GISERA
Gas Industry Social and Environmental Research Alliance

# Project Order

Proforma 2020

## 1. Short Project Title

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| Onshore gas water lifecycle management options framework |

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| Long Project Title | Developing a wastewater lifecycle management Framework for onshore gas development in the Northern Territory |
| GISERA Project Number | W.24 |
| Proposed Start Date | 01/08/2020 |
| Proposed End Date | 28/02/2022 |
| Project Leader | Nerida Horner |

## 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**

This project will develop an options framework and decision criteria for water and wastewater management for Northern Territory onshore gas development that affords a high level of environmental protection for community and government while remaining cost-effective for industry. The primary focus of the project is to assist refining management options of onshore gas wastewater in the NT. The framework will also consider, and where relevant ensure applicability, to other forms of onshore petroleum fuels as per the Petroleum Act 1984. The project will apply the framework to two case studies (discussed below) in the Beetaloo Basin, NT to verify its utility and efficacy. This project will directly address **Recommendation 5.5** of the *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* (2018) and will explore the options for safe disposal of wastewater **(Recommendation 7.9 and 7.17).**

Water management in shale gas is one of the main concerns held by communities regarding development of shale gas in the Northern Territory, and indeed across Australia (Pepper et al 2018; Cook et al 2013). This project will design a framework based on sustainable water management principles and informed by community concerns identified through the Pepper Inquiry, to be used by industry and regulators to guide the optimization of wastewater management decisions for improved outcomes for the Northern Territory. Outputs from such a framework will be fit-for-purpose water treatment alternatives, accounting for cost, environmental and social outcomes. The project will work consultatively with industry, government and selected community groups to identify and parameterize key performance indicators for a range of social, environmental and economic assessment criteria, that will be incorporated into a framework to guide wastewater management decisions. Use of the framework will assist industry and regulators to effectively and efficiently manage wastewater for optimal benefits to broader society and community, that the community expects and that the Hydraulic Fracturing Inquiry recommended.

**Description**

This project will identify approaches to closed loop water cycle management for shale gas operations in the NT to optimise for environmental, social and economic objectives. These objectives will be co-created by industry, government and community stakeholders during the project, and supported by relevant guidelines where appropriate. The project will engage with these stakeholders at key stages throughout the project, inviting a 'stop and review' approach at the end of each stage to seek input, identify and work through issues and reach acceptance before moving to the next stage. The project is technology agnostic, and will not seek to prescribe particular technology choices, but rather a range of possibilities informed by key indicators important to the environmental, social and economic context. The project will also include a 'stage gate' between stages 2 and 3, where endorsement from the NT RRAC will be sought before proceeding to case studies in stage 3 and 4. This approach will ensure cross-pollination of the different perspectives and enable a fuller understanding by all parties of the potential multiple benefits approach to managing shales gas wastewaters.

This project will identify the water quantities and qualities likely at each stage of the production process, identify process, treatment or offtake opportunities to reduce environmental impacts, develop a framework for identifying and maximising beneficial use and reuse opportunities and reduce costs and potential risk of negative environmental legacy from wastewater. This project will ground truth water quality with current data from NT test wells and a regional review of use options and incorporate these into a NT framework for management, reuse and treatment of onshore gas wastewaters.

*Water use in shale gas development*

Wastewater produced from petroleum wells include flowback fluid, produced water, drilling fluids, completion fluids, well suspension fluids and non-aqueous drilling fluids, residual drilling waste, e.g. muds and cuttings (which may be more or less in a solid state) in addition to fluids. Other ancillary uses of water for site management such as dust suppression are relatively insignificant. Well drilling muds provide lubrication and cooling to the drill bit during drilling and are the lowest volume of wastewater generated during well development (typically 1-2ML per well) (Pepper et al 2018). These are typically contained in lined sedimentation pits, where the clarified saline water is removed for treatment and the mud can be recycled for use in further drilling (Huddleston-Holmes et al 2017). Quantities of drill cuttings will be of the order of 150 to 200 $m^3$ of drill cuttings for a 3,000 m well interval with a 2,000 m lateral extension drilled using rotary mud drilling methods (Huddleston-Holmes et al 2017). In the NT, it was noted that management of wastewater (including drill cuttings) from unconventional gas is similar to many other mining and industrial processes, although treatment of produced water may vary (Hawke 2014).

During operations, shale gas wells both consume water from available local sources and generate flowback and produced water. Well development requires water, to which additives are mixed to form hydraulic fracturing fluid. The resulting fluid is then injected deep into the target shale formation to stimulate gas flow. In the Northern Territory, water for fracturing fluids will be sourced from groundwater sources, unless it can be obtained and recycled from other uses/users, as use of surface water is prohibited. Community consultation during the 2018 Scientific Inquiry into Hydraulic Fracturing in the NT has identified an appetite to see the industry utilise lower qualities of water than those of use to others (stock and domestic) (Pepper et al 2018), and this will need to be explored as part of a water management framework for industry.

Flowback water[1] contains both the chemical additives from the hydraulic fracturing fluid, and the native chemistries present deep in the shale formations. The composition of shale formations can yield flowback water that is saline, and may comprise of ions such as barium, strontium and bromine; low concentrations of heavy metals; organic matter; and naturally occurring radioactive materials (NORM) from the rock and formation water (Cook et al., 2013; Huddleston-Holmes et al 2017). For this reason, the final chemistries and volumes of flowback and produced waters are highly dependent on the local geologies in the target formation and other localised conditions. Cook et al. (2013) estimated that between 25% - 75% of the volume injected during hydraulic fracturing returns to surface, with the initial chemistry reflecting the hydraulic fracturing fluid, but over time would become more influenced by the chemistry of the target formations. Flowback and produced water are often reinjected at depth as a disposal method in other countries and regions, but in the NT this method of disposal is prohibited. Plans are required to be developed to best treat and reuse the water where possible, and until ultimate treatment and disposal, wastewater must be stored in closed tanks (Pepper et al 2018).

[1] Flowback water is the return of the hydraulic fracturing fluid that has been injected into the well back to the surface.

Produced water is formation water that is released during the fracture stimulation at depth and returns to surface through the gas extraction process. Produced water by its nature reflects the chemistry of target formations, and may include barium, strontium, bromine, heavy metals, organic matter and NORM. The relative quantity of produced water to flowback water is quite low in shale gas resources. For a 6000-well development, a cumulative total of 45,600ML of flowback water and 1,710ML/year of produced water might be expected over the life of a project (Cook et al., 2013; Huddleston-Holmes et al 2017). Depending on development size, flowback and produced waters in shale gas can be stored onsite (in closed tanks in the NT) before being piped to onsite treatment constructed for the purpose or transported by tanker to appropriate regional water treatment facilities (Huddleston-Holmes et al 2017).

The chemical composition of produced water for shale gas wells is likely to contain increased levels of contaminants and potential regulated wastes, therefore will need higher levels of water treatment. Wastewater storage capacity and onsite treatment are likely to be significantly less than for CSG.

The amount of water used in shale gas developments is in the order of between 5 and 20 megalitres (ML) per well, and is likely to vary depending on local conditions (King, 2012; Cook *et al.*, 2013; Council of Canadian Academies, 2014; US Environmental Protection Agency, 2016b; Huddleston-Holmes et al 2017). At a scale of a 1000-well shale gas development, up to 20,000 ML would be required (Huddleston-Holmes et al 2017). Whilst this volume of water is not large when compared to other water users such as agriculture, local impacts at catchment or aquifer scale may need to be carefully managed (p. xv, Hawke, 2014). Competition with other water users could be reduced if some quantity of the water demand was able to be recycled, or if a saline water source is used (Council of Canadian Academies, 2014).

The exact quantities and qualities of flowback water and produced water likely to be generated for shale gas and oil development in the Northern Territory is highly uncertain, and dependent on local geologies and methods employed in extraction.

*Water use through the project lifecycle*

The life cycle of unconventional oil and gas (UOG) development can be summarised into four stages: predrilling construction, drilling, hydraulic fracturing, and ongoing production (Figure 1). The water used in UOG production can be categorised further as direct, indirect, or ancillary water use. Direct water use is defined as the water used for drilling and hydraulic fracturing a well and for maintaining the well during ongoing production. Indirect water use is defined as the water used at or near a well pad. The water used for dust abatement also is considered an indirect use but may be applied away from the well pad. Ancillary water use is defined as the additional local or regional water use resulting from a change (for example, population) directly related to UOG development throughout the life cycle that is not used directly in the well or indirectly for any other purpose at the well pad. Of the four stages in the life cycle, drilling, hydraulic fracturing, and ongoing production involve direct water use. The drilling stage includes water used directly in drilling the well and cementing the casing. The hydraulic fracturing stage includes water used directly for mixing the hydraulic fracturing fluid and injecting into the well. The ongoing production stage includes water used directly for maintaining the well, such as descaling the casing, and for potentially refracturing the well.

