Project Order

Proforma 2018

1. Short Project Title (less than 15 words)

Baseline measurement and monitoring of methane emissions in the Beetaloo sub-basin

Long Project Title	Measurement and Monitoring of Background Landscape Methane Concentrations and Fluxes in the Beetaloo sub-Basin, Northern Territory
GISERA Project Number	G5
Proposed Start Date	30 July 2018
Proposed End Date	31 March 2019
Project Leader	Cindy Ong

2. GISERA Region

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

3. GISERA Research Program

- ☐ Water Research
- ☒ **GHG Research**
- ☐ Social & Economic Research
- ☐ Biodiversity Research
- ☐ Agricultural Land Management Research
- ☐ Health Research

4. Project Summary

Objective

Community concerns regarding methane emissions by the onshore gas industry (otherwise known as 'fugitive emissions') have been identified by the recent *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*. To address these concerns, it is necessary to complete baseline monitoring of methane concentrations and fluxes at least six months prior to any exploration activity so as to determine the quantity of any fugitive emissions over and above background. This research project will provide the community with robust, transparent and representative baseline measurements of background methane emissions. The research project will provide:

a) background landscape concentration levels of methane, and

b) investigate fluxes and identify sources where elevated methane levels are found.

Description

The Northern Territory Government's 'Scientific Inquiry into Hydraulic Fracturing' Final Report identified significant community concerns regarding the potential of the onshore gas industry to release fugitive methane emissions to the atmosphere. In order to determine the level of any future potential fugitive emissions it is necessary to know what the background baseline methane emissions are. The 'Hydraulic Fracturing Inquiry' Final Report goes on to state that methane measurement and monitoring must occur prior to the advent of exploration and production activities by gas companies. Specifically, **Recommendation 9.3** of the Final Report requires:

'*That baseline monitoring of methane concentrations be undertaken for at least six months prior to the grant of any further exploration approvals. In areas where hydraulic fracturing has already occurred, the baseline monitoring should be undertaken at least a year prior to the grant of any production approvals*.'

While this project provides, first and foremost, information to the community on what the levels of background baseline methane emissions are, it also will generate useful information as per Recommendation 9.3. This proposal also represents the first stage of a larger methane baseline project with the objective of acquiring baseline measurement and monitoring data of 'methane concentrations' across a larger area of the Beetaloo Basin in order to provide a comprehensive baseline of background methane emissions across this landscape. This first stage will deploy the most practical and instantly deployable technologies and associated methods to obtain as comprehensive as possible background methane concentrations across the central region of the Beetaloo sub-basin in a timely manner in the next 6 months. This means that mobile surveying using vehicles will primarily be relied on. The establishment of fixed site monitoring techniques is much more challenging and will be addressed in later stage projects (to be defined over the next 6 months).

CSIRO has been actively conducting research and development in methane emissions over 30 plus years across a range of industries, and, in recent years, CSIRO has conducted comprehensive work on the coal seam gas (CSG) operations in Surat basin as well as the exploration and potential gas operations in Narrabri and background methane emissions in Victoria. This work builds on that knowledge and experience.

In this proposal, and for reasons of clarity, use of the word *concentration* is a measure of the abundance of gas (in this case methane) in air, usually defined in terms of the proportion of the total volume it accounts for in air (units are ppm or ppb). *Flux* is defined as the rate of flow of gas per unit area (g/s). Both measurements are required to be able to provide baseline levels of methane and quantify the natural and anthropogenic methane emissions, where these background emissions are occurring and how much methane is being released to the atmosphere.

