Scissors Creek Hydrogeological and Geophysical Water Supply Study:

SMA Environmental Forum 2018

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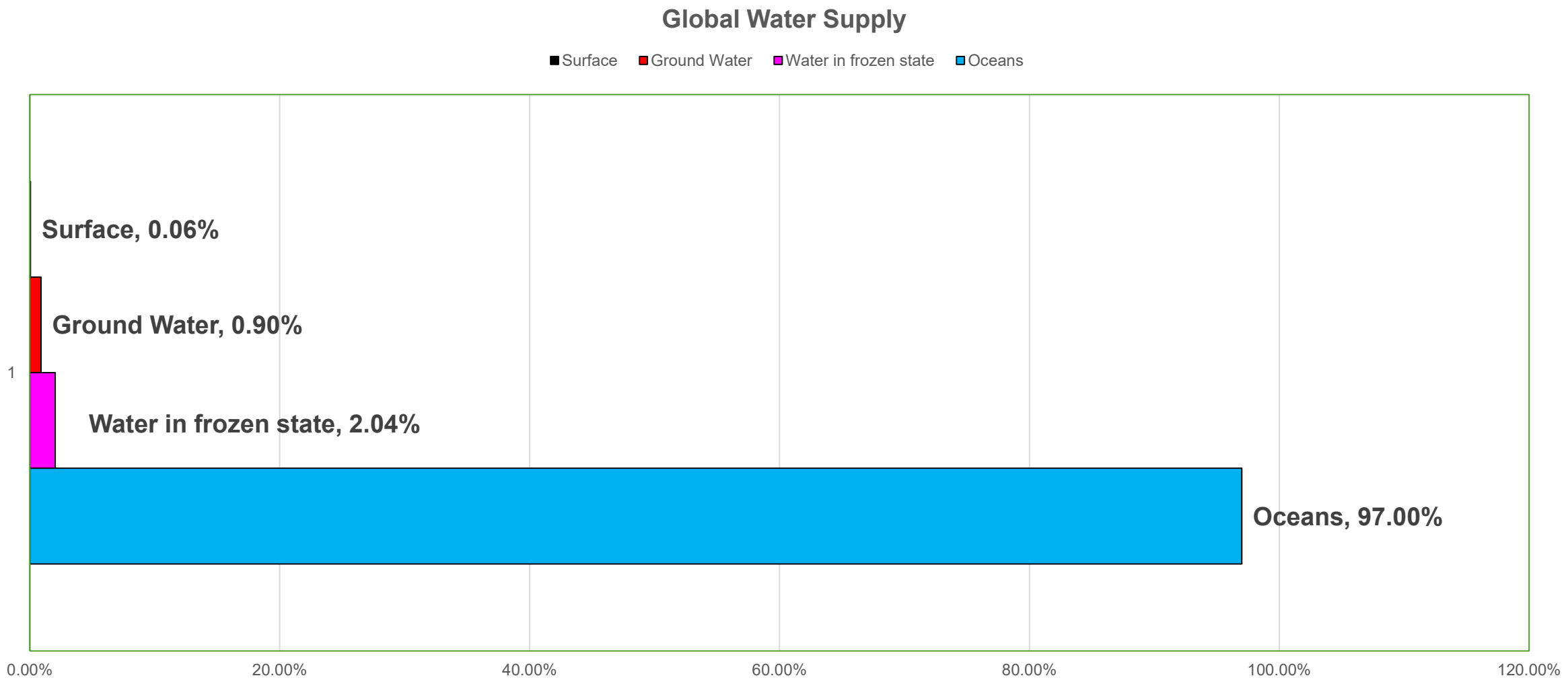
October 17, 2018

Outline

- Water Facts
- Project Background
- Phase 1 - Hydrogeological Study
- The Electromagnetic (EM) Geophysical Method
- Helicopter Electromagnetic (HEM) Method and Results
- Water Supply Well Completion

Fun Facts about Water



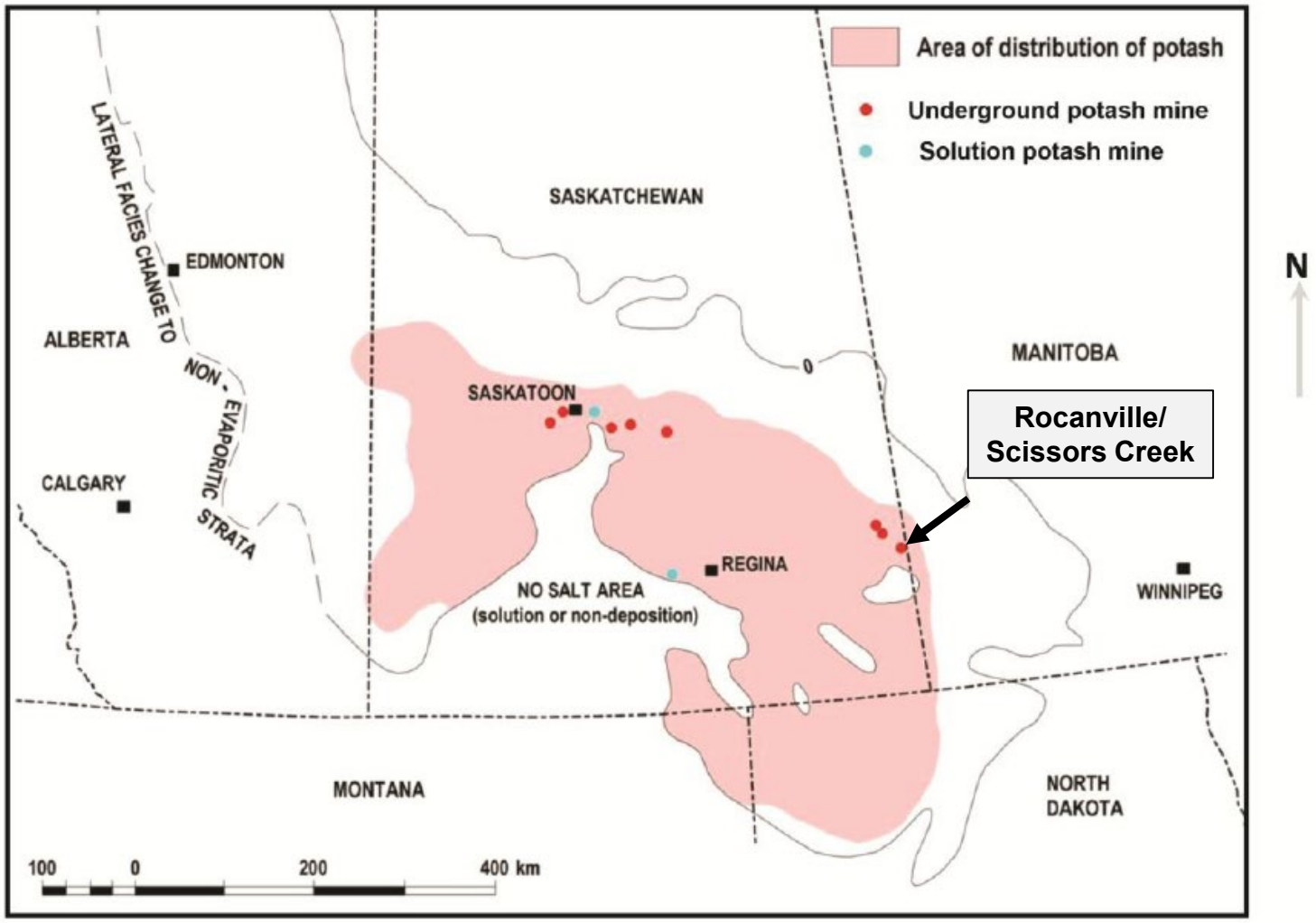
USGS Water Science School (https://water.usgs.gov/edu/earthhowmuch.html)

Finding Water – Drilling Boreholes is not enough!

- A 6 inch borehole represents less than 1/millionth of one acre.
- Provides precise information about geology in the immediate vicinity of the borehole.
- Any inferences made about the surrounding geology is a leap of faith.

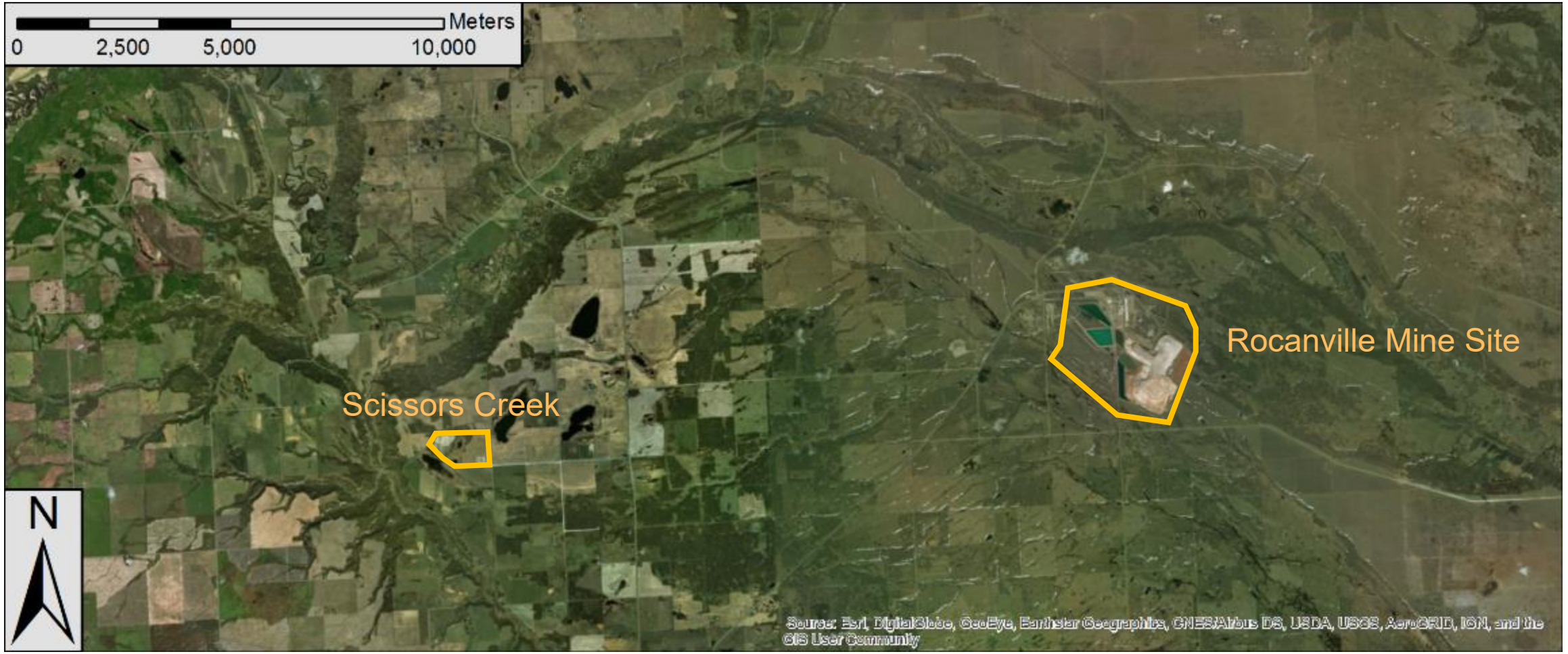
Project Background

Site Location



(from Potash in Saskatchewan by Fuzesy, 1982)

Site Location



Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Project Background

Estimated Water Demand	
During Construction ~500 m^3/day (up to June 2012)	**After Construction ~75 m^3/day**
• Freeze plant 327.5 m^3/d • Shaft sinking assumed <100 m^3/d • Potable water supply 44.1 m^3/d • Washing, roads, etc. ~20 m^3/d	• Potable water supply 42 m^3/d • Irrigation of grounds 10 m^3/d • Maintenance Shop 10 m^3/d • Washrooms at the shaft <10 m^3/d • Shaft Operating tanks <10 m^3/d

The groundwater source used to fill an onsite water storage pond ~ 500 m^3

Water required for emergency fire suppression would be taken from the on-site pond and would not affect the water supply requirements.

