9 Dagworth and Green Hills dams and irrigated sugarcane

Authors: Perry Poulton, Graham Bonnett, Tony Webster, Geoff Podger, Cuan Petheram, Linda Holz, Shaun Kim, Daniel Aramini, Michael Kehoe, Scott Podger, Peter R Wilson, David McLennan, Justin Hughes, Arthur Read, David Rassam, Nathan Waltham, Damien Burrows, Lisa Brennan McKellar, John Hornbuckle, Seonaid Philip, Andrew Higgins, Marcus Barber, Rebecca K Schmidt and Audrey Wallbrink

In this case study, the potential of an irrigation development involving two dams on the Gilbert and Einasleigh rivers was investigated, both as a pair and singly (Figure 9.1). The development under consideration would enable sugarcane to be supplied to a newly established sugar mill in the Gilbert catchment. Irrigation water would be supplied from dams built at one or both of Green Hills and Dagworth stations.

The feasibility of this irrigation development is analysed with respect to:

- the physical capacity to create a water storage and water distribution scheme, supply water to agriculturally suitable soils and grow sugarcane
- the capacity of the scheme to generate positive net revenues, based on a consolidated developer–owner–operator model
- the capacity of the farm to generate positive net revenues, when water development and supply costs are borne by off-farm interests
- the capacity to develop and sustain a sugar mill at Georgetown.

The financial analysis for this case study investigates whether the projected revenues from the sale of sugarcane is sufficient to cover the costs of irrigation development and sugarcane production. This perspective is appropriate to adopt if the investor does not have interests in sugarcane milling, but no assumptions are made that this is a likely or appropriate investment model. Rather, the analysis, consistent with the other case studies, is seeking to provide insights into the transformation of irrigation investments into agricultural output and what costs and benefits are incurred within these bounds. The case studies are indicative rather than definitive. The strong interconnectedness of the component parts of the sugar industry supply chain is acknowledged, and this brings the likelihood of a range of investment models and financial outcomes for irrigation development, some of which could connect growing and milling interests.

The analysis of the irrigation development is presented at both the scheme scale and the farm scale, using results under scenarios A and B. Both scenarios use the same 121-year historical climate data (from 1890 to 2011). Scenario A includes historical climate and current development, while Scenario B includes historical climate and future irrigation development (i.e. such as the irrigation development specified in this case study). All results in the Assessment are reported over the ‘water year’, defined as the period 1 July to 30 June. This allows each wet season to be counted in a single 12-month period, rather than being split over two calendar years (i.e. counted as two separate seasons).

In presenting this case study, no consideration is given to legislative issues that will need to be addressed for any development of this scale to proceed. These issues include, but are not limited to, legislation relating to land tenure, planning and infrastructure, cultural heritage, native title, vegetation management, wildlife protection, water resources, fisheries, and environmental protection.

In undertaking this analysis, the case study assessment included an allowance to avoid impacts on the reliability with which existing entitlement holders could extract water. For more details see Holz et al. (2013).
9.1 Summary

The case study concludes that the physical conditions exist to enable a combined dam, irrigation and sugar mill development.

- Dams capable of storing a combined volume of 725 GL were identified near Green Hills (227 GL) and Dagworth (498 GL) properties on the Gilbert and Einasleigh rivers, respectively. The combined annual water yield of these two dams is 498 GL at the dam wall at 85% reliability. The estimated cost of these two water storages is $809 million (with a likely range of $730 million to $1050 million) which would enable the controlled release of water from the storage at a unit cost of $1625/ML.
- For the two dams approximately 40% (weighted average) of the water at the dam wall would be lost in transmission and application to the crop. Delivery to crop from the potential Green Hills dam would be considerably more efficient (68%) than from the potential Dagworth dam (48%). This is largely due to the former’s closer proximity to proposed irrigated land and the difficulty in constructing and maintaining a re-regulation structure on the wide Einasleigh River.
- More than 25,000 ha of soils moderately suited to irrigated sugarcane production were identified within 10 km of the Gilbert River between the potential Green Hills dam and where the Gulf Development Road crosses the Gilbert River. More than 50,000 ha of soils moderately suited to irrigated sugarcane production were identified within 10 km from the Einasleigh River channel downstream of the potential Dagworth dam. Given adequate irrigation, the alluvial sandy silt loam soils of the case study area could potentially support mean sugarcane yields of between 110 and 120 t/ha per year (averaged over a 5-year rotation). With appropriate fertiliser and irrigation management, yields over 130 t/ha could be attainable on the heavier textured clay soils, adjacent to some parts of the Einasleigh River.
- Secondary salinity risk is relatively low on the highly permeable soils – large rises in watertable levels are unlikely and there are low levels of accumulated salts. Before irrigation development, however,
area would require more intensive assessment of the usable soils and to assess the risk of secondary salinisation, particularly on the heavier soils associated with the Dagworth dam irrigation development.

Combined dam and irrigation developments paid for and operated by the same entity were not, under the conditions examined in this case study, able to be economically sustained for either the paired or individual dams. Examination of 92 separate 30-year investment windows occurring in each of the past 121 years was unable to identify any conditions under which a positive net present value (NPV) or internal rate of return (IRR) could be generated from investment in combined water supply and farm operations. To generate a positive NPV, at the specified discount rate of 7%, the Dagworth dam irrigation development would require the price of sugarcane to be $77/t and the Green Hills dam irrigation development would require the price of sugarcane to be $68/t. Market prices for sugarcane are highly variable but are in the vicinity of $39/t. A high price for sugarcane is $45/t.

With a sugar mill in Georgetown there was, however, a clear capacity to generate on-farm profits using water and related capital supplied by and paid for by a third party. Using default sugarcane prices ($39/t), positive farm-scale gross margins were possible in all years, and NPVs analysed for 92 thirty-year windows were all positive at the specified discount rate of 7%. At the default price for sugarcane and for the median 30-year NPV, farmers at Green Hills dam and Dagworth dam irrigation developments would have the capacity to pay a water charge of about $34/ML and $24/ML, respectively, to help offset operation and maintenance of the scheme. For both the irrigation developments and for the default price, the median 30-year NPV is only positive when a mill is located in Georgetown.

To be profitable to transport sugarcane from the Green Hills dam irrigation development to a mill in Mareeba, the price of sugarcane would need to be $69/t if the mill paid 50% of the transport costs and $103/t if the grower had to pay 100% of the transport costs. To be profitable to transport sugarcane from the Dagworth dam irrigation development to a mill in Mareeba, the price of sugarcane would need to be $77/t if the mill paid 50% of the transport costs and $118/t if the grower had to pay 100% of the transport costs. These are well in excess of current market prices.

9.2 Storyline for this case study

This case study assesses the viability of a sugarcane growing district located along the Einusleigh and Gilbert rivers. Water for the sugarcane district would be supplied from dams on either the Einusleigh River at the Dagworth station or a dam on the Gilbert River on the Green Hills station, or both (Figure 9.2). Sugarcane would be transported to a factory near Georgetown or Mareeba for processing to raw sugar, which would then be transported by road to the Port of Townsville for export. Sugarcane was selected because sugar is a well-established industry in north Queensland, with considerable existing infrastructure and bulk-handling facilities at the Port of Townsville. Sugar is also a high-value export commodity, with well-established export markets and marketing infrastructure.

In the Georgetown area, sugarcane would be planted after the wet-season rains have ceased, generally from about April, and the planting season would continue until June. Sugarcane is a perennial crop, harvested the year after it is planted. The harvesting season would extend from June to about November, although there may be benefits in starting the harvest in May. After harvesting the plant crop, the crop regrows (called ratooning) and the first ratoon crop grows for a further year before being harvested. The crop will continue to ratoon after each harvest, but yields tend to decline with subsequent ratoons. Most farmers only harvest three or four ratooned crops before ploughing in the crop and replanting. Between ploughing in the final ratooned crop and planting the next crop, a fallow period of approximately six months is done, during which a legume break crop such as cowpea or soybean is often grown. The consequence of this fallow is that there is a year in the sugarcane growing cycle when there is no sugarcane harvest. However, the plant crop tends to be higher yielding, in part because it has a longer growing season. In reality, all sugarcane farms have a mix of different-aged crops, so farmers that routinely practise cropping with three ratoons have 20% of their farms assigned to each crop age (including the fallow), and only harvest 80% of their area in any single year.
Sugarcane requires crushing at a mill before export and needs to be crushed within 24 hours of harvest to prevent quality deterioration, which can result in loss of raw sugar in the final product. The majority of sugar mills in Australia are located on the north-east Queensland coast. Because cane transport is a significant cost in the supply chain, and raw sugar comprises only about 15% of the mass of a sugarcane crop, sugar mills are typically located within about 50 km of sugar-growing farms.

The nearest sugar mill to the Georgetown area is at Mareeba, 346 km from Georgetown. Transporting sugarcane using B-double trucks from the Dagworth dam and Green Hills dam irrigation developments to Mareeba has a cost of about $81/t (406 km) and $67/t (~500 km), respectively (Brennan McKellar et al., 2013). Comparably, it only costs $8.3/t to transport cane to the mill from the farms supplying the Maryborough sugar mill, a typical sugar mill on the east Queensland coast. For this reason, this case study investigates the viability of sugarcane irrigation developments in the Gilbert catchment when sugar is transported (i) to the existing mill in Mareeba and (ii) to a newly constructed mill located in Georgetown.

The outline of this case study is as follows.

- Section 9.3 describes the soils of the case study area.
- Section 9.4 describes the suitability of the climate for growing sugarcane near Georgetown.
- Section 9.5 describes the configuration of the irrigation developments and cropping systems.
- Section 9.6 describes two financial analyses.
  - The first (in Section 9.6.1) surveys different ‘scheme areas’.
  - The second (in Section 9.6.2) undertakes a more detailed assessment of the profitability at the scheme and farm scale for a single scheme area. The profitability of alternative locations of a sugar mill are considered.
- Section 9.7 describes some potential on-site and off-site impacts associated with the scheme area selected in Section 9.6.2.

The case study area is shown in Figure 9.2. To provide a sense of scale and an indicative sense of place, a potential irrigation development of 19,200 ha is delineated for each dam. Before irrigation development, the area would require a more intensive assessment of usable areas.
Figure 9.2 (a) Satellite image and (b) relief map area surrounding Green Hills and Dagworth dams

Data used to develop flood map was captured using MODIS satellite imagery. This figure illustrates the maximum percentage of MODIS pixels inundated between 2000 and 2010.
9.3 Soils along the Gilbert and Einasleigh rivers

This section describes the soils of the Green Hills dam and Dagworth dam irrigation developments.

