Quantification of the effects of gravity-driven groundwater flow by coupling field observations and numerical model in Wood Buffalo National Park, Canada

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Hydrogeology
Earth and Atmospheric Sciences

Early Career Hydrogeologists' Network

INTRODUCTION

- Canada's largest national park
- UNESCO World Heritage site, Ramsar Convention
- Peace-Athabasca delta
  - wetland of international importance
- Only nesting area of highly endangered Whooping Cranes
- Beautiful examples of salt plains, karst geomorphology, surface waters with distinct chemical composition, phreatophyte vegetation

(http://friendsofthewildwhoopers.org/wood-buffalo-national-park-launches-new-whooping-crane-iconic-experience/)


40 cm


140 m


(Photo by Mike Vassal)

WHY IS IT IMPORTANT?

- hydrogeology is poorly studied (protected status and poor accessibility)
- increased recreational use of the park necessitates evaluation of natural resources
- potential impacts of anticipated mining activities to the north and oil-sand development to the south require quantification
- only nesting area of the highly endangered Whooping Crane needs protection

(http://www.cbc.ca/news/canada/north/number-of-whooping-cranes-rising-in-the-n-w-t-1.2724879)

HYPOTHESIS, METHODS

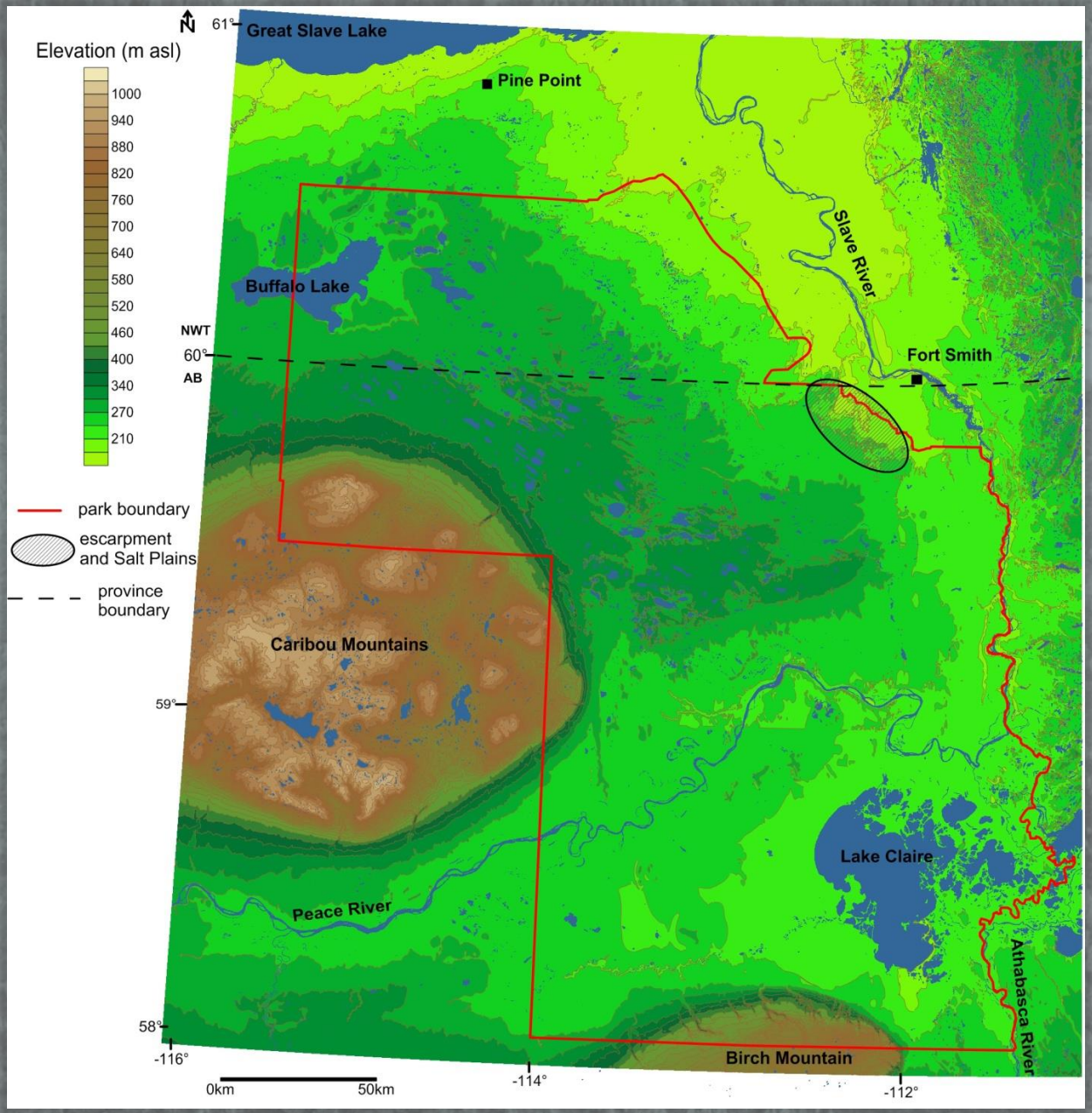
Working hypothesis

Groundwater flow in the park is controlled by water-table relief and observed surface phenomena reflect the different orders and segments of groundwater flow systems

