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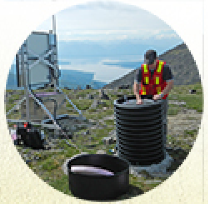


Geological Survey of Canada
Scientific Presentation 128

Public presentations of October 13, 2021:
Groundwater Geoscience program, current status of research projects for the 2019–2024 program cycle

N. Jacob, H.A.J. Russell, B. Brodaric, C. Rivard, N. Benoît, and D. Paradis

2021

Canada

Public presentations of October 13, 2021: Groundwater Geoscience program, current status of research projects for the 2019–2024 program cycle

Date presented: October 13, 2021

Permanent link: https://doi.org/10.4095/329085

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Publications in this series have not been edited; they are released as submitted by the author.

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Groundwater Geoscience Program (GGP)
Public presentation of project plans for 2019-2024

On October 13, 2021 all five project leaders under the GGP presented the status of six research projects to 60 participants (50 internal and 10 external).

All six of the PowerPoint presentations prepared for this event are included in this synthesis and the recorded presentations can be seen on YouTube: **https://www.youtube.com/channel/UCHIc7ff3vEdII708VhgsLsg**

Key words: groundwater classification, methods development, groundwater portal, characterization, shallow aquifers, Fox Creek, water resource, modelling, Ring of Fire, regional assessment, Canada 1 Water and modelling framework.

Canada

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Groundwater Geoscience Program (GGP)
Current status of research projects for the 2019-2024 program cycle

Canada

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Archetypal Aquifer Project: 2021 Update

Groundwater Geoscience Program 2019-2024

Hazen A.J. Russell
Geological Survey of Canada hazen.russell@nrcan-rncan.gc.ca.ca

GSC contributors
Alpay, S., Bunn, M., Crow, H.L., Dietiker, B., Knight, R.D., Larmagnat, S., Logan, C.E., Pugin, A., Rivera, A., Sharpe, D.R.,

GGP: 2021-10-13

Canada

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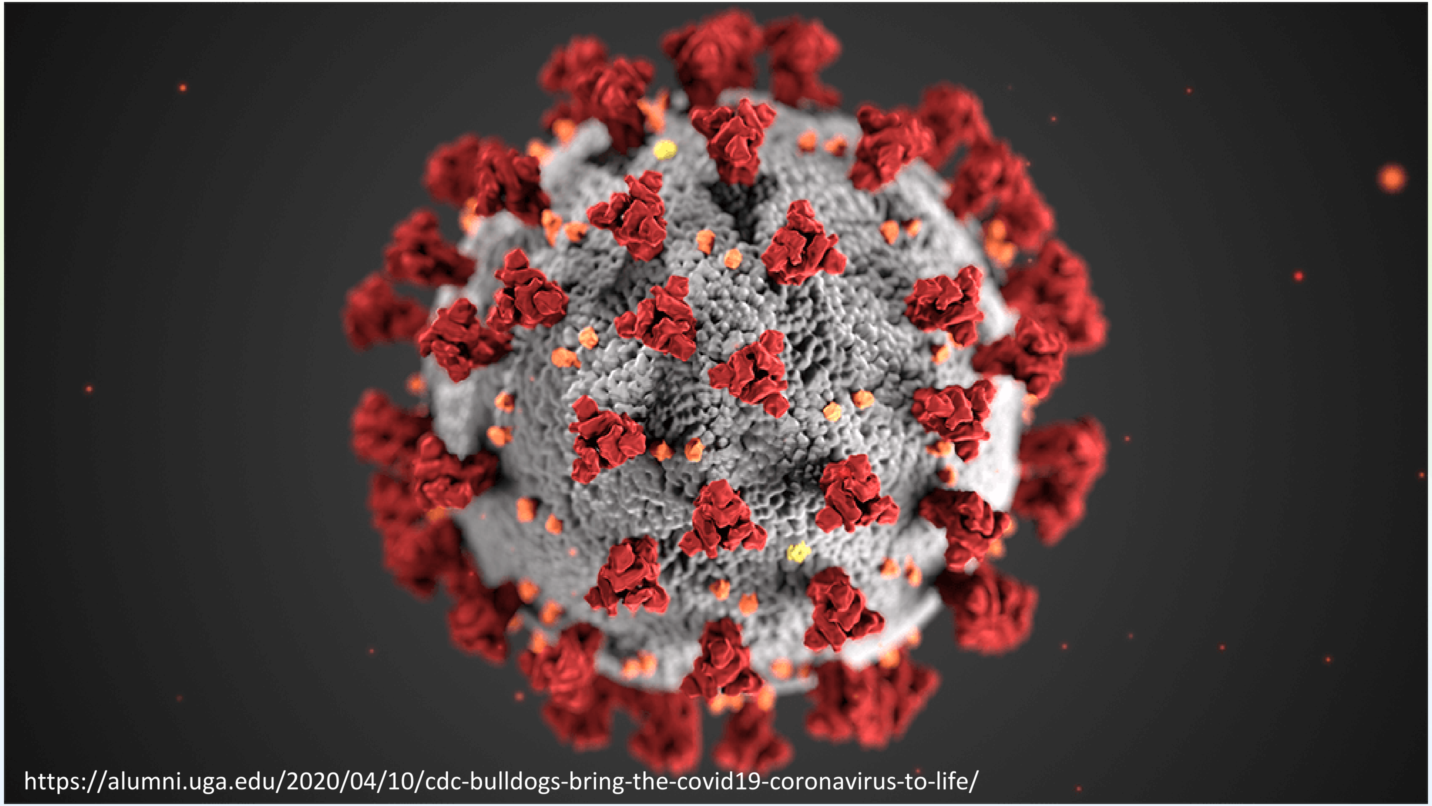
Environment Climate Change Canada
Institut national de research scientifique (INRS)
Public Safety Geoscience Program (GSC)
Rideau Conservation Authority
South Nation Conservation Authority
University of Guelph
University of Ottawa

COVID



- has both negatively and positively impacted activities within the project.
- activity leads have adapted with resourcefulness and patience to a range of challenges
- overall activities are making good progress

Content

1. Field Laboratories
    1. Regional (seismic reflection and passive seismic)
    2. Embrun esker hydrogeophysical
    3. Bells Corners bedrock downhole
2. pXRF protocol and data release
3. Bilberry Creek Study: Aquitard hydrogeology
4. 3D geological modelling

Aquifer Classification and Archetypes

Applied Ontology 0 (0) 1
IOS Press

Water Features and Their Parts

Boyan Brodaric [a,*], Torsten Hahmann [b] and Michael Gruninger [c]

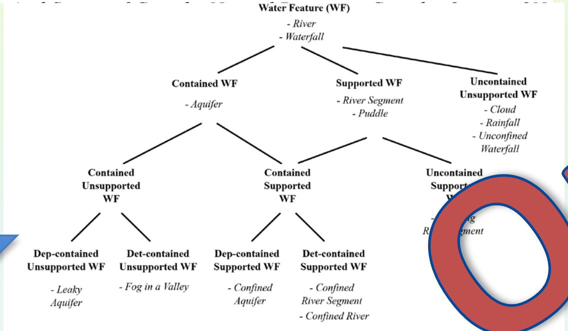


Fig. 4. Water feature taxonomy using containment, support and dependence as differentiae.

- Plethora of local exampl
- Need to consoli e i orn tion and dis characteristics
- Create mo el o arc etype
- To rov
  - Norn
  - mework for future work
  - Prediction
  - Guide in areas of sparse data

On Hold

Sediment-aquifer play types in a list of 30 key Canadian aquifers

Russell, H.A.J.[1], Sharpe, D.R.[1], and Cummings, D.C.[2]
[1] *Geological Survey of Canada, 601 Booth St. Ottawa, ON., K1A 0E8*
[2] *DC Geosciences, 12 Decarie Street, Aylmer, QC. J9H 2M3*

geohydro 2011.ca

Table 2. Terminology and concepts for petroleu and groundwater plays in unconsolidated sedimen

Petroleum play	Groundwater play	Comments
Source (charge)	Hydrology	"Hydrology" integrat precipitation, evaporation/transpiration infiltration, recharge a discharge.
Reservoir	Aquifer	defined by formati process, most commor the depositional setting
Seal Trap	Confining units	Aquitard units. Hydrostratigraphic architecture;

Impacts des changements climatiques sur les eaux souterraines et de surface pour un développement durable au Canada

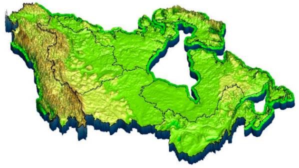
Canada 1 Water

Projet

Ressources naturelles Canada (RNCan) lance le projet **Canada 1 Water (C1W)** : une plateforme de modélisation des eaux souterraines et des eaux de surface intégrée à des informations sur les changements climatiques et sur l'utilisation du sol afin de fournir une aide à la prise de décision pour les évaluations fondées sur les risques. Des modèles de pointe seront construits et des scénarios de changements climatiques seront simulés pour les six principaux bassins de drainage du Canada, couvrant près de dix millions de kilomètres carrés.

Pour la première fois, le Canada disposera d'une plateforme complète basée sur la physique de l'écoulement de l'eau pour simuler le système intégré d'évaluation des risques climat / eau souterraine / eau de surface. Il pourra aussi bénéficier d'outils d'aide à la prise de décision sur les sécheresses, les inondations, la capture du carbone, les risques d'incendie, les changements du pergélisol, les services écosystémiques et la quantité d'eau de surface et d'eau souterraine.

Le projet contribuera à relever un défi de longue date identifié par le Conseil des académies canadiennes, c'est à dire de comprendre la durabilité des ressources en eau du Canada. Le cadre d'aide à la prise de décision de la plateforme fournira un moyen intégré d'évaluer les réponses,les risques associés aux produits utiles



(c.-à-d., foresterie, agriculture, exploitation minière), et les risques associés aux changements climatiques projetés et aux changements induits par l'utilisation des sols.

C1W abordera les questions relatives aux ressources en eau de surface et en eau souterraine associées aux préoccupations des autochtones, telles que les effets cumulatifs, les impacts de la perte de pergélisol et les inondations.

Partenaires et financement

C1W est une initiative de RNCan (Programme géoscience sur les eaux souterraines) et d'Aquanty Inc. ainsi qu'Agriculture et Agroalimentaire Canada (AAC), et les universités de Toronto et de Waterloo.

Le projet est cofinancé par l'appel de propositions 2019 du Programme canadien pour la sûreté et la sécurité (PCSS) de Recherche et développement pour la défense

Canada (RDDC) dans le cadre du volet Sécurité et sûreté publiques. Le projet contribue à la mission du PCSS, qui consiste à renforcer la capacité du Canada à s'adapter au changement climatique. L'engagement avec d'autres partenaires stratégiques du projet est en cours.

Nouvelles

Surveillez le fil de nouvelles du Réseau d'information sur les eaux souterraines pour obtenir des mises à jour sur l'avancement du projet à :
https://ries.es-info.net et **https://canada1water.ca**

Contact

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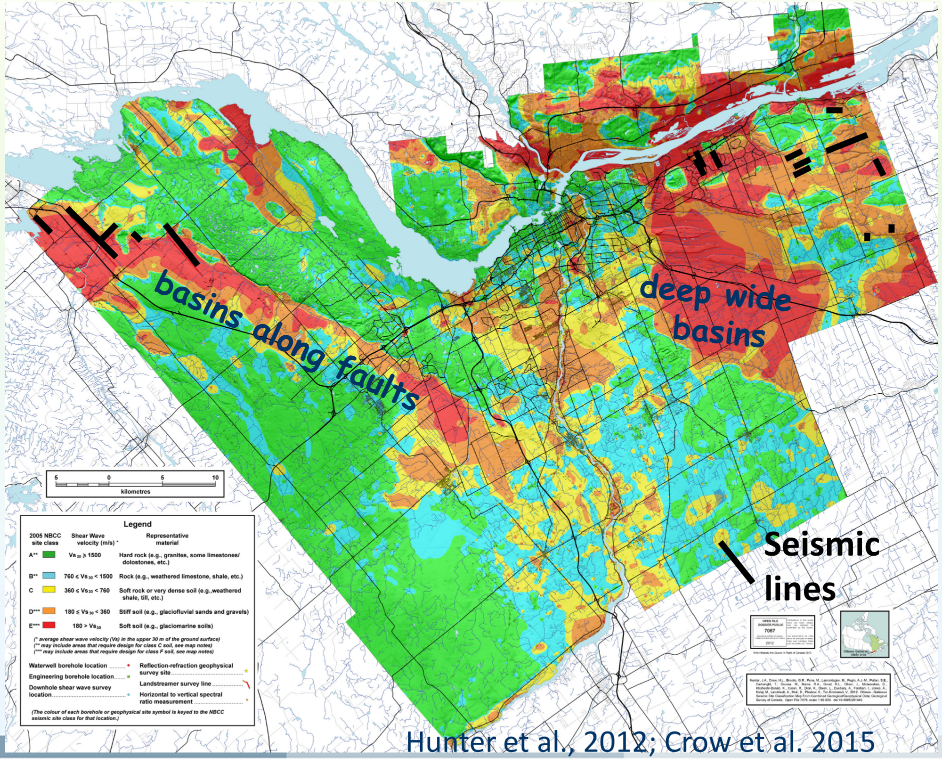
Ressources naturelles Canada / Natural Resources Canada — Agriculture et Agroalimentaire Canada / Agriculture and Agri-Food Canada — aquanty

Field Laboratories

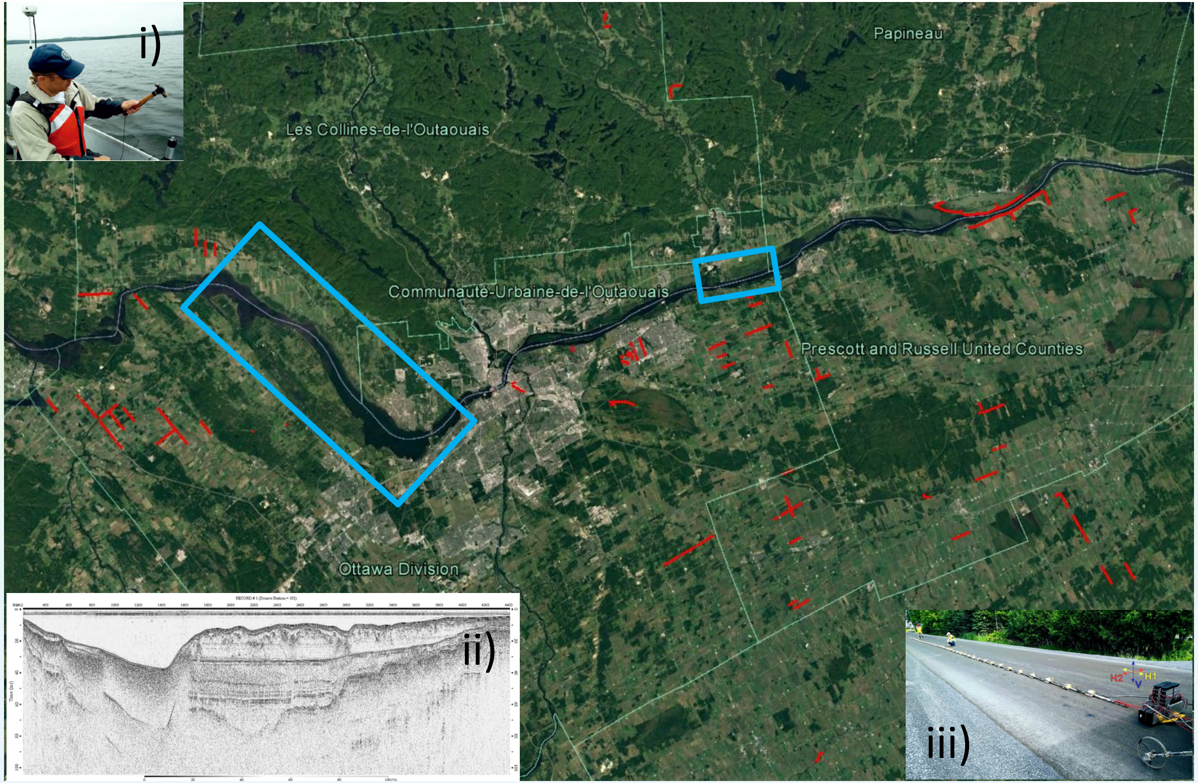
- methods Development
- archetypal characterization

- Regional
  - seismic methods
- Bells Corners
  - fractured Precambrian and Paleozoic bedrock
- Embrun
  - esker and Champlain Sea muds



Hunter et al., 2012; Crow et al. 2015

Seismic Methods

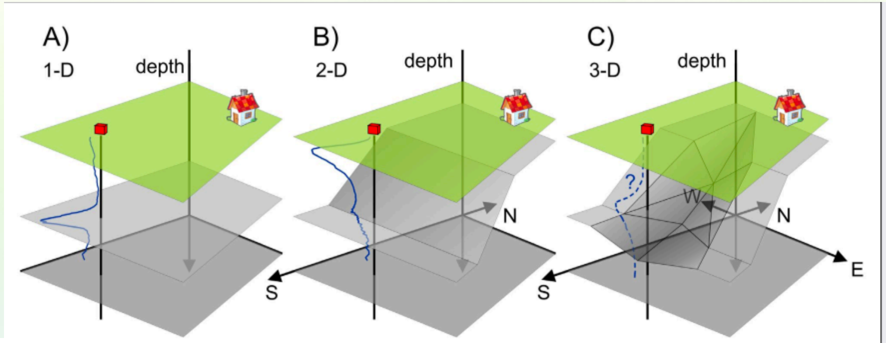


- reflection seismic
- passive seismic HVSR
- regional data collection
  - red lines terrestrial
  - blue boxes water borne

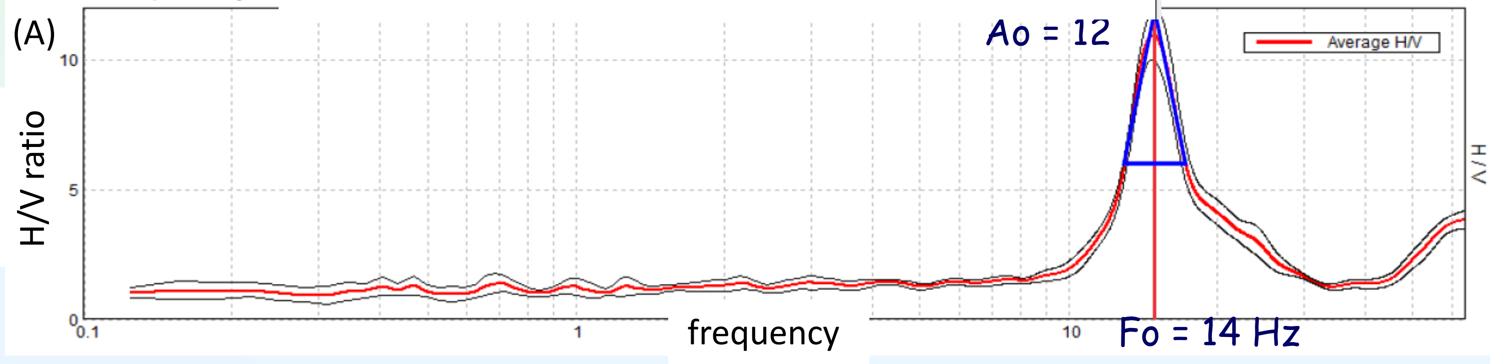
- source development
  - water based (i & ii)
  - microvibe development (iii)
  - minivibe upgrades

- signal processing
  - 3 component
  - frequency

Depth to Bedrock: Horizontal to Vertical Spectral Ratio (HVSR)



- dimensionality Problem
- estimates of depth to bedrock commonly assume a one-D model



- Ratio of H/V in frequency domain (spectral) signal (A) with maximum or peak amplitude (Fo) related to geometry and lithology of a site

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Contact: Barbara Dietiker

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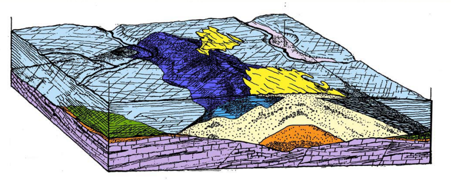
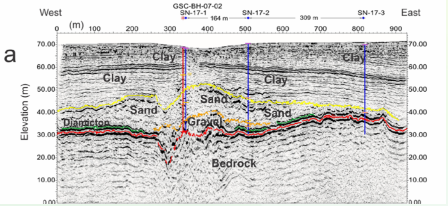
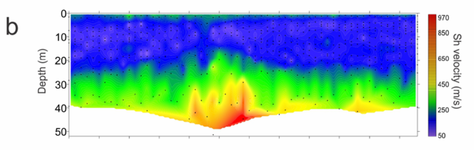
Embrun Esker Site

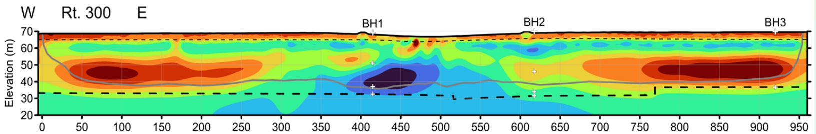


Sequence stratigraphy of a glaciated basin fill, with a focus on esker sedimentation

Don I. Cummings[1,2], George Gorrell[2], Jean-Pierre Guilbault[3], James A. Hunter[1], Charles Logan[1], Dmitri Ponomarenko[1], André J.-M. Pugin[1], Susan E. Pullan[1], Hazen A.J. Russell[1], and David R. Sharpe[1]







Oldenborger, G.A., 2021. Electrical resistivity surveys, Vars-Winchester esker aquifer, Ontario; Geological Survey of Canada, Open File 8769, 69 p. https://doi.org/10.4095/328037

Near Surface Geophysics EAGE EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

Near Surface Geophysics, 2020 doi: 10.1002/nsg.12120

Downhole nuclear magnetic resonance logging in glaciomarine sediments near Ottawa, Ontario, Canada

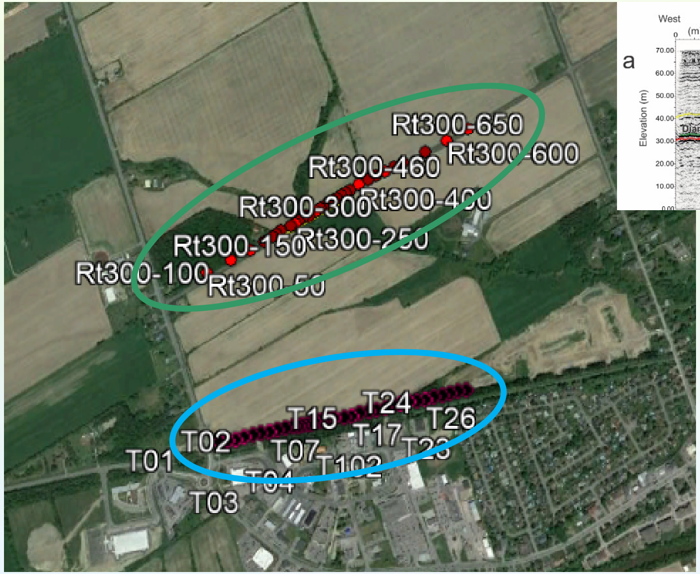
Heather L. Crow[1*], Randolph J. Enkin[2], Jeanne B. Percival[1] and Hazen A.J. Russell[1]

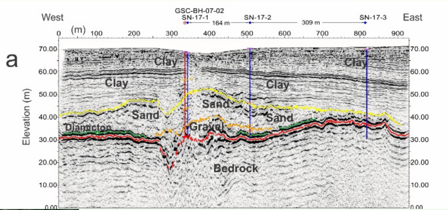
Datasets

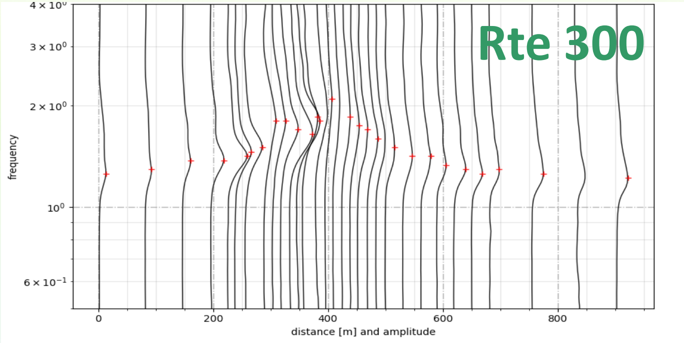
- hydraulic
- geophysical
  - seismic reflection
  - seismic passive
  - resistivity
  - borehole
    - litho logs
    - NMR

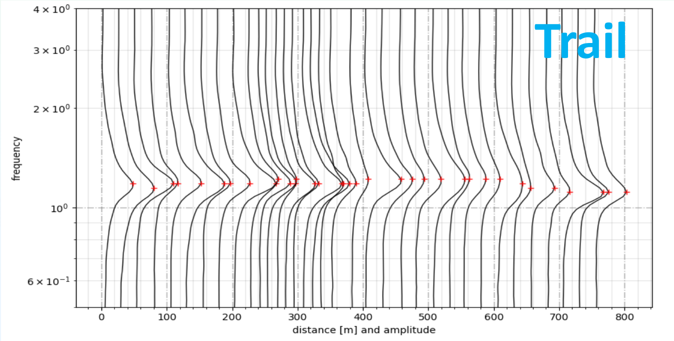
In review: Crow et al.
Hydraulic conductivity from NMR logs in an unconsolidated aquifer with elevated magnetic susceptibilities

Embrun Esker: Enhanced Delineation



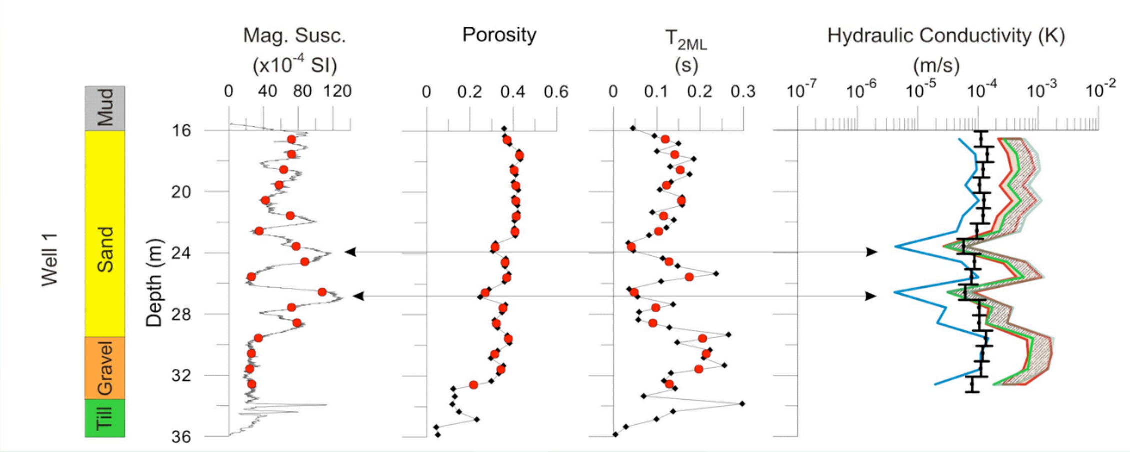




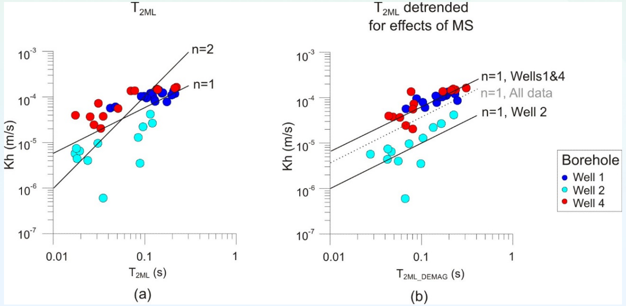


Additional Passive Seismic Profile along recreational trail (**T**) shows no esker signature compared to **Rte 300** further north

Embrun NMR and Magnetic Susceptibility



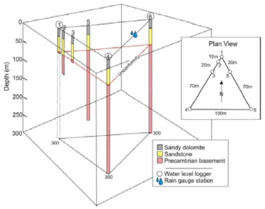
- unconsolidated aquifer
- hydraulic conductivity
- magnetic susceptibilities – moderate to elevated (10^{-4} to 10^{-2} SI)



- identified refinements in data analyses and interpretation workflows integrating MS logs and grain size information to improve K_{NMR} estimates in these higher MS environments

Bells Corners Deep Borehole Research Site

GSC Borehole Calibration Facility, Bells Corners Ottawa, Ontario
New core and downhole geophysical data sets



- The Bells Corners site has a 40 plus year history as a bedrock geophysics calibration facility.
- Over the past few years the site has been rehabilitated and new data collected to enhance the role as a calibration facility and to broaden the use of the site for groundwater work.
- Borehole arrangement and lithological succession to left.

