Hughenden Irrigation Project Corporation Pty Ltd

Hughenden Irrigation Project Dam Yield Study

HIP Preliminary Business Case Study

February 2020

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1. **INTRODUCTION**

This report details the dam yield assessments undertaken for the Hughenden Irrigation Project (HIP) Preliminary Business Case (PBC) Study. The HIP aims to establish an irrigated agriculture development in the vicinity of the township of Hughenden through the construction of a surface water storage and supply scheme. The proponent for the HIP is Hughenden Irrigation Project Corporation Pty Ltd (HIPCo).

Dam yield assessments were undertaken for the following aspects of the PBC Study:

- Options assessment; and
- Reference Project (proposed Project configuration).

The options assessment phase involved the investigation of the following two bulk water storage options:

- Alstonvale Dam site on Betts Gorge Creek located on the northern side of the Flinders River approximately 25 km to the north-west of Hughenden.
- Dam site/s near the outlet of the Stewart Creek catchment located on the northern side of the Flinders River approximately 45 km to the north-west of Hughenden.

The Reference Project proposed for the HIP is a variation of the Stewart Creek dam options and comprises a 190 GL storage capacity dam (Saego Dam) on Stewart Creek and Back Valley Creek approximately 45 km to the north-west of the township of Hughenden, with associated gravity diversion infrastructure on the Flinders River and a delivery system to irrigation areas located to the south of the Flinders River.

The dam yield assessments were performed using a catchment hydrology and dam reservoir operation simulation model developed using the GoldSim software. The dam yields were independently assessed by Hydrology and Risk Consulting (HARC) using the Flinders Source Model developed by the Queensland Government for the Gulf Water Plan. An assessment of the potential impacts of future climate change on the dam yield estimates for the Reference Project was also undertaken.

The following additional investigations were undertaken for the Reference Project and are detailed in the Reference Project section (Section 10) of the PBC Report but are not included in this report:

- Assessment of impacts to stream flow regimes downstream of the Project.
- Assessment of impacts to existing water users.
- Consideration of water licencing and allocation requirements for the Project.
2. **BACKGROUND**

2.1 **Yield Objectives**

As part of the PBC Study, options were identified to address the service need of supplying water to the Flinders Shire for agricultural use. For the purpose of the options identification, it was assumed that a water yield of 50 to 100 GL/year would be required to have a significant beneficial impact on the economic activity and associated socio-economic wellbeing within the Flinders Shire. There are sufficient volumes of water within the remaining unallocated water reserves in the Flinders River catchment to support the required water yield.

2.2 **Review of Previous Studies**

2.2.1 **Historical Dam Investigations**

There have been a number of historical investigations of potential dam sites and irrigation areas in the vicinity of Hughenden. These include:

- **Upper Flinders River Irrigation Scheme - Flinders River Damsite 828.5km Investigations (QWRC, 1985):**
  - Investigation of dam site on Flinders River at Glendower (north-east of Hughenden) by the Queensland Government
  - Dam storage capacity: 200 GL
  - Estimated water supply yield: 25 GL/year at 100% reliability (historical no failure yield) to 30 GL/year at 75% annual reliability
  - Dam capital cost: $85 to $100 million

- **Irrigation Project – Alstonvale (SMEC, 2003):**
  - Investigation of dam sites at Alstonvale on Betts Gorge Creek (north-west of Hughenden) and Mt Beckford on the Flinders River (east of Hughenden) commissioned by Flinders Shire Council.
  - A number of different irrigation scheme options were assessed for each dam option.
  - Alstonvale Dam scheme not considered viable due to high cost of external catchment diversion works required to augment the scheme yield.
  - Mt Beckford Dam scheme involved:
    - Dam storage capacity: 250 GL
    - Estimated water supply yield: 60 to 70 GL/year at 92 to 96.5% monthly reliability
    - Irrigation area: 15,000 to 17,000 ha
    - Scheme capital cost: $90 to $100 million (including irrigation delivery system)
2.2.2 Flinders and Gilbert Agricultural Resource Assessment (FGARA)

The feasibility of in-stream dams within the Flinders River catchment was assessed as part of the CSIRO Flinders and Gilbert Agricultural Resource Assessment (FGARA) (Petheram et al., 2013). Fifteen potential dam locations in the Flinders River catchment were identified and assessed (dam locations shown in Figure 2.1). These dam locations were all in the upper reaches of the Flinders and Cloncurry River catchments. The topography in the middle and lower reaches of the Flinders River catchment is not suitable (too flat) for large dams.

Seven of the fifteen dam options identified are within the Flinders Shire part of the Flinders River catchment (i.e. most upstream part of catchment). These dam options are summarised in Table 2.1. The dam option with the highest water supply yield was Glendower Dam with an estimated yield (85% annual reliability) of 57 GL/year.

Figure 2.1 Locations of New Dam Options Assessed in CSIRO FGARA study (Source: Petheram et al., 2013)
Table 2.1 Dam Options Identified by CSIRO FGARA study within Flinders Shire

<table>
<thead>
<tr>
<th>Dam ID</th>
<th>Dam Name</th>
<th>Watercourse</th>
<th>Catchment Area (km²)</th>
<th>Storage Capacity (GL)</th>
<th>85% Annual Reliability Dam Yield (GL/year)</th>
<th>Dam Capital Cost as at 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alston Vale</td>
<td>Betts Gorge Ck</td>
<td>1,132</td>
<td>241</td>
<td>12</td>
<td>$275M</td>
</tr>
<tr>
<td>8</td>
<td>Flinders 856 km</td>
<td>Flinders River</td>
<td>1,694</td>
<td>89</td>
<td>39</td>
<td>$275M</td>
</tr>
<tr>
<td>9</td>
<td>Glendower</td>
<td>Flinders River</td>
<td>1,912</td>
<td>309</td>
<td>57</td>
<td>$375M</td>
</tr>
<tr>
<td>10</td>
<td>Mt Beckford</td>
<td>Flinders River</td>
<td>2,065</td>
<td>245</td>
<td>45</td>
<td>$450M</td>
</tr>
<tr>
<td>11</td>
<td>Mt Oxley</td>
<td>Flinders River</td>
<td>690</td>
<td>62</td>
<td>22</td>
<td>$225M</td>
</tr>
<tr>
<td>13</td>
<td>Porcupine Creek</td>
<td>Porcupine Creek</td>
<td>1,051</td>
<td>31</td>
<td>11</td>
<td>$179M</td>
</tr>
<tr>
<td>15</td>
<td>White Mountains</td>
<td>Flinders River</td>
<td>1,085</td>
<td>111</td>
<td>34</td>
<td>$225M</td>
</tr>
</tbody>
</table>

Three of the fifteen potential dam sites in the Flinders catchment were short-listed and assessed in more detail because each was initially deemed to be one of the more promising sites in each of three distinct geographical areas (Hughenden, Richmond and Cloncurry). The selection of these three sites was based on consideration of topography of the dam axis, geological conditions, proximity to suitable soils and water yield. The short-listed sites were:

- Cave Hill Dam on the Cloncurry River upstream of Cloncurry – 248 GL storage capacity dam (capital cost $249M) with 40 GL/year yield
- O’Connell Creek Offstream Storage – 127 GL storage capacity dam (capital cost $229M) with 34 GL/year yield
- Porcupine Creek Dam – details provided in Table 2.1.

2.2.3 Flinders River Water Resources and Irrigation Project

SMEC (2014) developed a concept design of a water supply scheme on the Flinders River downstream of Hughenden on behalf of Flinders Shire Council. Details of the proposed scheme are as follows:

- 200 GL storage capacity weir on the Flinders River downstream of the confluence with Galah/Porcupine Creek
\begin{itemize}
  \item Gravity canal system supplying irrigation water from the Flinders River dam to irrigation areas (up to 18,000 ha) on the southern side of the Flinders River extending for a distance of approximately 80 km to the west of Hughenden
  \item Separate water storages on Walker Creek, Sloans Creek and Cannum Creek connected to the irrigation areas and Flinders River dam by gravity canals
  \item Estimated water supply yield: 60 GL/year
  \item Estimated capital cost: $357 million.
\end{itemize}

2.2.4 HIPCo Initial Dam Investigations

Grace Detailed – GIS Services investigated dam options in the Flinders Shire on behalf of HIPCo. These investigations were undertaken in two stages:

\begin{itemize}
  \item Stage 1 (Grace Detailed – GIS Services, 2018a): Preliminary assessment of dam site suitability (including catchment areas, dam storage characteristics, catchment inflows and feasibility of external catchment diversions) for the following dam sites (refer Figure 2.2):
    \begin{itemize}
      \item Mt Beckford dam site on the Flinders River – not considered feasible due to interactions with road and rail infrastructure
      \item Alstonvale dam site on Betts Gorge Creek – considered feasible
      \item Porcupine Creek diversion into Alstonvale Dam – not considered feasible due to the expected high cost of the required diversion works
      \item Dam site on Stewart Creek upstream of confluence with Jones Valley Creek – not considered feasible due to smaller catchment area and catchment inflows.
      \item Dam site at The Gap on Stewart Creek downstream of confluence with Jones Valley Creek – considered feasible
      \item Dutton River diversion into The Gap dam site – considered possibly feasible.
    \end{itemize}
  \item Stage 2 (Grace Detailed – GIS Services, 2018b): Further feasibility assessment of Alstonvale and The Gap dam sites including dam yield assessment and consideration of construction costs:
    \begin{itemize}
      \item The Gap dam site (with or without the Dutton River diversion) was not considered feasible based on unfavourable storage characteristics (high storage losses) limiting the dam yield.
      \item Alstonvale Dam configuration assessed:
        \begin{itemize}
          \item 224 GL storage capacity dam
          \item 24 GL/year water supply yield at 89% annual reliability
          \item Irrigation area supported: 2,500 ha
          \item Capital cost: $112 million
        \end{itemize}
    \end{itemize}
\end{itemize}
2.2.5 15 Mile Irrigated Agricultural Development Project

Flinders Shire Council is currently progressing the development of the 15 Mile Irrigated Agricultural Development Project (GHD Pty Ltd, 2018) approximately 15 km to the north-west of Hughenden.

The site for the 15 Mile Project (Lot 168 SP262319) is located on the southern bank of the Flinders River immediately downstream of the confluence with Galah/Porcupine Creek (refer Figure 2.3). Council purchased the site from the Queensland Government in 2016 and has since been undertaking necessary works to facilitate the project.

Initial crops planned for the Project will comprise intensive horticulture and tree crops consisting of 60 ha of table grapes and 60 ha of citrus. These will fulfil current market opportunities within Council’s initial third-party investor’s supply chains for major supermarkets within Australia and internationally. These crops are planned to be grown on alluvial soils which are considered suitable for irrigated agriculture, having excellent drainage, good root depth and texture, and few chemical limitations.

The estimated water use for the third-party investor development crops is 2,160 ML/year which is planned to be supplied from groundwater aquifers (Flinders River Alluvium and Great Artesian Basin).
Council also holds a surface water licence (Licence No. 618019) for extraction of up to 5,000 ML/year from the Flinders River under certain flow conditions; however, Council do not intend on relying on this licence for the Project.

The Project was recently awarded Coordinated Project status by the Queensland Government.
3. DAM OPTIONS INVESTIGATED

3.1 Options Assessment

3.1.1 Initial Options Screening

Based on the outcomes of the previous dam feasibility studies in the Flinders River catchment, a list of dam options were identified for further assessment. The dam options were selected to meet the following key requirements linked to the identified service need and other regulatory and stakeholder constraints:

- Proximity to the town of Hughenden
- Proximity to large areas of land extending to the west of Hughenden and on the southern side of the Flinders River that are suitable for irrigated agriculture due to soils characteristics and topography, are outside of floodplain areas and are mostly already cleared due to the current grazing land use of these areas
- Dam locations which are suitable to achieving a water supply yield of 50 to 100 GL/year either via direct catchment inflows or through external catchment diversions into the dam
- Suitable topography at dam sites for economic dam construction and efficient storage characteristics
- Suitable geotechnical conditions for dam construction
- Minimal impacts to third party infrastructure
- Dam locations will not inundate high value environmental or cultural/social features
- Potential for future expansion of water storage infrastructure (i.e. dam raising).

All of the previously identified dam sites on the Flinders River do not comply with a number of the criteria listed above and were excluded from the assessment. The topography in the lower reaches of Galah/Porcupine Creek is also not considered suitable for a large dam.

