Can river water data be leveraged to understand groundwater circulation for a large area?

Brian Smerdon, Alberta Geological Survey
Payton Gardner, University of Montana
GSA 2016
Provincial Groundwater Inventory Program

- Characterize Alberta’s groundwater resources
  - Regional-scale mapping and inventory
  - Basis for assessing cumulative effects of development

- Ensure geoscience is meaningful at the ‘regional’ scale
  - Area-based regulation
  - Land-use planning regions

- Established techniques:
  - 3D geomodelling (HSUs)
  - Hydrodynamic data
  - Hydrochemistry (TDS)
West-Central Alberta Project

- Forested, unpopulated region
- Unconventional hydrocarbon development
- Surface water and non-saline groundwater used for hydraulic fracturing

Utilize river water as integrator of groundwater circulation?

Combine environmental tracer findings with established techniques to develop conceptual model
Study Area Extent

- Relatively shallow bedrock
- Uppermost bedrock forms a major aquifer system
- Headwater rivers incised into bedrock
- 22,000 km²
Bedrock Hydrogeology

Smerdon et al., 2016; AGS OFR 2016-02

Legend
- Till, clayey sediment
- Sand, gravelly sand
- Gravel, bouldery gravel
- Shale, mudstone, claystone
- Sandstone
- Siltstone
- Coal

Resistivity (ohm-m)
- Water well screen
- Static water level
- Vibrating wire piezometer
- Ground surface elevation

Hydraulic head contours (masl)
- Interpreted groundwater flowpath

60x vertical exaggeration
Environmental Tracer Sampling

- 3 rivers spanning geological formations
- Sampled at low flow (September 2015)
- ~20 km sample spacing
- 3 groundwater samples
- Analytes:
  - Major ions
  - $\delta^2$H, $\delta^{18}$O
  - $^{222}$Rn
  - $\text{SF}_6$, $^3$H
  - Noble gases
$\delta^{2H}, \delta^{18}O$

- **Snowmelt recharge signal**
- **Downstream trend**
  - Slight difference in source?
  - Elevation effect?
222Rn

**Method**
- RAD7 detector

**Result**
- Low concentrations in river relative to groundwater
- Spatial variation could be related to discharge rate rather than bedrock geology
Method

- Helium in-growth
  - University of Utah

Result

- Concentrations represent modern input
- Spatial variation appears related to water circulation rate
  - Subtle differences
  - Locally recharged
Groundwater Discharge Modelling

Method

- Steady-state advective transport model
  - RADIN13, Peter Cook
  - Visual fit to $^{222}\text{Rn}$, $^{3}\text{H}$
- Assumed groundwater concentrations

Result

- High inflow areas align with known sandstone distribution
- Some insight, but needs more constraint
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- Decreasing GW inflow downstream
- Local GW source

- Increasing GW inflow downstream
- Local GW source
- Rapid circulation from recharge to discharge

- Constant GW inflow
- Mix of GW sources?

Lean field program

- Learned that rivers capture localized flow systems
- 1st order GW inflow rates
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Lean field program

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Has this helped?

- Additional information at a suitable scale
- Reinforced concept of water movement
- Knowledge → guidance for regulation
Future Work

- Integrate with 3D geological model
- Strategic groundwater sampling
Thank you
Future Work

Mixing models
Mean-transit-time
Recharge-Discharge Mapping

- Estimate of recharge-discharge potential
- Potentiometric surface of uppermost bedrock relative to ground surface