Groundwater and Underground Coal Gasification in Alberta

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Objectives

- Underground Coal Gasification has potential in Alberta
  - UCG background
  - UCG and groundwater
  - Laurus Energy Demonstration Project
- Multi-disciplined approach to project assessment
  - Geologic and hydrogeologic setting
  - Geologic mapping
  - Hydrogeologic numerical model

What is UCG?

- coal gasification converts coal into synthesis gas (syngas)
- can be applied to mined coal at the surface (Genesee)
- UCG applied to non-mined coal seams using injection and production wells
- oxidant injected, coal is ignited and burns (up to 1250 ^{o}C), series of chemical reactions = syngas
- syngas uses: chemical feedstock or fuel for electrical power generation (e.g. IGCC)
- UCG produces a relatively pure stream of H_2 (upgrading)
- CO_2 byproduct is easily stripped from syngas (CCS, EOR)

UCG Timeline

- Late 1800's
  - Theory Development
- 1930's to 1960's
  - More than 12 commercial plants in USSR
- 1960's to 2000
  - Pilot projects in North America and Europe
- 21st Century
  - Commercial development in North America, Australia and Africa

How can UCG effect groundwater?

- water is needed as a reactant
- the rate of water influx into the coal seams influences the quality and composition of the syngas.

Basic Equation: Coal + O_2 + $H_2O \longrightarrow H_2 + CO$

Water gas shift: $H_2O + CO \longrightarrow CO_2 + H_2$

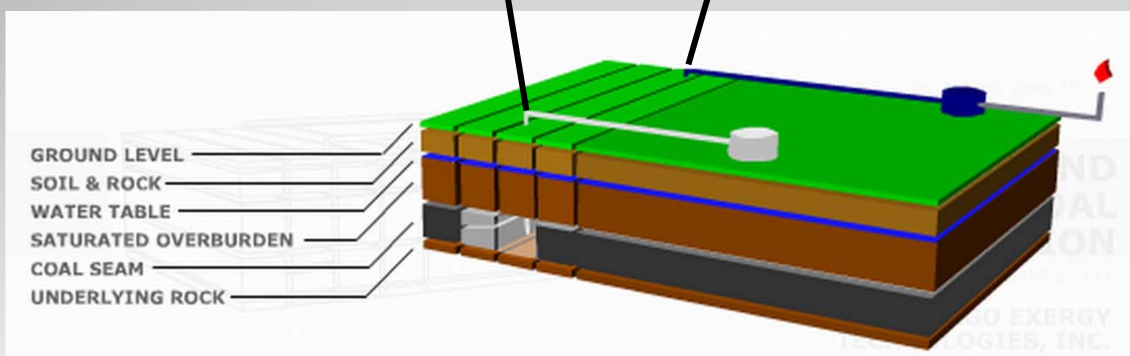
- byproducts created include heat, water with dissolved concentrations of ammonia, phenols, salts, polyaromatic hydrocarbons, and liquid organic products from the pyrolysis of coal.

εUCG Process Overview

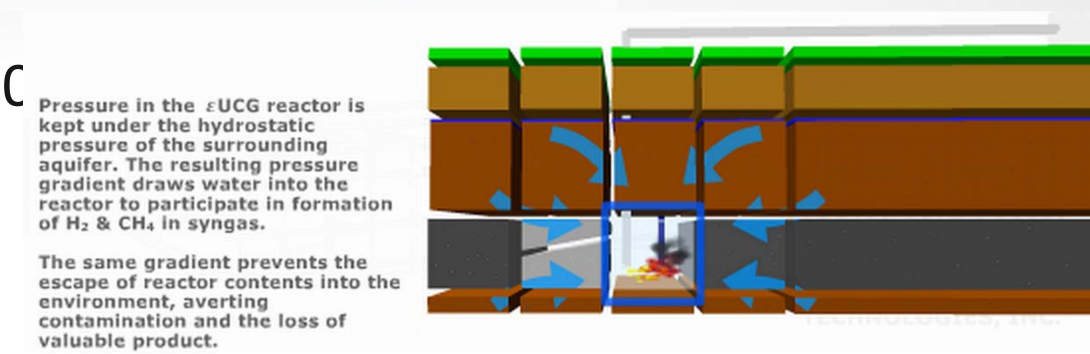
- Laurus has licensed εUCG from Ergo Exergy Technologies Inc.

Injection Well

Production Well



Ergo Exergy, 2010



εUCG Process Overview

- εUCG Process successfully applied at Chinchilla site in Australia from 1999-2003:
- no groundwater contamination
- no subsidence
- no surface contamination
- controlled shutdown
- property returned to prior use
- annual independent audits and full compliance with environmental regulations

Courtesy of Ergo Exergy Technologies Inc.

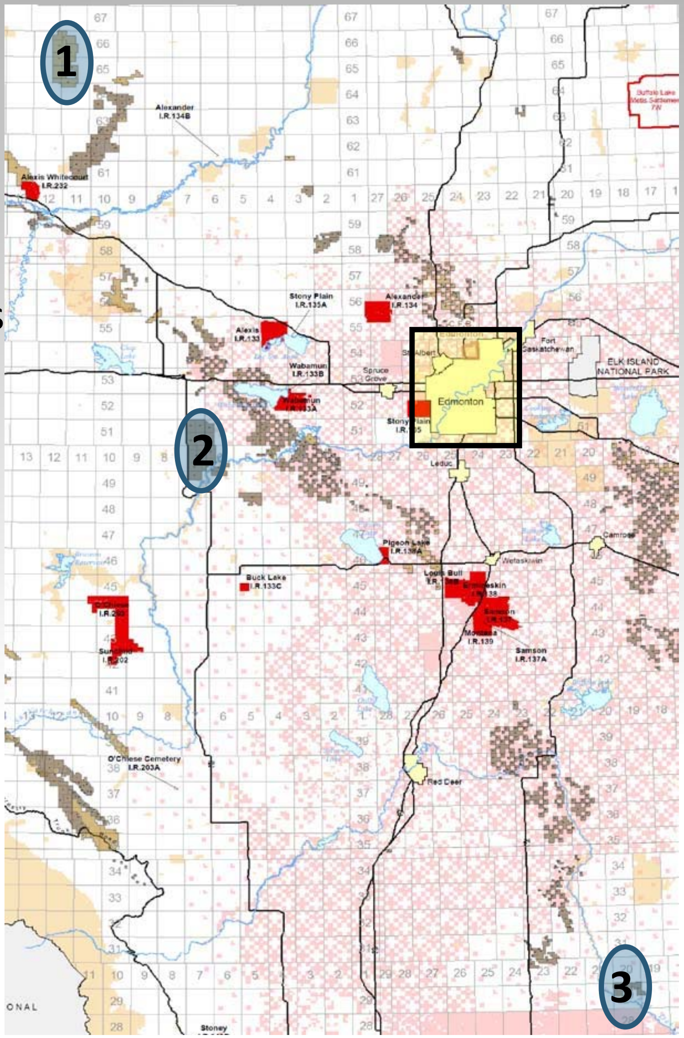
UCG in Alberta

Geologic conditions:

- seam thickness
- structurally integral, continuous

Hydrogeologic conditions:

- saturated conditions
- sufficient hydrostatic pressure
- hydraulically isolated from surrounding aquifers



1. Mannville coals

   Swan Hills Synfuels with Alberta Energy Research Institute, 2008

2. Ardley coals

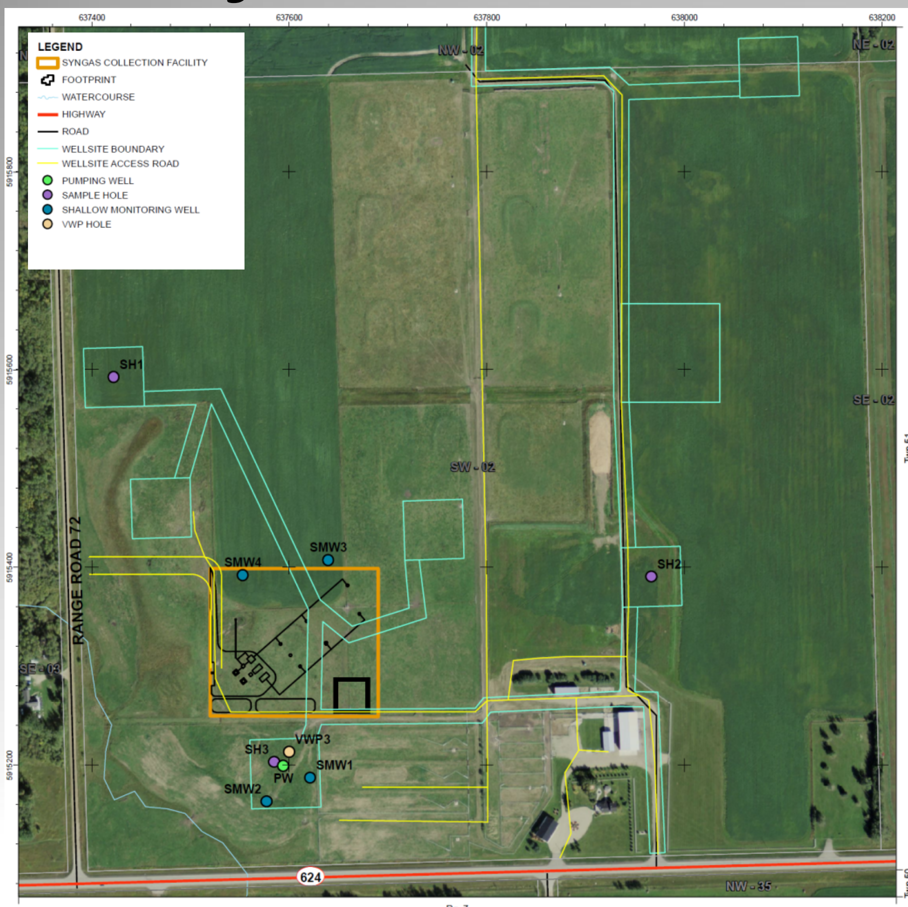
   Laurus Energy, 2008

3. Horseshoe Canyon coals

   Nordic Oil and Gas, 2009

(Alberta Department of Energy, Coal Activity Map, July 30, 2009), Information from Pana (2009)