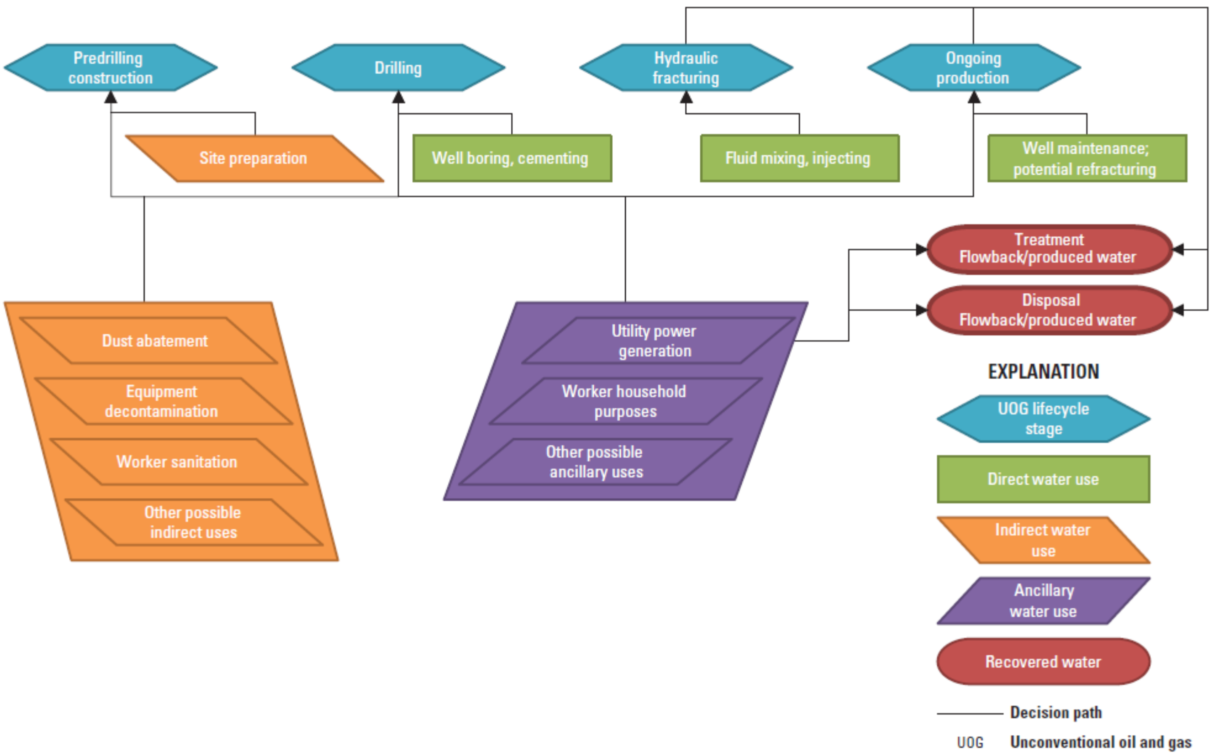



**Figure 1. Direct, indirect, and ancillary water uses associated with the life cycle of unconventional oil and gas development.** (From: Valder et al 2018)

*Challenges in shale gas water management*

The NT HF Inquiry found that shale gas production remains controversial in the NT due in part to concerns over impacts associated with the storage, transport, and disposal of fluids that return to the surface during hydraulic fracturing (Pepper et al 2018). Three main sources of fluids are produced during the shale gas extraction process (1) drilling mud water: used to drill the initial wellbore; (2) flowback water: returned to the surface in the first few weeks to months after hydraulic fracturing has occurred; and (3) produced water: from the shale layer produced over the lifetime of the well. Drilling fluids contain the original fluid, some formation fluids and cuttings of the formation being drilled and other materials used in well drilling activities e.g. cement, LCM etc. Drilling fluids can have a substantial volume of solids derived from additives (such as bentonite clay) and drill cuttings.

At this early stage of the industry in the NT, the current approach to shale gas wastewater management consist of local storage of HF wastewaters, evaporation to reduce volumes and the final transport of the remaining liquid wastes to treatment and disposal facilities in Queensland (Santos 2019; Origin 2019). The nearest wastewater facility is currently over 2400km away in Jackson, Queensland, requires considerable risk management and controls along regional transport routes to manage spill risks and is anticipated to be at a significant cost to industry. Decisions on disposal of the residual flowback and produced waters for future stages of the industry are yet to be made pending results of well testing during the current appraisal stages (Santos 2019; Origin 2019). These inevitable logistical and economic challenges are anticipated to escalate as the industry expands. If decisions at future stages of development are made based on advice of current wastewater disposal service providers, there is the potential for only a narrow range of options to be explored. Wastewater management practices are often largely driven by the economics and logistics of disposal options, but with shale gas expected to maintain a significant role in our energy systems for decades to come, new strategies will be crucial to minimise environmental and social impacts. Industry estimates between 1,000 -1,150 wells on 104 -140 drilling pads in the Beetaloo and likely to use 2,500-5,000 ML per year (Pepper et al 2018).

While the generation of large volumes of water in a short time frame makes flowback waters amenable to reuse in subsequent wells or frac sites, the produced waters that constitute the majority of total wastewater production are typically not reused due to logistical challenges associated with storing and transporting incremental and variable wastewater volumes. Produced fluid reuse may also be precluded by inadequate water quality, such as excessive levels of TDS or divalent cations that promote scale formation. Evaporation ponds have been used as a cost-effective method of disposing of highly saline wastewaters when compared to reuse. In multi-well pad operations overseas, there is a growing practice to re-use flowback and produced waters in subsequent hydraulic fracturing operations in what is known as ‘‘internal reuse” (NT Scientific enquiry report, 2018). The internal reuse minimises the wastewater environmental impact and treatment costs while reducing the need for fresh water as fracking fluid, but on the other hand, the accumulation of high concentrations of dissolved solids can lead to operational problems.

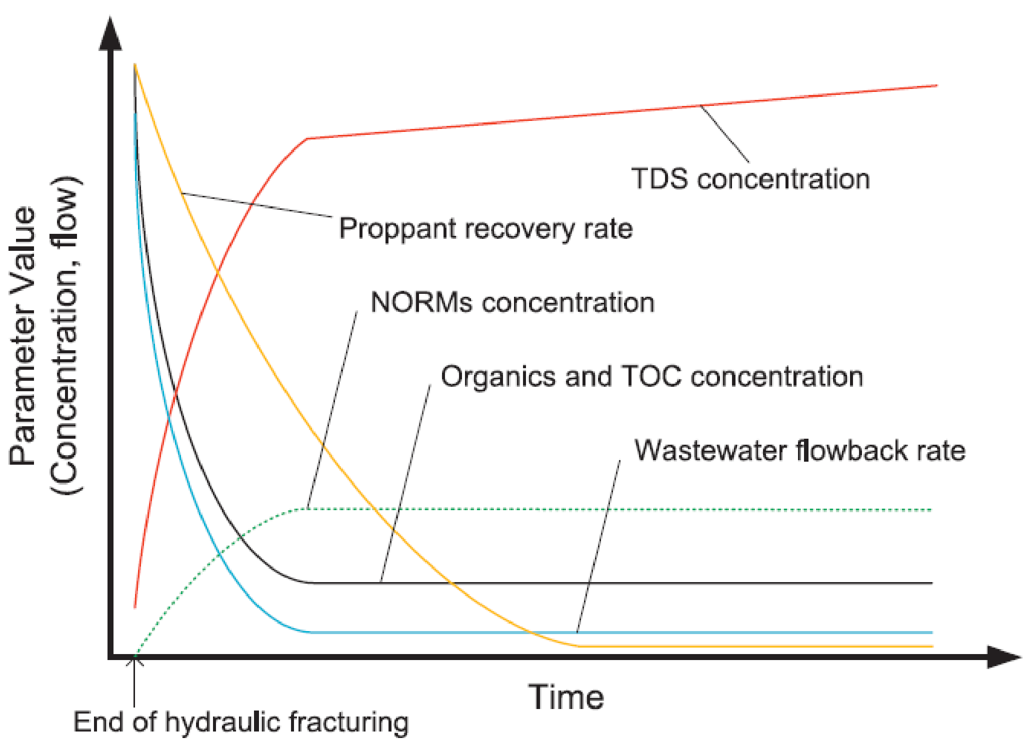



**Figure 2**: Conceptual profiles of different parameters associated with wastewater production after hydraulic operations (adapted from Estrada and Bhamidimarri, 2016).

