Perspectives on Produced Water Treatment:

Challenges, Trends, Environmental Issues and Opportunities

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What is Produced Water? …Why is it so important?

- *"Produced Water" is :*
  - *water trapped in or injected into underground hydrocarbon bearing formations that is brought to the surface along with oil or gas during exploration and production.*
  - *the largest volume byproduct (waste) associated with oil and gas production.*
  - *must be either reused or disposed of…..but different regions of the world have different standards or no standards at all*
  - *volumes in US are estimated at 21billion bbl a year with additional production of > 50 billion bbl a year for rest of world (Note: 1 bbl of water = 42 gal)*

- *For certain regions of the world where water scarcity is an issue, produced water and its recycle/reuse is a critical necessity for their operations (eg Enhanced Oil Recovery – EOR)…*

Focus of this Presentation

Two (2) markets will be discussed in this presentation:

1. **Canada's Alberta Oil Sands**
    1. **Athabasca**
    2. **Peace River**
    3. **Cold Lake**

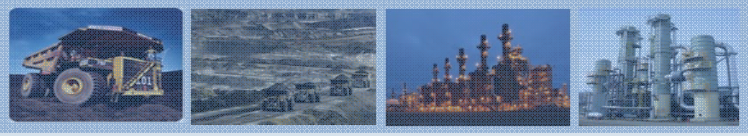
2. **Australia's Coal Seam Gas (CSG)**
    1. **Queensland**
    2. **New South Wales**

Alberta's Oil Sands: Facts & Figures

- Oil Sands (aka Tar Sands) are naturally occurring mixtures of butimen (extremely heavy crude oil), sand & water

- >40 year old market/industry
- Area of 140,200 km2 (54,000 sq mi)
- Estimates indicate Oil Sands contain 1.7 trillion barrels butimen
- Existing technology only 10% is recoverable (reserves) = 170 billion barrels, placing Canada 3rd behind Saudi Arabia and Venezuela in proven reserves.

- Canada is the largest supplier of crude oil to US: 2.4MBPD (2012); KSA (1.4M BPD) ; Mexico (1.0M BPD)
- Production - Bitumen:
  2011: 676 Million barrels = 1.85M BPD (approx)
  2019: 1.2 Billion barrels = 3.3M BPD (projected)



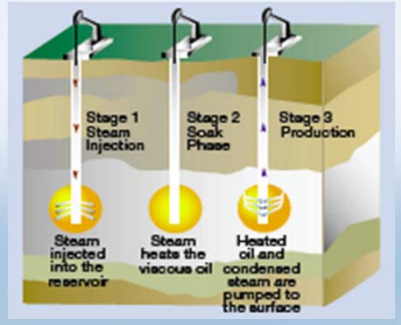
Oil Sands – Production Methods

Surface Mining

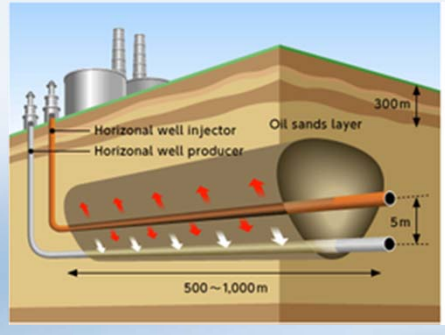
- Approx 20% of Oils Sands is recoverable by Surface Mining at depths <75m (<245 ft)

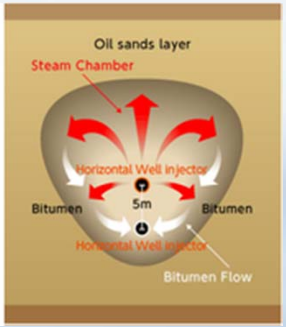
In-Situ

CSS



SAGD





- Approx 80% of Oils Sands is recoverable by In-Situ at depths between 300 to 400 m (1000 to 1300 ft)
- Inject steam into the deposit to liquefy butimen, either by CSS (Cyclic Steam Stimulation aka “Huff & Puff”) or predominantly by SAGD (Steam Assisted Gravity Drainage) process
- Steam to Oil Ratio (SOR) is important as this drives the water treatment capacity requirements

Oil Sands - Water Usage

Surface Mining

2 to 4 barrels M/U Water

8 to 10 barrels of Recycled Water

140 million m3

2.7 barrels

In 2011, mining required an average 2.7 barrels of fresh water for every barrel of bitumen produced. Source: CAPP 2012