Need & Scope

Natural gas offers significant opportunity to help address domestic and global energy needs, manage costs and reduce greenhouse gas (GHG) emissions over the next 30-40 years. The 'cleaner than coal' property that natural gas offers is one of the central reasons why this opportunity exists where gas can be used as a bridging fuel to future low carbon economies. Yet, natural gas is a fossil fuel and thus there is a need to understand the actual greenhouse benefits, especially as the global warming potential (GWP) of fugitive emissions consisting mainly of methane, which is significantly higher than carbon dioxide and hence needs to be carefully managed and monitored. These community concerns regarding industry fugitive emissions were expressed in significant detail in the NT Government's *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*. An important part of understanding emissions related to the extraction of natural gas is developing a comprehensive set of baseline of methane levels prior to activities (exploration and production) by the gas industry.

The *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* has addressed such concerns and recommends (9.8) that the Northern Territory Government and the Commonwealth Government seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT. Providing baseline methane levels is a requirement to address part of Recommendation: 9.3 of the Northern Territory 'Scientific Inquiry into Hydraulic Fracturing'. To ensure that the community has confidence that these recommendations are achieved by the NT Government, it is necessary that the initial baseline measurements that fugitive emissions are compared against are undertaken by a reputable and trustworthy research organization (CSIRO) before gas industry activities take place and that these results are independent and transparent to the public (through the CSIRO GISERA independent reporting process).

This research project represents important steps that will acquire data and provide knowledge to ensure these aspirations can be met. It will provide independent, trusted, publicly available baseline data for an extended period before operations begin which is important to assuage community concerns regarding the potential impacts of the gas industry on relevant greenhouse gas emissions.

Methodology

In the Beetaloo sub-basin a range of background sources of methane are expected. These include natural sources such as fires, natural geological seeps and wetlands, and, anthropogenic sources such as water bores and from existing mineral and petroleum wells. These sources are disparate in spatial size, concentrations, and some are seasonal and dynamic. For example, water bores and mineral and exploration wells are expected to be small both spatially and in concentrations while the emissions related to fires are expected to be spatially large and are seasonal. Natural geological seepages are expected to be small both spatially and in concentrations but possibly dynamic. We propose the use of two complementary methods below which in total allows us to capture as much as possible the variability described: mobile and fixed site surveys.

i. Mobile surveys

The core method to be relied on for this project is mobile survey. The use of mobile surveys for collecting Northern Territory baseline methane data is the most effective and practical method deployable in the 6 months between July 2018 and March 2019. It is proposed that three mobile surveys of 10-14 days for each trip occurs across the dry (July - August 2018), fire (September - October 2018) and wet (December 2018 – January 2019) seasons. For each of these surveys, up to 2000 km of trafficable roads/track will be covered and up to 50 known sources will be surveyed. It is expected that a comprehensive number of the areas and known sources can be covered during the dry season. However, during the wet season, it is expected that access will be limited and measurements will predominantly be directed towards broad-scale landscape background monitoring.

Background data compilation before the survey

The team will need to compile maps of national roadworks and tracks, geographic location and identities of water bores, minerals and petroleum exploration wells and any known position of natural geological seepages for the campaign area.

- Design and plan campaign to cover the interest area based on an estimation that 3-5 wells can be surveyed per day across the terrain in the Beetaloo sub-Basin and up to 200 km of trafficable (sealed and unsealed tracks) roads per day.
- Upload information into GPS for roads, tracks, water bores, mineral and petroleum exploration wells and location of natural seepages.
- Prepare field record sheet - for each day's work.
- Ensure all operators have read and signed Standard Operating Procedures (SOPs) for the operation of the PICARRO G2201-I and/or the LGR Ultraportable, 100 Ah gel batteries, and D-size gas cylinders.

Preferred travel times and study sites can be confirmed once future exploration and production locations are confirmed with industry.

Instrumentation

The mobile surveys will be performed using a PICARRO G2201-i $CO_2/CH_4/H_2O$ analyser (PICARRO) and/or a Los Gatos Research (LGR) Ultraportable $C_2H_2/CH_4/H_2O$ Gas Analyser mounted in a four-wheel drive vehicle. The performances of both these instruments are similar with resolutions of approximately 1 part per billion (ppb), which enables very small sources to be reliably detected. It is likely that both instruments will be used during the surveys. There are complementary advantages to both instruments.

