Australia’s National Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Project Order

Short Project Title

Background Seismicity of Beetaloo Sub-basin and Seismic Hazard

Long Project Title	Quantification of background seismicity of Beetaloo Sub-basin, NT and physics based estimation of seismic hazard
GISERA Project Number	Oth.1
Start Date	01/06/2022
End Date	01/06/2024
Project Leader	Erdinc Saygin

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
- ☒ Other (Induced seismic activity)

1. Project Summary

The primary aim of this project is to establish a long-term baseline seismic monitoring catalogue that will characterise the current natural seismic activity and cultural seismic noise sources (e.g., quarry blasts) within the Beetaloo Basin and its surroundings. This baseline data will be used to distinguish any potential increase in seismic activity due to future gas extraction operations. This activity will be carried out using only existing passive seismic datasets including:

- the current six element seismic monitoring array of Geoscience Australia deployed in 2021;
- other current seismic stations (eight stations);
- previously operated seismic stations (eight stations); and
- operator collected passive seismic datasets.

No new seismic station installations will be conducted. We will then analyse the aggregated seismic data with state-of-the-art seismological techniques to build the baseline earthquake activity catalogue.

The project will provide important information to community and regulators of the baseline seismic activity in the Beetaloo Basin in a transparent and available way to the public.

In the second part of the project, the seismic hazard caused by any future earthquake (natural & induced) activity will be predicted using physics-based ground motion computations. This activity will estimate any ground shaking that the infrastructure will be subjected to for various earthquake scenarios.

2. Project description

Introduction

Hydraulic fracturing is a key enabling technology that has helped unlock vast reserves of unconventional oil and gas resources within low permeability hydrocarbon rocks globally. The production takes place by injecting high pressure engineered fluids to create permeable pathways for fluid flow in the production. The injected fluids are generally, later on, disposed of at other wells for long term storage, where this is not the case in NT with no known potential onshore sites. Hydraulic fracturing is expected to create weak seismicity when opening existing fractures to enhance permeability of the reservoir (also called operationally induced seismicity) (Atkinson et al., 2020). The fracturing can also trigger earthquakes in the critically stressed faults, as in the magnitude 5.7 earthquake in Sichuan Basin, China and a magnitude 4.5 earthquake in British Columbia, Canada (Atkinson et al., 2020).

Beetaloo Sub-basin is an onshore basin located in Northern Territory, Australia, with a proven significant shale gas potential. In the case of prospective unconventional resource development activities, it is expected that hydraulic fracturing technologies will be used. A monitoring plan is needed to distinguish between induced and baseline seismicity (natural earthquakes). Around the world, several seismic networks have been deployed and operated before, during and after the resource development operations. A good example is U.S. TexNet array, in which several seismographs are operated to provide real-time information about the seismic activity. In Australia, the Kimberley array is being deployed by the Geological Survey of Western Australia. CSIRO Scientists are analysing the data from this project to quantify the baseline seismicity. Also, CSIRO and GSWA scientists are developing an information portal as part of the GISERA, W25 project (Saygin et al.).

Since mid-2021, Geoscience Australia has operated a six-element seismic broadband array in the Beetaloo Basin. The data is real-time telemetered and freely open to the public (Figure 1, blue triangles). In this project, we will use state-of-the-art seismic detection and location algorithms with this dataset to create a background catalogue of natural earthquakes and any other activity, e.g., quarry blasts, which offers higher earthquake detection & location rates than the tools employed by Geoscience Australia. Other seismic stations around the Beetaloo Basin from the previous and current experiments and the operator datasets collected as a part of hydraulic fracturing operations will be included in the analyses.

