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Water Disposal in the Oil Sands: Challenges & Strategies

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Oil Sands Water Disposal Challenges

- Considerable volumes of in-situ blowdown and mine de-pressurization water generated in future
- SAGD blowdown quality (30,000 mg/L TDS or more)
  - Primarily Ca, Mg, Ba, Sr, Si, B
  - High scaling potential
- Mine dewatering (<500 to 84,000 mg/L TDS)
  - Variable hard Ca-HCO_3 to Na-Cl type waters
  - Variable scaling potential

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Vision

- Explore the feasibility of a regional or sub-regional strategy to waste fluid disposal
- Reduce the environmental net effect of blowdown and de-pressurization water management
- Develop a framework to address the disposal challenge based on collaboration, cooperation, and enhanced sustainability
  - Economic, environmental, and social risks
  - Technical and operational opportunities

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Objectives

- Conduct a qualitative assessment of regional disposal potential particular to the Athabasca & Cold Lake oil sands for next 50 years
- Identify gaps to conduct more full quantitative assessment
- Develop disposal scenarios based on:
  - One regional collection system with one disposal centre *(within or outside study area)*
  - Sub-regional network with multiple disposal centres
- Identify risks/challenges/opportunities and develop basis for strategy to minimize environmental net effect

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Assumptions & Limitations

- AGS geological data is very regional in scale and will not capture subtle changes in formation properties
- Accumap data assumed to be an accurate reflection of the various formations properties and measurements taken
- Regional overview is only meant to identify potential areas where large-scale disposal capability may exist; local heterogeneities <u>will</u> obviously play an important role

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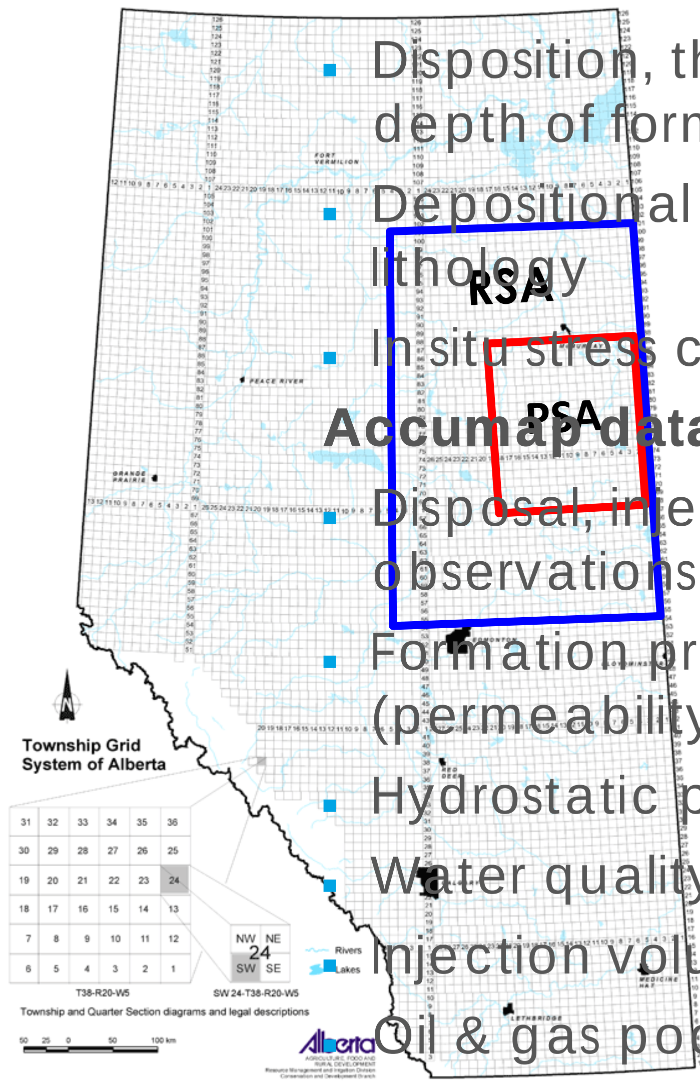
Study Area & Information Used



