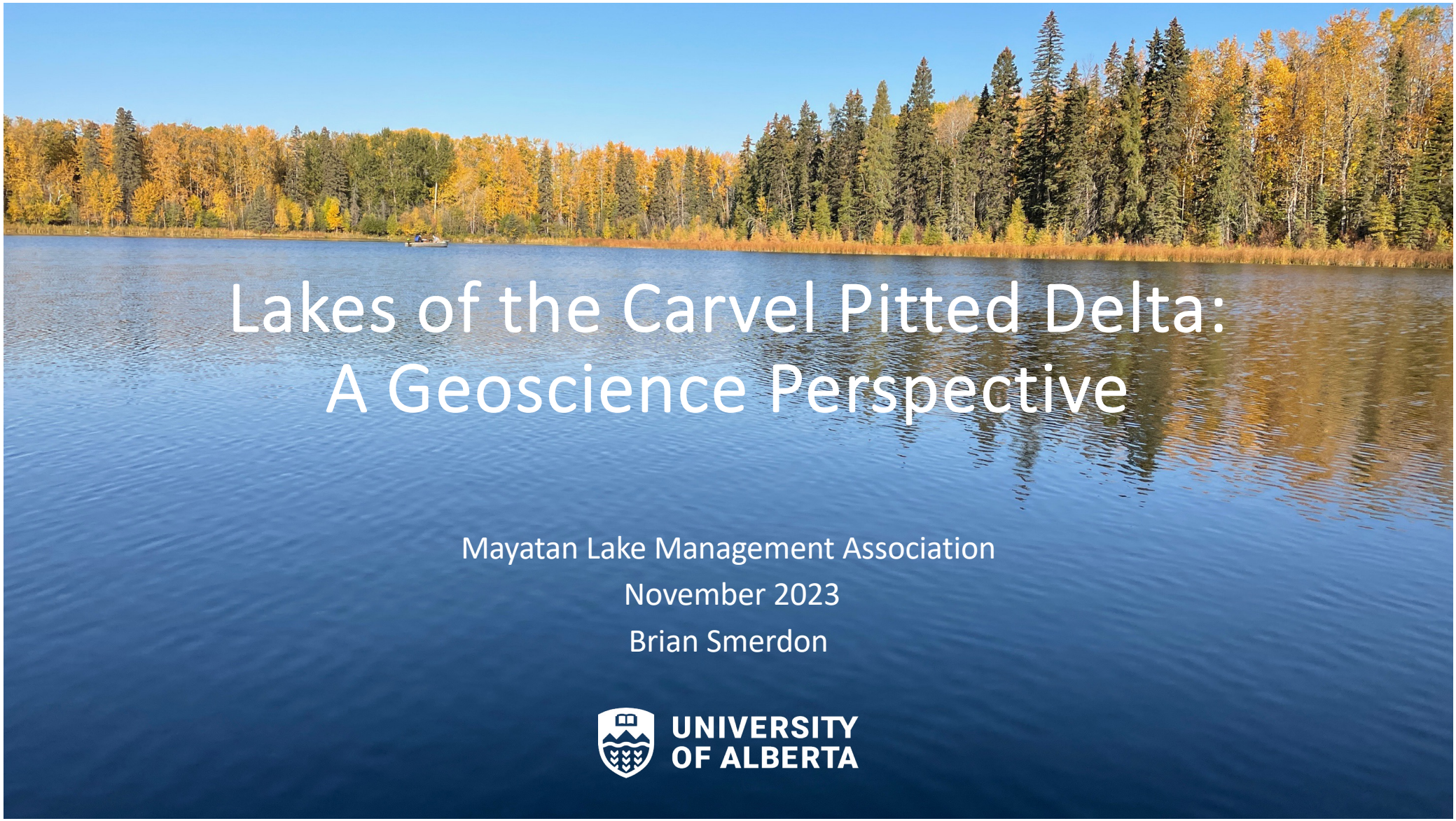


Lakes of the Carvel Pitted Delta: A Geoscience Perspective

Mayatan Lake Management Association

November 2023

Brian Smerdon

UNIVERSITY OF ALBERTA

Contributors

Dave Trew, Walter Neilson, Dave Mussell

- Lake stewardship & enthusiasm for citizen science
- Water sampling

Joel Pumple

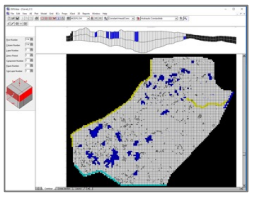
- Permafrost Archives Laboratory Lab Manager
- Stable isotope analysis

