Australia's National Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

Review of potential environmental impacts of shale gas related wastewater disposal options

Long Project Title	Review of potential environmental impacts of shale gas related wastewater disposal options
GISERA Project Number	W.39
Start Date	2 June 2025
End Date	31 March 2026
Project Leader	Cameron Huddlestone-Holmes

GISERA State/Territory

- ☐ Queensland
- ☐ New South Wales
- ☒ **Northern Territory**
- ☐ South Australia
- ☐ Western Australia
- ☐ Victoria
- ☐ National scale project

Basin(s)

- ☐ Adavale
- ☐ Amadeus
- ☒ **Beetaloo**
- ☐ Canning
- ☐ Carnarvon
- ☐ Clarence-Morton
- ☐ Cooper
- ☐ Eromanga
- ☐ Galilee
- ☐ Gippsland
- ☐ Gloucester
- ☐ Gunnedah
- ☐ Maryborough
- ☒ **McArthur**
- ☐ North Bowen
- ☐ Otway
- ☐ Perth
- ☐ South Nicholson
- ☐ Surat
- ☐ Other (please specify)

GISERA Research Program

- ☒ **Water Research**
- ☐ Health Research
- ☐ Biodiversity Research
- ☐ Social & Economic Research
- ☐ Greenhouse Gas Research
- ☐ Agriculture Research
- ☐ Land and Infrastructure Management Research
- ☐ Other (please specify)

1. Project Summary

A component of shale gas development is the production of wastewater, primarily from used drilling fluids and flowback from hydraulic fracturing activities. How this wastewater is managed, with a particular focus on potential environmental impacts, is an issue that continues to be of concern to communities in the Beetaloo region of the Northern Territory (NT).

CSIRO's GISERA project, *Developing a wastewater lifecycle management framework for onshore gas in the Northern Territory* (Kumar et al., 2023), developed a high-level framework to evaluate the environmental, social and economic aspects of a range of wastewater management approaches. The project was constrained by the limited data available from the industry's exploration and appraisal activities and focused on a multi-criteria analysis of wastewater treatment options. The wastewater management options that were identified can be broadly categorised as those that treat or concentrate wastewater. While some of these methods produce a treated water stream for recycling, they all result in waste material that requires disposal. The multi-criteria analysis did not place an emphasis on the ultimate disposal of residual wastewater or the waste materials that result from wastewater treatment.

This project will assess wastewater management and treatment options, including associated waste disposal requirements, and their potential for environmental harm. The project's focus will be on wastewater derived from drilling, hydraulic fracturing and flowback activities associated with shale gas development. Wastewater from other industries will also be considered to provide additional context.

A significant component of this project will look at approaches to reduce the volume of wastewater and waste to be managed. These approaches include reuse of untreated residual drilling, hydraulic fracturing and flowback fluids in shale gas activities. The project will place an emphasis on evaluating the potential impacts of the reinjection of wastewater into deep formations (which was not considered by Kumar et al (2023)). Wastewater reinjection, though widely used in other jurisdictions is prohibited in the Northern Territory in response to a recommendation from the Independent Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory. This recommendation was based on the uncertainty around potential impacts and indicated that wastewater reinjection may be permitted if the risks could be managed.

This assessment will be based on a review of wastewater management and treatment options used in other jurisdictions in Australia and internationally, considering how these options may be applied in the context of the Beetaloo Sub-basin. The ultimate disposal of residual wastewater or the waste materials that result from wastewater treatment will be included in the assessment. The results of this project will be a comparison of the relative potential environmental impacts of the options considered, how those impacts are mitigated elsewhere, along with the level uncertainty. This information may be used to inform the community, industry and regulators about future approaches to wastewater management from shale gas development.

2. Project Description

Introduction

An aspect of shale gas developments is the use and production of water. Shale gas and oil developments use water primarily for drilling and hydraulic fracturing. The amount of water used varies, depending on local conditions, but is in the order of 20 to 40 ML per well (Geological and Bioregional Assessments Program, 2021a). After drilling and hydraulic fracturing operations are completed, wastewater will remain that needs to be disposed of.

The potential environmental impacts of wastewater, including during treatment and disposal of residual waste, continues to be one of the main concerns held by communities regarding development of shale gas resources. The ultimate disposal of residual wastewater, or other waste material that remains after wastewater is treated, is an important issue to the community.

The main sources of wastewater are drilling fluids, flowback water and produced water:

- **Drilling fluids** are made up of water and various additives and are designed to provide lubrication and cooling to the drill bit, remove drill cuttings from the well, and provide hole stability and well control during drilling[1]. At the end of drilling operations, a quantity of remaining fluid will contain a mixture of drill cuttings (solid material), formation water and residual drilling fluid. The volume of wastewater generated during drilling is in the order of 1 to 2 ML per well.

- **Flowback fluid** is defined in the *Petroleum (Environment) Regulations 2016 (NT)* as "fluid that is a mixture of hydraulic fracturing fluid and formation fluid that is allowed to flow from the well following hydraulic fracturing." Flowback fluid is water containing the chemical additives used in the hydraulic fracturing fluid and their breakdown products along with water and chemicals from the formations that were hydraulically fractured. The final composition and volumes of flowback fluid are highly dependent on site-specific conditions, such as the geology of the target formation.

- **Produced water** is defined *in the Petroleum (Environment) Regulations 2016 (NT)* as "naturally occurring water that is extracted from the geological formation following hydraulic fracturing." Production from conventional hydrocarbon resources also results in produced water due to the hydrocarbon extraction process. Produced water by its nature reflects the geology of the target formation.

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[1] Non-water based drilling fluids can also be used in shale wells. Management of these fluids and any waste stream produced will require specific treatment and disposal options are outside the scope of this project.

