Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Progress report

Beetaloo basin shale long-term competency after decommissioning

Progress against project milestones

Progress against milestones/tasks are approved by the GISERA Director, acting with authority in accordance with the GISERA Alliance Agreement.

Progress against project milestones/tasks is indicated by two methods: Traffic light reports and descriptive Project schedule reports.

1. Traffic light reports in the Project Schedule Table below show progress using a simple colour code:

- **Green**:
  - Milestone fully met according to schedule.
  - Project is expected to continue to deliver according to plan.
  - Milestone payment is approved.
- **Amber**:
  - Milestone largely met according to schedule.
  - Project has experienced delays or difficulties that will be overcome by next milestone, enabling project to return to delivery according to plan by next milestone.
  - Milestone payment is withheld.
  - Milestone payment withheld for second of two successive amber lights; project review initiated and undertaken by GISERA Director.
- **Red**:
  - Milestone not met according to schedule.
  - Problems in meeting milestone are likely to impact subsequent project delivery, such that revisions to project timing, scope or budget must be considered.
  - Milestone payment is withheld.
  - Project review initiated by GISERA Director.

2. Progress Schedule Reports outline task objectives and outputs and describe, in the 'progress report' section, the means and extent to which progress towards tasks has been made.

Project schedule table

TASK NUMBER	TASK DESCRIPTION	SCHEDULED START	SCHEDULED FINISH	COMMENT
1	Literature review of the concept of shale barriers, experimental studies, and possible stimulation mechanisms	15 Aug 2022	15 Oct 2022	Complete
2	Acquire the shale core samples from the Beetaloo basin and quantify the shale mineralogy and chemoporomechanical properties	15 Sep 2022	15 Jan 2023	Complete
3	Perform triaxial creep tests under different downhole conditions to characterize Beetaloo shale behaviour	15 Nov 2022	15 Jan 2024	Complete
4	Results interpretations	15 May 2023	15 Feb 2024	Complete
5	Develop a decommissioned well leakage simulator to bound potential contaminant flux over the long-term	15 Mar 2023	15 Jul 2023	Complete
6	Define key long-term decommissioned well integrity concepts such as timescale, and contamination grade	15 Jun 2023	15 Nov 2023	Complete
7	Update decommissioned well leakage simulator with Beetaloo shale properties	15 Jul 2023	15 Apr 2024	Complete
8	Project reporting	15 May 2023	15 May 2024	Complete
9	Communicate findings to stakeholders	Project duration		This task will be complete end October/early November 2024.

Project schedule report

TASK 1: Literature Review

BACKGROUND

Stimulating and activating the shale can happen through temperature and pressure changes imposed on the shales and also utilizing some chemicals. Chemical activation might be more straightforward than imposing temperature changes in field applications. The chemical solutions are circulated through the annular space by casing perforations with a workstring and packer arrangement.

TASK OBJECTIVES

The main emphases of the literature review will be placed on:

- 1.1) Experimental input data collection includes downhole conditions, wellbore characteristics, nominating chemicals
- 1.2) Shale barriers validations using logging techniques with the intent to qualify the formed shale barrier.
- 1.3) Techniques and approaches to stimulate and activate shale in decommissioned wells
- 1.4) Theoretical and experimental lab investigations to confirm the design of the studies in task 3.2

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

An internal report summarizing the literature review on the concept of shale barriers, experimental studies, and possible activation mechanisms will be delivered. This internal report will be incorporated into the project's final report.

PROGRESS REPORT

This milestone is complete, the literature review has been completed and will be incorporated in the final report.

The literature review Executive Summary is provided below:

Executive Summary

This literature review describes the current scientific knowledge of shale creep behaviour related to petroleum well integrity and forms Milestone 1 of the project 'Assessing the long-term sealing competency of the Beetaloo Basin after gas well decommissioning'. This technical document will inform the project methodology and be incorporated into the project's publicly released final report.

Decommissioned petroleum wells

After petroleum wells have reached the end of their serviceable life, the final stage of the well life cycle is to seal and decommission the wells. Community concerns have been expressed broadly about the potential for decommissioned wells to leak from subsurface geological layers into an overlying groundwater aquifer or to the surface. Therefore, an improved understanding of how the integrity performance of decommissioned wells in the Beetaloo basin is expected to evolve over the long term is important.