Jenna Maccagno

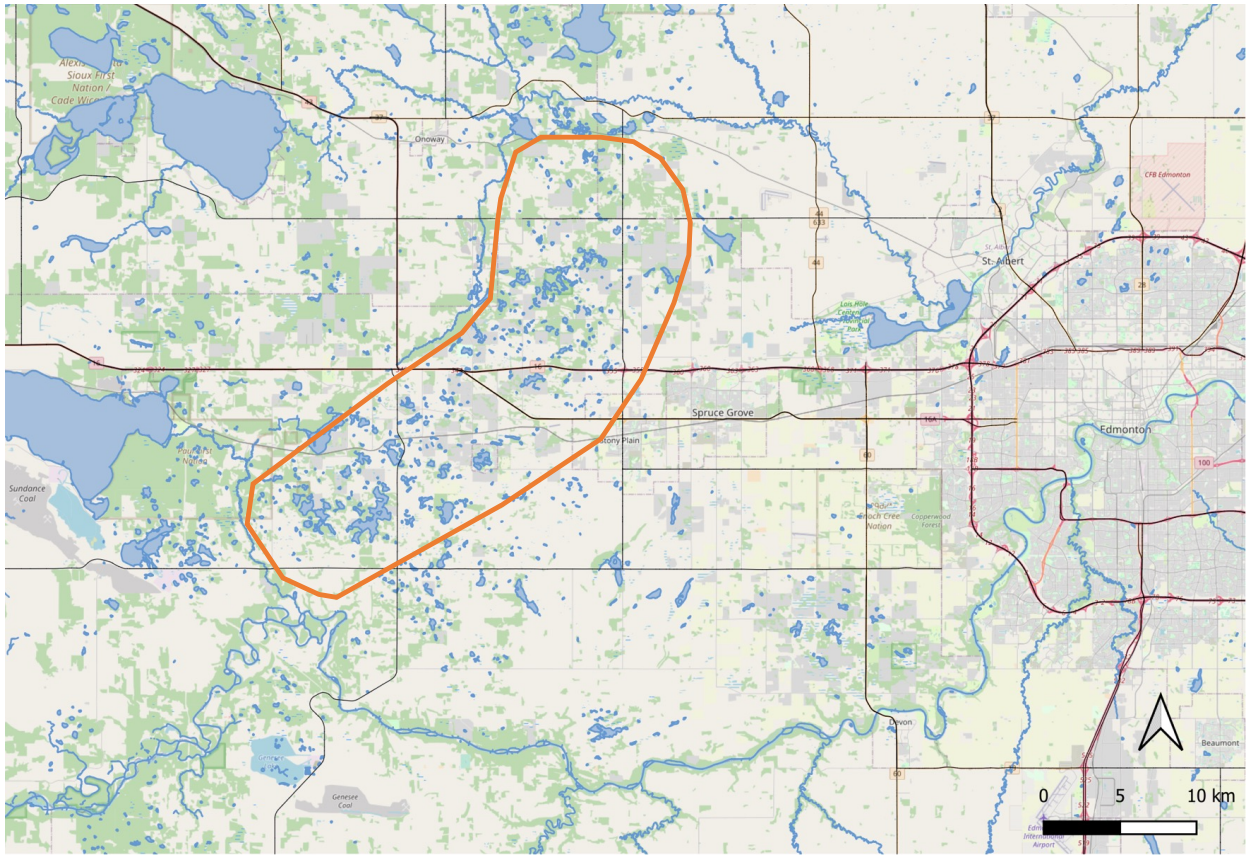
- MSc student
- Radon analysis

Darby Burns

- Research Assistant
- Water table mapping



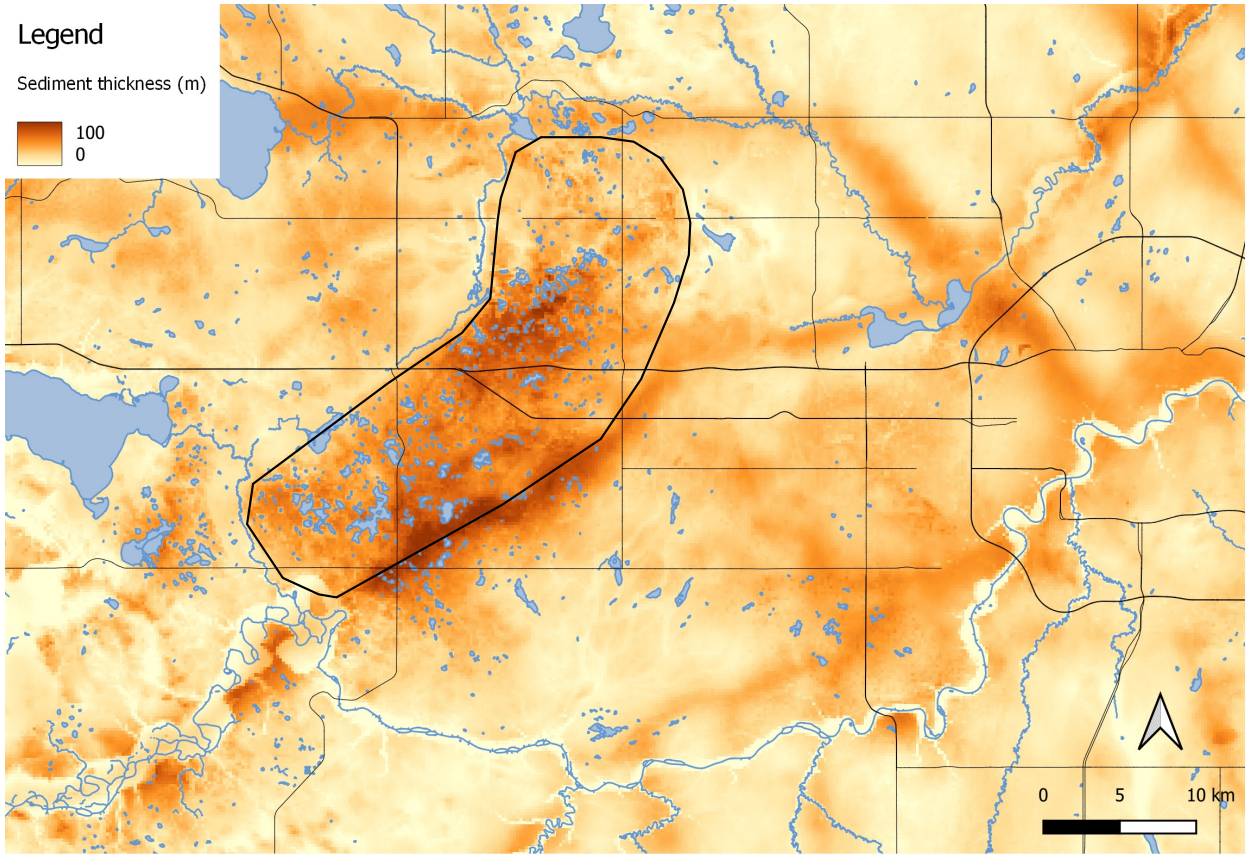
Lakes of the Carvel Pitted Delta



- Dozens of small kettle lakes with unique ecological value
  - Support fish, wildlife and waterfowl
  - Recreation
- Threatened by a changing landscape
  - How will they respond to anthropogenic development?
- Limited information led to citizen-science water quality surveys from 2021 to 2023

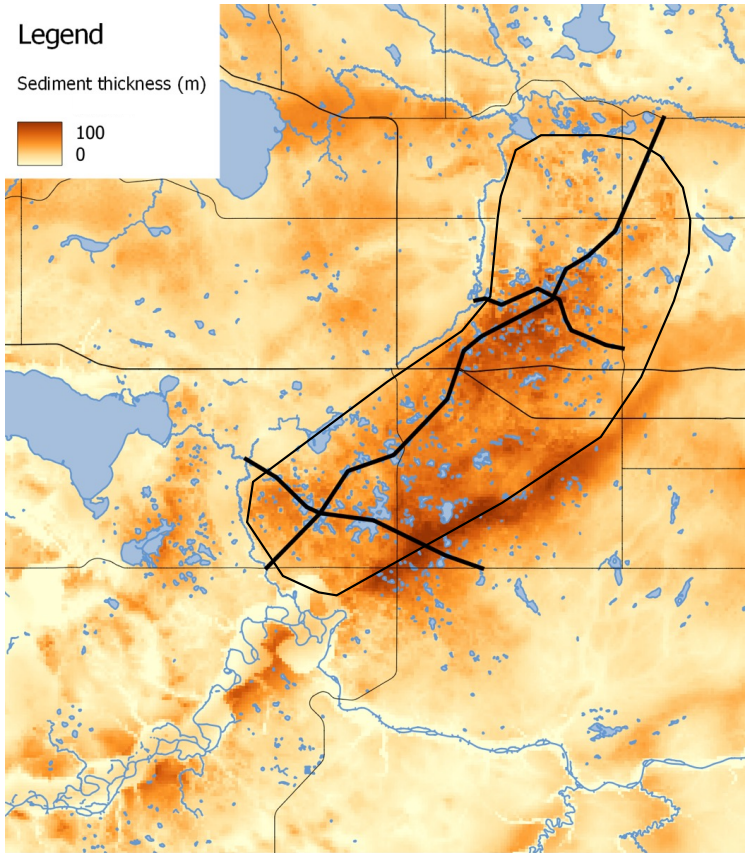
  - *From "I don't know" to Idano: How Visiting a Little Known Lake Instigated a Lake District Survey*

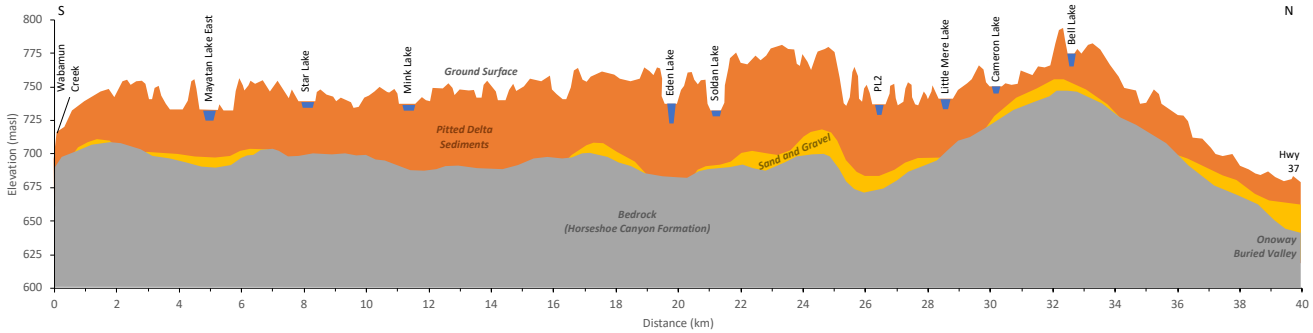
What is the Carvel Pitted Delta?



- Deposits of silt, sand and gravel with hummocky topography
- Formed where rivers flowed off glacial ice into Glacial Lake Edmonton
- Sitting on bedrock
  - Horseshoe Canyon Formation
- Sediments are up to 100 m thick

What is the Carvel Pitted Delta?





- Deposits of silt, sand and gravel with hummocky topography
- Sitting on bedrock
  - Horseshoe Canyon Formation
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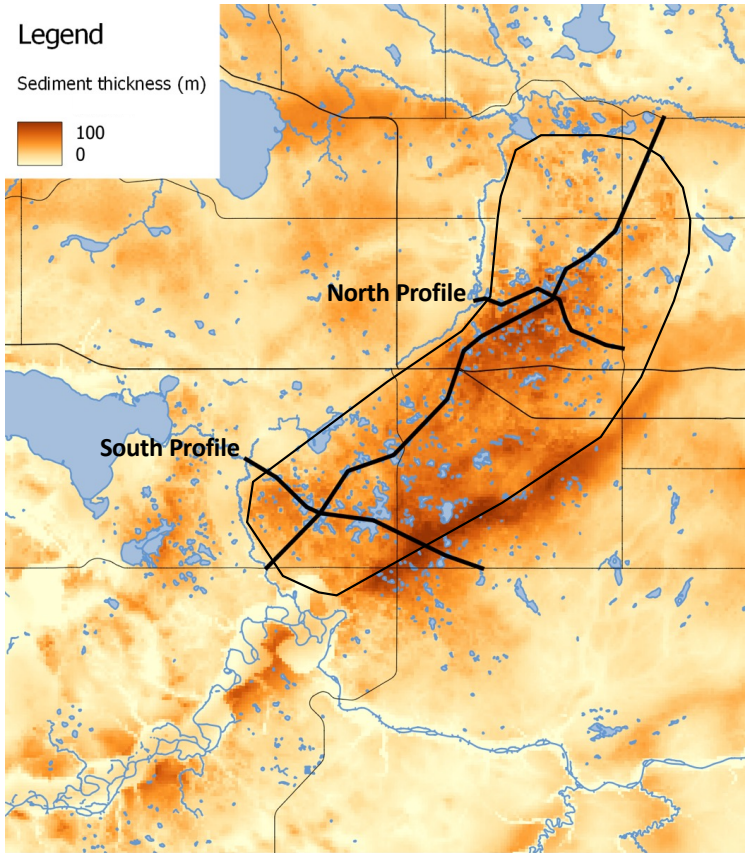
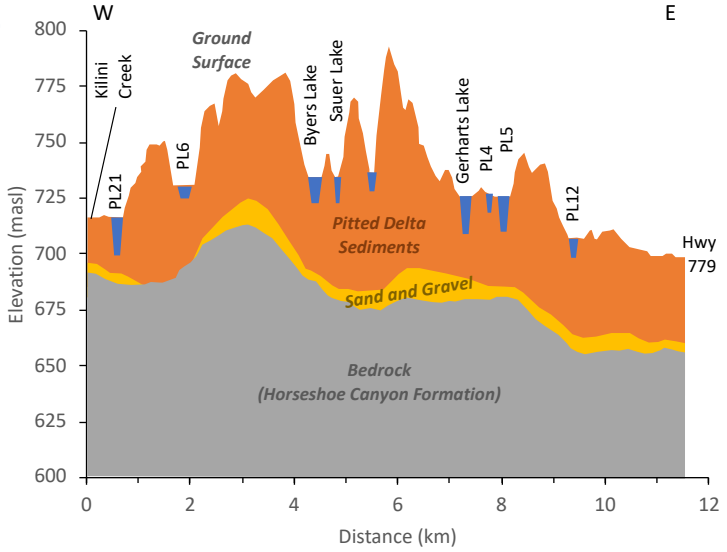
Alberta Geological Survey data

