Project Order
Proforma 2013

1. Short Project Title (less than 15 words)

Hydrocarbons in groundwater, Surat and Bowen Basins

Long Project Title	Review of dissolved hydrocarbons in groundwater in the Surat and Bowen Basins
GISERA Project Number	W5
Proposed Start Date	Oct 2014
Proposed End Date	Sep 2015
Project Leader	Grant Douglas / Richard Schinteie

2. GISERA Research Program

☐ Biodiversity Research	☐ Marine Research	☐ Land Research
☒ Water Research	☐ Social & Economic Research	☐ GHG Research

3. Research Leader, Title and Organisation
(Include time commitment to project by the Research Leader)

Grant Douglas
CSIRO Land and Water
Floreat, WA
0.38 FTE

4. Summary

This research proposal relates to carrying out a review and evaluating existing open source and company held data on the presence of organic compounds in groundwater in the Surat and Bowen Basins, Queensland. The study will include assessments of the relationships of

the compounds with geological setting, coal characteristics, hydraulic fracturing and related drilling fluids, and where relevant any correlation with seeps or microbial processes. Equal emphasis will be placed on the volatile, partially water-soluble volatiles, semi-volatile and water soluble hydrocarbons (HCs) and organic compounds, found in sedimentary basins (i.e. aliphatic HCs, TPH (Total Petroleum Hydrocarbons), BTEX and PAHs (Benzene, Toluene, Ethyl benzene, Xylenes; Poly Aromatic Hydrocarbons) and phenols); particularly if they are a potential compound of concern and for which the companies will have relevant available data. Acquiring and interpreting comprehensive datasets on water compositions, and consequently increasing scientific understandings of the entire chemical/ geological/ hydrogeological systems will inform public discussion of water quality and the complexities involved. The broad-based, integrated approach should allow insights to be made into the complex interactions involved in sedimentary basins, aquifers and coal seam gas (CSG) related water production. To meet these requirements, the research program involves chemistry, organic geochemistry, petrology, coal geology, physics/petrophysics, hydrology, hydrogeochemistry and hydrogeology to understand the interaction of sedimentary strata including organic rich strata, with water and gases at depth. The research objectives are:

1. To collate and provide a summary, of the available information on existing hydrocarbons in groundwater in the Surat and Bowen Basins, Queensland leading to,
    a. A robust and scientifically defensible data set and interpretations to support the research conclusions,
    b. Context and potential explanations for possible future detection and reporting of hydrocarbons during compliance monitoring programmes.
2. Outline strategies related to differentiation of naturally occurring hydrocarbons and those inadvertently introduced during drilling, completion and hydraulic stimulation.
3. Interpretations on possible sources of the hydrocarbons encountered based on previous studies and new information gained in the proposed study.

The study will focus on the CSG production zones, as well as other Great Artesian Basin formations commonly utilised as aquifers and considered significant groundwater resources.

The study involves the Surat and Bowen Basins but will draw on knowledge gathered from other Australian and international basins where relevant.

All hydrocarbon compounds of concern (TPHs, BTEX and PAHs) will be considered as well as phenols, for which concerns also exist, subject to data availability.

Two phases of work and reporting are proposed:

- Phase 1: Review of existing literature and supplied data relating to the occurrence of dissolved hydrocarbons and other organic compounds in the Surat and Bowen Basins.
- Phase 2: Review of any additional sampling/monitoring data acquired by the sponsors, statistical analysis of the data, interpretation and final report. Through GISERA, a comprehensive communications plan supporting the public release of the report will be prepared and executed.

5. Budget Summary (From Excel Budget Pack worksheet "Project Plan Summary")

Expenditure	2011/12	2012/13	2013/14	2014/15 Year 1	2015/16 Year 2	Total
Labour				489,309	16,772	506,081
Operating				65,700	0	65,700
Total Costs				**555,009**	**16,772**	**571,781**
CSIRO						
Total Expenditure				**555,009**	**16,772**	**571,781**

Expenditure per Task	2011/12	2012/13	2013/14	2014/15 Year 1	2015/16 Year 2	Total
Task 1				284,092	6,194	290,286
Task 2				270,917	10,578	281,495
Total Expenditure				**555,009**	**16,772**	**571,781**

Cash Funds to Project Partners	2011/12	2012/13	2013/14	2014/15 Year 1	2015/16 Year 2	Total
CSIRO				388,507	11,740	400,247
Sub Total						
Total Cash to Partners				388,507	11,740	400,247

