Water Security for Northern Australia

Co-design final report

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CRCNA
DEVELOPING NORTHERN AUSTRALIA

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Acronyms

AAAs	Annual Announced Allocations
AFANT	Amateur Fishing Association NT
BoM	Bureau of Meteorology
CDU	Charles Darwin University
CQU	Central Queensland University
CRCDNA	Cooperative Research Centre for the Development of Northern Australia
DEPWS	Department of Environment, Parks and Water Security
DITT	Department of Industry, Tourism and Trade
DPIRD	Department of Primary Industries and Regional Development
DWER	Department of Water and Environmental Regulation
JCU	James Cook University
NAILSMA	Northern Australian Indigenous Land and Sea Management Alliance
NAUA	Northern Australia Universities Alliance
NLC	Northern Land Council
NT	Northern Territory
ORIA	Ord River Irrigation Area
QDAF	Queensland Department of Agriculture and Fisheries
QLD	Queensland
RDA	Regional Development Australia
RDMP	Research Data Management Plan
SAWRs	Strategic Aboriginal Water Reserves
SREBA	Strategic Regional Environmental and Baseline Assessment
WA	Western Australia
WAPs	Northern Territory Water Allocation Plans
WSNA	Water Security for Northern Australia
WP	Work Package
The Northern Hub	Northern Western Australia and Northern Territory Drought Resilience Adoption and Innovation Hub

Project Participants

Executive Summary

There are many proposals to further develop water resources in northern Australia. However, there are many potential uses of available water and many other questions remain to be answered before sustainable utilisation of available water can be achieved. In addition, the issues that need to be investigated are different in each catchment, requiring locally-derived solutions. To assist in this process, the CRC for Developing Northern Australia has developed a program – Water Security for Northern Australia – to fund research into key issues for sustainable utilisation of water resources in northern Australia. This program has identified 4 key focal nodes where pressure for increased water utilisation is high – Gilbert (QLD), Daly-Katherine (NT), Ord (WA), and lower Fitzroy (QLD) – to be the focal nodes for this research program. To determine the most appropriate research questions for each focal node, we undertook a co-design phase with relevant regional stakeholders in each focal node. This co-design phase and its outcomes are described here. The result includes the generation of 15 research projects that are now proposed for funding under the Water Security for Northern Australia program.

Introduction

One of the most likely prospects for economic growth for northern Australia is the development of water resources. However, there are many considerations involved in establishing sustainable water resource development, especially in a distant, remote, and often harsh environment, such as northern Australia.

A particular challenge to developing water resources in northern Australia is that there is a need for concurrent developments in inputs (such as skilled labour and supply chains) and outputs (such as irrigation systems, processing facilities and value-added systems) to make schemes viable. This complicates planning and approval processes, as it requires a systems approach to identifying necessary inputs, uses and outputs of water resources in contrast to the atomistic approaches that are typically used.

One way of tackling the complexity of a systems approach to new water resources is to apply a case study lens by focusing on a precinct development rather than simply providing more water resources. Focusing within a precinct constrains the problem to be more manageable while maintaining the focus on what is the real challenge – how to plan and organise development at a systems level to efficiently use water from a new precinct.

The CRC for Developing Northern Australia (CRCNA) has developed a program around Water Security for Northern Australia. It is intended that this program would develop and implement a series of research projects that address problematic issues that are constraining sustainable water resource utilisation in 4 key precincts or focal nodes across northern Australia. These focal nodes are (Gilbert (QLD), Daly-Katherine (NT), Ord (WA) and lower Fitzroy (QLD)). These focal nodes were selected by the CRCNA based on prior assessments and consultation indicating they are likely locations of further water resource development pressure. In order to develop such a series of research projects, it was first required that the relevant stakeholders in each focal node be engaged in a co-design process. The co-design phase of the Water Security for Northern Australia program has spent 4 months engaging with relevant stakeholders in the 4 focal nodes. This process and outcomes of this co-design phase is reported here. The engagement process and research priorities identified by stakeholders during the co-design phase for each focal node are presented. Of the identified research priorities, a series of 15 priorities were selected for development into research proposals to be considered for funding under the implementation phase of the Water Security for Northern Australia program. These proposals are also presented here in the Appendices.

Engagement process and stakeholder research prioritisation

The co-design process was conducted from August-November 2022. The contextual environment for each focal node is different, largely depending on government processes and the state and regional history of water resource development. Thus, stakeholder engagement within each focal node has been approached differently, and the issues associated with each region also differs substantially. The co-design process undertaken in each focal node is described below:

The general principle is that key lead actors in each focal node were identified by the CRCNA for initial consultation. These lead actors were either individuals or established stakeholder groups. From this initial discussion, the stakeholder engagement was widened to include other stakeholders relevant to each node/focal region. Workshops were held in each node to share information and discuss emerging priorities. Consultation was also conducted by node leaders outside the node stakeholders. For example, with researchers familiar with the nodes or other government agency staff or relevant people. In each node, the engagement process was led by a node leader, funded through the current CRCNA project. These node leaders were Associate Professor Nathan Waltham (Gilbert node), Dr Dylan Irvine (Ord and Daly-Katherine nodes), and Professor John Rolfe (lower Fitzroy node). The overall program was coordinated by Professor Damien Burrows and Dr Yvette Williams and this group of 5 leaders collectively reported to a CRCNA project manager (Anthony Curro) and the CRCNA Chief Scientist – Professor Alan Dale who had established contact with the major actors in each node prior to project commencement, and who participated in many of the stakeholder engagement events reported here.

Gilbert River Catchment

Node lead – Associate Professor Nathan Waltham, JCU

Contextual Background

The Gilbert River catchment is located in the Gulf region of north-west Queensland (Figure 1) and covers an area of 46,200 km^2. It has a population of approximately 1200 with the largest urban centre being Georgetown (population of 243). It has a semi-arid tropical climate, with a mean and median annual rainfall spatially averaged across the catchment are 775 mm and 739 mm respectively (Petheram et al. 2013). The historical annual rainfall series for the Gilbert catchment shows considerable variation between years. The highest catchment mean annual rainfall (2187 mm) occurred in 1974, and was nearly three times the median annual rainfall value (farmers, however, outline that the rainfall is pretty reliable). Spatially, mean annual rainfall varies from about 1050 mm on the coast in the north of the catchment to about 650 mm in the south-east of the catchment.

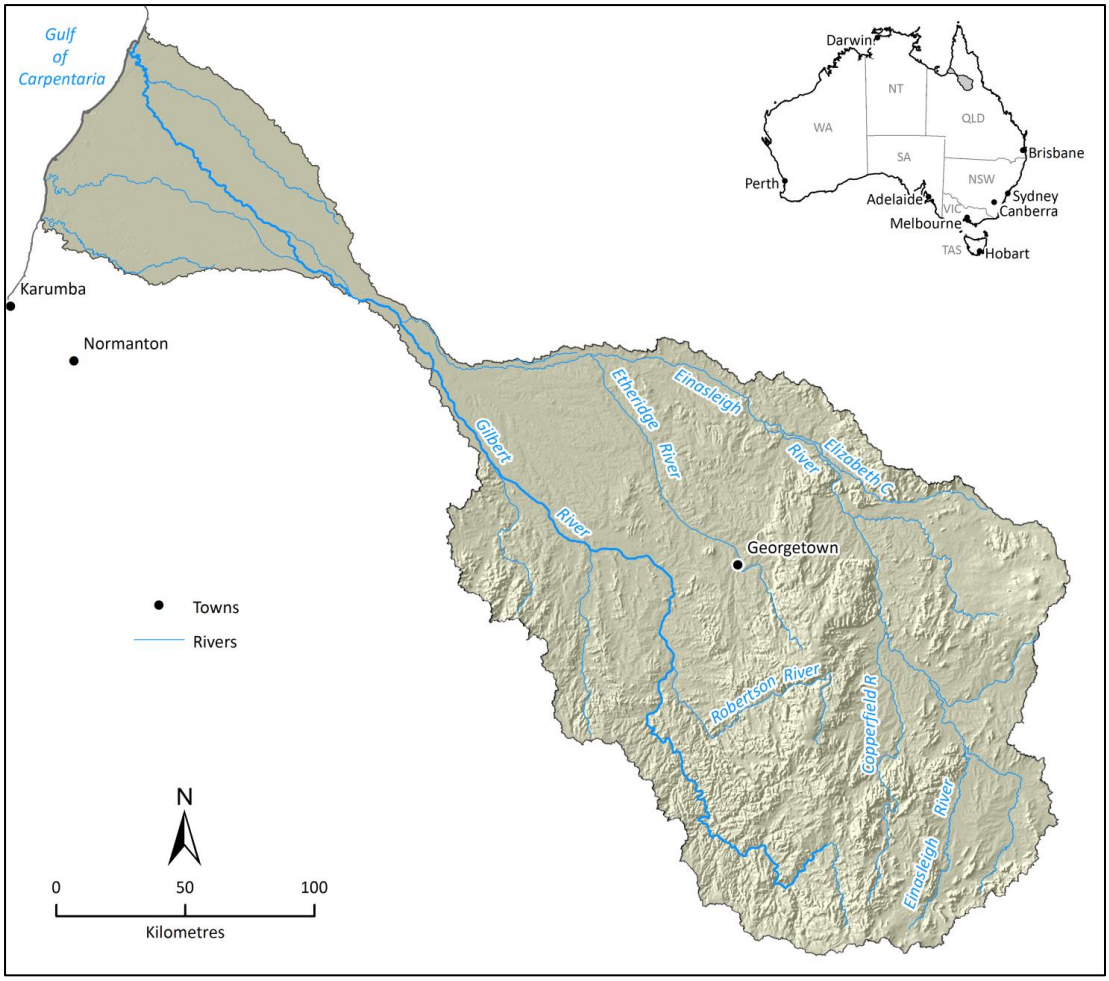


Figure 1 Relief map of the Gilbert catchment showing main rivers and townships (sourced Waltham et al. (2013))

Regional vegetation communities in the Gilbert catchment consists mostly of *not of concern dominant* (Figure 2). There are extensive areas that hold *of concern sub-dominant* and *dominant* communities, particularly over much of the upper Einasleigh and most of the coastal plains. Small areas support *endangered sub-dominant* and *dominant* communities, particularly in the upper Einasleigh catchment. Much of the regional ecosystems of elevated significance are either located along drainage lines or on floodplains thus indicating some form or extent of water dependence.

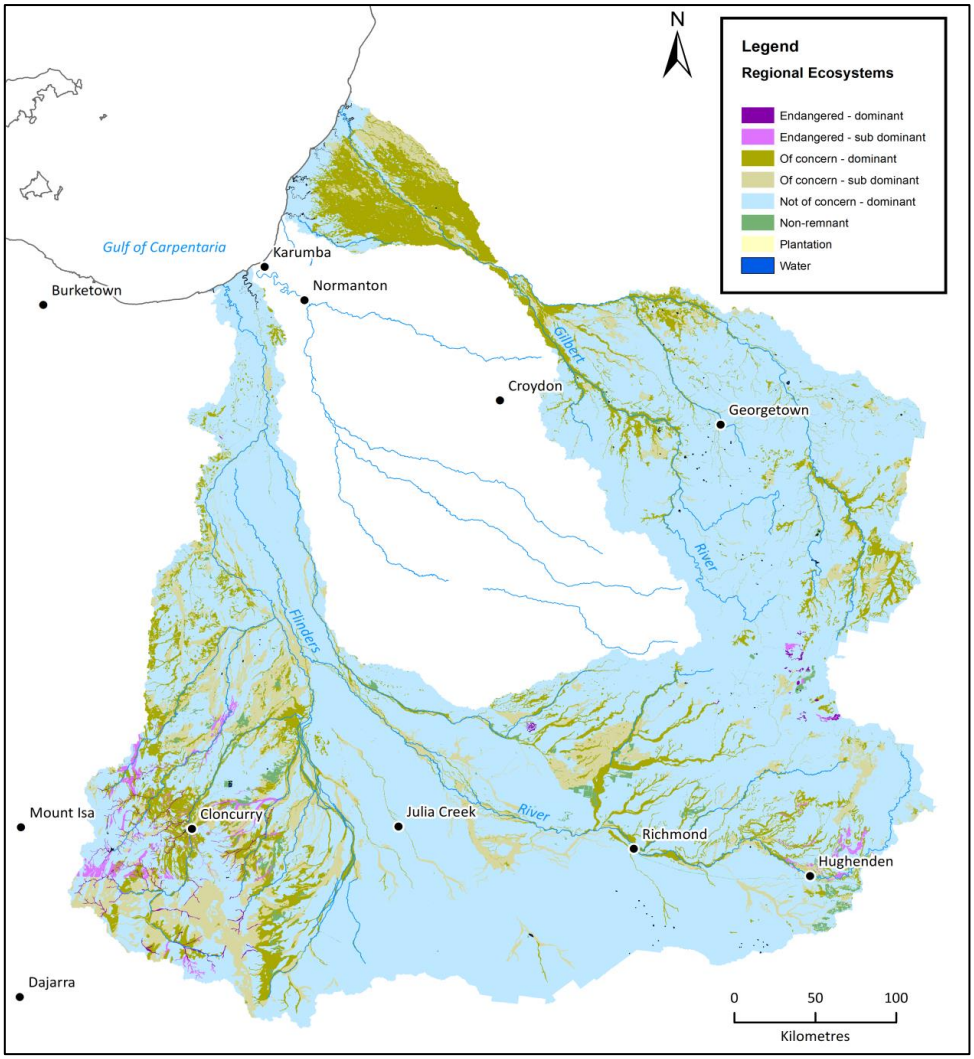


Figure 2 Extent of Regional Ecosystems (v7.0) across the Flinders and Gilbert catchments. Data sourced from Queensland Government. Definitions in Vegetation Management Act 1999 (Waltham et al. 2013).

The landscape of the catchment must be considered against a background of significant historical climate variation and shifting landmasses which provide a key to understanding contemporary distributions of species and communities. For much of the Pleistocene age (approximately 2.6 million years before present to 10,000 years ago) Australia was part of the Sahul landmass which comprised the Australian mainland, Tasmania and New Guinea. During this period a series of ice ages reduced sea levels and exposed land bridges across the globe including the Australia–New Guinea continental shelf and putatively connected many rivers across northern Australia. During the last glacial episode the Gulf of Carpentaria was dominated by a large inland lake, Lake Carpentaria (Torgersen et al. 1985). Evidence for the existence of this large inland lake from studies of sediments and organic matter trapped within them, suggest that this lake oscillated between brackish and freshwater before the final incursion of marine waters into the lake at around 10,800 years before present (Reeves et al. 2007).

The current day fragmented distributions and low endemicity of many freshwater fish and crustaceans throughout the Gulf region probably reflects this historical hydrological connectivity with Lake Carpentaria acting as a conduit that periodically allowed species to move between the rivers of the Gulf. This pattern of periodic connection and movement is supported by genetic research on a variety of freshwater fauna in the Gulf rivers including

pennyfish (*Denariusa bandata*), redclaw crayfish (*Cherax quadricarinatus*), giant freshwater prawn (*Macrobrachium spinipes*; formally *Macrobrachium rosenbergii* until Ng and Wowor (2011)), spangled perch (*Leiopotherapon unicolor*) (Bostock et al. 2006, Baker et al. 2008, Cook et al. 2011). However, the timing for when freshwater faunas across northern Australia became disjunct and fragmented into the distributions found today is unclear. The Pleistocene age was characterised by drier periods of lower rainfall which may have played a part in limiting the exchange of species across northern Australia and further afield (Unmack 2001). However, this is a complicated story as even today, large floods may establish connectivity between adjacent river systems, facilitating dispersal of freshwater biota and mixing of gene pools.

In a review and classification of the hydrology of northern Australian river systems (Kennard et al. 2010) revealed that the upper and middle reaches of the Gilbert catchment were grouped into class 10 (predictable summer; highly intermittent flow), although a stable summer base flow (class 3) was also identified. An extensive appraisal of the river hydrology has been completed as part of the Flinders Gilbert Agricultural Resources Assessment, including wetland connectivity in lower catchment and coastal floodplain (Karim et al. 2015), while river system flows under climate change and proposed development scenarios is in another companion report (Petheram et al. 2013). McJannet et al. (2014) also examined the persistence of dry season waterholes and determined that the duration of zero flow is typically much longer in the Flinders catchment, particularly in the Cloncurry and mid-Flinders, compared to the Assessment areas in the upper Gilbert catchment. These assessments were critical for the proposed development precincts identified in the catchment at the time, and though useful some of the data are generally considered limited in a spatial context. Understanding the water resource development potential in the catchment needs to consider broader consequences, particularly downstream areas and ecosystems, including a large commercial fisheries sector (Kenyon et al. 2004, Burford et al. 2010, Kenyon and Donovan 2012, Robins et al. 2020). In addition to coastal fisheries, the tidal coastal mudflats provide incredibly important habitat for migratory birds which is a consequence of the nutrient and sediment rich floodwater flows from the Gilbert and other catchments in the southern gulf (Burford et al. 2016, O'Mara et al. 2022). There has also been major die back of mangroves along the most of the gulf coastline, including the Gilbert River estuary and coast (Duke et al. 2017).

Unlike other Gulf of Carpentaria catchments, the Gilbert River catchment has significant prospects for development (Alluvium 2022), where under the Gulf Water Plan 2007 there is an allocation of 467, 000 ML of water for agricultural use, however, only a small proportion (~10%) has been activated. The main reasons for this relates to stringent land clearing approval requirements, environmental significance of the catchment and its downstream floodplain to coastal fisheries, and the cost to prepare documents for approval to develop and build the water infrastructure. Given the strong desire to increase development and use the allocated water in the catchment, the timing of this research project is ideal, with the results and outcomes having direct impact on several major initiatives underway in the catchment, including the Etheridge Shire's Etheridge Agricultural and Irrigation Precinct project proposal and the Gulf Water Plan review which is commencing in 2025 ahead of a 2027 release.

Engagement with the Gilbert River catchment stakeholders

To assist in the coordination and governance of stakeholder engagement in the Gilbert River node for the WSNA program a Technical Reference Group (TRG) for the Gilbert River catchment was convened and chaired by the Etheridge Shire Council, with members drawn from various landholders, government agencies, NRM and Indigenous partners, and will likely continue to expand as the various programs and projects continue over the coming years (Table 1). Membership of the TRG is voluntary and it has the key roles to:

- Advise and guide research design to ensure the project meets the needs of the Gilbert Catchment project and is aligned with the needs of the Etheridge Agricultural and Irrigation Precinct project;
- Provide access to data, research reports, other documents, and contacts, to support the researchers' objectives;
- Identify and advise on risks and issues, as they arise during implementation stage; and
- Communicate effectively and collaboratively with stakeholders and researchers.

The TRG met four times during the co-design phase and development of the forward-looking research projects for the catchment. The meeting dates were 14 October 2022, 4 November 2022, and 18 November 2022, and a final co-design meeting on 9 December 2022. All meetings were held on-line and attended by members to ensure the effective design of the research projects. From February 2023 until the completion of the project, it is anticipated that TRG will continue to meet regularly, to assist with the implementation and impact of the research results particularly given the agricultural development opportunities in the catchment.

Table 1: Members of the Gilbert River catchment Technical Reference Group

Roles	**Position**
Chair	Mayor, Etheridge Shire Council
Process Chair	Chief Scientist, CRCNA
Members	CEO, Regional Development Australia Tropical North
	Managing Director, Sundown Pastoral Company
	Director, BDR Projects
	Gulf Savannah NRM
	Rivers Project Officer, Qld Conservation Council
	Principal, Environment North
	Regional Manager, DRDMW
	Manager, Regional Agribusiness Development
	Northern Qld Water Infrastructure Authority
	Department of Environment and Science
	Department of Mines and Lands
	Northern Queensland Land Council
	Australian Fisheries Management Authority
	CEO, Gulf Savannah Development
	James Cook University
Secretariat	CRC for Developing Northern Australia James Cook University

Priority issues raised

The discussions and contribution offered by TRG members during the co-design process was professional and positive, the group has also increased membership since the first meeting, which was a positive sign on the level of interest and expertise needed to oversee research in the catchment. Each meeting had an agenda which was followed and there was a continual process of opening the floor to members to raise concerns and questions - following a good governance model. Some of the important points/messages raised during the meeting included:

- Need to examine ecosystem services under threat with any developments planned in the catchment;
- Concerns about downstream economically important fisheries;
- Indigenous cultural values and opportunities for water development;
- Lack of environmental data for the catchment;
- Need for coordination and information share of knowledge in the catchment; and
- Use of existing data and reports completed in the catchment under previous investment.

During these meetings it was identified that WSNA research program would need to closely integrate with the Etheridge Shire Agricultural and Irrigation Precinct project that is jointly in preparation with Etheridge Shire Council and Regional Development of Australia Tropical North. During TRG meetings, it was agreed that the alignment between these two projects was important and would ensure support and share of information to ensure strong outcomes for the region.

In addition to the TRG meetings, numerous individual stakeholder meetings were held, via online meetings (some up to 2hrs), to further understand and define the critical issues and concerns, and development barriers and opportunities in the catchment. These meetings were very well received, Stakeholders appreciated the opportunity to participate in the co-design phase. Some of the main concerns raised were:

- Development in the catchment and changes in the delivery of nutrient and sediment rich freshwater may have undesirable consequences for primary production in the estuary and nearshore zone. This primary production provides important basal sources for fisheries production and nearshore important feeding and resting areas for migratory shorebirds.
- The State Government will start preparation for the Gulf Water Plan review in 2025, ahead of a revised plan for release 2027 for the region. This project timing is therefore important and could provide meaningful data as part of the plan review.
- Need to ensure research projects align with what community, council and landholders desire for the catchment, and the vision to ensure the information is shared and trusted by partners.

