Part III  Case studies

The Assessment considered three case studies in the Flinders catchment, as described in chapters 8 to 10 in Part III. These case studies are based on the information in chapters 3 to 7, and use the methods as described in Chapter 2. Their purpose is to help evaluate the type of opportunity for irrigation in selected geographic areas of the catchment. By analysing water storage options and potential crops, they allow the reader to better understand the viability and sustainability of irrigated agriculture.

The geographic areas of the case studies were determined by the location of the more promising water storage options in the Flinders catchment. The storyline for each case study is a narrative about a hypothetical development and is based on a range of information, including consultation with local stakeholders, local knowledge and aspirations, biophysical opportunities, market and infrastructure factors, and transport logistics.

The case studies are illustrative only; the Assessment is not recommending these developments – or types of development – for the Flinders catchment. No proposals or funding are currently in place to finance these irrigation developments.

The financial analysis for these case studies adopts the common perspective of investigating whether the projected revenues from the sale of the crop is sufficient to cover the costs of irrigation development and crop production. The agricultural opportunities investigated in these case studies may, however, be pursued under a range of investment models, including investments that integrate component parts of the supply chain – for example, growing and processing. These alternatives are beyond the scope of the Assessment, but the analyses presented here can be used in further investigations of such options.
In this case study, a potential irrigation development near Cloncurry was investigated (see Figure 8.1). The development would enable sorghum (grain) to be supplied to newly established local feedlot and abattoir facilities to grow the regional beef industry. Irrigation water would be supplied from a dam built at Cave Hill. The prime efficiency drivers for establishment of a local abattoir are freight savings and increases in quality enabled by the local slaughter of cattle.

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

- the physical capacity to create a water storage and water distribution infrastructure, to supply water to agriculturally suitable soils, and to grow crops
- 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 sustain a feedlot with a throughput of 65,000 head per year based on feed supplied from the irrigation development.

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 (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).
8.1 Summary

The case study concludes that the physical conditions enable a combined dam, irrigation and abattoir development. The case study found the following:

- A dam capable of storing 248 GL can potentially be located at Cave Hill, south of Cloncurry. Because of and high inter-annual streamflow variability and high evaporative losses, its yield would be 40 GL/year (at 85% reliability). The estimated storage cost of $249 million and annual yield of 40 GL results in a unit cost of $6170 per ML supplied in 85% of years. Approximately half of the water released from the dam would be lost in conveyance and application to the crop.
- More than 71,000 ha of soils moderately suited to irrigated cereal crop production are located downstream of the dam site. Given adequate irrigation and fertiliser, these soils are capable of supporting median crop yields of approximately 8 t/ha for sorghum (grain).
- Irrigation in this area is associated with considerable risk of secondary salinity.

A dam and irrigation development paid for and operated by the same entity is not, under the conditions examined in this case study, able to be economically sustained. 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 price of sorghum (grain) would need to be $865/t. Market prices are highly variable but are in the vicinity of $230/t. A high price for sorghum (grain) is $300/t.

There is no capacity to generate on-farm profits using water, dam infrastructure and related capital supplied by and paid for by a third party. Using default and high grain prices, all farm-scale NPVs are negative.

Therefore, although the physical conditions exist for this irrigation development, there is limited economic capacity to support a 65,000-head feedlot and abattoir based on cattle fed using locally irrigated sorghum (grain).
Under the conditions used in the Assessment, the gross margins generated from sorghum (grain) do not exceed the on-farm capital and overhead costs. They do not come close to meeting the full cost of irrigation development, which includes scheme-scale capital and operating costs. Furthermore, in only about 70% of years could the irrigation development generate sufficient sorghum (grain) to supply a feedlot with throughput of 65,000 head of cattle.

Under the irrigation development outlined in this case study, the watertable level could rise to the ground surface in 10 to 25 years. Any rise in watertable level is likely to mobilise soluble salts in the substrate and clay subsoils.

Meateng et al. (2012) concluded that a new abattoir for northern outback Queensland would be likely to generate improved net return outcomes for local producers, but could only expect to generate a marginal return on its investment. Given this information and the results of this analysis, it is unlikely that the incorporation of an unprofitable water supply and irrigation development with a feedlot and abattoir would result in an improved return on investment.

### 8.2 Storyline for this case study

In this case study, a potential irrigation development near Cloncurry was investigated. The development would enable sorghum (grain) to be supplied to newly established local feedlot and abattoir facilities. Water would be supplied from a dam built at Cave Hill. The prime efficiency drivers for establishment of a local abattoir are the opportunity to provide value-add finishing of cattle within the north-west Queensland region, and to reduce the costs of transport of other classes of slaughter cattle (cull cows, animals on better country that meet Japanese market specifications) that are currently transported to abattoirs on the east coast of Queensland.

Currently, the majority of young cattle produced in north-west Queensland are exported from the region to be finished in other parts of Queensland. Other markets for beef cattle include sales to meatworks and live export to Asia. Of the cattle sent to meatworks, 75% of cattle from northern outback Queensland are slaughtered in coastal abattoirs between Townsville and Rockhampton, and the remaining 25% in abattoirs in the Brisbane area (Meateng et al., 2012). Regional producers bear substantial costs in live cattle transport, carcass shrink losses and tick line treatments, as well as in meeting regulations governing truck driver fatigue and animal welfare. These costs significantly reduce net returns to producers. For cattle of low value (e.g. cull cows), the transport costs to abattoirs may not cover revenue.

A study on establishing a meat processing industry in the region (Meateng et al., 2012) identified the potential for developing finishing operations in some parts of the Flinders catchment, which could support a local abattoir. One of the locations identified was Cloncurry. A throughput of 100,000 head per year would be required to support an operationally efficient abattoir (Meateng et al., 2012); this is achievable based on existing regional turn off rates. The 100,000-head throughput would be predominantly sourced from finishing of cattle, with the balance coming from culled animals. It is possible that slaughter of culled animals (aged and cull cows, surplus heifers, bulls) could take the throughput well beyond 100,000 head per year. No operational large-scale feedlots exist in the Flinders catchment, and the generally low quality of the tropical pastures supporting livestock in the region means that the prospects for well-finished cattle on pasture are limited (see Chapter 4). The majority of large feedlots in Queensland are located in southern and central Queensland, due to close proximity to both grain supplies and meat processing facilities. The availability of reliable fodder and/or grain supplies could enable a local feedlot (or feedlots) to be operated in conjunction with an abattoir.

Using the TRAnsport Network Strategic Investment Tool (McFallan et al., 2013), the average transport distance of 100 representative properties to Cloncurry is 530 km, resulting in an average transport cost of $27/head. This is a saving of $34/head over the cost of transporting cattle to existing abattoirs along the east coast of Queensland between Townsville and Brisbane (using the existing road network and vehicle configuration). If the Cloncurry abattoir slaughters 100,000 head of cattle per year, the collective transport cost saving would be $3.26 million/year. This does not include additional benefits in terms of improved
animal condition on arrival at the abattoir, and reduced greenhouse gas emissions from transport (see companion technical report about irrigation costs and benefits (Brennan McKellar et al., 2013)).