The exact quantities and qualities of flowback water and produced water likely to be generated for shale gas development in the NT is highly uncertain, and dependent on local geology and methods employed in extraction. Cook et al. (2013) estimated that between 25 to 75% of the volume injected during hydraulic fracturing returns to surface as flowback fluid (10 to 30 ML, assuming 40 ML injected) but may only yield produced water volumes in the order of a few 100's of thousands of litres per year (Cook et al., 2013; Geological and Bioregional Assessments Program, 2021a; Huddlestone-Holmes et al., 2017).

The overall approach to industrial wastewater management in the NT follows a waste management hierarchy, which is enacted through section 27 of the *Environment Protection Act 2019* (NT). The hierarchy applied to wastewater, in order of priority, requires:

- elimination or substitution of an activity that results in wastewater;
- decreasing the amount of wastewater produced as part of a process or activity;
- re-use of wastewater for the same or alternative activity without treatment, or with minimal treatment;
- beneficial re-use of wastewater for another purpose without treatment, or with minimal treatment;
- recycling of wastewater through treatment to improve water quality;
- treatment of wastewater to make the quality suitable for disposal; and
- disposal of wastewater (and any other residual waste) in an environmentally sound manner.

The global shale gas industry, and upstream petroleum sector more broadly, actively manages wastewater by applying this hierarchy. The amount of wastewater produced through shale gas development can be decreased through wellfield optimisation and design of hydraulic fracturing activities. There is a growing trend to re-use flowback water with minimal to no treatment in subsequent hydraulic fracturing activities, which can substantially reduce water use and wastewater production (Feder, 2020; Rassenfoss, 2011). Wastewater treatment technologies are well established that can produce a stream of treated water suitable for re-cycling, beneficial use by other industries or release to the environment. These treatment technologies also produce a small volume of concentrated waste that requires disposal. The final disposal options[2] for wastewater or any residual waste include reinjection into deep formations, burial in landfills on site, or transport to an off-site waste management facility (Geological and Bioregional Assessments Program, 2021a; US Environmental Protection Agency, 2016).

These options all have trade-offs in terms of their technical performance, economics, environmental performance and social acceptability. The environmental performance is a key factor for the

[2] Some of these options are not permitted for hydraulic fracturing wastewater in the Northern Territory.

community and is an important contributor to social acceptance. The potential environmental impacts of wastewater management, treatment and disposal options are primarily related to contamination of the environment and will depend on the specific nature of an activity and its location. The most likely pathways for contamination are through unintended events, such as a spill from a truck transporting waste, or a release from a tank holding wastewater, or failure of the containment of a land fill (Huddlestone-Holmes et al., 2021). Other potential environmental impacts include wildlife interaction with wastewater in storage ponds, and provision of artificial water sources for wildlife and invasive species. Regulations require that control measures be implemented to mitigate against these potential impacts.

When considering options for managing wastewater and reducing potential environmental impacts, it is important to consider the full life cycle of water use, including how much wastewater is generated (including avoidance of wastewater through re-use), how the wastewater is treated or managed (including for re-use and recycling), and the volumes and quality of residual wastewater and other wastes that will need disposal.

Wastewater reinjection

Flowback and produced water are often reinjected at depth as a disposal method in other countries and regions. The Council of Canadian Academies (2014) cites that the optimum practice in the oil and gas industry in North America for the disposal of wastewater is to inject it underground. The formations that are targeted for waste fluid injection are often depleted oil and gas reservoirs or saline aquifers because of their ability to accommodate large volumes of fluid. This method is used in other jurisdictions in Australia, including South Australia and Queensland (Geological and Bioregional Assessments Program, 2021b). The Independent Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory (Pepper Inquiry, Pepper et al., 2018) considered wastewater reinjection and the panel concluded that they were unable to assess the risk of seismic activity or aquifer contamination that could be caused by this practice due to the uncertainty around potential impacts. Based on that assessment, they made the following recommendation:

> ***Recommendation 7.9***
>
> *That prior to the grant of any further exploration approvals, the reinjection of wastewater into deep aquifers and conventional reservoirs and the reinjection of treated or untreated wastewaters (including brines) into aquifers be prohibited, unless full scientific investigations determine that all risks associated with these practices can be mitigated.*

Wastewater reinjection was prohibited through amendments to the *Water Act 1992* that were made in 2019. As a result, studies like Kumar et al (2023) and the Geological and Bioregional Assessments considered wastewater reinjection to be out of scope. The Pepper Inquiry did recognize the prevalence of wastewater reinjection in other jurisdictions. Recommendation 7.9 would allow wastewater reinjection to be permitted if it can be shown that all risks associated with these practices can be mitigated. This project will include wastewater reinjection as a disposal option.

Prior Research

CSIRO's GISERA project, *Developing a wastewater life cycle management framework for onshore gas in the Northern Territory* (Kumar et al., 2023), developed a high level framework to evaluate the environmental, social and economic aspects of a range of wastewater management approaches. To develop the framework, Kumar et al (2023) compiled information on water use and wastewater development in shale gas developments, the regulatory context in the Northern Territory, wastewater treatment practices being used during the exploration phase in the Beetaloo region, along with wastewater treatment technologies being used or developed globally. A set of Key Performance Indicators were developed around environmental, operational, social licence and economic aspects and these were applied to a wastewater treatment options analysis.

For the environmental aspects, Kumar et al (2023) compiled a high set of indictors to compare different treatment options. However, their assessment did not consider how residual waste streams from these treatment approaches would be managed, except to note that the current practice at this stage of development in the Beetaloo Region is to transport the waste off site (and in some instances to waste disposal facilities in Queensland). The broad scope of the project also limited their ability to look at wastewater minimisation through re-use of flowback water in subsequent hydraulic fracturing activities, and the resulting implications for potential environmental impacts. Nor were they able to examine the logistical, operational and infrastructure implications of various options. For example, technologies that are modular can be employed at a well pad whereas technologies that require a central plant require gathering line to move the wastewater to the plant – this creates different potential impact pathways. Wastewater reinjection, widely used in other jurisdictions in Australia and internationally, was not considered.