- The boreholes intercept Paleozoic carbonates and sandstones that overlie Precambrian granitoid rocks with varying mineralogy and alteration.
- Illustrative examples to the left are from Figure 9 in the report and are i) sandstone, ii) granitic gneiss, and iii) granitic gneiss with chlorite alteration

Analyses reported include:
i) laboratory strength and permeability testing (left, servo-controlled MTS Rock Mechanics Testing System, photo S.Gaines);
ii) Nuclear magnetic resonance measurements of water content and pore size distributions;
iii) complex resistivity measurements on core samples;
iv) downhole geophysical data include: optical and acoustic televiewer, total gamma, full waveform sonic, fluid temperature, fluid conductivity, heat pulse flow meter, and p- and s-wave velocity.

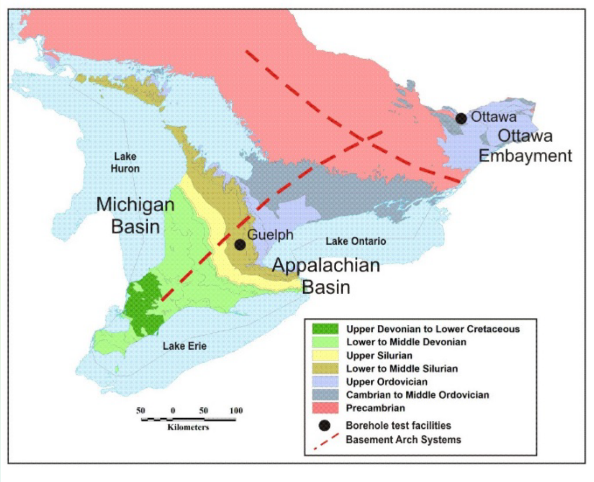
Crow, H.L., Brewer, K.D., Cartwright, T.J., Gaines, S., Heagle, D., Pugin, A.J.-M., and Russell H.A.J., 2021. New core and downhole geophysical data sets from the Bells Corners Borehole Calibration Facility, Ottawa, Ontario; Geological Survey of Canada, Open File 8811, 1 .zip file. https://doi.org/10.4095/328837

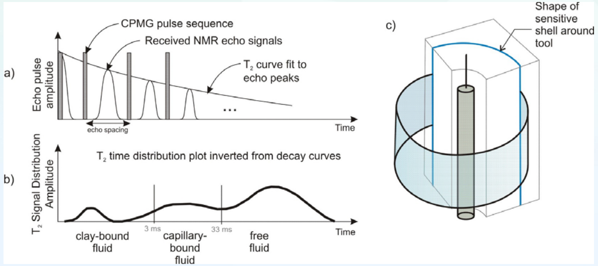
Ongoing work with respect to:

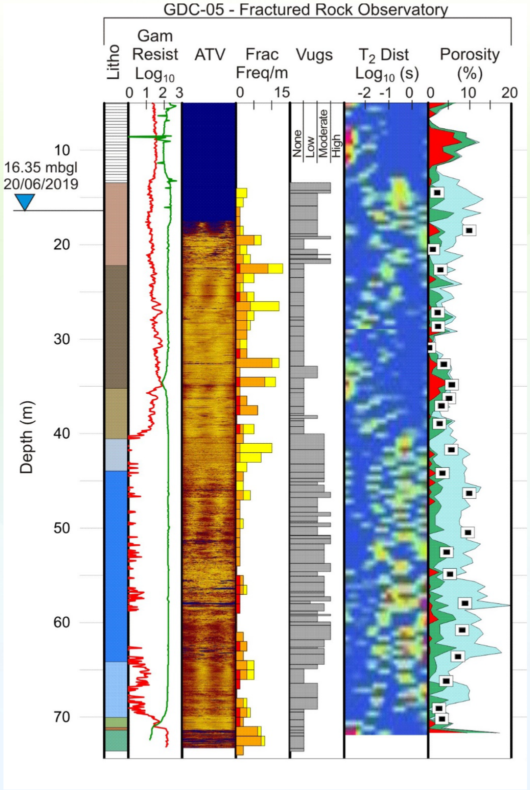
- gochemical characterization
- hydrogeological setting
- CTscan porosity analysis
- NMR logging
- comparative studies with University of Guelph borehole facility –Fractured Rock Observatory (FRO)
- integration with other sites intercepting Nepean sandstone

Contact: Heather Crow

BMR Tool Assessment

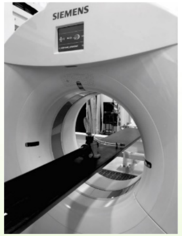


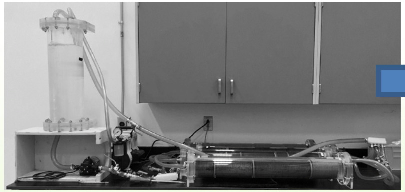




- collaborative Guelph – GSC BMR tool assessment
- void volume estimation
- repeatability measurements hrs-days
- logging speeds
- threshold response
- evaluation against lithologs
- Deployment on sandstone and limestone-dolostone

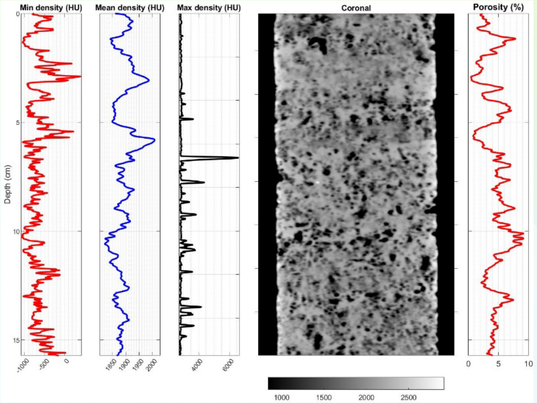
CT Scan Core Analysis





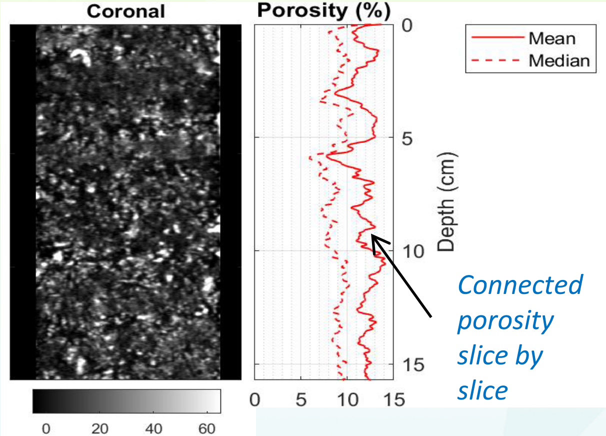
Connected porosity: Core-flooding and Dry/sat CT-scans substraction

Dry CT-scans: total porosity is evaluated using the mixel theory



- *comparison of dry scans and 'connected porosity' in 3D = checking macropores contribution to connected porosity*

Ex. DGR core – A1 carbonate

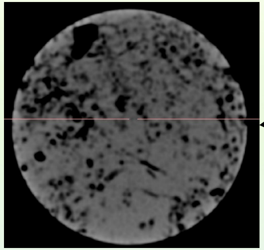


Average porosity value = 12%

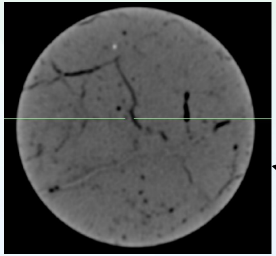
- **comparison with conventional core plug analysis using Boyle's Law**

= insight into scale dependence of petrophysical measurements

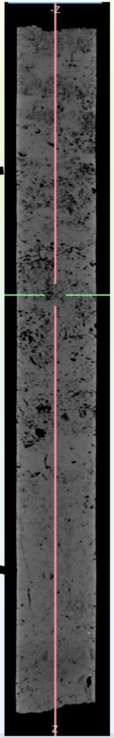
Results - Porosity profiles along sections/depths comparable with NMR logs



Vugs and moldic macropores



Fracture and/or fenestral macropores



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Contact: Stephanie Larmagnat

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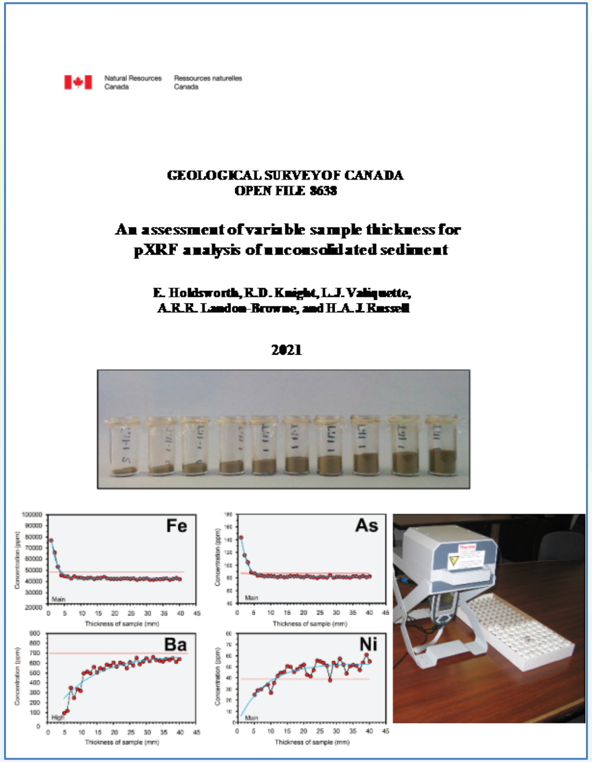
Geochemistry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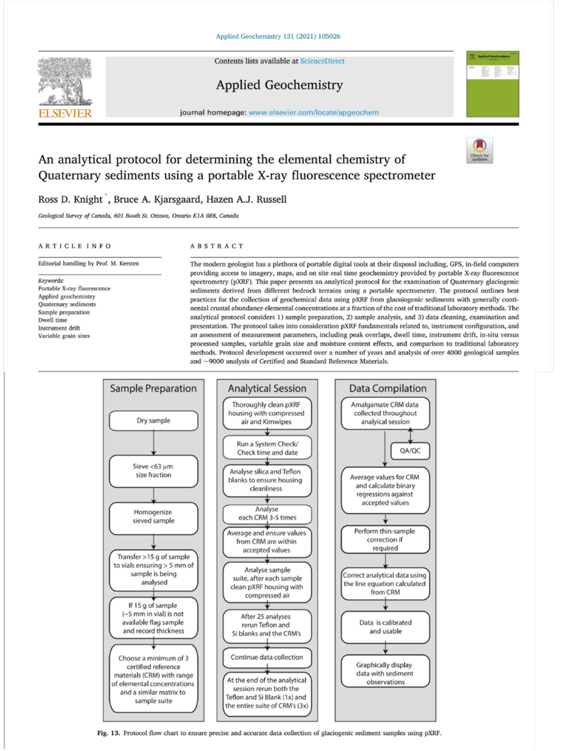
GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8638

An assessment of variable sample thickness for pXRF analysis of unconsolidated sediment

E. Holdsworth, R.D. Knight, L.J. Valiquette, A.R.R. Landon-Browne, and H.A.J. Russell

2021



Applied Geochemistry 131 (2021) 105026

Contents lists available at ScienceDirect

Applied Geochemistry

journal homepage: www.elsevier.com/locate/apgeochem

An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer

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Geological Survey of Canada, 601 Booth St. Ottawa, Ontario K1A 0E8, Canada

ARTICLE INFO

Editorial handling by Prof. M. Kersten

Keywords:
Portable X-ray fluorescence
Applied geochemistry
Quaternary sediments
Sample preparation
Dwell time
Instrument drift
Variable grain sizes

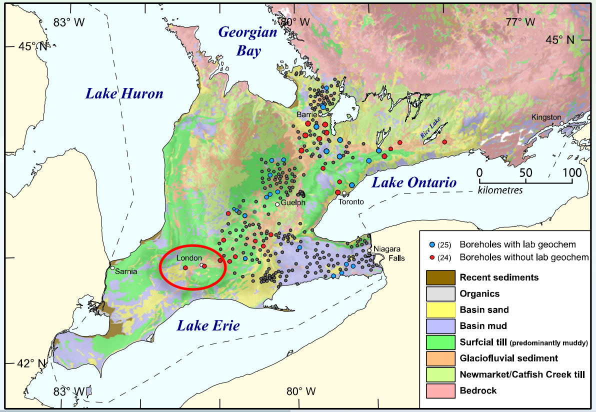
ABSTRACT

The modern geologist has a plethora of portable digital tools at their disposal including, GPS, in-field computers providing access to imagery, maps, and on site real time geochemistry provided by portable X-ray fluorescence spectrometry (pXRF). This paper presents an analytical protocol for the examination of Quaternary glaciogenic sediments derived from different bedrock terrains using a portable spectrometer. The protocol outlines best practices for the collection of geochemical data using pXRF from glacoiogenic sediments with generally continental crustal abundance elemental concentrations at a fraction of the cost of traditional laboratory methods. The analytical protocol considers 1) sample preparation, 2) sample analysis, and 3) data cleaning, examination and presentation. The protocol takes into consideration pXRF fundamentals related to, instrument configuration, and an assessment of measurement parameters, including peak overlaps, dwell time, instrument drift, in-situ versus processed samples, variable grain size and moisture content effects, and comparison to traditional laboratory methods. Protocol development occurred over a number of years and analysis of over 4000 geological samples and ~9000 analysis of Certified and Standard Reference Materials.

Fig. 13. Protocol flow chart to ensure precise and accurate data collection of glaciogenic sediment samples using pXRF.

3 active activities

- publish remaining borehole geochemistry southern Ontario London area
- Nanaimo area, Vancouver Island geochemistry
- Ottawa area bedrock



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Contact: Ross Knight

Canada

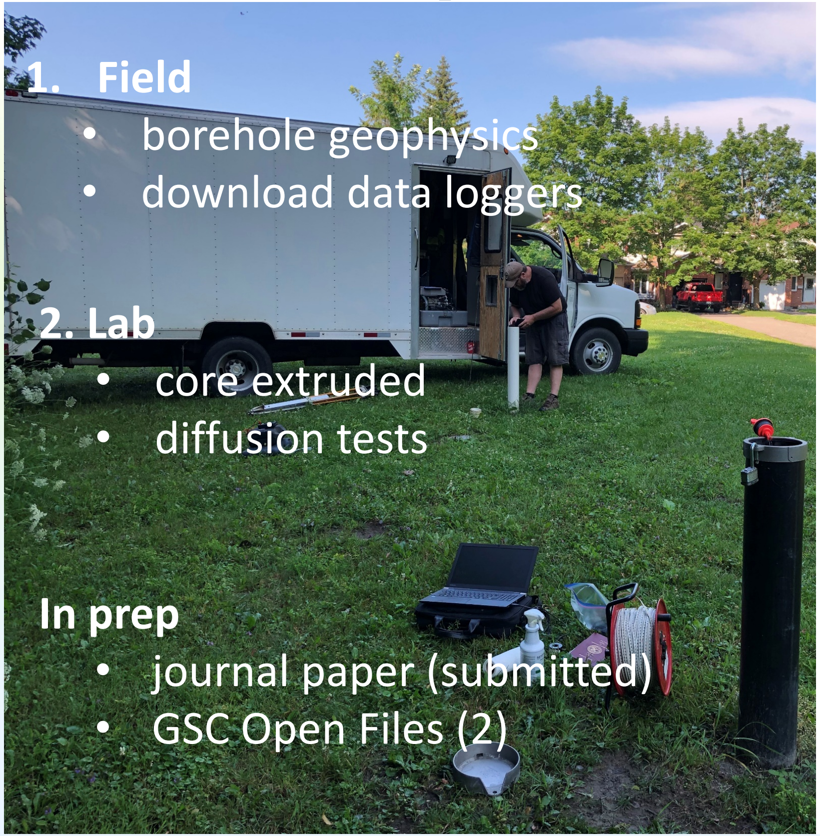
Champlain Sea Mud Characterization

- year 3 of study
- Bilberry Creek, Orleans
- hydrogeological and geotechnical
- sedimentological setting
- geochemistry
- integrate properties /processes
- establish two reference sites

After Aylsworth, 2012

Contact Marc Hinton and Sam Alpay

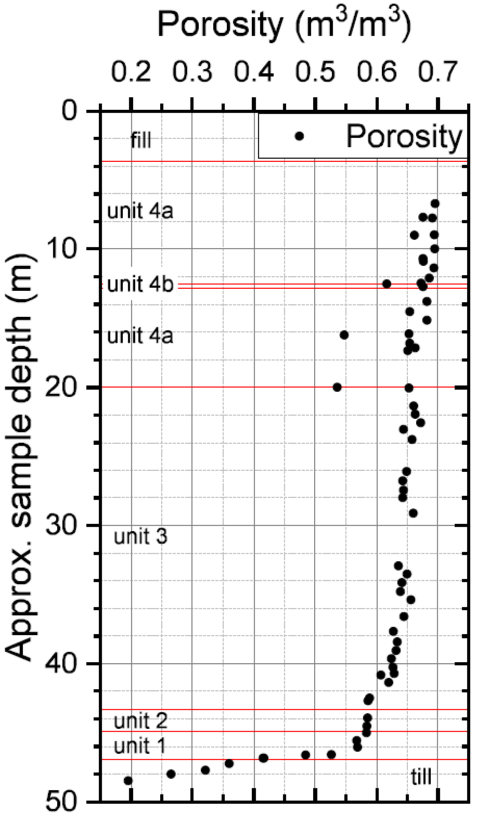
Champlain Sea Aquitard –Update



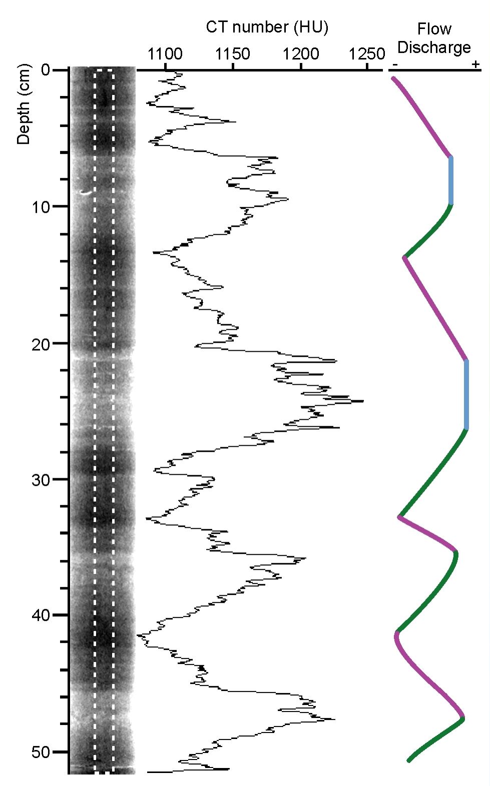
1. **Field**
   - borehole geophysics
   - download data loggers

2. **Lab**
   - core extruded
   - diffusion tests

In prep
- journal paper (submitted)
- GSC Open Files (2)



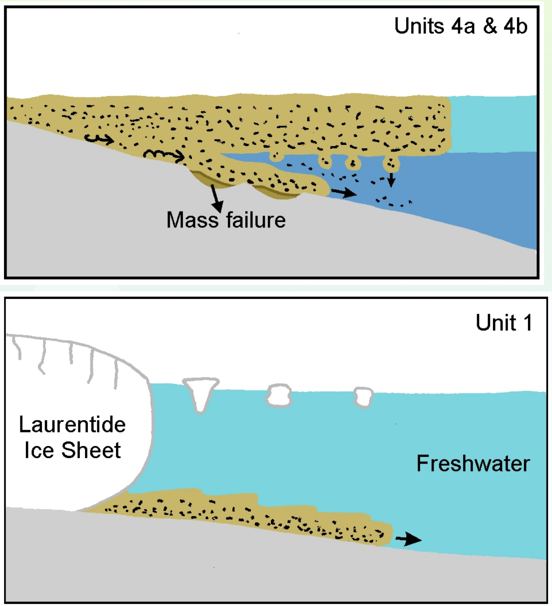
Champlain Sea Sedimentology

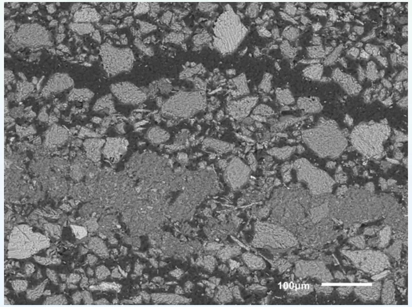


Hounsfield Units*

Unit 4a: well-stratified mud	~ 250-300
Unit 4a: diffusely stratified or structureless mud	~ 50
Unit 3: banded mud	~ 80-120
Unit2: bioturbated mud	~ 50-100
Unit1: mud rhythmites	~ 300
	* spread

Depositional Framework





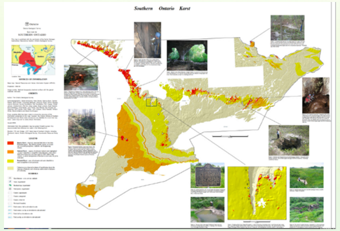
Future Work

Microfabric analysis

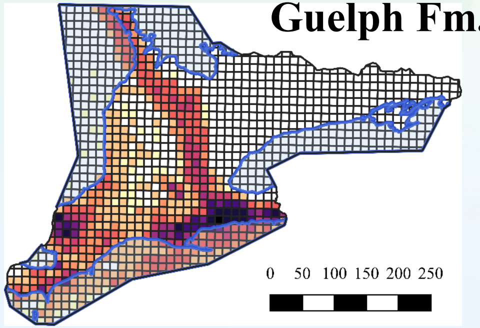
Contact: Al-Mufti, Ottawa U

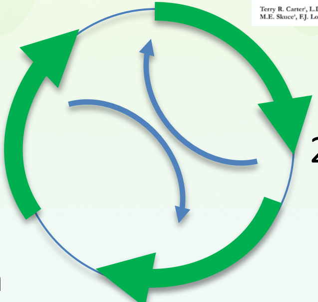
Hydrostratigraphic Model: S-Ontario

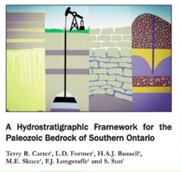
QA/QC

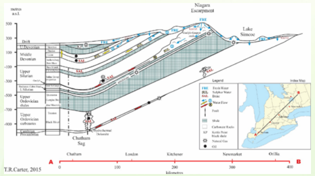


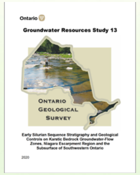
Confidence Modelling

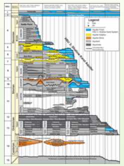








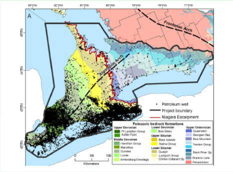




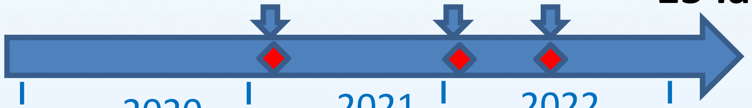
Fresh

Sulphur

Brines



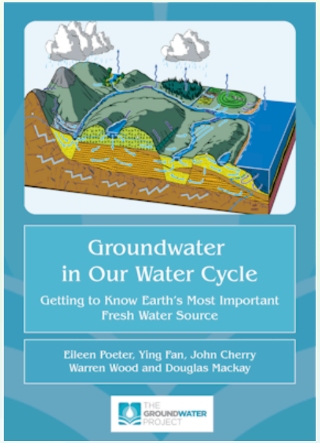
Data sources
Data quality
Data accessibility
Data support