A local feedlot supplying cattle to the abattoir would provide a ready market for local irrigation development. The area of irrigation required to support the operation of a local feedlot (or farm feedlots) would be linked to the animals’ feed requirement to reach market condition, the capacity of the feedlot(s), and the size and output capability of an associated abattoir. The demand for locally produced feed to support a feedlot would be influenced by the feed types and ratios used (e.g. 75 to 80% grain, 10% protein from cottonseed or canola cake, and 10% hay or silage), as well as the feed conversion rate achieved by the animals before slaughter. Cattle usually enter a feedlot between about 300 and 500 kg in weight and remain in the feedlot for 50 to 120 days, depending on their age, store condition and feed conversion efficiency, as well as whether they are destined for the domestic, short-fed or long-fed markets. To be marketed as grain-fed, cattle would need to spend at least 70 days in a feedlot.

For this case study, the target market for the abattoir is assumed to be Japan (grain-fed steers for meat trade). The weight specification for the Japanese feeder steer market is a carcase minimum of 300 kg (live weight approximately 580 kg), with animals generally being no older than 24 to 30 months (four tooth). It is assumed that cattle enter the feedlot at approximately 420 kg and spend a minimum of 100 days in the feedlot, growing at 1.8 kg/day to reach a target live weight of 600 kg. Assuming a grain consumption of 2.5% of body weight and an average weight of 510 kg, a throughput of 65,000 head would require 82,500 tonnes of grain per year, assuming that all the grain was sourced locally. There is an assumption that the hay required (10% of diet) would also be grown locally, using independent small-scale irrigation operations on beef enterprises.

The outline of this case study is as follows.

- Section 8.3 describes the soils of the case study area.
- Section 8.4 describes the suitability of the climate for growing sorghum (grain) near Cloncurry.
- Section 8.5 describes the configuration of the irrigation scheme developments and cropping systems.
- Section 8.6 describes two financial analyses.
  - The first (in Section 8.6.1) surveys a range of different combinations of (i) the ‘scheme area’ (the area of the irrigation development), and (ii) planted crop area based on a crop area decision. These combinations were assessed with respect to crop yield, financial outcomes, and production and economic risk.
  - The second (in Section 8.6.2) undertakes a more detailed assessment of the profitability at the scheme and farm scale for a single combination of scheme area and crop area decision.
- Section 8.7 describes some potential on-site and off-site impacts associated with the scheme area selected in Section 8.6.2.

The case study area is shown in Figure 8.2. To provide a sense of scale and an indicative sense of place, a potential irrigation development of 12,000 ha is delineated. Before irrigation development, the area would require more intensive assessment of usable areas and the effect of irrigation on watertable level.
Figure 8.2 (a) Satellite map and (b) relief map of the area surrounding Cave Hill dam. The red rectangle on the inset map of the Flinders catchment indicates the location of the case study area. Locations of streamflow gauging stations are approximate.
8.3 Soils near Cloncurry

The potential Cave Hill dam site is a natural constriction of the Cloncurry River, 20 km upstream of Cloncurry. At the dam site, the river has eroded through a ridge in the very old metamorphic geology surrounding the area. The soils near Cloncurry and the case study area are shown by the soil generic group map in Figure 8.3a and described below. Figure 8.3b shows a land suitability map for sorghum (grain) under spray irrigation.

Downstream of the proposed dam site, and as far as approximately 18 km downstream of Cloncurry, are moderately wide (1 to 2 km) alluvial plains on both sides of the river. At this point, the relatively narrow alluvial plains emerge from the surrounding undulating hills to form very broad alluvial plains. The rocky hills that bound the plain are dominated by very shallow, stony soils with no potential for irrigation development.

Approximately 4400 ha of soils adjacent to the river channel are very deep, well-drained, sandy, red-coloured massive soils and sandy-surfaced soils with moderately permeable clay subsoils (corresponding to friable non-cracking clay or clay loam soils). These highly permeable to moderately permeable soils are well suited to horticultural crops that can withstand occasional flooding. In the arid climate around Cloncurry, these soils are severely wind eroded but are still potentially suited to horticulture. Crops could help prevent wind erosion by providing ground cover.

The plains further from the river are dominated by about 6660 ha of texture contrast soils with a sandy surface over well-drained, slowly permeable, dispersible clay subsoils (these correspond to sand or loam over sodic/intractable clay). Very severe wind erosion has removed much of the sandy topsoil, resulting in scalded clay soils that are difficult to manage. These soils have limited development potential because of surface sealing, which makes plant establishment and water infiltration difficult. Furrow- or spray-irrigated crops may be possible with soil conditioners (such as gypsum incorporated into the soil surface or through application in the irrigation water). However, the relatively narrow and dissected nature of the land makes cropping of large areas difficult. Wind erosion of cropped areas will continue to be a problem because of the cultivation and fallow periods necessary for irrigated crops. These sandy soils continue the full length of the Cloncurry River.

The broader alluvial plains from 18 km downstream of Cloncurry are quite extensive (approximately 33,850 ha) and have a complex distribution of moderately well-drained, slowly permeable, brown cracking clay soils. The complex distribution is due to previous migration of the river over the broad plains. These soils are moderately suitable to a broad range of spray- or furrow-irrigated crops, and some horticultural crops that can withstand occasional flooding. Soils are also moderately suitable for construction of ring tanks for on-farm water storage. The main restriction is the complex distribution of soils, resulting in rather small areas of uniform profiles. These plains are frequently dissected by regularly flooded stream channels.

Further from either side of the Cloncurry River are approximately 26,230 ha of high-level, flood-free, moderately well-drained, very slowly permeable grey and brown cracking clays covering extensive alluvial plains. Dense gravel patches are common. These clay soils have restricted rooting depth and only a moderate water-holding capacity, as a result of very high salt levels in the subsoil. Large areas are suited to furrow- and spray-irrigated crops. Associated with the heavy clay soils are relatively small areas of loamy-surfaced, well-drained soils, with massive to structured clay subsoils. These soils are well suited to spray-irrigated horticultural crops, but gravel patches may be a restriction in some areas.

The potential irrigation development outlined in Figure 8.2 and Figure 8.3 predominantly comprises the friable clay loam soils and the cracking clay soils. Before irrigation development, the area would require more intensive assessment of usable areas. Figure 8.4 shows the landscape of the potential Cave Hill dam irrigation development.
Figure 8.3 (a) Soil generic group map and (b) land suitability map of the area surrounding Cave Hill dam for spray-irrigated sorghum (grain).

The land suitability map does not take into consideration flood risk or water availability. The red rectangle on the inset map of the Flinders catchment indicates the location of the case study area.
8.4 Climate suitability for sorghum (grain) at Cloncurry

The mean and median annual rainfall at Cloncurry under the historical climate (1890 to 2011) is 477 mm and 435 mm, respectively. Rainfall at Cloncurry is highly variable between years and also highly seasonal (Figure 8.5), with 78% of rain falling from December to March. Sorghum (grain) in northern Australia typically has a planting window between September and June. For Cloncurry, simulations used a representative soil with a plant available water capacity of 150 mm and the sorghum module of the Agricultural Production Systems Simulator (APSIM) crop model for a range of sowing dates (September to May). The simulations indicate that sowing in March on a relatively full soil water profile maximises grain production while minimising the amount of irrigation required to meet crop demand (Webster et al., 2013). The wet season has, by that time, progressed sufficiently that a good estimate of the dam water level can be made at the time of planting, and evaporative losses from the dam are minimised. Although median rainfall during a March sowing is relatively low (30 mm), wetter years on these high clay content soils may result in delayed crop establishment because of access problems for cultivation and planting machinery.