The following dam sites (refer Figure 3.1) were selected for further assessment based on their conformance with the key project criteria listed above:

- Alstonvale Dam site on Betts Gorge Creek located on the northern side of the Flinders River approximately 25 km to the north-west of Hughenden – excellent dam site but will require external catchment diversions from Galah/Porcupine Creek and/or the Flinders River to provide sufficient water supply yield.
- Dam site/s near the outlet of the Stewart Creek catchment located on the northern side of the Flinders River approximately 45 km to the north-west of Hughenden – dam sites
are not as suitable as Alstonvale Dam but are located further downstream and in closer proximity to the Flinders River which makes them potentially suitable to achieve the required water supply yield at a lower infrastructure cost.

These dam options are generally consistent with the outcomes of the preliminary HIPCo dam investigation studies (Grace Detailed – GIS Services, 2018a,b) which recommended the Alstonvale and The Gap dam sites as suitable for further assessment.

![Preferred Dam Sites for Options Assessment](Image source: Queensland Globe)

### 3.1.2 Alstonvale Dam Options

The Alstonvale Dam site is an excellent dam site from a topographic perspective because the Betts Gorge Creek valley is closely surrounded by steep basalt plateaus on both sides of the valley. These topographical features will provide an economical dam construction (short dam wall length) and efficient storage characteristics (low ratio of ponded area to storage capacity) to minimise storage losses (evaporation and seepage).

The catchment area of Betts Gorge Creek is only 1,127 km² at the proposed dam site and previous investigations have identified that only a small water supply yield (approximately 20 GL/year) is possible based on the direct catchment area of the dam.

The Flinders River and Galah/Porcupine Creek (lower reaches referred to as Galah Creek) catchments are larger adjacent catchments to the south of Betts Gorge Creek and options
for diversion of stream flows from these catchments into Alstonvale Dam to increase the yield of the scheme were assessed. This identified that gravity diversions from the Flinders River and Galah Creek into Canterbury Creek (small creek between Galah Creek and Betts Gorge Creek) were feasible; however, the presence of the 70 m high plateau between Canterbury Creek and Betts Gorge Creek is a significant constraint to the gravity flow of water into Alstonvale Dam.

Options considered for the gravity flow of water between Canterbury Creek and Betts Gorge Creek (minimum diversion distance of 4 km) included either an excavated channel or a tunnel through the plateau (plateau is formed from basalt flows overlying mudstone). Both gravity diversion options were not considered to be feasible due to high capital costs, concerns over the long-term stability of either an excavated channel or tunnel constructed through low strength mudstone, and the absence of an elevation difference between Canterbury Creek and Betts Gorge Creek which will prevent gravity flows from occurring when there is a significant volume of water stored in Alstonvale Dam.

The preclusion of gravity transfers meant that a pumped diversion system between Canterbury Creek and Alstonvale Dam would be required. This system requires another water storage to be constructed on Canterbury Creek to provide temporary storage to buffer the imbalance between the gravity diversion inflows from Galah Creek/Flinders River (high flows but of relatively short duration corresponding to periods of high stream flow in the waterways) and the pumped outflows to Alstonvale Dam (smaller flow capacity but of significantly longer duration than the gravity inflows).

Review of topographic data identified the following preferred scheme to facilitate flow diversions from the Flinders River and Galah/Porcupine Creek into Alstonvale Dam (refer Figure 3.2):

- **Gravity diversion between the Flinders River and Galah Creek:**
  - Diversion weir on the Flinders River near Glendower, approximately 35 km to the north-east of Hughenden
  - Excavated diversion channel between the Flinders River and Orange Tree Creek (Orange Tree Creek flows into Boundary Creek which then flows into Galah Creek)

- **Gravity diversion between Galah Creek and Canterbury Creek:**
  - Diversion weir on Galah Creek, approximately 23 km to the north-east of Hughenden
  - Excavated diversion channel between Galah Creek and Coolibah Creek (Coolibah Creek flows into Canterbury Creek)
  - Levee across Crescent Creek where the diversion channel crosses Crescent Creek

- **Dam on Canterbury Creek approximately 14 km to the north-east of Hughenden**

- **Pump station at Canterbury Creek Dam with rising main pipeline over the basalt plateau between Canterbury Creek Dam and Alstonvale Dam.**

- **Alstonvale Dam on Betts Gorge Creek.**
Figure 3.2 Concept Infrastructure Arrangement for Alstonvale Dam Irrigation Scheme
Potential for pumped hydropower generation utilising the pumping system between the Canterbury Creek Dam and Alstonvale Dam reservoirs.

Storage characteristics at the Alstonvale and Canterbury Creek dam sites were assessed using LiDAR ground survey of these areas acquired by HIPCo in May 2019. The storage characteristics are shown in Figure 3.3.

![Figure 3.3 Storage Characteristics for Alstonvale Dam and Canterbury Creek Dam](image)

A number of different sub-options were assessed for the Alstonvale Dam scheme which represent different combinations of the following infrastructure configurations:

- Alstonvale Dam storage capacity
- Canterbury Creek Dam storage capacity
- Flow capacity of pumping system between Canterbury Creek Dam and Alstonvale Dam.

The total catchment area reporting to the Alstonvale Dam scheme is 5,071 km², comprising:

- 1,127 km² catchment area for Betts Gorge Creek upstream of Alstonvale Dam
- 1,935 km² catchment area upstream of the diversion weir on the Flinders River
- 1,912 km² catchment area upstream of the diversion weir on Galah Creek
97 km² catchment area for Canterbury Creek upstream of Canterbury Creek Dam.

3.1.3 **Stewart Creek Dam Options**

The Stewart Creek dam options are based on a primary impoundment area on the Saego Plains property (Lot 2 DU15) near the mouth of Stewart Creek, approximately 47 km to the north-west of Hughenden. This dam site is located in a low energy area on the northern floodplain of the Flinders River. The impoundment area is surrounded by steep basalt plateaus to the west and north, and by a low height mudstone ridge to the east which divides the lower reaches of Stewart Creek from the adjacent Back Valley Creek (refer Figure 3.4).

![Saego Impoundment Area Locality Plan](image)

**Figure 3.4 Saego Impoundment Area Locality Plan**

The Saego impoundment area has relatively poor storage characteristics (high ratio of ponded area to storage capacity) at low storage volumes, but once the floor of the valley is fully submerged (i.e. water ponded against the surrounding plateau walls) the storage capacity increases with only minor increase in ponded area.

The Saego impoundment area is connected to a much larger natural basin upstream of a narrow opening between the basalt plateaus known as The Gap. This basin is formed at the confluence of Stewart Creek and Jones Valley Creek and is referred to as Expressman Downs. The storage characteristics of the Expressman Downs basin area are even poorer than the Saego impoundment area and a dividing wall will be required in The Gap to prevent the Saego impoundment area from expanding out into the Expressman Downs basin upstream of The Gap, resulting in high storage losses.
The following water diversion and storage infrastructure was identified for the Stewart Creek dam options (refer Figure 3.5):

- Diversion weir on the Flinders River downstream of the confluence with Betts Gorge Creek
- Excavated diversion channel to facilitate gravity diversions of water out of the Flinders River into the Catch Dam on Back Valley Creek
- Catch Dam on Back Valley Creek to provide buffer storage between the gravity diversions out of the Flinders River and pumped transfers into Saego Dam
- Saego Dam on Stewart Creek approximately 800 m upstream of the confluence with the Flinders River (Saego Dam shares a common embankment with the Catch Dam)
- Pumping system to allow transfers of water from the Catch Dam into Saego Dam (gravity transfers are possible through a sluice gate arrangement when storage levels are low in Saego Dam)
- Dam wall across The Gap to confine the impoundment area of Saego Dam to minimise storage losses (the elevation of The Gap dam wall is nominally equal to the Saego Dam wall elevation)
- Pumping system to transfer water impounded behind the Gap dam wall (from Stewart Creek and Jones Valley Creek inflows) into Saego Dam.

Storage characteristics for the Saego Dam, The Gap Dam and Catch Dam sites were assessed using LiDAR ground survey of these areas acquired by HIPCo in May 2019. The storage characteristics are shown in Figure 3.6.

A number of different sub-options were assessed for the Stewart Creek dam options which represent different combinations of the following infrastructure configurations:

- Saego Dam storage capacity
- Flow capacity of pumping system between Catch Dam and Saego Dam.
Figure 3.5 Concept Infrastructure Arrangement for Stewart Creek Dam Options
The total catchment area reporting to the Stewart Creek dam options is 7,652 km², comprising:

- 6,568 km² catchment area upstream of the diversion weir on the Flinders River
- 957 km² catchment area for Stewart Creek and Jones Valley Creek upstream of the Gap Dam
- 64 km² catchment area between Gap Dam and Saego Dam
- 63 km² catchment area for Back Valley Creek upstream of the Catch Dam.

### 3.2 Reference Project

The preferred project option for the HIP is a variation of the Stewart Creek dam options and involves gravity diversions out of the Flinders River directly into a smaller Saego Dam on Stewart Creek, without the need for the Catch Dam, Gap Dam or any pumping into Saego Dam.

The Reference Project comprises a 190 GL storage capacity dam (Saego Dam) on Stewart Creek and Back Valley Creek approximately 45 km to the north-west of the township of Hughenden, with associated gravity diversion infrastructure on the Flinders River and a delivery system to irrigation areas located to the south of the Flinders River.
The total catchment area reporting to the Reference Project is 7,652 km², comprising:

- 6,568 km² catchment area upstream of the diversion weir on the Flinders River
- 1,084 km² direct catchment area of Saego Dam comprising the Stewart Creek, Jones Valley Creek and Back Valley Creek catchments.

Key infrastructure elements for the Reference Project include:

- In-stream diversion weir on the Flinders River downstream of the confluence with Betts Gorge Creek
- Excavated diversion channel to facilitate gravity diversions of water out of the Flinders River (upstream of the diversion weir) into the Saego Dam
- 190 GL storage capacity Saego Dam on the lower reaches of Stewart Creek and Back Valley Creek
- Irrigation delivery system to supply water from Saego Dam to the irrigation areas on the southern side of the Flinders River.

The general infrastructure arrangement for the Reference Project is shown in Figure 3.7.

Two different cropping scenarios have been investigated for the Reference Project in the PBC Study:

- Diversified cropping scenario – supply of higher reliability water for horticulture crops (avocados, mangoes, lemons and mandarins) and lower reliability water for cereal grains, hay and fodder crops to support the local cattle industry
- Grazier support scenario – supply of medium reliability water for cereal grains, hay and fodder crops to support the local cattle industry.
Figure 3.7 General Infrastructure Arrangement for the Reference Project Water Diversion and Storage Infrastructure
4. HYDROLOGIC SETTING

4.1 Waterways and Catchments

The Alstonvale Dam site is located on Betts Gorge Creek which is a tributary of the Flinders River. The confluence of Betts Gorge Creek and the Flinders River is 40 km downstream of Hughenden and 90 km upstream of Richmond. Nearby tributaries include Galah Creek and Canterbury Creek which feed into the Flinders River upstream of Betts Gorge Creek.

The Saego Dam site is located on the lower reaches of Stewart Creek and Back Valley Creek which enter the Flinders River downstream of Betts Gorge Creek. Jones Valley Creek flows into Stewart Creek within the Saego Dam impoundment area.

Catchments have been delineated for the study area using the SRTM-derived 1 second digital elevation data and are shown in Figure 4.1. A summary of key catchment areas relating to the dam options is provided in Table 4.1.

Table 4.1 Catchment Area Summary

<table>
<thead>
<tr>
<th>Locations</th>
<th>Catchment Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alstonvale Dam</td>
<td>1,127</td>
</tr>
<tr>
<td>Canterbury Dam</td>
<td>97</td>
</tr>
<tr>
<td>Saego Dam</td>
<td>1,084</td>
</tr>
<tr>
<td>Betts Gorge Creek to Flinders River confluence</td>
<td>1,377</td>
</tr>
<tr>
<td>Galah Creek to Flinders River confluence</td>
<td>2,191</td>
</tr>
<tr>
<td>Flinders River to Hughenden</td>
<td>2,438</td>
</tr>
<tr>
<td>Flinders River at Betts Gorge Creek confluence</td>
<td>6,574</td>
</tr>
</tbody>
</table>
4.2 Gauging Network

The Department of Natural Resources, Mines and Energy (DNRME) have historically and continue to operate several stream flow gauging stations on the upper reaches of the Flinders River and tributaries. The stream gauging network in the vicinity of the Project is shown in Figure 4.2 and summarised in Table 4.2. A stream flow gauging station was operated on Betts Gorge Creek 3 km upstream of the proposed Alstonvale Dam site from 1969 to 1988 (19 years).

The upper Flinders River catchment has limited coverage of rainfall gauges over the Project area catchments. The rainfall gauges historically and currently operated by the Bureau of Meteorology (BoM) are shown on Figure 4.2.