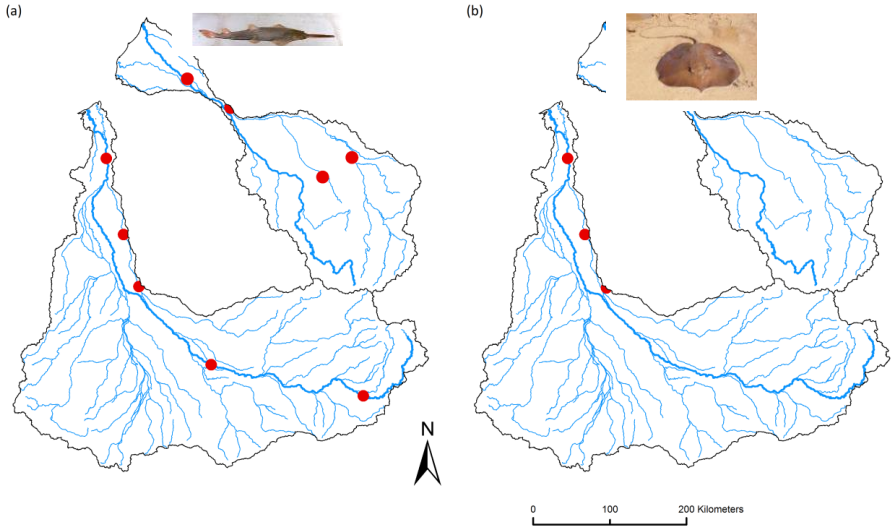
During the co-design period there have been also several other projects operating. The Node Leader for the Gilbert has kept involved in these via a range of workshops, online meetings and discussions to ensure these additional projects are considered in the WSNAA project herein. These additional projects included:

- Strategic Assessment of Agricultural development potential (Mitchell, Flinders and Gilbert catchments – led by Alluvium Consulting);

- CSIRO – State and transition models to support ecosystem accounts in Flinders, Norman and Gilbert River catchments;
- Griffith University, NESP Resilient Landscape Hub, research in Gilbert, Flinders, and Mitchell Catchments to train rangers to collect environmental data; and
- Etheridge Shire Development Precinct.

All these projects and identified information gaps were important and useful in formulating the research projects proposed under the WSNA (Table 2).

Table 2: Research topics prioritised by stakeholders for the WSNA program – Gilbert **Proposing Organisation, brief project description, and overview of research skills/techniques**	**Primary Node and priority of proposing org (Top/ High/ other)**	**Skills/ question relevant in other nodes**	**University/ researcher involvement/ expertise required**	**Likelihood of partner funding and/or in-kind**
Project 1: *Floodplain, rivers and tributary aquatic flora and fauna inventory* There is limited, explicit, aquatic flora and fauna (including water quality) data collected in the Gilbert River and the tributaries. Studies completed to date have been restricted to proposed development precincts (e.g. Flinders and Gilbert Agricultural Resources Assessment) and floodplain areas (TraCK). The Gulf Water Plan uses species data to test and set flow hydrometrics for species presumed or historically documented in the region. According to Australian Living Atlas, the sawfish (*Pristis pristis*) and the freshwater whipray (*Urogymnus dalyensis*) are known in the catchment, with the sawfish listed as critically endangered under the EPBC Act 1999 (the sawfish is an indicator species for development impacts on waterholes in the Ord River catchment). This research project focuses on firstly completing a literature review of previous field surveys in the catchment to inform gaps in knowledge in the catchment. With this knowledge, and in consultation with our project partners, an inventory of aquatic flora and fauna species in various habitats within the catchment will be completed. Once completed, we will then overlay functional and lifecycle ecology trait requirements on current distribution to understand the potential future risks to development in the catchment (this same approach has been applied in the Ord River for example). For rare and threatened species, and those aquatic species modelled in the Gulf Water Plan (e.g. catfish, purple spot gudgeon, freshwater turtles) specific habitat requirement surveys and manipulative experiences will be completed to determine sensitivity to altered flow and environmental conditions in the future (e.g. thermal and oxygen exposure risks in key refugia under future expected conditions). These data will assist the Queensland Government in the review of the Gulf Water Plan and preparation of the next iteration due 2027. In addition, the	Gilbert (Top)	Ord/Daly	JCU – aquatic ecology, hydrology CDU – aquatic ecology	High (Qld Government committing funding to hire TO rangers and will provide field staff to assist with sampling)

data will be useful for any planned future monitoring and evaluation of development that occurs in the catchment.  Figure 3: Captures or sightings across the Flinders and Gilbert catchments. (a) freshwater sawfish (*Pristis pristis*), photo sourced S. Peverell; b) freshwater whipray (*Urogymnus dalyensis*), photo sourced B. Pusey (Waltham et al., 2013).				

Project 2: ***Persistence and extent of waterholes in the Gilbert River and tributaries, and groundwater contribution to permanency*** Seasonal rivers of northern Australia remain connected following the wet season for a period, until flow ceases when they then gradually become disconnected and exist as a series of waterholes. These waterholes gradually further dry as the season continues, some completely, through for some that remain in a permanent state until the next wet season are critical freshwater refugia habitat for species. While permanent waterholes are critical resources, they are also susceptible to poor water quality conditions, particularly as the dry season advances, some reaching conditions that are intolerable for some aquatic life. The balance and risk that these permanent waterholes face until the next wet season means they are also at risk from land use changes, which might pose a threat to their utility as important refugia habitat. For example, land use change might change important limnological processes (i.e., making them more turbid, or changing the diel cycling of oxygen and temperature) meaning that the waterholes contribute little to broader ecosystem services. In addition, we plan to also evaluate the interaction of water flow and waterhole distribution in the catchment in relation to river bed sands.	Gilbert (Top)	Ord/Daly	JCU – Remote sensing, connectivity analysis CDU – water origins groundwater-surface water interactions	High (Qld Government committing funding to hire TO rangers and will provide field staff to assist with sampling)

 Figure 4: Major permanent waterhole on Einasleigh River, Gilbert River catchment				
Project 3: Examining the ecosystem services gained and lost for proposed development areas A major barrier to development in the Gilbert River catchment, despite available water for development, is the prohibition on broadscale clearing of natural vegetation unless the project has been declared a coordinated project under the *State Development and Public Works Organisation Act 1971* (Qld) and such	Gilbert (Top)	All catchments	JCU – Soils and farm scale modelling	Farmers involved in the project in-kind

clearing is approved. This declaration requires the approval of the Coordinator-General and involves the requirement for preparation of an EIS or other form of impact assessment. This can be an expensive and time-consuming process and is considered to be beyond the resources of individual proponents for all but the largest of developments. Other approvals are also required and of these, approval under the application of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) is probably the most onerous. Even with coordinated project status, there is no certainty that broadscale clearing will be approved unless it can be shown to be sustainable with minimal risk, if any, to the environment. This requires at the very least that the remaining natural vegetation post-development provides adequate biodiversity and other ecosystem services within the context of the broader catchment and that management is required. Planning should seek to avoid, minimise, or mitigate impacts on values. As a last resort, offsets (biodiversity) may be required to ensure that proposed clearing is sustainable. A separate issue is soil carbon. Local data (20 year time series) is available at some locations/farms and this suggests that carbon sequestration is accruing due to farming techniques, possibly at a greater rate than in natural vegetation. Other data at other properties may be available and may assist in obtaining a broad picture of the role of advanced farming techniques across the catchment. While carbon sequestration is unlikely to be considered to be an offset to biodiversity losses, it is nonetheless a factor in considering development proposals as a whole.			CQU – agro-economics CDU	
Project 4: *Indigenous values mapping and water resource enterprise product identification* The Gulf of Carpentaria holds incredible natural resources and many of these are important to Indigenous people and their connection with Country. There is an allocation of water in the Gilbert River catchment for Indigenous enterprise/use, however, access and use of the allocated water has not progressed. There is a critical need to work closely with TO groups, to drive forward the identification and document cultural values in the Gilbert River catchment (akin to the Walking the Landscape developed by DES). Preliminary research was completed during the	Gilbert (Top)	All nodes	JCU – Social scientists, Indigenous engagement CDU CQU	High (Qld Government committing funding to hire TO rangers and will provide field staff to

CSIRO Flinders Gilbert Agricultural Resources Assessment to identify cultural values in the catchment, but this was limited to a small area, to within the identified development areas for that study. In this research project, there is a critical need to engage and consult TO groups in the catchment, to map out the natural resources that includes Indigenous cultural areas, and to develop a plan of enterprise development for water use that is prosperous for groups (based on cultural values calendar or similar approaches). This project could be supported by the CRC for Indigenous and Environmental and Futures (JCU). By way of example, this research project might focus on freshwater turtles in the catchment, which hold cultural value, and require access to suitable habitat for breading (riparian areas on banks) and access to appropriate waterholes for feeding and shelter. Freshwater turtles are heavily predated on by feral animals, for example pigs, which could be also impact populations in this catchment. Freshwater turtles are also a key species used in the hydrometric modelling for water resource planning in the region. This project aims to firstly, map the natural resources that relate to cultural values, and in doing so identify potential enterprise product opportunities. Secondly it will also complete a threats analysis that development poses to the values (e.g. freshwater turtles) and identify implementation strategies for conservation and protection of these cultural valued resources in the catchment.				assist with sampling)

Priority research areas going forward

From the range of research priorities discussed during the co-design phase, four were selected to be put forward for the implementation phase of the WSNA program:

Project 1.1 – Floodplain, rivers and tributary aquatic flora and fauna inventory

Project 1.2 – Persistence and extent of waterholes in the Gilbert River and tributaries, groundwater contribution to permanency

Project 1.3 – Examining the ecosystem services gained and lost for proposed development areas

Project 1.4 – Indigenous values mapping and water resource enterprise product identification

These projects were all identified as addressing major issues of relevance for the catchment where results could potentially have major impacts on the viability and scope of future operations and developments. Importantly, there has been a focus on providing data and information for a range of project partners, given the huge potential for development and the ecological sensitivity of the region. Further details are provided in Appendix A.

Daly River Catchment - Katherine

Node lead – Dr Dylan Irvine, CDU

Contextual Background

The Daly River Catchment (Figure 3) includes the townships of Pine Creek and Katherine, where Katherine is approximately 320 km south of Darwin. Rainfall is distinctly seasonal throughout the catchment, where mean monthly rainfalls are generally lowest (<10 mm) between May and September (peak dry season) and highest (>100 mm) between December and March (wet season) (Erskine et al 2003). The mean annual rainfall generally increases from the south-east to north-west, ranging from 690 mm at Willeroo to 1300 mm at Daly River (Erskine et al 2003).

There are several rivers within the catchment, including the Daly, Douglas, Flora, Katherine, amongst many others (Erskine et al 2003, also, see Fig. 1 below). Groundwater plays an important role in sustaining year round flows in several of these rivers, including (but not limited to) the Katherine River (Northern Territory Government, 2019a) and the Daly River (Northern Territory Government, 2019b), where groundwater discharges to springs from the underlying Tindall Limestone and/or Oolloo Dolostone aquifers. Given the connection between groundwater and surface water in the catchment, groundwater and surface water are conjunctively managed in both the Katherine-Tindall Limestone Aquifer (Northern Territory Government, 2019a) and the Oolloo Dolostone Aquifer (Northern Territory Government, 2019b) Water Allocation Plans.

The Daly River Catchment supports a broad range of agricultural activity including hay, melons, and mangoes, as well as some forestry (Northern Territory Government 2022a). A 2016 investigation identified that for profitable broadacre crops to be grown in the region, a two crop cropping system is likely required to generate suitable cash flow, with likely crops including peanuts, aromatic rice and/or mung beans (North Australian Agribusiness Management, 2016). Research projects have been proposed in the catchment that investigate both agricultural and water resources-based questions.

The original area proposed to investigate included both the Daly and Roper River catchments. However, the project area was refined to the Daly catchment, partially due to the fact that the Daly has greater agricultural development, and to avoid overlap with

projects being conducted in the Roper catchment by CSIRO, funded through the National Water Grid Authority (CSIRO, 2022).

Proposed research projects in the Daly catchment were selected to (a) improve the understanding of water requirements of ecosystems and investigated potential impacts from proposed surface water take, (b) to understand motivations and barriers to further agricultural development in the area, (c) to investigate water sources of springs that discharge to the Daly River and to inform the conceptualisation of a numerical groundwater-surface water model, and (d) to investigate potential impacts of future climate change on future water resources. The focus on potential climate change may inform each of the previous projects, as well as projects within the Water Security for Northern Australia WSNA Program

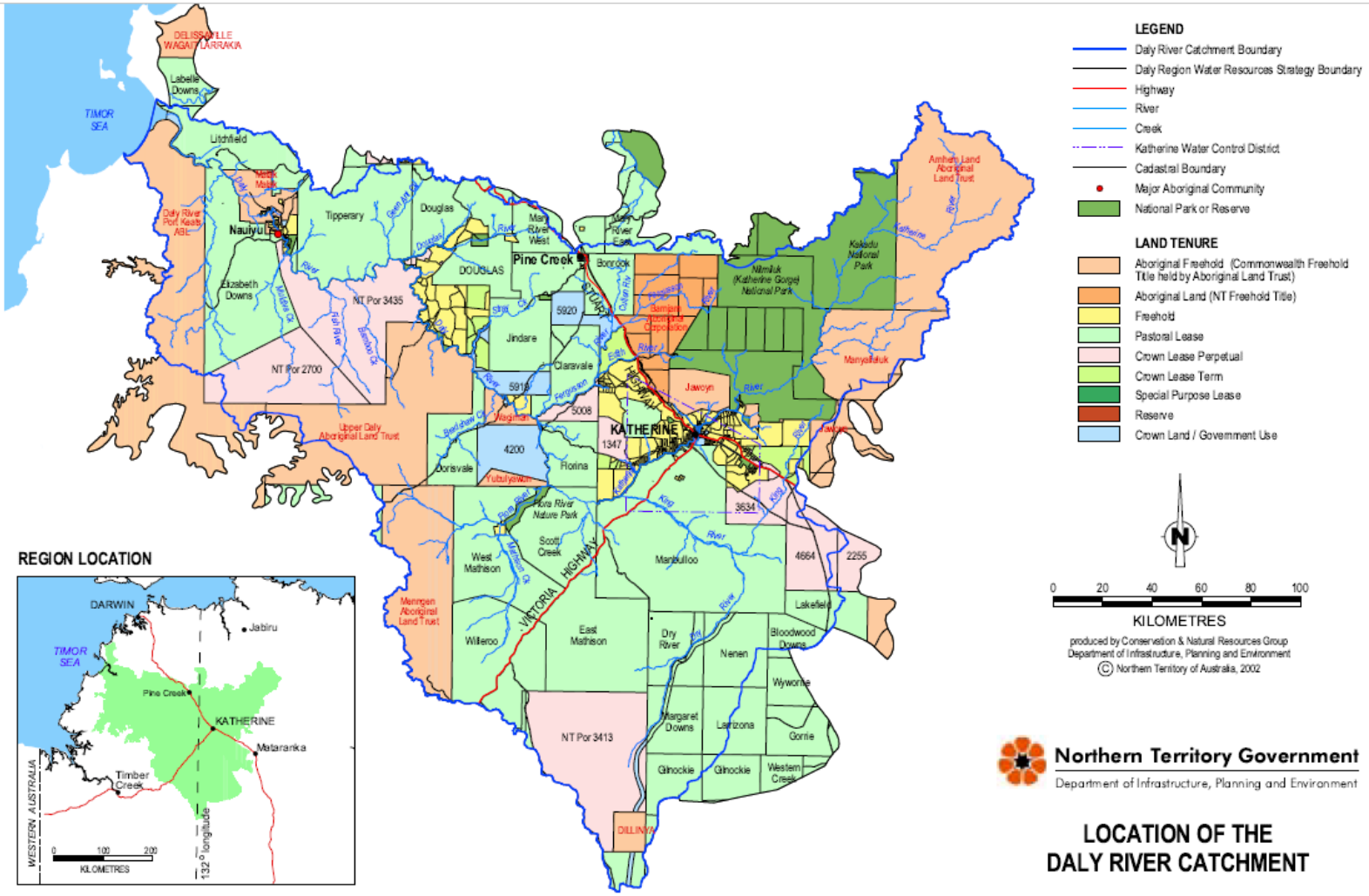


Figure 5: Map of Daly river catchment (from Erskine et al 2003, original source DPIE, NT Government).

Engagement with the Daly River catchment -Katherine stakeholders

The Department of Industry, Tourism and Trade (DITT) has been the primary contact in the development of the research program for the Daly River Catchment. The Department of Environment, Parks and Water Security (DEPWS) have also played a central role in the development of the research plan. The research questions were developed through consultation with the government departments, and refined through further consultation with the departments, universities and the project management working group.

Workshops were held on the 3rd and 10th of November. The workshops were slightly delayed due to staff absences from the relevant departments. The technical reference group contained senior representatives from NT Farmers, the Northern Land Council (NLC), the Malak Malak Ranger group, the Northern Western Australia and Northern Territory Drought Resilience Adoption and Innovation Hub (The Northern Hub), the Environment Centre NT and Regional Development Australia (RDA). Representatives from The Amateur Fishing Association NT (AFANT) and the Northern Australian Indigenous Land and Sea Management Alliance (NAILSMA) were unable to attend the workshops.

The consultation process was driven through meetings that were held on an as needs basis with both DITT and DEPWS. Both in person and Microsoft Teams were used for meetings, with meeting times generally varying between 1-2 hours. In addition to official meetings, information was exchanged throughout the co-design process via emails and conversations at numerous conferences and events attended by government departments and researchers from CDU (i.e., the Voices in the Bush and Water in the Bush conference, meetings of the International Association of Hydrogeologists, and regular research meetings between the government departments and CDU). In addition to meetings with stakeholders, discussions were held amongst CDU researchers, and regular updates on progress were provided to the Gilbert and Rookwood node leaders (Dr Nathan Waltham, James Cook University and Prof John Rolfe, Central Queensland University) and relevant researchers from each university.

Priority issues raised

Table 3: Research topics prioritised by stakeholders for the WSNA program - Daly

Proposing Organisation, brief project description, and overview of research skills/techniques	**Primary Node and priority of proposing org** **(Top/ High/ other)**	**Skills/ question relevant in other nodes** **Potential for impact**	**University/ researcher involvement/ expertise required**	**Likelihood of partner funding and/or in-kind**
Proposing Org: DEPWS Water allocations involving water from the Daly River where it overlies the Oolloo Dolostone rely on a coupled numerical surface water-groundwater model. The model is run during the wet season to project water availability for the remainder of the year to inform the Annual Announced Allocations (AAAs). The model currently poorly reproduces river flows, requiring adjustments to model outputs prior to projections being made. This mismatch is likely driven by poor representation of key hydrological processes and creates the potential for undesirable issues with water allocation. A project that has the goals of (1) determining the origins of water from a select number of springs, and (2) identifying likely causes for model mismatch has been requested. This project also provides the ability to work with Traditional Owners to document changes in spring condition, and for two-way learning on hydrological function of the springs. Groundwater tracers will be used to determine spring water origins, with the goal to identify water sources, and potential limitations from the existing numerical model. This work will improve the understanding of the system, providing greater surety for water managers, and may inform local scale water allocations (i.e. in the capture zone of important springs), whilst protecting sites of cultural significance.	Daly (DEPWS top priority)	Skills: Water chemistry, hydrology, management Relevant elsewhere: Gilbert Impact Potential: Very high.	CDU	High

Proposing Org: DEPWS – Investigation of the potential impacts of the proposed draft surface water take policy (Northern Territory Government, 2022b) were proposed by DEPWS, with significant interest from multiple members of the technical reference group. The proposed policy follows the decision-making hierarchy of (1) scientific work to define suitable volumes of extraction, (2) contingency rules based on typical wet season flows (5% of the lowest quartile of the wettest months over the preceding 50 year period). Surface water take during the wet season is expected to influence river flows and floodplains/ wetlands throughout the year. These impacts may include hydrological and ecological function of the river and floodplain environments. Investigating the likely impacts of surface water take on the Daly (or other rivers in the catchment) could focus on: reduction in bank storage and associated return flows, investigating the paired use of aerial imagery/ remote sensing and river flow statistics to investigate ecosystem health during dry years (as a proxy for future conditions), and investigating the longitudinal and lateral connectivity of pools and floodplains to determine the potential impacts to key species (through their full life cycle) and ecosystems.	Daly (High)	Skills: Hydrology, numerical modelling, remote sensing, freshwater ecology. Relevant elsewhere: Gilbert Impact potential: Very high	CDU, JCU	Med-High
Proposing Org: DEPWS – Human capacity and skills in water DEPWS are setting up First Nations reference groups to support the implementation of water allocation plan in priority areas across the Territory. The terms of reference will be established in collaboration with the members, which will provide a mechanism to build understanding of the water management approaches and Indigenous knowledge. There will also be opportunities to run practical on ground activities with Traditional Owners who do work on country to conduct environmental monitoring, developing skills to ensure that monitoring process follows scientific standards is important and options for development of sampling/training courses.	Daly	Skills: Hydrology, education, Indigenous engagement Potentially relevant over all of northern Australia	All universities, although project not suitable for this program at this stage	Med-High