In-Situ (avg 3:1 Ratio Water to Oil)

0.25 to 0.5 M/U Water

2.5 to 2.75 Recycled Water (Produced)

18 million m3

0.4 barrels

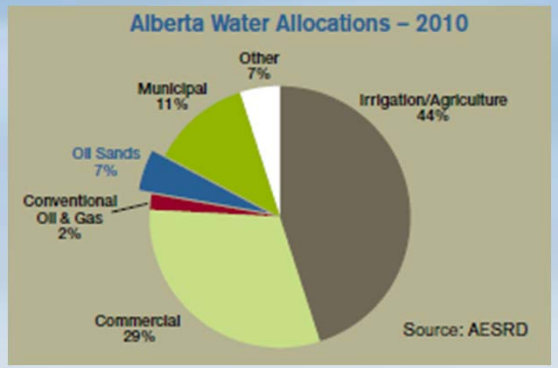
In 2011, drilling (in situ) required an average 0.4 barrels of fresh water for every barrel of bitumen produced. Source: CAPP 2012

158 million m^3

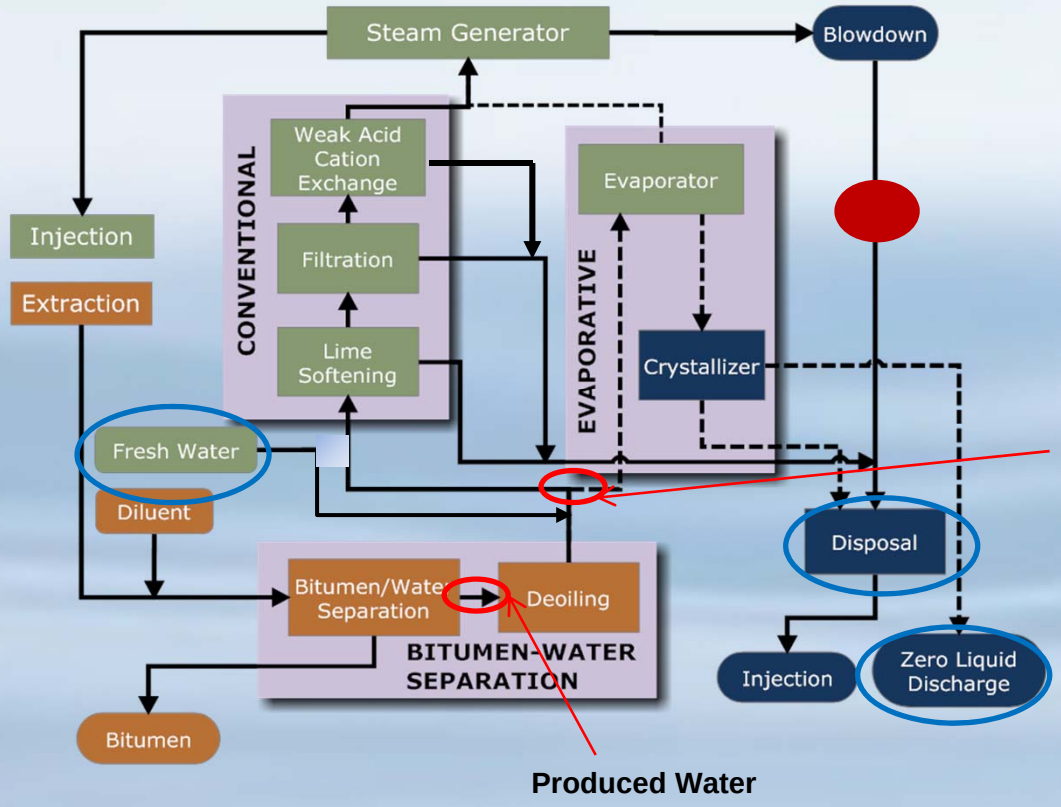
Oil sands fresh water use in 2011 was approximately 158 million m^3.

