles and other streambed features
  - the natural seasonality of flows and zero flows
  - the replenishment of refuge pools that enable movement of instream biota
  - groundwater flows
  - the contributions from aquifers to the flow of water in watercourses
  - the lateral connectivity between rivers in the plan area and their adjacent riverine environments, including floodplains
- the matters mentioned in Section 23(1)(b) i.e. the impact the taking of, or proposed taking of, or interfering with, water may have on:
  - water quality

- the natural movement of sediment
- the bed and banks of a watercourse or lake
- the inundation of habitats
- the movement of fish and other aquatic animals
- the recreation and aesthetic values of the plan area
- cultural values including, for example, cultural values of local Aboriginal or Torres Strait Islander communities.

The above list does not limit the matters the chief executive may consider in preparing and implementing a process for granting unallocated water.

In addition, the Gulf Resources Operations Plan (Department of Natural Resources Mines, 2015) requires that:

- (under Section 31) a submission for unallocated water where the water is proposed to be used under a water entitlement for irrigation must be accompanied by information that demonstrates the potential suitability of the land for sustainable irrigation having regard to the following matters that may constrain the extent and location of any irrigation development:
  - the availability of land where a vegetation clearing application may be made under the Vegetation Management Act 1999 (State of Queensland, 2017a)
  - the occurrence of ecological assets and other high value environmental features such as wetlands
  - suitability of the topography, including the slope of the land intended to be irrigated
  - known cultural heritage sites and
  - attributes of the soil, including potential salinity, sodicity and drainage concerns.
- (under Section 35) when deciding an application for unallocated water, the chief executive must consider the effect of granting from the unallocated water reserves on indigenous cultural values and the social and economic wellbeing of local indigenous communities.

Many of the matters listed above will be examined in the DBC and then assessed in detail as part of an Environmental Impact Study for the project if/when it proceeds to this step.

3.1.5 Prescribed model

The Gulf water plan stipulates that the plan's objectives be assessed using the department's Source computer program. Compliance against plan objectives was assessed by BWR using the department's Source model, post-processing software and pre-development flow file. These assess plan performance over an extended simulation period (viz. from July 1889 to June 2011 for water allocation security objectives and from July 1890 to June 2011 for environmental flow objectives).

3.1.6 Environmental flow objectives

Section 17 of the water plan specifies performance indicators for environmental flow objectives ('EFOs') for periods of low flow, medium to high flow and wet season flow. EFOs for the Flinders River are specified at Flinders River at Walkers Bend (at AMTD 103.0km) (which is referred to as 'Node 7') within Schedule 5 of the Gulf water plan (State of Queensland, 2017b).

Table 2 sets out the performance indicators and required values of the EFOs specified by the water plan for Node 7 on the Flinders River.

Table 2 - Environmental flow objectives specified for Node 7 on the Flinders River at Walker's Bend (AMTD 103.0km) (State of Queensland, 2017b)

EFO performance indicators	Environmental flow objectives	Definition of metrics
Low flow objectives		
1. the proportion of no flow days in the simulation period	be no more than 70%	*the proportion of no flow days means the total number days on which the flow is less than 5ML/day, expressed as a percentage of the total number of days, in the simulation period*
Medium to high flow objectives		
2. the mean annual flow in the simulation period, expressed as a percentage of the mean annual flow for the pre-development flow pattern in the simulation period	be at least 90%	*the mean annual flow means the total volume of flow in the simulation period divided by the number of years in the simulation period.*
3. the median annual flow ratio in the simulation period, expressed as a percentage of the median annual flow for the pre-development flow pattern in the simulation period	be at least 78%	*the median annual flow means the annual flow volume that is equalled or exceeded in 50% of years in the simulation period.*
4. the 1.5 year daily flow volume in the simulation period, expressed as a percentage of the 1.5 year daily flow volume for the pre-development flow pattern in the simulation period	be at least 90%	*the 1.5 year daily flow volume means the daily flow that has a 67% probability of being reached at least once a year*
5. the 5 year daily flow volume in the simulation period, expressed as a percentage of the 5 year daily flow volume for the pre-development flow pattern in the simulation period	be at least 96.5%	*the 5 year daily flow volume means the daily flow that has a 20% probability of being reached at least once a year*
6. the 20 year daily flow volume in the simulation period, expressed as a percentage of the 20 year daily flow volume for the pre-development flow pattern in the simulation period	be at least 98%	*the 20 year daily flow volume means the daily flow that has a 5% probability of being reached at least once a year*
Wet season flow objectives		
7. the median wet season flow in the simulation period, expressed as a percentage of the median wet season flow for the pre-development flow pattern in the simulation period	be at least 75%	*the median wet season flow, for a node, means the total volume of flow during the months of January, February and March that is equalled or exceeded in 50% of years in the simulation period*

3.1.7 Water allocation security objectives

The plan also requires assessment against water allocation security objectives (WASOs).

Section 19 of the water plan states that the WASO performance indicators for taking supplemented surface water are:

- the **annual supplemented water sharing index** which, for water allocations to take supplemented surface water in a particular priority group, is defined to mean the percentage of years in the simulation period in which the allocations are fully supplied
- the **monthly supplemented water sharing index** which, for water allocations to take supplemented surface water in a particular priority group, is defined to mean the percentage of months in the simulation period in which the allocations are fully supplied.

WASOs are only currently specified for supplemented surface water allocations in existing water supply schemes which are located in the Upper Leichhardt subcatchment area.

There are no unsupplemented water allocations in the Flinders River catchment at this time. However, as mentioned in section 3.1.4 above, the chief executive must consider "the impact the proposed taking of, or interfering with, the water may have on existing water users in the plan area" (State of Queensland, 2017b). This means that attention must be given to examining the potential impacts on water entitlement (licence) holders downstream of the proposed project (see section 4.3.4 below).

3.1.8 Transferability of surface water licences

The Gulf water plan does not prohibit the transfer of surface water licences within the plan area. The Gulf resource operations plan states rules for transferring of water licences.

There are three sets of rules that apply to water licences (note that these rules do not apply to water allocations):

- the general water licence transfer rules (115D) – these include provisions that limit the total volume of water licences within each unsupplemented zone within the plan area. The project is located in Flinders River Water Management Zone 7 for which Table 6A of the Gulf Resource Operations Plan states a maximum annual volumetric limit for water licences of 10,000ML.
- specific rules for transferring water licences that state "transfer group B" (115E) – in Section 39A, the Gulf water plan mentions that transfers of water under a water entitlement granted from the general reserve in the Flinders River must be in accordance with the group B water transfer rules.
- additional rules for transfer to or within an unzoned area (115F) (Department of Natural Resources Mines, 2015).

The Gulf Resource Operations Plan also specifies:

- water licence seasonal assignment rules (Section 115J)
- general rules and limitations that apply to the transfer of all water licences (Sections 115A, 115B, 115C and 115D) (Department of Natural Resources Mines, 2015).

Potential strategies and water planning implications associated with acquiring existing water licences to mitigate the project's impacts on environmental flow objectives are discussed in section 4.3.6 below.

3.1.9 Other Gulf water plan requirements applicable to supplemented surface water

Section 46 of the Gulf water plan sets out matters that must be considered by the chief executive when deciding the infrastructure operating rules to be included in the resource operations plan[9] for water infrastructure for supplemented surface water (State of Queensland, 2017b). These matters include:

- the impact of the infrastructure's operation on:
  - instream water levels
  - bed and banks of watercourses
  - riparian vegetation
- the extent to which artificial variations in instream water levels and flows may adversely affect natural ecosystems
- the impact of the transfer of water between watercourses
- the likelihood of fish deaths caused by the operation of the infrastructure
- the matters mentioned in Section 23(1)(a) and (b) as listed within section 3.1.4 above.

[9] Which is being replaced by an operations manual and water management protocol as discussed in section 2.

3.2 The Gulf water plan – alluvial groundwater

3.2.1 Introduction

The Gulf water plan identifies several groundwater management areas, one of which is named the 'Great Artesian Basin Groundwater Management Area' which includes the area of Flinders River catchment. This groundwater management area overlies the formations of the GAB. The Gulf water plan has jurisdiction over groundwater in any aquifers overlying the GAB aquifers. Groundwater in the underlying GAB aquifers fall under jurisdiction of the GABORA water plan, as detailed in a later section.

Until recently, there has been very little use of groundwater, other than from the underlying GAB aquifers, within the boundaries of the Flinders catchment and very little knowledge of such resources exists. As a result, the Gulf water plan does not require a licence to take groundwater from aquifers in the Flinders catchment. However, interest in the use of unmanaged groundwater is increasing and there are localised areas where intensive take has commenced or is being investigated. Currently there is indirect regulation of access to groundwater close to the river as described in the following section.

3.2.2 Groundwater within 1 km of a river

Groundwater in alluvium adjacent to a watercourse can be connected closely to the watercourse. As a result water pumped from a bore near a watercourse can intercept flow in the watercourse. In several locations throughout Queensland this issue has been overcome by declaration that the groundwater within some distance of a watercourse is surface water. This enables management arrangements to be established for management of the surface and groundwater as a single resource.

In the Flinders catchment, where the taking of groundwater is not regulated directly, any risk of the interception of stream flow has been addressed in the Gulf water plan by including a declaration. Section 8 of the Gulf water plan sets out provisions relating to the Declaration about a watercourse (under Section 1006(2) of the Water Act). The declaration applies to groundwater in an aquifer under a prescribed watercourse, or under land within 1km of a prescribed watercourse. Section 8(4) of the Gulf water plan states the meaning of a prescribed watercourse.

This effectively means that any groundwater within 1km of the river is considered surface water. As a result, the taking of any groundwater within 1km of the Flinders requires a licence to take surface water, but the taking of groundwater more than 1km from the river does not require a water licence at all. The declaration applies throughout the whole of the area of the Gulf water plan, however in some parts of the plan area beyond the Flinders catchment, a water licence is required to take groundwater.

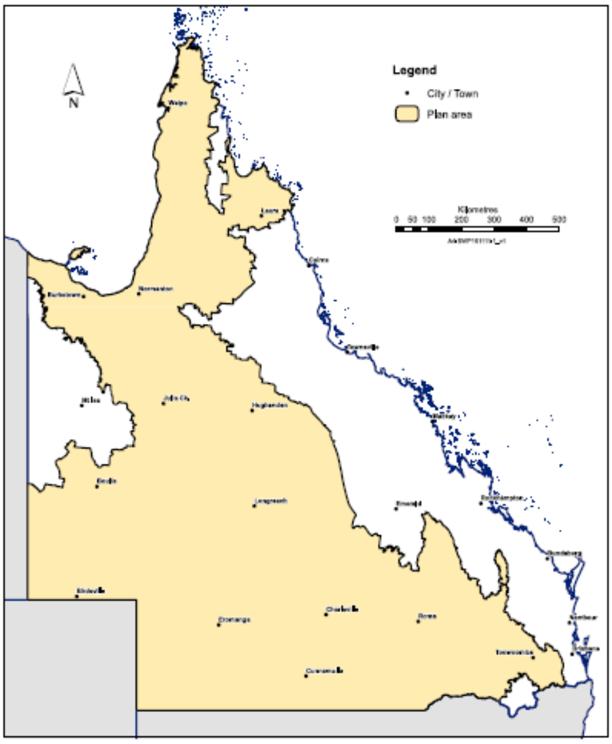
The declaration includes scope for the DRDMW to decide that the declaration does not apply to a part of a watercourse if satisfied that the part is not hydraulically connected to the watercourse.

3.3 The GABORA Water Plan – GAB groundwater

3.3.1 Introduction

Water in the aquifers of the GAB (Figure 5) is allocated and managed under the Water Plan (Great Artesian Basin and other Regional Aquifers) 2017 Water Plan (the 'GABORA water plan') (Queensland Government, 2017). The GABORA Water Management Protocol establishes rules to give effect to the GABORA water plan. Those instruments deal with many aquifers, however, in the project area the potential source aquifers are the Hooray Sandstone and the underlying Hutton Sandstone of the Eromanga sub-basin of the GAB.

Figure 5 - GABORA water Plan area (Queensland Government, 2017)



3.3.2 Interference with GDEs and existing water bores

The GAB is a multilayered aquifer system. Except in areas where an aquifer outcrops near the margins of the basin, an aquifer will be overlain by a low permeability confining layer and potentially additional overlying aquifers and confining layers. Where an aquifer is confined, as at the project site, water is stored through elastic compression of the aquifer and stored water. The recoverable amount of water stored under these conditions is much smaller than for an unconfined aquifer.