While this is an important task, and universities could play a role in the development of training materials, the project is not well suited to a research program.		Would have significant impact, but is not research		
Proposing Org: DEPWS (interest from DITT, DPIRD, DWER) Impacts of climate future climate change (i.e., changes in rainfall patterns and increases in temperature) are important factors across all of Australia, particularly northern Australia. The project will gather spatial (gridded) climatic datasets (both historical and projections) from global climate modelling. While primarily focused on the Northern Territory, and potential changes in water future water availability, the project will likely generate outputs that inform other projects within the Water Security Program. The Bureau of Meteorology have recently produced a CSA tool (Australian Government, 2022) which is intended to inform farmers about potential changes to temperature and rainfall. Utilising the data that underpins the tool will allow further, more detailed hydrogeological investigations. Communicating this tool with potential users is an additional component to the project. Outputs from the project will likely include a review of potential climate impacts across northern Australia, a case study that investigates potential changes in groundwater recharge, as well as providing data outputs to inform other projects within the program.	Daly (likely also Ord)	Skills: Climate science, statistics, computer coding, hydrology Relevant elsewhere: All catchments Impact potential: Working with climate model outputs will inform many likely projects.	CDU (likely BoM or UTas)	low
Proposing Org: DITT: Crop types and future change DITT are interested in understanding what factors are involved in transitioning to higher value crops. Growing higher value crops may limit the need for land clearing, while producing higher returns. Answering this question requires multiple, mostly desktop investigations.	Daly	Skills: Ag/ soils/ water use requirements, climate change	CQU/ CDU	Mid

The start point is on desktop research. Existing reports and datasets will be utilised to identify what could be grown, their soil, climate, and water requirements. After the desktop review, a mixed methods social science research approach will be used to understand farmers' current farming systems approaches, as well as the current barriers and motivations to further development. This work may focus on farming systems, i.e., with the change of crops grown and/or irrigation strategies, wide ranging changes may be required. Following the mixed methods social science research, numerical plant-water-soil modelling will be investigated, paired with economic modelling, to further inform potential profitability of crops, by soil and crop type.		Relevant: Potentially all catchments Impact potential: Could inform government departments on current practices and future changes to cropping		
Proposing Org: DITT – Utilisation of the Strategic Aboriginal Water Reserves and Indigenous-led development on Indigenous land Northern Territory Water Allocation Plans (WAPs) reserve a proportion of allocatable water to be utilised for Strategic Aboriginal Water Reserves (SAWRs). This water, were available, can be used by Traditional Owners. Issues with the approach occur, where regions are already over-allocated, resulting in new water (i.e., to SAWRs water) in the system being unavailable. One possibility, where water is available, but there is no intention for SAWRs to be used for development, is for this water to be traded to generate income. While the NT currently does not have a charge for water, water can generate a value if new developers wish to come into a system that is already fully allocated. This project was ultimately not selected, given the fact that the issues limiting the SAWRs are policy issues that are not readily impacted by further research.	Daly	Indigenous engagement, agriculture, economics, water resources management NT specific research. Limited impact, given water likely not available.	Some skills possessed across northern universities, but external collaborators would be required.	Low

Proposing Org: DITT – Trial crop testing on the Katherine research farm Development in the Northern Territory is often hindered by developers moving to the NT with an incomplete understanding of the challenges involved. i.e. challenges in obtaining a water licence, restrictions on clearing, unknown pests, and challenges in the distance to market. Limited understanding of operating in the Norther Territory has led to farm developments failing before harvesting a crop. A potential solution to these problems is for potential crops to be grown on the DITT research station where cleared land and a water licence is available. If crops can be demonstrated to be viable and suitable to the Northern Territory, they can then be rolled out on a commercial scale, thus reducing risks to be assumed by potential developers. Farming/cropping experts from CQU highlighted that this kind of project is only successful with significant input from commercial industries, rather than projects driven by governments and/or universities. This project likely has merit but is not suitable for the current CRCNA Water Security Program.	Daly	Agriculture/ cropping, economics. Research farms are available in multiple catchments. Potentially high potential to 'de-risk' but significant industry support required.	CQU and potentially CDU once the strategic professor in cropping science joins the university	High
Proposing Org: DEPWS – Water quality frameworks Water management and monitoring includes water quality, DEPWS are in the process of establishing a water quality framework to include in water resources planning. The goal is to potentially include water quality into water allocation plans. DEPWS has identified that there is a lack regionally derived environmental water quality guidelines for several new Plan areas, particularly in the Arid Zone.	Daly	Water quality, water resources management. Water quality is included in some coastal water management plans. Likely importance to	All universities have water quality expertise	Mid

Project was not progressed given that projects with a higher priority were proposed.		other catchments Work is needed, but priority is low compared to volumes in many cases, noting that water quality issues are acute in some NT communities.		
Proposing Org: DEPWS – Flora River hydro(geo)logical investigation The Flora River Region, within the Daly Catchment, is one of the next regions where a water allocation plan will be developed. Both recent investigations through the Strategic Regional Environmental and Baseline Assessment (SREBA) studies into potential impacts from shale gas extraction, and previous studies of the area have shown that it is hydrogeologically complex. For example, the system of sinkholes likely lead to rapid groundwater recharge, potentially leading to mixing with much older waters from further to the south of the basin. Rainfall over the last 30 years is generally higher than the long-term average in the area. This point could potentially explain the increase in water stored in the aquifer. Further work is required to better understand this system. While this work is important, it was given a lower priority than other projects. The field-based nature of the project makes it difficult to accommodate this project with other (high cost) field-based projects within the Water Security Program.	Daly	Hydrogeology, hydrology, use of groundwater tracers NT specific question. Significant benefits of government-university involvement in investigations.	CDU	Mid

Proposing Org: DITT – Co mapping of regions with support for Indigenous led development Staff at DITT have previous experience with projects to identify regions of the Tiwi islands that would have support from Traditional Owners for development to proceed. DITT proposed interest in a similar process to be investigated within the Daly River Catchment. Challenges with this approach include the fact that much of the region is either fully allocated, or over-allocated, meaning that new developments in the area are limited (whether they have Traditional Owner support or not). Further challenges include the skill sets available at CDU, JCU and CQU. The project is important, but would require significant inputs/support, likely from the NLC, in order for it to be successful, that were not able to be negotiated in time.	Daly (but could be implemented anywhere in the Northern Territory with sufficient support)	Indigenous engagement, water resources management, agriculture. Process could be implemented anywhere in Northern Australia. The project could have significant benefits. However, it would also take significant time to implement.	Some expertise for the project is available at the universities, but significant input from NLC would be required.	Significant interest, so at least in-kind contributions likely

Priority research areas going forward

Following consideration of which of the above suggested topics are best suited to the WSNA program, the below projects were selected to be put forward to the CRCNA for funding. Detailed research proposals for these can be found in Appendix B.

Topic	Summary
Project 2.1 - Oolloo Dolostone spring water origins project (DEPWS).	This project was selected as it has direct potential to inform/improve the allocation of water in the Daly Catchment. The project directly aligns with skills at CDU and provides opportunities for genuine collaboration with Traditional Owner groups to determine water requirements to sustain culturally significant springs. The project aims to improve the understanding of spring flow mechanisms to improve the current numerical model that is used in the determination of annual announced allocations of water.
Project 2.2 - Impacts of reduced flows on ecosystems (DEPWS).	This project alights with the interests of DEPWS to understand the water use requirements of ecosystems and allows the investigation of potential impacts of a new NT Government surface water take policy on key species and floodplain/wetland ecosystems. The project also directly aligns with expertise at CDU and JCU. The project will investigate potential impacts of surface water take on floodplains using available river flow and remote sensing data. The project will conduct targeted field work to validate the outcomes of the remote sensing work.
Project 2.3 - Potential impacts of future climate change (DITT and DEPWS).	This project is vitally important to a research program into water security. Outputs from the project will lead to research outputs in its own right and will inform several other projects. Further input from climate scientists (outside of CDU, JCU or CQU) will be required for its successful delivery. The project will utilise outputs from global climate models to inform potential impacts to water resources in catchments in northern Australia.

Project 2.4 - Understanding farmer motivations and barriers to change (DITT).	This project started with the goal to determine what is required for farmers to make the transition to higher value crops. To get to this point, DITT require an understanding of soils, potential crops and their water requirements, potential climate change and crop suitability, plus an understanding of motivating factors and current barriers to further development. This project leverages off of other projects (climate change impacts, related questions in the Ord) and utilises input from researchers at CQU. The research will be driven by a mixed methods social science research approach to understand farming practices. These outputs will inform a paired plant growth-water use and economic modelling.

Ord River Catchment - Kimberley

Node lead – Dr Dylan Irvine, CDU

Contextual Background

Irrigated agriculture in the Ord River Irrigation Area (ORIA) began with the completion of the Kununurra Diversion Dam and main irrigation channel in 1963 (DPIRD, 2021a). The ORIA is often referred to in two parts:

- Stage 1 – the original irrigated farmland comprising 14,500 ha (DPIRD, 2021a), and
- Stage 2– the expanded farmland area of Goomig and Knox comprising approximately 13,000 ha of irrigated land (at full development) enabled by the extension of the main irrigation supply channel and other public infrastructure in 2012 and 2013.

Whereas the Stage 1 farming area is comprised of many, smaller farms, the Stage 2 farming area is comprised of two large farming areas, Goomig and Knox. Figure 4 shows the extent of the first two stages.

Irrigated agriculture development is also proposed for Carlton Plain and Mantinea adjacent to the lower Ord River (Figure 2). Carlton Plain Stage 1 is approved and under development.

Future expansion of the ORIA to the Keep River Plains in the Northern Territory has also been proposed.

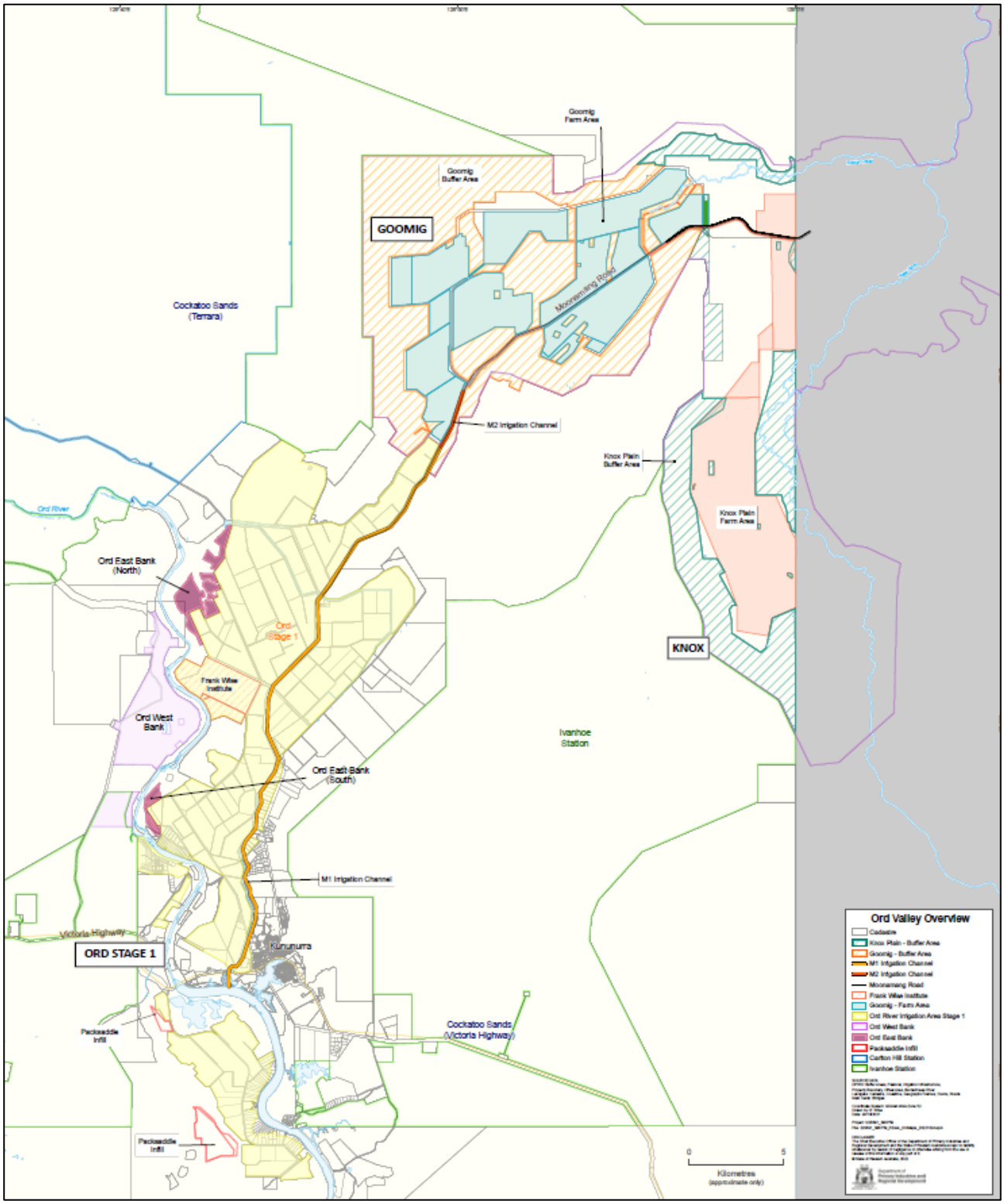


Figure 6: Map of the Ord River Irrigation Area (Provided by the Department of Primary Industries and Regional Development, DPIRD).

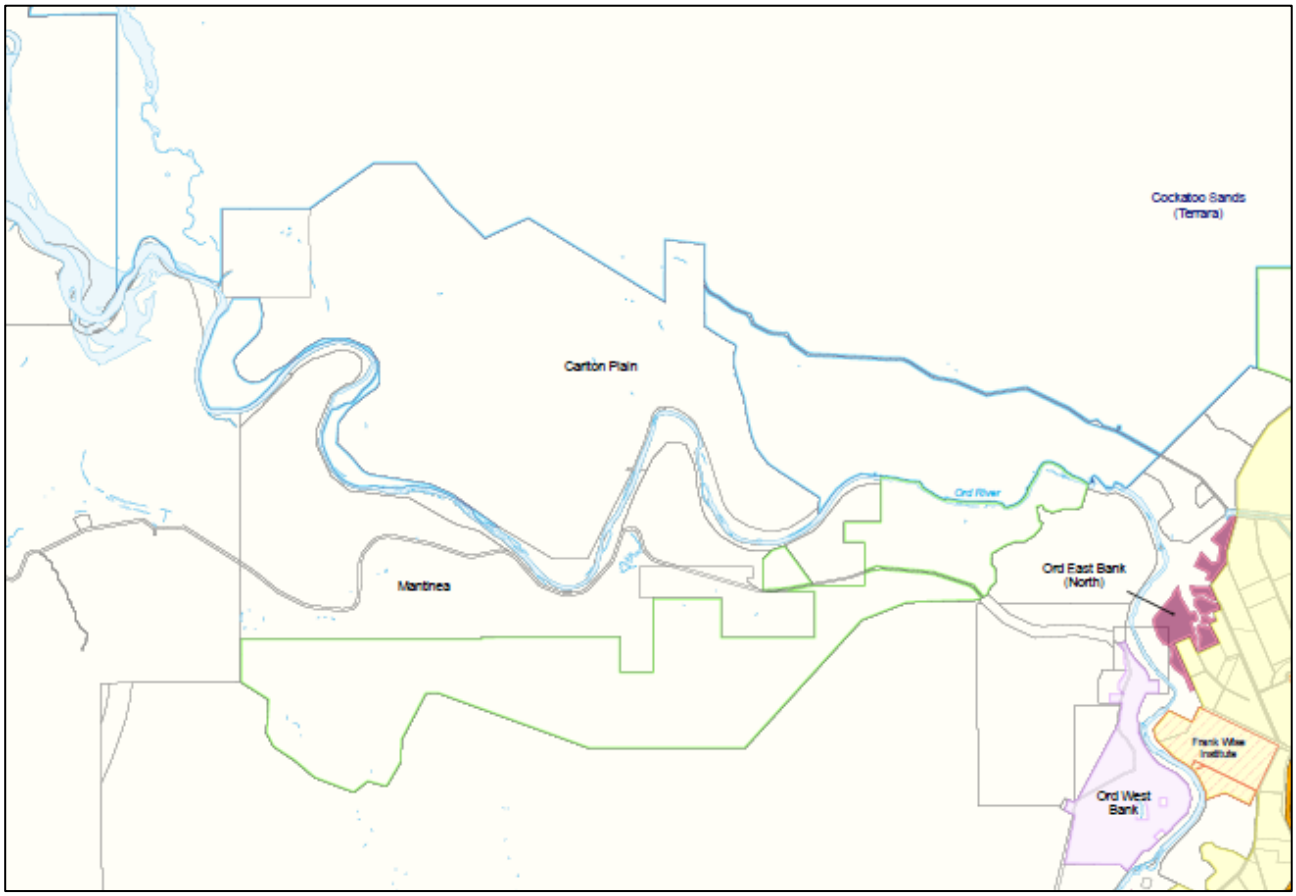


Figure 7. Carlton Plain and Mantinea development areas (map provided by the Department of Primary Industries and Regional Development, DPIRD).

The significant agricultural outputs from the ORIA, as well as the water use requirements to produce these outputs make the strong case for its inclusion in the CRCNA Water Security for Northern Australia (WSNA) Program. Originally, two key research themes were introduced in the ORIA:

(1) an investigation of water use efficiency, with a focus on the implementation of tail water recycling (associated with Stage 1 farms), and

(2) impacts on water quality, with a focus on the Keep River which is habitat for EPBC listed species (associated with Stage 2 farms).

Three research outputs have been proposed for the ORIA:

(a) Through the co-design process, the research question related to water use efficiency and tailwater recycling was modified, owing to the fact that retrofitting tailwater recycling was identified as an approach that would only likely be implemented following several other measures first being. implemented. The revised approach to research in the Stage 1 farming area aims to gain an understanding of farmers' current and potential future farming practices and to gain an understanding on their thoughts of potential water management in the region.

(b) To investigate agricultural runoff monitoring methods and data (especially for pesticides) to determine risks, and following this investigation, to potentially design an optimal sampling strategy for the system.

(c) Finally, a review of catchment/water management in tropical catchments was proposed. This review can cover both Australian and international management plan examples, as well as a review of peer-reviewed literature to document management approaches and their potential benefits to inform water management in the ORIA.

Engagement with the Ord River catchment stakeholders

The research questions were developed through consultation with the Western Australian (WA) Department of Primary Industries and Regional Development (DPIRD) and were refined through further consultation, the WA Department of Water and Environmental Regulation (DWER), universities and, local stakeholders (which included farmers, members of the Goomig Independent Review Group, amongst others). DPIRD was the primary contact throughout the consultation process.

Meetings with government organisations were held using Microsoft Teams, aside from the workshops held in Kununurra on the 27th and 28th of October. Generally, meetings varied in duration between 30 minutes and 2.5 hours, depending on the size of the group involved in the meeting. Given the interest from farmers in the area, rather than a dedicated Technical Reference Group, the two workshops were attended by multiple organisations and farmers/ farming companies. Organisations in attendance included DPIRD, DWER, Kimberley Agricultural Investment, Ceres Farm, Ord Irrigation Corporation, the president of the Shire of Wyndham East Kimberley, Acadia Farms, Oasis Farms, Boab Metals, the Independent Review Group and the Northern Hub.

The consultation process was driven through meetings that were held on an as needs basis, predominantly driven by DPIRD. In total, 11 dedicated Ord meetings were held between September 20th and November 25th. The meetings prior to the workshops included the DPIRD, DWER and Water Corporation. In addition to formal meetings, the project design process benefited from regular contact with Renee Zuks from DPIRD to organise meetings and the workshops.

In addition to meetings with stakeholders, discussions were held amongst CDU researchers, and regular updates on progress were provided to the Gilbert and Rookwood node leaders (Dr Nathan Waltham, James Cook University and Prof John Rolfe, Central Queensland University) and relevant researchers from each university. For example, cross university discussions were held with Prof Phil Brown (CQU), Prof John Rolfe (CQU), Dr Dianne Jarvis (JCU) and Dr Kamal Sangha (CDU).