Alberta Energy Regulator | AGS ALBERTA GEOLOGICAL SURVEY

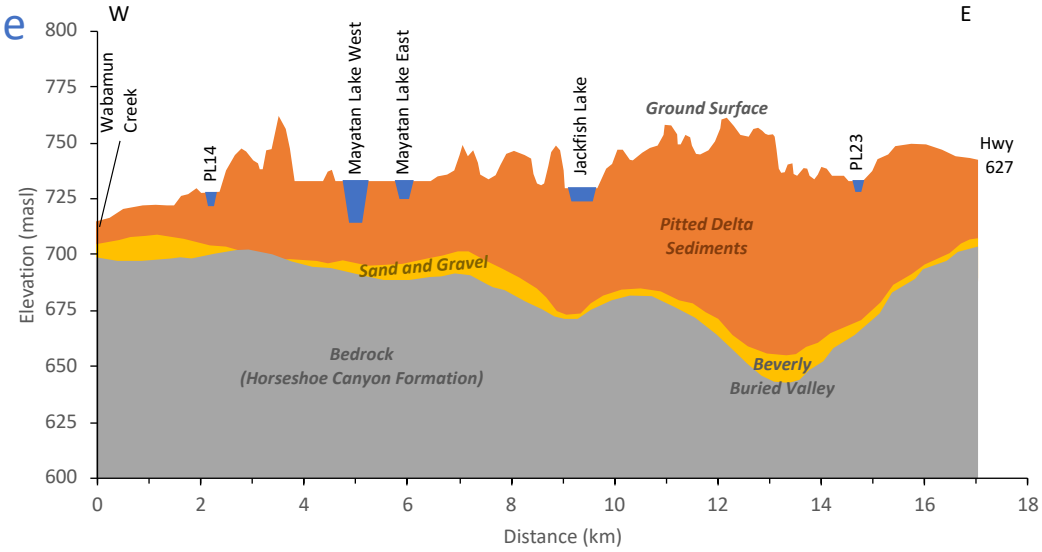
Hartman et al., 2020

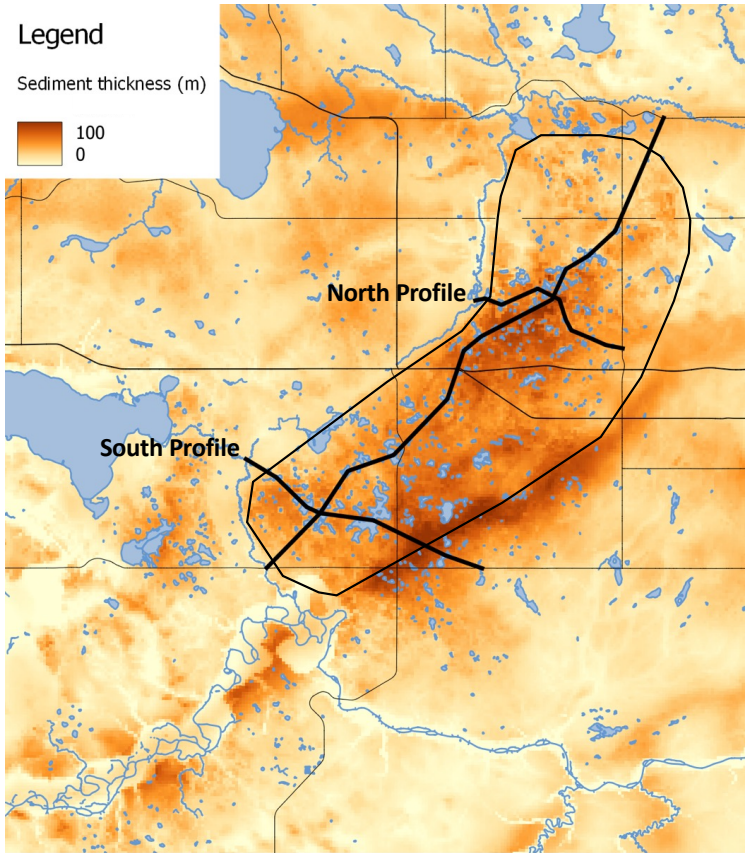


North Profile

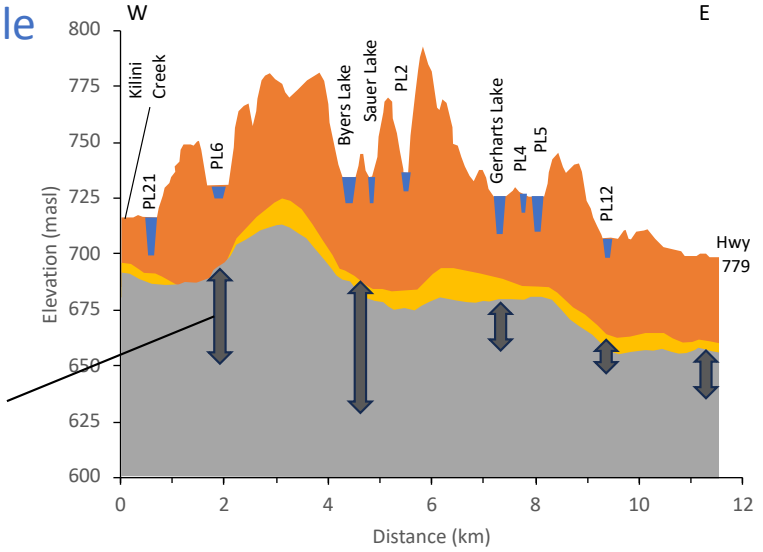


South Profile



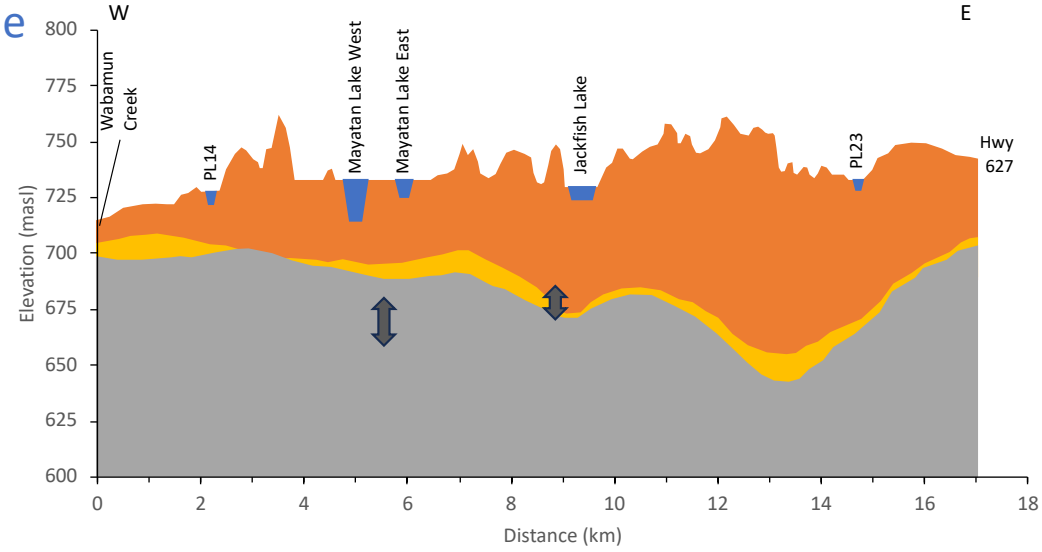


North Profile



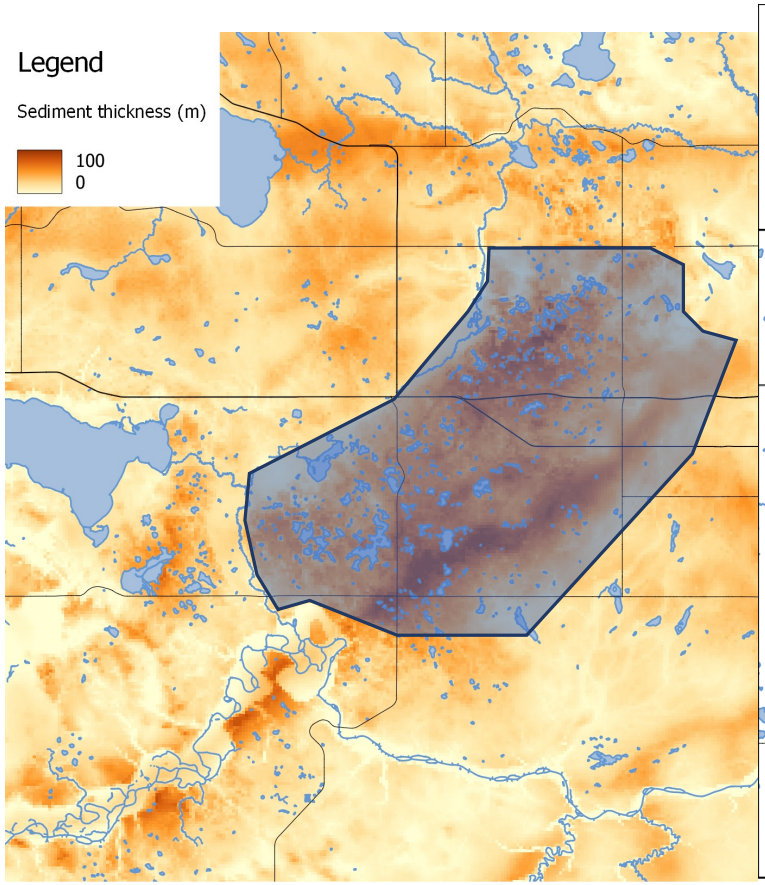
Depth of most water wells

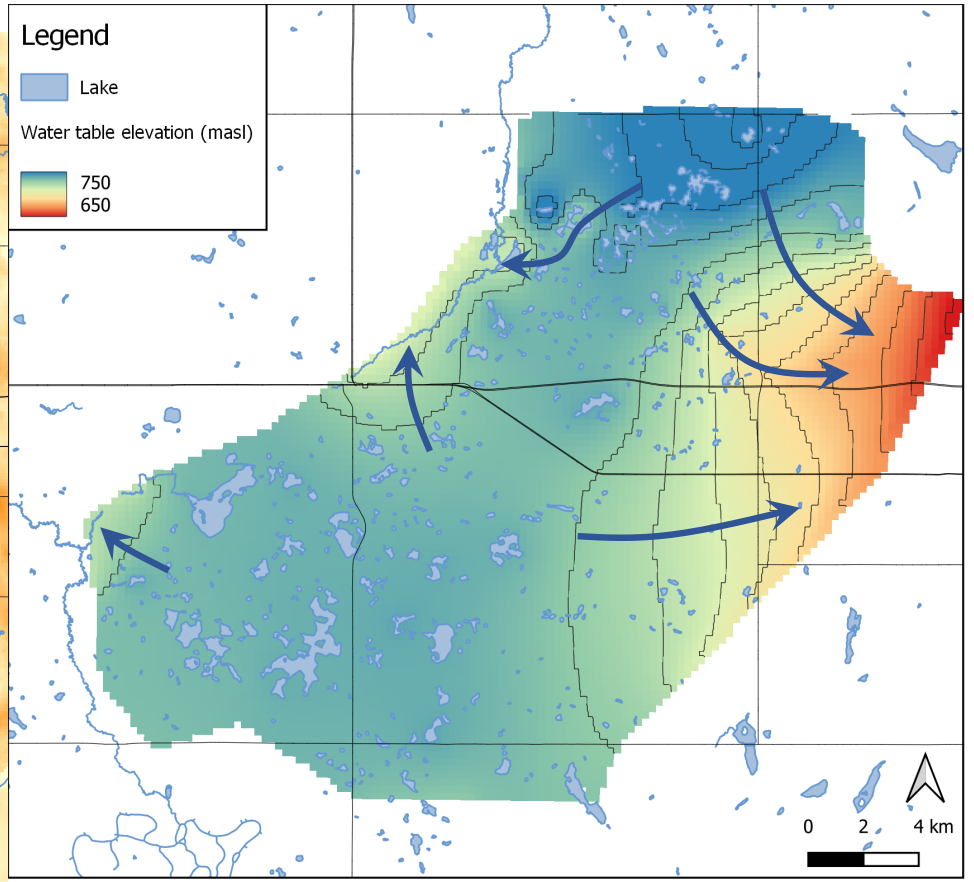
South Profile



Groundwater Movement

- The Carvel Pitted Delta is an area of groundwater recharge
- GW flow directions:
  - East towards Big Lake
  - West towards Kilini Creek