Source of Cash Contributions	2011/12	2012/13	2013/14	2014/15 Year 1	2015/16 Year 2	Total
GISERA				388,507	11,740	400,247
Total Cash Contributions				388,507	11,740	400,247

In-Kind Contribution from Partners	2011/12	2012/13	2013/14	2014/15 Year 1	2015/16 Year 2	Total
CSIRO				166,502	5,032	171,534
Total In-Kind Contribution from Partners				166,502	5,032	171,534

	Total funding over all years	Percentage of Total Budget
GISERA Investment	400,247	70%
Total Partner Investment	171,534	30%
Total Other Investment		
TOTAL	571,781	100%

Task	Milestone Number	Milestone Description	Funded by	Participant Recipient	Start Date (mm-yy)	Delivery Date (mm-yy)	Fiscal Year	Fiscal Quarter	Payment $
Task 1	1.1	Literature review on interactions involved in sedimentary basins, aquifers and coal seam gas (CSG) related water production.	GISERA	CSIRO	Oct 14	Mar 15	14/15	3	-
	1.2	Summary of available information on existing hydrocarbons in groundwater in the Surat and Bowen Basins, Queensland	GISERA	CSIRO	Oct 14	Mar 15	14/15	3	-
	1.3	Stage 1 Report	GISERA	CSIRO	Mar 15	Mar 15	14/15	3	203,200
Task 2	2.1	Statistical analyses and interpretation of the data.	GISERA	CSIRO	Apr 15	Sep 15	15/16	1	-
	2.2	Provide strategies to differentiate naturally occurring hydrocarbons and those inadvertently introduced during drilling, completion and hydraulic stimulation.	GISERA	CSIRO	Jul 15	Sep 15	15/16	1	-
	2.3	Provide interpretations on possible sources of the hydrocarbons encountered based on previous studies and new information gained in the proposed study.	GISERA	CSIRO	Jul 15	Sep 15	15/16	1	-
	2.4	Final report	GISERA	CSIRO	Aug 15	Sep 15	15/16	1	197,047

6. Other Researchers (include organisations)

Researcher	Time Commitment (project as a whole)	Principle area of expertise	Years of experience	Organisation
Stephen Sestak	0.18	Organic and Isotope Geochemistry	10	CSIRO
Richard Schinteie	0.28	Geology and Organic Geochemistry	10	CSIRO
Kaydy Pinetown	0.21	CSG, Coal Geology, Organic Petrology, GIS	12	CSIRO
Christine Trefry	0.23	Data sets, Databases, GIS data	12	CSIRO
Colin Johnston	0.05	Pollutant Fate and Remediation	30	CSIRO
Trevor Bastow	0.10	Analytical chemist	15	CSIRO
Grant Douglas	0.18	Geochemist	25	CSIRO
Petra Kuhnert	0.20	Statistician	11	
Wendy McLean		Consultant: Hydrogeologist, Hydrogeochemist	10	EMGA Mitchell McLennan

7. GISERA Objectives Addressed

Carrying out of research and improving and extending knowledge of social and environmental impacts and opportunities of CSG-LNG projects for the benefit of the CSG-LNG industry, the relevant community and the broader public.

Informing government, regulators and policy-makers on key issues regarding policy and legislative framework for the CSG-LNG industry.

8. Program Outcomes Achieved

See section 13

9. Program Outputs Achieved

Details are provided in *Section 15. Project Objectives and Outputs*

10. What is the knowledge gap that these research outputs will address?

There are currently limited strategies to differentiate naturally occurring hydrocarbons and those potentially introduced during drilling, completion and hydraulic stimulation. This project will integrate complex interactions involved in sedimentary basins, aquifers and coal seam gas (CSG) related water production to provide information and strategies to assess possible sources of the hydrocarbons encountered.

11. How will these Research outputs and outcomes be used in State Government and other water managers to achieve Adaptive Management of Water Resources?

The research outputs and outcomes will help to inform government, regulators and policy-makers on key issues regarding policy and legislative framework for the CSG-LNG industry, particularly in the area of differentiating naturally occurring hydrocarbons and those potentially introduced during drilling, completion and hydraulic stimulation.

12. Project Development (1 page max.)

The project was developed in consultation between Australia Pacific LNG (Ned Hamer and Mohinudeen Faiz), QGC (BG Group) (Craig Noble, Alan Davie), Santos (Antony Volcich), Arrow Energy (St John Herbert) and CSIRO.