Carter, T.R., Logan, C.E., Clark, J.K., Russell, H.A.J., Brunton, F.R., Cachunjua, A., D'Arienzo, M., Freckelton, C., Rzyszczak, H., Sun, S., and Yeung, K.H., 2021. A three-dimensional geological model of the **Paleozoic bedrock** of southern Ontario— version 2; Geological Survey of Canada, Open File 8795, 1 .zip file. https://doi.org/10.4095/328297

Groundwater Project Contribution

- Contributions
  - Rivera book (chapter) reviews
  - Rivera guidelines for Major Aquifer Systems of the world
  - Rivera – presentation for the Groundwater Book Webinar series
  - Sharpe – Major Aquifer Systems – Oak Ridges Moraine



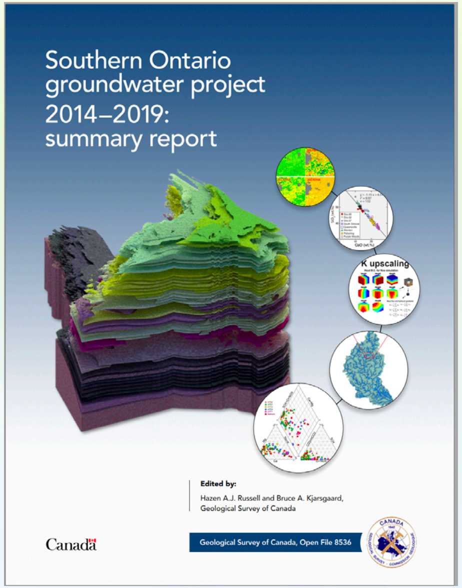
Graphic from Hinton 2014

Summary

- archetypal aquifer studies are focused on eskers and glaciomarine muds. (e.g., Bilberry Creek)
- field laboratories – methods development
  - seismic collection and signal processing
  - HVSR signal processing
  - NMR and CTscan work
- 3D modelling southern Ontario

Contact Info

- Hazen Russell
  - hazen.russell@nrcan-rncan.gc.ca
  - linkedIn
- Groundwater Geoscience Program
  - Eric Boisvert GSC: eric.boisvert2@nrcan-rncan.gc.ca
- Geological Survey Publications
  - Geoscan: https://geoscan.nrcan.gc.ca
  - GIN: https://gin.gw-info.net



Natural Resources Canada
Ressources naturelles Canada

Groundwater Information Network

GIN

Réseau d’Information sur les Eaux Souterraines

Boyan Brodaric & GIN Team

October 13, 2021

Canada

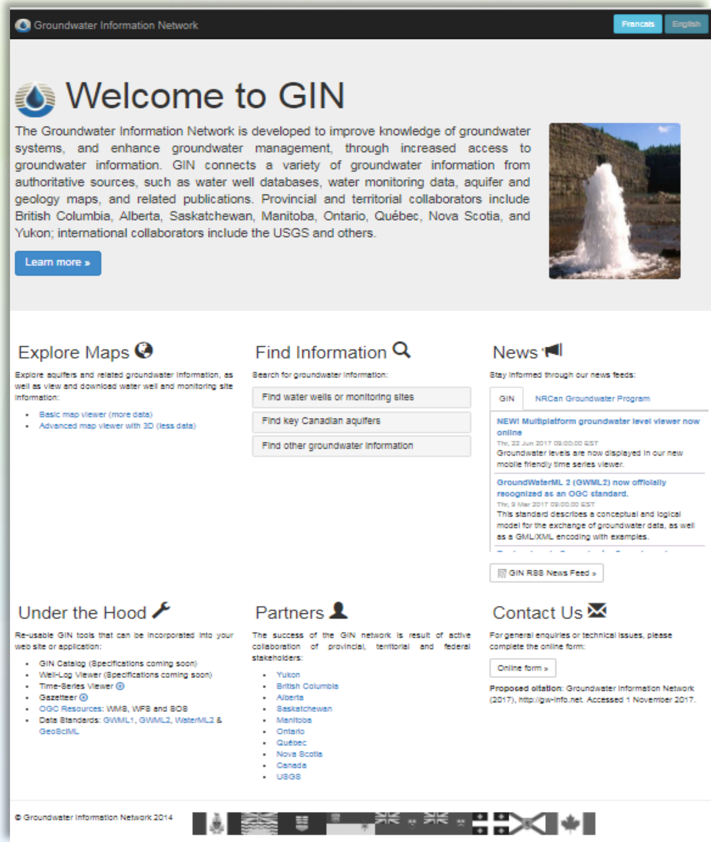
ABSTRACT

- **Groundwater Information Network**

Fed-prov-terr-int'l collaboration to share groundwater data online, using international standards; aligned with FGP, GOC Open Data Portal and Open Science, Google Dataset Search.

Third program cycle, since 2010.

https://gw-info.net



Groundwater Information Network

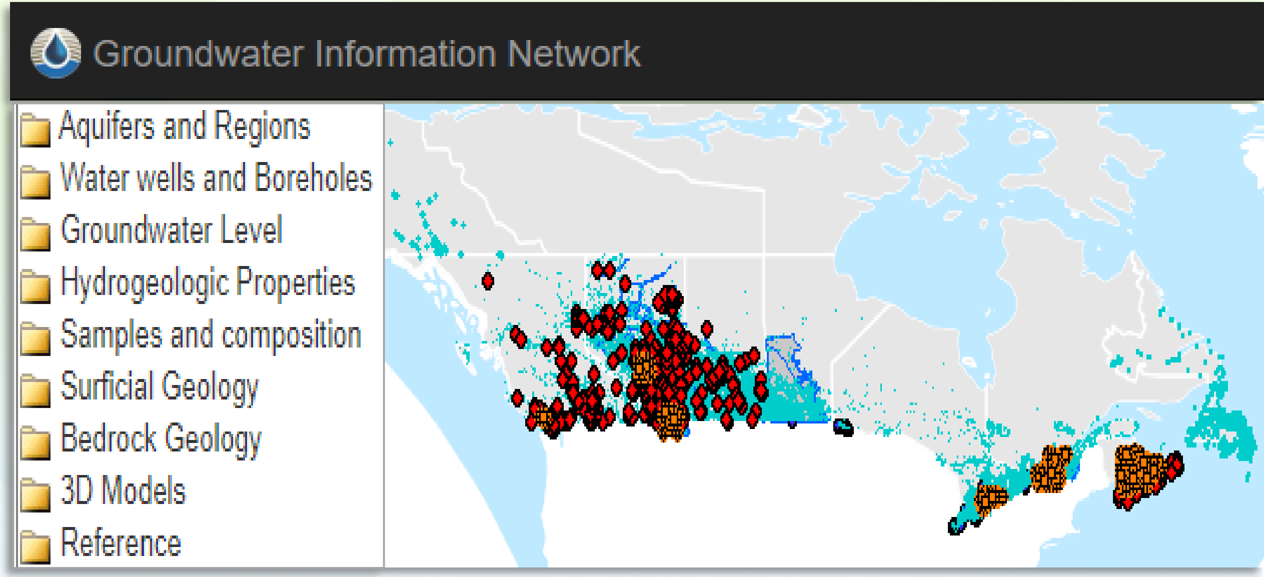
Key Activities

- data network: national, international
- web portal: view, access, download
- data standards: international
- tech transfer: PIN
- Internet of Water: Linked Data

GIN Highlights

Data sharing Canada

- **GIN**
  national
  data network



YK BC* AB SK* MB ON QC NS* NL* + FGP + OGP

*new well or monitoring data 2015-2019

GIN Highlights 2020-21

DATA SHARING Canada

- renew partnerships
  - provinces, territories
- more data
  - updated, missing, real-time
  - advanced API: SensorThings, OpenAPI

OGC®
Making location count.

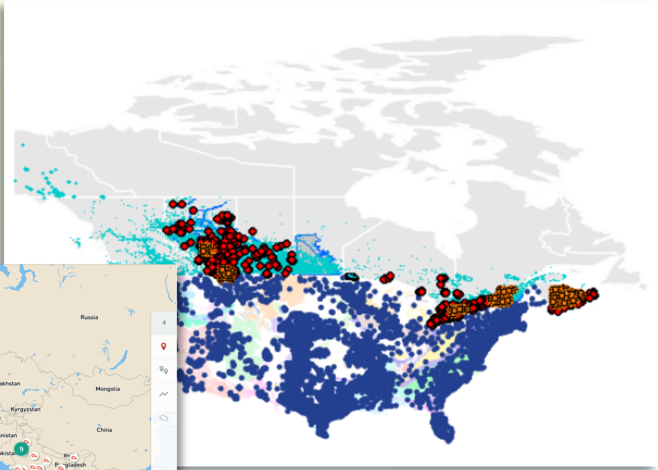
OGC SensorThings API

done in progress planned

GIN Highlights

DATA SHARING Global

- **GIN**
  international
  data network



US Nat'l GW
Monitoring
Network

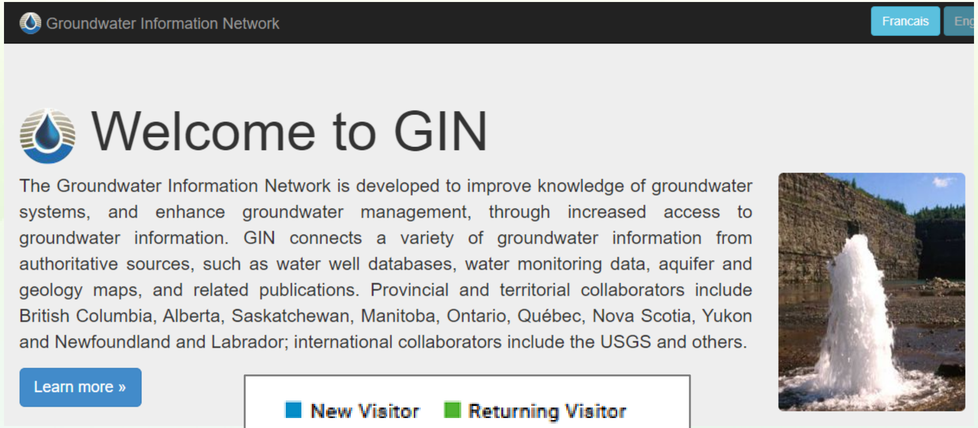
IGRAC-UNESCO Global
Groundwater Monitoring Network

GIN Highlights 2020-21

Web portal

- **GIN** online
  https://gw-info.net

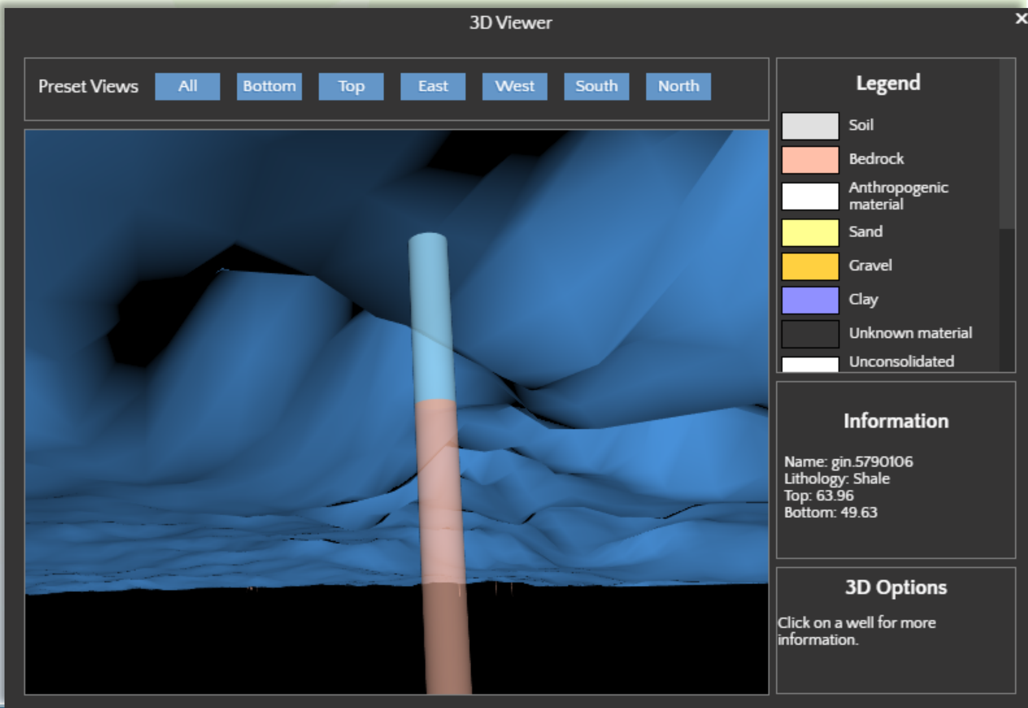
  ~900 users / mth
  8000 water well views
  ~100 data downloads



GIN Highlights 2020-21

Web portal

- new user interface
  - advanced mapping application
- new tools
  - 3D / multi-param well viewer
  - aquifer dashboard
  - water level calculator



done in progress planned

GIN Highlights

Standards

- **GIN** data standards development

1. GGP Data Standards

Natural Resources Canada / Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8584

Data Product Specifications for Standardized Groundwater Datasets

2. OGC GWML2

OGC Making location count. ABOUT MEMBERSHIP STANDARDS & RESOURCES

OGC WaterML 2: Part 4 – GroundWaterML 2 (GWML2)

3. OGC GeoSciML

OGC Making location count. ABOUT MEMBERSHIP STANDARDS & RESOURCES

OGC Geoscience Markup Language (GeoSciML)

4. WMO

GIN Highlights 2020-21

Standards

- **GWML2**
  - new release 2.2.1
- Adoption
  - WMO, UNESCO

OGC WaterML 2: Part 4 - GroundWaterML 2 (GWML2)

Open Geospatial Consortium

Boyan Brodaric Editor

Submission Date:
2019-04-15

Approval Date:
2019-09-15

Publication Date:
2021-01-20

External identifier of this OGC® document:
http://www.opengis.net/doc/IS/GWML/2.2.1

done in progress planned

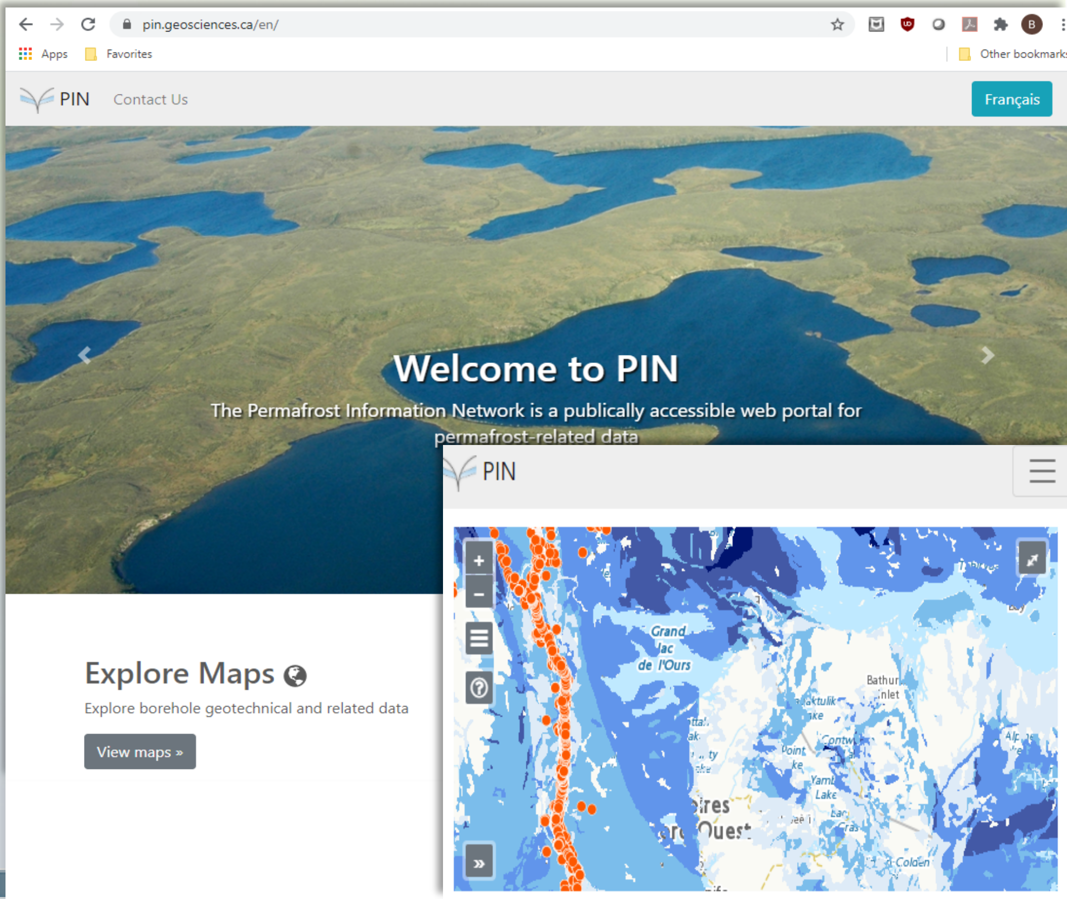
GIN Highlights 2020-21

Tech transfer

- **PIN**
  Permafrost Info Network
  https://pin.geosciences.ca

- new release
  - new UI, more data

done | in progress | planned



GIN Highlights

Linked Data linking water data across the water cycle

atmospheric water
gauges,…
Climate data
(http://climate.weather.gc.ca)

surface water
rivers, lakes, watersheds,…
Nat'l Hydro Network
(www.geobase.ca)

surface water
gauges,…
Nat'l Hydrometric Network
(www.wateroffice.ec.gc.ca)

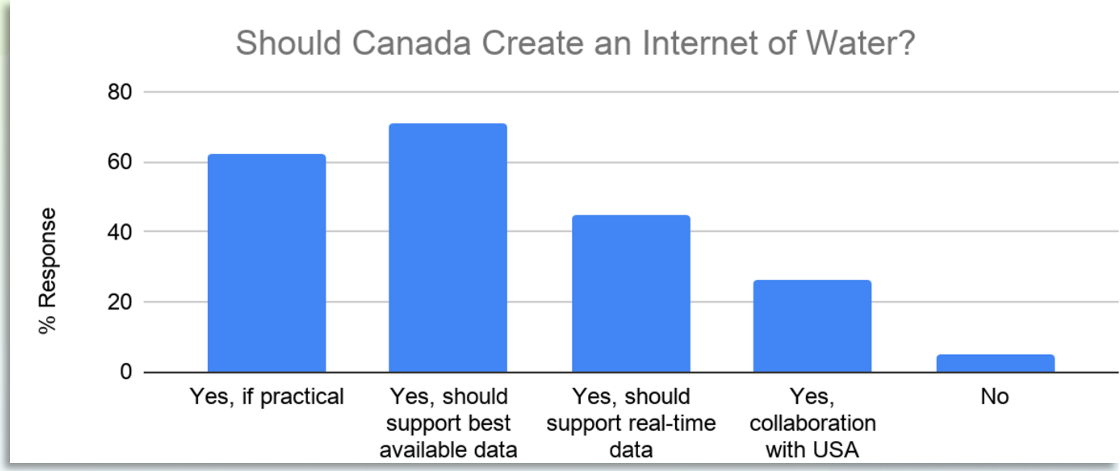
groundwater
aquifers, wells, gauges…
GW Info Network
(www.gw-info.net)

GIN Highlights 2020-21

Internet of Water

- infrastructure
  - web-centric
- partnerships
  - NRCan, USGS, CWA

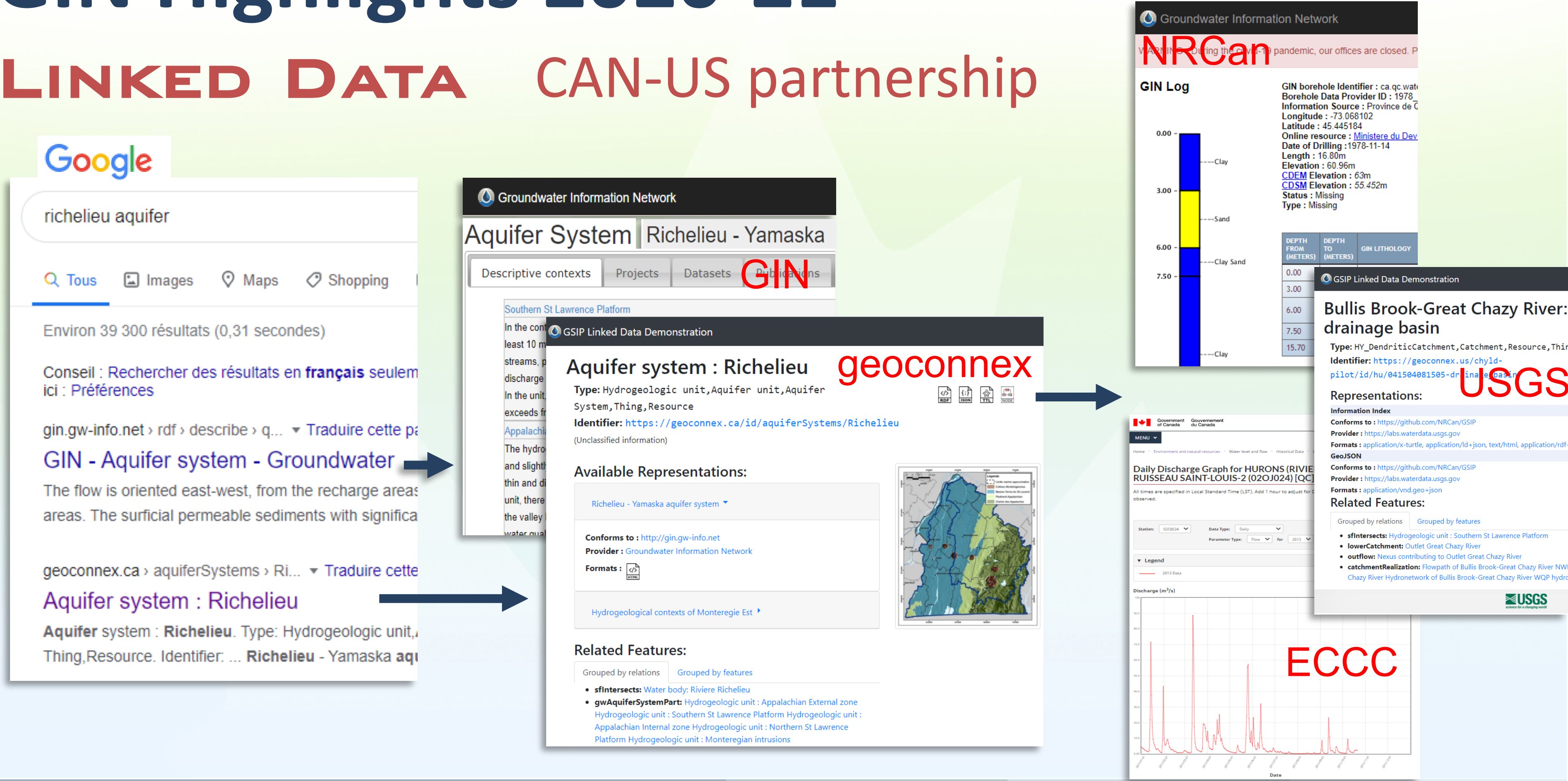
NHN Workshop 4 – July 2020



done | in progress | planned

GIN Highlights 2020-21

Linked Data CAN-US partnership



GIN Highlights 2020-21

Linked Data CWA

- Internet of Water

Canada Water Agency

data strategy

PROJECT MEMBERS

Groundwater Information Network
Réseau d'Information sur les Eaux Souterraines

- Boyan Brodaric
- Éric Boisvert
- Héryk Julien
- François Létourneau
- Étienne Girard
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- Simon Gagnon

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- https://gw-info.net

Thank you / Merci!

Ressources naturelles Canada | Natural Resources Canada

Caractérisation des aquifères superficiels et évaluation des impacts potentiels liés aux activités pétrolières et gazières sur ces aquifères dans la région de Fox Creek (AB)

– mise à jour d'octobre 2021

Characterization of shallow aquifers and assessment of potential impacts of oil and gas development activities on these aquifers in the Fox Creek area (AB) - October 2021 update

Christine Rivard

Canada

ABSTRACT

A multidisciplinary and multi-institutional project was initiated in the Fox Creek area (west-central Alberta) in April 2019 to study environmental impacts of hydrocarbon development activities. The initial objective was to specifically study potential impacts on shallow groundwater. However, different Sectors within NRCan later identified the Fox Creek area as a region of interest for developing regional cumulative effects evaluation methods in support of new impact assessment legislation. As a result, the scope is now much broader and the project includes studies of vegetation, forest, snow cover, wetlands, and contributes to a woodland caribou habitat study. The project involves many collaborators from the federal and provincial governments, as well as from the academic community.This project is supported by the GGP and EGP programs.