Due to the infancy of the shale gas industry in the Northern Territory, the project team will need to utilise data from the few available Environmental Management Plans (EMPs), work with industry and regulators to review company data on exploration and test well waters, and look to the literature from other states and countries for applicable ranges in what may be expected for NT conditions. Provision has been made to verify water qualities available at the current phases of production during the project, if necessary. Managing increasing quantities of high-salinity produced waters containing hydrocarbons, sometimes naturally occurring radioactive materials, and other organic and inorganic compounds within regulatory constraints will be a critical challenge in the Northern Territory as wastewater volumes threaten to overwhelm the limited existing infrastructure, or become cost prohibitive in the case of transport and treatment interstate.

The project will investigate current and likely potential future practices available to the industry through a literature review and survey of industry, regulators and community in the NT, including related or potentially symbiotic industries who may have arising or similar treatment needs to shale gas or potential or symbiotic feedwater needs for industrial processes. The project will also seek to assess opportunities for centralisation or decentralisation of treatment approaches at various stages of the industry to ascertain if those are likely candidates for optimisation of wastewater management in the NT. We will develop a framework tool for the application of a holistic approach incorporating treatment and reuse options with the consideration of balancing community/social, and environmental benefits/outcomes.

**Need & Scope**

*Australian and Northern Territory context*

The NT Hydraulic Fracturing Inquiry identified key concerns about wastewater for a shale gas and oil industry in the Northern Territory. The Inquiry recommended that discharge of wastewaters to surface waters and reinjection of wastewater at depth into shale formations were prohibited as methods for wastewater disposal (Pepper et al 2018). It further recommended that a framework for the management of wastewater be developed by government in consultation with industry and community. The need for EMPs at individual project scales in the NT require wastewater management plans specific to single tenements or company developments, however there is currently no industry-wide solution to address wastewater management at scale. Whilst the quantities of flowback and produced water in shale gas are inverse to those in coal seam gas developments, lessons can be learnt from observing the coal seam gas experience in Queensland with respect to wastewater management (Kelly 2019, Huddleston-Holmes et al 2017). Brine volumes are a considerable challenge given the widespread adoption of reverse osmosis as the main treatment option for CSG production waste waters. Optimal planning and management of NT shale gas water based on agreed objectives will decrease potential management challenges, environmental impacts and alleviate community concerns. Frameworks of this type can identify a reduction in volumes of water required (through reuse and recycling), minimisation of potential pollutants (through industrial ecology/waste to resource options) and by canvassing optimal treatment technologies and alternative disposal options for wastewater.

Whilst the industry is currently in its infancy, there is both a need and a window of opportunity to develop a cost-effective framework for managing water used in, and wastewater from, a future shale gas and oil industry in the NT that maximises protection of environmental and social values and evaluates cost efficiencies. This may also lead to economies of scale in potential options if multiple onshore petroleum developments identify similar or complementary treatment approaches from the framework. There is a need to optimise wastewater management across the water life cycle for industry and community needs, science and process possibilities and regulatory requirements to ensure the implementation of recommendations from the Hydraulic Fracturing Inquiry and relevant codes of practice can lead to innovative outcomes for industry, community and environment as the industry develops.

*Scientific contribution*

The scientific value of this project is that there are few examples of optimisation of wastewater for sustainability outcomes in the shale gas industry despite over 60 years globally. Business as usual treatment of wastewaters produced in the shale gas production process in the NT poses a big challenge for the development of the shale gas industry, given the Pepper Inquiry recommendations and high community expectations (Pepper 2018). There is a growing body of research aimed at providing innovative solutions (Chang et al., 2019; Sun et al., 2019) to the challenges posed by wastewater generated in the hydraulic fracturing industry. Although most of these membrane-based technologies and high strength effluents segregation techniques are at very early stages of development (mainly laboratory scale), these will be drawn upon and assessed for their potential for use in Australia. Geza et al (2018) and Ma et al (2018) have identified decision support tools for this process in well-established industries in the US shales, however it is unknown if the basic options space for these tools are applicable to the Australian experience. There is a need to understand the composition and time-evolution of flowback and produced waters in the different Australian shale plays where hydraulic fracturing takes place. Once these wastewaters have been characterised, it will be possible to identify approaches within a framework to guide industry and regulators to optimise the most appropriate approaches for re-use, recycling, treatment and disposal of wastewater based on 'fit for purpose' approach.

**No single technology is likely to result in the effluent requirements for discharge or re-use in outside hydraulic fracturing**. More likely, a combination of pre-treatment techniques, existing use of evaporation ponds for disposal of highly saline wastewaters and new desalination technologies available will have to be optimised in order to minimise the environmental impact of wastewaters from shale gas production by hydraulic fracturing. Identification of a framework for undertaking wastewater optimisation in shale gas processing would be a positive contribution to science, industry and the community both within the NT and with the potential for broader application to other jurisdictions. It is envisaged that such a framework would assist in identifying optimal approaches for different applications in different regions, petroleum developments and communities.

*Scope*

The project will engage with key industry, government and community stakeholders in the NT at key stages throughout the project, **inviting a 'stop and review' approach** at the end of each stage to seek input, identify and work through issues and reach logical conclusions before moving to the next stage. This project will review, in consultation with industry, potential treatment technologies and determine the feasibility of their practical implementation and develop an in depth understanding of features important to promote the adoption and optimisation of treatment technologies by the shale oil and gas industry. In addition, a 'stage gate' between stages 2 and 3 will require RRAC endorsement of the approach to be taken in Stages 3 and 4, based on findings from the earlier stages. Whilst this staged approach can take more time than desktop approaches, it will ensure cross-pollination of the different perspectives and enable a fuller understanding by all parties of the potential multiple benefits approach to managing shales gas wastewaters. From experience in optimising wastewater management in the wine industry, this approach has been shown to lead to greater acceptance, ownership and adoption of project outcomes (Day et al 2011, Kumar et al 2009). No single treatment approach is likely to cater for all situations in shale gas water treatment. We propose a framework that will be based on multiple criteria for achieving optimal treatment outcomes for particular regions and applications.

In this way, the project will consider the following questions:

- What are likely water quantity and quality requirements for a range of shale gas and oil development scenarios?
- What are the water quality requirements for reuse or recycling of water in and from shale gas and oil activities?
- What water management processes are available for reuse (such as blending, hydraulic fracturing fluid design, process design to enable waste stream diversions, etc)?
- Is there industrial ecology/waste to resource potential in other existing or likely future industries within economic distance?
- What treatment technologies are available to treat water to allow for recycling?
- In addition to the use of evaporation ponds, what other disposal options are available for wastewater (from shale gas and oil activities?
- What treatment technologies available to treat water to allow for safe disposal given the available disposal options?
- What are the costs and environmental performance of the available options?
- How do these change under different industry development trajectories?
- What are the advantages of using particular treatment technologies?
- What is the economic feasibility of the treatment technology based on the infrastructure establishment and operational costs?
- What is the optimal energy requirement for implementing a specific treatment technology?
- What are major environmental and social barriers for the implementation of the treatment technology.

The criteria used for assessment of different technologies will be based on Table 1 below.

In order to minimise the concentration of TDS in wastewater for disposal into water bodies or reuse outside hydraulic fracturing operations, advanced treatment is needed beside the techniques described as options for water reuse.

Application of the highly saline water for other beneficial uses can also be explored. By way of example, the use of flowback water as a medium for the cultivation of commercial marine microalgae or for inland marine aquaculture has been investigated (Racharaks et al., 2015). Feasibility of these alternative beneficial reuse options will be explored during the review process, alongside practices such as evaporation ponds currently common amongst mining and extraction industries especially in areas with high evaporation rates and low land costs. In addition, cultural values in relation to Aboriginal land, ecological values for pastoral land and other related values will also be considered.

The results of literature review and technical assessment of treatment technologies will be used as basis in the development of the decision tool based on multicriteria analysis as proposed in Task 5.