Source: CAPP 2012

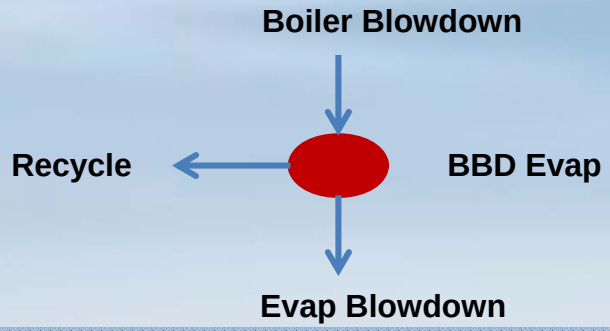
158 million m^3 is about 40% of the City of Toronto's annual water consumption. Source: City of Toronto



Oil Sands – SAGD Produced/Water Treatment Flowchart

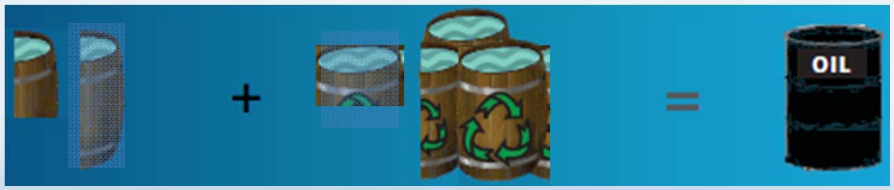


- Conventional technology/process included De-oling/HLS or WLS/Filtration/IX-Softening
- During late 1990's, evaporator technology made a breakthrough. It is here to stay…..but conventional will still have a major role
- Typical Blended water feed:
- 2000- 4000 ppm TDS
- 25-50 ppm Hardness (as $CaCO_3$)
- 250 ppm SiO_2
- 10 ppm Oil



Oil Sands – Water Usage

In-Situ (avg 3:1 SOR: Steam to Oil Ratio)



0.25 to 0.5
M/U Water
~ 10%

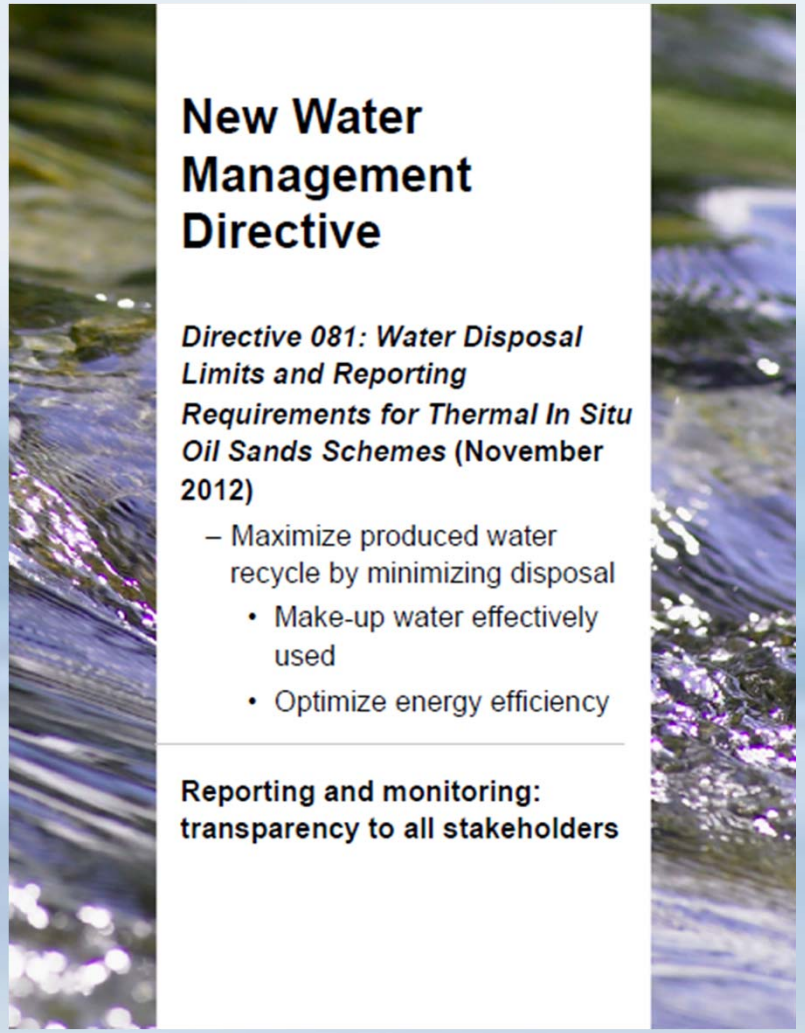
2.5 to 2.75
Produced (Recycled) Water
~ 90%

(as an example)

10,000 BPD Bitumen production

30,000 BPD of water
= 1,260,000 gal/day of water (@ 42 gals = 1 barrel)
= 875 GPM of water

