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Developing Integrated Surface and Groundwater Model in Moose Lake Area of Athabasca Oil Sands Region

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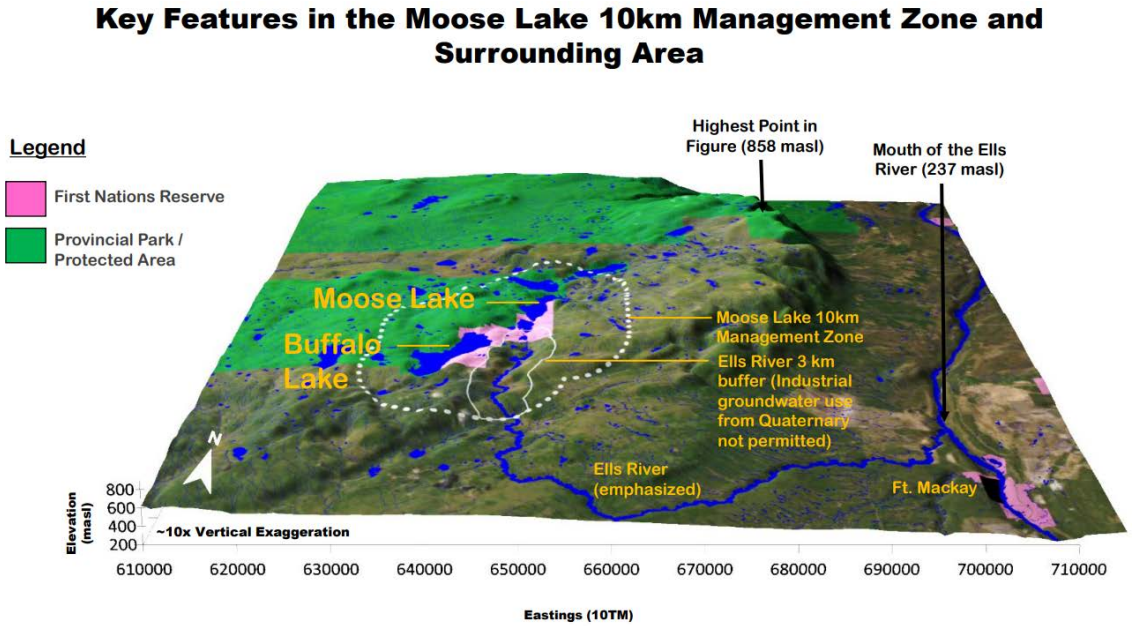
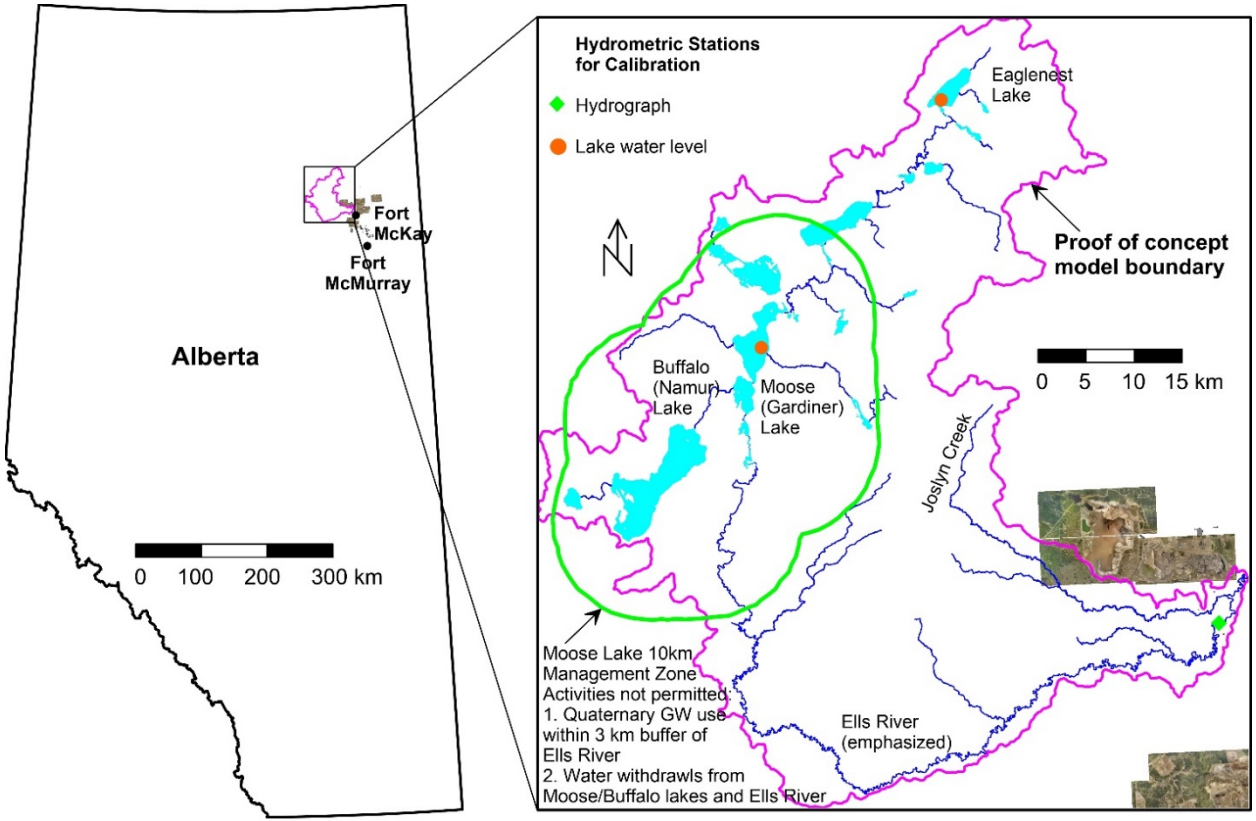
Purpose of the Groundwater – Surface Water Model