Traditionally, wellbore barriers in decommissioned wells are constructed by employing annular cement, steel casing and cement plugs to provide complete zonal isolation. The engineering properties of the materials used in casing and cement are well understood; however, the characteristics of the geological formations are variable. Observations of sonic and ultrasonic logs in some fields have shown that some formations, shale in particular, could creep into open spaces (such as a well annulus). This behaviour would be advantageous in maintaining long-term well integrity.

This project aims to quantify the extent to which the shale geological formations through which the wells are drilled in the Beetaloo basin could be expected to either remain static over time or if the formations could be expected to creep and close around a well, thus providing a seal between the well and the surrounding rock. Implications for well design and decommissioning will be considered.

Creep behaviour of rocks

Creep is a time-dependent deformation (visco-elastoplastic) behaviour of rocks, which may occur in saturated, sub-saturated or dry rocks. The creep process is similar to swelling; however, swelling only happens in the presence of water and is not dependent on imposed stresses, while creep may occur with or without the presence of water and is driven by the mechanical stresses acting on the rock.

Shales are a class of sedimentary rock that can be prone to creep behaviour as they often have a relatively high clay content and relatively low stiffness, which makes deformation through internal rearrangement of particles possible under the application of stress. Mineralogy of the shale is a good indicator of the propensity of shales to exhibit creep behaviour where shales with high amounts of clay content (i.e., comparatively high smectite content, low amounts of quartz and carbonate cementation) are likely to creep.

The magnitude of the creep deformation is dependent on, but not limited to, mineralogy, applied temperature, pressure and chemistry of the fluids to which the shale is exposed.

The creep rate depends on several rock property characteristics, including shale internal structure rearrangement, particle sliding and compression, delayed water which relocates and groups shale macro-pores, failure of internal particle bonds, movement of the molecular bonds, adsorbed water flow in double layers of clay particles, and viscous adjustments of clay structure.

Shale acts as a well barrier to prevent fluid movement

The Norwegian Standard Organization (NORSOK) consider shales to be an acceptable well barrier provided that they have low stiffness and high ductility (low Young's Modulus, low cohesion, low friction and dilation angles), high clay content (i.e., comparatively high smectite content, low amounts of quartz and carbonate cementation), moderately high porosity and low compressional wave velocity.

Artificial stimulation of creep

Studies have found that creep can also be artificially stimulated though exposing the shale to changes in pore pressure, temperature, and fluid chemistry. Two creep stimulation techniques that may be suitable for wells in the Beetaloo basin are temperature changes and exposure to engineered fluids. Changing annulus pressure is considered less suitable as it may have unintended detrimental consequences to the mechanical integrity of the shale. In Task 3 of the project, samples from the Beetaloo basin will be exposed to temperature and fluid chemistry changes to see if creep behaviour could potentially be stimulated in those rocks.

Modelling of creep behaviour

There is a range of analytical (Rheological) and numerical models that can be utilized to simulate the creep response of a shale material to downhole or artificially stimulated conditions. The suitability of each model depends on the specific shale properties, well geometries, and downhole conditions. A suitable model will be selected for inclusion in the leakage rate simulator (developed in Task 4). This model describing creep behaviour will be verified through matching with the experimental results undertaken in Task 3.

Formations identified in the Beetaloo basin to exhibit the potential for creep behaviour will then be characterized as naturally self-sealing or able to be actively stimulated to creep and the potential impact of the creep behaviour on the long-term well integrity performance.

Experimental design

The best practices identified in this literature review are being implemented into the design of the experimental campaign to assess the propensity of Beetaloo basin shale formations to exhibit creep behaviour both in downhole (in situ) and stimulated conditions.

Specimens from Beetaloo basin core samples have been extracted and are undergoing mineralogy studies and initial chemo-poro-mechanical analyses (Task 2), and samples are being prepared for triaxial compression creep tests (Task 3).

TASK 2: Evaluation of the Beetaloo shale mineralogy and chemoporomechanical properties

BACKGROUND

Shale mineralogy (mainly the amount of clay and also the proportion of other constituents, including Smectite, which acts as a bonding agent) plays a critical role in the performance of the shale to act as an appropriate barrier. In addition, the response of shale to different annular fluids chemistry influences the time-dependent creep behaviour. In order to study the swelling and shrinkage of the shale, the chemoporomechanical properties, including the determination of chemoporoelastic properties including hydraulic diffusivity ($\mathrm{D_h}$) and ionic diffusivity ($\mathrm{D_c}$) should be measured.