Phase 1 - Hydrogeological Study

Phase 1 – Hydrogeological Study

Review of Published Information

- WSA Water Well Records
- Oil and Gas Well logs
- Regional Mapping

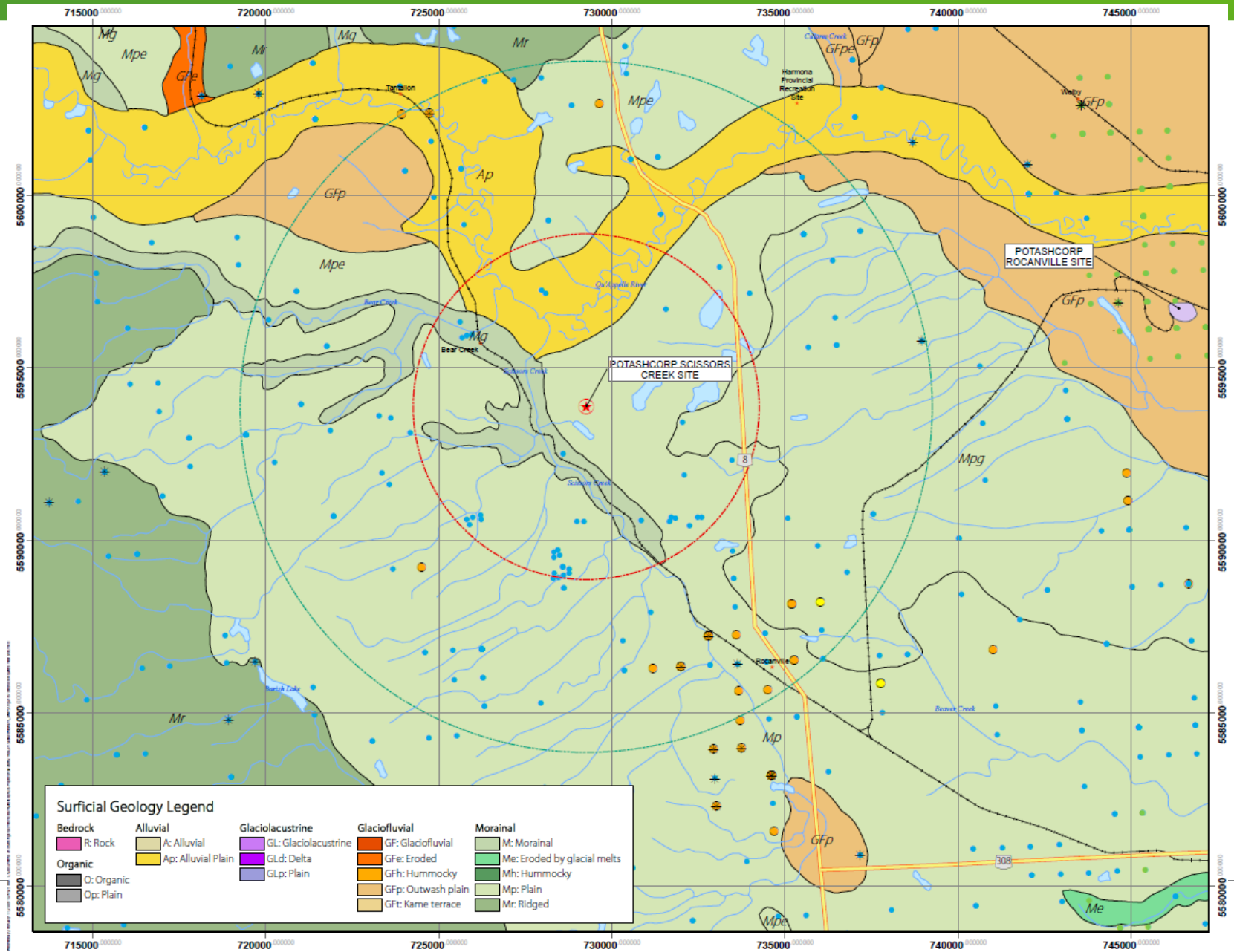
Review of some limited site specific information

- Some limited drilling had been conducted as part of the EIS for this project

Identification of potential drilling targets

- These targets were selected based on; hydrogeological, access and proximity to the site

Surficial Geology and Regional Well Information



Legend

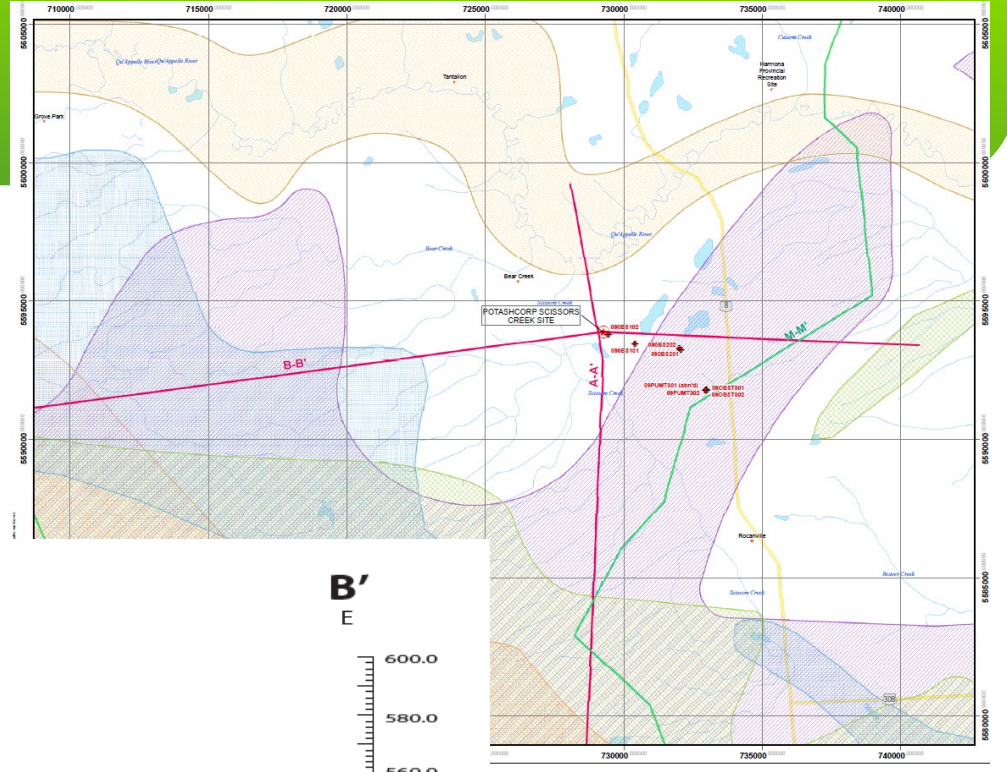
- Well in Glacial aquifer
- Domestic & Other groundwater wells
- Industrial well
- Irrigation well
- Municipal well
- Primary Highway
- Railway
- 5km radius from Site
- 10km radius from Site

