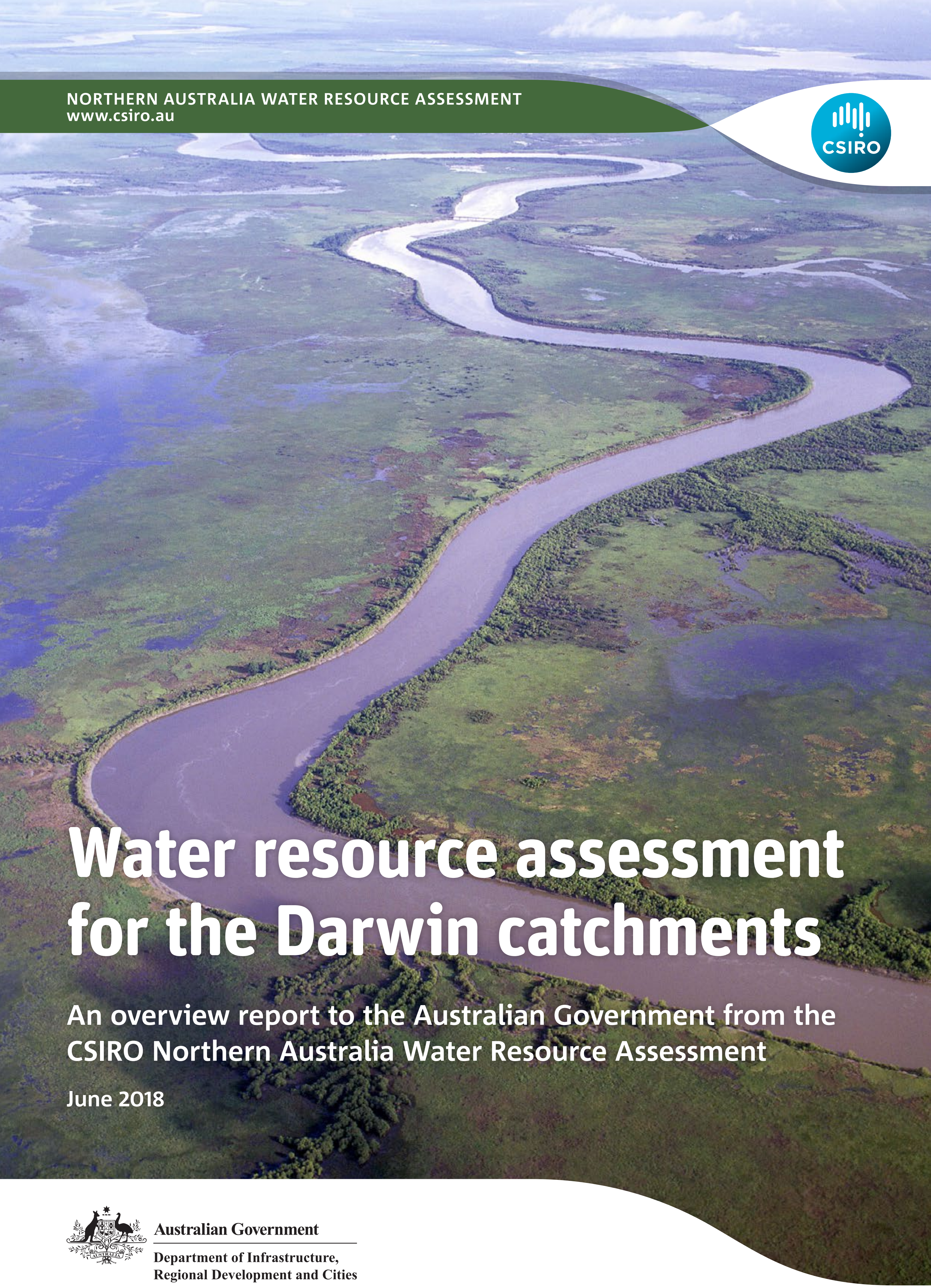


Water resource assessment for the Darwin catchments

An overview report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment

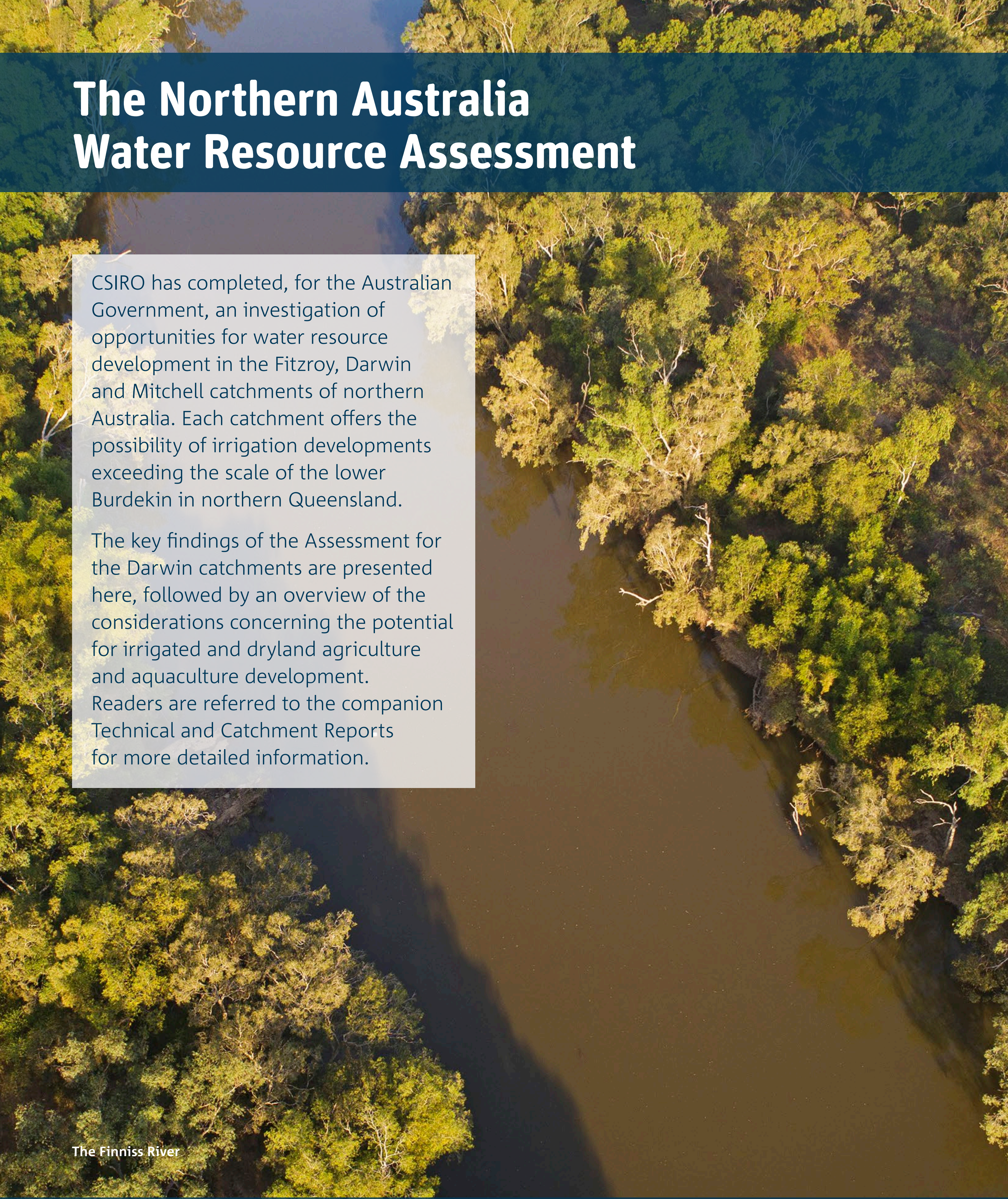
June 2018

Australian Government
Department of Infrastructure, Regional Development and Cities

The Northern Australia Water Resource Assessment

CSIRO has completed, for the Australian Government, an investigation of opportunities for water resource development in the Fitzroy, Darwin and Mitchell catchments of northern Australia. Each catchment offers the possibility of irrigation developments exceeding the scale of the lower Burdekin in northern Queensland.

The key findings of the Assessment for the Darwin catchments are presented here, followed by an overview of the considerations concerning the potential for irrigated and dryland agriculture and aquaculture development. Readers are referred to the companion Technical and Catchment Reports for more detailed information.