Energy Resource Conservation Board (ERCB): Directive 081



New Water Management Directive

Directive 081: Water Disposal Limits and Reporting Requirements for Thermal In Situ Oil Sands Schemes **(November 2012)**

- Maximize produced water recycle by minimizing disposal
  - Make-up water effectively used
  - Optimize energy efficiency

Reporting and monitoring: transparency to all stakeholders

Courtesy of ERCB presentation January 2013

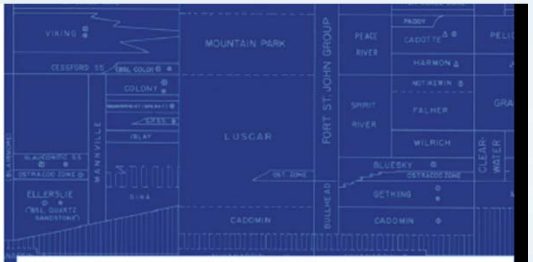
New Water Management Directive

Key features

Sets an annual water disposal limit unique to each thermal in situ oil sands scheme

Three years for existing schemes to meet the disposal limit

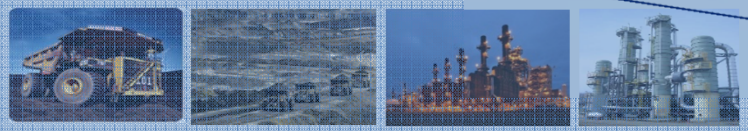
Maximum monthly facility water imbalance and reporting requirements for conducting a monthly water balance



Allowed Disposal Volume (m^3)
= Dp·(Produced In)+Df·(Fresh In)+Db·(Brackish In)

	SAGD	CSS
Dp	0.10	0.07
Df	0.03	0.03
Db	0.35	0.35

- **Further reduce fresh water use per barrel o f production**
- **Maximize water recycling**
- **Where possible, avoid using fresh water by using water from deep saline (not fit for human consumption or irrigation) water zones (>4000 ppm TDS) or recycled industrial waste water**



Alberta's Oil Sands – Potential Future Market Size

Oil Sands Mining and In-Situ Projects – Summary

Project Status	Production Capacity (barrels per day) Mining	Production Capacity (barrels per day) In -Situ
Projects in Operation	921,000	932,650
Projects Under Construction	295,000	419,905
Projects with Regulatory Approval	1,390,000	809,650
Projects Under Regulatory Review	600,000	1,381,270
Projects Announced/Disclosed	100,000	1,389,500
Total Production Capacity	**3,306,000**	**4,932,975**

= 3,580,420 BPD

= 10,741,260 BPD of water

= 451,132,920 gals of water

= 313,286 gpm of water

Data as of January 2012 courtesy of Oil Sands Developers Group

Assuming a 30,000 BPD production
= 2625 GPM Water system

120 projects !!

De-rate by 50%

60 projects over next 10-15 years

In Summary……What Does this all Mean?

The challenges and opportunities include:

- **What will or can environmental legislation bring?**
  - **Directive 081's impact**
  - **Minimizing make-up water consumption (fresh vs brackish)**
  - **Higher produced water recycling/reuse rates >>90%**

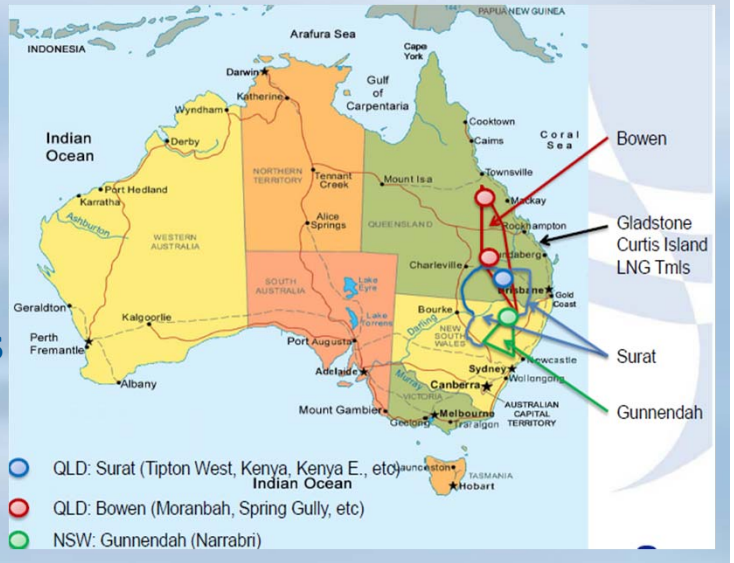
- **Brine/Waste management –**
  - **Onsite vs Offsite Disposal**
  - **Trucking vs Deep well injection vs ZLD) (Liquid vs Solid)**
  - **CAPEX vs OPEX evaluation**

