

# UNCONVENTIONAL GAS, HYDRAULIC FRACTURING AND WATERSHEDS

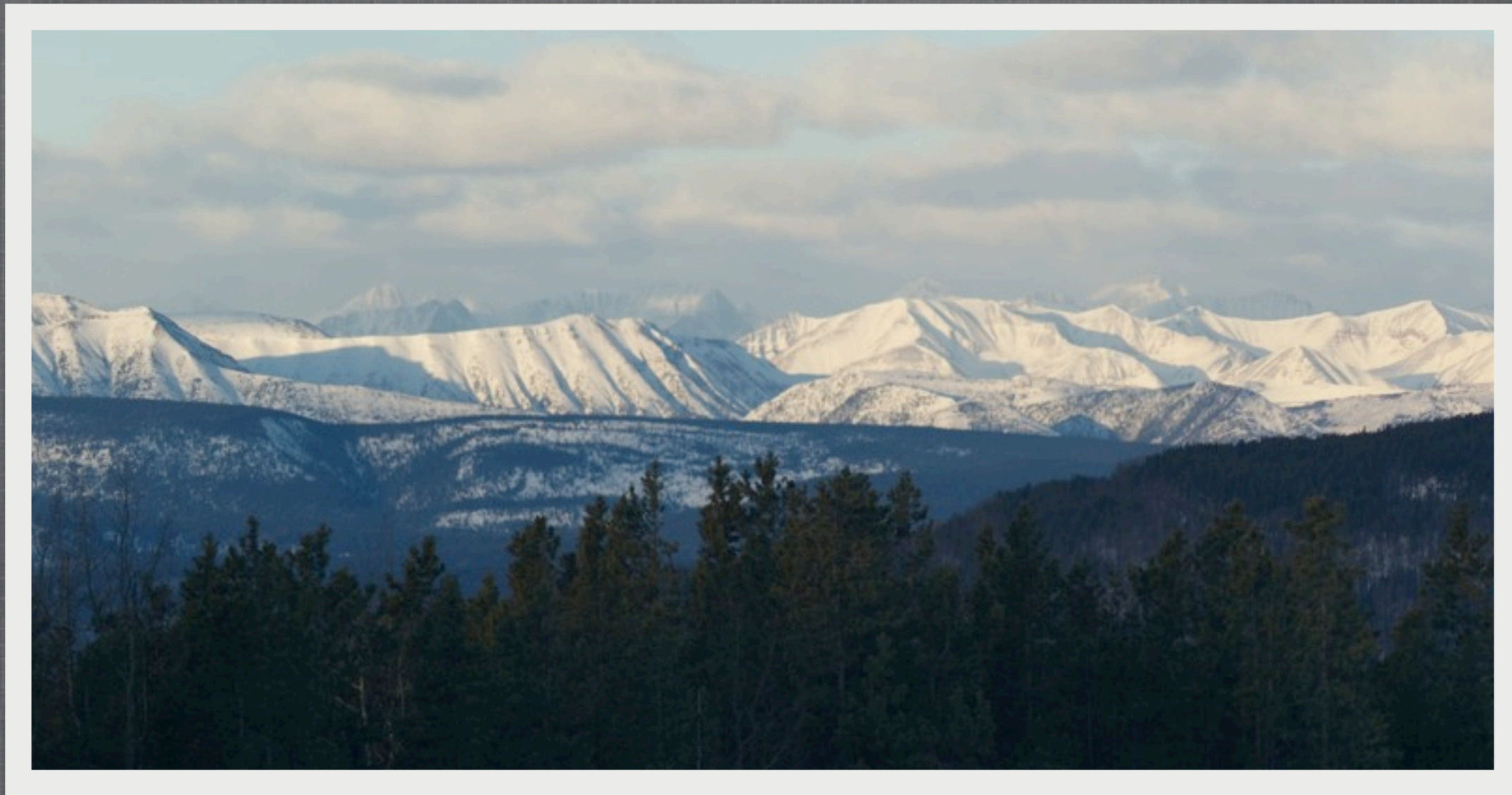


Photo: Gilles Wendling

Whitehorse, January 2014

# OUTLINE

- Access to shale gas - basic principles
- Groundwater - presence and movement
- Wells 100% sealed? Forever?
- Surface water and groundwater interaction
- Potential effects - cumulative - delayed