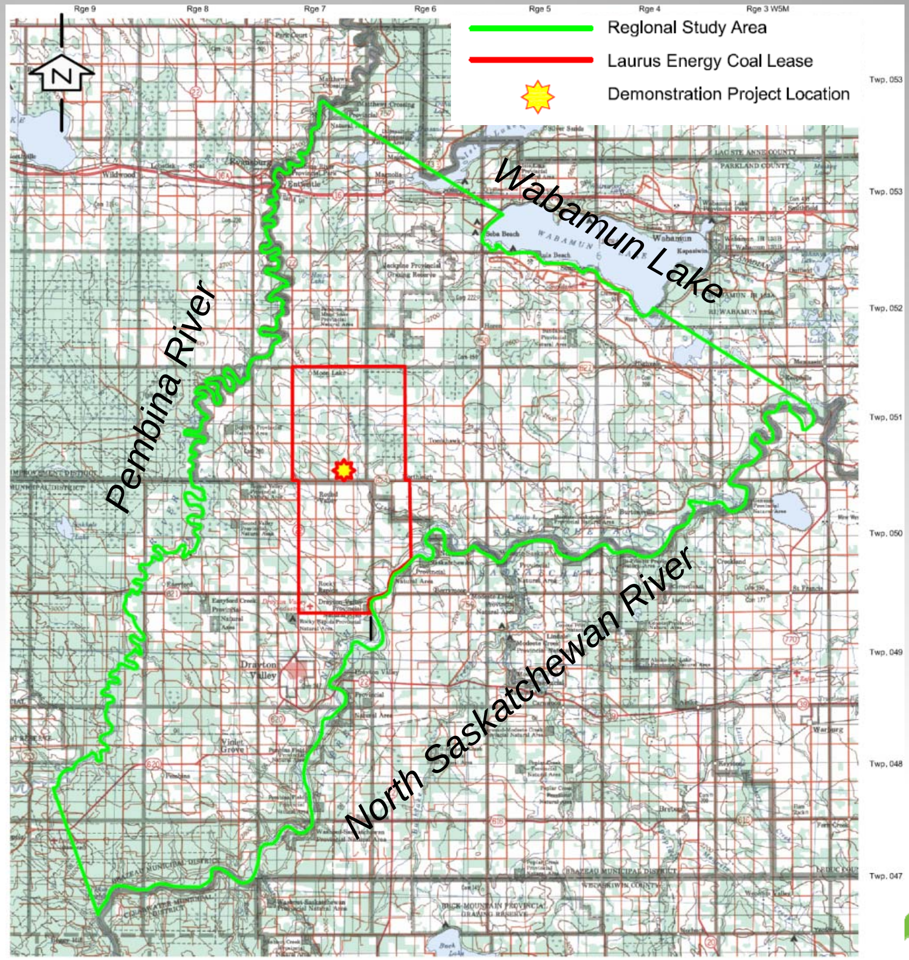
Laurus Energy Demonstration Project



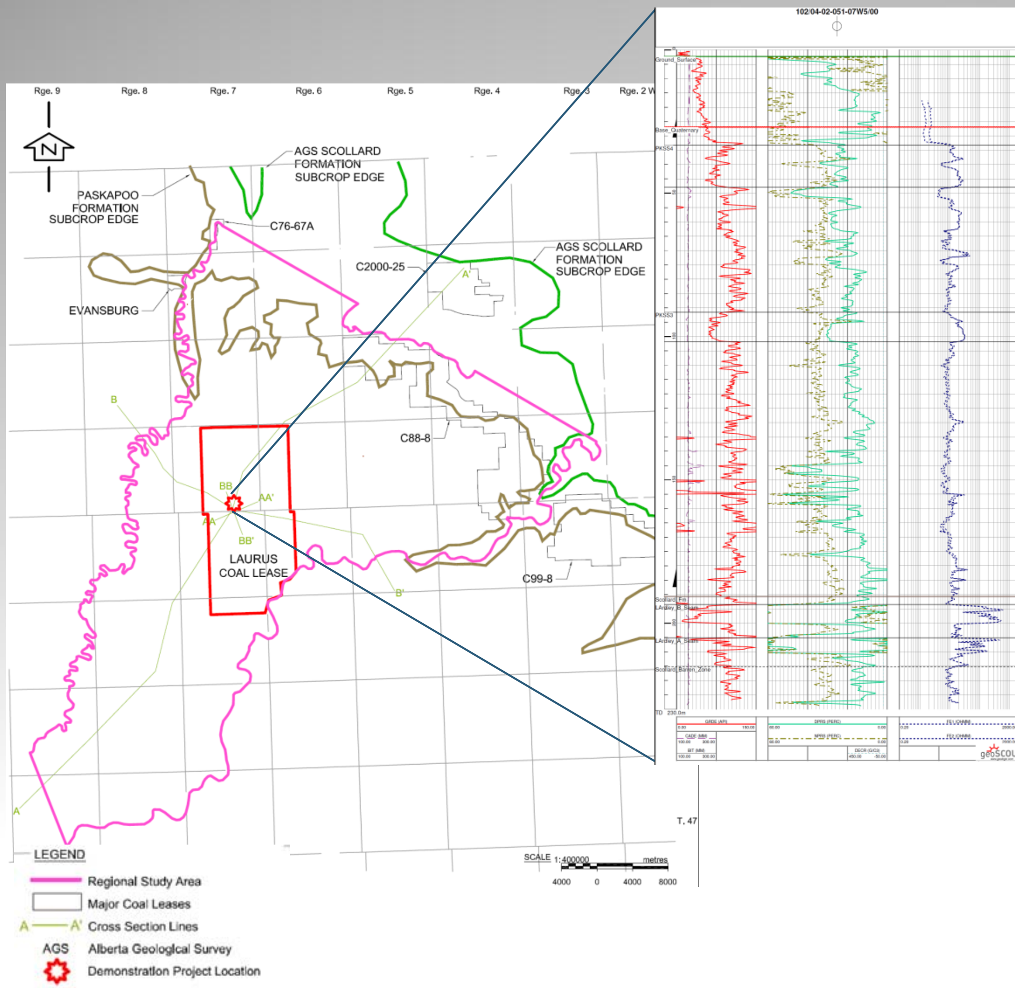
- near Drayton Valley, Alberta
- Demonstration to produce 70,000 Sm^3/d of syngas for one year, approx 9,865 t of coal to be extracted
- groundwater monitoring before, during and after demonstration project

Hydrogeology Assessment

- study area boundaries based on surface hydrologic features where possible
- surface topography is rolling
- high in SW decreasing towards NE and Wabamun Lake
- Farmland with active oil and gas production, coal mining



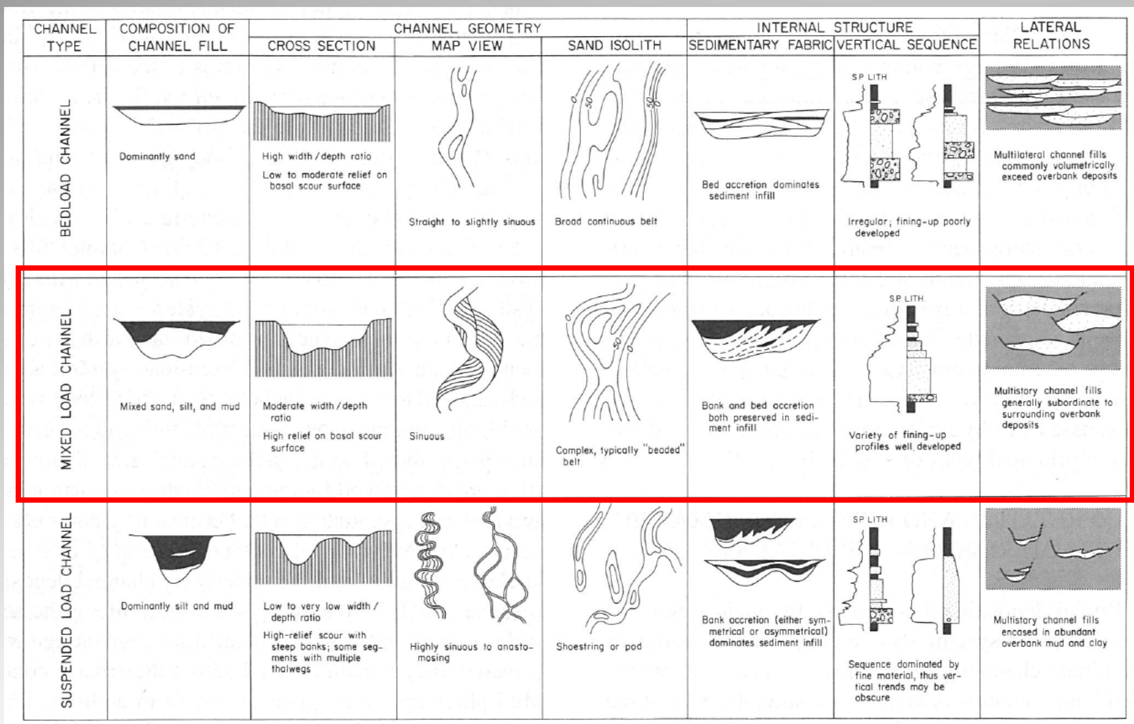
Geological Setting



- target for gasification is the Ardley
- geologic units dip gently towards SW
- Ardley coal zone subcrops near Wabamun Lake
- Ardley at 200 m depth at project
- 111 wells within the RSA reviewed and 2 regional cross sections, integrated with public data (AGS, etc.)

