# Project Order, Variations and Research Progress

Project Title: Improving current groundwater flow models to better account for the relationships between coal seam reservoir properties, like well arrangements and groundwater flow

This document contains three sections. Click on the relevant section for more information.

# 1 Original Project Order

# Project Order

## Proforma 2016

### 1. Short Project Title

Improving groundwater models to better represent coal seam gas extraction impacts in the Namoi region

| | |
|---|---|
| Long Project Title | Improving current groundwater flow models to better account for the relationships between coal seam reservoir properties, likely well arrangements and groundwater flow |
| GISERA Project Number | W.9 |
| Proposed Start Date | 1 December 2016 |
| Proposed End Date | 30 November 2018 |
| Project Leader | Luke Connell |

### 2. GISERA Region

☐ Queensland ☒ New South Wales ☐ Northern Territory

### 3. GISERA Research Program

☒ Water Research ☐ GHG Research ☐ Social & Economic Research

☐ Biodiversity Research ☐ Agricultural Land Management Research ☐ Health

### 4. Research Leader, Title and Organisation

Luke Connell, Research Scientist, CSIRO Energy, 20% of time on project

## 5. Background

The GISERA stakeholders have identified water impacts as key questions, i.e. "WQ01 What amount of water is used by the CSG industry and where does it come from." In addition, the top ranked research topic by the GISERA stakeholders was "Groundwater levels – including depletion and contamination of surrounding aquifers." Both of these issues are largely investigated using groundwater modelling. However, existing groundwater models used in CSG impact assessment do not and cannot represent the details of the actual flow process within the CSG well field, instead rely on simplified relationships or estimates of the CSG water production. In reality groundwater flow and CSG water production are closely coupled. The existing CSG groundwater impact modelling compensate for these inaccuracies by using conservative assumptions to ensure impacts are over-estimated. This project would significantly improve the accuracy with which CSG groundwater impacts are assessed for the Namoi region by more accurately representing the effects of CSG production in the groundwater modelling of this area. As part of this work, the project would develop an approach with more general application suitable for use in other CSG groundwater assessments.

Coal seam gas (CSG) is extracted by producing water through wells to lower the pore pressure within the coal. Reducing the pore pressure leads to methane desorption from the coal with the resultant gas production determined by a number of processes which also affect the rate of water production. A challenge is representing these complex coupled reservoir flow processes, which operate at relatively small scales around the producing wells, in the large scale models used to assess groundwater impacts. Several studies have shown that this is an important effect with significant impact on the resulting CSG groundwater assessment (Commonwealth of Australia, 2014; Moore et al., 2015; Herckenrath et al., 2015).

The Queensland Office of Groundwater Impact Assessment (OGIA) developed a procedure to improve the representation of coal seam gas impacts in their groundwater modelling assessments (Herckenrath et al., 2015). This was based on compiling a series of simulation results from the ECLIPSE reservoir model where various reservoir processes operating during gas production were represented. The ECLIPSE results showed that during production the degree of water saturation tended to asymptote over time to a monotonic relationship with respect to pressure. This relationship was used in a version of MODFLOW that represented unsaturated flow. For the cases considered, the resultant MODFLOW predictions of drawdown due to the coal seam gas wells were found to compare well to those from the ECLIPSE modelling. However, not all the reservoir processes were included in the ECLIPSE modelling; for example, the relationship that permeability has with respect to effective stress and the effects of matrix shrinkage were neglected. These processes interact to determine the impacts of CSG production related water use on groundwater levels, the top ranked research topic identified by GISERA stakeholders.

## 6. Project Description

This project would evaluate and further develop the procedure used in the OGIA modelling to represent CSG well field groundwater impacts and apply it to the Namoi region. The project would develop a procedure that would be used in other groundwater modelling being conducted under GISERA for Namoi. The developed relationship for the CSG impacts would then be implemented in the groundwater model being developed under the current GISERA project "Impacts of CSG depressurization on GAB flux project" in work supported under the this project.

