Australia's National
Science Agency

GISERA | Gas Industry Social and Environmental Research Alliance

Progress report

Groundwater modelling and predictive analysis to inform CSG impact assessment, monitoring and management

CSIRO | Australian Government Department of Industry, Science and Resources | NSW Government | Supported by Government of South Australia | Queensland Government | Northern Territory Government | origin | Australia Pacific LNG | QGC | Santos

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	Project inception meeting	Sep-22	Mar-23	Completed
2	Updating, calibrating and prediction analysis including data-worth using Namoi subregional model	Oct-22	Dec-23	Completed
3	Groundwater recharge and discharge	Oct-22	Dec-23	Completed
4	Data assimilation and water balance	Jul-23	20 Dec 24	Completed
5	Machine Learning methods and application	Sep-23	20 Dec 24	Completed
6	New groundwater model development	Mar-24	Jun-25	
7	Paired simple and complex model analysis	Jul-24	Jul-25	
8	Interactive dashboard	Jan-23	Mar-25	
9	Student engagement	Sep-22	Jul-25	
10	Project reporting	Sep-22	Jul-25	
11	Communication findings to stakeholders	Full duration of project – 30 October 2025		

Project schedule report

TASK 1: Project inception and stakeholder meeting

BACKGROUND

Santos Limited, NSW DPIE and the Office of Water are key stakeholders of the project. These stakeholders would be able to provide information about CSG water production rates and times and other valuable data and knowledge regarding the hydrogeological context.

TASK OBJECTIVES

Set the scene for the project, establish contact points with stakeholders, establish the technical reference group and facilitate data provisions.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

Stakeholder meeting completed.

PROGRESS REPORT

Meetings with the stakeholders completed. Meetings were held with relevant stakeholder of the project in Santos (Oct-22, Apr-23) to give an overview of the project and to discuss about data availability from Santos's hydrogeological investigations and timeline of Narrabri Gas Project.

Meeting was also held with the relevant stakeholders in the Water Division of NSW DPE to present an overview of the project, timeline and relevant data provisions. Contact points have been established to communicate during the course of the project.

TASK 2: Updating and calibrating the Namoi subregional model and predictive analysis including data-worth analysis

BACKGROUND

Previous GISERA/BA modelling considered a wide range of CSG water production rates to quantify and bracket potential maximum impacts to groundwater heads and fluxes. Those studies used a rejection sampling approach to constrain predictions and were not calibrated to observed groundwater heads and fluxes and estimated CSG and mine water production rates through history matching. This task will refine those predictions by calibrating the model to the maximum water production rate of 37.5 GL over a 25-year period. A PEST++ -based approach will be used for history matching to observed groundwater levels and fluxes as well as time series of estimated CSG water production rates.

TASK OBJECTIVES

The model set up will be updated and calibrated to observed groundwater heads and estimated CSG production rates; predictive analysis of CSG impacts conducted using updated and calibrated model.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

Updated and calibrated model, predictive analysis including relative data-worth for monitoring decisions. Report the findings in a peer-reviewed journal paper.

PROGRESS REPORT

This task is complete. Updated data-worth analysis for monitoring network design is published in the peer-reviewed journal Frontiers in Water. Simulation-optimization -based predictive analysis developed in the previous project was improved to using a novel neural network approach to undertake the predictive analysis of maximum flux and drawdown impacts. The updated model will be used for water balance analysis in task 4.

TASK 3: Groundwater recharge and discharge (including evapotranspiration)

BACKGROUND

Conceptual understanding and data pertaining to groundwater recharge and discharge processes are important to quantify the dynamic water balance of aquifers. This is in turn important to assess the impacts caused by CSG development and other cumulative stresses. Climate change impacts will have a considerable impact on the groundwater balance of the GAB and alluvial aquifers of the Namoi region in the coming decades. Assessment of impacts from resource development should account for the cumulative impacts including that of climate change to devise management strategies.

TASK OBJECTIVES

Investigating recharge and discharge processes including groundwater contribution to evapotranspiration based on current and improved understanding of conceptual models for the

Namoi Alluvium and Pilliga Sandstone aquifers using appropriate methods including Water Table Fluctuation, chloride mass balance and/or modelling. Key changes to these processes due to climate change for major aquifers will also be investigated to include in the simulation of long-term groundwater balance.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

Estimate of recharge and discharge including groundwater contribution to evapotranspiration and its representation in the numerical groundwater model.

PROGRESS REPORT

This task is completed. AWRA-L model results have been generated for simulating water balance components - groundwater recharge and discharge. Simulated recharge patterns compare well with long-term chloride mass balance. The resulting recharge and EVT patterns have been generated at the MODFLOW model nodes for further use in task 4.