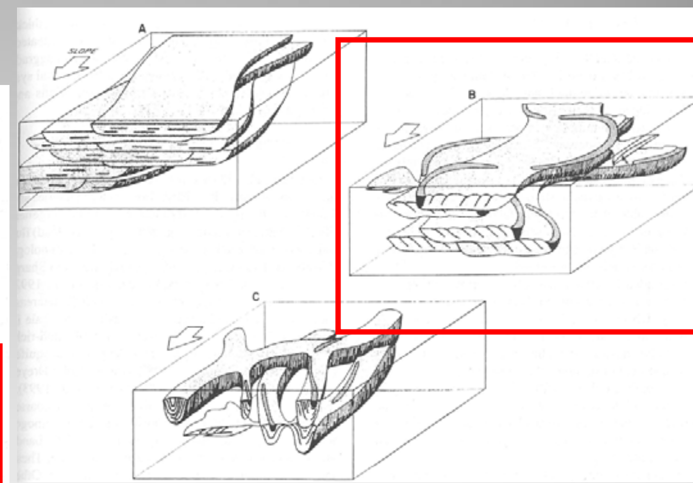
Paskapoo Formation

Facies Models



CHANNEL TYPE	COMPOSITION OF CHANNEL FILL	CHANNEL GEOMETRY: CROSS SECTION	CHANNEL GEOMETRY: MAP VIEW	CHANNEL GEOMETRY: SAND ISOLITH	INTERNAL STRUCTURE: SEDIMENTARY FABRIC	INTERNAL STRUCTURE: VERTICAL SEQUENCE	LATERAL RELATIONS
BEDLOAD CHANNEL	Dominantly sand	High width / depth ratio Low to moderate relief on basal scour surface	Straight to slightly sinuous	Broad continuous belt	Bed accretion dominates sediment infill	SP LITH Irregular; fining-up poorly developed	Multilateral channel fills commonly volumetrically exceed overbank deposits
MIXED LOAD CHANNEL	Mixed sand, silt, and mud	Moderate width / depth ratio High relief on basal scour surface	Sinuous	Complex, typically "beaded" belt	Bank and bed accretion both preserved in sediment infill	SP LITH Variety of fining-up profiles well developed	Multistory channel fills generally subordinate to surrounding overbank deposits
SUSPENDED LOAD CHANNEL	Dominantly silt and mud	Low to very low width / depth ratio High-relief scour with steep banks; some segments with multiple thalwegs	Highly sinuous to anastomosing	Shoestring or pod	Bank accretion (either symmetrical or asymmetrical) dominates sediment infill	SP LITH Sequence dominated by fine material, thus vertical trends may be obscure	Multistory channel fills encased in abundant overbank mud and clay

From Galloway and Sharp (1998)



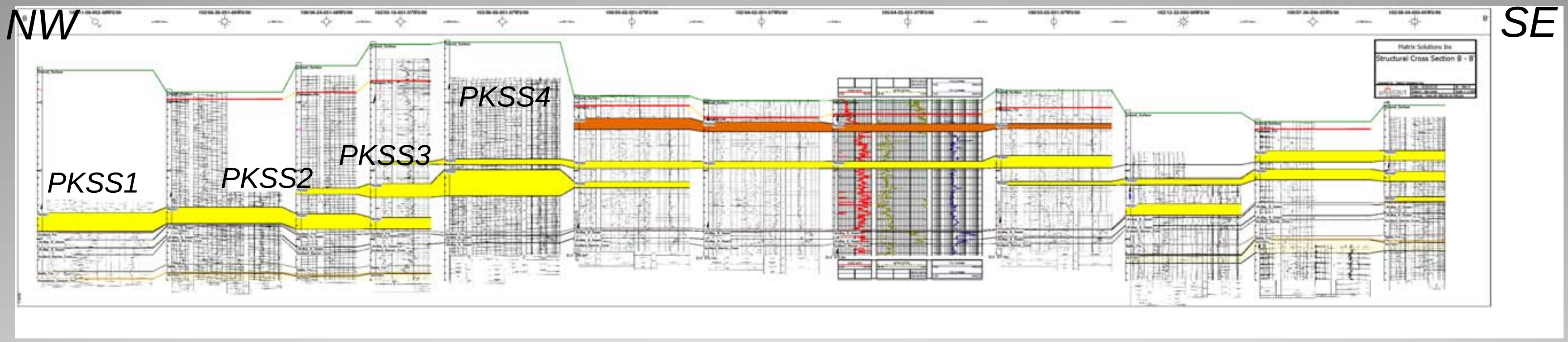
Laramie River, Wyoming
Wikipedia, 2010

Paskapoo Formation

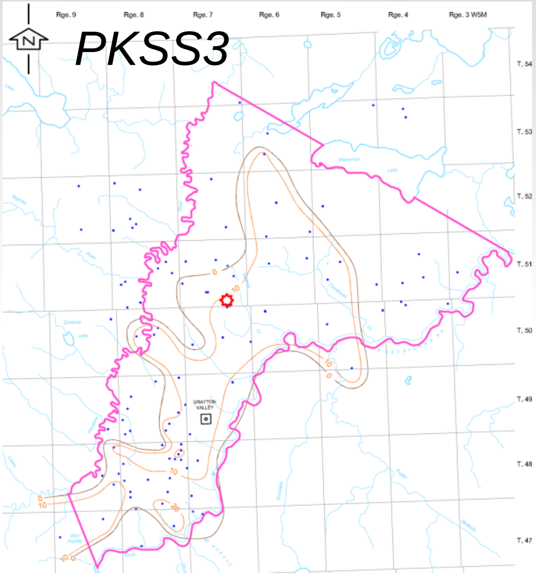
- deposited in ancient non-marine, fluvial channels and floodplains (Dawson *et al., 1994)*
- Stacked and amalgamated channels up to 50 m thick (Pana, 2007 and Grasby *et al., 2008)*
- sandstone exposed in outcrop due to weathering, actually >50% siltstone and shale in subsurface (Grasby *et al., 2008)*