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>Catchment Area (km²)</th>
<th>Period of Record</th>
<th>Mean Annual Flow (GL)</th>
<th>Mean Annual Flow (ML/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>915004A</td>
<td>Flinders River at Hughenden</td>
<td>2,519</td>
<td>1969-1988</td>
<td>127</td>
<td>50</td>
</tr>
<tr>
<td>915007A</td>
<td>Betts Gorge Creek at Alstonvale</td>
<td>1,077</td>
<td>1969-1988</td>
<td>47</td>
<td>43</td>
</tr>
<tr>
<td>915008A</td>
<td>Flinders River at Richmond</td>
<td>17,380</td>
<td>1971-2019</td>
<td>536</td>
<td>31</td>
</tr>
<tr>
<td>915010A</td>
<td>Dutton River at Perisher</td>
<td>1,458</td>
<td>1971-1988</td>
<td>53</td>
<td>36</td>
</tr>
<tr>
<td>915011A</td>
<td>Porcupine Creek at Mt Emu Plains</td>
<td>540</td>
<td>1971-2019</td>
<td>32</td>
<td>59</td>
</tr>
<tr>
<td>915015A</td>
<td>Flinders River at Glendower Crossing</td>
<td>2,146</td>
<td>2012-2019</td>
<td>17</td>
<td>8</td>
</tr>
</tbody>
</table>
4.3 **Existing Surface Water Licences**

There are no supplemented surface water entitlements (water entitlements linked to water storage infrastructure) currently within the Flinders River section of the Gulf Water Plan (Queensland Government, 2017) area. All existing surface water extraction entitlements are unsupplemented water harvesting entitlements that are based on run-of-river flows and are typically defined by:

- A daily volumetric limit (DVL) representing the maximum daily extraction volume
- An annual volumetric limit (AVL) representing the maximum annual extraction volume
- Flow conditions under which extraction can occur (typically a flow threshold which must be exceeded before extraction can commence).

Properties with surface water licences in the vicinity of the HIP study area are shown in Figure 4.3. There are no surface water licences upstream of the Alstonvale Dam scheme (including the Flinders River and Galah Creek diversion locations). There are a number of licences to extract surface water out of the Flinders River upstream of and at the confluence of the Flinders River and Stewart Creek. The total volume of these licences (AVL) is approximately 10,500 ML.

![Properties with surface water licences in vicinity of HIP](image)

**Figure 4.3** Properties with surface water licences in vicinity of HIP (Source: Queensland Government Water Entitlement Viewer)
4.4 Unallocated Water Reserves

The Project study area is within the upper reaches of the Flinders River catchment which falls within the Gulf Water Plan area (refer Figure 4.4). The Project location is within the Flinders River Water Management Area Zone 7 (refer Figure 4.5).

Figure 4.4 Gulf Water Plan area (Source: Water Plan (Gulf) 2007)

The current status of the unallocated water reserves in the Flinders River section of the Gulf Water Plan area is summarised in Table 4.3. The total volume of unallocated water currently remaining in the Flinders River catchment is 166,000 ML.

The Queensland Government has provided for the release of the general reserve unallocated water in the Gulf Water Plan area through two separate tender processes:

- Public tender commencing in mid-2017 (tender process is still open) for the sale of the general reserve in the Gilbert catchment and remaining general reserve (not sold in first tender) in the Cloncurry River section of the Flinders catchment.
In the Flinders catchment, the general reserve was offered for sale as two different unsupplemented water entitlements (Product 1 and Product 2) each with different AVLs, daily extraction limits and flow thresholds/conditions. Product 2 had higher flow thresholds than Product 1 and accordingly has a lower reliability of supply compared to Product 1. Limits were applied on the volumes of Products 1 and 2 offered for sale in different parts of the catchment. The outcome of the general reserve tender processes for the Flinders River catchment are summarised in Table 4.4.
Table 4.4 Outcomes of Tender Processes for Release of General Reserve in Flinders Catchment

<table>
<thead>
<tr>
<th>Part of Catchment</th>
<th>Product 1 Volume Available for Sale (ML)</th>
<th>Product 1 Volume Sold (ML)</th>
<th>Product 2 Volume Available for Sale (ML)</th>
<th>Product 2 Volume Sold (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach 1 – Flinders River and tributaries upstream of Richmond Gauging Station</td>
<td>25,000</td>
<td>18,000</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Reach 2 – Flinders River and tributaries between Richmond Gauging Station and Cloncurry River confluence</td>
<td>10,000</td>
<td>4,500</td>
<td>7,000</td>
<td>0</td>
</tr>
<tr>
<td>Reach 3 – Cloncurry River catchment</td>
<td>7,500</td>
<td>7,500</td>
<td>50,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Reach 4 – Flinders River and tributaries downstream of Cloncurry River confluence</td>
<td>12,500</td>
<td>12,500</td>
<td>184,650</td>
<td>7,500</td>
</tr>
<tr>
<td>Total for Flinders River Catchment</td>
<td>55,000</td>
<td>42,500</td>
<td>184,650</td>
<td>57,500</td>
</tr>
</tbody>
</table>

The process for making available and dealing with unallocated water is specified in Chapter 2 of the Gulf ROP and Chapter 5, Part 1, Division 2 of the Gulf Water Plan. Key conditions relating to the release of unallocated water include:

- The process for granting unallocated water is a process stated in the Water Regulation 2016, Part 2, Division 2, Subdivision 2. This allows the release of unallocated water by either public auction, tender, fixed price sale or grant for a particular purpose.

- In preparing and implementing the process for granting unallocated water, the chief executive must consider the following:
  - 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 stream flows required to maintain the following:
    - 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 impact the taking of, or proposed taking of, or interfering with, water may have on the following:
  - 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.

- Unallocated water volumes granted must be within the annual volumetric limits for the indigenous, strategic and general reserves specified in Schedules 6A, 7 and 8 respectively of the Gulf Water Plan.

- Unallocated water held as an indigenous reserve (indigenous unallocated water) may be granted only for helping indigenous communities in the Cape York Peninsula Region area, Flinders River catchment area, Gilbert River catchment area, Morning Inlet catchment area, Settlement Creek catchment area, Staaten River catchment area or the Gregory River subcatchment area to achieve their economic and social aspirations.

- Unallocated water held as a strategic reserve (strategic unallocated water) may be granted only if it is to be taken for a State purpose, which is:
  - A coordinated project; and/or
  - A project of regional significance.

- Water entitlements granted from the general reserve in the Flinders River and Gilbert River catchment areas 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 the group B water transfer rules.

4.5 Environmental Flow Objectives

Environmental Flow Objectives (EFOs) for the Flinders catchment are detailed in Schedule 5 of the Gulf Water Plan and represent key performance objectives that must be achieved to meet the Water Plan outcomes for the sustainable management of surface water.
The EFOs for the Flinders catchment are specified at the Walkers Bend gauging station 915003A location and are summarised as follows:

- The proportion of no flow days in the simulation period should be no more than 70%
- The mean annual flow as a percentage of pre-development flow should be at least 90%
- The median annual flow as a percentage of pre-development flow should be at least 78%
- The median wet season (January to March) flow as a percentage of pre-development flow should be at least 75%
- The 1.5 year daily flow volume as a percentage of pre-development flow volume should be at least 90%
- The 5 year daily flow volume as a percentage of pre-development flow volume should be at least 96.5%
- The 20 year daily flow volume as a percentage of pre-development flow volume should be at least 98%.
5. CATCHMENT HYDROLOGY

5.1 Overview

A daily rainfall runoff model was developed to determine daily stream flow sequences for the direct catchments of the proposed water supply dams on Betts Gorge Creek, Canterbury Creek, Stewart Creek and Back Valley Creek. The daily rainfall runoff model was calibrated to flow gauging data for the Alstonvale stream gauging station on Betts Gorge Creek (Station Number 915007A).

A calibrated rainfall runoff model for the Betts Gorge Creek catchment was previously developed by the Queensland Government as part of the water resource modelling (Flinders Source Model) undertaken for the Gulf Water Plan. HIPCo requested an independent assessment of the stream flow characteristics of the Betts Gorge Creek catchment as part of the PBC studies.

Stream flow sequences for the external catchment diversions on the larger drainage systems (Flinders River and Galah Creek) were obtained from the Flinders Source Model.

The following tasks were completed as part of the stream flow modelling for the Betts Gorge Creek catchment:

- Development of a hydrologic model (Australian Water Balance Model (AWBM)) of the Betts Gorge Creek catchment.
- Calibration of the hydrologic model to flow gauging data for the Alstonvale stream gauging station on Betts Gorge Creek (Station Number 915007A).
- Comparison of the model calibration performance against the stream flow sequence for Betts Gorge Creek included in the Flinders Source Model.
- Development of a long-term historical catchment inflow sequence for Alstonvale Dam using the calibrated hydrologic model for use in the dam reservoir simulation model.
- Comparison of the developed long-term inflow sequence for Alstonvale Dam to the corresponding sequence in the Flinders Source Model.

5.2 Hydrology Model Description

The Betts Gorge Creek hydrology model was developed using the Australian Water Balance Model (AWBM) and simulated on a daily timestep. A schematic representation of the AWBM is provided in Figure 5.1. The AWBM can be summarised as:

- Three surface stores simulate partial areas of runoff, with the water balance of each surface store calculated independently of the others.
At each time step, rainfall (mm) is added to each of the three surface stores and evapotranspiration (mm) is subtracted from each store.

If the depth of water in any store exceeds the capacity of that store, a defined fraction of the rainfall excess moves to the surface runoff store and the remainder moves to the baseflow store.

The excess is released from the surface runoff store and the baseflow store according to a regression constant.

The total runoff is the sum of the baseflow and surface runoff components.

5.3 Hydrology Model Calibration

5.3.1 Recorded Streamflow Data

The hydrologic model (AWBM) was calibrated to the Betts Gorge Creek at Alstonvale Gauging Station (915007A) for the period of record (01/10/1969 to 30/09/1988). A summary of the Alstonvale gauging station details is provided in Table 5.1.
Table 5.1 Betts Gorge Creek at Alstonvale Gauging Station (9159007A) Details

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment Area</td>
<td>1.077 km²</td>
</tr>
<tr>
<td>Period of Record</td>
<td>01/10/1969 - 01/10/1988 (19 years)</td>
</tr>
<tr>
<td>Gauging Control</td>
<td>Sand</td>
</tr>
<tr>
<td>Maximum Gauged Flow</td>
<td>1.2 m³/s</td>
</tr>
<tr>
<td>Maximum Recorded Flow</td>
<td>781 m³/s</td>
</tr>
</tbody>
</table>

The Betts Gorge Creek gauging station has low manually gauged flows (less than 1.2 m³/s) and a poor flow control (sand). Verification of the flow gauging data was undertaken by comparing the Betts Gorge Creek flow data to other regional flow gauging data for a common period of record to the Betts Gorge Creek gauge. The nearby gauges were compared for mean annual flow relative to catchment area (Table 5.2) and cumulative flow (Figure 5.2). The location of the nearby streamflow gauging stations used to validate the Betts Gorge Creek gauging station record are listed in Table 5.2 and shown in Figure 4.2.

The validation of the Betts Gorge Creek gauging station recorded data for the period 01/10/1971 to 01/10/1988 shows:

- Betts Gorge Creek gauging station recorded a similar mean annual flow relative to catchment area to the nearby gauging stations.

- Betts Gorge Creek gauging station recorded flow events at similar times to the other gauging stations.

The Betts Gorge Creek gauging record is considered reliable and was adopted for the calibration of the AWBM.

Table 5.2 Comparison of Betts Gorge Creek Gauging Station Mean Annual Flow to Nearby Gauges for the Period 01/10/1971 to 01/10/1988

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>Catchment Area (km²)</th>
<th>Mean Annual Flow (ML/year)</th>
<th>Mean Annual Flow (ML/year/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>915004A</td>
<td>Flinders River at Hughenden</td>
<td>2,519</td>
<td>131,575</td>
<td>52.2</td>
</tr>
<tr>
<td>915005A</td>
<td>Stawell River at Thirty Mile Hut</td>
<td>2,274</td>
<td>109,431</td>
<td>48.1</td>
</tr>
<tr>
<td>915007A</td>
<td>Betts Gorge Creek at Alstonvale</td>
<td>1,077</td>
<td>47,965</td>
<td>44.5</td>
</tr>
</tbody>
</table>
### Table 1: Station Details

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>Catchment Area (km²)</th>
<th>Mean Annual Flow (ML/year)</th>
<th>Mean Annual Flow (ML/year/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>915008A</td>
<td>Flinders River at Richmond</td>
<td>17,380</td>
<td>393,651</td>
<td>22.6</td>
</tr>
<tr>
<td>915010A</td>
<td>Dutton River at Perisher</td>
<td>1,458</td>
<td>52,757</td>
<td>36.2</td>
</tr>
<tr>
<td>915011A</td>
<td>Porcupine Creek at Mt Emu Plains</td>
<td>540</td>
<td>34,000</td>
<td>63.0</td>
</tr>
</tbody>
</table>

#### Figure 5.2 Comparison of Betts Gorge Creek Gauging Station Cumulative Streamflow to Nearby Gauges

#### 5.3.2 Climate Data

Daily rainfall and potential evapotranspiration (Morton’s potential evapotranspiration) data for the hydrology model was extracted from the SILO (Scientific Information for Land Owners) Data Drill database maintained by the Queensland Governments’ Department of Environment and Science (DES). Daily rainfall and evapotranspiration were averaged from the gridded Data Drill daily climate data in the Betts Gorge Creek catchment.