This project seeks to identify the similarities and differences that need to be considered to enable optimisation for Australian conditions, and the science that underpins those options to be explored and defined. The approach is necessarily transdisciplinary, requiring the synthesis of water treatment/chemical engineering, environmental and agricultural sciences, industrial ecology, economics and social sciences. A logical outcome of this research could be to provide the necessary inputs to test the effectiveness of international iDST tools through a subsequent collaboration project, or lead to the development of a modified Australian integrated decision support tool to enable its development for Australian conditions and for use by Australian industry and regulators.

*Multicriteria analysis*

As a dry continent, the competition for water among water use sectors in parts of Australia is intensifying with increasing extreme climate conditions. There is a pressing need to better manage or reuse wastewater within and among gas production sites for increasing water use efficiency inside and outside the industry and minimising social and environmental impacts as a precondition to securing social licence for gas production. However, quantifying the effects of onshore gas wastewater management practices remains difficult partly because the wastewater use has cumulative impacts. The identification of good practices is critical for site managers to adopt more rational and sustainable management solutions by referring to good management cases. However, the optimal selection of water management practices requires the comprehensive evaluation/prioritization of current and potential future management options against numerous requirements, thus, becomes a problem in multiple criteria decision-making analysis (MCDA) (Zhang et al 2010).

MCDA will be used to assess the field of potential treatment options, due to its strong record of successful application in water management both in Australia and internationally, and its transparency in dealing with the complexity of multiple stakeholders and triple bottom line analysis (Petheram et al 2018, Hajkowicz and Collins 2007). We will conduct a multi-criteria analysis and develop a framework tool for the application of a holistic approach incorporating technical (treatment, reuse options), environmental (water quality and quantity) and economic analysis (treatment costs, operational costs) with the consideration of balancing community/social benefits/outcomes. The approach will be technology agnostic and will enable the 'switching on and off' of different objectives by managers to assist them to determine the optimal solutions under different scenarios. For example, where it has become clear a certain storage or treatment feature is required for health and safety reasons.

MCDA is a structured approach for measuring the performance of alternatives that are based on multiple attributes (Chen et al 2015, 2013, 2012, 2010). The different methods that fall within this category can support the decision analysis process for issues in which more than one criterion—also known as attribute—is simultaneously evaluated. These decision analysis tools enable the inclusion of relative importance, or weight, for each criterion. The weight is used to rank the performance of the alternatives to be implemented against the selected criteria. These methods have the potential impact of improving transparency, auditability, and analytical rigor of decision-making processes in complex contexts. Numerous MCDA techniques provide decision makers and analysts the opportunity to properly and effectively address decision problems. The selection criteria could include capital cost, operating and maintenance (O&M) costs, space (footprint) requirement, commercial availability, mobility, and energy demand, and will be determined through stakeholder engagement as outlined on page 2 above 'Description'. Based on the criteria selected and prioritised during Task 2, a decision support framework that combines selection criteria will suggest efficient treatment trains capable of treating non-traditional waters to the target water quality required for beneficial use or discharge to the environment.

A wastewater treatment train for a water reuse project can be selected based on the end use of wastewater for achieving economic efficiency and environmental sustainability. Such treatment is referred to as fit-for-purpose wastewater treatment. It aims to avoid overtreatment and obviously under-treatment as constrained by environmental regulations. Water quality depends on the level of water and wastewater treatment, which is dictated by the end use of water.

**NT Hydraulic Fracturing Inquiry Recommendations**

This project will directly address **Recommendation 5.5** of the HF Inquiry;

> *That prior to the grant of any further exploration approvals, in consultation with the gas industry and the community, the Government develops a wastewater management framework for any onshore shale gas industry. Consideration must be given to the likely volumes and nature of wastewaters that will be produced by the industry during the exploration and production phases. That the framework for managing wastewater includes an auditable chain of custody system for the transport of wastewater (including by pipelines) that enables source-to-delivery tracking of wastewater. That the absence of any treatment and disposal facilities in the NT for wastewater and brines produced by the gas industry be addressed as a matter of priority.*

While the Code of Practice for Petroleum Activities in the Northern Territory partly addresses this recommendation by providing the objectives and minimum standards for a wastewater management framework, it does not present available options for managing water used in shale gas and oil operations, or which options may become available as the industry develops. In addition, two other HF Recommendations place specific limitations on disposal options for shale gas hydraulic fracturing wastewater. This project will explore the remaining options for safe disposal of this wastewater, within the bounds of these limitations:

> ***Recommendation 7.9***
>
> *That prior to the grant of any further exploration approvals, the reinjection of wastewater into deep aquifers and conventional reservoirs and the reinjection of treated or untreated wastewaters (including brines) into aquifers be prohibited, unless full scientific investigations determine that all risks associated with these practices can be mitigated.*
>
> ***Recommendation 7.17***
>
> *That prior to the grant of any further exploration approvals, the discharge of any onshore shale gas hydraulic fracturing wastewater (treated or untreated) to either drainage lines, waterways, temporary stream systems or waterholes be prohibited.*

This project will identify and evaluate options for the management and treatment of water and wastewater in shale gas and oil operations, including minimisation, beneficial reuse and safe disposal, with a strong focus on optimising for sustainable water management outcomes based on social, environmental and economic principles. That is, these types of frameworks assist decisions makers to go beyond regulation and duty of care by adding value to their decisions. By identifying performance criteria, the framework is technology agnostic, and options that arise do so by identifying with the key criteria for a particular circumstance.

**Methodology**

The project will be conducted in four stages over 18 months, involving the following key areas:

- Industry, government and community engagement throughout key stages of the project to provide scope, context and frame the options envelope to the NT context;
- Broad review of wastewater treatment, management and optimisation from literature, current practices of industry and relevant other industries, regulations, codes of practices and reports;
- Development and evaluation of KPIs for wastewater treatment based on engagement with NT stakeholders;
- Options assessment through MCDA;
- Stage gate to seek endorsement from RRAC design and approach to further stages
- Case study verification and testing and
- Framework development and communication.

The project will involve stakeholder engagement through face to face, digital and survey methods, a , a minor field component, and desktop review of literature, industry reports, EMPs and other soft literature. The study will address the research questions by developing and considering a range of criteria to be co-created by stakeholders. These criteria will consider:

- confidence in available data on likely water quality (lower confidence may require a certain level of flexibility in technology and processes);
- stage of industry development (exploration versus production);
- environmental values that may be impacted;
- external factors – climate/weather events that may influence process water management;
- technology options to be considered (for water treatment and for water reuse, including current methods);
- technology readiness;
- technology complexity and suitability for field deployment; and
- technology costs (capital and ongoing operating costs).

These criteria will be synthesised into a decision guide that will allow industry and government to optimise choices of water management processes, water treatment technologies, and wastewater disposal options for the NT.

The project will proceed in four stages, each of 4-9 months duration;

**Stage 1 – Industry, Technology and Stakeholder Scan (4 months).** This first stage will set the relevant context for the research in terms of what is known of the local industry water qualities and wastewaters, technology options and stakeholder needs, and is separated into two tasks which will run concurrently.

Task 1 (3 months): includes a review of existing water qualities and technology use across other shale gas areas in Australia and overseas, innovative examples of sustainable and holistic water treatment approaches, review of regulations that apply to NT. Scan of current and future industries in the NT for beneficial reuse options.

Task 2: includes identification of stakeholders, undertaking a stakeholder analysis and developing an engagement plan for the project. Design and complete a stakeholder survey and collate results. The outcome from this stage will be a review, of the current situation, including industry consultation on current situation for wastewaters, results of the e stakeholder analysis and engagement plan and results from the survey, including stakeholder feedback on preferred format of final product (written guidelines, handbook, framework).

**Stage 2 – Options analysis and Decision Framework development (9 months).** This stage will undertake three main tasks;

Task 3 – (3 months) **Wastewater KPI development**, link with Code of Practices, obtain key stakeholder feedback - develop KPIs for optimisation assessment, obtain stakeholder feedback on draft criteria (mixed or segmented by stakeholder group – regulator/proponents), link KPIs with code of practices.

Task 4 – (3 months) **Review potential treatment options against the KPIs**, address any knowledge gaps and complete optimisation criteria. This stage will ensure key stakeholders in industry and government, in particular for this stage the regulatory body has opportunity to test and input to KPIs, through a workshop/s or direct inputs.