This project would be based on detailed reservoir simulation of CSG production at Namoi using the SIMEDWin reservoir simulator. This model would use the coal seam reservoir properties and likely well arrangements for Namoi. The results from these simulations would be used to evaluate the potential of the saturation vs pressure relationship as described by Herckenrath et al. (2015) or other potential relationships between key driving variables that could prove suitable for implementation in MODFLOW. The developed relationship would then be used to update the MODFLOW model developed for the Namoi under the GISERA GAB flux project. The results would also be compared with how the CSG well field is represented in the Santos EIS and CSIRO's Bioregional Assessment groundwater modelling and potential impacts that this could have on the predictions from this work considered. Since the developed relationship would be based on reservoir simulations for the Namoi it would be specific for that location. The coal formations to be focused on are the Hoskissons Coal formation and seams in the Maules Creek Formation in the Gunnedah Basin.

## 7. Budget Summary

| Expenditure | 2016/17 | 2017/18 | 2018/19 | Total |
|---|---|---|---|---|
| Labour | 74,496 | 160,415 | 63,585 | 298,496 |
| Operating | 700 | 1,400 | 700 | 2,800 |
| Subcontractors | - | - | - | - |
| **Total Expenditure** | **75,196** | **161,815** | **64,285** | **301,295** |

| Expenditure per Task | 2016/17 | 2017/18 | 2018/19 | Total |
|---|---|---|---|---|
| Task 1 | 32,615 | - | - | 32,615 |
| Task 2 | 14,348 | - | - | 14,348 |
| Task 3 | 28,233 | 74,114 | - | 102,347 |
| Task 4 | - | 73,161 | - | 73,161 |
| Task 5 | - | 14,540 | 7,856 | 22,396 |
| Task 6 | - | | 56,429 | 56,429 |
| **Total Expenditure** | **75,196** | **161,815** | **64,285** | **301,295** |

| Source of Cash Contributions | 2016/17 | 2017/18 | 2018/19 | Total |
|---|---|---|---|---|
| GISERA Industry Partners (25%) | 18,799 | 40,454 | 16,071 | 75,324 |
| - Santos (12.5%) | 9,400 | 20,227 | 8,035 | 37,662 |
| - AGL (12.5%) | 9,400 | 20,227 | 8,035 | 37,662 |
| NSW Government (25%) | 18,799 | 40,454 | 16,071 | 75,324 |
| Federal Government (25%) | 18,799 | 40,454 | 16,071 | 75,324 |
| **Total Cash Contributions** | **56,397** | **121,361** | **48,214** | **225,971** |

| In-Kind Contribution from Partners | 2016/17 | 2017/18 | 2018/19 | Total |
|---|---|---|---|---|
| CSIRO (25%) | 18,799 | 40,454 | 16,071 | 75,324 |
| **Total In-Kind Contribution from Partners** | **18,799** | **40,454** | **16,071** | **75,324** |

| | Total funding over all years | Percentage of Total Budget |
|---|---|---|
| GISERA Investment | 75,324 | 25% |
| NSW Government Investment | 75,324 | 25% |
| Federal Government Investment | 75.324 | 25% |
| CSIRO Investment | 75,324 | 25% |
| Total Other Investment | - | |
| **TOTAL** | **$301,295** | |

| Task | Milestone Number | Milestone Description | Start Date (mm-yy) | Delivery Date (mm-yy) | Fiscal Year Completed | Funded by | Payment $ (excluding CSIRO contribution) |
|---|---|---|---|---|---|---|---|
| **Task 1** | 1.1 | Completion of review and data collation | 12-16 | 3-17 | 2016/17 | GISERA | $24,461.25 |
| **Task 2** | 2.1 | CSG model construction complete | 3-17 | 5-17 | 2016/17 | GISERA | $10,761.00 |
| **Task 3** | 3.1 | Coal seam gas simulations conducted to identify how groundwater production is related to water table level or other key driving variables suitable for use in MODFLOW for the Namoi | 5-17 | 12-17 | 2017/18 | GISERA | $76,760.25 |
| **Task 4** | 4.1 | Approaches to representing coal seam gas groundwater impacts at the spatial scale of the MODFLOW grid. | 12-17 | 5-18 | 2017/18 | GISERA | $54,870.75 |
| **Task 5** | 5.1 | Implementing the results of Tasks 3 and 4 in MODFLOW to represent CSG well field influences. | 5-18 | 8-18 | 2018/19 | GISERA | $16,797.00 |
| **Task 6** | 6.1 | Updating of Namoi MODFLOW model predictions and assessment of other groundwater modelling for Namoi | 5-18 | 12-18 | 2018/19 | GISERA | $42,321.75 |