TASK OBJECTIVES

2.1) Acquiring the shale core samples from the Beetaloo basin

2.2) Determination of core mineralogy by X-ray diffraction (XRD). Main mineral constituents and organic-matter contents will be quantified prior to the experiments
2.3) Commissioning the MicroRX rig
2.4) Sample preparation
2.5) Preparing the fluids test and the chemical solutions
2.6) Measuring the chemoporoelastic properties

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

An internal report summarizing the results of XRD studies, along with mineral quantifications, rig calibration, and chemoporoelastic properties will be incorporated into the project's final report.

PROGRESS REPORT

This milestone is complete.

2.1) **Acquiring the shale core samples from the Beetaloo basin**

Shenandoah-1A well core samples have been collected from the target formations in the Beetaloo sub-basin, Velkerri and Kyalla formations, from the Northern Territory Geological Survey (NTGS) core library in Darwin. The acquired samples were obtained from the depth of approximately 1590 m and 2316-2511 m to encompass the aforementioned target formations.

The stratigraphy of the Beetaloo sub-basin, the schematics of Shenandoah-1A well, along with the Hylooger images of core trays in NTGS were incorporated in the internal milestone report for task 2.

2.2) **Determination of core mineralogy by X-ray diffraction (XRD). Main mineral constituents and organic-matter contents will be quantified prior to the experiments**

X-ray diffraction (XRD) and X-ray fluorescence (XRF) examinations have been completed on samples obtained from the Velkerri and Kyalla formation. Powder X-ray diffraction was applied in this study to determine the mineralogical composition of shale samples. In addition, XRF analyses quantified the characteristic X-rays emitted by components in a sample, which led to determining and measuring the sample's chemical composition.

The outcomes of these examinations were incorporated in the internal milestone report for task 2.

2.3) **Commissioning the MicroRX rig**

MicroRx has been fully commissioned and is currently operational. The re-commissioning procedures and the measures taken to modify the rig were incorporated in the internal milestone report for task 2.

2.4) **Sample preparation**

The MicroRX specimens (cylinders with 4.47 mm diameter and 4-5 mm length) were prepared (via coring, sanding, etc.) to run the chemoporoelastic tests.

2.5) **Preparing the fluids test and the chemical solutions**

Solutions containing Sodium Chloride (NaCl) and Water (reverse osmosis water) with two different salinity concentrations were prepared and measured accurately before each test.

Due to the osmotic effects, a higher concentration of Sodium Chloride (NaCl) leads to less swelling and less increase in water content compared to a lower NaCl concentration which can be attributed to the osmotic relations between shale pore water and clay interlayer space.

The scale of NaCl concentrations and the associated osmotic pressure descriptions were incorporated in the internal milestone report for task 2.

2.6) **Measuring the chemoporoelastic properties**

Measuring the chemoporoelastic properties of samples obtained from Velkerri and Kyalla formations has been completed.

The governing equations, experimental procedures and interpretation of the results were incorporated into the internal milestone report for this task.

TASK 3: Performing triaxial creep tests and investigating the effect of pore fluid chemistry on the creep behaviour

BACKGROUND

The data obtained from performing a series of triaxial creep experiments on samples under downhole pressure conditions are to be utilized to describe creep behaviour. The set-up is designed in a way to be able to run the tests under dry conditions while no fluid enters the system or run the tests while artificial pore fluid with different brine concentrations flows into the system. In addition, different fluids with different chemical solutions enter the system during each creep test to investigate the effect of changing the chemistry of annular fluid on the acceleration of the creep processes.

TASK OBJECTIVES

3.1) Running triaxial creep tests under dry downhole pressure condition
3.2) Running triaxial creep tests while artificial pore fluid with different brine concentrations flows into the system
3.3) Preforming the triaxial creep tests under downhole conditions along with investigating the effect of chemical solutions

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

The experimental results along with results interpretations will be summarized and incorporated into the final results.

PROGRESS REPORT

This milestone is complete.

CSIRO was supplied by the NTGS core library with core sections from Kyall formation through Shanandoah-1A well in the Beetaloo basin. The received cores were systematically imaged using a Siemens SOMATOM, known as a medical X-ray Computed Tomography (XRCT) scanner.