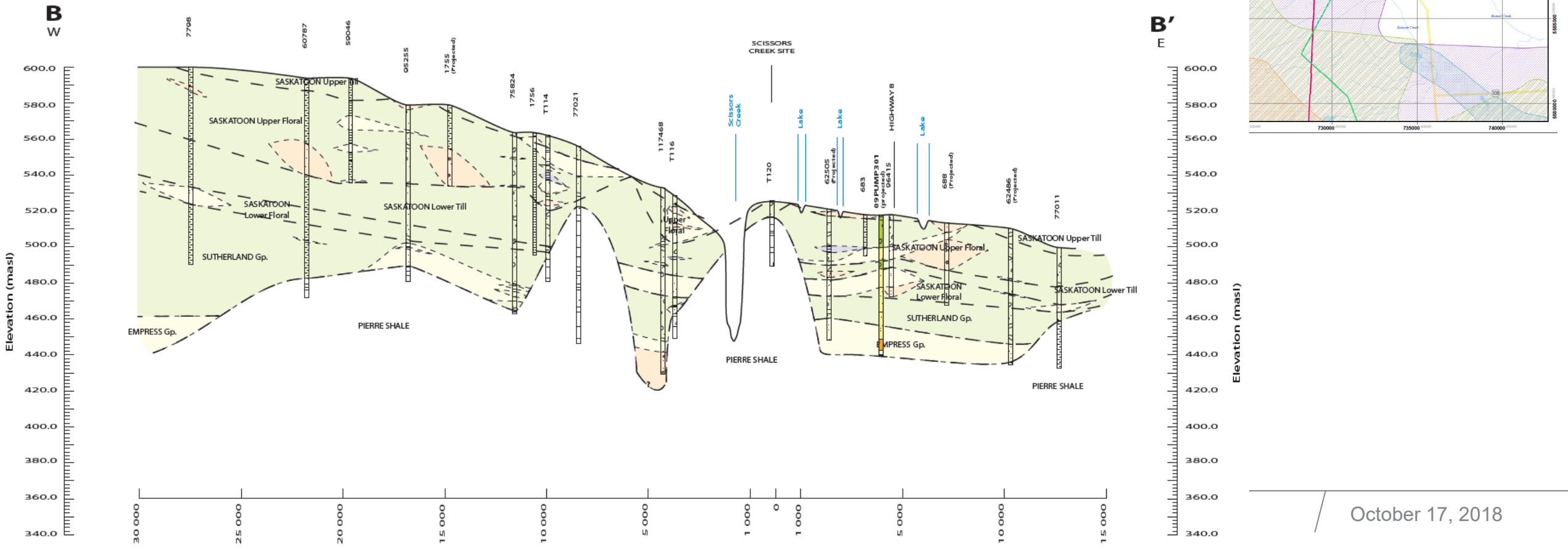
Regional Stratigraphy

Period	Composite Stratigraphy*			Lithology	Hydrostratigraphic Unit
Quaternary	Surficial Stratified Deposits			Silt and sand	Surficial Sand Aquifers
	Saskatoon Group	Battleford Formation		till	Saskatoon Group Aquifers
				sand and gravel	
		Floral Formation	Upper Floral Till	till	
			Riddell Member	sand and gravel	
			Lower Floral Till	till	
				sand and gravel	Interglacial Aquifers
	Sutherland Group	Warman Formation		till	Sutherland Group Aquifers
				sand and gravel	
		Dundurn Formation		till	
				sand and gravel	
		Warman Formation		till	
Tertiary	Empress Group			sand and gravel	Empress Group Aquifers
	"Bredenbury Formation"			sand and gravel	Tertiary Aquifers
Cretaceous	Bearpaw Formation	Pierre Shale		clay and silt	clay and silt	
	Judith River Formation			sand and silt	clay and silt	minor aquifer
	Lea Park Formation			clay and silt	clay and silt	Aquitard
	Upper Colorado Gp. 2nd White Specs.	Niobrara Fm. And Morden Shale		clay and silt		
		Favel Formation				
	Lower Colorado Group Ashville Formation			clay and silt		

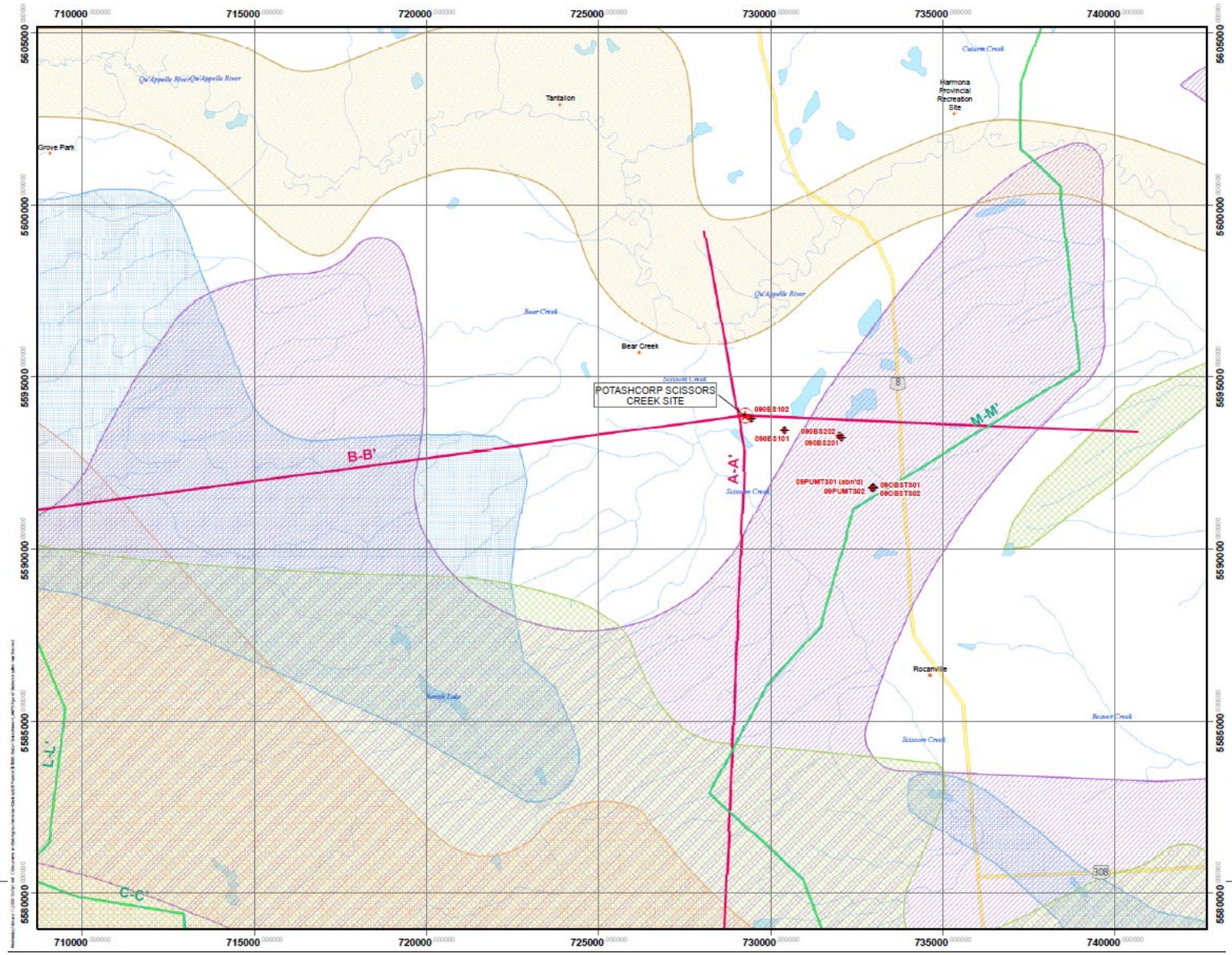
* Modified after Christiansen, 1992 and Caldwell, 1968

Cross Section B (West) – B’ (East)





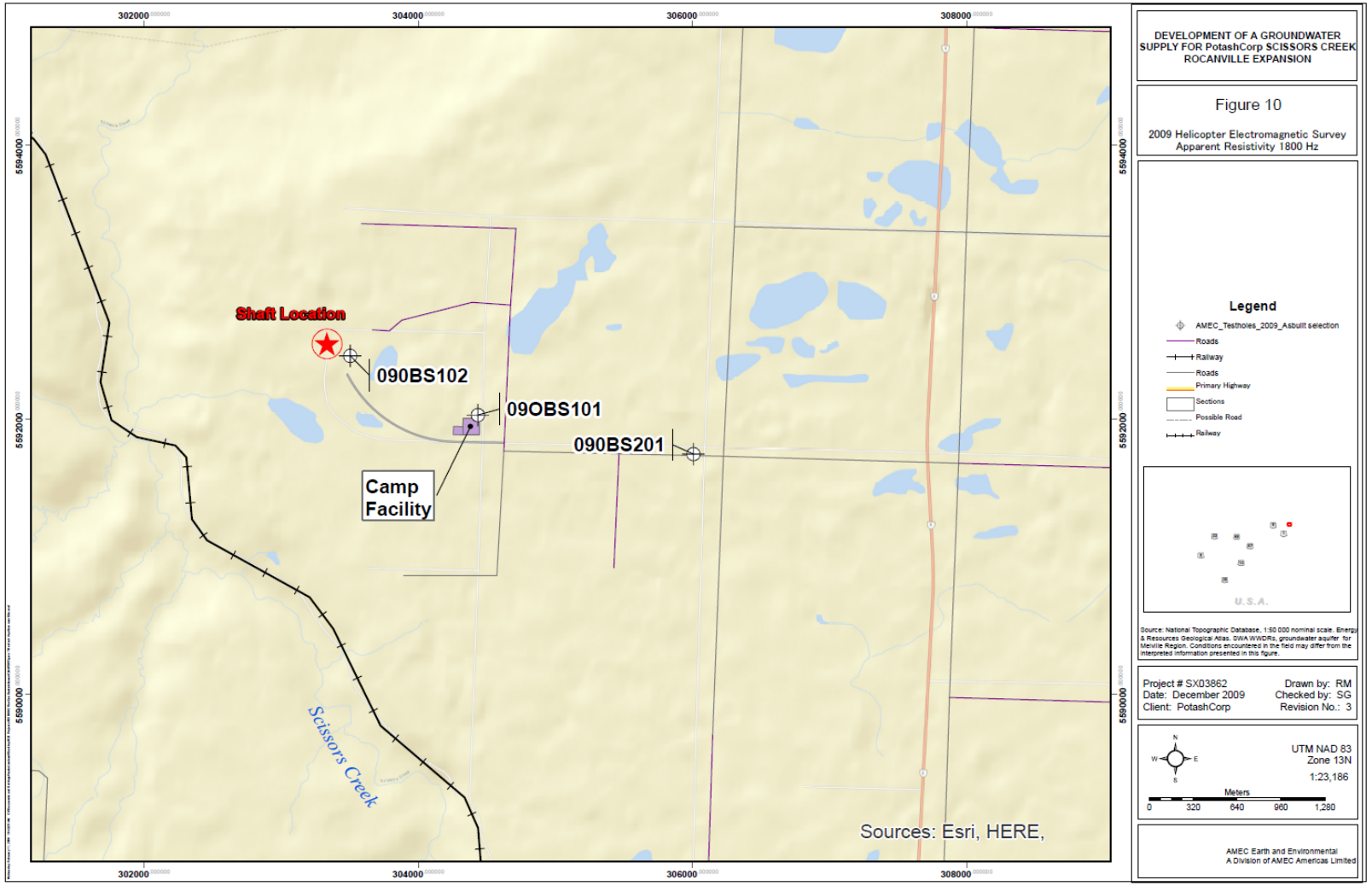
Regional Aquifer Interpretation



Legend

- AMEC 2009 Testholes (as built)
- SRC Cross Section Locations
- AMEC Cross Section Locations
- Interglacial Aquifer
- Qu'Appelle Valley Alluvium Aquifer
- Saskatoon Group Aquifer
- Sutherland Group Aquifer
- Empress Group Aquifer
- Primary Highway