## 8. Other Researchers

| Researcher | Time Commitment (project as a whole) | Principle area of expertise | Years of experience | Organisation |
|---|---|---|---|---|
| Luke Connell | 20% | CSG reservoir and groundwater simulation | 30 | CSIRO |
| Nick Lupton | 20% | CSG reservoir engineering | 5 | CSIRO |
| Regina Sander | 10% | CSG reservoir engineering | 5 | CSIRO |
| Sreekanth Janardhanan | 40 days | Groundwater modelling | 10 | CSIRO |

## 9. Subcontractors

| Subcontractors (clause 9.5(a)(i)) | Subcontractor | Role |
|---|---|---|
| | N/A | |
| | | |

## 10. Project Objectives and Outputs

Groundwater impact is a key issue of concern with CSG development. In the NSW CSG research interest stakeholder survey groundwater levels were identified as the top ranked research topic. This project would contribute directly to improving the prediction of groundwater impacts by ensuring accurate representation of the effects of CSG production in the groundwater models being developed for the Namoi region. Preliminary research work completed in Queensland and presented in Moore et al. (2015) indicates that prediction of groundwater drawdown impacts by conventional models can have significant errors. These uncertainties are compensated for in existing CSG impact modelling by applying conservative assumptions such that potential impacts are over-predicted. The degree of over-prediction is difficult to estimate as there are a broad range of influences operating with each site being unique. The research will help to underpin the next-round of regional scale CSG impact assessments using improved understanding of the reservoir processes.

## 11. GISERA Objectives Addressed

This project would address the top ranked research topic identified by GISERA stakeholders; groundwater levels in response to CSG. It would improve the reliability of groundwater assessments by developing an approach that can be incorporated into existing groundwater flow models and captures the influence of the range of processes operating around CSG wells that determine the water flow and production. The final task of the project will update the GISERA MODFLOW model for the GAB fluxes using the relationships identified for groundwater production. The estimates of groundwater production used in other groundwater modelling of the Namoi by Santos and CSIRO Bioregional Assessments will be compared to that predicted by the developed approach and the potential impacts on model predictions discussed.

## 12. Project Development

The project was developed through a review of the literature, the project leader's involvement in previous work on upscaling of CSG well field simulations for MODFLOW modelling funded by QGC, and discussions with CSIRO staff Sreekanth Janardhanan and Luk Peters who are involved in the Bioregional Assessments and GISERA groundwater modelling. From this it was clearly identified that there was a need to develop improved approaches to describing the integrated impact of the CSG well field on groundwater systems. The project would further develop the approach used in the OGIA groundwater modelling as described by Herckenrath et al. (2015) and apply this to the Namoi region. The immediate application of this work would be in the GISERA project "Impacts of CSG depressurization on GAB flux project" where it would be used to improve the representation of water production from the CSG well field in groundwater flow modelling. It would develop an approach that could be used with future groundwater assessment modelling and therefore directly improve the accuracy of that work.

This project would be based on detailed reservoir simulation of CSG production at Namoi using the SIMEDWin reservoir simulator. This model would use the coal seam reservoir properties for Namoi and likely well arrangements. The results from these simulations would be used to evaluate the potential of the saturation vs pressure relationship as described by Herckenrath et al. (2015). The developed relationship would then be used to update the MODFLOW model developed for the Namoi under the GISERA GAB flux project. The results would also be compared with how the CSG well field is represented in the Santos EIS and CSIRO's Bioregional Assessment groundwater modelling. These models have been constructed using conservative assumptions to ensure impacts are not under estimated. The comparison with the current modelling will consider the magnitude of the over prediction resulting from these conservative assumptions.