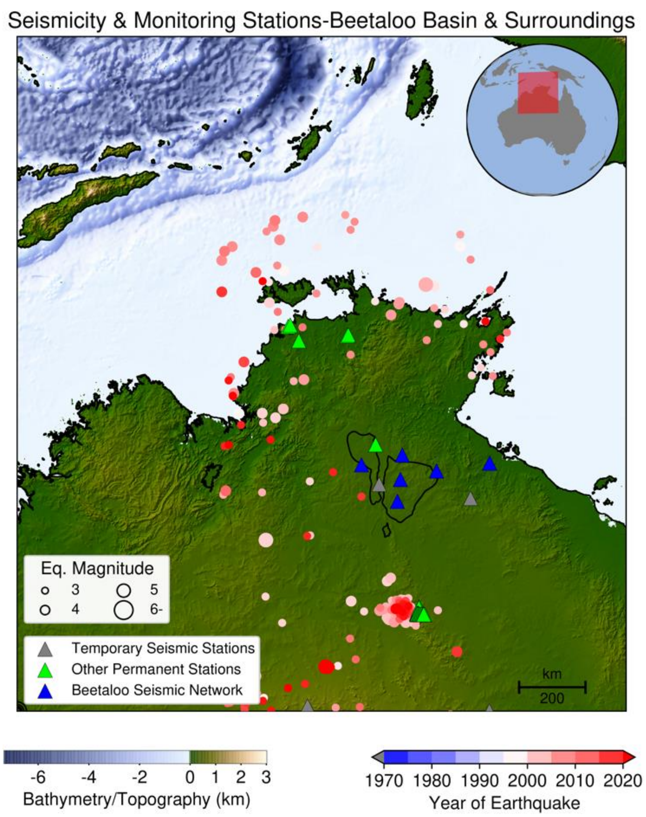

Figure 1: The distribution of seismic monitoring stations and the seismicity. The location of the currently operating Beetaloo Seismic Monitoring stations of Geoscience Australia is marked with blue triangles and other temporary stations with green and grey. Earthquake locations are obtained from Geoscience Australia catalogue.

One of the other important aspects of the earthquake activity is quantifying the seismic hazard arising from this activity. Over the years, several empirical methods have been developed to predict the distribution of the ground motion intensity from an earthquake. With the advent of computational resources, physics-based ground-motion models are developed. This is done by taking into account the earthquake rupture, magnitude and depth and then simulating the wave propagation in a three-dimensional medium to predict the nature of the arriving waves in the surface in the form of time series. These time series are then analysed to estimate the maximum peak horizontal velocity during shaking at any arbitrary location within the computational domain. This analysis can be repeated multiple times for different earthquake scenarios, and a robust seismic hazard analysis can be estimated. With the new passive seismic dataset in Beetaloo Sub-basin and other open-source seismic reflection profiles, we will build a 3D seismic velocity model, and compute the 3D ground motion prediction to map out the seismic risk for both natural and induced events that may occur in the future.

Prior Research

The resources industry has conducted several seismic reflection surveys in Australia to estimate the prospectivity of the Beetaloo Sub-basin. These datasets show the subsurface structure, including inactive faults. Regarding passive seismic monitoring, Geoscience Australia is operating six-element seismic array since mid 2021 covering Beetaloo Basin. This dataset is open and available to the public in real time as well as other publicly open datasets from previous temporary passive seismic campaigns in the vicinity of the network (See Incorporated Research Institutions for Seismology (IRIS)).

Our understanding of the Australian continent's general seismic activity is generally poor due to the sparse station coverage. Most small earthquakes (less than 2) often get undetected and leave a large gap in understanding the different small magnitude events.

Because of the relatively sporadic seismic activity in the Australian continent, it is often not easy to estimate earthquake hazard. The earthquake hazard is a combination of an earthquake's character (rupture mechanism, magnitude, depth, and distance), Earth's subsurface structure (attenuation), and the condition of the surface infrastructure. With the advent of high computational power in recent years, it is possible to calculate the wave propagation within the Earth for hypothetical earthquakes of different magnitudes, depths and rupture mechanisms and estimate the shaking at an arbitrary location within the computational domain. This activity so far has not been trialled in Australia due to the data and computational limitations. However, it is routinely applied in places such as California in the U.S (Figure 2).