The Betts Gorge Creek catchment has poor weather gauging data coverage as shown in Figure 4.2. The SILO Data Drill daily climate data is interpolated from the BoM weather stations and therefore the lack of gauged rainfall data available for the calibration period is a limitation on the calibration accuracy.
5.3.3 Climate Conditions During Calibration Period

The Betts Gorge Creek flow regime is highly ephemeral making it difficult to calibrate runoff model parameters that accurately predict stream flow during extended dry and wet periods. Calibrating a hydrology model to a short period of data may result in the model only accurately estimating stream flow volumes for the conditions during the calibration period. The Betts Gorge Creek gauging period is limited to 19 years and this may be a limitation on the accuracy of the AWBM calibration.

Rainfall recorded at the Hughenden Post Office (Station No. 030024) and Hughenden Station (Station No. 030025) rainfall stations was compared for the Betts Gorge Creek calibration period and the full available period of rainfall data to characterise the rainfall conditions during the calibration period. It was found that rainfall conditions during the calibration period were generally above-average indicating the AWBM has been calibrated to above-average streamflow conditions. Therefore, the calibrated AWBM may not accurately estimate runoff volumes during lower rainfall years. Without additional stream flow gauging data, it is not possible to resolve this limitation.

Figure 5.3 Comparison of Rainfall During Calibration Period to Long-Term Rainfall Record
5.3.4 Calibration Performance

The AWBM model parameters were calibrated so the modelled stream flow volumes produced the best possible fit to the gauged flow data. The calibration process involved the following:

- Matching modelled and recorded annual and monthly stream flow volumes
- Matching the daily flow duration curve
- Reproducing daily runoff volumes and timing of the largest recorded individual runoff events.

The three initial soil store depths and partial areas were adjusted to match runoff volumes for the small, medium and large runoff events and the Baseflow Index and recession constants were adjusted to match stream flow duration characteristics. The calibrated AWBM parameters are shown in Table 5.3 and the calibration results are summarised in Table 5.4. Detailed calibration results are provided in Figure 5.4 to Figure 5.11.

Flow statistics at the Betts Gorge Creek gauging station location from the Flinders Source Model have been presented on the calibration result graphs to compare the calibration performance of the AWBM against the Flinders Source Model runoff model calibration for the Betts Gorge Creek gauging station.

Generally, the calibration found:

- The AWBM produced a reasonable calibration to the Betts Gorge Creek stream flow gauging station for both runoff volumes and flow duration characteristics.
- The AWBM accurately reproduced annual and monthly runoff volumes in both large and low runoff years as shown in Figure 5.4, Figure 5.5 and Figure 5.6.
- When comparing the Flinders Source Model prediction of annual and monthly runoff volumes to the AWBM, it appears the Flinders Source Model slightly over-predicts stream flows during higher rainfall periods and under-predicts stream flows during lower rainfall periods.
- The AWBM and Flinders Source Model produced reasonable fits to the largest individual streamflow events (January 1974, January 1981 and January 1984). Accurately reproducing daily runoff volumes for individual events using a hydrology model is dependent on accurate spatial distribution of rainfall data which was not available for the Betts Gorge Creek catchment for these events.
Table 5.3 Betts Gorge Creek Calibrated AWBM Parameters

<table>
<thead>
<tr>
<th>Soil Store Depths (mm)</th>
<th>Partial Areas</th>
<th>Baseflow Index (BFI)</th>
<th>Surface Recession Constant (Ks)</th>
<th>Baseflow Recession Constant (Kb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>C2</td>
<td>C3</td>
<td>A1</td>
<td>A2</td>
</tr>
<tr>
<td>39</td>
<td>250</td>
<td>371</td>
<td>0.25</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Table 5.4 Betts Gorge Creek AWBM Calibration Results Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Observed</th>
<th>AWBM</th>
<th>Flinders Source Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Annual Flow (GL)</td>
<td>46.5</td>
<td>46.8</td>
<td>46.5</td>
</tr>
<tr>
<td>Median Annual Flow (GL)</td>
<td>21.4</td>
<td>23.4</td>
<td>19.2</td>
</tr>
<tr>
<td>Daily Nash Sutcliffe Coefficient</td>
<td>-</td>
<td>0.47</td>
<td>0.54</td>
</tr>
<tr>
<td>Annual Nash Sutcliffe Coefficient</td>
<td>-</td>
<td>0.82</td>
<td>0.79</td>
</tr>
<tr>
<td>Monthly Nash Sutcliffe Coefficient</td>
<td>-</td>
<td>0.79</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Figure 5.4 Betts Gorge Creek AWBM Calibration - Cumulative Stream Flow Volumes
Figure 5.5 Betts Gorge Creek AWBM Calibration - Annual Stream Flow Volumes

Figure 5.6 Betts Gorge Creek AWBM Calibration - Monthly Stream Flow Volumes
Figure 5.7 Betts Gorge Creek AWBM Calibration – Daily Flow Duration Curve

Figure 5.8 Betts Gorge Creek AWBM Calibration – Top End Of Flow Duration Curve
Figure 5.9  Betts Gorge Creek AWBM Calibration – January 1974 Event

Figure 5.10  Betts Gorge Creek AWBM Calibration - January 1984 Event
5.3.5 Calibration Summary

The AWBM calibration for the Betts Gorge Creek catchment can be summarised as:

- The AWBM calibration shows a good fit to recorded annual and monthly stream flow volumes as well as the recorded daily streamflow duration curve and large individual runoff events.

- The comparison of the AWBM and Flinders Source Model calibration for the Betts Gorge Creek catchment indicates that the AWBM produces a slightly better calibration since it predicts stream flow volumes more accurately in very wet and dry years.

- Two key limitations of the AWBM calibration were:
  - The AWBM calibration period was only 19 years in duration and comprised generally above-average rainfall conditions. The accuracy of the AWBM during very low rainfall years is unknown.
  - There was limited spatial distribution of rainfall monitoring data within the Betts Gorge Creek catchment during the calibration period which limits the accuracy of the model calibration.
5.4 Alstonvale Dam Inflow Sequence

The calibrated AWBM was used to develop a long-term historical daily inflow sequence for Alstonvale Dam for the period 01/07/1889 to 01/07/2011 for use in the dam yield assessment. The proposed Alstonvale Dam location is 3 km downstream of the Betts Gorge Creek gauging station. The catchment area at the Alstonvale Dam site is 1,127 km² which is 50 km² larger than at the Alstonvale gauging station site.

Climate data for the Alstonvale Dam catchment was developed using the same approach adopted for the AWBM calibration (Section 5.3.2). The cumulative Alstonvale Dam inflow sequence calculated from the calibrated AWBM is shown in Figure 5.12. The estimated average annual streamflow for the long-term period was 34 GL/year which is 27% lower than the calibration period (47 GL/year).

The Flinders Source Model long-term stream daily flow series at the Betts Gorge Creek gauging station location was scaled to the Alstonvale Dam site based on catchment area to compare against the AWBM flow sequence. The scaled cumulative Flinders Source Model Alstonvale Dam stream flow series is shown on Figure 5.12. A comparison of annual Alstonvale Dam flow statistics from the AWBM and the Flinders Source Model is shown in Figure 5.13.

The comparison of the AWBM and Flinders Source Model long-term historical inflow sequences for Alstonvale Dam shows:

- The AWBM and Flinders Source Model predict similar average annual flow volumes.
- The Flinders Source Model predicts a long-term median annual stream flow (12.5 GL/year) that is significantly lower than the median annual flow recorded at the upstream Alstonvale gauging station during the period of record for the gauging station (21.4 GL/year).
- The Flinders Source Model predicts lower runoff in dry years and higher runoff in wet years compared to the AWBM. The Flinders Source Model median annual runoff is 12.5 GL/year compared to 23.7 GL/year for the AWBM.
- The AWBM predicts stream flow in 85% of years while the Flinders Source Model predicts stream flow in only 75% of years.

As stated in Section 5.3.5, the calibrated AWBM is considered to produce a better estimate of the historical daily stream flow sequence for the Betts Gorge Creek catchment than the stream flow sequence contained within the Flinders Source Model.
Figure 5.12  Predicted Alstonvale Dam Long-Term Inflow Sequences - Cumulative Daily Inflows

Figure 5.13  Predicted Alstonvale Dam Long-Term Inflow Sequences - Annual Flow Statistics
6. **DAM YIELD ASSESSMENTS FOR OPTIONS ASSESSMENT**

6.1 **Overview**

The dam options were assessed in terms of the water supply yield and the infrastructure costs. Water supply yields were identified for a 90% monthly supply reliability (i.e. the yield able to be supplied in 90% of months). Infrastructures costs were estimated as the present value (PV) cost corresponding to the capital cost and annual operating costs over a 50 year operating period. The options were compared using the PV cost of the infrastructure per unit volume of annual yield that can be supplied by the options (i.e. $/ML supplied).

6.2 **Dam Yield Assessment**

6.2.1 **Modelling Methodology**

Water supply yields for the Alstonvale and Stewart Creek dam options were assessed using a continuous historical reservoir simulation model. The reservoir simulation model was developed using the GoldSim Montecarlo simulation software. GoldSim is a general-purpose simulation software for dynamically modelling complex systems in business, engineering and science. GoldSim supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems. GoldSim is used extensively for modelling of water resource applications and was selected for its’ ability to undertake complex simulations efficiently with short simulation timeframes. Given the large number of options to be assessed for the HIP, GoldSim was considered a more efficient simulation platform than the Flinders Source Model used by the Department of Environment and Science (DES) for the Gulf Water Plan.

The GoldSim reservoir simulations were undertaken for the same historical period as the Flinders Source Model (122 water years spanning the period July 1889 to June 2011) since some of the stream flow sequences from the Flinders Source Model were used as inputs for the GoldSim model. The reservoir simulations were undertaken using a daily time step.

For the options assessment, the water supply yields were identified for a 90% monthly supply reliability which is defined as the yield able to be supplied in 90% of months in the historical simulation period.

Key aspects of the dam yield modelling simulations are detailed in Table 6.1.