Priority issues raised

Table 4: Research topics prioritised by stakeholders for the WSNA program - Ord

Proposing Organisation, brief project description, and overview of research skills/techniques	**Primary Node and priority of proposing org** **(Top/ High/ other)**	**Skills/ question relevant in other nodes** **Potential for impact**	**University/ researcher involvement/ expertise required**	**Likelihood of partner funding and/or in kind**
Proposing Org: DPIRD – water quality monitoring of agricultural runoff The stage 2 farms of the Ord River Irrigation scheme have high environmental regulations for farm runoff, given that the receiving environment (the Keep River) is the habitat of EPBC listed species (e.g., sawfish, sharks). These regulations include water quality monitoring. Responses to detection of exceedance of pesticide/herbicides in farm runoff are currently restricted by 7+ day sample analysis times. Sampling in the receiving environment is also challenging in the wet season, due to road access. Proposed project to investigate available data to understand chemicals in use and their risks, then explore the potential addition of (1) quick tests (lower resolution, but immediate response) and (2) passive samplers (to detect presence/absence of chemicals) to the current 'grab sample' sampling approach. Both additional approaches can inform management of the system to maintain water quality in the Keep River, by providing rapid information on potential issues (quick tests) and allowing post investigations if point in time samples missed key events (passive samplers). If not prohibitively expensive, drone samplers may be used to collect Keep River water samples during the wet season.	Ord (top priority)	Skills: Water chemistry, hydrology, management Relevant elsewhere: Impact Potential: Very high.	JCU/ CDU	High

Proposing Org: DPIRD Potential add on investigations to investigate farm run off could include: • a snapshot investigation of ecosystem health. This would likely involve investigations into a lower order species (below sawfish) to collect samples to look for evidence of toxicants in a part of the food web. This investigation would serve two purposes (1) to potentially be used as a baseline in case fish kill events occur, and (2) as a proof of concept study which may lead to follow up research. • Similarly, an investigation into the transport properties of various agricultural chemicals, and information on how/when they are used will allow modelling scenarios to investigate transport pathways and risks. • Extended survey techniques to potentially identify the presence of other EPBC species in the Keep River. • It may also be possible to sample in the Keep River during the wet season using drones. Wet season sampling has not been possible for some pools due to safety concerns. Elements mentioned here *may* be incorporated into the water quality focused research project. The eventual design will depend on data availability, chemicals used, and the available quick tests for the chemicals in use in the ORIA.	Ord (mid low)	Skills: Freshwater ecology Relevant elsewhere: Potentially Daly Impact potential: Mid Low	CDU/JCU	Unclear (DPIRD)
Proposing Org: DPIRD – Water use efficiency in the Ord River Irrigation Area Initially, the discussions for the stage 1 farms were framed around a cost benefit analysis of the retrofitting of tailwater recycling on stage 1 farms. However, discussions with a wider group of stakeholders revealed several questions which should be investigated prior to any consideration of tail water recycling. This project was modified to gain a deeper understanding of water use approaches and views on water management in the ORIA. Discussions with a wider group demonstrated that retrofitting tailwater recycling would only be considered after many other water saving approaches were first implemented.	Ord (low)	Skills: Social science, water management, economics, environmental science Relevant elsewhere:	CDU/ CQU	In kind likely

There is little motivation with the current approach for management to drive water use efficiency. Thus, this project in its original form was not progressed. Although, it should be noted that none of the stakeholders were against the cost benefit analysis of the tailwater recycling, it was more seen that it was of limited interest. There may be opportunities for a system to be retrofitted to the research farm in the ORIA. Additionally, discussions about retrofitting the research farm in the area with a tailwater recycling system was discussed. This option could be progressed by DPIRD, potentially with input from the Drought Hub.		Likely all catchments		
Proposing Org: DPIRD: (DITT and others may benefit) Elements of the proposed research below may be of benefit in both the Ord, and other catchments. The research outlined below combines elements from potential project options which were discussed throughout the co-design process. The design of the research requires two elements: 1. Through discussions/ questionnaires with farmers and DPIRD, identify soil type, crops grown and irrigation practices. Through this consultation, also enquire about thoughts on water resources management and their potential economic implications for individual farmers and as well as for the broader region. A mixed methods approach to understand water use practices, future plans for changes to cropping systems and appetite for risk could be useful in all catchments to assist departments with planning. 2. Demonstrate changes in crop type or irrigation changes (by soil type) in a numerical model plant-water-energy model. Paring this analysis with an economic/cost benefit analysis modeller allows the investigation of the potential water use and economic impacts of potential changes (including climate change).	Ord (high-mid)	Skills: Hydrology, cropping, economics Relevant elsewhere: Elements of study could Impact potential: Low, but useful	CQU/ CDU/ JCU	

Proposing Org: DPIRD (elements from DWER) Some of the management approaches in the Ord may be drawn from examples in catchments that are unlike the ORIA. There is interest from DPIRD in the production of a literature review on water management in tropical catchments. The review could draw upon both Australian and international examples, highlighting approaches used in similar catchments The review would provide insights that may be useful in all nodes in the project (as well as other catchments in Northern Australia). Somewhat similar studies for groundwater have been recently published in the Journal of Hydrology: Regional Studies.	Ord (mid)	Skills: Hydrology, hydrogeology, water resources management Relevant: All nodes Impact potential Mid	CDU/ JCU/ CQU	Very minor in kind likely
Proposing Org: DWER There was a question of economics and surety of supply in the Ord. Currently, the 95% surety of supply is related to the allocatable pool of water. Is 95/100 optimal to maximise economic benefit of the region (while providing suitable reliability for growers)? To increase the allocatable pool (without needing to open up more land), reducing the surety increases the volume of allocatable water. However, the question is whether or not this would this drive increased economic benefits. This question has been incorporated into the project "understanding approaches to farming and views on water management".	Ord (mid low)	Skills: Ag, economics Relevant elsewhere: Perhaps elements	CDU/ JCU/ CQU	Minor.
Other proposed projects Through the workshops, discussions were held into whether the instructions for use on agricultural chemicals are suitable for use in tropical catchments/ the	Ord	Agricultural runoff, environmental management.	JCU/CQU	Unclear. Discussions did not progress.

ORIA. i.e., is there a need for locally relevant guidelines to agricultural chemical use, relating this to catchment health. The project was not progressed, given the high priority that was placed on the investigation of optimal sampling approaches to detect agricultural runoff and the impact that project could have on management of the ORIA system.				

Priority research areas going forward

Detailed summaries of priority research proposals can be found in Appendix C. Of the above proposed projects, the following are going ahead:

Topic	Summary
Project 3.1 - Review of catchment/ water resources management approaches in the tropics.	This project is going ahead as it can inform the management of the Ord River Irrigation Area. While the review will be conducted with the Ord in mind, it is expected to produce benefits across Northern Australia, and provides genuine opportunities for collaboration across the three universities in the Water Security Program. The review will utilise available water allocation plans from across northern Australia, as well as research outputs from peer reviewed journal articles, and recent reporting from previous projects including TRaCK and projects by CSIRO.
Project 3.2 – Improved water quality sampling for agricultural runoff to the Keep River.	Minimising the impacts of agricultural runoff on the Keep River is of interest/concern to both DPIRD and the farmer groups in the Ord area. Current sampling approaches can have large delays between samples being collected, and the data being returned from the laboratory. Investigations into the potential risks from agricultural chemicals in use, as well as potential updates to the sampling design to achieve optimal results are both highly beneficial research outputs for the region.
Project 3.3 - Understanding the values of water in the Ord River Irrigation Area.	This project combines elements of multiple projects that were originally proposed. The project was originally intended as a cost benefit analysis of the installation of tail water recycling. The installation of tailwater recycling was identified as an approach that would be considered only after multiple other water savings approaches were implemented. The research will be driven by a mixed methods social science research approach to understand farming practices and farmers' views on potential water allocation approaches. These outputs will inform a paired plant growth water use and economic modelling.

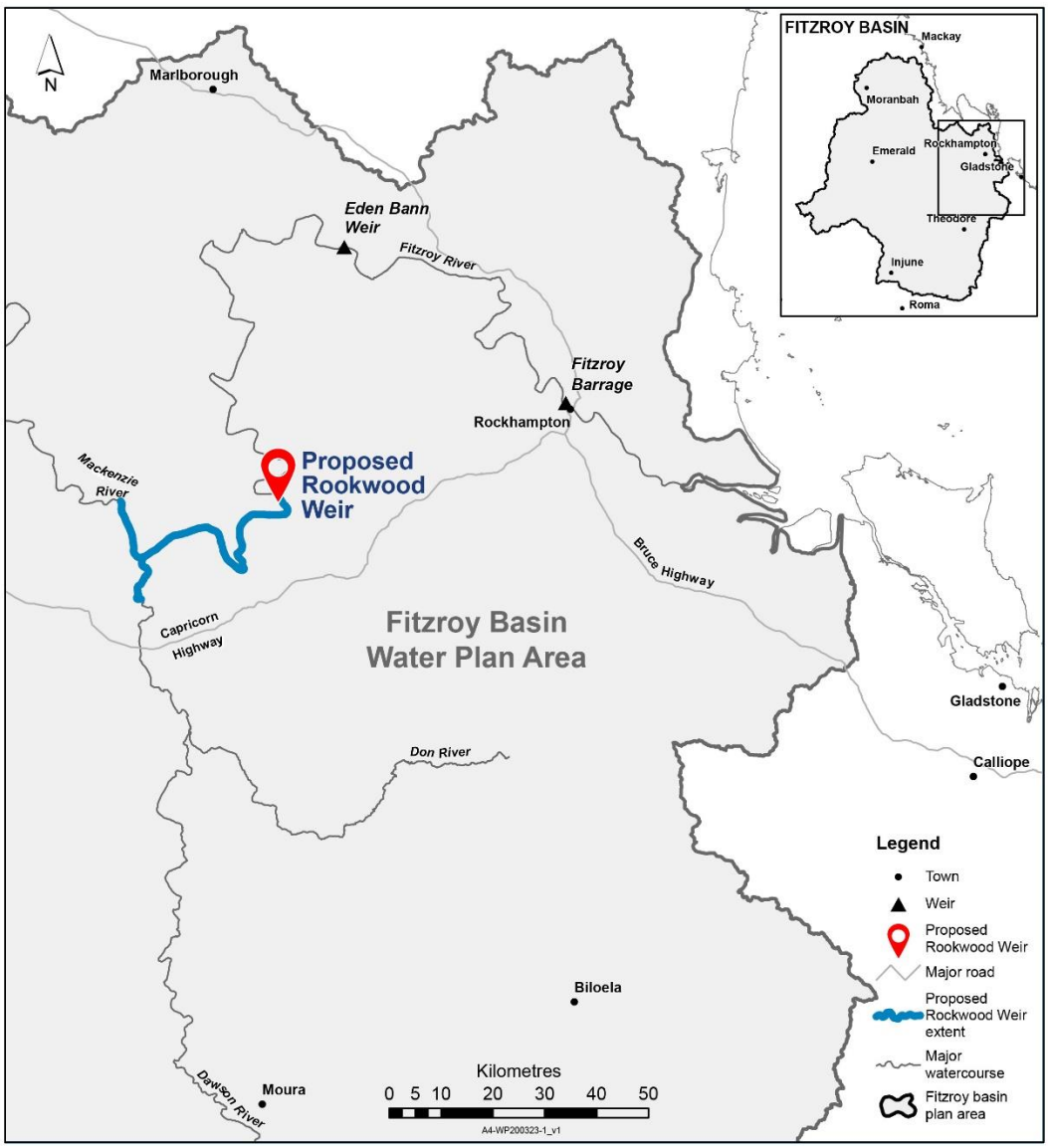
Lower Fitzroy River catchment - Rookwood Weir

Node lead – Prof. John Rolfe, CQU

Contextual Background

The Rookwood weir project, which is jointly funded by the federal government and Queensland government in partnership with Sunwater, is located on the lower Fitzroy River, approximately 66 kilometres south-west of Rockhampton (Figure 6). The construction of Rookwood weir, which is managed by Sunwater, is estimated to cost $367 million and planned to be completed by 2023. The weir is expected to provide approximately 76,000 ML of water per annum, of which at least 37,500 ML is to be allocated to agriculture (Advance Rockhampton, 2022; Queensland Government, 2018, 2022).

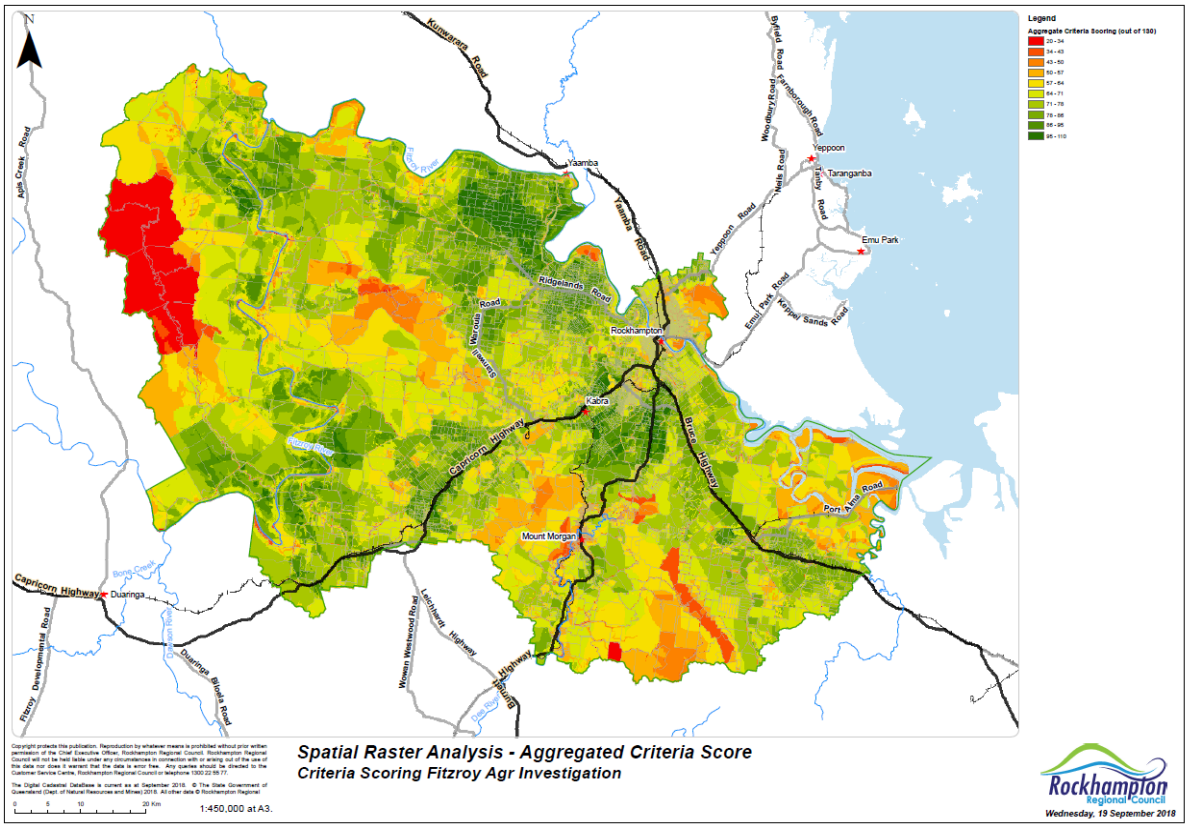
Figure 8. Location of Rookwood weir in central Queensland



Source: https://www.rdmw.qld.gov.au/water/consultations-initiatives/rookwood-weir#about

The water from Rockwood weir is likely to support intensive livestock and significantly expand the range of crops grown, including perennial horticulture crops such as mandarins, pecans, lychees, mangoes, and table grapes, as well as broadacre crops such as soybeans and peanuts. There may be opportunities for value-adding through processing and attracting more infrastructure investment in the region. These advantages are seen to be viable, given that the region also benefits from access to established agricultural logistics chains, transportation and port terminals for connection with domestic and export markets. An assessment of the potential for irrigated agriculture in the Rockhampton Local Government Area conducted by the Rockhampton Regional Council on multiple criteria such as soils mapping and proximity to the river and key infrastructure is shown in the figure below. This shows that suitability is quite fragmented and that multiple areas along the river system exist where development might feasibly occur.

Figure 9: Mapping suitability assessment for irrigated agriculture in the Rockhampton LGA



Source: Rockhampton Regional Council

With the increased availability of reliable water from the Rookwood weir, macadamias and mandarins are expected to be particularly attractive opportunities, given the strong growth in production, profitability, and export demand of these products (Sunwater, 2020). For example, Sunwater's (2020) anticipated market outlook report estimates that net returns from macadamia production within the Rookwood weir area would range from around $2,400 to $4,600 per hectare per annum.

The development of Rookwood weir is expected to boost and maximise Central Queensland's economy by $1 billion annually through the expansion of agriculture and multiplication effects (Smith, 2018; Sun Water, 2020). Specifically, it will provide opportunities to shift towards more integrated and value-rich supply chains as well as a more circular economy. This would present

the chance for the region to transition, grow, and intensify the agricultural sector to meet the demand in the Asia Pacific market (Advance Rockhampton, 2022; Communities in Transition, 2019; Sun Water, 2020).

There has already been 30,000 ML of medium security agricultural water sold from the Rookwood allocation, with a large proportion of this water allocated to the establishment of macadamias (Rural Funds Management) and a 60,000 head feedlot (Mort and Co) in the Gogango area. Currently another 7,500 ML of water are being tendered in up to 500 ML lots, with the aim of supporting the development of smaller scale irrigation ventures. It is unclear exactly where new agricultural developments will occur along the river system, but it is expected that the South Yaamba district will be one area where growth will occur.

The Rookwood weir project is different to other past water infrastructure projects in Australia in that the project is only about developing water infrastructure, and not the subsequent agricultural development. Water distribution systems and other mechanisms to establish an irrigation district need to be supported from other agencies and sources. An additional complication is that while the weir will be built and operated by Sunwater, ownership of the water will reside with the Queensland Government, as distinct from the existing Eden Bann weir and Rockhampton Barrage, where water is owned and administered by Sunwater and the Rockhampton Regional Council respectively.

The need to improve coordination around development has already been recognised, with an alliance between the Rockhampton Regional Council, the CRCNA and the Queensland Department of Agriculture and Fisheries already formed to fund five research projects in priority areas:

1. Defining a supply chain and development precincts vision
2. Visionary land use planning to facilitate development precincts
3. Mobilising strong water governance arrangements
4. Integrating nutrient, waste and energy streams in agricultural development
5. Achieving reef water quality requirements in new agricultural development.

While these projects have been recently contracted, a number of major information gaps still exist about the challenges to realising the development potential in the lower Fitzroy region. Many of the coordination, governance and planning issues are becoming more visible as the Rookwood weir draws closer to the operational stage and industry grapples with the opportunities and challenges of development.

There are two major reasons why the Rookwood weir and lower Fitzroy region have been chosen as a node for analysis within the northern Australia region. The first is that there are a large number of challenges in coordination and development for the new irrigation region that require attention, particularly given the disconnect between new water infrastructure development and the growth of an associated agricultural precinct. The second is that the Rookwood case study provides a template of the issues that are likely to be relevant for future water schemes in northern Australia, and hence identification, analysis and solutions design of the challenges that emerge is likely to provide a useful template relevant to other regions.

Engagement with the lower Fitzroy River catchment stakeholders

The focus of the project was to identify through a review and consultation process priorities for further research in the node to improve water security and agricultural development in the region. Substantial material and expertise were available to draw on, including:

- Planning and advocacy for development in the lower Fitzroy region from the 1990s,
- Business case, approvals and design for the Rookwood weir from 2012 onwards, and
- More recent analysis and review work by the Making Water Work steering committee over the past three years.

The issue identification and prioritisation work involved a number of approaches, including:

- Desktop review of key documentation about Rookwood and issues
- Engagement with Advance Rockhampton and the Marking Water Work steering committee
- A number of one-on-one interviews, including with staff and experts from:
    - Advance Rockhampton,
    - Rockhampton Regional Council
    - Queensland Department of Agriculture and Fisheries (QDAF)
    - Queensland Department of Regional Development, Manufacturing and Water
    - Sunwater
    - Regional Development Australia
    - CQUniversity
    - Agricultural sector.
- A workshop with QDAF staff (20th September).

The material from the different approaches was then drawn together to generate a preliminary set of potential issues and research priorities for the lower Fitzroy. A workshop was then held with a cross section of stakeholders on the 31st of October to test and refine the list of potential issues. A final meeting was then held in mid-December to check the suggested research plan with the node stakeholders.

Priority issues raised

A large number of issues were raised during the process to identify priority areas for future research. These were grouped into 16 areas of potential research focus. Some issues fell within the ambit of the five current projects in the Making Water Work portfolio, so were not considered further. Some other issues were more aligned to government planning processes than research priorities, so were also not considered for further analysis. The remaining issues identified were grouped into six broad areas for further consideration, out of which four were selected as particularly relevant to the lower Fitzroy and northern Australia more generally (Table 5).