  - Downwards into the underlying bedrock

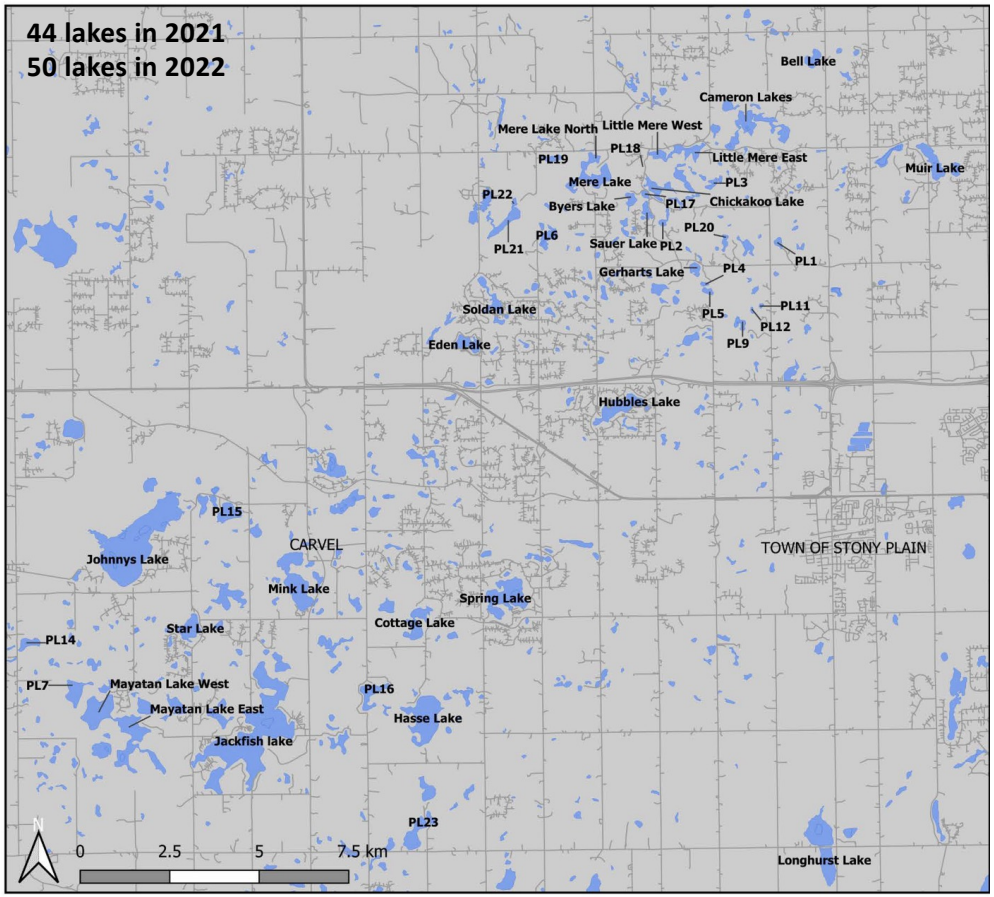




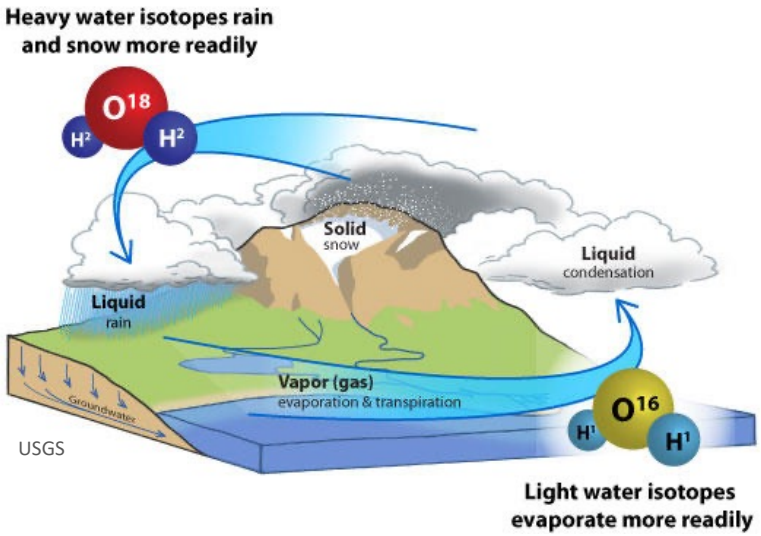
Community-based Water Quality Survey

- Developing a regional overview of lake quality
- Lots of limnological data (clarity, T, DO, chemistry, nutrients…)

- ***How about some isotopic tracers too!***



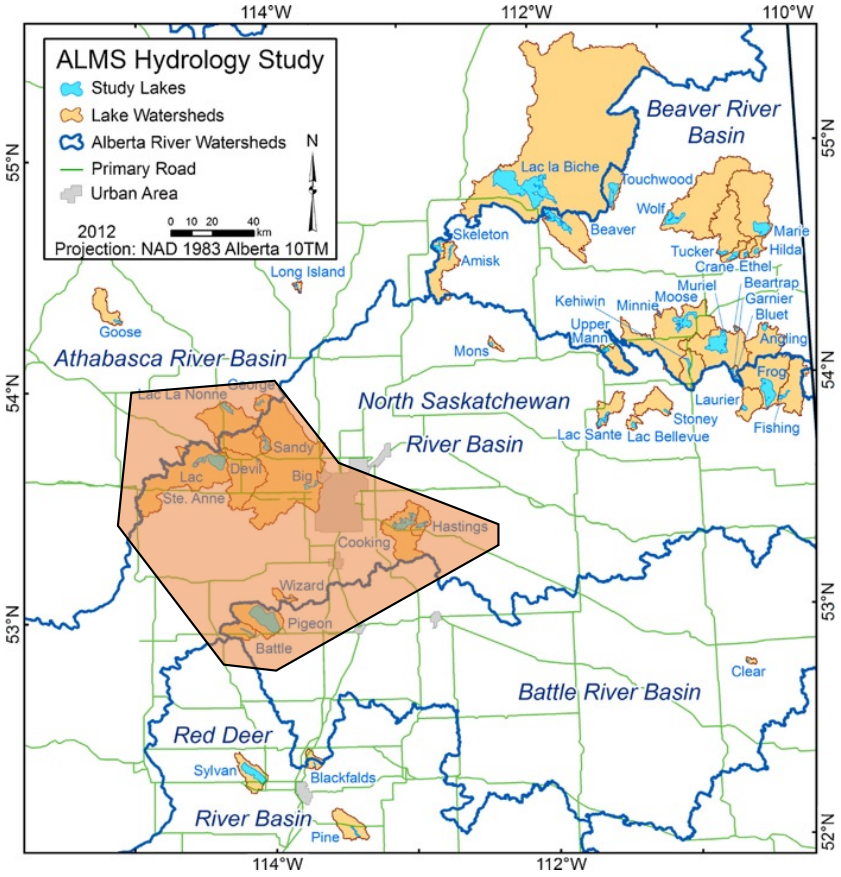
Stable Isotopes of Water



- Lighter isotopes evaporate more readily
- Heavier isotopes condense more readily
- Easy to measurement of isotopic ratio (heavy/light; $^{18}O/^{16}O$; $^{2}H/^{1}H$)
- Very useful in hydrology