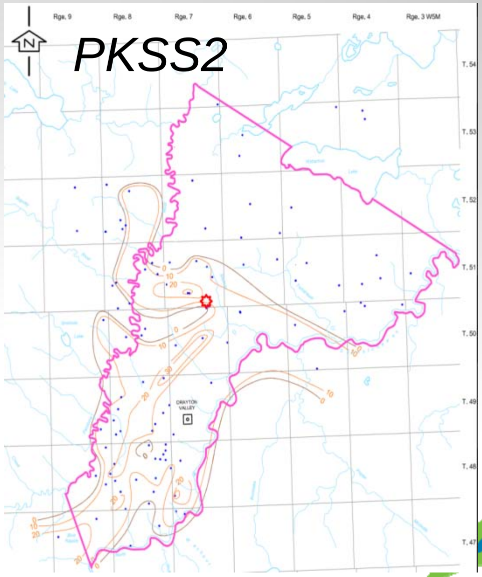
Paskapoo Formation sandstone , Calgary, Wikipedia, 2010

Paskapoo Formation



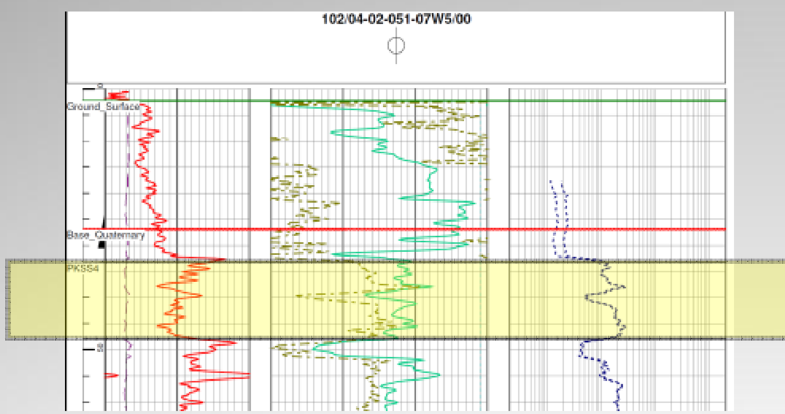
- sheet-like, laterally extensive, amalgamated channel sandstone bodies (Pana, 2007)