Naturally occurring dissolved organic compounds such as hydrocarbons and phenols have been detected in sedimentary basins in Australia and elsewhere. In some cases these hydrocarbons occur in volumes commercially viable for production, but in other areas they occur in only trace amounts in groundwater (e.g. below drinking water guidelines) or are not detectable at all. Potential exists for inadvertent introduction of hydrocarbons during drilling and completion of CSG production wells, water production wells, and groundwater monitoring bores or, in all cases, from leaking well casings. A need exists to collate all existing information on hydrocarbon and organic compound presence in the Surat and Bowen Basins, and gather additional data (including green-field baseline data) to ensure that a scientifically defensible explanation for the possibility of encountering hydrocarbons in groundwater during CSG exploration and production programs is readily available.

The majority of organic matter in coal is derived from lignin, but some originates from other material such as carbohydrates which have been highly modified; polymerised terpenes and other alkenes (Wilson, 1994) and lipids. The constituents of coal are essentially aromatic in structure and the water soluble components of coal are also aromatic compounds (Van Krevelen, 1994). BTEX and other aromatic hydrocarbons are components in many, but not all, coal deposits. In a range of coal and shale occurrences from across the USA, aromatic compounds have been detected at concentrations of >0.01% of the bulk material in 70% of

the samples (Li et al., 1997). Mono cyclic aromatic hydrocarbons are volatile and partially soluble in water; for example, the solubility of benzene in water is about 1700 mg/L. The other BTEX HCs have progressively lower water solubilities due to the more hydrophobic nature imparted by the aliphatic substituents on the core benzene ring nucleus. Similarly, polycyclic aromatic hydrocarbons progressively become insoluble in water as the number of fused benzene rings increase.

The organic hydrochemistry of groundwaters associated with coals can include a wide variety of oxygen-bearing aromatic hydrocarbons (e.g. phenols, aldehyes, ketones and various carboxy-, hydroxyl- and methoxy-bearing compounds), nitrogen-bearing compounds (pyridines and amines), mono- and polycyclic aromatic hydrocarbons and aliphatic compounds (Santamaria and Fisher, 2003). These water-soluble organics are produced by the cleavage of the aromatic structures within the coal matrix either by thermal stress accompanied by burial, igneous intrusions, chemical oxidation during burial, or as the consequence of the introduction of oxygenated water or air. Coals can also be solubilised to a limited extent by microorganisms (Klein et al., 2001).

In relation to produced hydrocarbons from CSG, most gas samples are dominated by methane with smaller amounts of carbon dioxide and nitrogen. In a small percentage of samples however, traces of longer chain hydrocarbons (e.g. ethane, propane, butane, oil shows or oil seeps) have been detected.

CSIRO previously completed a desk top literature review for AGL which focussed on Permian basins in NSW. A desktop study of the occurrence of Total Petroleum Hydrocarbon (TPH) and partially water-soluble organic compounds in Permian coals and associated coal seam groundwater. This document provides some terms of reference for a similar study for the Surat and Bowen Basins.

Klein, J., Fakoussa, R.M., Holker, U., Hofrichter, M., Schmiers, H., Sinder, C. and Steinbuche, A. 2001. Biotechnology in coal. Biotechnology Vol.10, Rehm, H.J. (Ed.). VCH-Wiley, Frankfurt.

Li, W, Lazar, I.M., Wan, Y.J., Butala, S.J., Shen, Y., Malik, A., Lee, M.L. 1997. Determination of volatile hydrocarbons in coals and shales using supercritical fluid extraction and chromatography. Energy and Fuels: 11, 945-950.

Santamaria, A.B. and Fisher, J. 2003. Dissolved organic constituents in coal-associated waters, and implications for human and ecosystem health. Toxicological Sciences: 72, 396-397.

Tissot, B.P., Welte, D.H., 1984. Petroleum formation and occurrence, 2nd edition, 699 pp, Springer, Berlin.

Wilson, M.A., 1994. The role of hydrogen in coal. Proceedings of the 6th Australian coal science conference: 17-19th of October 1994, Newcastle (Australia).

Van Krevelen, D. W. 1993. Coal: Typology, physics, chemistry, constitution 1993. Elsevier, Amsterdam.