## 13. Project Plan

**Commence Project**

*Stage 1*

**Development of model for CSG well fields for the Namoi suitable for use in MODFLOW**
(includes review of existing approaches, data collation for the Namoi, SIMEDWin CSG modelling for the Namoi, development of mathematical relationships to explain CSG well field impacts for MODFLOW modelling of Namoi)

**Decision Point**

Enables discussion/decision making about the developed modelling before proceeding to its implementation in Namoi Modlfow models and updating of the GAB flux model

The GISERA Director to provide approval to proceed

**Proceed with Stage 2 of Project**

*Stage 2*

**Implementation of CSG model into MODFLOW, updating of GAB flux predictions for Namoi, comparison with other existing Namoi groundwater models, presentation of Final report**

## 13.1 Project Schedule

| ID | Task Title | Task Leader | Scheduled Start | Scheduled Finish | Predecessor |
|---|---|---|---|---|---|
| **Task 1** | Completion of review and data collation | Luke Connell | 1/12/2016 | 1/3/2017 | |
| **Task 2** | CSG model construction complete | Nick Lupton | 1/3/2017 | 1/5/2017 | Task 1 |
| **Task 3** | Coal seam gas simulations conducted to identify how groundwater production is related to water table level or other key driving variables suitable for use in MODFLOW for the Namoi | Luke Connell | 1/5/2017 | 1/12/2017 | Task 2 |
| **Task 4** | Approaches to representing coal seam gas groundwater impacts at the spatial scale of the MODFLOW grid. | Luke Connell | 1/12/2017 | 1/5/2018 | Task 3 |
| **Task 5** | Implementing the results of Tasks 3 and 4 in MODFLOW to represent CSG well field influences. | Nick Lupton | 1/5/2018 | 1/8/2018 | Task 4 |
| **Task 6** | Updating of Namoi MODFLOW model predictions and assessment of other groundwater modelling for Namoi | Sreekanth Janardhanan | 1/8/2018 | 1/12/2018 | Task 3,4,5 |

**Task 1**

**TASK NAME:** Review and collation of Namoi site data for CSG reservoir simulation

**TASK LEADER:** Luke Connell

**OVERALL TIMEFRAME:** 3 months

**BACKGROUND:** This task involves the review of previous scientific work on CSG upscaling with a particular focus on the OGIA approach and that of Moore et al. (2014). An important part of this review will be a consideration of the differences in aquifer geology (i.e. confined vs unconfined) between the Namoi and for the areas considered in the previous work. This review would comprise a chapter in the final report and a section of the milestone report for this Task. The second activity in this task would be collation of the properties required for CSG reservoir simulation for the Namoi. This information would be largely sourced from published studies on the Namoi under GISERI, Santos EIS and CSIRO Bioregional Assessments but some properties may need to be estimated from the literature. The results of this task would be summarised in a milestone report.

**TASK OBJECTIVE:** Review of previous work related to the representation of CSG well field impacts into groundwater modelling and collation of site data required for reservoir simulation

**TASK OUTPUTS:** A summary of previous approaches to representing CSG groundwater impacts and collated site properties for the Namoi area of interest.

**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

**Task 2**

**TASK NAME:** Construction of Namoi CSG models

**TASK LEADER:** Nick Lupton

**OVERALL TIMEFRAME:** 3 months

**BACKGROUND:** In this task a series of Namoi CSG models will be constructed to cover the range of likely production scenarios and ranges of reservoir properties. The role of the model boundary will investigated using progressively larger model sizes to verify that the boundary does not artificially influence the simulation results. The production scenarios will be based on information presented in the Santos Namoi EIS.

**TASK OBJECTIVE:** A series of CSG models in SIMEDWin to represent Namoi production scenarios.

**TASK OUTPUTS:** SIMEDWin input data files for Namoi CSG production.

**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

**Task 3**

**TASK NAME:** Relationships between groundwater pressure and production rate for the CSG field.

**TASK LEADER:** Luke Connell

**OVERALL TIMEFRAME:** 6 months

**BACKGROUND:** In this task a series of simulations for likely CSG well field arrangements in terms of well spacings and the other key groundwater parameters will be performed and the simulation results compiled to investigate the potential for developing simple relationships between the key driving variables operating and groundwater production in a similar manner to that used in the OGIA modelling described by Herckenrath et al. (2015).

