Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

Key controls or contributors to methane emissions from CSG water holding ponds

Long Project Title	Addressing knowledge gaps on key controls or contributors to methane emissions from CSG water holding ponds in the Surat Basin, Queensland
GISERA Project Number	G.10
Start Date	01/09/2023
End Date	31/07/2025
Project Leader	Se Gong

GISERA State/Territory

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

Basin(s)

- ☐ Adavale
- ☐ Amadeus
- ☐ Beetaloo
- ☐ Canning
- ☐ Western Australia
- ☐ 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**
- ☐ Agricultural Land Management Research
- ☐ Land and Infrastructure Management Research
- ☐ Other (please specify)

1. Project Summary

The CSIRO GISERA phase 1 project 'Methane contributions from CSG water holding ponds' a desktop-based study of emissions from CSG holding ponds in Queensland, revealed that not only had few ponds been measured in terms of their emissions in Queensland, but there were significant knowledge gaps about key factors that contribute to, or control methane emissions from such ponds. Without this knowledge it will be very difficult to reduce uncertainties associated with the flux of methane from CSG water holding ponds of various types.

This project will provide data to contribute to our understanding of CSG water holding ponds as sources of methane emissions. The data will focus on the role that methane generating and eating microbes, algae, brine and sediment play in the methane emission contributions of water holding ponds. Such data will assist in understanding the potential of the CSG industry to contribute to emissions in the Surat Basin/Western Downs region of Queensland.

Improved understanding of methane emissions from CSG water holding ponds is important as multiple, independent reviews have demonstrated that emissions and the environment are a major issue of concern to community, government, and industry (e.g., Lloyd et al., 2013). Furthermore, this and similar studies have indicated that an improved scientific understanding of the scale of the industry's potential methane emissions (and effective communication of this scientific knowledge) will improve community comprehension of the risks and value of natural gas in the energy transition (Bec et al., 2016; Walton and McCrea 2020). Important questions that this work will seek to resolve include:

> *Can methane from CSG water holding ponds be mitigated by methanotrophs (microbes eating methane) in these ponds?*
>
> *Do algae contribute to emissions by mobilising geological carbon from bicarbonates?*
>
> *Are brine ponds possible sources of emissions and, if so, by how much?*
>
> *What is the nature of the sediments, especially coal particulates which could be a huge carbon source for methane, that are held in CSG water holding ponds?*

This project is one of two phase 2 projects developed from the outcomes of GISERA phase 1 project - a desktop study on 'Methane contributions from CSG water holding ponds'. The other phase 2 project seeks to directly measure methane flux from representative CSG water holding ponds.

2. Project description

Introduction

Small waterbodies, whether they are natural or constructed (e.g., garden or municipal ponds), disproportionately contribute to greenhouse gas emissions (Holgerson and Raymond, 2016; Grinham et al., 2018). In these waterbodies, microbes break down complex carbon-containing compounds to smaller compounds and, in air-less environments (called anoxic zones) these smaller carbon compounds accumulate as methane in a process called 'methanogenesis', literally making methane. There are numerous physical, chemical and biological reasons why small ponds contribute disproportionately in terms of emissions, these topics are covered in detail in the GISERA phase 1 project report - 'Methane contributions from CSG water holding ponds' (Gong et al., in progress).

CSG holding ponds, including produced water ponds and brine ponds, are no exception to this behavior, as most likely fall into the category of 'small' being mostly less than 10 ha in size. There are, however, some reasons (elevated nutrients, readily accessible carbon sources) to believe that emissions from these ponds may be greater than small natural waterbodies and indeed, the few measures that have been undertaken from produced water ponds to date indicate that this is true (Day et al., 2016; Kelly et al., 2022).

Methane that is produced in the anoxic zone escapes and makes its way through the water column to the atmosphere either as a bubble (in a process called ebullition) or as methane dissolved in the water. While this escaping methane is held in the water column, there is an opportunity for this carbon to be captured by an opposed process called methanotrophy (methane-eating). This balance of methanogens and methanotrophs in the waterbodies is critical for understanding methane emissions in such environments. In some instances, methanotrophic microbes can virtually eliminate methane emissions from waterbodies. Thus, understanding these factors is critical in developing a model for how holding ponds function in terms of their emissions.