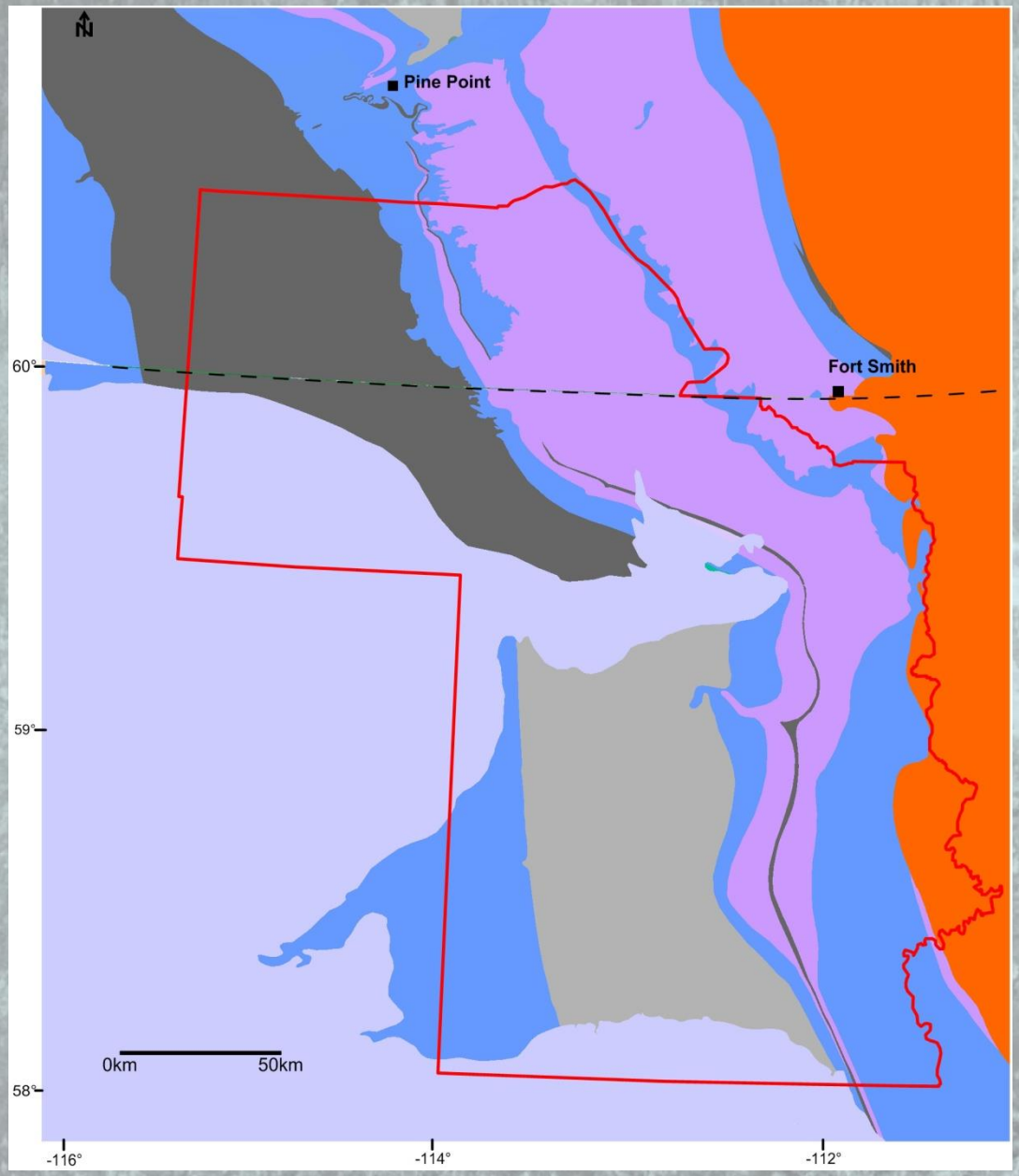
Phases of research process

1. Chemical characterization of ~500 water samples from springs and surface waters (TDS, hydrochemical facies)
2. 2D-numerical model in selected region
3. Comparison of numerically calculated flow fields and field data