The significance of this is that the water pressure impact of water extraction from a bore tapping a confined aquifer spreads a long distance away from the bore, potentially affecting the flow of water to groundwater dependent ecosystems (GDEs), which are ecological assemblages associated with GAB springs and aquifer fed sections of watercourses, as well as the operation of other water bores.

The GABORA water plan establishes arrangements to protect GDEs and the supply from existing water bores. These factors can be limiting on the potential to increase the water extraction at a location through grant of unallocated water or through water trading.

Interference with GDEs

Under the GABORA water plan, the DRDMW is required to maintain a register of GDEs and the cumulative impact of water extraction at each GDE. The GABORA water plan sets the maximum cumulative impact at a registered GDE, over the long term, at 0.4m. The GABORA water protocol sets out the way this can be calculated using lookup tables, although there is provision for a proponent to propose a calculation using site specific hydraulic parameters. Appendix A includes extracts from the GABORA water plan and the GABORA water management protocol, relevant to assessing the impact of a proposed annual extraction of water on registered GDEs.

Interference with existing water bores

The GABORA water plan sets a maximum drawdown impact at the location of existing bores. It requires that the licenced take from any new water bore is not to cause a water pressure reduction at an existing bore of more than 5m. The GABORA water protocol sets out arrangements to give effect to this requirement in the form of minimum separation distance between bores for different extraction rates. It provides a lookup table for each aquifer giving the relationship between bore separation distance and licensed annual extraction rates, although there is also provision for site specific calculations.

Appendix A includes extracts from the GABORA water plan and the GABORA water management protocol related to bore separation requirements.

3.3.3 Unallocated water

Water moves very slowly through the sandstone aquifers of the GAB. As a result, the volume that can be allocated on a sustainable basis is very small. The volume used by uncontrolled distribution of artesian water through open bore drains caused water pressures to fall for many years. However, improvements in the efficiency of stock watering through the capping and piping of uncontrolled artesian bores has enabled the provision for the granting of new water licences. The GABORA water plan establishes a general reserve and a state reserve (GABORA Schedule 4). The reserves relate to individual areas and aquifers (GABORA Schedule 2 and 3). The reserves relevant potential source aquifers in the project area are:

- State Reserve - Hutton Sandstone and Hooray Sandstone (together) – 16,400 ML/a
- General Reserve - Hooray Sandstone – 1545 ML/a, and
- General Reserve - Hutton Sandstone – 1545 ML/a.

3.3.4 Process for granting unallocated water

Appendix A sets out a copy of excerpts from the GABORA water plan and the GABORA water management protocol (State of Queensland, 2019b) relating to the process for granting unallocated surface water from the GAB. The project is in a location that would qualify for access to the state reserve. The total volume available over the whole of the Hooray and Hutton Groundwater Units is 16,400 ML/a. These groundwater units share essentially the same footprint and underly an area more than one third of the Queensland section of the GAB water plan area, although most of that large area has a low population and limited development.

Criteria for assessing an application for the grant of a licence from the reserve (GABORA s23) include the availability of alternative water supplies. These would include trade of existing underutilised licences; the installation of watertight distribution systems on uncontrolled artesian bores to generate water efficiency savings for trade; and the development of a managed aquifer recharge (MAR) scheme involving the storage in GAB aquifers of surface water during periods high surface water availability for later recovery during periods of low availability. It could be expected it would only be if such alternative options were not viable that water licences would be granted from the reserve.

The volume that that could be utilised from the state reserve would also be limited by the impact of extraction on GDEs and to a lesser extent the impact on existing water bores. It is likely that impact on GDEs would be more limiting than the willingness of the DRDMW to grant licences in consideration of current demands and potential future demands for water in other parts of the GAB.

The process used by DRDMW to release water has varied over time in accordance with the local water needs, and the local characteristics of the aquifer system. A process for a release from the state reserve in the project area could be expected to focus on the impact on GDEs of the proposed new extraction.

3.3.5 Water trading - relocatable water licenses

Most water licenses to extract water from the GAB are restricted to the purpose of ‘stock watering’ (which excludes feed lot operations). Stock watering licences do not have volumetric limits. The volume of water that can be taken is limited by the restriction on the purpose to the watering of stock, and bore owners are being progressively required to control artesian bores and distribute water to stock through piped systems.

Other water licences that do not have volumetric limits include most licences to take water for domestic purposes, and for environmental and cultural purposes. However, most water licences for purposes other than stock watering have an annual volumetric limit. The water licences attach to land and operate to the benefit of the land to which it attaches. However, the Water Act provides (Section 126) that a water licence can be relocated to attach to other land if a water plan or water protocol allow for relocation. Relocation then becomes a form of 'permanent trading' of water entitlements that can operate before any conversion of water licences to tradable water allocations separate from land, which will not occur in GAB in the foreseeable future.

The GABORA water plan and the GABORA water management protocol do allow for relocation of a water licence that has a volumetric limit in whole or in part. If an application were made to relocate a water licence the impact of the increased take of water at the receiving location on GDEs and existing water bores would be the primary consideration.

Water licences resulting from a release of water from the state reserve cannot the be traded to other land for use for some purpose other than the purpose proposed in seeking the release. If a water licence granted from the state reserve was no longer required, it would revert to the state.

The water available under a water license in any water year can be seasonally assigned by the licensee to another entity if it the licensee does not intend taking the water. This process is sometimes referred to as 'temporary trading'. Although as previously mentioned a water licence granted to a licensee from the state reserve cannot be traded permanently to another entity on other land, the water available can be seasonally assigned.

licensees can only participate in permanent or temporary trading if the relevant water licences are metered either by listing in Schedule 11 of the Water Regulation or because of a condition set on the water licence.

3.3.6 Uncontrolled artesian bores

The GAB has a legacy of uncontrolled artesian bores discharging into a system of open bore drains to distribute water for stock watering. Many of the bores have been repaired or replaced to enable flow to be controlled, and many of the bore drain systems have been replaced by piped systems, however many remain. The GABORA water plan sets in place measures to require that by 2027 bore owners bring the remaining bores under control and replace bore drains with water-tight stock water distribution systems, although there is provision for time extensions.

When a bore owner completes the required work without any government funding, 30% – and potentially more than 30% – of the volume saved can be converted to a volumetric water licence. The licence can then be relocated to other land.

3.3.7 Water accounting

Most water licences to take water for purposes other than stock watering set an annual volumetric limit. For each water licence DRDMW maintains a water account. If the annual volumetric limit is not fully used, the unused portion is carried over as a credit to the water account for the subsequent year.

The maximum carry over volume is twice the annual volumetric limit. The carryover itself can only accumulate up to a maximum equal to the volumetric limit, therefore maximum combined of volumetric limit plus carryover would be twice the volumetric limit.

4 Surface water modelling

4.1 Introduction

This section describes key inputs, assumptions and results associated with hydrologic modelling of the project undertaken for Jacobs by BWR.

4.2 Source model

BWR analysed a range of cases using the department's Source river system hydrology model for the Gulf water plan. The model used and developed by BWR is based on the version originally developed by CSIRO and later updated by DES for DRDMW[2] for the Gulf water plan. The department's model has been further debugged and modified by BWR in liaison with DES to incorporate the various project scenarios and configurations of interest in the DBC analyses.

The Source model simulates daily stream flows, flow management, storages, releases, instream infrastructure, water diversions, water demands and other hydrologic events in the plan area over a defined historical simulation test period (see section 3.1.5). It is the prescribed assessment computer program used by the departments when assessing the Flinders catchment for consistency with the environmental flow objectives and the water allocation security objectives set out in the water plan.

4.2.1 Base case

The base case in Source (representing full development of current water entitlements including unallocated water reserves) was originally developed by DRDMW as part of their development of the Gulf water plan. The relative hydrologic benefits and impacts of various project configurations are assessed against this base case.

4.2.2 Pre-development flow sequence

The pre-development flow sequence (representing a theoretical modelled historical flow sequence with all dams and instream water infrastructure removed and with no water taken under water authorisations from the system[10]) is generated for the entire Gulf water plan area and extracted from the Source model for analysis at node 7.

The pre-development flow sequence is used to assess the extent to which the river's flow regime – as represented by the EFO performance indicators – might be impacted under the modelled cases. It is used to report whether the required values of the Gulf water plan's EFOs are likely to be met (see section 0).

4.2.3 Hydrologic metrics

The hydrologic metrics reported for each modelled case are summarised in Table 3.

Table 3 - List of hydrologic metrics

Hydrologic metrics:	Target performance:
Environmental flows	
A. The seven EFO performance indicators at node 7 as set out in columns 1 and 3 in **Table 2**.	To achieve the corresponding values of the EFOs in column 2 in Table 2.
Supplemented water allocations	
B. Monthly reliability – this is equivalent to the monthly supplemented water sharing index for a priority group of new supplemented water allocations associated with the project which is defined in the Gulf water plan to mean the	No target specified within the Gulf water plan. Scenarios were generally examined in terms of: • the maximum annual volume of demand that could be supplied at 80% monthly reliability (which represented

[10] This provides information on the simulated flow regime of the system without any water resource development.

Hydrologic metrics:		Target performance:
	percentage of months in the simulation period in which the allocations are fully supplied.	the maximum volume of medium priority water allocations) or • the maximum annual volume of demand that could be supplied at 95% monthly reliability (represents the maximum volume of high priority water allocations)
Unsupplemented water licences		
C.	Volume of mean annual diversion (calculated over the simulation period) modelled as taken by each group of existing unsupplemented water entitlements located downstream of the proposed dam and are represented as separate nodes within the model.	No target specified. Metric reported to compare the potential implications for existing unsupplemented water allocations under different cases against the base case
Unallocated water reserves		
D.	Volume of mean annual diversion (calculated over the simulation period) modelled as taken by unallocated water reserve nodes located downstream of the proposed dam and are represented as separate nodes within the model.	No target specified. Metric reported to compare the potential implications for downstream unallocated water reserves under different cases against the base case.

4.2.4 General assumptions and inputs

The following is a summary of key inputs and assumptions underpinning the hydrologic modelling of the various scenarios and project configurations discussed below:

- All existing and new water entitlements, as well as the portion of remaining unallocated water reserves that not assumed to be assigned to the project – are assumed to be fully developed and utilized. This assumption is consistent with that applied by the department in developing, and assessing compliance against, water plans
- Rainfall and rates of evaporation within the simulation period are as per the department's base case (e.g. the department's assumed mean annual open water evaporation rate is approximately 1926 mm/a)
- Storage volume and surface area to storage height relationships are derived from information provided by Jacobs for the various scenarios and configurations (noting that the Saego scenarios are based on more accurate LiDAR survey whereas other scenarios are not)
- The rate of seepage from project storage is assumed to be 300 mm/a which is consistent with the assumed seepage rates generally assumed by the department for other storages in Queensland. This is considered conservative in that engineering solutions and applying best management practice approaches to the management of seepage could reduce the assumed rate of seepage.
- The volumes of water allocations modelled as being supplied from the project are assumed to be direct from the main storage itself and net of operational losses (storage evaporation and seepage) within the project's main storage(s). The irrigation distribution system is assumed to be a pressurised pipeline with minimal transmission losses
- All daily water demand patterns for the project are uniform for throughout the year (although this assumption does not preclude customers taking water over a shorter period of time within each water year). This assumption is considered appropriate given the extent to which the capacity of the project's water storage exceeds the volume of the annual demand
- Bypass flows are based on flows released from the diversion weir equalling flows into the diversion weir up to the maximum bypass flow rate for each model run at which point the bypass flows are capped at the maximum bypass flow rate

- The maximum bypass flow rate through the diversion weir on the Flinders Weir is assumed to be 100 ML/day (unless stated otherwise). This is considered to be an appropriate and relatively conservative volume to supply fish passage works compared to most other fishways in Queensland which are designed to operate with bypass flows of around 40 to 50 ML/day. A Bypass flow rate capacity of 100 ML/day is also likely to provide sufficient flexibility and maximum bypass flow capacity to achieve ecological and other objectives under section 23 of the water plan (including addressing potential impacts on downstream unsupplemented water users discussed in section 4.3.5) as well as to ultimately secure the environmental approvals required for the project. An analysis of the sensitivity of project yield to this assumption is discussed in section 4.3.1 and illustrated in Figure 6
- Dam and diversion spillway discharge capacities are based on assumed to be unconstrained above full supply levels except for the DBC configuration which are based on relationships derived from the DBC design
- Dead storage volumes for the various scenarios and configurations are assumed to be minimal. This assumes that future further detailed design of the project (post DBC) will seek to maintain the total useable volume (i.e. its full supply volume minus dead storage volume) close to the DBC useable volume
- The daily flow capacity of the diversion channel connecting the Flinders River diversion weir and the main Saego Dam storage area is assumed to be not impacted by backwater effects or extent of available hydrologic head. The daily flow capacity of the diversion channel is assumed to be up to 21,600 ML/day unless specified otherwise including for:
  - the split system Saego configuration scenarios in which transfer rates are limited to 500 ML/day whenever the main storage area is at a higher water level than the catch dam storage area, and
  - the DBC design configuration which is assumed to be 15,020 ML/day after optimisation through sensitivity testing
- The alignment of the project walls, diversion weir, diversion channels and spillways are based on information provided by Jacobs as part of their DBC design work
- Availability to supplemented water supplies within the project would be shared between medium and high priority water allocations using a continuous water sharing and accounting system
- The proposed project is not designed as an overland flow style development. The source modelling represents the project as a supplemented scheme that utilises a system of instream storages created by a weir, dam, and embankment and connected by a major diversion channel. These structures are designed to divert and store instream flows from a number of adjacent catchments rather than as an overland flow interception scheme. In addition, overland flows within the irrigation area are not assumed to be captured (other than for contaminated agricultural runoff capture purposes which are not considered to be overland flows under the Queensland Water Act).

