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Part IV Economics of development and accompanying risks

Chapters 6 and 7 describe economic opportunities, constraints and risks for water development in the Darwin catchments. This information covers:

- economic opportunities and constraints (Chapter 6)
- a range of risks to development (Chapter 7).

6 Overview of economic opportunities and constraints

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Chapter 6 examines which types of opportunities for irrigated agriculture development in the Darwin catchments are most likely to be commercially viable. The chapter considers the costs of building new infrastructure (both within the scheme and beyond), the financial viability of different types of schemes (considered from an investor's perspective), and the regional economic impacts (the direct and flow-on effects for businesses across the catchment) (Figure 6-1).

The intention is not to provide a full economic analysis, but to focus on costs and benefits that are the subject of normal market transactions. Non-market impacts and risks are dealt with in chapters 3 and 7, but, given the often subjective and publicly contested nature of valuing such impacts, these are not converted to dollar amounts here. Commercial factors are likely to be one of the most important criteria in deciding between potential development opportunities. Those options that can be clearly identified as being commercially non-viable at the pre-feasibility stage could likely be deprioritised. More detailed and project-specific agronomic, ecological, social, cultural and regulatory assessments could then be focused on those opportunities identified as showing the most commercial promise.

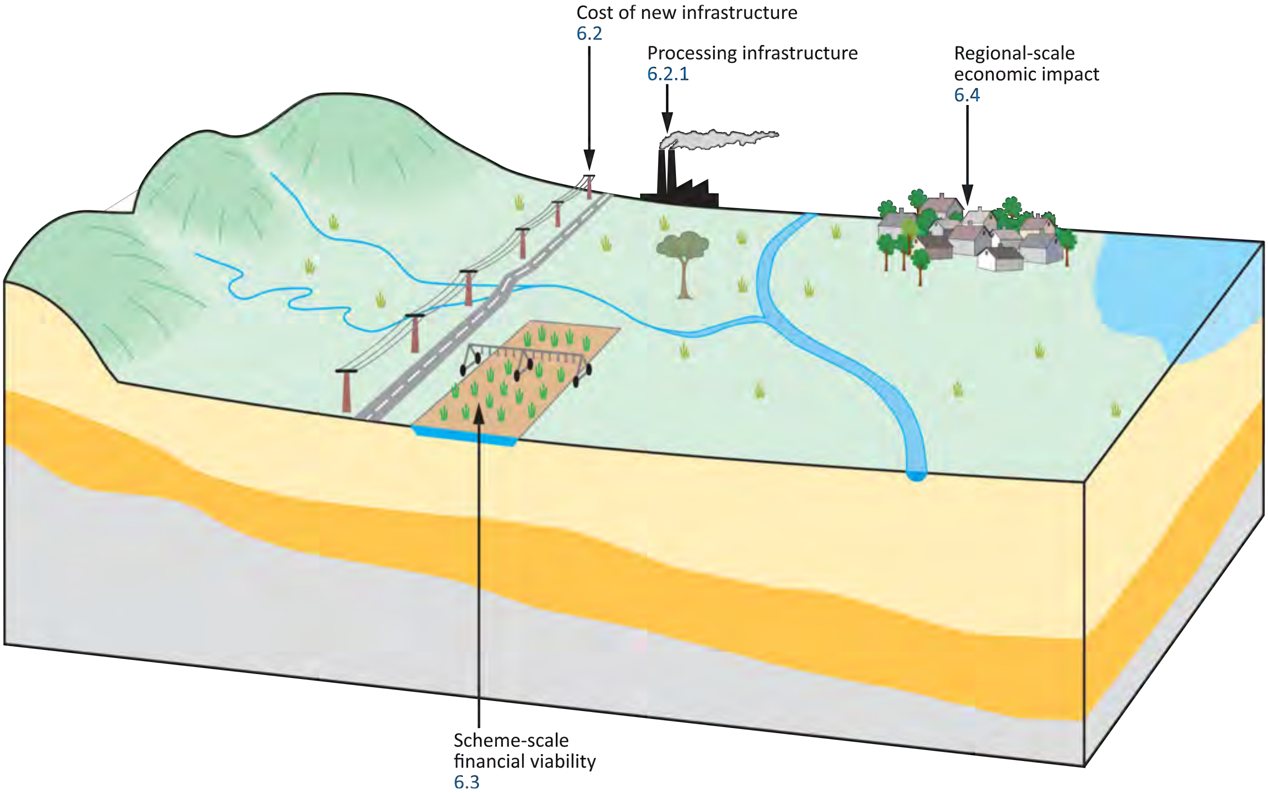

Figure 6-1 Schematic diagram of key components affecting the commercial viability of a potential greenfield irrigation development opportunity

6.1 Summary

6.1.1 KEY FINDINGS

Scheme-scale financial viability

Viable new irrigation development in the Darwin catchments would require challenging combinations of low-cost infrastructure, high-productivity farms, management of a wide range of risks, and/or off-farm value adding. The capital cost of development is the dominant factor affecting scheme viability. It is unlikely that farm gate revenue from irrigated broadacre agriculture alone would be sufficient to fully cover the development costs of irrigation schemes with capital costs above $15,000/ha (plus farm setup costs of about $7000/ha). Adding a processor to a scheme (i.e. vertical integration) could provide increases in revenues (from processed versus unprocessed goods) that are proportionally larger than the additional capital cost of the processing facility. This, or other off-farm, value-adding options, can assist in improving the commercial viability of a scheme, but can also add risk. Viable processors, particularly in remote locations, rely on secure supplies of raw farm commodities at scale. This requires upfront commitments from farmers supported by assured access to the required water and land.

Farm performance can be affected by a range of risks, including water reliability, climate variability, price fluctuations, and learning to adapt farming practices to new locations. Setbacks that occur early on after a scheme is established have the largest effect on scheme viability. There is a strong incentive to start any new irrigation development with well-proven crops and technologies, and to be thoroughly prepared for the anticipatable agronomic risks of establishing new farmland. Staging development can reduce some of the early learning risks. Risks that cannot be avoided need to be managed, mitigated where possible, and accounted for in determining the realistic returns that may be expected from a scheme, and the capital buffers that would be required.

Regional economic impacts

Justifying the costs of public investment in new water infrastructure and/or supporting community infrastructure in the Darwin catchments could well depend on indirect benefits beyond the irrigation scheme. It was found that during the initial construction phase of a new irrigation development in the Darwin catchments, there could be an additional $1.06 of indirect regional benefits, over and above the direct benefits of each dollar spent on construction within the local region. During the ongoing production phase of a new irrigation development, there could be an additional $0.46 to $1.82 of indirect regional benefits for each dollar of direct benefits from increased agricultural activity (gross revenue), depending on the type of agricultural industry. Indirect regional benefits would be reduced if there was leakage of some of the extra expenditure generated by a new development outside the catchment. Each $25 million increase in agricultural activity could create about 40 to 340 jobs, depending on the agricultural industry.

6.1.2 INTRODUCTION

Large infrastructure projects, such as new irrigation developments in the Darwin catchments, are complex and costly investments. The difficulty in accurately estimating costs and the chance of incurring unanticipated expenses during construction, or not meeting revenue projections when completed, means that there are risks to the viability of developments if they are not thoroughly planned and assessed. For example, in a global review of dam-based megaprojects, Ansar et al. (2014) found forecast costs were systematically biased downwards, with three-quarters of projects running over budget and the mean of actual costs almost double the initial estimates. In recent decades there has been growing emphasis in Australia on greater accountability and transparency in how water resources are managed and priced (e.g. the reforms under the National Water Commission (2004 to 2015)). Part of this shift has involved greater scrutiny of the commerciality of potential new dams.

Ultimately, economic factors are likely to be one of the most important criteria in deciding between potential development opportunities in the Darwin catchments. Ash et al. (2014), in an assessment of 13 agricultural developments in northern Australia, found that while the natural environments are challenging for agriculture, the most important factors determining the viability of developments were management, planning and finances. Even at a pre-feasibility stage, those options that can be clearly identified as being financially non-viable could likely be deprioritised, instead focusing expensive, more detailed and project-specific agronomic, ecological, social, cultural and regulatory assessments on more promising opportunities. This chapter aims to assist in planning and evaluating investments in large-scale irrigated development by highlighting the types of projects that are more likely to be commercially viable, quantifying the costs, benefits and risks involved. The intention is to provide a generic information resource that is broadly applicable to a range of irrigated agriculture development opportunities, rather than examining any specific options in detail. Results are presented in a way that allows readers to estimate whether particular projects they are interested in are likely to be commercially viable, using costs, risks and farm productivity specific to those particular opportunities.

Chapter 4 assessed the viability of new irrigated agriculture and aquaculture opportunities in the Darwin catchments at the enterprise level. Section 6.2 provides indicative costs for a variety of hard, post-processing and community infrastructure that may be required for large water and irrigation developments, beyond the costs presented in Chapter 5. Section 6.3 builds on this with a financial evaluation of new developments at the scheme scale (water infrastructure and associated new farms) from an investor’s perspective using a discounted cashflow framework. Section 6.4 then quantifies the regional economic impacts of irrigated development using regional input–output (I–O) analysis. Other non-market impacts were addressed in Chapter 3, and additional risks are discussed in Chapter 7.

6.2 New infrastructure costs

A range of infrastructure would be required to support development of a new irrigation scheme in the Darwin catchments, both within the scheme itself and beyond. Infrastructure can be considered ‘hard’ or ‘soft’, which within the context of a large irrigation development can be broadly defined as follows:

- Hard infrastructure refers to the physical assets necessary for the functioning of a development and can include water storage, roads, irrigation supply channels and energy, but also processing infrastructure, such as sugar mills, cotton gins, abattoirs and feedlots.
- Soft infrastructure refers to the specialised services required to maintain the economic, health, cultural and social standards of a population. They are indirect costs of a development and are usually less obvious than hard infrastructure costs. They can include expenses that continue after the construction of a development has been completed. Soft infrastructure can include:
  - physical assets, such as community infrastructure (e.g. schools, hospitals, housing)
  - non-physical assets, such as institutions, supporting rules and regulations, compensation packages, law enforcement and emergency services.

New processing infrastructure and community infrastructure are particularly pertinent to large, remote, greenfield developments, and these costs to other providers of infrastructure can be substantial even after a new irrigation scheme is developed. For example, a review of the Ord-East Kimberley Development Plan (for expansion of the Ord irrigation system by about 15,000 ha) found that there were additional costs of $114 million to the Western Australian Government, and $195 million to the Australian Government beyond the planned $220 million state investment in infrastructure to directly support the expansion (Western Australian Auditor General, 2016).