- Support consistency and transparency across stakeholders
- Assessment of the interaction between groundwater and surface water
- Assessment of lake-level and streamflow impacts
- Prediction of potential effects to groundwater
- Inform monitoring program
- Inform decision-making



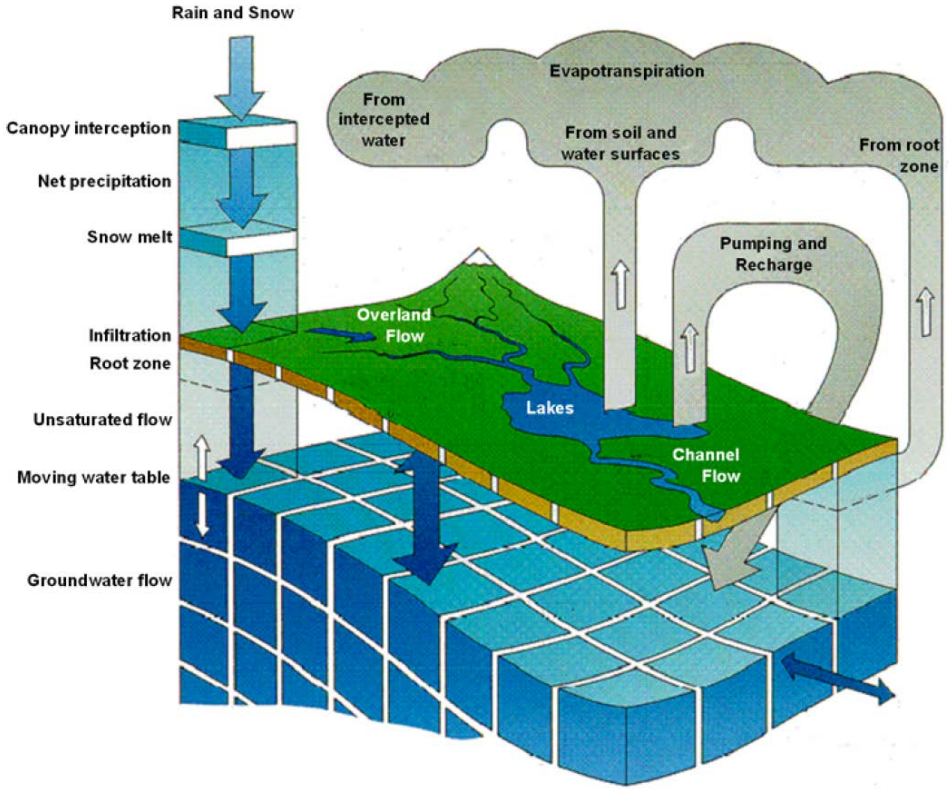
Proof of Concept

- Preliminary model for proof of concept
- Ells River HUC 8 watershed
- Will be expanded to fully include 10 KMZ in next phase