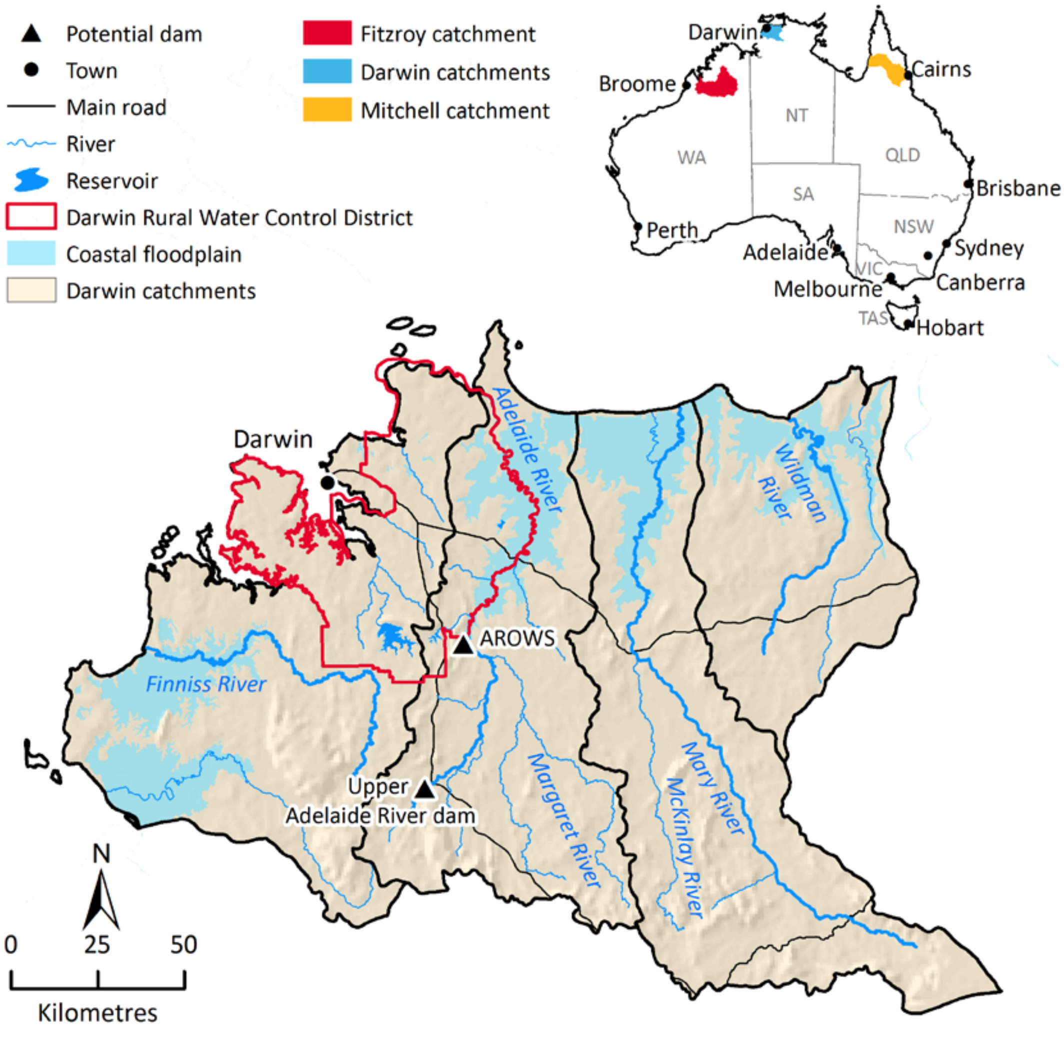
The Finniss River

CITATION

CSIRO (2018) Water resource assessment for the Darwin catchments. An overview report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments. CSIRO, Australia.

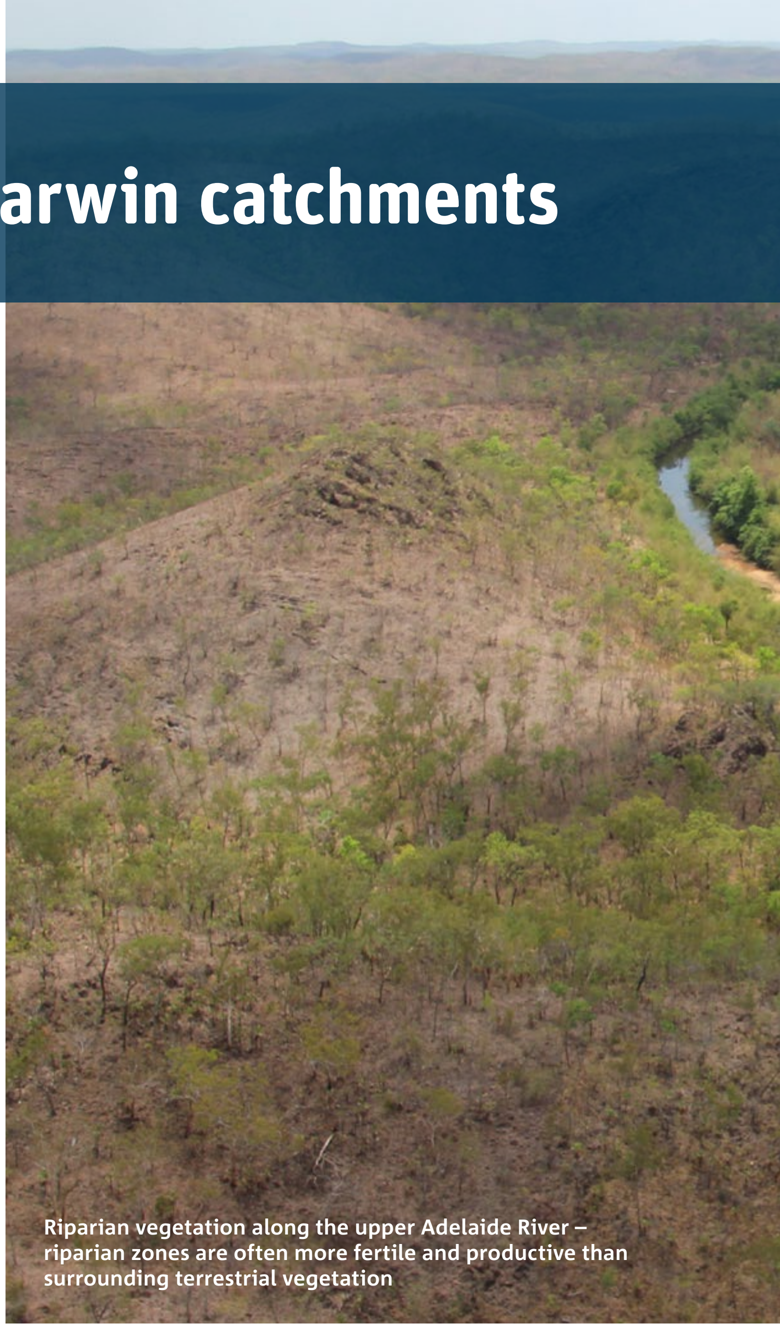
This is an overview of the following report: Petheram C, Chilcott C, Watson I and Bruce C (eds) (2018) Water resource assessment for the Darwin catchments. A report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments. CSIRO, Australia.

- The three study areas support diverse land uses and contain largely free-flowing rivers that sustain areas of high biodiversity and aquatic ecological value, and support valuable industries.
- The Assessment identified that:
  - The Fitzroy, Darwin and Mitchell catchments differ significantly in their physical and social characteristics and, as a consequence, the extent to and methods by which agricultural development might occur.
  - In the Fitzroy catchment, water harvesting (water pumped into ringtanks) could potentially support 160,000 ha growing one dry-season crop a year in 85% of years. Independent of surface water, groundwater could potentially support up to 30,000 ha of hay production in all years.
  - In the Darwin catchments, a combination of major dams, farm-scale offstream storages and groundwater could potentially support up to 90,000 ha of dry-season horticulture and mango trees.
  - In the Mitchell catchment, large instream dams could potentially support 140,000 ha of year-round irrigation. Alternatively, water harvesting could potentially enable up to 200,000 ha, growing one dry-season crop per year.
- If irrigated opportunities were pursued to their fullest extent they would only occupy about 3% of the Assessment area. Impacts on ecological function are not confined to the direct development footprint and would warrant attention, especially immediately downstream of the development and in drier years.
- Understanding how diverse stakeholder, investor and developer perspectives interact will be crucial in building and maintaining ongoing social licence to operate for future water and agricultural development.



The Darwin catchments

Key findings for the Darwin catchments



Riparian vegetation along the upper Adelaide River – riparian zones are often more fertile and productive than surrounding terrestrial vegetation

In the Darwin catchments the Finniss, Adelaide, Mary and Wildman rivers flow through extensive coastal and marine floodplains into the Arafura Sea. Land use in the 30,000 km² that make up the Darwin catchments is dominated by conservation and natural environments (38%), extensive grazing (32%) and dryland and irrigated cropping (7%). About 140,000 people live in the 2% of the landscape comprising urban and peri-urban development.

Indigenous people have continuously occupied and managed the Darwin catchments for tens of thousands of years and retain significant and growing rights and interests in land and water resources, including crucial roles in water and development planning and as co-investors in future development.

Agriculture and aquaculture opportunities

The Darwin catchments have up to 1 million ha of potentially irrigable agricultural soils. Of this land area, 800,000 ha are suitable for trickle-irrigated crops such as mangoes, whereas about 90,000 ha are suitable for flood-irrigated crops such as rice. A further 420,000 ha of land is moderately suitable for aquaculture, including species such as prawns and barramundi, grown in lined ponds. For all of these uses the land is considered moderately suitable with considerable limitations and would require careful soil management.

Groundwater is the Darwin catchments' most important consumptive water resource. Aquifers in the Darwin Rural Water Control District (DRWCD) currently provide an estimated 25 gigalitres (GL) for the purpose of irrigated agriculture, horticulture, public water supplies and local domestic use. New groundwater resources outside of the DRWCD (35 GL) could, if allocated, enable an additional 7800 ha of trickle-irrigated vegetable production, which could add $320 million and 345 jobs to the regional economy.

Significant new instream surface water storage is possible. Potential dams at Mount Bennett on the Finniss River (343 GL capacity) and the upper Adelaide River (298 GL capacity) could release approximately 436 GL for agriculture in 85% of years. This could support 40,000 ha of mangoes or 60,000 ha of trickle-irrigated vegetables, enabling just 2% of the area of the catchment to add $2.3 billion and 2500 jobs to the regional economy.

Offstream water harvesting is possible on the Margaret River in the Adelaide catchment (200 GL) and the McKinley and Mary rivers in the Mary catchment (400 GL). This could provide water sufficient to trickle irrigate 50,000 ha of vegetables, although the proximity of irrigable soils to locations suitable for water storage may be a limitation of this area.