Potential environmental impacts

There is a significant body of literature around the potential environmental impacts of shale gas development, including the impacts relating to wastewater management. A thorough review of this literature is a component of this project, however some key studies include:

- a review of the environmental impacts of shale gas conducted by the Council of Canadian Academies, (Council of Canadian Academies, 2014);
- a review of unconventional gas development conducted by the Australian Council of Learned Academies (Cook et al., 2013);

- a comprehensive US Environmental Protection Agency review titled "Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States" (US Environmental Protection Agency, 2016);
- a review of the potential impacts of shale gas and oil development in Queensland (Huddlestone-Holmes et al., 2017);
- The Independent Scientific Inquiry into Hydraulic Fracturing of Onshore Unconventional Reservoirs in the Northern Territory (Pepper et al., 2018); and
- the Geological and Bioregional Assessment (GBA) program's assessment of potential environmental impacts in the Beetaloo region (Huddlestone-Holmes et al., 2021).

These studies identified a number of potential environmental impacts associated with wastewater from shale gas extraction. The majority of these are related to the potential for accidental spills during the storage, handling, treatment and disposal of wastewater at the surface. The studies have identified that controls can be put in place to mitigate these risks, although there are some rare instances where localised impacts have been observed.

The GBA assessment for the Beetaloo region was based on an understanding of potential impacts elsewhere, the characteristics of the study area, the regulations in the Northern Territory and current industry practices. This assessment found that accidental release of wastewater at the surface was of potential concern and that the risks could be mitigated if current regulations were complied with. As discussed above, the GBA assessment did not consider wastewater reinjection.

Wastewater reinjection and potential environmental impacts

Wastewater reinjection is a common practice in many jurisdictions in Australia and internationally, with over 90% of flowback and produced waters disposed of in this way in the United States (US Environmental Protection Agency, 2016). Treated wastewater from Coal Seam Gas activities is reinjected in Queensland, with Origin injecting over 400 ML of treated water a month into the Great Artesian Basin (OGIA, 2024). Wastewater from conventional petroleum extraction is also reinjected in the Cooper Basin (Holland et al., 2021). CSIRO's GISERA has conducted several projects on reinjection of treated water into aquifers in Queensland, covering geochemical effects (Prommer et al., 2016) and management of clogging (Torkzaban et al., 2015).

The Pepper Inquiry identified two broad areas of risk related to the reinjection of wastewater into deep aquifers or conventional reservoirs (Pepper et al., 2018). The first are the risks related to contamination of aquifers and surface water and the second is the risk of induced seismicity.

There is comparatively little literature on aquifer contamination risks associated with wastewater reinjection. Any risks will be related to unintended release or flow of the injected wastewater into aquifers other than the intended target. This could occur as a result of well integrity issues in the wells used for reinjection, or as a result of flow between aquifers. The Geological and Bioregional

Assessments program considered these pathways in the assessment for the Cooper Basin (Holland et al., 2021) and found them to be of low concern.

The potential for induced seismicity impacts related to shale gas and oil projects is well covered in the scientific and engineering literature for North America, and the mechanisms for these potential impacts will be the same in the Northern Territory. Induced seismicity directly related to hydraulic fracturing is likely to have very low intensity at the surface and not cause any impact. However, reinjection of wastewater at a large scale has been associated in more intense seismic events (Rubinstein & Mahani, 2015).

The injection of wastewater fluids into the subsurface can change stress conditions, primarily by changing pore pressure thereby reducing confining pressure, which may lead to movement along critically stressed faults if they are present. Ellsworth (2013) found that an increase in the number of earthquakes in the mid-continental US in 2011 and 2012 may have been triggered by nearby wastewater injection wells, although the number of events is small when considering that there are over 30,000 wastewater injection wells in the US. However, the local geological conditions are an important factor in determining whether induced seismicity may occur (Langenbruch & Zoback, 2016).

The role of local geology is highlighted by the fact that induced seismicity impacts have been observed in some but not all wastewater disposal regions in the United States (Langenbruch & Zoback, 2016; Petersen et al., 2017). There are a number of studies that investigate the geological factors that might make a region more susceptible to induced seismicity (Atkinson & Geiss, 2017; Eaton & Schultz, 2018; Hu et al., 2018; Kao et al., 2018; Langenbruch et al., 2018; Pawley et al., 2018; Schultz et al., 2020; Schultz et al., 2016). The increased understanding of the role of geological factors has allowed for the development of mitigation measures, such as avoiding areas with faults, managing injection rates and monitoring.

The final report of the Pepper Inquiry points out aspects that need further investigation. These include understanding the likelihood of seismic activity in response to wastewater reinjection (section 7.6.4 of Pepper et al., 2018) and understanding the quantity and quality of wastewater to be reinjected, the composition of target aquifers, connectivity between aquifers and long term impacts on aquifers (section 7.6.4 of Pepper et al., 2018).