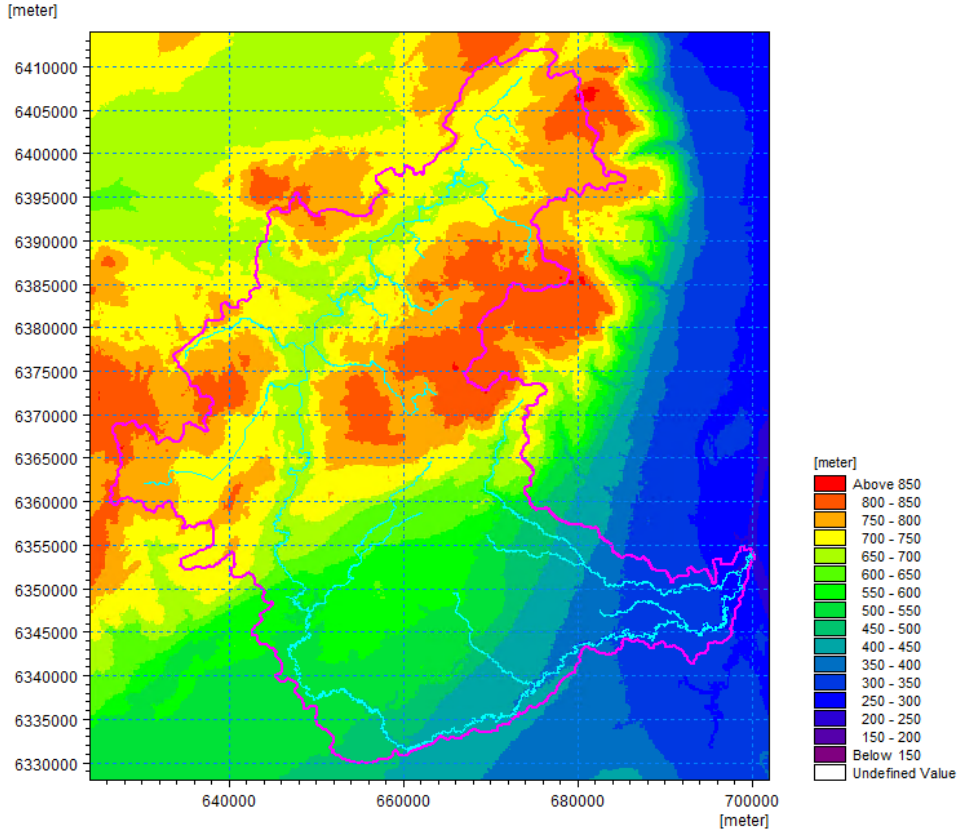
Modelling Tool MIKE SHE

- A mature integrated code with long/successful tract record of applications globally
- Overall appreciation for Moose Lake application over other available integrated codes
- Includes all aspects of the hydrological cycle, and delivers truly integrated modelling of surface water, groundwater, recharge, evapotranspiration and water quality