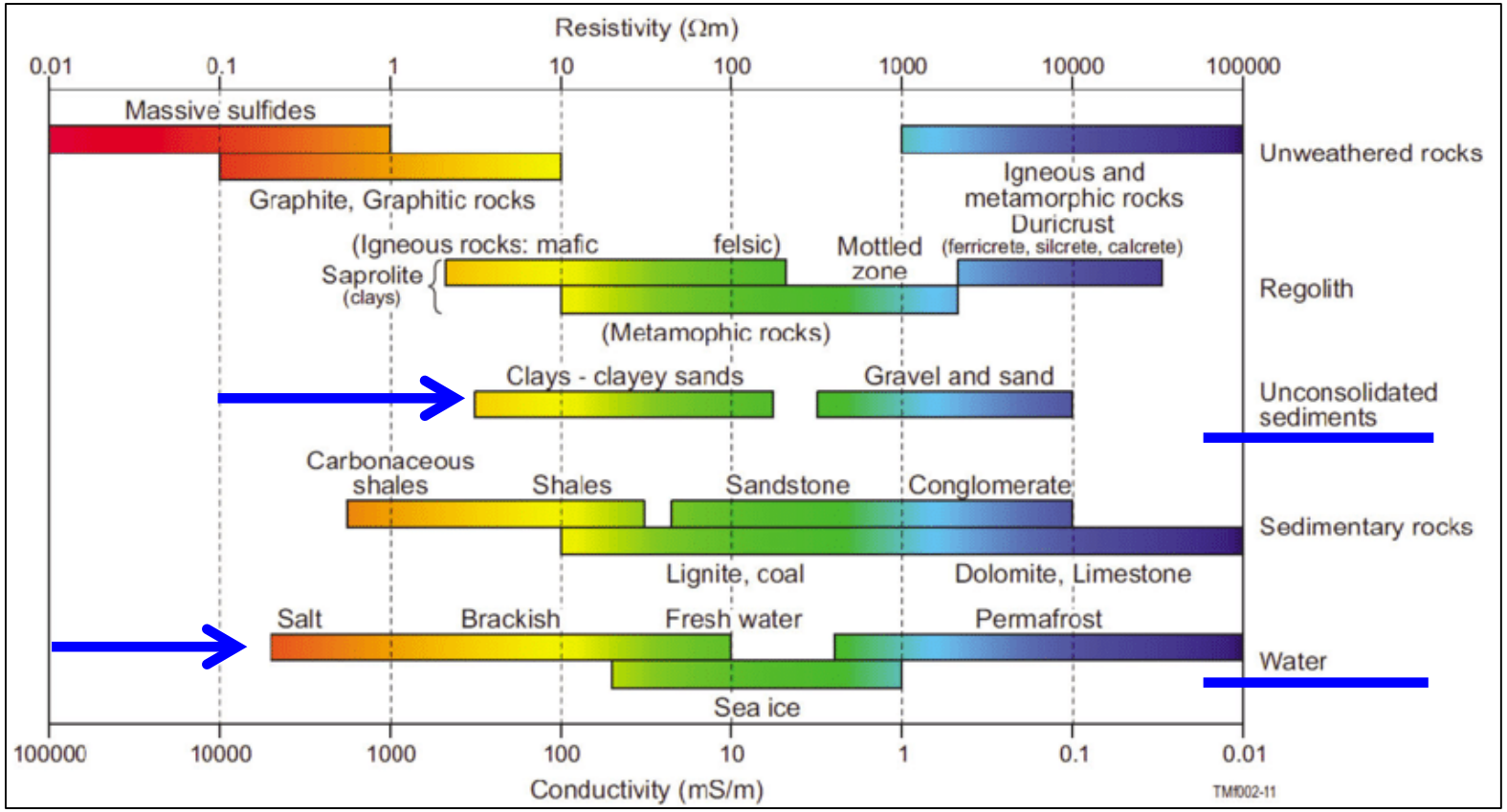
Initial Drilling Locations



Electromagnetic (EM) Geophysical Method

Electromagnetic (EM) Geophysical Methods

EM is particularly useful among geophysical methods since there is a strong correlation between measured resistivity/conductivity and the lithology of the subsurface



Typical ranges of resistivity/ conductivity of rocks
(from Electromagnetic Methods in Applied Geophysics
Volume 1, Misac Nabighian, 1987)

EM GEOPHYSICAL METHOD IN PRACTICE

Frequency domain (FDEM)

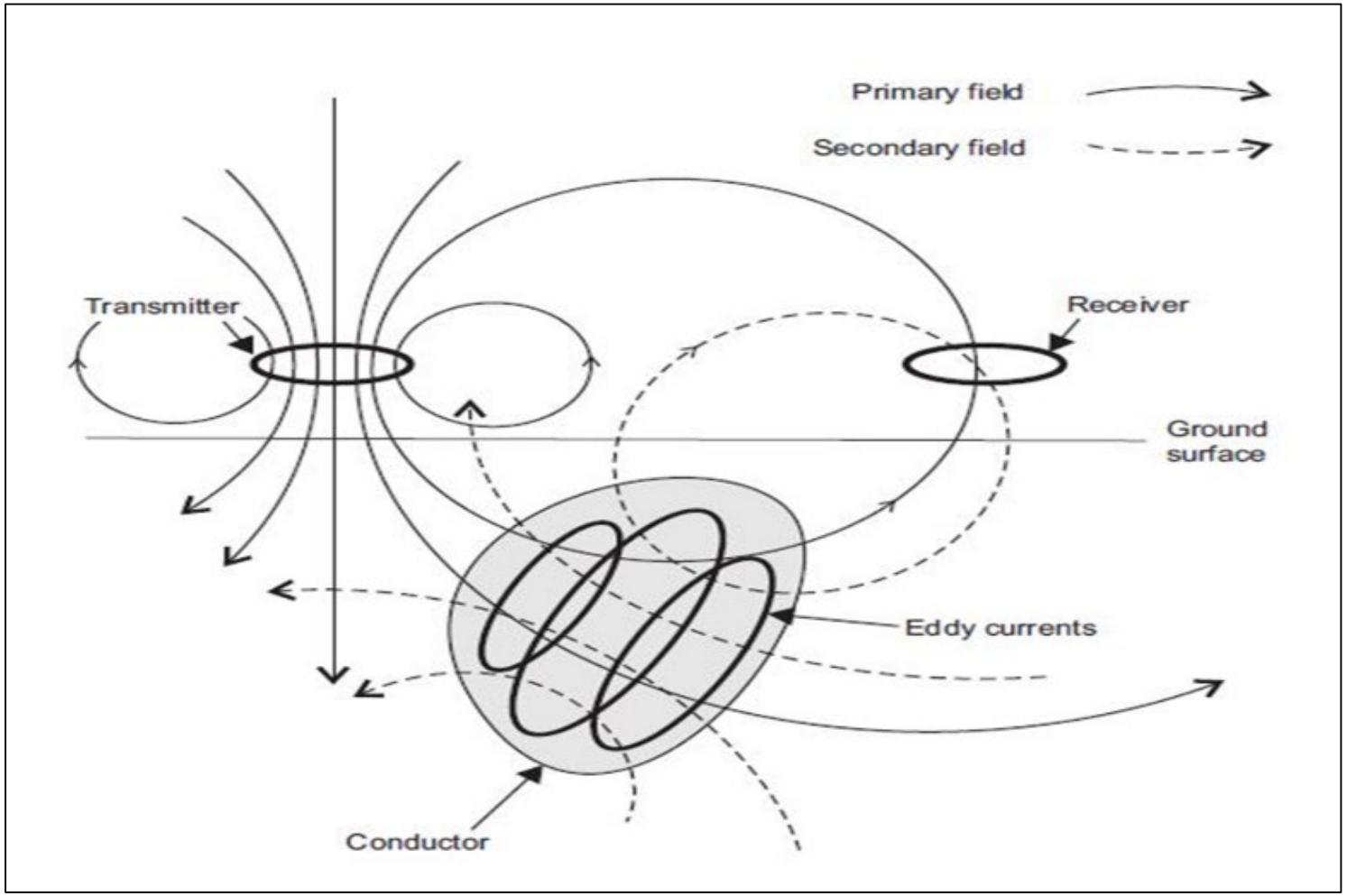
- Continuous sinusoidal wave source
- Single or multiple frequency
- Compact instrumentation
- Fixed source-receiver interval
- Rapid data acquisition
- Shallow penetration

Time domain (TDEM)

- Discontinuous source waveform
- Measurement are typically done after the source is turned off
- Broad frequency range
- Variable source-receiver interval
- Deep penetration