A sequence of experiments was then carried out on samples labelled 3991, 3992, 3993, and 3994. The samples underwent geomechanical testing, including single-stage triaxial compression (STXL) and multi-stage triaxial creep tests (MSTXL).

3.1) Running triaxial creep tests under dry downhole pressure condition

Single Stage Triaxial Compression (STXL) and Multi-Stage Triaxial Creep Tests (MSTXL) were conducted under dry conditions on samples 3991 and 3932, respectively. The geomechanical testings are performed at in-situ pressure and temperature conditions, i.e. confining pressure of 20-22 MPa and temperature of 82°C. The axial and radial deformations of the specimen were measured by employing two diametrically opposed LVDTs (Linear Variable Differential Transformers) mounted between the sample end platens to measure axial deformation of the sample; four cantilever (orthogonal) radial gauges mounted at the mid-height of the sample to measure radial deformation.

- Single Stage Triaxial Compression (STXL)

The Single-Stage Triaxial Compression (STXL) test installation for sample 3991 involves applying a cell pressure of 0.7 MPa to ensure stability and contact between the platens and the ends of the sample. Temperature is gradually increased to 82°C at a rate of approximately 18°C/hr, stabilising overnight. Subsequently, a cell pressure of 20 MPa is applied steadily at the rate of 2 MPa/min. Finally, loading commences once stabilisation is achieved, applying a differential axial load at a constant displacement rate equivalent to a strain rate of 5×10^{-7} per second, halting upon peak and residual strength detection.

- Multi-Stage Triaxial Creep Tests (MSTXL)

The Multi-Stage Triaxial Creep (MSTXL) test installation process in dry conditions for sample 3922 involves applying a cell pressure of 0.7 MPa to ensure stability and contact between the platens and the ends of the sample. Temperature is gradually increased to 82°C at a rate of approximately 18°C/hr, stabilising overnight. Subsequently, a cell pressure of 20 MPa is applied steadily at the rate of 2 MPa/min. Once the sample stabilises sufficiently, the minimum wait is 6 hours, and an incremental axial load is applied at a constant loading rate. The applied stress is maintained at the targeted value (holding stage) until the creep strain does not increase for a relatively long time. The procedure was repeated for several stages (in this instance, differential stress stages (σ_d) are as follows: 25,50,75,100 and 125 MPa), whilst the confining pressure (P_c) remained at 20 MPa, and temperature remained constant at 82°C until the specimen failed or the system was unstable.

3.2) Running triaxial creep tests while artificial pore fluid with different brine concentrations flows into the system

A multi-stage triaxial creep test (MSTXL) was conducted on sample 3993, and the sample was saturated for two weeks using a synthesised brine prior to testing. A portion of the core was extracted to acquire 200 grams of powder utilised to obtain a chemically balanced brine. It is crucial to obtain a synthesised chemically equilibrated brine for saturation purposes. The chemical composition of the brine was analysed, and the quantification and concentration of different minerals were mentioned in the milestone report. The sample was placed into a dedicated saturation cell to reach full sample saturation. The cell was vacuumed for six hours before being filled with the saturating fluid. The fluid pressure was maintained at 2.5MPa through a separator for two weeks. In order to facilitate a comparative analysis of creep characteristics and geomechanical behaviour of the samples, multi-stage triaxial creep testing remained mostly consistent with the procedures described previously. Sample 3993 underwent four stages of increasing and holding stages (each stage lasted for two weeks) whilst the confining pressure (P_c) remained at 20 MPa, and the temperature remained constant at 82°C. Ultimately, it failed at 104 MPa after 60 days.

3.3) Performing the triaxial creep tests under downhole conditions along with investigating the effect of chemical solutions

Multi-Stage Triaxial Creep Test (MSTXL) was conducted on sample 3994 while the sample was saturated for two weeks using sodium silicate solution (Na_2SiO_3) formulated as 10% v/v 2.6 SiO2:Na2O (silicate-to-alkali). This ratio was obtained by mixing commercially available 37% sodium silicate with the synthetic brine. pH of the solution prior to saturating the sample was equal to 10.5. The sample was placed into a dedicated saturation cell, which was vacuumed for six hours before being filled with the saturating fluid to reach full sample saturation. The fluid pressure was maintained at 2.5MPa through a separator for two weeks. The procedures for applying strain rates, ensuring instrumentation accuracy, and installing protocols were upheld consistently throughout all testing processes. During the test, the differential stress was increased in sequential stages: 25 MPa, 50 MPa, 75 MPa, 100 MPa, and 125 MPa, and eventually sample failed at σ_d = 136.66 MPa after 75.95 days, whilst the confining pressure (P_c) remained at 22 MPa and a constant temperature of 82°C during the experiment.