13. Project Objectives and Outputs

The research objectives are:

- To collate and provide a summary, of the available information on existing hydrocarbons in groundwater in the Surat and Bowen Basins, Queensland leading to,
    - A robust and scientifically defensible data set and interpretations to support the research conclusions,
    - Context and potential explanations for possible future detection and reporting of hydrocarbons during compliance monitoring programmes.
- Outline strategies related to differentiation of naturally occurring hydrocarbons and those inadvertently introduced during drilling, completion and hydraulic stimulation (e.g. stable isotopic fingerprinting of the hydrocarbons could assist with delineating coal derived hydrocarbons versus 'refined' petroleum derived hydrocarbons).
- Interpretations on possible sources of the hydrocarbons encountered based on previous studies and new information gained in the proposed study.

This project aims to develop a baseline composition of hydrocarbons in the Surat Basin, Queensland, that will form the basis of ongoing monitoring, reporting and compliance procedures thereby providing a sound basis for understanding natural and induced variations. In addition it will provide a rationale and recommendations for future hydrocarbon water quality sampling for inclusion in CSG companies' monitoring programmes and the findings will serve as a useful input to future production water treatment and 'beneficial use' studies.

Two phases of work and associated reporting are envisioned:

Phase 1 (Duration: 6 months from the receipt of all data from the 4 companies): transfer of water quality electronic data held by the participating companies and subsequent conversion to a central CSIRO database (Microsoft Access or Excel) to allow efficient storage and retrieval of the large sets of data. Access, Excel or CSV files will enable suitable compatibility with company databases and systems. With the likelihood of inconsistencies between databases, location maps, well completion reports and labelling, cross-matching of data will be required to achieve a consistent data set; this will most likely involve visits to the four companies to resolve mismatches in data. CSIRO will liaise with Dr Sue Vink (UQ) on the Water Atlas Research work to identify potential sharing opportunities subject to commercial-in-confidence requirements. Review of existing literature and supplied data and develop a sampling programme that could be

considered for the CSG companies' ongoing, collaborative monitoring programmes, as well as any specialised sampling of water, core or gas that could be carried out by CSIRO.

It is anticipated that the four sponsor companies will each contribute ~1000 water quality sample results to the proposed study. Each of the water quality results will consist of multiple fields of data embedded for each sample (e.g. BTEX, dissolved methane (where available), TPH, TOC, TSD, DIC, phenols, alkalinity, pH, pressure, depth of water production, coal seam information).

To achieve the goals for Phase 1 and 2of the project, the four companies will need to provide CSIRO access to their basin wide geological model, construction details for the water bores where data is provided (to determine coal seams and aquifers intersected). Data will have to be of sufficient completeness and quality to allow both Phases of the project to proceed.

Where hydraulic fracturing or well under-reaming has been conducted to stimulate well production, investigation of hydraulic fracturing fluids used and any monitoring data (where available) from flow back water will be examined to determine the potential to differentiate between naturally occurring hydrocarbons and any hydrocarbons inadvertently introduced.

Phase 2 (Duration: 6 months after the completion of Phase 1): review of any additional sampling/monitoring data acquired by the sponsors, statistical analysis of all data, interpretation and provision of final report. It is planned that Phase 2 will be completed no longer than 6 months after the Phase 1 report is submitted. Phase 2 will complete the work undertaken in Phase 1 regarding statistical analyses of the data, interpretation and final report production.

14. Project Plan

The research programme is structured to span 12 months from receiving company held data, including a draft Phase 1 report after 6 months and the Stage 2 final report completed after 12 months. .

14.1 Project Schedule

ID	Task Title	Task Leader	Scheduled Start	Scheduled Finish	Predecessor
Task 1	Literature review on interactions involved in sedimentary basins, aquifers and coal seam gas (CSG) related water production.	Richard Schinteie	Oct 14	March 15	
	Summary of available information on existing hydrocarbons in groundwater in the Surat and Bowen Basins, Queensland	Richard Schinteie	Oct 14	March 15	
	Stage 1 Report	Richard Schinteie	Oct 14	March 15	
Task 2	Statistical analyses and interpretation of the data.	Grant Douglas	April 15	Sep 15	Task 1
	Provide strategies to differentiate naturally occurring hydrocarbons and those inadvertently introduced during drilling, completion and hydraulic stimulation.	Grant Douglas	July 15	Sep 15	Task 1
	Provide interpretations on possible sources of the hydrocarbons encountered based on previous studies and new information gained in the proposed study.	Grant Douglas	July 15	Sep 15	Task 1
	Final report	Grant Douglas	Sep 15	Sep 15	Task 1

Task 1.

