Water Management in Queensland Coal Seam Gas

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Background:

Water Management in the Coal Seam Gas industry in Queensland is a complex and expensive undertaking.

Huge pipeline gathering systems together with large reverse osmosis / evaporation systems are being built at tremendous cost.

The CSG associated water is relatively low salinity and relatively high quality.

The CSG projects are already economically marginal.

The waste product of RO / Evap is a concentrated brine that must be disposed – incurring additional cost and environmental risk due to transportation.

Is this really what is being done?

Is the approach (RO/Evap/Brine Disposal) unique for CSG?

What are the alternatives?

Does it make economic and technical sense?
Queensland CSG Water Volumes – The Scope

159 L = 1 bbl
2013: 250 ML/d = 1.6 MM BWPD (million bbl water / day)
2018 – 2012 peak: 450 ML/d = 2.8 MM BWPD
Is the approach to Water Management Unique?

Specifically, is there precedence or are there analogs for:

- the construction of a vast water gathering pipeline system,
- together with centralized IX/RO/Evap systems,
- followed by some form of brine disposal

in the development of coal bed methane (coal seam gas)?
Are the Water Characteristics Unique?

Characteristics of Coal Seam Associated Water:

- Water seeping thru recharge areas and the coal seams encounters different minerals along its path
- Feldspar materials of marine origin will increase Na\(^+\) and Cl\(^-\) concentrations in the water
- The biodegradation processes which produced the CH\(_4\) also produced CO\(_2\) and ultimately HCO\(_3^-\) species
- Ca\(^{+2}\) and Mg\(^{+2}\) solubility decreases with increase in HCO\(_3^-\) and causes some precipitation of calcite and dolomite species in the coal seams. Ion exchange with clays intercepted within the seams will also decrease the Ca\(^{2+}\) and Mg\(^{2+}\) content while increasing the Na content of the water.
- Other ions common to marine waters (eg halides) will also dissolve into the water flowing through the coal seam.
- In essence, seawater that has undergone some ion exchange and carbonation. There are local variations in ion exchange and extent of carbonation.

These are the same geological processes, and water characteristics seen elsewhere for CSG / CMB water.
Hill-Piper Diagram for Queensland CSG

1: alkaline earth > alkalis
2: alkalis > alkaline earth
3: weak acids > strong acids
4: strong acids > weak acids
5: carbonate hardness > 50 %
6: non-carbonate hardness > 50 %
7: non-carbonate alkalinity > 50 %
8: carbonate alkali > 50 %
9: no dominance

Rich in Na⁺
Rich in Cl⁻ and HCO₃⁻ (roughly 50/50)
pH range: 8-9

CGS Water characteristics similar to other parts of the world
Surat & Bowen Basins – Main CSG Producing Basins

To understand salinity & rainfall maps, we need a bit of a geography lesson.
Australia average rainfall per year:
Rainfall Map Superimposed on the Coal Seam Basin Map

CGS is mostly in dry / arid parts of country
This area is a bit north of the Bowen and Surat Basins, as well as north of Fairview and Roma.

Significant salinity hazard – can’t surface discharge w/o desalination.
CSG Water and Brine Injection – The Great Artesian Basin

The GAB is essentially fresh water.

Regulations only allow injection of water of quality equal to or better than the target reservoir.

This effectively prohibits disposal injection into most of the potential subsurface targets.

Don’t want to risk contamination of the Great Artesian Basin
Limited Shallow (< 2 to 6 km) Disposal Targets

Taroom Trough

- ~6km (19,680’) of sediment (**estimated**)
- Bound by the Comet Ridge to the west and a major fault to the east (Burunga - Leichardt Fault)

Limited injection reservoirs
## Surface Discharge Quality – Wyoming, Colorado, Queensland