Topography

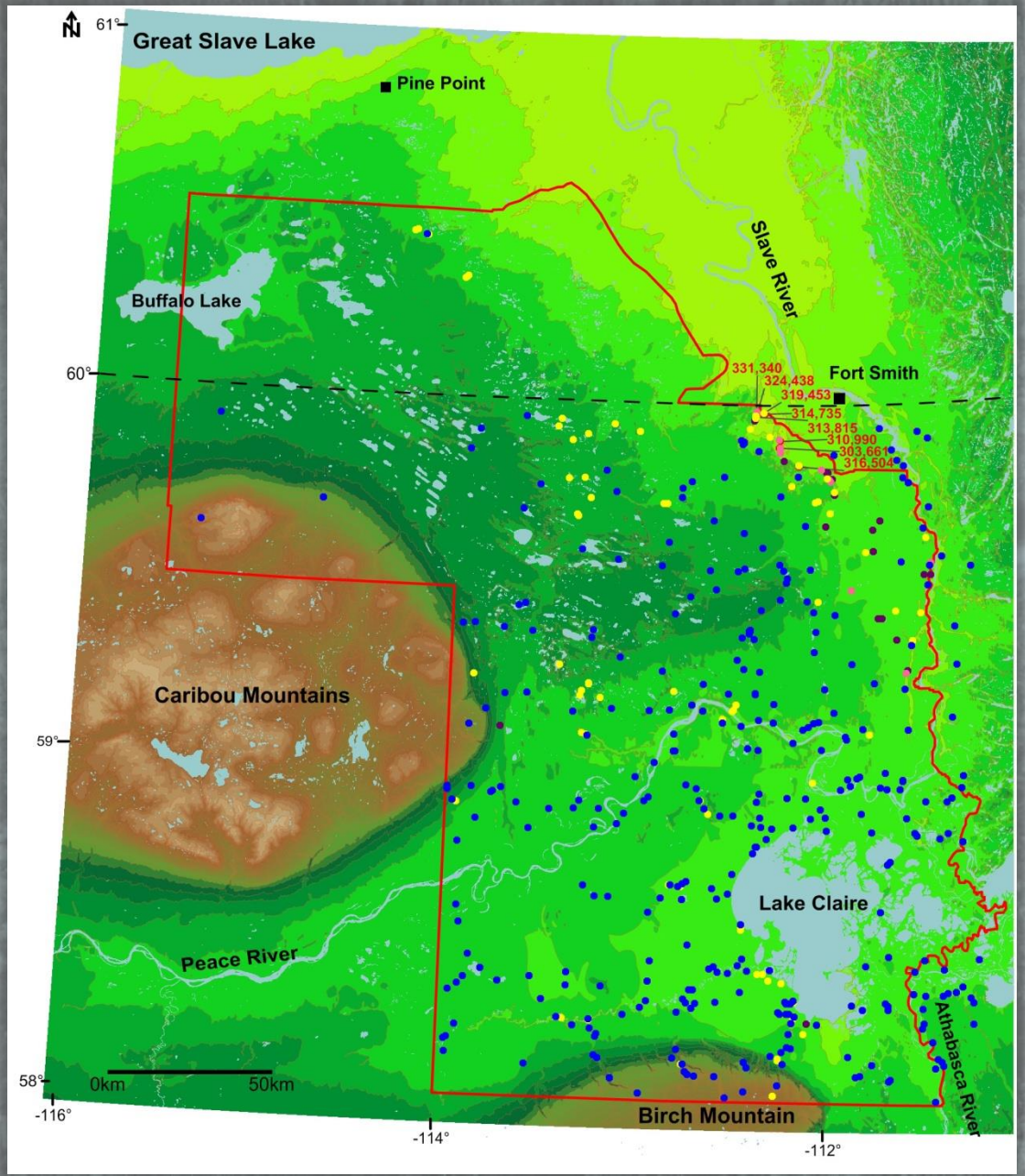

N
Elevation (m asl)
1000
940
880
820
760
700
640
580
520
460
400
340
270
210
park boundary
escarpment and Salt Plains
province boundary
61°
Great Slave Lake
Pine Point
Slave River
Buffalo Lake
NWT
60°
AB
Fort Smith
Caribou Mountains
59°
Lake Claire
Peace River
Athabasca River
58°
-116°
Birch Mountain
-114°
-112°
0km
50km

Bedrock geology



- Mudstone, siltstone, sandstone — Cretaceous
- Carbonates (limestone and dolostone) — Devonian
- Calcareous shale and carbonate — Devonian
- Shale — Devonian
- Evaporite (dominantly anhydrite) — Devonian
- Crystalline basement — Precambrian