The soon to be completed CSIRO GISERA project "*Quantification of background seismicity of Beetaloo Sub-basin, NT and physics based estimation of seismic hazard*[3]" will provide information on background seismicity within the Beetaloo region and will be directly relevant to understanding the potential for induced seismicity in the region. Work conducted through the Geological and Bioregional Assessments Program and the Strategic Regional Environmental and Baseline Assessment (SREBA)[4]

[3] https://gisera.csiro.au/research/land-and-infrastructure/background-seismicity-in-the-beetaloo-sub-basin/

[4] https://environment.nt.gov.au/onshore-gas/sreba

for the Beetaloo Sub-basin provide data and an understanding of potential impacts that can be built upon for this project

Need & Scope

The potential environmental impacts associated with the management of wastewater from shale gas activities in the Northern Territory has been highlighted as an important issue for various stakeholders. While there have been previous studies that have considered wastewater management options at a high level, there is still uncertainty about the relative risk posed by the various approaches to life cycle management of water, wastewater, treatment and disposal options in the Beetaloo and surrounding regions. Previous studies have not considered wastewater reinjection. Nor have there been studies to compare wastewater management from shale gas with the approaches used in other industries.

This project will provide further information on the strengths and weaknesses of water and wastewater management options (including wastewater reinjection) for the shale gas industry in the Northern Territory that may be used by decision makers to inform policy choices.

Objectives

The aims of this study are to:

- develop a set of scenarios for the management of water and wastewater associated with shale gas development in the Beetaloo region. These scenarios will document plausible life cycle wastewater management and treatment options (including logistical, operational and infrastructure implications) and determine the likely quantity and quality of wastewater and any residual waste that will require disposal;

- review the current literature on the environmental risks associated with wastewater reinjection; and

- assess the potential environmental impacts of these scenarios, and how these impacts can be mitigated, using a common framework to allow these impacts to be compared.

The project will also consider waste and wastewater management for other industries in the Northern Territory to identify possible synergies.

Methodology

This project will conduct a desktop appraisal of life cycle shale gas wastewater management, treatment and disposal options and their potential environmental impacts in the Beetaloo and surrounding regions in the Northern Territory. This work will build on the wastewater management framework developed by Kumar et al (2023) and the impact assessment carried out in the GBA program. The project team will engage with stakeholders to identify key issues.

Task 1: Scenario development and impact assessment scoping

The first task for this project will be to develop plausible scenarios for life cycle shale gas water use, wastewater management, treatment and disposal in the Beetaloo region. As the industry is still in its early stages of development in the Northern Territory, there is a high degree of uncertainty on a range of aspects of the water cycle. The scenarios and their characteristics are necessary inputs into Task 2's assessment of potential environmental impacts and to constrain this uncertainty. Clearly documenting the scenarios and the assumptions used in their development will provide important context for the results of this project. The justification for excluding technologies or management options from the scenarios will also be documented for transparency, along with the circumstances that may make them viable.

The following characteristics will be captured for each scenario:

- the original source of water and its quality,
- how the water is used, the likely volumes required, and composition of used water,
- how water may be re-used at the scale of a well pad, and implications for volumes and composition of used water,
- how water may be re-used between well pads,
- water treatment options, considering:
    - whether they are small scale, modular or large-scale centralised facilities,
    - whether they produce a stream of high-quality treated water for re-cycling or discharge,
    - whether they reduce volume of wastewater only (such as evaporation),
    - the volume and characteristics of residual waste,
- logistical, operational and infrastructure implications, considering:
    - storage requirements for different components of the water cycle,
    - handling requirements (such as whether water or wastewater would need to be moved between well pads),
    - energy and land use requirements,
- residual waste and wastewater disposal requirements, considering:

- the quantity and quality of wastewater and other residual waste,
- off-site transport and disposal, and
- reinjection of wastewater.

The major components of the water cycle for a shale gas development are shown in Figure 1. This diagram is not intended to cover all possible scenarios but does show the complex interactions that need to be considered when looking at various options. The quantity and quality of water moving along each arrow will depend on the wastewater management, treatment and disposal options being evaluated. For example, if drilling fluid and flowback fluid are re-used, the volume of water requiring treatment would be reduced. If evaporation is used to treat wastewater, then no treated water will be produced.

The focus for the scenarios will be on the overall wastewater lifecycle rather than the specifics of any particular technology. For example, there are a number of water treatment technologies that produce a treated water stream that can be recycled along with a waste stream, such as reverse osmosis or multi-effect distillation. Other approaches (such as evaporation) reduce the volume of wastewater and only have a waste stream. The treatment technologies are less important for this project than the quantity and quality of the waste streams that will ultimately require disposal. The characteristics of the waste streams will be important when evaluating the potential environmental impacts of waste disposal options.

This task will also update the review of water and wastewater management methods and technologies conducted by Kumar et al (2023). A scan of waste and wastewater management for other industries in the Northern Territory will also be conducted as part of this task. The aim will be to identify similar wastewater or waste streams to identify possible synergies with the shale gas sector.