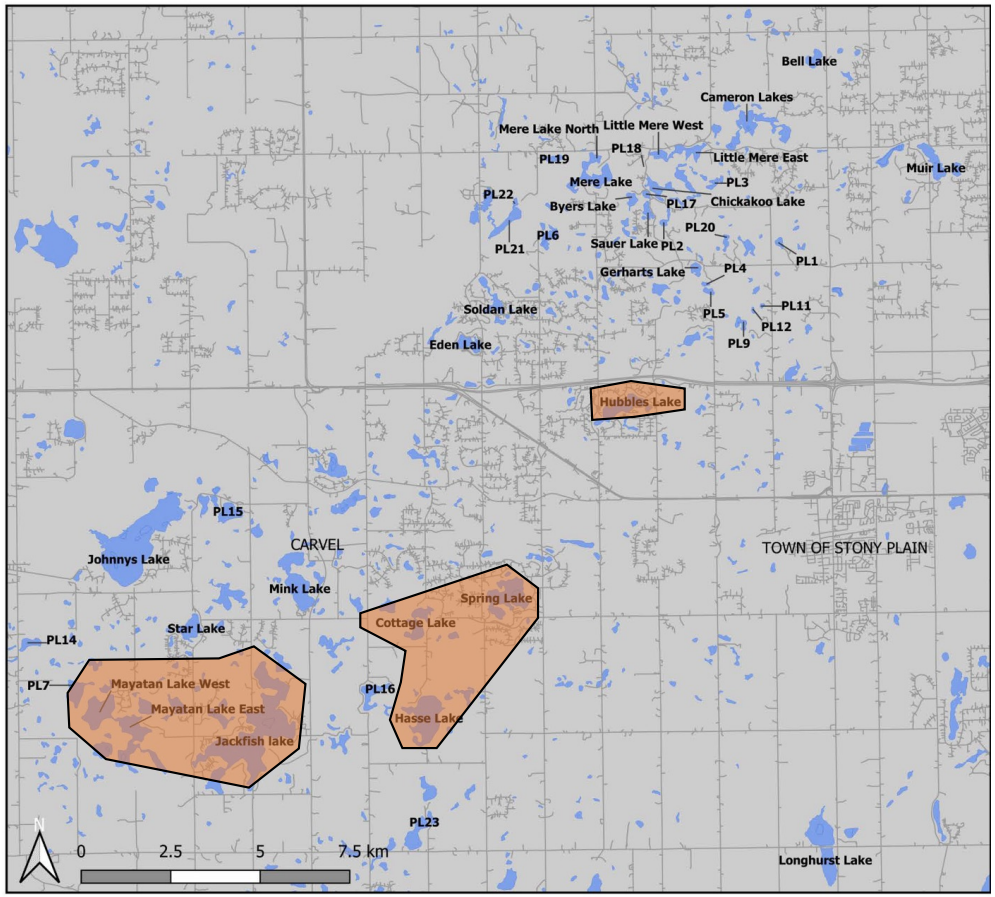
WHAT THEY TELL US: How much evaporation a lake experiences

Stable Isotopes of Water

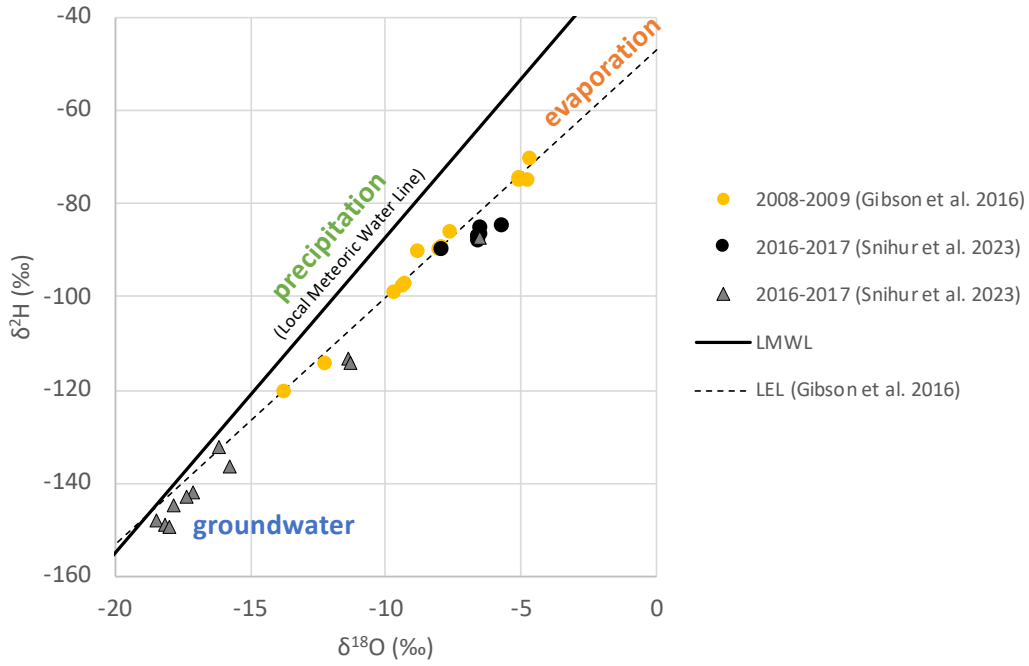


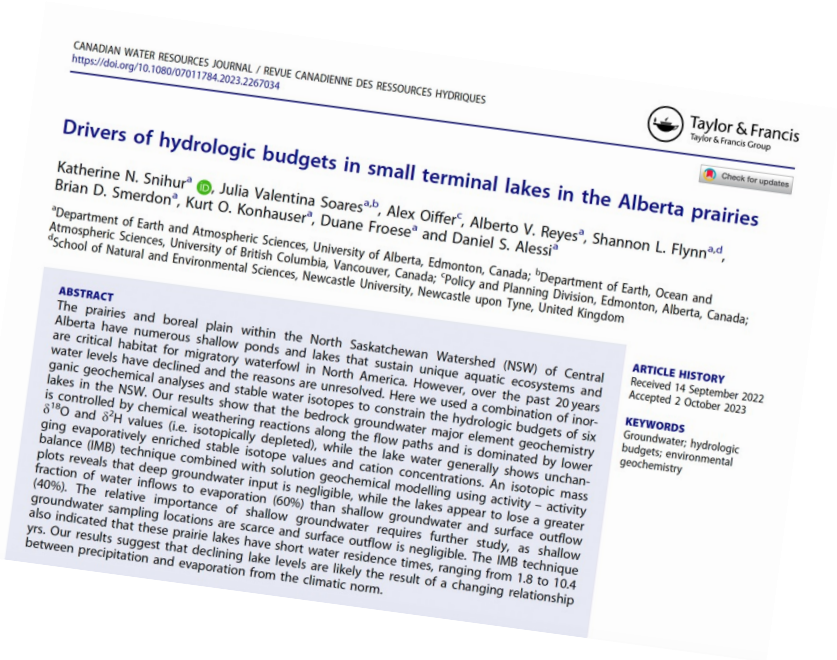
Gibson et al., 2016 JofH

Snihur et al. 2023 CWRJ



Stable Isotope Results





CANADIAN WATER RESOURCES JOURNAL / REVUE CANADIENNE DES RESSOURCES HYDRIQUES
https://doi.org/10.1080/07011784.2023.2267034

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Drivers of hydrologic budgets in small terminal lakes in the Alberta prairies

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[a]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada; [b]Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada; [c]Policy and Planning Division, Edmonton, Alberta, Canada; [d]School of Natural and Environmental Sciences, Newcastle University, Newcastle upon Tyne, United Kingdom

ABSTRACT

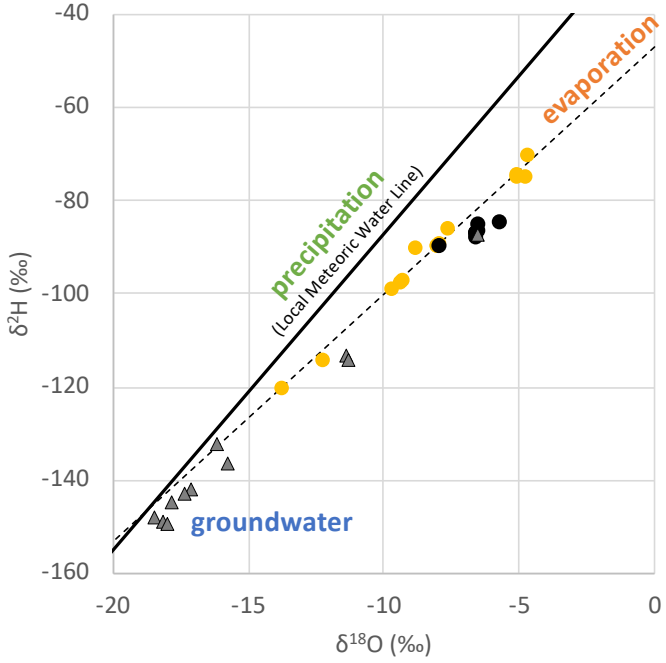
The prairies and boreal plain within the North Saskatchewan Watershed (NSW) of Central Alberta have numerous shallow ponds and lakes that sustain unique aquatic ecosystems and are critical habitat for migratory waterfowl in North America. However, over the past 20 years water levels have declined and the reasons are unresolved. Here we used a combination of inorganic geochemical analyses and stable water isotopes to constrain the hydrologic budgets of six lakes in the NSW. Our results show that the bedrock groundwater major element geochemistry is controlled by chemical weathering reactions along the flow paths and is dominated by lower $\delta^{18}O$ and $\delta^{2}H$ values (i.e. isotopically depleted), while the lake water generally shows unchanging evaporatively enriched stable isotope values and cation concentrations. An isotopic mass balance (IMB) technique combined with solution geochemical modelling using activity – activity plots reveals that deep groundwater input is negligible, while the lakes appear to lose a greater fraction of water inflows to evaporation (60%) than shallow groundwater and surface outflow (40%). The relative importance of shallow groundwater requires further study, as shallow groundwater sampling locations are scarce and surface outflow is negligible. The IMB technique also indicated that these prairie lakes have short water residence times, ranging from 1.8 to 10.4 yrs. Our results suggest that declining lake levels are likely the result of a changing relationship between precipitation and evaporation from the climatic norm.