AGS Atlas of WCSB for:

- Disposition, thickness & depth of formations
- Depositional settings and lithology
- In situ stress conditions

Accumap data for:

- Disposal, injection & observations well locations
- Formation properties (permeability and porosity)
- Hydrostatic pressure
- Water quality
- Injection volumes
- Oil & gas pools

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Stratigraphic Section Considered

Lower Mannville (clastics) topographic flow control

Sub-Cretaceous unconformity some connectivity

Wabamun (carbonates) flow SW-NE

Winterburn (carbonates) some topographic control

Ireton aquiclude (calcareous shale) reefs

Woodbend (carbonates) flow S-N regional drain

Beaverhill Lake (carbonates)

Prairie Evaporite aquiclude (salts, collapse breccia) reefs

Elk Point (carbonates) flow SW-NE

Cold Lake/Ernestina/Lotsberg aquiclude (salts, carbonates)

Cambrian (clastics) flow SW-NE

Precambrian aquiclude (granite, meta-sediments)

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Current Challenges

- Pressure build-up in some areas
  - Cumulative effects and limited disposal capacity
  - Trans-boundary issues (Saskatchewan)

- Potential impacts to existing oil/gas/bitumen reserves
  - McMurray
  - Wabamun/Winterburn
  - Woodbend

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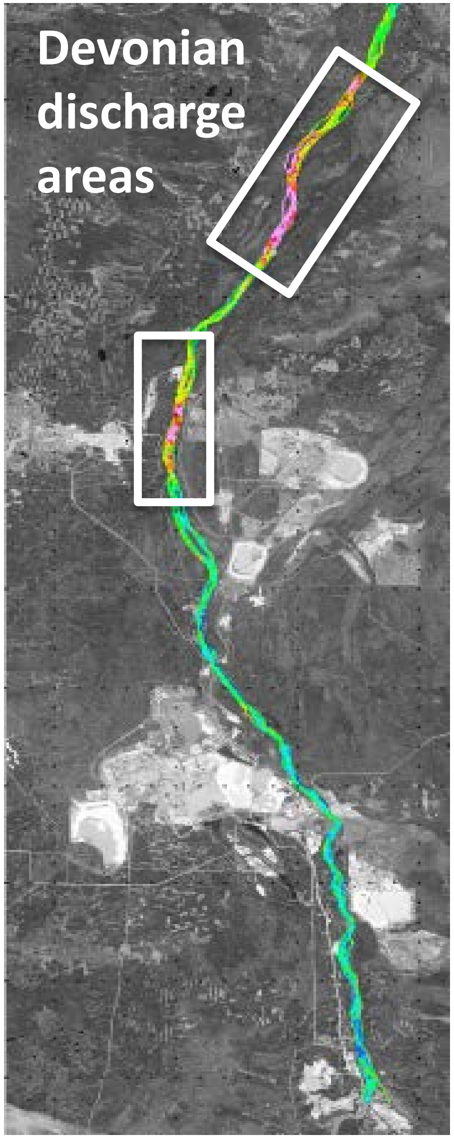
Current Challenges



- Waste containment
- Scaling potential
  - Formation plugging
  - Reduced well efficiency
  - Plugging of pipeline

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Current Challenges

- Induced seismicity?
  - Documented for other large-scale injection schemes *(e.g., Prague, Oklahoma)*
  - Subsurface structure mapping indicates numerous features beneath study area
  - Stress patterns in WCSB are conducive
  - Nothing noted to date, but injection volumes have been low

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Methods

Multi-Criteria Analysis (MCA)

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What is an MCA?