The Green Hills dam irrigation development is confined to the dominant alluvial plain along the Gilbert River upstream of the Georgetown to Croydon Road crossing (Figure 9.4). These alluvial plains are largely influenced by the diverse range of rock types in the Gilbert catchment, such as strongly altered metamorphic rocks as well as granites and sedimentary rocks. There are also shallow rocky soils on undulating to steep low hills and rises adjacent to the alluvial plains, which have limited development potential. The landscape of the Gilbert River case study area is shown in Figure 9.3.

The Dagworth dam irrigation development is located above the confluence of the Einasleigh and Gilbert rivers at Strathmore station (Figure 9.4), and contains several landscapes. The area is dominated by alluvial plains that are largely influenced by the diverse range of geologies in the Einasleigh catchment, including metamorphic rocks, granites, sedimentary rocks and basalt. The other prominent landscapes adjacent to the irrigation development are the ‘downs’ on the Great Artesian Basin in the vicinity of Abingdon station, and the old highly weathered sedimentary rock that forms plateaus, plains and dissected hills from Abington station to Strathmore station.

Alluvial plains along the Gilbert River downstream of Green Hills dam

Adjacent to the Gilbert River and upstream of where the Georgetown to Croydon Road crosses the Gilbert River, there are 4150 ha of very deep, well-drained, loamy-textured, brown massive and structured soils (corresponding to friable non-cracking clay or clay loam soils, and sand or loam over friable earthy clay). Subsoils may have clay textures. These moderately permeable soils are very deep with a moderate to moderately high water-holding capacity and are well suited to a wide variety of irrigated crops, particularly using spray- and micro-irrigation methods. Soils may be inundated by occasional floods. The main restriction in this area is the narrow width of the alluvial soil plains, restricting the area most suited for cropping.

The plains further from the river are dominated by very deep, texture contrast and gradational soils (corresponding to loam over sodic/intractable clay soils) with a loamy to silty surface over imperfectly to moderately well-drained, slowly permeable, dispersible clay subsoils (4050 ha). Soils have moderate water-holding capacity and development potential for furrow-irrigated crops; the main restrictions being surface sealing and difficulty with plant establishment and water infiltration. The relatively narrow areas make cropping of large areas difficult. Areas may be subject to occasional flooding and seasonal waterlogging.

In the low-lying areas, generally occurring as depressions on the alluvial plains, there are 5400 ha of imperfectly to poorly drained, slowly permeable, mottled hard-setting, mottled grey gradational soils (corresponding to friable non-cracking clay or clay loam soils, and sand or loam over friable or earthy clay) and minor grey cracking clays. These soils have some limited potential for spray- or furrow-irrigated crops that can withstand regular flooding and seasonal waterlogging. The other restriction is the relatively small size of uniform areas.

Either side of the Gilbert River (but mainly on the eastern side), there are over 15,000 ha of high-level, flood-free, very deep, well-drained to imperfectly drained, moderately permeable, sandy- to loamy-surfaced soils (corresponding to sand or loam over friable or earthy clay soils) on elevated, gently undulating, alluvial plains. Subsoils are massive to structured red and brown clays. Low-lying areas correspond to imperfectly drained, mottled brown subsoils. These soils have a moderate water-holding capacity. Moderately large areas are moderately suitable to spray-irrigated field crops and micro-irrigated horticulture. Seasonal waterlogging may be a restriction on lower slopes.

From the soils available, a potential area of about 19,400 ha has been delineated in Figure 9.2. This area predominately contains sand or loam over friable or earthy clay soils (high-level, flood-free alluvium). These soils are relatively close to the river, the proposed dam site and a potential mill at Georgetown. According to the regional land suitability assessment, these soils are potentially the best available (Figure 9.4). Their actual distance from the river will incur relatively high pumping costs and soils are only marginally suitable.
for construction of on-farm storages due to the moderate to high subsoil permeability. Before irrigation
development, the area would require a more intensive assessment of usable areas.

There are more than 25,000 ha of soil moderately suitable for irrigation between the Green Hills dam and
where the Gulf Development Road crosses the Gilbert River.

**Alluvial plains along the Einasleigh River downstream of Dagworth dam**

The soils adjacent to the river channel in the Einasleigh River case study area comprise 5700 ha of very
deep, well-drained, loamy textured, brown massive or structured soils (corresponding to friable non-
clay cracking or clay loam soils, and sand or loam over friable or earthy clay). Subsoils may have clay
textures. These moderately permeable soils are very deep with a moderate to moderately high water-
holding capacity and are moderately suitable to a wide variety of irrigated crops, particularly using spray-
and micro-irrigation methods. Soils may be inundated by occasional floods. Downstream of Abingdon, the
alluvial plain widens with a complex distribution of soils due to the migration of the Einasleigh River over
the alluvial plains. The main restriction in this area is the narrow width of the soil most suited for cropping.

The alluvial plains further from the river (15,250 ha) are dominated by texture contrast (duplex) and
gradational soils with a loamy to silty surface over imperfectly to moderately well-drained, slowly
permeable, dispersible clay subsoils. Soils have moderate water-holding capacity with development
potential for furrow-irrigated crops. The main restrictions are surface sealing, and difficulties with plant
establishment and water infiltration. The relatively narrow width of this soil makes cropping of large areas
difficult. Areas may be subject to occasional flooding and seasonal waterlogging.

The low-lying areas, generally occurring as depressions on the plains, cover 17,100 ha and have imperfectly
to poorly drained, slowly permeable, mottled grey cracking clays and hard-setting, mottled grey gradational
soils. The clay soils are a reflection of the large areas of basalt in the upper catchment. The broader alluvial
plains downstream of Abingdon station have a complex distribution of soils due to previous migration of
the river over the broad plains. These soils have limited potential for spray- or furrow-irrigated crops that
can withstand regular flooding and seasonal waterlogging. The other restriction is the complex distribution
of soils, resulting in relatively small uniform areas.

Either side of the Einasleigh River, high-level flood-free, very deep, moderately well-drained, moderately
permeable, sandy-surfaced soils occur on elevated gently undulating alluvial plains. Subsoils are massive to
structured clays. Dense gravel is common on lower slopes, usually corresponding to imperfectly drained
mottled yellow and brown subsoils. These soils cover 19,800 ha and have a moderate water-holding
capacity, limited by the sandy topsoil. Moderately large areas are suited to spray-irrigated crops and micro-
irrigated horticultural crops. Seasonal waterlogging and gravel patches may be a restriction on lower
slopes.

Adjacent to the case study area, red, yellow and grey loamy and earthy soils are mainly associated with
plains and dissected tablelands on the deeply weathered sedimentary rocks between the confluence of the
Gilbert and Einasleigh rivers. These moderately permeable soils have variable soil depth over short
distances, but are predominantly moderately deep (0.5–1.0 m) and occasionally deep (1.0–1.5 m). Soil
water storage is low to moderate (50–100 mm) with higher water storage on the deeper soils (75–
100 mm). Well-drained red earthy soils occur on the rises and edges of the plateaus, while imperfectly
drained yellow and grey earthy soils occur on the plains and lower landscape positions. An attribute of all of
these soils is that they are nutrient deficient; hence, irrigated cropping would require very high fertiliser
inputs. On the deeper of these soils, irrigation potential is limited to spray- and drip-irrigated crops.
Seepage from irrigation development above scarps may contribute to rising watertable levels and salinity
issues below the scarps, particularly at the break of slope. Due to localised variability, this area requires
further investigation before development.

A potential area of 19,200 ha is delineated with two polygons shown in Figure 9.4. It has a complex
distribution of friable clays, sand or loam over friable or earthy clay soils (high-level flooded and flood-free
alluvium), regular and grey loam earthy soils and relatively minor grey cracking clays, and sand or loam over
sodic or intractable clays. Seasonal wetness will restrict farming operations and access during the wet
season. These soils are a considerable distance from the river. Soils are suitable for construction of on-farm
storages on the heavy textured impermeable clay soils. Before irrigation development, the area would require more intensive assessment of usable areas due to the complex distribution of sand, loamy and clay soils.

There are more than 50,000 ha of soil moderately suitable for irrigation within 10 km of the Einasleigh River downstream of Dagworth dam.

Figure 9.3 Photo of the landscape near the potential Green Hills dam irrigation development
Site where the photograph was taken is shown in Figure 9.2.
Figure 9.4 (a) Soil generic group map and (b) land suitability map for the middle reaches of the Gilbert and Einasleigh rivers for spray-irrigated sugarcane

The land suitability map does not take into consideration flood risk.
9.4 Climate suitability of sugarcane in the Georgetown area

Rainfall in the Gilbert catchment is highly variable among years and highly seasonal – 90% of rain falls between December and March (Figure 9.5). Although potential evaporation is also seasonal (Figure 9.5), driven largely by temperature (Figure 9.6), there is very little year-to-year variation in evaporative demand (Figure 9.5b). The daily average maximum temperature remains above 30°C year round, with greater seasonal variation in the average minimum temperature (Figure 9.6). Consequently, with sufficient water, a tropical perennial grass crop such as sugarcane could produce high biomass yields. Like the Burdekin region, the dry winter months would allow withholding of irrigation to allow the soil to dry down, reduce growth and potentially increase sucrose content before harvest. However, there is some evidence from the Ord district that in that environment, the sugarcane crop does not respond in a similar way to the established regions in Queensland (Leslie and Byth, 2000; Bonnett et al., 2006). Therefore, caution is needed in translating results based on these other regions to new regions. The lack of rain during May to October also provides an ideal break for harvesting sugarcane.

Figure 9.5 (a) Monthly rainfall and (b) monthly potential evaporation, under Scenario A at Dagworth
Scenario A is the historical climate (1890 to 2011). The A range is the 20th to 80th percentile exceedance.

Figure 9.6 (a) Maximum monthly temperature and (b) minimum monthly temperature, under Scenario A at Dagworth
Scenario A is the historical climate (1890 to 2011). The A range is the 20th to 80th percentile exceedance.
9.5 Scheme configuration and cropping systems

This section provides a description of the configuration of the irrigation developments and cropping systems associated with the Green Hills and Dagworth dams. It provides information on the dams, outlines the configuration and costs for water supply and irrigation development, examines the relationship between applied irrigation water and crop yield at production potential and discusses production risks.