Given the systematic tendency of proponents of large infrastructure projects to substantially under estimate development costs (Wachs, 1990; Odeck and Skjeseth, 1995; Flyvbjerg et al., 2002; Ansar et al., 2014; Western Australian Auditor General, 2016), the purpose of this section is to provide a reference of component infrastructure cost estimates that are as unbiased as possible. The intention here is not to diminish the potential benefits of development and population growth in a region, but to highlight potentially overlooked costs that are required to realise those benefits.

6.2.1 COSTS OF HARD INFRASTRUCTURE

Establishing new irrigated agriculture in the Darwin catchments would involve the initial costs of developing water and land resources, and additional farm setup costs for equipment and facilities on each new farm. It may also involve costs associated with constructing processing facilities, extending electricity networks and upgrading road transport.

Costs of water storage and conveyance are provided in sections 5.3 and 5.4, respectively. Indicative costs for processing facilities are provided in Table 6-1 and indicative costs for roads and electricity infrastructure are provided in Table 6-2. Indicative costs for transporting goods to key markets are also listed (Table 6-3). All tables are summarised from information provided in the companion technical report on socio-economics (Stokes et al., 2017).

Table 6-1 Indicative costs of agricultural processing facilities

ITEM	CAPITAL COST	OPERATING COST	COMMENT
Meat works	$33 million	$315/head	Operational capacity 100,000 head/y
Cotton gin	$30 million	$1 million/y plus $22 to $30/bale	Operational capacity of 2000 bales/day Operating costs depend on scale of gin and source of energy
Sugar mill	$396 million	$33 million/y	Operational capacity of 1000 t cane/h, 6-month crushing season Basic mill producing sugar only (no electricity or ethanol)

Table 6-2 Indicative costs of road and electricity infrastructure

ITEM	CAPITAL COST	COMMENT
Roads		
Seal dirt road	$0.25 to $2 million/km	Upgrade and widen dirt road to sealed road
New floodway	about $20 million	Costs of bridges and floodways vary widely
Electricity		New generation capacity may also be required
Transmission lines	$0.4 to $1.1 million/km	High-voltage lines deliver bulk flow of electricity from generators over long distances
Distribution lines	$0.2 million/km	Lower-voltage lines distribute power from substations over shorter distances to end users
Substation	$10 to $50 million	Transformers and switchgear connect transmission and distribution networks

Table 6-3 Indicative road transport costs between Adelaide River and key markets and ports

DESTINATION	TRANSPORT COST ($/t)
Sydney	507
Darwin	17
Brisbane	429
Adelaide	323
Melbourne	451
Perth	448
Windham Port	88

6.2.2 COSTS OF SOFT INFRASTRUCTURE

The availability of community services and facilities would play an important role in attracting or deterring people from living in a new development in the Darwin catchments. If local populations increase as a result of new irrigated developments, then there would be increased demand for public services in the Darwin catchments, and provision of those services would need to be anticipated and planned. Indicative costs for constructing a range of different facilities that may be required to support population growth are listed in Table 6-4. Each 1000 people in Australia require 4.0 hospital beds served by 28 full-time equivalent hospital staff and $4.0 million/year funding to maintain current mean national levels of hospital service (AIHW, 2017). Health care services in remote locations generally focus on primary and some secondary care, while the broadest range of more specialised tertiary services are concentrated in referral hospitals that are mainly located in large cities but serve large surrounding areas. Primary schools tend to be smaller and more widespread, while larger secondary schools are more centralised.

Demand for community services is growing both from population increases in Australia and rising community expectations. New infrastructure that is built to service that demand would occur irrespective of any development in the Darwin catchments. However, if new irrigation projects shift some people to live in the Darwin catchments, this could then shift the locations of where some services are delivered and associated infrastructure is built. The costs of delivering services and building infrastructure is generally higher in more remote locations like the Darwin catchments. The net cost of any new infrastructure that is built to support development in the Darwin catchments is the difference in the cost of shifting some infrastructure to this more remote location (not the full cost of facilities (Table 6-4) that would otherwise have been built elsewhere).

Table 6-4 Indicative costs of community facilities

Costs are quoted for Darwin as a reference capital city for northern Australia. Costs in remote parts of northern Australia are estimated to be about 30 to 60% higher than those quoted for Darwin. School costs were estimated separately from a range of sources across northern Australia. See companion technical report on socio-economics (Stokes et al., 2017) for details.

ITEM	CAPITAL COST	COMMENT
Hospital	\$0.2 to \$0.5 million/bed	Higher end costs include major operating theatre and larger area of hospital per bed
School	\$25,000 to \$33,000 per student	Secondary schools tend to be larger and more centralised than primary schools
House (each)	\$485,000 to \$850,000	Single or double storey house
Unit (each)	\$260,000 to \$390,000	Unit, fewer than 10 stories, 90 to 120 m^2
Offices	\$2,200 to \$2,800/m^2	1 to 3 stories

6.3 Scheme-scale financial viability

Designing a new irrigation project in the Darwin catchments would require balancing a number of factors to find combinations that might collectively constitute a viable investment. Four key determinants of irrigation scheme financial performance examined here are:

1. capital cost of development (Section 6.3.2)
2. farm performance (Section 6.3.2)
3. risks (and associated required level of investment return) (Section 6.3.3)
4. value adding beyond the farm gate (Section 6.3.4).

Other assumptions were limited as much as possible, restricting these to factors with greater certainty and/or lower sensitivity, so that the principles derived would be as generalisable as possible.

A key finding of the irrigation scheme financial analyses is that no single factor is likely to provide a silver bullet to meet the substantial challenge of designing a commercially viable new irrigation scheme. Bridging the financial gap to viability would likely require contributions from each of the above factors, with careful selection to piece together a workable combination. The broad principles for balancing each of these factors are summarised below. However, to understand the discussions of how these factors influence irrigation scheme financial performance in the Darwin catchments, some background information is needed, and this is provided next.

6.3.1 DISCOUNTED CASHFLOW FRAMEWORK, TERMS AND ASSUMPTIONS

Scheme financial evaluations used a discounted cashflow framework to evaluate the commercial viability of irrigation developments. The framework, detailed in the companion technical report on socio-economics (Stokes et al., 2017), was intended to provide a purely financial evaluation of the conditions that would be required to produce an acceptable return from an investor's perspective. It is not a full economic evaluation of the costs and benefits to other industries, nor does it consider 'unpriced' impacts that are not the subject of normal market transactions, or the equity of how costs and benefits are distributed. For the discussion that follows, a scheme was taken to be all the costs and benefits from the development of the land and water resources to the produce leaving the farm gate.

Initially, a generic 'top-down' approach was taken, working backwards from the costs of developing a new irrigation scheme to determine the farm gross margins that would be required to make the investment commercially viable. This approach complements the 'bottom-up' approach to calculating indicative farm gross margins for different farming options in Chapter 4.

A discounted cashflow analysis considers the lifetime of costs and benefits following capital investment in a new project. Costs and benefits that occur at different times are expressed in constant real dollars, with a discount rate applied to streams of costs and benefits. This section explains the terminology and standard assumptions used.

The discount rate is the percentage by which future cost and benefits are discounted each year (compounded) to convert them to their equivalent present value (PV). A discount rate of 7% is typically used when evaluating public investments.

For an entire project, the net present value (NPV) can be calculated by subtracting the PV of the stream of all costs from the PV of the stream of all benefits. The benefit–cost ratio (BCR) of a project is the PV of all the benefits of a project divided by the PV of all the costs involved in achieving those benefits. To be commercially viable (at the nominated discount rate), a project would require an NPV that is greater than zero (in which case the BCR would be greater than one).

The internal rate of return (IRR) is the discount rate at which the NPV is zero (and the BCR is 1). The project's target IRR needs to be above the appropriate discount rate for a project to be considered commercially viable based on the risk profile of the development and alternate investment opportunities available to developers.

A project evaluation period of 30 years was used for scheme-scale assessments in this chapter. This project life was selected to reflect the life of the principal infrastructure assets in the scheme.

To simplify the tracking of assets (particularly where staged development is later considered) assets were approximated into three categories of life spans: 15, 40 and 100 years. It was assumed assets would be replaced at the end of their life, and costs were accounted for in full in the actual year of their replacement. At the end of the 30-year evaluation period, a residual value was calculated to account for assets that had not reached the end of their working life. Residual values were calculated as the proportional asset life remaining multiplied by the original asset price.

Capital costs of infrastructure were assumed to be the costs at completion (accounted for in full in the year of delivery), such that the assets commenced operations the following year. The capital costs of developing the water and land resources for irrigated farming (evaluated for costs of

$10,000/ha to $40,000/ha) were considered separately to the additional setup costs for buildings, vehicles and equipment required to establish each new farm (assumed to total $7424/ha).

The main costs for operating a large dam and associated water distribution infrastructure are fixed costs for administering and maintaining the infrastructure, expressed here as percentage of the original capital cost, and variable costs associated with pumping water into distribution channels.

At the farm scale, fixed overhead costs are incurred each year whether or not a crop is planted in a particular year. For a generic broadacre crop, these costs were assumed to be $600/ha plus 1% of the original capital value of farm assets. Fixed costs were dominated by the fixed component of labour costs, assuming four full-time equivalent staff per 500 ha farm. Overheads included a lease fee to account for the use of the land prior to irrigation. Other components of overheads include maintenance, insurance, professional services and registrations.

A farm annual gross margin is the difference between the gross income from crop sales and variable costs of growing a crop each year. Net farm revenue is calculated by subtracting fixed overhead costs from the gross margin. Variable costs vary in proportion to the area of land planted, the amount of crop harvested and/or the amount of water and other inputs applied. Farm gross margins can vary substantially within and between locations, as indicated in Section 4.5. Gross margins presented here are the values before subtracting the variable costs of supplying water to farms, with these costs instead accounted for in the capital costs of developing water and land resources (and equivalent unit costs of supplying water presented separately below).

6.3.2 BREAK-EVEN ANALYSES OF DEVELOPMENT OPTIONS FOR GENERIC SCHEMES

The capital costs of developing water and land resources in the Darwin catchments vary widely, such that even when technically feasible options are found, many of these are unlikely to be profitable at the returns and over the time periods expected by many investors. The results presented below suggest that development costs above $15,000/ha (plus $7424/ha farm setup costs) would be difficult to cover from farm gate revenues alone. Gross margins (excluding water supply costs) would need to be above $3000/ha, before accounting for the negative effects of risks. There is little that potential investors can do in this regard other than focusing on the cheapest development options. However, consideration also needs to be given to ongoing maintenance and operating costs, which are typically higher for lower cost, lower life span infrastructure (particularly where assets are engineered to a lower standard).