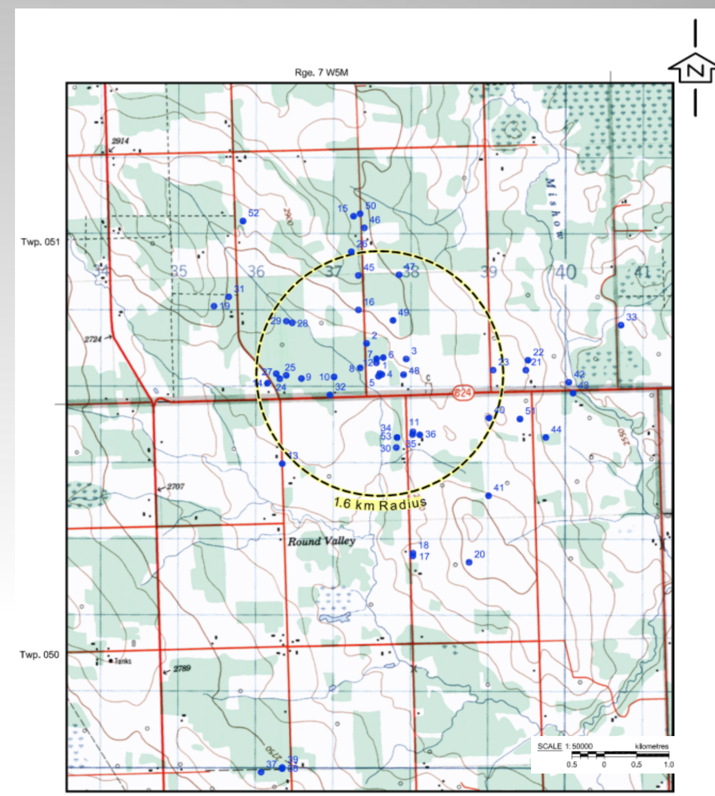




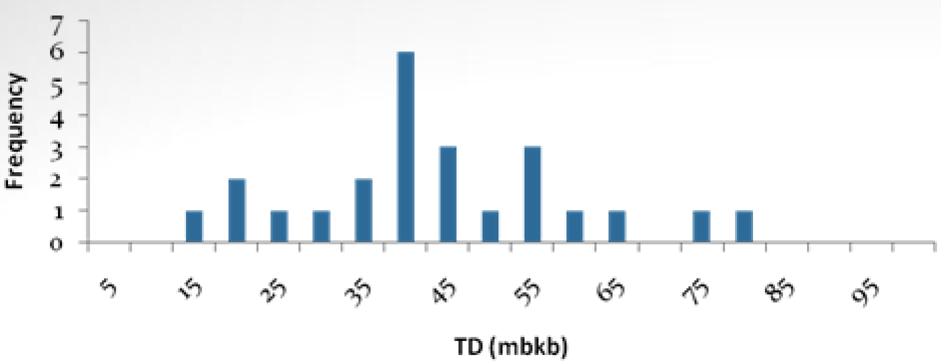
Hydrogeological Setting

- Domestic use Aquifer



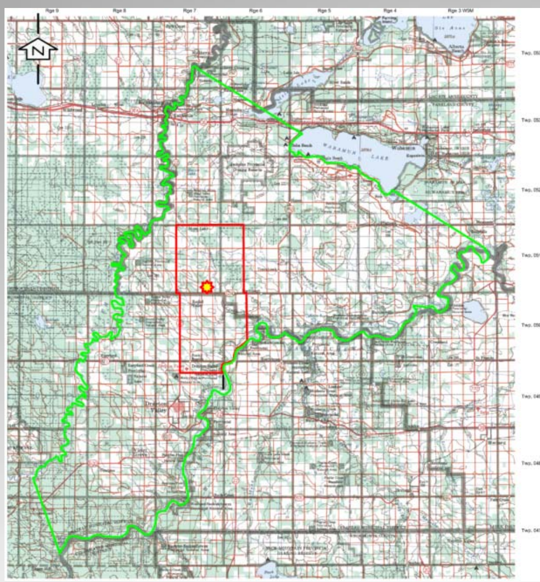


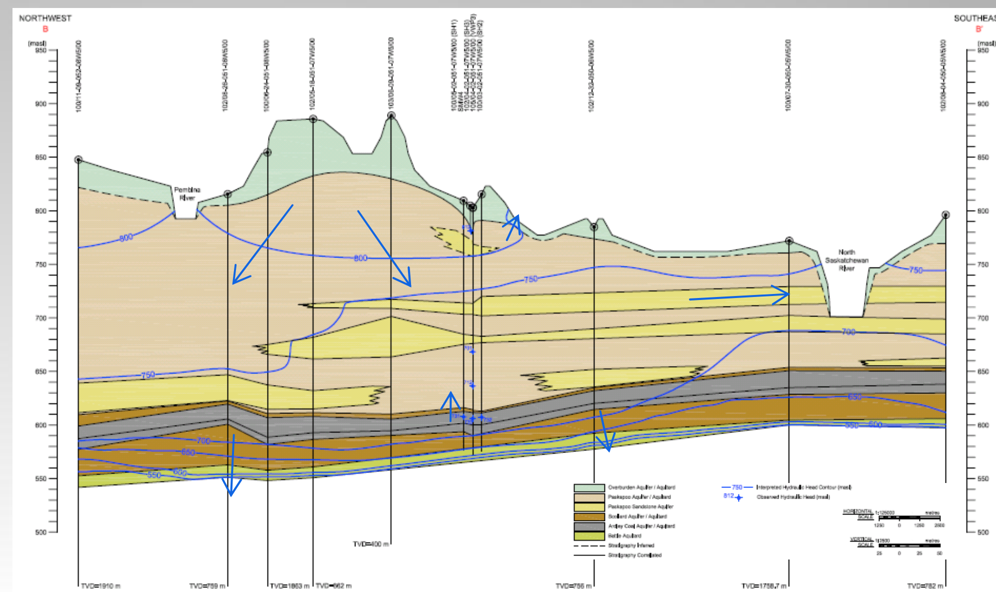
Water Well TD Histogram



Geology and Hydrogeology

How does Paskapoo geology data help hydrogeological interpretation?

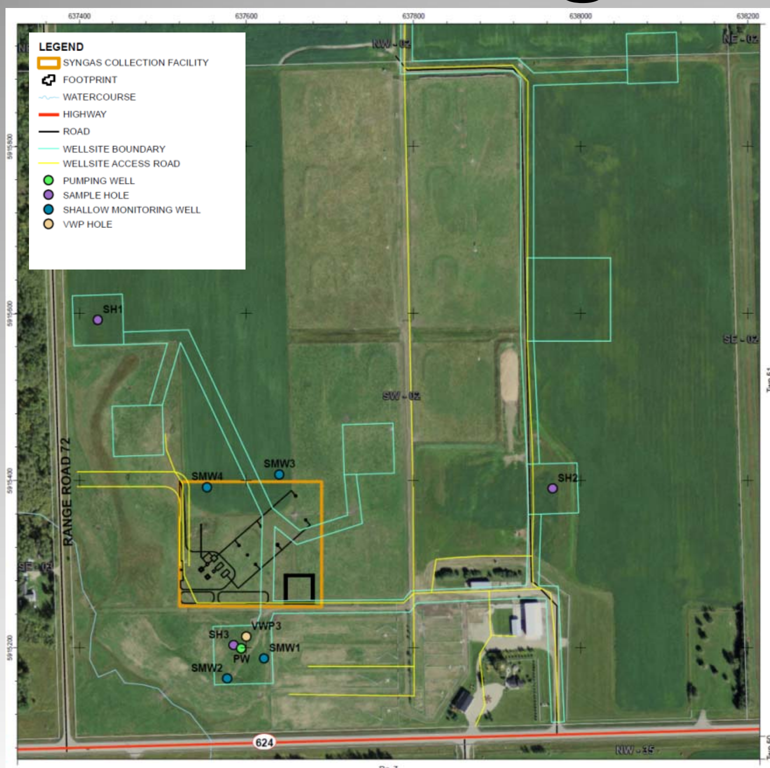


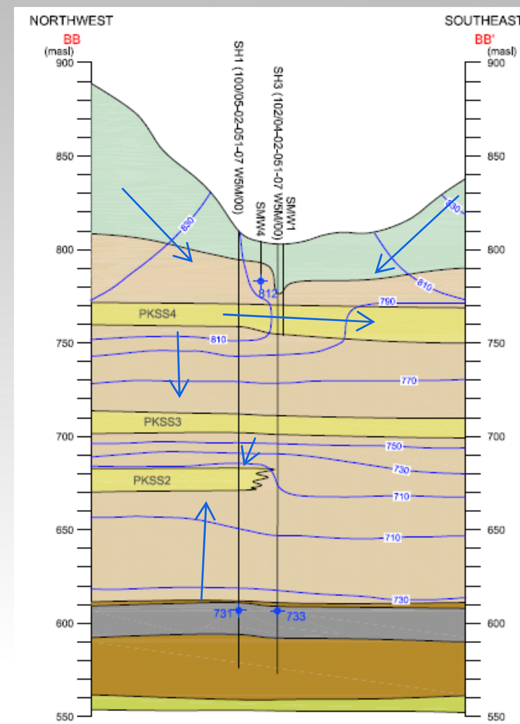


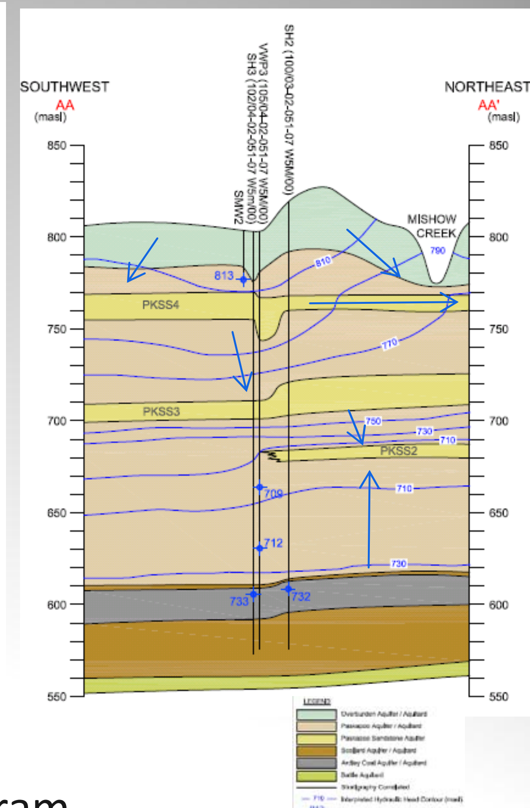
- area with undulating topography (~250 m of relief) and incised river valleys
- discrete sand packages on regional scale separated by low bulk hydraulic conductivities (shale and thin siltstone/sandstone)