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Table 5: Research topics prioritised by stakeholders for the WSNA program – lower Fitzroy **Proposing Organisation, brief project description, and overview of research skills/techniques**	**Primary Node and priority of proposing org (Top/ High/ other)**	**Skills/ question relevant in other nodes**	**University/ researcher involvement/ expertise required**	**Likelihood of partner funding and/or in-kind**
Potential project 1: Prospects for specialty crops in lower Fitzroy region Completion of the Rookwood Weir will create new opportunities for irrigated cropping in the Lower Fitzroy region. New crops that have traditionally not been part of the dryland cropping and grazing systems in the region will become viable. These would include broadacre pulse and grain crops as well as annual and perennial horticulture crops. While suitability of prospective crops to soil and environmental conditions can be inferred from studies in other regions, the decision by farmers to transition to new crops is strongly influenced by locally generated crop performance data. This includes crop economic data, crop performance data (e.g. pest and disease susceptibility), and compatibility of the crop management with other components of the farming system. On-farm crop performance trials and qualitative data from growers on farming system decision making processes will support the transition to higher value farming systems that utilise new irrigation infrastructure. There may be particular locational advantages in trialling pulse crops (high demand, low fertilizer/pesticide requirements, potential to supply into feedlot industry). The potential for biofuels will also be examined, because of potential linkages to renewable energy sectors at Gladstone. *Research skills required*: crop agronomy expertise is needed for crop performance trials. Farming systems expertise and qualitative research methodology expertise are required for research focussed on farmer decision making and farming systems transformation.	Rookwood	Gilbert/Daly	CQU – Crop agronomy, farming systems, qualitative research	High (good networks with industry associations; CQU already works closely with industry and farmers on other trials)

Potential project 2: Prospects for agricultural technology into new agricultural developments Overview: Agriculture is entering a period of transformation, the so-called Agriculture 4.0 or fourth agricultural revolution, with digital technologies and automation delivering new agtech products and services to improve productivity, profitability and sustainability of farming systems. Regions like the Lower Fitzroy are in a strong position to capture the benefits of agtech as new agricultural developments can incorporate the technologies at establishment stage rather than retrofitting technologies into existing systems. Research on farming system design that incorporate emerging agtech is needed to provide growers/investors with strategies for developing Agriculture 4.0 systems. One component of this activity is demonstration of available technologies and applied research to optimise technologies in the farming systems as well as generating ROI and productivity/sustainability gain data. This approach has been successfully implemented in the Bundaberg region by CQU through the Hinkler AgTech Initiative. The approach included detailed grower needs assessment and building of new technology connections and knowledge capability within established and trusted industry networks. Research skills required: farming systems expertise and domain specific agtech expertise is required for system design and tech trial research. Social science research expertise to assist with qualitative research on technology adoption and grower needs assessments.	Lower Fitzroy	Ord/Daly	CQU – Farming systems, Ag Tech JCU Ag Tech has complementary expertise	High (CQU researchers already working closely with Ag Tech sector)
Potential project 3: *Optimising water quality monitoring* As part of the licence conditions for Rookwood weir, Sunwater have to develop a long-term water quality monitoring approach. Currently regular baseline monitoring is being undertaken at several sites above and below the weir and a large number of parameters (about 250) are being tested (including > 150 pesticide components on top of physchem, nutrient and other parameters). The costs of sampling and assessment are roughly about $3,000 per site per event, so if there are multiple sites and regular sampling, the cost blows out. For example, 10 sites with monthly sampling would be $360K/year, while 30	Rookwood	All catchments	CQU and JCU – water chemistry and modelling, water monitoring, statistical analysis	High (CQU already involved with Sunwater and FBA on scoping the issues)

sites with monthly sampling would be $1.3M per year. These costs ultimately will be passed through to growers as a part of water user charges. One major challenge is to assess what should be done for sampling with major flow events, as the regulators are very keen for high flow events to be monitored. However, flow events are difficult and costly to monitor: a ten day flow event with five sample sites and 12 hour sampling windows would add another $300,000 to the monitoring costs (and bring the annual monitoring cost up to $20/ML for Rookwood). This is a potential problem across northern Australia where high flow events are common. Options to streamline monitoring programs are to incorporate continuous monitors and mechanical grab samplers into sampling procedures, to target pesticides for testing from farm records or land use management plans, or to use modelling approaches to extrapolate for data gaps. Research skills required: Water quality assessment, monitoring program design, statistical analysis, engagement and negotiation with multiple stakeholders				
Potential project 4: Developing minimum standards for feedlots in northern Australia Currently there is limited practicality for feedlots in northern Australia because of the difficulties in operation in hot conditions and during wet seasons. Designs and approvals processes are focused on conditions in southern-eastern Australia, including southern Queensland. However, the opportunities for feedlotting are particularly in the north, where there is currently a large cattle herd and limited opportunity for value adding. Using new irrigation districts to grow fodder for feedlots has some of the highest returns of all options, as it avoids some of the transport and processing requirements of other crops. If pressures increase to reduce live exports, then increased feedlotting will be one option to maintain viability for the industry. However, it is unclear whether it is feasible to establish feedlots in many areas and what design and operating constraints would be required for their operations. Research skills required: Animal welfare, beef cattle and feedlot performance, supply chain logistics engagement and negotiation with multiple stakeholders	Rookwood	All catchments	CQU – Beef cattle management, smart beef technology, animal welfare management, stakeholder design (Mark Trotter, Delwar Akbar, John Rolfe)	High (DAF identified the project need and that there is currently no assessment framework for feedlots in tropical Qld)

Project 5: *Capacity building for traditional owners to be involved in water enterprises* An allocation of water (500ML) from Rookwood Weir has reserved for traditional owners. As well a large parcel of land is held by traditional owners on the lower Fitzroy. However there has been very limited participation to date of those groups in discussions about the potential use of the water. One important area of work is to engage with the Traditional Owner groups and help them to be more involved in decisions and options about the use of water.	Lower Fitzroy (Rookwood)	All nodes	CQU has limited skills with TOs and agricultural development JCU and CDU	Medium (High priority for Advance Rockhampton but unclear how much the TO groups are interested)
Project 6: Model the upstream and downstream supply chain needs and identify how synergies can create efficiencies Input needs can be limiting for major developments, particularly when high costs are involved. Examples of key inputs include equipment, fuel, labour, electricity and fertiliser, all of which have been exposed to shortages or higher prices in recent years. These effects are rarely predicted at a scheme or precinct level because the issues of procurement and supply rest with a number of smaller agents. However, if bottlenecks do exist, they will reduce viability and create perverse incentives to focus on low value crops that have smaller risks. The project would combine direct engagement and modelling to build a prediction tool for key supply chain requirements. To avoid undue complexity, it would focus on predicting needs for key inputs by certain crops, so that changes in water allocations or crop mixes will generate changes in input requirements. The framework can then be used to extrapolate to potential solutions, such as the housing and training needs of new labour force estimates, or total fertiliser requirements at a precinct or district level. A strength of the framework is that it can also be used to model indirect outputs, such as greenhouse emissions or nutrient emissions. Then the effects of solutions such changes in crop mix, moves to renewables or biofuels, or changes in farm management can be estimated. Of particular interest are options that create synergies within a precinct, such as the use of feedlot waste for fertiliser into cropping, The predictive framework will be able to	Lower Fitzroy (Rookwood)	All nodes	CQU has good supply chain and modelling expertise	Medium (High priority for Advance Rockhampton but unclear how much the TO groups are interested)

capture the changes in inputs and outputs generated by these synergies and provide some estimates of the efficiency benefits generated. The model can be parameterised from existing irrigation operations, such as in the lower Fitzroy and the Ord. The aim will be to develop a predictive tool that can be relevant to all irrigation precincts in northern Australia				

Priority research areas going forward

Four projects from the initial list of 16 potential areas for work were identified to progress:

Project 4.1: Prospects for new agricultural technology across northern Australia

Project 4.2: Optimising water quality monitoring

Project 4.3: Prospects for specialty crops

Project 4.4: Model the upstream and downstream supply chain needs and identify how synergies can create efficiencies

These projects were all identified as addressing major issues of relevance for the lower Fitzroy region where results could potentially have major impacts on the viability and scope of future operations and developments. Further details are provided in Appendix D.

WSNA research project proposals

After 4 months of consultation with stakeholders in the 4 nodes a total of 15 research projects have been prioritised (Table 6). Projects proposed to be carried out in each node have been taken from the research priorities identified from each Technical Reference Group or advisory stakeholders. A summary of each project proposal can be found in the Appendices of this report.

To understand how the various proposed research activities in each node relate to research in other nodes, the 15 projects have been categorised into 5 work packages (WP) which reflect the thematic areas which will be covered by the WSNA program. The work packages illustrate where, even over a large geographic range, water security research priorities for northern Australia have similarity or complementarity. The work packages are:

WP 1: Cross northern Australia

During the co-design consultation phase with stakeholders a number of research priorities that apply across several or all of the focal regions/nodes were identified and supported by stakeholders. These cross northern Australia research proposals have been aggregated into work package 1 – Cross northern Australia. Each of these 4 projects will be carried out within a node for the WSNA program.

WP 2: Water quality and the environment

A key priority across three of the research proposals is the monitoring and maintenance of water quality within nodal catchments for both environmental and regulatory needs. These proposals will support the baseline collection of pre-development environmental data along with determining the best sampling methodology post development.

WP 3: Water availability and the environment

Four of the research proposals will look at above and below ground water availability within catchments to better understand the impacts of current and future water extraction and how this might be impacted by climate change. Knowledge based water allocation for catchments will help ensure sustainable water availability to agriculture and the environment now and into the future.

WP 4: Cropping systems and new crops

Development of catchment infrastructure will create new opportunities for irrigated cropping. New crops that have traditionally not been part of the dryland cropping and grazing systems in these regions will become viable. While suitability of prospective crops to soil and environmental conditions can be inferred from studies, the decision by farmers to transition to new crops is strongly influenced by locally generated crop performance data. Two of the projects will investigate crop economics, crop performance data and compatibility with other components of the farming system.

WP 5: Supply chain and alternative economies

Input needs can be limiting for major developments, particularly when high costs are involved. Examples of key inputs include equipment, fuel, labour, electricity and fertiliser, all of which have been exposed to shortages or higher prices in recent years. These effects are rarely predicted at a scheme or precinct level because the issues of procurement and supply rest with a number of smaller agents. Projects in WP5 will combine direct engagement and modelling to build a prediction tool for key supply chain requirements.

Table 6: Proposed research projects in each node.

Project	Title	Work package	Node – River catchment
1.1	Floodplain, rivers and tributary aquatic flora and fauna inventory	WP 2	Gilbert
1.2	Persistence and extent of waterholes in the Gilbert River and tributaries, groundwater contribution to permanency	WP 3	Gilbert
1.3	Examine the ecosystem services gained and lost for proposed development areas	WP 5	Gilbert
1.4	Indigenous values mapping and water resource enterprise product identification	WP 1	Gilbert
2.1	Investigation of multi-catchment climate change models - modelling impacts over Northern Australia	WP 1	Daly
2.2	Improving the understanding of the Oolloo Dolostone springs and the coupled groundwater-surface water model	WP 3	Daly
2.3	Investigation of wet season water take on floodplains and water requirements of ecosystems	WP 3	Daly
2.4	Cropping systems in the Daly River catchment, present and future	WP 4	Daly
3.1	Review of water/catchment management in tropical environments	WP 1	Ord
3.2	Agricultural runoff and impacts to the Keep River	WP 2	Ord
3.3	Understanding the values of water in the Ord River Irrigation Area	WP 3	Ord
4.1	Prospects for new agricultural technology across northern Australia	WP 1	Lower Fitzroy
4.2	Optimising water quality monitoring	WP 2	Lower Fitzroy
4.3	Prospects for specialty crops	WP 4	Lower Fitzroy
4.4	Modelling the upstream and downstream supply chain needs and identify how synergies can create efficiencies	WP 5	Lower Fitzroy

Knowledge repository

During the co-design phase in each node, it became apparent that many stakeholders, and the research team in some instances, were not aware of key previous data or research relevant to their node. Also, the project team had trouble accessing previous work that they knew existed. Both of these instances point to the need for greater access to data and reports from previous projects. Currently there is no central repository of this knowledge. Equal access to existing knowledge and data sources is important for equity and greater understanding of relevant development and environment issues. Thus it was agreed that, creating a knowledge repository of such information for each node would be a useful activity of the WSNA program. It is envisaged that this knowledge repository would store and make readily available reports and data relevant to each node in a publicly available and accessible platform such as a dedicated website.

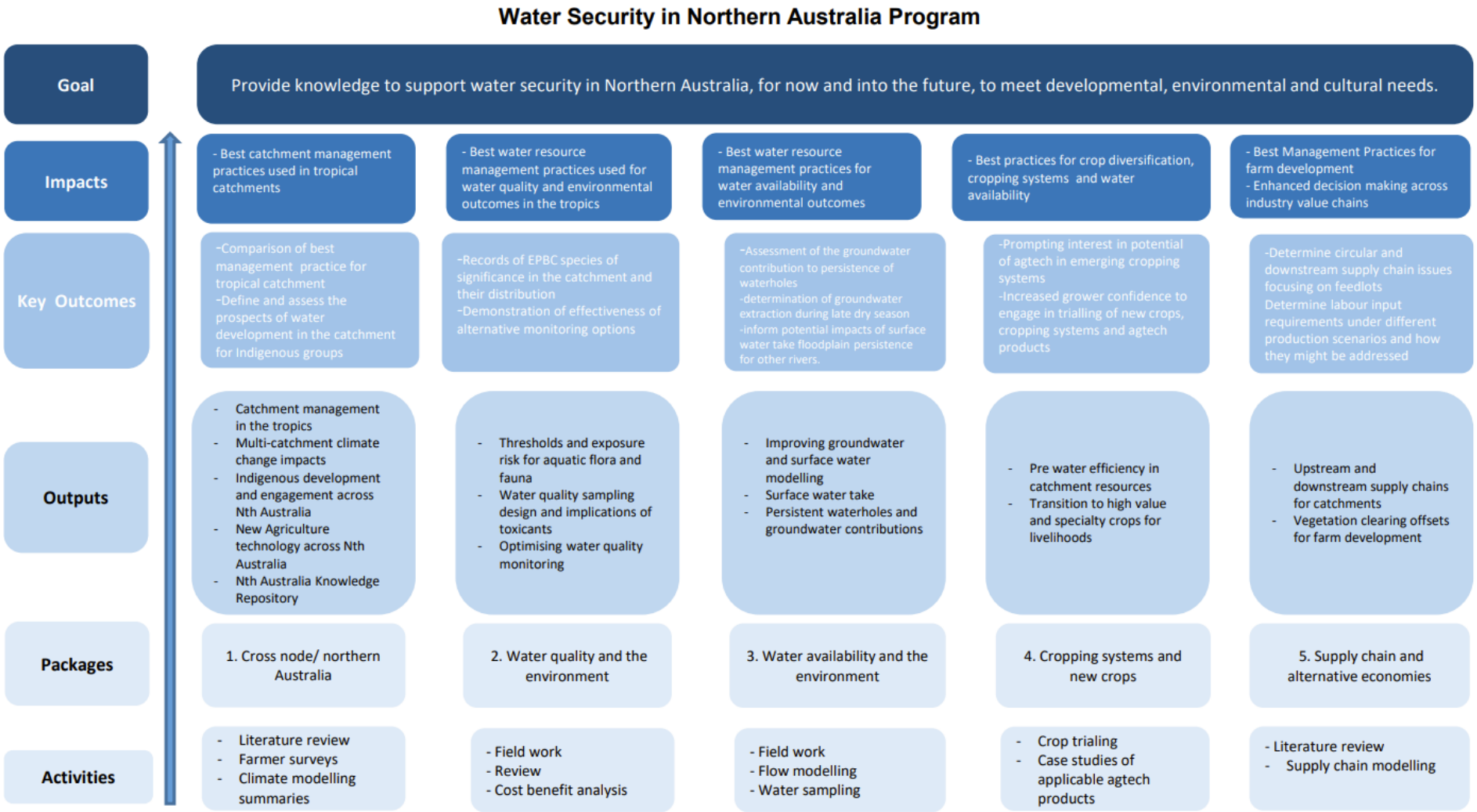
The WSNA knowledge repository will be a funded project within this program. Initially we will consider the best way to approach this repository as all research institutions have their own data repositories, such as Research Data JCU which is an integrated data management platform that supports all stages of the Research (Data and Information) Asset Lifecycle. This platform helps to maximise the efficiency and integrity of research, increases research visibility and impact, assists with meeting compliance requirements for funders, publishers and the Australian Code for the Responsible Conduct of Research. This platform would also ensure data and information is Findable, Accessible, Interoperable and Reusable under Australia's FAIR Access Policy Statement. This repository will ensure that documents and data for northern Australia are more visible and managed to maximise knowledge brokering into the future.

Potential Co-supervised Doctorate and Masters

At this stage, only one doctoral student (listed below) is linked to this program, though others may join once the program has been established.

Project aligned	Topic	Funding source	Lead supervisor
2.1	Climate change impacts on water resources.	CDU to provide scholarship and standard PhD project funding.	Dr Dylan Irvine

WSNA implementation plan



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Appendix A

Research proposals for Gilbert River catchment

Research priority – Gilbert project 1.1			
Primary Node	Gilbert River catchment		
Project Name	Floodplain, rivers and tributary aquatic flora and fauna inventory		
Work package	2 – Water quality and the environment		
Project Lead Institution	James Cook University		
Project Leader	Assoc Prof Nathan Waltham		
Start date	Feb 2023	**Finish date**	Mar 2026

Project description

There is limited, explicit, aquatic flora and fauna (including water quality) data completed in the Gilbert River and the tributaries. Studies completed to date have been restricted to proposed development precincts (e.g. Flinders and Gilbert Agricultural Resources Assessment) and floodplain areas (TraCK). The Gulf Water Plan uses species data to test and set flow hydrometrics for species presumed or historically documented in the region. According to Australian Living Atlas, the sawfish (*Pristis pristis*) and the freshwater whipray (*Urogymnus dalyensis*) are known in the catchment, with the sawfish listed as critically endangered under the EPBC Act 1999 (the sawfish is an indicator species for development impacts on waterholes in the Ord River catchment). This research project focuses firstly on completing an inventory of aquatic flora and fauna species in the catchment, and secondly, overlay functional and lifecycle ecology trait requirements on current distribution to understand the potential future risks to development in the catchment (this same approach has been applied in the Ord River for example). These data will assist State Government in the review of the Gulf Water Plan and preparation of the next revision due 2027. In addition, the data will be useful for any planned future monitoring and evaluation of development that commences in the catchment.

Methodology

The final location of sites will be determined in consultation with Gulf Savannah NRM, Indigenous groups, Queensland Government (DES, DRDMW, DAF), Etheridge Shire Council, and landholders. This will be completed in the first inception meeting and planning. The nominal sampling schedule will follow annual surveys following wet season and late dry season.

Water sampling

During each survey, vertical depth profiles were conducted for pH, conductivity, temperature, dissolved oxygen, and turbidity at two random locations, plus a third location at the deepest position of each waterhole, using a hand-held Hydrolab QANTA (multiprobe) calibrated in the laboratory before and after use on each field trip. Depth profile will be standardised to 0.1 m, 0.2 m, 0.5 m, 1.0 m and thereafter at each 0.5 m increment until approximately 0.1 m above the bottom. On each sampling occasion, a single water sample will be collected at a mid-channel position at a depth of approximately 0.3 m below the water surface. Samples will be stored in portable 12V freezers (~–15 ^{o}C) until being returned to the TropWATER Analytical Laboratory for

further processing. Sampling method, sample bottles and preservation techniques, and analytical methods, will be all in accordance with standard methods (i.e. DERM 2009, APHA 1998).

Water samples will be analysed for nutrients including nitrogen (total nitrogen, ammonia, nitrite, nitrate, oxidised nitrogen, dissolved organic nitrogen, urea, dissolved inorganic nitrogen), and phosphorus (total phosphorus, dissolved organic phosphorus, filterable reactive phosphorus, and particulate phosphorus). Samples will be also examined for Total Suspended Solids, cations/anions (Ca, Mg, Na, K, Cl, SO4), Total Organic Carbon, Dissolved Organic Carbon and Dissolved Inorganic Carbon. A secchi disk (0.3 m diameter) will be used to measure water column light attenuation. In situations where the bottom of the waterhole is visible from above, the horizontal secchi distance will be measured instead. As a measure of algal biomass, a known volume of water will be collected from the waterhole surface (0.3 m depth) and field filtered onto glass fibre filter paper (Whatman GFF) to determine chlorophyll a concentration. A second water sample will be collected to measure depth integrated chlorophyll a concentration. All water samples will be processed in the TropWATER water laboratory in Townsville.

A calibrated Hydrolab multi-probe data logger (DS5X) will be deployed in the near-surface water layer (0.2 to 0.4 m below the surface) to monitor the diel periodicity (cycling) of temperature, pH, electrical conductivity and dissolved oxygen at 20 min intervals. The loggers will be deployed for between 24 hrs and 36 hrs during field trips.

Aquatic flora and fauna

Instream habitat will be assessed along a 100 m reach at location during all sampling trips. In freshwater regions, instream aquatic plants (% cover and species present), benthic microalgae (% cover), large woody debris (% cover along pool margin), leaf litter (% cover of substrate), sediment substrate characteristics (% cover based upon Wentworth grain size classifications), and riparian shading (expressed as the % cover over the waterhole) estimated. The extent (%) of habitat type (dry, silty, sandy, rocky, riffle or run) within the waterhole reach will be also estimated. In addition, climate conditions (cloud cover, wind), and hydrological stage (swift flow, recent flow, baseflow or no flow) will be recorded.

Riparian vegetation condition will be assessed once per waterhole. Briefly, the width of the riparian zone as a proportion of the mean stream width will be calculated from the most recent available Google Earth imagery. Riparian vegetation condition will be assessed along a 100 m transect parallel to the waterhole extending to the full width of the riparian zone. Within the transect, data relating to vegetation linear continuity and the degree of bank protection offered by riparian vegetation will be collected. Data were used to generate a score from 1 (poor) to 5 (very good). A total riparian condition score for each waterhole will be then generated by summing the three scores to give a maximum possible score of 15 and a minimum score of 3.

Aquatic invertebrate communities will be sampled at each waterhole using a standard dip net (triangular frame: 0.3 m x 0.3 m x 0.3 m, 0.65 m bag depth, mesh size 250 µm). Sampling will be stratified across different habitat types (bank edges, pool bottom, macrophytes) where available, with three replicates completed in each habitat type. ‘Kick samples’ of benthic habitat within waterhole environments will be collected at all waterholes (over an area of 2 m2). On site live picking of aquatic invertebrates will be conducted for 45 min in total for each habitat type (15 min for each of the three replicates). Specimens will be stored in vials and preserved in 70% ethanol before detailed laboratory processing. Specimens will be identified to family level where possible, although some of the more taxonomically challenging groups will be identified to higher taxonomic levels.

Freshwater fish assemblages will be sampled predominantly using a backpack electrofisher (Smith Root Model 12-B and an ETS unit), however, in deeper and more extensive waterholes we will use a boat mounted electrofisher set up. Typically, the entire waterhole will be sampled (at least along the margins) in a single pass, so that most or in some cases, the entire waterhole was surveyed. Where feasible/necessary (particularly on the floodplain and in the estuary), a gill net (30 x 2 x 0.075 m stretch mesh) will be deployed for approximately two hrs soak time. Bait traps (0.2 x 0.2 x 0.4 m) will be set at waterholes for approximately two hrs soak time, though traps might need to be set overnight to capture more nocturnal species. Captured specimens will be identified and released immediately.

eDNA tracing of diadromous fish species

To complement the field sampling of fish species, particularly species that have a lifecycle ecology that need to migrate between freshwater and tidal saline areas of river catchments (e.g. barramundi and the nationally protected sawfish), we will also use environmental DNA test (finger printing) where water samples will be collected extensively across waterholes and floodplains to test for these species following wet season. This sampling technology has the advantage to rapidly examine for DNA fragments of target species. This technique will complement our field sampling where catching individuals is necessary to understand the stock structure, where eDNA only confirms presence of species.