Task 5 – (3 months) **Develop a MCDA framework tool** – an application of holistic approach incorporating technical, environmental and economic analysis with the consideration of balancing community/social benefits/outcomes. Analyse options against the KPIs and optimisation criteria requirements to develop decision support for wastewater management. Derive criteria weights using analytic hierarchy process (AHP). Aggregate multiple identified treatment options and wastewater reuse criteria. This includes a set of collective evaluation runs using different weighted criteria based on different prioritised options. Compare usefulness of treatment and reuse options and report writing.

Stage Gate – Seek endorsement from RRAC on above design before continuing to stages 3 and 4.

**Stage 3 - Develop and Test two Case Studies (4.5 months).** Stage three will involve two case studies to be selected to demonstrate produced water treatment technologies and beneficial reuse options considering realistic site-specific conditions, assumptions, and future projections such as well numbers and locations, water demands, flowback and produced water quality and quantity, disposal availability, and costs. There is very limited data on the composition of flowback and produced water occasioned by onshore shale gas extraction in Australia, and this makes the need for empirical data from test wells all the more important. The case studies may involve collecting site specific water use and water quality data.

The team will identify costs and impacts of potential future options, and gain stakeholder feedback on the draft framework and identify potential case studies (subject to industry or regulator approval). This stage will:

1. Test framework at one or two locations as case studies (subject to industry agreement).
2. Conduct wastewater analyses at one site and assess treatment and reuse options
3. Document case studies and assess their economical, social and environmental feasibility
4. Assess different scenarios, including centralised and decentralised treatment options

**Stage 4 – Synthesise and Finalise Framework (4.5 months).** This final task involves the development and delivery of final report/handbook of operating guidelines for wastewater management and key stakeholder briefings. The team will collate the relevant prior report sections into a single cohesive final report. This will include writing up the final decision framework into a Final Report/Guide, including Case Studies (if available). The project products will include a Regulator 'short guide' to the decision framework or similar as defined by stakeholder analysis/needs. The team will also conduct regulator and industry briefings to conclude the project engagement and communicate the identified approaches.

**As mentioned above, we will apply 'stop and review' approach** at the end of each stage to seek input, identify and work through issues and reach logical conclusions before moving to the next stage.

## 5. Project Inputs

**Research**

CSIRO (Cameron Huddleston-Holmes and Anu Kumar) developed the industry codes of practice on wastewater for the NT government. While the Code of Practice for Petroleum Activities in the Northern Territory partly addresses the HFI recommendations by providing the objectives and minimum standards for a wastewater management framework, it does not present options for managing water used in shale gas and oil operations. There are also gaps in understanding the specific NT context, and optimisation of wastewater treatment to achieve social, environmental and economic objectives will require a close review of the water qualities arising from specific NT shales, the proximity to industries for beneficial reuse, and the specific economic and environmental context of the NT that will drive the options space.

Extensive reviews for Queensland (Cameron Huddleston-Holmes and Nerida Horner, CSIRO) and NT Governments (others, HF Inquiry) on the environmental and social impacts of shale gas development have identified a range of potential wastewater qualities and quantities that may arise from the unconventional gas industry in the Northern Territory. Flowback and produced waters are specific to geology, and the potential impacts and beneficial reuse opportunities are site- and region- specific. Drilling and hydraulic fracturing techniques, and the arising wastewater qualities are dependent on the geology and lead to a broad range of impacts (Huddleston-Holmes et al 2017, Pepper et al 2018). This project will ground truth water quality with current data from NT test wells and a regional review of use options and incorporate these into a NT framework for management, reuse and treatment.

The NT Government has also recently undertaken a review of the infrastructure and logistics needs of a potential shale gas industry, including wastewater treatment requirements. It is understood from discussion with DTBI contacts that this review largely covers domestic wastewater requirements of the workforce that may arise from potential development trajectories, and that a fuller analysis of the industrial wastewater requirements is still required. This will also provide insight on the industry requirements for future investment by industry and governments to optimise benefits to the Northern Territory.

This project was developed by Nerida Horner, Anu Kumar, Cameron Huddleston-Holmes and Yun Chen, and informed by selected conversations with industry and government contacts in DTBI and EPA and environmental consultants locally.

## Resources and collaborations

| Researcher | Time Commitment (project as a whole) | Principle area of expertise | Years of experience | Organisation |
|---|---|---|---|---|
| Dr Cameron Huddlestone-Holmes | 3 days | Shale gas industry development, geology, environmental and social impacts. Senior science technical advice and guidance. Lead for the Australian Government Geological and Bioregional Assessment Program including in the NT's Beetaloo Basin. | 25+ | CSIRO |
| Nerida Horner | 59 days | Environmental Engineer, Project Management, Stakeholder engagement, utility scale water engineering, NT water and engineering industry understanding, contacts and experience, co-authored Shale gas environmental and social impacts study for Qld government (Huddleston-Holmes et al 2017). | 20 | CSIRO |
| Dr Anu Kumar | 69 days | Wastewater chemistry, treatment and process engineering; wastewater benchmarks and KPIs based on 'fit for purpose' approach, shale gas water treatment, significant experience in wine industry wastewater treatment optimisation. | 25 | CSIRO |
| Dr Yun Chen | 44 days | Multi-criteria decision analysis, optimisation of water treatment for sustainable development in CSG, water treatment and multiple related industries. | 30 | CSIRO |
| L&W Band 5 RS TBC | 35 days | Literature review support, wastewater process analysis | 10+ | CSIRO |

| Subcontractors (clause 9.5(a)(i)) | Time Commitment (project as a whole) | Principle area of expertise | Years of experience | Organisation |
|---|---|---|---|---|
| Local NT environmental consultant or Uni collaborator | 15-30 days | Water quality sampling and preliminary data analysis | 10+ | Ecoz or similar or CDU |
| Local NT engineering consultant | 15 days | Infrastructure and operational costs on treatment technologies and beneficial reuse options | 20+ | GHD or similar |

**Budget Summary**

| Source of Cash Contributions | 2020/21 | 2021/22 | 2022/23 | % of Contribution | Total |
|---|---|---|---|---|---|
| GISERA | $161,412 | $145,963 | $0 | 75% | $307,375 |
| - Federal Government | $147,122 | $133,040 | $0 | 68.36% | $280,162 |
| - NT Government | $7,812 | $7,065 | $0 | 3.63% | $14,877 |
| - Origin Energy | $2,755 | $2,449 | $0 | 1.28% | $5,246 |
| - Santos | $2,755 | $2,491 | $0 | 1.28% | $5,246 |
| - Pangaea Resources | $968 | $876 | | 0.45% | $1,844 |
| **Total Cash Contributions** | **$161,412** | **$145,963** | **$0** | 75% | **$307,375** |
| | | | | | |
| **Source of In-Kind Contribution** | **2020/21** | **2021/22** | **2022/23** | **% of Contribution** | **Total** |
| CSIRO | $53,804 | $48,654 | $0 | 25% | $102,458 |
| **Total in-kind contribution** | **$53,804** | **$48,654** | **$0** | 25% | **$102,458** |