It is worth briefly commenting on brine ponds as they may appear to be sites at which no emissions occur, though in truth there is no data on emissions from brine ponds and some reason to believe that emissions may be greater than zero in brines. Firstly, the process of creating the brine increases the concentration of nitrogen, phosphorus and carbon, key nutrients for biological activities including methanogenesis. It is very likely that the extreme concentration of salt in the brine limits microbial diversity (we expect many fewer species in brines, only those tolerant of high salt concentrations, these are called halophiles, literally *salt-loving*). Limited diversity does not necessarily indicate low microbial activity. Indeed, some extreme environments are microbially active, it is simply that microbial diversity is low. Further, there are numerous halophilic methanogenic species (most are methylotrophic), though whether these occur in brines will be established in the present study. Data presented here will be the first set of data available on the microbiology of these brines and will indicate whether methanotrophic or methanogenic species occur in these water bodies.

This study will seek to examine:

1) **Methanogenic and methanotrophic microbial communities in CSG water holding ponds**
   - Microbes in the waterbodies are the key factor in methane flux being involved in both generation and consumption of methane.
   - No data to date has demonstrated the presence of either methane producing or methane consuming microbes in CSG holding ponds due to (a) very limited studies and (b) methods that necessarily exclude such species (e.g., culture on agar).
   - Brine ponds, another type of CSG water holding pond, account for nearly half of the CSG holding ponds in Queensland but no information on their microbiology that would suggest, or rule-out methane activity is indicated.

2) **Pools of carbon available in CSG water holding ponds**
   - In CSG holding ponds, there are different pools of carbon available for microbes involved in methane production or consumption, at present such pools are very poorly characterised.
   - Existing water chemistry data are limited to the water itself, and do not measure particulates which have settled to the bottom and are almost certainly the major source of organic carbon in CSG water holding ponds. Further, no information is available regarding the forms of carbon in these particles, their size, surface area or colonisation by microbes. All of which are important for understand their potential to be converted into emissions.

3) **The ability of algae to make the largely inaccessible inorganic carbon pool (bicarbonate) biologically available.**
   - Literature shows that bicarbonate can be used as a carbon source for microalgae (e.g., Kim et al., 2019).
   - This project will characterise algal communities of CSG water holding ponds and determine their ability to move previously inaccessible bicarbonate to organic carbon.

By filling these knowledge gaps, the project will provide a better understanding of how carbon pools are mobilized by various microbes and algae in CSG water holding ponds to generate methane emissions. This knowledge can contribute to further mitigation strategy to reduce methane emissions from CSG water holding ponds. Further, the project will provide more insights to community, government, and industry on why and how methane emissions are generated from CSG water holding ponds and their potential environmental impacts for the region.

Prior research

The CSIRO GISERA phase 1 project 'Methane contributions from CSG water holding ponds', was a desktop-based study designed to evaluate the available data and our current understanding of methane emissions from CSG water holding ponds in Queensland. This study revealed that not only had few ponds been measured in terms of their emissions, but there were significant knowledge gaps about key factors that contribute to, or control methane emissions from such ponds. Direct measurement aside, the GISERA phase 1 project desktop study concluded that information on key mechanisms that control, or contribute to, methane emissions from CSG water holding ponds are lacking. Specifically:

- No data exist on methanogenic and methanotrophic microbial communities in CSG water holding ponds. Microbial communities both contribute to emissions by making methane (a process called methanogenesis; literally, *methane-making*) from carbon pools in the ponds and mitigate emissions by removing methane produced in the ponds through a process called methanotrophy (*methane-eating*). Methane measurements from CSG water holding ponds (produced water ponds) in NSW (Day et al., 2016) and Queensland (Kelly et al., 2022) indicated the presence of methanogens (microbes producing methane) in CSG water holding ponds (produced water ponds), but there are no published data in Australia about the microbial communities of either the water or the sediment in such CSG holding ponds. As to brine ponds, it is even unknown whether methane emissions exist or not, let alone the microbial communities in the brine ponds. Those microbial data that do exist are of microbes that have been isolated from the ponds using nutrients in agar medium (e.g., Bos, 2021). To date there are about ~15 isolates that have been obtained from these ponds. For the non-microbiologist it is worth explaining that the majority of microbes are recalcitrant to isolation on agar, and those microbes detected here tend to be microbes that we know grow well on agar, rather than microbes involved in carbon-cycling (either methane production or consumption in the ponds). While these isolates have value for understanding the biology of these specific organisms, they are not helpful in understanding carbon fluxes in the ponds. As there are no data available in Australia, these would be the first set of data of their kind and would assist in determining where methane is produced in CSG water holding ponds and whether it is likely to be mitigated through methanotrophy.
- It is common practice for the gas industry to measure some of the carbon pools in the pond water or brine. Measured fractions tend to be total and dissolved organic carbon (which are pools of undefined carbon compounds) and various tests such as total recovery hydrocarbons (TRH as bulk of C6-C40 hydrocarbons; NICNAS, 2017) or compounds of specific environmental interest such as PAHs (polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylene and xylene) compounds (Orem et al., 2007; 2014). The carbon pools in CSG water holding ponds are, however, likely significantly more complex and, in general, are likely to be underestimated due to

the reliance on testing water as opposed to the sediment in these ponds. There has not been detailed characterisation of different organic compounds in the produced water or brine in CSG water holding ponds yet beyond direct measurement of the 'total' or 'dissolved' carbon pools, or total recoverable hydrocarbons.