Field work permits and approvals

TropWATER has all the necessary approvals (animal ethics and government permits) to start immediately. All the data collected with stored on JCU Research Data repository and will be made available to any other partner as necessary. All data will be examined using appropriate univariate and multivariate statistics for final reporting and publication. Any relevant historical data will be used here, to assist in meeting the aims of this research project.

Key outputs

Output	Outcomes
1. Inventory of aquatic species for the catchment which will be uploaded to Australian Living Atlas, Queensland Government Wildnet	List of aquatic flora and fauna species for the catchment for inclusion in national museum records.
2. Spatial distribution maps useful for Gulf Water Plan revisions	Spatial distribution maps for species across the catchment.
3. Data will be also useful in defining risks to threatened species (under EPBC Act, for example).	Records of EPBC species of significance in the catchment and their distribution, data that is critical for water resource planning
4. Publication of data in peer reviewed journals, conference presentations and	Scientific publication/s in peer reviewed international journals

University / researcher involvement

James Cook University - Nathan Waltham; Paula Cartwright; Natale Snape; Jordan IIse; Anthony Squires
Charles Darwin University - Keller Kopf
Central Queensland University - Nicole Flint

Partnering organisations

- Gulf Savannah NRM
- Queensland Government
    - Department of Environment and Science, Water Science Planning
    - Department of Regional Development, Manufacturing and Water
    - Department of Agriculture and Fisheries

Proposed milestones

Key Research activity	*Outputs - Key Output*	*Periods*	*Due dates*
Quarterly report due	Progress on: 1. Study site network planning (JCU) 2. Engagement of key staff (JCU) 3. Meet with CRCNA communication manager to discuss coms for project	01-Jan-23 to 31-Mar-23	14-Apr-2023
Quarterly report due	Progress on: 1. Complete site reconnaissance to establish field work network with stakeholders/landholders 2. Short article in Etheridge Shire Council newsletter/paper 3. Update to Technical Reference Group – presentation on project milestones and program 4. Build repository for literature and data for catchment, JCU database framework developed	01-Apr-23 to 30-Jun-23	14-Jul-2023
Annual report due	2023 Financial Year Annual Report to CRCNA.	01-Jul-23 to 30-Jun-23	31-Aug-2023
Quarterly report due	Progress on: 1. Update on field reconnaissance and confirm network of stakeholders 2. Update database repository with field data 3. Share data and emerging learning with key partners via presentations (online)	01-Jul-23 to 30-Sep-23	14-Oct-2023
Quarterly report due	Progress on: 1. Complete field work late dry season 2. Laboratory sample processing from field trip	01-Oct-23 to 31-Dec-23	14-Jan-2024

	3. Update to Technical Reference Group – presentation on project milestones and program		
Quarterly report due	Progress on: 1. Complete field work post wet season 2. Update database repository with field data 3. Update to Technical Reference Group – presentation on project milestones and program	01-Jan-24 to 31-Mar-24	14-Apr-2024
Quarterly report due	Progress on: 1. Laboratory and assess emerging data and trends 2. Short article in Etheridge Shire Council newsletter/paper 3. Update data repository for catchment, JCU database framework 4. Share data and emerging learning with key partners via presentations (online)	01-Apr-24 to 30-Jun-24	14-Jul-2024
Annual report due	2024 Financial Year Annual Report to CRCNA.	01-Jul-24 to 30-Jun-24	31-Aug-2024
Quarterly report due	Progress on: 1. Share data and emerging learning with key partners via presentations (online)	01-Jul-24 to 30-Sep-24	14-Oct-2024
Quarterly report due	Progress on: 1. Complete field work late dry season 2. Update to Technical Reference Group – presentation on project milestones and program	01-Oct-24 to 31-Dec-24	14-Jan-2025
Quarterly report due	Progress on: 1. Complete field work post wet season 2. Update to Technical Reference Group – presentation on project milestones and program	01-Jan-25 to 31-Mar-25	14-Apr-2025
Quarterly report due	Progress on: 1. Laboratory and emerging data and trends 2. Short article in Etheridge Shire Council newsletter/paper 3. Update data repository for catchment, JCU database framework	01-Apr-25 to 30-Jun-25	14-Jul-2025

	4. Share data and emerging learning with key partners via presentations (online)		
Annual report due	2025 Financial Year Annual Report to CRCNA.	01-Jul-25 to 30-Jun-25	31-Aug-2025
Quarterly report due	Progress on: 1. Complete final field work late dry season 2. Update to Technical Reference Group – presentation on project milestones and program	01-Oct-25 to 31-Dec-25	14-Jan-2026
Final report	**Delivery of:** 1. Final technical report 2. Data repository 3. Communications summary **4.** Audited financial report	01-Jan-26 to 31-Mar-26	14-Apr-2026

Research priority – Gilbert project 1.2			
Primary Node	Gilbert River catchment		
Project Name	Persistence and extent of waterholes in the Gilbert River and tributaries, groundwater contribution to permanency		
Work package	3 – Water availability and the environment		
Project Lead Institution	James Cook University		
Project Leader	Assoc Prof Nathan Waltham		
Start date	Feb 2023	**Finish date**	Mar 2026

Project description

Seasonal rivers of northern Australia remain connected following the wet season for a period, until flow ceases where they then gradually become disconnected and exist as a series of waterholes. These waterholes gradually further dry as the season continues, some completely, through for some that remain in a permanent state until the next wet season are critical freshwater refugia habitat for species. While permanent waterholes are critical, they are also susceptible to poor water quality conditions, particularly as the dry season advances, some reaching conditions that are intolerable for aquatic life. The balance and risk that these permanent waterholes exist until the next wet season means they are also at risk of land use changes, which might pose a threat risk to their utility as important refugia habitat. For example, land use change might change important limnological processes (i.e., making them more turbid, or changing the diel cycling of oxygen and temperature) meaning they contribute little to broader ecosystem services. As part of this research project we will also examine the surface and groundwater contribution to waterhole permanency, using a range of techniques with colleagues from Charles Darwin University.

Methodology

Waterhole identification
Landsat 5 imagery or similarly available imagery will be sourced from current to as far back in as possible (ideally 20yrs). All Landsat images will be orthorectified using at least 50 ground control points to minimise image registration errors and results in a root mean squared error of less than 0.5 pixels. All scenes will be radiometrically and atmospherically standardised so as to facilitate reliable comparison of radiance values over time. A catchment-specific calibration procedure will be used for identifying the water index threshold best suited for the catchment. For this calibration, the areas of individual water bodies will be manually digitised in Google Earth Pro.

Waterhole persistence and identification of key aquatic refugia
Waterhole extent was derived for each of the time series of Landsat scenes identified by classifying pixels within the defined buffer zone as either water or non-water. This time series of water body extent will be then used to track changes in waterhole area over time. The percentage of time (i.e. percentage of available images) that a given pixel was classified as water will be calculated as this provides a direct method by which to assess the persistence of waterholes between years.

Relationship between streamflow characteristics and in-stream waterhole area
In order to assess the potential impacts of changed streamflow regime on in-stream waterhole development (i.e. size, persistence), it is necessary to determine whether relationships exist between waterhole area and streamflow. Historical streamflow will be modelled for each river reach at the key gauging stations identified. Historical climate data to run the river model will be

sourced from the SILO data drill database, which provides interpolated historic daily climate data on a 0.058_0.058 grid.

Groundwater contribution to surface waters
Groundwater contribution to key/important pools will be investigated using a combination of hydrological tracer approaches. Tracers will include water chemistry (i.e. major ions), stable isotopes of water and radioisotopes. Where relevant, microbial-based approaches may also be applied.

Key outputs

Output	Outcomes
1) Spatial mapping files of the location and range extent of freshwater and floodplain wetlands in the catchment.	Spatial mapping GIS data of waterholes in the catchment and their size ranges over the course of dry season dry down. These spatial data are essential for water resource planning by Queensland Government
2) Risk assessment to waterholes and wetlands in the catchment under possible future climate change and water resource development (to be defined by the TAG)	Spatial mapping GIS data files for critical waterholes and their potential risk to future climate change and development scenarios. These spatial data are essential for water resource planning by Queensland Government
3) Spatial maps outlining the groundwater contribution to identified critical waterholes and wetlands (from Project 1) in the catchment and assessment of risk with water extraction and future climate change	Assessment of the groundwater contribution to persistence of waterholes, particularly critical waterholes in the catchment, and determination of groundwater extraction during late dry season.

University / researcher involvement

James Cook University - Nathan Waltham; Paula Cartwright; Mohammad Jahan; Anthony Squires
Charles Darwin University - Dylan Irvine; Post Doc TBA

Partnering organisations

- Gulf Savannah NRM
- Queensland Government
    - Department of Environment and Science, Water Science Planning
    - Department of Regional Development, Manufacturing and Water
- Department of Agriculture and Fisheries

Research priority – Gilbert project 1.3			
Primary Node	Gilbert River catchment		
Project Name	Examine the ecosystem services gained and lost for proposed development areas		
Work Package	5 – Supply chain and alternative economies		
Project Lead Institution	James Cook University		
Project Leader	Assoc Prof Nathan Waltham		
Start date	Feb 2023	**Finish date**	Mar 2026

Project description

Agricultural development in the Gilbert River catchment, despite available water for development under the Gulf Water Plan, is hindered by the requirement to prepare extensive and expensive environmental impact studies for each development (property) and, approval to clear vegetation for development activities (which requires various approvals). Working with farmers who have been collecting farm-scale data, specifically soil carbon data, and extending and complementing these data with the trade-offs in other ecosystem services provided, including biodiversity, cultural and water quality, this project focuses on examining the ecosystem services gained and lost for proposed development areas in the Gilbert River catchment. These data could be collected across several properties to road test requirements for development to help build confidence for approving agencies.

Methodology

The main elements to this research project involve determining: carbon stocks in soil and above-ground biomass, biodiversity services including vegetation and habitat assessments, cultural values and waterway/hydrology services that would be protected, modified or lost in place of expanding irrigated agriculture in the catchment. An important part of this research project is to gather all available data as part of determining baseline information for the hypothetical development, in parts of the catchment where there is the potential to expand cropping (though acknowledging that not al agricultural development will require irrigation). Farmers outline that the biggest barrier to expanding cropping land in the catchment, and therefore accessing the available water for irrigation, is the legislation and amount of information needed for approval. This project combines expertise and skills in soil and vegetation carbon, biodiversity (terrestrial and aquatic), cultural values and waterway/hydrology services. Specifically, we will undertake the following:

Carbon stock assessment

Carbon stocks in soil and vegetation will be assessed in developed areas and potential development areas. This will exploit time-series data from existing vegetation and soil surveys and farmer records, supplemented with sampling and analysis in key areas, with a focus on accounting for spatial variability and changes over time under nominated management regimes.

Biodiversity

Vegetation assessments will be undertaken. These assessments will examine flora diversity, abundance, cover and condition, following several condition method approaches that James Cook University regularly use for similar assessments in the region for mining impact studies (data which is used for compliance reporting). These surveys will also present the opportunity to confirm

regional ecosystem mapping and other available data for the catchment held by state, council and landholders.

Aquatic instream values will be examined within the partner properties, and in the region more broadly as part of Project 1. These surveys will describe the species diversity and abundance occupying waterways and waterholes, water quality conditions, and state of riparian areas (intact, impact from feral animals, erosion etc).

To understand the differences in biodiversity associated with proposed development, vertebrate communities (mammals, reptiles, amphibians and birds) will be also examined using a range of baited cages, acoustic recorders, motion cameras, drift lines with traps, arboreal cover boards and active searches. For comparison, and to understand patterns in the assemblage use of habitats in the landscape, sample plots will be positioned in existing agricultural areas, and in vegetated areas into which farmers may wish to expand. Sampling will occur several times each year, over the three-year program. Importantly, sampling will take into account different vegetation types, terrain, distance to water sources, disturbance and protected areas, as far as possible under the circumstances. The data will be used in the overall assessment of development in the catchment, and quantify risks to ecosystem services from water resources and agricultural development.

Development hypothetical assessment

We will examine hypothetical developments in terms of being feasible to supply water from the likely storage options, soil types, topography, flooding risk etc for crop suitability. For example, how large can the development be in terms of the constraints presented in the ecosystem services assessment (for example, likely types of crop(s) and cropping systems which will affect habitat loss and carbon balance. We will also examine within the development envelope, assess options/scenarios to determine overall pluses and minuses in terms of ecosystem services, including economics and related social benefits ideally, because any development is likely to be detrimental based on ecosystem services along so it would be most useful to determine net overall benefits. In addition, there is scope here to examine waterhole (Project 1.2) economic value, by applying the Australian Water Accounting Standard (or similar framework) to understand the water resource asset use, value and risk if not appropriately managed in existing development areas.

Government assessment

As part of this research project, we will road test the data and hypothetical development with the regulators to define if the development would be approved, or if not, what additional data is necessary for approval – or is the development just not possible. This project has the major benefit of tackling the barrier to development, regulatory approvals, in a catchment that is under subscribed in terms of water allocations. Meetings will be held with Regulatory groups in relevant state and federal government to work through a hypothetical development, using the field data and information. Several workshops will be held with government departments, in addition, to work through the approval process, where the team will capture the learnings and information needed for proponents to prepare and register development applications for expansion in the catchment. The outcomes of these workshops will be a framework for development approval.

Key outputs

Output	Outcomes
1) Assessment of the opportunities and constraints to water resource and associated agricultural development based on values.	Spatial mapping of proposed development areas identified at the farm scale, to be used in the overlay with existing environmental mapping data sets (e.g regional ecosystems)
2) Development of a scientific database for carbon, biodiversity and water quality conditions in developed and adjacent non-developed areas in the catchment.	Extensive database of soil carbon, biodiversity and water quality data in existing developed and future prospective developed areas.
3) NRM planning and, Monitoring and Evaluation performance	Data will be useful for NRM planning and future evaluation of the Gilbert River and ecosystems under development.
4) Inventory on flora and fauna in the catchment which will be uploaded to Australian Living Atlas, Queensland Government Wildnet	Soil data provided to National Soils Database, biodiversity provided to Australian Living Atlas and water quality useful for NRM planning

University / researcher involvement

James Cook University - Assoc Prof Nathan Waltham; Dr Cassie James; Assoc Prof Paul Nelson; Prof Yvette Everingham; Prof Lin Schwarzkoft

Partnering organisations

- Gulf Savannah NRM
- Etheridge Shire Council – Etheridge Agricultural and Irrigation Precinct project
- Queensland Government
    - Department of Environment and Science, Water Science Planning
    - Department of Regional Development, Manufacturing and Water
- Department of Agriculture and Fisheries
- North Queensland Land Council
- Regional Development Australia Tropical North
- Northern Queensland Water Infrastructure Authority

Research priority – Gilbert project 1.4			
Primary Node	Gilbert River catchment		
Project Name	Indigenous values mapping and water resource enterprise product identification		
Work package	1 – Cross Northern Australia		
Project Lead Institution	James Cook University		
Project Leader	Assoc Prof Nathan Waltham		
Start date	Feb 2023	**Finish date**	Mar 2026

Project description

The Gulf of Carpentaria holds incredible Indigenous values and connect with Country. In some instances, these values and connections with Country are shared with emerging leaders in Indigenous communities. There is an allocation of water in the Gilbert River catchment for Indigenous use, however, access and use of the allocated water has not progressed. There is a critical need to work closely with TO groups, for them to drive forward in the identification and documentation of cultural values in the Gilbert River catchment (akin to the Walking the Landscape developed by DES). Preliminary research was completed during the CSIRO Flinders Gilbert Agricultural Resources Assessment to identify cultural values in the catchment. In this research project, there is a critical need to map out Indigenous cultural areas in the entire catchment, and to develop a plan of enterprise development opportunities for water use that is prosperous for groups. This project could be supported by the CRC for Indigenous and Environmental Histories and Futures (JCU).

Methodology

Mapping Indigenous values

The Gilbert catchment has many natural resource values, high conservation areas and critically important waterways for a broad range of goods and services. How these relate to cultural values and desires is not known, however, and this project will work closely with the local Traditional Owners to map out these critical areas and capture the values to ensure these details are used in the revision to the Gulf Water Plan in the next few years. The team will work closely with the Indigenous Ranger groups through engagement and consultation in the catchment to map these values, and compare them to natural resource management areas in the region.

Review of Indigenous water resource enterprise

The second element to this research project will examine the potential water resource enterprise options available to Traditional Owner groups in Gilbert, but also other catchments under the NAUA. For example, in the Gilbert River, there is an allocation of water for Indigenous use, however, to date this water has not been accessed. The reason for this is not clear, but could be related to the ability to set up enterprise – not having the upfront capital funding or even land to set up. This research project focuses on investigating ways that these groups could access water, in addition to the barriers and scale of the opportunity. It will also explore barriers to implementation of enterprise ideas, pathways to enable enterprise ideas and outline simple pilot projects/activities to demonstrate and catalyse success.

Key outputs

Output	Outcomes
1) Understand and mapping to acknowledge the cultural values in the catchment	Spatial mappings and data on cultural values in the catchment, used for cultural training and sharing knowledge/stories in the catchment
2) Training of Traditional Ranger groups in water sampling and generally water condition monitoring	Data and field work will be useful in increasing capacity of Ranger groups in the catchment, through the NRM group
3) Develop an understanding of the potential for water resource development by Indigenous groups in the catchment	Define and assess the prospects of water development in the catchment for Indigenous groups, scale of the economics and opportunity

University / researcher involvement

James Cook University - Nathan Waltham; Diane Jarvis; ARC CoE Indigenous and Environmental Histories and Futures (TBA)
Charles Darwin University - Dylan Irvine
Central Queensland University - John Rolf

Partnering organisations

- North Queensland Land Council
- Ewamian People Aboriginal Corporation
- Tagalaka Aboriginal Corporation
- Gulf Savannah NRM
- Etheridge Shire Council – Etheridge Agricultural and Irrigation Precinct project
- Queensland Government
    - Department of Environment and Science, Water Science Planning
    - Department of Regional Development, Manufacturing and Water
- Department of Agriculture and Fisheries
- Regional Development Australia Tropical North
- Northern Queensland Water Infrastructure Authority

Appendix B

Research proposals for Daly – Katherine River catchment

Research priority – Daly project 2.1			
Primary Node	All		
Project Name	Investigation of multi-catchment climate change models - modelling impacts over Northern Australia		
Work package	1 – Cross Northern Australia		
Project Lead Institution	CDU		
Project Leader	Dylan Irvine		
Start date	Apr 2023	**Finish date:**	Mar 2026

Project description

Climate change has produced higher temperatures and modified rainfall patterns, which will continue into the future. Future climate change is expected to impact both water security as well and existing and proposed agricultural developments in northern Australia. While it is clear that temperatures will increase in northern Australia, the projected changes in rainfall rates and intensities are highly uncertain. To provide further understanding of the potential impacts on agriculture, the Bureau of Meteorology (BoM) have recently produced the Climate Services for Agriculture (CSA) tool (Australian Government, 2022). The CSA has tool been designed to communicate future climatic conditions to the agricultural sector. The BoM have also produced the Australian Water Outlook (AWO) tool (Bureau of Meteorology, 2022b) that provides gridded data sets, both historical and projections, which can be used to inform current and future water management decisions.

Various government departments including the Department of Environment, Parks and Water Security (DEPWS, Northern Territory), and the Department of Water and Environmental Regulation (DWER, in Western Australia) have flagged their interest in utilising climate model output in future water allocation planning. In particular, DEPWS have demonstrated interest in including projections of climate change in future Water Allocation Plans. DEWR have highlighted an interest in including climate projections in planning around water allocations in relation to the Ord River Irrigation Area, having utilised data from the BoM to inform planning in southwest Western Australia.

Project 1.2 aims to utilise climate model outputs and the CSA tool to inform water management in Northern Australia. While Project 1.2 will produce direct research outputs, it is expected to inform several other projects. For example, the impacts of future climate change are of relevance in each of the catchments in the Water Security Program (i.e., Daly - Katherine, Ord, Gilbert and lower Fitzroy (WA)).

Methodology

While the CMIP6 global climate models, the latest generation of climate models, have been recently released, the BoM tools (CSA, AWO) still utilise the previous CMIP5 model output, which are presently better understood. Decisions on the model outputs to use will be made following a preliminary review of the at the outset of the project.

The first phase of the project will involve collation of the required datasets, and a systematic review of the available reports and peer reviewed literature on the impacts of climate change, with a focus on northern Australia

Through consultation with BoM, the project will utilise the available data sets to project potential changes to groundwater recharge, with targeted sites in northern Australia. CMIP5 data is available through the AWO tool. Relevant temperature, rainfall and evapotranspiration datasets are typically available in NETCDF format, which can by unpacked using the Python scripting language, an area of expertise of Dr Irvine. Selection of appropriate climate models to use (specific models shown to be highly reliable in northern Australia, vs. multi-model mean approaches) will be identified through the project.

Investigations into potential changes in groundwater recharge at the catchment scale will draw upon existing approaches that have been applied elsewhere (i.e., Crosbie et al. 2010, Mourot et al., 2022), likely using climate model outputs as inputs for hydrological models.