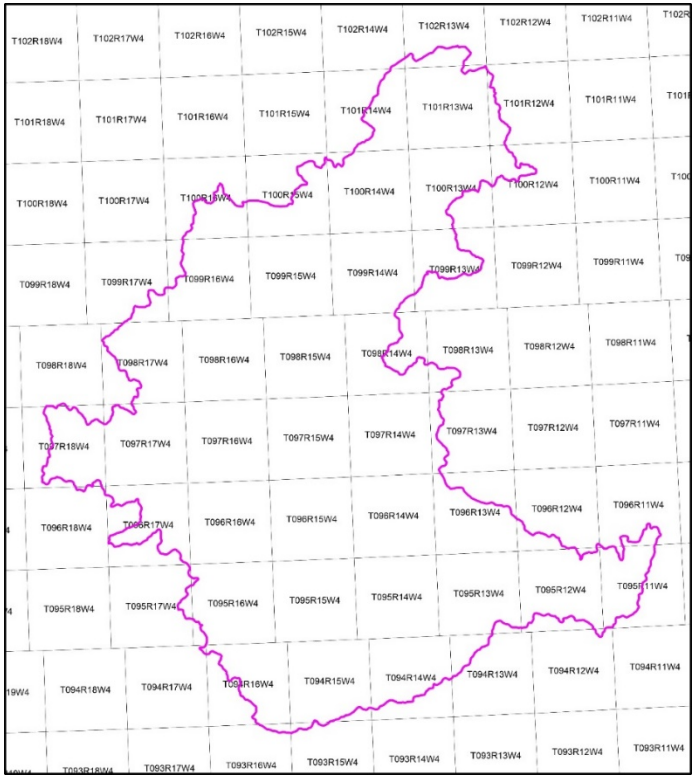
Model Inputs: Topography

- 5 m LiDAR DEM



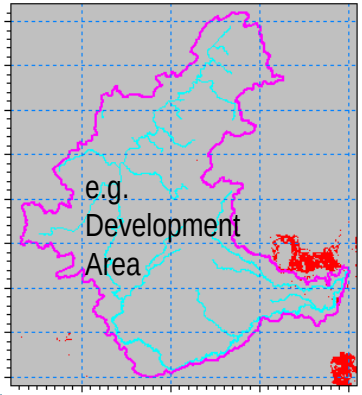
Model Inputs: Historical Climate

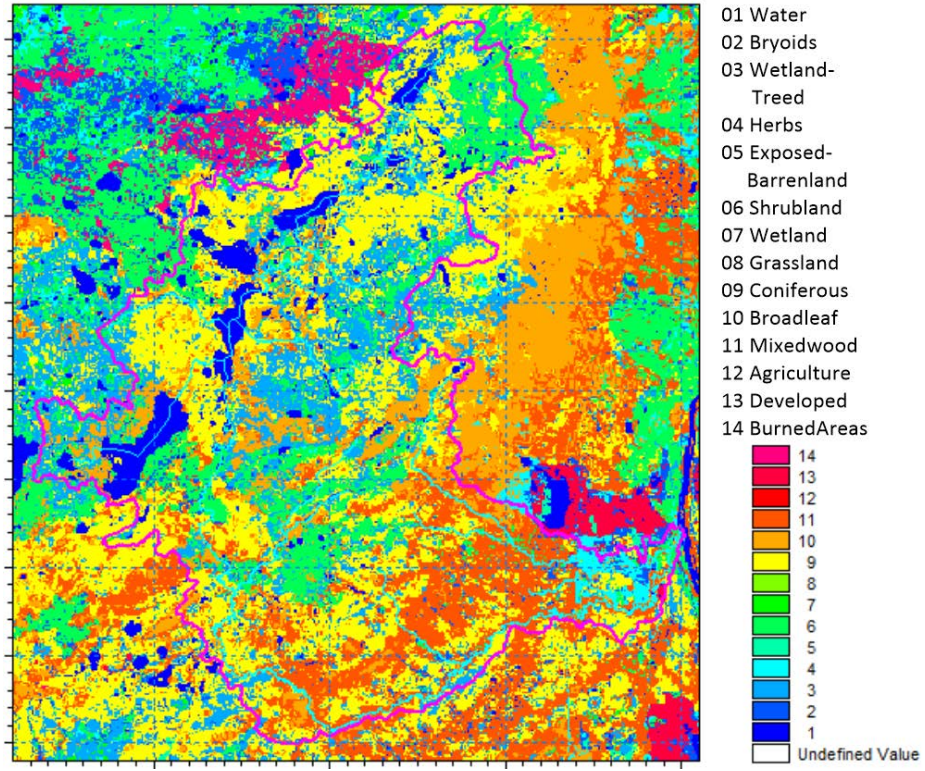
- Township climate data (interpolated with weighting up to the 8 nearest weather station observations): 50 within model footprint
- Parameters (1955-2021): daily air temperature, precipitation, solar radiation and relative humidity