The LGR measures CH_4 (methane) and C_2H_2 (acetylene) simultaneously. The advantage of the C_2H_2 capability is the ability to use C_2H_2 as a tracer for estimating the emission rate. Using such a method it is expected that an uncertainty of less than ±10% can be achieved (higher accuracy can be achieved using this method because the flux is directly related to the tracer flux and does not rely on assumptions related to plume modelling inherent in the plume traverse methods described below). Additionally, for the estimation of emission rates, the tracer method using the LGR instrument is more versatile as ideal meteorological conditions are not required. Therefore, this is the preferred option for quantifying fluxes.

In some situations, if access to CH_4 plumes from these sources are limited but access to surrounding areas are available and the meteorological conditions are favourable, it is possible to estimate the emission rate from the sources using the plume traverse method. Experience from previous studies indicate that the uncertainties with this method is greater than ±30%. Both the LGR and the PICARRO can be used to perform plume traverse measurements.

The PICARRO measures CH_4 and CO_2 simultaneously. In sufficient concentrations, the isotopic carbon ratio in both CO_2 and CH_4 can be measured at the same time by the PICARRO.

ii. Fixed sites – using flux Chambers and hybrid fixed atmospheric monitoring stations

A second method to be used is an autonomous methane analyser measuring soil flux and atmospheric concentrations. CSIRO has prototyped an autonomous monitoring system measurement of methane fluxes suited for remote area deployment. The deployment of such a system is proposed at a site where exploration is expected to commence within the next year in order to fully capture background baseline fluxes at these locations before exploration work commences. The intent of this deployment is to capture the natural temporal variations in the background soil fluxes and atmospheric concentrations for an extended period before any industry activity.

One of the most versatile and accurate methods for measuring CH_4 emission rates from ground sources is by static surface flux chambers. This method has high sensitivity and can reliably measure even low fluxes encountered in natural systems but also has the capacity to measure high flux rates. By making a series of closely spaced flux measurements on surfaces emitting CH_4 the spatial distribution of the emission source can be accurately mapped. In contrast to ambient concentration measurements, surface flux chambers yield emission flux data for ground sources. A key advantage of the flux chamber method is that it has the sensitivity to detect even very small changes in ground emissions that may be associated with drilling activities or leaking casings.

There are various designs available but essentially, all operate by enclosing an area of soil, A, by placing a chamber of known volume, V, on the ground surface and measuring the concentration of CH_4 (or other gas) within the chamber over time. Flux chamber measurements are mostly made in the 'static' mode where the gas concentration within the chamber is measured over a period of time. Since there is no exchange of air with the outside atmosphere, the methane concentration increases as gas flows from the soil into the chamber during the course of the experiment. By measuring the rate of change of concentration, dC/dt, the gas flux per unit area, F, can be calculated according to Equation 1.0.

$$F = \frac{dC}{dt} \times \frac{V}{A}$$

Eq 1.1

For high flow situations, flux chambers may also be operated in a flow through mode where a stream of diluent gas is passed through the chamber at a known rate, f. In this mode, the steady state concentration of the gas is measured and the flux is calculated by Equation 1.1.

$$F = (Cout - Cin) \times \frac{f}{A}$$

Eq 1.2

where C_{out} is the gas concentration in the outlet flow from the chamber and C_{in} is the gas concentration in the inlet flow.

Historically, flux chambers have been deployed manually, and the technique does require a relatively large number of individual measurements, which may be time consuming and labour-intensive. However, CSIRO has developed an automated system comprising multiple flux chambers which is operated remotely allowing measurements to be made continuously over time to capture data across a discrete area. Where the location of future wells is known, such a system would be valuable to be deployed at these locations to measure the natural variation of methane fluxes for an extended period before industry activity commences.

The emission flux data for ground sources provided by the flux chambers is appropriate for natural background variations of methane. The publication of these and future data is a transparent means of assessing whether any leakage may come from the infrastructure in the future. CSIRO has developed the ability to undertake additional atmospheric measurements together with associated meteorological stations for future monitoring of methane at these sites.