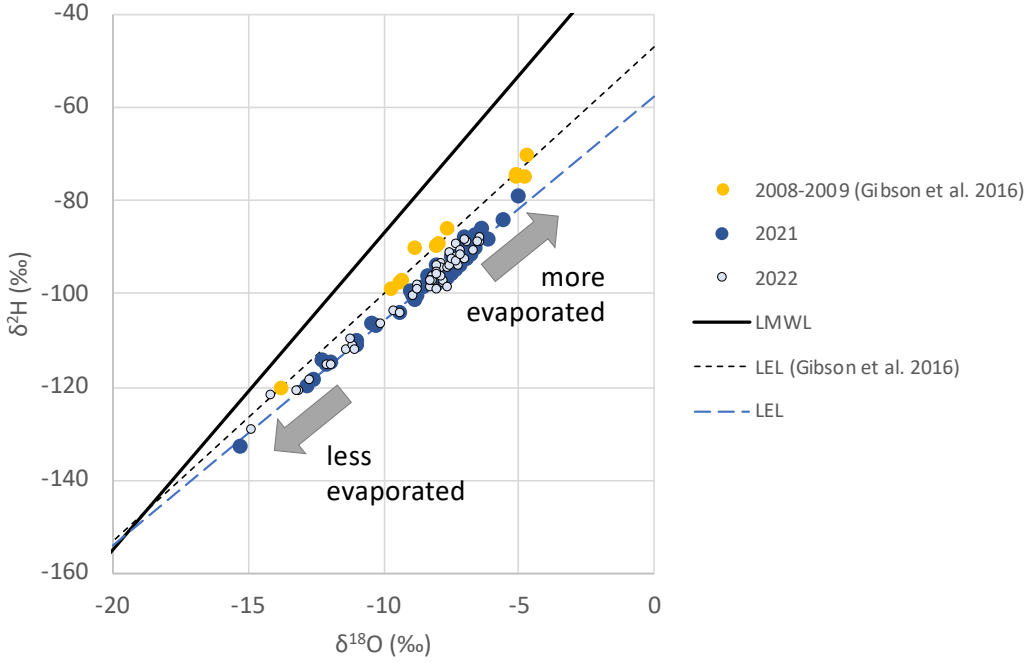
ARTICLE HISTORY
Received 14 September 2022
Accepted 2 October 2023

KEYWORDS
Groundwater; hydrologic budgets; environmental geochemistry

Stable Isotope Results

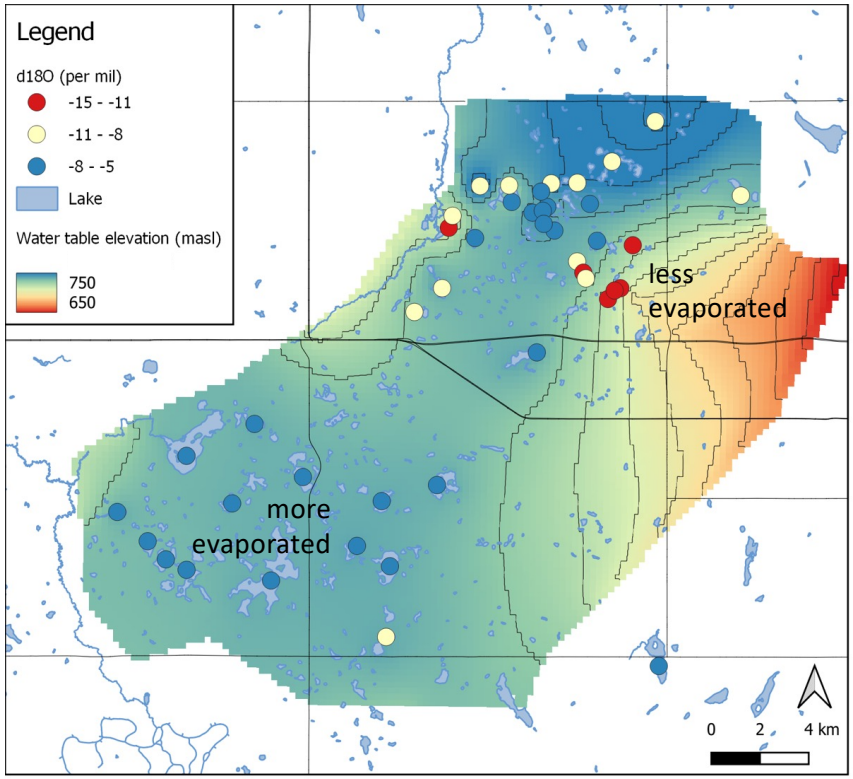
- All the lakes are experiencing some degree of evaporation
- Highly variable lake-to-lake, but consistent year-to-year

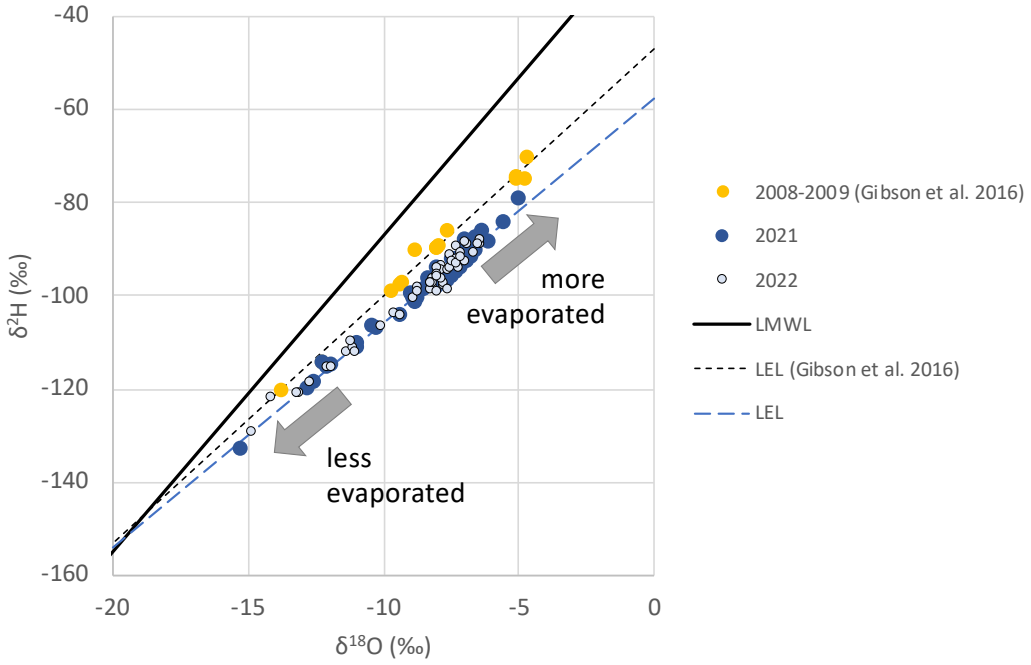




Spatial Trend

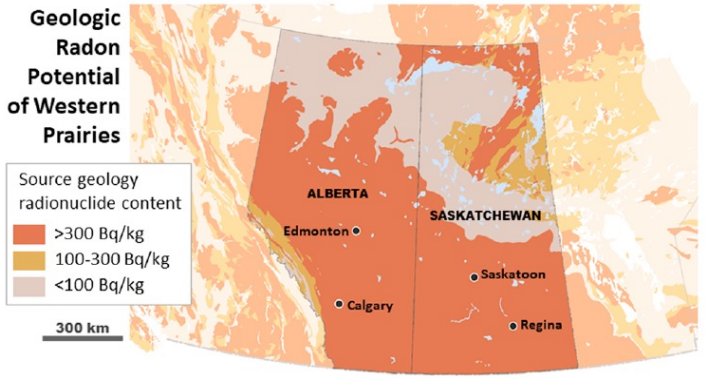
- Lake-to-lake variability appears to have a spatial pattern



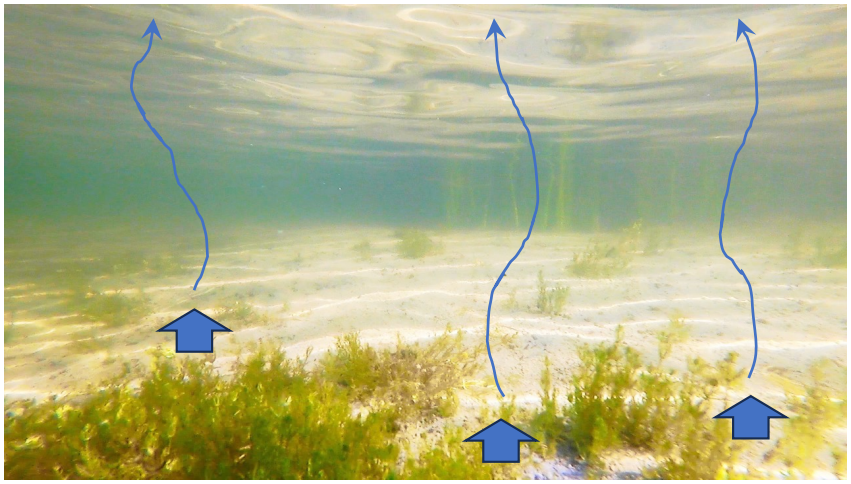


Radon

- Generated from geological material
- Widespread in the Western Prairies
- Radioactive decay
  - $t_{1/2}$ = 3.8 days



Stanley et al. (2019)



- Travels with groundwater as a dissolved gas
- Enters lakes then degasses to the atmosphere

WHAT IT TELLS US: an indicator of groundwater connection

Radon Results

- Average groundwater concentration is 15 Bq/L in the Edmonton area
- Some of the lakes have 8 to 12 Bq/L
- Again, lake-to-lake variability appears to have a spatial pattern