<table>
<thead>
<tr>
<th>Model Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation period</td>
<td>July 1889 to June 2011 (122 water years)</td>
</tr>
<tr>
<td>Simulation time step</td>
<td>1 day</td>
</tr>
<tr>
<td>Model Aspect</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| Stream flow sequences for Alstonvale Dam options | Betts Gorge Creek dam site: Historical daily stream flow sequence derived using AWBM daily rainfall runoff model calibrated to stream gauging data for Station No. 915007A (Betts Gorge Creek at Alstonvale)  
Canterbury Creek dam site: Historical daily stream flow sequence derived using AWBM daily rainfall runoff model with same parameters as Betts Gorge Creek  
Galah Creek diversion structure: Stream flows from Flinders Source Model scaled to diversion structure location  
Flinders River diversion structure: Stream flows from Flinders Source Model at Node 001-GS915013A (Glendower gauging station)  
(Note that there are no surface water licences upstream of the Alstonvale Dam scheme) |
| Stream flow sequences for Stewart Creek dam options | Gap Dam, Saego Dam and Catch Dam sites (Stewart Creek and Back Valley Creek): Historical daily stream flow sequences derived using AWBM daily rainfall runoff model with same parameters as Betts Gorge Creek  
Flinders River diversion weir: Stream flows from Flinders Source Model at confluence of Flinders River and Betts Gorge Creek (Node 009-confluence). Stream flows were applied for a minimum development scenario (i.e. no upstream water use) assuming that upstream water licences would be relinquished in lieu of the HIP |
| Historical daily rainfall data (for stream flow calculations and direct rainfall inflows to dam reservoirs) | SILO Data Drill gridded daily rainfall data  
For stream flow calculations, averaging of the gridded data within the catchment areas was undertaken. |
| Historical daily evapotranspiration data (for stream flow calculations) | SILO Data Drill gridded Morton’s potential evapotranspiration data  
For stream flow calculations, averaging of the gridded data within the catchment areas was undertaken. |
| Historical daily evaporation data (for evaporation losses from dam reservoirs) | SILO Data Drill gridded Morton’s lake evaporation data at dam site locations |
| Dam reservoir seepage losses | Constant seepage loss rate of 0.82 mm/day (300 mm/year) from the ponded surface areas of the dams |
| Dam storage capacities | Alstonvale Dam options:  
  - Alstonvale Dam: Different storage capacities investigated in range 150 to 700 GL |
<table>
<thead>
<tr>
<th>Model Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canterbury Creek Dam</strong></td>
<td>• Canterbury Creek Dam: Different storage capacities investigated in range 100 to 500 GL</td>
</tr>
<tr>
<td><strong>Stewart Creek dam options</strong></td>
<td>• Saego Dam: Different storage capacities investigated in range 300 to 500 GL</td>
</tr>
<tr>
<td></td>
<td>• Gap Dam: Storage capacity varies in response to Saego Dam storage capacity (Gap Dam has same full supply level as Saego Dam)</td>
</tr>
<tr>
<td></td>
<td>• Catch Dam: 35 GL (maximum storage capacity to allow gravity diversions out of Flinders River into Catch Dam)</td>
</tr>
<tr>
<td><strong>Dam dead storage capacities</strong></td>
<td>No dead storage volumes assumed for all dams (i.e. assumes all water in the dams is accessible for irrigation supply)</td>
</tr>
<tr>
<td><strong>Diversion/transfer capacities</strong></td>
<td><strong>Alstonvale Dam options:</strong></td>
</tr>
<tr>
<td></td>
<td>• Flinders River diversion structure (diversion to Galah Creek): 250 m$^3$/s (21.6 GL/d) diversion capacity</td>
</tr>
<tr>
<td></td>
<td>• Galah Creek diversion structure (diversion to Canterbury Creek Dam): 500 m$^3$/s (43.2 GL/d) diversion capacity (diversion of stream flows from both Flinders River and Galah Creek)</td>
</tr>
<tr>
<td></td>
<td>• Canterbury Creek Dam pumping system (pumped transfers to Alstonvale Dam): Different pumping capacities investigated in range 5 to 20 m$^3$/s (432 to 1,728 ML/d)</td>
</tr>
<tr>
<td><strong>Stewart Creek dam options</strong></td>
<td>• Flinders River diversion structure (diversion to Catch Dam): 250 m$^3$/s (21.6 GL/d) diversion capacity</td>
</tr>
<tr>
<td></td>
<td>• Catch Dam pumping system (pumped transfers to Saego Dam): Different pumping capacities investigated in range 10 to 600 m$^3$/s (864 ML/d to 51.8 GL/d)</td>
</tr>
<tr>
<td></td>
<td>• Transfers between Saego Dam and Gap Dam: Assumed that Saego Dam overflows into Gap Dam once the storage capacity in Saego Dam is reached</td>
</tr>
<tr>
<td></td>
<td>• Transfers between Gap Dam and Saego Dam: 23 m$^3$/s (2,000 ML/d)</td>
</tr>
<tr>
<td></td>
<td>• Transfers between Saego Dam and Gap Dam occur to maximise the volume of water stored in Saego Dam to minimise storage losses</td>
</tr>
<tr>
<td><strong>Environmental release/pass flow</strong></td>
<td><strong>Alstonvale Dam options:</strong></td>
</tr>
<tr>
<td>requirements</td>
<td></td>
</tr>
</tbody>
</table>
Model Aspect | Description
--- | ---
• Flinders River diversion structure: 4 m³/s (346 ML/d) pass flow (i.e. all upstream stream flows up to pass flow threshold allowed to pass the diversion structure)
• Galah Creek diversion structure: 4 m³/s (346 ML/d) pass flow (i.e. all upstream stream flows up to pass flow threshold allowed to pass the diversion structure)
• Alstonvale Dam: 1 m³/s (86.4 ML/d) capacity environmental release (environmental releases occur when there are catchment inflows to the dam)
• Canterbury Creek Dam: No environmental release

Stewart Creek dam options:
• Flinders River diversion structure: 8 m³/s (691 ML/d) pass flow (i.e. all upstream stream flows up to pass flow threshold allowed to pass the diversion structure)
• Saego Dam: No environmental release (dam location is near downstream limit of Stewart Creek)
• Catch Dam: No environmental release (dam location is near downstream limit of Back Valley Creek)

Note: Environmental release/pass flow requirements were assigned to achieve a compromise between the dam yield and downstream environmental flow requirements. Increased environmental release/pass flow thresholds were shown to cause a significant reduction in dam yield.

Irrigation demand | An annual water supply demand was applied for 6 months of the year from May to October. Annual supply demand rates were adjusted for each dam option to achieve a 90% monthly supply reliability (i.e. supply reliability calculated only for months in which there is an irrigation demand)

6.2.2 Dam Yield Results for Alstonvale Dam Options

A summary of the dam yield results for the Alstonvale Dam options is provided in Table 6.2 and includes variations of the following infrastructure configurations:

- Alstonvale Dam only (no external catchment diversions or Canterbury Creek Dam)
- Canterbury Creek Dam only (with Flinders River and Galah Creek catchment diversions but no Alstonvale Dam)
- Full scheme with Alstonvale Dam, Canterbury Creek Dam and Flinders River and Galah Creek catchment diversions.
The dam yield modelling for the Alstonvale Dam options indicated the following findings:

- The 90% monthly reliability yield for the option involving Alstonvale Dam only (no external catchment diversions) is only 14 GL/year. The yield is limited by the stream flows in Betts Gorge Creek rather than the storage capacity of Alstonvale Dam.

- The 90% monthly reliability yield for the options involving Canterbury Creek Dam only (no Alstonvale Dam) varies from 46 to 54 GL/year for dam storage capacities of 300 to 500 GL.

- The 90% monthly reliability yield for the options involving both Alstonvale Dam and Canterbury Creek Dam varies from 67 to 90 GL/year for the options investigated.

<table>
<thead>
<tr>
<th>Alstonvale Dam Storage Capacity (GL)</th>
<th>Canterbury Creek Dam Storage Capacity (GL)</th>
<th>Canterbury Creek Dam to Alstonvale Dam Transfer Capacity (m$^3$/s)</th>
<th>90% Monthly Reliability Yield (GL/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>No dam</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>500</td>
<td>200</td>
<td>7.5</td>
<td>86</td>
</tr>
<tr>
<td>500</td>
<td>300</td>
<td>7.5</td>
<td>90</td>
</tr>
<tr>
<td>500</td>
<td>100</td>
<td>7.5</td>
<td>74</td>
</tr>
<tr>
<td>700</td>
<td>100</td>
<td>7.5</td>
<td>76</td>
</tr>
<tr>
<td>300</td>
<td>100</td>
<td>7.5</td>
<td>69</td>
</tr>
<tr>
<td>300</td>
<td>100</td>
<td>5</td>
<td>67</td>
</tr>
<tr>
<td>300</td>
<td>100</td>
<td>10</td>
<td>71</td>
</tr>
<tr>
<td>300</td>
<td>100</td>
<td>20</td>
<td>72</td>
</tr>
<tr>
<td>500</td>
<td>100</td>
<td>5</td>
<td>72</td>
</tr>
<tr>
<td>500</td>
<td>200</td>
<td>5</td>
<td>82</td>
</tr>
<tr>
<td>500</td>
<td>200</td>
<td>10</td>
<td>87</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>-</td>
<td>46</td>
</tr>
<tr>
<td>400</td>
<td>400</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>No dam</td>
<td>500</td>
<td>-</td>
<td>54</td>
</tr>
</tbody>
</table>
The maximum possible yield for the full scheme with no restrictions on dam storage capacities or transfer capacity between the two reservoirs was determined as 130 GL/year (result not shown in Table 6.2).

Storage losses are significant and typically equal to 50 to 100% of the system yield depending on the infrastructure configuration.

The simulated reservoir performance and average annual inflows and outflows for the Alstonvale Dam option with the largest yield (500 GL Alstonvale Dam, 300 GL Canterbury Creek Dam and 7.5 m³/s pump transfer capacity between the reservoirs) are shown in Figure 6.1 and Figure 6.2 respectively.

![Simulated Reservoir Performance for 90 GL/year Yield Alstonvale Dam Option](image)
6.2.3 Dam Yield Results for Stewart Creek Dam Options

A summary of the dam yield results for the Stewart Creek dam options is provided in Table 6.3.

Table 6.3 Dam Yield Results for Stewart Creek Dam Options

<table>
<thead>
<tr>
<th>Catch Dam to Saego Dam Transfer Capacity (m³/s)</th>
<th>300 GL Saego Dam Storage Capacity</th>
<th>400 GL Saego Dam Storage Capacity</th>
<th>500 GL Saego Dam Storage Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>62</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>25</td>
<td>75</td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td>50</td>
<td>87</td>
<td>95</td>
<td>98</td>
</tr>
<tr>
<td>100</td>
<td>96</td>
<td>110</td>
<td>116</td>
</tr>
<tr>
<td>200</td>
<td>103</td>
<td>121</td>
<td>133</td>
</tr>
<tr>
<td>300</td>
<td>105</td>
<td>126</td>
<td>141</td>
</tr>
</tbody>
</table>
The dam yield modelling for the Stewart Creek dam options indicated the following findings:

- The 90% monthly reliability yield varies from 62 to 149 GL/year for the options investigated.
- A large pumping capacity (in excess of 50 m$^3$/s) is required between the Catch Dam and Saego Dam to achieve a yield of 100 GL/year.
- The maximum possible yield with no restrictions on dam storage capacities or transfer capacities was determined as 210 GL/year (result not shown in Table 6.3).
- Storage losses are significant and typically equal to 50 to 100% of the system yield depending on the infrastructure configuration.

### 6.3 Dam Cost Estimates

High-level concept designs and capital cost estimates were developed for the dams associated with the Alstonvale Dam and Stewart Creek dam options by ARQ Australia Pty Ltd (2019a and 2019b) in collaboration with Newman Engineering Pty Ltd.

Concept designs and capital cost estimates were developed for the following dam configurations:

- **Alstonvale Dam options:**
  - Alstonvale Dam: 300, 500 and 700 GL storage capacity
  - Canterbury Creek Dam: 100, 200 and 300 GL storage capacity.

- **Stewart Creek dam options:**
  - Catch Dam: 35 GL storage capacity
  - Saego Dam: 300, 400 and 500 GL storage capacity
  - Gap Dam: 325, 550 and 850 GL storage capacity (corresponding to full supply levels nominally 300 mm higher than each of the Saego Dam configurations).
No detailed geotechnical investigations were undertaken to support the concept dam designs (a site visit and minor test pitting was undertaken for the Alstonvale Dam site). Conservative assumptions were made in relation to foundation and cut-off depths for the Saego Dam and Catch Dam which would be expected to be founded on alluvial soils given the locations of the dams within the floodplain area of the Flinders River.

The following types of dam construction were considered suitable for the dams based on the dam configurations and expected foundation conditions:

- **Alstonvale Dam options:**
  - Alstonvale Dam: Roller compacted concrete gravity dam
  - Canterbury Creek Dam: Clay core rockfill embankment with concrete gravity spillway.

- **Stewart Creek dam options:**
  - Catch Dam: Clay core rockfill embankment with concrete gravity spillway
  - Saego Dam: Clay core rockfill embankment with concrete gravity spillway
  - Gap Dam: Roller compacted concrete gravity dam.

The capital cost estimates for the dams included the following allowances for direct and indirect costs:

- Lump sum allowances for construction accommodation camp, temporary construction facilities, permanent infrastructure and land acquisition costs
- 10% measurement growth allowance (applied to direct costs)
- 40% allowance for contractor preliminaries and general costs (applied to direct costs)
- 10% allowance for planning and design costs (applied to direct costs and preliminaries)
- 10% contingency allowance (applied to direct costs and preliminaries).

A summary of the dam design configurations and cost estimates is provided in Table 6.4 for the Alstonvale Dam options and Table 6.5 for the Stewart Creek dam options.