**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.

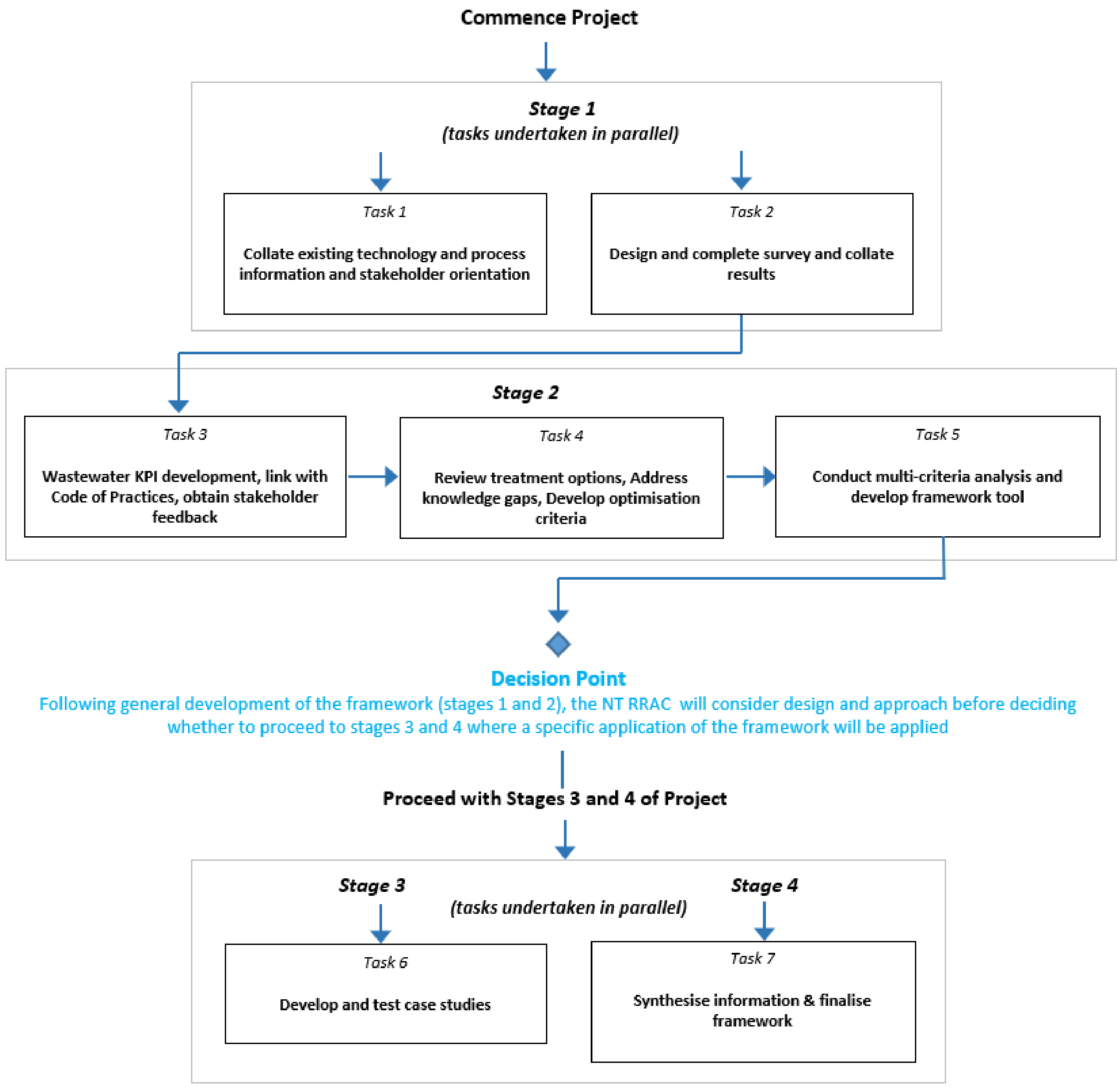
For all other GISERA projects (particularly environmental and social projects) where CSIRO researchers are not being escorted by industry, CSIRO will work with the NLC to apply this practice.

GISERA
Gas Industry Social and Environmental Research Alliance

## 6. Project Impact Pathway

| Activities | Outputs | Short term Outcomes | Long term outcomes | Impact |
|---|---|---|---|---|
| Stage 1: Technology, process and stakeholder scan | Technology, process and stakeholder scan report – Identifies industry and stakeholder needs, potential opportunities and leads. | Industry, community and government stakeholders and project team have shared expectations and knowledge of current state of NT shale gas wastewater management and future areas of investigation. | Inform industry, Government and regulators on the approaches to and challenges in wastewater management | • Optimise wastewater reuse opportunities<br>• Water treatment takes optimal path for environmental outcomes<br>• Reduced or removed risk of negative environmental legacy from wastewaters<br>• Improved outcomes for Territory people<br>• Beneficial use for water for other industries<br>• Whole of life costs for wastewater treatment reduced for industry, community and government |
| Stage 2: Develop KPIs and multicriteria framework for wastewater management | KPI based multicriteria framework (a report) | Industry and associated stakeholders are informed and have provided input to useful KPIs to manage wastewater. | | |
| Stage 3: Fit for purpose options analysis using case studies | Wastewater Options Analysis (document) | Approach to analysis well-documented for transparency and accountability for community, industry and governments | Improve Industry's knowledge and practices related to optimising social, economic & environmental outcomes for wastewater management | |
| Stage 4: Synthesis and develop decision support framework | Wastewater Optimisation Handbook (including operational guidelines ). | Tool to be used by industry and regulators to optimise and benchmark their performance. | | |

## 7. Project Plan



**Project Schedule**

| ID | Activities / Task Title<br><br>(should match activities in impact pathway section) | Task Leader | Scheduled Start | Scheduled Finish | Predecessor |
|---|---|---|---|---|---|
| **Task 1**<br>**Stage 1** | Collate existing information in published sources, existing industry practices | Anu Kumar | 01 August 2020 | 31 October 2020 | None |
| **Task 2**<br>**Stage 1** | Stakeholder analysis and engagement plan, design and complete stakeholder survey and collate results | Nerida Horner | 01 August 2020 | 30 November 2020 | Task 1 being half completed |
| **Task 3**<br>**Stage 2** | Wastewater KPI development, link with Code of Practices, obtain stakeholder feedback | Anu Kumar | 01 Dec 2020 | 30 March 2021 | Task 1,2 |
| **Task 4**<br>**Stage 2** | Review treatment options, Address knowledge gaps, Develop optimisation criteria | Anu Kumar | 01 April 2021 | 30 June 2021 | Task 3 |
| **Task 5**<br>**Stage 2** | Conduct multi-criteria analysis and develop framework tool – application of holistic approach incorporating technical (treatment, reuse options), environmental (water quality and quantity), economic analysis (treatment costs, operational costs) | Yun Chen | 01 July 2021 | 30 September 2021 | Tasks 1-4 |
| | | **Stage Gate** | | | |
| **Task 6**<br>**Stage 3** | Case Studies to test framework tool | Anu Kumar | 14 October 2021 | 28 February 2022 | Tasks 3-5 |
| **Task 7**<br>**Stage 4** | Delivery of final report/handbook on operating guidelines and a key stakeholder briefing. | Nerida Horner | 14 October 2021 | 28 February 2022 | Tasks 5, 6 |

Task description

**Stage 1 (tasks 1-2): Technology, process and stakeholder scan - 4 months**

**Task 1**

**TASK NAME:** Collate existing technology and process information and stakeholder orientation

**TASK LEADER:** Anu Kumar

**OVERALL TIMEFRAME:** 3 months (1 August 2020 – 31 October 2020)

**BACKGROUND:** Task 1 will involve research and review of the published literature, science reviews, company EMPs and industry reports to determine;

- What can we learn from onshore gas operations in other states and internationally?
- What are the currently experienced wastewater qualities, process steps, treatment options, issues, disposal challenges, chemistry issues, examples of successful beneficial reuse?
- What examples can be found of diverting various waste streams at points in production and treatment process.

This task will also identify key stakeholders for the onshore gas industry in the Northern Territory, identify a stakeholder list, contact Industry, community and government stakeholders on project, introduce the project and orient in readiness for subsequent activities (survey), determine their areas of interest, knowledge and concerns, identify how they prefer to engage in project.

During this task the team intends to undertake an orientation site visit to a site of current shale gas development in the NT. Should travel restrictions prohibit the site visit at this stage in the project, then it will be conducted at the earliest available opportunity within travel and seasonal limitations.

**TASK OBJECTIVES:**

1. Collate existing information based on literature searches and surveys.
2. Orientation site visit from research team (scheduled for earliest possible in project).
3. Conduct stakeholder analysis

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Literature Review and Stakeholder Analysis (will form relevant sections of final report).

**Task 2**

**TASK NAME:** Design and complete survey and collate results

**TASK LEADER:** Nerida Horner

**OVERALL TIMEFRAME:** 4 months (1 August 2020 – 30 November 2021)

**BACKGROUND:** During Task 2, the team will develop an industry survey/questionnaire to survey selected shale gas operator in Australia and ascertain current industry practices in water and wastewater relevant to the NT onshore gas development. The survey will determine all aspects of sources of wastewater within processes, treatment and reuse, beneficial use options and practices - including engagement with other industries on related practices. The key objectives for this survey will be to obtain baseline data on current practices used in the shale industry. It is anticipated that this initial survey would highlight knowledge gaps that would require more detailed follow up.

The survey target audience is intended to be regulators, industry proponents, related and proximal industries and key community stakeholders. The survey will include (but not limited to) the following;

- How are these industries' currently doing things/operating with wastewater?
- What should be included?
- What are current limitations and challenges?
- What the other industries are in the region?
- What existing treatment options are available and currently utilised?

**TASK OBJECTIVES:**

1. Design of survey of industry stakeholders in NT.
2. Run industry survey with identified groups.
3. Collate survey results and identify key insights.

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Technology, Process and Stakeholder Scan document (will become chapter in final report).