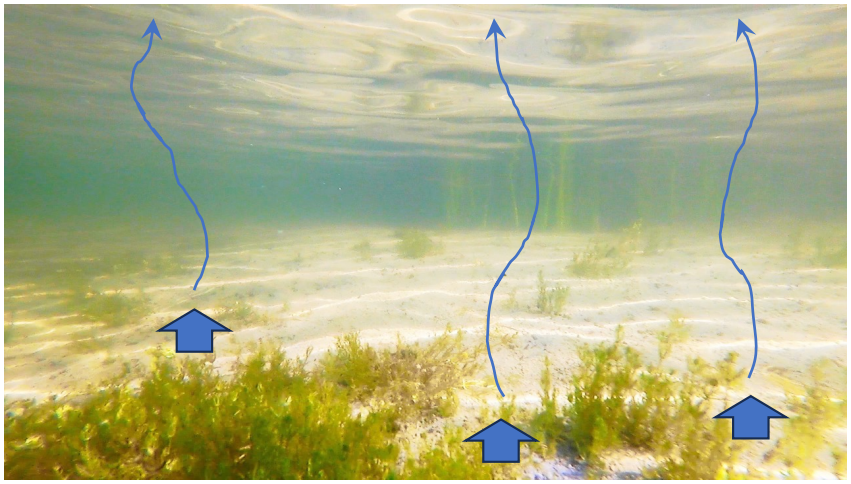
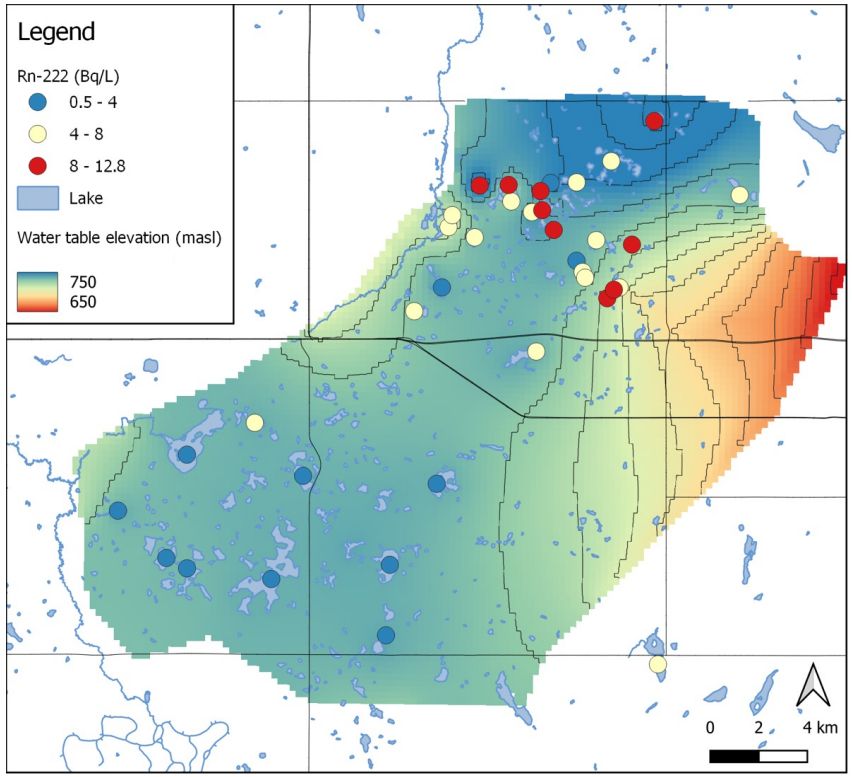
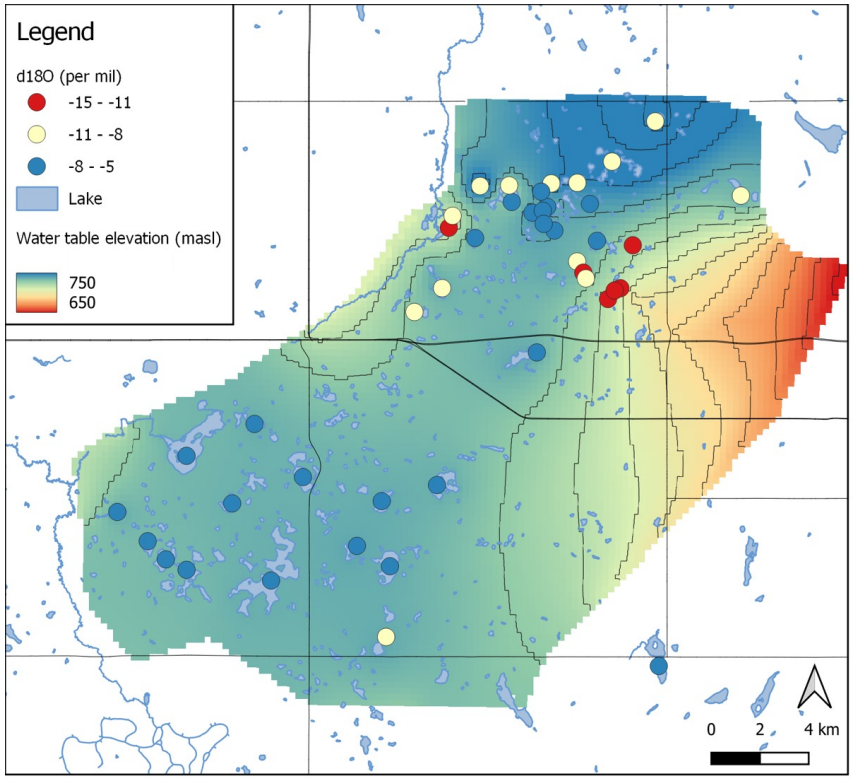
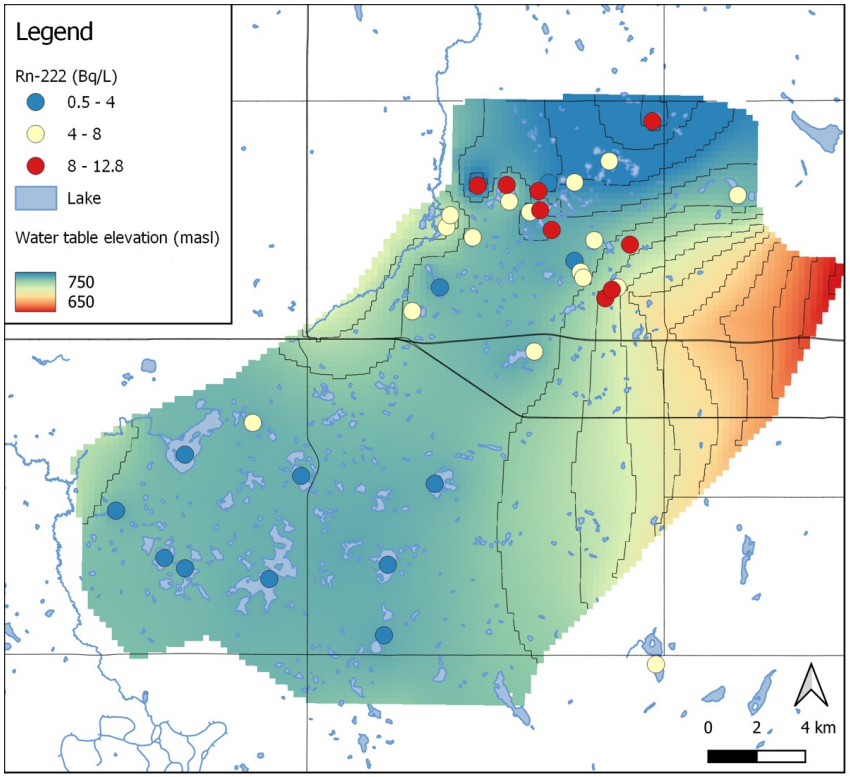


Photo by Dave Mussell

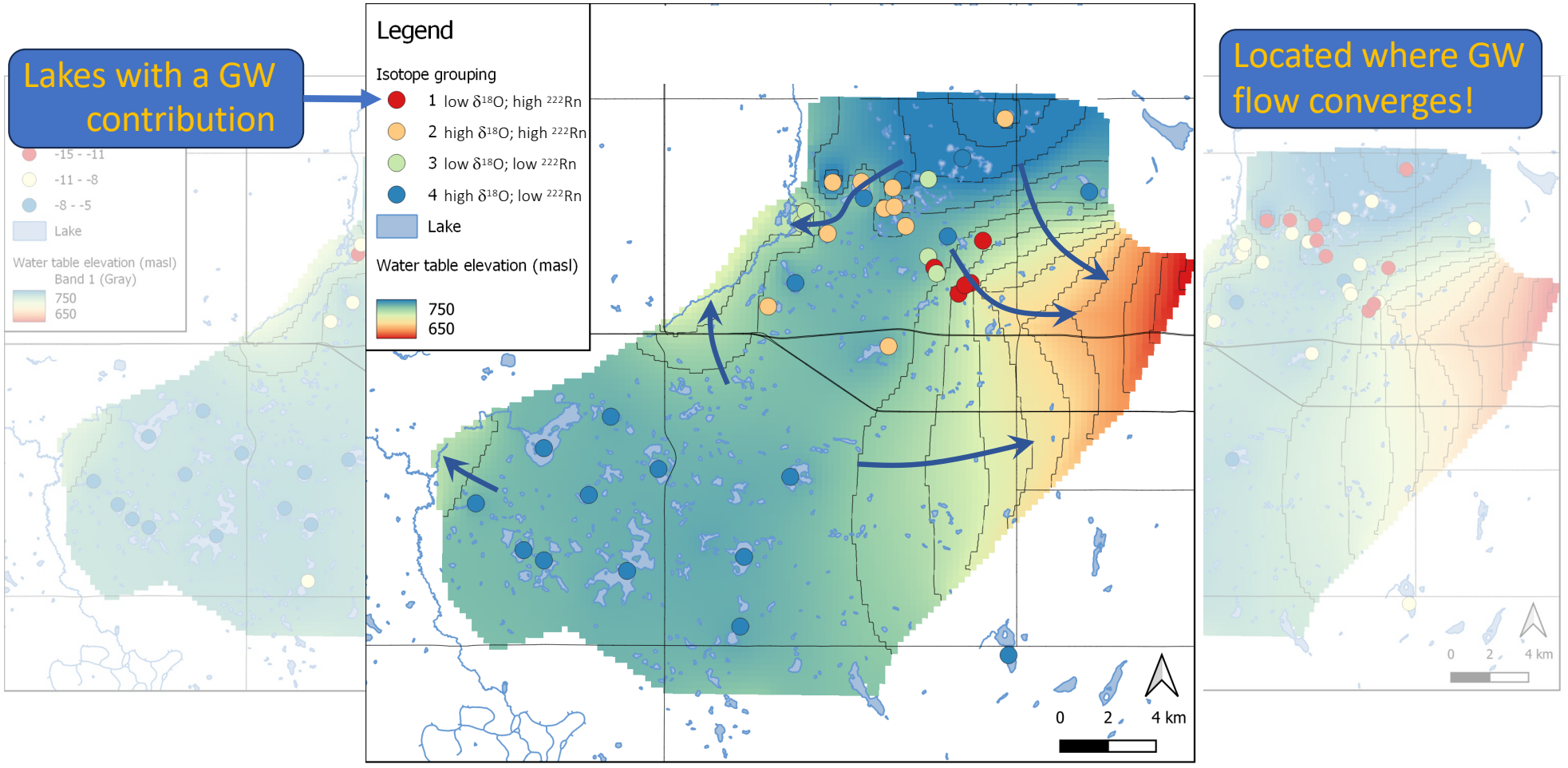


Different isotopes, yet a similar pattern





Isotope grouping indicates degree of groundwater connection



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https://doi.org/10.1080/07011784.2022.2107435