Reynolds (2011) An Introduction to Applied and Environmental Geophysics

FREQUENCY DOMAIN EM GEOPHYSICAL METHOD - BASIC THEORY



Grant and West (1965) Interpretation Theory in Applied Geophysics

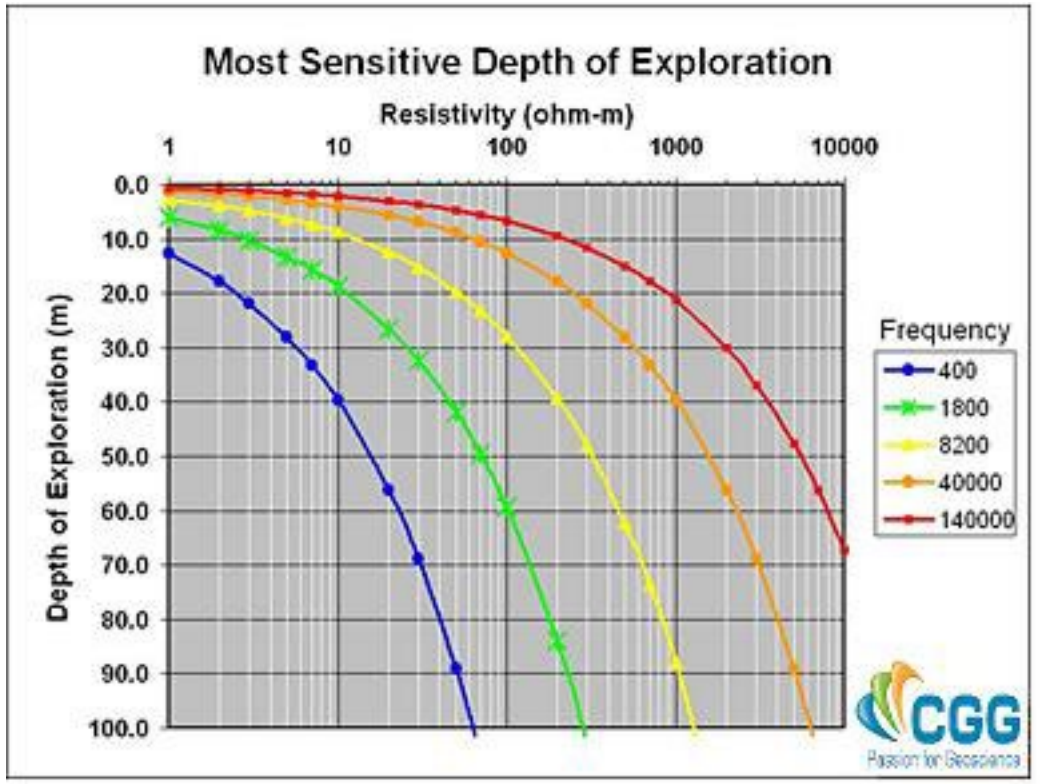
FDEM Depth of Penetration

- Depends on Frequency and Conductivity of Medium

- Penetration depth d is given by

$$d(m) = 503\sqrt{\rho(\Omega m)/f(Hz)}$$

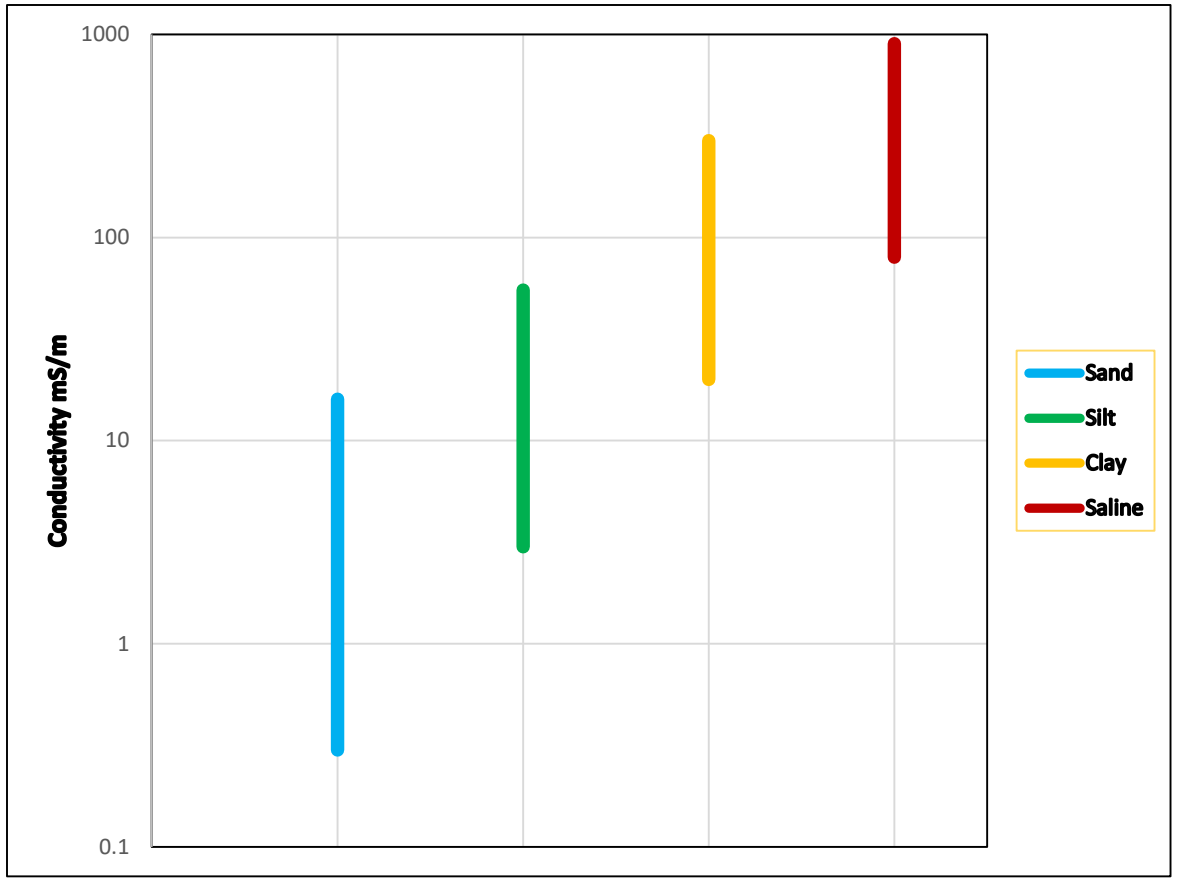
- ρ is resistivity, f is frequency

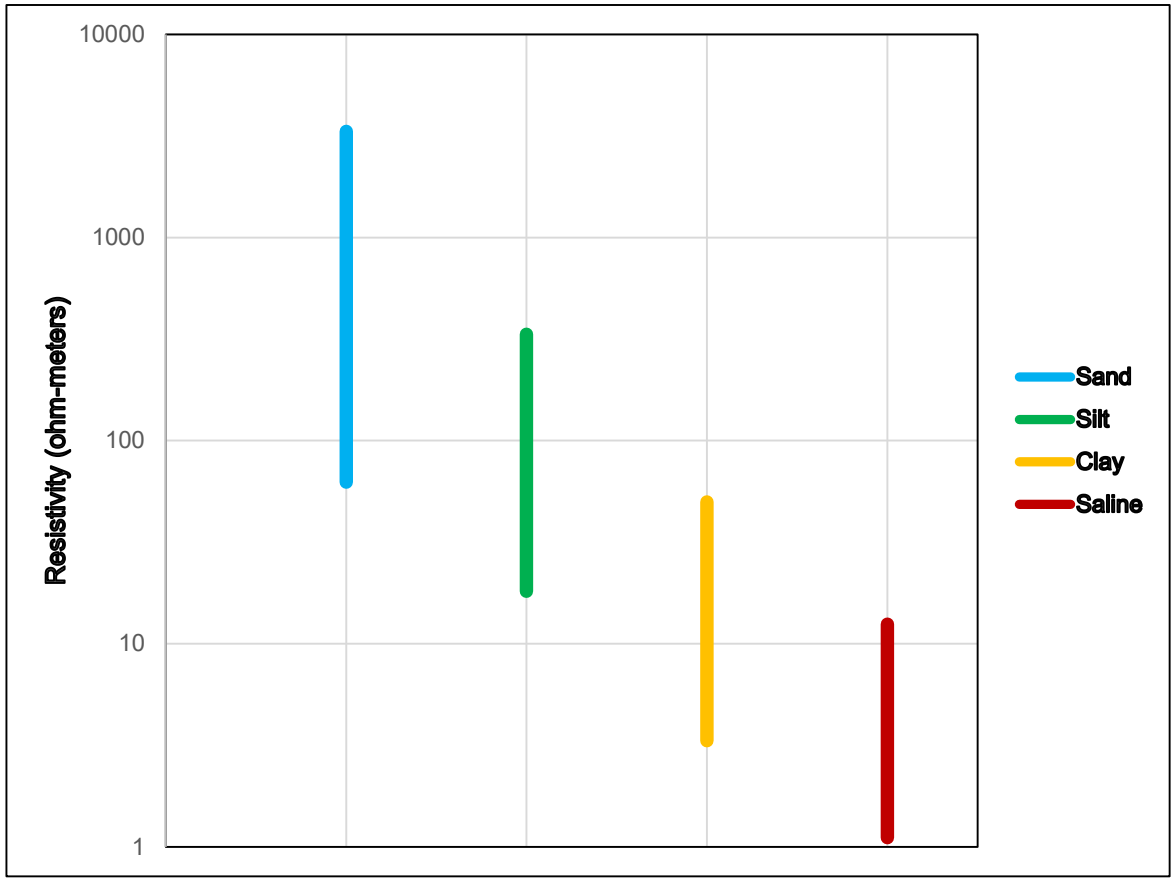


CGG Multiphysics HEM Resolve

Electrical Conductivity/Resistivity of Glacial Tills

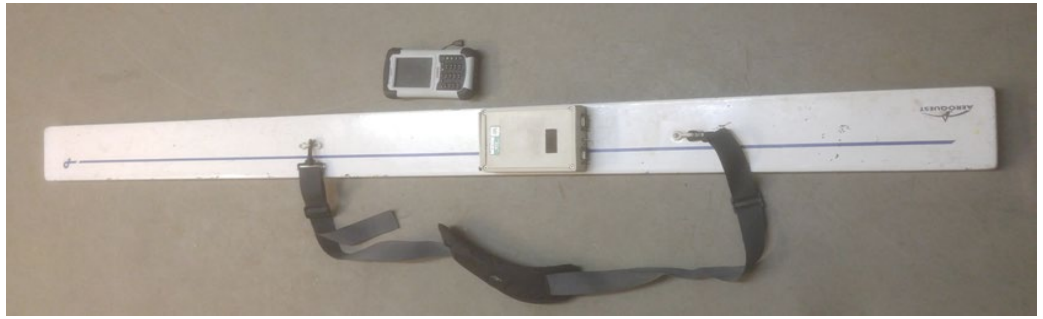
Conductivity (σ) $\sigma = 1/\rho$ Resistivity (ρ)





LSU AgCenter Pub 3185 What is Soil Electrical Conductivity?

Equipment: Frequency domain EM (Ground)