Impacts and risks

Whether based on groundwater, instream dams or offstream storage, irrigated agricultural development has a wide range of potential benefits and risks that differentially intersect diverse stakeholder views on ecology, economy and culture. The detailed reports upon which this summary

is based provide information that can be used to quantify the trade-offs required for agreed development plans.

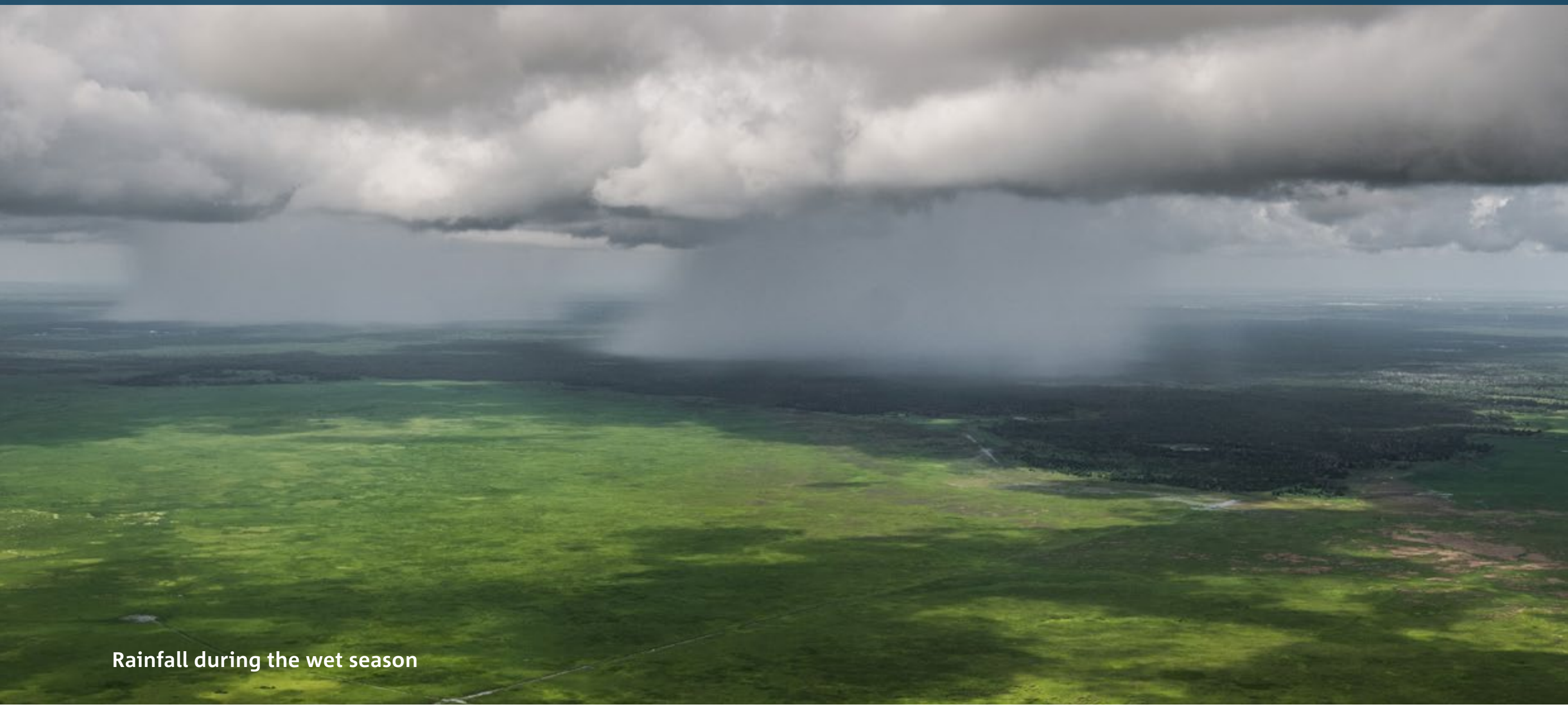
The general impacts of potential new groundwater-based developments may include a reduction in spring flows and an increase in the depth to groundwater beneath groundwater-dependent vegetation. These impacts can be reduced with good planning, such as evidence based water allocations and appropriately siting groundwater bore infrastructure. In some areas with existing groundwater development, there may be opportunity to intentionally recharge water to underlying aquifers, referred to as managed aquifer recharge (MAR), for subsequent recovery or to provide environmental benefit.

Instream storages, such as the potential upper Adelaide River dam, require trade-offs that occur over both time and space. Construction of large instream dams provide water that is generally secure across many years. This requires significant upfront investment that is intended to generate a future income stream that may contribute to the cost of investment. Instream dams significantly disrupt their immediate upstream and downstream environments but, when located high in the catchment, as with the potential upper Adelaide River dam, have negligible to minor impacts on coastal floodplains and their related mosaic of nationally important wetlands. Streams, wetlands and riparian areas remain of critical importance to Indigenous people. They have cultural significance and provide nutritional food.

Pumping water into offstream storages (water harvesting) generally has less impact on freshwater aquatic, riparian and marine ecosystems than major instream dams, in part because water extraction occurs mainly during floods and is restricted during low-flow periods. Offstream storages are readily scaled to match the availability of financial and physical capital. They are not usually capable of securing water for more than 1 year and, as a result, they 'make good wet seasons better' rather than reliably 'making dry seasons wet'.

Overview of the Darwin catchments

A highly seasonal climate



Rainfall during the wet season

The world's tropics are united by their geography but divided by their climates. Northern Australia's tropical climate is unique for the extremely high variability of rainfall between seasons and especially between years. This has major implications for the assessment and management of risks to development, infrastructure and industry.

The Darwin catchments have a hot and humid climate with a more reliable rainfall than other parts of northern Australia.

- The northerly and coastal position of the Darwin catchments ensures that wet-season rainfall is strongly influenced by the monsoon trough during 'active' monsoon phases.
- On average, the wet-season rain starts earlier in the Darwin catchments than anywhere else in northern Australia.
- The mean and median annual rainfall – averaged across the Darwin catchments – are 1423 mm and 1392 mm, respectively. However, there is a strong rainfall gradient that runs from the north-west coastal corner (1625 mm annual mean) to the south-east corner of the catchment (1250 mm annual mean).
- Annual rainfall totals in the Darwin catchments are reliable compared with other parts of northern Australia but less reliable than areas of similar total rainfall in southern Australia and comparable parts of the world.
- The intensity of dry periods in the Darwin catchments is similar to those of the Murray–Darling Basin and other parts of eastern Australia.
- The Darwin catchments experience equally long runs of consecutive dry and wet years and there is nothing unusual about the length of the runs of dry years.

The seasonality of rainfall presents challenges for both wet- and dry-season cropping.

- The wet season in the Darwin catchments is considerably more seasonal than in southern Australia, with 95% of the mean annual rainfall occurring in the wet season (November to April). During the wet season, rainfall can be very intense, increasing the risks of flooding, erosion and soil structural decline.
- The benefits to cropping of wet-season soil water are significantly offset by cloud cover that reduces radiation interception and crop growth. In addition, rainfall occurring over long periods can impair farm operations by restricting trafficability and paddock access.
- The dry season affords radiation that favours crop growth but, in the absence of irrigation water, dryland cropping is not likely to be economically viable.

- While annual rainfall is not always reliable and seasonal forecasting poor, farmers have the advantage of a clear view of water availability – soil water and dam storage levels – when they need it most, which is at the end of the wet season when planting decisions are made. This means farmers can manage risk by choosing crops that optimise use of the available water, or by deciding to forfeit cropping.

Large dams store water more efficiently than small dams.

- Potential evaporation (annual mean 1850 mm to 1950 mm) is only slightly higher than rainfall (annual mean 1423 mm) and, as such, net evaporative losses from major dams are lower than in most other parts of Australia.
- However, storing water in farm-scale storages over the dry season remains challenging. Appropriately sited large farm-scale ringtanks lose about 33% of their capacity to evaporation and seepage between April and September, highlighting the need to use irrigation water early in the dry period as part of a 'use it or lose it' irrigation regime.

Even though annual rainfall is increasing, plan for water scarcity.

- A trend for increasing rainfall has been observed in the Darwin catchments over the last three to four decades.
- Climate and hydrology data to support short- to medium-term water resource planning should encapsulate the full range of likely/plausible conditions and variability at different time scales, and particularly periods when water is scarce. These are periods that most affect businesses and the environment.
- Detailed scenario modelling and planning should be broader than just comparing a single climate scenario to an alternative future.

Cyclones pose a frequent risk to business and infrastructure.

- On average, the Darwin catchments receive at least one cyclone every two years. From 1970 to 2016, a single cyclone occurred in 36% of years and two cyclones occurred in 11% of years.

Climate change is unlikely to pose significant limitations to irrigated agriculture in the Darwin catchments.

- For the Darwin catchments, 24% of climate models project a drier future, 33% project a wetter future and 43% are within ±5% of the historical mean, indicating 'little change'. Recent research indicates tropical cyclones will be fewer but more intense in the future, although considerable uncertainties remain.
- Annual variability, particularly in rainfall, is likely to pose the greatest climate challenge for irrigated agriculture. The evidence suggests that challenges arising from any long-term trends in temperature or other climate variables can be addressed via improvements in new crop varieties and other improved technologies.