Sorghum is susceptible to frost and heat (greater than 40 °C) stress on pollen development during flowering (about 2 months after sowing), as well as water stress during grain development (about 3 months after sowing). A minimum soil temperature of 15 °C is required for seed germination. At Cloncurry, maximum air temperature during the case study growing season (March to August) is not a major limitation on crop development (Figure 8.6). The risk of frost during June to August is relatively low – the highest number of frost days occurs in July. Frost is experienced during July in 15% of years. Planting in March would usually avoid frost damage at development stages of flowering (May). Timing of crop establishment should consider the potential risk associated with frost during flowering or heat stress during grain filling, as well as crop demand for supplementary irrigation.
8.5 Configuration of irrigation developments and cropping systems

This section provides a description of the configuration of the irrigation developments and cropping systems associated with the Cave Hill dam. It provides information on Cave Hill dam, 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.

8.5.1 CAVE HILL DAM

The potential Cave Hill dam is an earth embankment dam (16 m high spillway) located on the Cloncurry River about 20 km upstream of Cloncurry. At this point, the river has a median annual flow of 95 GL (Table 8.1). Streamflow is highly variable between years (Figure 8.7).

The Cave Hill dam has a relatively large storage capacity (248 GL) compared with median annual flow but is shallow and would inundate parts of two stations and a large area of regional ecosystems ‘of concern’ (Section 5.2). More details on the dam can be found in Section 5.2. The coefficient of variation of annual streamflow provides a measure of the degree of variability in the system. For a given mean annual streamflow, the larger the variability in streamflow from one year to the next, the smaller the water yield

Figure 8.5 (a) Monthly rainfall and (b) monthly potential evaporation, under Scenario A at Cloncurry
Scenario A is the historical climate (1890 to 2011). The A range is the 20th to 80th percentile exceedance.

Figure 8.6 (a) Maximum monthly temperature and (b) minimum monthly temperature, under Scenario A at Cloncurry
Scenario A is the historical climate (1890 to 2011). The A range is the 20th to 80th percentile exceedance.
from the dam. The Cloncurry River is about two to three times more variable than other rivers in the world that have a similar climate and mean annual streamflow (Petheram et al., 2008).

Table 8.1 Streamflow on the Cloncurry River at the Cave Hill dam site

<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>Cloncurry River</td>
<td>1487</td>
<td>318</td>
<td>95</td>
<td>21</td>
<td>0</td>
<td>187</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Figure 8.7 Annual streamflow at the Cave Hill dam site under Scenario A

A consequence of the topography and high annual variability in streamflow at the site is that the water yield at 85% reliability is relatively low (Table 8.2). The dam would cost about $249 million, with estimates ranging between $225 million and $375 million (see companion technical report about water storage options (Petheram et al., 2013)).

Although Cave Hill is the most promising dam location in the Cloncurry area, considerable geological uncertainties with the site would need to be investigated (Section 5.2).

Table 8.2 Parameters for Cave Hill dam

<table>
<thead>
<tr>
<th>TYPE OF DAM</th>
<th>CATCHMENT AREA (km²)</th>
<th>SPILLWAY HEIGHT (m)</th>
<th>CAPACITY (GL)</th>
<th>FULL SUPPLY LEVEL (mEGM96)</th>
<th>WATER YIELD* (GL)</th>
<th>COST** ($ million)</th>
<th>UNIT COST*** ($/ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth embankment</td>
<td>5264</td>
<td>16</td>
<td>248</td>
<td>224</td>
<td>40</td>
<td>$249</td>
<td>$6200</td>
</tr>
</tbody>
</table>

* 85% annual time-based reliability using a perennial demand pattern for the baseline model under Scenario A. This is water yield at the dam wall (i.e. does not take into account distribution losses or downstream transmission losses). These water 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.
8.5.2 CONFIGURATION AND COSTS FOR WATER SUPPLY AND IRRIGATION DEVELOPMENT

Configuration for water supply and irrigation development

Under this nominal configuration, water would be released from the Cave Hill dam to a re-regulating structure 50 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 200-m-wide, 3-m-high sheet piling weir would need to be constructed (Section 5.2). Because the banks of the Cloncurry River are relatively low, the weir would have limited storage capacity (i.e. less than 1500 ML) and would primarily serve as a pool from which to pump. Constructing a sheet piling weir in the Cloncurry River and maintaining its ongoing operation is likely to be challenging.

Water would be pumped from upstream of the weir (assuming a 10-m head requirement) into a main distribution channel on the left bank. To ensure an effective riparian zone, the potential irrigation development is situated 1 km from the Cloncurry River.

Irrigation water is assumed to be distributed within a farm (i.e. from the farm gate to the field) using open channels. On-farm storages are sometimes used to improve the efficiency of supply of water from the farm gate to the field. For this development, it is assumed that there is minimal need for on-farm storage because of the relatively close proximity to the weir. Once at the field, water is applied using spray irrigation – more specifically, lateral move sprinklers. Lateral move sprinklers are used to optimise irrigation productivity from the limited water supply and minimise accessions to groundwater, which have the potential to cause secondary salinity problems in the area. Well-managed spray irrigation generates very little tailwater runoff (i.e. water leaving the field following an irrigation event), except during large rainfall events, which may occur immediately after irrigation on full soil profiles. In this case study, irrigation occurs during the dry season, and it is assumed that there is no need for on-farm tailwater recycling and on-farm water storages.

Runoff generated from heavy rainfall events during the wet season would not be captured. Instead, it would be allowed to run off into neighbouring areas that are not being irrigated, or directed back into the river system if water quality parameters were met.

Table 8.3 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 56%. These values are likely to represent best practice.

Table 8.3 Assumed conveyance efficiencies for the irrigation development associated with the Cave Hill dam

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>EFFICIENCY (%)</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>River conveyance efficiency</td>
<td>75%</td>
<td>Distance between dam and re-regulating structure is about 50 km. Long distance, relatively low volumes. The advantage is that the first releases of water occur towards the end of the wet season when the bedsands are already near saturation</td>
</tr>
<tr>
<td>Channel distribution efficiency</td>
<td>90%</td>
<td>Representative of evaporation loss from re-regulation structure and channel loss between river and farm gate. Assumed best practice</td>
</tr>
<tr>
<td>On-farm distribution efficiency</td>
<td>97%</td>
<td>Representative of on-farm evaporation and seepage loss from farm gate to edge of field. Assumed best practice</td>
</tr>
<tr>
<td>Field application efficiency (spray)</td>
<td>85%</td>
<td>Lateral move sprinklers</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>56%</td>
<td></td>
</tr>
</tbody>
</table>
Costs for water supply and 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.