5. Project Inputs

Research

Mobile survey technology, deploying highly precise and accurate methane analysers, able to measure down to parts per billion (ppb) levels, are one of the most widely used, reliable and well-developed methods for undertaking baseline measurements of methane fluxes in landscapes. Campaign style deployment of mobile surveys over time allow for accurate monitoring of methane emission under conditions which preclude immediate deployment of *in-situ* monitoring stations; such as remote regions of Australia where reliable power supply, temperature controlled instrument storage and easy access are lacking.

Mobile survey methods involve the use of state of the art methane analyser technologies, usually cavity ring down spectroscopy (CRDS), Off-Axis Integrated Cavity Output Spectroscopy (OA-ICOS), and, direct absorption Tunable Diode in a vehicle or other platform that is driven across the landscape to continuously measure ambient methane concentrations. This system has been used previously to locate and quantify methane sources and fluxes both in Australia and overseas (LTE, 2007; Phillips et al., 2013; Day et al., 2015; Day et al., 2016; Johnson & Heltzel, 2016; Ong et al., 2017; Feitz, et al. 2018). Recent advances in gas analysers have resulted in commercially available systems with sensitivity of around 1 ppb and high levels of stability so that the instruments can be used routinely in a mobile arrangement (Crosson, 2008).

Mobile surveys, limited to vehicle access areas and subject to meteorological conditions, are suitable for understanding at a very fine spatial scale the background concentrations of methane. The ability to travel over many thousands of kilometres enable broadscale measurement programs to be undertaken. These methods have been proven effective for the quantification of a range of methane sources particularly where the emission rates are very low such as water bores and gas wells (abandoned and operational) and known geological sources of natural seepages in studies completed by CSIRO in Queensland, New South Wales, Western Australia and Victoria. Concentration data from surveys, when combined with spatial and metorological data, and processed in GIS software allow the development of detailed maps of methane concentration as a function of location. It is important that concentration and meteorological measurements are made in the same location to enable interpretation of data to derive fluxes. Concentration measurements on their own do not provide information on emission rates of sources. CSIRO has been actively conducting research and development over many years of mobile survey methane monitoring technology, along with flux tower, bulk atmospheric concentration measurements, inverse atmospheric transport methods and remote sensing technology for application in the oil and gas industry. These later techniques require greater investment of time and money making them more suitable for longer campaigns but face considerable logistical difficulties in remote area applications such as in the Beetaloo Basin. CSIRO's mobile survey methods include plume traverse and modelling studies, the use of tracers and flux chambers deployed according to requirements and suitability. These later methods are suitable for robust, rapid deployment into the field while monitoring stations can be established. They also provide an additional means of interrogating signals detected by fixed monitoring stations thereby establishing cause of methane flux.

Resources and collaborations

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Cindy Ong	46 days	Fugitive Emissions Measurement & Monitoring, Remote Sensing	20+	CSIRO
Stuart Day	10 days	Fugitive Emission Measurement and Monitoring	30+	CSIRO
Alf Larcher	12 days	Chemistry	30+	CSIRO
Mederic Mainson	15 days	Data Processing, Sensors	10+	CSIRO
Bruce Maney	40 days	Engineering, Logistics	20+	CSIRO
David Downs	14 days	Engineering Technician	10+	CSIRO
Matthew Myers	21 days	Sensors, Engineering	15+	CSIRO

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

Budget Summary

Source of Cash Contributions	2017/18	2018/19	2019/20	% of Cash Contribution	Total
NT Government	-	$**305,297**	-	100%	$**305,297**
Total Cash Contributions	**-**	**$305,297**		**100%**	**$305,297**

Source of In-Kind Contribution	2017/18	2018/19	2019/20	% of In kind Contribution	Total
CSIRO	-	$0	-	0%	$0
Total In-Kind Contribution	**-**	**$0**	**-**	**0%**	**$0**

Note: As agreed in special condition 12.2 of the Funding Agreement Schedule between CSIRO and Northern Territory Government (NTG), this project will be fully funded by the NTG with CSIRO to issue an invoice to the NTG.

