Characterizing hydrogeological conditions to a depth of 1 km in West-Central Alberta

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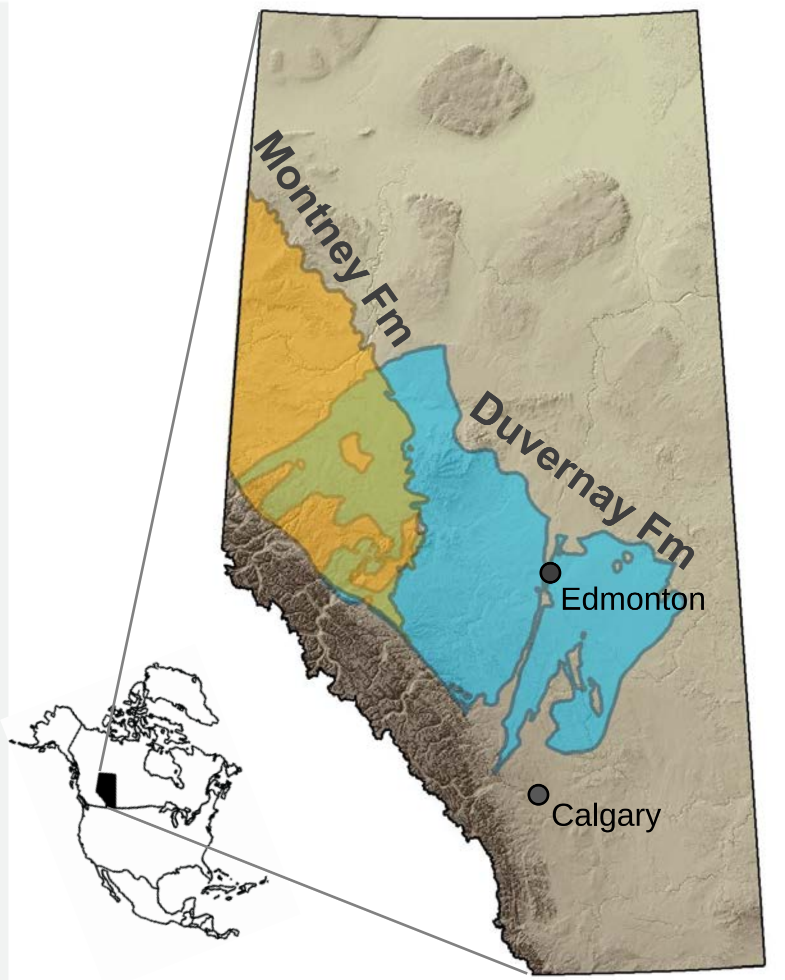
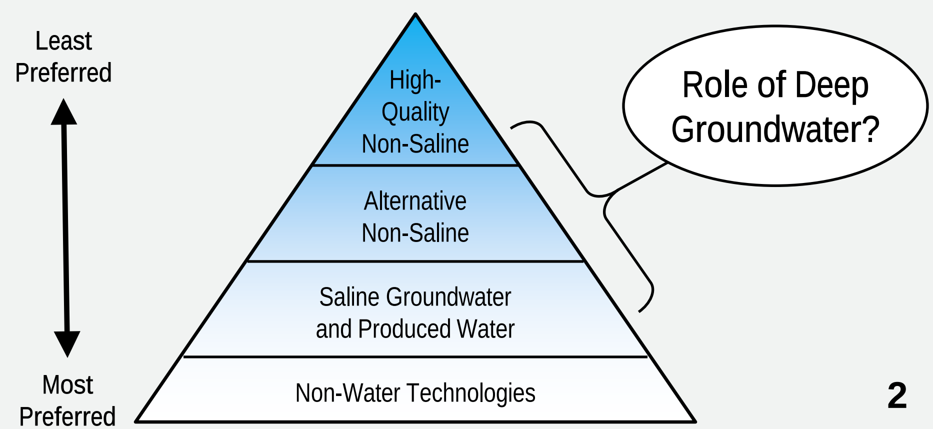
Alberta Energy Regulator

AGS ALBERTA GEOLOGICAL SURVEY

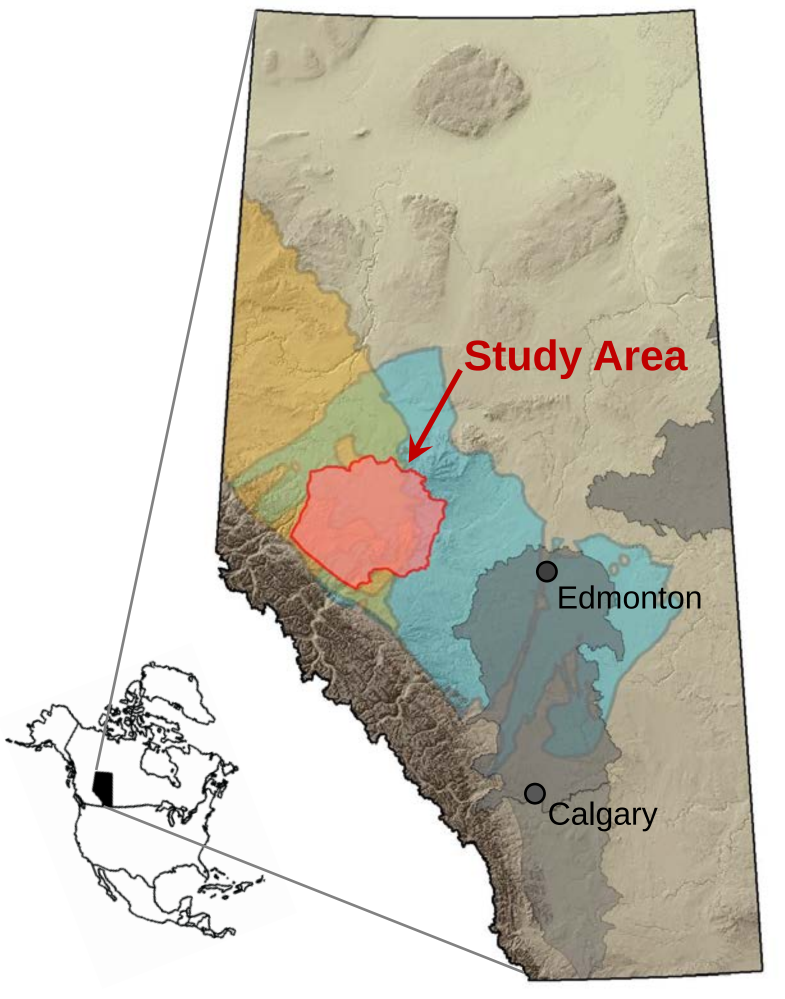
Project Impetus: Unconventional Shale Gas