- While CSG industry has methods to remove larger particulate material, e.g., coal fines, some small coal particles still make their way into holding ponds. There are no data on the physicochemistry (carbon content, surface area, ease of degradation) of these particles or their ability to serve as carbon sources for methanogenesis. The carbon content, surface area, colonisation and abundance of these particles is likely key to understanding the potential for methane generation in these holding ponds. Similarly, an understanding of the water-soluble hydrocarbons and solvent extractable hydrocarbons of the total carbon pool is important for understanding which compounds in these mixtures may contribute to methane emissions. These data are also currently lacking, and this study will provide the first set of data of this type in Australia.

- Microalgae growing in ponds may be able to use geological carbon (bicarbonate) in CSG water holding ponds and through this process, increase methane emissions. Most of the focus in research related to algae and CSG wastewater has been the use of wastewater to grow algae and this area has been the subject of some modest research both in Australia and overseas (Buchanan et al., 2013; Hamawand et al., 2014; Sullivan Graham et al., 2017; Alsufyani, 2022). Studies show that some submerged aquatic plants, such as macroalgae, microalgae and cyanobacteria, which live in water environment, can use bicarbonate as an alternative source of dissolved inorganic carbon for photosynthesis due to limiting of carbon dioxide with the low diffusivity in water (Fernanez et al., 2014; Wu et al., 2021). So far, however, there is no research on how algae in CSG water holding ponds may move previously inaccessible carbon from geological bicarbonate to organic carbon pools and thus potentially increase emissions.

Need & Scope

Work in GISERA phase 1 project 'Methane contributions from CSG water holding ponds' demonstrated that substantial knowledge gaps exist that would allow an understanding of contributors to, and controls on, methane emissions from CSG water holding ponds. This is important as numerous surveys of the local community demonstrate that emissions are an issue of significant importance to community and data from this study will, for the first time, provide data that addresses some key concerns: are microbes present in CSG holding ponds to make methane from various carbon pools? How much carbon present in the sediments of CSG holding ponds that may be able to fuel emissions? Does the water column in these ponds include microbes that may be able to mitigate the methane emissions produced in pond sediments? Do algae contribute to emissions through mobilisation of geological carbon?

Understanding these key concerns will provide better understanding of the whole lifecycle of methane emissions from CSG water holding ponds, which will subsequently assist to find ways to mitigate (reduce) the emissions from such environment. Australia's pledge to the methane reduction target means we absolutely need to better quantify and mitigate emissions from all sources. This is also an expectation of the community.

Two (phase 2) projects are resulted from the GISERA phase 1 project 'Methane contributions from CSG water holding ponds' desktop study with one focussed on filling knowledge gaps identified in original project so we can better understand how methane emissions are generated from CSG water holding ponds and their controls and contributors and the other project extensively conducting direct measurements of methane emissions from number of CSG water holding ponds in the Surat Basin to provide accurate quantum for regional methane budget accounting.

Objective

The GISERA phase 1 project 'Methane contributions from CSG water holding ponds' desktop study - revealed that not only had few ponds been measured in terms of their emissions, but there were significant knowledge gaps about key factors that contribute to, or control on methane emissions from CSG water holding ponds. Hence, two studies are proposed to cover the limitations and knowledge gaps from this desktop study. This phase 2 study aims to fill knowledge gaps in controls and contributors to methane emissions from CSG water holding ponds through a detailed study of a water holding pond and a brine pond. The other parallel phase 2 study focuses on direct measurement of emissions from a number of selected CSG water holding ponds in the Surat Basin so as to provide accurate emissions data for estimating the overall emissions from CSG water holding ponds in Queensland and providing accurate emissions for regional methane budget accounting.

In brief this project seeks to:

1) **understand methane-producing and methane-consuming microbial communities in produced water holding ponds and (if they occur there) brine ponds.**

This objective will provide key data on the microbes, particularly methanogens and methanotrophs, that occur in these ponds and their contributions to methane flux.