Cultural Monitoring Program

The cultural monitor program is considered mutually beneficial, increases engagement and participation of the local traditional owners and provides additional safeguards against the research proponent or other fieldworkers inadvertently entering into a sacred site or other culturally sensitive area. Cultural monitors are engaged via the NLC whenever a company or operator goes out in the field.

In GISERA projects where CSIRO researchers are being escorted onto leases by company representatives who have organised permit access, those company procedures will apply.

For all other GISERA projects (particularly environmental and social projects) where CSIRO researchers are not being escorted by industry, CSIRO will work with the NLC to apply this practice.

6. Project Impact Pathway

Activities	Outputs	Short term Outcomes	Long term outcomes	Impact
Dry season survey	Map of concentration of methane across the general study area and location of significant sources found.	General understanding of the background ambient methane levels across the Beetaloo sub-basin for the dry season in 2018, identification of the major drivers for methane emissions during this season	• The scientifically defendable data collected will be crucial in the long term to understand impacts from the industry allowing stakeholders such as regulators, operators and the community the ability to make informed decisions. • Data will inform regulators and is aligned with the recommendations of the fracking inquiry and therefore assist regulators and operators inform policy and decision making and operators satisfy their regulatory requirements.	*Environmental Impacts* • Provide scientific understanding of the seasonal variability of methane concentrations in the Beetaloo sub-basin contributing to crucial pre-exploration baseline data. • Generally, such comprehensive data have largely not been available in Australia hence such data will contribute significantly to scientific understanding of natural methane levels in general and in future more accurately quantify the impacts from the industry. *Economic Impacts* • This project will build the basic building blocks for a guideline/protocol for routine acquisition of methane concentration and fluxes. It is envisaged that CSIRO will be working closely with the local community to implement the final guidelines/protocols in the long term.
Fire season survey	Maps of concentration of methane across study area, measurement of significant sources found in previous survey, comprehensive measurements of concentrations and soil fluxes for targeted areas requested by operators.	Understanding of the background ambient methane levels across the Beetaloo sub-basin for the fire season in 2018, identification of the major drivers for methane emissions during this season, quantification background methane flux levels for targeted pre-exploration areas		
Wet season survey	Maps of concentration of methane across study area.	Understanding of the background ambient methane levels across the Beetaloo sub-basin for the wet season in 2018, identification of the major drivers for methane emissions during this season		
Final Report	Final report comprehensively describing the methodologies used, results, interpretation and recommendations for the future.	Understanding of the seasonal variability and identification of the significant sources of emissions in the Beetaloo sub-basin		

7. Project Plan

Project Schedule

ID	Activities / Task Title (should match activities in impact pathway section)	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Dry season survey	Cindy Ong	July 2018	August 2018	
Task 2	Fire season survey	Cindy Ong	September 2018	November 2018	
Task 3	Wet season survey	Cindy Ong	December 2018	January 2019	
Task 4	Final Report	Cindy Ong	February 2019	March 2019	Task 1, 2, 3

Task description

Task 1

TASK NAME: Dry season survey

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: July - August 2018

BACKGROUND: This initial survey during the dry season is to gain a high-level understanding of the ambient methane level for the region and to identify and quantify emissions detected during the survey.

TASK OBJECTIVES: To acquire comprehensive methane concentration measurements across trafficable area and to survey potential sources of emissions such as water bores, mineral and petroleum exploration wells, geological seepages and others and where detected to identify and quantify emissions.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

1. Maps of concentrations of methane along routes travelled and sites visited and location and levels of emissions quantified (if any).
2. Short report summarising findings of survey, an inventory of sources visited and quantification of those and general ambient values throughout the survey to be delivered 1 month after completion of survey.

