Arrow Energy
SURAT GAS PROJECT
EIS GROUNDWATER IMPACT ASSESSMENT
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Groundwater occurs in pores and fractures in rock and soil.

Aquifers are layers that transmit groundwater, mainly horizontally.

Aquitards impede the movement of groundwater and flow mainly vertically.

Groundwater flow is driven by differences in head, which is a measure of potential energy.

The rate of flow of groundwater is controlled by hydraulic conductivity, which can be different in different directions.
Groundwater flows due to differences in “head”
Groundwater is required for:

- Consumptive or productive uses (agriculture/aquaculture/mining)
- Biological integrity of groundwater dependent ecosystems (springs)
- Support to areas of cultural and spiritual importance (springs/wetlands)

Potential Impacts to groundwater systems include:

- Groundwater drawdown (reduced availability and/or flows)
- Land subsidence induced by drawdown
- Groundwater contamination
Groundwater environmental values (defined by legislation) are:

- Ecological values
- Biological integrity
- Potential uses (consumptive/productive)
- Cultural and spiritual values

Sensitivity of groundwater systems defined by:

- Conservation status (ecology, biological integrity, uses, cultural values)
- Rarity of occurrence, abundance or distribution of system
- Resilience to change (permeability and porosity)
- Hydrogeological processes (recharge and discharge mechanisms)
- Rehabilitation potential (rebound and recovery)
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GROUNDWATER SYSTEMS

Shallow groundwater system (*moderate sensitivity*)
- Condamine Alluvium (up to 150 m thick)

Intermediate groundwater system (*moderate sensitivity*)
- Kumbarilla Beds comprising Mooga, Gubberamunda and Springbok sandstones (100 to 200 m thick)

Coal seam gas groundwater system (*low sensitivity*)
- Walloon Coal Measures (100 to 500 m thick)

Deep groundwater system (*high sensitivity*)
- Hutton Sandstone/Marburg Subgroup (120 to 180 m thick)
- Precipice Sandstone (50 to 100 m thick)
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POTENTIAL IMPACTS

Direct impacts

- Walloon Coal Measures groundwater systems
- Depressurisation of aquifers (extraction of groundwater)
- Reduced supply to existing and future groundwater users
- Contamination of shallow aquifers by leaks, spills and seepage
- Contamination of groundwater systems by incorrect or incomplete well installation

Indirect impacts

- Depressurisation of adjacent aquifers caused by inter-aquifer flows
- Reduced supply to existing and future groundwater users
- Reduced flows to groundwater dependent ecosystems
- Land subsidence
Groundwater (numerical) modelling

- Undertaken by Schlumberger Water Services
- Peer reviewed by Lloyd Townley
- Explained in previous consultation sessions

Three scenarios modelled

- Arrow only (Scenario 1)
- Arrow, Queensland Gas Company (QGC) and Santos (Scenario 2)
- Arrow, Queensland Gas Company (QGC), Santos and Origin Energy (Scenario 3 cumulative impact)

Assumes 30 year project life and 20 year recovery period

Model calibrated using existing data
PREDICTED DRAWDOWN IN WALLOON COAL MEASURES
UNMITIGATED CUMULATIVE IMPACT
PREDICTED DRAWDOWN IN CONDAMINE ALLUVIUM
UNMITIGATED CUMULATIVE IMPACT (SHALLOW AQUIFERS)
PREDICTED DRAWDOWN IN HUTTON SANDSTONE
UNMITIGATED CUMULATIVE IMPACT (DEEP AQUIFERS)
## PREDICTED (UNMITIGATED) DRAWDOWN
### ARROW ONLY SCENARIO