TASK NAME: Literature review and summary of available information on existing hydrocarbons in groundwater

TASK LEADER: Richard Schinteie

OVERALL TIMEFRAME: Duration: 6 months from the receipt of all data from the 4 companies

BACKGROUND: Naturally occurring dissolved organic compounds such as hydrocarbons and phenols have been detected in sedimentary basins in Australia and elsewhere. Also, potential exists for inadvertent introduction of hydrocarbons during drilling and completion of CSG production wells, water production wells, and groundwater monitoring bores or, in all cases, from leaking well casings. A need exists to collate all existing information on hydrocarbon and organic compound presence in the Surat and Bowen Basins.

TASK OBJECTIVES:

To collate and provide a summary, of the available information on existing hydrocarbons in groundwater in the Surat and Bowen Basins, Queensland leading to,

- A robust and scientifically defensible data set and interpretations to support the research conclusions,
- Context and potential explanations for possible future detection and reporting of hydrocarbons during compliance monitoring programmes.

TASK OUTPUT: Collation of all existing information on hydrocarbon and organic compound presence in the Surat and Bowen Basins.

SPECIFIC DELIVERABLE: Report

Task 2.

TASK NAME: Strategies to differentiate hydrocarbons sources.

TASK LEADER: Grant Douglas

OVERALL TIMEFRAME: Duration: 6 months after the completion of Phase 1

BACKGROUND: Once existing information on hydrocarbon and organic compound presence in the Surat and Bowen Basins has been collated, there is a need to interpret this data to allow insights to be made into the complex interactions involved in sedimentary basins, aquifers and coal seam gas (CSG) related water production.

TASK OBJECTIVES:

Outline strategies related to differentiation of naturally occurring hydrocarbons and those inadvertently introduced during drilling, completion and hydraulic stimulation (e.g. stable isotopic fingerprinting of the hydrocarbons could assist with delineating coal derived hydrocarbons versus 'refined' petroleum derived hydrocarbons).

Interpretations on possible sources of the hydrocarbons encountered based on previous studies and new information gained in the proposed study. Explore changes in water quality due to CSG operations.

TASK OUTPUT: Scientifically defensible explanation for the possibility of encountering hydrocarbons in groundwater during CSG exploration and production programs is readily available.Provide recommended analytes that could be included for compliance monitoring to differentiate naturally occurring hydrocarbons and those inadvertently introduced during drilling, completion and hydraulic stimulation. Document water quality changes in CSG operations.

SPECIFIC DELIVERABLE: Report

15. Budget Justification

The budget for this project is to be agreed by the Research Advisory Committee and Management Committee.

16. Project Governance

Project management of tasks are specified in item 14. The research programme is structured to span 12 months from receiving company held data, with a draft Phase 1 report after 6 months and the Stage 2 final report completed after 12 months. An advisory committee will be established to review and provide advice during the project. Potential members of the advisory committee will include an industry representative, a regulator, an agricultural stakeholder, and a GISERA committee member. At the completion of the project, the final report will undergo external review by an appropriate Australian University academic expert in this field.

17. Communications Plan

GISERA will manage communications in accordance with GISERA's Alliance Agreement (available at: National GISERA Alliance Agreement.) and Communications Strategy.

18. Risks

Capacity to deliver this project will be managed by CSIRO. Risks in delivery will be mitigated using the breadth of skills across the organisation. Communication risks will be mitigated by adherence to the communications protocols outlined in the GISERA Communications Strategy and the GISERA Alliance Agreement. CSIRO will undertake all

project management tasks and will consult with APLNG on decision points and contingencies in the work program.

19. Intellectual Property and Confidentiality

Background IP (clause 10.1, 10.2)	**Party**	**Description of Background IP**	**Restrictions on use (if any)**	**Value**
	CSIRO	Chemistry, hydrogeology, geochemistry expertise and know how.		$
				$
Ownership of Non-Derivative IP (clause 11.3)	CSIRO			
Confidentiality of Project Results (clause 15.6)	Project results are not confidential.			
Additional Commercialisation requirements (clause 12.1)	Not applicable			
Distribution of Commercialisation Income (clause 1.1)	Not applicable			
Commercialisation Interest (clause 1.1)	**Party**		**Commercialisation Interest**	
	APLNG		None	
	CSIRO		None	
	QGC		None	