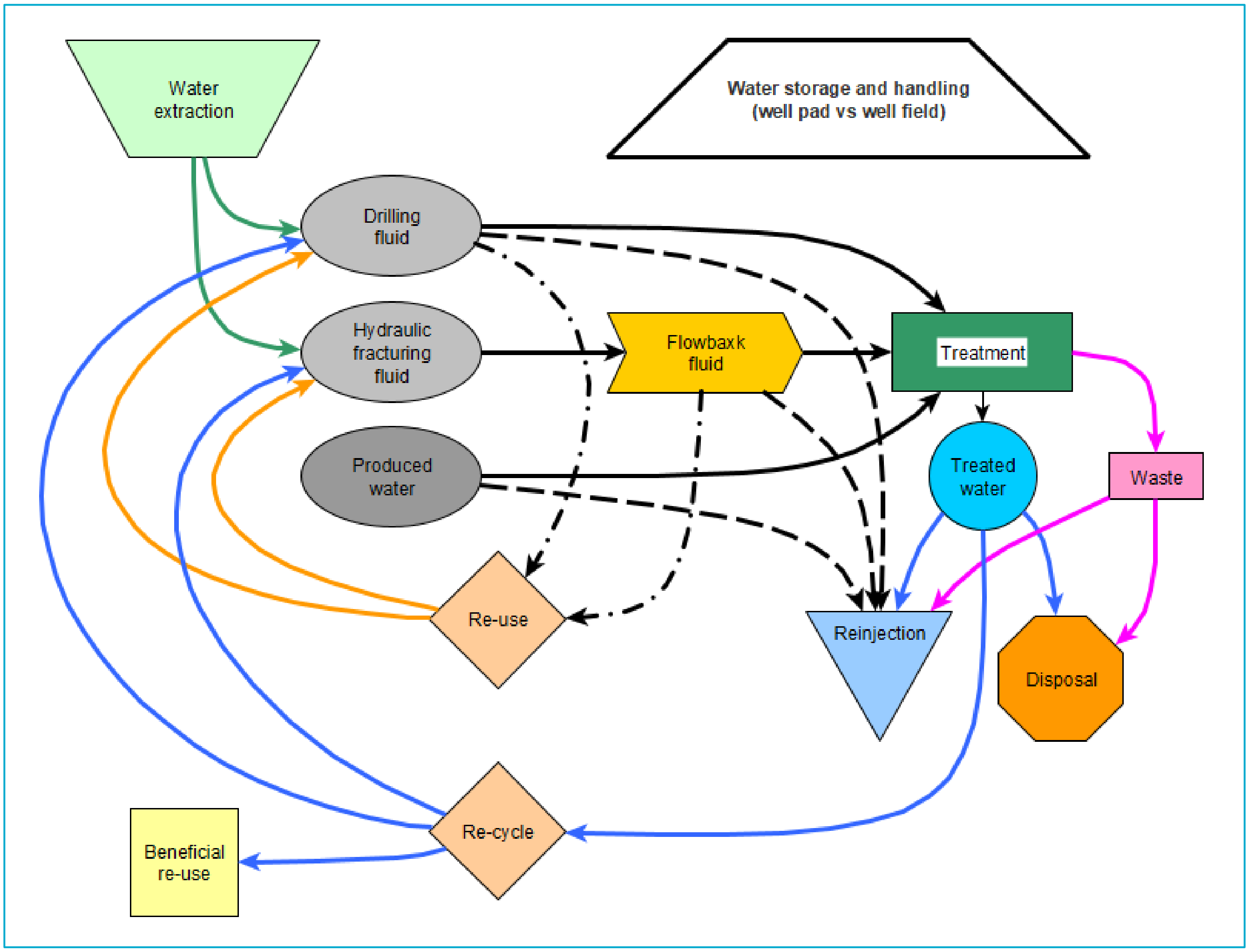

Figure 1: A schematic of the water cycle for a shale gas development showing potential flows of water and wastewater (indicated by arrows).

These scenarios will be refined through consultation with the project's Technical Reference Group (TRG) before being presented to a workshop of key stakeholders for refinement and endorsement. The TRG will be consulted to identify participants in the workshop, who are likely to include representatives from industry, the Northern Territory Government (Petroleum Operations Division, Department of Mining and Energy; Petroleum Regulation and Water Resources Divisions, Department of Lands, Planning and Environment), along with researchers from CSIRO.

The workshop will also be used to refine the scope of the assessment of potential environmental impacts of the wastewater management scenarios. This input will be important in making sure that the project delivers results that are of the most benefit to stakeholders.

Task 2: Assessment of potential environmental impacts

Task 2 will investigate the potential environmental impacts for the scenarios identified in Task 1. This assessment will look at the overall system for each scenario, in a similar way to the method used in the GBA stage assessments. Using a consistent framework to look at the overall potential impacts of the scenarios is important for allowing them to be compared. Figure 2 shows the causal network starting at the waste and wastewater management node. The GBA program assessed the potential impacts from wastewater management. GBA did not consider wastewater reinjection, however it did identify pathways for impact from general surface activities for waste and wastewater management. The GBA causal network will inform the assessment for this project, however, the methodology is too generalised for the purposes of this project and only allows for the assessment of a single scenario. Instead, the project will adopt a method that allows for a comparison of the different scenarios.

While this assessment will consider potential environmental impacts across the whole lifecycle for each scenario, the emphasis is likely to be on the options for final disposal of waste material. Other potential impacts are related to surface activities (infrastructure for wastewater handling of treatment) and these impacts are similar to other surface activities. Wastewater and waste disposal is a unique aspect of wastewater management. Ultimately, the scope of the assessment will be guided by input from the workshop conducted as part of Task 1.

A significant component of Task 2 will be a review of the potential environmental impacts due to wastewater reinjection, including induced seismicity and contamination of aquifers, based on international literature and experience in other jurisdictions. These potential impacts will be assessed in the context of the Beetaloo region and the scenarios involving wastewater reinjection developed in Task 1. A key outcome will be identifying where there is sufficient information to assess the identified impact pathways and where knowledge gaps exist. Available operational, monitoring and mitigation options to manage the identified impacts used in other jurisdictions will be considered.

Task 3: Final reporting

This task will involve the preparation of a final report that presents the results of Tasks 1 and 2. The outcomes of Task 2 will be discussed with the Technical Reference Group to ensure a broad range of perspectives have been considered. An emphasis of the final report will be to set out the criteria that can be used when comparing life cycle water and wastewater management options in regard to their environmental performance. Mitigation options to manage potential environmental impacts will be presented. Any knowledge gaps will be highlighted along with suggestions for future research.

Task 4: Communicate project objectives, progress and findings to stakeholders

Communication of project aims and results to broader stakeholder groups will take place via fact sheets, news articles, and presentations including a Knowledge Transfer session, with support from the GISERA Communication and Engagement Team.