The Mary River coastal floodplain is amongst the most important breeding sites for magpie geese in Australia

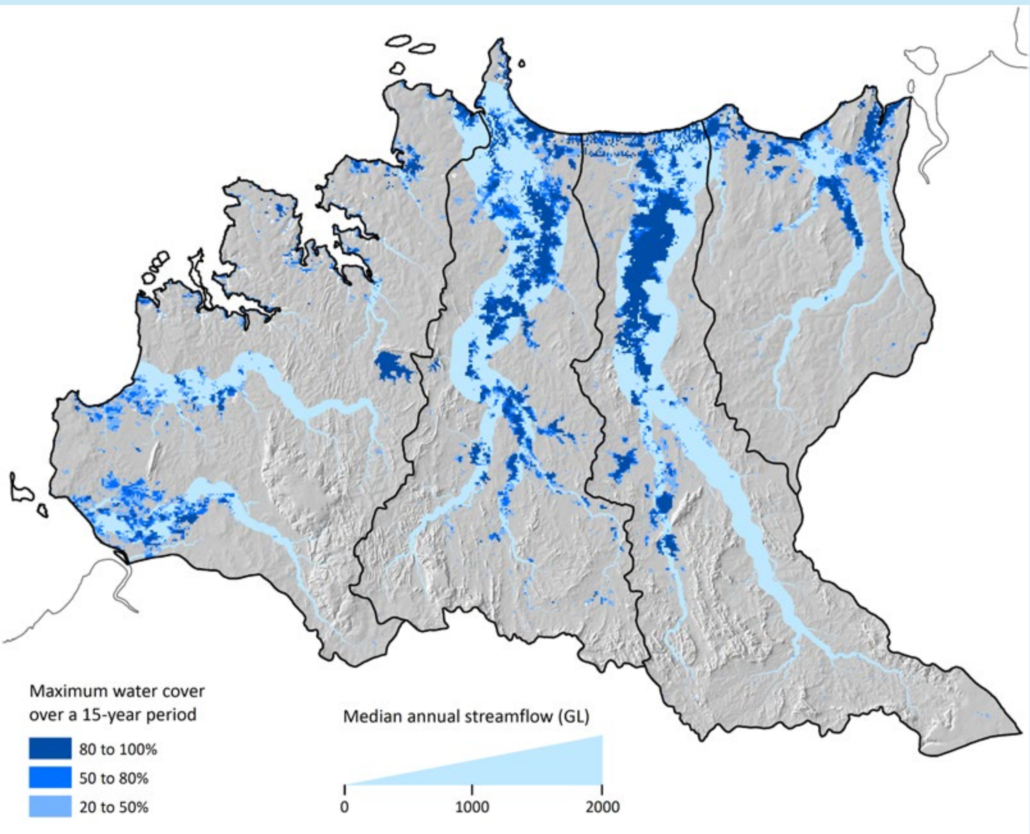
The Finniss, Adelaide, Mary and Wildman rivers

An unusually high proportion of rainfall enters streams.

- The mean annual discharge from the Darwin catchments is approximately 11,200 GL. About 40% of the runoff is generated on the tidally affected coastal floodplains, below the point at which it can be captured for consumptive use.
- Approximately 82% of runoff in the Darwin catchments occurs during the period between January and March, with the highest monthly totals occurring during March.
- There is a strong positive relationship between streamflow and fishery catches, especially for species of commercial and recreational importance.

Floods are relatively common, large and persistent.

- In the Darwin catchments, broad-scale flooding is largely limited to the coastal floodplains; these areas have limited agricultural value and can be inundated for more than 20 consecutive days. Where flooding does occur upstream of the coastal plains it is limited, with areas typically remaining inundated for less than 3 days.
- Relative to other parts of northern Australia, large flood events can occur over a longer part of the year, potentially reducing the window for cropping without flood protection. Of the ten largest flood events over the last 35 years at Dirty Lagoon on the Adelaide River, one event occurred during December, two in January, three in February, three in March and one in April.
- Flooding can potentially affect wet-season cropping. However, the speed of flood peaks in the tidally affected and relatively flat Darwin catchments are slow (~0.5 km/hour) and do not pose a risk to appropriately constructed storage embankments or levees.
- Flooding is ecologically critical because it connects offstream wetlands to the main river channels and connects and flushes out waterholes that sustain biodiversity during the dry season.



Historical (1890 to 2015) median annual streamflow and flood inundation (between 2000 and 2015) based on Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data in the Darwin catchments

Indigenous values, rights and development goals

Indigenous people make up a significant and growing proportion of the population of the Darwin catchments.

- As Traditional Owners they have recognised native title and cultural heritage rights, and control significant natural and cultural resources, including land, water and coastline.
- The history of pre-colonial and colonial patterns of land and natural resource use in the Darwin catchments is important to understanding present circumstances. That history also informs Indigenous responses to future development possibilities.

From an Indigenous perspective, ancestral powers are still present in the landscape and intimately connect people, country and culture.

- Those powers must be considered in any action that takes place on country.
- Riverine and aquatic areas are known to be strongly correlated with cultural heritage sites.

Indigenous land use agreements and Aboriginal land rights, native title and sacred sites legislation are important ways in which Indigenous interests in country are recognised and managed. Securing recognition through these pathways remains an important development goal for Indigenous people in the Darwin catchments.

- Indigenous people have strong expectations for ongoing involvement in water, catchment and development planning.
- Should development of water resources occur, participants in this study generally expressed preference for flood harvesting, which would fill offstream storages. Large instream dams in major rivers were consistently amongst the least-preferred options.
- Indigenous people have business development objectives designed to create opportunities for existing residential populations and to aid the resettlement and return of people currently living elsewhere.
- Indigenous people want to be owners, partners, investors and stakeholders in any future development. This reflects their status as residing in the catchments for the longest, with deep inter-generational ties to the catchments for the foreseeable future.

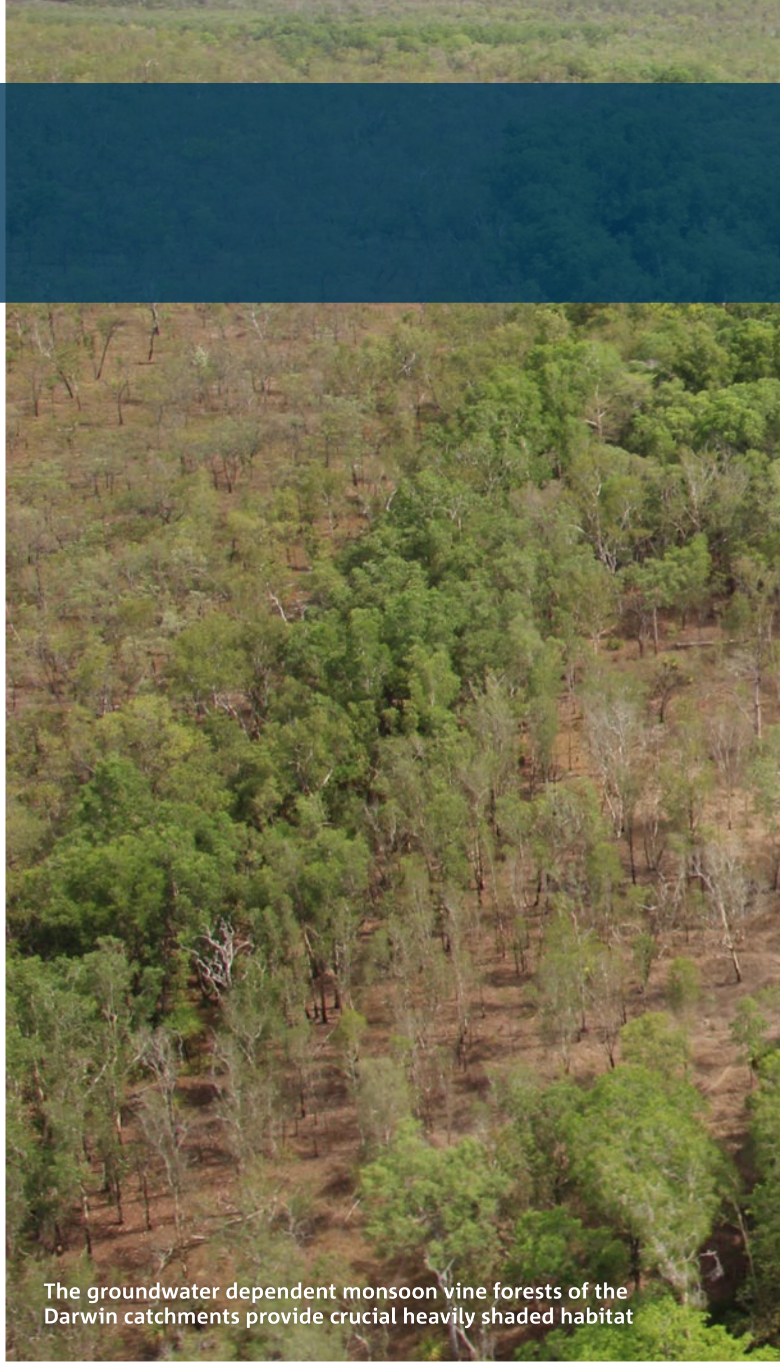
All the animals that live in the water, that we forage, we eat from the waterways and that's very important to helping people. It's one of the major things ... my ancestors have always been hunting and foraging on the river.

Traditional Owner from the Darwin catchments

We have got enough land and resources that if we plan it properly we should be able to coexist with other development. Good water is a part of that.