- Unconventional hydrocarbon development in west-central Alberta
  - 30,000 to 50,000 m^3 per well for hydraulic fracturing
- Easily accessible water sources during early development stage
  - Surface water, shallow groundwater
- Water Conservation Policy for Upstream Oil and Gas Operations

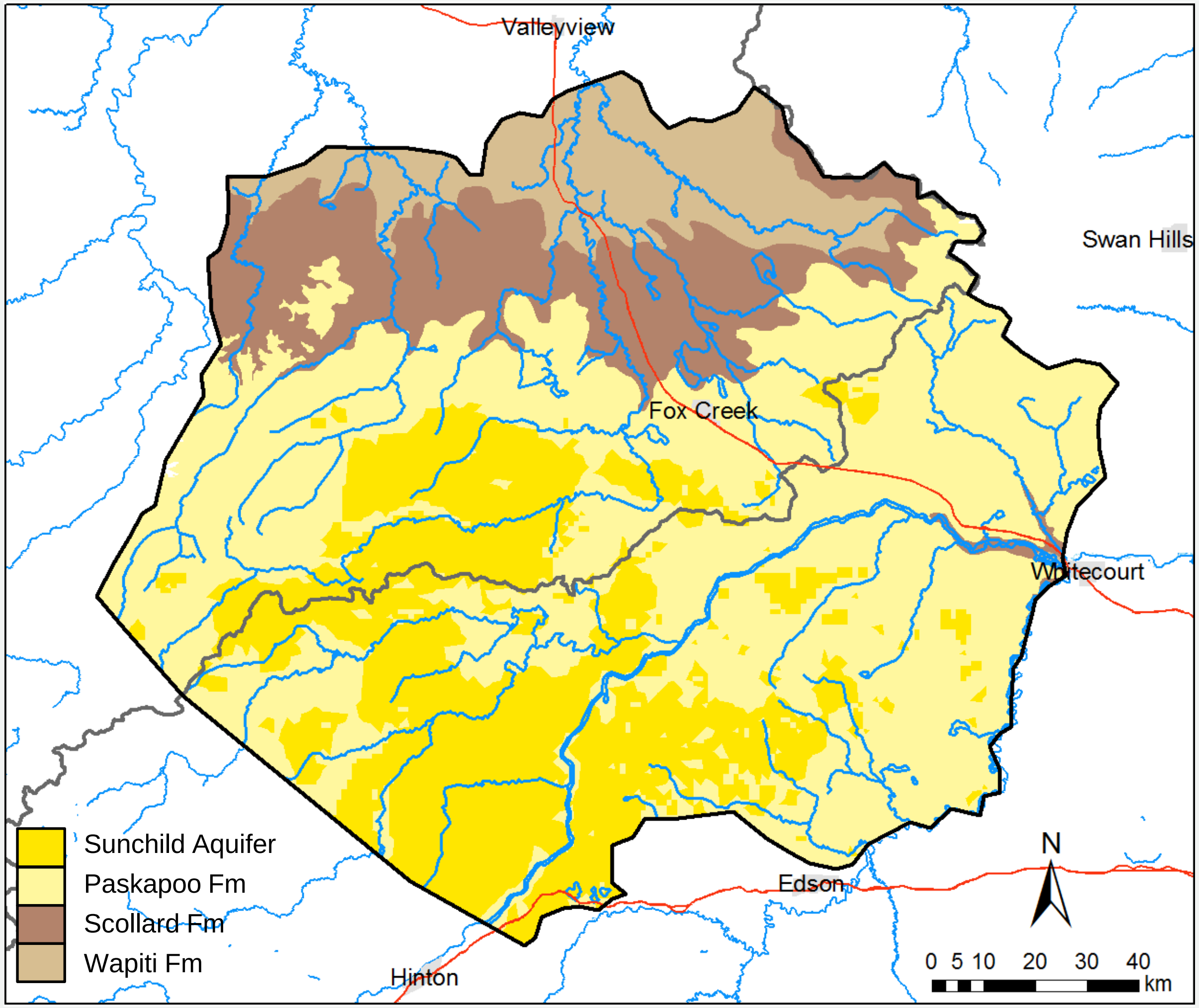


West-Central Alberta Project



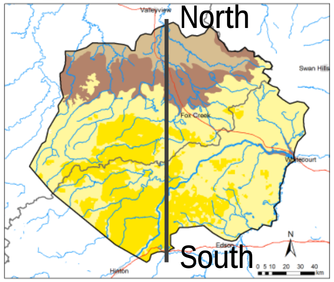
- Characterize Alberta's groundwater resources
  - Regional-scale mapping and inventory
  - Interaction with surface water
  - Provide basis for assessing cumulative effects of development
- Ensure geoscience is meaningful at the 'regional' scale
  - Area-based regulation
  - Land-use planning regions
- Approach
  - Hydrostratigraphic unit (HSU) mapping
  - Bedrock property modelling
  - Hydrogeology (flow patterns, TDS, groundwater residence time)