The model runs other than the DBC design configuration generally include a volume of water acquisitions made up of unallocated water plus water entitlement purchases as assumed in post-PBC reference case. These volumes are effectively removed from the Source model (by reducing the volumes in the unallocated water nodes) to offset the additional demands placed on the Flinders by the project infrastructure and water allocations and achieve the downstream EFOs. These volumes are not related to mitigating downstream impacts on existing water entitlements (which is discussed separately in section 4.3.5.

The model run for the DBC design configuration (scenario 12 in Table 5 and Table 6) was optimized and found not to require any water entitlement purchases (i.e. rely only on securing unallocated water for which a corresponding reduction was made to the volume of unallocated water nodes in the model).

The assumed volume removed from the model for the DBC design configuration, and volumes removed as assumed in the earlier model runs, are detailed in Table 4 below. Alternative strategies involving different combinations of unallocated water and water entitlement acquisitions are discussed in section 4.3.6.

Table 4 - Unallocated water reserves and water entitlements assumed as being acquired in the model runs

Unallocated water reserves and water entitlements assumed as being acquired	Volume generally removed from model runs other than the DBC design configuration runs(ML)[1, 2]	Volume removed from the DBC design configuration model runs (ML)[2]
Remaining 7,000 ML AVL of Product 1 unallocated water in Reach 1 (upstream of Richmond gauging station)	7000	0
5,000 ML AVL licence held by Flinders Shire Council (Licence No. 618019) upstream of the project	5000	0
1,000 ML AVL licence (Licence No. 616951) attached to the Saego Plains property at the project	1000	0
2,120 ML AVL of licences (Licence Nos. 43752J, 43864J and 100474) attached to the Riverside property at the project	2440	0
Remaining 5,500 ML AVL of Product 1 unallocated water in Reach 2 (between Richmond gauging station and Etta Plains gauging station	5500	0
Remaining 127,150 ML AVL of Product 2 unallocated water within the Flinders catchment (included in the Flinders Source Model upstream of Walkers Bend gauging station)	127150	82440
Total	**148090**	**82440**

[1] All model runs tested in this report other than for the DBC design configuration are assumed to include water acquisitions made up of unallocated water plus water entitlement purchases as assumed in post-PBC reference case.

[2] These volumes are effectively removed from the Source model to (a) offset the additional demands placed on the Flinders by the project infrastructure and water allocations and (b) achieve the downstream EFOs. The exact volume, selection and distribution of water entitlement purchases is likely to be different to this as discussed in section 4.3.6.

4.2.5 Description of key model runs

Table 5 describes the set of key hydrology model cases for which results are presented and discussed later.

Table 5 – Key hydrology model cases

Model case	Comment
1. Pre-development flow case	As per department's predevelopment flow case. Represents a theoretical modelled historical flow sequence with all dams and instream water infrastructure removed and with no water taken under water authorisations from the system. Used to calculate performance and compliance against EFOs.
2. Base case	Full utilisation of existing entitlements and of unallocated water reserves as reflected in DES model. Used to compare against existing water entitlement performance.
3. Alstonvale Dam	Short-listed alternative site to Saego damsite, dam located on Betts Gorge Creek with a catchment area of 1127 km^2
4. Gap Dam	Short-listed alternative site to Saego damsite, dam located on Stewarts Creek with a catchment area of 957 km^2
5. Galah Creek Dam	Short-listed alternative site to Saego damsite, dam on Galah Creek with a catchment area of 1943 km^2
6. Yirendali Dam	Alternative site to Saego damsite, 171.1 GL storage (FSL 261m AHD) located on the Flinders River approximately 16km downstream of Alderley Crossing
7. Yirendali Weir	Alternative weir site to Saego damsite, 52.6 GL (FSL 258m AHD) storage located on the Flinders River approximately 16km downstream of Alderley Crossing
8. Saego Dam – PBC reference case	190 GL dam at Saego as per configuration in PBC (Engeny, 2020a) but remodelled in updated Source model by BWR
9. Saego Dam – post PBC reference case	155 GL dam at Saego as per configuration in post PBC documentation (Engeny, 2020b) but remodelled in updated Source model by BWR
10. Saego Dam with internal storage split between main Saego and the catch dam	Alternative to enable stacking of water in larger Saego Dam plus maintain airspace in catch dam to maximise capture of river flows. Various sizes of main Saego storage compartment split from 16.5 GL catch dam plus diversion weir storage compartment. Water would be diverted from catch dam into main Saego at 21,600 ML/day when main Saego water level is less than catch dam level, or pumped at 500 ML/day otherwise

Model case	Comment
11. Saego Dam with storage cut off at the gap to reduce evaporation	Alternative involving a wall across the Gap to contain water in Saego Dam and reduce surface area at higher dam volumes
12. Saego Dam with internal low-level storage compartment	Alternative to enable stacking of water in an internal compartment within Saego Dam to reduce surface area at lower storage volumes. Would involve a submersible internal wall within Saego
13. Saego Dam with large offstream storage	Alternative to enable stacking of water in a 50GL, 6m deep offstream storage to reduce surface area at lower storage volumes and increase airspace in dam
14. Saego Dam – DBC design configuration case	160.9 GL dam and other water infrastructure as detailed in DBC
15. Saego Dam – DBC design configuration under climate change sensitivity cases	160.9 GL dam and other water infrastructure as detailed in DBC but with inflows changed to test sensitivity of water allocation performance to climate change impacts on storage inflows

4.3 Results of hydrologic modelling

4.3.1 Hydrologic yields

Table 6 presents a summary of the results of BWR's hydrologic modelling[11] in terms of two demand bookend scenarios: either the maximum annual volume of demand that could be supplied at 80% monthly reliability (medium priority allocations) or at 95% monthly reliability (high priority water allocations).

The maximum annual volumetric limits for the project in each scenario is equivalent to the total nominal volumes of medium priority water allocations required to authorise the maximum annual volume of demand that could be supplied at the 80% monthly reliability.

The rows shaded light green in Table 6 indicate the maximum yields for various scenarios and configurations under the suite of assumptions outlined in section 4.2.4. Modelling of the project configuration and size that has developed during the detailed business case has found that, subject to a suite of modelling assumptions listed in this report, a hydrologic yield of up to either 74 GL of medium priority supplemented water allocations (at 80% monthly reliability) or up to 32 GL of high priority supplemented water allocations (at 95% monthly reliability) is possible from a dam on the Flinders River with a total storage capacity of 160.9 GL at the Saego site.

Figure 6 presents the relationship between maximum 80% yields and total full supply volume available for selected scenarios/configurations. It illustrates that the hydrologic yield of the Saego option is:

- Very sensitive to the size of the bypass flow volume assumed at the diversion weir – i.e. yield increases as maximum bypass flow volumes decrease represented for selected scenarios by the vertical double arrowed blue line in the middle of Figure 6
- Strongly correlated to the overall full supply volume available to the project – represented for selected scenarios by the sloping orange line on Figure 6
- Only moderately increased for alternatives that target reductions in evaporation by reducing the storage's surface area – represented for selected scenarios by the vertical single arrowed line on the left-hand side of Figure 6.

In addition, modelling showed that the yield of the project is dependent on being able to capture flows from the Flinders River compared with standalone options on smaller tributaries which yielded lower or zero volumes of reliable water.

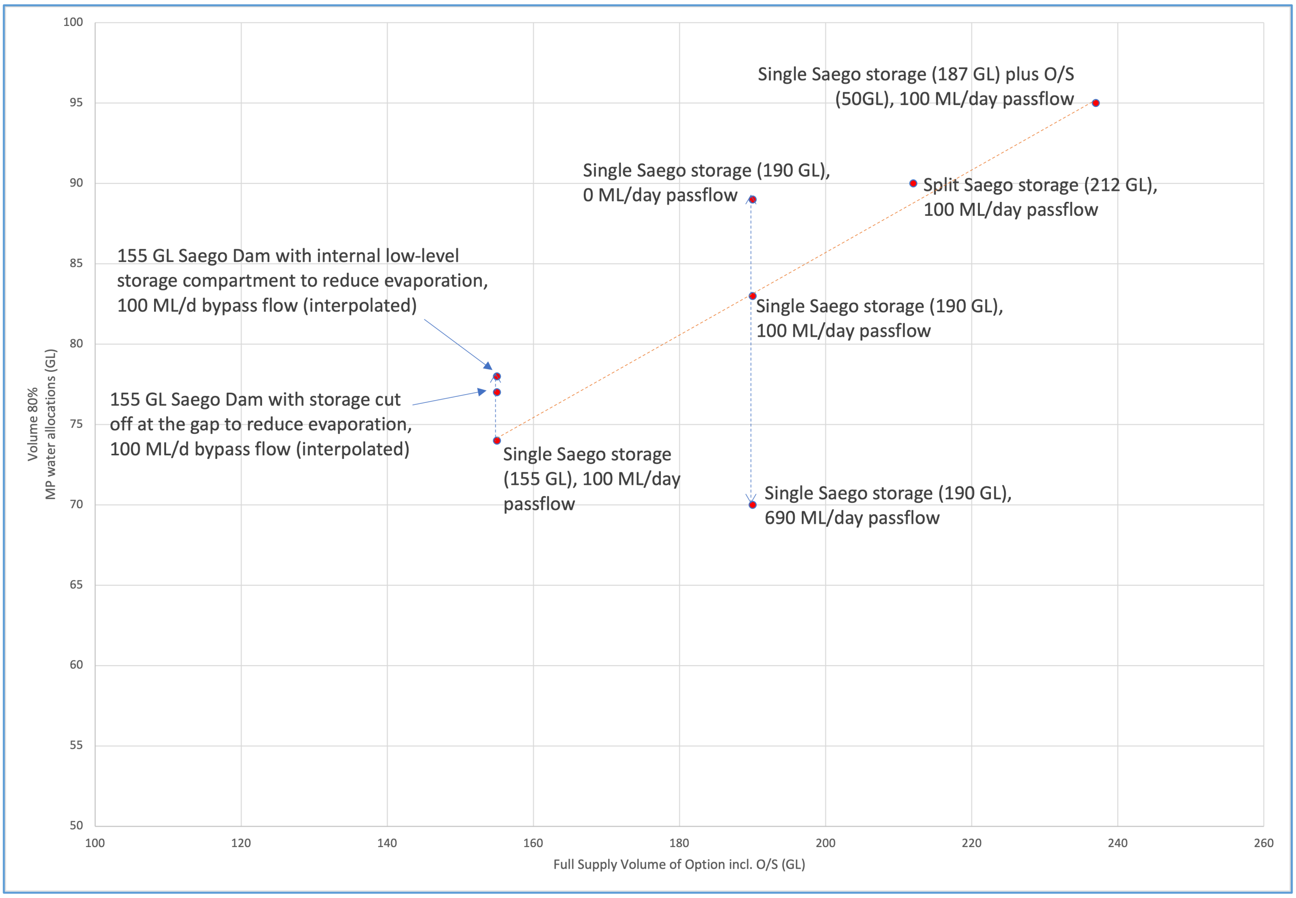
[11] A detailed set of modelling results are contained in *Summary Results 22_03_21v3.xlsx*