2) **understand different forms of carbon pools that are present in CSG water holding ponds**

Detailed water-soluble organic compounds in either water column or sediments require LC-MS (liquid chromatograph-mass spectrometry) technique to identify these compounds, while GC-MS (gas chromatograph-mass spectrometry) technique can characterise solvent extractable organic compounds in water and sediments in CSG water holding ponds. Another carbon pool in the sediments will entail a study of ultra-fine coal particulates in the sediments of CSG water holding ponds by looking at their size, distribution, abundance and (microbial) colonisation. This objective will provide *data on how readily accessible these different carbon pools are to being degraded and mobilised as emissions.*

3) **understand whether algae may play a role in mobilising geological carbon as methane**

For this work we will identify the kinds of algae present in the ponds using a molecular biology approach and using a growth experiment, determine their impact on geological, inorganic carbon (i.e., bicarbonate) concentrations.

4) **Communicate identified knowledge gaps (from GISERA phase 1 project 'Methane contributions from CSG water holding ponds') to local government and community stakeholders, and the methods for addressing these knowledge gaps, and outcomes of this study at two workshops to be held in 2024, and 2025 in Chinchilla (held in conjunction with the other phase 2 project workshops).**

Methodology

Sampling logistics and field campaign planning (Task 1)

Consultation with representatives from CSG companies will guide the pond selection (a produced water pond and a brine pond) of the study and provide insights on accessibility and required permissions for the selected ponds. Pond selection will also be undertaken in coordination with the other GISERA phase 2 project 'Methane emissions from CSG water holding ponds in Queensland' which focuses on direct measurement of methane emissions from CSG holding ponds. Detailed sampling requirement on samples and sampling equipment/reagents will be determined in Task 1. Task 1 will also include the safe and environmentally sensitive planning, provisioning, and logistics for the sampling campaign.

Field sampling trip (Task 2)

Collection of samples will involve two staff travelling to Queensland to collect all project samples, including those for water chemistry, microbial profiling of communities, algal characterisation, identification of different carbon pools, sediment-carbon characterisation (Task 2). Collection of water samples from CSG water holding ponds will be conducted systematically at both the surface, middle and bottom of the ponds.

Sample and data analyses (Task 3)

- *Methanogen and methanotroph community profiling*

The microbial and algal communities from the water and sediment samples collected from the selected CSG water holding ponds will be determined by DNA extraction followed by next-generation sequencing examining the 16S or 18S regions. These analyses will provide the first set of microbial and algal community data from CSG water holding ponds.

- *Identification of different carbon pools in CSG holding ponds*

Total organic carbon, dissolved organic carbon and total inorganic carbon of collected water and sediment samples are to be determined through a NATA accredited laboratory. TRH, PAHs, VOCs (volatile organic compounds), BTEX, volatile organic acids and phenols in collected water and sediment are to be determined through a NATA accredited laboratory. Detailed water-soluble organic compounds in water and sediment samples are to be determined by LC-MS technique through an external laboratory. Detailed solvent extractable organic compounds in water and sediment samples are to be determined by solvent extraction followed by GC-MS analysis (Task 3)

- *Sediment characterization*

Minerals of the sediment samples are to be identified by XRD (X-ray diffraction) technique. SEM (scanning electron microscopy) imaging provides information on biofilm in the sediment and also information on how coal particles bonded with other minerals which will assist to determine the separation of coal with other minerals. Surface area and particle size distribution of the collected sediment samples and coal fractions, if successfully separated, will be determined by Brunauer-Emmett-Teller and laser diffraction, respectively, through an external laboratory (Task 3).

- *Bioavailability of inorganic carbon by algae*

A growth experiment will be set up to investigate whether inorganic carbon (bicarbonate) can be converted to biologically accessible carbon (Task 3).

Communication and engagement with stakeholders (Tasks 4 & 6)

In addition to the initial stakeholder consultation (with CSG companies) to guide the selection of two CSG ponds for the study, the project will undertake two workshops in Chinchilla (held in conjunction with the other phase 2 project workshops) to inform and engage local government and community stakeholders throughout the project. The first workshop will be conducted at the early stages of the project to communicate knowledge gaps identified from the phase 1 project and this phase 2 project’s aims, scope, methods, timing and expected outcomes. The second workshop will be conducted at the end of the project to communicate project outcomes.