Currently an unsealed road (Sedan Dip Road) links the sealed Burke Development Road to the potential irrigation development (Figure 8.2b). 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, weir and pumping infrastructure. Inspection of digital elevation data and satellite imagery indicates that the topography in the vicinity of Sedan Dip Road is flat, with no creek crossings. This road would be relatively inexpensive to construct.

Indicative capital, operation and maintenance costs associated with the irrigation development are provided in Table 8.4. 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 hectare and per megalitre. 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 8.4 Scheme-scale and farm-scale costs for the irrigation development associated with the Cave Hill dam

<table>
<thead>
<tr>
<th>ITEM</th>
<th>LIFE SPAN</th>
<th>UNIT COST</th>
<th>UNIT</th>
<th>OPERATION AND MAINTENANCE COST</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(y)</td>
<td>($)</td>
<td></td>
<td>(%) capital costs</td>
<td></td>
</tr>
<tr>
<td>Scheme-scale costs: capital, operation and maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large dams</td>
<td>100</td>
<td>$249,000,000</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>50</td>
<td>$37,000,000</td>
<td>*</td>
<td>1%</td>
<td>200-m-wide, 3-m-high sheet piling weir</td>
</tr>
<tr>
<td>Main access roads</td>
<td>100</td>
<td>$6,300,000</td>
<td>*</td>
<td>1%</td>
<td>Upgrade 20 km of unsealed road to sealed (flat, no bridges). Nominal cost $315,000/km</td>
</tr>
<tr>
<td>Main supply channels</td>
<td>40</td>
<td>$7,850,000</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 years), earthworks, structures, overheads, contingency and corporate profit</td>
</tr>
<tr>
<td>Pump capital cost (river to channel)</td>
<td>16</td>
<td>$250</td>
<td>ha</td>
<td>2%</td>
<td>Cost required for pumping capacity to exceed peak daily evaporative demand for the scheme area</td>
</tr>
<tr>
<td>Pump energy cost (river to channel)</td>
<td>na</td>
<td>$16</td>
<td>ML</td>
<td>na</td>
<td>Assuming 10 m head requirement and pump operated on diesel</td>
</tr>
<tr>
<td>Scheme-scale costs: approvals</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 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>Farm-scale costs: capital</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>Based on $580,000 expenditure per 500-ha farm</td>
</tr>
<tr>
<td>Farm equipment</td>
<td>15</td>
<td>$1,160</td>
<td>ha</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>Farm-scale costs: operation</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>na</td>
<td>Includes maintenance costs, employee costs, land lease and other additional business overheads</td>
</tr>
</tbody>
</table>

na = not applicable
* These fixed costs are independent of the size of the irrigation development.
** Operation and maintenance costs are captured in farm-scale cost overheads.

Critical infrastructure

Critical infrastructure can enable greenfield irrigation developments. Investment can be limited by the absence of hard infrastructure (such as roads and energy) and community infrastructure (such as schools and housing), which are required to support large irrigation developments and the people who work there. Table 8.5 summarises critical infrastructure in the Cloncurry area. Processing infrastructure is likely to be the greatest impediment to development, and the range of requirements for hard and community infrastructure in the Cloncurry area appears unlikely to be a major barrier to small- to medium-size irrigation developments.
### Table 8.5 Critical infrastructure in the Cloncurry area

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Community infrastructure</strong></td>
<td>General: Any population increases attributable to irrigated grain would be expected to be small and accommodated within existing community infrastructure. Processing facilities (feedlots and/or abattoir) require labour that would increase the town’s population. The infrastructure capacity may therefore require review.</td>
</tr>
<tr>
<td>Schools</td>
<td>Cloncurry has a primary school with 332 enrolments. The nearest secondary school is Richmond, approximately 290 km away.</td>
</tr>
<tr>
<td>Hospital</td>
<td>Cloncurry has a small hospital (capacity of less than 50 beds).</td>
</tr>
<tr>
<td>Housing</td>
<td>Cloncurry 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>Chinaman Creek dam is the town’s main water supply. Aside from crop irrigation, increased demand for water would be driven by the feedlot and abattoir requirements, and any residential population growth. Currently, water in the Flinders River is pumped into Chinaman Creek dam. Rural domestic water use in a dry climate is 60 to 80 L per person per day (Glieck, 1996). For an added 100 people, this translates to about 3 ML per year, four orders of magnitude less than the water yield from Cave Hill dam.</td>
</tr>
<tr>
<td><strong>Hard infrastructure</strong></td>
<td>Roads: Cloncurry is situated on the Flinders Highway, linking Townsville and Mount Isa.</td>
</tr>
<tr>
<td></td>
<td>Rail: A railway links Cloncurry to Townsville. Its capacity is restricted; it is a single line track with multiple crossing loops. The track is mostly used for minerals, although two trains are scheduled per week for cattle transport to Townsville and Brisbane.</td>
</tr>
<tr>
<td></td>
<td>Energy: The electricity network is maintained by Ergon Energy. Cloncurry is serviced by a 66/11-kV substation, although the available capacity is not available.</td>
</tr>
<tr>
<td></td>
<td>Port: Not applicable, as it is assumed that grain is consumed locally in feedlot operations. Alternatively, grain is assumed to be delivered to the Burdekin region – 800 km east – for handling and marketing, at an estimated cost of $65/t to the local grower.</td>
</tr>
<tr>
<td><strong>Processing infrastructure</strong></td>
<td>Feedlot, abattoir: The processing infrastructure for this development does not currently exist: no active, registered feedlots are in the Flinders catchment, and no substantial inland beef processing plants currently serve northern Australia. The closest export-certified meatworks are at Townsville.</td>
</tr>
</tbody>
</table>

#### 8.5.3 APPLIED IRRIGATION WATER, CROP YIELD AND PRODUCTION RISKS

Applied irrigation water and crop yield for sorghum (grain) were simulated using the APSIM sorghum module and a soil representative of the Cloncurry area. Figure 8.8 illustrates the relationship between these two values, assuming perfect irrigation timing (i.e. no losses). For sorghum (grain), average crop yields greater than 8 t/ha are possible under full irrigation (4 ML/ha). Water applications greater than 4 ML/ha (400 mm) do not result in a higher crop yield, because the crop does not require any more water. At water applications less than 4 ML/ha, the crop becomes increasingly water stressed, and crop yields decrease, because the amount of water applied is insufficient to meet the crop water requirements.

The APSIM results presented in Figure 8.8 are representative of the production potential (i.e. nutrients are not limiting, and there is no damage to the crop due to disease, pests, poor irrigation management or farming practices). The APSIM crop yields represent an upper limit; actual yields are likely to be lower and to vary considerably from year to year.
Figure 8.8 Crop yield versus applied irrigation water under Scenario A for sorghum (grain) in the Cloncurry area. Crop is planted 15 March. Figures are representative of the production potential (i.e. assumes no nutrient limitations or pest damage) and assumes perfect irrigation timing (i.e. no losses). Scenario A is the historical climate (1890 to 2011). The range is the 20th to 80th percentile exceedance.