9.5.1 GREEN HILLS AND DAGWORTH DAMS

The potential Green Hills and Dagworth dams are 20 m and 30 m high roller compacted concrete dams, respectively. The Green Hills dam is located on the Gilbert River and the Dagworth dam is located on the Einasleigh River (Figure 9.4). Streamflow characteristics at the location of the dams on the Gilbert and Einasleigh rivers are given in Table 9.1. For a given mean annual streamflow, the larger the variability in streamflow, the smaller the water yield from the dam. The streamflow in the Gilbert and Einasleigh rivers is about two to three times more variable than rivers of the rest of the world of the same climate type (Petheram et al., 2008). This variation is highlighted in Figure 9.7 and Figure 9.8 where even when smoothed by presenting a 10-year moving average (calculated from a moving window centred on the year in question), large variation remains.

Table 9.1 Streamflow on the Gilbert and Einasleigh rivers at the potential Green Hills and Dagworth dam sites under Scenario A

<table>
<thead>
<tr>
<th>RIVER NAME</th>
<th>MAXIMUM FLOW (GL/y)</th>
<th>20% EXCEEDANCE FLOW (GL/y)</th>
<th>50% EXCEEDANCE FLOW (GL/y)</th>
<th>80% EXCEEDANCE FLOW (GL/y)</th>
<th>MINIMUM FLOW (GL/y)</th>
<th>MEAN FLOW (GL/y)</th>
<th>COEFFICIENT OF VARIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilbert River</td>
<td>8,653</td>
<td>1096</td>
<td>503</td>
<td>201</td>
<td>17</td>
<td>802</td>
<td>1.29</td>
</tr>
<tr>
<td>Einasleigh River</td>
<td>11,578</td>
<td>1521</td>
<td>777</td>
<td>245</td>
<td>12</td>
<td>1186</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Figure 9.7 Annual streamflow on the Gilbert River at the Green Hills dam site under Scenario A

Blue line indicates the 10-year moving average.
Figure 9.8 Annual streamflow on the Einasleigh River at the Dagworth dam site under Scenario A. Blue line indicates the 10-year moving average.

Green Hills and Dagworth are two of the most promising dam sites in the Gilbert catchment. The spillway height of the dam at the Green Hills site and Dagworth site is 20 m and 30 m respectively. This was deemed to be the optimal height without excessively large saddle dam requirements. The Green Hills roller compacted concrete dam and Dagworth roller compacted concrete dam are likely to cost between $300 million and $435 million and $425 million and $615 million, respectively. Their key parameters are summarised in Table 9.2. For more detail, see Petheram et al. (2013).

Table 9.2 Green Hills and Dagworth dam parameters

<table>
<thead>
<tr>
<th>DAM NAME</th>
<th>DAM TYPE</th>
<th>CATCHMENT AREA (km²)</th>
<th>SPILLWAY HEIGHT (m)</th>
<th>CAPACITY (GL)</th>
<th>FULL SUPPLY LEVEL (m)</th>
<th>ANNUAL WATER YIELD * (GL)</th>
<th>COST** ($ million)</th>
<th>UNIT COST*** ($/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Hills</td>
<td>Roller compacted concrete</td>
<td>8,310</td>
<td>20</td>
<td>227</td>
<td>254</td>
<td>172</td>
<td>$335</td>
<td>$1950</td>
</tr>
<tr>
<td>Dagworth</td>
<td>Roller compacted concrete</td>
<td>15,351</td>
<td>30</td>
<td>498</td>
<td>227</td>
<td>326</td>
<td>$474</td>
<td>$1450</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>725</td>
<td>498</td>
<td>$809</td>
<td>$1625 (average)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 85% annual time-based reliability using a perennial demand pattern for the baseline model under Scenario A. This is yield at the dam wall (i.e. does not take into account distribution losses or downstream transmission losses). These yield values do not take into account downstream existing entitlement holders or environmental considerations.

** Likely cost range is –10 to +30%. Price includes saddle dams. Should site geotechnical investigations reveal unknown unfavourable geological conditions, costs could be substantially higher.

*** This is the unit cost of annual water yield and is calculated as the capital cost divided by the water yield at 85% annual time reliability.

9.5.2 CONFIGURATION AND COSTS FOR WATER SUPPLY AND IRRIGATION DEVELOPMENT

Due to the geographic separation of the Green Hills dam and Dagworth dam irrigation developments, they are examined separately in this analysis.
Configuration for water supply for Green Hills dam irrigation development

Under this nominal configuration, water would be released from the Green Hills dam to a re-regulating structure (sheet-piling weir) at Prestwood, approximately 20 km downstream of the dam. The re-regulating structure allows for more efficient releases of water from the dam at key times required by irrigators, thereby reducing the transmission losses normally involved in supplemented river systems. As it is unlikely that rock foundations would be present, it is assumed that a 325-m wide, 3-m high sheet-piling weir would need to be constructed. This would be an unusually wide weir.

Water would be pumped from behind the weir in the river (assuming a 10-m head requirement) into a main distribution channel on the right bank. This channel would need to be lined due to the sandy nature of the soils. The potential irrigation development is situated 2 km from the river due to the presence of marginally suitable land in the vicinity of the river (Figure 9.4b). This enables a 2-km wide riparian zone to be maintained between the irrigation development and the river.

It is assumed that irrigation water is distributed within farm (i.e. from the farm gate to the field) using open, lined channels. On-farm storages are sometimes used to improve the efficiency with which water can be supplied from the farm gate to the field. It is assumed that, for this development, there is minimal need for on-farm storage due to the relatively close proximity of the Green Hills dam and the proposed irrigation area. Once at the field, water is applied using modern spray irrigation systems capable of delivering peak water requirements to the cane crop at periods of high evaporative demand. Overhead sprinklers are used to optimise irrigation productivity and minimise accessions to groundwater, which have the potential to cause watertable levels to rise and increase salinity risk. Well-managed spray irrigation generates very little tailwater runoff (i.e. water leaving the field following an irrigation event), except during large rainfall events that may occur immediately after irrigation on full soil profiles.

Table 9.3 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 68%. These values are likely to be representative of best practice.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>EFFICIENCY (%)</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>River conveyance efficiency</td>
<td>85%</td>
<td>Distance between dam and sheet-piling re-regulating structure is about 20 km. This is likely to be a generous assumption.</td>
</tr>
<tr>
<td>Channel distribution efficiency</td>
<td>95%</td>
<td>Representative of evaporation loss from re-regulation structure and channel loss between river and farm gate. Channel is lined due to sandy soils.*</td>
</tr>
<tr>
<td>On-farm distribution efficiency</td>
<td>99%</td>
<td>Representative of on-farm evaporation and seepage loss from farm gate to edge of field. Assumed lined channel.¹</td>
</tr>
<tr>
<td>Field application efficiency (spray)</td>
<td>85%</td>
<td>Assumed majority of loss goes to deep drainage.</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>68%</td>
<td></td>
</tr>
</tbody>
</table>

* Poorly constructed channels will have lower conveyance efficiency than those values listed in this table.

Configuration for water supply for Dagworth dam irrigation development

The width of the Einasleigh River downstream of Dagworth dam varies between 500 m to more than 1 km. The width of the river is such that the construction of a weir adjacent to the irrigation development would be very challenging. Under this nominal configuration, water would be released from the potential Dagworth dam to a series of sand dams approximately 70 km away. These sand dams are low embankments comprising river bedsands that partially span the lower Einasleigh River. They are constructed downstream of a natural waterhole to form a pool sufficiently deep from which to pump water. Although sand dams are cheap to construct, compared with a concrete or sheet-piling weir, they have much larger seepage losses beneath and through the dam wall, and need to be rebuilt every year.
Water is pumped from behind the sand dams (assuming a 15-m head requirement) into one of two 4000-ML ring tanks. These ring tanks act as balancing storages and serve to improve the efficiency with which water can be supplied from the Dagworth dam to the irrigation development. The potential irrigation development is situated 2 km from the river, enabling a riparian zone to be maintained between the irrigation development and the river. Water is supplied from the ring tanks to the irrigation farms by an open channel. Once at the field, water is applied using spray irrigation.

Making this water supply scheme configuration operational is likely to be challenging and losses are likely to be high (Table 9.4). Overall, the efficiency is estimated to be 48%.

Table 9.4 Assumed conveyance efficiency assumptions for the irrigation development associated with the Dagworth dam

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>EFFICIENCY (%)</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>River conveyance efficiency</td>
<td>70%</td>
<td>Distance between dam and sand dam re-regulating structure is about 70 km. Supplemented by flows from Etheridge River (tributary of Einasleigh River). When Etheridge River is flowing, it would in effect reduce transmission losses of water released from dam. Nevertheless a conveyance efficiency is likely to be generous.</td>
</tr>
<tr>
<td>Sand dam – re-regulation infrastructure</td>
<td>80%</td>
<td>Loss from sand dams (seepage) and balancing storages (seepage and evaporation).</td>
</tr>
<tr>
<td>Channel distribution efficiency</td>
<td>90%</td>
<td>Loss from balancing storage to farm gate* channel not lined.</td>
</tr>
<tr>
<td>On-farm distribution efficiency</td>
<td>95%</td>
<td>Loss from farm gate to field due to on-farm evaporation and seepage loss¹ channels on-farm not lined.</td>
</tr>
<tr>
<td>Field application efficiency (spray)</td>
<td>85%</td>
<td></td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>48%</td>
<td></td>
</tr>
</tbody>
</table>

* Poorly constructed channels will have lower conveyance efficiency than those values listed in this table.

Costs for water supply for Green Hills dam irrigation development

Irrigation development involves a wide range of capital, operation and maintenance costs. These are incurred at both the scheme and farm scale. Scheme-scale costs are those associated with major infrastructure (e.g. dams, channels, roads, earthworks), approvals (e.g. environmental impact statements) and delivery of water to the irrigation development (e.g. pumps). Farm-scale capital, operation and maintenance costs are those associated with irrigation systems and farm equipment.

The Gulf Development Road passes through the potential Green Hills dam irrigation development and, consequently, additional access road requirements are minimal.