TASK 4: Results interpretations

BACKGROUND

Shale mechanical properties, including young's modulus (E), are computed from the slope of the stress-strain curves at the loading stages. The data obtained from performing a series of triaxial creep experiments on samples at different applied differential stresses and subjected to changing pore fluid chemistry is utilized to define time-dependent creep behaviour.

TASK OBJECTIVES

4.1) Defining creep behaviour of the Beetaloo basin shale according to the obtained experimental outputs

4.2) Observing the impact of different pore fluid chemistry on the Beetaloo basin shale creep rate

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

Experimental results, observations, and data interpretations will be incorporated into the project's final report.

PROGRESS REPORT

This milestone is complete.

4.1) Defining creep behaviour of the Beetaloo basin shale according to the obtained experimental outputs

Based on the experimental outputs from geomechanical testing (single-stage triaxial compression (STXL) and multi-stage triaxial creep tests (MSTXL)), the geomechanical (creep behaviour) of Beetaloo basin shale was characterised through various parameters. Key parameters, including the bulk modulus (K), shear modulus (G), Young's modulus (E), and Poisson's ratio, were measured during testing, providing essential insights into the shale's mechanical properties. The response of shales to creep tests was described through distinct stages: initial elastic strain, primary (transient) creep, secondary (steady-state) creep, and tertiary (accelerating) creep, ultimately leading to material failure. The occurrence of secondary and tertiary creep stages was shown to depend upon various factors, including stress magnitude, duration of applied stress, environmental chemistry, and the geomechanical properties of the sample. By explaining these stages and considering the interplay of influencing factors, a comprehensive understanding of the creep behaviour of Beetaloo basin shale was attained.

All samples demonstrated time-dependent deformation over time to different extents. The general observation is that the strain responses were increased as the applied axial differential stresses were increased from one stage to the next stage. For each creep test conducted, comprehensive measurements were undertaken to capture critical parameters essential for characterising the shale's time-dependent creep behaviour. These measurements included the creep strain and creep rate for each stage, which signifies the deformation rate over time, enabling an assessment of the shale's long-term geo-mechanical response. Additionally, distinct creep stages (primary, steady-state, and accelerated creep) were identified by analysing and dissecting the creep deformation rate for each holding stage throughout different intervals. Furthermore, the threshold stress of creep behaviour was determined, indicating the point at which sample failure occurred.

Moreover, understanding how Beetaloo basin shales deform over time under stress requires a comprehensive exploration of creep constitutive models. These models are essential tools for analysing the processes that lead to creating a barrier in decommissioned wells, describing shale mechanical properties and creep deformation parameters and illustrating the interplay between rock stress, strain, and time. In this study, a range of empirical laws, including Parabolic, Logarithmic, Hyperbolic, Crack-Damage, and analytical models (rheological models), including Kelvin-Voigt, Standard linear model, and Burgers models, were employed to predict the creep strain long-term behaviour of the shale. These constitutive parameters were derived from single and multi-stage triaxial creep experiments. Short-term creep tests provide constitutive model parameters capable of foreseeing long-term shale deformations under specific tested conditions. It is crucial to pinpoint a model or models and their respective constitutive parameters that offer superior predictive abilities, customised to the tested specimen and considering the in-situ conditions. R squared (R^2) and standard error of residuals (stderr) serve as instrumental tools for assessing the goodness of fit. These statistical metrics provide valuable insights into the alignment between models and observed data. Higher R^2 values indicate a stronger fit, while lower standard errors of residuals suggest a reduced discrepancy between observed and predicted values. The analysis of R^2 and stderr specified that the parabolic and hyperbolic models exhibited superior performance, particularly with respect to samples 3992 and 3993.

All figures and detailed findings mentioned in this study are outlined in Chapter 3 of the final report.