Model Inputs: Land Use and Land Cover

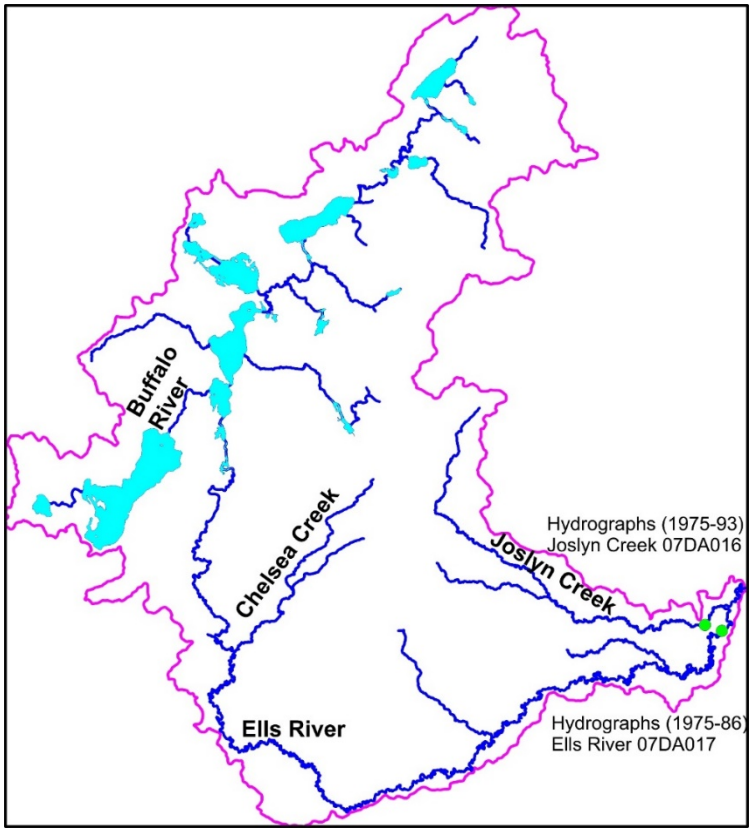
- Baseline: Derived from 2020 Sentinel-2 multispectral imagery (10 m)
- Land classification: 14 classes





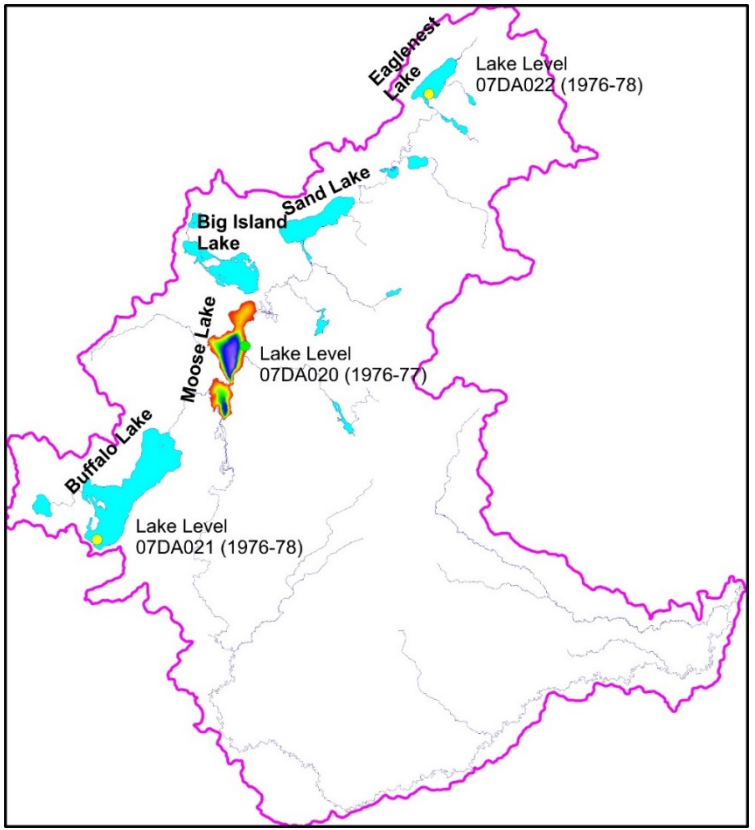
Model Inputs: River Network and Hydrograph

- Model includes all major rivers/streams with Strahler order 4 and above
- Channel flow:
  1D, fully dynamic Saint Venant Eqs
- Model river flows were calibrated using the hydrograph monitored at Ells River downstream hydrometric station 07DA017 (1975 – 1984)