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Wyoming</th>
<th>Colorado</th>
<th>Queensland</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC/EC</td>
<td>7,500 umhos/cm</td>
<td>6,500 µS/cm</td>
<td>3,000 µS/cm</td>
</tr>
<tr>
<td>pH</td>
<td>6.5 to 8.5</td>
<td>6.5 to 9.0</td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>5,000 mg/L</td>
<td>3,500 mg/L</td>
<td>700 to 900 mg/L</td>
</tr>
<tr>
<td>Chlorides</td>
<td>1,500 mg/L</td>
<td>1,500 mg/L</td>
<td>350 to 700 mg/L</td>
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<tr>
<td>Fluoride</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TPH</td>
<td>10 mg/L</td>
<td>10 mg/L</td>
<td></td>
</tr>
<tr>
<td>Radium 226</td>
<td>1 pCi/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfates</td>
<td>3,000 mg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>1.8 mg/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAR</td>
<td>10</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Boron</td>
<td></td>
<td>2 mg/L</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td>5 mg/L</td>
<td></td>
</tr>
<tr>
<td>WET</td>
<td></td>
<td>every quarter</td>
<td></td>
</tr>
</tbody>
</table>

**WET:** Whole Effluent Toxicity  
**SAR:** Sodium Adsorption Ratio  
\[
SAR = \frac{Na^+}{\sqrt{\left(Ca^{2+} + Mg^{2+}\right) / 2}}
\]

Queensland has stringent surface discharge water quality standards.
Santos CSG Water Management Strategy Options

1) Two Stage Reverse Osmosis (500 TDS permeate 90 to 95 % recovery)
   ▪ Permeate discharge to surface, including irrigation
   ▪ Permeate injection for aquifer recharge
   ▪ Temporary brine storage in ponds – several ultimate options being evaluated

2) Land Amendment Irrigation
   ▪ Water quality of moderate salinity and sodicity
   ▪ Carefully controlled use of agricultural grade gypsum and sodium bentonite sulphur to reduce bicarbonate levels and the proportion of sodium in soil solutions that have been irrigated with untreated water

3) Blended RO + untreated CSG water + amendment
   ▪ Combinations of (1) & (2) above – to maximize LAI option w/in quality limits
## Water Chemistry Comparison

Queensland vs Powder River Basin (PRB)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Queensland</th>
<th>Powder River Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>8.1 to 8.7</td>
<td>8.1 to 8.4</td>
</tr>
<tr>
<td>EC</td>
<td>µS/cm</td>
<td>1,000 to 11,000</td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>mg/L</td>
<td>1,500 to 10,000</td>
<td>500 to 5,000</td>
</tr>
<tr>
<td>Na⁺</td>
<td>mg/L</td>
<td>800 to 2,600</td>
<td>1,050</td>
</tr>
<tr>
<td>K⁺</td>
<td>mg/L</td>
<td>2 to 700</td>
<td>10 to 60</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>mg/L</td>
<td>1 to 30</td>
<td>5 to 40</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>mg/L</td>
<td>0.1 to 20</td>
<td>1 to 20</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>mg/L</td>
<td>400 to 2,200</td>
<td>400 to 3,000</td>
</tr>
<tr>
<td>CO₃⁻²</td>
<td>mg/L</td>
<td>20 to 200</td>
<td>20 to 300</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>mg/L</td>
<td>400 to 2,200</td>
<td>30 to 300</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>mg/L</td>
<td>1 to 2</td>
<td>1 to 2</td>
</tr>
<tr>
<td>F⁻</td>
<td>mg/L</td>
<td>1 to 5</td>
<td>1 to 2</td>
</tr>
<tr>
<td>Ba²⁺</td>
<td>mg/L</td>
<td>0.1 to 15</td>
<td>1 to 2</td>
</tr>
<tr>
<td>Sr²⁺</td>
<td>mg/L</td>
<td>0.1 to 10</td>
<td>1</td>
</tr>
<tr>
<td>SiO₂</td>
<td>mg/L</td>
<td>20 to 80</td>
<td>10 to 20</td>
</tr>
</tbody>
</table>

QLD slightly higher TDS than PRB, and PRB has higher bicarbonate to chloride ratio.