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Se Gong	90 days	Geochemistry	+16 years	CSIRO
Carla Mariani	32 days	Organic Chemistry/Microbiology	+5 years	CSIRO
Tania Vergara	10 days	Chemistry and biomolecular	+12 years	CSIRO
Stephen Sestak	2 days	Analytical chemistry and engineering	+25 years	CSIRO
David Midgley	34 days	Microbial ecology, bioinformatics	+16 years	CSIRO
Nai Tran-Dinh	25 days	Microbiology	+20 years	CSIRO
Mihaela Grigore	18 days	Material Science	+20 years	CSIRO
Nicholas Lupton	3 days	Reservoir Engineering	+14 years	CSIRO

Subcontractors (clause 9.5(a)(i))	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
ALS	1-2 weeks turnaround on receipt of samples.	Testing water chemistry	Many. Commercial laboratory.	ALS. NATA accredited laboratory.
Sequencing service provider	6-8 weeks turnaround on receipt of samples	DNA sequencing, microbial and algal communities	Many. Commercial DNA sequencing facility	Molecular Research DNA Laboratories, Texas, USA

Technical Reference Group

The project will establish a Technical Reference Group (TRG) that will include the project leader and a group of different stakeholders as appropriate which may include:

- Australia Pacific LNG representative
- Shell/QGC representative
- Origin Energy representative
- Arrow Energy representative
- UQ’s Centre for Natural Gas representative
- Office of Groundwater Impact Assessment representative
- QLD Government representative

Budget Summary

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
GISERA	$0	$50,335	$233,018	$32,464	80%	$315,817
- Federal Government	$0	$37,751	$174,763	$24,348	60%	$236,863
- APLNG	$0	$5,663	$26,214	$3,652	9%	$35,529
- Origin Energy	$0	$5,663	$26,214	$3,652	9%	$35,529
- QGC	$0	$1,258	$5,825	$812	2%	$7,895
Total Cash Contributions	**$0**	**$50,335**	**$233,018**	**$32,464**	**80%**	**$315,816**

Source of In-Kind Contribution	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
CSIRO	$0	$12,584	$58,254	$8,116	20%	$78,954
Total In-Kind Contribution	**$0**	**$12,584**	**$58,254**	**$8,116**	**20%**	**$78,954**

TOTAL PROJECT BUDGET	2022/23	2023/24	2024/25	2025/26	-	TOTAL
All contributions	$0	$62,919	$291,272	$40,580	-	**$394,771**
TOTAL PROJECT BUDGET	**$0**	**$62,919**	**$291,272**	**$40,580**	**-**	**$394,771**

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 objective of the project.	At project commencement
		Local government and community groups invited to a community workshop (face-to-face) to convey the knowledge gaps discovered in GISERA phase 1 project (Methane contributions from CSG water holding ponds) and the commencement of the two subsequent phase 2 emissions projects.	At project commencement
		Project progress reported on GISERA website to ensure transparency for all stakeholders including regional communities.	Ongoing
		Local government and community groups invited to a community workshop (face-to-face) to communicate the project outcome.	At project completion
		Public release of final reports. Plain English fact sheet summarising the outcomes of the research.	At project completion
Gas Industry & Government	To communicate the final results of the project	Fact sheet that explains the objective of the project.	At project commencement
		Gas company consultation to identifying accessible ponds for sampling.	At project commencement
		Project progress reporting (on GISERA website)	Ongoing
		Final project report and fact sheet.	At project completion
		Presentation of findings at joint gas industry/government Knowledge Transfer Session	At project completion
Scientific Community	Provide scientific insight into the key controls of methane emissions from CSG holding ponds in the Surat Basin.	Peer-reviewed scientific publication (optional). Dataset(s) available through CSIRO's data repository.	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, roadshows, newsletters and development of other communication products.

5. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
Logistics	● a series of documents describing the contacts, samplings, relevant permissions, sampling equipment and OH&S considerations for this project by establishing the volume and type of available samples from two CSG water holding ponds. ● Identification of any permits or travel documents required to allow this travel to occur. ● HSE documents to ensure safe work practices during this time.	This project will provide the first set of microbial community data from CSG water holding ponds, the first set of data on carbon information of the sediments in the holding ponds, the characterisation of different forms of carbon in the holding ponds, the information on accessibility of inorganic carbon by algae.	● Assist in informing governments, regulators as well as policy-makers on the key controls and contributors on methane emissions from CSG holding ponds in Queensland. ● Improve community's awareness about the potential of the CSG industry to contribute to emissions in the Western Downs region and the impact of methane emissions on the environment. ● Improve industry's knowledge on microbial and algal communities, different forms carbon available in CSG water holding ponds and the possibility of algae accessing inorganic carbon, which will further assist the future mitigation of methane emissions from CSG water holding ponds.	The impact of this research extends to government, industry and everyday Australians. All Australian communities that are located in coal seam gas regions as well as industry will benefit from the outcomes of this research, through increased understanding and awareness of the key controls and contributions on methane emissions from CSG water holding ponds in future.
Field trips	Provision of water and sediment samples			
Sample and data analyses	Provision of microbial and algal communities in the water or brine from CSG water holding ponds, microbial communities in the sediments from a CSG water holding pond, water soluble and solvent extractable organic compounds in water and sediment samples from CSG water holding ponds, mineral composition, surface area, particle size distribution and biofilm imaging of sediment sample from a CSG water holding pond.			
Information sharing with the community stakeholders	Two workshops will be organised: ● The first at early stages of the project to discuss knowledge gaps identified in earlier GISERA phase 1 project (Methane contributions from CSG water holding ponds) and present objectives of the two subsequent phase 2 emissions projects ● The second at project completion to present research outcomes			
Communications	● GISERA Communication team will develop a plain English fact sheet at project commencement. ● Completed fact sheet(s) with key findings for distribution via the GISERA website and at community engagement events. ● Final report with detailed outcomes will be prepared. ● Manuscripts will be prepared for submission to scientific journals (optional).			

6. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Sampling logistics and field campaign planning	Dr. Se Gong	1 September 2023	31 November 2024	n/a
Task 2	Field trips	Dr. Se Gong	1 June 2024	31 March 2025	Task 1
Task 3	Data and sample analyses	Dr. Se Gong	1 July 2024	31 July 2025	Task 1
Task 4	Coordination between the two CSG holding pond projects	Dr. Se Gong	1 September 2023	31 July 2025	Task 1-5
Task 5	Project reporting	Dr. Se Gong	1 September 2023	31 July 2025	Task 1-5
Task 6	Communicate findings to stakeholders	Dr. Se Gong	1 September 2023	31 July 2025	Task 1-5

Task description

Task 1: Sampling logistics and field campaign planning

OVERALL TIMEFRAME: September 2023 - November 2024

BACKGROUND: During this task, we will consult with representatives from CSG companies in Queensland to select two CSG holding ponds with one produced water pond and one brine pond. This task will prepare for sampling of water and sediment samples of the CSG holding ponds in the Surat basin, and develop the safe, environmentally sensitive planning and logistics for sampling campaign.

TASK OBJECTIVES:

1. Establish contact with representatives from CSG companies to guide the pond selection and further sampling campaign.
2. Select two representative CSG water holding ponds in the Surat basin based on pond dimensions (e.g., area and depth) and existing water chemistry.
3. Identify the accessibility and the required permission for the selected ponds.
4. Establish sampling requirements, e.g., volume, size, sampling depth, number.
5. Prepare sampling equipment/reagents.
6. Prepare for remote sampling fieldwork including accommodation, vehicle hire and OH&S considerations.
7. Establish logistics of transporting equipment and samples between CSIRO laboratory in Sydney and collection sites in Queensland.
8. Detail the analytical requirements from external laboratories.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: This task will yield a series of documents describing sampling equipment, sampling details, analysis plan, field trip details and OH&S considerations.

Task 2: Field trips

OVERALL TIMEFRAME: June 2024 – March 2025

BACKGROUND: This task will involve two staff travelling to Queensland with the purpose of collecting water samples for a variety of analyses to fill the knowledge gaps on understanding methane emissions from the CSG water holding ponds in the Surat basin. This project will carry out two field trips with one in summer and one in winter to cover the variation of microbial communities in different seasons.

TASK OBJECTIVES:

1. Collect water samples from CSG water holding ponds identified in Task 1 for water chemistry analysis.
2. Collect water samples from CSG water holding ponds identified in Task 1 for microbial community and algal characterisation.
3. Collect water samples from CSG water holding ponds identified in Task 1 for evaluating water soluble organic compounds and solvent extractable organic compounds.
4. Collect sediment samples from CSG water holding ponds identified in Task 1 for microbial community, chemistry analyses, surface area and particle size distribution.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Collection of water and sediment samples from selected CSG water holding ponds.

Task 3: Sample and data analyses

OVERALL TIMEFRAME: July 2024 – July 2025

BACKGROUND: Methanogen and methanotroph communities in CSG water holding ponds will provide critical information to fully understand the controls of methane emissions from CSG water holding ponds. The kinds of carbon in CSG water holding ponds will provide how accessible these different carbon pools and how these types of carbon are biodegraded or mobilised as emissions. CSG water holding ponds contain high content of inorganic carbon (bicarbonate) which could possibly be converted to organic carbon by algae. This task will analyse water and sediment samples either in-house or in different commercial laboratories.