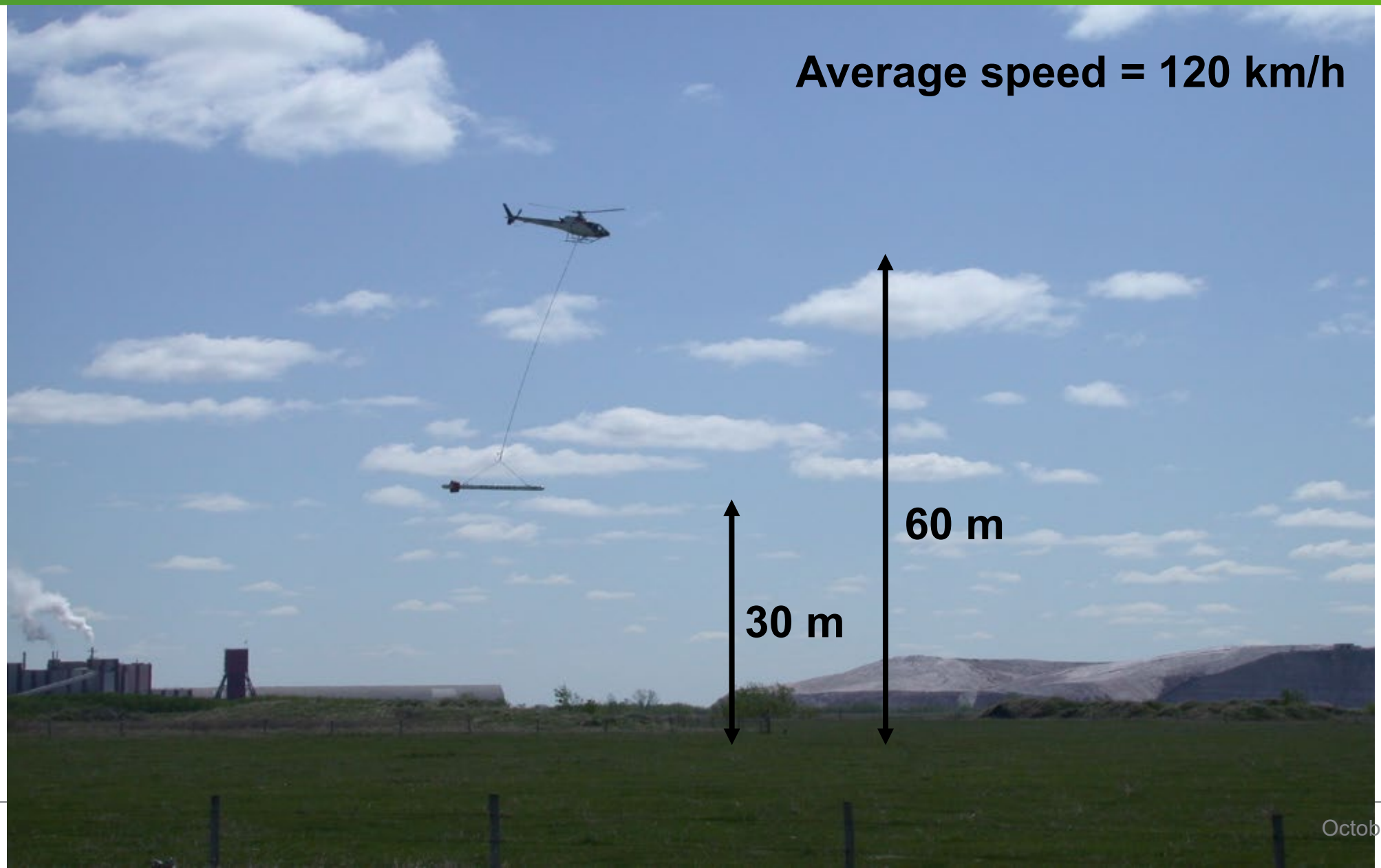
Geophex GEM-2
Multi-frequency
EM Induction meter

Helicopter (HEM) Geophysical Method

Equipment: Helicopter EM, CGG (Fugro) Resolve

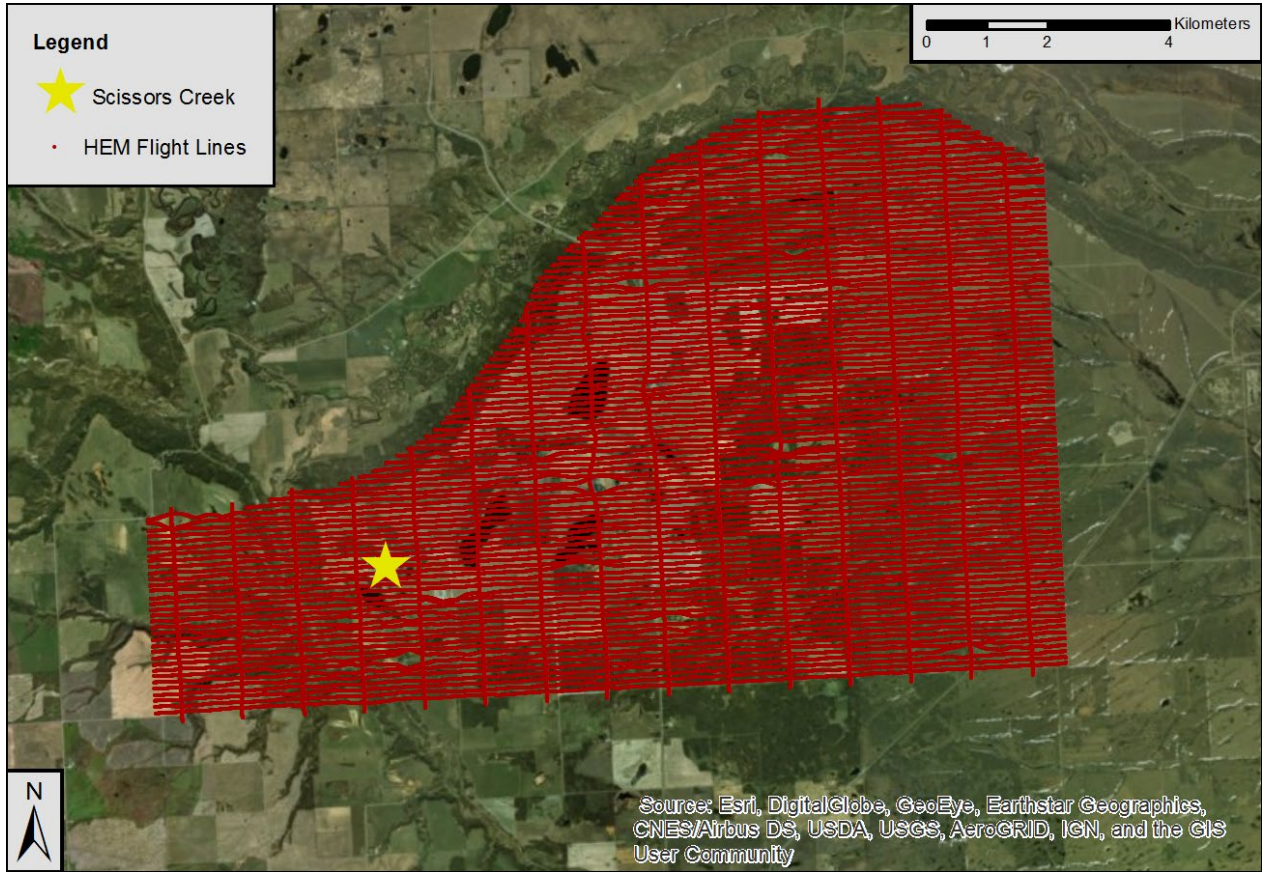
- Multi-frequency operation
- Records five frequencies simultaneously (400, 1800, 8200, 40000, and 140000 Hz)
- Deploys a powerful transmitter (penetrates deeper)
- Covers ground extremely quickly with good spatial resolution.

Rocanville HEM Data Acquisition



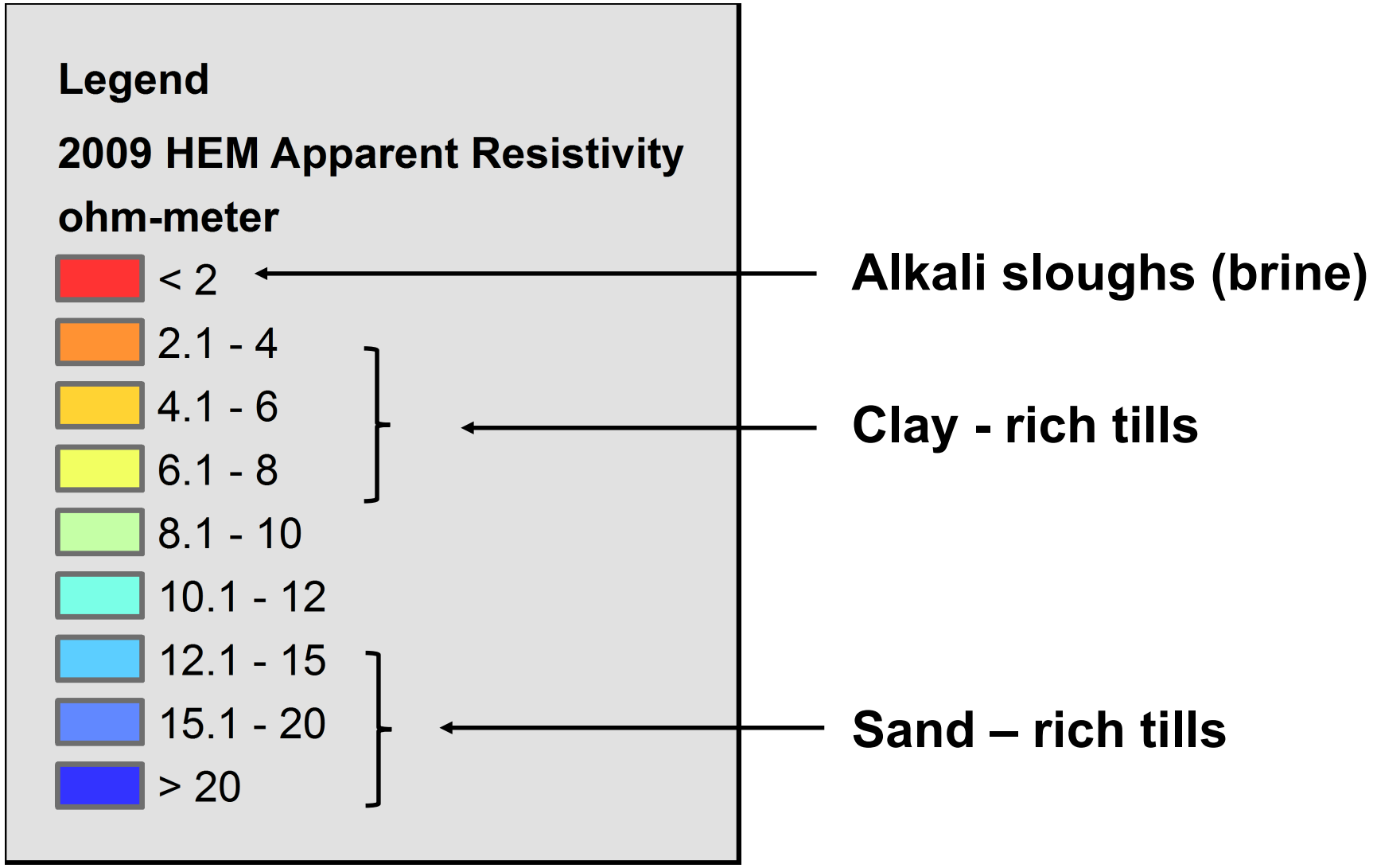
Helicopter EM, Flight lines

- Flight lines flown in 90/270 degree orientation ~ 100 m separation
- Tie lines flown, orthogonal ~ 1000 m separation.
- Total coverage ~ 100 square kilometers
- Sample Interval ~ 3.3 meters