Project members

(including EGP, GGP and cumulative effects)

C. Rivard[1], C. Paniconi [2], E. Konstantinovskaya[3], O. Haeri Ardakani[1], H. Crow[1], G. Bordeleau[2], L.I. Guarin-Martinez[2,1], B.J. Meneses-Vega[1,2], D. Kononovs[3], D. Degenhardt[4], D. Alessi[3], B. Xu.[5], P. Leblanc-Rochette[1,6], R. Lavoie[6], D. Lavoie[7], B. Smerdon[3,8], D. Palombi[8], J. Lovitt[9], W. Chen[9], R. Chalaturnyk[10], H. Kao[1], S. Heckbert[8], B. Giroux[2], I. Aubin[4], S. Grasby[1]

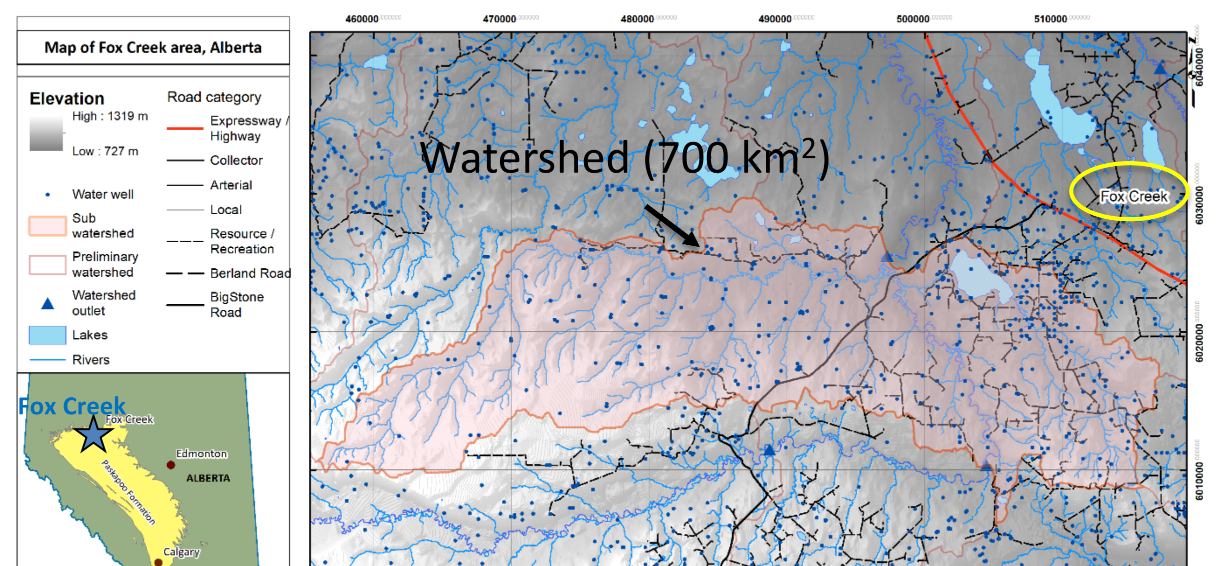
[1] *Geological Survey of Canada, Natural Resources Canada, Québec, QC; Ottawa, ON; Calgary, AB; and Victoria, BC;*
[2] *Institut national de la recherche scientifique – Eau Terre Environnement (INRS-ETE), Québec, QC*
[3] *University of Alberta, Department of Earth and Atmospheric Sciences, Edmonton, AB*
[4] *Canadian Forest Service, Natural Resources Canada, Edmonton, AB and Sault-Sainte-Marie, ON*
[5] *Northern Alberta Institute of Technology (NAIT), Edmonton, AB*
[6] *Université Laval, École supérieure d'aménagement du territoire et de développement régional, Qu*
[7] *Consultant, geologist, Quebec, QC*
[8] *Alberta Energy Regulator and Alberta Geological Survey, Edmonton, AB*
[9] *CCMEO, Natural Resources Canada, Ottawa, ON*
[10] *University of Alberta, Faculty of Engineering, Edmonton, AB*

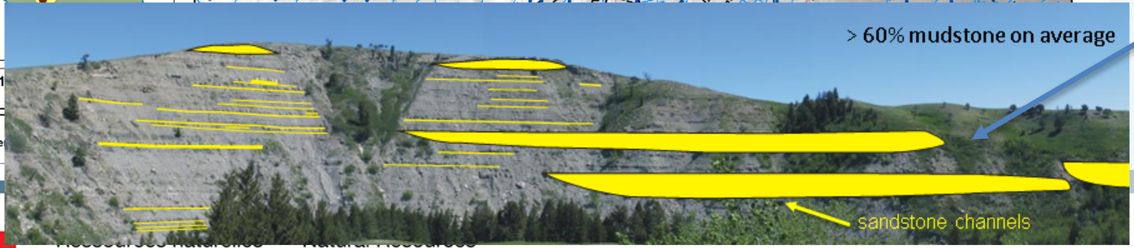
≈25 people

3 MSc students
1 PhD students

Description of the study area

Fox Creek, west-central Alberta: one of the most active regions for O&G production in the last 50 years





The study area is mainly forested and unpopulated

Elevations range from 785 to 1180 m

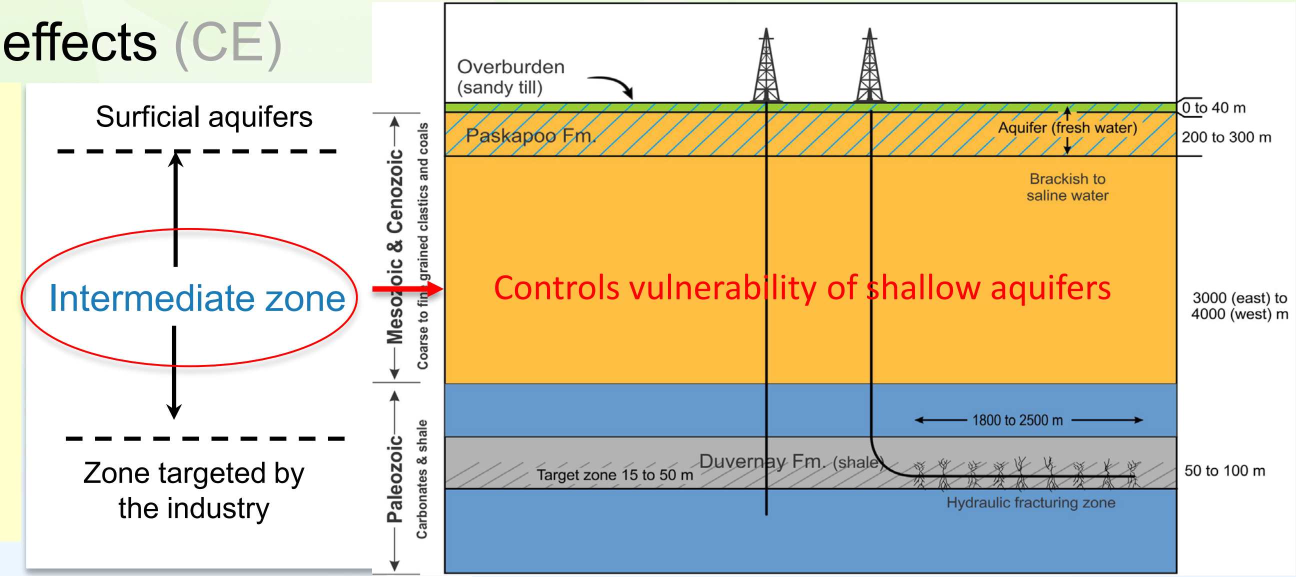
The regional aquifer is located in the Paskapoo Fm.: a complex succession of interbedded mudstone and siltstone with sandstone channels

Project objectives

1) Characterize the regional shallow aquifer (GGP)
2) Study the intermediate zone integrity (EGP)
3) Assess cumulative effects (CE)

Mean water-well depth in the Paskapoo Fm: ≈50 m

Mean O&G well depth: 3000-3500 m



3) Assess cumulative effects (CE)

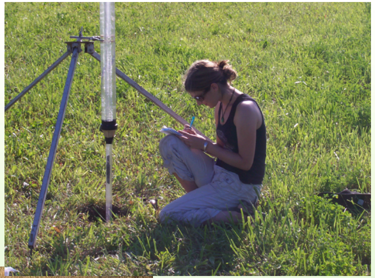
Fieldwork in 2021

(August - October 2021)

Monitoring wells (9): depths from 35 to 90 m

- Permeability (slug) tests in the 9 monitoring wells
- Groundwater sampling (in monitoring wells and 13 water wells from O&G operators)
- Permeability tests in unconsolidated sediments
- Download of pressure transducers

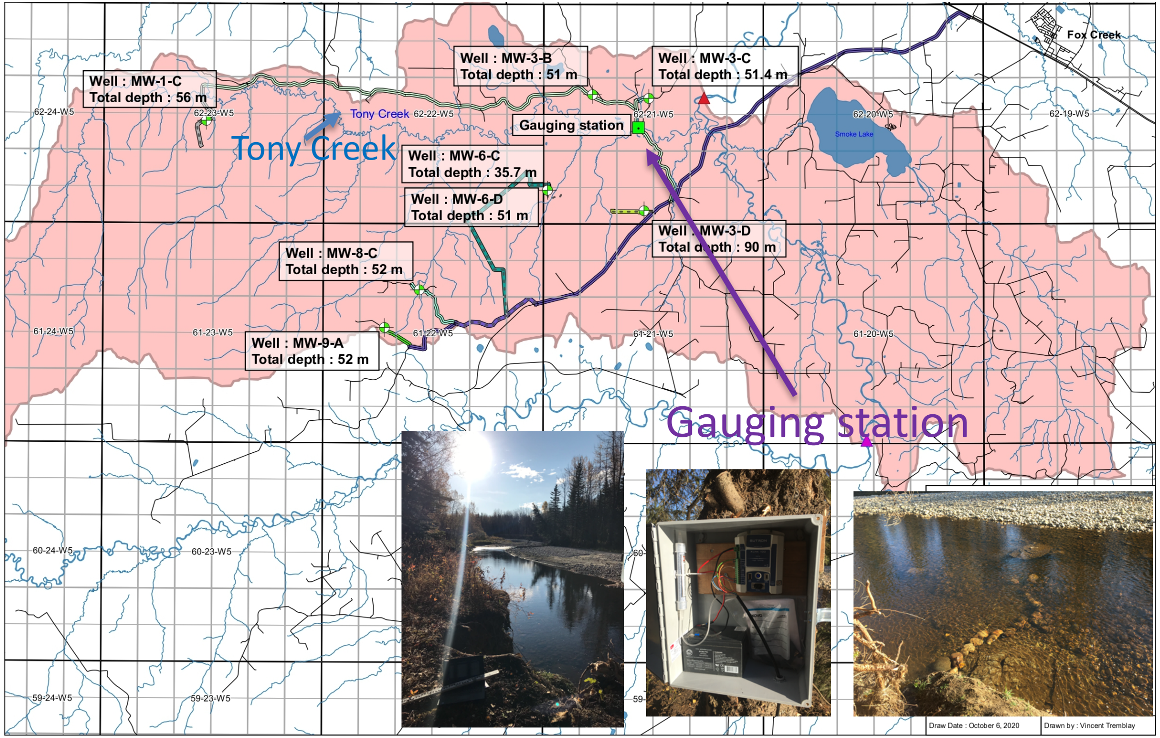
Installation of lysimeters, soil moisture sensors, rain gauges and rain collectors at 5 sites in vegetated and unvegetated (impacted) areas.

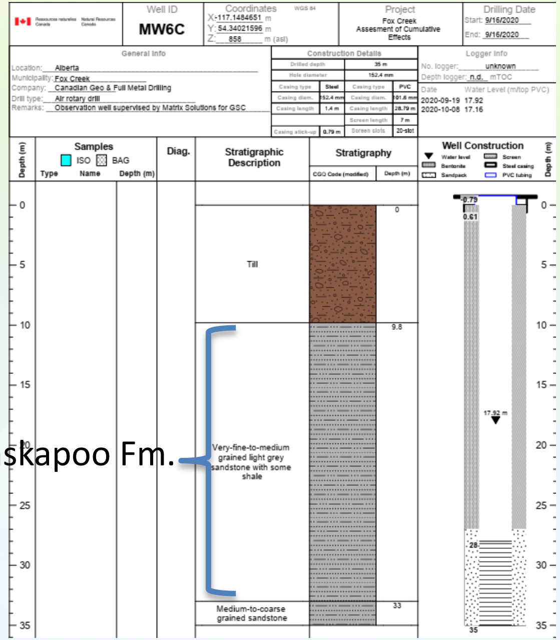




Fieldwork in 2020 and 2021

8 wells drilled on Crown land, including twin wells (MW-6) + 1 well drilled on an active O&G well pad





Paskapoo Fm.

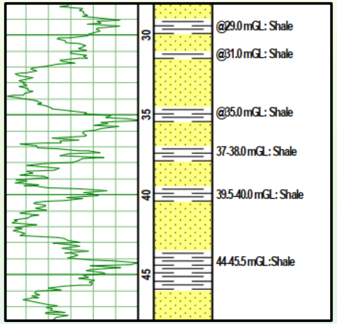
Borehole geophysical logging

Objectives :

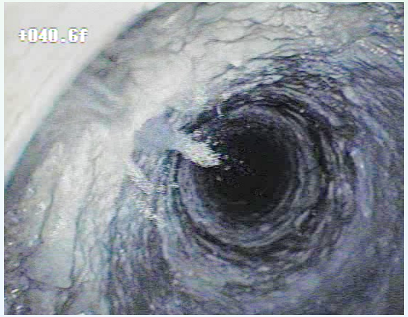
1) identify lithological, hydrogeological, and mechanical/structural conditions in the near surface bedrock

2) Support the shallow aquifer characterization

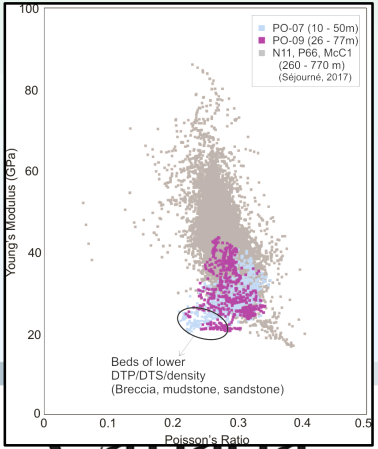
Lithological logs



Fluid flow



Geomechanical properties



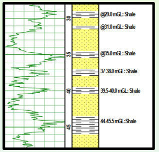
Pipe and screen installation

by Heather Crow

Borehole geophysical logging

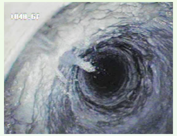
Lithological logs

- Natural gamma → stratigraphy based on changes in mineralogy
- Resistivity → stratigraphy based on changes in electrical properties



Hydrogeophysical logs

- Fluid temp/conductiv.
- Flow meters (2)
- Video camera



Structural/Geomechanical logs

- Acoustic Televiewer → identify frequency and orientation of structures
- Sonic tool → measure travel times P&S waves
- Gamma-gamma density

Logs collected:

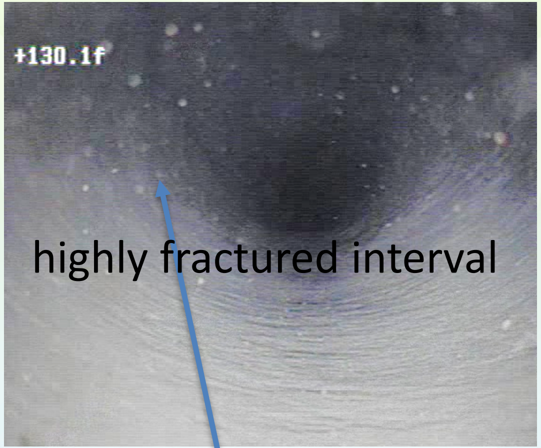
	Lithologic		Hydrogeologic				Geomechanical		
Well	Gamma	Resist.	Fluid logs Temp/Cond	Camera	Flowmeter Impeller	Flowmeter HPFM	ATV	Density	Sonic
MW-1-C	✓		✓	✓		✓	✓	✓	✓
MW-3-B	✓	✓	✓	✓	✓	✓	✓	✓	✓
MW-3-C	✓	✓	✓	✓		✓	✓	✓	✓
MW-3-D	✓	✓	✓	✓	✓	✓	✓	✓	✓
MW-6-C	✓	✓	✓	✓		✓	✓	✓	✓
MW-8-C	✓	✓	✓	✓		✓	✓		✓
MW-9-A	✓	✓	✓	✓			✓		
MW-10-A	✓	✓	✓	✓	✓	✓	✓	✓	✓

by Heather Crow

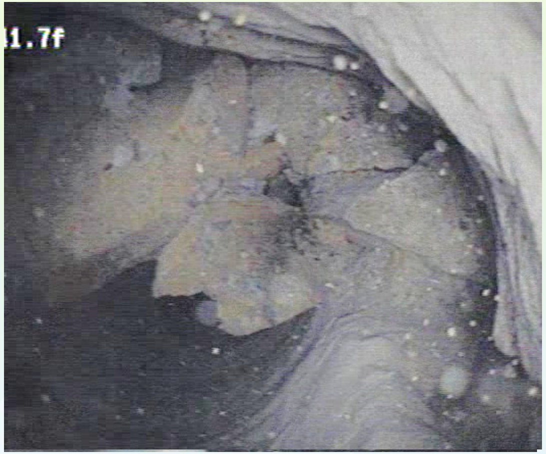
Borehole geophysical logging

Camera images from three monitoring wells

(above the WT)
GW is pouring into the borehole through a fractured zone near the top of bedrock



(under water)
Floating silty particles

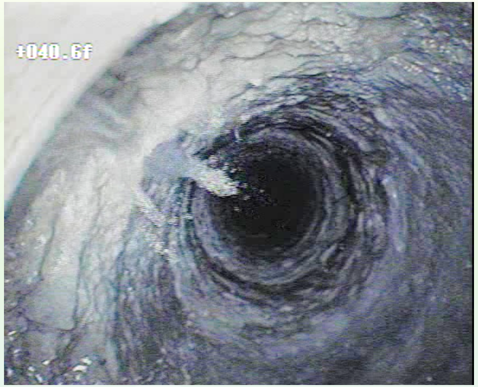


(under water)
Highly fractured interval

Borehole geophysical logging

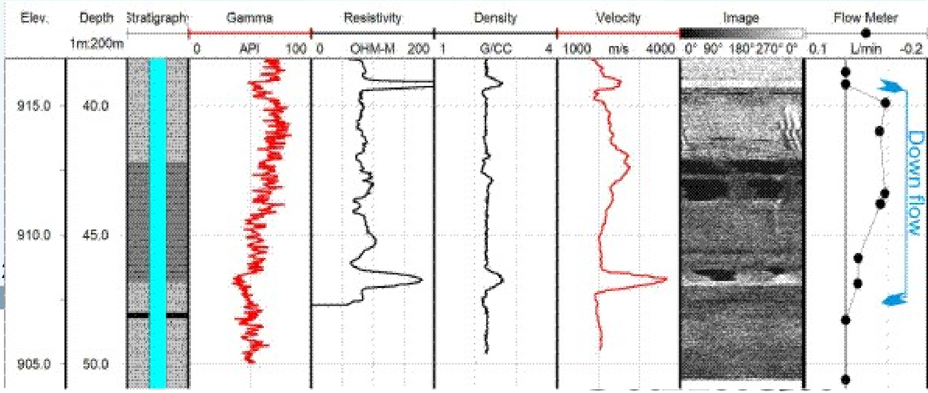
Preliminary analyses:

- Groundwater (4 – 6°C) is flowing naturally in all wells:
  - Recharge (down flow) occurring in 7 wells at rates of 0.05 to >4 L/min
  - Discharge (up flow) occurring in 1 well at rates of 0.10 to 0.2 L/min
  - Flow occurs both along fractures and through permeable sandstone



- Rock properties:
  - Gamma and resistivity logs can support/refine stratigraphic analyses from cuttings
  - Density average: 2.34 g/cm^3 (2.05 – 2.63 g/cm^3 ± 2 SD)
  - Velocity (Vp) average: 2300 m/s (1630 – 3000 m/s ± 2 SD)

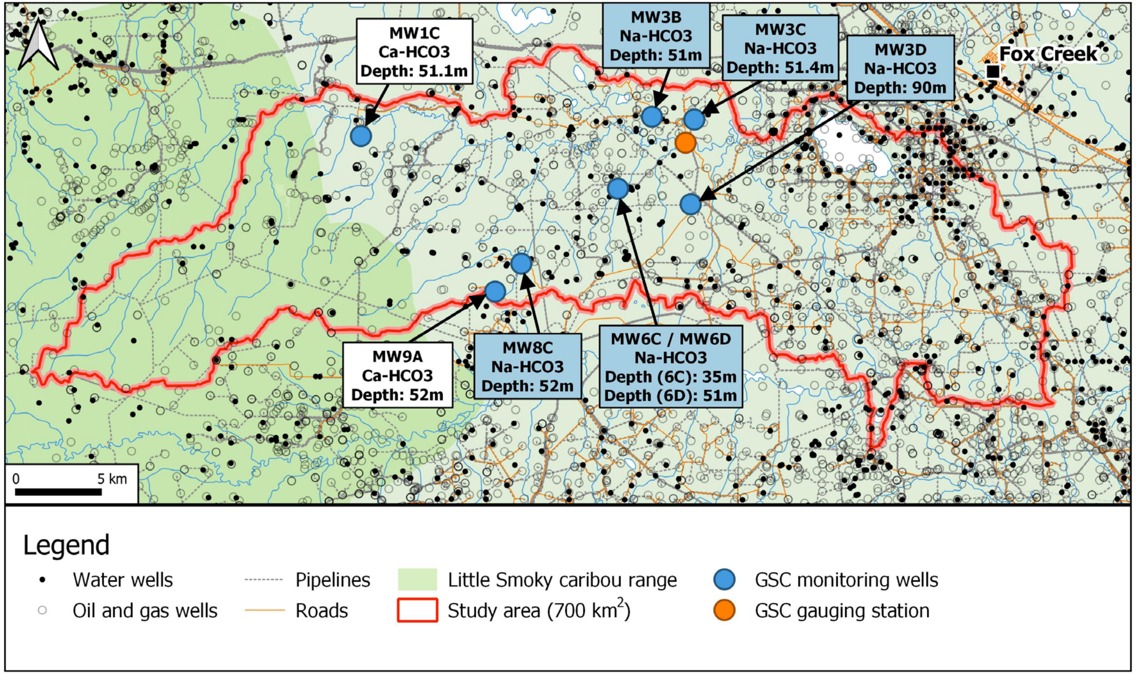
- Structural features:
  - Bedding is ~horizontal, some high angle joints
  - Stereonet/fracture frequency analyses from borehole imagery to come
  - Borehole wall roughness influences data analyses



by Heather Crow

Geochemistry - Groundwater

Map of water types

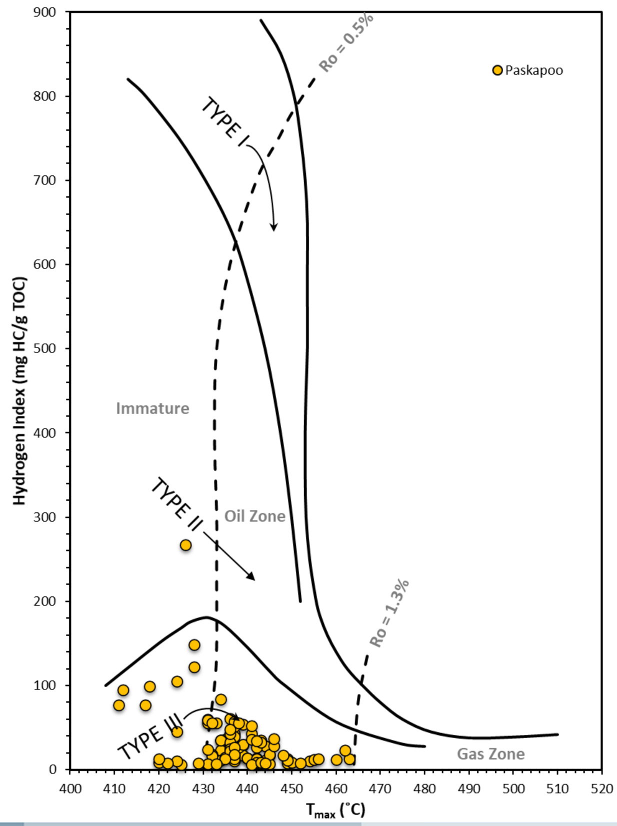


Only 4 wells contained dissolved methane: MW-3-D (90 m) and three private wells.
All of **microbial** origin.

Geochemistry - sediments

HAWK (pyrolysis) analyses were performed on 97 samples.

- Based on their TOC (total organic carbon) content, 18 samples were selected for petrography
- TOC values range from 0.2 to 8.8 wt.% with a mean value of 0.95 ± 1.6 wt. %
- Thermal maturity varies from immature to mature
- The organic-rich layers is composed of Type III (terrestrial) kerogen.