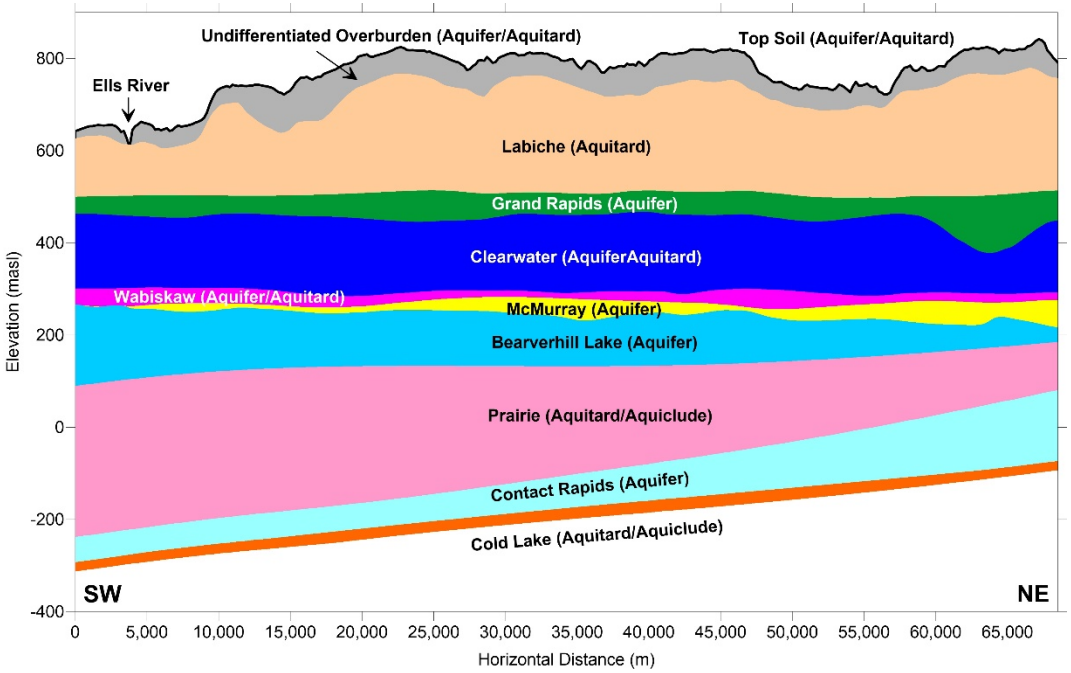
Model Inputs: Lakes and Water Levels

- Model includes 14 major lakes
- Lake levels used for model calibration:
  - Eaglenest lake 07DA022 (1976-78), daily
  - Moose Lake 07DA020 (1976-1977), monthly



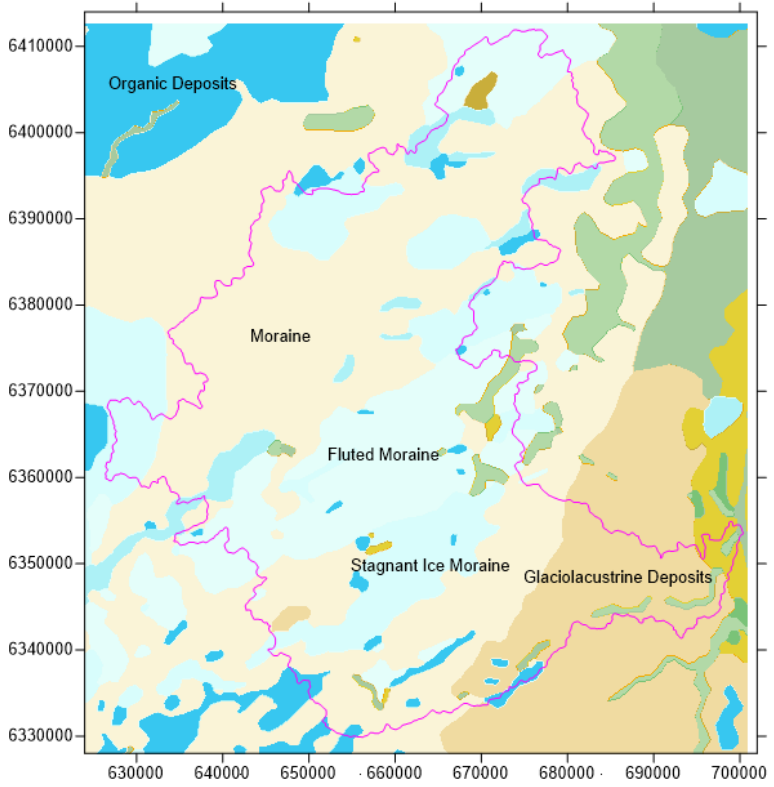
Model Inputs: Geological Setting

- Geological Framework of Alberta version 3
- Hydrostratigraphy: 11 geological layers (ground surface – base of Devonian Cold Lake Formation)