**Stage 2 (tasks 3-5): Options analysis and framework development - 9 months**

**Task 3**

**TASK NAME:** Wastewater KPI development, link with Code of Practices, obtain stakeholder feedback

**TASK LEADER:** Anu Kumar

**OVERALL TIMEFRAME:** 3 months (1st December 2020 – 31 March 2021) **spanning 4 months to allow for 15 Dec-15 Jan 4 weeks offline for key resources.*

**BACKGROUND:** The survey data will be used to quantify both typical values for key performance indicators (KPIs) and realistic target values (benchmarks). KPIs for technical, environmental, economic, and social aspect would provide a complete framework for water management. This lack of an overall framework was the gap identified. KPIs in relation to water use can include information on the sources of water for completions (hydraulic fracturing) at the operations by volume and percentage of total volume. Water quality as a KPI can include reporting frequency of pre- and post-drilling water testing by area of operations. KPIs for produced water and flowback water storage, treatment, and reuse will be developed in consultation with the stakeholders.

**TASK OBJECTIVES:**

1. Develop water use, water quality, treatment, reuse KPIs. *KPIs are to measure treatment, reuse, what can be more efficient. Holistic life cycle approach. Systematic approach to understanding what processes generate what waste and what options for management may be possible.* This approach helps to gain industry and regulator trust, ownership and buy-in to KPIs, and gives industry an adaptive approach to managing WW – accessible approach.

2. Link KPIs with code of practices – ensure regulatory body has opportunity to test and input to KPIs. Workshop or direct input (more regulatory focus).
3. Stakeholder engagement to update stage 2 findings. (talk to all stakeholders for refining KPIs).

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Document on KPIs for Wastewater Management in the NT (will become chapter in final report).

**Task 4**

**TASK NAME:** Review treatment options, Address knowledge gaps, Develop optimisation criteria

**TASK LEADER:** Anu Kumar

**OVERALL TIMEFRAME:** 3 months (1 April 2021 to 30 June 2021)

**BACKGROUND:** We will review the treatment technologies and determine the feasibility of their practical implementation, and an in depth understanding of features important to promote the adoption of treatment technologies by the shale oil and gas industry. The treatment of wastewaters produced in the shale gas production process poses a big challenge for the development of fracking industry. There is a need to understand the composition and time-evolution of flowback and produced waters in the different shale plays where hydraulic fracturing takes place. Once these effluents have been characterised, it will be possible to select and optimise the most appropriate treatment technologies for each scenario. The general treatment process of the produced water includes the separation of oil and water, removing suspended solids and organic compounds including naturally occurring radioactive material, and the total dissolved solids (TDS) reduction. Especially, the removal of total suspended solids (TSS) and TDS is important for discharging or reuse of the produced water. It is because the high concentration of TSS and TDS in the produced water can cause scaling in the wells or contamination of adjacent water and soil. In the treatment process, segregating techniques such as a centrifuge, hydro-cyclones, or dissolved air flotation are firstly applied to separate oil and to remove TSS. Then, an individual or a combined water treatment technique such as membrane distillation (MD), reverse osmosis (RO), or evaporative crystallization (EC) is applied to reduce TDS. The selection of the most adequate technology for produced/ flowback wastewater treatment will ultimately depend on the specific properties and pollutants of the effluent considered as well as the volume of wastewater to be treated in a single unit.

The criteria used for assessment of different technologies will be based on the Table 1 (above). The results of literature review and technical assessment of treatment technologies will be used as basis in the development of the decision tool based on multicriteria analysis as proposed in Task 5.

**TASK OBJECTIVES:**

We will review the treatment technologies and determine the feasibility of their practical implementation, and an in depth understanding of features important to promote the adoption of treatment technologies by the shale oil and gas industry:

1. Determine what treatment options are available to achieve the KPIs.

2. Conduct SWOT analyses of treatment options – including water use, cost for infrastructure, operational costs, energy consumption, social acceptability, sustainability, waste generated, water quantities. Centralised vs decentralised treatment approaches, single industry vs multi-industry approaches.
3. Documenting end use water quality specifications/requirements for categories of beneficial reuse. E.g. growers, cattlemen, likely industrial users e.g. where highly saline water or rich in chemicals, can we collect that potent water and then improve the wastewater quality.
4. Perform economic feasibility of the treatment technologies based on the infrastructure establishment and operational costs?
5. Identify major environmental and social the barriers for the implementation of the treatment technology.
6. If poor data availability, may need to address knowledge gaps.
7. Engage local NT engineering subcontractor support to ascertain infrastructure treatment costs for industry trajectories.
8. Incorporate monitoring for water quality and water quantity - at process level, treatment level.
9. Confirm local water qualities, through industry or contractor, collect new samples if necessary.

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Document treatment options and criteria, i.e. Wastewater Options Analysis (document) (to be chapter in final report)

**Task 5**

**TASK NAME:** Conduct multi-criteria analysis and develop framework tool

**TASK LEADER:** Yun Chen

**OVERALL TIMEFRAME:** 3 months (1 July 2021- 30 September 2021)

**BACKGROUND:** Multi-criteria decision analysis (MCDA) is a structured approach for measuring the performance of alternatives that are based on multiple attributes. The different methods that fall within this category can support the decision analysis process for issues in which more than one criterion—also known as attribute—is simultaneously evaluated. These decision analysis tools enable the inclusion of relative importance, or weight, for each criterion. The weight is used to rank the performance of the alternatives to be implemented against the selected criteria. These methods have the potential impact of improving transparency, auditability, and analytical rigor of decision-making processes in complex contexts. Numerous MCDA techniques provide decision makers and analysts the opportunity to properly and effectively address decision problems. The selection criteria will include capital cost, operating and maintenance (O&M) costs, space (footprint) requirement, commercial availability, mobility, and energy demand. Based on the criteria selected and prioritised during TASK 2, a decision support framework that combines a large number of selection criteria will suggest efficient treatment trains capable of treating non-traditional waters to the target water quality required for beneficial use or discharge to the environment.

Determination of criterion weights is crucial in MCDA. The Analytical Hierarchy Process (AHP) is a popular mathematical method for this purpose when analysing complex decision problems. It derives the weights through pairwise comparisons of the relative importance between each two criteria. All weighted criteria can then be aggregated using a weighted combination method (e.g. ordered weighted averaging (OWA), or fuzzy OWA) to generate output ranking(s) from the decision support framework. These evaluation results will illustrate the usefulness/effectiveness of the proposed solution.

**TASK OBJECTIVES:**

1. Develop a MCDA framework tool – an application of holistic approach incorporating technical (treatment, reuse options), environmental (water quality and quantity) and economic analysis (treatment costs, operational costs) with the consideration of balancing community/social benefits/outcomes (Duration: 4 weeks).
2. Analyse options against the KPIs and beneficial use and optimisation criteria requirements to develop decision support for wastewater management. This includes the selection of criteria and determination of their thresholds (Duration: 2 weeks).
3. Derive criteria weights using analytic hierarchy process (AHP). This includes the construction of various pairwise comparison matrixes and identification of relative importance between each pair of criteria (Duration: 2 weeks).
4. Aggregate multiple identified treatment options and wastewater reuse criteria. This includes a set of collective evaluation runs using different weighted criteria based on different prioritised options (Duration: 2 weeks).
5. Compare usefulness of treatment and reuse options and report writing (Duration: 2 week)

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Document MCDA analysis and framework tool (to be chapter in final report)

**STAGE GATE**: Seek RRAC endorsement of design and approach to stage 3 and 4

**<u>Stage 3: Develop and Test Case Studies - 5 months</u>**

**Task 6**

**TASK NAME:** Develop Case Studies

**TASK LEADER:** Anu Kumar

**OVERALL TIMEFRAME:** 4.5 months (14 October 2021 – 28 February 2022)

Two case studies will be selected to demonstrate produced water treatment technologies and beneficial reuse options considering realistic site-specific conditions, assumptions, and future projections such as well numbers and locations, water demands, flowback and produced water quality and quantity, disposal availability, and costs. There is very limited data on the composition of flowback and produced water occasioned by onshore shale gas extraction in Australia, and this makes the need for empirical data from test wells all the more important. The case studies may involve collecting site specific water use and water quality data.

**TASK OBJECTIVES:**

1. Test framework at one or two locations as case studies (subject to industry agreement).
2. Conduct wastewater analyses at one site and assess treatment and reuse options
3. Document case studies and assess their economical, social and environmental feasibility
4. Assess different scenarios- (centralised and decentralised treatment options)

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Document framework and examples into Final Report

**Stage 4: Synthesise information and finalise framework (5 months).**

**Task 7**

**TASK NAME:** Delivery of final report/handbook of operating guidelines for wastewater management and key stakeholder briefing.