- **Knowledge Sharing and innovation Promotion amongst the Producers**
  - **COSIA (Canadian Oil Sands Innovation Alliance) formed in 2012; 12 producer companies members**
  - **Pilot testing/demonstration plant at producer's site**

- **Can technologies/innovations improve cost and schedule "certainties" ?**

Australia's Coal Seam Gas (CSG): Facts & Figures

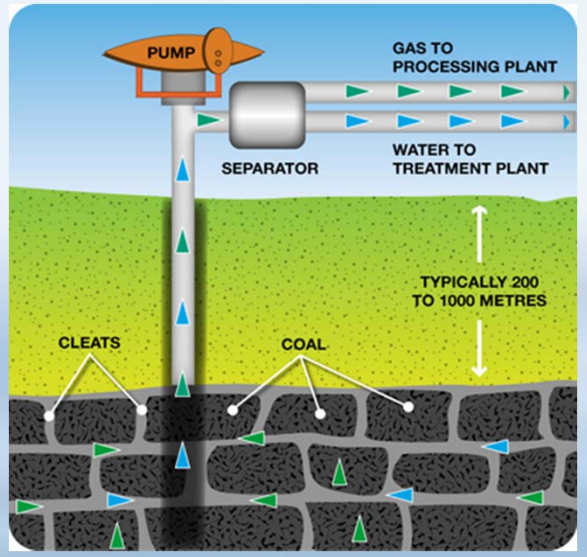
- Predominantly focused in the QLD (Surat & Bowen Basins) and now includes NSW (Gunnendah)
- Industry is relatively young (15 years) but the boom ("gold rush") has occurred since 2006/07.
- Dominated by 4 main players: Arrow Energy, Origin Energy, QGC and Santos
- Multi billion $ gas export deals are in place
- This is an LNG Export driven industry: 3 LNG terminals under construction in the Gladstone, combined will provide:
  - >$50B in investment terminals construction
  - >40Mtonnes/yr capacity
  - 1280 Km (800 mi) of pipeline
  - Under review: Additional 5 LNG terminals that would bring the total capacity >50Mtonnes/yr

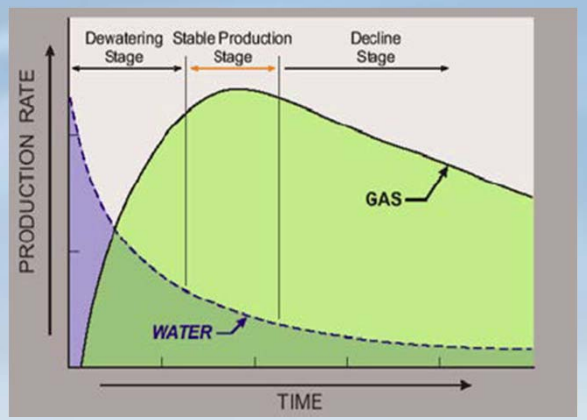





What is Coal Seam Gas (CSG)?

- Coal Seam Gas, aka Coal Seam Methane or Coal Bed Methane, is a natural gas mainly composed of methane (95-98%), and small amounts of N_2 and CO_2
- Methane gas is trapped/adsorbed in "coal seams and cleats" by water pressure forming a thin film/layer on the surface of the coal, typically found at 200 – 1000 m below ground
- Water is extracted/pumped from the seams to reduce pressure and release the gas which is further processed to separate the water from gas
- <10% of the wells are "fracked" in QLD.
- Well life average of 20 - 25 years
- "Produced" or "Associated" water production rates are opposite to the conventional petroleum industry