Table 6 – Summary of modelling results (BWR)

Scenario / configuration	Full supply level (FSL) AHD	Storage capacity @ FSL	Low flow bypass	Demand scenario bookends		HP to MP conversion factor	EFOs met? (Note 1)
				Max Demand @ 95% mthly reliability	Max Demand @ 80% mthly reliability		
1. Pre-development flow case	n/a						
2. Base case	n/a						Yes
3. Alstonvale Dam	Up to maximum FSL was tested	-	Nil	0GL	0GL	-	Not reported
4. Gap Dam		-	Nil	0GL	0GL	-	Not reported
5. Galah Creek Dam		401.9 GL	Nil	-	30 GL	-	Not reported
6. Yirendali Dam	261m	171.1 GL	Nil	27GL	64GL	2.4	Yes
7. Yirendali Weir	258m	**52.6 GL**	Nil	11.5GL	31.5GL	2.7	Yes
8. Saego Dam – PBC reference case	266m	**Dam 190 GL**	690ML/day	27GL	70GL	2.6	Yes
			100 ML/day	**37GL**	**83GL**	**2.2**	**Yes**
			Nil	42.5GL	89GL	2.1	Yes
9. Saego Dam – post PBC reference case	265.1m	**Dam 155 GL**	690ML/day	23GL	60GL	2.6	Yes
			100 ML/day	**32GL**	**74GL**	**2.3**	**Yes**
			Nil	35GL	78GL	2.2	Yes
10. Saego Dam with internal storage split between main Saego and the catch dam	Saego 268m Catch 265.25m	Saego 237.5GL Catch 16.5 GL **Total 254 GL**	690ML/day	37GL	85GL	2.3	No
			Nil	47GL	95GL	2.0	No
	Saego 266.6m Catch 265.25m	Saego 190GL Catch 16.5 GL **Total 206 GL**	690ML/day	-	-	-	No[12]
			500ML/day[12]	34GL	81GL	2.4	Yes
			100ML/day	**38GL**	**88GL**	**2.3**	**Yes**
			Nil	41GL	91GL	2.2	Yes
	Saego 266.7m Catch 265.25m	Saego 195GL Catch 16.5 GL **Total 212 GL**	**100ML/day**	**40GL**	**90GL**	**2.3**	**Yes (just)**
11. Saego Dam with storage cut off at the gap to reduce evaporation	265.1m	D/S cut-off wall 142.6GL U/S cut-off wall 12.0 GL **Total 155 GL**	690ML/day	24.9GL	62GL	2.5	Yes
			Nil	37GL	79.5GL	2.1	Yes
12. Saego Dam with internal low-level storage compartment	Internal wall 262m Dam FSL 265.1m	**Total 155 GL**	690ML/day	26.5GL	64GL	2.4	Yes
			Nil	38GL	80.5GL	2.1	Yes
13. Saego Dam with large offstream storage	O/S 6m deep Dam FSL 265.1m	O/S storage 50 GL Dam 155 GL **Total 205 GL**	690ML/day	30GL	75GL	2.5	Yes
			Nil	44GL	90GL	2.0	Yes
	O/S 6m deep Dam FSL 265.9m	O/S storage 50 GL Dam 187 GL **Total 237 GL**	**100ML/day**	**44.5GL**	**95GL**	**2.1**	**Yes (just)**
14. Saego Dam – DBC design configuration with optimised water acquisitions	265.1m	**Total 160.9 GL**	**100 ML/day**	**32**	**74**	**2.31**	**Yes (just)**

[12] Reducing low flow bypass volume from 690 ML./d to 500 ML/d was required to achieve the 5-year high flow EFO in this scenario. This is because reducing bypass flows resulted in weir spilling more often and satisfying this EFO.

Figure 6 – Maximum 80% yields (which is equivalent to the annual volumetric limit for each scenario) plotted against the total full supply volume available for selected scenarios/configurations



4.3.2 Environmental flow objectives

Most scenarios and configurations that were investigated, including all those indicated in light green in Table 6, were found to be fully compliant with the Gulf water plan EFOs under the suite of assumptions that were outlined in section 4.2.4[13].

The EFO results for selected scenarios and configurations as modelled by BWR are presented in Table 7.

The scenarios involving the largest (254 GL) Saego Dam configurations (with internal storage split between main Saego and the catch dam) did not pass EFOs. It was also found that a slightly smaller version of this configuration with a large bypass flow volume also did not achieve one of the medium to high flow EFOs (specifically the five year daily flow volume EFO). However, slightly reducing the bypass flow volume resulted in all EFOs being achieved. This suggests that reducing bypass flows would result in the weir spilling more often and thereby satisfying this particular EFO.

[13] Of particular importance to the achievement of EFOs is the assumed level of water acquisitions within the model runs as discussed earlier.

Table 7 – Summary of performance against environmental flow objectives for selected scenarios (BWR).

Scenario / configuration	Total storage capacity	Max demand	Monthly reliability	Proportion of no flow days	Mean annual flow percentage	Median annual flow percentage	Median wet season flow percentage	1.5 year daily flow volume percentage	5 year daily flow volume percentage	20 year daily flow volume percentage
Gulf water plan requirement	**n/a**	**n/a**	**n/a**	**<70%**	**>90%**	**>78%**	**>75%**	**>90%**	**>96.5%**	**>98%**
Base Case	n/a	n/a	n/a	68.7%	92.7%	83.4%	82.7%	92.8%	98.2%	99.2%
Saego Dam – PBC reference case with 100 ML/d bypass flows	190 GL	83 GL	80%	69.1%	92.8%	84.1%	82.7%	91.3%	97.6%	99.1%
Saego Dam – post PBC reference case with 100 ML/d bypass flows	155 GL	74 GL	80%	69.1%	93.2%	85.9%	82.7%	91.3%	97.7%	99.2%
Saego Dam with internal storage split between main Saego and the catch dam and with 100 ML/d bypass flows	212 GL	90 GL	80%	69.1%	92.6%	84.5%	82.7%	91.3%	96.5%	99.1%
Saego Dam with large offstream storage and with 100 ML/d bypass flows	237 GL	95 GL	80%	69.1%	92.3%	83.8%	82.7%	91.3%	96.9%	99.0%
DBC design configuration with 15,020 ML/day diversion channel capacity, 100 ML/day bypass flows and optimised water acquisitions	160.9 GL	74GL	80%	69.1%	91.8%	82.3%	79.6%	91.3%	96.6%	98.8%

4.3.3 Water products and conversion factors

Table 6 presents the hydrologic yields in terms of either the maximum annual volume of demand that could be supplied at 80% monthly reliability (medium priority allocations) or at 95% monthly reliability (high priority water allocations).

As a rule of thumb, under a continuous sharing system the factor that may be applied to convert a high priority water allocation to a medium priority water allocation may be deduced by dividing the medium priority yield by the high priority yield for any given scenario. These factors are reported in Table 6 and may be used to derive any mix of the two water products that might be supplied from any particular dam scenario and configuration[14].

An example of how to use conversion factors

The following is an example of how this may be applied using the medium and high priority relationship derived from modelling undertaken by BWR of the model case 14 (i.e. the DBC design configuration). Under this configuration the project is likely to yield:

- A maximum volume of "medium priority" water allocation that may be supplied from the project (represented by 80% monthly reliability) of 74 GL/a, or
- Alternatively, a maximum volume of "high priority" water allocation supplied from the project (represented by 95% monthly reliability) of 32 GL/a.

An approximate HP to MP conversion factor may be derived from these results that equates to 74 / 32 = ~2.31 i.e. 1 ML HP = ~2.31 ML HP. A relationship may then be derived to determine the mix of the two water allocation groups that might be supplied from that particular project configuration e.g.:

The volume of HP allocations that may be released:

= (The maximum volume of MP allocations – the volume of MP allocations proposed to be released) / 2.31

= (74,000 - the volume of MP allocations proposed to be released) / 2.31

Or alternatively:

The volume of MP allocations that may be released:

= The maximum volume of MP allocations – (the volume of HP allocations proposed to be released x 2.31)

= 74,000 – (the volume of HP allocations proposed to be released x 2.31).

4.3.4 Potential for individuals to customise their personal monthly reliability

Under continuous sharing, a water allocation holder may choose to voluntarily reduce the volume of water that they take each year (i.e. less than their nominal volume and annual entitlement to take water under) as a means of saving their water for future years and improving their individual monthly reliability. This is possible under a continuous sharing system of water accounting because unlike announced allocation water sharing rules in place in many existing Queensland supplemented water supply schemes, all unused water stored in an individual water allocation holder's water account is carried over from one water year to the next (subject only to progressive deductions for storage losses).

The Source model was used to explore this relationship which was found to be essentially linear. The analysis suggests that if a high priority water allocation holder were to voluntarily restrict their take of water from their continuous sharing account to 56% of their HP volume each year, they might achieve a long-term monthly reliability (as assessed over the historical period in the Source model) of 100%.

Appendix B provides an overview of the continuous sharing system.

[14] Sensitivity analysis using the Source model suggests that these relationships are approximately linear.

4.3.5 Implications for existing downstream unsupplemented water entitlements

The model was used to quantify the potential implications for existing unsupplemented water entitlements that are located downstream of the project. Impacts were reported in terms of the reduction in mean annual diversions for groups of unsupplemented water licences when compared to the base case after adjusting it to remove the volumes of unallocated water and water entitlement acquisitions as described in Table 4.

Table 8 presents a summary of these impacts for selected scenarios. It indicates that the total potential impact on downstream water entitlements from the project for selected scenarios (under the assumptions listed in section 4.2.4) might be between approximately 5,000 and 6,000 ML/a when measured in terms of modelled mean annual flows.

These impacts might be mitigated by a range of strategies such as, for example, optimising the timing and volumes that bypass flows are released from the diversion weir downstream (preferably in ways that also align with making passing flows that mitigate local downstream ecological impacts) and/or by purchasing a portion of the potentially impacted water entitlements. Further work will be required post DBC as part of the environmental impact assessment process and operations manual development process to quantify these potential local impacts in more detail (taking into account mitigating factors such as access to local waterholes for example) and then to refine, assess and optimise strategies for mitigating any impacts. Future work in this regard might include:

- Assessment of the local water resource availability and licence conditions applicable to each downstream unsupplemented water entitlement holder. This may be important in understanding the extent to which the potential modelled impacts might be naturally mitigated by local factors such as the presence of large waterholes, the current utilization of, or potential for using, groundwater bores to access surface water (given the provisions mentioned in section 3.2.2)
- Optimisation of weir release operating rules (through both the gates and fishway/outlet works) both to minimize the local impacts on downstream unsupplemented water entitlements and to maximise local ecological outcomes downstream of the project. This approach is currently being deployed by Sunwater and DRDMW in the development of operating arrangements for Rookwood Weir as part of the development of a Resource Operations Licence and Operations Manual for that project. This could also involve liaison with DRDMW to examine and assess the scope for introducing unsupplemented water sharing rules for the zone downstream of the project as part of a future Gulf water management protocol and
- Consultation with potentially impacted downstream water entitlement holders as part of the assessment of local conditions, potential impacts and alternative mitigation strategies.