The project will also provide outputs from the global climate models to inform other projects throughout the WSNA Program. For example, the impact of climate change (i.e., temperature, rainfall) is expected to inform investigations into cropping and water management/allocation in the Daly and Ord River catchments.

Key outputs

Output		Outcomes
1	Collation of climate model output data and review of available reports and peer reviewed literature.	Collation of projected climate impacts on Northern Australia to date will be provided to relevant state government departments, with a focus on water resources and agriculture. The collation of climate model outputs facilitates the remainder of this project and will allow impacts of climate change to be assessed in other projects in the WSNA program.
2	Targeted investigation of potential impacts to water resources in a catchment (or catchments) in Northern Australia.	Targeted understanding of potential climate change impacts on water resources at the catchment scale.
3	Preparation of datasets to inform projects across the WSNA program.	Allowing the impacts of climate change to be investigated across Northern Australia and in a range of projects in the WSNA program.

University / researcher involvement

Charles Darwin University - Dylan Irvine; External researchers, PhD candidate

Partnering organisations and any funding involvement
Department of Environment, Parks and Water Security.

Research input from the BoM.

Research priority – Daly project 2.2			
Primary Node	Daly		
Project Name	Improving the understanding of the Oolloo Dolostone springs and the coupled groundwater-surface water model		
Work package	3 – Water availability and the environment		
Project Lead Institution	CDU		
Project Leader	Dylan Irvine		
Start date	Apr 2023	Finish date	Mar 2026

Project description

Annual Announced Allocations (AAAs) in the region of the Oolloo Dolostone aquifer are determined using a coupled groundwater-surface water numerical model. The model is run during the wet season to determine the available water for allocation for the remainder of the (water) year. The model currently produces a mismatch between observed and simulated flows in the Daly River, with the modelled outputs requiring adjustment to appropriately reproduce field observations, before AAAs can be defined. Further field investigations are required to better inform the numerical models to improve model predictions.

The project aims to improve the understanding of the water origins of the springs that discharge to the Daly River through targeted water sampling and to conduct investigations to inform the conceptual model of the system to assist effective water resources management. The identification of key springs to study will require input (and approvals) from Traditional Owners, the NT Government and researchers. The study of springs provides opportunities to engage with ranger groups and Traditional Owners to understand water requirements to sustain culturally significant springs.

Working with Traditional Owners provides genuine opportunities for two-way learning about the interactions between the Oolloo Dolostone and the Daly River and to understand how this has changed over time. For example, knowledge of spring water origins from Traditional Owner groups, passed through stories may provide useful input to inform the understanding of key springs for management purposes. Developing a deeper understanding of the functioning of culturally significant springs, and the hydro(geo)logical conditions required to sustain them can further inform the allocation of groundwater in catchment areas of the springs.

Methodology

The first stages of the project involve collating available data and reviewing available literature. At the outset of the project, engagement with Traditional Owners and the Northern Land Council (NLC) is vitally important. Identifying which springs are of interest to Traditional Owners and can be studied, as well as agreeing to data use agreements can take significant time.

To determine the water origins of springs, multiple water tracer techniques will be required, using both spring and groundwater samples. Potential techniques include, but are not limited to:

Temperature: Temperature data are inexpensive to collect and can provide information on likely source depths of discharging waters.

Stable isotopes of water (e.g., δ^2H and $\delta^{18}O$): Stable isotopes of water, δ^2H and $\delta^{18}O$, are inexpensive tracers that can be used to determine whether or not groundwater recharge is locally

derived. When rainfall time series data are available, stable isotope data from groundwater or springs can be used to inform the age of water.

Major ions: Samples for major ions provide multiple opportunities to understand spring water origins. For example: (1) spring source temperatures (and as a result, depths) via so-called geothermometers (see Keegan-Treloar et al., 2022). (2) Major ions can also be used to 'fingerprint' water origins.

Radioisotopes: Radioactive isotopes including tritium (^{3}H), carbon-14 (^{14}C) and chlorine-36 (^{36}Cl), amongst other naturally occurring radioactive tracers, can be used to determine the age of water. Given that groundwater is generally expected to increase with both depth and distance from a recharge zone, groundwater/spring water mean residence times can inform likely water origins.

Microbial source tracking: Microbial DNA-based tracers are relatively new to hydrogeology. Microbial DNA-based techniques have been used in conjunction with hydrogeological tracers to inform sources of contamination in other tropical catchments (i.e., Duvert et al., 2019). Utilising complementary techniques can provide multiple lines of evidence, which can be a major benefit in highly complex aquifer systems, such as the groundwater system that underlies the Daly River.

Key outputs

Output	Outcomes
1. Review of existing reports and data and preliminary discussions with Traditional Owners and/or ranger groups, preliminary work to obtain the required research, access, data use permits.	Project sampling design to be informed by review of existing literature and discussions Springs that can be studied to be identified at this stage, noting that the required approvals process can take significant time.
2. Results from preliminary water sampling/ field campaign.	Documentation of preliminary findings to inform model calibration project undertaken separately by DEPWS.
3. Report on cultural significance of springs and their water use requirements.	Document the water requirements to maintain spring systems of cultural significance.
4. Final results documenting spring water origins to inform management and the numerical model.	Findings to inform groundwater and surface water management in the region where the Oolloo Dolostone underlies the Daly River.

University / researcher involvement

Charles Darwin University **-** Dylan Irvine, Clement Duvert, Karen Gibb, Nicola Stromsoe

Postdoctoral fellow funded through the project

Partnering organisations and any funding involvement

Department of Environment, Parks and Water Security.

Research priority – Daly project 2.3			
Primary Node	Daly		
Project Name	Investigation of wet season water take on floodplains and water requirements of ecosystems		
Work package	3 – Water availability and the environment		
Project Lead Institution	CDU		
Project Leader	Dylan Irvine		
Start date	Apr 2023	**Finish date**	Mar 2026

Project description

The Northern Territory Government has recently released a draft surface water take policy that relates to the take of surface water during the wet season. The policy allows for scientific investigation to establish a maximum volume of water that can be extracted in a river basin. Where scientific investigation is not available, the contingent allocation rule determines the maximum volume that can be extracted based on river data over the preceding 50-year period. The consumptive pool is based on 5% of the 25th quartile of Jan-March (i.e., the wet season months) (Northern Territory Government, 2022b).

Understanding the potential environmental impacts of taking surface water during the wet season was identified as an important research area by the Department of Environment, Parks and Water Security (DEPWS). With the potential increase in the take of surface water, as well as the potential impacts from more variable rainfall patterns, potential impacts on river floodplains (and the species that they support) requires further investigation.

Surface water flows in northern Australia are highly variable. Even the Daly River, a perennial river with significant groundwater inputs, can be highly variable. For example, total flow at the Mt Nancar gauge was 11353 and 1843 GL/y for the water years (Sept to Aug) of 2018 and 2019, respectively. Surface water take may lead to permanent reductions in river flows in both the wet and subsequent dry seasons (Bureau of Meteorology, 2022a). The reduced flow conditions may impact adjacent floodplains. Research questions relating to floodplains are interdisciplinary in nature, benefitting from input from by hydrological and ecological disciplines, amongst others.

The specifics of the research design will be informed by a detailed literature review. Likely components of the research include: (1) an investigation of the timing, frequency and duration of floodplain inundation and relating these wetting periods to the water requirement of key species, and (2) investigations into persistence and longitudinal connectivity of pools which act as refugia through the dry season (or dry years). Both the floodplain (large rivers) and connected pools (generally tributaries) questions have implications for the life cycles of several aquatic species. Investigations will target rivers in the Daly catchment, the approaches implemented in the project may provide a mechanism to inform management decisions relating to other rivers.

Methodology

Given that a significant body of work exists on the influence of surface water take on surface water bodies and their associated floodplains, the first task is to complete a review of available literature. For example, King et al. (2015) reviewed impact dry season take of water take on the hydrology of ecology of tropical savannah rivers. Leigh and Sheldon (2008) reviewed impacts of water resource development on selected Australian floodplain rivers. The review will refine research questions and

identify target sites for investigation, utilising peer-reviewed literature, and outputs from previous projects, including research in the Daly catchment by Tropical Rivers and Coastal Knowledge (TRaCK).

The relationship between river flows and the duration/ area of inundation of floodplains can be investigated through the use of hydrograph data available for various rivers in the catchment (e.g. Douglas, Daly, and Katherine Rivers) and historical remote sensing data/ aerial imagery. Pairing analyses of floodplain inundation with the water requirements of floodplain species, through their full life cycle, can inform potential impacts of surface water take. Including projections from global climate models (i.e., rainfall and evapotranspiration) may allow the projection of future scenarios.

The literature review process will be used to identify knowledge gaps relating to longitudinal connectivity of pools and will drive the selection of the target river reaches and species. The project aims to inform thresholds whereby the lack of water availability impacts key species (for example water levels required to maintain connectivity of pools, or to maintain riffles). The project outputs are expected to first be driven primarily by a desktop review, followed by targeted field validation/investigations.

Key outputs

Output	Outcomes
1. Review of impacts of water extraction on floodplains.	Collating existing knowledge on impacts of water take for government departments. Informing decisions on the design of subsequent components of the project.
2. Reporting from comparison of river flow and floodplain inundation area analysis.	Improved understanding of the relationship between flows and floodplain processes in the Daly catchment. Analyses are expected to inform potential impacts of surface water take floodplain persistence for other rivers.
3. Reporting from investigation of pool connectivity/ water requirements of instream environments.	Improved understanding of the importance of connectivity of pools for dry season (or dry year) refugia.

University / researcher involvement

Charles Darwin University - Dylan Irvine; James Cook University - Nathan Waltham, WSNA Researchers

Partnering organisations and any funding involvement
Department of Environment, Parks and Water Security.

Research priority – Daly project 2.4			
Primary Node	Daly		
Project Name	Cropping systems in the Daly River catchment, present and future		
Work package	4 - Cropping systems and new crops		
Project Lead Institution	CDU		
Project Leader	Dylan Irvine		
Start date	Apr 2023	**Finish date**	Mar 2026

Project description

The Daly River Catchment supports a broad range of agricultural activity including hay, melons, and mangoes, as well as some forestry (NT Government 2022). A 2016 investigation identified that for profitable broadacre crops to be grown in the region, a two crop cropping system is likely required to generate suitable cash flow, with likely crops including peanuts, aromatic rice and/or mung beans.

The catchment includes areas with existing water allocation plans, and those that are under development. Of the available plans, the Katherine-Tindall Limestone Aquifer Water Allocation Plan area is currently over-allocated, with no new water available. The Oolloo Dolostone Water Allocation Area has not yet fully allocated its estimated sustainable yield, however, the northern region was overallocated at the time of publication (2019). Additionally, water allocation plans for the Mataranka Tindall Limestone Aquifer and Flora regions are in development.

The proposed work in this project is motivated by the Department of Industry, Tourism and Trade (DITT), with a focus on the Daly River Catchment. The primary goal of the project is to better understand current farming approaches, as well as understanding current barriers and potential motivations to change. An improved understanding of farming practices will allow DITT to better work with their stakeholders in the region. Knowledge of these various factors will be generated through mixed methods social science research approach which will be applied to understand farmers current approaches to farming practices as well as views on future change.

The outputs from the mixed methods social science research will be utilised with available soil and climate data (both past and projected) to inform numerical plant-water-energy modelling and paired economic modelling to better inform DITT to make management decisions and to support agricultural development in the region. The project aims to identify cropping water use requirements and to progress triple-bottom-line sustainable development planning at the catchment scale.

The focus on water use requirements of the project also aligns with interests of the Department of Environment, Parks and Water Security (DEPWS), who have highlighted that future water licence applicants in the Northern Territory will be requested to provide realistic water use requirements in licence applications.

Methodology

Current and future cropping in the Daly Catchment

A mixed methods social science research (i.e., a combination of interviews, workshops and questionnaires, with the exact approach to be developed within the project) will be used to gain a deeper understanding farming in the catchment. The goal of the research is to provide DITT with a deeper understanding of current farming strategies, motivations to make change to farming practices (or barriers that prevent changes). The research will support DITT to understand the requirements to facilitate a transition to higher value crops. Potential benefits to growing higher value crops on the available land may produce economic benefits and/or reduce the need for further land clearing in the area.

Paired physical/ economic modelling

With the improved understanding of the approaches to farming, plus the collation of available soil types, and likely future climate, several cropping systems can be numerically simulated. There are various numerical model codes capable of simulating plant growth for given soil, climate and nutrient inputs (e.g., LEACHM (Hutson and Wagenet, 1995), WAVES (Zhang and Dawes, 1998), and/or APSIM, (Holzworth et al., 2014)). By pairing the physical numerical models with economic modelling, the economic outcomes from various farming approaches can also be explored. Understanding the water requirements of crops both currently, and into the future, can inform long term planning.

Key outputs

Output		Outcomes
1	Mixed methods social science research design and ethics approvals. Collation of existing soils data.	Ethics approvals to allow the research to proceed. Understanding of soils to facilitate data analysis.
2	Conduct the mixed methods social science research, and collation relevant climate model outputs and soil data.	With Output 1 and Output 2, the climate model output data provides the inputs to allow the simulation of cropping approaches, including under climate change.
3	Summary report of mixed methods social science research results.	Output 3 provides DITT with a deeper understanding of the farmers' approaches to farming and obtains their input to inform future water management.
4	Outputs from paired physical-economic modelling.	To provide DITT with likely economic implications for management and farming practices changes in the Daly River Catchment.

1. **University / researcher involvement**
   Charles Darwin University - Dylan Irvine
   CQU - Phil Brown, John Rolfe, NAUA Researchers

2. **Partnering organisations and any funding involvement**
   Department of Industry, Tourism and Trade (DITT)

Appendix C

Research proposals for Ord River catchment

Research priority – Ord project 3.1			
Primary Node	All nodes		
Project Name	Review of water/catchment management in tropical environments		
Work Package	1 – Cross Northern Australia		
Project Lead Institution	CDU		
Project Leader	Dylan Irvine		
Start date	Apr 2023	**Finish date:**	Dec 2024

Overview of research

The effective management of water resources is of increasing importance with the drive to develop water resources in Northern Australia, and projected impacts from climate change. The WA Department of Primary Industries and Regional Development (DPIRD) suggested that a desktop review of catchment management approaches to water quality management in tropical environments would be beneficial. This suggestion was in the context of the Keep River catchment where part of the ORIA lies or otherwise discharges to. The review of water quality management approaches also applies to other tropical catchments in Northern Australia.

The focus on tropical environments is necessary, to ensure that the documentation of management models and practices is appropriate and relevant to the ORIA. The review will focus predominantly on examples of irrigation management from northern Western Australia, the Northern Territory and northern Queensland, predominantly focusing on the Ord, Daly and Burdekin irrigation districts). The review will also utilise peer-reviewed journal articles on water resources management. Where relevant, the review may also draw upon international examples of management approaches in tropical catchments.

The project will generate outputs (the review) that are of significance for water management in Australia's tropical north and will provide opportunities for genuine multi-institutional collaboration across the universities in the Northern Australia Universities Alliance.

Methodology

The review will investigate the range of possible catchment management models that could applied to the Keep River catchment. The review will document the merits, and limitations of various approaches. The review will utilise a wide range of resources that focus on relevant elements of surface and/or groundwater management with respect to water quality.

The first stage of the project will be to identify and refine the scope of the review and the context for the management of the Keep River, namely to: (a) Delineate the Keep River catchment, or sub-catchment for investigation, and collate required datasets to frame the context of the review (i.e., land use and its projected change, identify environmental discharges and likely risks), and (b) contextualise the setting of the catchment (stakeholders, the local context and constrains surrounding current management approaches). Following the first stage, the review will be conducted. Relevant documents will be sourced from the Western Australian, Northern Territory

and Queensland government departments. Peer reviewed journal articles will be obtained through literature searches using widely used databases including Scopus and/or Web of Science, and relevant outputs from previous large-scale investigations in northern Australia (e.g., TRaCK and/or CSIRO). Interviews with local experts are envisaged.

Following the completion of the final review, a stakeholder meeting will be held to discuss potential implications of the implementation of a shortlist of potential approaches. Input from these discussions will be utilised in the final report, where recommendations will be delivered.

The exact scope for the review will be driven by the literature search and further consultation with DPIRD. However, likely elements include a historical account of water management in tropical Australia, and environmental issues and their management (amongst others), and a summary of available peer-reviewed literature. The review will be informed by (and differentiated from) recent reviews of Australian water management, many of which include NAUA researchers, e.g.:

- *Land use change in the river basins of the Great Barrier Reef, 1860 to 2019: A foundation for understanding environmental history across the catchment to reef continuum* (Lewis et al. 2021).
- *Hydrological processes in tropical Australia: Historical perspective and the need for a catchment observatory network to address future development* (Duvert et al., 2022)
- *Sustainable management of groundwater extraction: An Australian perspective on current challenges* (Cook et al., 2022),

We would also propose to present the results of this review to a full meeting of stakeholders in the ORIA, who requested this work.

Key outputs

Output	Outcomes
1. Preliminary review of water management approaches in tropical regions.	A review of water management approaches to ensure water quality in tropical regions will inform water resources management in the Ord Irrigation Scheme area (and likely for all of Australia's tropical north).
2. Presentation and discussion of review findings to ORIA stakeholders outlining a shortlist of management approaches.	Refinement of possible management approaches to identify suitable options for the Keep River catchment.
3. Final report with recommendations.	Identification of optimal approach for managing water quality in the Keep River.

University / researcher involvement

Charles Darwin University - Dylan Irvine,

James Cook University - Nathan Waltham, Aaron Davis

CQU - John Rolfe, NAUA researchers

Research priority – Ord project 3.2			
Primary Node	Ord		
Project Name	Improving water quality sampling for agricultural runoff to the Keep River		
Work package	2 – Water quality and the environment		
Project Lead Institution	JCU (with input from CDU and CQU)		
Project Leader	Zoe Bainbridge/ Steve Lewis		
Start date	Apr 2023	**Finish date**	Mar 2026

Project description

The Keep River is the receiving environment of agricultural runoff from the Stage 2 farms. The Keep River discharges to the Joseph Bonaparte Gulf, on the Northern Territory side of the WA-NT border. The Keep River has much lower flows, relative to the Ord River, and is the habitat of *Glyphis glyphis*, *Glyphis garricki*, *Pristis clavate* and *Pritis pristis,* EPBC listed species (Hale, 2008), and potentially also the Northern River Shark (*Glyphis garricki*). Given the low flows and presence of important species, Stage 2 farms have stringent conditions to monitor agricultural runoff. Farmers are required to collect samples of stormwater runoff. Delays in sample analysis times are a limitation to water quality management, whereby herbicide/ pesticide analyses take >7 days to produce results. A major question from DPIRD is how to manage the system while waiting for the laboratory results. This limitation will become more significant as the ORIA expands into the Knox Creek Plain.

Water and sediment samples are also collected from the Keep River via point in time (or 'grab') samples when defined farm stormwater flow events occur. However, grab samples can lead to two issues: (1) time delays in return of results, and (2) particularly in receiving environments, whether the timing of the sample missed a key event. Additionally, inability to access pools in the wet season limits sampling during these months.

Current monitoring approaches of agricultural runoff lead to uncertainties in the optimal approach to manage the system. i.e., what if a laboratory result identifies concentrations exceeding limits weeks after an event has occurred? The proposed research will first produce a desktop analysis of mobility and risk of the pesticides used in the catchment area using the Pesticide Impact Rating Index (PIRI, Kookana et al., 2005), or other suitable tools identified through the project. Following the review, the second phase of the project may investigate the benefits of the inclusion of additional monitoring strategies to the current sampling approach, and/or design an improved monitoring program to provide DPIRD with more detailed information on toxicant and nutrient levels to inform management of the system. Elements of the Project will align with research being undertaken in relation to the Rookwood weir in the Fitzroy River (Qld).

Methodology

Phase 1: A desktop review will be required to identify crops grown, typical fertiliser applications (e.g., timing, rates) and a list of pesticides in use. Collating these data will facilitate the PIRI analysis to identify risks from agricultural runoff (including pesticide and nutrient runoff). Existing water quality data (if available) will be compiled and reported. The process will also allow the documentation of transport properties of agricultural chemicals in use, potentially allowing transport scenarios to be simulated using the updated surface model being developed for DPIRD.

Phase 2: The data collation and PIRI risk analysis, can inform the design of an improved sampling regime. The design of the sampling regime will be dependent on the pesticides in use, and whether so called 'quick tests' are available for these pesticides. If available for pesticides in use, quick tests may provide rapid information of the presence/absence of these chemicals. In addition to the quick tests (if possible), the deployment of passive samplers (4-8 week deployments) in the receiving environment are proposed to provide insights on whether field sampling in the receiving environment has missed any key events due to timing of the sampling.

The overarching goal of the project is to inform the management of the system to protect the Keep River.

Key outputs

Output	Outcomes
1. Phase 1: Documentation of pesticides in use and collation of existing data and reports and risk analysis.	Collation of data required to inform the remainder of the project design. Improved understanding of risks associated with presently (and historically) used pesticides.
2. Phase 2: Preliminary report on proposed sampling strategy, with preliminary demonstration of revised sampling approach.	Improved understanding of management actions to runoff events and understanding of transport behaviour of pesticides. Demonstration of passive samplers to identify validity of grab sampling approach. If relevant, recommendation on use of quick tests and/ or potential proxies to provide more rapid assessment of ecological risk.
3. Final report on the sampling strategy.	At the conclusion of the project, key results will be documented, highlighting future research needs and possible management interventions.