- Overcomes limitations of unstructured decision making environments
- Combine many attributes using a flexible method
- Resultant scores give relative distribution of high value targets

$$1 < f(attribute) < 5$$

$$Aggregated\ Score = \sum Attribute\ Rank \times Weighting\ Factor$$

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Approach to Assessing Injection Potential
Step 1

- Multi Criteria Analysis based on:
  - Selection of key attributes:

    Geological Facies
    Porosity
    Permeability
    Total Dissolved Solids
    Production/Disposal
    Pressure Head
    Institutional Knowledge

- Numerical ranking utilized

  1= low potential

  5 = high potential

- Multiplied by weighting factors and additively combined
- Layers aggregated to provide map of **“Injection Potential”**

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Approach to Assessing Injection Potential

Step 2

$$T = \frac{1.22\,Q}{S_{max}}$$

(Logan's Method – based on Thiem steady state equation)

Where:

S_{max} = max. drawdown (m)
T = transmissivity (m^2/d)
Q = flow rate (m^3/d)

$$Q = \frac{T\,S_{max}}{1.22}$$

(Re-arrangement of equation to provide ***Theoretical Injection Rate****)*

Where:

S_{max}= max. build-up (in m to 90% FP)

T = transmissivity (m^2/d)
Q = flow rate (m^3/d)