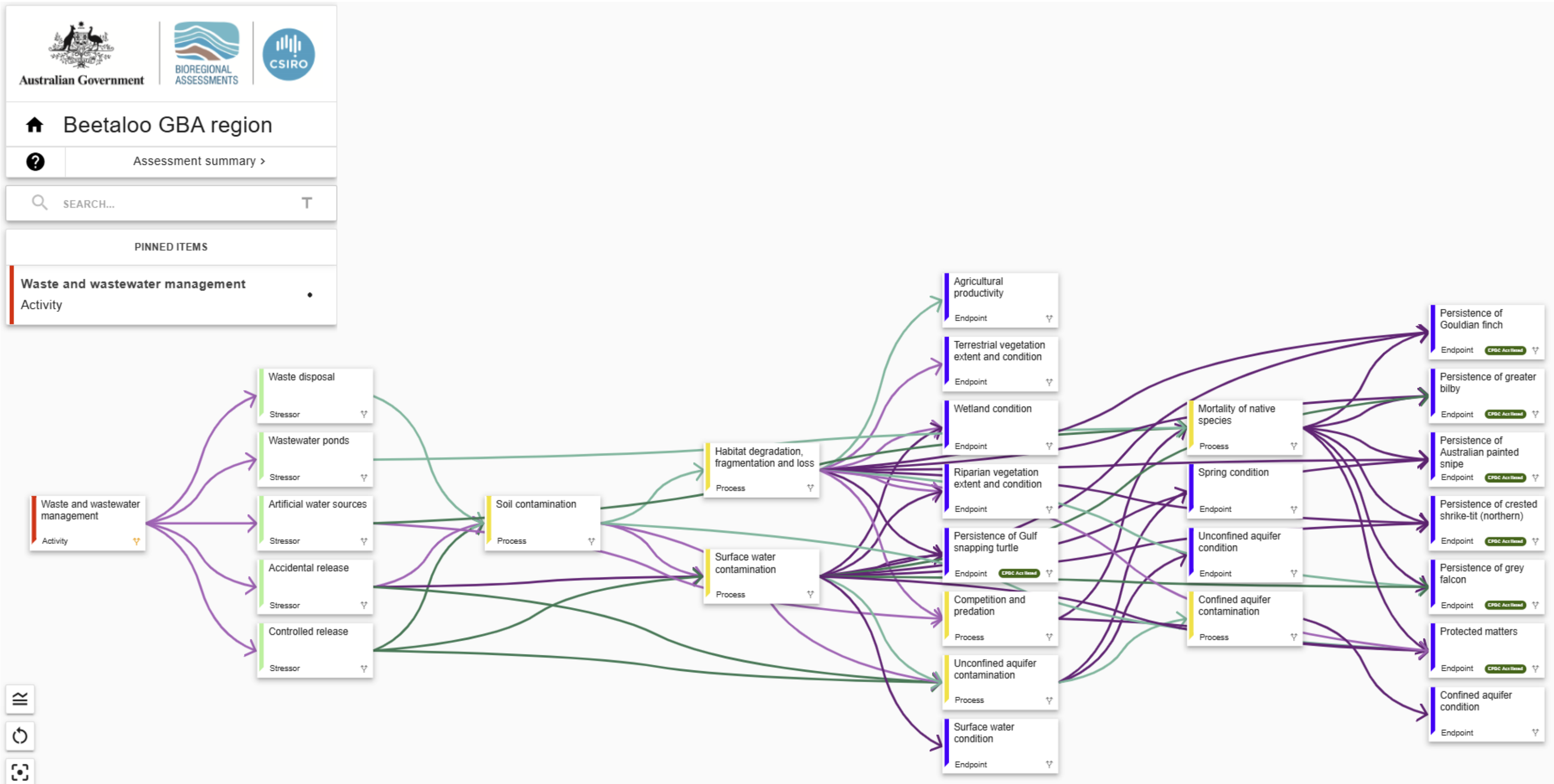

Figure 2: Extract from the GBA causal network for the Beetaloo GBA region showing the pathways identified for waste and wastewater management. This causal network will provide a starting point for this project's assessment of potential impacts. The scenarios will create a more detailed set of activities (the red node at the left) for the assessment.

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Cameron Huddlestone-Holmes	67 days	Geologist and impact assessment	+25 years	CSIRO
Jason Czapla	36 days	Mechanical/Petroleum Engineer	+20 years	CSIRO
Matthias Raiber	36 days	Hydrogeologist	+20 years	CSIRO

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Nil				

Technical Reference Group

The project will establish a Technical Reference Group (TRG) aimed at seeking peer-to-peer technical advice on contextual matters and to discuss research needs as well as outputs as the project progresses. The TRG will include the project leader and relevant stakeholders, including:

- Regulators: *Petroleum Operations, Department of Mining and Energy; Petroleum Regulation and Water Resources Divisions, Department of Lands, Planning and Environment*
- Company representatives: *Santos. Tamboran and Empire Energy*
- Technical expertise (from CSIRO, other research institutions, industry, consultants)

The TRG will be formed and will hold its first meeting within a month of the commencement of this project. The Terms of Reference for the TRG will be established at the first meeting.