The costs of developing water and land resources for a new irrigation development can vary substantially, depending on a wide range of case-specific factors dealt with in other parts of this Assessment. These factors include the type and nature of the water source, the type of water storage, geology, topography, soil characteristics, the water distribution system, the type of irrigation system, the type of crop to be grown, land preparation requirements, and the level to which infrastructure is engineered. Initial analyses focused on the capital costs of development, given their importance in determining the financial performance of a scheme, and the high variability in these costs between potential development opportunities. The above financial framework was applied generically, working backwards from broad assumptions about developments with different capital costs to determine the farm gross margins that would be required for the scheme as a whole to break even (scheme NPV = zero, scheme BCR = 1). The baseline assessments considered the simplest case, where costs and farm performance stayed the same over time: first for a scheme built around a large inchannel dam, and then for an indicative on-farm water source.

Generic scheme based on a large, off-farm dam

Assumptions

The first assessment considered the case where a single developer would invest in a scheme in the Darwin catchments that included all costs and benefits from initial construction of a large dam (>25 GL/year) off-farm and land preparation up to the revenue received for produce at the farm gate. A range of development costs and target rates of return were considered. A relative breakdown of dam development costs was used to apportion infrastructure assets for dams with different costs of development (Table 6-5). This breakdown was based on costings for two indicative dams in the companion technical report on socio-economics (Stokes et al., 2017). 'Core' infrastructure consisted of off-farm assets, such as the dam wall, weir, main supply channel, scheme access road and costs of approvals. 'Area-dependent' infrastructure consisted of those assets that scaled with each extra unit of additional irrigated land, such as land development costs, farm roads, and channels for distributing water to each farm. In addition to the costs of developing land and water resources, irrigators would have setup costs for purchasing buildings, vehicles and equipment for each new farm (assumed here to total an extra $7424/ha, Table 6-5).

Table 6-5 Assumed capital and operating costs for a new irrigation scheme with a new, large dam
Annual operating and management (O&M) costs are expressed as a percentage of the capital costs of assets.

SCHEME COMPONENT	ITEM	LIFE SPAN (y)	UNIT COST ($)	UNIT	O&M COST (% capital cost)
Water supplier capital and operating costs (water and land development)					
Capital costs (split as per percentages below)			$10,000 to $40,000	ha	
'Core' infrastructure %	100-year infrastructure	100	57%		0.4%
	40-year infrastructure	40	9%		1.6%
'Area-dependent' infrastructure %	100-year infrastructure	100	0%		
	40-year infrastructure	40	34%		1.0%
Operating costs (+ asset O&M costs)	Pumping from weir		$30	ML	
Irrigator capital and operating costs (farm buildings and equipment)					
Farm setup capital costs (setup costs total $7,424/ha)	Buildings and structures	40	$2,190	ha	1.0%
	Irrigation system	15	$3,960	ha	1.0%
	Vehicles and equipment	15	$1,274	ha	1.0%
Farm overheads (annual) (+ O&M costs: 1% of capital costs)	Labour, services etc.		$600	ha	

Water losses affect volumes of water passing various points from the dam to the crop (see Section 5.4). The analyses required the volume of water reaching the farm gate (used as the pricing point in the next section) and volume of water being pumped from re-regulation structures into supply channels. Analyses assumed that 6 ML/ha/year of irrigation water was used by crops (before accounting for application losses) with an application efficiency of 85%, on-farm distribution efficiency of 90% and channel distribution efficiency of 90%. On this basis, applied irrigation water at the farm gate would be 7.8 ML/ha/year (= 6 ÷ (85% × 90%) ML/ha/year, after accounting for distribution losses) and water pumped by the water supplier would be 8.7 ML/ha/year (= 7.8 ÷ 90% ML/ha/year). Water supplies were assumed to be 100% reliable and all other factors affecting farm performance were ignored for the initial baseline set of analyses. Sources of risk affecting farm performance are covered separately in Section 6.3.3 and provide a set of risk adjustment multipliers for these baseline results.

The assumed applied irrigation water has a relatively small direct effect on these analyses, by contributing to scheme operating costs. The main way in which applied irrigation water influences results below is indirectly, through the effect on development costs per hectare. A given water supply will be able to irrigate a smaller area for farming options that use more water, so scheme development costs per hectare would be higher and would need to be paid for from a smaller area of farmland.

Break-even farm gross margins

Cost and benefit streams, totalled across the scheme, were tracked in separate components for the water supplier and irrigator operations. For the water supplier, these streams were (i) the capital costs (including replacement costs and residual values) of developing the water and land resources, and (ii) the costs of maintaining and operating those assets. For the farm, these streams were (i) the capital costs of the farm buildings and equipment; (ii) the fixed overhead costs, applied to the full area of developed farmland; and (iii) the total farm gross margin (across all farms in the scheme), applied to the mean proportion of land in production. Table 6-6 shows farm annual gross margins that would be required for a scheme to break even (scheme NPV = zero) for a range of different capital costs of development and target IRR. The costs of supplying water to the farm gate are accounted for in the capital costs of development (rather than being subtracted as a variable cost in the farm gross margins presented).

Table 6-6 Break-even farm gross margins required for schemes with different dam development costs to meet target investment returns (IRR)

Assumes 100% farm performance in all years and an additional $7424/ha farm setup cost for buildings and equipment (Table 6-5). Gross margins exclude costs of water supply. Risk adjustment multipliers are provided in Section 6.3.3.

TARGET IRR	BREAK-EVEN FARM GROSS MARGIN ($/ha/y)					
	Capital costs for developing water and land ($/ha)					
	$10,000	$15,000	$20,000	$25,000	$30,000	$40,000
0%	1,576	1,695	1,813	1,932	2,050	2,287
1%	1,697	1,854	2,011	2,168	2,325	2,640
2%	1,822	2,019	2,216	2,413	2,610	3,004
3%	1,951	2,189	2,427	2,665	2,904	3,380
5%	2,221	2,545	2,868	3,192	3,515	4,162
7%	2,506	2,919	3,331	3,744	4,156	4,982

TARGET IRR	BREAK-EVEN FARM GROSS MARGIN ($/ha/y)					
10%	2,956	3,507	4,059	4,610	5,162	6,265
12%	3,267	3,914	4,561	5,207	5,854	7,148
14%	3,586	4,329	5,073	5,816	6,560	8,047

As expected, higher farm gross margins are required to cover higher capital costs and higher investment returns. These generic tables can be used together with information on costs and returns for particular cases. For example, Chapter 4 showed that indicative farm gross margins for broadacre crops were unlikely to exceed $3000/ha (depending on crop, location and soils), and scheme development costs for the most promising potential dam sites in this Assessment were estimated at about $18,000/ha to $25,000/ha (assuming crop applied irrigation water of 6 ML/ha, 45% water losses from dam to crop, and $11,000/ha scheme development costs after building the dam wall, before allowing for contingencies or farm setup costs). On this basis, farm gate revenues alone would fall short of reaching a 7% return on capital invested (Table 6-6).

Break-even pricing of dam water

If the water supplier and farmers were separate investors, then a price would need to be set for the delivery of water from the dam operator to the irrigators. This arrangement is broadly analogous to some large SunWater-operated irrigation schemes in Queensland, such as the Burdekin Haughton Water Supply Scheme and the Mareeba–Dimbulah Water Supply Scheme. From the water supplier's perspective, two options for pricing water were considered. The first was on a fully commercial basis for the same combinations of development costs and target IRRs used above (Table 6-7). The second, as a lower bound, was the water pricing that would be required to cover just the ongoing maintenance and operating costs (excluding the initial capital costs of constructing the dam and developing the land) (Table 6-8).

Table 6-7 Break-even water pricing required for schemes with different dam development costs to meet target investment returns (IRR) for the water supplier (developer of dam, water distribution infrastructure and land)
Water priced at farm gate to cover both capital and operating costs of water supplier, assuming applied irrigation water of 7.8 ML/ha/year at farm gate, 8.7 ML/ha/year at weir, scheme pumping costs of $30/ML at weir, and 100% farm performance.

TARGET IRR	WATER PRICE THAT WATER SUPPLIER WOULD NEED TO CHARGE TO BE PROFITABLE ($/ML AT FARM GATE)					
	Capital costs for water supplier to develop water and land ($/ha)					
	$10,000	**$15,000**	**$20,000**	**$25,000**	**$30,000**	**$40,000**
0%	64	79	94	109	124	154
1%	73	93	114	134	154	194
2%	84	109	134	159	184	234
3%	94	124	155	185	216	276
5%	116	157	198	240	281	363
7%	139	191	244	296	349	454
10%	174	244	315	385	455	596
12%	198	281	363	446	528	693

TARGET IRR	WATER PRICE THAT WATER SUPPLIER WOULD NEED TO CHARGE TO BE PROFITABLE ($/ML AT FARM GATE)					
14%	223	318	412	507	602	792

Table 6-8 Minimum price water supplier would have to charge for water for schemes with different costs of development to cover annual O&M costs

Fully covers annual water supplier operating costs each year, so discount rate assumptions have no effect. Water was priced at farm gate assuming applied irrigation water of 7.8 ML/ha/year at farm gate, 8.7 ML/ha/year at weir, scheme pumping costs of $30/ML at weir, and 100% farm performance.

WATER PRICE TO COVER ONLY WATER SUPPLIER OPERATING COSTS ($/ML AT FARM GATE)					
Capital costs for water supplier to develop water and land ($/ha)					
$10,000	**$15,000**	**$20,000**	**$25,000**	**$30,000**	**$40,000**
43	47	52	57	61	71

Water pricing was then considered from the irrigator's perspective and the capacity of irrigators to pay. Table 6-9 shows water prices for a farm to break even (farm NPV = zero) for a range of different farm gross margins and applied irrigation water combinations.

Under a favourable scheme for a broadacre crop with a gross margin of $3000/ha and an irrigator seeking an IRR of 7%, irrigators would be able to pay $202/ML for a crop using 6 ML/ha/year (of irrigation water before application losses, Table 6-9). Water payments from irrigators at these water prices would more than cover the ongoing operating costs of a water supplier (<$100/ML across a wide range of development costs, Table 6-8), but would fall short of covering the full costs of supplying water at a commercial rate of return (e.g. $244/ML for a 7% IRR on supplier capital development costs of $20,000/ha, Table 6-7).