Coal Seam Gas: Reserves & Production

Figure 2: Queensland coal seam gas – 2P reserves *(proved and probable)*

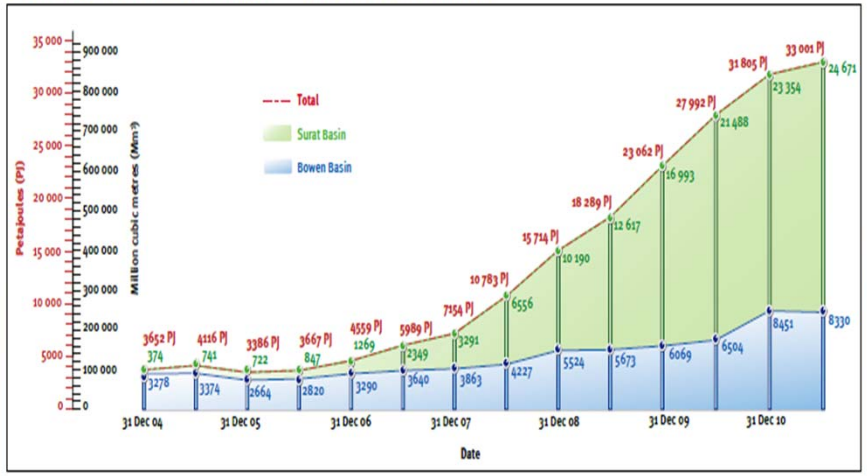
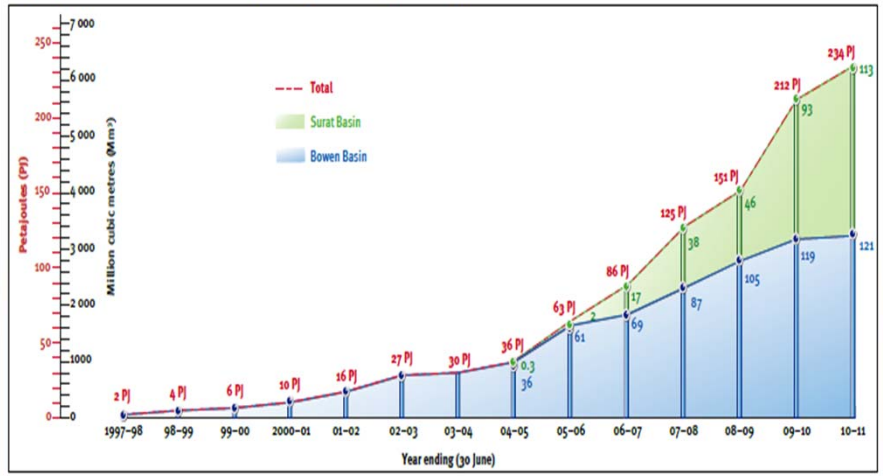


Figure 3: Queensland coal seam gas – production period 1997–2011



Data courtesy of Queensland Government

- Reserves (est) based on 2P (Proved & Probable) = 33,001 PJ (PetaJoule) in QLD (Surat + Bowen basins),
- 1 PJ = 26.7 Million m3 of Natural Gas

- Production: Gas
- 1997-98: 2PJ ; 2006-07: 86 PJ ; 2010-11: 234 PJ

- Production: Produced Water
- 2006-07: 9,491 ML = 110 ML per PJ
- 2010-11: 16,000 ML (approx) = 68 ML per PJ

Over the next 25-30 years…..

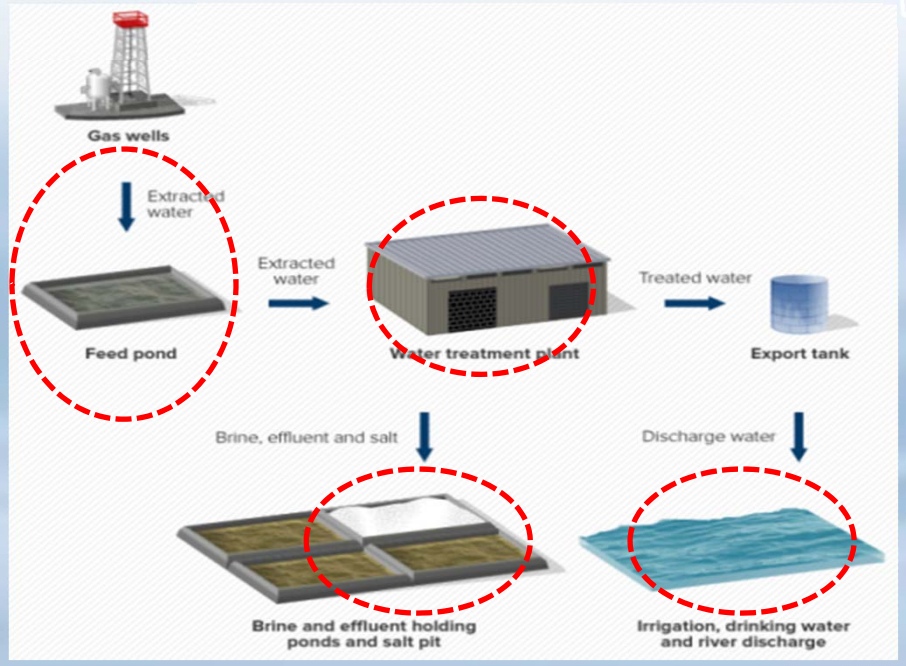
- Australian National Water Commission is estimated avg of **300 GL/yr** = 300,000 ML/yr = **822 ML/day**
- The Big Three (Santos, QGC, Origin estimate only **61 GL/yr** = 61,000 ML/yr = **172 ML/day**
- Federal Gov'ts "Water Group" indicated **1500 GL/yr,** with a **low range of 468 GL/yr**