Task 2

TASK NAME: Fire Season survey

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: September-November 2018

BACKGROUND: This survey is to acquire ambient background methane levels with a focus on understanding sources related to fires and biomass burning. Where practicable, CSIRO will also acquire measurements as guided by operators during this survey and may test the deployment of an automated flux measurement system at a targeted location where operations will occur in the near term. Here, it is expected that requesting operators will assist in obtaining the permissions to access the sites, providing the necessary guide and where not trafficable by 4WD, will transport the necessary personnel and equipment to the site and provide any necessary OSHE and other training required to perform the work at these sites. Where overnight accommodation is required, the requesting operator is also expected to accommodate the CSIRO personnel involved in the work. It must be noted that there will be opportunity where practicable to conduct surveys in areas where operator has requested specific measurements.

TASK OBJECTIVES: To understand the methane emissions resulting from fire and acquire measurements in greenfields areas.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

1. Maps of concentrations of methane along routes travelled and sites visited and location and levels of emissions quantified (if any).

2. Short report summarising findings of survey, an inventory of sources visited and quantification of those and general ambient values throughout the survey to be delivered 1 month after completion of survey.

Task 3

TASK NAME: Wet season survey

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: December 2018 - January 2019

BACKGROUND: Survey to acquire ambient background methane levels for the wet season. During the wet season, it is expected that access will be limited and measurements will predominantly be directed towards broad-scale landscape background monitoring.

TASK OBJECTIVES: To understand the background methane levels during the wet season

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

1. Maps of concentrations of methane along routes travelled and sites visited and location and levels of emissions quantified (if any).
2. Short report summarising findings of survey, an inventory of sources visited and quantification of those and general ambient values throughout the survey to be delivered 1 month after completion of survey.

Task 4

TASK NAME: Final Report

TASK LEADER: Cindy Ong

OVERALL TIMEFRAME: February – March 2019

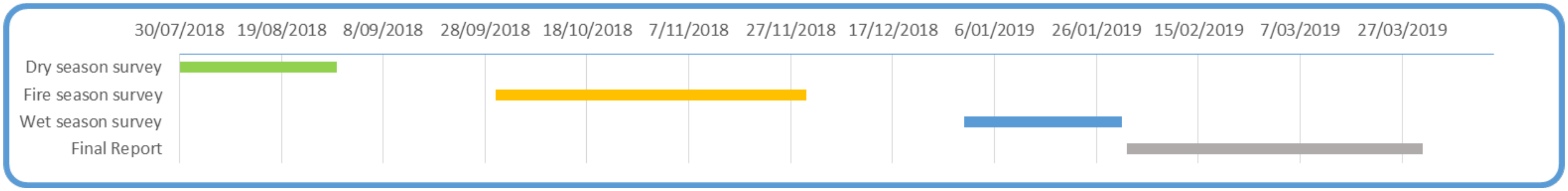
BACKGROUND: A final report will be produced that describes the methodologies used, results including an inventory of sources visited and quantification of those and general ambient values throughout the survey, interpretation and recommendations for the future.

The report will include the results from all the mobile surveys completed in the Beetaloo sub-Basin region to quantify the current background levels of methane in the study area. In time, the baseline formed can be used to assist understanding the magnitude of emissions from gas development along with other sources in the region.

TASK OBJECTIVES: To document methodologies and findings from the study

TASK OUTPUTS AND SPECIFIC DELIVERABLES: Final report comprehensively describing the methodologies used, results, interpretation and recommendations for the future.

Project Gantt Chart



8. Technical Reference Group

A range of subject matter experts from government and industry will be invited to participate in the technical reference group that have strong levels of experience in compiling and calculating GHGs, developing and delivering GHGs inventories, developing protocols for data and operational knowledge of natural gas assets and their operational processes, or the landscapes and the systems these assets are likely to operate in.