Table 8 – Summary of potential implications on for existing downstream unsupplemented water entitlements. *Note that the project has not been optimised to minimise or mitigate these impacts.*

Model nodes on Flinders River between Saego Dam and Walker's Bend	Mean annual diversion for adjusted base case (excludes reductions in unallocated water and from assumed project acquisitions) (GL)	**Reductions in mean annual diversions from adjusted base vase**							
		Saego Dam – 190 GL PBC reference case with 100 ML/d bypass flows		Saego Dam – 155 GL post PBC reference case with 100 ML/d bypass flows		212 GL Saego Dam with internal storage split between main Saego and the catch dam and with 100 ML/d bypass flows		237 GL Saego Dam with large offstream storage and with 100 ML/d bypass flows	
		83 GL @ 80%	*37 GL @ 95%*	*74 GL @ 80%*	*32 GL @ 95%*	*90 GL @ 80%*	*40 GL @ 95%*	*95 GL @ 80%*	*44.5 GL @ 95%*
015 - WH1 AMTD 615Km Silver Hills	3102.5	-665.7	-620.6	-653.5	-575.3	-664.7	-586.4	-683.4	-651.9
025 - WH AMTD 575Km 3200 ML/a	2644.3	-58.6	-58.6	-58.6	-58.6	-58.7	-43.7	-58.6	-58.6
110 - WH-Recreation AMTD 624Km	18.0	-7.4	-6.4	-7.0	-5.8	-7.4	-6.2	-8.0	-7.0
113 - Recreation Richmond AMTD 624km	37.0	0.1	0.1	0.1	0.1	-1.2	-0.9	0.1	0.1
119 - WH AMTD 540 Km 1600 ML/a	908.6	-12.9	-11.3	-12.8	-11.0	-12.7	-11.2	-15.0	-11.9
132 - WHNewalloc_XXXX8	21373.3	-1077.6	-962.0	-1019.7	-879.5	-1110.6	-935.5	-1117.1	-1016.8
159 - Unreg Irr AMTD 109.4 Km	571.6	-2.5	-2.3	-2.4	-2.2	-2.4	-1.9	-2.4	-2.4
205 - WH Irr 720ML/a AMTD 730km Off	455.6	-455.6	-455.6	-455.6	-455.6	-455.6	-455.6	-455.6	-455.6
207 - WH Irr 1000 ML/a ATMD 730 km Off	719.7	-719.7	-719.7	-719.7	-719.7	-719.7	-719.7	-719.7	-719.7
240 - WH2 AMTD 613 Km Silver Hills	8399.7	-1638.5	-1576.9	-1635.7	-1459.2	-1651.1	-1371.2	-1699.9	-1632.3
GR2_SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GR4_SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NWU10_P1_SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NWU10_SP Reduced	4217.4	265.6	280.3	280.3	302.5	250.8	280.3	250.8	273.0
NWU4_SP Reduced	3329.2	-21.8	15.1	6.9	27.4	-5.4	15.1	-30.0	6.9
NWU5_SP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SR3_SP	1620.3	-252.8	-252.6	-252.6	-252.5	-350.1	-307.2	-252.9	-252.6
XXXX9	17791.2	-894.5	-769.3	-841.4	-630.9	-882.6	-688.6	-924.5	-837.8
Total	**65188.5**	**-5542.1**	**-5139.7**	**-5371.7**	**-4720.4**	**-5671.4**	**-4832.6**	**-5716.2**	**-5366.8**

4.3.6 Implications for project water acquisitions

As discussed in section 4.2.4, the hydrologic analyses are based on the assumption that a volume of water acquisitions (made up of unallocated water plus water entitlement purchases as detailed in Table 4) is effectively removed from the Source model to offset the additional demands placed on the Flinders by the project infrastructure and water allocations, as well as to achieve the downstream EFOs. (This is separate to the mitigating potential impacts on existing unsupplemented water entitlements which is discussed in section 4.3.5 above).

The total provisional volume of water acquisitions that was initially assumed for all the PBC project configurations was 148 GL. Further modelling was undertaken by BWR to determine the minimum volume of water acquisitions required in order for the DBC design configuration to just meet the EFOs at node 7. The total modelled volume of water acquisitions for the DBC design configuration (model case 14) to just meet the EFOs was found to be reduced to 82.44 GL.

Alternative approaches involving different combinations of unallocated water and water entitlement acquisitions than that assumed in the model (and set out the right hand column in Table 4) are, of course, possible. The preferred (and simplest) approach would be to secure 83GL from the general unallocated surface water reserve.

Another approach might involve securing a volume of general unallocated water equivalent to the maximum volume of medium priority water allocations for the DBC project configuration (i.e. 74 GL) with the additional volume made up of a combination of water entitlements purchased from existing water entitlement holders and cancelled by DRDMW, and/or securing (through appropriate negotiation) a volume of unallocated water from the indigenous unallocated reserve. However, any alternative which involves the cancelling of existing water entitlements purchased by the project from other water licence holders would require support from DRDMW to expedite such cancellations through the water planning framework. Notably, a similar approach was proposed within the DBC for the Granite Belt Irrigation Project (Jacobs, 2019) and is understood to be currently being applied by the department and its proponents to that project.

Ultimately, the preferred approach is likely to be influenced by such factors as:

- the volume of unallocated water reserves that the state government is prepared to release to the project
- whether the project is eligible to secure water from the strategic and/or indigenous unallocated water reserves (in addition to the general unallocated water reserve)
- the extent to which existing private water entitlements might be available (and affordable) for purchase by the project within the Flinders sub-catchment and
- the appetite for the department to expedite cancelling of water entitlements purchased by the project to enable EFOs to continue to be met in the long-term with the project in place.

4.3.7 Climate variability and change implications

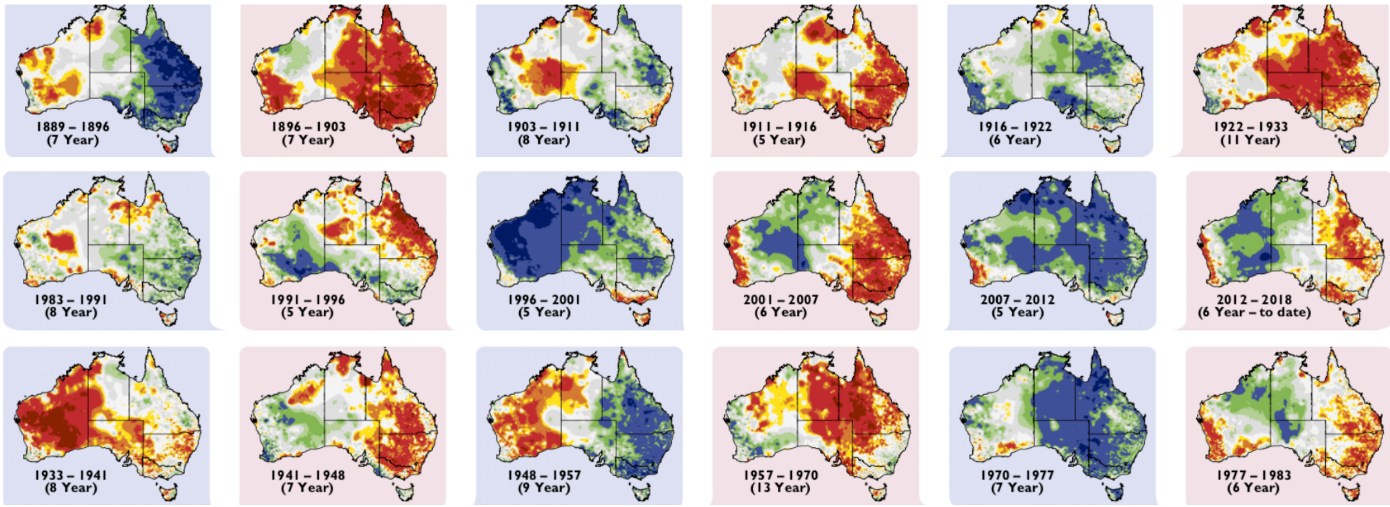
Mean annual and seasonal climate change measures should be considered along-side natural climate variability – both spatially and temporally – which is an important feature of Queensland's climate. Understanding both climate variability and likely future climate change is therefore crucial for adaptation and preparedness (Queensland Government, 2021).

Queensland is typically impacted with episodic droughts, floods and tropical cyclones with droughts potentially persisting for a number of years. Rainfall variability occurs at interannual, quasi-decadal, multi-decadal and centennial time scales (Queensland Government, 2020).

Increased climate variability does not necessarily mean that stream flows changes are identical to changes in mean rainfall. Increased climate variability could in some instances lead to increased rainfall and resultant stream flows. In addition, stream flow reductions may not necessarily be as large as rainfall reductions. Such changes and relationships are difficult to predict given the limitations of current models.

Australia's historical climate variability is illustrated in Figure 7. This illustrates how rainfall totals that are well-below average have been experienced in North-West Queensland over durations spanning up to over a decade (e.g. 1922 to 1933).

Figure 7 – Australia's extended wet and dry periods (April to March) relative to historical records 1889 – 2018 (Queensland Government, 2021)



The Queensland Department of Environment and Science (DES) developed a comprehensive set of high-resolution climate change projections for Queensland to underpin the Queensland Climate Adaptation Strategy[15]. These suggest:

- That there is a wide variation in estimated changes in mean annual precipitation with the global climate-change models (Table 9) ranging between -34% and +13% and a relatively small (between 3.1% decrease to 0.01% increase) change in the 50 percentile estimates of mean annual precipitation by the GCM models.
- Climate is likely to be characterized by increased rainfall variability with slight increases in precipitation in summer and during a wet season (Figure 8 and Figure 9)[16]. Increased rainfall variability could potentially lead to increased stream flow and/or storage capture even if the median or average annual precipitation is reduced. The intensity of heavy rainfall events is also likely to increase resulting in more intense downpours (State of Queensland, 2019a)
- There is likely to be higher temperatures and hotter and more frequent hot days (with forecast temperatures that gradually increase over time, in particular during autumn (see Figure 10[16]). This could lead to harsher fire weather (State of Queensland, 2019a) and higher rates of annual evaporation. Figure 11 shows the potential increase in pan evaporation for the Flinders Shire, noting that lake evaporation rates are typically up to 30%

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[15] An inter-active "Queensland Future Climate Dashboard" is also produced by the Queensland Government and "summarises information of 11 state-of-the-art climate models with regional scale simulations until the end of the current century". The Dashboard includes a range of climate metrics including, for example, precipitation (rainfall), temperature and pan evaporation (Queensland Government, 2021).

[16] Based on long-term changes relative to reference period (1986–2005) and Representative Concentration Pathway 4.5 (CO_2 concentrations increase steady until after mid-century, with CO_2 concentrations stabilising around 2060 and reaching 540 ppm by 2100) Queensland Government. (2021, 29 January 2021). *The Long Paddock — Queensland Future Climate Dashboard*. https://longpaddock.qld.gov.au/qld-future-climate/dashboard/#responseTab1

less than pan evaporation rates (Yihdego Y & J, 2018). The Queensland Government Department of Main Roads Technical Note WQ 30 provides historically-derived pan evaporation rates for Hughenden that equate to an annual lake evaporation of 1,674 mm/a (Queensland Government, 2000). This compares with the open water evaporation rate in the department's model of 1,926mm/a. This suggests that the current model may be conservative in its representation of storage evaporation when compared to historical records, and already reflect the higher rates of evaporation predicted by climate change models.

Table 9 – Changes in mean annual precipitation in the Flinders Shire

Global change model estimates	Change in annual precipitation in 2030	Change in annual precipitation in 2050	Change in annual precipitation in 2070
Minimum	-33.0%	-34.0%	-30.0%
50 percentile	-3.1%	-1.3%	+0.01%
Maximum	+9.7%	+13.0%	+11.0%

Figure 8 – Mean precipitation changes across seasons (2060–2079) and over time, Flinders Shire (Queensland Government, 2021)

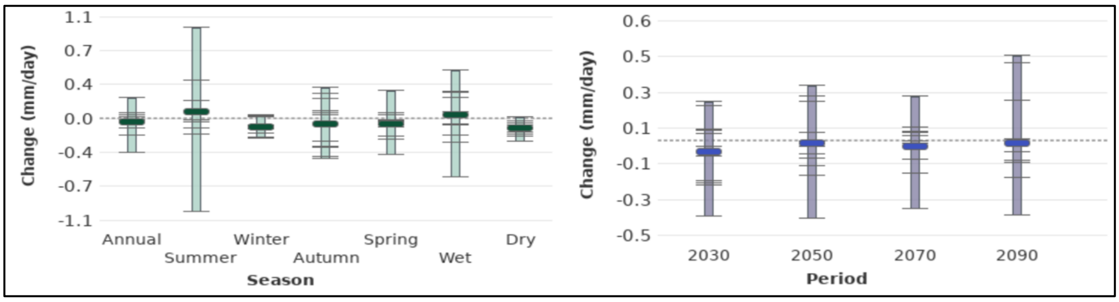


Figure 9 – Long-term percentage precipitation changes across seasons (2060–2079) and over time, Flinders Shire (Queensland Government, 2021)