Model Inputs: Topsoil

- Source: Surficial Geology of Alberta Map 601
- Dominant soils: Moraine and Glaciolacustrine Deposits
- Depth: 1 m from ground surface



Model Parameterization

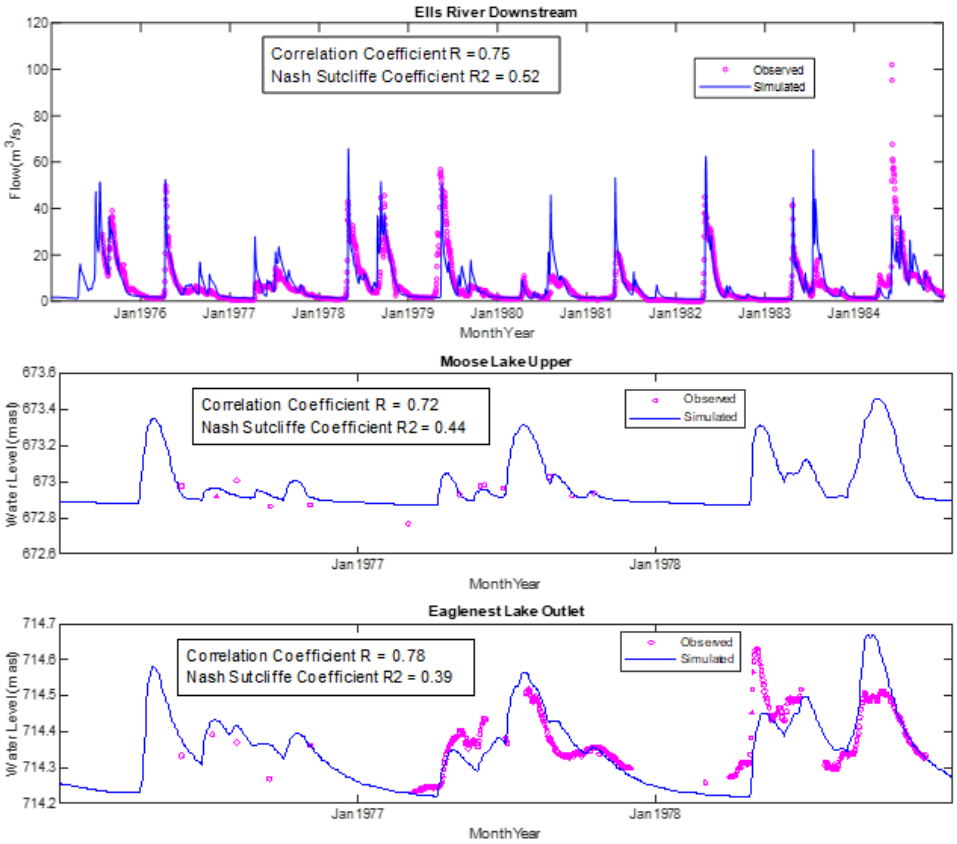
- Based on publications, available data, previous models and surface water calibration

Period	Hydrostratigraphic Unit	Saturated Zone				Unsaturated Zone			Source
		K_{hs} m/s	K_{vs} m/s	S_y	S_s 1/m	θ_s	θ_f	θ_w	
Top Soil	Moraine (Aquifer/Aquitard)	1.20E-06	1.20E-07	0.15	5.00E-05	0.45	0.30	0.145	Data provided by AGS, Model calibration, DHI (2016), van Genuchten (1980), WorleyParsons (2010)
	Fluted Moraine (Aquifer/Aquitard)	1.80E-06	1.80E-07	0.15	5.00E-05	0.45	0.30	0.145	
	Stagnant Ice Moraine (Aquifer/Aquitard)	1.40E-06	1.40E-07	0.15	5.00E-05	0.45	0.30	0.145	
	GlacioLacustrine (Aquifer/Aquitard)	1.30E-06	1.30E-07	0.15	5.00E-05	0.45	0.30	0.145	
Quaternary	Undiff. Quaternary (Aquifer/Aquitard)	1.47E-06	1.47E-07	0.15	5.00E-05	0.45	0.30	0.145	
Cretaceous	Labiche Aquitard (Aquitard)	2.48E-08	2.48E-09	0.10	1.00E-05	0.20	0.10	0.036	
	Grand Rapids (Aquifer)	3.20E-06	3.20E-07	0.15	5.00E-05	0.45	0.30	0.145	
	Clearwater (Aquifer)	2.00E-06	2.00E-07	0.15	5.00E-05	0.45	0.30	0.145	
	Wabiskaw (Aquitard)	2.97E-07	2.97E-08	0.10	1.00E-05	0.26	0.16	0.086	
	McMurray (Aquifer)	7.12E-06	7.12E-07	0.15	5.00E-05	0.45	0.30	0.145	
Devonian	Beaverhill Lake (Aquifer)	5.60E-06	5.60E-07	0.15	5.00E-05	0.45	0.30	0.145	
	Watt Mountain (Aquitard/Aquiclude)	3.20E-10	3.20E-10	0.05	2.00E-06	0.15	0.10	0.042	
	Contact Rapids (Aquifer)	4.08E-06	4.08E-07	0.15	5.00E-05	0.45	0.30	0.145	
	Cold Lake (Aquitard/Aquiclude)	1.60E-10	1.60E-10	0.05	2.00E-06	0.15	0.10	0.042	