Table 6-9 Break-even water pricing for the amount an irrigator could afford to pay depending on the annual gross margin of the farm, crop applied irrigation water (before application losses), and the irrigator's target internal rate of return (IRR)

Assumes water volumes metered at the farm gate were 1.31 times the crop applied irrigation water after accounting for losses (based on 90% on-farm distribution efficiency and 85% application efficiency).

TARGET IRR (%)	GROSS MARGIN ($/ha)	IRRIGATOR CAPACITY TO PAY FOR WATER AND STILL BE PROFITABLE ($/ML AT FARM GATE)				
		Crop applied irrigation water [and farm gate applied irrigation water] (ML/ha)				
		4 [5.2]	**6 [7.8]**	**8 [10.5]**	**10 [13.1]**	**12 [15.7]**
3%	**$1500**	55	37	27	22	18
	$2000	151	100	75	60	50
	$2500	246	164	123	98	82
	$3000	342	228	171	137	114
7%	**$1500**	15	10	8	6	5
	$2000	111	74	56	44	37
	$2500	207	138	103	83	69
	$3000	302	202	151	121	101
10%	**$1500**	na†	na	na	na	na

TARGET IRR (%)	GROSS MARGIN ($/ha)	IRRIGATOR CAPACITY TO PAY FOR WATER AND STILL BE PROFITABLE ($/ML AT FARM GATE)				
	$2000	78	52	39	31	26
	$2500	174	116	87	70	58
	$3000	269	180	135	108	90

†na = not applicable, situations where farm is not profitable even if there was no charge for water

Generic modular development using an on-farm water source

The second baseline case considered an irrigation development in the Darwin catchments that substituted the large dam (above) with an on-farm source of water. The indicative on-farm water source was based on greenfield development using bores and pivots. A detailed breakdown of costs for this option is provided in the companion technical report on socio-economics (Stokes et al., 2017). Aside from being on-farm, this option contrasted with the dam water option in using an alternative water source (ground versus surface water) and using shorter life span infrastructure (potentially cheaper upfront capital costs but higher ongoing costs). It is also very modular, which would be more amenable to staging (Section 6.3.3), alternative models of investment (less reliant on a single large investor/developer) and developments across a wide range of scales (from part of a farm to large schemes).

Assumptions

Assumptions for the costs of developing and operating on-farm water sources were the same as for the off-farm dam example above, except that the dam water source was replaced with costs of developing and operating a series of bores (Table 6-10). Analyses initially assumed the developed water source would fully meet crop demand (with 100% reliability). Pumping costs would be part of the variable costs that would have to be included in the farm gross margin for a particular cropping option before comparing to the break-even gross margins calculated here (whereas for the dam option above, pumping costs for delivering water to the farm gate were a scheme cost, recovered through the price charged to farms for supplying water).

Table 6-10 Assumed capital and operating (O&M) costs for a new development using an on-farm water source
Modular on-farm development involves only separate 'Area-dependent' infrastructure for each farm, and there is no shared 'Core' infrastructure (as there was for the large dam).

SCHEME COMPONENT	ITEM	LIFE SPAN (y)	UNIT COST ($)	UNIT	O&M COST (% capital cost)
Costs of developing on-farm water resource and preparing land					
Capital costs (split as per percentages below)			$5,000 to $40,000	ha	
'Area-dependent' infrastructure % (no 'Core' infrastructure)	40-year infrastructure	100	49%		1.0%
	15-year infrastructure	40	51%		1.0%
Irrigator capital and operating costs (farm buildings and equipment)					

SCHEME COMPONENT	ITEM	LIFE SPAN (y)	UNIT COST ($)	UNIT	O&M COST (% capital cost)
Farm setup capital costs	Buildings and structures	40	$2,190	ha	1.0%
	Irrigation system (spray)	15	$3,960	ha	1.0%
	Vehicles and equipment	15	$1,160	ha	1.0%
Farm overheads (annual) (+ O&M costs: 1% of capital costs)	Labour, services etc.		$600	ha	

Break-even farm gross margins

Table 6-11 shows the farm gross margins that would be required for the scheme to break even (NPV = zero). Note that while shorter life span infrastructure may reduce development costs of on-farm infrastructure, this leads to more frequent asset replacement, so higher farm gross margins were required for the scheme to break even relative to the same development cost per area for a large dam (Table 6-6). Thus, although some on-farm options for water development may be cheaper than building a new large dam, higher ongoing costs associated with shorter life span infrastructure offset some of that advantage. Small offstream storages, an alternative on-farm water source, can also be less reliable water sources than large instream dams, and are less able to carry water through the dry season, which limits farming options.

Table 6-11 Break-even farm gross margins required for schemes with different costs of developing on-farm water sources to meet target investment returns (IRR)

Assumes an additional $7424/ha farm setup costs for buildings and equipment (Table 6-11) and that the developed water source is able to fully meet crop requirements to deliver 100% farm performance in all years. Risk adjustment multipliers are provided in Section 6.3.3.

TARGET IRR	BREAK-EVEN FARM GROSS MARGIN ($/ha/y)						
	Capital costs for developing water and land ($/ha)						
	$5,000	**$10,000**	**$15,000**	**$20,000**	**$25,000**	**$30,000**	**$40,000**
0%	1,359	1,640	1,921	2,202	2,483	2,764	3,326
1%	1,432	1,743	2,054	2,365	2,676	2,987	3,609
2%	1,508	1,851	2,193	2,536	2,878	3,221	3,906
3%	1,588	1,964	2,339	2,715	3,090	3,466	4,217
5%	1,758	2,204	2,650	3,095	3,541	3,986	4,878
7%	1,940	2,461	2,982	3,503	4,023	4,544	5,585
10%	2,233	2,874	3,515	4,156	4,798	5,439	6,721
12%	2,438	3,164	3,890	4,616	5,342	6,068	7,519
14%	2,651	3,464	4,277	5,090	5,904	6,717	8,343

6.3.3 RISKS ASSOCIATED WITH VARIABILITY IN FARM PERFORMANCE

This section assessed the impacts of two types of risks on scheme financial performance: those that reduce farm performance through the early establishment and learning years, and those occurring periodically and continuously. Setbacks that occur early on after a scheme is established were found to have the largest effect on scheme viability, particularly at higher discount rates. There is a strong incentive to start any new irrigation development with well-established crops and technologies, and to be thoroughly prepared for the anticipatable agronomic risks of establishing new farmland. Analyses showed that delaying full development for longer periods than the learning time had only a slight negative effect on IRRs, whereas proceeding to full development before learning was complete had a much larger impact. This implies that it would be prudent to err on the side of delaying full development (particularly given that in practice, it would only be possible to know when full performance was achieved in retrospect, not in advance). An added benefit of staging would be limiting losses where small-scale testing proves initial assumptions of benefits to be over-optimistic and that full-scale development could never be profitable, even after trying to overcome unanticipated challenges.

For an investment to be viable, farm gross margins need to be sustained at high levels over long periods. Thus, variability in farm performance poses risks that need to be considered and managed. Gross margins can vary between years either because of short-term initial underperformance or because of periodic shocks. Initial underperformance is likely to be associated with learning as farming practices are adapted to local conditions, overcoming initial challenges to reach their long-term potential. There would be further unavoidable periodic risks associated with water reliability, climate variability, flooding, outbreaks of pests and diseases, periodic technical/equipment failures, and fluctuations in commodity prices and market access. Periodic risks, such as reliability of water supply, are less easy to avoid. Risks that cannot be avoided need to be managed, mitigated where possible, and accounted for in determining the realistic returns that can be expected from a scheme. This would include having adequate capital buffers to survive through challenging periods. Another perceived risk for investors is that of uncertainty around future policy changes and delays in regulatory approvals. Reducing this, or any other sources of risk, would contribute to making marginal investment opportunities more attractive.

Results for analyses of both periodic and learning risks are shown below. Findings are also presented for how staging might be able to mitigate the costs of learning, and additional risks that staging could introduce. Throughout this section, farm performance in a given year is quantified as the proportion of the long-term mean gross margin a farm attains, where 100% performance is when this level is reached and zero % equates to a performance where revenues only balance variable costs (gross margin = $zero).

Risks from periodic underperformance

Analyses considered periodic risks generically, without assuming any of the particular causes listed above. Periodic risks were characterised in terms of three components to test their effects on scheme financial performance:

- reliability: the proportion of 'good' years where the 'full' 100% farm performance was achieved, with the remainder of years being 'failures' where some negative impact was experienced
- severity: the farm performance in a 'failed' year where some type of setback occurs
- timing: for 'early' timing a 10-year cycle was used where, for example, with 80% reliability failures would occur in the first 2 years of the scheme and the first 2 years of each 10 years in a cycle after that. For 'late' timing, the 'failures' came at the end of each 10-year cycle. Where

timing was not used, each year was represented as having the long-term mean farm performance of 'good' and 'failed' years (frequency weighted).

Table 6-12 summarises the effects of a range of different reliabilities and severities for periodic risks (without considering timing of impacts) on scheme viability. Periodic risks had a consistent proportional effect on break-even gross margins, irrespective of development options or costs, so results were simplified as a set of risk adjustment multipliers (which could be applied to the baseline tables of break-even gross margins presented before). These same multipliers apply to the break-even water prices that irrigators can afford to pay.

As would be expected, the greater the frequency and severity of 'failed' years, the greater the impact on scheme viability and the greater the increase in farm gross margins that would be required to offset these impacts. As an example, the reliability of water supply is one of the more important sources of unavoidable variability in productivity of irrigated farms. If the planted area of land was reduced in years without a full supply ('failed' years) so that the cropped area was always fully irrigated, then the water reliability is the same as the periodic risk reliability (Table 6-12), and the proportion of water available in a 'failed' year is equivalent to the mean farm performance. For example, if a water supply was 85% reliable and provided on average 75% of its full supply in 'failed' years, the risk adjustment multiplier that would have to be applied to baseline break-even gross margins (Table 6-6 and Table 6-11) would be 1.04 (Table 6-12). This means that a 4% higher gross margin would be required to break even than if water could be supplied at 100% reliability. For crops where the quality of produce is more important than the quantity, such as annual horticulture crops, the approach of reducing planted land area in proportion to available water in 'failed' years seems reasonable. However, for perennial horticulture or tree crops it may be difficult to reduce (or increase) areas on an annual basis. Farmers of these crops will therefore tend to opt for systems with a high degree of reliability of water supply (e.g. 95%). For many broadacre crops, it may be possible to deficit irrigate a larger area to slightly mitigate the impact of years with lower water allocations. As shown in Section 4.5, the agronomic optimum does not necessarily equal the economic optimum. Measures such as deficit irrigation could partially mitigate impacts on farm performance in years with reduced water availability, as could carryover effects from inputs (such as fertiliser) in a failed year that reduce input costs the following year.