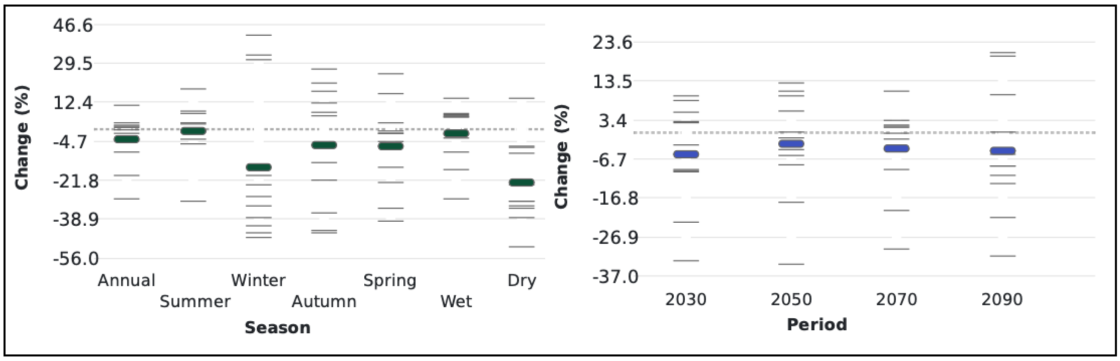


Figure 10 - Mean temperature changes across seasons (2060–2079) and over time in the Flinders Shire (Queensland Government, 2021)

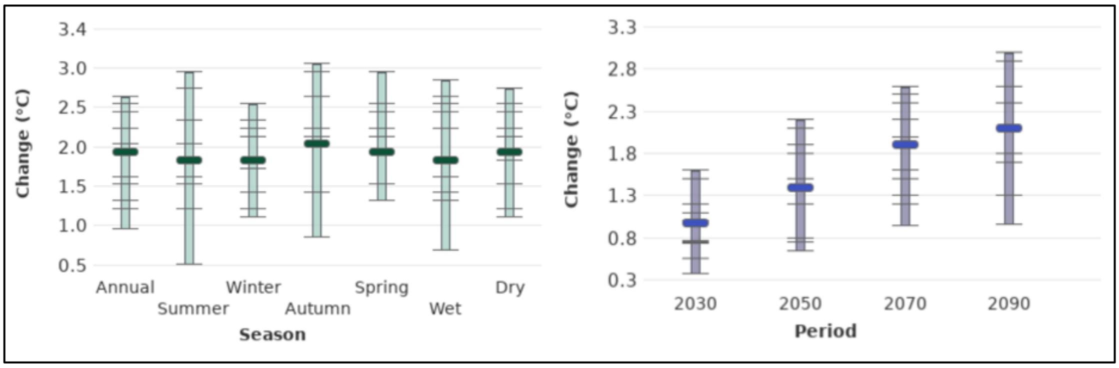
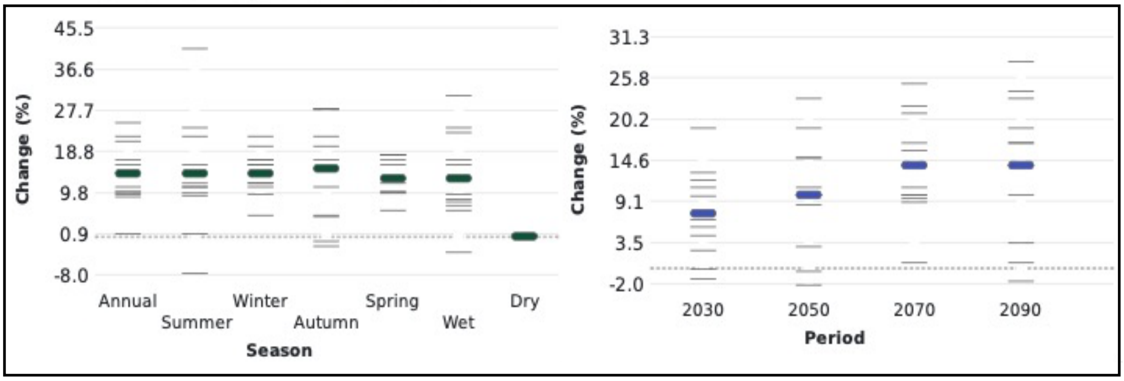


Figure 11 – Long-term percentage pan evaporation changes across seasons (2060–2079) and over time, Flinders Shire (Queensland Government, 2021)



4.3.8 Sensitivity of project hydrologic performance to climate change

BWR undertook a series of model runs to explore the sensitivity of the long-term hydrologic performance of the project (under the DBC design configuration) to climate change.

BWR liaised with DES in relation to climate change-related sensitivity testing for this catchment. DES advised that climate change adjusted rainfall/streamflow data was not available for the Flinders Source model. This means that it is difficult to predict the potential and collective impact of changed evaporation and precipitation on streamflows at this time.

To test the sensitivity of project performance to climate changes, BWR applied similar percentage changes to the net upstream inflows to the predicted range of percentage changes in mean annual precipitation (i.e. –30% to +10%)[17]. The modified inflows were then used as inputs to the project using the DBC design configuration model to assess the impacts on the monthly reliabilities of medium priority water allocations.

This approach assumes that the overall impact on the daily water storage balance (which is made up of changes in storage inflows combined with potential lake evaporation) is simply and directly proportional to potential changes to mean annual precipitation. As discussed in section 4.3.7, this is clearly not necessarily the case but is considered an adequate assumption for this high level assessment given the large variability in the climate change predictions in this catchment and the already conservative assumptions relating to lake evaporation in the department's Source model.

[17] To simulate this in the Source model, BWR reduced the upstream flows by applying a constant scaling factor (between +30% to -10%) to the instream loss nodes within the model.

Subject to these limitations and assumptions, the relationship between upstream streamflows and monthly reliability was explored using the Source model and is presented in Table 10.

Table 10 - Results of climate change sensitivity model runs (case 15)

Change in upstream inflows (compared to case 14)	Change in MP monthly reliability (compared to case 14)
-30%	-10.6%
-20%	-6.6%
-10%	-3.4%
0%	0%
+10%[18]	+3.3%

The sensitivity analyses suggests that a 1% change (increase or decrease) in medium priority monthly reliability might be expected for each 3% change (increase or decrease) in upstream inflows compared to the historical baseline streamflow conditions.

4.3.9 Suggested future steps – surface water

With respect to future surface water investigations, the following future (post-DBC) steps are suggested:

- As part of the environmental impact assessment process and operations manual development process, quantify the potential local impacts on downstream unsupplemented water entitlements in more detail (taking into account mitigating factors such as access to local waterholes for example) and then refine, assess and optimise strategies for mitigating any impacts in consultation with DRDMW and water entitlement holders (as discussed in section 4.3.5).
- Liaise with DRDMW in relation to the water planning related process requirements and regulatory steps that might be required to facilitate the future implementation of the project in the context of government's future decisions about the release of unallocated water for the project and release or reserve of unallocated water to other proposals in the Flinders Catchment
- Examine the implications of the matters that are listed in sections 3.1.4 and 3.1.9 as part of detailed assessment within a future Environmental Impact Study.

5 Groundwater

5.1 Introduction

The project is primarily based on storing surface water to provide a water supply suitable for irrigation. However, groundwater could help to support irrigation during dry periods when the surface water storage is depleted.

Groundwater and surface water have different characteristics. A portion of rainfall replenishes the soil moisture store where it is consumed by evapotranspiration and is lost to the water cycle. Another portion of rainfall runs off the land quickly providing limited opportunity for consumptive use, unless retained in a dam or weir. A small proportion of rainfall infiltrates beneath the soil moisture into aquifer systems where it is retained for long periods before eventually discharging to GDEs such springs, baseflow to watercourses, or direct to sea.

[18] Based on linear extrapolation.

Aquifers provide natural storages of water that can be exploited for consumptive use. However, just as a dam retaining stream flow for later use has to be constructed and operated in a way that meets environmental flow objectives and the needs of downstream users, so extraction from a groundwater system must be operated with a view to minimising reductions to natural discharge to GDEs and minimising impact on other water users.

Groundwater is a drought resilient resource in comparison surface water. It does not evaporate and is likely to be available when surface water resources are exhausted. Some groundwater systems are more drought resilient than others. For example, the bed sands of a watercourse are quickly replenished during stream flow, provide store of water for a time after stream flow ceases, but tend to dry out during drought periods even under natural conditions. At the other extreme are groundwater systems such as the GAB which store water over very long periods and are very drought resilient, but recharge very slowly with the result that the total volume of water that can be extracted on a sustainable basis is relatively small.

The optimal use of water resources is to use the ephemeral but large surface water resources when available and drought resilient groundwater resources during drought.

5.2 The importance of groundwater to this project

5.2.1 Objective

The proposed project would exist in a high evaporation area and the dam would be relatively shallow and occasionally subject to extended periods of low or no inflows. As a result, there would be periods when there is restricted or no supply from the project.

For annual cropping, farming decisions could be managed to allow for these periods as they occur. However, interruptions to supply can be expected for high priority water products as well as medium priority products. If small volumes of groundwater could be made available for the holders of high priority allocations during non-supply periods, then tree crops could be sustained through drought periods.

5.2.2 Assessment of opportunities/constraints of using alluvial groundwater

Summary of past studies

There is bed sand in the Flinders River and alluvium associated with earlier paths of the river. A report prepared to support the development of the Gulf water plan (Qld Department of Natural Resources Mines and Water, 2006) noted that the alluvial strip associated with river can be 10km wide, that it can contain aquifer material to a depth of 25m, and that infiltration of rainfall is the likely recharge mechanism. This is a regional, high level report but provides context for more local assessments.

Local experience in Hughenden area it that is possible to locate aquifer material, but that it is shallow and difficult to find. Aquifer materials (permeable sands and gravels) are very localised. A local water bore driller considers that the chances of finding a useful bore are less than one in four.

A study of the potential of the shallow groundwater resources of Glendalough station (Innovative Groundwater Solutions, 2014) some 6 km upstream of the river crossing from the proposed dam for the project, noted that four alluvial bores on Glendalough station were reported as capable of pumping rates as high as 40 l/s, that recovery was fast after pump shutdown, and that the bore supply was resilient to drought. The study proposed the possibility of recharge to the alluvium from basalt aquifers to north. However, it is difficult to conceptualise how water could move from the basalts to the alluvium without being intercepted by the river.

A later report (Innovative Groundwater Solutions, 2020) further assessed the groundwater resources of the same area using geophysical data and a stochastic modelling approach. The report noted that due to the limited value of historical aquifer pumping tests at Glendalough station the hydraulic properties of the of the alluvium were effectively unknown. The modelling studies therefore used a wide range of possible values. The report suggested that if a wellfield of 40 production bores could be established a sustainable extraction limit between 1400 ML/a to 17,800 ML/a may be achievable. The report also concluded that there is little opportunity to pump water into the alluvium for storage (i.e. 'managed aquifer recharge') because the significantly porous material capable of storing water for recovery is located below the water table. Recharge was considered to be by direct infiltration from rainfall or from the basalt to the north, not from stream flow.

In 2015 an investigation was carried out into the potential of the alluvium at 15-Mile reserve some 30 km upstream of the project site (Rob Lait and Associates Pty Ltd, 2017). That work was updated in 2018 (Rob Lait and Associates Pty Ltd, 2018). The study involved test drilling and the pump testing of six bores. The alluvial material was considered to be narrow sand aquifers deposited in paleo channels eroded into basement rocks at depth of up to 18m. Standing water level was approximately 11 m below ground resulting in typically only 5m of available drawdown. The bores were tested at up to 22 l/s, but in some cases broke suction because of the limited available drawdown. The volume in storage was estimated at 1038 ML. It was concluded that recharge was from slow infiltration from rainfall not river flow.

On the DRDMW database there are records of test drilling near the proposed river crossing for the project and also some 10km downstream. The test drilling found basement at depths of 18m to 24m but no useful water supplies being recorded.

Conclusions

Conclusions about the potential for groundwater supplies to be utilised from the alluvium for the project are as follows:

- There is some potential to establish water supply bores in the alluvium at the project site, but the likelihood of success is not high.
- If successful bores were established:
  - it is likely that the depth to basement would be small (approximately 18m – 24m) and the available drawdown small (approx. 5) raising issues about the resilience of the supply to periods of low recharge and high demand.
  - water level behaviour in response to test pumping stress would need to be monitored over a range of seasons to provide confidence in an assessment of sustainable yield
  - they would need to be located more than 1km from the Flinders River, or a case would need be to be developed that the alluvium in the area is not connected to the river and DRDWM would need to agree with that conclusion.
- Future geotechnical investigations associated with dam site investigation could provide opportunity to further assess groundwater potential.

In summary it may be possible to establish a drought resilient water supply from the alluvium, but even if bores could be found it would take some years to have confidence that the bores could provide a reliable drought supply for the project.