Indicative capital, operation and maintenance costs associated with the irrigation development are provided in Table 9.5. Costs of infrastructure that are independent of the size of the irrigation development (e.g. dam, weirs, main access roads) are listed as a fixed price. Costs directly linked to the size of the irrigation development are expressed as a cost per ha and per ML. This enables irrigation developments of different sizes to be quickly evaluated (see Section 2.2). These costs were obtained from information presented in Chapter 4 and 5.
### Table 9.5 Scheme- and farm-scale costs for the irrigation development associated with Green Hills dam

<table>
<thead>
<tr>
<th>ITEM</th>
<th>LIFESPAN</th>
<th>UNIT COST</th>
<th>UNIT</th>
<th>OPERATION AND MAINTENANCE COST</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scheme-scale costs: capital, operational and maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large dam</td>
<td>100</td>
<td>$335,000,000</td>
<td>*</td>
<td>0.4%</td>
<td>All costs associated with dam, including access roads, environmental impact statements, legal, contingency</td>
</tr>
<tr>
<td>Weir</td>
<td>40</td>
<td>$55,000,000</td>
<td>*</td>
<td>2%</td>
<td>325-m wide × 3-m high sheet-piling weir</td>
</tr>
<tr>
<td>Access roads</td>
<td>100</td>
<td>$1,580,000</td>
<td>*</td>
<td>1%</td>
<td>5 km of additional all-weather access road</td>
</tr>
<tr>
<td>Main supply channel</td>
<td>40</td>
<td>$9,420,000</td>
<td>*</td>
<td>1%</td>
<td>Includes structures and overheads</td>
</tr>
<tr>
<td>Area works</td>
<td>40</td>
<td>$7,740</td>
<td>ha</td>
<td>1%</td>
<td>Includes roads (life span 100 y) earthworks, structures, overheads, contingency and corporate profit</td>
</tr>
<tr>
<td>Pump capital cost (weir to channel)</td>
<td>15</td>
<td>$250</td>
<td>ha</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Pump energy cost (weir to channel)</td>
<td>na</td>
<td>$24</td>
<td>ML</td>
<td>na</td>
<td>Assuming 15-m head requirement and pump operated on diesel</td>
</tr>
<tr>
<td><strong>Scheme-scale costs: approvals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area works approvals</td>
<td>na</td>
<td>$6,000,000</td>
<td></td>
<td></td>
<td>Includes environmental impact statements, Native Title Claims and cultural heritage</td>
</tr>
<tr>
<td>Legal</td>
<td>na</td>
<td>$1,000,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Farm-scale costs: capital</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation system (spray)</td>
<td>15</td>
<td>$4,000</td>
<td>ha</td>
<td>**</td>
<td>Includes land development costs, equipment, pumps</td>
</tr>
<tr>
<td>Farm equipment</td>
<td>15</td>
<td>$1,160</td>
<td>ha</td>
<td>**</td>
<td>This refers to equipment not included in the irrigation system (e.g. vehicles, cultivation equipment)</td>
</tr>
<tr>
<td><strong>Farm-scale costs: operational</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overheads</td>
<td>1</td>
<td>$660</td>
<td>ha</td>
<td></td>
<td>Includes maintenance costs, employee costs, land lease and other business overheads</td>
</tr>
</tbody>
</table>

* na = not applicable

* Indicates fixed cost independent of the size of the irrigation development.

** Operation and maintenance costs are captured in farm-scale cost overheads.

### Costs for water supply for Dagworth dam irrigation development

Currently, an unsealed road links the sealed Gulf Development Road to the potential irrigation development. The unsealed road would need to be upgraded to a sealed road to ensure year-round access for vehicles and heavy machinery to the irrigation development, sand dams and pumping infrastructure. Inspection of digital elevation data and satellite imagery indicates the topography between the Gulf Development Road and potential irrigation development is gently undulating and there are several creek crossings. This road would be moderately expensive to construct.

Indicative capital, operation and maintenance costs associated with the irrigation development are provided in Table 9.6. Costs of infrastructure that are independent of the size of the irrigation development (e.g. dam, sand dams, main access roads) are listed as a fixed price. Those costs directly linked to the size of the irrigation development are expressed as a cost per hectare and per megalitre. This enables irrigation developments of different sizes to be quickly evaluated. These costs were obtained from information presented in Chapter 5.
### Table 9.6 Indicative irrigation development, scheme-scale and farm-scale costs associated with the Dagworth dam irrigation development

<table>
<thead>
<tr>
<th>ITEM</th>
<th>LIFE SPAN (y)</th>
<th>UNIT COST ($)</th>
<th>UNIT</th>
<th>OPERATIONAL AND MAINTENANCE COST (% capital costs)</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scheme-scale costs: capital, operational and maintenance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large dam</td>
<td>100</td>
<td>$474,000,000</td>
<td>*</td>
<td>0.4%</td>
<td>All costs associated with dam, including access roads, environmental impact statements, legal, contingency</td>
</tr>
<tr>
<td>Sand dams</td>
<td>1</td>
<td>$150,000</td>
<td>*</td>
<td>NA</td>
<td>Two sand dams</td>
</tr>
<tr>
<td>Balancing storages</td>
<td>40</td>
<td>$10,000,000</td>
<td>*</td>
<td>1%</td>
<td>Two 4000-ML ring tanks</td>
</tr>
<tr>
<td>Main access road</td>
<td>100</td>
<td>$33,250,000</td>
<td>*</td>
<td>1%</td>
<td>Approximately 70 km of road requiring upgrading</td>
</tr>
<tr>
<td>Main supply channels</td>
<td>40</td>
<td>$21,230,000</td>
<td>*</td>
<td>1%</td>
<td>Includes structures and overheads</td>
</tr>
<tr>
<td>Area works</td>
<td>40</td>
<td>$7,740</td>
<td>ha</td>
<td>1%</td>
<td>Includes roads (life span 100 y) earthworks, structures, overheads, contingency and corporate profit</td>
</tr>
<tr>
<td>Pump capital cost (sand dam to on-farm channel)</td>
<td>15</td>
<td>$250</td>
<td>ha</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Pump energy cost (river to channel)</td>
<td>na</td>
<td>$24</td>
<td>ML</td>
<td>na</td>
<td>Assuming 15-m head requirement and pump operated on diesel</td>
</tr>
<tr>
<td><strong>Scheme-scale costs: approvals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area works approvals</td>
<td>na</td>
<td>$6,000,000</td>
<td>na</td>
<td></td>
<td>Includes environmental impact statements, Native Title Claims and cultural heritage</td>
</tr>
<tr>
<td>Legal</td>
<td>na</td>
<td>$1,000,000</td>
<td>na</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Farm-scale costs: capital</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation system (spray)</td>
<td>15</td>
<td>$4,000</td>
<td>ha</td>
<td>**</td>
<td>Includes land development costs, equipment, pumps</td>
</tr>
<tr>
<td>Farm equipment</td>
<td>15</td>
<td>$1,160</td>
<td>ha</td>
<td>**</td>
<td>This refers to equipment not included in the irrigation system (e.g. vehicles, cultivation equipment)</td>
</tr>
<tr>
<td><strong>Farm-scale costs: operational</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overheads</td>
<td></td>
<td>$660</td>
<td>ha</td>
<td>na</td>
<td>Includes maintenance costs, employee costs, land lease and other business overheads</td>
</tr>
</tbody>
</table>

na = not applicable

* Indicates fixed cost independent of the size of the irrigation development.

** Operation and maintenance costs are captured in farm-scale cost overheads.

### Critical infrastructure

In the absence of hard infrastructure (such as roads and energy supplies) and community infrastructure (such as schools and housing), required to support large irrigation developments and the people who work there, investment in infrastructure will need to be made. Table 9.7 summarises critical infrastructure in the Georgetown area. With the exception of processing infrastructure, hard and community infrastructure is unlikely to be a barrier to small- to medium-sized irrigation developments.
Table 9.7 Critical infrastructure requirements in the Georgetown area

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Community infrastructure</strong></td>
<td>General</td>
</tr>
<tr>
<td>Schools</td>
<td>A primary school in Georgetown currently has 47 enrolments and hard infrastructure (classrooms) can be added if needed.* Additional staffing needs, if any, would be expected to depend on the number and composition of new enrolments.</td>
</tr>
<tr>
<td>Hospital</td>
<td>Georgetown does not have a hospital. It has a clinic, and the area is serviced by a flying doctor and nurse. Facilities could require expansion under population growth.*</td>
</tr>
<tr>
<td>Housing</td>
<td>Georgetown currently has a supply of unoccupied dwellings; however, the quality of available housing, and whether new construction is required, would require further assessment.</td>
</tr>
<tr>
<td>Water</td>
<td>Water for the town is sourced from bedsands of the Etheridge River. It is treated and then gravity fed to the town. There are concerns about whether the bedsand aquifers could support a larger population. The Etheridge Shire Council has commissioned the construction of an 8-ML dam at Forsyth to secure town water supplies. However, the dam can only service small increases in demand and would be unlikely to be sufficient if the population reached 2500 residents. There is no sewerage treatment plant in Georgetown – a septic system is used. If there was a large increase in population, a sewerage treatment plant would be needed. *</td>
</tr>
<tr>
<td><strong>Hard infrastructure</strong></td>
<td>Roads</td>
</tr>
<tr>
<td>Rail</td>
<td>There is a tourist train to Einasleigh.</td>
</tr>
<tr>
<td>Energy</td>
<td>The electricity network is maintained by Ergon Energy. This area is serviced by feeders from the Georgetown 66 kV zone substation. The projected maximum demand growth (9.4 MVA in 2020) is significantly less than the rated capacity (44 MVA). However, dependent on location of the facilities some infrastructure upgrade to single-wire earth return may be required. Irrigators will need to use diesel for pumping, which is more expensive than electricity.* Irrigators will need to use diesel for pumping, which is more expensive than electricity.*</td>
</tr>
<tr>
<td>Ports</td>
<td>Existing sugar bulk-handling facilities at Townsville would be used (this will require an analysis of current capacity and how additional deliveries could be managed).</td>
</tr>
<tr>
<td><strong>Processing infrastructure</strong></td>
<td>Mill</td>
</tr>
</tbody>
</table>

* Sourced from discussions with elected members and staff of Etheridge Shire Council.