TASK OBJECTIVES:

1. Filter collected water samples, complete DNA extractions from all samples and process DNA for 16S NGS sequencing.
2. Perform water chemistry analyses of collected water samples through a NATA accredited laboratory.
3. Quantify hydrocarbons such as TRH, BTEX, VOCs, PAHs, volatile organic acids, phenols through a NATA accredited laboratory.
4. Determine detailed water-soluble organic compounds in the water and sediment samples through LCMS technique in a commercial laboratory.
5. Determine detailed solvent extractable organic compounds in the water and sediment samples using a GC-MS instrument in CSIRO laboratory.
6. Identify minerals in the sediment samples XRD technique.

7. Perform SEM (scanning electron microscopy) imaging on sediment samples which will provide the status of microbial colonisation in the sediment and also inform how coal particles bonded with other minerals which can determine the possibility of separation of coal from other minerals.
8. Characterise the surface area, particle size distribution of collected sediment samples by Brunauer-Emmett-Teller and laser diffraction and their coal fractions provided that coal fraction can be successfully separated.
9. Set up a growth experiment to assess whether inorganic carbon (bicarbonate) in CSG water holding ponds could be consumed by certain algae species.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: This task aims to deliver insights of methanogen and methanotroph communities as well as algal species, information of different carbon pools in the ponds, accessibility of inorganic carbon by algae.

Task 4: Coordination between the two CSG holding pond projects

OVERALL TIMEFRAME: September 2023 - July 2025

BACKGROUND: This project focuses on filling the knowledge gaps on emissions from CSG holding ponds. This project is closely linked with the other phase 2 pond emissions project 'Methane emissions from CSG water holding ponds in Queensland' which measures emissions from CSG holding ponds. The results from the first round of fieldwork (Task 3 Field trip I) in the emissions measurement project will be used to guide selection of holding ponds for examination in this project. The project leaders of these two projects should work closely and communicate with each other on pond selection, sampling plan and analyses.

TASK OBJECTIVES: To ensure the two phase 2 pond emissions projects link and communicate effectively.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: The project leaders of the two phase 2 pond emissions projects work closely to communicate project findings with the aims to reduce the uncertainties on emissions from CSG holding ponds in Queensland and fill knowledge gaps to understand emissions lifecycle related to CSG holding ponds.

Task 5: Project reporting

OVERALL TIMEFRAME: September 2023 - July 2025

BACKGROUND: Information from this project is to be made publicly available after completion of standard CSIRO publication and review processes.

TASK OBJECTIVES: To ensure that the information generated by this project is documented and published after thorough CSIRO internal review.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

1. Ensure coordination between the two follow-up projects coming out of GISERA phase 1 project ‘Methane contributions from CSG water holding ponds’.
2. Preparation of a final report outlining the scope, methodology and findings.
3. Following CSIRO Internal review, the report will be submitted to the GISERA Director for final approval; and
4. Provide 6 monthly progress updates to GISERA office.

Task 6: Communicate findings to stakeholders

OVERALL TIMEFRAME: September 2023 - July 2025

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 findings to stakeholders through meetings, a Knowledge Transfer Session, fact sheets, project reports and journal article/s, in collaboration with the GISERA Communication team.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Communicate results to GISERA stakeholders according to standard GISERA project procedures, which will include but are not limited to:

1. Presentation/engagement with local government and community members/groups via two workshops held in Chinchilla (held in conjunction with the other phase 2 project workshops):
    a. one at the early stage to convey the knowledge gaps discovered in GISERA phase 1 project ‘Methane contributions from CSG water holding ponds’ and to present objectives of the two subsequent phase 2 emissions projects; and
    b. a second workshop at the completion of the project to present project outcomes.
2. Knowledge Transfer Session with relevant government/ gas industry representatives.
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. Preparation of an article for the GISERA newsletter.
5. Peer-reviewed scientific manuscript ready for submission to relevant journal (optional).