→ amalgamated sand aquifers control regional GW flow and pressure distribution

Laurus Energy Groundwater Monitoring



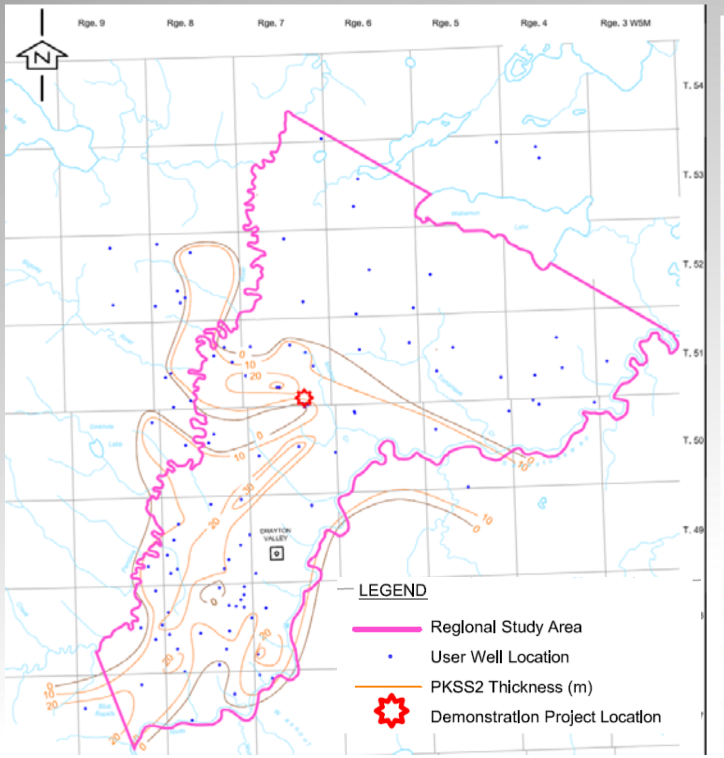


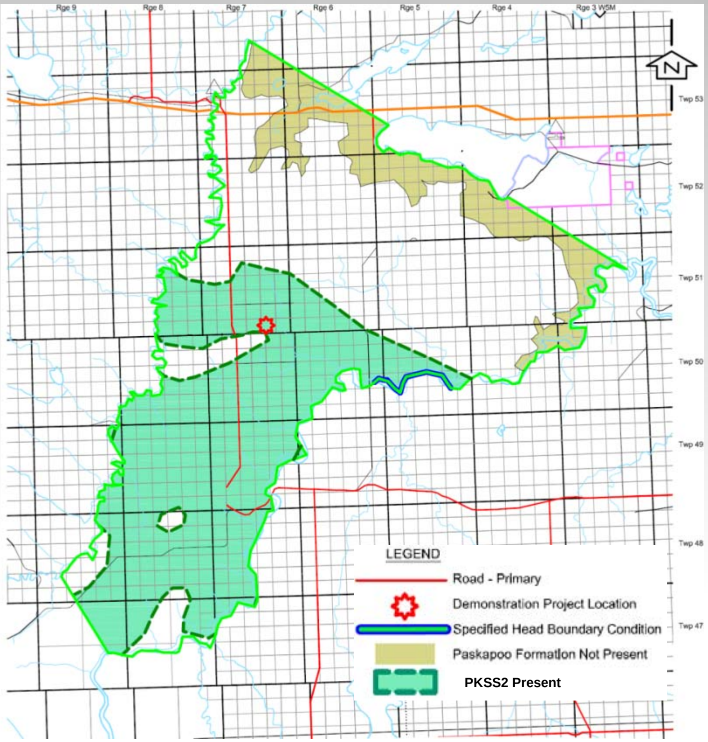


- Laurus completed detailed groundwater monitoring drilling program (geophysical well logs, pressure transducers, vibrating wire piezometers)
- data used for geology interpretation and hydrogeological numerical model

→ enabled a detailed site specific hydrogeological assessment

Hydrogeologic Numerical Model



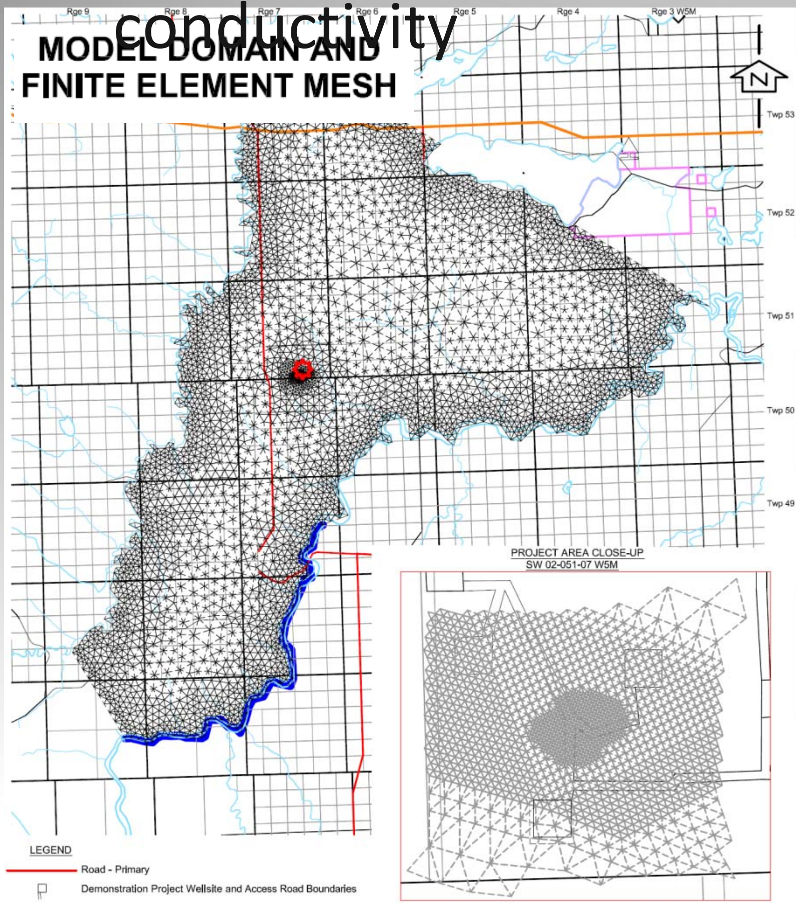


Structure and isopach

of geological units imported into model

Hydrogeologic Numerical Model

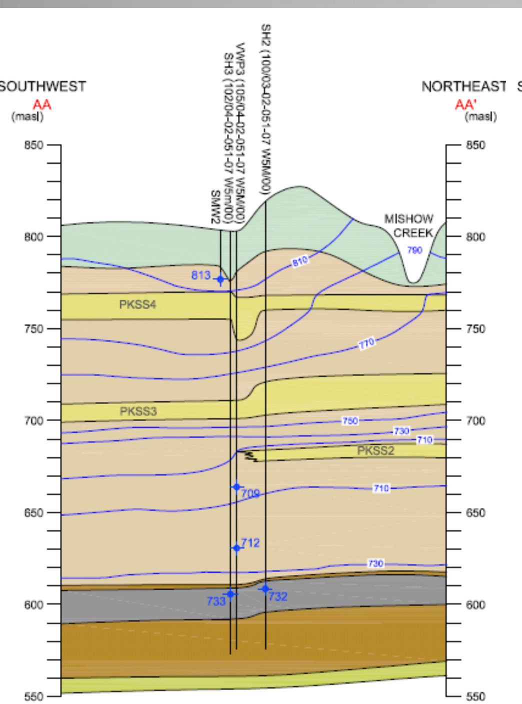
Integration of geometry and hydraulic conductivity