9.5.3 APPLIED IRRIGATION WATER, CROP YIELD AND PRODUCTION RISK

Applied irrigation water and crop yield data for sugarcane were simulated using the sugarcane module of the Agricultural Production Systems Simulator (APSIM) crop model, and soils representative of the Green Hills dam and Dagworth dam irrigation developments. Figure 9.9 illustrates the relationship between applied irrigation water and crop yield assuming perfect irrigation timing (i.e. no losses). Mean sugarcane
yields of about 110 to 120 (t/ha) occur at the mean water application rate of 12.5 ML/ha. At applications of less than 12.5 ML/ha, the crop becomes increasingly water stressed and reductions in yield occur as the allocation has insufficient water to meet the crop demand. Reducing water application by 50% from fully irrigated reduces crop yield by about 40%.

The APSIM results presented in Figure 9.9 are modelled production potential under optimum management (i.e. nutrients are not limiting; there is no damage to the crop due to disease, pests, flood, cyclone or poor management practice), for a soil that is representative of a ‘sand or loam over relatively friable clay subsoils’ (Bartley et al., 2013). This soil type is found in many parts of the case study area (Figure 9.4). The companion technical report about agricultural productivity (Webster et al., 2013) presents sugarcane yield potential for this soil, plus three other generic soil groups identified in the Gilbert catchment from the companion technical report about land suitability (Bartley et al., 2013). The other three soils had higher modelled yield potentials than the ‘sand or loam over relatively friable clay subsoils’ used in this case study. The median sugarcane yield value of 128 t/ha reported in Section 5.5, is an average of all modelled soils in the Gilbert catchment, and hence is higher than the values reported in this case study.

![Figure 9.9 Crop yield versus applied irrigation water under Scenario A for sugarcane for a sand or loam over relatively friable clay subsoil](image)

**Figure 9.9** Crop yield versus applied irrigation water under Scenario A for sugarcane for a sand or loam over relatively friable clay subsoil. Green Hills Assumes perfect timing of irrigation. Results are an average of the plant crop and four ratoons. Representative of the production potential (i.e. assumes no nutrient limitations or pest damage). Scenario A is the historical climate (1890 to 2011). The range is the 20th to 80th percentile exceedance.

**Production risks**

Although sugarcane is a generally resilient crop, it will require irrigation through the dry-season climate experienced in the Gilbert catchment. With full irrigation, mean potential crop yields of 110 to 120 t/ha are possible on the ‘sand or loam over relatively friable clay subsoils’ Gilbert catchment, which are considered good by industry standards. In years when insufficient irrigation water is available through the dry season, there is a risk the crop could be killed. If sugarcane crops are killed, they need to be replanted; if large areas of crop are killed, there can be a whole season of very little sugarcane harvested. Planting is an expensive exercise and, usually, only 20% of a farm would need to be planted each year. Under extreme scenarios where all of the sugarcane is killed, there would be nothing available on-farm to plant (sugarcane is planted vegetatively from existing sugarcane plants). This could be mitigated in part by concentrating the application of any water available to those crops that could supply the material to replant. Analyses later in the chapter, however, show that this would be a rare occurrence under a historical climate scenario and a 16,000 ha planting. The financial consequences of a killed crop are severe.

Sugarcane mills require a critical area of sugarcane to be grown and delivered to remain financially viable. For the operation of a sugarcane mill to be established in the Gilbert catchment, it is crucial that there be enough land, farmers and infrastructure to supply sugarcane sufficient to support the mill. There would be considerable ‘ramp up’ required in producing enough sugarcane in a district to support a mill, and these costs would need to be factored into establishing a milling enterprise. As with any agricultural industry in the Gilbert catchment, there is very little local expertise or labour force currently in residence. Fortunately, sugarcane growing districts are relatively close and expertise is accessible. In districts with established
sugarcane industries, there are fertiliser- and agri-input supply facilities, agronomic advisors, mill staff and a casual labour force (at least ten harvesting contractors would be needed to harvest 1 million t of sugarcane).

Cyclones and flooding would not pose a serious risk to sugarcane production, so long as vulnerable flood areas are avoided. Sugarcane can survive damaging cyclonic winds on the coast (with reduced crop yield and quality from lodging), and strong winds are likely to be much less prevalent and severe in the Gilbert catchment compared to the coast.

Pests, diseases and weeds need to be managed in sugarcane production and, with good management, they do not severely limit crop production. Occasionally, a pest or disease (such as sugarcane smut) can cause district-wide problems, and the Gilbert catchment would be no more or less sensitive to these than existing cane-growing areas.

Soils in the potential irrigation areas may include some soils poor in nutrients. These soils are more difficult to manage, requiring greater monitoring, and fertiliser and ameliorant input. With excessive ploughing, these soils can also have reduced water infiltration rates, resulting in waterlogging and reduced crop yields.

9.6 Financial analysis

This section addresses crop yields, crop gross margins and financial analysis at both farm scale and scheme scale.

The scheme scale analysis assumes that the whole scheme is funded and operated by a single developer who incurs all of the costs and receives all of the benefits of development. The question asked is, are the projected revenues sufficient to cover all expenditures? The strong possibility of different funding and operation models is recognised, but is beyond the scope of this case study.

The farm-scale analysis considers the net benefits after only farm-scale costs are deducted from gross margins. This analysis assumes that the investor purchases irrigation water from a third-party scheme water supplier who bears the scheme’s capital and operating costs. Water prices are initially set at zero, but the farm-scale investor’s capacity to pay for water is also estimated. This provides an estimate of the extent to which a scheme developer may recoup operation, maintenance or capital costs through water charges.

All financial analyses in this section are reported in 30-year investment windows, as this was the selected investment time frame (see the companion technical report about irrigation costs and benefits (Brennan McKellar et al., 2013) for a discussion on the choice of investment planning period). Using the 121 years of historical data, the total number of 30-year investment windows is 92. For example, the first 30-year window is 1891 to 1920, and values are calculated for this window. The second window is 1892 to 1921, and a second set of values are calculated for this window. This sampling – and subsequent calculating – was repeated 92 times in total, with the final window corresponding to 1981 to 2011. The median value from calculations for each of the 92 windows is presented. For example, where a mean value is calculated for each of the 30-year windows, the median 30-year mean (M30M) is reported. A straight-line depreciation approach was used to calculate the residual value of long-life infrastructure (i.e. infrastructure with a service life of greater than 30 years). This is a generous assumption compared with the alternative, which is to assume the infrastructure has no value at the end of the investment period.

A commonly used term in this section is ‘scheme area’. Scheme area refers to the maximum area that is planted to sugarcane at any one time. In addition to this area, there will be an additional 20% of land under fallow, which is included in the area works calculation.

Two financial analyses are presented. The first analysis (in Section 9.6.1) explores an appropriate scheme area for the irrigation development. Because sugarcane is a perennial crop, typically lasting five years (the plant crop plus four ratoons), it is not realistic to change the planted area each season based upon the water level in the dam reservoir, as occurred in analyses of annual crops in other case studies. It is assumed that land is not a constraint and that all capital costs were incurred in the first year. It also assumes a local mill at Georgetown.
In the second analysis (in Section 9.6.2), a single scheme area is selected, based on scheme- or farm-scale profitability, minimum size to support additional processing infrastructure (such as a sugar mill in this case study) or the availability of suitable land.

Because there are two irrigation developments being examined, one supplied by the Green Hills dam and one supplied by the Dagworth dam, the results are presented as column charts for each development as well as contour plots for both the Green Hills and Dagworth scheme areas. The selected scheme areas for one or both irrigation developments are then chosen based upon scheme- or farm-scale profitability, or minimum crop size required to support additional processing infrastructure mentioned in the storyline, in this case a sugar mill.

### 9.6.1 **DIFFERENT COMBINATIONS OF SCHEME AREA FOR GREEN HILLS DAM AND DAGWORTH DAM IRRIGATION DEVELOPMENTS**

In this section information is presented on how much water is applied to the crop, reservoir behaviour and change to the downstream median flow for different combinations of scheme-area for the Green Hills and Dagworth dam irrigation developments. Information is then presented on crop yield and gross margins and NPV and IRR at both the scheme-scale and farm-scale.

**Water supply, reservoir characteristics and changes in downstream flow**

Figures of the style presented in Figure 9.10 allow the reader to explore different combinations of scheme area for the Green Hills dam and Dagworth dam irrigation developments. For example in Figure 9.10a, if the scheme area of the Dagworth dam irrigation development is 10,000 ha and the scheme area of the Green Hills dam irrigation development is 5,000 ha, then their combined mean annual applied irrigation water is about 160,000 ML. Similarly, if the scheme area for Dagworth dam irrigation development is 16,000 ha and the Green Hills dam irrigation development did not exist (i.e. a scheme area of 0 ha), then the mean annual applied irrigation water would be about 160,000 ML.

The larger the scheme area, the larger the total volume of water supplied to and used by the irrigation development (Figure 9.10a), but the lower the amount of water supplied to each hectare of the crop (Figure 9.10b).

*Figure 9.10* (a) Mean annual total applied irrigation water supplied to the field (ML) and (b) ML applied per hectare under Scenario B for the irrigation developments associated with Green Hills and Dagworth dams

Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.
Figure 9.11 presents the ratio of water lost to evaporation to water supplied at the dam wall for Green Hills and Dagworth dams. With low scheme areas, water is not fully used and, if water is carried over to the following year, a large amount of water is lost to evaporation. With high scheme areas, the ratio of evaporation to supply is low because all available water is used every year (i.e. reservoir is treated as within-year storage).

Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 9.11 shows the percentage of time that the Green Hills and Dagworth dam reservoirs are less than 20% of its full supply level (FSL) volume. This provides an indication of the recreational amenity of these reservoirs. For example, for scheme areas greater than 20,000 ha, both reservoirs are less than 20% full for more than 25% of the time. In these circumstances, there may be reduced opportunity to use the reservoirs recreationally.

Figure 9.12 shows the percentage of time the volume of the reservoir is less than 20% of the full supply level volume under Scenario B for (a) Green Hills dam and (b) Dagworth dam. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 9.13 shows the median annual flow quotient at locations just below the irrigation areas for both the Green Hills dam and Dagworth dam. This provides an indication of the extent to which the median annual streamflow may change under different size irrigation developments. The smaller the number the larger
than change in median annual streamflow. The median annual streamflow quotient is between 0.62 and 0.88 below the Green Hills dam irrigation development at 917001D and between 0.7 and 0.9 below the Dagworth dam irrigation development (virtual gauge 355).