K_{hs} = Saturated horizontal hydraulic conductivity K_{vs} = Saturated vertical hydraulic conductivity S_y = Specific yield S_s = Specific storage θ_s = Saturated moisture content (typically equal to porosity) θ_f = Field capacity θ_w = Wilting point

Model Calibration

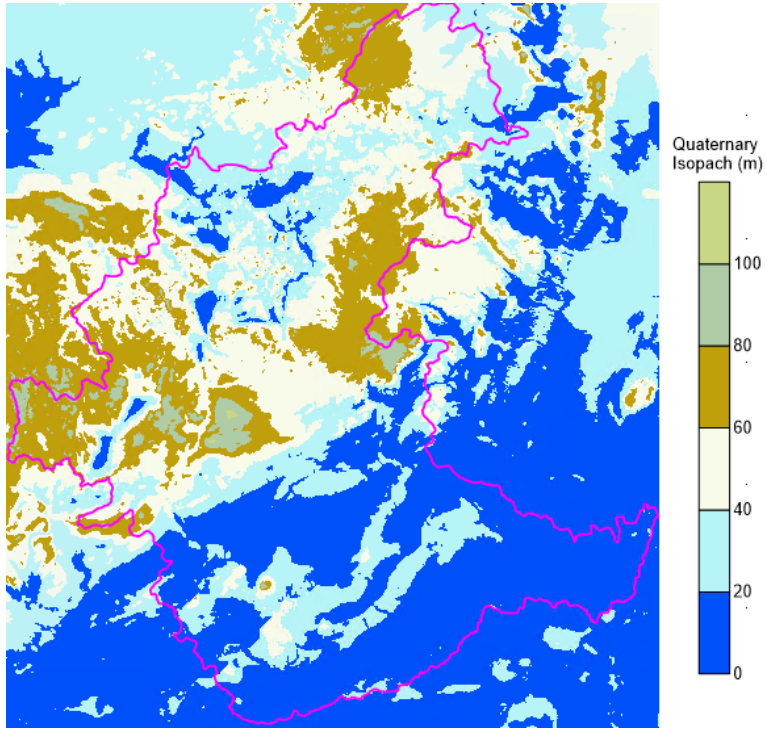
- Preliminary: demonstrating model performance
- Hydrograph: 10 years, downstream of Ells River
- Lake levels: 2 – 3 years, Eaglenest and Moose lakes
- Statistics: correlation and Nash coefficients



Sensitivity Analysis

- Preliminary
- Sensitivity of simulation to inherent uncertainty in model inputs of horizontal/vertical hydraulic conductivities of Quaternary

Baseline conditions		Sensitivity Run	Multiplier of Quaternary hydraulic conductivity	Percent change from baseline condition	
Mean baseflow (m^3/s)	Mean recharge (mm/a)			Mean baseflow (%)	Mean recharge (%)
1.40	11	Case 1	2	15	12
		Case 2	0.5	-10	-7



Next Step

- Expand model domain to fully include 10 KMZ
- Refine Quaternary stratigraphy, such as mapping basal Quaternary unit and till aquitard, etc.
- Revisit surface water calibration
- Fully calibrate groundwater model
- Scenario simulations and analyses

Questions