# WE ARE NOT ALONE

## GERMANY, UK, SOUTH AFRICA

Panel of experts

### Hydrofracking Risk Assessment

*Executive Summary*

Study concerning the safety and environmental compatibility of hydrofracking for natural gas production from unconventional reservoirs

C. Ewen, D. Borchardt, S. Richter, R. Hammerbacher



### STATE OF THE ART: FRACKING FOR SHALE GAS EXPLORATION IN SOUTH-AFRICA AND THE IMPACT ON WATER RESOURCES

Feb 2012

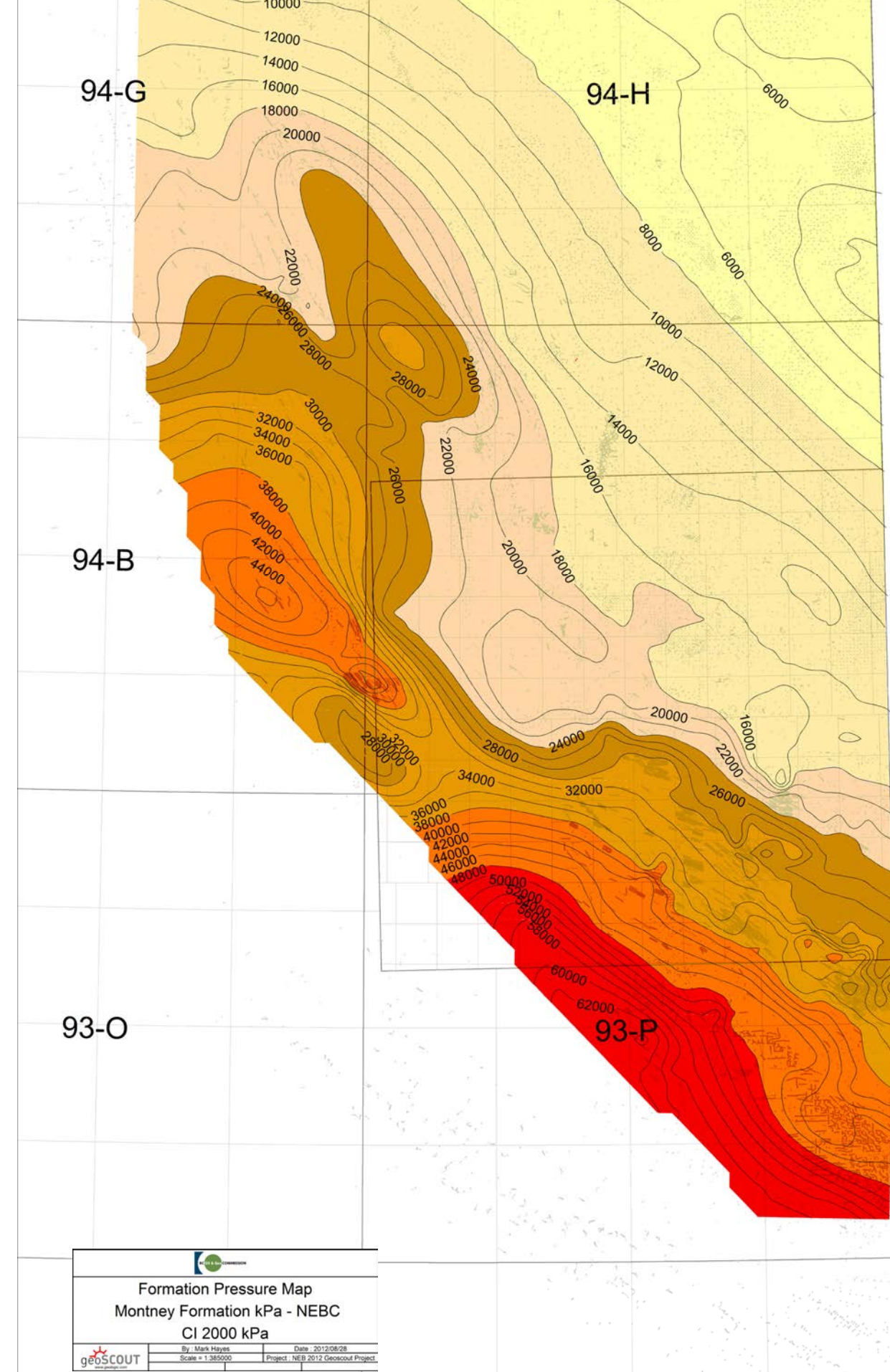
Report to the  
Water Research Commission