HYDROCHEMISTRY: TOTAL DISSOLVED SOLIDS

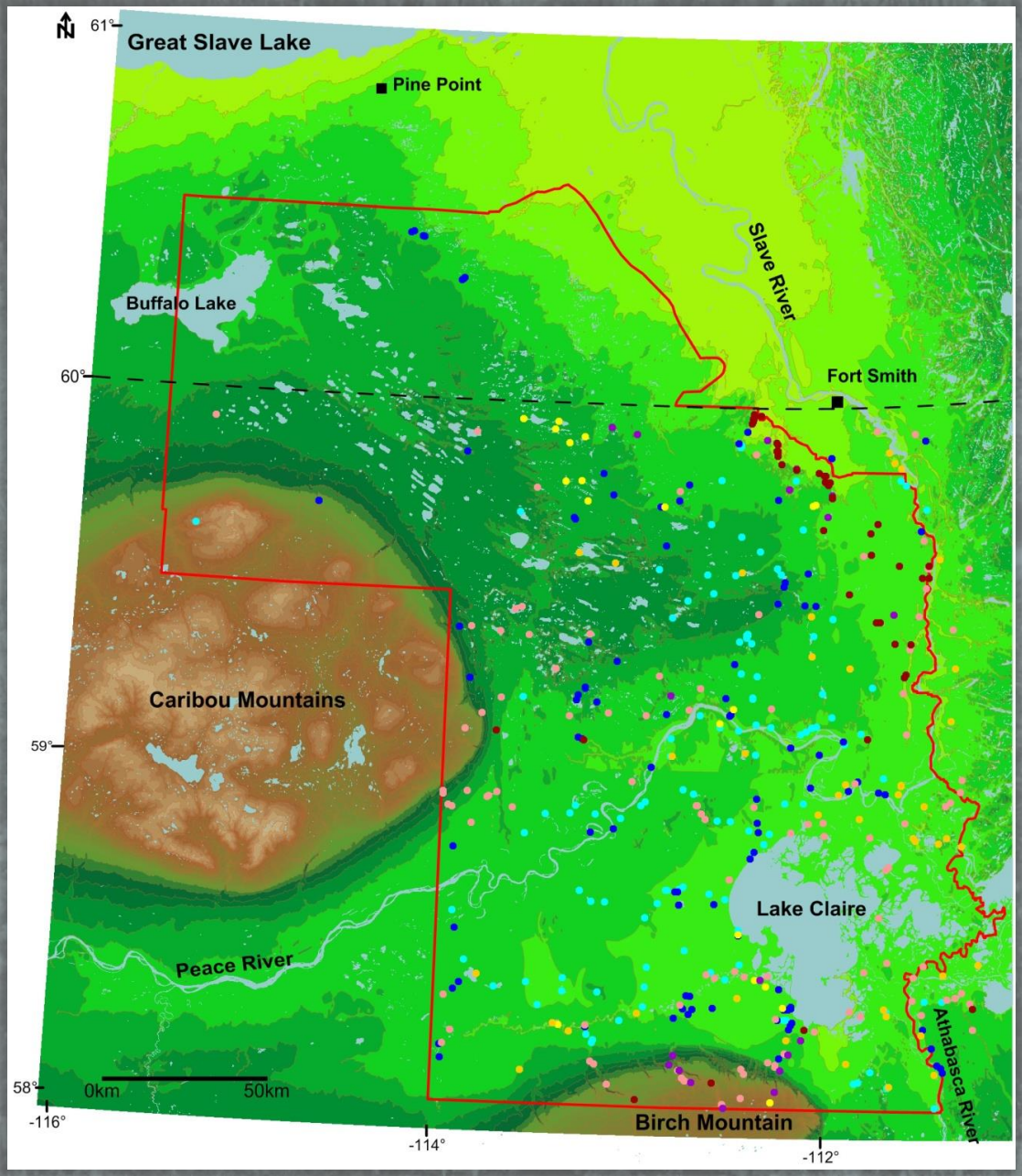


TDS (mg/L)