Budget Summary

Source of Cash Contributions	2024/25	2025/26	2026/27	% of Contribution	Total
GISERA	$8,471	$252,739	$0	80%	$261,210
- NT Government	$3,298	$98,402	$0	31.15%	$101,700
- Santos	$3,298	$98,402	$0	31.15%	$101,700
- Tamboran	$1,408	$42,006	$0	13.3%	$43,414
- Empire	$467	$13,929	$0	4.4%	$14,396
Total Cash Contributions	**$8,471**	**$252,739**	**$0**	**80%**	**$261,210**

Source of In-Kind Contribution	2024/25	2025/26	2026/27	% of Contribution	Total
CSIRO	$2,118	$63,185	$0	20%	$65,303
Total In-Kind Contribution	**$2,118**	**$63,185**	**$0**	**20%**	**$65,303**

TOTAL PROJECT BUDGET	2024/25	2025/26	2026/27	-	TOTAL
All contributions	**$10,589**	**$315,924**	**$0**	-	**$326,513**
TOTAL PROJECT BUDGET	**$10,589**	**$315,924**	**$0**	**-**	**$326,513**

4. Communications Plan

Stakeholder	Objective	Channel (e.g. meetings/media/factsheets)	Timeframe (Before, during at completion)
Regional community stakeholders including landholders, traditional owners and wider public	To communicate project objectives, and key messages and findings from the research	A fact sheet at commencement of the project that explains in plain English, the objectives of the project.	At project commencement
		Project progress reported on the GISERA website to ensure transparency for all stakeholders including regional communities.	Ongoing
		Public release of final reports. Plain English fact sheet summarising the outcomes of the research.	At project completion
		Preparation of an article for the GISERA newsletter and other media outlets as advised by GISERA's communication team.	At project completion
Gas Industry & Government	To communicate the objectives and outcomes of the project.	Fact sheet that explains the objectives of the project.	At project commencement
		Project progress reporting (on GISERA website).	Ongoing
		Final project report. Plain English fact sheet summarizing the outcomes of the research.	At project completion
		Presentation of findings at joint gas industry/government Knowledge Transfer Session.	At project completion
		Peer-reviewed scientific publication.	After completion of project

In addition to project specific communications activities, CSIRO's GISERA has a broader communications strategy. This strategy incorporates activities such as webinars, presentations, attendance at regional shows, newsletters and development of other communication products where relevant.

5. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
Update of the review of current water treatment technologies presented in Kumar et al (2023). Development of scenarios for the water life cycle in shale gas and the resulting wastewater and other waste management requirements. Assessment of potential environmental impacts from wastewater management based on scenarios developed.	Technical report including an overview of available wastewater treatment option, a set of scenarios for the shale gas water life cycle, and an assessment of the potential environmental impacts of the scenarios. The report will include an assessment of the potential impacts of wastewater reinjection. Facts sheets about the project and its results for the broader community.	Improved knowledge of the water life cycle in shale gas and the resulting wastewater and other waste management requirements. Improved knowledge of potential environmental impacts of wastewater reinjection and how these impacts may be mitigated. Improved knowledge of potential environmental impacts and how they compare between different wastewater management approaches and scenarios.	The results of this project will inform Governments, regulators & policy-makers on issues regarding wastewater management for the gas industry. The information will provide information that can improve community's awareness about the economic potential environmental impacts wastewater management from onshore gas development. The results will provide a method that can be used by industry to evaluate the environmental performance of wastewater management.	*Long term environmental* Government, regulators and industry able to provide better governance of wastewater management to improve overall environmental performance. *Long term social* Increased community knowledge and confidence in shale gas wastewater management options in the NT. *Long term economic* Wastewater management approaches that are appropriate to the level of risk.

6. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Scenario development and impact assessment scoping	Cameron Huddlestone-Holmes	2 June 2025	30 August 2025	
Task 2	Assessment of potential impacts and uncertainties	Cameron Huddlestone-Holmes	1 September 2025	31 October 2025	Task 1
Task 3	Project reporting	Cameron Huddlestone-Holmes	1 October 2025	28 February 2026	Task 2
Task 4	Communicate project objectives, progress and findings to stakeholders	Cameron Huddlestone-Holmes	Full duration of project		

Task description

Task 1: Scenario development and impact assessment scoping

OVERALL TIMEFRAME: 3 months (2 June 2025 to 31 August 2025)

BACKGROUND: To evaluate the potential environmental impacts of shale gas wastewater management it is important to first understand the water management and treatment options that are available. Water and wastewater management can be complex with a range of approaches available. Previous assessments have tended to focus on specific technologies and have oversimplified the overall water and wastewater management systems. Development of a set of scenarios that consider overall approaches to water and wastewater management that consider the waste management hierarchy. These scenarios will form the basis for the assessment of environmental impacts.

TASK OBJECTIVES: This task will develop scenarios for life cycle shale gas water use, wastewater management, treatment and disposal in the Beetaloo region. To get a broad range of perspectives on the scenarios, the project will engage with stakeholders from the regulator, industry, and technical experts through a workshop. The workshop will endorse the scenarios to be taken through to Task 2 and provide input into the scope of the assessment of potential environmental impacts. A scan of recent literature on wastewater management for shale gas (building on the work conducted by Kumar et al 2023) and waste and wastewater management practices in other industries in the Northern Territory will be conducted as part of this task.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Technical Reference Group established and terms of reference agreed. Workshop with key stakeholders. Scenarios for water and wastewater management from shale gas, identifying key characteristics for each scenario. Scope for the assessment of potential environmental impacts of the scenario. These outputs will be used in Task 2 and will be incorporated into the project's final report.

Task 2: Assessment of potential impacts and uncertainties

OVERALL TIMEFRAME: 2 months (1 September 2025 to 31 October 2025)

BACKGROUND: The potential environmental impacts of wastewater, including during treatment and disposal of residual waste continues to be one of the main concerns held by communities regarding development of shale gas resources. The ultimate disposal of residual wastewater, or other waste material that remains after wastewater is treated, is an important aspect to the community. Assessing the potential impacts of water and wastewater management from shale gas requires the life cycle of water use to be considered and the potential impacts will vary depending on the options chosen. Comparing the potential impacts of the different scenarios will allow the potential strengths and weaknesses of the scenarios to be considered. The potential environmental impacts of wastewater reinjection will be a focus area for this task. Other impact pathways will be drawn from existing studies, including the Geological and Bioregional Assessments.