<table>
<thead>
<tr>
<th>Groundwater system</th>
<th>Predicted drawdown (Arrow only)</th>
<th>Predicted drawdown (Cumulative)</th>
<th>Drawdown and recovery period</th>
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</thead>
</table>
| Shallow groundwater system *Condamine Alluvium* | Greater than 0.1m to less than 1m | 2.5m | Maximum drawdown in 2059  
Longer recovery beyond 2071 |
| Intermediate groundwater system *Kumbarilla Beds* | 30m | 60m | Maximum drawdown in 2029  
Significant recovery by 2061 |
| Coal seam gas groundwater system *Walloon Coal Measures* | 50m to greater than 75m | Greater than 75m | Maximum drawdown in 2024  
Significant recovery by 2061 |
| Deep groundwater system *Hutton Sandstone/Marbug Subgroup Precipice Sandstone* | 20m to 30m | 75m | Maximum drawdown between 2027 and 2042  
Significant recovery by 2061 |
PREDICTED DRAWDOWN HYDROGRAPHS
SHALLOW, INTERMEDIATE, DEEP AND COAL SEAM GAS

Shallow groundwater system
*Condamine Alluvium*

Intermediate groundwater systems
*Kumbarilla Beds (Springbok Sandstone)*

Coal seam gas groundwater system
*Walloon Coal Measures*

Deep groundwater systems
*Hutton Sandstone/Precipice Sandstone*

Source: Schlumberger Water Services
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MANAGEMENT MEASURES

Adaptive management framework

- Dynamic behaviour of groundwater systems
- Groundwater monitoring
- Refinement of groundwater models - improve predictability of impacts
- Develop appropriate responses

Queensland Water Commission

- Surat Cumulative Management Area
- Independent modelling using all available information
- Cumulative underground water impact reports
  - Establish make good provisions
  - Define monitoring programs (aquifers/springs)
  - Impose strategy to mitigate impacts on springs (Springs Impact Management Strategy)
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MITIGATION AND MANAGEMENT MEASURES

Statutory Obligations

- “Make good”
- Baseline assessments

Proposed management measures

- Coal seam gas water management strategy
- Groundwater monitoring program (connectivity/drawdown/water quality)
- Bore & Baseline assessment for third party bores (impaired capacity)
- Well integrity management system (Code of Practice for Constructing and Abandoning Coal Seam Gas Wells in Queensland (DEEDI, 2011))
- Injection into aquifers
- Substitution of groundwater allocations

Investigations

- Groundwater system connectivity
- ALOS surveys to monitor regional subsidence
Arrow has completed:

- 35 monitoring bores in the Condamine alluvium
- 9 bores to monitor the effect of groundwater abstraction associated with CSG including bores:
  - to collect data on aquifer connectivity at new pilots;
  - installed into the Hutton and Precipice aquifers of the GAB
- 29 bores to monitor CSG associated infrastructure

Arrow has plans to install further bores:

- to monitor aquifers above and below coal seams; and
- investigate the degree of hydraulic connection between the Condamine Alluvium and Walloon Coal Measures
In 2010-2011 the Condamine was subject to substantial flood events.

From the DERM Groundwater Bore Database an initial 82 bores in the Condamine with water level data through this period were identified.

Monitoring data from bores through this period has been assessed to understand more about the behaviour of the groundwater in the Condamine.
Much of this data showed groundwater levels increasing over the flood period as shown in a typical bore hydrograph below.
Summary Data

- 136 Data points
- Mean increase in water level 1.8m
Injection Studies:

- Tipton-153 showed good permeability in the Precipice Sandstone but low permeability in the Hutton Sandstone;
- The well will be perforated in the Precipice and groundwater samples will be collected;
- A 30-day production test from Tipton-153 is planned;
- An assessment of the risk of undertaking an injection trial in a new well will be completed.
- Subject to government approval, a 6-month injection test is planned for the new injection well;
- At least one other well will be used for monitoring the trial injection
- The source of water for the injection trial will be treated water from the Tipton RO plant site. The chemistry of the injected water will be adjusted to match the chemistry of the water in the Precipice Sandstone
Connectivity Studies

- Four sites have progressed - additional locations sought;
- Will study groundwater pressure and quality where;
  - CSG abstraction has/will occur;
  - Agricultural abstraction takes place; and
  - Historical abstraction has resulted in drawdown.
- Will include drilling of new monitoring bores with aim to core through base of alluvium.

Modelling

- Model refinement and analysis progressing
Questions and Answers

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