4.2) Observing the impact of different pore fluid chemistry on the Beetaloo basin shale creep rate

Observing the impact of different pore fluid chemistry on the creep rate of Beetaloo basin shale reveals distinct behaviours and failure mechanisms in samples 3992 (subjected to dry conditions) and 3994 (post-saturation with sodium silicate solution) under multi-stage triaxial creep tests. Sample 3992, subjected to stress stages ranging from 25 to 125 MPa, reaches a maximum observed strain of approximately 0.0075, experiencing failure during the hold stress stage of 125 MPa. Conversely, sample 3994 endures the same stress stages, withstanding the final stress of 125 MPa for 15 days before failing at a stress of 136.66 MPa, reaching a maximum observed strain of approximately 0.0149. Comparing the stress-strain responses of the two samples, it's evident that the curve corresponding to sample 3992, under dry conditions, exhibits a steeper slope, indicating higher stiffness or resistance to deformation (higher brittleness), with an average Young's modulus of 20.95 GPa. In contrast, samples 3993 and 3994 display more ductile behaviour, with an average Young's modulus of 15.33 and 16.37 GPa, respectively. The comparison between the responses of the dry sample (3992) and the sample saturated with Na_2SiO_3 solution (3994) underscores the significant role of incorporating chemical solutions in stimulating creep deformations and creating barriers during decommissioning. In other words, increased shale softening correlates with greater creep deformations, and this correlation results in a decrease in Young's modulus and hardness.

This finding suggests that as shale becomes more compliant, its viscous deformation becomes more prominent. Softening shales in the Beetaloo basin (Kyalla formation, depth 1590 m) initially transform them from brittle rocks into more viscous rocks, exhibiting significant creep deformations over time.

All figures and detailed findings mentioned in this study are outlined in Chapter 3 of the final report.

TASK 5: Developing a leakage rate simulator

BACKGROUND

A simple leakage simulator model will be developed to quantify the consequences of compromising a barrier or multiple barriers, which results in leakage from a plugged and decommissioned well to the surrounding environment. The leakage calculator will consider all physical processes affecting the potential movement of fluids along possible pathways within a well and to the surface. Independent review for the leakage simulator will be sought from industry and research peers.

TASK OBJECTIVES

The main emphases in developing the simulator will be placed on:

5.1) Developing a leakage rate simulator for formation fluids flowing from the reservoir to the potential leakage pathways.

5.2) Quantifying the contamination intensity due to the well leakage.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

A chapter explaining the simulator and the development processes will be incorporated into the project's final report.

PROGRESS REPORT

This milestone is complete.

5.1) Developing a leakage rate simulator for formation fluids flowing from the reservoir to the potential leakage pathways.

A simple leakage simulator was developed to quantify the consequences of compromising a barrier or multiple barriers, which results in leakage from a plugged and decommissioned well to the surrounding environment. The leakage calculator considers mechanical processes, including leakage through created micro-annuli and through cracks within the cement bulk affecting the potential movement of fluids along possible pathways within a well and to the surface.

5.2) Quantifying the contamination intensity due to the well leakage.

Quantifying the contamination intensity due to the well leakage was performed through comparison to international recorded flow rates from leaky wells.

TASK 6: Defining the key long-term decommissioned well integrity concepts

BACKGROUND

Defining key long-term decommissioned well integrity concepts such as timescale, and contamination grade.

TASK OBJECTIVES

6.1) Defining key long-term decommissioned well integrity concepts such as timescale and contamination grade.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

A chapter explaining long-term decommissioned well integrity concepts with further refinements will be incorporated into the project's final report.

PROGRESS REPORT

This milestone is complete.

Ongoing discussions with Government and industry stakeholders are complete.

The potential leakage of formation fluids into the surrounding environment poses a significant environmental risk, encompassing the release of saline water, liquid hydrocarbons, and gases such as methane, propane, and ethane. Therefore, monitoring, measuring, and analysing these emissions is of utmost importance. Understanding the adverse effects of contaminations on air, soil, and groundwater is detailed in the milestones report 6. Furthermore, the aging and deterioration of well components over time are critical considerations. Section 4 in the report explains the degradation of cement and casing due to exposure to downhole conditions and formation fluids. The efficacy of newly formed shale barriers may undergo alterations based on changes in in-situ stress, highlighting the dynamic nature of well infrastructure. Lastly, the report describes the complexities of ensuring long-term well integrity "in perpetuity." Engineering challenges emerge in quantifying the maximum allowable leakage rate, necessitating innovative solutions and a comprehensive understanding of the dynamic interplay between well components and the surrounding geological environment.