**TASK OBJECTIVE:** To develop relationships for groundwater production from the Namoi CSG well field of a form suitable for incorporation into MODFLOW groundwater modelling.

**TASK OUTPUTS:** A tested functional relationship for groundwater production modelling in MODFLOW that captures the near well processes operating during CSG production and the integration between groundwater flow and CSG water production.

**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as milestone report.

### Task 4

**TASK NAME:** Approaches to representing coal seam gas groundwater impacts at the spatial scale of the MODFLOW grid.

**TASK LEADER:** Luke Connell

**OVERALL TIMEFRAME:** 5 months

**BACKGROUND:** In this task the role of the spatial scale will also be investigated to assess potential approaches for upscaling the CSG well field simulations to larger scales amenable to the grid block sizes used in regional scale MODFLOW groundwater modelling such as that used in the GISERA project on the GAB fluxes. The approach described by Moore et al. (2014) for upscaling will be used as a starting point for this work.

**TASK OBJECTIVE:** To develop relationships suitable for MODFLOW modelling that allow larger grid block sizes to used and still accurately represent the integration between groundwater production from the CSG well field and groundwater flow at local and regional scales.

**TASK OUTPUTS:** An approach to upscaling the Namoi CSG well field for MODFLOW regional scale modelling for Namoi.

**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

### Task 5

**TASK NAME:** Implementing the results of Tasks 3 and 4 in MODFLOW to represent CSG well field influences.

**TASK LEADER:** Nick Lupton

**OVERALL TIMEFRAME:** 2 months

**BACKGROUND:** In this task the outcomes from Tasks 3 and 4 will be implemented in the version of MODFLOW used in the groundwater assessment work performed under GISERA.

**TASK OBJECTIVE:** To develop relationships suitable for MODFLOW modelling that allow larger grid block sizes to be used and still accurately represent the integration between groundwater production from the CSG well field and groundwater flow at local and regional scales.

**TASK OUTPUTS:** An approach to upscaling the CSG well field suitable for MODFLOW regional scale modelling.

**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

### Task 6

**TASK NAME:** Updating of Namoi MODFLOW model predictions and assessment of other groundwater modelling for Namoi

**TASK LEADER:** Sreekanth Janardhanan

**OVERALL TIMEFRAME:** 6 months

**BACKGROUND:** Regional scale groundwater models are commonly used for predicting the groundwater impacts caused by coal seam gas development. Unlike reservoir models groundwater models built using popular codes like MODFLOW are unable to simulate the gas/water dual phase flow occurring near the gas wells. Discounting the dual phase flow near the CSG wells in regional groundwater models result in large scale over prediction of groundwater drawdown in the coal seams and nearby formations. These near-field over prediction of drawdown could also potentially result in uncertainties in the prediction of impacts at a wide range of risk receptors like farmers' bores, groundwater dependent ecosystems, springs etc. In this task the data/knowledge derived from the well field scale reservoir simulations will be used to develop and improve method for the representation of near-field desaturation of coal measures in regional scale groundwater model simulations. The developed methods will be used to minimise uncertainties in the prediction of groundwater impacts in the Namoi region. The groundwater model used in the GISERA GAB flux project will be used for this task.

This task will also compare the predictions of groundwater production with how the CSG well field is represented in the Santos EIS and CSIRO's Bioregional Assessment groundwater modelling.

**TASK OBJECTIVE:** Updating the regional scale groundwater impact predictions in the Namoi region by incorporating the near field desaturation processes.

**TASK OUTPUTS:** Improved representation of near-field processes in a regional groundwater model for the Namoi region.

**SPECIFIC DELIVERABLES:** Report/chapter describing the methods and application.

Gantt Chart

| | 2016 | 2017 | | | | | | | | | | | 2018 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1. Review and site data collation | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | |
| 2. Namoi csg models | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | |
| 3. Groundwater relationships | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | |
| 4. Upscaling | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| 5. Links to MODFLOW | | | | | | | | | | | | | | | | | | | ■ | ■ | | | | | |
| 6. Updating Namoi groundwater model | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | |

## 14. Communications Plan

Communication of the results of the project will be managed in accordance with GISERA's communication strategy. This may include presentations at community and industry meetings, conferences and publication of reports, scientific articles and factsheets. In addition, communication with relevant state and federal government departments including NSW Chief Scientist Office will be maintained to ensure that they are aware of the outcomes of the research and possible policy implications.