University / researcher involvement

James Cook University - Zoe Bainbridge, Steve Lewis

Charles Darwin University - Dylan Irvine (CDU), WSNA researchers

Partnering organisations and any funding involvement
DPIRD

Research priority – Ord project 3.3			
Primary Node	Ord		
Project Name	Understanding the values of water in the Ord River Irrigation Area		
Work package	3 – Water availability and the environment		
Project Lead Institution	CDU		
Project Leader	Dylan Irvine		
Start date	Apr 2023	**Finish date**	Mar 2026

Project description

The original intention of the project was to focus on water use efficiency. The interest in water use efficiency was motivated by recent years where water restrictions were considered due to low rainfall. After discussions with DPIRD, the DWER, and stakeholders at the workshop held in Kununurra, focus on water management approaches in the ORIA with wider a ranging scope than simply efficiency was selected.

Water resources in the ORIA are utilised by a broad range of end users. Lake Argyle (10,760 GL capacity) provides water for town water supplies, in hydro-electricity production (350 GL/y), irrigated agriculture and to maintain environmental assets. Annual water entitlement limits for non-hydro-electric uses from Lake Argyle are 865 GL/y (Department of Water, 2014).Future use may also include in green hydrogen generation. Water is managed to produce a high reliability of supply, where irrigators receive their full allocation in 95 out of 100 years (Department of Water, 2014). The reliability of supply is directly related to the volume of water that can be allocated under the scheme.

The ORIA has not had to implement water restrictions, or use Annual Announced Allocations, as is the case in other water management areas. With the ORIA being in operation for less than the 100-year timeframe, and the fact that system is not yet at full allocation, the 95% reliability approach has not been seriously tested. There currently no common understanding of the 95% reliability approach and how it would be implemented in low water years amongst ORIA stakeholders. The project will bring a broad range of stakeholders together to design and implement a socio-economic investigation of water and water management. The investigations will seek to define the 95% reliability concept, document stakeholders' views on important water management decisions and to explore the implications of water management on the economics of the region. The project will focus on the potential impacts of changing the water reliability (i.e., a greater area of land that can be used for cropping, vs. increased number of years requiring water restrictions), and what potential impacts future climate change may have on water resources in the system.

Methodology

The first stage of the project involves collating previously published data (historical, current and projected) in the ORIA, including reservoir modelling scenarios, cropping information, climate data/projections and water requirements of the current water storage system (i.e., requirements the maintain dam walls and hydro-electricity generation). For example, future cropping scenarios can leverage off of previous government modelling (e.g., double cropping and/or high-water use crops). Projected water use requirements of the systems can consider current, or future approaches (i.e., increased use of tailwater recycling).

Following the collation and reporting of the existing data/information, the questions to be posed in the mixed method social science research (i.e., questionnaires, workshops, interviews) will be co-designed, involving local stakeholders. The design of the questions will utilise the report that documents the current requirements of the system, as well the views of the stakeholder group. Questions are expected to focus on two broad themes:

(1) To seek to reach a common definition/understanding on the reliability of supply in the area, gauging the views of stakeholders on a range of topics, including how to manage/allocate water in dry years, and

(2) To explore the economic implications of both the current and potential future reliabilities of supply, including understanding the appetite for risk and views of water security vs. a focus on growth. This component of the research can also focus on the water allocation tools/approaches available.

Following the development and implementation of the social science research, results will be collated and could be used to inform various investigations of the ORIA. For example, outputs may be utilised to develop/inform updated reservoir modelling scenarios (conducted by DWER) to explore the future reliability of supply. Models could consider different climate scenarios and agricultural and other development conditions (i.e., green hydrogen), as well as water management approaches.

Key outputs

Output	Outcomes
1. Collate and review available reservoir modelling reports, current, and potential future crops to be grown, and current/future climate data/projections	To set the scene for the group on the current and potential future conditions on Lake Argyle to frame context to inform remaining project outcomes.
2. Mixed methods social science research design and ethics approvals. Preliminary workshops to identify key questions to seek input on.	Ethics approvals to allow the research to proceed. Co-developing questions with stakeholders to maximise the likelihood of capturing a wide range of views on water management.
3. Conduct the mixed methods social science research	Bringing a wide group of stakeholders together to seek a common understanding on water management, implications for future development and the economics of the region.
4. Summary report of mixed methods social science research results and identification of potential project outputs to inform future modelling scenarios.	Collating the outputs of the project will allow the design and running of various future scenarios of the ORIA system.

University / researcher involvement

Charles Darwin University - Dylan Irvine, CQU - John Rolfe; WSNA Researchers

Partnering organisations
Department of Primary Industries and Regional Development (DPIRD), Department of Water and Environmental Regulation (DWER)

Appendix D

Research proposals for lower Fitzroy River catchment

Research priority – Fitzroy project 4.1			
Primary Node	Lower Fitzroy River catchment		
Project Name	Prospects for new agricultural technology across northern Australia		
Work Package	1 - Cross Northern Australia		
Project Lead Institution	CQU (with close alignment with CQU-led project 4.3)		
Project Leader	Phil Brown		
Start date	Apr 2023	**Finish date**	Aug 2024

Project description

Agriculture is entering a period of transformation, the so-called Agriculture 4.0 or fourth agricultural revolution, with digital technologies and automation delivering new agtech products and services to improve productivity, profitability and sustainability of farming systems. Regions like the Lower Fitzroy are in a strong position to capture the benefits of agtech as new agricultural developments can incorporate the technologies at establishment stage rather than retrofitting technologies into existing systems. Research on farming system design that incorporate emerging agtech is needed to provide growers/investors with strategies for developing Agriculture 4.0 systems. One component of this activity is demonstration of available technologies and applied research to optimise technologies in the farming systems as well as generating ROI and productivity/sustainability gain data. This approach has been successfully implemented in the Bundaberg region by CQU through the Hinkler AgTech Initiative. The approach included detailed grower needs assessment and building of new technology connections and knowledge capability within established and trusted industry networks.

The proposed work in Project 4.1 will establish a process for identifying and assessing the agtech products and services with highest potential to benefit emerging cropping industries in northern Australia. Where information from other industries using the technologies is available, case studies of the technologies will be generated. Unbiased, independent assessment of emerging agtech products is crucial for rapid adoption of technologies by industry, and the documented assessments of technologies potentially applicable to northern Australian cropping systems will facilitate the initial awareness and interest generation phase of the adoption process. Outputs generated through this project will feed into Project 4.3 where evaluation trials by growers of technologies they feel are most applicable to their cropping investments will be assessed.

Methodology

Phase 1: A list of commercially available (and late-stage commercialisation) technologies that are potentially applicable to northern Australian cropping systems will be compiled. The project team will undertake a technical evaluation of technology applicability (evidence of strengths and weaknesses of the technologies) and farming system integration compatibility (how well does the technology fit with other elements of the production system). A ‘potential future technologies’ list

will also be generated through a review of the literature and will cover technologies that are not yet commercially available or likely to soon be available but could be game changers if the technology ideas translate into viable commercial products.

Phase 2: A format and methodology for documenting unbiased, independent evidence of agtech product performance and value for end-users will be generated. Research to identify key information needs for growers will be undertaken to inform development of the methodology. This process will be used to generate case studies for technologies identified in phase 1 that have been used commercially and/or independently evaluated in Australia. These case studies will include available evidence of product complexity, compatibility within production systems, trialability, flexibility for modifications to suit specific farm needs, technical support requirements, and return on investment calculations where sufficient data are available.

Phase 3: Information generated in phases 1 and 2 will be presented to growers in the lower Fitzroy node (and potentially in other nodes if of value to projects being delivered in the Ord, Daly - Katherine or Gilbert regions). This will facilitate design of technology evaluation trials by growers engaged in Project 4.3 (and potentially projects in other nodes).

The overarching goal of Project 4.1 is to identify the potential for new agricultural technology to transform the opportunities and prospects for agriculture in northern Australia

Key outputs

Output		Outcomes
5	Phase 1: Report listing commercially available agtech for Nth Aust cropping systems, and emerging tech prospects.	Awareness of technologies raised in Rookwood node, prompting interest in potential of agtech in emerging cropping systems.
6	Phase 2: Method and format for case study generation documented, with a minimum of 5 case studies documented.	Increased grower confidence to engage in trialling of agtech products.
7	Phase 3: Grower presentation in Rookwood node.	Increased grower confidence to engage in trialling of agtech products.

University / researcher involvement

CQU – Phil Brown; Researchers - CQU is recruiting a new Associate Professor/Professor in Crop Science and it is anticipated that this person will contribute to the project. CDU is recruiting a Professor of Cropping who may also be engaged in the project if activity in the Ord/Daly is incorporated.

Research priority – Fitzroy project 4.2			
Primary Node	Lower Fitzroy River catchment		
Project Name	Optimising water quality monitoring		
Work package	2 – Water quality and the environment		
Project Lead Institution	CQU (with input and close alignment with JCU-led project 1.1 and CDU-led project 3.2)		
Project Leader	Nicole Flint		
Start date	Apr 2023	**Finish date**	Mar 2026

Project description

As part of the Australian Government's approval conditions for the Lower Fitzroy River Infrastructure Project (the Rookwood Weir Project), Sunwater are required to develop a staged Water Quality Monitoring Program for the Project. Condition 1b of the approval specifies that the Program must be capable of predicting potential, and detecting actual, impacts from the action on the Great Barrier Reef World Heritage Area and National Heritage place that may result from changes in nutrient concentrations and oxygen levels due to decaying vegetation (i.e., the effects of impoundment), and agricultural development facilitated by the action (i.e., the effects of land use changes resulting from water sales). During the current construction phase of the project, regular monitoring is being undertaken at 12 sites above, below and within the weir site, and a large number of parameters (about 250) are being tested, including pesticides (>150), metal(loid)s, nutrients and physicochemical parameters.

Given the size of the catchment, the sampling sites are relatively distant from each other and from the regional city of Rockhampton. The long travel times to sites and the quantity of laboratory analysis required for the parameters that are required to be monitored result in high monitoring costs, at approximately $3,000 per site per event. With multiple sites and regular sampling required over a long time period once the weir construction is complete, the overall monitoring costs will be very high. For example, if ongoing monitoring is required at 10 sites, a monthly sampling program would cost $360,000 per year, while monthly sampling at 30 sites would cost $1.3M per year. These costs will ultimately be passed through to growers as a part of water user charges.

In addition to the cost of regular monitoring requirements, a major challenge is to determine the sampling regime required during high flow events. High flow events are particularly relevant in terms of water quality impacts on the Great Barrier Reef, so are of high importance to the regulator. However, high flow events are difficult and costly to monitor: for illustration a ten-day flow event conducted at five sites, sampled 12 hourly, would add another $300,000 to the monitoring costs. Higher monitoring costs pass through to higher charges for irrigation water and reduce commercial viability. In addition, there are logistical, and health and safety issues associated with manual water sampling during flood events in large rivers like the Fitzroy. This is a potential problem across northern Australia where high flow events are common.

Some options to streamline monitoring programs include incorporating continuous monitors and automatic samplers into the monitoring program, to better target pesticides (and other toxicants) for testing based on farm records or land use management plans, or to use modelling approaches to extrapolate for data gaps. This project will investigate these and other options, to identify the risks, costs and benefits of various sampling regimes.

Methodology

The aim of project 4.2 is to identify the potential for more targeted water quality sampling options that reduce logistical challenges and costs, while maintaining an appropriately rigorous monitoring program. The project will be conducted in four phases, as follows.

Phase 1: Assessing issues and risks – discussion and consultation with stakeholders to define issues, desktop review of monitoring options, statistical analysis of Rookwood's baseline and construction monitoring data to inform monitoring requirements, risk assessment of monitoring program options, ongoing coordination between requirements in projects 1.1 and 3.2.

Phase 2: Testing alternative field monitoring options – field trials of monitoring options in the Fitzroy River, e.g., in situ loggers, automated samplers, passive samplers (metal(loid)s and pesticides). Analysis of results in comparison to standard monitoring regime (consultants using hand-held instruments and collecting water samples for analysis).

Phase 3: Optimising management of monitoring programs – access information on pesticide use via individual land use management plans (Sunwater), irrigator groups, Queensland Government agencies (note the potential to link with project 3.2). Collate information on other monitoring programs in the area where data could be shared to reduce duplication (consult with DES, FBA, regulated industries). Investigate modelling approaches to fill data gaps.

Phase 4: Cost benefit analysis of monitoring options – develop options for monitoring programs, calculate costs and benefits of each option and provide recommendations for Rookwood. The CBA and recommendations are likely to also be relevant to other northern Australian rivers.

Key outputs

Output	Outcomes
1. Phase 1: summary of results of consultation and desktop reviews/analyses	List of issues experienced by stakeholders. List of monitoring options Statistical analysis of monitoring data. Risk assessment of monitoring options.
2. Phases 2 and 3: report on results of field trials and duplication analysis.	Demonstration of effectiveness of alternative monitoring options. Results of duplication analysis.
3. Phase 4: Cost benefit analysis and final report.	Cost benefit analysis. Recommendations on monitoring program options.

University / researcher involvement

CQU - Nicole Flint; John Rolfe; Senior research officer

There are strong synergies between this project and projects 1.1 in the Gilbert and 3.2 in the Ord, so we expect to build a team with CDU and JCU involvement that overlaps between the projects.

Partnering organisations

Expect to have discussions with key stakeholders including Sunwater, Queensland Department of Environment and Science, and Queensland Department of Regional Development, Manufacturing and Water in early 2023.

Research priority – Fitzroy project 4.3			
Primary Node	Lower Fitzroy River catchment		
Project Name	Prospects for specialty crops		
Work Package	4 – Cropping systems and new crops		
Project Lead Institution	CQU (with close alignment with CDU-led projects 3.3 and 2.4)		
Project Leader	Phil Brown / Suyra Bhattarai		
Start date	Apr 2023	**Finish date**	Mar 2026

Project description

Completion of the Rookwood Weir will create new opportunities for irrigated cropping in the Lower Fitzroy region. New crops that have traditionally not been part of the dryland cropping and grazing systems in the region will become viable. These would include broadacre pulse and grain crops as well as annual and perennial horticulture crops. While suitability of prospective crops to soil and environmental conditions can be inferred from studies in other regions, the decision by farmers to transition to new crops is strongly influenced by locally generated crop performance data. This includes crop economic data, crop performance data (eg pest and disease susceptibility), and compatibility of the crop management with other components of the farming system. On-farm crop performance trials and qualitative data from growers on farming system decision making processes will support the transition to higher value farming systems that utilise new irrigation infrastructure.

There may be particular locational advantages in trialling pulse crops (high current demand and growing interest in plant protein crops, low fertilizer/pesticide requirements, potential to supply as forage source into the feedlot industry). Existing relationships CQU has with plant breeding companies and the crop processing sector will facilitate access to pulse and grain crop germplasm that the suppliers are enthusiastic to promote in northern Australia. The potential for biofuels will also be examined, because of potential linkages to renewable energy sectors at Gladstone.

The research will compile existing information of potential cropping options and will incorporate social science research to gain an understanding of current farming strategies, and motivations and barriers to developing new farming systems and practices. This research will inform farming system design planning; identifying prospective opportunities for new crop types, production practices for those crops (including potential for new technologies), and integration of these new elements into current production system components. Research trials evaluating new crops, new technologies and new production systems will be conducted with participating growers to build confidence for broader adoption of these innovations.

Methodology

Phase 1: A mixed methods social science research (i.e., a combination of interviews, workshops and questionnaires, with the exact approach to be developed within the project) will be used to gain a deeper understanding farming systems and practices in the catchment. The goal of the research is to generate an in depth understanding of current farming strategies, and farmer perceptions of the opportunities and barriers to adoption of new crops and cropping practices. Consultation with growers will also contribute to design of new crop trials and trials of relevant ag tech advances. Coordination between this project and projects 3.3 and 2.4 will allow a more

comprehensive, publishable data set to be generated on grower perceptions of new crop opportunities.

Phase 2: Based on the outcomes of phase 1, and engagement with stakeholders involved in supply of crop germplasm, a series of initial small plot crop evaluation trials will be conducted. Incorporation of crop evaluation trial data into crop performance models (using APSIM) will allow simulation of crop performance over a broader range of sites, environments and production systems.

Phase 3: Technology (determined using project 4.1 information) and farming systems trials will be conducted with participating growers, concurrently with phase 2 crop trials. Ground truthing of technologies and both qualitative and quantitative data generation for assessment of benefits and weaknesses of technologies and systems will be undertaken. This data will add to existing technology case studies generated in Project 4.1 and allow new case studies to be documented where no existing data were previously accessible.

Phase 4: Grower-led demonstrations of new cropping options, technologies and production system components will be supported. This phase will be a combination of extension activities, designed to assist farmers to make decisions on adoption of new crops, technologies and farming systems, and trial evaluation research to add to the volume of data on new crop and technology performance.

The overarching goal of project 4.3 is to identify the potential for specialty and higher value crops and cropping systems and technologies to be to be introduced that will generate greater economic benefits to the region(s)

Key outputs

Output	Outcomes
1. Report and publication on grower perceptions of new crop, technology and farming system opportunities	Strong grower input and engagement in design of new crop and technology trials
2. Crop models developed for selected new crops	Simulation of new crop performance to assist in grower decision making on crop adoption
3. Case studies of applicable agtech products documented	Increased grower confidence to engage in trialling of agtech products.
4. Grower-led demonstrations of new crop, technology and farming system performance	Increased grower confidence to engage in trialling of new crops, cropping systems and agtech products

University / researcher involvement

CQU – Phil Brown; Suyra Bhattarai; Researchers - CQU is recruiting a new Associate Professor/Professor in Crop Science and it is anticipated that this person will contribute to the project. CDU is recruiting a Professor of Cropping who may also be engaged in the project if activity in the Ord/Daly is incorporated.

JCU AgTAC Centre researchers – Yvette Everingham

Research priority – Fitzroy project 4.4	
Primary Node	Lower Fitzroy River catchment
Project Name	Model the upstream and downstream supply chain needs and identify how synergies can create efficiencies
Work package	5 – Supply chains and alternative economies
Project Lead Institution	CQU (with close alignment with CQU-led project 4.3)
Project Leader	Delwar Akbar / John Rolfe
Start date	Apr 2023 to Mar 2026

Project description

Input needs can be limiting for major developments, particularly when high costs are involved. Examples of key inputs include equipment, fuel, labour, electricity and fertiliser, all of which have been exposed to shortages or higher prices in recent years. These effects are rarely predicted at a scheme or precinct level because the issues of procurement and supply rest with a number of smaller agents. However, if bottlenecks do exist, they will reduce viability and create perverse incentives to focus on low value crops that have smaller risks.

The project would combine direct engagement and modelling to build a prediction tool for key supply chain requirements. To avoid undue complexity it would focus on predicting needs for key inputs by certain crops, so that changes in water allocations or crop mixes will generate changes in input requirements. The framework can then be used to extrapolate to potential solutions, such as the housing and training needs of new labour force estimates, or total fertiliser requirements at a precinct or district level.

A strength of the framework is that it can also be used to model indirect outputs, such as greenhouse emissions or nutrient emissions. Then the effects of solutions such changes in crop mix, moves to renewables or biofuels, or changes in farm management can be estimated. Of particular interest are options that create synergies within a precinct, such as the use of feedlot waste for fertiliser into cropping, The predictive framework will be able to capture the changes in inputs and outputs generated by these synergies and provide some estimates of the efficiency benefits generated.

The model can be parameterised from existing irrigation operations, such as in the lower Fitzroy and the Ord. The aim will be to develop a predictive tool that can be relevant to all irrigation precincts.

Methodology

Phase 1: The first phase of the project will be to build a production model at the precinct level. We will draw on production models for different crop types to parameterise it, and constrain the model by relevant limits (e.g. available water). The model will essentially allow different mixes of crops / production types to be entered up to the limit relevant to the precinct, and the resulting input requirements (e.g. energy, labour, land, fertiliser) can then be estimated, as well as the outputs (e.g. production, by products, wastes).

Phase 2: The second phase of the project will focus on one of the input (upstream supply) variables for detailed analysis, identifying how supplies might be available over time under the different scenarios. We expect to focus on labour requirements and supply strategies for this phase.

Phase 3: The third phase of the project will focus on one of the output (downstream supply) variables for detailed analysis, identifying how fodder production and by products might be used in the feedlot sector, focusing on how to optimise production under different scenarios.

Phase 4: A key benefit of developing a precinct model is that it will identify wider input and output streams relevant to emerging issues. Three areas of particular focus are of interest: new energy requirements (and potential substitution with green energy sources), net greenhouse emissions from the precinct development, and potential pesticide use under different crop mixes (the latter will be a key input into the design of water monitoring programs).

Key outputs

Output	Outcomes
1. Phase 1: Precinct supply chain model	Development of a precinct production system model that demonstrates linkages to upstream and downstream supply chain elements under varying scenarios
2. Phase 2: Upstream supply chain – labour	In depth analysis of labour input requirements under different production scenarios and how they might be addressed
3. Phase 3: Downstream supply chain – feedlots	In depth analysis of circular and downstream supply chain issues focusing on feedlots
4. Phase 4: Intersection with emerging pressures	Analysis of the energy requirements, greenhouse emissions, fertiliser and herbicide uses under different scenarios

University / researcher involvement

CQU - Delwar Akbar; John Rolfe; Research staff

There are strong synergies between this project and projects 3.3 in the Ord, 2.4 in the Daly and 1.3 in the Gilbert, so we expect to build a team with CDU and JCU involvement that overlaps between the projects.

Partnering organisations

We have had preliminary discussions with Queensland DAF, Advance Rockhampton and Mort and Co on the research topic and will now work with them to identify their potential involvement.