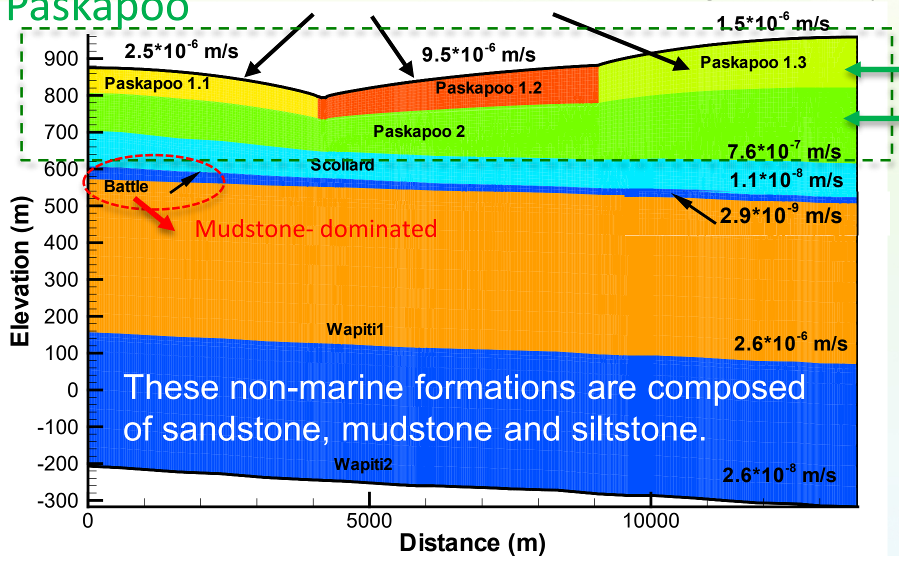


Hydrogeological modeling

2D model (FLONET)

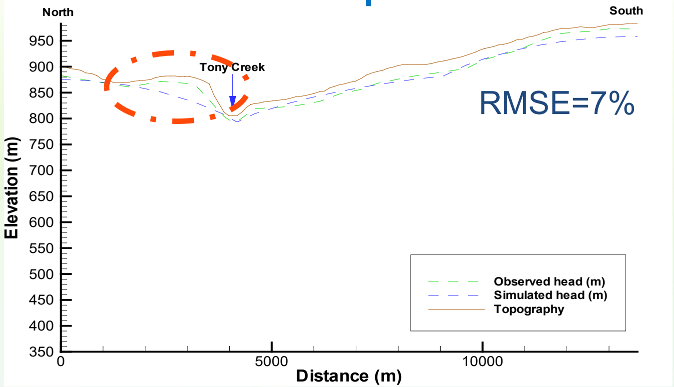
Paskapoo

Recharge = 70 mm/y



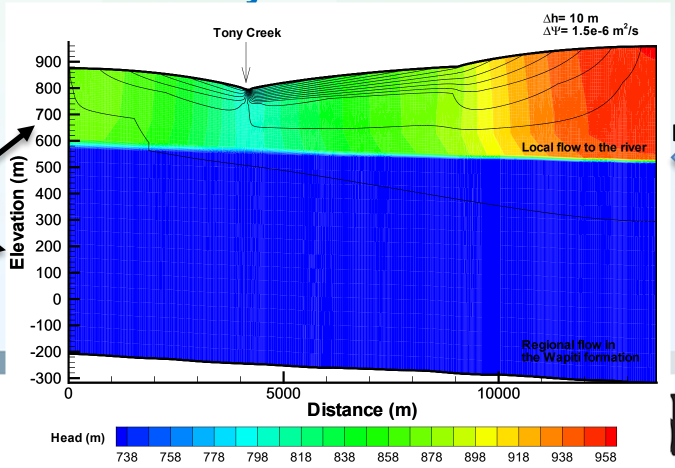
Highly fractured

Simulated versus interpolated water table



RMSE=7%

Hydraulic heads



Battle Fm.

Two hydrogeological systems separated by a nearly impermeable unit (Battle Fm.).

However, the Battle Fm. is not always present across the study area.

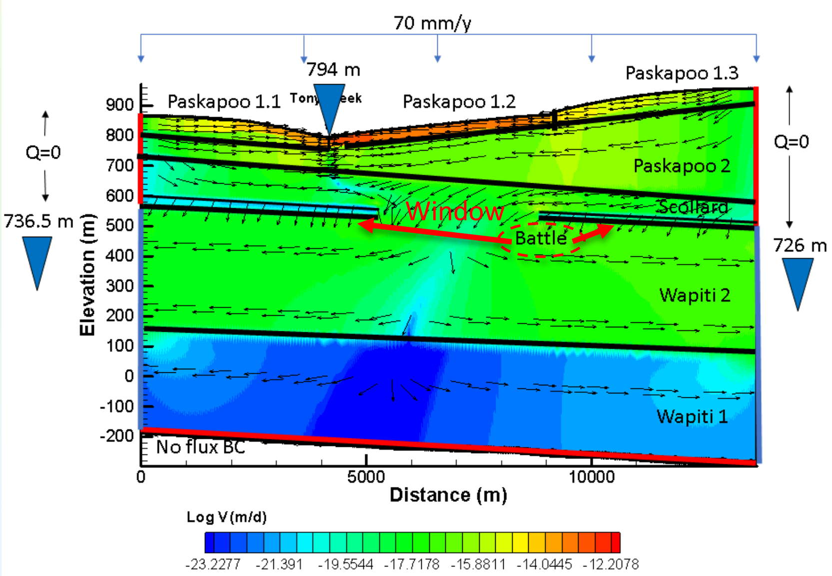
Ressources naturelles Canada

by Laura I. Guarin-Martinez, M.Sc. student

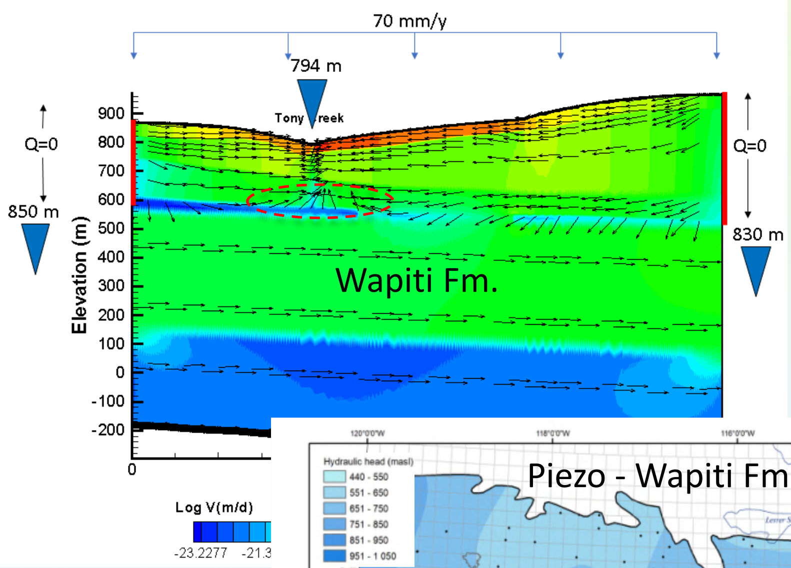
Hydrogeological modeling

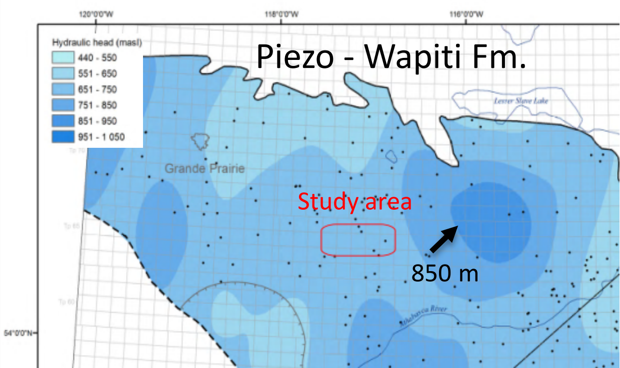
Scenarios with a discontinuous Battle Fm. – Upward flow?

Base case boundary conditions



Higher hydraulic heads in the Wapiti Fm.



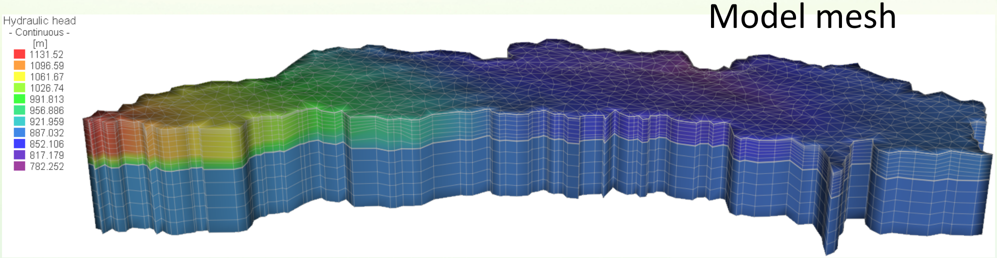


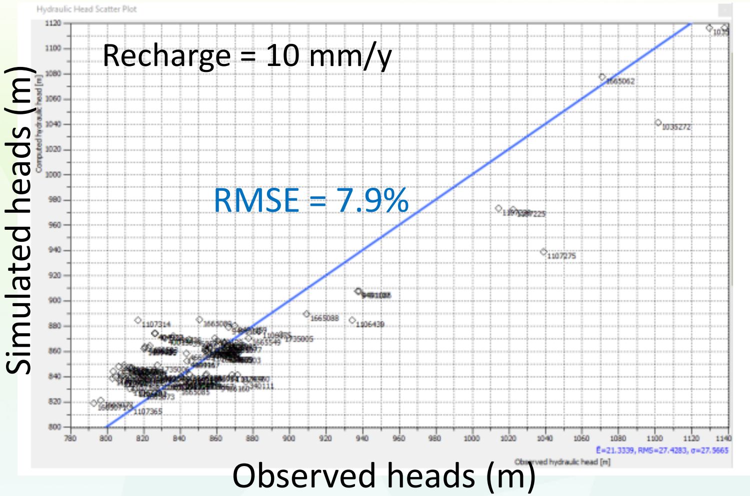
by Laura I. Guarin-Martinez, M.Sc. student

Hydrogeological modeling

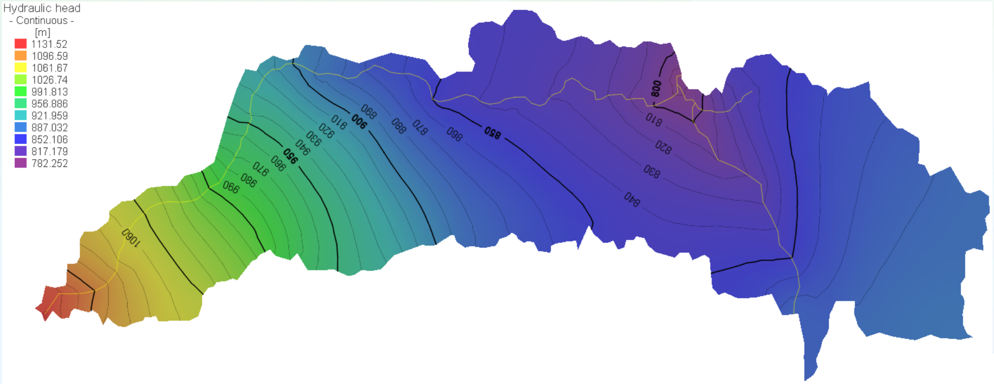
3D model (FEFLOW)

Model mesh





Hydraulic heads



- More heterogeneity will be integrated
- Different scenarios will help better understand the (shallow and deeper) hydrodynamics
- Ecohydrological model
- Study on soil moisture and snow cover

} to come

Cumulative effects assessment (CEA)

Objectives:

1. Provide an overview of the state of scientific knowledge on CEAs through a literature review.

2. Learn about the opinions, views and concerns of Indigenous communities on CEAs and hear their recommendations on the CEA process and their involvement/participation in this process to improve the practice of CEA in general, via (virtual) focus groups.

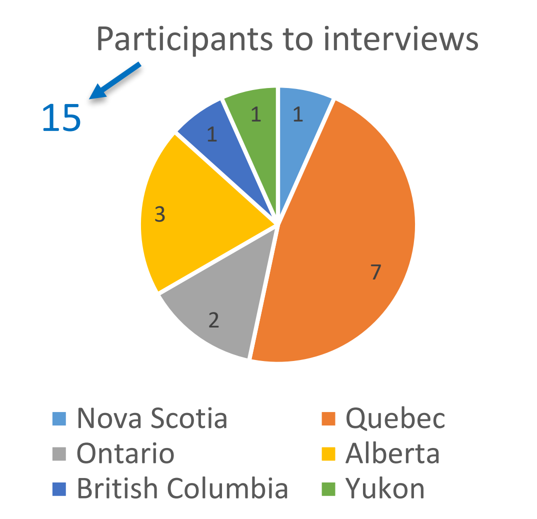
3. Identify hindrances faced by consultants in the CEA process in Canada and hear their recommendations for improving the practice, via (virtual) interviews.

4. Based on the content analysis of the discussions, make concrete and realistic recommendations to address the difficulties and barriers currently encountered in the practice of CEAs in Canada, so that they can be conducted more effectively and respectfully.

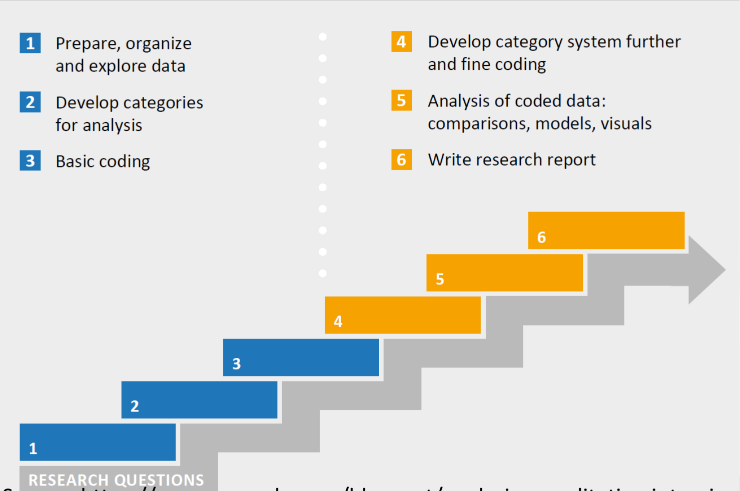
by Philippe Leblanc-Rochette, M.Sc. student

Cumulative effects assessment (CEA)

1) 15 semi-structured interviews with environmental assessment (EA) practitioners and federal government managers working in EAs
2) 5 focus groups with Indigenous communities and committees (QC, AB)
3) Data analysis of the interview/discussion transcriptions using the MAXQDA software



Analyzing Qualitative Interviews with MAXQDA in 6 Steps



Source: https://www.maxqda.com/blogpost/analyzing-qualitative-interviews-in-6-steps

THANK YOU!

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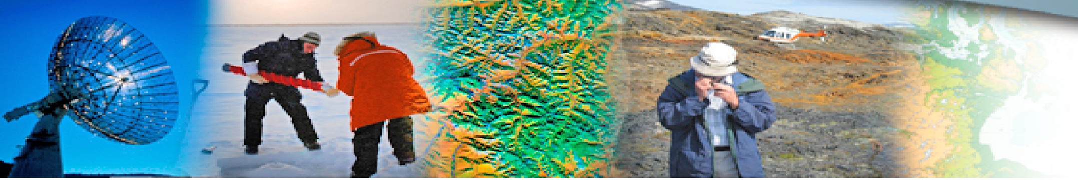


Recent development for the characterisation and modeling of aquifer systems

Daniel Paradis

October 13, 2021

Current Activities

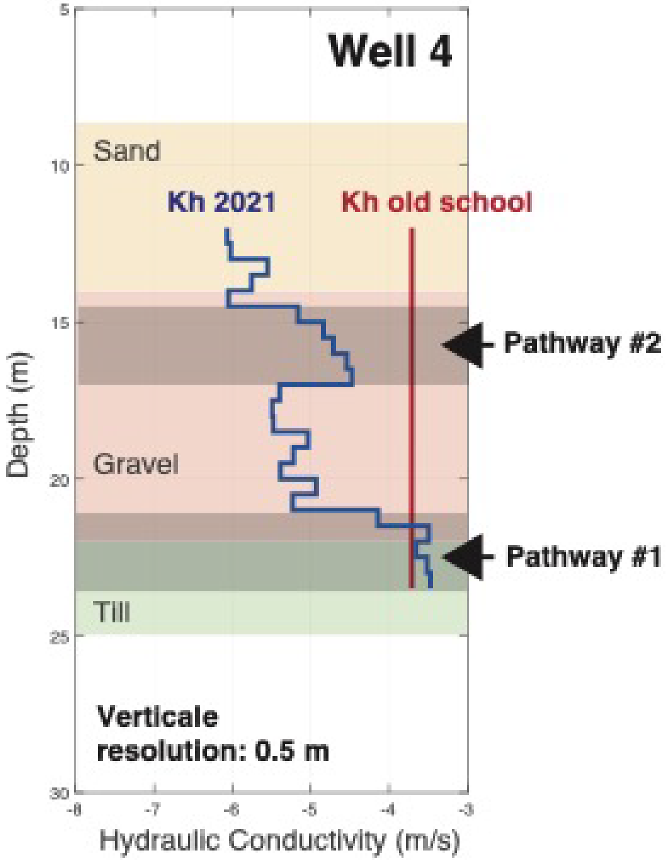
- **High-resolution aquifer characterization for the optimization of a pump-and-treat system:** Paradis, Gloaguen, Claprood
- **Hydraulic conductivity from NMR logs in sediments with elevated magnetic susceptibilities:** Crow, Paradis, Grunewald, Liang, Russell
- **Development of oscillatory hydraulic tomography:** Nefzi, Lefebvre, Paradis, Bourg
- **Coupled temperature and hydrological modelling for assessing low flow conditions:** Arzola, Paradis, Lefebvre, St-Hilaire
- **AI for real-time water resources forecasting:** Liang, Gloaguen, Paradis
- **Numerical modelling of groundwater flow and age in an Appalachian aquifer system :** Mathis, Lefebvre, Molson, Paradis

High-resolution aquifer characterization for the optimization of a pump-and-treat system

- Background:
  - Operating of a pump-and-treat system to capture contaminants in a sand-gravel-till-roc aquifer system
  - The system is costly to operates as large volumes of water are unnecessary treated
  - A better characterization of the heterogeneity could help to optimize the system
  - A GSC-INRS collaboration

Characterization Program Objectives

- Developed a modern characterization program to:
  - Quantify hydraulic properties values (incl. Kv) for each sediments (sand, gravel, silt, till, roc)
  - Identify the main contaminant pathways (if any)



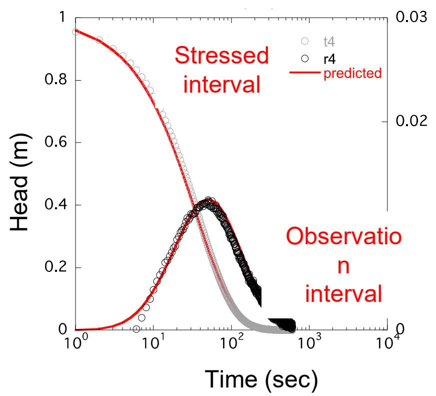
GSC-INRS Testing Method

Journal of Hydrology 478 (2013) 102–118

Contents lists available at SciVerse ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol



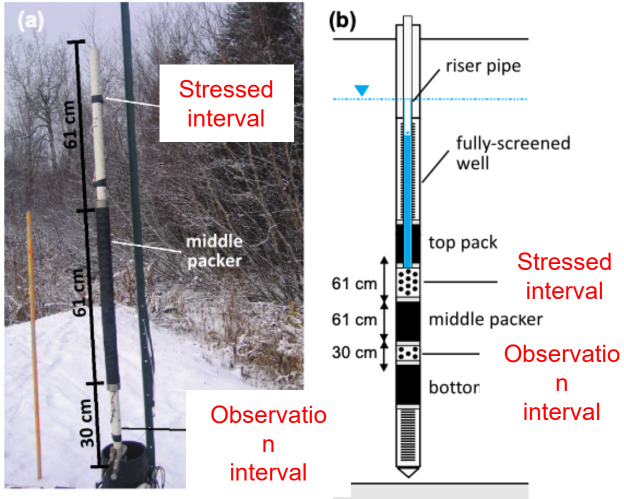
Single-well interference slug tests to assess the vertical hydraulic conductivity of unconsolidated aquifers

Daniel Paradis [a,b,*], René Lefebvre [b]

[a] Geological Survey of Canada, 490 Rue de la Couronne, Quebec City, Canada G1K 9A9

[b] Institut National de la Recherche Scientifique, Centre Eau Terre Environnement (INRS-ETE), 490 Rue de la Couronne, Quebec City, Canada G1K 9A9

- Developed by the GSC-INRS to overcome the lack of field method to estimate vertical permeability



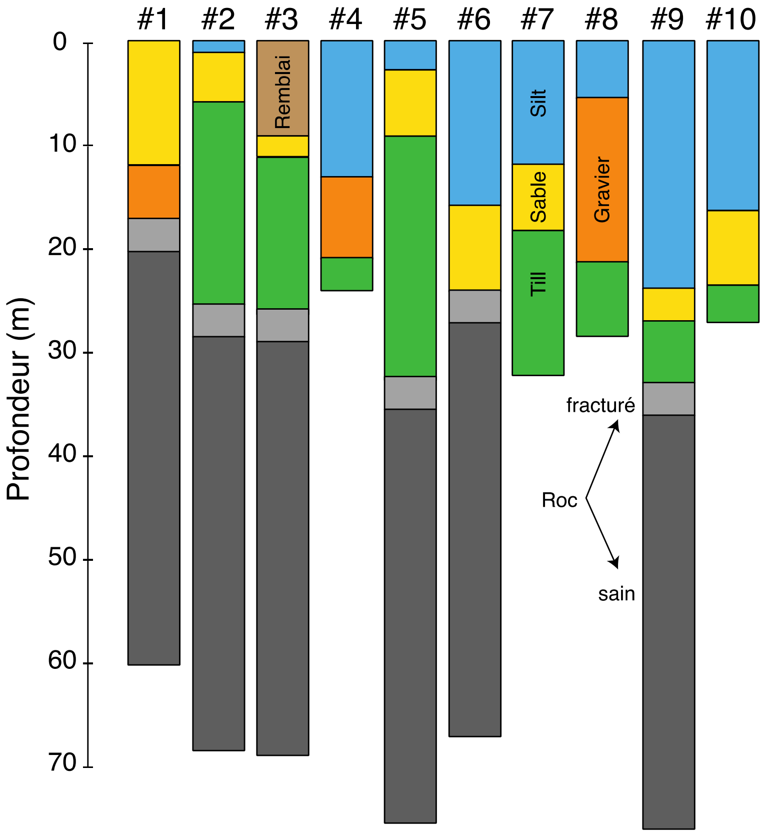
Characterization Challenges for the Site

- Acquire **high-quality** and **high-resolution** data for all materials in a **reasonable amount of time**…
  - Several wells (in sediments and roc)
  - Sediments with contrasting properties

Silt

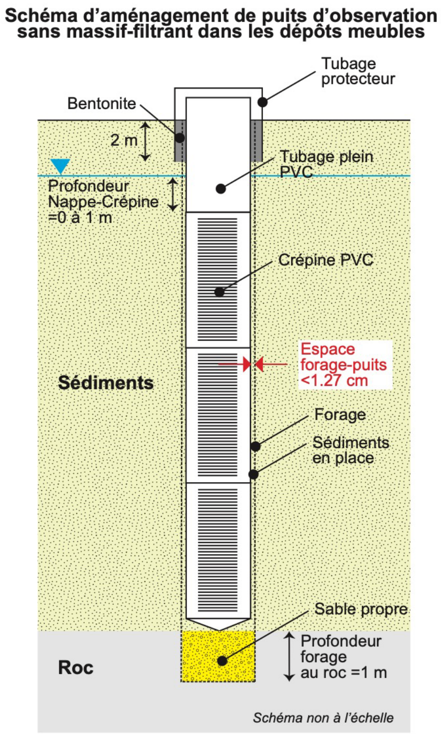
Gravel

Till



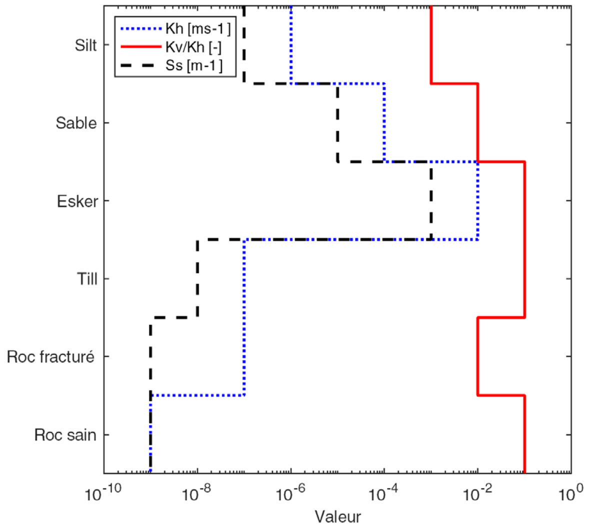
Special Well Installation in Sediments

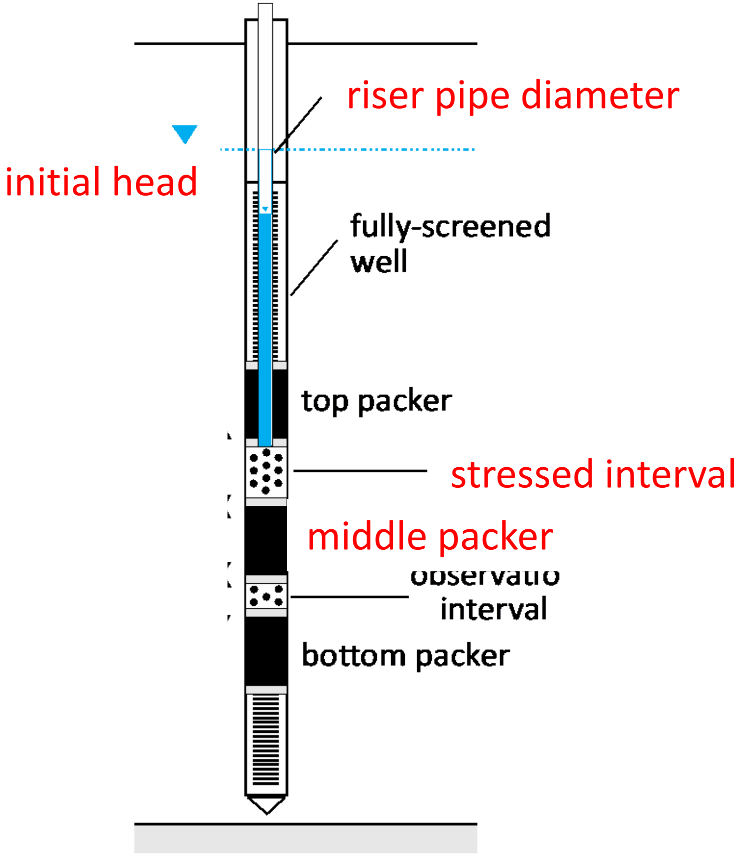
- Adapted drilling rig to have screen in direct contact with sediments (no sand-pack; small hole-well space)
- Fully-screened well across the aquifer
- Essential for high-resolution profiling