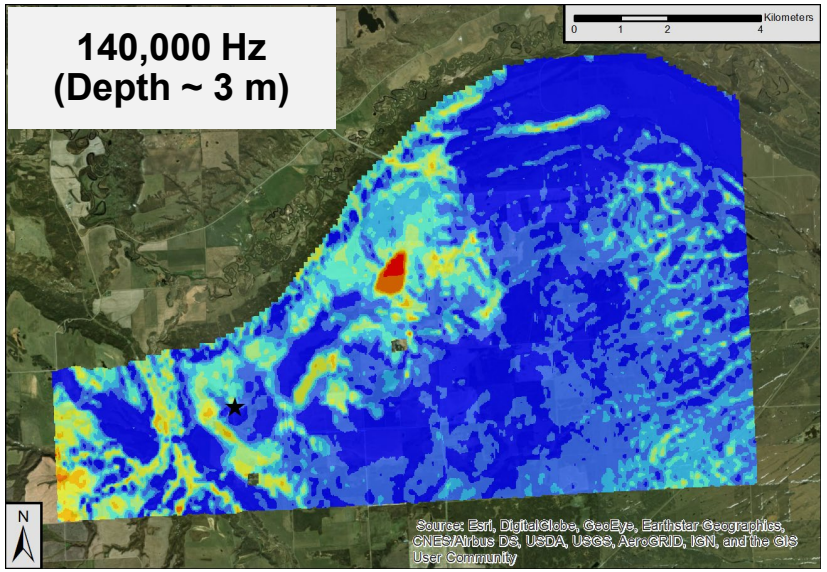
Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

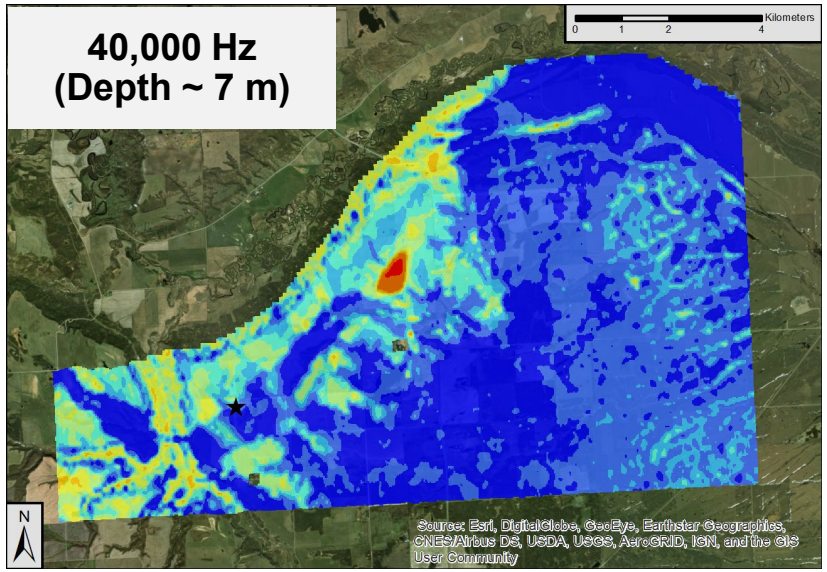
In the near-surface glacial till environment:

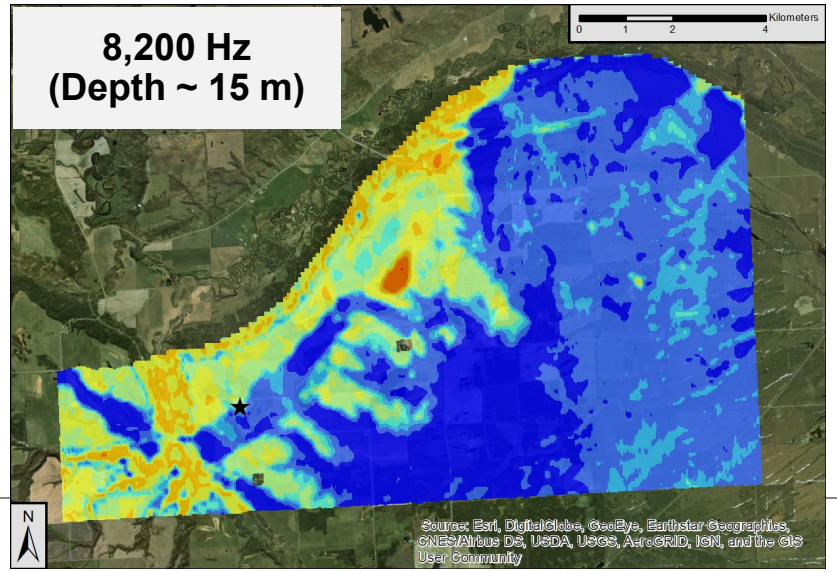


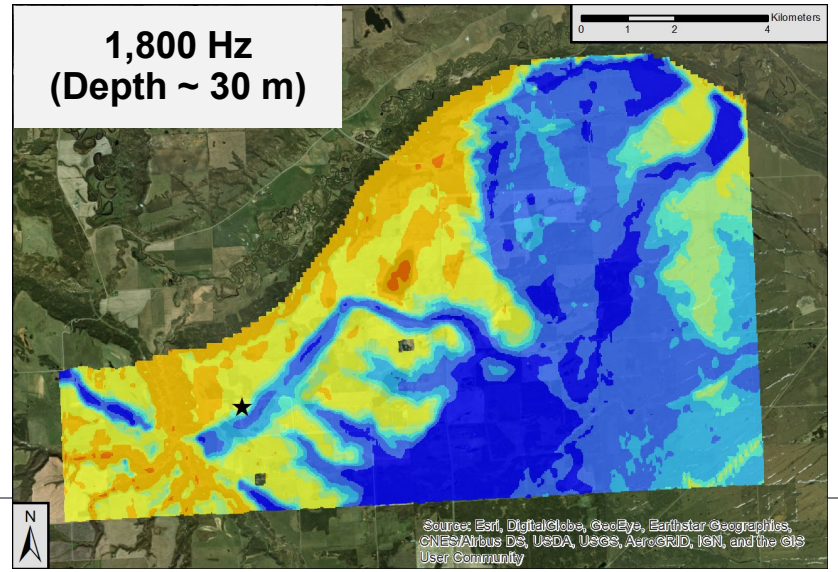
Apparent Resistivity Maps – Rocanville 2009 HEM West

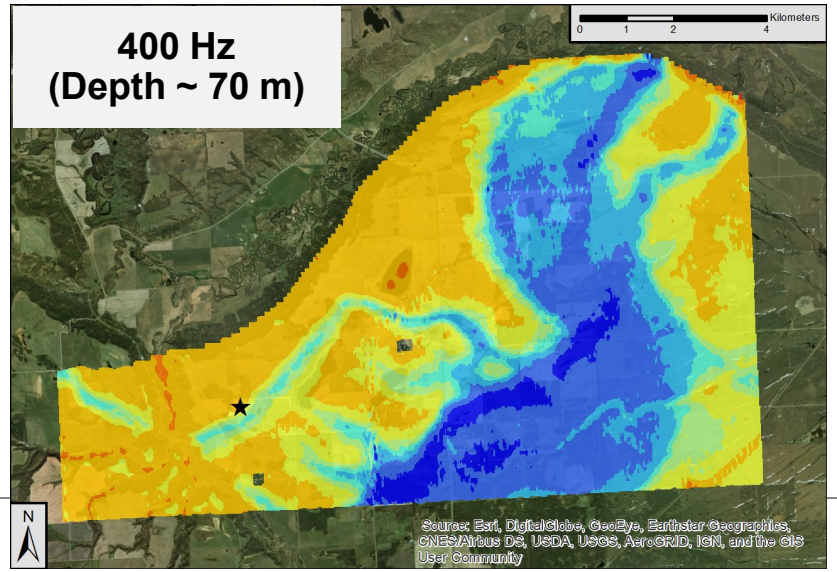
Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