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Natural controls on phosphorus concentrations in small Lakes in Central Alberta, Canada

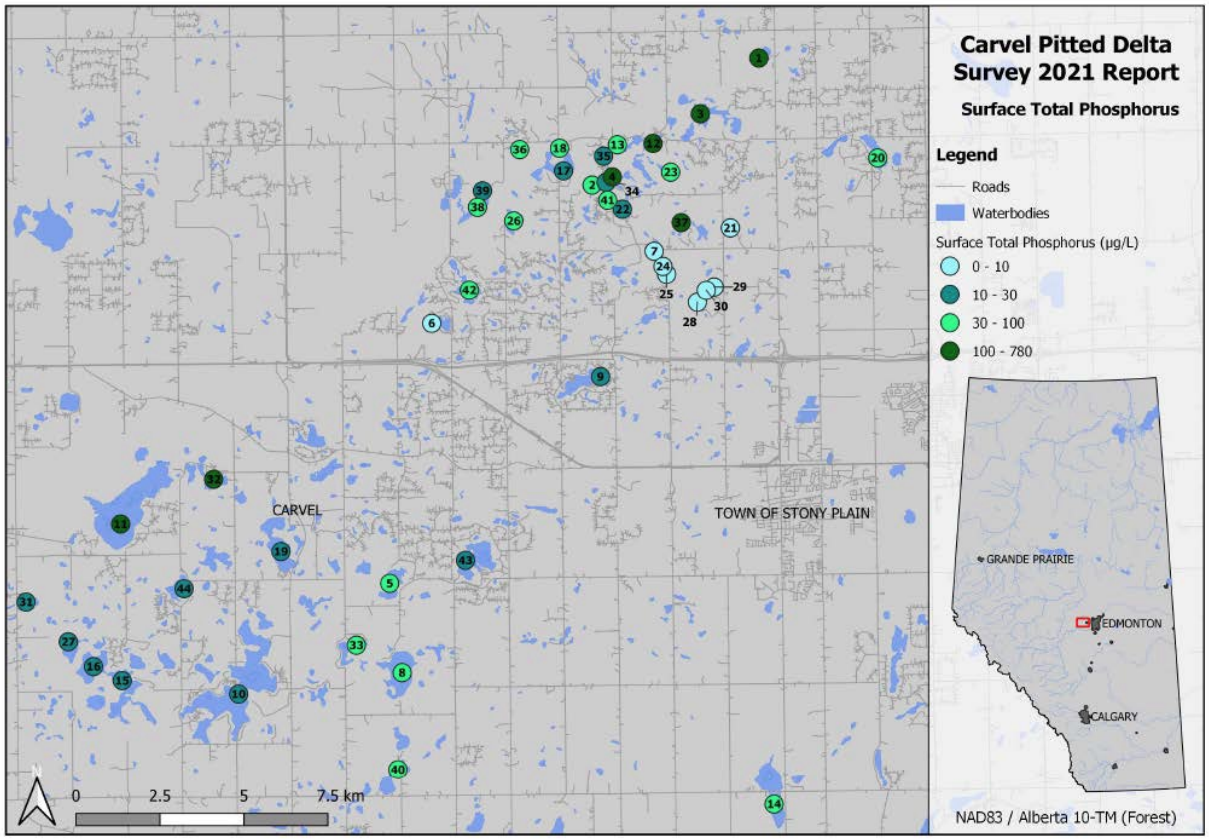
Konstantin von Gunten[a], David Trew[b], Brian Smerdon[a] and Daniel S. Alessi[a]

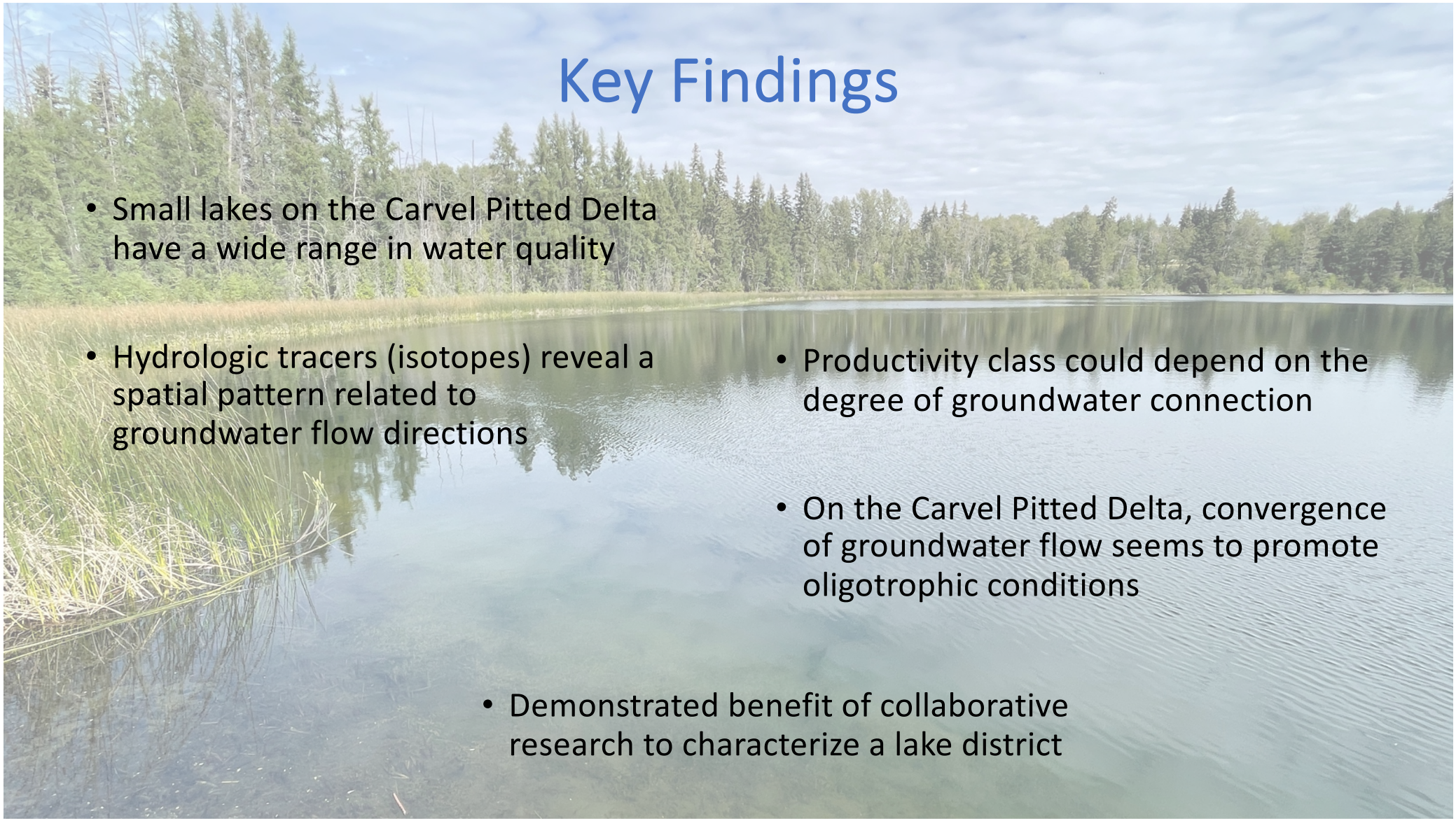
[a]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada; [b]North Saskatchewan Watershed Alliance, Edmonton, Alberta, Canada

ABSTRACT

Small lakes can act as environmental sensors for understanding regional hydrogeological conditions and elemental cycles. Because of their small size, they react quickly to changes in nutrient runoff, groundwater exchange and climate. In the post-glacial landscape of Alberta, the Carvel Pitted Delta harbours a variety of small lakes, which, despite being close together, can have markedly different chemistries and nutrient characteristics. Here, we focused on nine lakes with surface areas <10 ha and maximal depths ranging from 5 to 18 m. We hypothesised that differences in their trophic states are caused by variations in Ca concentrations, controlled by groundwater inputs. All lakes tended toward permanent stratification due to small mixing depths (1.6–2.4 m). The deeper lakes were oligotrophic with high concentrations of Ca and a high fraction of phosphorus (Ca-bound P) in the sediments (HCl extractable fraction). A correlation was found between Ca-bound P and aqueous Ca concentrations at 0.5 m depth, suggesting that P stability could be estimated based on surface water chemistry. Calcium was shown to be concentrated in groundwater located above the bedrock, suggesting that groundwater inputs controlled Ca concentrations in the lakes. We conclude that the hydrogeological conditions and Ca inputs act as natural regulators for P availability and, by extension, water quality in these lakes.

- Similar pattern observed in lake productivity
  - Total P
  - Chlorophyll-a





Key Findings

- Small lakes on the Carvel Pitted Delta have a wide range in water quality
- Hydrologic tracers (isotopes) reveal a spatial pattern related to groundwater flow directions
- Productivity class could depend on the degree of groundwater connection
- On the Carvel Pitted Delta, convergence of groundwater flow seems to promote oligotrophic conditions
- Demonstrated benefit of collaborative research to characterize a lake district