Testing Assembly Optimization

- Trade-off between test duration and quality of data
- Simulated sensitivities and heads for different sediments and testing assembly configurations

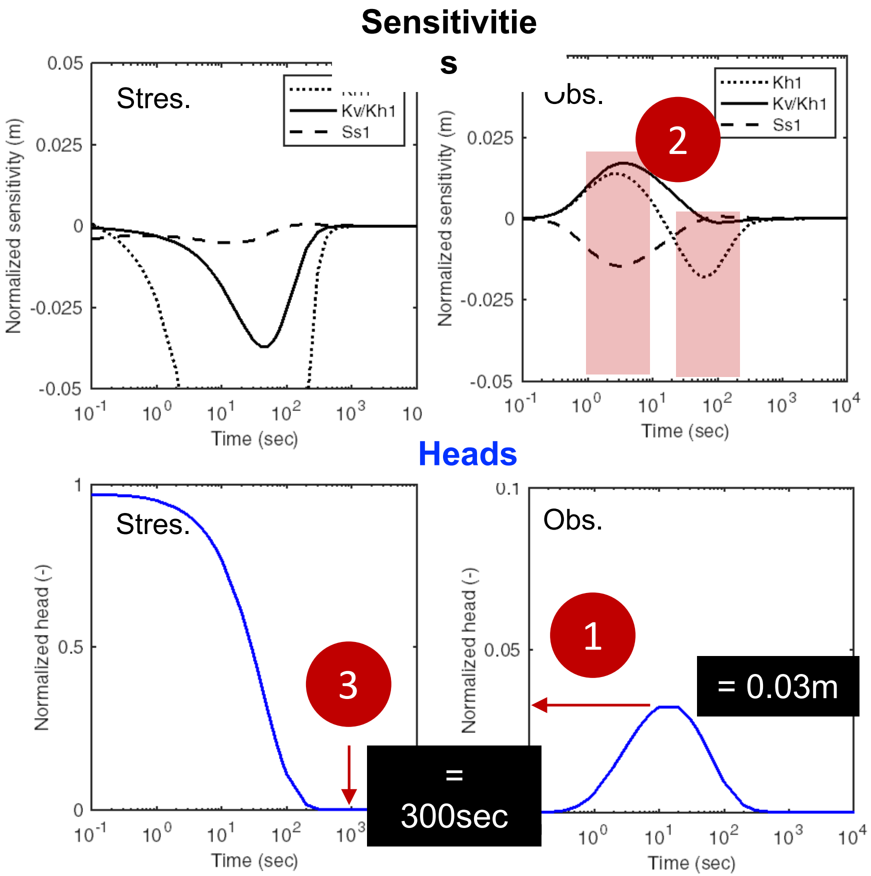




Example of Optimization

Optimization criteria:

1. Heads (in Obs.)
2. Sensitivities for each hydraulic property (in Obs.)
3. Duration of the test

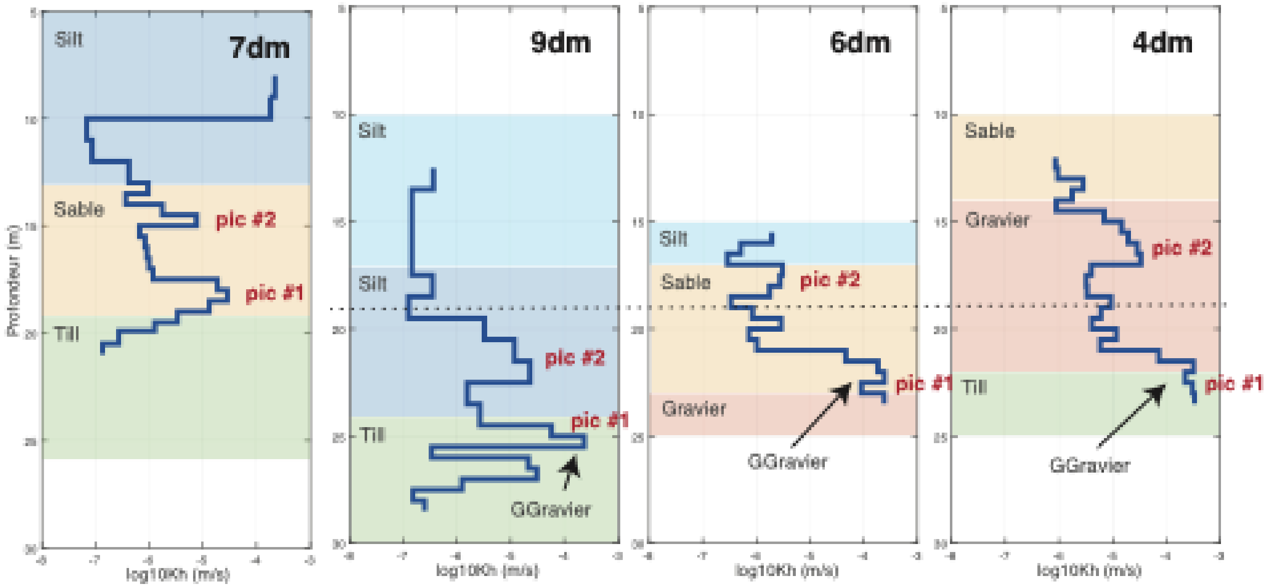


Assembly and Test Parameters

Material	Assembly				Test	
	L (m)	D (m)	rw (in)	rc (in)	Duration	H0 (m)
Silt	2.0	0.5	4	1.5	42 min	1
Sand	0.5	0.5	4	2.5	5 min	2
Gravel	0.25	0.5	4	2.5	< 1 min	4
Till	2.0	0.5	4	1	2h00	1
Fractured roc	2.0	0.5	3	1	2h45	1
Roc	5.0	0.5	3	0.5	>24h	1

Results: Contaminant Pathways

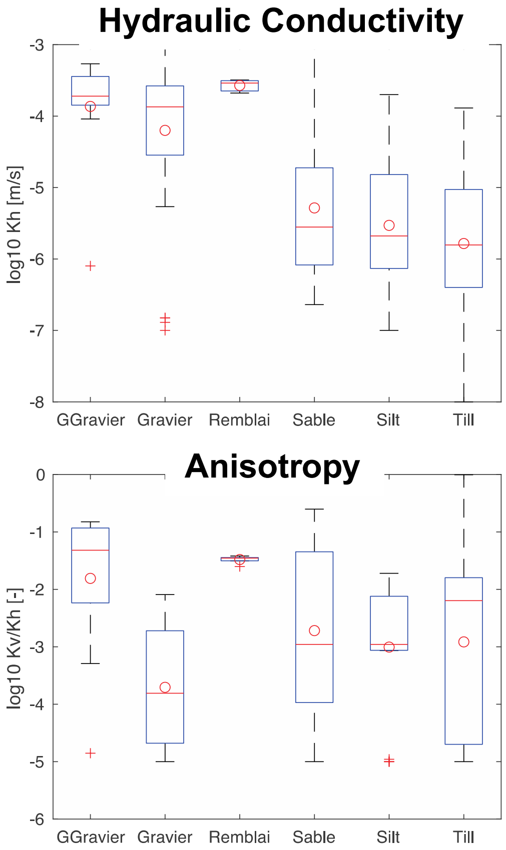
- >250 hydraulic tests @0.5-2 m vertical resolution
- Large variations in permeability (~4 orders)
- Recognition of two high-permeability pathways



Approx. separation between wells 1.5 km

Results: Hydraulic Properties Distributions

- Define the distribution of **hydraulic conductivity** and **anisotropy** values for each sediments unit (6 units)



Conclusions

- Provide new insights about the potential migration pathways of contaminants
- Quantify hydraulic property values for all sediments (incl. anisotropy)
- Will help to improve the **security** of the pump-and-treat system and to lower its **cost of operation**

Contact Information

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Natural Resources Canada   Ressources naturelles Canada

Ring of Fire: Reconstructing long-term environmental records to support regional assessment

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Josué Jautzy - Josue.Jautzy@NRCan-RNCan.gc.ca

October 13th, 2021

Canada

Background

Ring of Fire (RoF) = large mineral deposits of Ni/Cu/Zn/Cr and PGM

- Located in one of the world's largest wetland system;
- Sensitive to climate change (Hadley et al., 2019) and anthropogenic stresses (Leclair et al., 2015)

Additional knowledge on environmental conditions required:

- Baseline conditions response to climate change + remote anthropogenic stresses
- Changes to groundwater flow dynamic, geochemical fate of metal(loid)s in surface storage of tailings and waste rocks over time.
- Natural presence/behavior of metal(loid)s needs to be carefully assessed

Main objective

Improve knowledge on the evolution of the wetlands baseline conditions in response to climate and anthropogenic stresses and their effects on metal(loid)s mobility.

PROJECT TEAM

J. Jautzy[1], N. Benoit[1], J. Marion[1], M. Parsons[1], Paul Gammon[1], Pierre Pelchat[1], A. Desbarats[1], G. Légaré-Couture[2], P. Bergeron[1], M. Parent[1], J. Galloway[1], J. Ahad[1], B. Fosu[1], C. Bégin[1], É. Girard[1], E. Berryman[3], J. Girard[4], M. Garneau[5], M. Bunn[1], F. Letourneau[1], M. Nastev[1], A. Dixit[1], N. Balliston[6], S. Finkelstein[7], Finn Viehberg[8]

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[5]Université du Québec à Montréal
[6]University of Waterloo
[7]University of Toronto
[8]Greifswald Universität

Activities

- Remote RoF geoscience baseline conditions : regional hydrostratigraphy and surficial geology mapping;
- Environmental archives study on a pre-mining analog context of chromite deposit – Menarik lake (Qc);
- Environmental study on a post-mining analog context of chromite deposits – Chaudière-Appalache (Qc);
- Analytical development of Chromium speciation analyses in water: laboratory and field development;

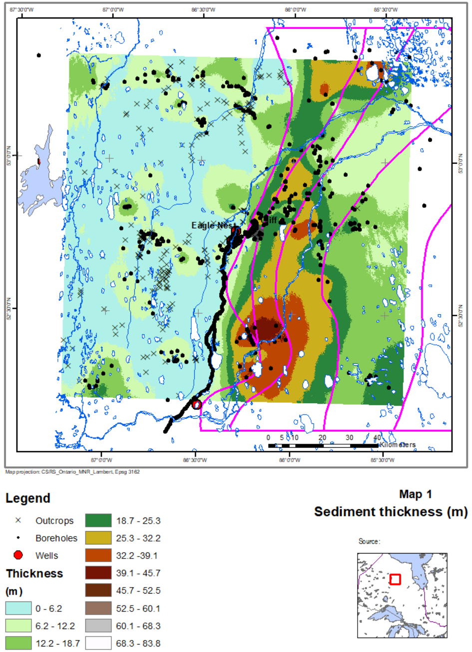
Study areas

- Ring of Fire: McFauld lake area
- Analog site 1: Menarik lake pre-mining context (580 km)
- Analog site 2: Chaudière-Appalaches post-mining context (1300 km)

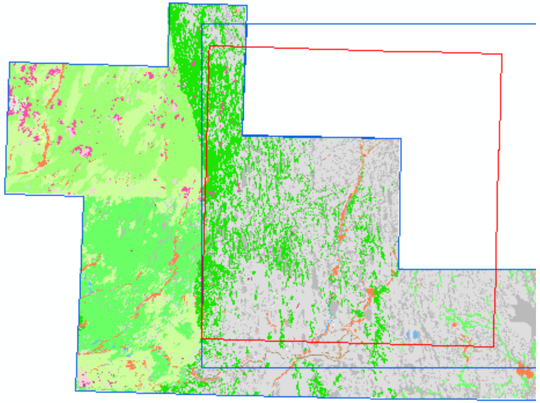
RoF geoscience baseline conditions

Improve the regional hydrostratigraphy knowledge of the Ring of Fire area.

Sediment thickness estimation

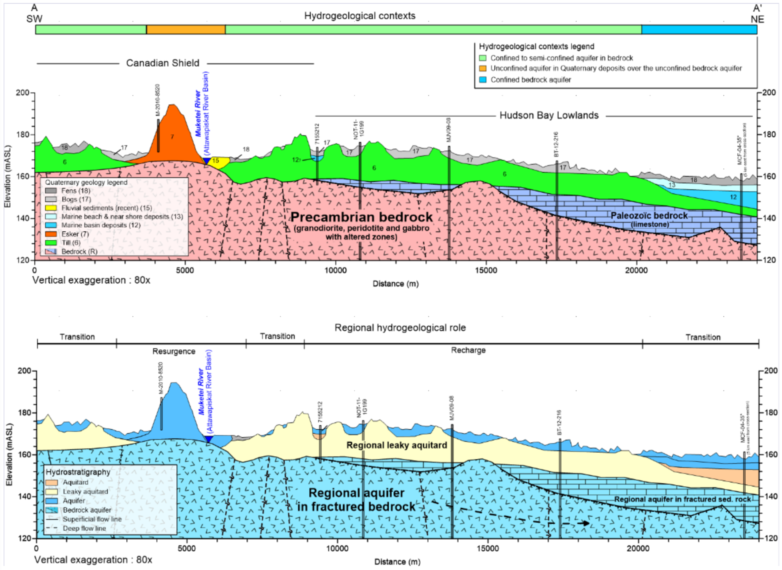


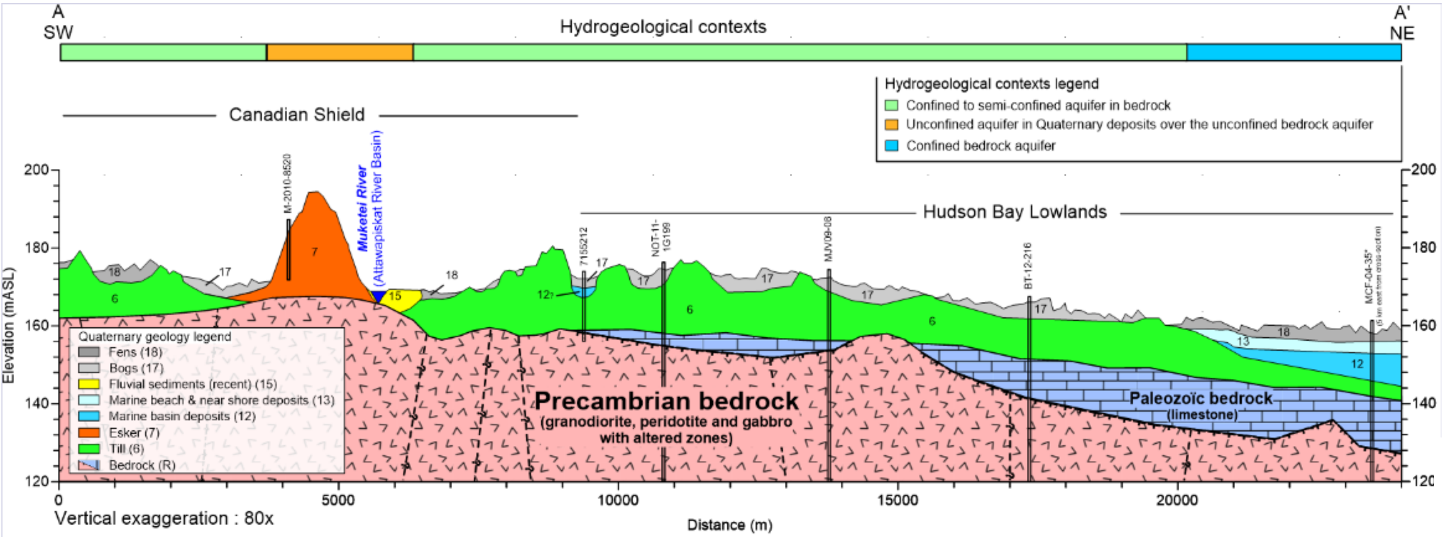
Surficial geology

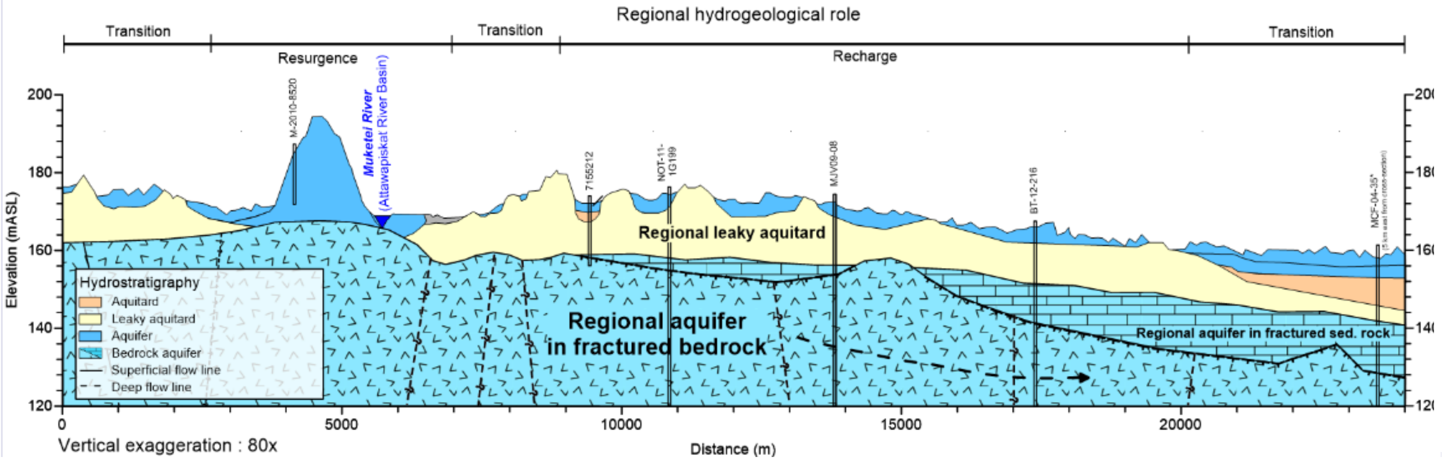


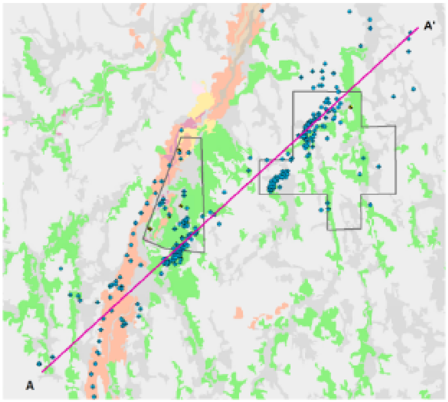
Incomplete mapping

Conceptual model of the hydrostratigraphy









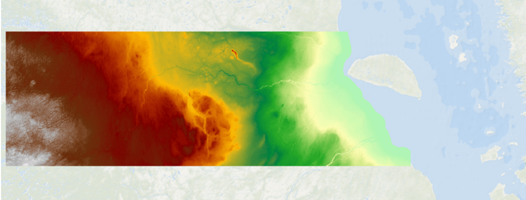
- Wetlands omnipresent: underlying low permeability deposits
- Water table near to surface
- Eskers have a high permeability (mostly dry)
- Surface till = leaky aquitard recharging the bedrock
- Silts and clays associated with the Tyrrel Sea
- Quality data and 3D model is needed

Surficial geology: Machine Learning workflow

Data

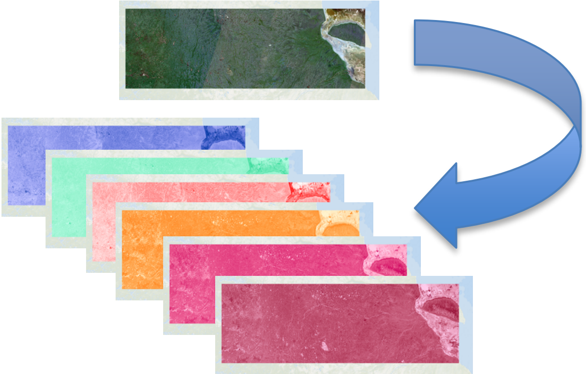
Surficial geology

Digital elevation model



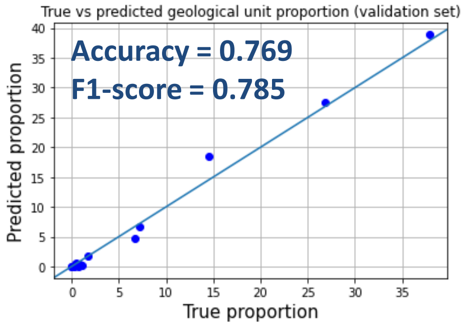
Satellite images

Data processing

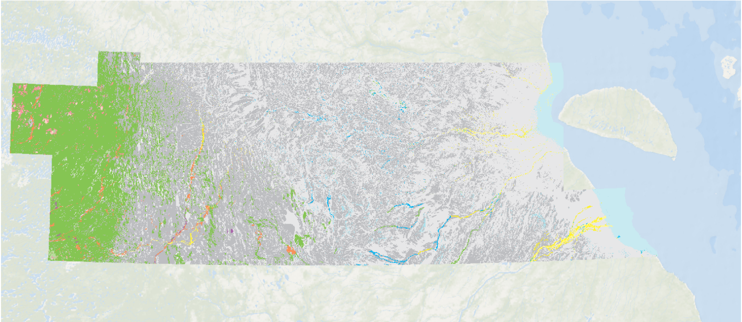


Algorithms implementation CNN and RF

Model Training and optimisation



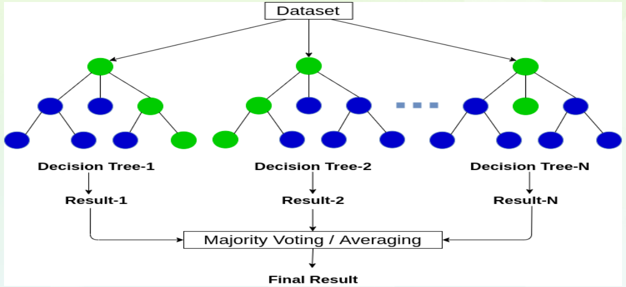
Prediction and validation



Major challenge: class imbalance (p>14%=f1>0.72; p<14%=f<0.57)

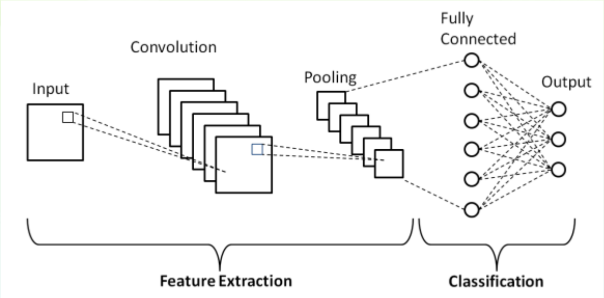
Random Forest vs Convolutional Neural Nets

RF



- ⊖ Generic machine learning algorithm for tabular data
- ⊕ Requires less data and easier to train
- ⊕ Easy to deal with missing data and categorical data
- ⊖ Each pixel is modeled independently from its neighbours