The project will establish a Technical Reference Group (TRG) aimed at seeking advice on contextual matters and to discuss research needs as well as outputs as the project progresses. The TRC will include the project leader and a group of different stakeholders, as appropriate (noting NSW Chief Scientist Office have been approached and declined).

## 15. Intellectual Property and Confidentiality

| | | | | |
|---|---|---|---|---|
| Background IP (clause 11.1, 11.2) | **Party** | **Description of Background IP** | **Restrictions on use (if any)** | **Value** |
| | CSIRO/UNSW | SIMEDWin | Jointly owned | License fee $20,000 |
| | | | | |
| 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 (clause 13.4) | Not applicable | | | |
| Commercialisation Interest (clause 1.1) | **Party** | | **Commercialisation Interest** | |
| | Santos | | | |
| | AGL | | | |
| | CSIRO | | | |

# 2 Variations to Project Order

Changes to research Project Orders are approved by the GISERA Director, acting with authority provided by the GISERA National Research Management Committee, in accordance with the National GISERA Alliance Agreement.

The table below details variations to research Project Order.

### Register of changes to Research Project Order

| Date | Issue | Action | Authorisation |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

# 3 Progress against project milestones

Progress against milestones are approved by the GISERA Director, acting with authority provided by the GISERA National Research Management Committee, in accordance with the National 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 approved for one amber light.
     - 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 and undertaken by GISERA Research Advisory Committee.

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

| ID | Task Title | Task Leader | Scheduled Start | Scheduled Finish | Predecessor |
|---|---|---|---|---|---|
| **Task 1** | Completion of review and data collation | Luke Connell | Dec-16 | Mar-17 | |
| **Task 2** | CSG model construction complete | Luke Connell | Mar-17 | May-17 | Task 1 |
| **Task 3** | Coal seam gas simulations conducted to identify how groundwater production is related to water table level or other key driving variables suitable for use in MODFLOW for the Namoi | Luke Connell | May-17 | Dec-17 | Task 2 |
| **Task 4** | Approaches to representing coal seam gas groundwater impacts at the spatial scale of the MODFLOW grid. | Luke Connell | Dec-17 | May-18 | Task 3 |
| **Task 5** | Implementing the results of Tasks 3 and 4 in MODFLOW to represent CSG well field influences. | Luke Connell | May-18 | Aug-18 | Task 4 |
| **Task 6** | Updating of Namoi MODFLOW model predictions and assessment of other groundwater modelling for Namoi | Luke Connell | May-18 | Dec-18 | Task 3,4,5 |

GISERA
Gas Industry Social and Environmental Research Alliance

# Project Schedule Report

## Task 1

**TASK NAME: Review and collation of Namoi site data for CSG reservoir simulation**
**TASK LEADER:** Luke Connell
**OVERALL TIMEFRAME:** 3 months
**BACKGROUND:** This task involves the review of previous scientific work on CSG upscaling with a particular focus on the OGIA approach and that of Moore et al. (2014). An important part of this review will be a consideration of the differences in aquifer geology (i.e. confined vs unconfined) between the Namoi and for the areas considered in the previous work. This review would comprise a chapter in the final report and a section of the milestone report for this Task. The second activity in this task would be collation of the properties required for CSG reservoir simulation for the Namoi. This information would be largely sourced from published studies on the Namoi under GISERI, Santos EIS and CSIRO Bioregional Assessments but some properties may need to be estimated from the literature. The results of this task would be summarised in a milestone report.
**TASK OBJECTIVE:** Review of previous work related to the representation of CSG well field impacts into groundwater modelling and collation of site data required for reservoir simulation.
**TASK OUTPUTS:** A summary of previous approaches to representing CSG groundwater impacts and collated site properties for the Namoi area of interest.
**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

### PROGRESS REPORT:

Tasks performed:

- Literature review undertaken which will form chapter of final report. Review has examined:
- Previous representation of CSG fields in regional groundwater models and the effects on impact assessment as documented in previous work of Moore et al. (2015) and Commonwealth of Australia (2014).
- Methodology developed by Herckenrath et al. (2015) to represent desaturation near CSG wellbores in regional groundwater models, and detail of how this approach and associated upscaling was applied by OGIA in regional groundwater modelling of Surat basin Cumulative Management Area (CMA).
- Summary and comparison of hydrogeology in the Surat CMA and in the Namoi subregion.
- Data on properties required for CSG reservoir simulation have been collated from published reports of CSIRO bioregional assessments, Santos Narrabri EIS, Santos Namoi groundwater modelling.

## Task 2

**TASK NAME: Construction of Namoi CSG models**
**TASK LEADER:** Nick Lupton
**OVERALL TIMEFRAME:** 3 months
**BACKGROUND:** In this task a series of Namoi CSG models will be constructed to cover the range of likely production scenarios and ranges of reservoir properties. The role of the model boundary will investigated using progressively larger model sizes to verify that the boundary does not artificially influence the simulation results. The production scenarios will be based on information presented in the Santos Namoi EIS.

**TASK OBJECTIVE:** A series of CSG models in SIMEDWin to represent Namoi production scenarios.
**TASK OUTPUTS:** SIMEDWin input data files for Namoi CSG production.
**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

## PROGRESS REPORT:

- Collation of coal seam properties for Namoi has been completed. A key property is the reservoir permeability and has been estimated from the values of hydraulic conductivity from previous work. The initial reservoir pressure, gas contents and adsorption isotherms have been estimated from public sources of information such as well reports in the NSW DPI database.
- The target coal seams were identified from the Santos EIS document.
- A modelling methodology has been derived based on the previous approaches used in the OGIA work and presented in Herckenrath et al 2015.
- The base model has been constructed to represent the key production targets of the Maules Creek sequence.

## Task 3

**TASK NAME: Relationships between groundwater pressure and production rate for the CSG field.**
**TASK LEADER:** Luke Connell
**OVERALL TIMEFRAME:** 6 months
**BACKGROUND:** In this task a series of simulations for likely CSG well field arrangements in terms of well spacings and the other key groundwater parameters will be performed and the simulation results compiled to investigate the potential for developing simple relationships between the key driving variables operating and groundwater production in a similar manner to that used in the OGIA modelling described by Herckenrath et al. (2015).
**TASK OBJECTIVE:** To develop relationships for groundwater production from the Namoi CSG well field of a form suitable for incorporation into MODFLOW groundwater modelling.
**TASK OUTPUTS:** A tested functional relationship for groundwater production modelling in MODFLOW that captures the near well processes operating during CSG production and the integration between groundwater flow and CSG water production.
**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as milestone report.

## PROGRESS REPORT:

- The objective of this project is to improve the representation of groundwater production from coal seam gas fields in regional groundwater flow modelling, addressing the key challenge of upscaling the complex coupled reservoir flow processes that occur during CSG production. This involves conducting simulations using a detailed model of CSG production for Namoi, and identifying relationships that can capture these flow processes in a simplified fashion suitable for use in groundwater flow models.
- A series of simulations have been completed for a likely production scenario and well field arrangement for the Namoi CSG field. The production scenarios were based on information presented in the Narrabri EIS, and well field arrangement and reservoir properties based on published reports of CSIRO bioregional assessments, Santos Namoi groundwater

modelling, and well completion reports. Model performance was benchmarked against projected water and gas production outlined in the Narrabri EIS.

- The project is on track, having used the developed Namoi CSG symmetry model to complete an investigation of potential simple relationships between key driving reservoir variables and groundwater production (e.g. average reservoir pressure and production rate). Investigations have examined grid block scale relationships, similar to the method used in OGIA modelling (Herckenrath et al., 2015), and examined relationships among upscaled variables to suggest approaches for incorporation into MODFLOW groundwater models.