![Figure 9.13 Median streamflow quotient at (a) Green Hills dam (gauge 917001D) and (b) Dagworth dam (virtual gauge 355)](image)

Median streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development. Location of streamflow gauging stations shown on Figure 9.2

**Crop yield**

Larger scheme-scale median 30-year crop yields are attained for larger scheme areas. Because sugarcane yield declines by only 40% with a 50% reduction in irrigation volume from that required for maximum yield (Figure 9.14a), larger scheme-scale median 30-year yields are attained at high scheme areas even if there is insufficient water to meet full irrigation needs. However, the variability in 30-year crop yields is high and increases for larger scheme areas (Figure 9.14b).

![Figure 9.14 (a) Median of the 30-year mean (M30M) values for crop yield and (b) standard deviation of the 30-year mean values (S30M) for crop yield, under Scenario B for the irrigation development associated with the Green Hills and Dagworth dams. Circles in (a) correspond with lines in Figure 9.15 Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows from 1890 to 2011. Both the median and the standard deviation of the mean values for each of the 92 windows are presented.](image)
The higher crop yields and higher variability for larger scheme areas are illustrated in Figure 9.15. Although the combined 16,000-ha of sugarcane (i.e. 8000-ha at Green Hills irrigation development and 8000-ha at Dagworth irrigation development) has the lowest combined crop yield, there is always sufficient water in the dam to ensure a constant supply of sugarcane from the two irrigation developments. Larger scheme areas have larger yields but also exhibit large variation.

Figure 9.15 Crop yield from the combined scheme area under Scenario B for three different scheme areas marked in Figure 9.14a. Lines correspond with circles in Figure 9.14. Note that the crop yields are the combined crop yields of the Dagworth dam and Green Hills dam irrigation developments.

Figure 9.16a illustrates the percentage of years that 2 million t of sugarcane is exceeded in the two irrigation developments. For example, if each irrigation development had a scheme area of 5000 ha, their combined production does not exceed 2 million t of sugarcane in any year. If each irrigation development had a scheme area of 16,000 ha, their combined production would exceed 2 million t of sugarcane in more than 95% of the years. The median 30-year mean specific yield (i.e. yield per hectare) is presented in Figure 9.16b. If Green Hills and Dagworth irrigation developments each had a scheme-area of 16,000 ha the M30M specific yield (yield per hectare) is between 100 and 105 t/ha. This is lower than the mean crop yield per hectare under modelled production potential (Figure 9.9) because water is limiting crop yield in some years.
Crop gross margins

A crop gross margin is the difference between the gross income and variable costs of growing a crop. It does not include overhead or capital costs; these must be met regardless of whether or not a crop is grown.

Variable costs (also known as direct costs) vary in proportion to farm activity. They include irrigation pumping costs, as well as other crop inputs, such as costs of fertiliser, chemicals and harvesting.

Water charges are also a variable cost when charged on a $/ML basis, but are omitted from the gross margin calculations here because water costs are not known. Instead, as part of this financial analysis, farmers’ capacity to pay a water charge is determined. The crop gross margin is calculated using simulated crop yield and water use. Table 9.8 lists the key assumptions in the gross margin calculations for sugarcane used in this analysis. For details on crop gross margin calculations, see the companion technical report about irrigation costs and benefits (Brennan McKellar et al., 2013).

Table 9.8 Key assumptions in the gross margin calculations for sugarcane
See Brennan McKellar et al. (2013) for more detail.

<table>
<thead>
<tr>
<th>KEY ASSUMPTIONS</th>
<th>VALUE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar cane price ($/t)</td>
<td>$39, $45</td>
<td>Default and maximum price</td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest and transport to siding ($/t)</td>
<td>$8.20</td>
<td>Mill responsible for costs</td>
</tr>
<tr>
<td>Siding to mill ($/t)</td>
<td>$0</td>
<td>Mill responsible for costs</td>
</tr>
<tr>
<td>Pumping cost ($/ML)</td>
<td>$58.90</td>
<td>Spray irrigation, diesel</td>
</tr>
<tr>
<td>Other ($/ha)</td>
<td>$642</td>
<td>Average for all plant crop, ratoons and fallow. Details provided in Brennan McKellar et al. (2013)</td>
</tr>
</tbody>
</table>
Figure 9.17a shows that total scheme-scale gross margins are higher at larger scheme areas because the gross margin per hectare is being multiplied over larger areas. Figure 9.17b shows the median 30-year gross margin per hectare.

### Whole-of-scheme net present value

As a new capital project requiring investment in equipment and infrastructure, the irrigation development is assessed for the costs expended and benefits incurred over a 30-year project life. When the costs for this period are subtracted from the benefits to give a net benefit stream, a discount rate of 7% is applied to yield a NPV for the development. A zero or positive NPV value indicates that the scheme is profitable at the specified discount rate.

The whole-of-scheme NPV calculation takes into consideration the scheme- and farm-scale capital, operational and maintenance costs, and scheme-scale gross margins. Asset replacement and residual values are considered within the 30-year project period. Further details on the framework for discounted cash-flow financial analysis and assumptions are presented in the companion technical report about irrigation costs and benefits (Brennan McKellar et al., 2013).

The scheme-scale NPV is negative under all combinations of scheme areas, because the revenue generated from the scheme (total crop gross margins) does not offset the capital, operation and maintenance costs of the scheme-scale and on-farm infrastructure for the life of the investment (Figure 9.18a). Therefore, losses are minimised by not developing an irrigation development.
Figure 9.18 a) Median of the 30-year mean (M30M) values for scheme-scale net present value and (b) standard deviation of the 30-year mean (S30M) values for scheme-scale net present value under Scenario B for the irrigation developments associated with the Green Hills and Dagworth dams

Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows from 1890 to 2011. The median and the standard deviation of the mean values for each of the 92 windows are presented.

Farm-scale net present value

A situation may arise involving independent funding and ownership of off-farm (water storage and transmission) and on-farm (land, equipment) development capital.

In these circumstances, investment decisions made by irrigators could be confined to consideration of on-farm costs only. For this purpose, the NPV of an on-farm investment is calculated. This calculation considers the capital, annual operating and maintenance (overhead) costs of on-farm infrastructure. The capacity to contribute to scheme-scale operation and maintenance costs, and possibly capital costs, through a water price depends on the extent to which the NPV is positive.

In this case study, the total crop gross margins are sufficient to cover the capital and overhead costs over the investment period (Figure 9.19). The largest farm-scale NPVs occur when each irrigation development has a scheme area of 16,000 ha.
Figure 9.19 Median of the 30-year mean values for farm-scale net present values and (b) standard deviation of the 30-year mean values for farm-scale net present value, under Scenario B for the irrigation developments associated with the Green Hills and Dagworth dams.

Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows from 1890 to 2011. The median and the standard deviation of the mean values for each of the 92 windows are presented.

9.6.2 DETAILED ANALYSIS FOR A GIVEN SCHEME AREA

To allow more detailed investigation, a scheme area of 16,000 ha (with an extra 20% fallow at any one period in time) was selected for each of the Green Hills dam and Dagworth dam irrigation developments. For this analysis, construction costs were staged during the first three years of the 30-year investment time period (Table 9.9). This is likely to be a more realistic assumption, compared with assuming that all costs are incurred and full revenue is attained in the first year. Furthermore, for this case study, staging construction costs is about 10% more profitable than without staging.

Table 9.9 Staging of construction, farm development and crop production

<table>
<thead>
<tr>
<th>YEAR NUMBER</th>
<th>CONSTRUCTION PROGRAM</th>
<th>FARM DEVELOPMENT</th>
<th>CROP PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50% dam costs; 100% approvals and legal costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>50% dam costs; 50% area work costs</td>
<td>50% farm development</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>50% area works costs</td>
<td>50% farm development</td>
<td>50% revenue</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>100% revenue</td>
</tr>
</tbody>
</table>

Gross margins

Figure 9.20 (Green Hills dam) and Figure 9.21 (Dagworth dam) present a time series of annual gross margins ($/ha) simulated using APSIM for each year of the 121-year historical climate record, assuming various market prices for sugarcane. On the right-hand side of the plot, the range of gross margins for each sugarcane price assumption is indicated by a black vertical line and the median (50th percentile) is indicated by the black horizontal line. The top and bottom of the coloured box indicates the gross margin at the 25th and 75th percentile. The large difference between the 75th percentile and the minimum gross margin indicates that relatively few very low gross margins were simulated.

Gross margins per hectare are notably higher at the Dagworth dam irrigation development than at the Green Hills dam irrigation development because of the larger volume of water that can be supplied from
the Dagworth dam and the higher the crop yield per unit water at the Dagworth dam irrigation development.

Figure 9.20 Gross margins for sugarcane ($/ha) under Scenario B for the irrigation development associated with Green Hills dam: (a) time series and (b) box plot
Scenario B is the historical climate (1890 to 2011) with irrigation development. Results are shown for both the default price of sugarcane ($39/t) and the highest price paid in the past 10 years ($45/t). In (b), the mean for each price is indicated by the black horizontal line, and the range is indicated by the black vertical line. The top and bottom of the coloured boxes indicate the 25th and 75th percentile, respectively.

Figure 9.21 Gross margins for sugarcane ($/ha) under Scenario B for the irrigation development associated with Dagworth dam: (a) time series and (b) box plot
Results are shown for both the default price of sugarcane ($39/t) and the highest price paid in the past 10 years ($45/t). In (b), the mean for each price is indicated by the black horizontal line, and the range is indicated by the black vertical line. The top and bottom of the coloured boxes indicate the 25th and 75th percentile, respectively.

A range of other costs could also impact on the gross margin. If, for example, sugarcane had to be delivered to a distant mill, then the cost of transport may need to be incorporated into the gross margin calculation. This is examined below. It should also be noted that the gross margins presented in Figure 9.20 and Figure
9.21 do not include a water charge ($/ML). This is, however, another cost that would be expected to be reflected in the gross margin.

**Scheme-scale analysis**

Using the 121-year distribution of simulated gross margin outcomes presented in Figure 9.20, it was possible to sample 30-year gross margin windows and calculate the NPV of the income stream after accounting for scheme-scale, and on-farm capital and annual operating costs in a 30-year investment planning period. In addition to NPV, IRR was calculated. The IRR represents the break-even discount rate – that is, the discount rate that will bring the NPV to zero. A viable investment has an internal rate of return higher than the discount rate.

The purpose of sampling from the 121-year distribution is to show how the overall investment performance is sensitive to the particular set of underlying climate conditions during the 30-year investment period.

For this analysis, it is assumed that there is a sugar mill in Georgetown. The cost of construction and operating a mill is not included in the analysis.