Production risks

It is very important to recognise that actual on-farm crop yields are highly dependent on the critically important – yet difficult to define – trait of ‘management skill’, the process by which the best decisions and actions occur at the best times. This grows with experience and, until it reaches a high level, the challenges associated with the relative lack of cropping experience in the Assessment area should not be underestimated. Until a pool of expertise develops and builds over several years, with the growing ability to anticipate challenges that first need to be experienced (such as pest and disease pressures), actual crop yields would be expected to be significantly lower than potential crop yields. The difference between actual and potential crop yields, often referred to as the ‘yield gap’, usually closes slowly over time, and this needs to be factored into individual enterprise and regional development plans.

8.6 Financial analysis

This section addresses crop yields, crop gross margins (based on feed grain sales), and financial analysis at both farm scale and scheme scale.

The 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 changes the underlying assumption to the investor being a water purchaser from scheme water suppliers who bear the scheme 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 and maintenance costs or capital costs through water charges.

All financial analyses in this section are reported in 30-year 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 windows is 92. For example, the first 30-year window is 1891 to 1920, and values are calculated over this window. The second window is 1892 to 1921, and a second set of values is calculated over this window. This sampling – and subsequent calculating – was repeated 92 times in total, with the final window corresponding to the period from 1981 to 2011. The median value from calculations for each of the 92 windows is presented. A straight-line depreciation approach was used to calculate the residual value of long-life infrastructure (i.e. infrastructure with a service life of more than 30 years). This is
a generous assumption over the alternative, which is to assume that the infrastructure has no value at the end of the investment period.

Two commonly used terms in this section are ‘scheme area’ and ‘crop area decision’. Scheme area refers to the size of the irrigation development and represents the maximum area that can be planted in any one year. Crop area decision is an annual crop water allocation (e.g. 3 ML/ha) and is used to explore the profitability of different levels of combined physical and financial risk. At sowing, the area planted is nominally equal to the water in the storage minus conveyance and application losses, divided by the crop area decision. This means that, for a given volume of water in the storage, the lower the crop area decision, the larger the area that could be planted. It follows that a 2-ML/ha crop area decision will result in a larger area planted than a 4-ML/ha decision. The actual amount of water needed by the crop will be determined by the crop water requirements and climate during the growing season. It is independent of the crop area decision. The greater the divergence of the crop area decision below the actual crop water requirement, the higher the risk of crop failure. The greater the divergence of the crop area decision above the actual crop water requirement, the more water is stored in the reservoir for the following year.

Two financial analyses are presented. The first analysis (in Section 8.6.1) explores an appropriate scheme area for the irrigation development and an appropriate level of (farmer) risk in terms of area planted each year, given knowledge of the water storage at the time of sowing. The results are presented as contour plots of scheme area and crop area decision (see Section 8.6.1). It is assumed that land is not a constraint and that all capital costs were incurred in the first year.

In the second analysis (in Section 8.6.2), a single combination of scheme area and crop area decision is selected, based on scheme- or farm-scale profitability, minimum size to support additional processing infrastructure (such as an abattoir in this case study), or the availability of suitable land.

8.6.1 DIFFERENT COMBINATIONS OF SCHEME AREA AND CROP AREA DECISION

Water supply, reservoir characteristics and changes in downstream flow

Figure 8.9 and Figure 8.10 present information on mean and median annual applied irrigation water, respectively. These figures were generated by calculating this value for different combinations of scheme area and crop area decision, and then presenting the information as a contour plot. The different shades of blue and red indicate different amounts of applied irrigation water, as indicated by the legend on the right side of the plot. For example, in Figure 8.9a, for a scheme area of 40,000 ha and a crop area decision of 6 ML/ha, the mean annual applied irrigation is about 38,000 ML. Many figures in this section are of this form.

The larger the scheme area and the lower the crop area decision, the larger the total volume of water supplied to and used by the irrigation development (Figure 8.9a), but the smaller the amount of water applied per hectare of planted area (Figure 8.9b).
Figure 8.9 Mean annual applied irrigation water supplied to the field in (a) ML and (b) ML/ha under Scenario B for the irrigation development associated with the Cave Hill dam. Results are presented as a function of scheme area and crop area decision. 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 8.10 (a) Median annual applied irrigation water supplied to the field and (b) percentage of years that the maximum area is planted under Scenario B for the irrigation development associated with the Cave Hill dam. Results are presented as a function of scheme area and crop area decision. 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.

The median annual water supplied is highest across most crop area decisions for scheme areas between 8,000 ha and 16,000 ha. Figure 8.10b illustrates the percentage of years that the entire scheme area is planted. Lower crop area decisions result in the scheme area being more fully planted in more years.

Figure 8.11 presents the ratio of water lost to evaporation to water supplied at the dam wall. At low scheme areas, water is not fully used, and a large amount of water is lost to evaporation when water is carried over into the following year. At high scheme areas and low crop area decisions, 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).
Figure 8.11 Ratio of evaporation from the reservoir to the applied irrigation water under Scenario B for the irrigation development associated with the Cave Hill dam. Results are presented as a function of scheme area and crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 8.12 (a) Percentage of time the volume of the reservoir is less than dead storage volume and (b) percentage of time the volume of the reservoir is less than 20% of the full supply level volume under Scenario B for the irrigation development associated with the Cave Hill dam. Results are presented as a function of scheme area and crop area decision. 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 8.12 shows the percentage of time that the Cave Hill dam reservoir is less than dead storage volume and less than 20% of its full supply level (FSL) volume. When the dam volume is below the dead storage volume, it is unable to supply water. Figure 8.12b can be used as an indication of the recreational amenity of the reservoir. For example, for scheme areas greater than 30,000 ha and crop area decisions less than 6 ML/ha, the reservoir is less than 20% full nearly 80% of the time. A figure of 20% of the FSL volume corresponds to a depth of about 9 m at the dam wall and 37% of the reservoir FSL surface area. In these circumstances, there may be reduced opportunity to use the reservoir recreationally.

Figure 8.13 illustrates the mean annual streamflow quotient at a streamflow gauging station between the dam and the irrigation development (915203A) and near the mouth of the Flinders River (915003A). This
provides an indication of the extent to which the mean annual streamflow would change under irrigation for different combinations of scheme area and crop area decision. For small scheme areas there are moderate changes to the mean annual streamflow at station 915203A (Figure 8.13a) because water is held in the reservoir and some is consequently lost to evaporation. For large scheme areas and small crop area decisions the change in mean annual streamflow is small because water is immediately released to irrigate large planted areas and consequently little water in the reservoir is lost to evaporation. Very little change in mean annual streamflow occurs at the mouth of the Flinders River (Figure 8.13b) because the catchment of the Cave Hill dam is small relative to the entire Flinders catchment.

![Figure 8.13 Mean annual streamflow quotient at (a) gauge 915203A and (b) gauge 915003A for the irrigation development associated with the Cave Hill dam](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 8.2.