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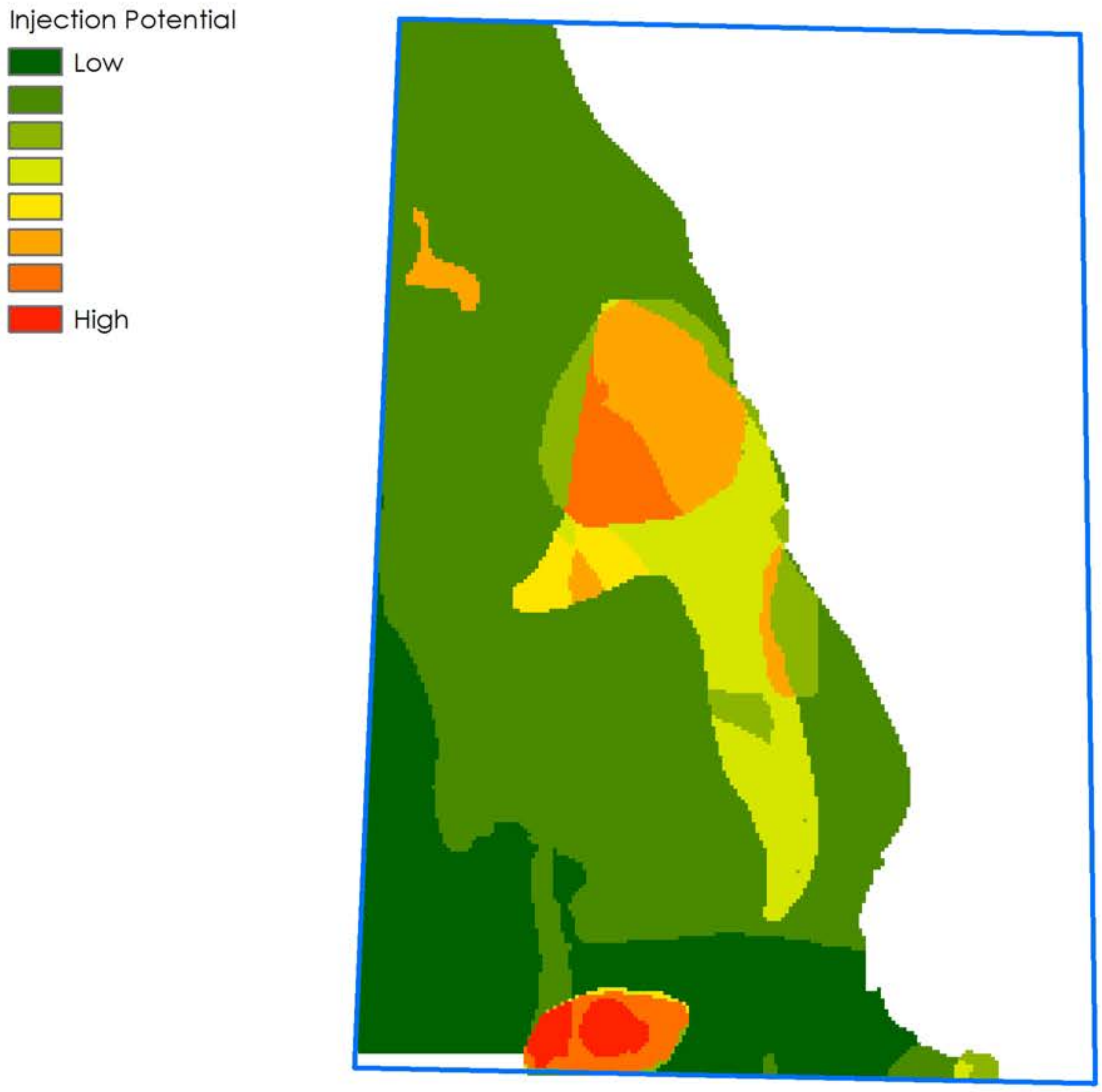
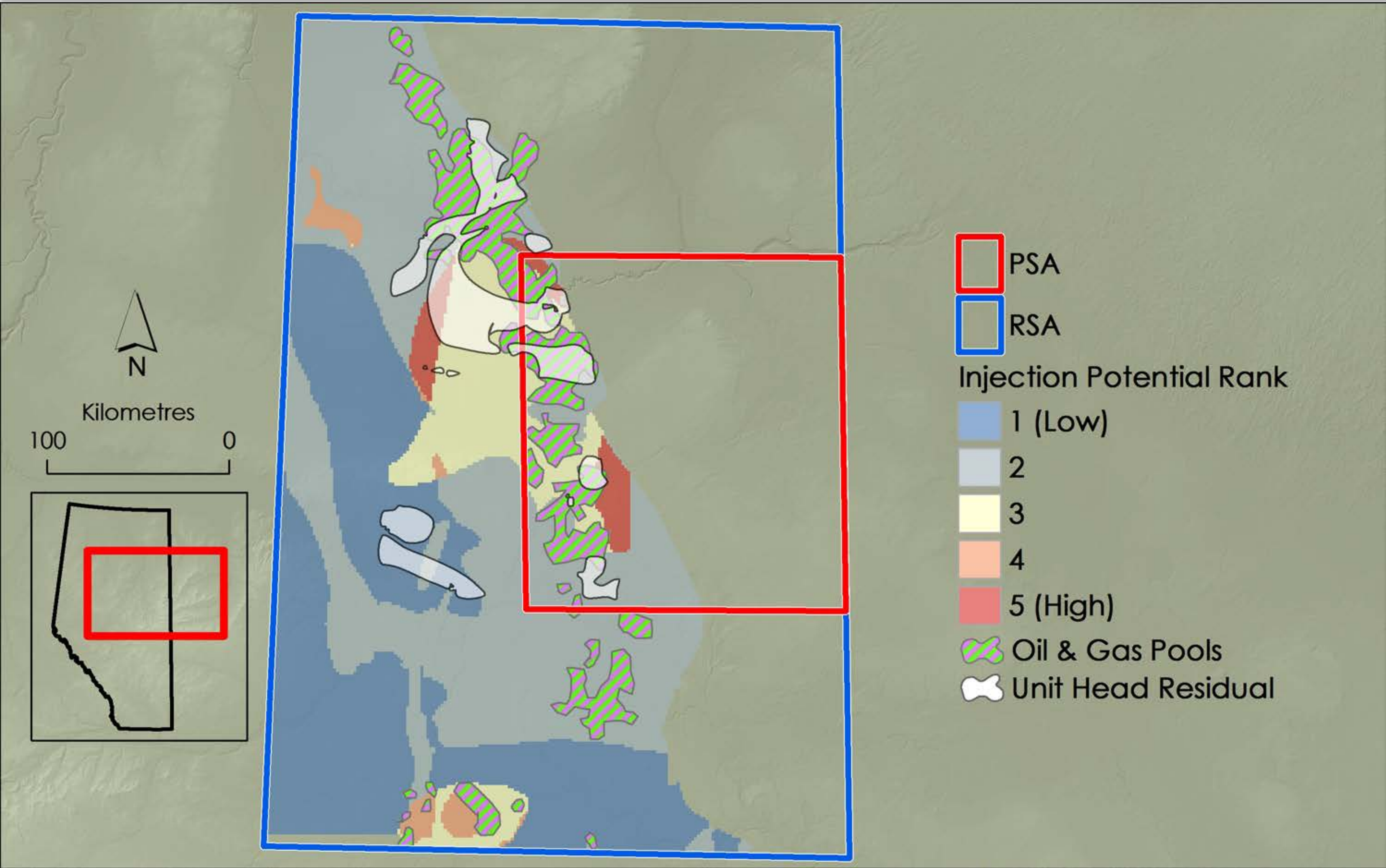
Additive Combination of Parameters