- <1,000
- 1,000-5,000
- 5,001-10,000
- 10,001-100,000
- 100,001-332,000

314,735 brine samples

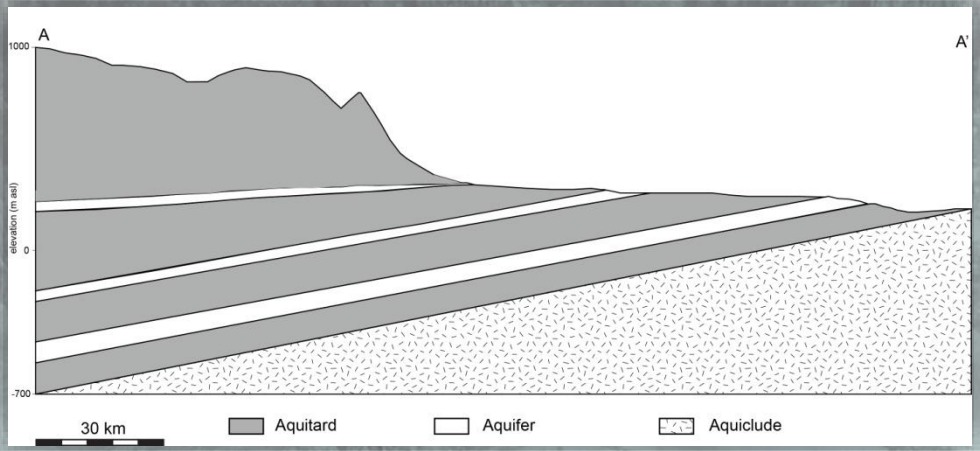
HYDROCHEMISTRY: HYDROCHEMICAL FACIES

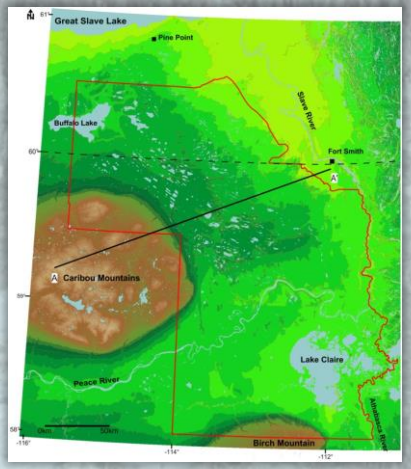


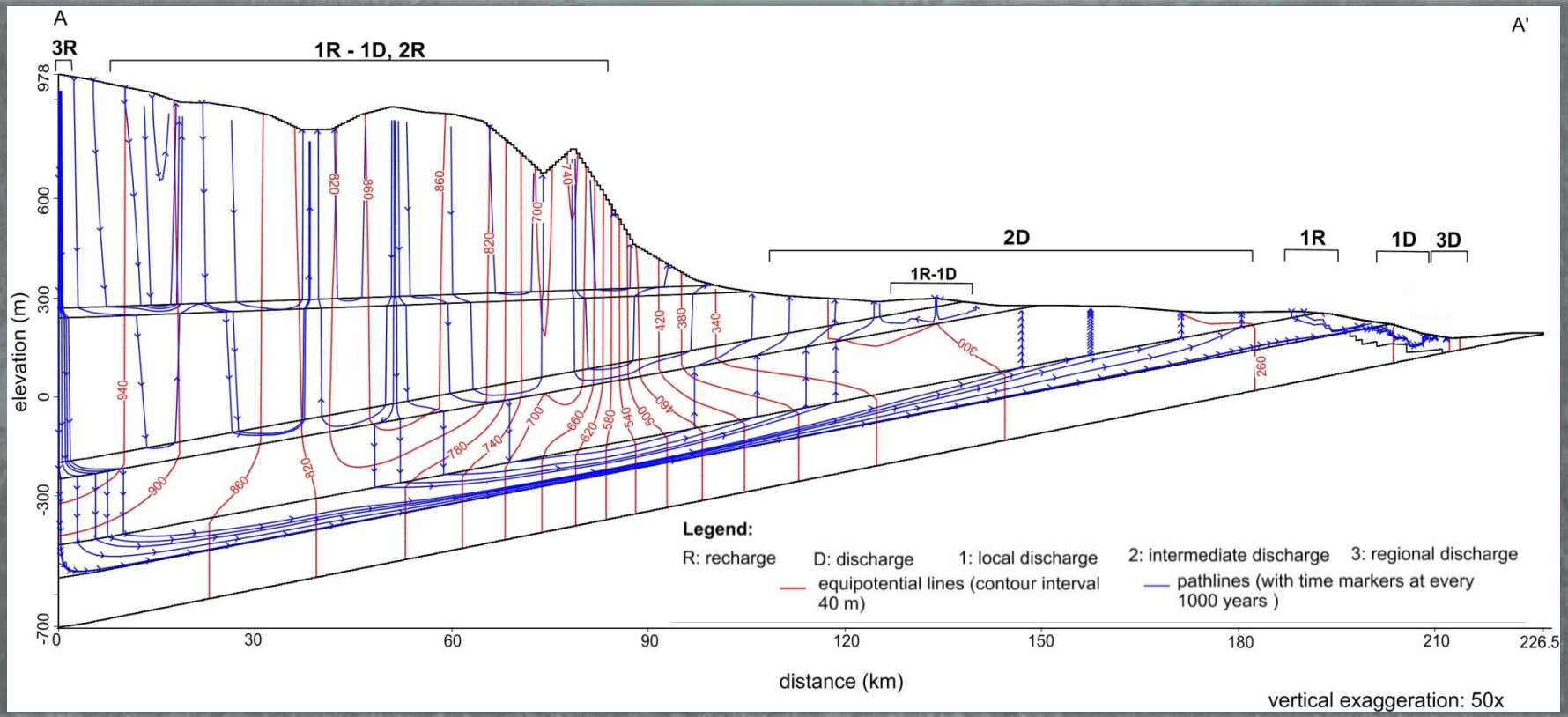
Facies

- Ca(-Mg), HCO3
- Ca(-Mg), HCO3-(Cl-)SO4 or Ca(-Mg). (Cl-)SO4-HCO3
- Ca/Mg(-Na), HCO3
- Ca(-Mg), (Cl-)SO4
- Ca/Mg(-Na), HCO3(-Cl-SO4) or Ca/Mg(-Na), (Cl-)SO4(-HCO3)
- Ca(-Na), (Cl-)SO4
- Na, Cl(-SO4)