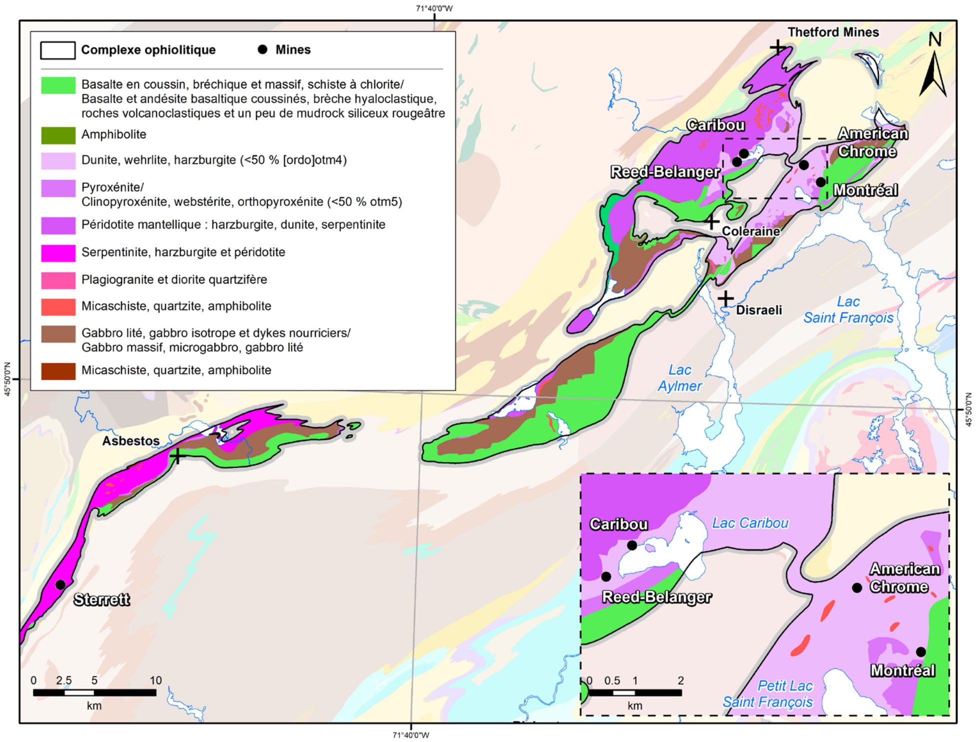
CNN



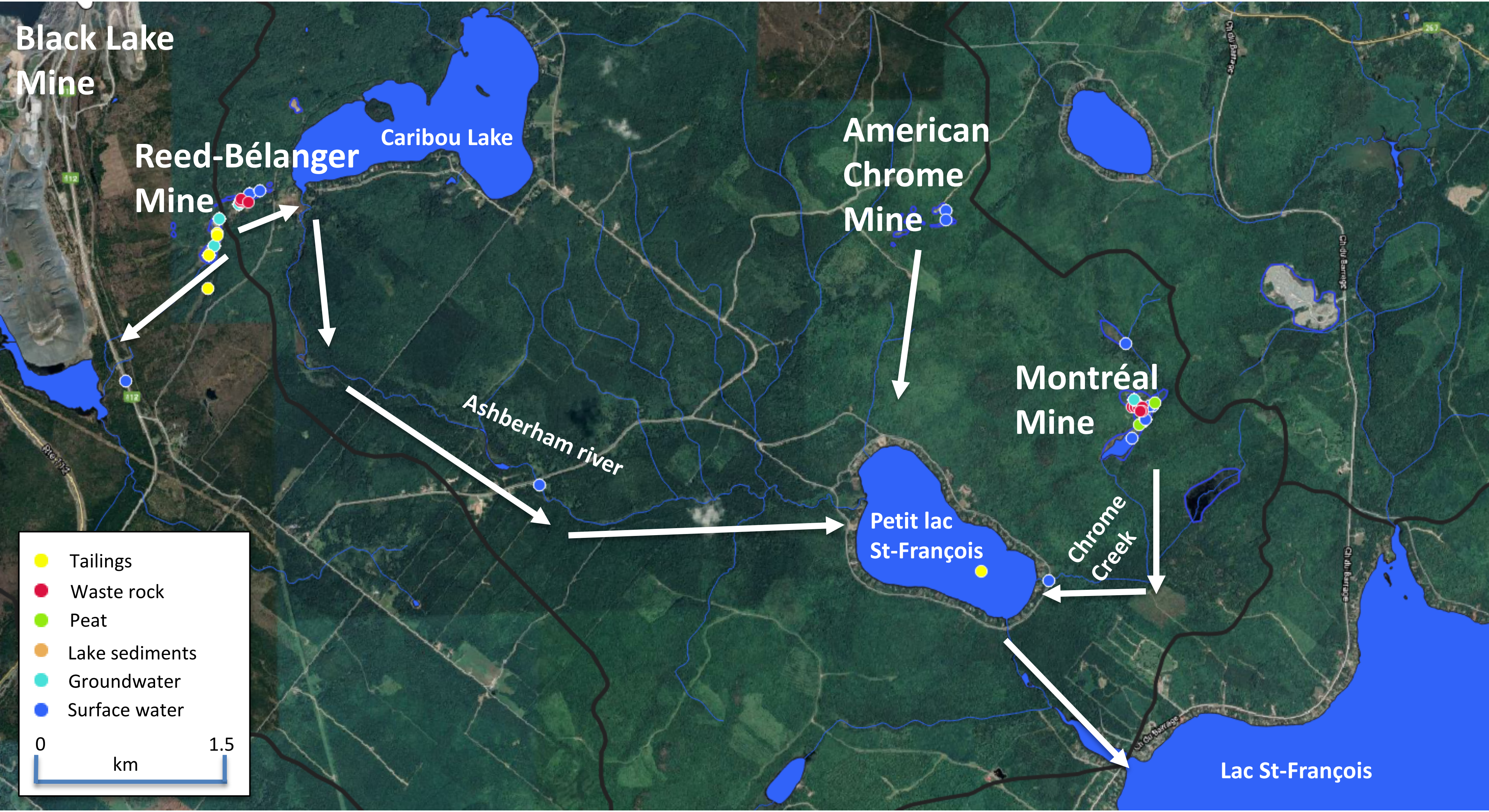
- ⊕ Deep learning algorithm designed specifically for processing images
- ⊖ Computationally expensive (requires GPU)
- ⊖ Requires more careful data pre-processing
- ⊕ Detects and models correlations between neighbouring pixels

Post-mining context

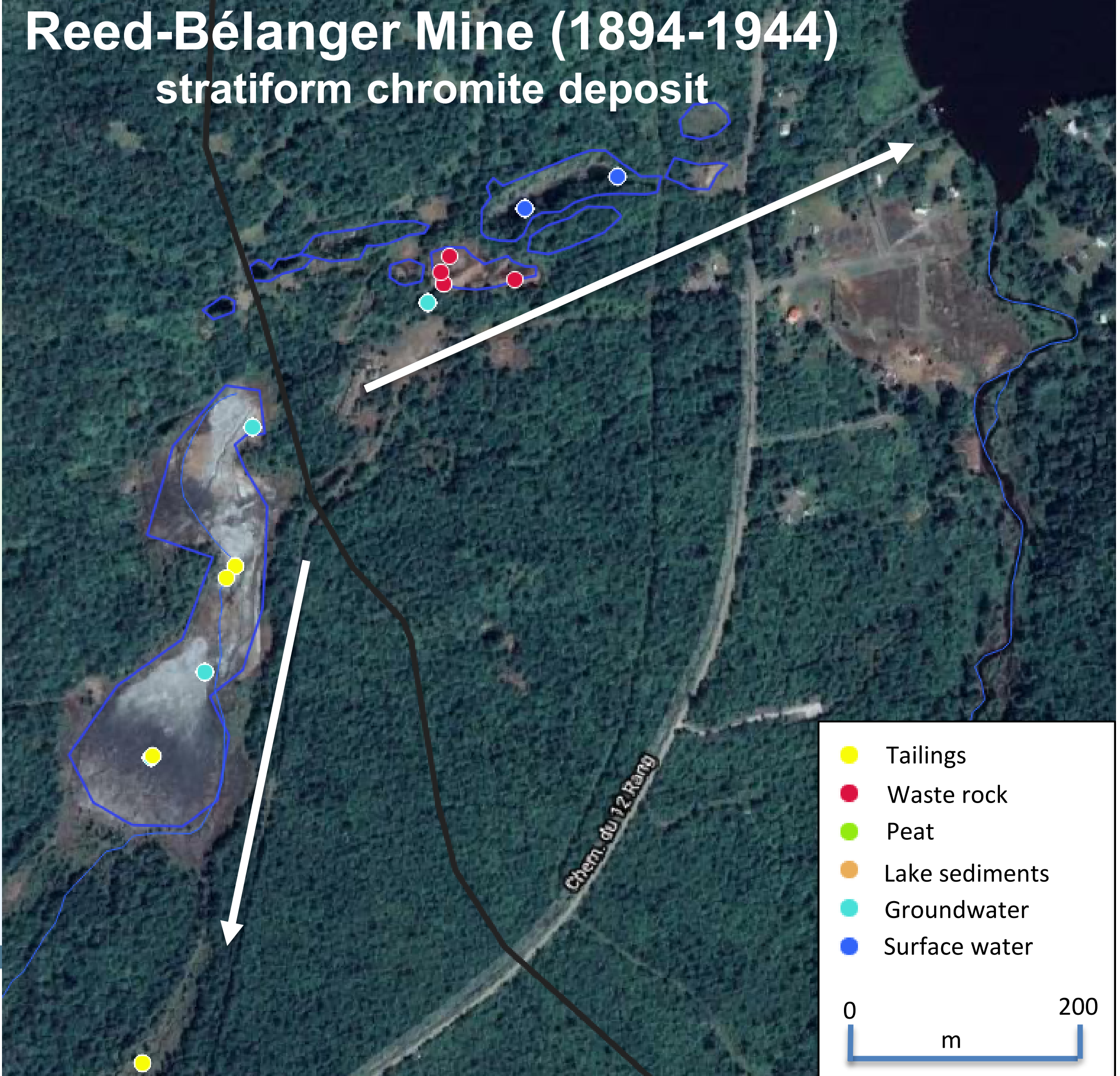
- Analog chromite deposit context; Ophiolitic complex of Thetford
- 5 abandoned mines (American Chrome, Montreal, Reed-Belanger, Caribou, Sterrett)
- Field work focusing on chromium availability/mobility

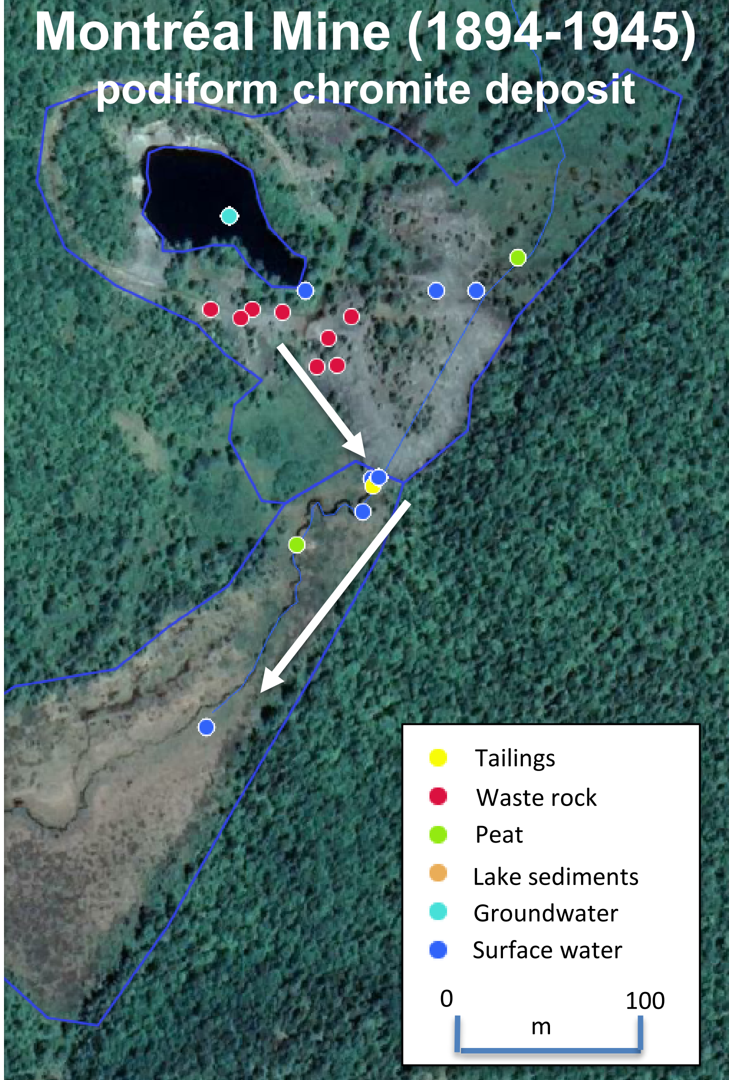


Field work: Post-mining site



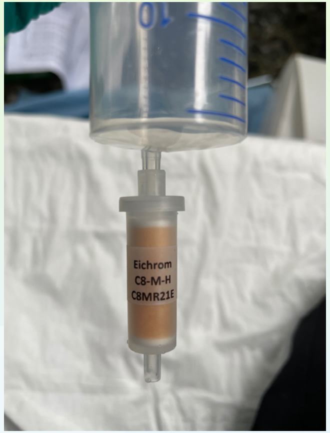
Black Lake Mine
Caribou Lake
Reed-Bélanger Mine
American Chrome Mine
Ashberham river
Montréal Mine
Petit lac St-François
Chrome Creek
Lac St-François
Tailings
Waste rock
Peat
Lake sediments
Groundwater
Surface water
0
1.5
km


Reed-Bélanger Mine (1894-1944)
stratiform chromite deposit
Chem. du 12 Rang
Tailings
Waste rock
Peat
Lake sediments
Groundwater
Surface water
0
200
m


Montréal Mine (1894-1945)
podiform chromite deposit
Tailings
Waste rock
Peat
Lake sediments
Groundwater
Surface water
0
100
m

Analytical development of Cr speciation in water

- Analyses of Cr in the environment is complicated due to its possible interspecies conversion from the time of sampling to the time of analyses.
- Development of analytical methodologies at the GSC to mitigate this issue.
- Inter-laboratory comparison with different measurement techniques are anticipated to validate the developed methodology.



Water sampling → filtering 0.22um → separation of CrIII/ CrVI

Conclusion

- Preliminary regional hydrostratigraphic conceptual model for the RoF;
- Surficial geology mapping using Machine Learning: encouraging preliminary results; better address unbalanced data set
- Fields works are completed (water, rock, sediments, peat);
- Samples analysis is the next phase;

CONTACT INFORMATION

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- Josue.Jautzy@NRCan-RNCan.gc.ca

Thank you / Merci!

Natural Resources Canada
Ressources naturelles Canada

Canada One Water:
Integrated Groundwater – Surface-Water – Climate Modelling for Climate Change Adaptation

Hazen A.J. Russell and Steven K. Frey
Geological Survey of Canada, Groundwater Geoscience Program
Aquanty Inc. aquanty

GGP: 2021-10-13

Canada

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  - Historic climatology: Dan McKenney
  - Soil characterization: David Lapen and Xiaoyuan Geng
  - Geology: Hazen Russell and Boyan Brodaric
  - Permafrost: Brendan O'Neill
  - HydroGeoSphere modelling: Steve Frey
  - Decision support and risk analysis: Aquanty
  - Validation: Watershed water balances – Shusen Wang
  - Validation: GRACE modelling – John Crowley

- Science Advisors:
  - Ed Sudicky (FRSC) and Richard Peltier (FRSC)

Scientific Expertise

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- Éric Boisvert
- Melissa Bunn
- Eric De Kemp
- Chris Fletcher
- Tyler Herrington
- Michael Hillier
- Eric Kessel
- Omar Khader
- Fraser King
- Heather MacDonald
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- Canadian Centre for Mapping and Earth Observation (CCMEO)
- Surveyor General Branch (SGB)

Aquanty:

Agriculture and Agri-Food Canada (AAFC):

University of Toronto

- Earth Atmospheric and Planetary Physics

University of Waterloo

- Earth and Environmental Sciences

Abstract

Canada 1 Water is a 3 year governmental multi-department–private-sector–academic collaboration to model the groundwater–surface-water of Canada coupled with historic climate and climate scenario input. To address this challenge continental Canada has been allocated to one of 6 large watershed basins of approximately two million km^2. The model domains are based on natural watershed boundaries and include approximately 1 million km^2 of the United States. In year one (2020-2021) data assembly and validation of some 20 datasets (layers) is the focus of work along with conceptual model development. To support analysis of the entire water balance the modelling framework consists of three distinct components and modelling software. Land Surface modelling with the Community Land Model will support information needed for both the regional climate modelling using the Weather Research & Forecasting model (WRF), and input to HydroGeoSphere for groundwater–surface-water modelling. The inclusion of the transboundary watersheds will provide a first time assessment of water resources in this critical international domain. Modelling is also being integrated with Remote Sensing datasets, notably the Gravity Recovery and Climate Experiment (GRACE). GRACE supports regional scale watershed analysis of total water flux. GRACE along with terrestrial time-series data will serve provide validation datasets for model results to ensure that the final project outputs are representative and reliable. The project has an active engagement and collaborative effort underway to try and maximize the long-term benefit of the framework. Much of the supporting model datasets will be published under open access licence to support broad usage and integration.

Project Objectives

- develop fully-integrated groundwater –Surface-water model(s) for Canada
- use models to evaluate the potential influence of Climate Change on water resources (large scale)
- translate model output into societal-relevant metrics

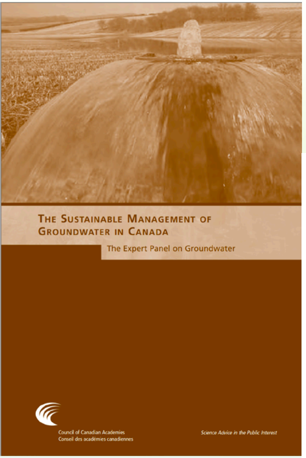
Project Symbolism / Vision

Colour and symbolism

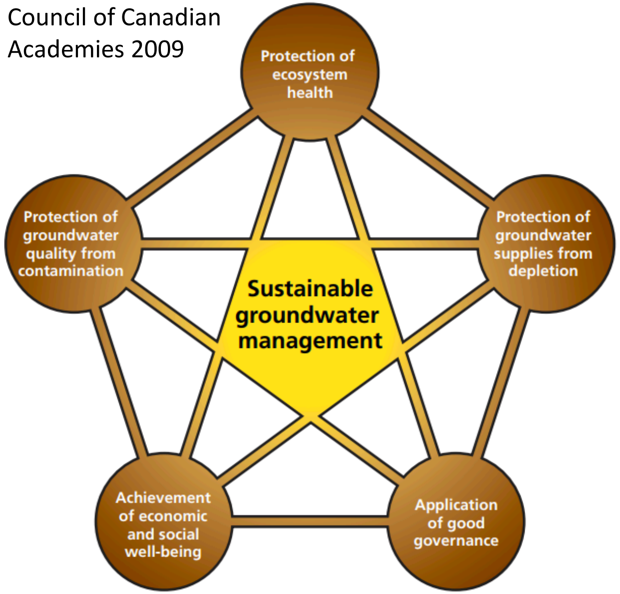
- elements that make up the water cycle.

- **yellow and white rays:** signifies the sun and the solar energy that drives the system.
- **rays** are also an abstraction of a graduated measure to signify quantification of the water balance.
- **water droplet:** introduces water with –
  - green leaf conveying land cover and evapotranspiration,
  - pale blue fleche signifying atmospheric water.
- **dark blue lower semi-circle:** groundwater–surface-water is represented and symbolising the coupled nature of groundwater–surface-water.
- **upward form of the water droplet:** can also be imagined as symbolizing the re-entrainment of water through evaporation and evapotranspiration to the atmosphere.

Groundwater Sustainability



Council of Canadian Academies 2009



- integrated resource management
- climate change scenarios
- decision support
- communication
- open access

Continental Modelling Timelines

Journal of Hydrology **9** (1969) 237-258; © *North-Holland Publishing Co., Amsterdam*

BLUEPRINT FOR A PHYSICALLY-BASED, DIGITALLY-SIMULATED HYDROLOGIC RESPONSE MODEL

R. ALLAN FREEZE
Inland Waters Branch, Department of Energy, Mines and Resources, Calgary, Alberta, Canada
and
R. L. HARLAN
Forestry Branch, Department of Fisheries and Forestry, Calgary, Alberta, Canada

Abstract: In recent years hydrologists have subjected the various subsystems of the hydrologic cycle to intensive study, designed to discover the mechanisms of flow and to arrive at physical and mathematical descriptions of the flow processes. As a consequence, meaningful results are now available in the form of numerical solutions to mathematical boundary value problems for groundwater flow, unsaturated porous media flow, overland flow, and channel flow. These developments in physical hydrology, together with the tremendous advance in digital computer technology, should provide the impetus for a necessary redirection of research in hydrologic simulation. In this paper, a blueprint for the development of physically-based hydrologic response models is presented; the level of sophistication that can be achieved with presently available methodology is discussed; and areas for necessary future research are pinpointed.

"The ability to accurately predict behavior is a severe test of the adequacy of knowledge in any subject."

CRAWFORD and LINSLEY[1])

Introduction

"There is a group of hydrologists who espouse the pursuit of scientific research into the basic operation of each component of the hydrologic cycle in order to gain a full understanding of their mechanisms and interactions. Although the immediate motivation of an individual researcher may not transcend the narrow confines af a set of special phenomena, it is implicit that a full synthesis of the hydrologic cycle may eventually be sought. This concept of a full synthesis is held to be the only rational approach to hydrology."

Amorocho and Hart[2])

A complete physically-based synthesis of the hydrologic cycle is a concept

2021

Canada 1 Water (**2021**)

Chen et al. (**2020**) **Proof of concept Canada Scale fully-integrated model**

Erler et al. (**2019**) **Framework for coupling HGS to WRF for CC projections**

HydroGeoSphere Real Time (**2018**) released operationally

Davison et al. (**2015**) **HGS fully coupled with WRF**

Bierkens et al. (**2015**) Large scale hyper-resolution modelling – visions for future

Hwang et al. (**2014**) **HGS parallelized**, drastically increased model size

Aquanty (**2012**) formed to bring fully-integrated modelling to mainstream geoscience

Sudicky – CWN (**2009**) Canada-scale fully integrated GW-SW modelling initiative begins

Lemieux and Sudicky (**2009**) Canada scale density dependent groundwater flow

Lemieux et al. (**2008**) Canada scale groundwater recharge and seepage modelling

Therrien and Sudicky (**1996**) – HydroGeoSphere foundational work

Freeze and Harlan (**1969**) – Fully integrated modelling blueprint

1969

CANADIAN WATER RESOURCES JOURNAL / REVUE CANADIENNE DES RESSOURCES HYDRIQUES
https://doi.org/10.1080/07011784.2019.1671235
Taylor & Francis
Taylor & Francis Group
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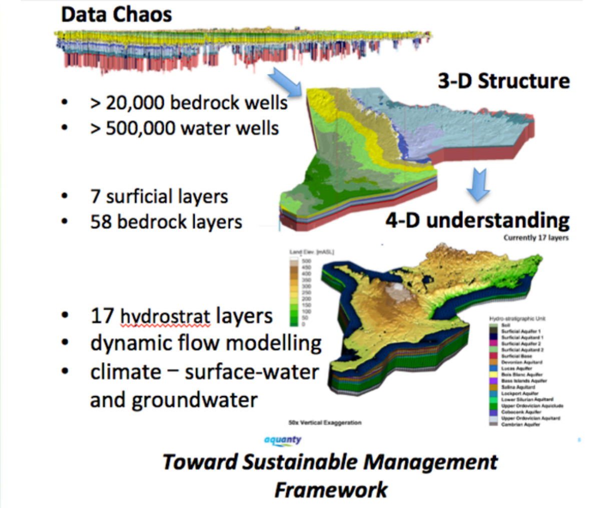
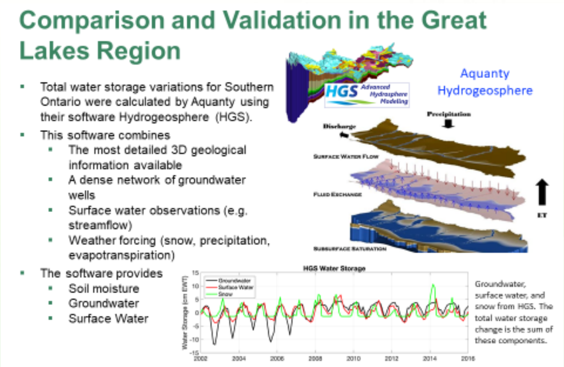
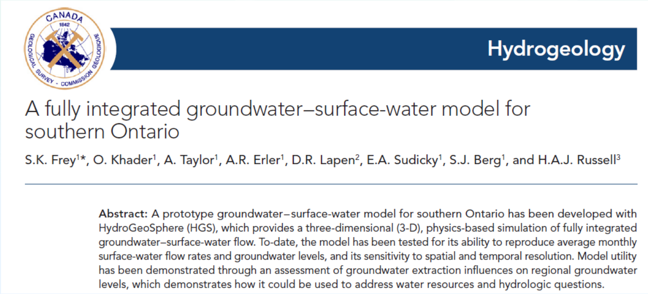
Towards a climate-driven simulation of coupled surface-subsurface hydrology at the continental scale: a Canadian example

J. Chen[a,b], E. A. Sudicky[a,d], J. H. Davison[e], S. K. Frey[a,d], Y.-J. Park[a], H.-T. Hwang[a,d], A. R. Erler[c,d], S. J. Berg[a,d], M. V. Callaghan[d], K. Miller[d], M. Ross[a] and W. R. Peltier[c]

Team Experience







Hydrogeology

A fully integrated groundwater–surface-water model for southern Ontario

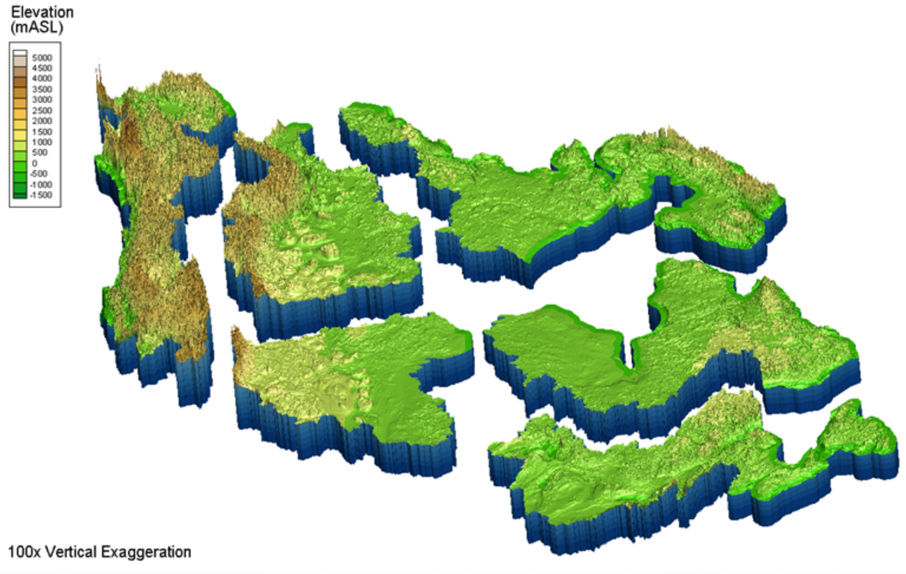
S.K. Frey[1]*, O. Khader[1], A. Taylor[1], A.R. Erler[1], D.R. Lapen[2], E.A. Sudicky[1], S.J. Berg[1], and H.A.J. Russell[3]

Abstract: A prototype groundwater–surface-water model for southern Ontario has been developed with HydroGeoSphere (HGS), which provides a three-dimensional (3-D), physics-based simulation of fully integrated groundwater–surface-water flow. To-date, the model has been tested for its ability to reproduce average monthly surface-water flow rates and groundwater levels, and its sensitivity to spatial and temporal resolution. Model utility has been demonstrated through an assessment of groundwater extraction influences on regional groundwater levels, which demonstrates how it could be used to address water resources and hydrologic questions.