## Task 4

**TASK NAME: Approaches to representing coal seam gas groundwater impacts at the spatial scale of the MODFLOW grid.**
**TASK LEADER:** Luke Connell
**OVERALL TIMEFRAME:** 5 months
**BACKGROUND:** In this task the role of the spatial scale will also be investigated to assess potential approaches for upscaling the CSG well field simulations to larger scales amenable to the grid block sizes used in regional scale MODFLOW groundwater modelling such as that used in the GISERA project on the GAB fluxes. The approach described by Moore et al. (2014) for upscaling will be used as a starting point for this work.
**TASK OBJECTIVE:** To develop relationships suitable for MODFLOW modelling that allow larger grid block sizes to used and still accurately represent the integration between groundwater production from the CSG well field and groundwater flow at local and regional scales.
**TASK OUTPUTS:** An approach to upscaling the Namoi CSG well field for MODFLOW regional scale modelling for Namoi.
**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

## PROGRESS REPORT:

- The objective of this task is to investigate and develop relationships between key driving variables of CSG production at a grid block scale that can be incorporated in the MODFLOW groundwater model, enabling integration between groundwater production at the CSG field scale and groundwater flow at regional scales.
- A multi-well field model was constructed representing a symmetry element of a producing Namoi CSG field. Model development included simplification of layering to improve computational efficiency, determination of an appropriate model spatial boundary, and calibration of reservoir parameters of the field model to ensure accurate matching to projected full-field water and gas production quoted in the Narrabri EIS.
- The calibrated multi-well field model was used to characterise the changes in relationships between key reservoir variables when moving from well-scale to field-scale. The examined relationships were similar to those derived in Task 3 (e.g. grid block saturation and pressure, and averaged data). Model simulations were also used to characterise effects on these relationships of grid block size, vertical and spatial upscaling, and the boundary between well-field and adjacent aquifers.

- The project is on track, having used the Namoi CSG field model to investigate the role of spatial scale, and possible approaches to upscaling the simulations to scales employed in the MODFLOW regional groundwater flow model.

## Task 5

**TASK NAME: Implementing the results of Tasks 3 and 4 in MODFLOW to represent CSG well field influences.**
**TASK LEADER: Nick Lupton**
**OVERALL TIMEFRAME:** 2 months
**BACKGROUND:** In this task the outcomes from Tasks 3 and 4 will be implemented in the version of MODFLOW used in the groundwater assessment work performed under GISERA.
**TASK OBJECTIVE:** To develop relationships suitable for MODFLOW modelling that allow larger grid block sizes to be used and still accurately represent the integration between groundwater production from the CSG well field and groundwater flow at local and regional scales.
**TASK OUTPUTS:** An approach to upscaling the CSG well field suitable for MODFLOW regional scale modelling.
**SPECIFIC DELIVERABLES:** A chapter in the final report also presented as a milestone report.

## PROGRESS REPORT:

- The objective of the project is to improve representation of groundwater production from coal seam gas fields in regional groundwater flow modelling, addressing the key challenge of upscaling the complex coupled reservoir flow processes that occur during CSG production. This involves simulating CSG production scenarios for Namoi, identifying relationships that can capture these flow processes in a simplified fashion suitable for use in groundwater flow models, and implementation of these relationships into groundwater modelling software.
- Relationships between key driving variables of gas production, identified using the Namoi CSG well symmetry model in Task 3 and 4, have been modelled using the van Genuchten (1980) desaturation equation in order to implement the approach documented by Herckenrath et al. (2015) to representing CSG production in groundwater flow models. A single-phase groundwater flow model equivalent to the Task 3 and 4 Namoi CSG reservoir model was constructed using a modified version of MODFLOW-USG, and performance was validated against a single-phase version of the Namoi CSG reservoir model. CSG groundwater production simulations were then undertaken using a dual-phase version of the Namoi MODFLOW-USG model that implemented the identified relationships.
- The project is on track, having investigated a range of scaling approaches to modelling reservoir flow processes using the van Genuchten equation, and to deploying these approximations into the groundwater model. Effects of implementation on water production and pressure drawdown predictions were quantified. Implementation of the relationships derived in Task 3 and 4 into the Namoi MODFLOW-USG model reduced error in water production predictions by up to 63% and improved the predictions of pressure drawdown beyond the CSG field boundary.