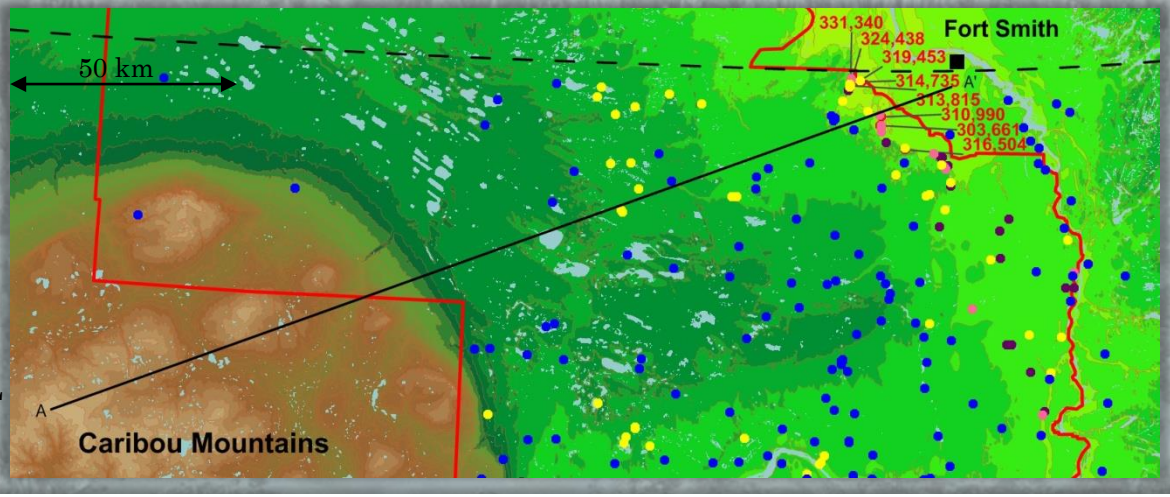
NUMERICAL MODEL



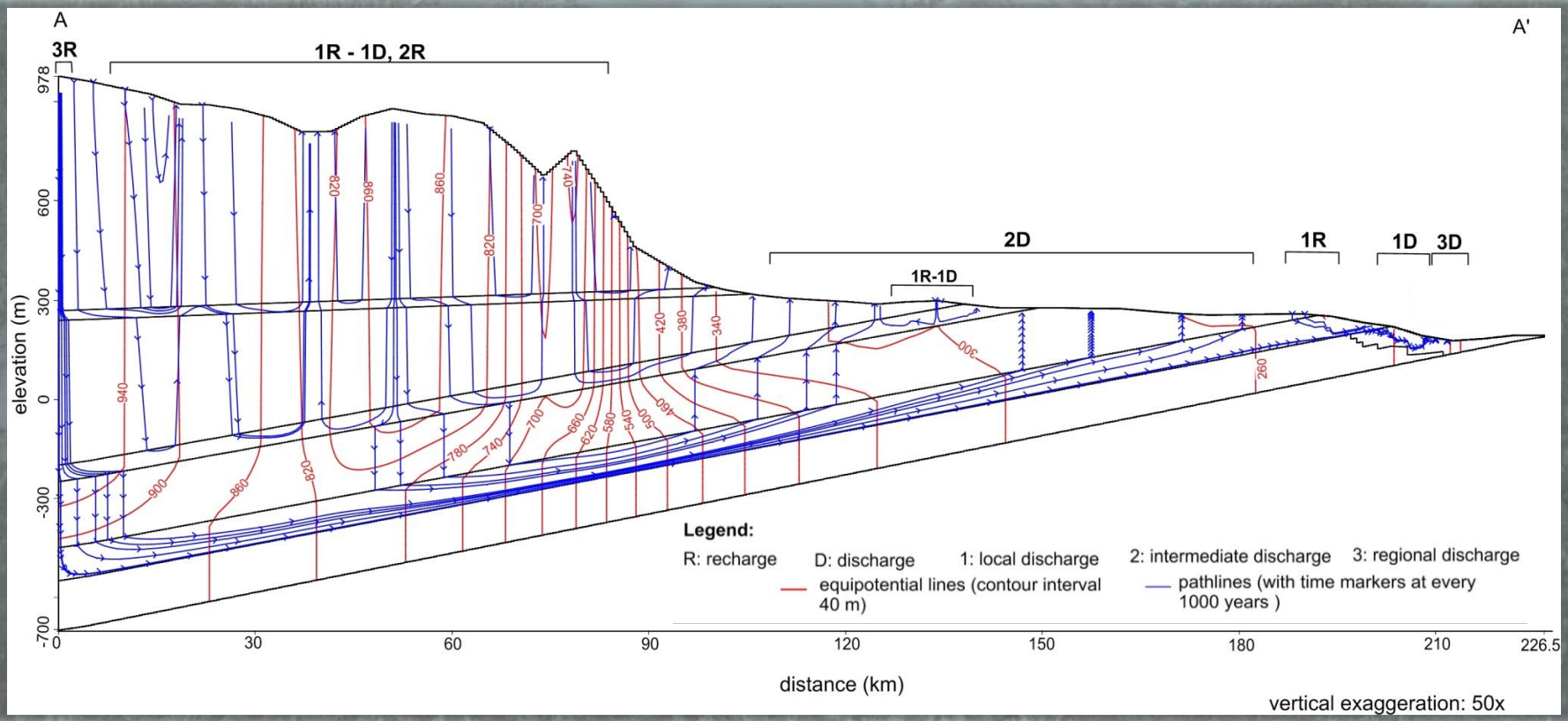




NUMERICAL MODEL AND FIELD CHEMISTRY 1.