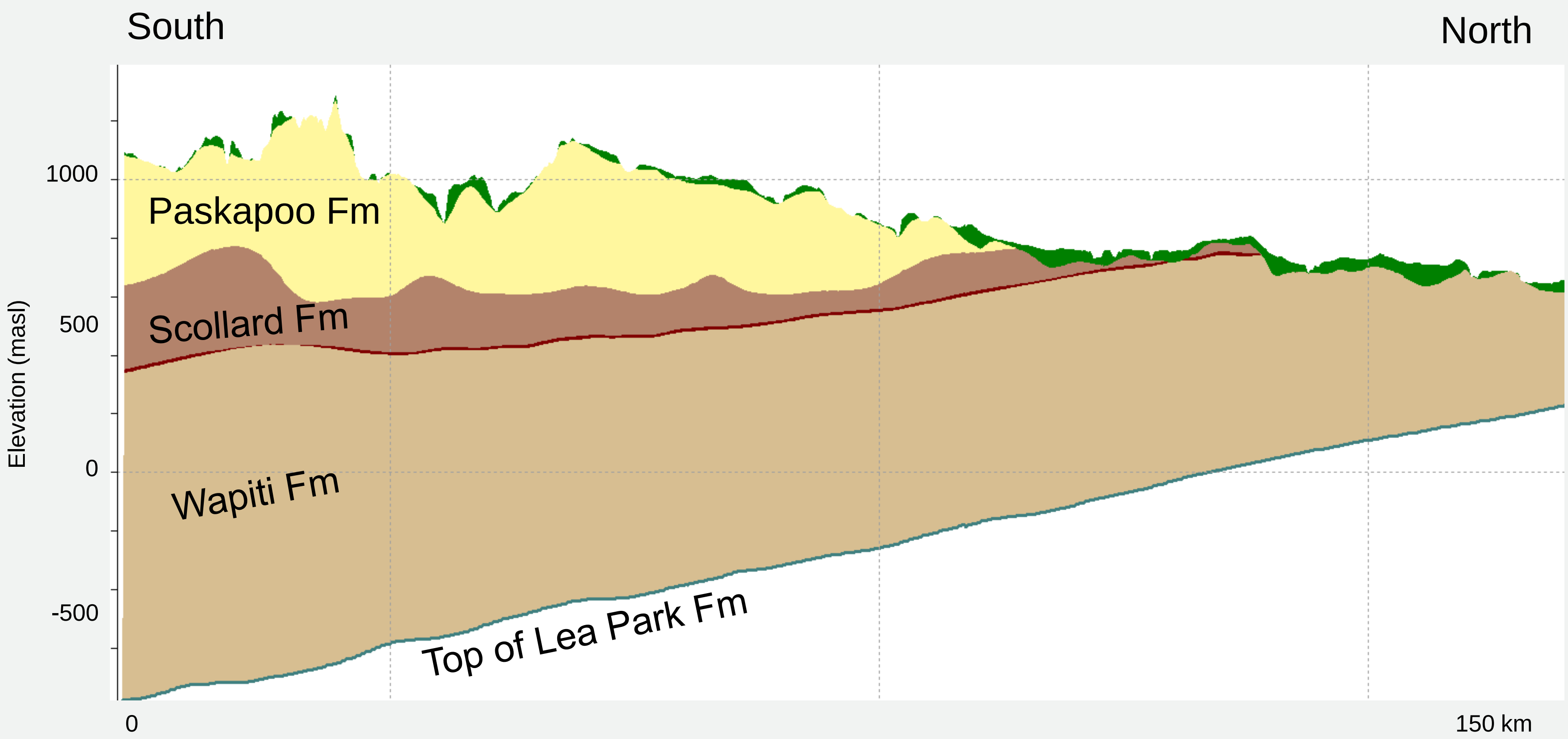
Study Area Extent



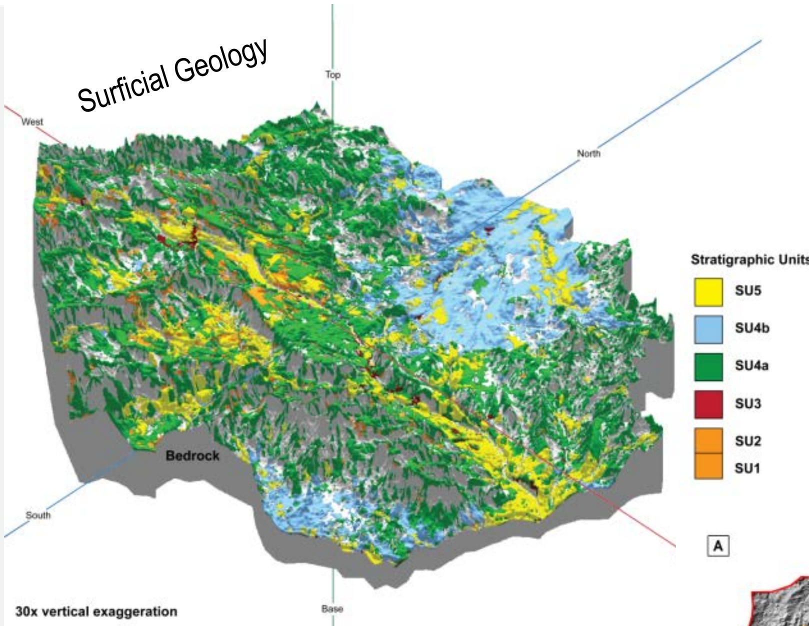
- Relatively shallow bedrock
- Uppermost bedrock forms a major aquifer system in Alberta
- Headwater rivers incised into bedrock
- 22,000 km^2