Traditional Owner from the Darwin catchments

A diversity of habitats



The groundwater dependent monsoon vine forests of the Darwin catchments provide crucial heavily shaded habitat

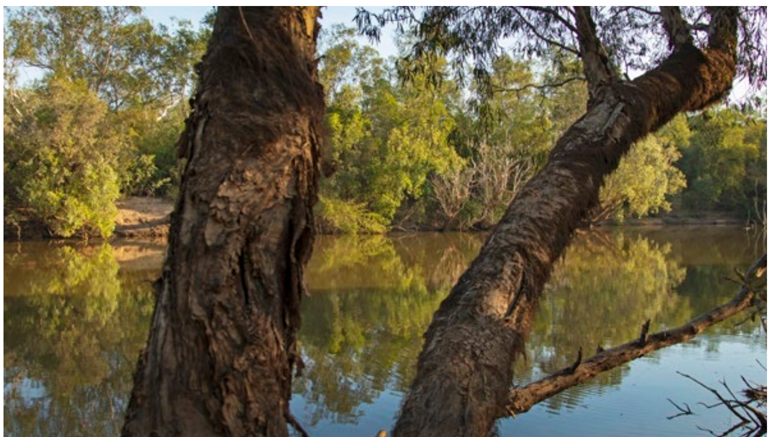
The Darwin catchments contain an enormous diversity, with large coastal floodplains that support freshwater, estuarine and marine habitats and species. These ecological assets have conservation, recreational, commercial and cultural values.

The Darwin catchments include both highly modified urban and agricultural landscapes, operational and legacy mines, and large areas of relatively intact landscapes.

- More than half of the population of the NT lives in the Darwin catchments, yet 53% of the total area is retained as conservation lands and other natural environments, much of it relatively undisturbed.
- These landscapes are important for the wide range of ecosystem services they provide: Darwin's water supply, recreational activities, tourism, cattle grazing on native pastures, and varied conservation and environmental values.
- Even intact landscapes face environmental threats from invasive plant species and from feral animals such as buffalo, feral pigs and cane toads.

Freshwater coastal floodplains of the Darwin catchments form a mosaic of highly productive and nationally significant wetland habitats.

- The floodplains and their waterways are home to a number of threatened species such as the northern river shark, marine turtles and other reptiles, several bird species and the northern quoll. The Darwin catchments also support large populations of some of northern Australia's most iconic wildlife species, such as saltwater crocodiles and barramundi.
- The Adelaide and Mary river coastal floodplain systems in particular are amongst the most important breeding sites for magpie geese in Australia.
- Five of the 33 wetlands of national importance in the NT are found in the Darwin catchments.



The Darwin catchments support a number of important terrestrial habitats.

- The groundwater-dependent ecosystems such as monsoon vine forests provide crucial heavily shaded habitat for a range of animals including fruit-eating birds and bats. Birds move between monsoonal forest patches and require many patches over a large area to maintain their populations.
- Riparian vegetation zones adjacent to watercourses are highly diverse and remain largely intact and provide an important link between terrestrial and aquatic communities. Riparian zones are often more fertile and productive than surrounding terrestrial vegetation.

Opportunities for agriculture and aquaculture

The Darwin rural area within the Darwin catchments currently has the largest area of land under irrigation in the NT.

- Approximately 4400 ha of land are currently under irrigation in the Darwin catchments, mostly for mangoes, melons, Asian vegetables and other vegetables and minor crops.
- There is currently very little broadacre cropping in the Darwin catchments.

Dryland cropping in the Darwin catchments is opportunistic and carries considerable risk, with failure likely in many years.

- In wetter-than-average years, the amount of soil water at the end of January combined with the rainfall received in the following 90 days is sufficient to grow a short-season (e.g. mungbean) or medium-season (e.g. sorghum, maize) crop. However, in these seasons, poor trafficability and limited dry days to enable sowing operations will regularly delay sowing until later in the season, with the likelihood of lower yields.
- Unlike other areas of northern Australia, in drier-than-average years the soil water stored at sowing and the rainfall received in the following 90 days may still be sufficient to grow a short-season crop. In such years, trafficability will be less of a constraint, permitting early establishment of a crop. A risk associated with cropping in these years is dry spells of 2 weeks or more, especially during crop establishment.
- It is possible to achieve break-even yields of dryland medium-season crops, such as sorghum, 5 years in 10. The main limitation is insufficient soil water during the mid- to later parts of the growing season (in the dry season).

Irrigation provides not only for higher yields, but also more reliable production compared with dryland crops.

- A wide range of crops are potentially suited to irrigated production in the Darwin catchments. These include cereals, pulses, forages, vegetables and perennial fruit tree crops as well as industrial crops such as sugarcane and cotton.
- Seasonal water use by crops can vary enormously depending on crop type and season of growth; for example, a rice crop planted at the start of the wet season and reliant only on supplementary irrigation in the final stages of growth can use as little as 1 ML/ha, while a rice crop grown during the dry season requires around 8 ML/ha before accounting for conveyance and field application losses.

Up to 1 million ha of the Darwin catchments are classified as moderately suitable with considerable limitations (Class 3) for irrigated agriculture, depending on the crop and irrigation method chosen.

- These Class 3 soils have considerable limitations that lower production potential or require more careful management than more suitable soils (i.e. Class 1 or Class 2). In this respect, they do not differ from many of Australia's agricultural soils.

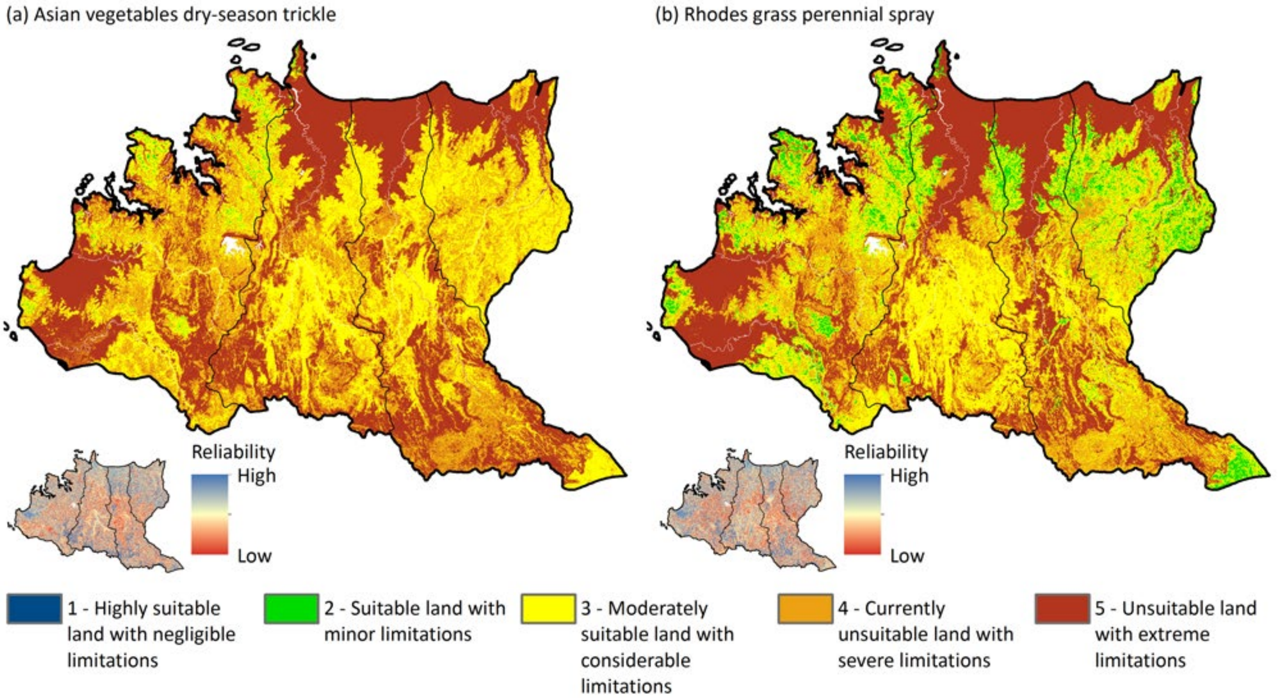
Descriptions of each Class (1 to 5) are found in the map legend. The classes were derived from a set of attributes such as erodibility, slope, soil depth, permeability, rockiness and others.

The area estimates given here are derived from assessing soil, landscape and climate factors within the whole catchment, as an upper starting point. The area actually available for irrigation will be less – once considerations relating to land tenure, land use, flooding risk, availability of water for irrigation and other factors are taken into account.

- Just over 1 million ha, or 33%, of the Darwin catchments are considered to be Class 3 for perennial forage, such as Rhodes grass, under spray irrigation. About 350,000 ha are classified similarly for forage sorghum, using spray irrigation in the dry season.
- About 800,000 ha, or 26%, of the Darwin catchments are considered to be Class 3 mangoes under trickle irrigation.
- For cotton, and some cereals, pulses, oilseeds and forages, approximately 650,000 ha or 22% of the Darwin catchments are considered to be Class 3 for irrigated cropping using spray irrigation in the dry season.
- About 460,000 ha are Class 3 for upland rice under spray irrigation in the dry season. For lowland rice under flood irrigation, there are about 90,000 ha which are Class 3 in the dry season and 67,000 ha in the wet season.
- The loamy soils of the elevated coastal plains, the lower slopes of hills and upper catchment plateaus are most suitable for spray irrigation, although they must be managed to limit water erosion.
- The northern and coastal parts of the Darwin catchments and the floodplains of the major rivers are dominated by seasonally or permanently wet soils. These are poorly drained, regularly flooded and susceptible to cyclone storm surges. They have little to no potential for irrigated agriculture.
- Further inland, shallow and/or rocky soils limit agricultural potential to isolated pockets of better soil, limiting agricultural development to small patches.

An excess of water also carries risk.