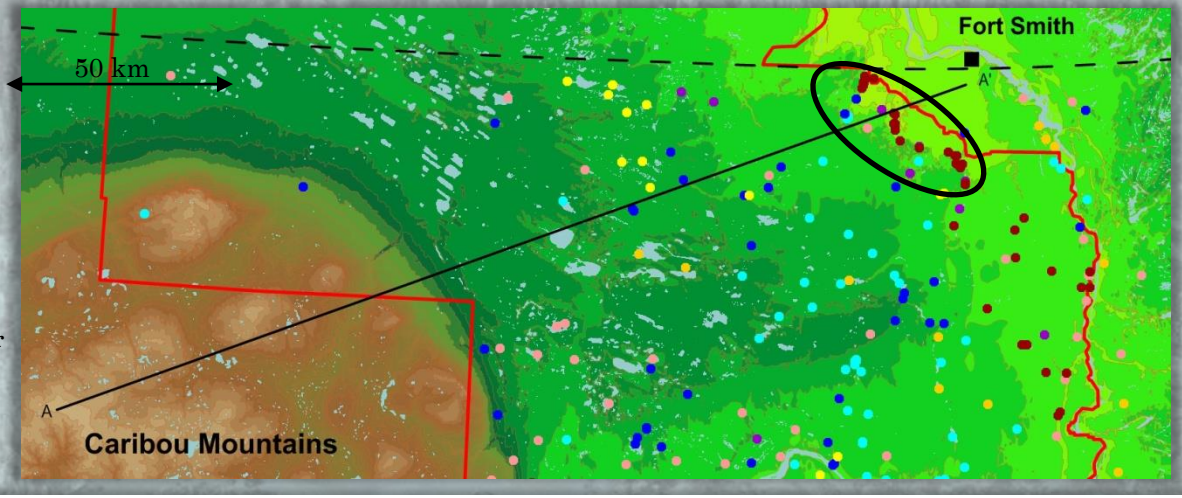


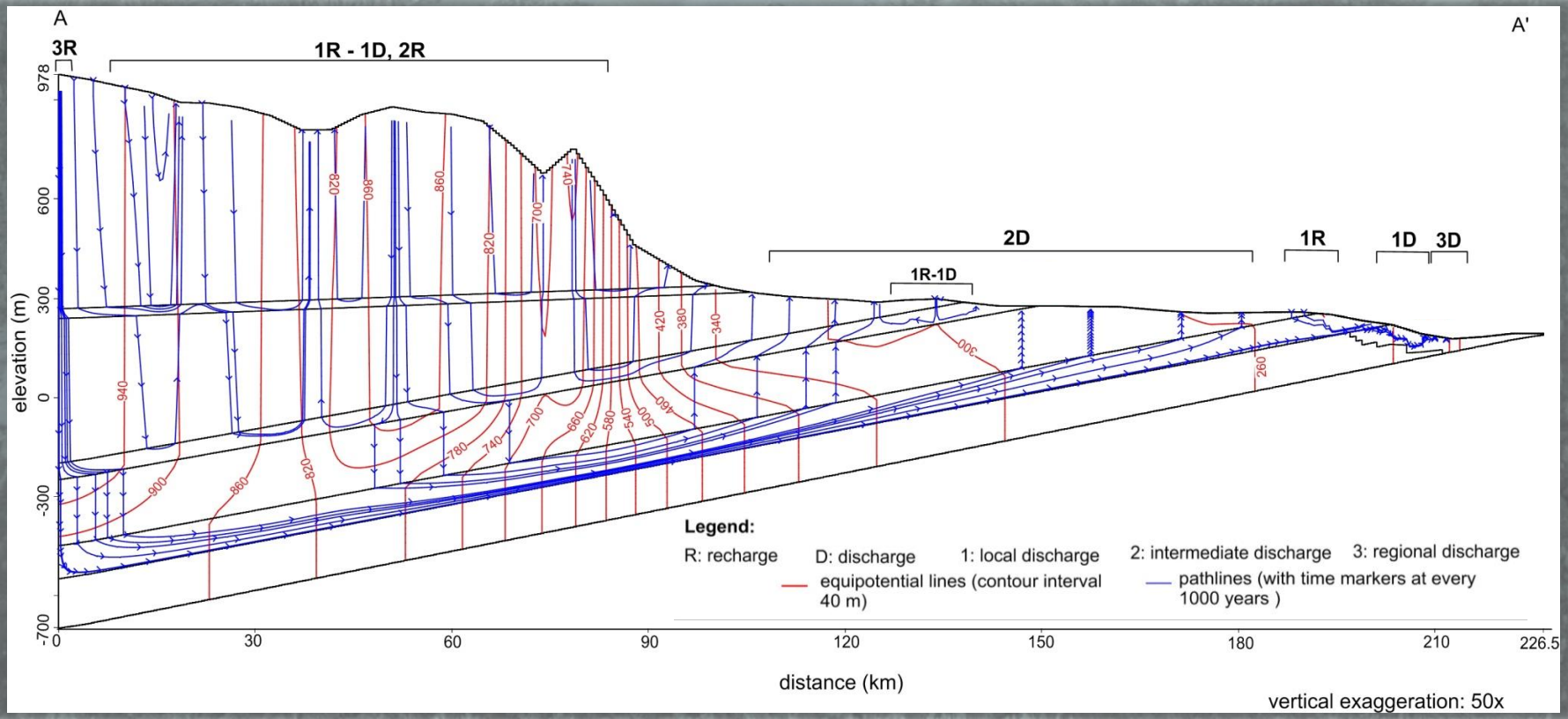
- <1,000 mg/L
- 1,000-5,000 mg/L
- 5,001-10,000 mg/L
- 10,001-100,000 mg/L
- 100,001-332,000 mg/L