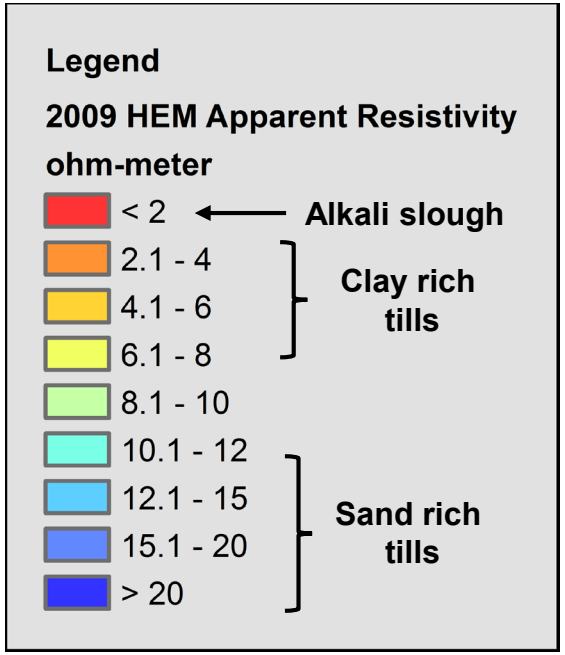










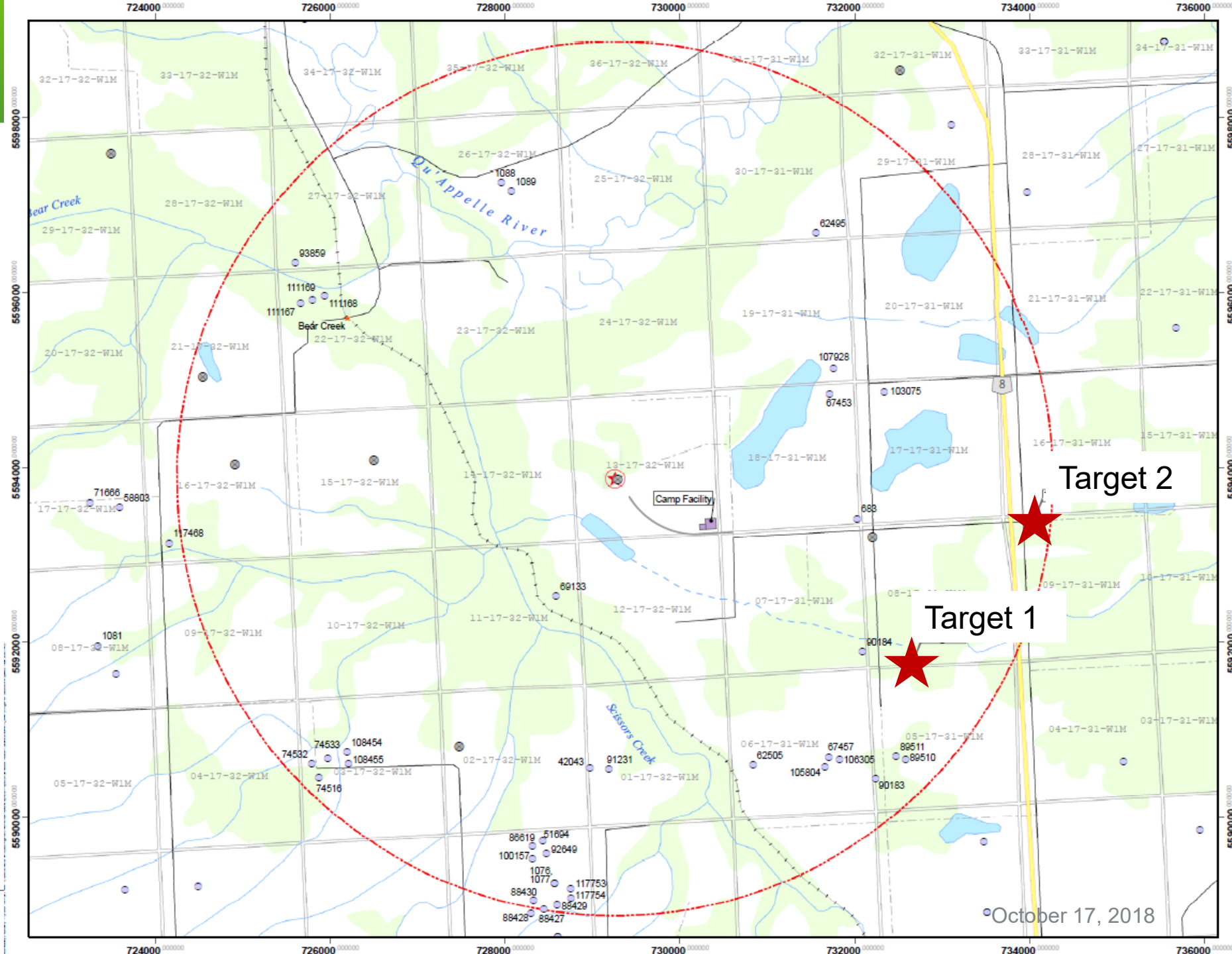


Water Supply Well

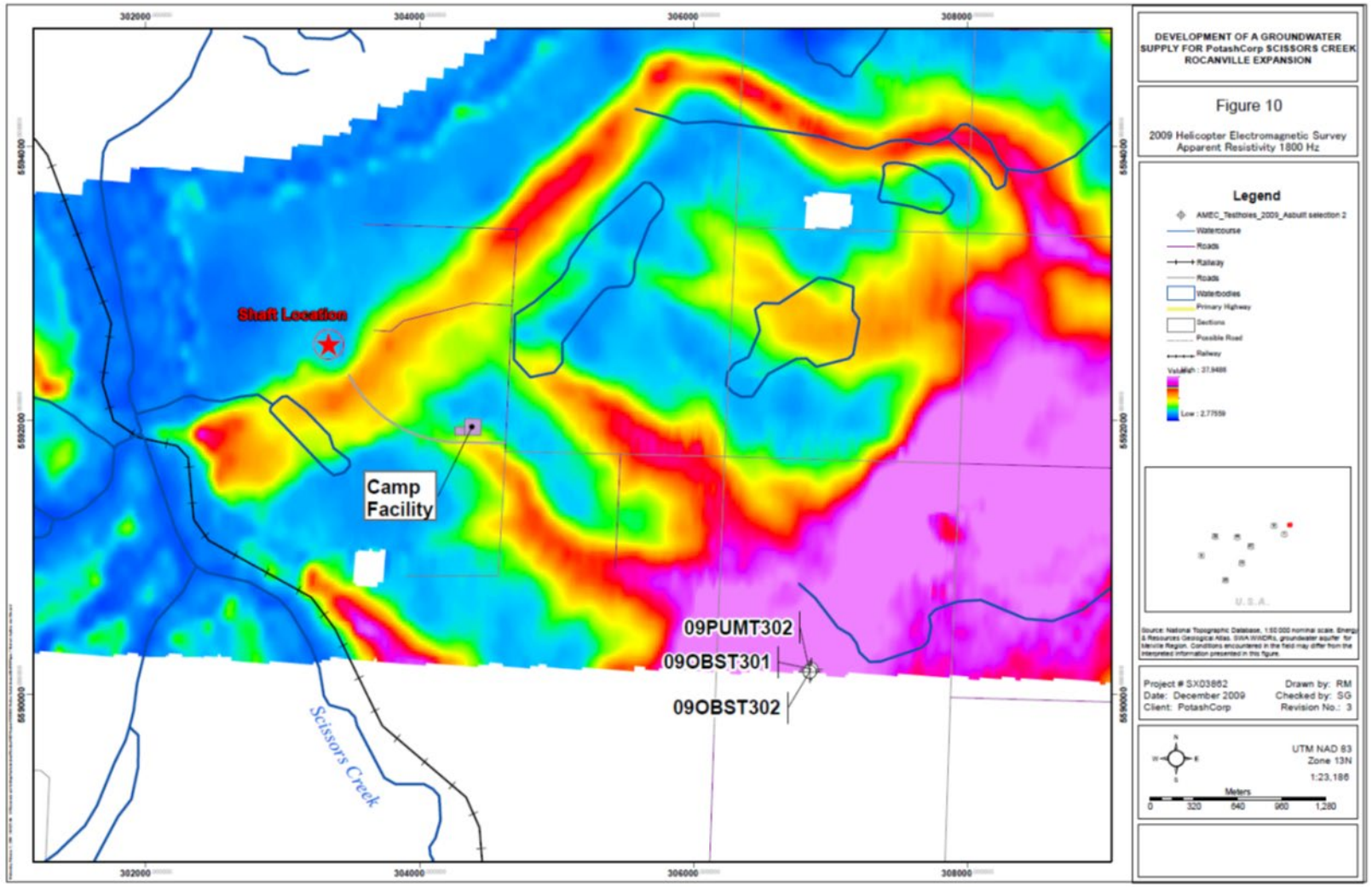
HEM Targets

Based on the results of the HEM (especially the 1,800 Hz or 30 m depth) we chose two target areas that would be worth investigating.

Access, proximity to the site and location in the HEM target area all supported drilling Target Area 1 first.

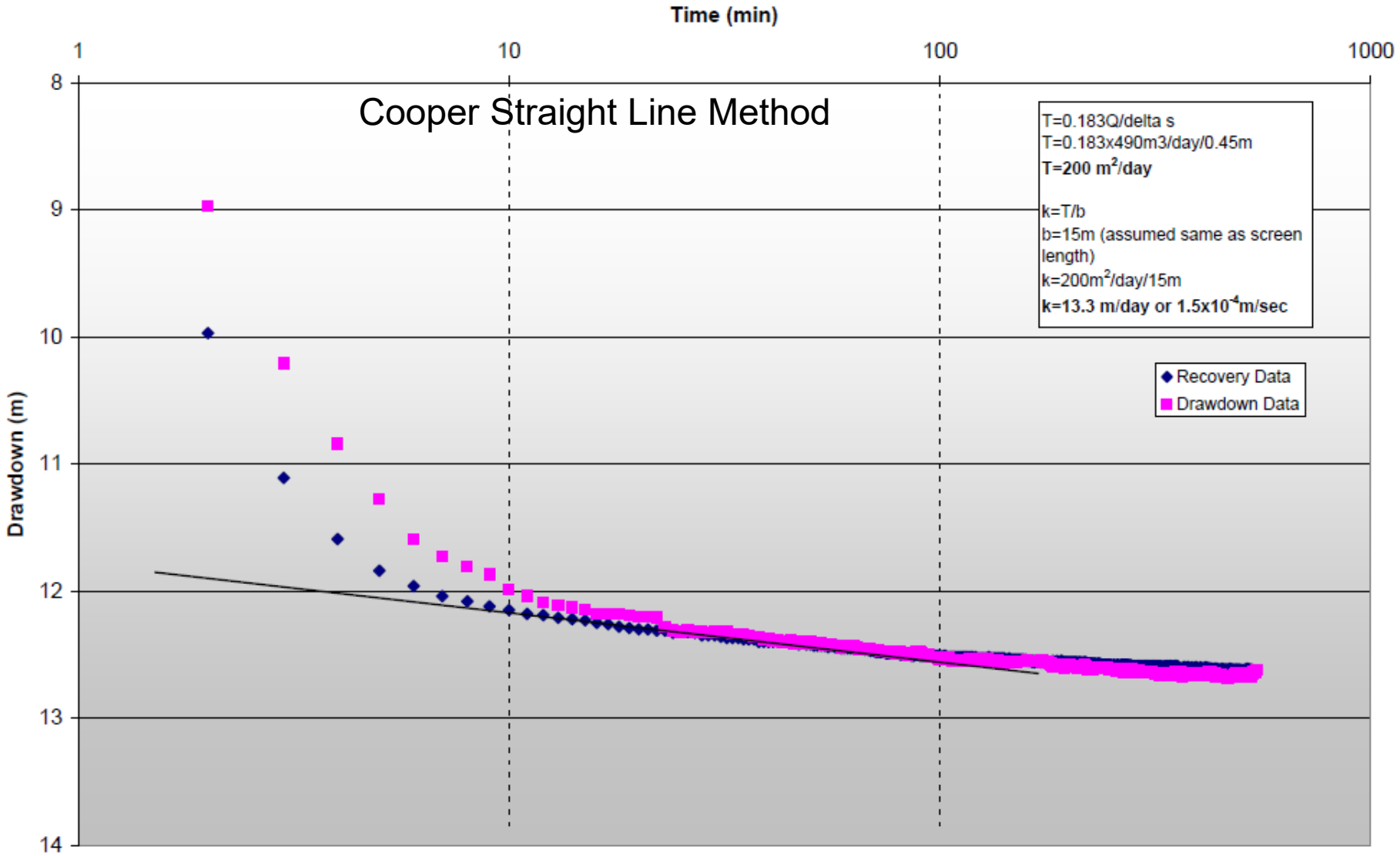


Location of the Water Well



Water Supply Well – 09PUMT302

Pumping Test Results



Conclusions

Well was permitted for a maximum diversion of 3.79 L/s or 327.5 m^3/day

This study showed that, in Saskatchewan, HEM can be very valuable in refining where to drill the water well.

Acknowledgments …… and Questions?

- Jeff Meadows
- Balazs Nemeth
- Arnfinn Prugger
- CGG Multiphysics (Fugro)
- Todd LeBlanc
- Samantha Matheson
- Simon Gautrey
- Dennis Huber