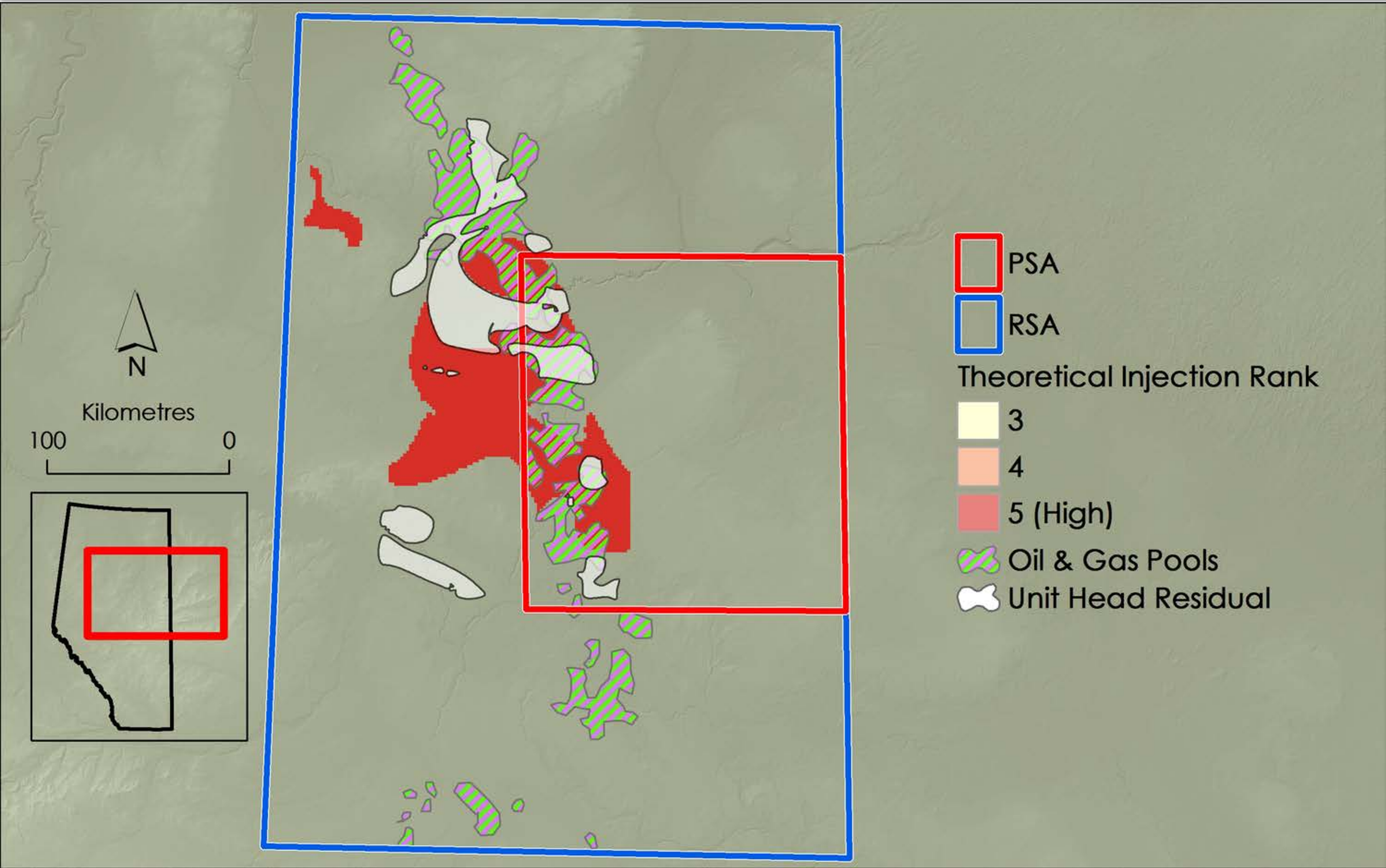
Permeability
+ Porosity
+ Pressure
+ Production
+ Total Dissolved Solids
+ True Vertical Depth
+ Institutional Knowledge
+ Geological Facies