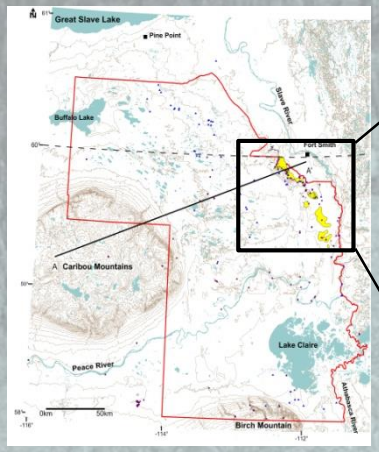
NUMERICAL MODEL AND FIELD CHEMISTRY 2.

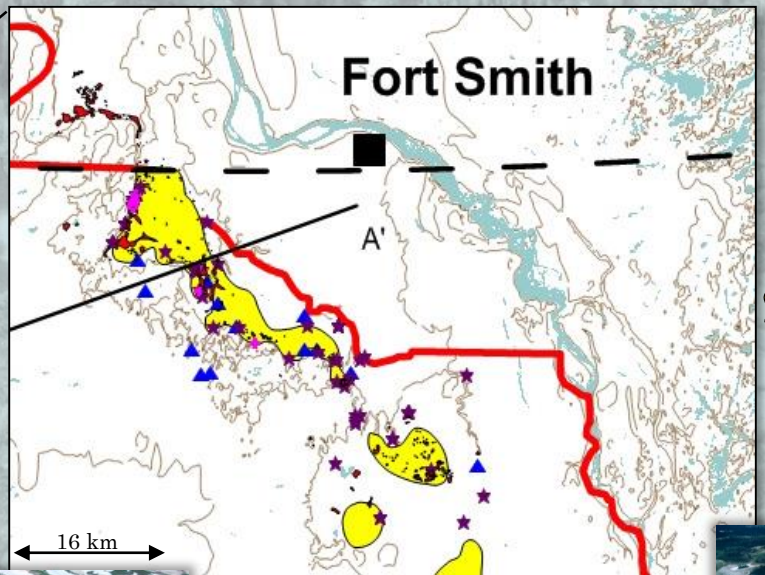
- Ca(-Mg), HCO3
- Ca(-Mg), HCO3-(Cl-)SO4 or Ca(-Mg). (Cl-)SO4-HCO3
- Ca/Mg(-Na), HCO3
- Ca(-Mg), (Cl-)SO4
- Ca/Mg(-Na), HCO3(-Cl-SO4) or Ca/Mg(-Na), (Cl-)SO4(-HCO3)
- Ca(-Na), (Cl-)SO4
- Na, Cl(-SO4)





MANIFESTATIONS OF REGIONAL GROUNDWATER FLOW





- Spring discharge
- Open waters in winter
- Brine springs
- Salt plains
- Phreatophyte vegetation (cattail)

Halophyte vegetation (*Salicornia Rubra)*

Salina spring and salt accumulation

Salt plains

SUMMARY AND CONCLUSION

- significant variability in TDS and hydrochemical facies
- TDS ranges from less than 1,000 mg/L to more than 300,000 mg/L
- hydrochemical facies show examples from young Ca-HCO_3-type to more evolved Na-Cl-type waters
- strong correlations between the modelled flow field and the chemical character of water samples
- differences in water chemical character are good indicators of different orders and segments of groundwater flow systems in Wood Buffalo National Park and can be considered manifestations of topography-driven groundwater flow

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Wood Buffalo National Park, Canada