Study Area Depth Interval

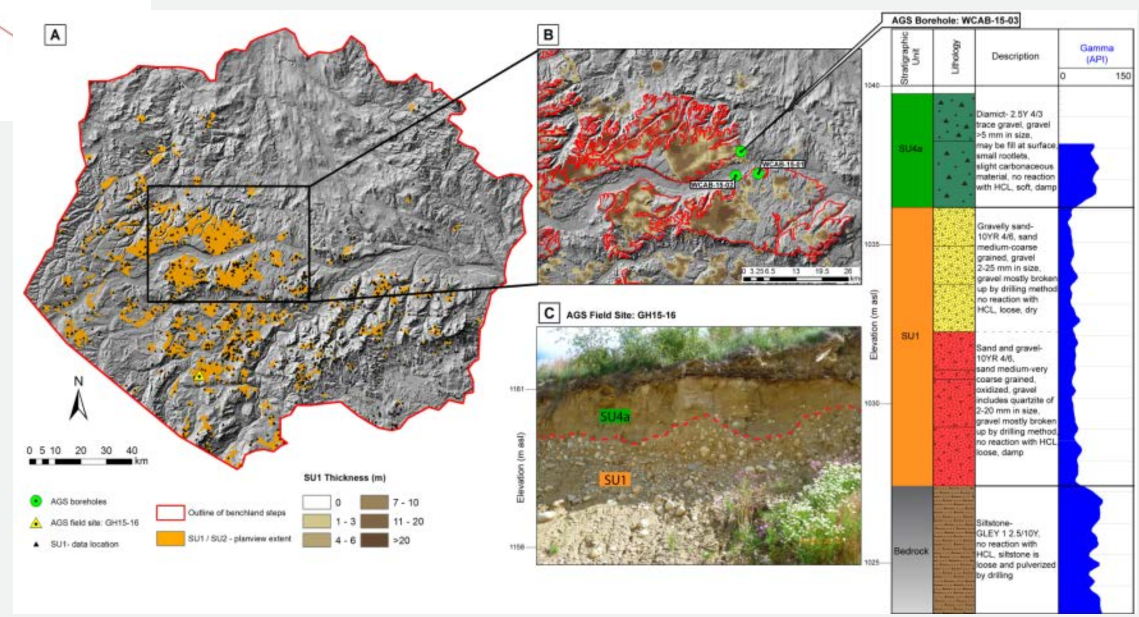




HSU Mapping



- Develop an understanding of hydrostratigraphy
  - Map/refine the near-surface geology
  - Desktop data sources with strategic field work
  - Identify potential recharge zones



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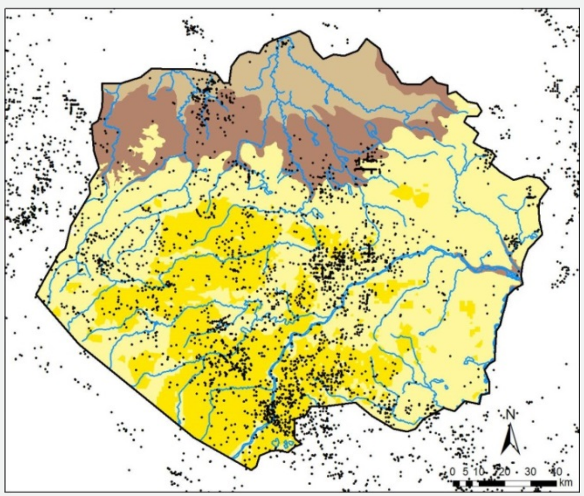
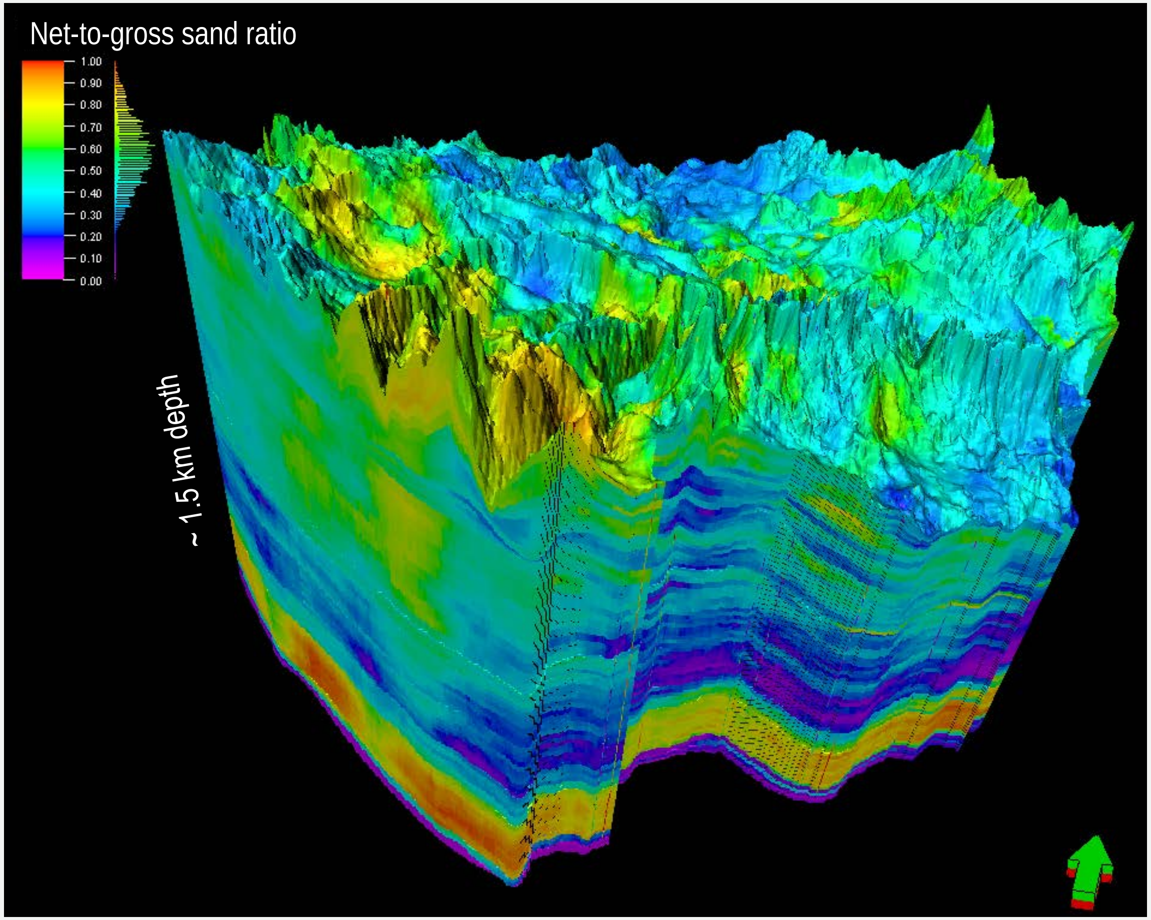
Bedrock Property Modelling