Table 6-12 Risk adjustment multipliers for break-even gross margins, accounting for the effects of reliability and severity (level of farm performance in 'failed' years) of periodic risks

Results are not affected by discount rates. 'Good' years = 100% farm performance; 'Failed' = <100% performance. 'Failed year performance' is the mean farm gross margin in years where some type of setback is experienced relative to the mean gross margin when the farm is running at 'full' performance.

FAILED YEAR PERFORMANCE	BREAK-EVEN GROSS MARGIN RISK ADJUSTMENT MULTIPLIER (VS BASE 100% RELIABILITY TABLES)									
	Reliability (Proportion of 'good' years)									
	1.00	**0.90**	**0.85**	**0.80**	**0.70**	**0.60**	**0.50**	**0.40**	**0.30**	**0.20**
85%	1.00	1.02	1.02	1.03	1.05	1.06	1.08	1.10	1.12	1.14
75%	1.00	1.03	1.04	1.05	1.08	1.11	1.14	1.18	1.21	1.25
50%	1.00	1.05	1.08	1.11	1.18	1.25	1.33	1.43	1.54	1.67
25%	1.00	1.08	1.13	1.18	1.29	1.43	1.60	1.82	2.11	2.50

FAILED YEAR PERFORMANCE	BREAK-EVEN GROSS MARGIN RISK ADJUSTMENT MULTIPLIER (VS BASE 100% RELIABILITY TABLES)									
0%	1.00	1.11	1.18	1.25	1.43	1.67	2.00	2.50	3.33	5.00

Table 6-13 summarises how timing of periodic impacts affects scheme viability, providing break-even risk adjustment multipliers for a range of reliabilities for an impact that had 50% severity with late timing, early timing, and no (long-term frequency, weighted mean performance) timing.

These results show that any negative disturbances that reduce farm performance will have a larger effect if they occur early on after the scheme is established, and that this effect is greater at higher discount rates (or higher target IRRs). For example, at a 7% discount rate and 70% reliability with 'late' timing (where setbacks occur in the in the last three of every 10 years) the gross margin multiplier is 1.13, meaning the annual farm gross margin would need to be 13% higher than if farm performance were 100% reliable. In contrast, for the same settings with 'early' timing, the gross margin multiplier is 1.23, so impacts of early setbacks are more severe and the farm gross margin would have to be 23% higher than if farm performance were 100% reliable.

Table 6-13 Risk adjustment multipliers for break-even gross margins, accounting for the effects of reliability and timing of periodic risks

Assumes 50% farm performance during 'failed' years, where 50% farm performance means 50% of the gross margin at 'full' potential production.

TARGET IRR	TIMING OF FAILED YEARS	BREAK-EVEN GROSS MARGIN RISK ADJUSTMENT MULTIPLIER (VS BASE 100% RELIABILITY TABLES)								
		Reliability (proportion of 'good' years)								
		1.00	**0.90**	**0.80**	**0.70**	**0.60**	**0.50**	**0.40**	**0.30**	**0.20**
3%	**Late**	1.00	1.05	1.10	1.16	1.22	1.30	1.39	1.50	1.63
	Mean – no timing	1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
	Early	1.00	1.06	1.13	1.20	1.28	1.37	1.47	1.58	1.70
7%	**Late**	1.00	1.04	1.08	1.13	1.19	1.26	1.35	1.46	1.59
	Mean – no timing	1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
	Early	1.00	1.07	1.15	1.23	1.32	1.41	1.51	1.62	1.74
10%	**Late**	1.00	1.03	1.07	1.12	1.17	1.24	1.32	1.42	1.56
	Mean – no timing	1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
	Early	1.00	1.08	1.16	1.25	1.35	1.45	1.55	1.66	1.77

Risks from initial 'learning' period

Another form of risk arises from the initial challenges in establishing and adapting agriculture in a new part of the Darwin catchments, and includes setbacks from delays, such as gaining regulatory approvals. Some of these risks are avoidable if investors and farmers learn from past experiences of development in northern Australia (e.g. Ash et al., 2014), avoid previous mistakes, and select farming options that are already well proven in analogous locations. However, even if developers are well prepared, there are likely to be initial challenges in adapting to the unique circumstances of a new location. Newly developed farmland can take some time to reach its productive potential as soil nutrient pools are established, soil limitations are ameliorated, suckers and weeds are controlled, and pest management systems are established.

‘Learning’ (used here to broadly represent all aspects of overcoming initial sources of farm underperformance) was assessed in terms of two simplified generic characteristics:

- initial level of performance: represented as described before, as the proportion of the long-term, mean gross margin that the farm achieves in its first year
- time to learn: the number of years taken to reach the long-term, mean farm performance. Performance was represented as increasing linearly over the learning period from the starting level to the long-term, mean performance level (100%).

The effect of learning on scheme financial viability was considered for a range of initial levels of farm performance and learning times. As before, learning had consistent proportional effects on break-even gross margins, so results were simplified as a set of risk adjustment multipliers (Table 6-14). As would be expected, the impacts on scheme viability are greater the lower the starting level of farm performance, and the longer it takes to reach the long-term performance level. Since these impacts, by their nature, are weighted to the early years of a new development, they have more impact at higher discount rates (and investors’ target IRRs). To minimise risks of learning impacts, there is a strong incentive to start any new irrigation development with well-established crops and technologies, and to be thoroughly prepared for the anticipatable agronomic risks of establishing new farmland. Higher-risk options (e.g. novel crops, equipment or practices that are not currently in profitable commercial use in analogous environments) could be tested and refined on a small scale until locally proven.

Table 6-14 Risk adjustment multipliers for break-even gross margins, accounting for the effects of learning risks
Learning risks were expressed as the level of initial farm underperformance and time taken to reach full performance levels. Initial farm performance is the initial gross margin as a percentage of the gross margin at ‘full’ performance.

TARGET IRR	INITIAL FARM PERFORMANCE	BREAK-EVEN GROSS MARGIN RISK ADJUSTMENT MULTIPLIER (VS BASE 100% RELIABILITY TABLES)					
		Learning time (years to 100% performance)					
		2	**4**	**6**	**8**	**10**	**15**
3%	**85%**	1.01	1.02	1.03	1.03	1.04	1.05
	75%	1.02	1.03	1.04	1.05	1.07	1.10
	50%	1.04	1.06	1.09	1.12	1.14	1.21
	25%	1.06	1.10	1.14	1.19	1.23	1.35
	0%	1.08	1.14	1.20	1.26	1.33	1.53
7%	**85%**	1.02	1.03	1.04	1.05	1.05	1.07
	75%	1.03	1.05	1.06	1.08	1.09	1.13
	50%	1.06	1.10	1.13	1.17	1.21	1.29
	25%	1.09	1.15	1.22	1.28	1.35	1.51
	0%	1.12	1.21	1.31	1.41	1.52	1.83
10%	**85%**	1.02	1.03	1.05	1.06	1.07	1.09
	75%	1.04	1.06	1.08	1.10	1.11	1.15
	50%	1.08	1.12	1.17	1.21	1.26	1.35
	25%	1.12	1.20	1.28	1.36	1.44	1.65
	0%	1.16	1.28	1.41	1.55	1.69	2.10

Risks and benefits of staged development

One possible strategy for dealing with learning risks could be to stage development, so that the bulk of the overall capital investment is delayed until farming systems have been tested and locally adapted to new parts of the Darwin catchments on a smaller scale. Illustrative examples are provided below to demonstrate general principles about the risks and benefits of staging.

Table 6-15 shows the effects on scheme financial returns for seven severities of learning risk: initial farm performance was set at levels from 100 to –20% and performance was increased by 10% each year so that corresponding learning times to full performance were zero to 12 years (as per the first two columns of Table 6-15).

Staging considered four options, in which initially only 5% of the total land area was developed, and the remaining area was developed after delays of zero, 4, 8 and 12 years (where the zero-year delay corresponds to no staging). Staging was considered for both the dam and on-farm water source development options used in the baseline assessments (Section 6.3.2), retaining the standard assumptions (Table 6-5 and Table 6-10). However, some extra details had to be specified in order to run the analyses. These were set towards the more favourable end of what might be possible, but with an emphasis on making relative comparisons between staging options. Both the dam and the on-farm water source developments used a farm gross margin of $2500/ha (representative of the upper range for broadacre crops, see Section 4.5) and an annual water reliability of 85%, with 77% of the full water supply available on average in the other 15% of years. The total costs at project completion were assumed to be unaffected by how the project was staged (i.e. no wasted test infrastructure from stage 1, or cost inefficiencies from developing parts of the assets at different times).

For the dam development option, staging involved building the weir first and delaying building the main dam. It was assumed that the weir and other ‘core’ off-farm infrastructure (e.g. access road, channels and approvals) required to get the test stage of development operational would cost 7% of the total project costs for ‘core’ infrastructure (Table 6-5). ‘Area-dependent’ infrastructure was scaled linearly with the area developed, so 5% of those costs (Table 6-5) were incurred in the test stage. Costs for developing water and land resources were assumed to be $20,000/ha.

The on-farm water source was assumed to be entirely modular, so that each unit of farmland could be developed entirely independently of the next, scaling total project costs to the proportion of land developed (5% in the test stage). Costs for developing water and land resources were assumed to be $10,000/ha.

A comparison of IRRs between staging options (Table 6-15) shows that the financial penalties for not staging increase as learning risks become more severe (in terms of lower starting performance and longer learning times). The impacts of learning risks could best be offset by matching the delay in proceeding to full-scale development to the learning time (i.e. completing development only once the test stage had reached full financial performance). Delaying full development for longer periods than the learning time had only a slight negative effect on IRRs, whereas proceeding to full development before learning was complete had a much larger impact. This implies that it would be prudent to err on the side of delaying full development (particularly given that in practice, it would only be possible to know when full performance was achieved in retrospect, not in advance).