Injection Potential
(Woodbend Gp Example)

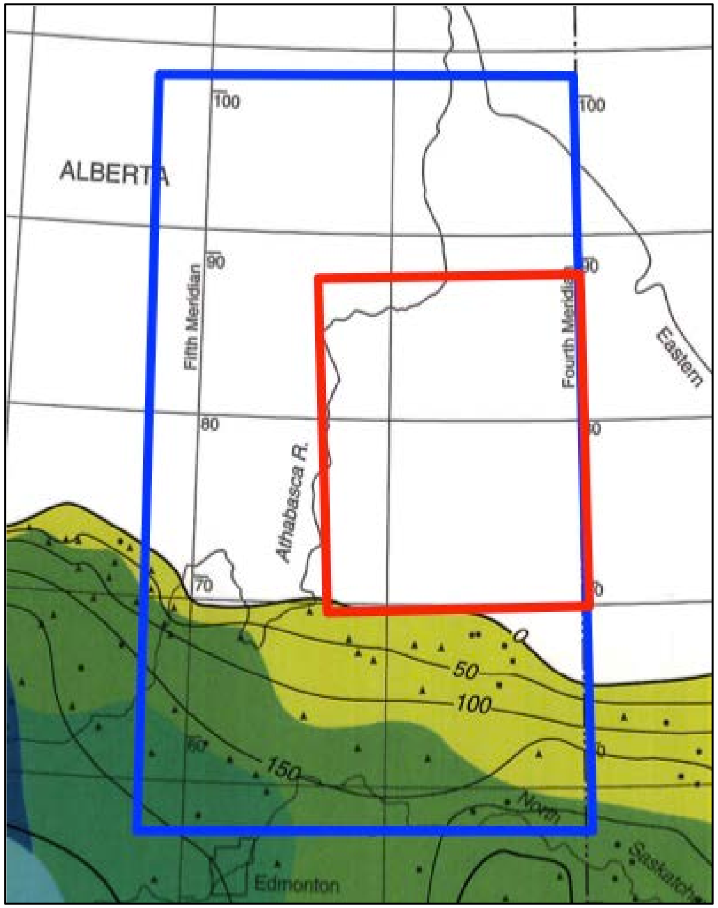


Theoretical Injection Capacity
(Woodbend Gp Example)



Most Promising Targets

- Cambrian Sandstone
  - Deep regionally extensive interval; thick permeable sandstone
  - Devoid of hydrocarbons
  - Estimated injection rates up to 12,000 m^3/d per well
  - Hypersaline *(>200,000 mg/L TDS)*; scaling potential generally restricted to clays *(affected by aluminum content of waste waters)*