**Table 6.4 High-Level Capital Cost Estimates for Alstonvale Dam Options**

<table>
<thead>
<tr>
<th>Dam</th>
<th>Storage Capacity (GL)</th>
<th>Full Supply Level (m AHD)</th>
<th>Dam Crest Level (m AHD)</th>
<th>Dam Capital Cost ($million)</th>
<th>Unit Cost ($ per ML of storage capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alstonvale Dam</td>
<td>300</td>
<td>314</td>
<td>318</td>
<td>$283M</td>
<td>$944</td>
</tr>
<tr>
<td>Alstonvale Dam</td>
<td>400</td>
<td>320</td>
<td>324</td>
<td>$326M</td>
<td>$652</td>
</tr>
</tbody>
</table>
### Dam Storage Capacity (GL) and Full Supply Level (m AHD)

<table>
<thead>
<tr>
<th>Dam</th>
<th>Storage Capacity (GL)</th>
<th>Full Supply Level (m AHD)</th>
<th>Dam Crest Level (m AHD)</th>
<th>Dam Capital Cost ($million)</th>
<th>Unit Cost ($ per ML of storage capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alstonvale Dam</td>
<td>500</td>
<td>325</td>
<td>329</td>
<td>$361M</td>
<td>$566</td>
</tr>
<tr>
<td>Canterbury Creek Dam</td>
<td>100</td>
<td>308</td>
<td>311.5</td>
<td>$184M</td>
<td>$1,843</td>
</tr>
<tr>
<td>Canterbury Creek Dam</td>
<td>200</td>
<td>311.5</td>
<td>315</td>
<td>$239M</td>
<td>$1,194</td>
</tr>
<tr>
<td>Canterbury Creek Dam</td>
<td>300</td>
<td>314</td>
<td>317.5</td>
<td>$278M</td>
<td>$928</td>
</tr>
</tbody>
</table>

### Table 6.5 High-Level Capital Cost Estimates for Stewart Creek Dam Options

<table>
<thead>
<tr>
<th>Dam</th>
<th>Storage Capacity (GL)</th>
<th>Full Supply Level (m AHD)</th>
<th>Dam Crest Level (m AHD)</th>
<th>Dam Capital Cost ($million)</th>
<th>Unit Cost ($ per ML of storage capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch Dam</td>
<td>35</td>
<td>269</td>
<td>274</td>
<td>$581M¹</td>
<td>$16,606¹</td>
</tr>
<tr>
<td>Saego Dam</td>
<td>300</td>
<td>278.5</td>
<td>282.5</td>
<td>$869M</td>
<td>$2,898</td>
</tr>
<tr>
<td>Saego Dam</td>
<td>400</td>
<td>283.5</td>
<td>287.5</td>
<td>$1,229M</td>
<td>$3,072</td>
</tr>
<tr>
<td>Saego Dam</td>
<td>500</td>
<td>288.5</td>
<td>292.5</td>
<td>$1,313M</td>
<td>$2,626</td>
</tr>
<tr>
<td>Gap Dam</td>
<td>325</td>
<td>278.8²</td>
<td>282.8</td>
<td>$202M</td>
<td>$622</td>
</tr>
<tr>
<td>Gap Dam</td>
<td>550</td>
<td>283.8²</td>
<td>287.8</td>
<td>$263M</td>
<td>$478</td>
</tr>
<tr>
<td>Gap Dam</td>
<td>850</td>
<td>288.8²</td>
<td>292.8</td>
<td>$333M</td>
<td>$392</td>
</tr>
</tbody>
</table>

¹ Catch Dam cost includes diversion weir on Flinders River and diversion channel into Catch Dam.
² Gap Dam full supply levels are nominally 300 mm higher than corresponding Saego Dam full supply levels.

The estimated cost of Saego Dam is significantly higher than the other dams, primarily as a result of the long embankment length and the deeper foundation and cut-off requirements.

To facilitate assessment of the options, a smaller list of options was selected to determine capital and operating costs. These options were assessed as the options considered likely to be the most cost effective (cost per unit yield) options for each of the Alstonvale Dam and Stewart Creek dam schemes. The options selected for costing are as follows:
Alstonvale Dam options:
- 500 GL capacity Alstonvale Dam, 300 GL capacity Canterbury Creek Dam and 7.5 m³/s transfer capacity between the dams
- 300 GL capacity Canterbury Creek Dam only (no Alstonvale Dam).

Stewart Creek dam options:
- Three options corresponding to Saego Dam storage capacities of 300, 400 and 500 GL with a transfer capacity between the Catch Dam and Saego Dam of 100 m³/s
- Three options corresponding to Saego Dam storage capacities of 300, 400 and 500 GL with a transfer capacity between the Catch Dam and Saego Dam of 200 m³/s.

High-level capital cost estimates were developed for the following infrastructure elements:

Alstonvale Dam options:
- Alstonvale Dam and/or Canterbury Creek Dam (as detailed above)
- Flinders River diversion (i.e. diversion weir and channel)
- Galah Creek diversion (i.e. diversion weir and channel)
- Canterbury Creek Dam to Alstonvale Dam pump transfer system (electric powered)
- Irrigation delivery system assumed to consist of a regulating weir on the Flinders River downstream of the confluence with Betts Gorge Creek (dams to release water to the regulating weir) and a pumping system (electric powered) between the regulating weir and the irrigation area on the southern side of the Flinders River (no further allowance for distribution of water within the irrigation area)
- Electricity supply upgrade to the new pump station sites.

Stewart Creek dam options:
- Catch Dam (includes diversion weir and channel on Flinders River), Saego Dam and Gap Dam (as detailed above)
- Catch Dam to Saego Dam pump transfer system (diesel powered)
- Irrigation delivery system comprising a pumping system (electric powered) between Saego Dam and the irrigation area on the southern side of the Flinders River (no further allowance for distribution of water within the irrigation area)
- Electricity supply upgrade to the Saego Dam irrigation delivery pump station.

A summary of the infrastructure capital cost estimates for the selected options is presented in Table 6.6 (Alstonvale Dam options) and Table 6.7 (Stewart Creek dam options).

Annual operating and maintenance costs and periodic sustaining capital costs were estimated as follows:

Infrastructure annual operating and maintenance costs (excluding power costs):
- Dams: 0.15% of capital cost
- Weirs and diversions: 1% of capital cost
- Pipelines: 0.25% of capital cost
- Electric pumps: 2% of capital cost
- Diesel pumps: 4% of capital cost.

Power costs for pumping:
- Electricity: 17.3c/kWh
- Diesel (Catch Dam to Saego Dam pumping system): $17/ML (assuming average 10 m pumping head and $1/L diesel cost after the diesel rebate).

Sustaining capital:
- Replacement of mechanical and electrical components of pump stations after 25 years.

Equivalent PV total project lifecycle costs for the capital, annual operating and maintenance and sustaining capital costs for the selected options were estimated over a project life of 50 years and assuming a discount rate of 7%. The total project lifecycle costs are summarised in Table 6.8 (Alstonvale Dam options) and Table 6.9 (Stewart Creek dam options).

To facilitate comparison of the cost effectiveness of the different options, the total project lifecycle costs were expressed as a unit cost per megalitre of yield. The unit costs of the selected options are listed in Table 6.10 (Alstonvale Dam options) and Table 6.11 (Stewart Creek dam options).

The unit costs for the Stewart Creek dam options are approximately 60% higher than the Alstonvale Dam options.

None of the long list options are considered economically viable, with a cost per megalitre significantly higher than what irrigators would be willing to pay for water allocations (around $2,000/ML).

Since none of the long list options were considered to be economically viable, a revised and flexible approach was adopted for the progression of the PBC study to consider smaller dams with less pumping/energy requirements. It was decided to proceed with further investigation of an alternative Stewart Creek dam option for the following reasons:

- A smaller Saego Dam can be filled with gravity diversions out of the Flinders River without the need for the separate Catch Dam reservoir or any pumping into Saego Dam.
- HIPCo advised that geological conditions along the majority of the Saego Dam and Catch Dam alignments are expected to comprise relatively shallow mudstone. Accordingly, dam foundation excavation and cut-off depths are likely to be significantly less than that assumed in the Stewart Creek dam options cost estimates prepared by ARQ Australia Pty Ltd.
- For a smaller Saego Dam, the Gap Dam may not be required since the incremental increase in yield that results from the Gap Dam (due to reduced storage losses) may be relatively minor.

- It may be possible to achieve gravity transfers of water from Saego Dam to the lower parts of the irrigation area.

- Operating the storages to provide a combination of higher and lower reliability water allocations to customers could allow higher value horticulture crops to be grown which will significantly improve the economic outcomes of the Project.

Further consideration of these factors and investigation of costs and yields for smaller Stewart Creek dam configurations led to the preferred Reference Project option which involves gravity diversions out of the Flinders River directly into a smaller Saego Dam on Stewart Creek, without the need for the Catch Dam, Gap Dam or any pumping into Saego Dam.
### Table 6.6 High-Level Capital Cost Estimates for Selected Alstonvale Dam Options

<table>
<thead>
<tr>
<th>Option Configuration</th>
<th>Capital Costs ($million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Alstonvale Dam Storage Capacity (GL)</td>
<td>Canterbury Creek Dam Storage Capacity (GL)</td>
</tr>
<tr>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>No dam</td>
<td>300</td>
</tr>
</tbody>
</table>

### Table 6.7 High-Level Capital Cost Estimates for Selected Stewart Creek Dam Options

<table>
<thead>
<tr>
<th>Option Configuration</th>
<th>Capital Costs ($million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Saego Dam Storage Capacity (GL)</td>
<td>Gap Dam Storage Capacity (GL)</td>
</tr>
<tr>
<td>300</td>
<td>325</td>
</tr>
<tr>
<td>Saego Dam Storage Capacity (GL)</td>
<td>Gap Dam Storage Capacity (GL)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>400</td>
<td>550</td>
</tr>
<tr>
<td>500</td>
<td>850</td>
</tr>
<tr>
<td>300</td>
<td>325</td>
</tr>
<tr>
<td>400</td>
<td>550</td>
</tr>
<tr>
<td>500</td>
<td>850</td>
</tr>
</tbody>
</table>
Table 6.8 High-Level Total Project Cost Estimates for Selected Alstonvale Dam Options

<table>
<thead>
<tr>
<th>Alstonvale Dam Storage Capacity (GL)</th>
<th>Option Configuration</th>
<th>Canterbury Creek Dam Storage Capacity (GL)</th>
<th>Canterbury Creek Dam to Alstonvale Dam Transfer Capacity (m³/s)</th>
<th>Total Capital Cost</th>
<th>Total Sustaining Capital Cost (cost every 25 years)</th>
<th>Total Annual Operating and Maintenance Cost (cost every year)</th>
<th>Present Value of Total Project Lifecycle Cost (50 year project life)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>300</td>
<td>7.5</td>
<td>$967M</td>
<td>$20M</td>
<td>$11.6M</td>
<td>$1,131M</td>
<td>$1,131M</td>
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<tr>
<td>No dam</td>
<td>300</td>
<td>-</td>
<td>$541M</td>
<td>$2M</td>
<td>$4.2M</td>
<td>$600M</td>
<td>$600M</td>
</tr>
</tbody>
</table>

Table 6.9 High-Level Total Project Cost Estimates for Selected Stewart Creek Dam Options

<table>
<thead>
<tr>
<th>Saego Dam Storage Capacity (GL)</th>
<th>Option Configuration</th>
<th>Gap Dam Storage Capacity (GL)</th>
<th>Catch Dam to Saego Dam Transfer Capacity (m³/s)</th>
<th>Total Capital Cost</th>
<th>Total Sustaining Capital Cost (cost every 25 years)</th>
<th>Total Annual Operating and Maintenance Cost (cost every year)</th>
<th>Present Value of Total Project Lifecycle Cost (50 year project life)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>325</td>
<td>100</td>
<td>$1,840M</td>
<td>$42M</td>
<td>$12.5M</td>
<td>$2,020M</td>
<td>$2,020M</td>
</tr>
<tr>
<td>400</td>
<td>550</td>
<td>100</td>
<td>$2,270M</td>
<td>$44M</td>
<td>$13.8M</td>
<td>$2,468M</td>
<td>$2,468M</td>
</tr>
<tr>
<td>500</td>
<td>850</td>
<td>100</td>
<td>$2,429M</td>
<td>$45M</td>
<td>$14.2M</td>
<td>$2,634M</td>
<td>$2,634M</td>
</tr>
<tr>
<td>300</td>
<td>325</td>
<td>200</td>
<td>$1,945M</td>
<td>$68M</td>
<td>$14.3M</td>
<td>$2,155M</td>
<td>$2,155M</td>
</tr>
<tr>
<td>Saego Dam Storage Capacity (GL)</td>
<td>Gap Dam Storage Capacity (GL)</td>
<td>Catch Dam to Saego Dam Transfer Capacity (m$^3$/s)</td>
<td>Total Capital Cost</td>
<td>Total Sustaining Capital Cost (cost every 25 years)</td>
<td>Total Annual Operating and Maintenance Cost (cost every year)</td>
<td>Present Value of Total Project Lifecycle Cost (50 year project life)</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------------------</td>
<td>-------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>550</td>
<td>200</td>
<td>$2,378M</td>
<td>$71M</td>
<td>$15.8M</td>
<td>$2,609M</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>850</td>
<td>200</td>
<td>$2,541M</td>
<td>$73M</td>
<td>$16.6M</td>
<td>$2,784M</td>
<td></td>
</tr>
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</table>
### Table 6.10 Unit Cost Estimates for Selected Alstonvale Dam Options