**9.6.2.1.1 Green Hills**

The ninety-two 30-year NPV and IRR values are presented in Figure 9.22 as percentage exceedance plots. All of the NPVs are negative (Figure 9.22a), ranging from −$460 million to −$545 million for the default price for sugarcane, and from −$345 million to −$450 million for the high prices. In other words, the cost of the investment exceeds the income over the 30-year investment period, for all 92 investment periods. The IRR is negative at the default and high price (Figure 9.22b). For the Green Hills dam irrigation development, to break even at a 7% discount rate (i.e. NPV equal to zero) the price of sugarcane would need to be $68/t assuming a sugar mill in Georgetown.

![Figure 9.22 Percentage exceedance plots of (a) net present value and (b) internal rate of return under Scenario B for the scheme-scale irrigation development of 16,000 ha associated with the Green Hills dam](image)

This financial analysis includes all scheme-scale and farm-scale capital and operating costs, and income from crop gross margins. Values are for a 30-year investment period.

**9.6.2.1.2 Dagworth**

The ninety-two 30-year NPV and IRR values are presented in Figure 9.23 as percentage exceedance plots. All of the NPVs are negative, ranging from −$605 million to −$685 million for the default prices for sugarcane, and from −$490 million to −$590 million for the high prices. In other words, the cost of the investment exceeds the income over the 30-year investment period, for all 92 investment periods. For the Dagworth dam irrigation development to break even at a 7% discount rate (i.e. NPV equal to zero) the price of sugarcane would need to be $76/t, assuming a sugar mill in Georgetown.
The scheme-scale NPVs are more negative for the Dagworth dam irrigation development than the Green Hills dam irrigation development because the Dagworth dam infrastructure costs are larger and this is only partially offset by higher scheme-scale gross margins.

The financial analyses are restricted to the question of whether projected revenues from the sale of sugarcane are sufficient to cover the costs of irrigation development and sugarcane production. An alternative investment perspective would produce different financial outcomes – for example, in an integrated growing and milling investment, sugarcane would be an input in the generation of products that could provide revenues from sugarcane milling, such as electricity, sugar, and ethanol. No particular investment model is proposed as performing better than another. This case study did not extend to these alternative options, but investigation of alternatives could build on the analyses presented here.

**Farm-scale analysis**

In the farm-scale analysis, all capital, operation and maintenance costs associated with the scheme-scale infrastructure are excluded from this analysis. Similar to the scheme-scale analysis, financial assessments are undertaken using 30-year windows and, unless otherwise stated, it is assumed there is a sugar mill in Georgetown.

### 9.6.2.1.3 Green Hills

The results in Figure 9.24a indicate that this investment at this scale is viable under the default prices, as all NPVs are positive. At the default price and high price, the IRR ranges between 8% and 23%, and 17% and 37%, respectively (Figure 9.24b).

For the default crop prices and for the median 30-year NPV, the investor could pay $34/ML for irrigation water and break even (i.e. an NPV of zero). Consequently, investors have some capacity to pay a water charge to help offset the operation and maintenance costs of the scheme.
This financial analysis includes farm-scale capital and operational costs, and crop gross margins. Values are for a 30-year window internal rate of return.

### 9.6.2.1.4 Dagworth

The results in Figure 9.25a indicate that this investment at this scale is viable under the default prices, as all NPVs are positive. At the default price and high price, the IRR ranges between 6% and 18%, and 15% and 32%, respectively (Figure 9.25b).

For the default crop prices and for the median 30-year NPV, the investor could pay $24/ML for irrigation water and break even (i.e. an NPV of zero). Consequently, investors have some capacity to pay a water charge to help offset operation and maintenance costs of the scheme.

The effect of transport to processing facility on the investment

The TRAnsport Network Strategic Investment Tool (McFallan et al., 2013) was used to calculate the cost of transporting sugarcane from the case study areas to Mareeba (Brennan McKellar et al., 2013). The impact of transporting sugarcane from the irrigation developments associated with Green Hills dam and Dagworth dam to Mareeba are illustrated in Table 9.10 and Table 9.11.
Two alternatives are explored. In the first, the grower pays 50% of the transportation cost to the Mareeba mill and the mill pays the other 50% of the transportation costs. In the second alternative, the grower pays 100% of the transportation cost to Mareeba. These are compared to the default alternative of a new mill in Georgetown.

Table 9.10 The impact of transporting sugarcane from the irrigation development associated with Green Hills dam to Georgetown and Mareeba

<table>
<thead>
<tr>
<th>MILL LOCATION</th>
<th>COST ($/t)</th>
<th>% PAID BY GROWER</th>
<th>M30M SUGARCANE GROSS MARGIN ($/ha)</th>
<th>MEDIAN 30-YEAR NET PRESENT VALUE ($ million)</th>
<th>CAPACITY TO PAY WATER CHARGE ($/ML)</th>
<th>BREAK-EVEN PRICE ($/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgetown</td>
<td>na</td>
<td>na</td>
<td>$1,873</td>
<td>$53</td>
<td>$34</td>
<td>$2,498</td>
</tr>
<tr>
<td>Mareeba</td>
<td>$67</td>
<td>50%</td>
<td>−$1,591</td>
<td>−$538</td>
<td>−$343</td>
<td>−$956</td>
</tr>
<tr>
<td>Mareeba</td>
<td>$67</td>
<td>100%</td>
<td>−$5,103</td>
<td>−$1,129</td>
<td>−$721</td>
<td>−$4,487</td>
</tr>
</tbody>
</table>

M30M = median of the 30-year mean; na = not applicable.

Table 9.11 The impact of transporting sugarcane from the irrigation development associated with Dagworth dam to Georgetown and Mareeba

<table>
<thead>
<tr>
<th>MILL LOCATION</th>
<th>COST ($/t)</th>
<th>% PAID BY GROWER</th>
<th>M30M SUGARCANE GROSS MARGIN ($/ha)</th>
<th>MEDIAN 30-YEAR NET PRESENT VALUE ($ million)</th>
<th>CAPACITY TO PAY WATER CHARGE ($/ML)</th>
<th>BREAK-EVEN PRICE ($/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgetown</td>
<td>na</td>
<td>na</td>
<td>$1,779</td>
<td>$40</td>
<td>$24</td>
<td>$2,417</td>
</tr>
<tr>
<td>Mareeba</td>
<td>$81</td>
<td>50%</td>
<td>−$2,459</td>
<td>−$667</td>
<td>−$395</td>
<td>−$1,834</td>
</tr>
<tr>
<td>Mareeba</td>
<td>$81</td>
<td>100%</td>
<td>−$6,715</td>
<td>−$1,373</td>
<td>−$814</td>
<td>−$6,100</td>
</tr>
</tbody>
</table>

M30M = median of the 30-year mean; na = not applicable.

For both the irrigation developments and for the default price, the median 30-year NPV is only positive when a mill is located in Georgetown.

To be profitable to transport sugarcane from the Green Hills irrigation development to a mill in Mareeba, the price of sugarcane would need to be $69/t if the mill paid 50% of the transport costs and $103/t if the grower had to pay all of the transport costs. To be profitable to transport sugarcane from the Dagworth irrigation development to a mill in Mareeba, the price of sugarcane would need to be $77/t if the mill paid 50% of the transport costs and $118/t if the grower had to pay all of the transport costs.

9.7 On-site and off-site impacts

Prior to irrigation development, the area would require more intensive assessment of any ecological impacts. This section provides an overview of some of the potential on-site and off-site impacts that may result from each of the irrigation developments analysed in Section 9.6.2. More detailed analysis of these issues is beyond the scope of this case study.
9.7.1 RISK OF RISE IN WATERTABLE LEVEL AND SECONDARY SALINISATION

Based on the best available information, a rise in watertable level is thought to be unlikely under a well-managed irrigation development associated with the Green Hills dam. Furthermore, there is little evidence of salt accumulation in the highly permeable soils and substrata. A rise in watertable level is thought more likely to occur under the more variable soils of the irrigation development associated with Dagworth dam. More detailed investigations would be required.

The rise in groundwater levels (Figure 9.26) was assessed using an analytical groundwater model developed as part of the Assessment. The irrigation development is assumed to commence 2 km from the river, allowing for a riparian buffer. A size of 14,400 ha is assessed because this is about the size of the larger of the two Dagworth irrigation development polygons delineated in Figure 9.1 and Figure 9.2. Recharge is calculated using annual simulated irrigation and rainfall data under Scenario B (see Jolly et al., 2013). The parameters and their values used in the analytical model are listed in Table 9.12. No field-based measurements of aquifer parameters were available for this part of the Gilbert catchment. The values used in Table 9.12 are considered a likely range, based on bore log information (Section 2.2). For more detail, see companion technical report about surface water – groundwater connectivity (Jolly et al., 2013).

<table>
<thead>
<tr>
<th>AQUIFER PARAMETER</th>
<th>VALUE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer thickness</td>
<td>29 m</td>
<td></td>
</tr>
<tr>
<td>Depth to groundwater</td>
<td>13 m</td>
<td></td>
</tr>
<tr>
<td>Distance from river</td>
<td>2 km</td>
<td></td>
</tr>
<tr>
<td>Recharge rate</td>
<td>131 and 215 mm/year</td>
<td>Lower and higher estimate. Recharge as a result of irrigation and rainfall</td>
</tr>
<tr>
<td>Saturated hydraulic conductivity (K)</td>
<td>1, 10 and 100 m/day</td>
<td>Lower, middle and higher estimate</td>
</tr>
<tr>
<td>Specific yield</td>
<td>0.2</td>
<td>Only has bearing on rate of rise, not maximum rise</td>
</tr>
</tbody>
</table>

It is thought unlikely that the watertable would rise close to the ground surface under well-managed irrigation on sand or loam over friable or earthy clay soils adjacent to the Gilbert and Einasleigh rivers. This is because these soils are highly permeable, and as a consequence have low salt concentrations, as evident from soil, bore log and airborne electromagnetic data. The saturated hydraulic conductivity of these soils and their substrate is likely to be closer to 100 m/day than 10 m/day. Hence under these assumptions, the drainage capacity of the aquifer is higher, which results in a slower rise in the watertable (Figure 9.26). On those parts of the Dagworth irrigation development with heavier soils there is a greater risk of watertable rise. Irrigation developments further from these rivers are also likely to have a greater risk of watertable rise as they will have a lower drainage capacity (see Section 7.2). More detailed investigations would be required if irrigation developments were to proceed.
9.7.2 ECOLOGICAL, SOCIAL AND CULTURAL CONSIDERATIONS

Table 9.13 summarises the potential ecological, social and cultural considerations with respect to the irrigation development associated with the Green Hills and Dagworth dams. Irrigation areas were set at 19,200 ha with about 16,000 ha planted in any season. This is similar in scale to the analysis undertaken in Section 9.6.2.