While they are similar, the TDS difference is significant. Compared to PRB water, a higher proportion of QLD water is above important thresholds.
Typical Queensland WTP Process

1. Associated Water Collection Pond
2. Pre-Treatment
3. Micro-Filtration
4. Ion Exchange
5. Reverse Osmosis
6. Permeate Water Collection Pond
7. Brine Management Pond
8. Evaporation
9. Crystallization
10. Purpose Build Regulated Waste Facility

Flow:
- From Pre-Treatment to Micro-Filtration
- From Micro-Filtration to Ion Exchange
- From Ion Exchange to Reverse Osmosis
- From Reverse Osmosis to Permeate Water Collection Pond
- From Brine Management Pond to Evaporation
- From Evaporation to Crystallization
- From Crystallization to To Market (NaHCO₃, NaCl)

Typical Queensland desalination process


Similar to Queensland process

Ref: J.P. Welch, OGJ (Oct 2009)
Typical CBM water from the Powder River Basin, Wyoming and two pre-treatment strategies: acid vs softening.

Similar to Queensland process

Ref: J.P. Welch, OGJ (Oct 2009)
CSG Brine Management Options:

- Transport to sea
- Inject down hole
- Dispose in Regulated Waste Facility
- Convert in Salt Selective Recovery
  - Sell some & dispose the rest
SURAT BRINE MANAGEMENT CONCEPT SELECT
MULTI-CRITERIA ANALYSIS

Diagram showing MCA Score for various brine management concepts:
- Selective Salt Recovery
- Enhanced NaCl Recovery
- Brine Injection
- Ocean Outfall
- Regulated Waste Facility - ZLD
- Regulated Waste Facility - Evaporation Dams

Graph categories include:
- Economic
- Non-Economic
- Total
Summary & Conclusions:

Water Management in the Coal Seam Gas industry in Queensland is a complex and expensive undertaking.

Huge pipeline gathering systems and large reverse osmosis / evaporation systems are being built at tremendous cost.

Permeate is used for irrigation. The waste product of RO / Evap is a concentrated brine that must be disposed – incurring additional cost and environmental risk due to transportation.

Why are they doing this (RO/Evap/Brine Disposal)?
- prevent salinity and SAR buildup in surface hydrological systems
- prevent contamination of the Great Artesian Basin

Is the situation unique?
- much of the water chemistry above threshold for surface discharge
- where it is below the threshold, surface discharge & beneficial use is practiced

Does it make sense?
- Yes. Though expensive, the environmental constraints result in no alternatives.
The End

The next several slides are extra material only
Indicative Cross-section

- **Evergreen Formation**: 2 bores, Aquitard
- **Walloon Coal Measures**: 166 bores, Confined aquifer
- **Condamine Alluvium**: 1,515 bores, Unconfined aquifer
- **Main Range Volcanics**: 5 bores
- **Precipice Sandstone**: 2 bores, Confined aquifer
- **Hutton Sandstone and Marburg Subgroup**: 48 bores, Confined aquifer
- **Mooga Sandstone**: 2 bores, Confined aquifer
- **Kumbarilla Beds**: 139 bores, Confined/unconfined aquifers and aquitards
- **Arrow Production Well**: Confined aquifer

**Cross-section of project development area**

**Geological Strata**
- Condamine Alluvium
- Main Range Volcanics
- Undifferentiated formations
- Griman Creek Formation and Roma Formation
- Surat Siltstone
- Coreena Member
- Doncaster Member
- Bungil Formation
- Orallo Formation
- Mooga Sandstone
- Gumbarumunda Sandstone
- Westbourne Formation
- Springbok Sandstone
- Upper Triassic strata

*The Mooga Sandstone can also be represented within the data for the Kumbarilla Beds.*
WILD TURKEY PLANT PERFORMANCE

RO recovery (permeate/feed water), %
Feed water silica, mg/l.
Silica design limit
Influent silica, ml/l.

RO system recovery


Ref: J.P. Welch, OGJ (Oct 2009)