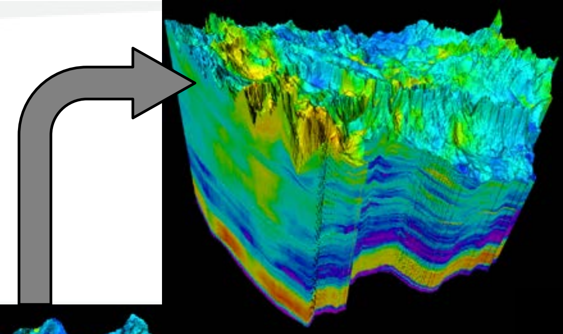
- Developed from gamma-ray logs
  - Government of Alberta mandate of wireline logging to surface since 2006
  - Thousands of wells to help define formation architecture

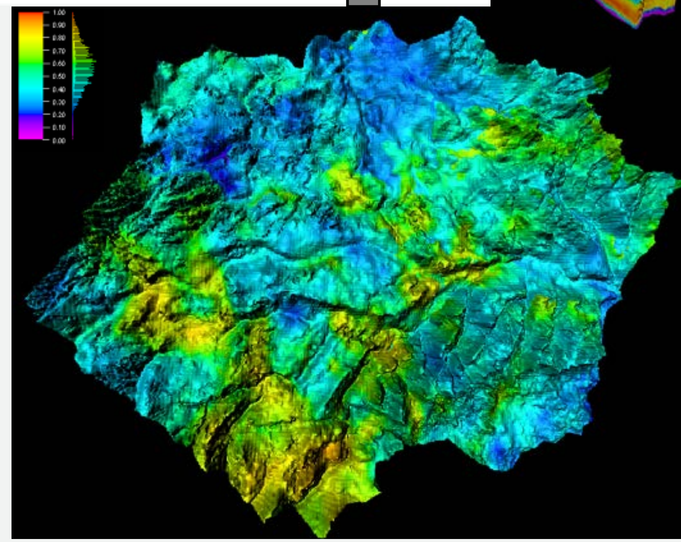




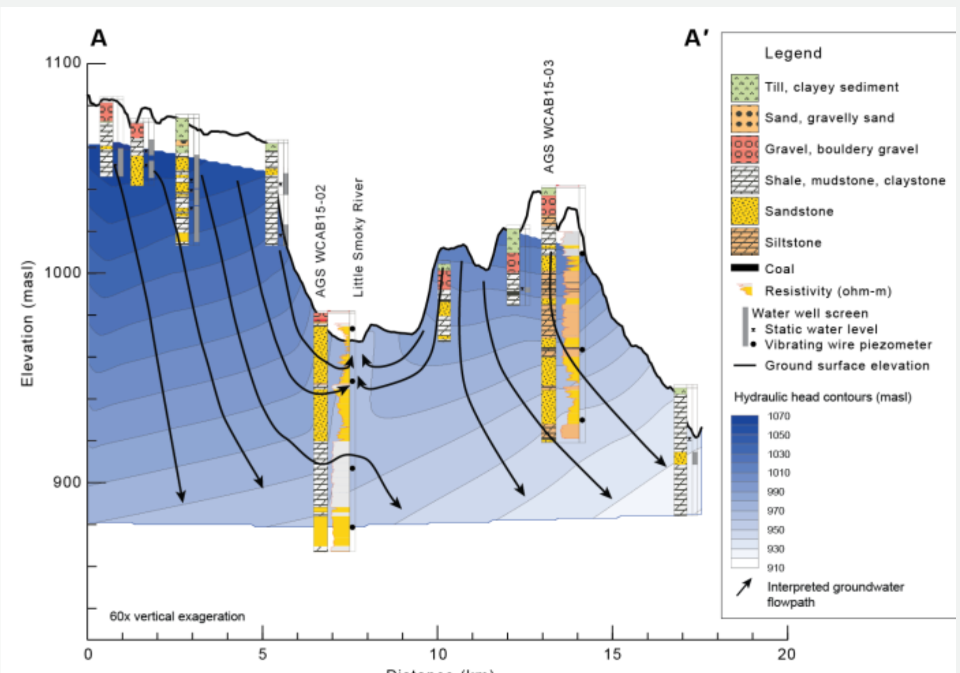
Shallow Groundwater

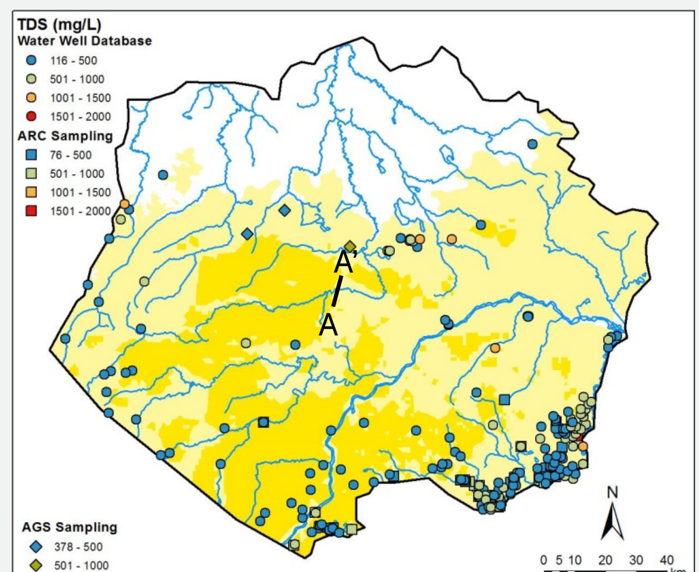
Paskapoo Formation





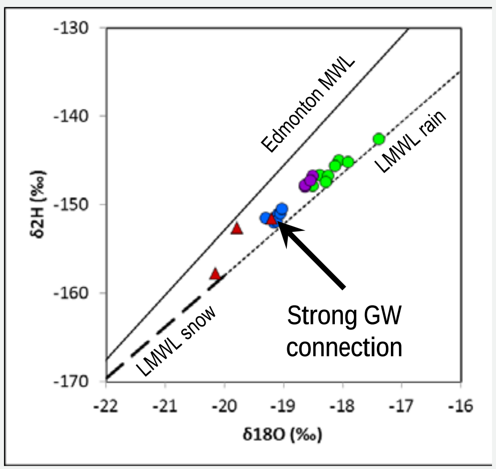
- Isolated sandstone channels within mudstone (highly heterogeneous)
- Rivers capture localized groundwater
- Dominantly recharge across study area
- TDS typically < 800 mg/L