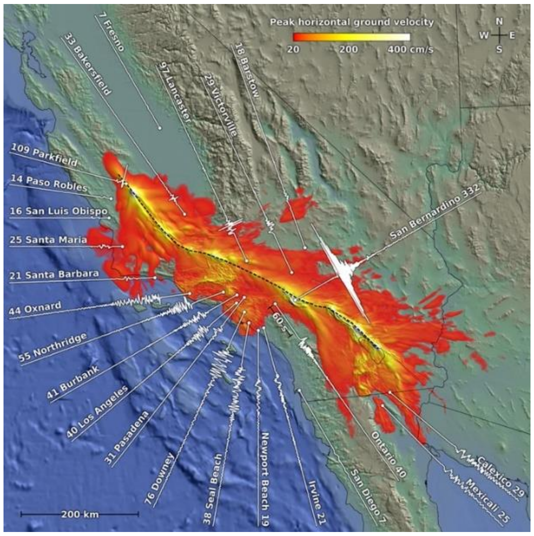

Figure 2: Simulation of a “wall-to-wall” rupture of the southern San Andreas Fault. The peak ground velocities during this magnitude-8 earthquake are shown in colour. White lines are seismograms at selected points (Jordan, T., 2015).

Need & Scope

The background seismic activity of the region is still largely unknown due to the lack of previous instrumentation coverage. It is vital to have a baseline of natural seismic activity before unconventional gas extraction activities are started to ensure that any industrial activities are not seen to be producing excessive seismic activity. This project will provide important information to the community and regulators of the baseline seismic activity in the Beetaloo Sub-basin in a transparent and available way to the public.

In this project, we aim to detect much smaller earthquakes by using new techniques.

The scope of this project includes:

- Identification of the potential sources of seismic activity using the existing datasets and maps within a desktop study.
- Application of state-of-the-art algorithms for detecting and discriminating smaller natural and induced seismic events which do not fall into the remit of the Geoscience Australia.
- Physics based ground motion characterisation to predict the effect of an earthquake due to hydraulic fracturing. These predictions will provide an overview of what kind of ground motions will be felt by the nearby communities and typical peak horizontal ground motions for the infrastructure and provide inputs to the future traffic light management systems.

Objective

The primary aim of this project is to establish a long-term baseline seismic monitoring catalogue that will characterise the current natural seismic activity and cultural seismic noise e.g., quarry blasts within the Beetaloo Sub-basin by using freely available continuous passive seismic datasets. This baseline will be used to distinguish any potential increase in seismic activity due to planned gas extraction operations. This will be done by analysing the data from Geoscience Australia's seismic monitoring array with state-of-the-art seismological techniques. This project will provide important information to the community and regulators of the baseline seismic activity.

The secondary aim of the project is to use the same dataset to construct a subsurface physical model of the Beetaloo Basin and then conduct physics-based ground motion characterisation. By employing high-frequency 3D wave propagation calculations, synthetic earthquakes will be generated in the computational domain within Beetaloo Sub-basin with different magnitudes and depths. The ground motions will be then predicted across the basin from these various earthquake scenarios. This activity will give insights into the expected shaking for a real induced earthquake.

Methodology

Stage 1 Desktop study to identify the potential location of natural and man-made seismic sources: Existing seismic catalogues, location of quarries or mines, and any other exploration activities will be investigated to identify the potential location of seismic activity and also assess the sensitivity of the recently installed seismic array.

Stage 2 Establishing and application of a data processing framework for the automatic detection, location and discrimination of any seismic events:

- automatic retrieval of continuous passive seismic data of Beetaloo Seismic Array of Geoscience Australia and other temporary arrays through IRIS, and obtain and integrate industry recorded continuous passive seismic datasets.
- scanning and detection of seismic activity, using parameters suitable for the study area,
- locating and discrimination of seismic events in the Beetaloo Sub-basin
- timely production of catalogue and maps of locations of seismic activity.

Stage 3 Physics-based ground motion characterization:

- Model building: a realistic 3D subsurface model will be constructed by using the model of Chen et al. (2022) and Qashqai et al. (2019) as well as the public seismic reflection datasets.