Project Gantt Chart

		2023/24										2024/25												25/26
Task	**Task Description**	**Sep 23**	**Oct 23**	**Nov 23**	**Dec 23**	**Jan 24**	**Feb 24**	**Mar 24**	**Apr 24**	**May 24**	**Jun 24**	**Jul 24**	**Aug 24**	**Sep 24**	**Oct 24**	**Nov 24**	**Dec 24**	**Jan 25**	**Feb 25**	**Mar 25**	**Apr 25**	**May 25**	**Jun 25**	**Jul 25**
1	Sampling logistics and field campaign planning	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
2	Field trips										■	■	■	■	■	■	■	■	■	■				
3	Data and sample analyses											■	■	■	■	■	■	■	■	■	■	■	■	■
4	Coordination between the two phase 2 CSG holding pond projects	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	Project reporting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	Communicate findings to stakeholders	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

7. Budget Summary

Expenditure	2022/23	2023/24	2024/25	2025/26	Total
Labour	$0	$57,419	$212,372	$40,580	$310,371
Operating	$0	$5,500	$43,900	$0	$49,400
Subcontractors	$0	$0	$35,000	$0	$35,000
Total Expenditure	**$0**	**$62,919**	**$291,272**	**$40,580**	**$394,771**

Expenditure per task	2022/23	2023/24	2024/25	2025/26	Total
Task 1	$0	$18,024	$14,022	$0	$32,046
Task 2	$0	$11,921	$37,132	$0	$49,053
Task 3	$0	$0	$126,830	$0	$126,830
Task 4	$0	$4,136	$2,849	$0	$6,985
Task 5	$0	$2,757	$84,988	$35,820	$123,565
Task 6	$0	$26,081	$25,450	$4,760	$56,291
Total Expenditure	**$0**	**$62,919**	**$291,272**	**$40,580**	**$394,771**

Source of Cash Contributions	2022/23	2023/24	2024/25	2025/26	Total
Federal Govt (60%)	$0	$37,751	$174,763	$24,348	$236,863
APLNG (9%)	$0	$5,663	$26,214	$3,652	$35,529
Origin Energy (9%)	$0	$5,663	$26,214	$3,652	$35,529
QGC (2%)	$0	$1,258	$5,825	$812	$7,895
Total Cash Contributions	**$0**	**$50,335**	**$233,016**	**$32,464**	**$315,816**

In-Kind Contributions	2022/23	2023/24	2024/25	2025/26	Total
CSIRO (20%)	$0	$12,584	$58,254	$8,116	$78,954
Total In-Kind Contributions	**$0**	**$12,584**	**$58,254**	**$8,116**	**$78,954**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$236,863	60%
APLNG investment	$35,529	9%
Origin Energy investment	$35,529	9%
QGC investment	$7,895	2%
CSIRO investment	$78,954	20%
Total Expenditure	**$394,771**	**100%**

Task	Milestone Number	Milestone Description	Funded by	Start Date (mm-yy)	Delivery Date (mm-yy)	Fiscal Year Completed	Payment $ (excluding CSIRO contribution)
Task 1	1.1	Sampling logistics and field campaign planning	GISERA	Sep-23	Nov-24	2023/24	$25,637
Task 2	2.1	Field trips	GISERA	Jun-24	Mar-25	2024/25	$39,242
Task 3	3.1	Data and sample analyses	GISERA	Jul-24	Jul-25	2025/26	$101,464
Task 4	4.1	Coordination between the two CSG holding pond projects	GISERA	Sep-23	Jul-25	2025/26	$5,588
Task 5	5.1	Project leadership and reporting	GISERA	Sep-23	Jul-25	2025/26	$98,852
Task 6	6.1	Communicate findings to stakeholders	GISERA	Sep-23	Jul-25	2025/26	$45,033

8. Intellectual Property and Confidentiality

<table>
<tr><td rowspan="3">Background IP
(clause 11.1, 11.2)</td><td>Party</td><td>Description of Background IP</td><td>Restrictions on use (if any)</td><td>Value</td></tr>
<tr><td></td><td></td><td></td><td>$</td></tr>
<tr><td></td><td></td><td></td><td>$</td></tr>
<tr><td>Ownership of Non-Derivative IP
(clause 12.3)</td><td colspan="4">CSIRO</td></tr>
<tr><td>Confidentiality of Project Results
(clause 15.6)</td><td colspan="4">Project Results are not confidential.</td></tr>
<tr><td>Additional Commercialisation requirements
(clause 13.1)</td><td colspan="4">Not Applicable</td></tr>
<tr><td>Distribution of Commercialisation Income
(clause 13.4)</td><td colspan="4">Not applicable</td></tr>
<tr><td rowspan="5">Commercialisation Interest
(clause 13.1)</td><td colspan="2">Party</td><td colspan="2">Commercialisation Interest</td></tr>
<tr><td colspan="2">CSIRO</td><td colspan="2">N/A</td></tr>
<tr><td colspan="2">APLNG</td><td colspan="2">N/A</td></tr>
<tr><td colspan="2">QGC</td><td colspan="2">N/A</td></tr>
<tr><td colspan="2">Origin Energy</td><td colspan="2">N/A</td></tr>
</table>

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