Shallow Groundwater Residence Time

- Environmental Tracers
  - ^{2}H, ^{18}O, ^{222}Rn, ^{3}H, SF_6, ^{4}He
  - 1st order GW inflow rates to rivers
  - Snowmelt recharge



- Residence Time
  - 30 to 50 years for groundwater samples
  - 7 to 10 years for river samples

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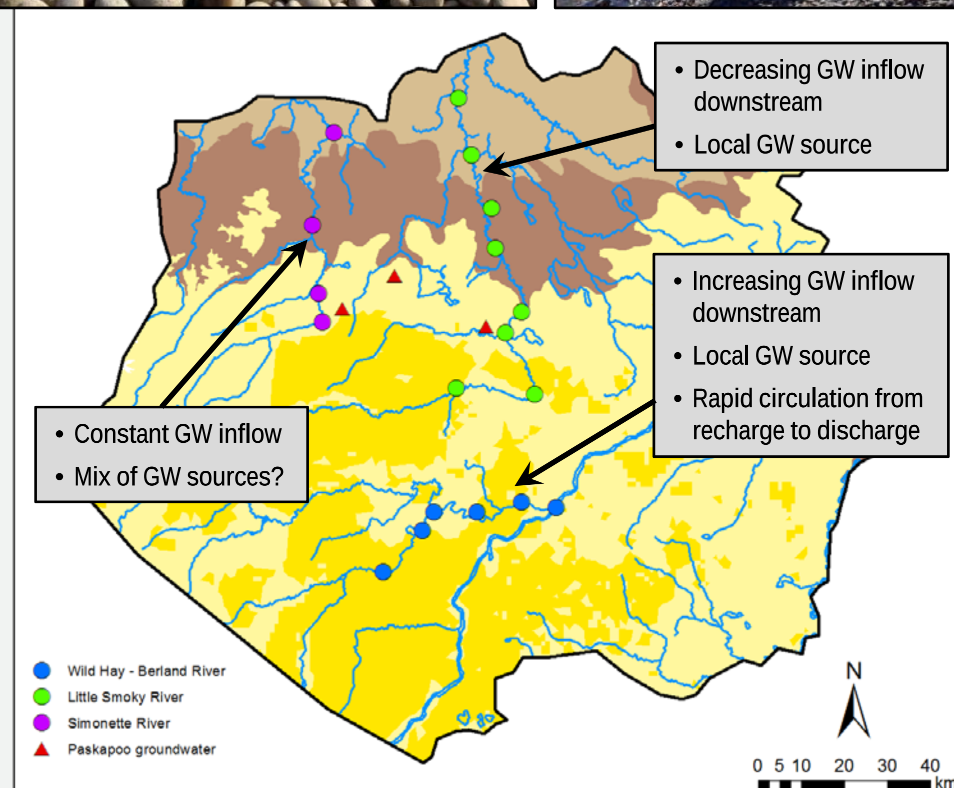
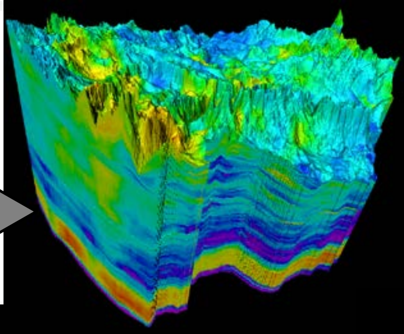
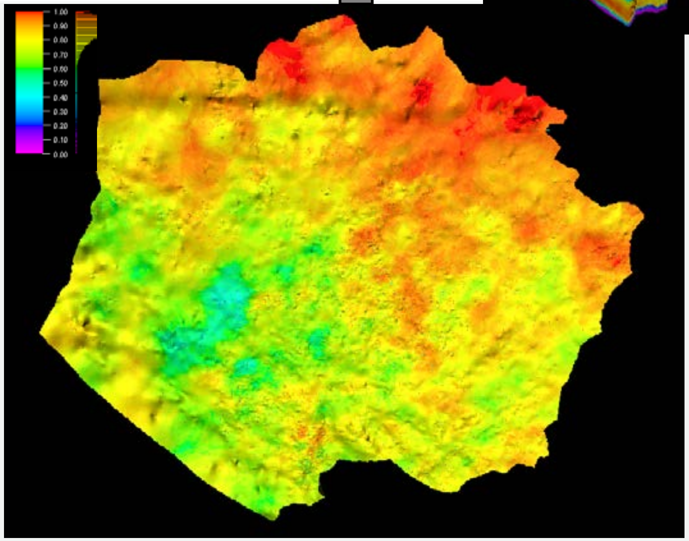