- Simulation: Full 3D elastic wave simulations will be conducted for a series of hypothetical and real earthquakes within the region with different magnitudes and rupture mechanisms to predict the shaking across the region. Machine learning based physics informed networks will be used to speed up the calculations and increase the frequency content of the simulated waveforms (often a very challenging and time-consuming task).

- Benchmarking: Predicted earthquakes will be also benchmarked with the real natural earthquakes detected by using the data from GA's Beetaloo seismic network (inputs will be from Stage 2).
- Aggregation: Results will be collated to quantify the seismic risk for any natural and induced earthquakes.

3. Project Inputs

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Erdinc Saygin	62 days	Observational & Computational Seismology	19	CSIRO
Mehdi Qashqai	122 days	Observational & Computational Seismology	8	CSIRO
Peng Guo	120 days	Observational & Computational Seismology	8	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 a group of different stakeholders as appropriate which may include:

- Dr Trevor Allen, Geoscience Australia, Principal Research Scientist, Seismology, Natural Hazards, Operator of the Passive Seismic Network in the Beetaloo Basin
- Prof. Phil Cummins, The Australian National University, Professor of Natural Hazards, Seismology
- A representative from the Northern Territory Geological Survey
- A representative from Santos
- A representative from Origin Energy
- A representative from the NT Department of Industry, Tourism and Trade (DITT)

Budget Summary

Source of Cash Contributions	2021/22	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
GISERA	$0	$212,807	$166,994	$0	$0	80%	$379,802
- Federal Government	$0	$133,005	$104,372	$0	$0	50%	$237,376
- NT Government	$0	$26,601	$20,874	$0	$0	10%	$47,475
- Santos	$0	$26,601	$20,874	$0	$0	10%	$47,475
- Origin	$0	$26,601	$20,874	$0	$0	10%	$47,475
Total Cash Contributions	**$0**	**$212,807**	**$166,994**	**$0**	**$0**	**80%**	**$379,802**

Source of In-Kind Contribution	2021/22	2022/23	2023/24	2024/25	2025/26	% of Contribution	Total
CSIRO	$0	$53,202	$41,749	$0	$0	20%	$94,950
Total In-Kind Contribution	**$0**	$53,202	$41,749	**$0**	**$0**	**20%**	**$94,950**

TOTAL PROJECT BUDGET	2021/22	2022/23	2023/24	2024/25	2025/26	-	TOTAL
All contributions	**$0**	**$266,009**	**$208,743**	**$0**	**$0**	-	**$474,752**
TOTAL PROJECT BUDGET	**$0**	**$266,009**	**$208,743**	**$0**	**$0**	**-**	**$474,752**

4. Communications Plan

Stakeholder	Objective	Channel (e.g. meetings/media/factsheets)	Timeframe (Before, during at completion)
Regional community / wider public	To communicate project objectives and key messages from the research	Fact sheets (including development of one at commencement of project which will explain in plain English the objective of the project and one at the end of the project – these may be updated periodically as project progresses). Project progress reported on GISERA website to ensure transparency for all stakeholders including regional communities. Media release (optional)	From commencement of project and with updates as they come to hand. As required At completion
Government	To report on research being undertaken	Factsheets, newsletters, website or webcast	During
Gas Industry	Improve knowledge on baseline seismic activity in the Beetaloo Sub-basin	Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At Completion
Government	Advice provided to senior bureaucrats / ministers / policy makers	Presentation of findings at joint Gas Industry/Government Knowledge Transfer Session	At Completion
Community stakeholders	Presentation of research findings	Presentation of findings through community forums or briefings	At Completion
Regional community/wider public, government, scientific community and industry	To report on key findings	Public release of final report	At project completion
Traditional Owner communities	To explore collaboration opportunities for information exchange.	Engagement with representatives of relevant land councils where appropriate to determine interest/availability in making information available to communities	Ongoing

5. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
Identification of potential seismic sources	Location of existing & potential seismic activity due to man-made activities.	Assess the sensitivity of the recently installed seismic array.	Will improve community, government and community knowledge on baseline seismic activity in the Beetaloo Basin. Aid interpretation of the seismic activity and increase fundamental knowledge.	Better discrimination of sources such as earthquakes vs. man-made activities. Accurate characterisation of induced seismic hazard due to hydraulic fracturing. Potential to provide baseline seismic activity information for guidelines of the operation of extraction industries within the appropriate Codes of Practice and Legislation.
Detection and location of background seismicity	An automated process stream that receives data, detects events, filters non-seismic events, and produces seismic activity locations.	Building a catalogue of detected natural and human induced seismic events.		
Seismic velocity model building	Seismic velocity model from surface to mid crust with P & S-wave velocities, attenuation, and realistic density values ready to be utilised in Physics Based Ground Motion Simulations	Refinement of the locations of the detected earthquakes. It will also enable the physics based seismic hazard quantification.		
Physics based ground motion modelling	Distribution of ground motion intensity for multiple earthquake scenarios within Beetaloo Basin	Estimation of Seismic hazard arising from natural and induced earthquake activity.		
Reporting	Interim and final reports	Progress tracking along the way	A final report detailing the system put in place and the products released.	

6. Project Plan

Project Schedule

ID	Activities / Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Identification of Potential Seismic Sources	Mehdi Qashqai	01 July 2022	31 August 2022	
Task 2	Detection and Location of Background Seismicity	Mehdi Qashqai	01 September 2022	31 March 2024	Task 1
Task 3	1st Interim Report	Erdinc Saygin	01 September 2022	31 October 2022	Tasks 1 & 2
Task 4	Seismic Velocity Model Building	Peng Guo	01 July 2022	30 June 2023	
Task 5	2nd Interim Report	Erdinc Saygin	01 May 2023	30 June 2023	Tasks 1, 2, 3, 4
Task 6	3D Seismic Wave Simulations	Peng Guo	01 August 2023	30 May 2024	Task 4
Task 7	Final Report	Erdinc Saygin	01 March 2024	30 June 2024	Tasks 1, 2, 3, 4, 5, 6
Task 8	Communicate findings to stakeholders	Erdinc Saygin	Full duration of project		

Task description

Task 1: Identification of Potential Seismic Sources

OVERALL TIMEFRAME: 1 July 2022 – 31 August 2022

BACKGROUND**:** The identification of existing seismic sources including man-made ones prior to the installation of the network is critical in discrimination in later stages.

TASK OBJECTIVES**:** Conduct desktop study to identify and map existing seismic sources from legacy data.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Time dependent 2D maps of seismic sources showing the variation historical seismicity. These maps will also indicate the information gap.

Task 2: Detection and Location of Background Seismicity

OVERALL TIMEFRAME: 1st of September 2022 – 31st of March 2024

BACKGROUND: Since mid 2021, a six-element passive seismic array is being operated by Geoscience Australia. The collected data from this array is freely open to anyone, and contains important information about small magnitude local earthquake activity. However, the modern data processing techniques needs to be applied to extract more from the data. In addition to data from GA array, other datasets from temporary seismic deployments exist as well as operator recorded seismic data as part of hydraulic fracturing operations.

TASK OBJECTIVES: To develop workflows that receive and process seismic data and produce a location and magnitude for each event using the state-of-the-art detection and location algorithms**.**

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

a) Retrieve freely available continuous passive seismic data from GA's current seismic array, and other seismic deployments stored at Incorporated Research Institutions for Seismology (IRIS). Obtain continuous passive seismic data from industry as part of hydraulic fracturing operations.

b) Set up and refine triggering algorithms specific to the stations in this study with the aim of capturing magnitude 1.5 events and larger

c) Automate location and magnitude calculations of seismic activity from the triggered events

d) Incorporate outputs from Task 4 to refine the depth and magnitude estimates. Consider relocation of historic events using the refined velocity model

e) Produce a listing of the seismic activity details suitable for publication

f) Estimate the magnitude-frequency distribution of natural earthquake activity.

Task 3: 1st Interim Report

OVERALL TIMEFRAME: 1St of September 2022 – 31st of October 2022

BACKGROUND: The desktop study regarding the potential seismic sources aims to determine the location of existing sources and classify them. The workflow for detection and location of earthquakes will process the incoming data from Geoscience Australia's passive seismic network.