**Crop yield**

Total crop yields from a scheme area are highest for larger scheme areas and smaller crop area decisions. This is because, in the years the reservoir is full or nearly full, the planted area is less constrained by the scheme area. It also occurs because reducing water to the crop by 50% (from the full median requirement of 4 ML/ha to 2 ML/ha) reduces crop yield by only 25% (Figure 8.14a). The highest total yields from a scheme are attained at higher levels of risk—the variability in 30-year crop yields is high at large scheme areas and low crop area decisions (i.e. the risk is high; see Figure 8.14b).

The higher crop yields and higher variability for larger scheme areas are illustrated in Figure 8.15 with three combinations of scheme area and crop area decision shown by the circles in Figure 8.14a. Although the 6000-ha 6.72-ML combination has the lowest total crop yield, there is usually sufficient water in the dam to ensure that there is not a complete crop failure. An irrigation development with a 40,000-ha 1.12-ML combination is unlikely to be able to provide drought relief because there will be no water in the storage in the dry years; it all would have been used in the previous season.
Figure 8.14 (a) Median of the 30-year mean values (M30M) 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 Cave Hill dam. Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows in the period 1890 to 2011. The median and the standard deviation of the mean values for each of the 92 windows are presented. Circles in (a) indicate the time series selected for demonstrating the variability in crop yield presented in Figure 8.15.

Figure 8.15 Annual crop yield from the irrigation development under Scenario B for three different scheme areas. The specific yield (i.e. yield per hectare planted) decreases with lower crop area decision, because at low crop area decisions sorghum crops are more often under water stress and have lower yields (Figure 8.16a).

Section 8.2 identified that supporting a 65,000-head feedlot would require about 82,500 t of grain per year. Assuming this grain is to be locally sourced, the percentage of years that 82,500 t of grain is exceeded for different scheme area and crop area decisions is presented in Figure 8.16b. Scheme areas less than 8000 ha never achieve 82,500 t of grain per year (Figure 8.16b). At high crop area decisions (i.e. greater than 4 ML/ha), the crop yields per hectare are high, but the annual area planted is too low to regularly exceed 82,500 t. For high scheme areas (e.g. greater than 30,000 ha) and low crop area decisions (i.e. less than 4 ML/ha), even though the planted areas are often high, the specific crop yield is such that 82,500 t is only exceeded in about 50% of years.
The combination that results in grain yields exceeding 82,500 t most often (approximately 70%) is a scheme area of about 12,000 ha and a crop area decision of 2 to 4 ML/ha (Figure 8.16b). Under this best-bet regime, the 82,500-t target of scheme-level grain production is not achieved in 3 years in 10. This may have implications for the longer-term profitability of a combined irrigation, feedlot fattening and abattoir system. However, the abattoir will not be solely dependent on finishing cattle because other classes of cattle will contribute to the 100,000-head annual throughput.

The years in which grain production does not reach 82,500 t are generally below average in rainfall. Rangeland pasture production will also be below average in those years, meaning that there are likely to be more cattle needing to be sold and processed in response to forage deficits in grazed pastures.

![Figure 8.16](image-url) (a) Median of the 30-year mean values (M30M) for specific yield and (b) percentage of time 82,500 t of grain is exceeded under Scenario B for the irrigation development associated with the Cave Hill dam. Results are presented as a function of scheme area and crop area decision. Specific yield is crop yield per hectare planted. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows in the period 1890 to 2011. The median of the mean values for each of the 92 windows is presented.

**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 directly in proportion to the output of a crop enterprise. They include irrigation operating costs that vary in proportion to the volume of water used on-farm (e.g. pumping costs), as well as other crop inputs and management operations, 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 (pumping costs, however, are included). 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 8.6 lists the key assumptions in the gross margin calculations for sorghum (grain) 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 8.6 Key assumptions in the gross margin calculations for sorghum (grain) for the irrigation development associated with the Cave Hill dam

<table>
<thead>
<tr>
<th>KEY ASSUMPTIONS</th>
<th>VALUE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>$230/t or $300/t</td>
<td>$230/t is the default price, and $300/t is the high price investigated</td>
</tr>
</tbody>
</table>

**Variable costs**

| Freight to depot | $2.35/t | Assumes local delivery to feedlot |
| Pumping cost     | $58.90/ML | Spray irrigation, diesel |
| Other            | $973/ha | Includes fertilisers, pesticides, harvesting costs, planting and all other variable costs. Details provided in Brennan McKellar et al. (2013) |

Low crop yields per hectare result in low gross margins per hectare. However, low gross margins per hectare over a large planted area (e.g. scheme area of 40,000 ha and crop area decision of 4 ML/ha) can result in higher total gross margins from the scheme area than a high gross margin per hectare occurring over a smaller planted area (e.g. scheme area of 10,000 ha and crop area decision of 8 ML/ha). Negative gross margins occur under a small set of circumstances, when yields are too low to generate income sufficient to cover the variable costs (Figure 8.17a).

Median 30-year average scheme-scale gross margins increase with scheme area up to the size at which the scheme area no longer constrains the planted area. Gross margins remain the same for larger scheme areas. The largest scheme-scale crop gross margins occur at a crop area decision of between 3 and 4 ML/ha and at a scheme area of about 40,000 ha (Figure 8.17a).

![Figure 8.17](image-url) (a) Median of the 30-year mean values (M30M) for gross margin and (b) median of the 30-year mean values for gross margin per hectare under Scenario B for the irrigation development associated with the Cave Hill dam.

Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows in the period 1890 to 2011.

**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 over this period are subtracted from the benefits to give a net benefit stream, a discount rate of 7% is applied to
yield an NPV for the development. A zero or positive NPV 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, operation 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 the 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 area and crop area decision, 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 over the life of the investment (Figure 8.18a). Losses are minimised by not undertaking an irrigation development.

Figure 8.18 (a) Median of the 30-year net present values and (b) standard deviation of the 30-year net present values under Scenario B for the irrigation development associated with the Cave Hill dam

Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows in the period 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 farm-scale NPV is positive.

In this case study, the total crop gross margin from the scheme is not sufficient to cover the capital and overhead costs over the duration of the investment period, for any combination of scheme area and crop area decision (Figure 8.19).
Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows in the period 1890 to 2011. The median and the standard deviation of the mean values for each of the 92 windows are presented.

### 8.6.2 DETAILED ANALYSIS FOR A GIVEN SCHEME AREA AND CROP AREA DECISION

Since the proposed irrigation development is unlikely to be profitable at both the scheme and farm scale, the minimum size of scheme required to maintain a feedlot supplying an abattoir is now investigated. The scheme area that exceeds 82,500 t of grain most often is about 12,000 ha, with a crop area decision of 2 to 4 ML/ha. For this more detailed investigation, a scheme area of 12,000 ha and a crop area decision of 4 ML/ha was therefore selected.

For this analysis, construction costs were staged over the first 3 years of the 30-year investment time period (Table 8.7). This is likely to be a more realistic assumption than assuming that all costs are incurred and full revenue is attained in the first year. In this case study and for the selected scheme area staging construction costs is about 7% more profitable than not staging. Small differences in the NPV calculations in Section 8.6.1 and Section 8.6.2 are due to differences in staging and differences in the methods for predicting crop yield (see Chapter 2).