Coal Seam Gas (CSG): Produced Water Treatment Flowchart

- Salts ranging 200 – 10,000 mg/l TDS (common 1000 to 6000 mg/l)
- Na, Cl, CO3 & HCO3
- Flow can range from 5 MLD to 100 MLD

Typical Treatment Technology:
MF (or UF) – IX – RO (85-90% R)



- Evaporation Ponds (Dams) have now been discontinued/prohibited as "primary" means.
- Aggregate dams for "storage" of CSG water, CSG water concentrate/brine must meet new regulations
- BC or Evaporators are being used as part of design to treat RO concentrate (eg. QGC Kenya, Northern projects)

31 million tonnes

Waste salt produced by CSG extraction over 30 years, based on National Water Commission's water-use estimate of 300 GL per year*

Assuming avg of 3444 mg/l TDS of Associated Water

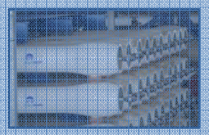
"Beneficial Use Possibilities:

- Aquifer Recharge, Irrigation, Drinking Water, River Discharge, Industrial Supply
- But must meet "suitably treated standards" set by the government
- QGC's pipeline from Kenya site to Chinchilla Weir to supplement water supply

CSG Produced Water Issues & Trends

- **CSG Water "has the potential to cause environmental harm if released to land or waters through inappropriate management ."**
- **QLD Gov't Dept of Environment and Resource Management (DERM) has come out with various position papers and policies/laws (June 2010):**
  - **CSG Producers are responsible for treating and disposing of CSG water**
  - **CSG Water Management Plan (CWMP) is required as part of the Environmental Management Plan (EMP) for an application for Level 1 Environmental Authority.**
  - **Treated CSG Water must meet DERM standards before disposal or supply to others (beneficial use)**
  - **Evaporation dams (ponds) are discontinued/prohibited as "primary" means for disposing of untreated CSG water. Aggregate dams for "storage" of CSG water, CSG water concentrate/brine must meet new regulations**
  - **Mgmt, treatment and disposal of brine and salt, a hierarchy of preference has been established:**
    1. **Waste reuse/recycling to create useable or saleable products (eg soda ash)**
    2. **Injection of brine under certain conditions**
    3. **Waste disposal under certain conditions**
- **Requested CSG Producers to devise a Salt Plan by 2013**



What Does this All Mean?

The challenges and opportunities include:

- **How will produced water and brine management be handled? Expect NSW gov't to follow QLD's initiatives/policies/laws**
- **Each of the major producer are handling of Brine management differently.**
- **Which CSG producers handle the variability of water during the life of a well? Combination of fixed and mobile (or portable) systems**
- **Which producers will favor larger flowrate, centralized systems ? vs smaller, multiple decentralized systems?**
- **Trends indicate high recovery RO (>97%) and evaporation technologies to minimize waste volume.**
- **How realistic is the saleable salt market?**

Summary

- Both the Canadian Oil Sands and Australian CSG markets show a promising future
- Each market has their respective issues with social, political views in addition to actual treatment/handling of waste, ability to deal and work with all stakeholders
- Oil Sands view produced water as an essential need in their exploration and production operations
- Whereas the CSG market views “associated” or “produced” water as “thorn in its side”, yet there are “beneficial” uses that can come about from the treatment.
- Both markets have a need for a “holistic” approach through technology and service solutions to solving their issues.

THANK YOU !

Questions??