5.2.3 Assessment of opportunities/constraints of using GAB groundwater

Physical availability and suitability of GAB water

The aquifers of the Hooray sandstone and underlying Hutton sandstone are widespread and reliable aquifers. The bore logs do not always distinguish between the aquifers, particularly for older bores, but in terms of physical availability of water it is not important which aquifer is accessed. However, water licences distinguish between the two sources and depending on the water licence held a new bore would need to target one or the other aquifer. Near the project an initial assessment is that the Hooray would be found between approximately 90 to 120m and the Hutton between 140m to 240. These estimates could be refined.

The water licensing requirement may limit the annual volumetric limit for a new GAB water bore to approximately 500 ML per day, as discussed in a following section. A bore from either aquifer is likely to capable of delivering 25 l/s, and potentially well in excess of that rate, which would be more than enough to provide the water available under licence. The water is likely to exist under artesian pressure.

Water is likely to be of good quality at approximately 600 mg/l total dissolved salts throughout the area. Irrigation is successful carried in the area using GAB water.

The cost of drilling a new water bore would depend on depth but is estimated to be $250k per bore.

The groundwater dependent ecosystem constraint

The impact of increased water extraction on GDEs, which are springs or baseflow fed sections of watercourses, is likely to be the biggest constraint on developing new bores based on water licences released from the unallocated water reserve, and potentially on water licences obtained through trade. For example, under the rules in the GABORA water management protocol (Attachment 4.2 of the protocol), an additional extraction of 1000ML/a from the Hutton sandstone, at the project site, would cause a pressure impact of more than the maximum allowed limit of 0.4 m in a hypothetical GDE even 200km from the project site that sources water from the Hutton Sandstone. The constraint falls away by a factor of 10 at a distance of 320km and disappears completely at 710km.

The impacts in the Hooray sandstone would be about half as much as for the Hutton, but there are more Hooray sourced GDEs closer to the project site than Hutton sourced GDEs.

Impact on GDEs would be a factor in the consideration of applications to relocate existing water licence to the project site and could provide either a constraint or an opportunity. If the existing licence were located between a sensitive GDE and the project site, the relocation would cause a reduction in impact, potentially opening the way for an increased water extraction at the project. However, if a proposed relocation would result in an increase in impact at a sensitive GDE, it would be a constraint.

There are more than 700 GDEs in Queensland fed from GAB aquifers. Knowledge about the connectivity of the GDEs to underlying aquifers is variable. The source aquifer for some GDEs is well understood but the local hydrogeology around others is less clear. As a result, the rules in the GABORA water management protocol make conservative assumptions about the connectivity where knowledge is poor. If a particular GDE were likely to limit the potential for increased extraction at the project site, an assessment could be made of the possible benefit of carrying out a detailed hydrogeological assessment of connectivity at the site.

The GABORA does not set explicit set-back distances for irrigation licences from GDEs (e.g. springs). However, the cumulative impact on GDEs resulting from a relocation would need to avoid exceeding the maximum of 0.4 m for any GDE. This may represent a constraint on the extent to which any particular relocation can occur.

Interference with existing water bores

The Hooray and Hutton Sandstones are artesian in the project location. Many bores utilise artesian pressure to distribute water for stock watering or fill storages for irrigation. The GABORA limits pressure impact between bores to 5m, and new bores need to operate within that constraint. The GABORA water management protocol (Attachment 5 of the protocol) requires that new bore extracting 450ML/a (as an example) from the Hooray would need to be 8.2 km from an existing bore. For the Hutton the separation distance would need to be 1km. For a larger extraction of 750 ML/a, the bore separation distance would be 25km for the Hooray and 6.6km for the Hutton. Clearly bore separation requirements could be a significant constraint for the Hooray, but less of an issue for the Hutton.

Bore separation issues relate more to bores on properties neighbouring the proposed project. Interference between bores on the project that take water under the authority of water licences attached to the same project lands would not be constrained.

Availability of unallocated water

The GABORA has established a state reserve of 16,400 ML/a from the Hooray and Hutton Sandstone together, from which water could be allocated for the project. Considerations would be competition for access to the reserve now and in the future. It could be expected that water would only be released from the reserve if availability from other sources such as trade, capping and piping, or a MAR scheme, were not viable options.

However, it is likely that issues around impact on GDEs would be at least as limiting, if not more limiting, than the availability of water from the state reserve.

It is understood that releases to date from the general or state reserves have been at a price of approximately $1500/ML

Availability of water through trade

There is approximately 22,000 ML/a held under volumetric water licences in the North Hutton and Hooray Sandstones (Klohn Crippen Berger, 2016). More than half is licences for town supply and to a lesser extent mining or industrial purposes and is therefore likely to be closely held. However, there is more than 9,000 ML/a licensed for irrigation and therefore more likely to be available for trade.

However, as previously mentioned, the impact on GDEs would be a consideration for any proposed relocation. The relocation could provide opportunity to reduce impact on GDEs or be refused because of the resulting increase impact on GDEs. Purchasing land on or near the project to which water licences already attach would avoid difficulties with GDE impacts as well as bore interference issues. An initial assessment found 3,000 ML of entitlement on or around the proposed development area, although most if not all is in use.

The relocation market is not an active market. DRDMW publishes reports on relocation of water licences. Over the 13-year period to the end of 2020 there have been 112 trades mostly in the Surat sub-basin, and none at all in the in the northern Hutton or Hooray. The maximum price was $4000/ML for 280 ML. The maximum volume was 1018 ML traded at a price of $2383 /ML. The minimum price was $1500.

Availability of water through capping and piping

There are some 107 uncontrolled artesian bores tapping in the North Hutton and Hooray Sandstones discharging more than 23,000ML/a, as well as another 146 bores that are controlled but still discharging more than 36,000ML/a into open bore drains (Klohn Crippen Berger, 2016). If the bore owners were not assisted with government funding to control bores and replace bore drains with piped systems, at least 30% of the volume of water saved could be converted into a water licence that could be relocated.

However, the impact on GDEs of any such proposed relocation would be a consideration in any proposed relocation.

Using a GAB aquifer for temporary water storage (MAR)

Water from the surface water scheme during periods of high water availability could potentially be injected into a GAB aquifer for later recovery during periods of low availability. Arrangements of this type are known as managed aquifer recharge (MAR) schemes. In the Surat sub-basin of the GAB treated CSG water is being injected into sandstone aquifers, not for direct recovery, but rather to generally improve aquifer water pressure that has been lowered over time by extraction for urban and stock use. That scheme has the advantage that the feed water comes from a CSG water treatment plant, and therefore has no suspended solids and a stable water chemistry.

There are significant engineering and water chemistry challenges in implementing MAR schemes. However, use of the GAB in this way would have the advantage of avoiding any impact on GDEs.

Conclusions

The following conclusions may be made about the potential for groundwater supplies to be established from the GAB for the project:

- There is a very high probability that water would be physically available from the Hutton and Hooray sandstone aquifers of the GAB and that it would be of suitable quality for irrigation.
- There is a state reserve of 16,400 ML/a from which water which can be allocated for extraction from the Hooray and/or Hutton sandstone. However, it could be expected that an allocation would only be made if alternative supplies were not available.
- Volumetric water licences are relocatable and therefore there is the potential to obtain water for the project through trading.
- Assisting the owners of uncontrolled bores to repair or replace the bores and convert open bore drains to piped systems would enable volumetric water licences to be granted and relocated to other land.
- The biggest constraint on obtaining GAB water using the above mechanisms are:
  - The net impact on water pressures at GAB GDEs (e.g. springs). Meeting statutory requirements for net impact needs to be a central focus.
  - Interference with existing water bores. This may be an issue but may be successfully overcome by locating project bores to minimize impact and limiting pumping rates of individual bores.

Separately from using the GAB as a water source, the aquifers of the GAB could be used to store surface water for later recovery.

5.3 Assessment of how much GAB water might be required

5.3.1 Undertaking a High-level water balance

The modelled surface water monthly irrigation demands over the 122 year simulation period was used to identify the timing and duration of the periods that high priority water allocations would not be supplied with water from the project. As the volume of the project's high priority water allocations is set to achieve 95% monthly reliability, this means that the total number of months where monthly demands cannot be met equates to 5% of the total months in the simulation period.

As high priority water users are considered likely to want some access to water even during extended dry period, analysis was undertaken to estimate how much groundwater entitlement from the GAB might be needed to enable high priority water allocations to be supplemented from groundwater with at least a portion of their monthly demands during such shortfall periods[19].

The assessment took into account the GAB water accounting rule that allows some carryover of unused water entitlement from year to year. This is based on allowing a volume of water entitlement that is not taken by the end of one water year to be carried over into water account for use in the following year. The maximum volume allowed in a GAB water entitlement's water account in any year is limited to two times its licenced volume (adjusted for any seasonal water assignments into or out of the water account within the year). For the project, during wet periods when full supply is available from the dam, unused GAB water would be carried over ready for use in the next period of failed supply.

The results in Table 11 below provide an example of this. They are based on an example scenario with 15,000 ML/a of 95% HP water allocations being supplied from the dam when surface water supplies are available (which would be 95% of months) and then using groundwater entitlements to maintain supply of 45% of monthly HP demand during periods of restricted or failed dam supply (5% of months). The assumption is that HP water allocations would continue to be supplied from the dam during dry periods until available surface water supplies could supply less than 45% of monthly demand, at which point the supply would then be supplemented at 45% of normal demand with groundwater.

The table illustrates the benefit of increasing the volume of groundwater entitlement under which water might be supplied to HP water allocation holders during periods of shortfall in dam supplies in this way. Increasing groundwater entitlement volume reduces the months that HP water allocations might be supplied with no water (i.e. a failure month means a month in which there is no water available from and the dam and the amount that can be taken under the groundwater entitlement has reached its authorised limit).

The table shows that, for the volume of high priority water allocations assumed in this example, a groundwater entitlement of 3,200 ML/a would enable a supply of 45% of monthly demand to be maintained throughout the whole of the historic period. If on the other hand only 1,500 ML/a were available, there would be a total of 32 months of failed supply over the 122 year period, which would include a period of 6 consecutive months.

Table 11 – Example of potential benefit of increasing the volume of groundwater entitlement under which water might be supplied to HP water allocation holders during periods of shortfall in dam supplies

Parameter	Value			
Assumed volume of high priority water allocation with a 95% monthly reliability being supplied by the dam (ML/a)	15,000	15,000	15,000	15,000
Volume of groundwater entitlement under which water is available to be taken by HP water allocation holders in periods of shortfall in dam supplies (ML/a)	0	1500	2500	3,200
Percentage of monthly demand supplied from groundwater during periods of shortfall in dam supplies	45%	45%	45%	45%
Maximum number of sequential months of failure	15	6	3	0
Total number of failure months in the 122 year simulation period	70	32	11	0

[19] This is separate and in addition to the unallocated water reserve volume discussed in Section 4.3.6.

As a further example, Table 12 shows the increasing volumes of GAB water entitlement that might need to be secured and developed to supply 10, 15 and 20 GL of high priority water allocations with say, 50% of monthly demands during periods of shortfall from a 190 GL Saego Dam.

Table 12 - Volumes of GAB water entitlement that might need to be secured and developed to supply various volumes of high priority water allocations with 50% of monthly demands during periods of shortfall from the dam (based on a 190 GL Saego dam scenario)

Volume of high priority (95% monthly reliability) water allocation being supplied from a 190 GL dam	GAB licence volume required to provide 50% supply during dam shortfall months and achieve no monthly failures in simulation period	Long-term mean annual diversion from GAB	Maximum diversion from GAB within any water year as allowed under the GABORA water plan
10 GL	2,400 ML	211 ML/a	4,800 ML/a
15 GL	3,600 ML	316 ML/a	7,200 ML/a
20 GL	4,800 ML	422 ML/a	9,600 ML/a

This analysis suggests that if GAB bores are used in this way (i.e. to provide 50% of monthly high priority demands during periods of shortfall from the dam), then:

- a total GAB licence volume that is approximately equivalent to a quarter of the high priority water allocation volume is needed to meet 50% of high priority demand in dam shortfall months
- in 95% of all months in the simulation period the dam would supply 100% of monthly high priority demand
- in 0.625% of all months in the simulation period (i.e. about 1/8th of the 5% shortfall months) the dam might supply around 75% (i.e. between 50% and 99%) of monthly high priority demand
- in 4.375% of all months in the simulation period (i.e. about 7/8ths of the 5% shortfall months) the GAB might supply 50% of the monthly high priority demand.

The combined performance of the two high priority products (i.e. the high priority dam water and the GAB back up supply) might then be estimated as follows:

$$0.95 \times 100\% + 0.00625 \times 75\% + 0.04375 \times 50\% = 97.6\%.$$

Of course, water would need to be physically able to be extracted from an appropriate number of bores set out with appropriate set-back distances for this approach to be viable.