TASK OBJECTIVES: Provide a general outline of the potential and historical seismic sources. Provide a preliminary assessment of the workflow's performance about the existing data.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: A detailed report showing the results of the desktop study of seismic sources through maps and digital datasets. Assessment workflow with respect to the already collected data.

Task 4: Seismic Velocity Model Building

OVERALL TIMEFRAME: 1st of July 2022 – 30th of June 2023

BACKGROUND: Physics based ground motion modelling predicts time series for an expected earthquake (induced & natural) at any point, which is then used in the seismic hazard characterisation. The modelling requires high resolution 3D seismic velocity models as a primary input.

TASK OBJECTIVES: Build a database of open-source seismic reflection/refraction interpretations and borehole data for extracting the general geometry of the geological layers. Conduct passive seismic imaging (P and S-wave velocities) with the current and legacy passive seismic datasets. Construct a hierarchical 3D seismic velocity model as in Guo et. al. (2022) by combining interpretations of reflection datasets, results from passive seismic imaging (new and Chen et al., 2022).

TASK OUTPUTS AND SPECIFIC DELIVERABLES: A 3D seismic velocity model from surface to mid crust with P & S-wave velocities, attenuation, and realistic density values ready to be utilised in Physics Based Ground Motion Simulations (Task 6).

Task 5: 2nd Interim Report

OVERALL TIMEFRAME: 1st of May 2023 – 30th of June 2023

BACKGROUND: The workflow for detection and location of earthquakes will process the incoming data from Geoscience Australia's passive seismic network. Meanwhile, the Seismic velocity model building activity will create a detailed 3D subsurface model that will be used in refining the earthquake locations, and physics based ground motion modelling.

TASK OBJECTIVES: Provide an update of the detected baseline natural seismic activity in the Beetaloo Basin and completed 3D seismic velocity model.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Examples of detected local seismic activity: location maps, magnitude information. 2D & 3D Visualisation of the seismic velocity model characterising the subsurface.

Task 6: Physics Based Ground Motion Modelling for Seismic Hazard Characterisation

OVERALL TIMEFRAME: 1st of August 2023 – 31st of May 2024

BACKGROUND: Physics based ground motion characterisation is used for predicting the effect of an earthquake due to hydraulic fracturing. These predictions will provide an overview of what kind of ground motions will be felt by the nearby communities and typical peak horizontal ground motions for the infrastructure and provide inputs to the future traffic light management systems.

TASK OBJECTIVES: Estimate the seismic hazard by aggregating the predicted ground motion time series for various earthquake scenarios including different rupture lengths, mechanisms, magnitudes and depths.

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Expected peak ground horizontal motions for any realistic earthquake scenarios.

Task 7: Project Reporting

OVERALL TIMEFRAME: 1st of March 2024 – 30th of June 2024

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) Preparation of a final report outlining the scope, methodology, scenarios, assumptions, findings and any suggestions/options for future research including a detailed analysis of the future seismic monitoring needs should production scenarios occur.

2) Following CSIRO ePublish review, the report will be submitted to the GISERA Director for final approval; and

3) Provide 6 monthly progress updates to GISERA office.

Task 8: Communicate project objectives, progress and findings to stakeholders

OVERALL TIMEFRAME: Full duration of project

BACKGROUND: Communications of GISERA research are an important component of outreach and dissemination of findings to diverse audiences.

TASK OBJECTIVES: Communicate project objectives, progress and findings to stakeholders through meetings, knowledge transfer session, factsheet and journal article, in collaboration with GISERA Communications officers.

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

1) Knowledge Transfer session with Government/Gas Industry
2) Presentation of findings to Community members/groups
3) Preparation of article for GISERA newsletter and other media outlets e.g. The Conversation
4) Revision of project factsheet to include final results (a factsheet is developed at project commencement, and another will be done at completion)
5) Peer reviewed scientific manuscript ready for submission to relevant journal
6) Short animation about why there is a need for monitoring of baseline activity.