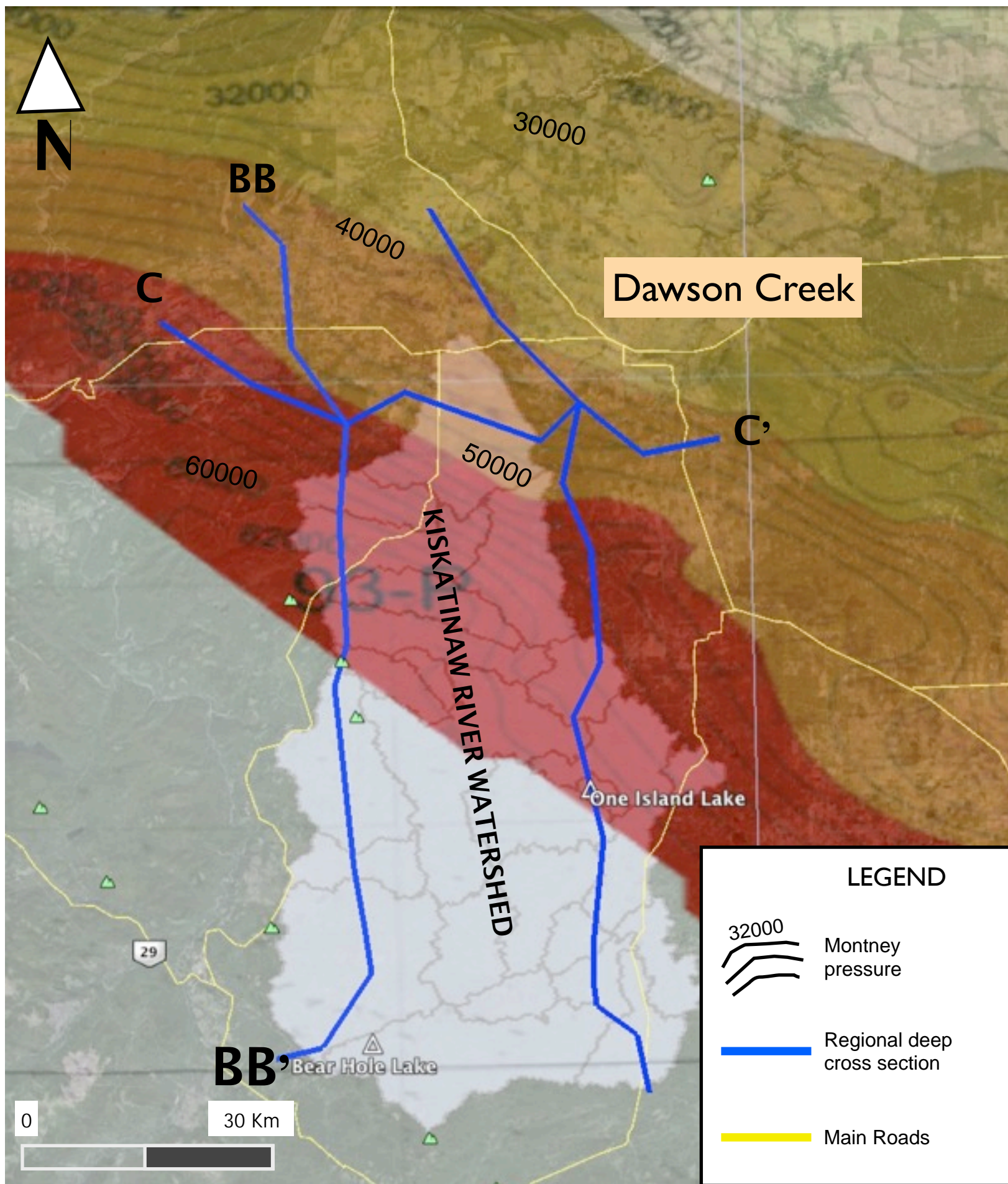
by

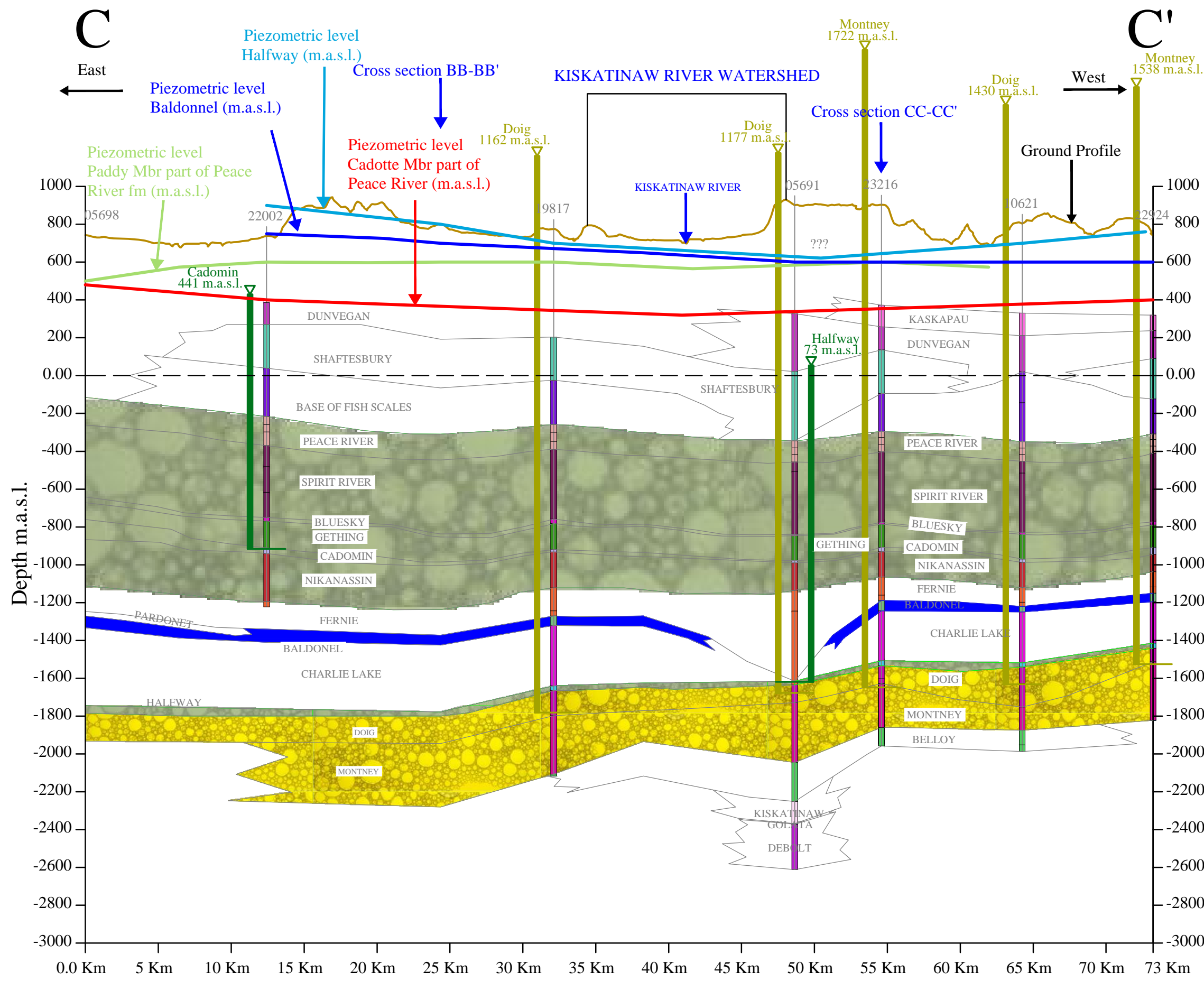
**Prof. G. Steyl<sup>1</sup>, Prof. G.J. van Tonder<sup>2</sup> and Dr. L. Chevallier<sup>3</sup>**

1. University of the Free State, Chemistry Department, Bloemfontein
2. University of the Free State, Institute for Groundwater Studies, Bloemfontein
3. Council for Geoscience, Western Cape branch, Bellville