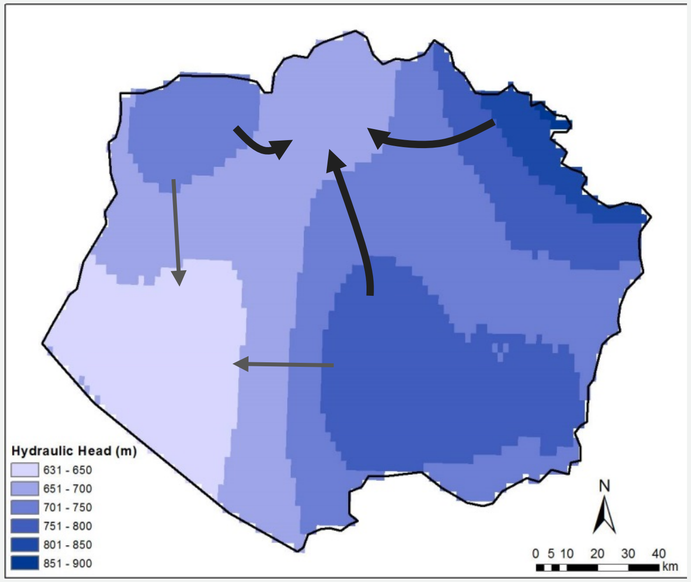
Deeper Groundwater

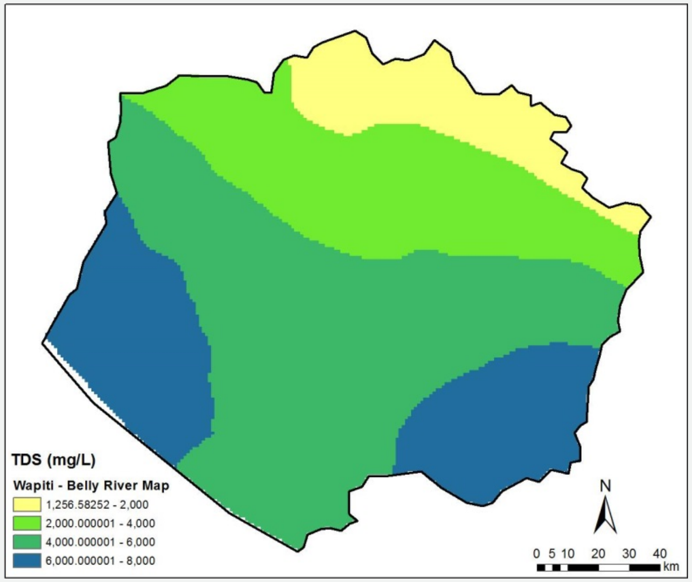
Wapiti Formation



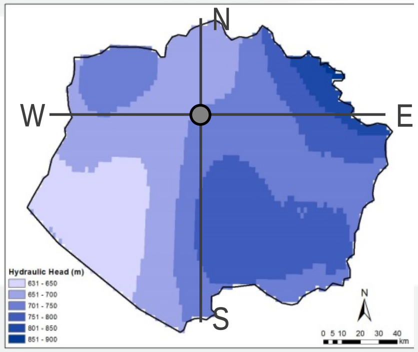
- Upper mudstone, lower sandstone
- Thick basal sandstone unit, coarse texture observed in outcrop
- Formation scale mapping (DST's)
  - Complex groundwater flow pattern (topographic effect and under-pressuring)
  - TDS varies from 600 to 8000 mg/L