- NRCAN-AAFC-Aquanty
- constructing vigorous, large scale models takes time and skill
- once constructed, many questions can be addressed
- best in class, uniform quality modelling tools can support future research projects
- open Access data layers

Southern ON. model is being used by: U Waterloo, U of T, MECP, Quinte Conservation, Oak Ridges Moraine Co….

Model Domain



Model	2Dmesh Nodes	2Dmesh Elements	Land Area (km2)	Coast Area (km2)	Total Area (km2)	Land Proportion of Canada (%)
Arctic	244346	484146	1.72E+06	6.20E+05	2.34E+06	17%
Hudson	243689	483269	2.02E+06	3.19E+05	2.34E+06	20%
Atlantic	195899	387132	1.60E+06	2.77E+05	1.87E+06	16%
Nelson	164883	326903	1.57E+06	1.58E+04	1.58E+06	16%
Mackenzie	188744	374161	1.80E+06	1.13E+04	1.81E+06	18%
Pacific	187883	371833	1.62E+06	1.79E+05	1.80E+06	16%
Total	1225444	2427444	1.03E+07	1.42E+06	1.17E+07	103%
Canada			9.99E+06			

- six drainage regions for the continental domain
- regions are approximately similar in size
- physiographic characteristics taken into account for drainage region delineation
- element edge length 1000 to 5000 m
- 7 or 8 subsurface layers
- 2.5 to 4 million 3D elements

Datasets: Development and Assembly

<u>GW–SW Model Construction</u>

- land surface DEM and major lake bathymetry
- surface water drainage network (rank ordered)
- land cover
- soils w/hydraulic properties
- 3D Hydrostratigraphic model (surficial, bedrock)
- permafrost distribution
- subsurface hydraulic property characterization
- validation data (GW, SW, soil moisture)
  - stream flow
  - observation wells etc.

<u>Atmospheric (Historic)</u>

- Precipitation
- snow accumulation and melt
- potential evapotranspiration
- surface temperature

<u>Atmospheric (Climate Projection)</u>

- CMIP6, CORDEX

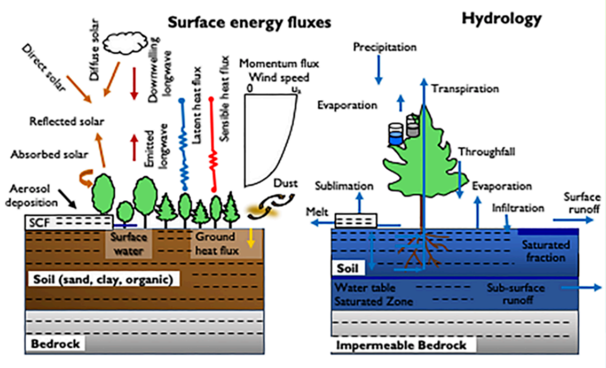
<u>Remote Sensing</u>

- GRACE
- soil Moisture
- surface Water

Model construction datasets will be harmonized across model domains and will support analysis at a range of spatial scales.

Modelling Framework

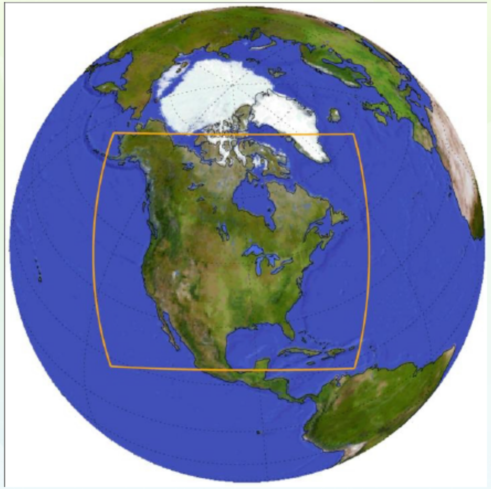
Land Surface Modelling — 5 km resolution ⇄ **Regional Climate Modelling** — 12.5 km resolution → **GW – SW Modelling** — 1 to 5 km resolution



The Community Land Model Version 5: Description of New Features, Benchmarking, and Impact of Forcing Uncertainty

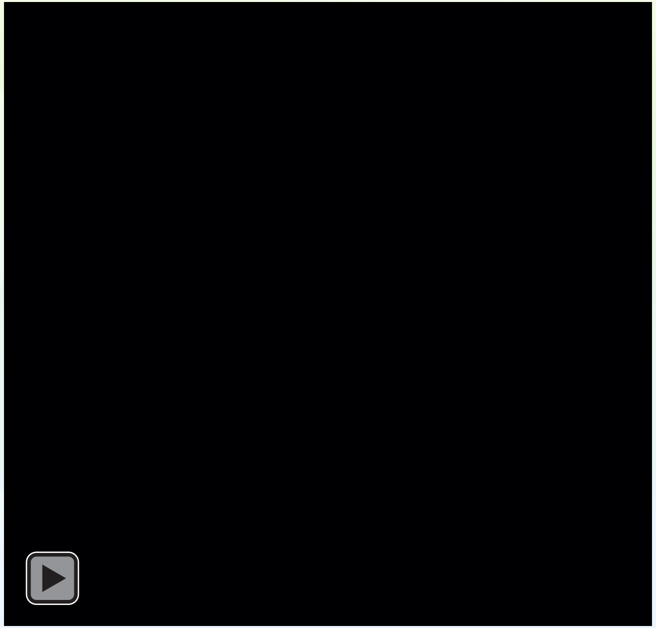
David M. Lawrence, Rosie A. Fisher, Charles D. Koven, Keith W. Oleson, Sean C. Swenson, Gordon Bonan, Nathan Collier, Bardan Ghimire, Leo van Kampenhout, Daniel Kennedy, ... See all authors

First published: 19 October 2019 | https://doi.org/10.1029/2018MS001583 | Citations: 184



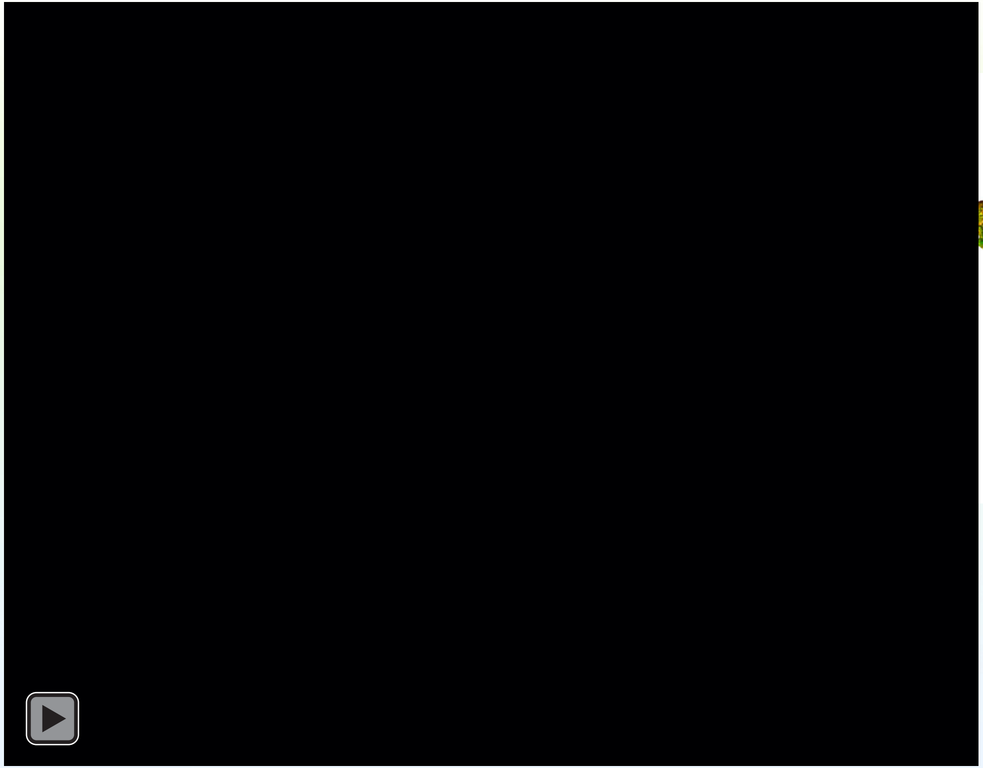
NCAR UCAR | National Center for Atmospheric Research
Mesoscale & Microscale Meteorology Laboratory

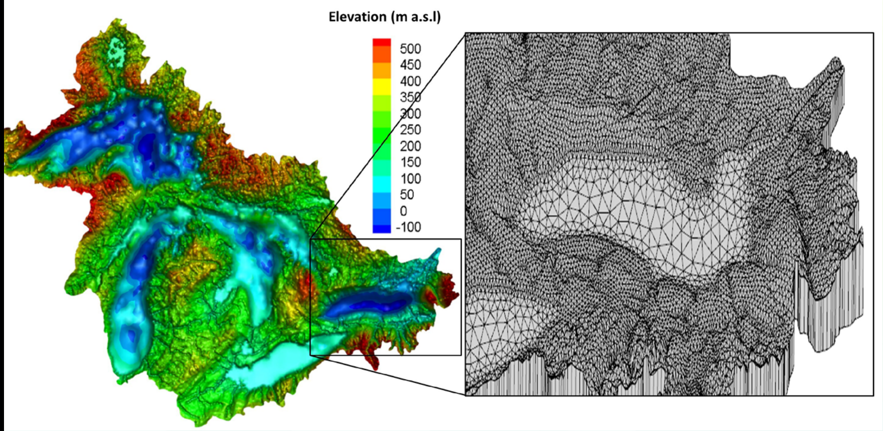
WRF THE WEATHER RESEARCH & FORECASTING MODEL



HydroGeoSphere (HGS) aquanty

Equivalent Resolution Example





Research papers

Investigating groundwater-lake interactions in the Laurentian Great Lakes with a fully-integrated surface water-groundwater model

Shu Xu [a], S.K. Frey [a,b,*], A.R. Erler [a,d], O. Khader [a], S.J. Berg [a,b], H.T. Hwang [a,b], M.V. Callaghan [a], J.H. Davison [c], E.A. Sudicky [a,b]

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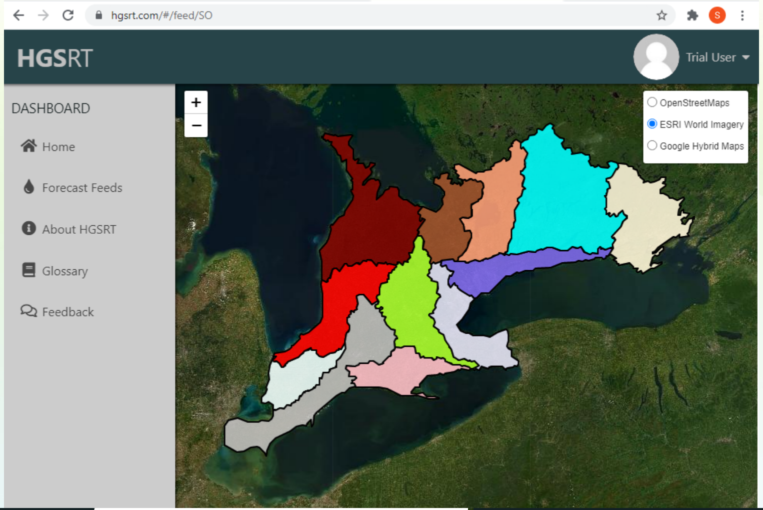
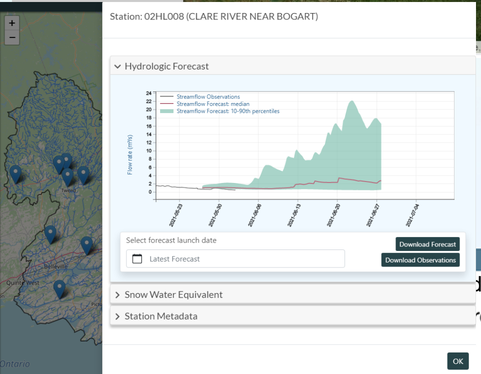
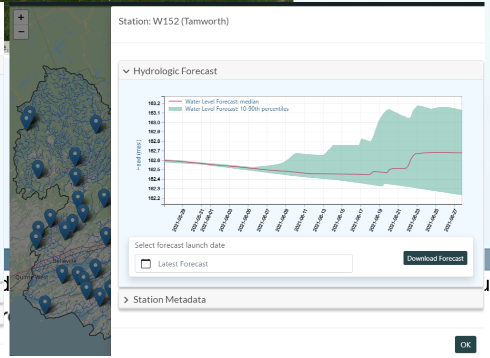
[b] University of Waterloo, Department of Earth and Environmental Sciences, 200 University Ave. W., Waterloo, ON N2L 3G1, Canada
[c] The Catholic University of America, Department of Civil and Environmental Engineering, 620 Michigan Ave., N.E., Washington, DC 20064, United States
[d] University of Waterloo, Department of Geography and Environmental Management, 200 University Ave. W., Waterloo, ON N2L 3G1, Canada

Decision Support Framework

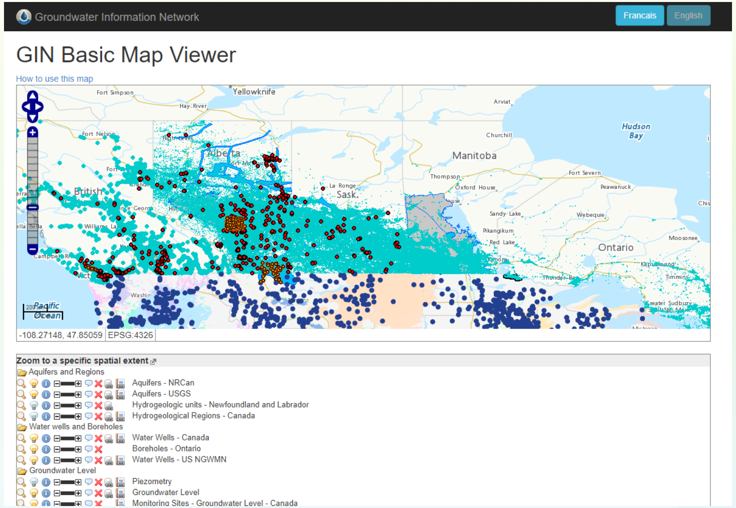
HGSRT Proof-of-concept





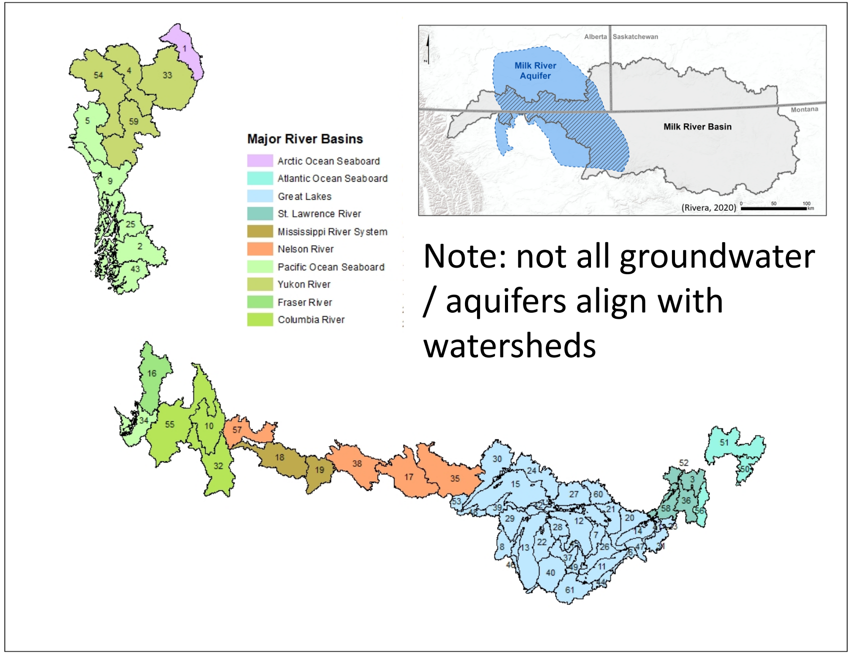


Groundwater Information Network



rces, 2021

Canada-USA Watersheds

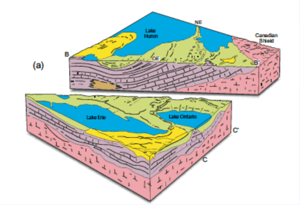


Note: not all groundwater / aquifers align with watersheds

- order: 4th
- number: 61
- Area: 2,350,443.30 km^2
- percentage Canada / USA: 45% / 55%
- Great Lakes watersheds account for 766,000 km^2 of which Lakes are 244,000 km^2
- aggregate information by hydrogeological regions (Sharpe et al. 2014)
- provide conceptualized bedrock and surficial aquifer types

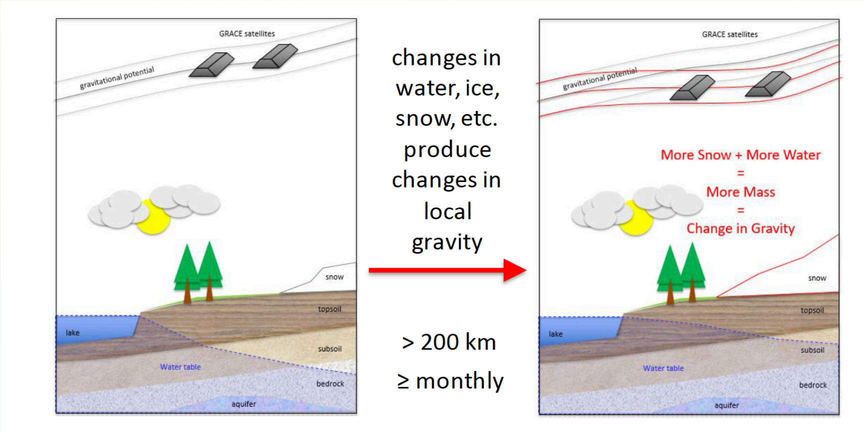
- population: 60,000,000
  - Per watershed: min: <200. max >6 million

e.g. karst aquifers



GRACE

Gravity Recovery and Climate Experiment (GRACE)



- note change in groundwater level and snow depth from left to right image

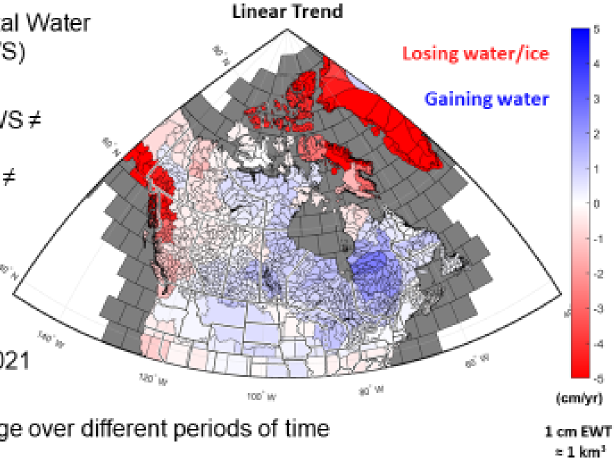
- mapping change in Mass
- 2 satellites
- track changes in spacing and elevation

- 15 year plus record
- global coverage
- watershed solution for
- large regional footprint ~100,000 km^2

GRACE

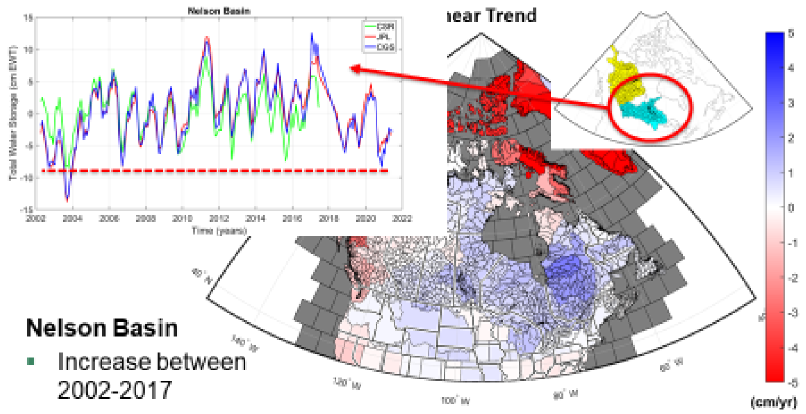
National Scale Changes: Trends

- Trends in Total Water Storage (TWS)
- Trends in TWS ≠ trends in groundwater ≠ trends in soil moisture
- Trend calculated over 2002-2021



- Trends change over different periods of time

National Scale Changes: Trends



Nelson Basin

- Increase between 2002-2017
- Decrease in storage since 2018 of ~ 50-100 km³ water
- Water storage at its lowest in two decades

GRACE comparative study underway in S-ON with regional model

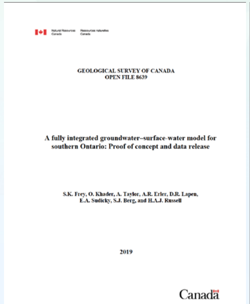
contact: John Crowley

Communication

- flyers – project announcement
- branding – logo
- web site – trilingual (www.Canada1Water.ca)
- newsletter – annual trimester cycle
- social Media
- science conference and meeting presentations, publications
- GSC Data release open file, open access
  - e.g., S-ON model Frey et al. (2019), Great Lakes model datasets Xu et al. (2021)


Impacts des changements climatiques sur les eaux souterraines et de surface pour un développement durable au Canada

Canada 1 Water

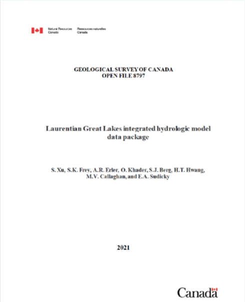

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8639

A fully integrated groundwater–surface-water model for southern Ontario: Proof of concept and data release

S.K. Frey, O. Khader, A. Taylor, A.R. Erler, D.R. Lapen, E.A. Sudicky, S.J. Berg, and H.A.J. Russell

2019

Canadä


GEOLOGICAL SURVEY OF CANADA
OPEN FILE 8797

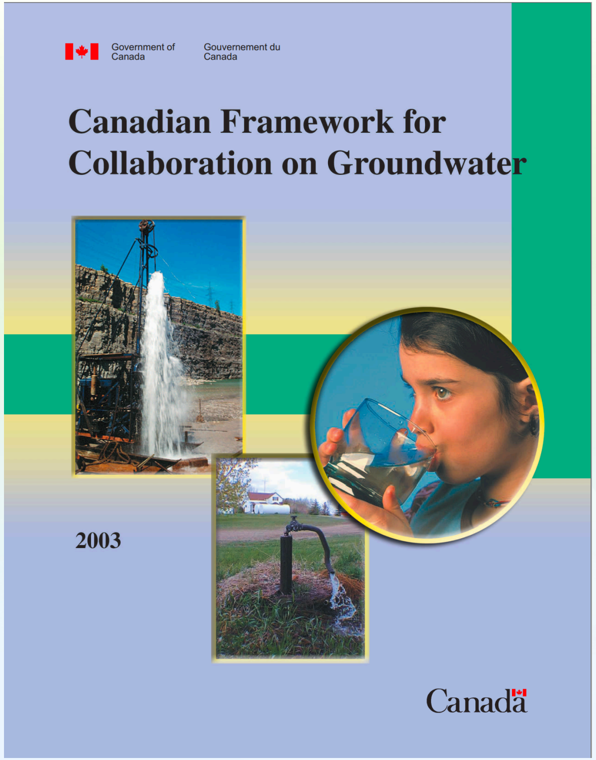
Laurentian Great Lakes integrated hydrologic model data package

S. Xu, S.K. Frey, A.R. Erler, O. Khader, S.J. Berg, H.T. Hwang, M.V. Callaghan, and E.A. Sudicky

2021

Canadä

Engagement



- National Dialogue on Groundwater (NDGW)
- One-on-one contacts with provinces
- Connecting with individual researchers
- Outreach to NGO organizations, Conservation Authorities, etc.
- First Nations engagement via GEM, CFS, etc.,

Summary

- 3 year funded project
- Physically based fully coupled GW-SW models with CC scenarios
- Monthly historic transient model
- Decision support pilot tests
- Supporting Communities – Geographic, Social, and Economic
- Open access data and results

Contact Info

- www.Canada1Water.ca

- Steven Frey, Aquanty: sfrey@aquanty.com
- Hazen Russell, GSC: hazen.russell@nrcan-rncan.gc.ca

- Groundwater Geoscience Program
  - Eric Boisvert GSC: eric.boisvert2@nrcan-rncan.gc.ca

> "Canada 1 Water represents a truly 21st century advancement in integrated climate-surface-groundwater modelling capabilities to assess water resource vulnerabilities across the Canadian landscape. Not only within Canada, but it lays out a science-based roadmap for scientific communities and government agencies around the globe."
>
> — Dr. Edward Sudicky, FCAE, FRSC

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Characterization of Shallow Aquifers in the Fox Creek Area: christine.rivard@nrcan-rncan.gc.ca
Ring of Fire - Regional Assessment: nicolas.benoit@nrcan-rncan.gc.ca
Water Resources Characterisation and Modelling (WRCM): daniel.paradis@nrcan-rncan.gc.ca
Canada 1 Water (C1W): hazen.russell@nrcan-rncan.gc.ca