- High rainfall and possible flooding means that wet-season cropping carries considerable risk due to potential difficulties with access to paddocks, trafficability and waterlogging of immature crops.
- Due to inadequate drainage of the soil profile in heavier soils, the area suitable for furrow irrigation is much lower than under spray or trickle irrigation.
- Under furrow irrigation, between 35,000 ha and 90,000 ha are Class 3 in the dry season, depending upon crop or forage type.
- Irrigation in the Darwin catchments, and the NT more generally, has predominantly been undertaken on loamy and sandy soils (e.g. Red Kandosols) with water sourced from groundwater. There is limited irrigated cropping experience on heavy clay soils of the NT based on surface water, and it will take time to establish reliable farming systems on these soils.



Modelled land suitability class for dry-season mungbean under (a) furrow irrigation and (b) spray irrigation in the Darwin catchments

The inset for each map shows the reliability of this classification.
This map does not consider risk of flooding or water availability.


Asian vegetables can produce high gross margins and supply markets off-season in southern Australia

Establishing irrigated cropping is challenging, with high input costs and high capital requirements for greenfield development.

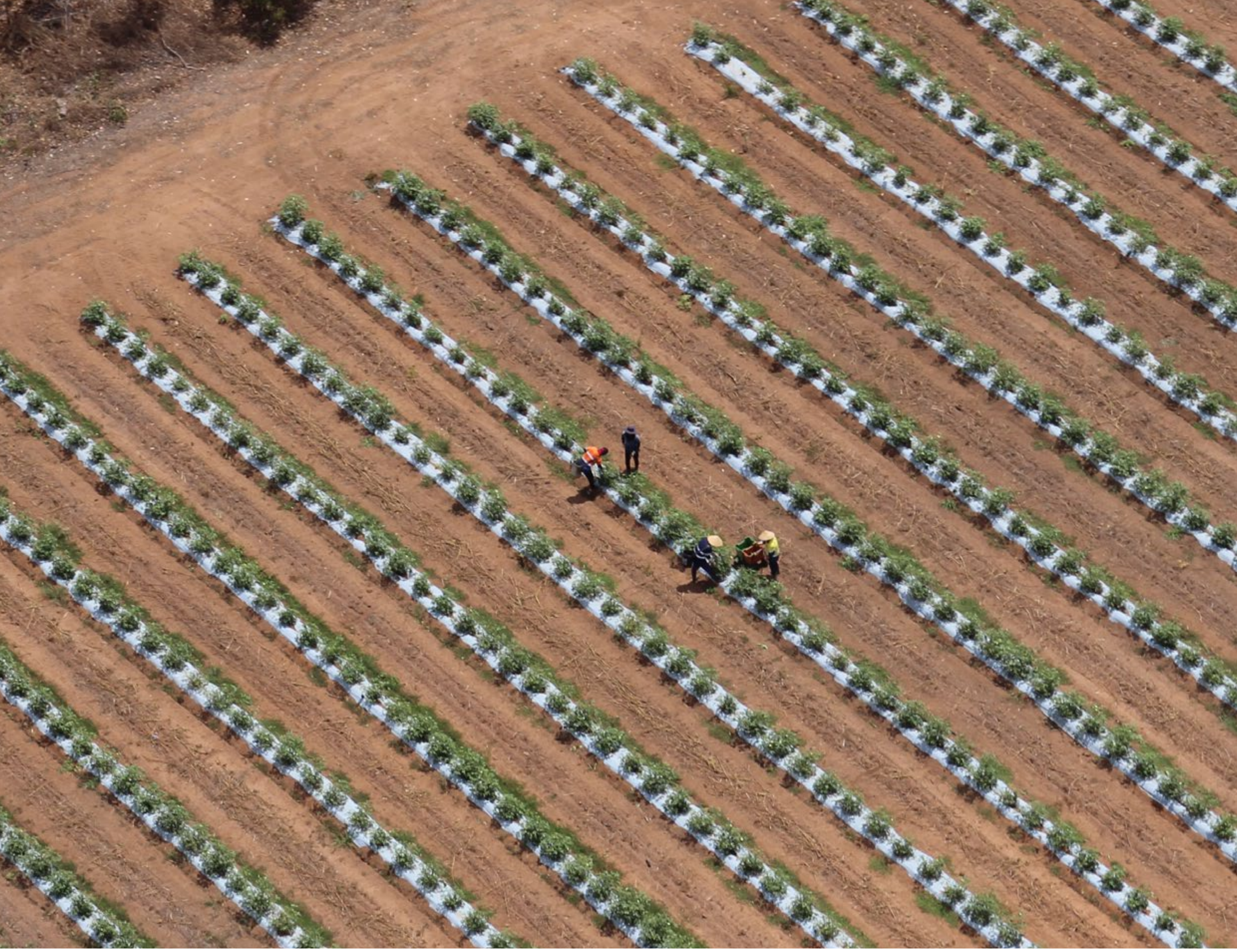
- Many irrigated crops are capable of consistently generating a positive gross margin. Careful planning, especially of projected cash flows, is required to identify crops and production methods that can generate the profits required to meet the capital costs of development.
- Gross margins of horticultural crops are generally much higher than those of broadacre crops but are highly price sensitive; establishing reliable market niches, such as early or late season supply, is critical to viability.
- Gross margins for the more established crops such as mangoes and melons are consistent with other regions in Australia.
- The availability of family labour is often an important determinant of profitability for labour intensive crops such as Asian vegetables.
- Amongst the broadacre crops, dry-season rice or a grass forage for hay appear most prospective.

More than one crop per year may be required to sustain greenfield irrigation developments.

- The cash generated from a single crop each year is unlikely to enable the capital costs of development to be met.
- There has been relatively little experience in implementing rotational, two-crops-per-year, broadacre cropping systems in the NT.
- In addition to the potential for higher gross margins, rotations can be designed to help manage disease, pests and weeds, minimise soil and nutrient losses and reduce the need for inorganic nitrogen inputs.
- A rotation system of rainfed wet-season soybean followed by dry-season irrigated rice may be capable of producing yields similar to the sum of the individually grown crops, and could be sufficient to meet capital costs of development in the order of $10,000 to $15,000/ha.
- The development of a range of two-crops-per-year rotation alternatives, and the management packages and skills to support them, is a likely prerequisite for economically sustainable irrigated broadacre cropping. The challenges in developing these should not be underestimated.

Irrigated cropping has the potential to produce off-site environmental impacts, although these can be reduced by good management and new technology.

- The pesticide and fertiliser application rates required to sustain crop growth vary widely amongst crop types. Selecting crops and production systems that minimise the requirement for these can simultaneously reduce costs and environmental impacts.
- Refining application rates of fertiliser to better match crop requirements, using controlled-release fertilisers, and improving irrigation management are all effective ways to minimise nutrient addition to waterways and, therefore, the risk of harmful microalgae blooms.
- The use of best management practices including controlled traffic and banded application of pesticides can substantially reduce their efflux to waterways.
- Adherence to well-established best management practices can significantly reduce erosion where intense rainfall and slope would otherwise promote risk.



- While cotton is not currently grown in the Darwin catchments, it is a good example of a genetically modified (GM) crop that allows industry to substantially reduce insecticide and herbicide application. In recent years GM cotton has resulted in cotton farmers in Australia using 85% less insecticide, 62% less residual-grass herbicide and 33% less residual-broadleaf weed herbicide. In addition to reducing the likelihood and severity of off-site impacts, GM crops offer health benefits to farmer workers through handling fewer chemicals. This technology has considerable application to northern Australia.

Pond-based prawn and barramundi aquaculture offer potentially high returns in the marine- and brackish-water environments of the Darwin catchments.

- For marine species, there are approximately 420,000 ha of coastal land at least moderately suitable for lined aquaculture ponds.
- On the coastal floodplains, flood protection levee banks may be required. Provided embankments are of sufficient height and appropriately constructed, the slow-moving nature of floodwater in the Darwin catchments should pose an operational risk rather than a risk to infrastructure.
- Although other aquaculture species are being trialled in northern Australia, prawns and barramundi have established land-based cultural practices and well-established markets for harvested products.
- Long transport distances for specially formulated feed and finished products contribute to the high cost of aquaculture production. Even so, skilfully managed prawn and barramundi pond-based aquaculture can be profitable enterprises in the Darwin catchments.
- The remote location of the Darwin catchments provides some biosecurity advantages to aquaculture production.
- Aquaculture enterprises are likely to encounter fewer regulatory constraints than those in catchments in other parts of Australia, such as those draining into the Great Barrier Reef. For example, while Australian prawn farms have been found to be some of the most environmentally sustainable in the world, approval processes and strict regulation constrain development along the east coast of Australia.

The economic development opportunities presented by groundwater are well-recognised in the Darwin catchments

Managing late dry season groundwater levels in the Darwin rural area using managed aquifer recharge is challenging.

- Groundwater resources in the Darwin catchments offer niche opportunities that are geographically distinct from surface water development opportunities.
- The interconnected sand and dolostone aquifers in the Wildman catchment offer opportunity for groundwater resource development in areas that coincide with suitable soil and minimal flood risk.
  - Groundwater is fresh with low salinity (<500 mg/L), has moderately high bore yields (>10 L/second) and the water-bearing formation is at economically viable depths.
  - Recharge to the interconnected sand and dolostone aquifers occurs as a combination of infiltration through the soil over large areas and preferentially at features such as sink holes. Recharge is estimated to be in the order of about 30 GL/year.
  - Appropriately sited groundwater bores could extract in total between 5 and 10 GL of water from the aquifers depending on their proximity to environmental assets.
- In other catchments groundwater is largely used for stock and domestic purposes, though total recharge to the Koolpinyah Dolostone Aquifer east of the Adelaide River, the Kulshill Group Sandstone and the Daly River Limestone is estimated to be in the order of about 100 GL/year. It is estimated that an additional 25 GL/year could potentially be extracted from groundwater in the Darwin catchments. Currently little is known about these systems.
- New groundwater extraction in the Darwin catchments could potentially enable an additional 7800 ha of Asian vegetables under trickle irrigation at an annual gross value of production of $220 million, assuming markets could support such an increase. This would occur at distinct locations widely spread across the Darwin catchments.