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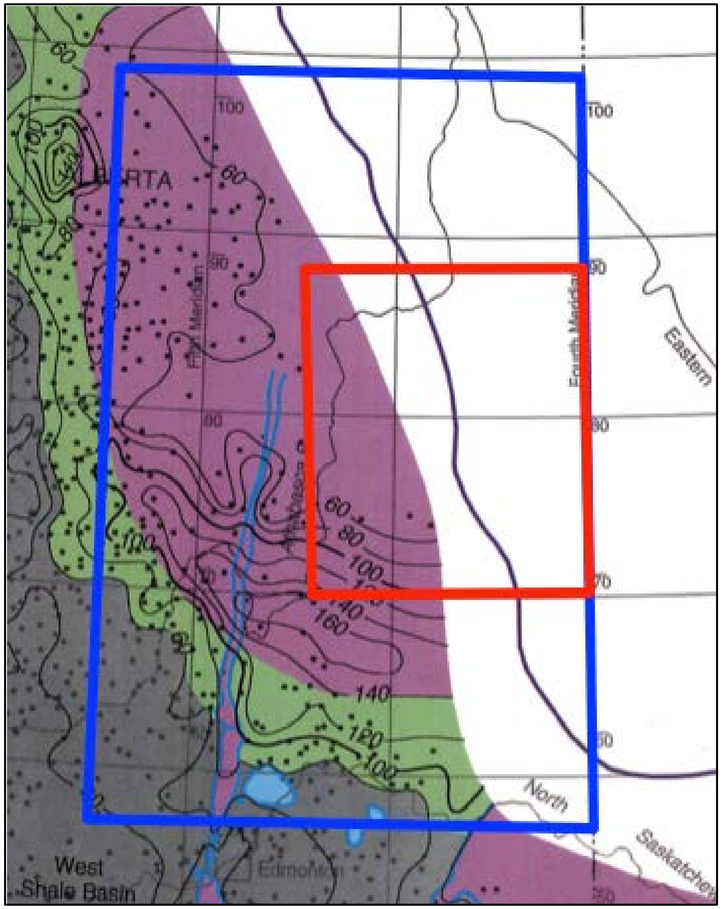
Most Promising Targets

- Woodbend Group
  - Relatively deep; thick permeable carbonates
  - Some hydrocarbons
  - Estimated injection rates up to 3,000 m^3/d or more per well
  - Saline *(30,000-60,000 mg/L TDS)*; higher scaling potential *(carbonates, silica, clays, zeolites)*



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Regional Disposal Strategies

- Avoid:
  - Hydrocarbon-rich areas *(Wabiskaw-McMurray & areas of Wabamun/Winterburn/Woodbend)* except depleted gas fields *(opportunity)*
  - Areas close to the Saskatchewan border *(e.g., within 6 Townships or so)*
  - Formations lacking sufficient cap-rock & with evidence of hydraulic connectivity
- Employ alternative technologies to manage pressure build-up *(e.g., horizontal wells)*
- Group facilities to establish sub-regional scheme *(utilizing different formations)*