9. Communications Plan

Stakeholder	Objective	Channel	Timeframe
Government and Industry	To facilitate a deeper understanding of research findings and implications for policy, programs, planning, and other initiatives	Knowledge transfer session that includes various locations in the NT (e.g. Darwin, Katherine and surrounds) with options to dial-in via videoconference or phone.	Towards completion
Regional Community / Wider public	To communicate project objectives and key messages from the research and to document methodologies and findings from the study	Fact sheets (including development of one at commencement of project which will explain the objective of the project – this will be updated periodically as project progresses).	From commencement of project and with updates as they come to hand.
		Project progress reported on GISERA website to ensure transparency for all stakeholders including regional communities.	As required
		Participation in roadshows, community workshops and meetings and other engagements where appropriate.	As required
		Maps and visuals - Key findings communicated with the use of maps and visual cues incorporated.	Towards completion
		GPS coordinates of locations surveyed and measurements collected (georeferenced data placed on google earth) will be made publically available.	At completion
		Final report comprehensively describing the methodologies used, results, interpretation and recommendations for the future.	At completion
Traditional Owner communities	To pursue relations with Traditional Owner communities (via cultural monitors)	Engagement with TO communities – as a wider context as part of CSIRO communications (considered mutually beneficial)	Ongoing

10. Budget Summary

Expenditure	2017/18	2018/19	2019/20	Total
Labour	-	$244,947	-	$244,947
Operating	-	$60,350	-	$60,350
Subcontractors	-	-	-	-
Total Expenditure	-	**$305,297**	-	**$305,297**

Expenditure per Task	2017/18	2018/19	2019/20	Total
Task 1	-	$100,622	-	$100,622
Task 2	-	$87,533	-	$87,533
Task 3	-	$62,828	-	$62,828
Task 4	-	$54,314	-	$54,314
Total Expenditure	**-**	**$305,297**	-	**$305,297**

Source of Cash Contributions	2017/18	2018/19	2019/20	Total
NT Government (100%)	-	$305,297	-	$305,297
Total Cash Contributions	**-**	**$305,297**	**-**	**$305,297**

In-Kind Contribution from Partners	2017/18	2018/19	2019/20	Total
CSIRO (0%)	-	-	-	-
Total In-Kind Contribution from Partners	**-**	**-**	**-**	**-**

	Total funding over all years	Percentage of Total Budget
NT Government Investment	$305,297	100%
CSIRO Investment	$0	0%
TOTAL	**$305,297**	**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	Dry season survey	CSIRO	July 2018	August 2018	2018/19	$100,622
Task 2	2.1	Fire season survey	CSIRO	September 2018	November 2018	2018/19	$87,533
Task 3	3.1	Wet season survey	CSIRO	December 2018	January 2019	2018/19	$62,828
Task 4	4.1	Final Report	CSIRO	February 2019	March 2019	2018/19	$54,314

11. 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="4">Commercialisation Interest (clause 1.1)</td><td colspan="2">Party</td><td colspan="2">Commercialisation Interest</td></tr>
<tr><td colspan="2">CSIRO</td><td colspan="2">Not applicable</td></tr>
<tr><td colspan="2">Origin</td><td colspan="2">Not applicable</td></tr>
<tr><td colspan="2">Santos</td><td colspan="2">Not applicable</td></tr>
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12. References