<table>
<thead>
<tr>
<th>Option Configuration</th>
<th>Alstonvale Dam Storage Capacity (GL)</th>
<th>Canterbury Creek Dam Storage Capacity (GL)</th>
<th>Canterbury Creek Dam to Alstonvale Dam Transfer Capacity (m³/s)</th>
<th>Present Value of Total Project Lifecycle Cost ($million)</th>
<th>90% Monthly Reliability Yield (GL/year)</th>
<th>Unit Cost ($million per ML of Yield)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500</td>
<td>300</td>
<td>7.5</td>
<td>$1,131M</td>
<td>90</td>
<td>$12,566</td>
</tr>
<tr>
<td>No dam</td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>$600M</td>
<td>46</td>
<td>$13,041</td>
</tr>
</tbody>
</table>

### Table 6.11 Unit Cost Estimates for Selected Stewart Creek Dam Options

<table>
<thead>
<tr>
<th>Option Configuration</th>
<th>Saego Dam Storage Capacity (GL)</th>
<th>Gap Dam Storage Capacity (GL)</th>
<th>Catch Dam to Saego Dam Transfer Capacity (m³/s)</th>
<th>Present Value of Total Project Lifecycle Cost ($million)</th>
<th>90% Monthly Reliability Yield (GL/year)</th>
<th>Unit Cost ($million per ML of Yield)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>300</td>
<td>325</td>
<td>100</td>
<td>$2,020M</td>
<td>96</td>
<td>$21,043</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>550</td>
<td>100</td>
<td>$2,468M</td>
<td>110</td>
<td>$22,436</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>850</td>
<td>100</td>
<td>$2,634M</td>
<td>116</td>
<td>$22,704</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>325</td>
<td>200</td>
<td>$2,155M</td>
<td>103</td>
<td>$20,921</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>550</td>
<td>200</td>
<td>$2,609M</td>
<td>121</td>
<td>$21,562</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>850</td>
<td>200</td>
<td>$2,784M</td>
<td>133</td>
<td>$20,930</td>
</tr>
</tbody>
</table>
7. DAM YIELD ASSESSMENT FOR REFERENCE PROJECT

7.1 Overview

The GoldSim reservoir operation simulation model described in Section 6.2.1 was used to identify the water supply yields available for the Reference Project. The scheme yield was also independently assessed using the Flinders Source Model developed by the Queensland Government for the Gulf Water Plan. An assessment of the potential impacts of future climate change on the dam yield estimates has also been undertaken.

7.2 Assumptions and Methodology

The GoldSim reservoir simulation model utilised for the assessment of the Stewart Creek dam options described in Section 6.2.1 was used for the dam yield assessment for the Reference Project with the following changes to reflect the revised infrastructure and operating details:

- The Catch Dam, Saego Dam and Gap Dam storages were combined into a single storage for Saego Dam with a maximum storage capacity of 190 GL (including the storage capacity upstream of the Flinders River diversion weir) and a direct catchment area of 1,084 km². The storage characteristics for Saego Dam are shown in Figure 7.1 and have been derived using LiDAR ground survey of the Saego Dam impoundment area acquired by HIPCo in May 2019.

- The irrigation demand pattern was changed to a constant demand pattern with water supplied over all 12 months of the year.

- Two different water allocation products were simulated for the diversified cropping strategy:
  - Higher reliability (Medium Priority) water allocations for irrigation of horticultural crops: 94% monthly reliability
  - Lower reliability (Low Priority) water allocations for irrigation of grazier support crops: 70% monthly reliability.

- A single water allocation product was simulated for the grazier support strategy representing a monthly reliability of 80%.

- The water sharing rules assumed for the diversified cropping strategy (i.e. two water allocation products) were as follows:
  - Saego Dam volume greater than 47.5 GL (i.e. greater than 25% full): 100% of allocations available for both Medium Priority and Low Priority allocations.
  - Saego Dam volume less than 47.5 GL (i.e. less than 25% full): 100% of allocations available for Medium Priority allocations and 0% of allocations available for Low Priority allocations (i.e. supply to Low Priority allocations ceases).
The same diversion configuration assumed for the options assessment phase was adopted for the Reference Project, comprising:

- A low flow (pass flow) threshold of $8 \text{ m}^3/\text{s}$ (691 ML/d) at the Flinders River diversion weir (i.e. all inflows to the diversion weir up to $8 \text{ m}^3/\text{s}$ are passed through the weir prior to diversion of stream flow into Saego Dam).

- A diversion flow capacity of $250 \text{ m}^3/\text{s}$ (i.e. maximum rate of water diversion out of the Flinders River into Saego Dam).

Figure 7.1  Storage characteristics for Saego Dam

### 7.3  Dam Yield Results

A summary of the dam yield results for the different cropping strategies is provided in Table 7.1.

For the diversified cropping strategy, the proposed scheme is capable of supplying:

- 30 GL/year of higher reliability water (Medium Priority allocations) at 94% monthly reliability (86% annual reliability) and 40 GL/year of lower reliability water (Low Priority allocations) at 70% monthly reliability (48% annual reliability).

- An equivalent average annual irrigation supply of 57 GL/year.

For the grazier support strategy, the proposed scheme is capable of supplying:
- 84 GL/year water at 80% monthly reliability (61% annual reliability).
- An equivalent average annual irrigation supply of 70 GL/year.

The simulated reservoir performance of Saego Dam over the historical period (1889 to 2001) for the two different operating/demand scenarios is shown in Figure 7.2 (diversified cropping scenario) and Figure 7.3 (grazier support scenario).

Table 7.1 Predicted Dam Yields for Reference Project

<table>
<thead>
<tr>
<th>Crop Strategy</th>
<th>Medium Priority Allocations (horticulture crops)</th>
<th>Low Priority Allocations (grazier support crops)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target Yield (GL/year)</td>
<td>Monthly Reliability</td>
</tr>
<tr>
<td>Diversified cropping</td>
<td>30</td>
<td>94%</td>
</tr>
<tr>
<td>Grazier support</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 7.2 Simulated Reservoir Performance for Saego Dam – Diversified Cropping Scenario
Figure 7.3  Simulated Reservoir Performance for Saego Dam – Grazier Support Scenario

The predicted reservoir time histories for the historical simulation period demonstrate:

- A greater number of water supply failures (reservoir empty) for the grazier support scenario as a result of the increased irrigation water use.
- Water supply failures can occur over extended periods (multiple years) as a result of prolonged drought. The worst drought sequence in the historical simulation period is a period of 6 years in the first decade of the 1900s.

The predicted annual irrigation supply volumes for the historical simulation period for the two different diversified cropping scenario water products are shown in Figure 7.4 (Medium Priority allocations) and Figure 7.5 (Low Priority allocations).

There are only two years predicted in the 122 year simulation period where there is less than 10 GL/year of Medium Priority irrigation water available for horticulture crops. It is expected that there would some replacement/replanting of older fruit trees in years with low volumes of Medium Priority water available.

There are several occurrences predicted of multiple consecutive years of no Low Priority irrigation water available for grazier support crops under the diversified cropping scenario. Farmers could decide not to plant grain/fodder/hay crops for irrigated production when Saego Dam is at low levels; however, dry-land farming could still occur on the properties.
Figure 7.4 Predicted Medium Priority Irrigation Supply Volumes – Diversified Cropping Scenario

Figure 7.5 Predicted Low Priority Irrigation Supply Volumes – Diversified Cropping Scenario
The predicted annual irrigation supply volumes for the historical simulation period for the grazier support scenario is shown in Figure 7.6. The annual volume of water available for irrigation will be less than 40 GL/year (approximately 50% of the total allocation volume) in only 15% of the years in the historical simulation period for the grazier support scenario.

![Graph showing predicted irrigation supply volumes for grazier support scenario.](image)

**Figure 7.6 Predicted Irrigation Supply Volumes – Grazier Support Scenario**

Average annual inflows and outflows for the Reference Project water supply scheme are displayed in Figure 7.7 (diversified cropping scenario) and Figure 7.8 (grazier support scenario). The diversion inflows from the Flinders River are significantly greater (almost four times larger) than the direct inflows from the Saego Dam catchment area.

The average storages losses from Saego Dam (evaporation and seepage) represent a significant loss from the system, at 63% of the average irrigation supply for the grazier support scenario and 90% of the average irrigation supply for the diversified cropping scenario. Opportunities to reduce storage losses will be investigated during subsequent phases of the Project.

The average annual flow diversion out of the river system (irrigation supply and storage losses) for the proposed HIP scheme will be 109 GL/year for the diversified cropping scenario and 114 GL/year for the grazier support scenario. These diversions out of the river system represent approximately 38% of the mean annual flow in the Flinders River system at the scheme location (i.e. confluence of the Flinders River and Stewart Creek), but only 4% of the mean annual flow at the mouth of the Flinders River.
Figure 7.7 Average Annual Inflows and Outflows – Diversified Cropping Scenario

Figure 7.8 Average Annual Inflows and Outflows – Grazier Support Scenario
7.4 Independent Yield Assessment Using Flinders Source Model

The scheme yield estimated for the HIP Reference Project was independently assessed for the grazier support scenario only (84 GL/year irrigation demand) using the Source model of the Flinders River catchment that was developed to inform the water resource planning aspects of the Water Plan (Gulf) 2017. The Source software was developed by eWater (https://ewater.org.au/products/ewater-source/) and is designed to simulate all aspects of water resource systems to support integrated planning, operations and governance from urban, catchment to river basin scales including human and ecological influences. Source accommodates diverse climatic, geographic, water policy and governance settings for both Australian and international climatic conditions.

The independent yield assessment was undertaken by Hydrology and Risk Consulting (HARC) under the instruction and direction of Engeny. The WRP/ROP Amendment version of the Flinders Source Model developed by the Department of Environment and Science (DES) was used for the assessment. This version of the model assumes full utilisation of all surface water entitlements (including unallocated reserves) and represents a ‘maximum water use’ scenario as allowed under the Gulf Water Plan. The same configuration and operating conditions (i.e. dam size, diversion configuration, seepage rate, irrigation demand, etc.) assumed for the Reference Project in the GoldSim reservoir simulation model were applied in the Source model. Key aspects of the assessment are as follows:

- The historical simulation period in the Flinders Source Model is identical to that adopted for the GoldSim model (i.e. July 1889 to June 2011).

- The stream flow sequence for Saego Dam (Stewart Creek and Back Valley Creek catchments) needed to be added to the Flinders Source Model since these catchments were not explicitly represented in this model (only included in larger residual catchment inflows between the Betts Gorge Creek confluence with the Flinders River and the Dutton River confluence with the Flinders River):
  - The stream flow sequence provided in the Flinders Source Model for inflow Node 008 – GS915007A Alstonvale (i.e. Betts Gorge Creek at Alstonvale gauging station) was adopted for the catchment inflow sequence for Saego Dam. The Betts Gorge Creek catchment is immediately adjacent to the Stewart Creek and Back Valley Creek catchments and the catchment areas of these catchments are almost identical (1,077 km² for Betts Gorge Creek at Alstonvale gauging station compared to 1,084 km² for the Saego Dam catchment).
  - The residual catchment inflows in the Flinders Source Model between the Betts Gorge Creek confluence with the Flinders River and the Dutton River confluence with the Flinders River were reduced by corresponding volumes to the added Saego Dam catchment inflows to prevent double counting of inflows.

- The Flinders Source Model was modified to represent the following assumed changes to the water licensing upstream of the proposed scheme that has the potential to impact the dam yield:
Previous sale of 12,000 ML of the general reserve unallocated water (Product 1) within Reach 1 (Flinders River upstream of Richmond gauging station) and the subsequent re-location of these new licences (licence numbers 618703 and 618704) to the lower reaches of the Stawell River (i.e. downstream of HIP scheme). Since the supply node associated with the Reach 1 general reserve in the Flinders Source Model (node GR1_SP) is upstream of the HIP scheme location (in vicinity of Hughenden), this change resulted in a reduction to the water use upstream of the HIP scheme (i.e. GR1_SP demand reduced by 12,000 ML/year).

An additional 6,000 ML of the general reserve unallocated water (Product 1) within Reach 1 was purchased by the owner of the Saego Plains property who subsequently sold 5,000 ML of this entitlement to Flinders Shire Council (licence number 618019), which is assigned to the property associated with the 15 Mile Irrigated Agricultural Development Project. Flinders Shire Council do not plan to utilise this licence for the 15 Mile Irrigated Agricultural Development Project (water planned to be supplied from groundwater extraction licences) and accordingly it was assumed that licence number 618019 will be relinquished (i.e. bought back and cancelled) as part of the HIP Project (i.e. GR1_SP demand reduced by 5,000 ML/year).