Staging is complex, and a wide range of other risks and benefits would need to be considered beyond these simple, illustrative examples. An added benefit of staging would be limiting losses, where small-scale testing proves initial assumptions of costs and benefits to be over-optimistic and that full-scale development could never be profitable, even after trying to overcome unanticipated challenges. In such cases, losses could be reduced by opting not to proceed with further development. Indeed, financiers of a development might stage release of loans for this reason as a risk control measure. However, staging can transfer risks from one party to another and might not be uniformly beneficial to all parties involved in a development. For example, staged finance might delay development stages beyond what is optimal for learning times, even when development options are well proven and developers would prefer to proceed more quickly. Similarly, if staging is implemented to control risks of farm performance, while farming practices are adapted to local conditions, this could transfer risks to investors in supporting infrastructure further down the supply chain. This is particularly the case for crops such as sugarcane and cotton, where local processing is integral to the industry and requires production at large scale to be viable. Delays in development beyond optimal learning times could also be imposed for other reasons, such as logistic constraints on the rate at which land could be developed, seed material could be propagated (for clonal crops) or skilled labour could be recruited. The IRRs in Table 6-15 indicate that short-term delays (<2 years) would likely have only a minimal impact on scheme financial performance.

Table 6-15 Effect of different staging options on scheme performance for a range of learning risks

Scheme performance was measured as the internal rate of return (IRR) for each combination of staging and learning. The staging delay with the highest IRR for each level of learning risk (row) is highlighted in darker green, and delays with IRRs within 0.2% of the best IRR are highlighted in lighter green. Staging involved initially developing 5% of the farmland for testing, then allowing for learning periods of different durations before proceeding to full development.

STARTING PERFORMANCE	LEARNING TIME (y)	IRR FOR STAGING OPTION (%)			
		Dam/weir staging options (no. years delay to full development)			
		0 (no staging)	**4**	**8**	**12**
100%	**0**	2.9	2.8	2.7	2.6
80%	**2**	2.8	2.8	2.7	2.6
60%	**4**	2.4	2.7	2.7	2.6
40%	**6**	1.9	2.4	2.6	2.6
20%	**8**	1.3	2.0	2.5	2.5
0%	**10**	0.6	1.4	2.2	2.4
–20%	**12**	–0.1	0.7	1.7	2.3
		On-farm bore staging options (no. years delay to full development)			
		0 (no staging)	**4**	**8**	**12**
100%	**0**	6.7	6.5	6.3	6.3
80%	**2**	6.3	6.4	6.3	6.2
60%	**4**	5.5	6.3	6.2	6.1
40%	**6**	4.5	5.6	6.1	6.0
20%	**8**	3.3	4.6	5.9	5.8

STARTING PERFORMANCE	LEARNING TIME (y)	IRR FOR STAGING OPTION (%)			
0%	**10**	2.1	3.5	5.1	5.6
–20%	**12**	0.9	2.2	4.1	5.3

Some of the assumptions in the illustrative examples were oversimplified. For example, staging may well incur extra costs if purchasing assets and services for development at different times is less efficient than doing so over one concentrated period, or if some of the infrastructure from the test stage does not fit with the requirements of the completed scheme. In addition, learning was considered to occur entirely at the small test scale and to then be completely scalable to full development. In reality, as highlighted by Ash et al. (2014), some of the most substantial challenges in past agricultural developments in northern Australia have come in the scaling-up phase. There is no guarantee that success at the level of an individual farm will necessarily scale easily to establishing a large, new industry in a certain location. This is particularly the case if success at the farm level is based on taking advantage of case-specific opportunities that are not easily duplicated at scale. Challenges in scaling up production could include the need for local processing facilities, access to sufficient capital, establishing and expanding markets and supply chains, training and recruiting skilled labour, availability of local support services, and building new transport and utilities infrastructure to address bottlenecks. There would be a component of learning associated with addressing these scaling challenges. An intermediate staging step, after the initial small-scale testing, might help with this learning. Such intermediate stages are better suited to developments using modular on-farm water sources than those that are based on a single, large dam.

6.3.4 POTENTIAL BENEFITS FROM INDUSTRY SYNERGIES AND INTEGRATION

Off-farm value adding and synergies could contribute to the viability of a potential new scheme in the Darwin catchments. The illustrative example explored here was adding a sugar mill to an irrigated sugarcane scheme, which demonstrated that the benefit from the higher value of the processed cane exceeds the additional costs of building and running a mill. This also suggested that an additional by-product, cogeneration of electricity, would likely be required if any such scheme were to be viable.

Sugar was used as an illustrative example because of the relatively high value adding from local processing to illustrate the upper-end potential of synergies beyond the farm gate (not because this was the most likely crop to be grown in the catchment). A wide range of other synergies could also be considered to improve scheme revenues or share costs, as listed at the end of this section. It should be noted, however, that the more complex a scheme becomes and the more strongly interdependent its components, the greater the risk that underperformance of one component could undermine the viability of the entire scheme.

Results are presented for two options for integrating a sugar mill into a scheme:

- a mill operating on a standard 6-month harvest/crushing season, producing sugar only
- a mill operating on a 6-month season with electricity cogeneration added.

Assumptions were the same as for the generic dam (Table 6-5) except that a specific scheme size was used, details of sugar cropping were added, a sugar mill was added (with associated extra streams of costs and benefits), and water supply was assumed to be 85% reliable, with 77% of the full water yield available on average in the other 15% of years (Table 6-16). Although some specific values had to be assumed for the purposes of the analysis, these should be considered as roughly indicative, and the emphasis was on the relative comparison between options rather than absolute values of results. Electricity cogeneration in remote locations is particularly difficult in this regard, given how site-specific it would be. Rough costs are provided in the assumptions below, which included a $20 million grid-connection cost. Wholesale electricity prices on the National Electricity Market (NEM) have more than doubled in the past 5 years, averaging about $90/MWh in 2017, and projected to be about $80/MWh in 2018 (AEMO, 2017). Renewable energy certificates (RECs) traded at about $85 per large-scale generation certificate (LGC, in units of MWh) in 2017, but the future of RECs is uncertain. Given the uncertainty in electricity prices over the life of the project, analyses used a conservative electricity price of $90/MWh, but also used a higher price of $165/MWh for comparison.

Table 6-16 Assumptions used for incorporating a sugar mill into an irrigation scheme

Two options for integrating a mill were explored. Cogen = cogeneration of electricity from bagasse (fibre); CCS = commercial cane sugar. Water reliability was assumed to be 85%, with a mean of 77% of the full water yield available in the other 15% of years.

ITEM	UNITS	6-mo SEASON SUGAR ONLY	6-mo SEASON + COGEN
Scheme size			
Scheme area	ha	50,000	50,000
Capital costs of water and land development†	$ million	1,000	1,000
Capital costs per ha for water and land development†	$/ha	20,000	20,000
Cropping			
Mean area under cropping (1 in 5 year fallow)	%	80	80
Crop applied irrigation water (before application losses)	ML/ha	10	10
Crop yield (excluding fallow years)	t cane/ha	120	120
Sugarcane CCS (sugar content mill can extract from cane)	%	15.0	15.0
Sugarcane fibre content (affects rate mill can crush cane)	%	15.0	15.0
Farm variable costs of growing crop	$/ha	1,100	1,100
Farm variable costs of harvesting crop	$/t cane	8.00	8.00
Cane price (industry formula based on sugar price)	$/t cane	44.55	44.55
Processing			
Length of crushing season	month	6	6
Mill capital cost (including connection to grid for cogen)	$ million	**481**	**716**
Mill throughput rate	t/h	1,214	1,214
Mill reliability (% time operational)	%	90	90
Cane transport costs (farm to mill)	$/t	3	3
Processing costs	$ million/y	34	35
Sugar transport costs (mill to port)	$/t	50	50

ITEM	UNITS	6-mo SEASON SUGAR ONLY	6-mo SEASON + COGEN
Raw sugar price	$/t	450	450
Net exported electricity generation (per t bagasse)	MWh/t	**na**‡	0.5
Electricity transmission losses	%	**na**	5.0
Electricity sale price	$/MWh	**na**	90 and 165

Source: Details for mill processing costs provided in companion technical report on socio-economics (Stokes et al., 2017)
†Water supplier development costs of $20,000/ha equate to a dam cost of $650/ML/year yielded at the dam wall (with 85% reliability), assuming overall system efficiency of 55% (18 ML/ha/year applied irrigation water at dam wall) and an additional $10,500/ha supplier development costs.
‡na = not applicable

Results for both options showed that proportional increases in revenues from processed versus unprocessed products (54% extra revenue for sugar processing only, to 60 and 81% for sugar processing and cogeneration assuming electricity prices of $90 and $165/MWh, respectively) exceeded the proportional increases in scheme capital costs from adding a mill (37% for sugar processing only, to 55% with cogeneration) (Table 6-17). Accordingly, scheme financial returns increased substantially from a level that was unlikely to be viable at the farm gate (IRR = 4.0%) to an IRR of 5.1% with milling (with cogeneration) and an IRR of 6.6% at the higher electricity prices (including LGCs). The latter level might start to become attractive to investors if a location with the right mix of characteristics could be found with more favourable costs and prices than those used in these rough assumptions, and if there was greater certainty in pricing of renewable energy generation.

Adding a mill without cogeneration made little improvement to financial returns beyond those at the farm gate without processing (IRRs of 4.2% and 4.0%, respectively). Cogeneration of electricity would likely be required to make an irrigated sugarcane scheme viable. However, given the complexity and uncertainty associated with doing this in a greenfield, remote location, it would be important to determine costings and risks in detail on a case-by-case basis.

Table 6-17 Comparison of financial performance of an irrigation scheme with and without a sugar mill included
Two options for integrating a mill were explored. Cogen = cogeneration of electricity from bagasse (fibre); IRR = internal rate of return. Given the uncertainty in wholesale electricity prices, the comparison is repeated at the bottom of the table for an alternate, higher electricity price (including large-scale generation certificates for renewable energy).

PERFORMANCE METRIC	UNITS	6-mo SEASON SUGAR ONLY	6-mo SEASON + COGEN
Scheme from dam to farm gate			
Revenue from sugarcane	$ million	214	214
Total capital cost of development	$ million	1297	1297
Scheme IRR (farm gate)	%	4.0	4.0
Scheme from dam to port (including processing, applies to both electricity prices below)			
Revenue from raw sugar	$ million	324	324
Revenue from molasses	$ million	6	6
Total capital cost of development	$ million	1778	2013
Scheme comparison: Processing vs farm gate (price for cogenerated electricity = $90/MWh)			
Revenue from electricity (to node, after losses)	$ million	0	31

PERFORMANCE METRIC	UNITS	6-mo SEASON SUGAR ONLY	6-mo SEASON + COGEN
% extra capital spent	%	37	55
% extra revenue generated	%	54	69
Scheme IRR (to port)	%	4.2	5.1
Scheme comparison: Processing vs farm gate (alternate price for cogenerated electricity = $165/MWh)			
Revenue from electricity (to node, after losses)	$ million	0	56
% extra capital spent	%	37	55
% extra revenue generated	%	54	81
Scheme IRR (to port)	%	4.2	6.6

Other synergies that could also be considered to improve scheme revenues or reduce costs would include: sequential cropping (increasing net farm revenue by producing more than one crop from the same field each year), local use of by-products (such as feed supplements for livestock), including small-scale, high-value crops in the mix of farms in a scheme; expanding the scale of a scheme, with extra dryland/opportunistic cropping around the irrigated core; improving transport infrastructure and supply chains (reducing the disadvantages of remote locations); generating hydro-electric power; and integrating farming industries (savings from synergies). Many of these options are untested, so location-appropriate details would need to be developed and proven before they could be seriously considered. Indirect costs and benefits beyond the irrigation scheme could also be important when considering public investment in new water infrastructure. Regional economic benefits are covered in the next section, while non-market impacts are covered in chapters 3 and 7, but are not converted to dollar values.