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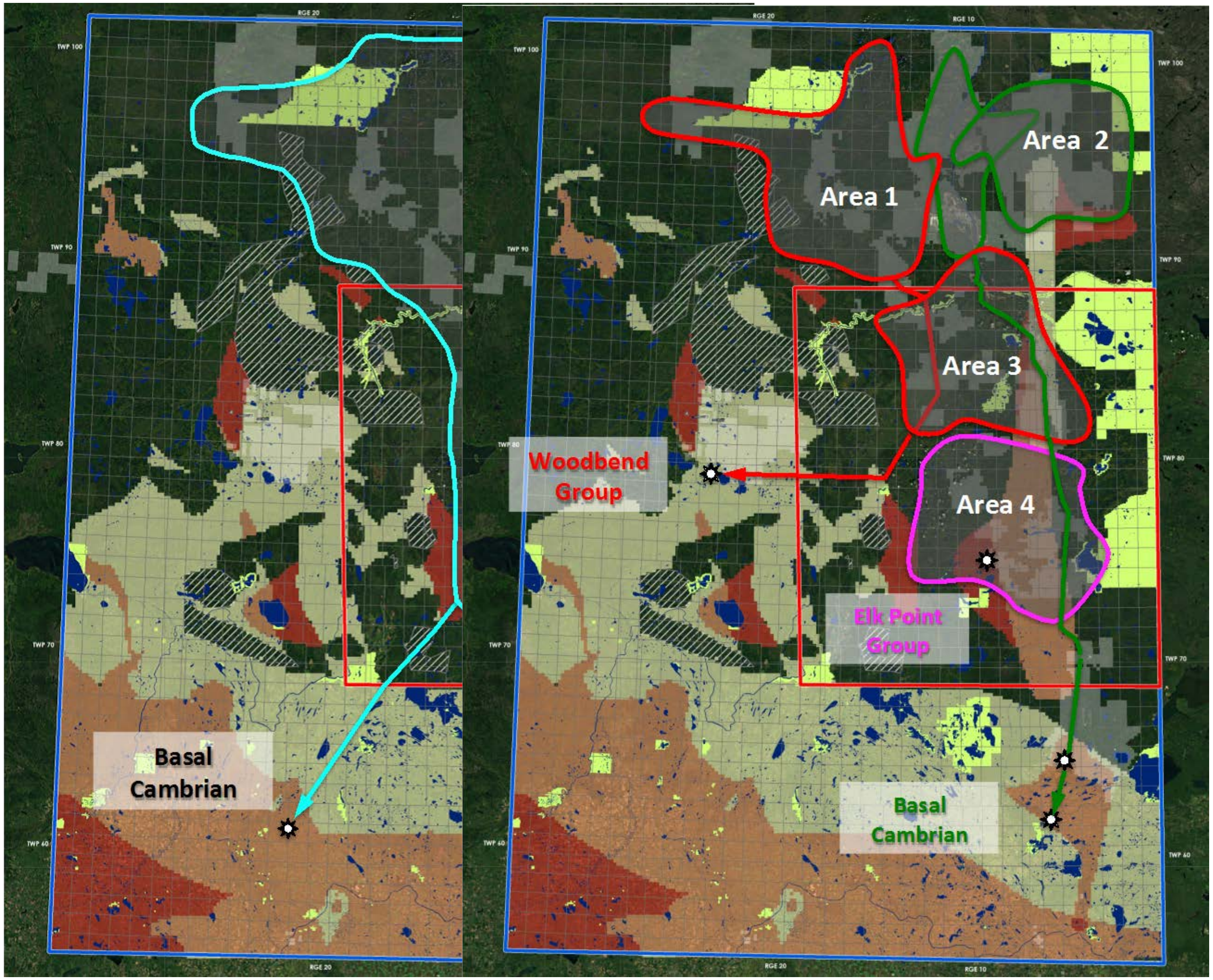
Potential Scenarios



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Conclusion & Recommendations

- Regional potential for disposal is significant
- Areas in the NE not recommended for large-scale disposal due to connectivity to surface
- Areas to the west and south of PSA appear most suitable *(particularly in Cambrian & Woodbend)*
- Sub-regional solution appears favourable utilizing more than one target formation *(spread the load)*
- Pressure management will ensure long term sustainability

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Future Needs to Refine

- Finalize selection of potential target areas & intervals
- Refine knowledge with:
  - Available petrophysical records
  - D51 reports
  - Cores
- Initiate assessment of prime targets by:
  - Exploratory drilling
  - Formation testing & sampling (DST; MDT)
  - Geochemical modelling to assess water compatibilities and potential long-term effects

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