**TASK LEADER:** Nerida Horner

**OVERALL TIMEFRAME: 4.**5 months (14 October 2021 – 28 February 2022, concurrently with Task 6)

**BACKGROUND:** In this final task, the team will collate the relevant prior report sections into a single cohesive final report. This will include writing up the final decision framework into a Final Report/Guide, including Case Studies (if available). The project products will include a Regulator 'short guide' to the decision framework or similar as defined by stakeholder analysis/needs. The team will also conduct regulator and industry briefings to conclude the project engagement and communicate the identified approaches.

**TASK OBJECTIVES:**

1. Write/Develop operating guidelines (document) – fit for purpose approach. Includes where the water can be used, decide what treatment options, under what scenarios.
2. Develop Operating Guidelines- presenting information to assist the planning and management of wastewater treatment and its disposal or recycling based on fit for purpose approach.
3. Develop tool by integrating information on WW management through LCA (life cycle analysis) approach (sourcing, use, stages of process water, treatment, reuse, disposal) and based on information collated in Tasks 1-5 proposed above
4. Write up final Decision Framework into Final Report as Handbook/Guide.
5. Conduct final regulator and industry briefings.

**TASK OUTPUTS AND SPECIFIC DELIVERABLES:** Final Report - Wastewater Optimisation Handbook (including results of case study assessment). Stakeholder briefing to key stakeholders.

**Project Gantt Chart**

| | | 2020-21 | | | | | | | | | | | 2021-22 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Task** | **Task Description** | **Aug 20** | **Sept-20** | **Oct-20** | **Nov-20** | **Dec-20** | **Jan-21** | **Feb-21** | **Mar-21** | **Apr-21** | **May-21** | **Jun-21** | **Jul-21** | **Aug-21** | **Sep-21** | **Oct-21** | **Nov-21** | **Dec-21** | **Jan-22** | **Feb-22** |
| 1 | Collate existing information and stakeholder orientation | ■ | ■ | ■ | | | | | | | | | | | | | | | | |
| 2 | Design and complete stakeholder survey and collate results | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | |
| 3 | Wastewater KPI development, link with Code of Practices, obtain stakeholder feedback | | | | | ■ | ■ | ■ | ■ | | | | | | | | | | | |
| 4 | Review treatment options, Address knowledge gaps, Develop optimisation criteria | | | | | | | | | ■ | ■ | ■ | | | | | | | | |
| 5 | Conduct multi-criteria analysis and develop framework tool | | | | | | | | | | | | ■ | ■ | ■ | | | | | |
| | STAGE-GATE | | | | | | | | | | | | ■ | ■ | ■ | | | | | |
| 6 | Case Studies to test framework tool | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ |
| 7 | Delivery of final report/handbook on operating guidelines and a key stakeholder briefing. | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ |

## 8. 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 most likely be composed of:

- Dr Cameron Huddleston-Holmes, Senior Research Scientist, CSIRO Energy
- Dr Simon Apte, Senior Principal Research Scientist, CSIRO Land and Water
- Representatives from NT Department of Environment and Natural Resources or Department of Trade, Business and Innovation *(to be confirmed)*
- Representative from NT EPA - potentially Leonie Cooper, Director Environmental Authorisations *(to be confirmed)*
- Relevant industry representatives

## 9. Communications Plan

| **Stakeholder** | **Objective** | **Channel**<br>(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 – this will be updated periodically as project progresses).<br><br>Project progress reported on GISERA website to ensure transparency for all stakeholders including regional communities.<br><br>Participation in roadshows, community workshops and meetings and other engagements where appropriate. | From commencement of project and with updates as they come to hand.<br><br>As required.<br><br>As required |
| Government and industry | To communicate project outputs | Regular stakeholder engagement based on each output. | Ongoing |

| | | | |
|---|---|---|---|
| Government and industry | To facilitate a deeper understanding of research findings and implications for policy, programs, planning, and other initiatives | Knowledge transfer sessions and through stakeholder workshops and meetings. | From commencement of project and with updates as they come to hand. |
| 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 |
| Regional Community/ Wider public, Government, Scientific community and Industry | To report on key findings | Final Report/handbook | At completion |

## 10. Budget Summary

| Expenditure | 2020/21 | 2021/22 | 2022/23 | Total |
|---|---|---|---|---|
| Labour | $180,216 | $162,117 | $0 | $342,333 |
| Operating | $5,000 | $2,500 | $0 | $7,500 |
| Subcontractors | $30,000 | $30,000 | $0 | $60,000 |
| **Total Expenditure** | **$215,216** | **$194,617** | **$0** | **$409,833** |

| Expenditure per Task | 2020/21 | 2021/22 | 2022/23 | Total |
|---|---|---|---|---|
| Task 1 | $50,510 | $0 | $0 | $50,510 |
| Task 2 | $42,800 | $0 | $0 | $42,800 |
| Task 3 | $56,604 | $0 | $0 | $56,604 |
| Task 4 | $65,302 | $0 | $0 | $65,302 |
| Task 5 | $0 | $72,294 | $0 | $72,294 |
| Task 6 | $0 | $58,280 | $0 | $58,280 |
| Task 7 | $0 | $64,045 | $0 | $64,045 |
| **Total Expenditure** | **$215,216** | **$194,617** | **$0** | **$409,833** |

| Source of Cash Contributions | 2020/21 | 2021/22 | 2022/23 | Total |
|---|---|---|---|---|
| Federal Government (68.36%) | $147,122 | $133,040 | $0 | $280,162 |
| NT Government (3.63%) | $7,812 | $7,062 | $0 | $14,877 |
| Origin Energy (1.28%) | $2,755 | $2,491 | $0 | $5,246 |
| Santos (1.28%) | $2,755 | $2,491 | $0 | $5,246 |
| Pangaea (0.45%) | $968 | $876 | $0 | $1,844 |
| **Total Cash Contributions** | **$161,412** | **$145,963** | **$0** | **$307,375** |

| In-Kind Contributions | 2020/21 | 2021/22 | 2022/23 | Total |
|---|---|---|---|---|
| CSIRO (25%) | $53,804 | $48,654 | $0 | $102,458 |
| **Total In-Kind Contributions** | **$53,804** | **$48,654** | **$0** | **$102,458** |

| | Total funding over all years | Percentage of Total Budget |
|---|---|---|
| Federal Government Investment | $280,162 | 68.36% |
| NT Government Investment | $14,877 | 3.63% |
| Origin Energy | $5,246 | 1.28% |
| Santos | $5,246 | 1.28% |
| Pangaea Resources | $1,844 | 0.45% |
| CSIRO Investment | $102,458 | 25% |
| **TOTAL** | **$409,833** | **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 | Collate existing information and stakeholder orientation | GISERA | Aug-2020 | Oct-2020 | 2020/21 | $37,883 |
| **Task 2** | 2.1 | Design and complete stakeholder survey and collate results | GISERA | Aug-2020 | Nov-2020 | 2020/21 | $32,100 |
| **Task 3** | 3.1 | Wastewater KPI development, link with Code of Practices, obtain stakeholder feedback | GISERA | Dec-2020 | Mar-2021 | 2020/21 | $42,453 |
| **Task 4** | 4.1 | Review treatment options, Address knowledge gaps, Develop optimisation criteria | GISERA | Apr-2021 | Jun-2021 | 2021/22 | $48,977 |
| **Task 5** | 5.1 | Conduct multi-criteria analysis and develop framework tool – application of holistic approach incorporating technical (treatment, reuse options) , environmental (water quality and quantity), economic analysis (treatment costs, operational costs) | GISERA | Jul-2021 | Sep-2021 | 2021/22 | $54,219 |
| **Task 6** | 6.1 | Case Studies to test framework tool | GISERA | Oct-2021 | Feb-2022 | 2021/22 | $43,710 |
| **Task 7** | 7.1 | Delivery of final report/handbook on operating guidelines and a key stakeholder briefing. | GISERA | Oct-2021 | Feb-2022 | 2021/22 | $48,034 |

## 11. 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<br><br>(clause 13.4) | Not Applicable | | | |
| Commercialisation Interest (clause 1.1) | **Party** | | **Commercialisation Interest** | |
| | CSIRO | | N/A | |
| | Origin Energy | | N/A | |
| | Santos | | N/A | |
| | Pangaea Resources | | N/A | |

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