Sampling groundwater in the Wildman catchment

Groundwater supplies in the Darwin rural area are currently fully allocated.

- The Koolpinyah Dolostone and other dolostone aquifers in the DRWCD supply an estimated 25 GL/year for irrigated agriculture, horticulture, public water supplies and local domestic use.
- In wet-seasons with low rainfall, groundwater levels in the dolostone aquifers in the DRWCD can fall below the depth of some bores resulting in bore failure.

Sampling spring water in the Wildman catchment

Groundwater, which is more economically attractive than managed aquifer recharge (MAR), will always be developed first. However, MAR can enhance the quantity of water available for extraction and help mitigate impacts to the environment.

- Demand management could potentially be used to help manage late dry-season groundwater levels in the Darwin rural area.
- Where additional groundwater storage capacity exists at the end of the wet season, MAR can increase groundwater availability by storing wet-season rainfall as a buffer against late dry-season drought. This would require a source of surface water.
- The compartmentalised nature of the Koolpinyah Dolostone and the seasonal variability in groundwater levels, would require MAR to have multiple injection sites at strategically selected locations to alleviate the effect of low groundwater levels late in the dry-season.
- The potential of MAR to enable greenfield mosaic irrigation developments in many locations in the Darwin catchments is limited by the available groundwater storage capacity at the end of the wet season.
- A potentially promising option for MAR in the Koolpinyah Dolostone is a large-scale (~5 GL/year) aquifer storage and recovery scheme in the confined portion of the aquifer, to the north of current groundwater use.

Groundwater discharge supports a diverse range of ecosystems.

- In the Darwin catchments, groundwater discharging to the natural environment supports springs and partially supports small patches of monsoon vine forests. Discharge is also likely to occur as 'submarine' groundwater discharge to the ocean.
- Any extraction of groundwater for consumptive purposes will result in a corresponding reduction in 'natural' discharge to rivers, springs and vegetation.
- The time lag between groundwater extraction and the corresponding change in the expression of groundwater where it naturally discharges may be many decades in intermediate scale groundwater systems and longer in regional systems. This presents management challenges.

Surface water storage potential

Although groundwater offers cheaper water at lower risk than surface water storage in the Darwin catchments, surface water storage can enable considerably larger scales of development.

There is no single water storage and supply solution. Maximising the scale and cost-effectiveness of water supply in the Darwin catchments may require adopting different options in different locations and at different times.

- Major dams at Mount Bennett and upper Adelaide River are potentially the most cost-effective ways of capturing and storing water for irrigation on the Finniss and Adelaide rivers, respectively. Together they could release approximately 436 GL of water in 85% of years. Collectively the two dams would cost about $373 million, or $855/ML released at the dam wall in 85% of years.
- The two dams together would have sufficient water to irrigate 60,000 ha (2% of the area of the Darwin catchments) of dry-season Asian vegetables or 40,000 ha of mangoes after conveyance and field application losses. These would generate an annual gross value of production of approximately $1.7 billion for Asian vegetables or $1.6 billion for mangoes, assuming markets could support such an increase.
- The Adelaide River offstream water storage (AROWS) could extract and store more than 50 GL of water per year at greater than 99% reliability. There is no land suitable for irrigated agriculture in the vicinity of the AROWS.
- The Marrakai potential dam site was deemed likely to have very high construction risks; it has poor foundation conditions and it is likely that considerable environmental impacts would be experienced during construction and operation of a dam at this site. Furthermore, the yield of a dam at this site would far exceed any potential future downstream demand.

The majority of streamflow within the Darwin catchments cannot be readily captured or stored offstream. For example, approximately 75% of total streamflow at Dirty Lagoon is discharged in the highest 10% of days, of which only a small proportion could be pumped.

- Water harvesting, where water is pumped from a major river into an offstream storage such as a ringtank, is the most cost-effective option of capturing and storing water from the Margaret River in the Adelaide catchment and the McKinley and Mary rivers in the Mary catchment.
- It is physically possible to extract 200 GL and 400 GL of water in 85% of years along the Margaret River and in the Mary catchment, respectively. After evaporation, conveyance and field application losses this is sufficient water to irrigate about 50,000 ha (1.7% of the Darwin catchments) of Asian vegetables at an annual gross value of production of $1.4 billion.
- The extracted water could potentially be stored in 150 ringtanks (each of capacity 4 GL) at a cost of about $330 million, or $820/ML released from the ringtank, not including the cost of pumping. Storing this much water in ringtanks may occupy nearly 20,000 ha of land and it is likely that land suitable for the construction of impermeable embankments will limit the scale of water-harvesting development.
- There is no land suitable for construction of ringtanks in the Finniss catchment that is also coincident with land suitable for irrigated agriculture.
- Large-scale water harvesting in the Darwin catchments results in small changes to small flood events and has negligible impact on moderate to large-size flood events.
- In the Darwin catchments there are few opportunities for large farm-scale gully dams in close proximity to soils suitable for irrigated agriculture. Hillslope dams, with higher excavation (cost) to storage ratios may enable small-scale irrigation developments upstream of the Arnhem Highway in specific areas.

The upper Adelaide River Dam could safeguard Darwin's future water supply and support 8500 ha of irrigated agriculture.

- Darwin's demand for water is projected to outstrip its system yield in the near future. By 2065 Darwin is projected to require an additional 10 to 20 GL of water annually.
- The upper Adelaide River dam site is the most topographically favourable potential dam site in the Darwin catchments and has a catchment area of 616 km^2, or 8% and 2% of the area of the Adelaide River catchment and Darwin catchments, respectively.
- The optimum construction for the Upper Adelaide River dam is a roller-compacted concrete dam. At the nominated full supply level it would cost an estimated $182 million to construct.
- Substantial land in the area is subject to current or future native title claims and there are a number of registered and/or recorded sacred or cultural heritage sites known to exist in the area that would potentially be inundated.
- The dam's potential reservoir would be able to release an additional 15 GL/year of high-security water (in more than 99% of years) to Darwin via a pipeline and 125 GL in 85% of years for irrigated agriculture. This would be sufficient water to irrigate 8500 ha of dry-season rice adjacent to the Adelaide and Margaret rivers, upstream of their confluence.
- This would triple the area under irrigation in the Darwin catchments and could generate an annual gross value of production of about $35 million.
- An upper Adelaide River dam would markedly change the volume and timing of flow immediately downstream of the dam to a re-regulating structure potentially 30 km downstream.
- The impact of a dam on streamflow reduces with distance downstream. Below the confluence of the Adelaide and Margaret rivers at Dirty Lagoon, the reduction in mean and median annual streamflow would be about 11% and 15%, respectively.

Upper Adelaide River dam site is the most topographically favourable potential dam site in the Darwin catchments

Changes in timing and volume of flow have ecological impacts

Magpie geese

Although irrigated agriculture typically occupies a very small proportion of the landscape, it can potentially result in large changes to the volume and timing of river flow and, hence, ecological function.

The impact of a major instream dam on aquatic, riparian and near-shore marine ecology is strongly related to its position in a catchment and the size of its reservoir relative to the volume of streamflow.

- The high position of the potential upper Adelaide River dam in the catchment means its ecological footprint would be largely localised. Its impact on the movement and migration of fish species would be relatively minor at the scale of the entire catchment, although this would also depend upon the position of any re-regulating structure downstream.
- The large changes in volume and timing of flow in the reach immediately below the dam and upstream of the point of extraction would have a major impact on species and their flow habitats including barramundi, largetooth sawfish and turtles, and a moderate impact on magpie geese, riparian vegetation, waterholes and wetlands.
- Below the junction of the Adelaide and Margaret rivers, species and their flow habitats would experience a minor impact. The upper Adelaide River dam would have a negligible impact on the inundation of the ecologically important coastal floodplain and minimal impacts on estuarine and coastal species.
- Pumping 50 GL/year of water during high flow in the wet season into the potential AROWS would have a negligible impact on the flow habitats of estuarine and coastal species.

At equivalent storage capacities, pumping water into offstream storages (water harvesting) has less impact on freshwater aquatic, riparian and marine ecosystems than major instream dams.

- Water harvesting less than 150 GL/year in the Mary catchment would have a negligible impact on the flow habitat of migratory fish, barramundi and magpie geese.
- Water harvesting less than 550 GL/year in the Mary catchment would have a minor impact on the flow habitat of estuarine and coastal species, such as crocodiles, sawfish, snub-nosed dolphin and white banana prawns.

Although intensive land management has the potential to improve some ecological outcomes, past experience suggests this is unlikely to occur; there are currently no incentives for irrigation developments to manage beyond their boundaries or for issues that do not impact their production.

- Direct impacts of irrigation on the terrestrial environment are typically small. However, indirect impacts, such as weeds, pests and landscape fragmentation, particularly to riparian zones, may be considerable.
- Generally, irrigated cropping systems have relatively well-developed invasive species management protocols and the economics of such systems is such that they can bear the cost of controlling weeds and pests that are of concern to them.

Commercial viability and other considerations

Irrigated agriculture currently makes a sizeable contribution to the economy of the Darwin catchments.

- The gross value of agriculture production in the Darwin catchments is about $135 million, of which $120 million is provided by irrigated fruit, particularly mangoes, and vegetables. Horticultural products are exported to southern domestic markets.
- Beef production in the Darwin catchments is mainly from small properties, with beef cattle production contributing around $13 million in gross agricultural production in the Darwin catchments. However, the Darwin catchments are important for holding cattle prior to live export and high-quality forage is in demand.