6.4 Regional-scale economic impact of irrigated development

A water storage development scheme to promote irrigated agriculture or aquaculture could provide economic benefits to the Darwin catchments and broader region in terms of both increased economic activity and jobs. The size of the total economic benefits experienced would depend on the scale of the development, the type of agriculture that is established, and how much spending from the increased economic activities occurs within the region. Regional economic impacts would be an important consideration for evaluating potential new water development projects.

It was estimated that each dollar spent on construction within the Darwin catchments generated an additional $1.06 of indirect benefits ($2.06 total regional benefits, including the direct benefit of each $1.00 spent on construction). Each dollar of direct benefit from new agricultural activity was estimated to generate an additional $0.46 to $1.82 in regional economic activity (depending on the particular agricultural industry).

If $2 billion capital was spent on developing an irrigated agricultural scheme within the Darwin catchments, and 50% of this capital cost was spent locally, the one-off total economic activity generated from this construction within the catchment and surrounding region would be $2.06 billion (from Table 6-21). Assuming this development directly enabled an extra $100 million of output per year on a continuing basis through the lifetime of the irrigation scheme from irrigated cropping, then the region would benefit from $146 million of economic activity recurring annually (from Table 6-19) and generate about 160 full-time equivalent jobs (from Table 6-20).

There would be additional national benefits from expenditure flowing to other regions, and the stabilising effect of geographic diversification on agricultural production in the face of local disruptions, such as climate variability or regional water reforms.

The full, catchment-wide impact of the economic stimulus provided by an irrigated agriculture or aquaculture development project extends far beyond the impact on those businesses and workers directly involved in either the short term (construction phase) or longer term (operational phase). Those businesses directly benefiting from the project would need to increase their purchases of the raw materials and intermediate products used by their growing outputs. Should any of these purchases be made within the surrounding region, then this provides a stimulus to those businesses from which they purchase, contributing to further economic growth within the region. Furthermore, household incomes increase as a result of those local residents who are employed (as a consequence of the direct and/or production-induced business stimuli). As a proportion of their additional income is spent in the region, this expenditure further stimulates the economic activity within the region. Accordingly, the larger the initial amount of money spent within the region, and the larger the proportion of that money re-spent locally, the greater the overall benefits that will accrue to the region.

The size of the impact on the local regional economy can be quantified by regional economic multipliers (derived from I–O tables that summarise expenditure flows between industry sectors and households within the region), where a larger multiplier indicates larger regional benefits. These multipliers can be used to estimate the value of increased regional economic activity likely to flow from stimulus to particular industries, focusing here on construction in the short term and different types of agriculture in the longer term.

It is also possible to estimate the increase in household incomes in the region. From this, an estimate can be made of the approximate number of jobs represented by the increased economic activity (including both those directly related to the increase in agriculture, and those generated indirectly within other industries in the region).

Not all of the expenditure generated by a large-scale development will occur within the local region. The greater the leakage (i.e. the amount of direct and indirect expenditure made outside the region), the smaller the resulting economic benefit that will be enjoyed by the region. Conversely, the more of the initial spend and subsequent indirect spend that is retained within the region, the greater the economic benefit and the number of jobs created within the local region. However, a booming local economy can also bring with it a range of issues that can place upward pressure on prices (including materials, houses and wages) in the region, negating some of the positive impacts of the development. If some of the unemployed or underemployed people within the Darwin catchments could be engaged as workers during the construction or operational phases of the development, this could reduce pressure on local wages and reduce the leakage resulting from the use of fly-in fly-out (FIFO) or drive-in drive-out (DIDO) workers, retaining more of the benefit from the project within the local region. Census 2016 data showed an unemployment rate of 4.7% within the Darwin catchments, indicating there may be difficulties in sourcing local workers from within the region.

The overall regional benefit created by a particular development depends on both the one-off benefits from the construction phase, and the ongoing annual benefits from the operational phase. The benefits from the operational phase may take a number of years to reach the expected level, as new and existing agricultural enterprises learn and adapt to make full use of the new opportunities presented by the development. It is important to note that the results presented here are based on illustrative scenarios incorporating broad assumptions, are derived from an I–O model developed for an I–O region that is much larger than the Darwin catchments study area, and are subject to the limitations of the method.

6.4.1 ESTIMATING THE SIZE OF REGIONAL ECONOMIC BENEFITS

To develop regional multipliers for the Darwin catchments, it was necessary to use available information and models for the Northern Territory input–output (NT I–O) region (Murti, 2001), within which the Darwin catchments sit. For more detail, see companion technical report on socio-economics (Stokes et al., 2017) and Figure 6-2. Additional data are presented to show how the economic circumstances of the Darwin catchments compare to the larger I–O region (Table 6-18). Both the NT I–O region and the Darwin catchments encompass both rural and remote areas plus the major regional city of Darwin. However, the NT I–O region is larger than the Darwin catchments study area, so the economic impact within the catchment is likely to be smaller than that estimated here.

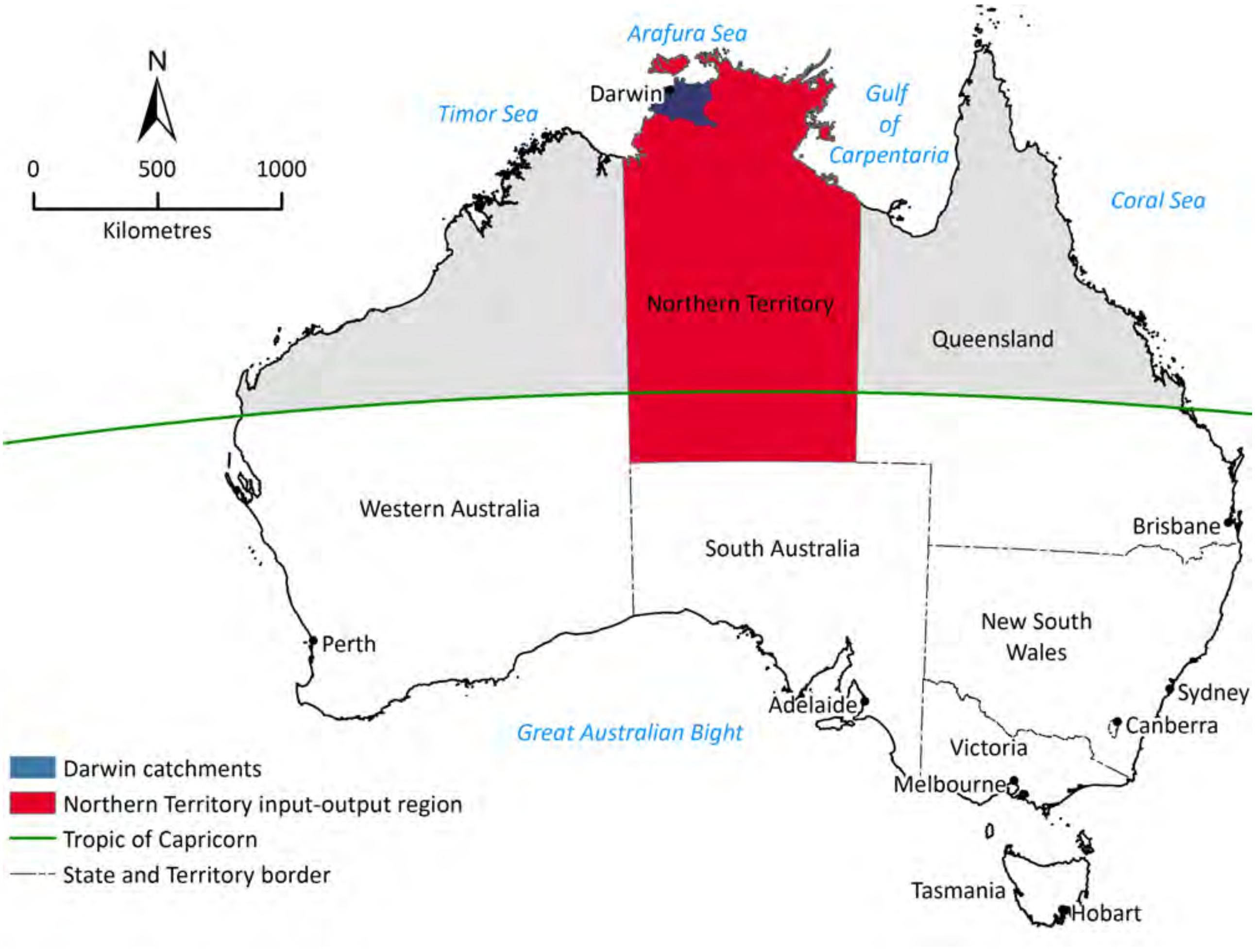

Figure 6-2 Northern Territory input–output region relative to the Darwin catchments

Table 6-18 Key 2016 data comparing the Darwin catchments with the related Northern Territory input–output region

INDICATOR	DARWIN CATCHMENTS	NORTHERN TERRITORY
Land area (ha ’000)†	2,985	135,316
Population‡	139,052	228,833
% male‡	52.5%	51.8%
% Indigenous‡	9.0%	25.5%
Median age‡	34	32
Median household income§	$110,760/y	$103,116/y

†Data sourced from ABS (2017)
‡Data sourced from ABS (2016a)
§Data sourced from ABS (2016b)

Wide variations can be seen in the size of the multipliers for different industries within the NT I–O region (Figure 6-3). Those industries with larger local regional multipliers would be expected to benefit more from development within the I–O region. For example, the ‘Beef cattle’ industry generated a smaller multiplier than ‘Wholesale and retail trade’, but a larger multiplier than ‘Mining’. However, a simple comparison of I–O multipliers can be misleading when considering different options for regional investment, because some impacts provide a short-term, one-off benefit (e.g. the construction phase of a new irrigation development), while others provide a sustained stream of benefits over the longer term (e.g. the production phase of a new irrigation scheme). A rigorous comparison between specific regional investment options would require NPVs of the full cost and benefit streams to be calculated.