TASK OBJECTIVES: The objectives of this task are to:

1) Establish the framework to assess the potential environmental impacts of the scenarios identified. This framework will be informed by the GBA Causal Network for the Beetaloo GBA region.
2) Review of the potential environmental impacts from wastewater reinjection.
3) Assess the potential environmental impacts of the scenarios for the management of water and wastewater from shale gas identified in Task 1.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: An assessment of the potential environmental impacts of the scenarios for the management of water and wastewater from shale gas. The results of this assessment will be incorporated into the final report.

Task 3: Project Reporting

OVERALL TIMEFRAME: 2 months (1 October 2025 to February 2026)

BACKGROUND: The final report for this project will collate the outputs from Tasks 1 and 2, and compare the strengths and weaknesses of the options that have been assessed. The report will also include a section on wastewater reinjection and how it is used in other jurisdictions, the potential environmental impacts and the mitigation measures that are used. Any knowledge gaps will be highlighted along with suggestions for future research.

TASK OBJECTIVES: Synthesize the outputs of tasks 1 and 2.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: A final report bringing together the outputs from all tasks.

Task 4: Communicate project objectives, progress and findings to stakeholders

OVERALL TIMEFRAME: Full duration of project (2 June 2025 – 31 March 2026)

BACKGROUND: Communication of GISERA's research is an important component of all research projects. The dissemination of project objectives, key findings and deliverables to relevant and diverse audiences allows discourse and decision making within and across multiple stakeholder groups.

TASK OBJECTIVES: Communicate project objectives, progress and findings to stakeholders through meetings, Knowledge Transfer Session, fact sheets, project reports and journal article/s, in collaboration with the GISERA Communication Team.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Communication of project objectives, progress and results to GISERA stakeholders according to standard GISERA project procedures which may include, but is not limited to:

1) Knowledge Transfer Session with relevant government/gas industry representatives.

2) Preparation of an article for the GISERA newsletter and other media outlets as advised by GISERA’s communication team.
3) Two project fact sheets: one developed at the commencement of the project, and another that will include peer-reviewed results and implications at completion of the project. Both will be hosted on the GISERA website.
4) Peer-reviewed scientific manuscript ready for submission to relevant journal.

Project Gantt Chart

Task	Task description	24-25	2025-26								
		Jun 25	Jul 25	Aug 25	Sep 25	Oct 25	Nov 25	Dec 25	Jan 26	Feb 26	Mar 26
1.	Scenario development and impact assessment scoping	■	■	■							
1.	Technical Reference Group established	◆									
2.	Assessment of potential impacts and uncertainties				■	■					
3.	Project reporting					■	■	■	■	■	
4.	Communicate project objectives, progress and findings to stakeholders	■	■	■	■	■	■	■	■	■	■

7. Budget Summary

Expenditure	2024/25	2025/26	2026/27	Total
Labour	$10,589	$287,424	$0	$298,013
Operating	$0	$28,500	$0	$28,500
Subcontractors	$0	$0	$0	$0
Total Expenditure	**$10,589**	**$315,924**	**$0**	**$326,513**

Expenditure per task	2024/25	2025/26	2026/27	Total
Task 1	$10,589	$70,051	$0	$80,640
Task 2	$0	$124,342	$0	$124,342
Task 3	$0	$100,913	$0	$100,913
Task 4	$0	$20,618	$0	$20,618
Total Expenditure	**$10,589**	**$315,924**	**$0**	**$326,513**

Source of Cash Contributions	2024/25	2025/26	2026/27	Total
NT Government (31.15%)	$3,298	$98,402	$0	$101,700
Santos (31.15%)	$3,298	$98,402	$0	$101,700
Tamboran (13.3%)	$1,408	$42,006	$0	$43,414
Empire (4.4%)	$467	$13,929	$0	$14,396
Total Cash Contributions	**$8,471**	**$252,739**	**$0**	**$261,210**

In-Kind Contributions	2024/25	2025/26	2026/27	Total
CSIRO (20%)	$2,118	$63,185	$0	$65,303
Total In-Kind Contributions	**$2,118**	**$63,185**	**$0**	**$65,303**

	Total funding over all years	Percentage of Total Budget
NT Government investment	$101,700	31.15%
Santos investment	$101,700	31.15%
Tamboran investment	$43,414	13.3%
Empire investment	$14,396	4.4%
CSIRO investment	$65,303	20%
Total Expenditure	**$326,513**	**100%**

Task	Milestone Number	Milestone Description	Funded by	Start Date	Delivery Date	Fiscal Year Completed	Payment $ (excluding CSIRO contribution)
Task 1	1.1	Scenario development and impact assessment scoping	GISERA	Jun-25	Aug-25	2025/26	$64,512
Task 2	2.1	Assessment of potential impacts and uncertainties	GISERA	Sep-25	Oct-25	2025/26	$99,474
Task 3	3.1	Project reporting	GISERA	Oct-25	Feb-26	2025/26	$80,730
Task 4	4.1	Communicate project objectives, progress and findings to stakeholders	GISERA	Jun-25	Mar-26	2025/26	$16,494

8. Intellectual Property and Confidentiality

Background IP (clause 11.1, 11.2)	**Party**	**Description of Background IP**	**Restrictions on use (if any)**	**Value**
				$
				$
Ownership of Non-Derivative IP (clause 12.3)	CSIRO			
Confidentiality of Project Results (clause 15.6)	Project Results are not confidential.			
Additional Commercialisation requirements (clause 13.1)	Not Applicable			
Distribution of Commercialisation Income (clause 13.4)	Not Applicable			
Commercialisation Interest (clause 13.1)	**Party**		**Commercialisation Interest**	
	CSIRO		N/A	
	Santos		N/A	
	Tamboran		N/A	
	Empire Energy		N/A	

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