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APPENDIX 1 – STEPS REQUIRED TO COMPLETE MOBILE CAMPAIGN

Start-up and checks before campaign each day

1. Each day, start up the PICARRO and/or LGR one hour before the day's field work is scheduled to start. Check all connections between PICARRO and/or LGR, pump, GPS, power, and air inlet operating accordingly.
2. Perform calibration of the analyser using the references gases to check for drifts (For the PICARRO we have a 3 ppm CH_4 / 500 ppm CO_2 and 10 ppm CH_4 / 1000 ppm CO_2 standards. For the LGR we have 1 ppm CH_4 / 1 ppm Acetylene and a 4 ppm CH_4 / 4 ppm Acetylene standards).
3. Note the daily calibration results in the calibration spreadsheet (Calibration_record.xlsx) saved on the laptop.
4. Ensure that the gases are secure and upright at the back of the ute, the analyser is secured on the back seat or the boot of the vehicle and the air intake valve is secured outside the vehicle.
5. Proceed to study area along roads and tracks as planned. A driver and an instrument operator will be required in the vehicle. Ensure the recorder has the laptop set up ready to monitor results with all appropriate windows open (VNC viewer, blank Notepad file already saved in desired location) and printed record sheets ready. The instrument operator will observe the CH_4 levels on the laptop/tablet screen as you travel along and direct the driver based on the measurements on the screen.

During each day's field campaign

6. Drive safely, maintaining sign posted speed limit (or under).
7. A vehicle mounted sonic anemometer will be used during the survey. However, due to the uncertainties in the measurement when the vehicle is moving, the procedure is to stop every 30 minutes where practicable to take a wind reading. A suggestion would be for the recorder to set a reminder using the phone alarm for every 30 minutes.
8. Each time the vehicle is stopped for a wind reading (leaving engine running), record the time, location, GPS, wind speed and direction and current CH4 and CO2 concentrations at the time. Save this spreadsheet on the laptop (Location_wind_flux_record.xlsx) or on a hardcopy.
9. When a large peak (for example ~3 ppm above a background of 1.8 ppm detectable from a moving vehicle travelling at or below the speed limit) is detected, stop, identify source of peak and perform quantification of emission rates from source if possible. The source may be cows, cattle trucks, biomass burns, termite mounds, springs, water bores, mineral and petroleum exploration bores. The two methods of performing quantification and method for doing them are outlined below. (Note that the preferred method for undertaking the emission quantification would be the tracer method where practicable).
    a. Plume traverse (PICARRO or LGR if cannot locate source)
        i. Record time, background concentration, maximum peak and approximate distance from source, wind, temperature and other environmental condition as set out on the field record sheet.

ii. Perform at least 6 traverses across the plume at slower speeds, ensuring safety at all times.

b. Tracer release (LGR)

i. Drive around the source. While doing the drive around record the time, background concentrations before the peak was detected, maximum peak recorded while doing the drive around, and approximate distance the peak was from source as set out on the field record sheet.

ii. Stop approximately where peak is detected. Set the acetylene down at the approximate location of the peak and turn on. Check the flow rate of the acetylene.

iii. Record the wind, temperature and other environmental condition as set out on the field record sheet. Depending on the wind condition, wait in the vehicle at an appropriate distance (10-200 m) downwind from the source/acetylene. The instrument operator will need to make a judgment on the distance based on the wind condition.

iv. Observe the CH_4 and acetylene trace. A well-mixed plume is achieved when the shape of the CH_4 and acetylene trace resemble each other. Preferably, observe 2-3 of such cases before ending the measurement.

After each day's campaign

10. Perform another calibration run and record the calibration results.
11. Download the data from the PICARRO and/or LGR and the GPS onto a USB.
12. Shut down the instrument(s) following the shutdown procedure in the PICARRO and/or LGR SOPs and turn off the vehicle
13. Put batteries on charge for the night
14. Combine the PICARRO concentration and GPS data. With LGR the LGR and GPS are sync so this is not required.
15. Make sure all records are complete and clean.
16. Data from the methane analysers and GPS will be digital recorded but any metadata or any associated information recorded on hard copy should be transcribed to digital format and added to the datasets.
17. Ensure that all digital data have been back-up on file.

After completion of the entire campaign

18. Download climate data (temp and wind most important) from the nearest BOM stations for the days of the complete campaign (http://www.bom.gov.au/climate/dwo/IDCJDW8013.latest.shtml). The installation of a semi-permanent met stations at specific locations may be considered in future stages of the project.
19. Turn the combined data into a KML file using a script.
20. Plot data into Google Earth including any relevant metadata pertaining to the measurements where relevant.