5.3.2 Suggested future steps – groundwater

The following future steps are suggested:

- Focus on the GAB water resources as a potential source of groundwater to support the project. The alluvium is unlikely to provide a suitable supply, however opportunities could be taken to further assess the potential of the alluvium during geotechnical testing associated with the project. The following recommendations relate to GAB water resources.
- Carry out a formal search of the water licence database and groundwater database to obtain details of:
  - volumetric water licences, associated water bores, and water use
  - stock bore licences that are uncontrolled and licenced to use bore drains
- For water licences and water bores on or near the project site assess the potential for acquisition and incorporation into the project, thus avoiding increased impact on GDEs and

existing water bores. If necessary, assess how additional bores could be established without unacceptable impact on neighbouring bores.

- Carry out a formal search of the GAB GDE register to identify GDEs in the possible impact range from the project site, and the current cumulative impact of licensed water extraction at the site.
- Based on outcomes of the above searches, assess if there is a need for, and a potential benefit in carrying out, a hydrogeological study of any particular GDEs to reduce uncertainty about the connectivity to underlying aquifers and reduce sensitivity to increased extraction at the project site.
- Synthesize the search data to identify potential paths to securing different levels of water entitlement (including relocation of GAB licences) while avoiding unacceptable impacts on GDEs (e.g. springs) and water users. The order of preference being local licenses and associated bores, capping of suitably located uncontrolled stock bores, suitably located volumetric water licences and then the state reserve.
- Investigate the potential to use the GAB not as a source of water, but as a place to store surface water during periods of high availability for later recovery during periods of low availability.

Appendix A – Requirements re process for granting unallocated groundwater

Excerpts from GABORA water plan

17 Purposes for which unallocated water may be granted

(1) Unallocated water may be granted from the general reserve for any purpose.

(2) Unallocated water may be granted from the State reserve for the following purposes—

(a) a coordinated project under the *State Development and Public Works Organisation Act 1971*;

(b) a project of regional significance;

(c) for water granted to a local government—town water supply purposes;

(d) an electricity generation project.

(3) A project is a ***project of regional significance*** for the plan area if the chief executive considers the project is significant for a region in the plan area, having regard to—

(a) the plan outcomes; and

(b) the economic or social impact the project will have on the region; and

(c) the public interest and the welfare of people in the region; and

(d) other matters the chief executive considers relevant.

23 Matters chief executive must consider

(1) In dealing with unallocated water, the chief executive must consider—

(a) the need for, and efficiency of, current and proposed uses of water, including—

(i) the extent to which water is currently being taken under water licences and statutory authorisations to take or interfere with water in the plan area; and

(ii) emerging requirements in the plan area for additional water and the likely timeframe in which the additional water will be required; and

(iii) water savings that may be made by improving the efficiency with which water is taken and used, including, for example, installing a watertight delivery system for a water bore; and

(b) the availability of an alternative water supply for the purpose for which water is required; and

(c) the impact the proposed taking of, or interfering with, water may have on—

(i) the flow of water to groundwater-dependent ecosystems; and

(ii) groundwater pressure and levels; and

(iii) on existing water licences and statutory authorisations to take or interfere with water.

24 Granting unallocated water from a reserve

(1) The chief executive may require an applicant for a water licence to take water from an unallocated water reserve to—

(a) investigate the likely impact the proposed taking of water may have on the following—

(i) the flow of water to groundwater-dependent ecosystems;

(ii) groundwater pressure and levels;

(iii) existing water licences and statutory authorisations to take or interfere with water; and

(b) carry out—

(i) studies relating to the relevant groundwater-dependent ecosystems and the groundwater units connected to the ecosystems; or

(ii) a hydrogeological assessment; and

(c) include the results of the investigation, studies or assessment with the application.

(2) If the chief executive grants a water licence for water from an unallocated water reserve, the chief executive may impose conditions on the licence requiring the holder of the licence to—

(a) provide and maintain access to alternative water supplies for existing water users who would be significantly adversely affected by the granting of the licence; and

(b) carry out and report on a stated monitoring program.

(3) However, if granting the water licence will result in the drawdown at a relevant location being more than the maximum drawdown, the chief executive must impose the conditions stated in subsection (2) on the licence.

Division 5 Ensuring water licence decisions protect flows of water to groundwater-dependent ecosystems, existing licences and particular authorisations

40 Application of division

(1) This division applies to a decision to—

(a) grant a water licence to take water from an unallocated water reserve; or

(b) grant a water licence to take water for stock or domestic purposes; or

(c) grant a seasonal water assignment for a water licence; or

(d) amend or relocate a water licence.

41 Protecting the flow of water to groundwater-dependent ecosystems

The chief executive must not make the decision unless the cumulative drawdown for the groundwater-dependent ecosystem, after making the decision, would be less than 0.4m.

42 Protecting existing water licences and particular authorisations to take water

The chief executive must not make the decision unless the drawdown at a location from which water may be taken under an existing water licence or particular authorisation, after making the decision, would be less than the maximum drawdown.

Schedule 6 Dictionary

maximum drawdown means a drawdown of 5m.

Excerpts from GABORA Water Management Protocol

48. Limit on water taken as carry over

For any water year, the combined take of volumetric limit and carry over water is limited to a maximum volume of water equal to two times the volumetric limit.

Part 2: Estimating cumulative drawdown and ensuring it is less than 0.4 metres, for section 41 of the plan

15. A method for estimating long-term drawdown when estimating cumulative drawdown

(1) Long-term drawdown may be estimated using the following formula –

LTD = PAT x LTDM ÷ 1000

Where: **LTD** = Long-term drawdown, in metres
PAT = Proposed additional take of water, in megalitres per water year
LTDM = Long-term drawdown multiplier

(4) The long-term drawdown multiplier to use for estimating the long-term drawdown is determined using either Attachment 4.1 for a take of water in an upper unit, or Attachment 4.2 for a take of water in a lower unit, based on –

(a) the groundwater unit in which the proposed additional take of water is located;

(b) the distance between a groundwater-dependent ecosystem and the location of a proposed additional take of water.

Attachment 4.2—Long-term drawdown multipliers for lower units

Column 1	Column 2																								
	Distance (kilometres)																								
Groundwater unit/ groundwater sub-area	0.001	0.1	1	5	10	20	40	50	80	100	120	140	160	180	200	220	240	260	280	320	360	400	500	600	710
• Betts Creek beds (all sub-areas) • Cadna-owie (all sub-areas) • Clematis (all sub-areas) • Gubberamunda • Laura Rolling Downs • Mooga • Normanton • Rolling Downs (all sub-areas) • Winton Mackunda (all sub-areas)	462.28614	261.61938	161.29334	91.34185	61.69177	33.63256	11.02257	6.12721	0.82102	0.16721	0.02721	0.00350	0	0	0	0	0	0	0	0	0	0	0	0	0
• Eromanga Hutton • Wyaaba beds	24.07414	14.95292	10.39233	7.20497	5.83324	4.46497	3.11043	2.68211	1.80925	1.41936	1.11998	0.88506	0.69853	0.54956	0.43042	0.33524	0.25945	0.19940	0.15209	0.08636	0.04736	0.02504	0.00428	0.00057	0

(Partial extract of Attachment 4.2 - as an example)

26. A method for being satisfied that the drawdown at a location will not exceed the maximum drawdown

(1) The minimum separation distance for a decision about a water licence, or seasonal water assignment, in a groundwater unit or sub-area shown in a row of column 1 of the table in Attachment 5, is the distance, in kilometres, shown in the corresponding row of column 2 for the proposed take of water, in megalitres per year.

Attachment 5—Minimum separation distances (kilometres)

Column 1	Column 2																			
	Proposed take of water (megalitres per year)																			
Groundwater units/ groundwater sub-area	≤2	5	10	25	50	75	100	125	150	250	350	450	750	1500	2500	3500	4500	6000	7500	10000
• Betts Creek beds (all sub-areas) • Cadna-owie (all sub-areas) • Clematis (all sub-areas) • Gubberamunda • Laura Rolling Downs • Mooga • Normanton • Rolling Downs (all sub-areas) • Winton Mackunda (all sub-areas)	0.3	0.5	0.6	1.0	4.1	8.9	13.3	17	20.2	29.4	35.5	39.9	48.6	59.8	67.5	72.4	75.9	79.8	82.8	86.6
• Eromanga Hutton • Wyaaba beds	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.9	1.0	6.6	35.7	72.0	99.5	120.7	145.1	164.0	187.8

Appendix B – Brief overview of continuous sharing

Continuous sharing is an alternative system of water sharing and accounting to the announced allocation system. It has been fully implemented in two water supply schemes in Queensland (viz. St George and MacIntyre Brook) and is consistent with, and supported by, Queensland's current water planning framework.

Conceptually, continuous sharing is like notionally running a scheme storage as a set of separate but inter-linked storages. It initially establishes each water allocation holder – irrigators, urban and industrial users alike – with a notional share of the total water storage capacity of the dam. A daily account is then kept of each holder's usage, share of evaporation losses, share of dam inflows, share of environmental releases, water trades to or from other accounts etc. In this way, a running water account balance is effectively kept within each individual's notional capacity share. Daily water account balances are calculated based on assumed daily and seasonal rates of evaporation and then reconciled periodically (typically monthly) to adjust for any differences between the actual volume of water stored in the dam and the end of period tally of total volume in the water accounts. This requires the initial establishment and ongoing maintenance and updating of a water accounting system by the resource operations holder as well as ongoing measurement of customer water deliveries, storage levels, water releases etc.

Continuous sharing insulates each individual's water account balance from being reset due to the different risk management decisions and water usage behaviours of other allocation holders. It also provides individuals with confidence and certainty that they will retain the benefits (across water years) of their decisions to either save their water supplies for the future or to purchase water from other water allocation holders in the scheme.

E-Water provide the following technical description (i.e. from a modelling perspective) of continuous sharing on their website[20]:

> [The] continuous sharing system is designed to set up a system of sharing a water resource where the behaviour of one user has as little effect on other users as possible. Each water user is accounted for separately with their own inflows to their share of the system's storage capacity and each separately paying for any storage, transmission, and operational losses. This tracking is performed using water user accounts.
>
> When a continuous sharing system is set up and each water user account is initialised, each is assigned:
>
> - a priority (high or medium)
> - a share factor
> - a maximum allowable account balance
> - a fractional share of the inflows into the system's storages
> - an annual resource cap.
>
> The fractional share of the inflows determines how much a water user's account will be credited with when there is an inflow to a storage (If two storages are in series then only the net inflow between the two would be shared as inflow. In more complex situations, for example where there is significant irrigation between the storages, the users may have different shares in each reservoir). The sum of all the inflow shares in a system should add up to

[20] E-Water, Water governance SRG website, Continuous sharing, 11 May 2017, accessed 20 September 2021, https://wiki.ewater.org.au/display/SD41/Continuous+Sharing+-+SRG

1. In some systems a group of users may be given priority access to inflows when the storages are low, in effect making them higher security users.

The maximum allowable account balance establishes how much water an account can accumulate at any one time. The sum of all the maximum allowable account balances must not exceed the total active storage in the system; thus all water users can store their maximum allowable balances at the same time.

Each user is responsible for covering the transmission and operational costs of delivering their water from the storage to the point of use. This cost is determined by the use of a delivery efficiency factor which represents the average efficiency of delivery to the water user's location and consequently influences the size of their share and the volume of water released when orders are made.

To allow for the management of the total use of water in a system each water user is assigned an annual resource cap which limits the amount of water they can use in any water year regardless of their account balances. The system may permit unused resource cap to be carried over to the following water year. There may be limits on how much resource cap can be carried over for an account and limits on the total amount carried over for a system.

The annual resource cap is a tradable item. A cap adjustment factor would be required to determine the value of an account's share of the cap for temporary trade, but this is not modelled in Source at this stage. Storage gains and losses are calculated from a fixed annual pattern and are shared amongst water user accounts in proportion to their share account volumes (account balances).

As the storage, transmission, and operational gains/losses are calculated using average values the sum of all the account balances in a system will start to diverge from the total active volume. To account for this divergence a reconciliation of account balances is carried out, periodically, to bring them into line with the total active volume. If the sum of the account balances is greater than the active volume, the difference is treated as a loss from the accounts; on the other hand, if the sum of the account balances is less than the active volume of the storage, the differences is treated as an inflow to the accounts.

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