The remaining 1,000 ML of the 6,000 ML general reserve unallocated water (Product 1) purchase by the owner of the Saego Plains property was retained as a water harvesting licence attached to the Saego Plain property (licence number 616951). This licence was also assumed to be relinquished as part of the HIP scheme (i.e. GR1_SP demand reduced by 1,000 ML/year).

The remaining 7,000 ML of the general reserve unallocated water (Product 1) within Reach 1 was assumed to be allocated to the HIP scheme (i.e. GR1_SP demand reduced by 7,000 ML/year).

The strategic State reserve unallocated water included in the Flinders Source Model at Hughenden (supply node SR1_SP with a demand of 3,000 ML/year) was assumed to be allocated to the HIP scheme (i.e. SR1_SP demand reduced to zero).

Existing surface water licences associated with the Riverside property (licence numbers 43752J, 43864J and 100474 with a combined annual volumetric limit entitlement of 2,120 ML/year) were assumed to be allocated to the HIP scheme (i.e. demand for supply nodes 205, 207 and 211 reduced to zero).

The simulated monthly and annual reliabilities of the annual irrigation supply for the grazier support scenario (84 GL/year demand) in the Flinders Source Model are compared to the GoldSim reservoir simulation model reliabilities in Table 7.2. The two different yield models produce very similar yield estimates, with the Flinders Source Model producing a slightly smaller monthly supply reliability and a corresponding 2 GL/year reduction (i.e. 3% reduction) in the average annual irrigation supply volume. The small differences in the dam yield estimates are attributed to:

- Relatively minor differences in the upstream water use assumptions between the two models—the GoldSim model assumed no upstream water use while the Flinders Source Model included a relatively small volume of extraction (approximately 1,000 ML/year) out of the Flinders River upstream of the Scheme.
Differences in the direct catchment inflow sequences for Saego Dam between the two models which relate back to the different runoff model calibration for the Betts Gorge Creek catchment adopted by Engeny for the GoldSim model compared to that adopted by DES in the Flinders Source Model.

Further refinement of the dam yield modelling in subsequent stages of the Project will utilise the Flinders Source Model.

Table 7.2 Comparison of Grazier Support Scenario Irrigation Supply Reliabilities – Flinders Source Model compared to GoldSim model

<table>
<thead>
<tr>
<th>Yield Model</th>
<th>Target Yield (GL/year)</th>
<th>Monthly Reliability</th>
<th>Annual Reliability</th>
<th>Average Annual Yield (GL/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flinders Source Model</td>
<td>84</td>
<td>78%</td>
<td>61%</td>
<td>68</td>
</tr>
<tr>
<td>GoldSim model</td>
<td>84</td>
<td>80%</td>
<td>61%</td>
<td>70</td>
</tr>
</tbody>
</table>

7.5 **Climate Change Impact Assessment**

An assessment of the potential impacts of future climate change on the dam yield estimates has also been undertaken for the Reference Project. This assessment was performed using the GoldSim reservoir simulation model.

The model climate data inputs were adjusted using the methodologies outlined in “Climate Change in Australia Technical Report” (CSIRO, 2015) to undertake the climate change impact assessment. The CSIRO report provides projections of future climate variables as a result of climate response to a number of greenhouses gas and aerosol emission scenarios (Representative Concentration Pathways).

Climate projections for Hughenden (Monsoonal North region) were obtained using the Projections Builder application provided on the Climate Change Australia website (https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections-builder/). Projections were obtained for the “Best” and “Worst” case scenarios which are based on the following:

- **Best Case** – higher rainfall and lower evaporation, improving dam yield; and
- **Worst Case** – lower rainfall and higher evaporation, reducing dam yield.

Projections are also provided for the “Maximum Consensus” which is the climate future projected by at least 33% of the climate models and which comprises at least 10% more models than any other. The “Maximum Consensus” is considered the most representative forecast of all the climate models.
Projected changes to average annual rainfall and evaporation/evapotranspiration were obtained for the following climate change scenario:

- 2070 projection year – suitable for a 50-year design life of the HIP
- Representative Concentration Pathway 4.5 (RCP4.5) – represents some intervention to reducing greenhouse gas and aerosol emissions, however not the most optimistic outlook.

The climate change sensitivity parameters are provided in Table 7.3.

### Table 7.3 Climate Change Impact Assessment Parameters

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Change in Average Annual Rainfall</th>
<th>Change in Average Annual Evaporation / Evapotranspiration</th>
<th>Model and Consensus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Case</td>
<td>7.5%</td>
<td>3.3%</td>
<td>Model – NorESM1-M</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Consensus – Low</td>
</tr>
<tr>
<td>Worst Case</td>
<td>-13.6%</td>
<td>4.3%</td>
<td>Model – HadGEM2-CC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Consensus – Low</td>
</tr>
<tr>
<td>Maximum Consensus</td>
<td>-0.4%</td>
<td>7.1%</td>
<td>Model – CanESM2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Consensus – Medium</td>
</tr>
</tbody>
</table>

The GoldSim reservoir simulation model daily climate data inputs were adjusted using the values in Table 7.2 to assess the impacts of the “best” case, “worst” case and “maximum consensus” climate change scenarios. The climate change impact assessment results for the diversified cropping scenario (target 30 GL/year of Medium Priority water and 40 GL/year of Low Priority water) are shown in Table 7.4.

The simulated monthly reliability of the Medium Priority water allocations (94% for the base case scenario with no climate change) is predicted to vary between 83% (“worst” case climate projection) and 96% (“best” case climate projection) with a “maximum consensus” projection of 91% (i.e. 3% reduction in reliability).

Similarly, the simulated monthly reliability of the Low Priority water allocations (70% for the base case scenario with no climate change) is predicted to vary between 47% (“worst” case climate projection) and 78% (“best” case climate projection) with a “maximum consensus” projection of 65% (i.e. 5% reduction in reliability).

The average annual irrigation supply volume (total of both water products) is predicted to vary from 46 GL/year (“worst” case climate projection) to 61 GL/year (“best” case climate projection).
projection) with a “maximum consensus” projection of 55 GL/year, which represents only a 3.5% reduction compared to the base case scenario with no climate change.

Table 7.4 Climate Change Impact Assessment Results – Diversified Cropping Scenario

<table>
<thead>
<tr>
<th>Climate Change Projection</th>
<th>Monthly Supply Reliability (%)</th>
<th>Annual Supply Reliability (%)</th>
<th>Average Annual Irrigation Supply (GL/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medium Priority Allocations</td>
<td>Low Priority Allocations</td>
<td>Medium Priority Allocations</td>
</tr>
<tr>
<td>Base Case (no climate change)</td>
<td>94%</td>
<td>70%</td>
<td>86%</td>
</tr>
<tr>
<td>“Best” case climate projection</td>
<td>96%</td>
<td>78%</td>
<td>91%</td>
</tr>
<tr>
<td>“Worst” case climate projection</td>
<td>83%</td>
<td>47%</td>
<td>67%</td>
</tr>
<tr>
<td>“Maximum Consensus” climate projection</td>
<td>91%</td>
<td>65%</td>
<td>83%</td>
</tr>
</tbody>
</table>

The climate change impact assessment results for the grazier support scenario (target 84 GL/year of irrigation water supply) are shown in Table 7.5. The simulated monthly reliability of the scheme (80% for the base case scenario with no climate change) is predicted to vary between 61% (“worst” case climate projection) and 86% (“best” case climate projection) with a “maximum consensus” projection of 77% (i.e. 3% reduction in reliability).

The average annual irrigation supply volume for the grazier support scenario is predicted to vary from 56 GL/year (“worst” case climate projection) to 74 GL/year (“best” case climate projection) with a “maximum consensus” projection of 68 GL/year, which represents only a 3% reduction compared to the base case scenario with no climate change.
The climate change impact assessment indicates that the potential impacts to the dam yields over a project life of 50 years are likely to be relatively minor (3% reduction to the average annual yield) under a “maximum consensus” climate projection. The predicted yield reductions are approximately 20% under a “worst” case climate projection.

It is noted that the climate change impact assessment has only considered projected changes to average climate conditions. Climate change research currently provides only limited information on changes to climate variability. It is envisaged that a more detailed climate change impact assessment will be undertaken in subsequent stages of the Project.

### Table 7.5 Climate Change Impact Assessment Results – Grazier Support Scenario

<table>
<thead>
<tr>
<th>Climate Change Projection</th>
<th>Monthly Supply Reliability (%)</th>
<th>Annual Supply Reliability (%)</th>
<th>Average Annual Irrigation Supply (GL/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case (no climate change)</td>
<td>80%</td>
<td>62%</td>
<td>70</td>
</tr>
<tr>
<td>“Best” case climate projection</td>
<td>86%</td>
<td>71%</td>
<td>74</td>
</tr>
<tr>
<td>“Worst” case climate projection</td>
<td>61%</td>
<td>40%</td>
<td>56</td>
</tr>
<tr>
<td>“Maximum Consensus” climate projection</td>
<td>77%</td>
<td>57%</td>
<td>68</td>
</tr>
</tbody>
</table>
8. CONCLUSIONS

Dam yield assessments were undertaken for the following aspects of the PBC Study:

- Options assessment; and
- Reference Project (proposed Project configuration).

The dam yield assessments were performed using a catchment hydrology and dam reservoir operation simulation model developed using the GoldSim software.

The options assessment phase involved the investigation of the following two bulk water storage options:

- Alstonvale Dam site on Betts Gorge Creek supplemented by external catchment diversions from the Galah Creek and Flinders River.
- Saego Dam near the outlet of the Stewart Creek catchment supplemented by external catchment diversions from the Flinders River.

The yield assessment for the options assessment phase indicated that water supply yields (90% monthly reliability) of up to 90 GL/year are possible for the Alstonvale Dam scheme and up to 150 GL/year for the Saego Dam scheme; however, the scale and cost of the water diversion and storage infrastructure to achieve these yields is prohibitive.

The Reference Project proposed for the HIP is a smaller variation of the Stewart Creek dam options and comprises a 190 GL storage capacity dam (Saego Dam) on Stewart Creek and Back Valley Creek, with associated gravity diversion infrastructure on the Flinders River and a delivery system to irrigation areas located to the south of the Flinders River.

Two different cropping (demand) scenarios were investigated for the Reference Project:

- Diversified cropping scenario – supply of higher reliability water for horticulture crops (avocados, mangoes, lemons and mandarins) and lower reliability water for cereal grains, hay and fodder crops to support the local cattle industry.
- Grazer support scenario – supply of medium reliability water for cereal grains, hay and fodder crops to support the local cattle industry.

For the diversified cropping scenario, the proposed scheme is capable of supplying:

- 30 GL/year of higher reliability water (Medium Priority allocations) at 94% monthly reliability (86% annual reliability) and 40 GL/year of lower reliability water (Low Priority allocations) at 70% monthly reliability (48% annual reliability).
- An equivalent average annual irrigation supply of 57 GL/year.

For the grazer support scenario, the proposed scheme is capable of supplying:
- 84 GL/year water at 80% monthly reliability (61% annual reliability).
- An equivalent average annual irrigation supply of 70 GL/year.

The dam yield for the Reference Project (grazier support scenario) was independently assessed using the Flinders Source Model developed by the Queensland Government for the Gulf Water Plan. The two different yield models produce very similar yield estimates, with the Flinders Source Model producing a slightly smaller monthly supply reliability and a corresponding 2 GL/year reduction (i.e. 3% reduction) in the average annual irrigation supply volume.

An assessment of the potential impacts of future climate change on the dam yield estimates for the Reference Project was also undertaken using the methodologies outlined in “Climate Change in Australia Technical Report” (CSIRO, 2015). Projected changes to average annual rainfall and evaporation/evapotranspiration were obtained for the following climate change scenario:

- 2070 projection year – suitable for a 50-year design life of the HIP
- Representative Concentration Pathway 4.5 (RCP4.5) – represents some intervention to reducing greenhouse gas and aerosol emissions, however not the most optimistic outlook.

The climate change impact assessment indicates that the potential impacts to the dam yields over a project life of 50 years are likely to be relatively minor (3% reduction to the average annual yield) under a “maximum consensus” climate projection.

The following additional investigations were undertaken for the Reference Project and are detailed in the Reference Project section (Section 10) of the PBC Report but are not included in this report:

- Assessment of impacts to stream flow regimes downstream of the Project.
- Assessment of impacts to existing water users.
- Consideration of water licencing and allocation requirements for the Project.
9. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This report does not provide legal advice.
10. REFERENCES