Table 9.13 Summary of likely ecological changes as a result of the Dagworth dam and Green Hills dam irrigation developments. This involved analysis of 16,000 ha of sugarcane under spray irrigation at both locations

<table>
<thead>
<tr>
<th>ECOLOGICAL AND SOCIAL CONSIDERATIONS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation at reservoir and irrigation development</td>
<td>The area inundated at full supply level for Dagworth and Green Hills dams covers a large area of regional vegetation communities that are a mixture of ‘Of concern’, ‘Not of Concern’ and ‘Non-remnant’ types. The site also contains riverine wetland or fringing riverine wetland vegetation that will be lost to inundation (Petheram et al., 2013).</td>
</tr>
<tr>
<td>Sediment infill of reservoir</td>
<td>It is predicted that about 5% (range of between 0.7% and 10%) of the storage volume of both Dagworth and Green Hills dam will infill with sediment after 30 years, and 18% (range of between 2% and 32%) of the storage volume will infill with sediment after 100 years (Tomkins, 2013).</td>
</tr>
<tr>
<td>Reservoir water quality</td>
<td>For both storages, the risk of blue-green algal blooms is moderate. The water column is predicted to be strongly thermally stratified from September to mid-May, but has the potential to be mixed during summer inflow events. The light climate will support blooms in summer and has the potential to support blooms in spring (Petheram et al., 2013). In light of the development of permanent stratification, downstream delivery of water needs to be carefully managed to avoid downstream delivery of cold oxygen-depleted water. Thermal impacts associated with release of such water are likely to be limited spatially during periods of warm weather, but may be spatially extensive during the cooler months and at night.</td>
</tr>
<tr>
<td>Sediment, nutrient and pesticide loads from irrigation development</td>
<td>An analysis at about the scale of this development is that phosphorus and nitrogen loads would increase 29% and 23%, respectively (Waltham et al., 2013). It is not possible to model likely losses of pesticides given lack of pesticide data for this land use type (Waltham et al., 2013).</td>
</tr>
</tbody>
</table>
Table 9.13 Summary of likely ecological changes as a result of the Dagworth dam and Green Hills dam irrigation developments. This involved analysis of 16,000 ha of sugarcane under spray irrigation at both locations (continued)

<table>
<thead>
<tr>
<th>ECOLOGICAL AND SOCIAL CONSIDERATIONS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment, nutrient and pesticide loads</td>
<td>The dams at Dagwood and Green Hills are likely to trap suspended sediment, nutrients and pesticides, but probably only during the wet-season flow. If trapped sediment remains in suspension for a significant portion of the year, then releases during the dry season may also contain high levels of suspended sediment. This is an important consideration in the Gilbert catchment given the large number of persistent waterholes within this region (McJannet et al., 2013). Even small increases in turbidity, especially in deep waterholes (which are typically the most ecologically significant in intermittent streams), can have significant negative impacts on the ecosystem processes and ecology of these waterholes. Other water quality problems may be experienced downstream of the dam. Waterholes may experience altered water temperatures regimes, depending on the location of water offtake, and low dissolved oxygen levels, which may also alter ecosystem processes and health of freshwater fauna (Waltham et al., 2013).</td>
</tr>
<tr>
<td>Fish passage</td>
<td>Dams at Dagworth and Green Hills and associated re-regulating weirs will act as local fish passage barriers. The dam at Dagworth is within the known extent of key fish species such as freshwater sawfish and barramundi, but their abundance and distribution upstream of the re-regulating weir is not well defined. Many hundreds of kilometres of stream are located above the Dagworth dam and access to this large area of instream aquatic habitat should be maintained for all aquatic species. The Dagworth dam is projected to be 30 m in height and will pose a significant challenge to the maintenance of fish passage. Passage is not just confined to fish, but also to turtles, crocodiles and invertebrates such as the Giant Freshwater Prawn (<em>Macrobrachium spinipes</em>), which migrate seasonally within northern rivers and its distribution extends to the very headwaters of most systems. These species are both culturally and ecologically important. The dam at Green Hills is at or beyond the maximum upstream extent of key fish species of high conservation value – freshwater sawfish, barramundi and giant whipray. Nonetheless, the dam (20 m high) and weir (3 m high) are significant barriers and would potentially alienate an extensive length of the Gilbert River and its upstream tributaries from downstream reaches. Most freshwater fishes of the region move extensively either to access newly inundated habitat or to reproduce. Reducing access is likely to result in significant changes in fish assemblage structure and even the long-term persistence of species as any local extinctions due to chance or drought will not be reversed by recolonisation from downstream refugia.</td>
</tr>
<tr>
<td>Freshwater and coastal aquatic ecology in response to flow alteration</td>
<td>The dams at Dagworth and Green Hills trap a significant proportion of flow of the upper Einasleigh River and Gilbert River, respectively. This will have a strong localised impact on flow regimes and trapping early wet-season flows critical for the flushing of downstream waterholes. Wet-season flood flows are also critical cues for migration and spawning in many species of freshwater fish and macrocrustaceans; it is likely that these functions will be shifted back in time. Reproductive success may be compromised by such a delay, because the length of time available for growth and acquisition of energy reserves necessary to enable organisms to persist during the dry season may be too short. The effect of the flow reduction shown in Figure 9.13 on coastal ecosystems is not clear, but worthy of further consideration. More importantly, however, the catchment located seaward of this gauge hosts a large number and area of wetlands requiring seasonal inundation. This floodplain area is likely to be of great significance to the ecology of the river and greater attention needs to be given to the impact of the dam on this area. The stream reach containing, and downstream of, the Dagworth impoundment, has been identified as containing a higher number of persistent waterholes compared to the rest of the Gilbert catchment (McJannet et al., 2013). Increased dry-season flows will connect these waterholes, which are often separated from each other. This alters their individual characters, making them more similar to each other, thus reducing diversity. Permanently watering otherwise intermittent reaches facilitates the movement of predatory fish species over large distances, which impacts on the assemblage structure of fish communities in pools.</td>
</tr>
</tbody>
</table>
Table 9.13 Summary of likely ecological changes as a result of the Dagworth dam and Green Hills dam irrigation developments. This involved analysis of 16,000 ha of sugarcane under spray irrigation at both locations (continued)

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<tr>
<th>ECOLOGICAL AND SOCIAL CONSIDERATIONS</th>
<th>COMMENT</th>
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<td>Freshwater and coastal aquatic ecology in response to flow alteration (continued)</td>
<td>There are few perennial waterholes in the reaches of the Gilbert River downstream of the Green Hills dam (McJannet et al., 2013) However, the lower reaches of the Gilbert River (below the confluence with the Einasleigh River) are distinguished by significant dry-season baseflow. Under a development scenario, median dry-season flows are reduced by about 20%, resulting in an increase in the median length of maximum length of zero flow from 0 days to about 50 days, and an increase in the absolute maximum dry-spell length from about 22 days to more than 100 days. Such changes are likely to result in substantial ecological change in the lower reaches. These changes essentially transform the lower river from a large-sized perennial system to a moderate-sized intermittent one. In addition to these changes, the flow regime of the Gilbert River was predicted to become more variable and this has consequences for biotic assemblage structure and regulation. The Green Hills dam reduces flood flows by about 20% and this may result in changes to downstream riparian vegetation, weed encroachment, instream habitat structure and, ultimately, channel form. These impacts are likely to be extensive, because changes in wet-season flows are experienced as far downstream as the most downstream gauge (917009A) when both this dam and the Dagworth scheme are in place. Dry-season water releases from the dam to the downstream re-regulating weirs will alter seasonal patterns of river flow and its water quality along the affected reach. Although unnatural, these releases may extend persistence of instream aquatic habitats providing some benefit to aquatic productivity. In other irrigation areas, such dry-season releases have, when in large volumes, greatly altered instream ecology, including allowing the development of instream vegetation and weed communities that would normally perish in the dry season.</td>
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<td>Terrestrial ecology</td>
<td>Requires site-based assessment, including examination of existing terrestrial flora and fauna databases. A number of protection and conservation areas that would support a range of plants and animals are present downstream of this site, which would require consideration.</td>
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<td>Impoundment ecology</td>
<td>The impoundments offers new, albeit unnatural, aquatic habitat in otherwise relatively dry catchments, and may also offer new recreational opportunities. Proposals for recreational fishery enhancement by stocking need to be very carefully considered. In this case, the proposed dam is within the natural distributional limits of barramundi, a popularly stocked species, and it may therefore be a suitable species for consideration. The fact that it may naturally occur in the region does not mean that large numbers of fish of reservoir origin may not have impacts upstream or indeed downstream if they leave the dam at times of overflow. Large dams may retain colloidal sedimentary material washed in during rain or flow events, in suspension for some time (e.g. Burdekin Falls Dam – see Burrows, 1999). Where such turbid water is released for irrigation, this will impact significantly upon downstream waterholes whose ecology is based on their high water clarity and depth of sunlight penetration. The Green Hills dam is upstream of the natural limit of barramundi and any calls to stock this impoundment with this species will need to be very carefully considered. Occupation of the impoundment will allow barramundi access to an extensive length of river from which they are currently absent. This large predator has significant effects on other fish species and invertebrates.</td>
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<td>Human ecology</td>
<td>The creation of a large, new standing body of water may have a range of effects on human behaviour and human use of the landscape. Recreational opportunities may be possible, but the shallow nature of the storage and frequency of low water levels may preclude boating and fish stocking. Altered or diminished downstream flow may impact on economic, recreational, subsistence, amenities and cultural values downstream (Barber, 2013).</td>
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<td>Cultural heritage considerations</td>
<td>No previous archaeological reporting relating specifically to the Dagworth or Green Hills case study areas has been located. However, results of investigations in these catchments more generally indicate that these areas are likely to have high archaeological potential. Further field surveys are required to assess the potential Indigenous archaeological impact of works in these case study areas. Any such investigation should be undertaken in consultation with the registered Aboriginal Party, the Ewamian people (Tamwoy et al., 2013).</td>
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</table>
9.8 References


Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