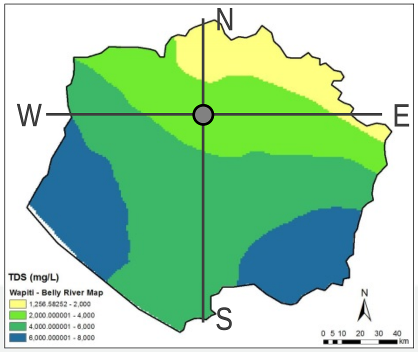


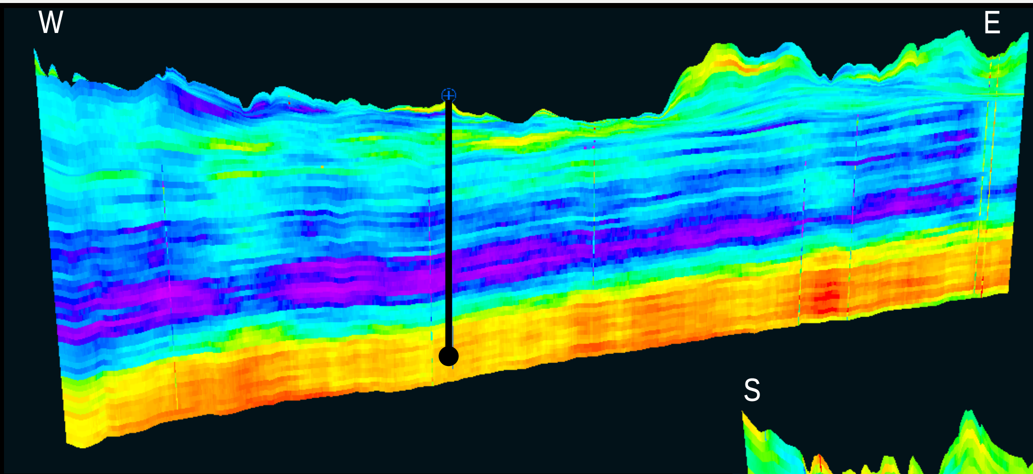


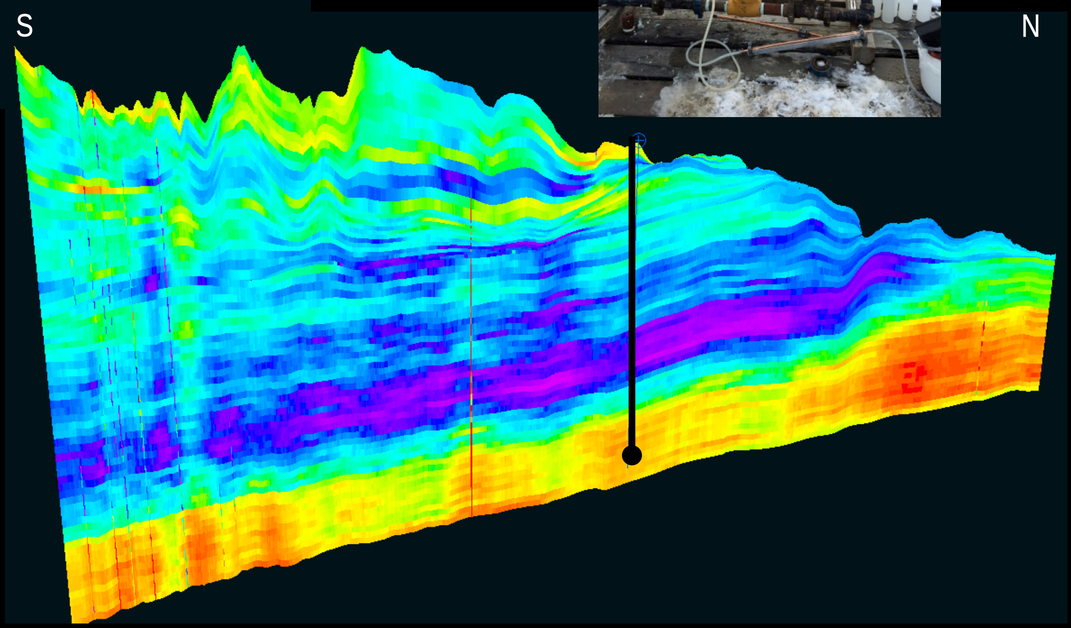


Deeper Groundwater Residence Time



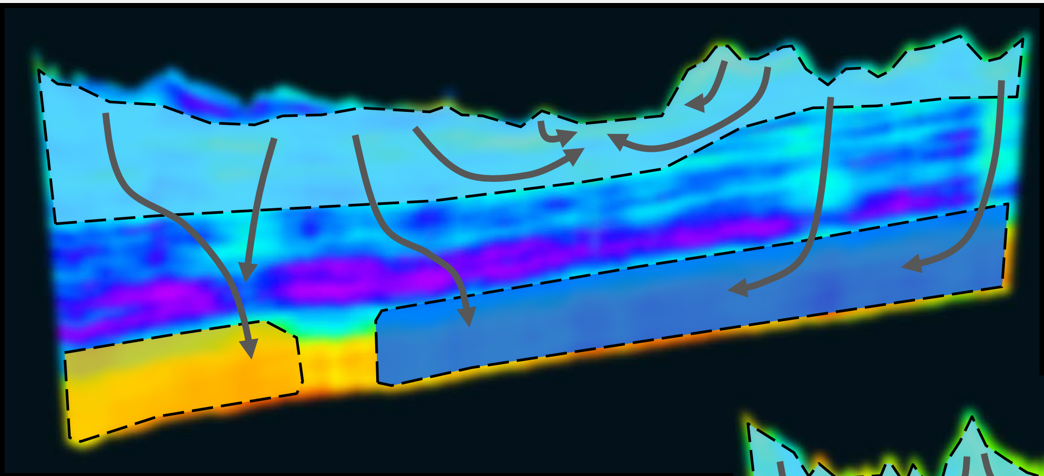




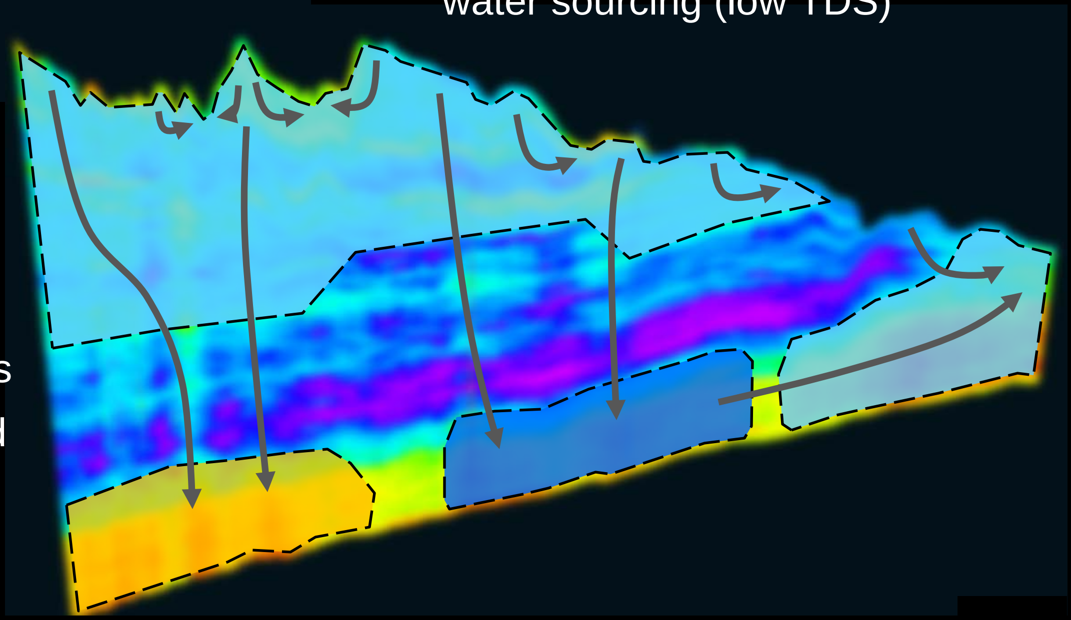


- Environmental Tracers
  - $^{3}H = 0.05$ TU
  - $^{14}C = 0.9$ pMC
  - $^{4}He = 1.8e{-}6$ ccSTP/g
- Residence Time?
  - ~135,000 years

Conceptual Model



- Shallow groundwater circulation
  - <10 years near rivers
  - 50+ years elsewhere
  - Regional recharge
  - Isolated permeable zones for water sourcing (low TDS)



- Deeper groundwater circulation
  - >100,000 years
  - More widespread permeable zones
  - Low TDS where actively recharged
  - High TDS where deeper and more stagnant

Conclusions

- Characterizing deeper groundwater systems
  - Requires a combination of mapping and modelling methods
  - Relies on partnership to overcome data sparsity
- Interaction between science and regulation
  - Depths encompass non-saline to saline transition in Alberta → *direct regulatory implication*
  - Conceptual models help industry and regulator identify and understand choosing deeper water sources

Thank you