What are the impacts on groundwater from CSG development in the Surat Basin?

A fast tour through some of the science

Jim Underschultz

Acknowledgements: Sam Guiton, Greg Keir, Sue Vink, Sven Arnold, Nena Bulovic, Alexandra Wolhuter, Neil McIntyre, Peter Pasini and Micaela Grigorescu.
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What are the main challenges to improving our understanding of groundwater impacts from CSG development?

1) The Water Balance
   - How effective is recharge and where?
   - How much recharge stays in the GAB?
   - How much water is being used and from where?

2) Heterogeneity of the Rocks
   - Where is the permeability?
   - Is it connected?

But First let’s get the right Tools and Data
   - But First lets get the right Tools and Data
   - Where is the water?
   - Where are the hydrocarbons?
   - How does gas production change this?

Sorry not enough time for this
Water Atlas demo
2) What about Surat Basin heterogeneity?
Great Artesian Basin (a simple view)

Our Study Area

After Habermehl 1980 and friends

http://www.travelling-australia.info/Infsheets/Greatartesianbasin.html
With a complex Surat basin geology

- Alluvial Aquifers (cotton irrigation)
- Minor coal
- Gubberamunda Aquifer (irrigation & town)
- Springbok Aquifer (stock and domestic)
- Commercial coal seam methane (Walloons)
- Hutton Aquifer (stock and domestic)
- Precipice Aquifer
Hodgkinson, Hortle and friends say: “wait a minute……..”

Desk Top Study and Modelling **grounded** in Laboratory and Field Measurement

Hodgkinson & Grigorescu (2012) AJES
Vertical Permeability Distribution on a Normal-Scale

[Graph showing vertical permeability distribution with depth and permeability in mD for Woleebee Creek GW4, highlighting specific intervals and layers such as Gubberamunda Fm, Westbourne Fm, Springbok Sst, Walloon Coal Measures, Lower Juandah Coal Measures, Tangalooma Coal Measures, Taroom Measures, Eurombah Fm, Hutton Sst, Evergreen Fm, Precipice Sst, and Moolayember Fm.]
Permeability Distribution on a Lorenz Function Plot

80% of the k in 10% of the rock
Vertical Permeability Distribution on a Cumulative-Scale

12% of permeability in the Gubberamunda

Let's Look at the Hutton

85% of permeability in the Precipice

3% of permeability in the Hutton
Hutton FW Head

- A strong influence of the topography
- Heterogeneity
- 80% of flux through 10% of the rock volume?
- Regions connected linearly through lows of hydraulic head
- Discharge to subcrop
Springs data: pins the discharge area

~170 – 200 m elevation

Local springs

Hutton Springs
Hutton FW Head

- Regions of various GW systems
- Yellow: recharge captured by high flux to local discharge
- Orange: separated from recharge but draining toward high flux local discharge
- Red: sheltered from recharge but draining toward high flux local discharge
- Boundaries are mixing zones

Virtually none of the recharge is heading to the regional GAB
3) The Nature of the Fluids

- **Recharge = Fresh**, \( \text{HCO}_3^- > \text{Cl} \) & high Mg, Ca

- **Trending to higher EC** NaCl dominant
Water Chemistry

- Cluster 6: Fresh & higher HCO$_3$, Ca, & Mg
- Cluster 5:
- Cluster 4:
- Cluster 3 & 2:
- Cluster 1: More saline & NaCl dominated has signature of coal?
Water Chemistry

- Cluster 6: Fresh & higher HCO$_3^-$, Ca, & Mg
- Cluster 5:
- Cluster 4:
- Cluster 3 & 2:
- Cluster 1: More saline & NaCl dominated
3) What about Gas?

Fugitive CH$_4$ is complicated:

- Natural levels of methane in atmosphere and sub-surface
- Surface emissions from infrastructure
- Surface emissions diverse sources
- Changes in sub-surface environments
- How do we measure and where?
- It all changes over time

CSIRO: Cape Grim, Tasmania

3) Sub-surface Gas?

Understanding methane occurrence in the groundwater of coal basins:

Can we use historical O&G and Water Monitoring data to help define a baseline?

Can we define a quantitative approach to estimating the distribution of Flux to Surface?

What does this say about aquitard performance?


<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>No. of Samples</th>
<th>Methane Range [ppm]</th>
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<tr>
<td>1983</td>
<td>Giligulgul (Wandoan)</td>
<td>258</td>
<td>2.5 - 48</td>
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<td>1987</td>
<td>Chinchilla</td>
<td>58</td>
<td>1.2 - 25.5</td>
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<td>1988</td>
<td>St George</td>
<td>314</td>
<td>1.9 - 89.1</td>
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<td>Bungil (South of Roma)</td>
<td>322</td>
<td>0.1 - 48.7</td>
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<td>1989</td>
<td>Kalima (near Roma)</td>
<td>158</td>
<td>1.7 - 14.8</td>
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<td>Chinchilla</td>
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<td>1.7 - 22.1</td>
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<td>1991</td>
<td>Glenmorgan</td>
<td>534</td>
<td>8.09 - 42.45</td>
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Gas Fields Commission, Queensland
How we explored the research question…

Create a Hydrocarbon Habitat:

- Burial History
- Source Rock
- H/C Generation
- H/C Pools
- H/C migration fingerprints

Chris Boreham 1999
Bowen and Surat Hydrocarbon Generation (Boreham and others)

<table>
<thead>
<tr>
<th>Age (Ma)</th>
<th>Palynological</th>
<th>Bowen Basin</th>
<th>Gunnedah Basin</th>
<th>Seismic horizons</th>
<th>Tectonic events</th>
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<td>280-260</td>
<td>Permian</td>
<td>Reids Dome beds</td>
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<td>250-240</td>
<td>Triassic</td>
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- 90% of Oil
- 65% of Gas
- 30% of Gas
Where did all the hydrocarbon Go?

Calculated H/C generation (50% uncertainty)
- >3,400 billion barrels of Oil
- >2,700 billion barrels Oil equiv Gas (Shaw et al. 2000)

Discovered Con & CSG
- >57 million barrels oil
- >5.6 billion barrels equiv Gas
- BREE (2014)

Still in source rock? Leaked out? Still to be found?
## What we found: Summary of Hydrocarbon Indicators

Pools below the Evergreen (plus Walloons Gas) and Migration between Evergreen and Surface

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Oil</th>
<th>CH₄</th>
<th>CH₆</th>
<th>CO₂</th>
<th>Flr</th>
<th>Stn</th>
<th>Show</th>
<th>Gas</th>
<th>CH₄</th>
<th>CH₆</th>
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<th>Pools</th>
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### Laboratory
- Oil
- CH₄
- CH₆
- CO₂

### Migration
- Flr
- Stn
- Show

### Shows & mud logs
- Gas
- CH₄
- CH₆

### Pools
- Oil
- Gas
What we found: Fingerprints of oil migration

Hydrocarbon fingerprints associated with:

• faults in some locations
• other areas are associated with internal aquifer migration
• some regions may relate to heterogeneity of intraformational seals
Conclusions:

1) The Water Balance (not shown)

- Recharge to GAB is uneven
- Water use uncertainty is dropping
- Better input for regional groundwater models

2) Heterogeneity of the Rocks

- 80% of the flux through 10% of the rock
- Loads of minor coal

3) The Nature of the Fluids

- Water chemistry matches heterogeneity of the rocks
- Hydrocarbons naturally migrate to surface
- We have the foundation of a baseline
THANK YOU

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