#### Table 8.7 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, and 100% approvals and legal costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>50% dam costs and 50% area works 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 8.20a is a time series of annual gross margins ($/ha) for each year of the 121-year historical climate data, assuming two prices for sorghum (grain). Figure 8.20b shows the range, as well as the 25th percentile, 50th percentile (median) and 75th percentile values of gross margins for each price. The large difference between the 75th percentile and the minimum gross margin indicates that a relatively small number of very
low gross margins were simulated. At the $230/t price, the gross margins exceed $328/ha in 75% of the years, $666/ha in 50% of the years, and $730/ha in 25% of the years. At the $300/t price, the gross margins exceed $790/ha in 75% of the years, $1231/ha in 50% of the years, and $1324/ha in 25% of the years.

![Figure 8.20](image)

Figure 8.20 Gross margins for sorghum (grain) under Scenario B for the irrigation development associated with the Cave Hill dam, with a scheme area of 12,000 ha and crop area decision of 4 ML/ha: (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 sorghum (grain) ($230/t) and the highest price paid in the past 10 years ($300/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.

Variability is a notable feature of this analysis, and this takes on further importance when it is considered that the analysis has been performed with a constant commodity price and that the variability is yield driven in response only to variations in climate and water availability (i.e. through streamflow). In reality, the effect of variability in commodity prices and production risks (e.g. pests, disease, flooding and access) combined with yield variability (due to variations in climate and water availability) is to increase the modelled variability in gross margin in Figure 8.20. The gross margin of sorghum, in particular, is sensitive to price movements. The 30% increase in price from $230/t to $300/t (Table 8.6) results in the median gross margin almost doubling. To put this in context, sorghum (grain) prices for domestic sales ranged from $197/t to $289/t, and from $248/t to $290/t for export sales, between 2011 and 2013 (ABARES, 2013); this corresponds to price increases above the lower of the two prices of 46% and 17%, respectively. These price movements have occurred in a period of overall high prices, compared with prices before the commodity price spikes that commenced in 2008.

A range of other costs could also affect the gross margin. For example, if sorghum (grain) was not supplied to local buyers, as much as $65/t would need to be deducted from crop returns to account for the cost of transport as far as the Burdekin region, approximately 800 km to the east.

The gross margins presented in Figure 8.20 do not include a water charge ($/ML). This is, however, another cost that would be expected to be reflected in the gross margin if water was supplied from off-farm interests.

**Scheme-scale analysis**

Using the 121-year distribution of simulated gross margin outcomes presented in Figure 8.20, 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 IRR 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.

The 92 30-year NPV and IRR values are presented in Figure 8.21 as percentage exceedance plots. All of the NPVs are negative (Figure 8.21a), ranging from −$470 million to −$510 million for the $230/t price for sorghum (grain), and from −$395 million to −$460 million for the $300/t price. In other words, the costs of the investment exceed the income over the 30-year investment period for all 92 investment periods. Likewise, the IRR is negative in all cases (Figure 8.21b). To generate a positive NPV, at the specified discount rate of 7%, the price of sorghum (grain) would need to be $865/t.

The only reason for the difference in the 30-year NPV (and IRR) results is the sampled 30-year window of gross margins. The year-to-year variation in gross margins reflects the climate-driven year-to-year variability in crop yield and water availability. For any given price for sorghum (grain), the difference between the highest and lowest NPV (and IRR) is therefore driven by the underlying climate conditions. In the case of the $230/t price, the maximum NPV is 20% higher than the lowest NPV. Discounting increasingly degrades the value of net benefits the further into the future they are received; therefore, the timing of high- and low-yielding years can have a notable effect on the NPV and IRR (Section 6.3).

Figure 8.21 Percentage exceedance plots of (a) net present value and (b) internal rate of return under Scenario B for the scheme-scale irrigation development of 12,000 ha associated with the Cave Hill dam

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.

Farm-scale analysis

In the farm-scale analysis, all capital, operation and maintenance costs associated with the scheme-scale infrastructure are excluded from the analysis. Similar to the scheme-scale analysis, financial assessments are undertaken using 30-year windows.

The results in Figure 8.22 show that investment at this scale is not viable for either the $230/t or $300/t price for sorghum (grain) because all NPVs are negative. For the $230/t price and for the median 30-year NPV, the investor would require a payment of $309/ML to break even (i.e. an NPV of zero); for the $300/t price, the investor would require $151/ML. Therefore, investors in this case have no capacity to pay a water charge to help offset operation and maintenance costs of the scheme.
Figure 8.22 Percentage exceedance plots of net present value under Scenario B for the farm-scale irrigation development of 12,000 ha associated with the Cave Hill dam
This financial analysis includes all farm-scale capital and operating costs and income from crop gross margins. Values are for a 30-year investment period.

For the median 30-year NPV, the break-even price is $367/t. Even if this price is achieved, the presence of irrigated agricultural land near a potential abattoir site does not guarantee that this land will be used to produce cattle feed, in the form of fodder or grain. Investors will invariably choose to grow the most profitable irrigated crop. However, some land types within the precinct may be only suitable for cattle fodder crops, and some cash crops may have by-products suitable for cattle fodder (e.g. cottonseed cake).

8.7 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 the 12,000-ha irrigation development analysed in Section 8.6.2.

8.7.1 RISK OF RISE IN WATERTABLE LEVEL AND SECONDARY SALINI\protectsion\n
Based on the best available information, it is estimated that the watertable level under a 12,000-ha irrigation development near Cloncurry would rise to within 2 m of the ground surface within 10 to 20 years.

The rise in watertable level (Figure 8.23) was assessed using an analytical groundwater model developed as part of the Assessment. The irrigation development is assumed to commence 1 km from the river, allowing for a riparian buffer. Recharge is calculated using annual simulated irrigation and rainfall data under the historical climate. The parameters and their values used in the analytical model are listed in Table 8.8. No field-based measurements of aquifer parameters were available for this part of the Flinders catchment. The values in Table 8.8 are considered a likely range, based on bore log information (Section 2.2). For more detail, see the companion technical report about surface water – groundwater connectivity (Jolly et al., 2013).
Table 8.8 Range of parameter values used in analytical groundwater model

<table>
<thead>
<tr>
<th>AQUIFER PARAMETER</th>
<th>UNIT</th>
<th>VALUE</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer thickness</td>
<td>m</td>
<td>12</td>
<td>Based on bore logs in the vicinity of the case study area</td>
</tr>
<tr>
<td>Depth to groundwater</td>
<td>m</td>
<td>9</td>
<td>Based on bore logs in the vicinity of the case study area</td>
</tr>
<tr>
<td>Distance of irrigation development</td>
<td>km</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Recharge rate</td>
<td>mm/y</td>
<td>67, 118</td>
<td>Lower and higher estimate. Recharge as a result of both irrigation and rainfall</td>
</tr>
<tr>
<td>Saturated hydraulic conductivity (K)</td>
<td>m/day</td>
<td>1, 10, 100</td>
<td>Lower, middle and higher estimate. Higher estimate is thought to be unlikely for these soils and substrata</td>
</tr>
<tr>
<td>Specific yield</td>
<td></td>
<td>0.2</td>
<td>Only has bearing on rate of rise, not maximum rise</td>
</tr>
</tbody>
</table>

Figure 8.23 indicates that under the low (1 m/day) and middle (10 m/day) values for saturated hydraulic conductivity, the watertable level under the 12,000-ha irrigation development reaches within 2 m of the ground surface in 10 to 25 years, depending on the recharge rate.