While the natural environment of northern Australia presents some challenges for agriculture, the most important factors determining the commercial viability of new developments are management, planning and finances.

- Large developments for agriculture are complex and costly. It would be prudent to ensure there are sufficient funds remaining after the construction phase to safeguard the operation of new enterprises in the likely occurrence of 'failed' years at the start of their operation.
- There is a strong incentive to start any new irrigation development with well-established and understood crops, farming systems and technologies as this will reduce the likelihood of initial setbacks and failures.
- There is a systematic tendency for proponents of large infrastructure projects to substantially under estimate development costs and risks and/or over estimate benefits. This can be in part due to financial return imperatives driving an overly optimistic assessment of the time frame for positive returns, unanticipated difficulties and project delays, and the difficulty of accurately planning and budgeting over many years.

It is prudent to stage developments to limit negative economic impacts during start-up and to allow small-scale testing on new farms.

- The initial challenge of establishing and adapting agriculture in a new location can be mitigated by learning from past experiences in northern Australia. However, even if well-prepared, each new location and development will provide unique challenges.
- Staging and allowing for sufficient learning time can limit losses where small-scale testing proves initial assumptions of costs and benefits to be overly optimistic or reveal unanticipated challenges in adapting farming practices to local conditions.

Synergies through vertical and horizontal integration present opportunities for commercial returns but increase risk.

- Aggregated farm revenue from broadacre agriculture is unlikely to cover the cost of infrastructure for an irrigation scheme under current farming systems. Value adding through processing will increase revenues and will greatly improve the commercial viability of an irrigation scheme.
- Vertically integrated agricultural enterprises require a sufficient scale of development in order to be viable, with supply commitments of raw farm products necessary to justify the investment in processing facilities.
- The more complex a scheme becomes and the more strongly interdependent the components become, the greater the risk that underperformance of one component could undermine the viability of the entire scheme.

Distance from the farm gate to agricultural processing plants places a significant cost burden on industry in the Darwin catchments.

- The Darwin catchments have advantages over other parts of northern Australia in that
  - there are some refrigerated backloading opportunities, which are best suited to crops that are harvested in most months (e.g. bananas) rather than crops with a short harvest season (e.g. mango or melon)
  - they have good access to Darwin Port for export of live cattle and general freight, access to southern markets via the Stuart Highway, and quality rail access.
- However, transport to major southern markets will add significant costs and make supplying lower-value broadacre crops unviable when competing against southern production. There are established export supply chains for live cattle and some frozen meat, however the exports of horticultural or broadacre crops out of Darwin Port into Asia are not yet at sufficient scale to justify investment in port infrastructure.
- The nearest processing facilities for higher-value broadacre crops, such as peanuts and sugar, are in Queensland, making these crops currently unviable. Local processing would ensure better farm-gate returns.
- Outside the Darwin urban area, the current road network is sparse and minor unsealed roads are prone to flooding, restricting wet-season access, particularly for those roads on black soils.

Aquaculture can potentially bring high returns

- The Arnhem Highway Road was closed 85 days over a 7-year period from 2005 to 2012.

Irrigated agriculture has a greater potential to generate economic and community activity than rainfed (dryland) production.

- Studies in the southern Murray–Darling Basin have shown that irrigation generates a level of economic and community activity that is three to five times higher than that generated by rainfed (dryland) production.
- In the Darwin catchments, irrigation development could result in an additional $1.06/year of indirect regional economic benefits for every $1.00 spent during the construction phase. The regional economic impact of an annual increase in irrigated agricultural output of $100 million/year is estimated to be an additional $46 million of increased economic activity.
- During the construction phase, aquaculture development may result in a regional economic benefit similar to that from irrigated agriculture. Once businesses have been established, the regional economic impact of aquaculture is considerably higher; each $100 million/year of output is estimated to create an additional $182 million of increased economic activity.
- Justification and support for public investment in new water infrastructure will in part depend on the flow-on and indirect benefits beyond the irrigation scheme.

Community infrastructure in the Darwin catchments could accommodate a large increase in irrigation development without additional investment.

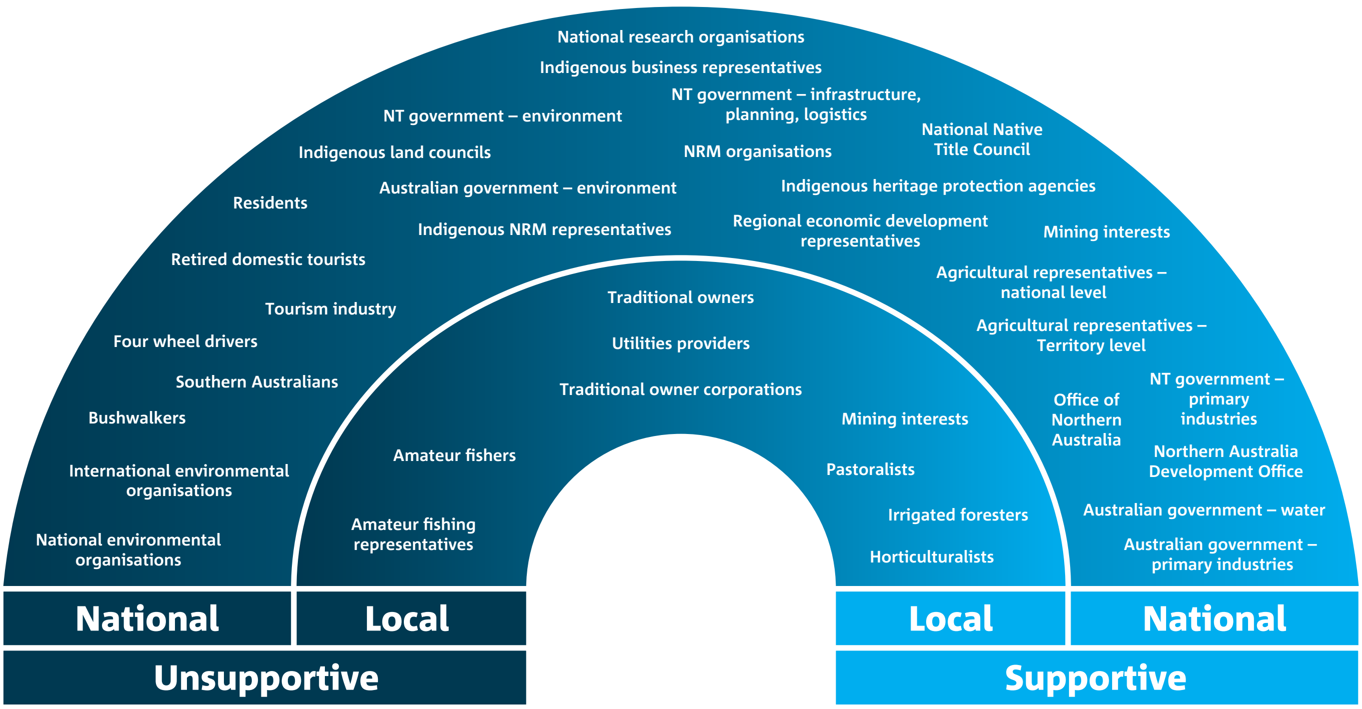
- The four Darwin catchments are unique in northern Australia in that they have a large urban centre on their doorstep, with a population of 139,000. The availability of community and soft infrastructure make developments in the Darwin catchments attractive to new workers.

Grading farmed prawns

- Unlike in many other parts of northern Australia, a development in the Darwin catchments would not likely require significant investments in new community or soft infrastructure, such as schools and hospitals, emergency services and law enforcement.

Sustainable irrigated development requires resolution of diverse stakeholder values and interests.

- Establishing and maintaining a social licence to operate is a precondition for substantial irrigation development.
- The geographic, institutional, social, and economic diversity of stakeholders increases the resources required to develop a social licence and reduces the size of the 'sweet spot' in which a social licence can be established.
- Key interests and values that stakeholders seek to address include the purpose and beneficiaries of development, the environmental conditions and environmental services that development may alter, and the degree to which stakeholders are engaged.
- Potential agricultural investors identified institutional certainty, simplicity and bureaucratic speed as key to enabling investment in irrigated agriculture.



Stakeholder classification according to their likely support for irrigated agriculture in a greenfield site in the Darwin catchments

Stakeholders to the right of the diagram are more likely to be supportive. Internal ring = local stakeholders, external ring = regional, national and international stakeholders.
NRM = natural resource management

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The Northern Australia Water Resources Assessment (NAWRA) was conducted for the Commonwealth of Australia represented by the Department of Infrastructure, Regional Development and Cities. As part of our engagement in delivery of the Australian Government's White Paper on Developing Northern Australia and the Agricultural Competitiveness White Paper, CSIRO was commissioned to investigate the potential of northern Australia's water resources to support increased regional development in three priority regions in northern Australia: Fitzroy catchment, Western Australia; Darwin catchments (Finniss, Adelaide, Mary, Wildman), Northern Territory; and Mitchell catchment, Queensland. Parts of the Assessment were undertaken in conjunction with the Northern Territory Government, the Western Australian Government, and the Queensland Government. It builds on our previous success in delivering the Flinders and Gilbert Agricultural Resource Assessment, and a broader body of work contributing to the sustainable development of northern Australia. NAWRA was funded through the Australian Government's National Water Infrastructure Development Fund, an initiative of the Agricultural Competitiveness White Paper.

Cover: The Mary River, along with the Adelaide, Finniss and Wildman rivers, are relatively flat catchments where flooding is ecologically critical

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