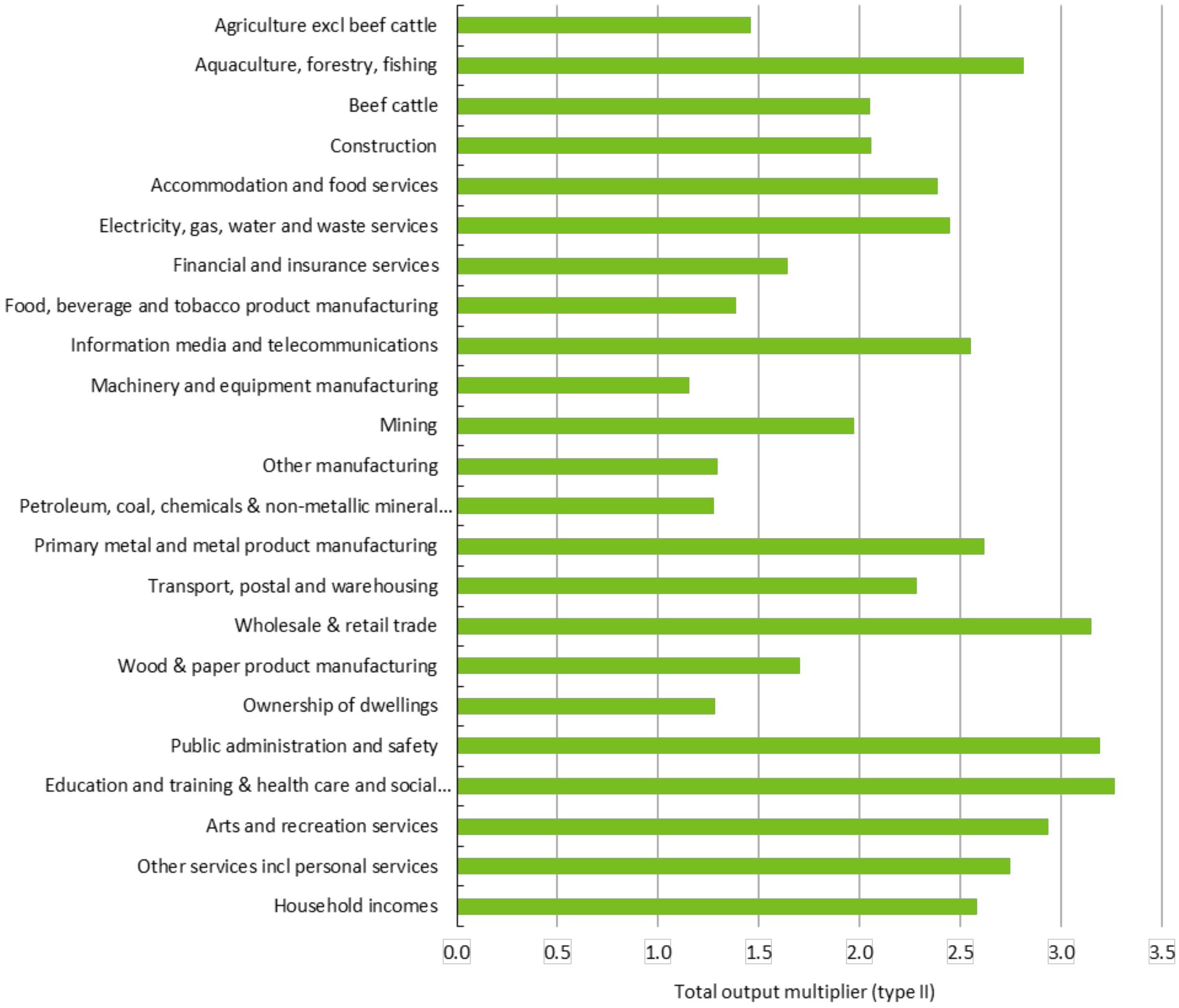

Figure 6-3 Multipliers for each industry within the Northern Territory input–output region
Shaded box highlights the multipliers for industries (in agriculture and construction) used to estimate regional economic benefits below. Multipliers used here (Type II) combine both the initial direct expenditure in a particular industry and the knock-on benefits to other businesses and industries along the supply chain. For detail on the development of multipliers, see companion technical report on socio-economics (Stokes et al., 2017).

6.4.2 INDIRECT BENEFITS DURING THE OPERATIONAL PHASE OF A DEVELOPMENT

Impacts of development on the I–O region are presented for four scales of increase in gross economic output ($25, $50, $100 and $200 million/year, indicative of potential outcomes) in each of three categories of agricultural activity (‘Beef cattle’, ‘Agriculture excluding beef cattle’, and ‘Aquaculture, forestry and fishing’). Impacts are shown as the total increased economic activity (Table 6-19) in the NT I–O region and the associated estimate of increase in employment (based median incomes in the I–O region) (Table 6-20). Note that all results scale linearly as the economic output of each type of agricultural activity increases.

Table 6-19 Estimated regional economic impact per year resulting from four scales of direct increase in agricultural output (rows) for each of three different categories of agricultural activity (columns) in the Northern Territory input–output (NT I–O) region

The value of increased agricultural economic activity can be calculated by multiplying the new area under irrigation by the mean increase in farm revenue received for the new (versus previous) agricultural produce.

DIRECT INCREASE IN AGRICULTURAL OUTPUT PER YEAR ($ MILLION)	TOTAL VALUE OF INCREASED ECONOMIC ACTIVITY IN NT I–O REGION – DIRECT, PRODUCTION INDUCED AND CONSUMPTION INDUCED ($ MILLION)		
	Type of agricultural development		
	Beef cattle	Agriculture excluding beef cattle	Aquaculture, forestry & fishing
25	51.3	36.5	70.4
50	102.6	73.0	140.8
100	205.3	145.9	281.5
200	410.5	291.8	563.0

As can be seen from the economic impacts (Table 6-19), an irrigation scheme that promotes ‘Aquaculture, forestry and fishing’ could have a larger regional impact in the NT I–O region than a scheme promoting ‘Beef cattle’ or ‘Agriculture excluding beef cattle’. These differences result from the different industry multipliers estimated for the NT I–O region (Figure 6-3).

Table 6-20 Estimated number of full-time equivalent jobs from four scales of increase in agricultural output (rows) for each of three different categories of agricultural activity (columns) in the Northern Territory input–output (NT I–O) region

DIRECT INCREASE IN AGRICULTURAL OUTPUT PER YEAR ($ MILLION)	TOTAL NUMBER OF ADDITIONAL JOBS IN NT I–O REGION – DIRECT, PRODUCTION INDUCED AND CONSUMPTION INDUCED		
	Type of agricultural development		
	Beef cattle	Agriculture excluding beef cattle	Aquaculture, forestry & fishing
25	175	39	335
50	350	78	671
100	699	157	1341
200	1398	314	2683

The results for employment (Table 6-20) are closely related to those for impacts on regional economic activity, but the two measures do reveal some differences. These additional full-time equivalent jobs arising in the NT I–O region may require additional community infrastructure (e.g. schools, health services) if workers move to fill these jobs from other parts of the country, resulting in population growth within the NT I–O region. However, should these additional jobs be filled by currently unemployed or underemployed local people, then additional infrastructure would not be necessary.

6.4.3 INDIRECT BENEFITS DURING THE CONSTRUCTION PHASE OF A DEVELOPMENT

While initially the building of new infrastructure (on-farm and off-farm development, including construction of related supporting infrastructure, such as roads, schools and hospitals) comes at a cost, the additional expenditure within a region (which puts additional cash into people's and businesses' pockets) would increase regional economic activity. This creates a fairly short-term economic benefit to the region during the construction phase, provided that at least some of the expenditure is within the region and is not all lost from the region due to leakage.

The proportion of expenditure during the construction phase that would be spent within the region depends on the different costs, including for labour, materials and equipment. For labour costs, it is likely that the wages will be paid to workers sourced from within the region and from elsewhere, with the likely proportion of labour costs relating to each source of workers being dependent on the availability of appropriately skilled labour within the region. For example, a highly populated region (more than 100,000 people) with a high unemployment rate (more than 10%) and skilled labour force is likely to be able to supply a large proportion of the workers required from within the region. However, a sparsely populated region with a low unemployment rate (less than 5%) is more likely to need to attract many workers from outside the region, either on a FIFO/DIDO basis or by encouraging migration to the region. Similarly, for materials and equipment, some regions may be better able to supply a large proportion of these items from within the region, whereas construction projects in other locations may find they are unable to source what they need locally, and instead import a significant proportion into the region from elsewhere.

Based on a review of different dam projects across the country, it would appear that the proportions of local construction spend sourced within a region (as opposed to being imported, which has no impact on the regional economy) vary significantly. Thus, analyses considered three levels for the proportion spent locally: 65% (low leakage), 50 and 35% (high leakage). However, it should be noted that for a very remote region, the potential exists for leakage to be higher than 65%.

Table 6-21 shows estimates of the regional economic benefit of the construction phase of a new development for five scales of scheme capital cost ($0.25 billion to $4 billion) and the three levels of leakage noted above.

Table 6-21 Estimated regional economic benefit of the construction phase of a development designed to promote an irrigated agricultural development within the Northern Territory input–output (NT I–O) region

SCHEME-SCALE CAPITAL COST ($ BILLION)	TOTAL REGIONAL ECONOMIC ACTIVITY WITHIN NT I–O REGION AS A RESULT OF THE CAPITAL COST OF THE SCHEME ($ BILLION)		
	Proportion of total construction capital costs made locally within the I–O region		
	65%	50%	35%
0.250	0.33	0.26	0.18
0.500	0.67	0.52	0.36
1.000	1.34	1.03	0.72
2.000	2.68	2.06	1.44
4.000	5.35	4.12	2.88

These results show that the size of the regional economic benefit experienced increases substantially as the proportion of scheme construction costs spent within the region increases. Given the proximity of potential Darwin catchments dam sites to Darwin, leakage may be towards the middle of the range examined. For example, if $2 billion was spent on construction for a new dam project and 50% of that was spent within the NT I–O region, the construction multiplier (2.06, Figure 6-3) would only apply to the $1 billion spent locally, to give an overall regional economic benefit of $2.06 billion (with additional benefits flowing to other regions where the remaining $1 billion was spent).

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