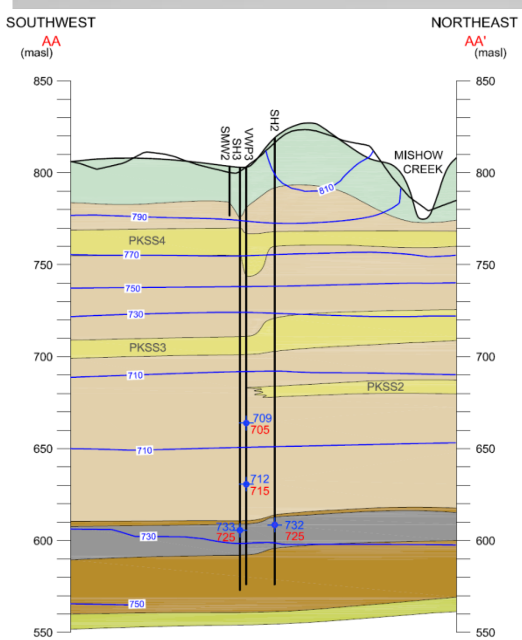


Geologic Surface	Data Source	Reference
Ground Surface	Digital Elevation Model	Matrix (this study)
Top of Paskapoo Formation Structural Elevation	Top of Bedrock Map, 1:250000 Scale (Carlson, 1970)	Carlson, 1970
	Paskapoo Subcrop Edge	Alberta Geological Survey (modified from)
	Geophysical well log picks (68 Wells)	Matrix (this study)
PKSS3 Base Structural Elevation	Geophysical well log picks (45 wells)	Matrix (this study)
PKSS3 Isopach	Geophysical well log picks (45 wells)	Matrix (this study)
PKSS2 Base Structural Elevation	Geophysical well log picks (55 wells)	Matrix (this study)
PKSS2 Isopach	Geophysical well log picks (55 wells)	Matrix (this study)
Top of Scollard Formation Structural Elevation	Geophysical well log picks (104 wells)	Matrix (this study)
Base of Lower Ardley A Coal Structural Elevation	Alberta Coal Exploration Hole Data	Lawrence Consulting and Resources Ltd. (this study)
Top of Lower Ardley B Coal Structural Elevation	Alberta Coal Exploration Hole Data	Lawrence Consulting and Resources Ltd. (this study)
Top of Battle Formation Structural Elevation	Geophysical well log picks (102 Wells)	Matrix (this study)

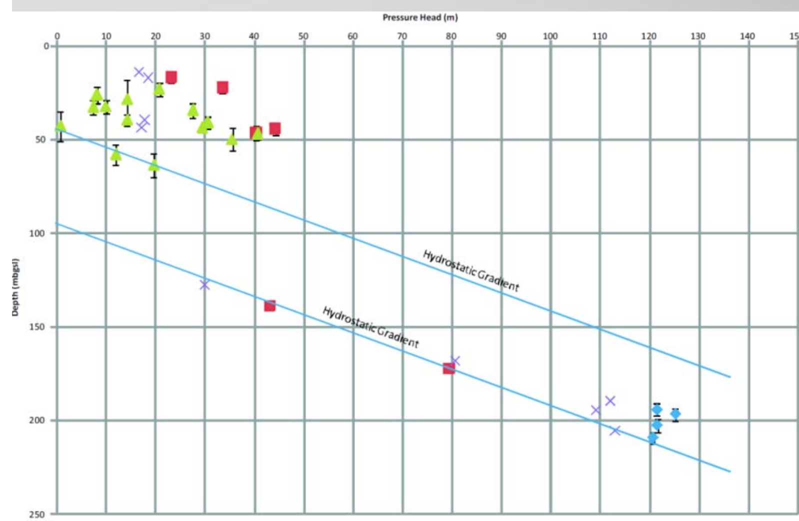
Hydrostratigraphic Unit	Top Slice	Number of Layers	Steady State Solution		
			K_h (m/s)	K_v (m/s)	S_s (m^{-1})
Overburden Aquitard	1	2	3E-08	3E-08	1E-04
Upper Paskapoo Aquifer/Aquitard	3	3	5E-05	1E-11	1E-04
PKSS3	6	1	8E-04	8E-07	1E-04
Middle Paskapoo Aquitard	7	2	3E-06	1E-11	1E-04
PKSS2	9	1	8E-04	8E-07	1E-04
Lower Paskapoo Aquifer/Aquitard	10	3	3E-06	1E-11	1E-04
Upper Scollard Aquifer/Aquitard	13	2	3E-06	1E-11	1E-04
Lower Ardley Coal Zone B	15	1	3E-08	1E-11	1E-04
Middle Scollard Aquifer/Aquitard	16	1	3E-06	1E-11	1E-04
Lower Ardley Coal Zone A	17	1	3E-08	1E-11	1E-04
Lower Scollard Aquifer/Aquitard	18	1	3E-06	1E-11	1E-04
Base of model	19	n/a	no flow		

Model Calibration





Steady state results compared to measured hydrogeological data



Hydrogeologic Numerical Model - Conclusions

- modeled geologic geometry and hydraulic conductivities result in a reasonable representation of the hydrogeological system
- discrete sand packages in the Paskapoo control regional groundwater flow gradients
- easily reproduced in numerical model with simple boundary conditions

Hydrogeology Assessment - Conclusions

- Underground Coal Gasification has potential in Alberta and risks to groundwater can be minimized by a properly designed project
- project planning and site selection needs to involve a multi-disciplined approach including detailed geologic mapping and hydrogeologic mapping
- in complex hydrogeological settings, good geological understanding at an appropriate scale simplifies the problem


Questions

References

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