Project Gantt Chart

		2022/23												2023/24											
Task	**Task Description**	**Jul 22**	**Aug 22**	**Sep 22**	**Oct 22**	**Nov 22**	**Dec 22**	**Jan 23**	**Feb 23**	**Mar 23**	**Apr 23**	**May 23**	**Jun 23**	**Jul 23**	**Aug 23**	**Sep 23**	**Oct 23**	**Nov 23**	**Dec 23**	**Jan 24**	**Feb 24**	**Mar 24**	**Apr 24**	**May 24**	**Jun 24**
1	Identification of Potential Seismic Sources	■	■																						
2	Detection and Location of Background Seismicity			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
3	1st Interim Report			■	■																				
4	Seismic Velocity Model Building	■	■	■	■	■	■	■	■	■	■	■	■	■											
5	2nd Interim Report											■	■	■											
6	3D Seismic Wave Simulations														■	■	■	■	■	■	■	■	■	■	
7	Final Report																					■	■	■	■
8	Communicate findings to stakeholders	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

7. Budget Summary

Expenditure	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Labour	$0	$264,009	$201,743	$0	$0	$465,752
Operating	$0	$2,000	$7,000	$0	$0	$9,000
Subcontractors	$0	$0	$0	$0	$0	$0
Total Expenditure	**$0**	**$266,009**	**$208,743**	**$0**	**$0**	**$474,752**

Expenditure per task	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Task 1	$0	$20,769	$0	$0	$0	$20,769
Task 2	$0	$103,401	$94,252	$0	$0	$197,653
Task 3	$0	$8,501	$0	$0	$0	$8,501
Task 4	$0	$118,825	$0	$0	$0	$118,825
Task 5	$0	$10,956	$0	$0	$0	$10,956
Task 6	$0	$0	$88,959	$0	$0	$88,959
Task 7	$0	$0	$21,873	$0	$0	$21,873
Task 8	$0	$3,557	$3,659	$0	$0	$7,216
Total Expenditure	**$0**	**$266,009**	**$208,743**	**$0**	**$0**	**$474,752**

Source of Cash Contributions	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Federal Govt (50%)	$0	$133,005	$104,372	$0	$0	$237,376
NT Govt (10%)	$0	$26,601	$20,874	$0	$0	$47,475
Santos (10%)	$0	$26,601	$20,874	$0	$0	$47,475
Origin (10%)	$0	$26,601	$20,874	$0	$0	$47,475
Total Cash Contributions	**$0**	**$212,807**	**$166,994**	**$0**	**$0**	**$379,802**

In-Kind Contributions	2021/22	2022/23	2023/24	2024/25	2025/26	Total
CSIRO (20%)	$0	$53,202	$41,749	$0	$0	$94,950
Total In-Kind Contributions	**$0**	**$53,202**	**$41,749**	**$0**	**$0**	**$94,950**

	Total funding over all years	Percentage of Total Budget
Federal Government investment	$237,376	50%
NT Government investment	$47,475	10%
Santos investment	$47,475	10%
Origin investment	$47,475	10%
CSIRO investment	$94,950	20%
Total Expenditure	**$474,752**	**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	Identification of Potential Seismic Sources	GISERA	Jul-22	Aug-22	2022/23	$16,615
Task 2	2.1	Detection and Location of Background Seismicity	GISERA	Sep-22	Mar-24	2023/24	$158,122
Task 3	3.1	1st Interim Report	GISERA	Sep-22	Oct-22	2022/23	$6,801
Task 4	4.1	Seismic Velocity Model Building	GISERA	Jul-22	Jun-23	2022/23	$95,060
Task 5	5.1	2nd Interim Report	GISERA	May-23	Jun-23	2022/23	$8,765
Task 6	6.1	3D Seismic Wave Simulations	GISERA	Aug-23	May-24	2023/24	$71,167
Task 7	7.1	Final Report	GISERA	Mar-24	Jun-24	2023/24	$17,498
Task 8	8.1	Communicate findings to stakeholders	GISERA	Jul-22	Jun-24	2023/24	$5,773

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	
	Origin Energy		N/A	

9. References

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