TASK 4: Data assimilation from field and remote sensing data and water balance and data-worth analysis

BACKGROUND

In addition to observed water levels in the alluvial and GAB aquifers there is a large amount of remote sensing data and other information available to constrain water balance. This includes fine scale (30) estimates of evapotranspiration, estimates of recharge, estimates of groundwater pumping and observed inter-aquifer head gradients. Estimation of pre-development water balance is important to set the baseline trends in groundwater balance and storage trends. Similarly, future water balance corresponding to a combination of scenarios including gas development and climate change are required to inform individual and cumulative impacts of CSG with other stresses including groundwater use and climate change.

TASK OBJECTIVES

Use field and remote sensing data sets to constrain modelled water balance for the Namoi alluvial aquifers and the Pilliga Sandstone aquifer (GAB) and quantify the relative data-worth of multiple data types and data sets in informing aquifer water balance.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

- Improved baseline and future water balance for the GAB and alluvial aquifers in the simulation model for CSG impacts assessment.
- Relative data-worth of different data types in informing the groundwater level and water balance simulation quantified
- Findings summarised in a factsheet and methodology written up as a journal paper manuscript

PROGRESS REPORT

This task is completed. The Namoi subregional groundwater model was updated with improved data pertaining to recharge processes (diffuse, river and flood recharge). Model calibration and data assimilation was completed using the latest PEST-IES approach. Groundwater modelling

section of the draft report is updated with the results from these analyses including water balance results.

TASK 5: Machine Learning method for differentiating groundwater trends and impact predictions

BACKGROUND

The Namoi subregion has very complex hydrogeology and spatiotemporal patterns in groundwater levels and aquifer connectivity varies significantly across the region. Recharge processes are also complex. In such regions, it is difficult to differentiate, and attribute observed trends in data, e.g., groundwater levels to specific recharge processes. Nor is it easy to attribute an observed drawdown to any specific stressor, e.g., irrigation water use or CSG water production. Current and future observations of groundwater drawdown in the GAB or alluvial aquifers could potentially be caused by gas development, mining, over allocation for irrigation or climate change impacts. However, spatiotemporal patterns invisible to the human eye could be assessed using advanced Machine Learning techniques. Such analyses may help develop improved conceptual understanding of processes and better constrain models.

TASK OBJECTIVES

Develop and test a methodology based on simulations and Machine Learning to differentiate trends in observed and simulated groundwater patterns.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

Novel methodology for differentiating trends in observed and simulated spatiotemporal patterns in groundwater variables and application to the Namoi subregion.

PROGRESS REPORT

This task has been complete. Alternative Machine Learning methods, and spatial lumping approaches have been explored to develop emulators/surrogate models for evaluating trends in groundwater levels and water balance components obtained from the numerical model. The methodology and the model set up to emulate the trends at the SDL-resource unit scale have been finalized. Groundwater balance components lumped to these SDL-resource units in the vicinity of the NGP have also been produced from the numerical model.

TASK 6: New model development based on improved conceptual model

BACKGROUND

A relatively simplified 15-layer conceptualization of the subsurface geology was adopted for the Namoi subregional model. The simplified conceptualisation provided a robust model that could be evaluated for a wide range of plausible parameterisations to quantify prediction uncertainties. However, the simplification of the geology can potentially cause bias and uncertainties induced by the model structure in prediction. In this task a numerical model based on an improved conceptual model (that is developed in parallel in the companion GISERA project by Raiber et al. (2022)) will be developed. This will be a 2D or 3D model to suit the purpose of paired simple and complex model evaluation.

TASK OBJECTIVES

Develop a new model based on the improved conceptualisation to refine predictions in the Namoi subregional model with improved representation of geology obtained from Raiber et al. (2022) and data analyses in the previous tasks.

TASK OUTPUTS AND SPECIFIC DELIVERABLES

Numerical model based on improved conceptual model.

PROGRESS REPORT

This task will be completed in June 2025.

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	AUTHORISATION
25/10/2023	Milestones delayed due to staff and data availability issues.	Milestones 2 & 3 extended from October 2023 to December 2023.	
05/06/2024	Milestones are delayed due to negotiating data with NSW Gov for components of these tasks.	Milestones 4 & 5 extended from June 2024 to 20 December 2024.	
19/10/24	This milestone is dependent on the completion of GISERA Project W28's (Geochemical modelling and geophysical surveys to refine understanding of connectivity between coal seams and aquifers) conceptual model which will not be ready until December 2024. Once W28's model is complete, the W29 team will need 6 months to deliver milestone 6.	Milestone 6 extended from December 2024 to June 2025.	

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us

1300 363 400
+61 3 9545 2176
csiro.au/contact
csiro.au

For further information

1300 363 400
gisera.csiro.au

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.