TASK 7: Updating decommissioned well leakage simulator with Beetaloo shale properties

BACKGROUND

The leakage simulator model will be updated based on the findings of the previous tasks.

TASK OBJECTIVES

7.1 Updating (tailoring based on the Beetaloo basin characteristics) the leakage rate simulator for formation fluids flowing from the reservoir to the potential leakage pathways

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

A chapter explaining the simulator and the development processes will be incorporated into the project's final report.

PROGRESS REPORT

This milestone is complete.

In this task, the Parabolic creep ($\varepsilon = At^m$) model was integrated into the leakage simulator to assess the state of the annulus gap between the casing and shale formation. This incorporation aimed to provide insights into whether the annulus would gradually fill and close over time due to shale creep or remain open. By utilising the predictive capabilities of the Parabolic (power law) model, the simulator could predict the long-term behaviour of the shale and its interaction with the casing, offering valuable information for decision-making in well integrity studies.

The integration of the parabolic creep law is placed under the micro-annulus section within the simulator. Users are required to input parameters including the casing diameter, mean, and standard deviation of the micro-annulus gap, the parabolic constitutive parameters represented by A and m, time duration, and the formation width (outer radius minus inner radius). The simulator will produce graphs showing the evolution of formation strain caused by creep (based on the Parabolic model) and the corresponding leakage rate from micro-annulus (m^3/s) versus time. By factoring in both the mean micro-annulus gap and its standard deviation, users gain insights into variability and uncertainty in calculating leakage rates and gap closure, enabling better preparation for diverse scenarios and outcomes.

TASK 8: Project Reporting

BACKGROUND

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

TASK OBJECTIVES

To ensure that the information generated by this project is documented and published after thorough CSIRO Internal review.

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

8.1) Preparation of a final report outlining the scope, methodology, scenarios, assumptions, findings and any suggestions/options for future research.

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

8.3) Provide 6 monthly progress updates to GISERA office.

PROGRESS REPORT

This task is complete. The report comprises project aims, methods, results and implications. Following peer review, the report is now submitted to the GISERA Director for final approval.

TASK 9: Communicate project objectives, progress and findings to stakeholders

BACKGROUND

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

TASK OBJECTIVES

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

TASK OUTPUTS AND SPECIFIC DELIVERABLES:

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

9.1) Knowledge Transfer session with Government/Gas Industry

9.2) Presentation of findings to Community members/groups

9.3) Preparation of article for GISERA newsletter and other media outlets e.g. The Conversation

9.4) Revision of project factsheet to include final results (a factsheet is developed at project commencement, and another will be done at completion)

9.5) Peer reviewed scientific manuscript ready for submission to relevant journal

PROGRESS REPORT

This task will be completed by early November 2024. A knowledge transfer session was conducted on 21 June and another on 24 June 2024. The project lead is working with CSIRO’s communications team on an article and factsheet.

Variations to Project Order

Changes to research Project Orders are approved by the GISERA Director, acting with authority, in accordance with the GISERA Alliance Agreement. Any variations above the GISERA Director's delegation require the approval of the relevant GISERA Research Advisory Committee.

The table below details variations to research Project Order.

Register of changes to Research Project Order

DATE	ISSUE	ACTION	AUTHORIZATION
11/10/23	The project team have experienced difficulties in obtaining suitable samples and with maintenance issues in performing Task 3, which hinders the completion of Tasks 4, 6 & 7	Milestone 3 extended from 15 Jul 2023 to 15 Jan 2024, Milestone 4 extended from 15 Aug 2023 to 15 Feb 2024, Milestone 6 extended from 15 Jul 2023 to 15 Nov 2023 & Milestone 7 extended from 15 Oct 2023 to 15 Apr 2024.	
11/10/23	The above delays have also hindered the completion dates of Tasks 8 and 9	Milestone 8 & 9 extended from 15 Nov 2023 to 15 May 2024	

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GISERA is a collaboration between CSIRO, Commonwealth and state governments and industry established to undertake publicly-reported independent research. The purpose of GISERA is to provide quality assured scientific research and information to communities living in gas development regions focusing on social and environmental topics including: groundwater and surface water, greenhouse gas emissions, biodiversity, land management, the marine environment, and socio-economic impacts. The governance structure for GISERA is designed to provide for and protect research independence and transparency of research.