For the higher estimate of saturated hydraulic conductivity (100 m/day), the drainage capacity of the aquifer is higher, which results in a slower rise in watertable level. For the lower and higher recharge rates, the watertable level would approach to within 2 m of the ground surface in about 20 to 50 years.

No information on salt concentrations in the soil or groundwater is available.

Any rise in watertable level is likely to mobilise soluble salts in the substrate and clay subsoils. This could potentially cause secondary salinisation when watertable levels rise to within 2 m of the ground surface. Watertable level is unlikely to rise in the friable loamy soils along the river bank due to their highly permeable substrate and close proximity to the river channel (Figure 8.3).

![Figure 8.23](image-url)

Figure 8.23 Change in depth to watertable for different values of saturated hydraulic conductivity (K): (a) low recharge rate of 67 mm/year and (b) high recharge rate of 118 mm/year

8.7.2 ECOLOGICAL, SOCIAL AND CULTURAL CONSIDERATIONS

Table 8.9 summarises the potential ecological, social and cultural considerations with respect to the 12,000-ha Cave Hill irrigation development of sorghum (grain) under spray irrigation.
Table 8.9 Summary of potential ecological, social and cultural considerations with respect to the 12,000-ha Cave Hill dam irrigation development

<table>
<thead>
<tr>
<th>ECOLOGICAL, SOCIAL AND CULTURAL 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 covers a large area of regional vegetation communities that are ‘Of concern’ and riparian vegetation that is ‘Endangered’ (Petheram et al., 2013). 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 3.5% (range between 0.5 and 7%) of the storage volume of Cave Hill reservoir will infill with sediment after 30 years, and 11.5% (range between 3 and 23%) of the storage volume will infill with sediment after 100 years (Tomkins, 2013).</td>
</tr>
<tr>
<td>Reservoir water quality</td>
<td>Under conditions where the reservoir is supplying 40 GL of water annual (at 85% annual time reliability), the risk of blue-green algal blooms is low. The water column is predicted to be generally mixed, and dissolved oxygen drawdown is unlikely to be a problem under most circumstances (Petheram et al., 2013).</td>
</tr>
<tr>
<td>Sediment, nutrient and pesticide loads from irrigation development</td>
<td>Suspended sediment and nitrogen loads in the Flinders River are not predicted to increase to a large extent under 12,000 ha of irrigated sorghum. Phosphorus loads are predicted to increase moderately (~17%) and are likely to result in some downstream impact (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>
<tr>
<td>Fish passage</td>
<td>The Cave Hill dam and weir will act as a local fish passage barrier but are beyond the maximum upstream extent of key fish species of high conservation value – freshwater sawfish, barramundi and giant whipray (Petheram et al., 2013). Nonetheless, they will both act as a barrier to the movement of other fish species, the majority of which make migratory movements for reproduction or to access newly inundated habitat. Given the location high in the catchment, the length of river affected is relatively small.</td>
</tr>
<tr>
<td>Freshwater and coastal aquatic ecology in response to flow alteration</td>
<td>In many years, the dam may trap a large proportion (over one-third) of streamflow. Early wet-season flows critical for the flushing of downstream waterholes are especially impacted by the dam. Loss or delay of wet-season floods is likely to result in changes in downstream form, increased sedimentation, and encroachment of vegetation into the stream channel, due to reduced flood scouring. Dry-season water releases from the reservoir to the re-regulating weir will create elevated flows early in the dry season. This reduction in wet-season flows and increase in dry-season flow alters natural seasonal patterns of river flow along the affected reach. It is likely that water quality will also be affected. Although unnatural, these releases may extend persistence of instream aquatic habitats. 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. However, because demand for water does not extend over the entire dry season, discharge drops to naturally very low levels over August through November; thus the reach downstream of the dam still retains its intermittent character, although intermittency lasts for a shorter period. The ecological consequences of this change are difficult to predict but unlikely to be great. Modelling of streamflow downstream of the dam under scenarios A and B (Holz et al., 2013) indicates that the mean and median annual flow is reduced by approximately 5 and 13%, respectively, at the nearest downstream gauging station (Cloncurry) and by less than 5% at the most downstream gauging station in the Flinders catchment (Walkers Bend); other flow metrics do not notably change. Using the relationships developed by Dutta et al. (2013) no notable differences in floodplain inundation extent and persistence are observed under scenarios A and B. The effect on other coastal ecosystems is not clear; this may require further consideration because this area is of substantial economic importance in the northern prawn fishery.</td>
</tr>
<tr>
<td>Terrestrial ecology</td>
<td>The effect on terrestrial ecology requires site-based assessment, including examination of existing terrestrial flora and fauna databases. The potential for localised salinisation within the irrigation site as a result of a raised watertable requires that attention be placed on best-practice irrigation methods. If salinisation were to occur it would be likely to impact on vegetation communities and ultimately on nearby freshwater habitats.</td>
</tr>
</tbody>
</table>
Table 8.9 Summary of potential ecological, social and cultural considerations with respect to the 12,000-ha Cave Hill dam irrigation development (continued)

<table>
<thead>
<tr>
<th>ECOLOGICAL, SOCIAL AND CULTURAL CONSIDERATIONS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impoundment ecology</td>
<td>The impoundment offers new, albeit unnatural, aquatic habitat in an otherwise relatively dry part of the catchment. Stocking programs of native fish species has successfully occurred in impoundments constructed elsewhere in the catchment. Careful consideration to which species are stocked needs to occur given that the reaches upstream of the proposed dam do not support barramundi, a popularly stocked, predatory, species.</td>
</tr>
<tr>
<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 and subsistence opportunities, including fish stocking may be possible depending on how often low water levels prevail and on the accessibility of the storage. Altered or diminished downstream flow may impact on economic, recreational, subsistence, amenity, and cultural values downstream (Barber, 2013).</td>
</tr>
<tr>
<td>Cultural heritage considerations</td>
<td>The area contains cultural heritage sites already registered in the DATSIMA database. The presence of existing registered sites and the results of wider archaeological investigations in the catchment indicate that the Cave Hill area is likely to contain a substantial number of Indigenous cultural sites, including archaeological pre-colonial sites. Further field surveys are required to assess the potential Aboriginal archaeological impact of works in this case study area. Any such investigation should be undertaken in consultation with the registered Aboriginal Parties, the Mitakoodi and the Kalkadoon peoples (McIntyre-Tamwoy et al., 2013).</td>
</tr>
</tbody>
</table>

8.8 References


Jolly I, Taylor A, Rassam D, Knight J, Davies P and Harrington G (2013) Surface water – groundwater connectivity. A technical report to the Australian Government from the CSIRO Flinders and Gilbert...
Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.