**ECONOMIC  
WHEN PASSIVE METHOD OF  
EXTRACTION**







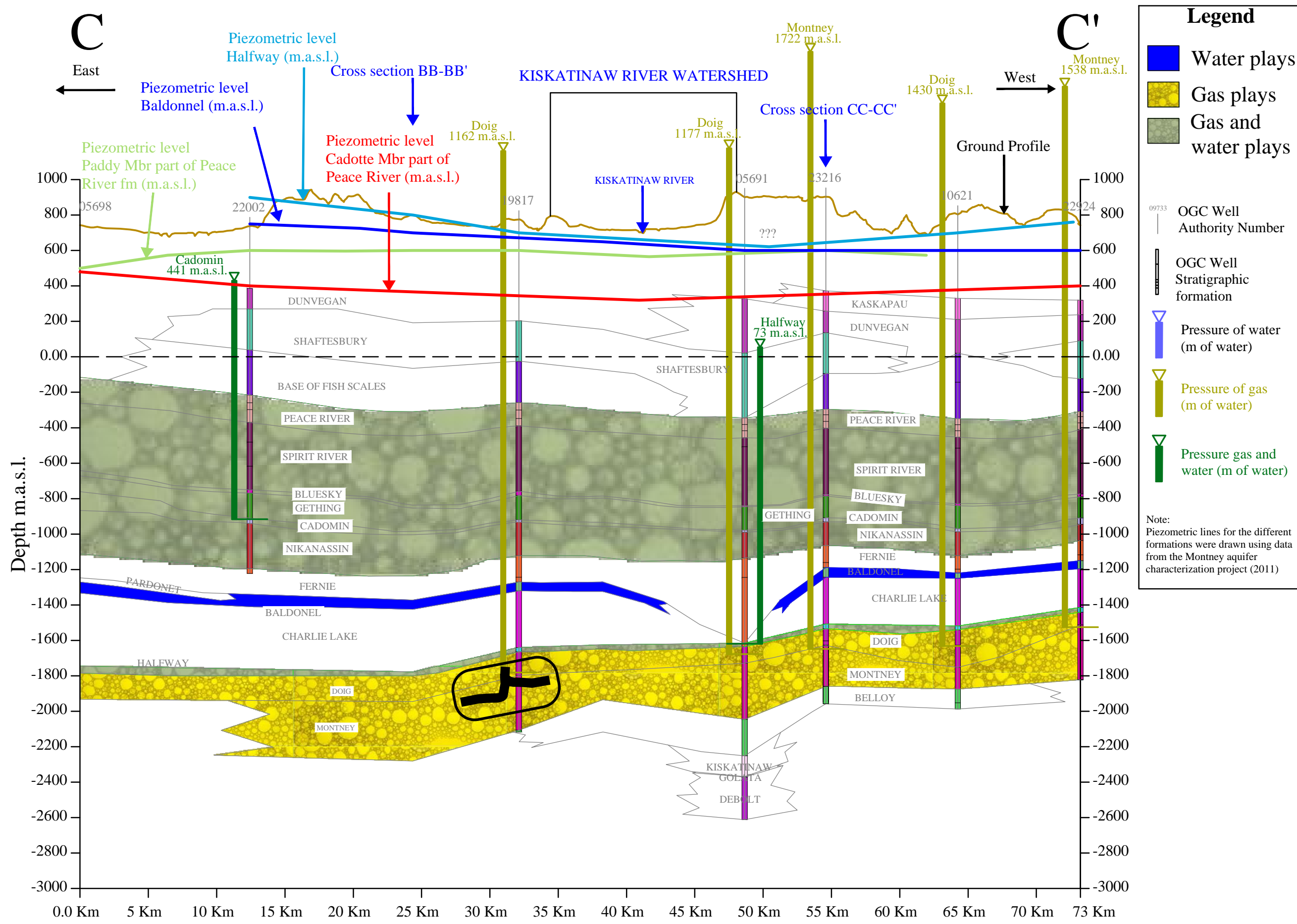
### Legend

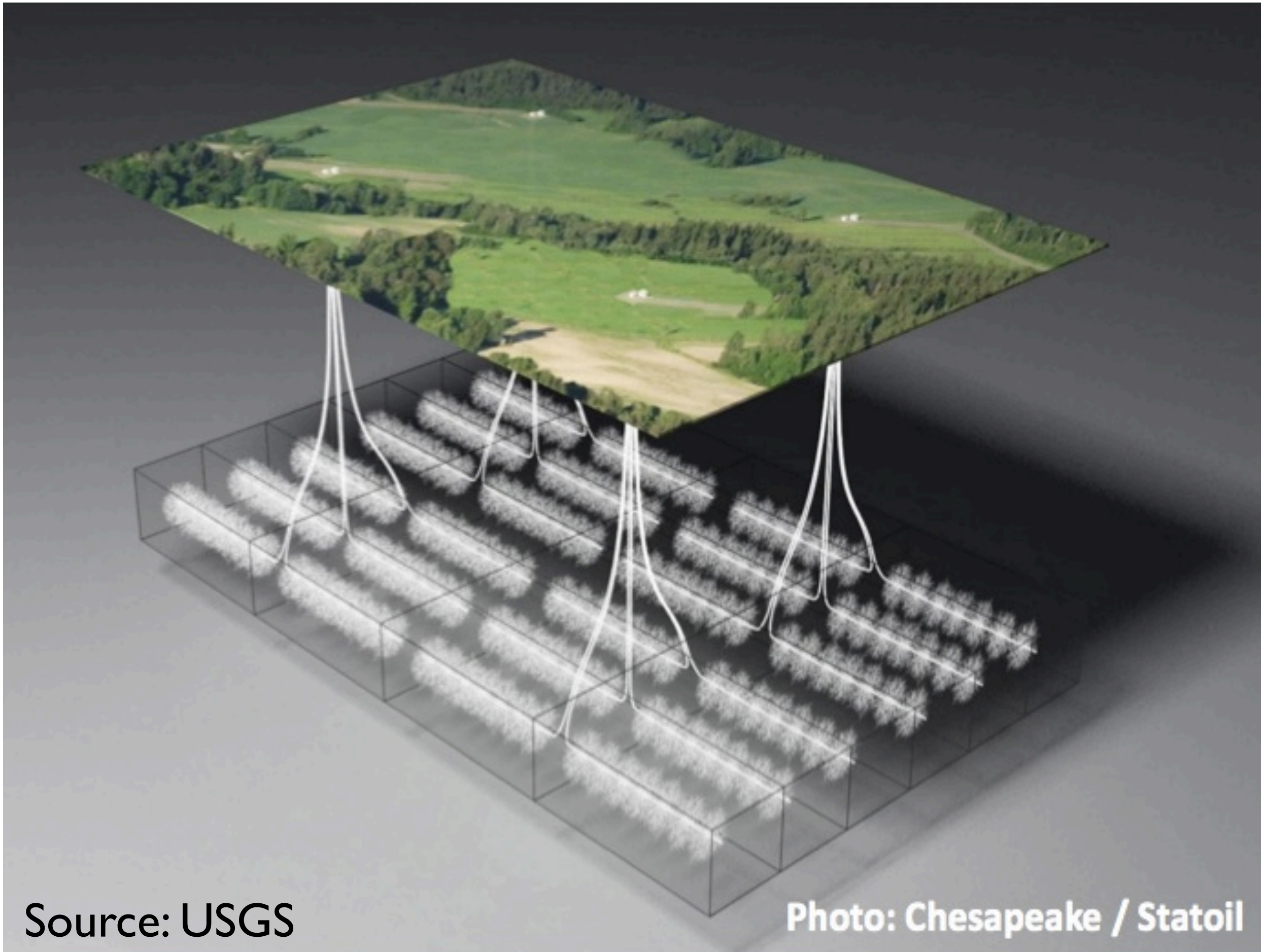
- Water plays
- Gas plays
- Gas and water plays
- OGC Well Authority Number
- OGC Well Stratigraphic formation
- Pressure of water (m of water)
- Pressure of gas (m of water)
- Pressure gas and water (m of water)

Note:  
Piezometric lines for the different formations were drawn using data from the Montney aquifer characterization project (2011)

**IDENTIFICATION OF PLAY  
AND  
MAKING THAT PLAY AS  
PERMEABLE AS POSSIBLE**



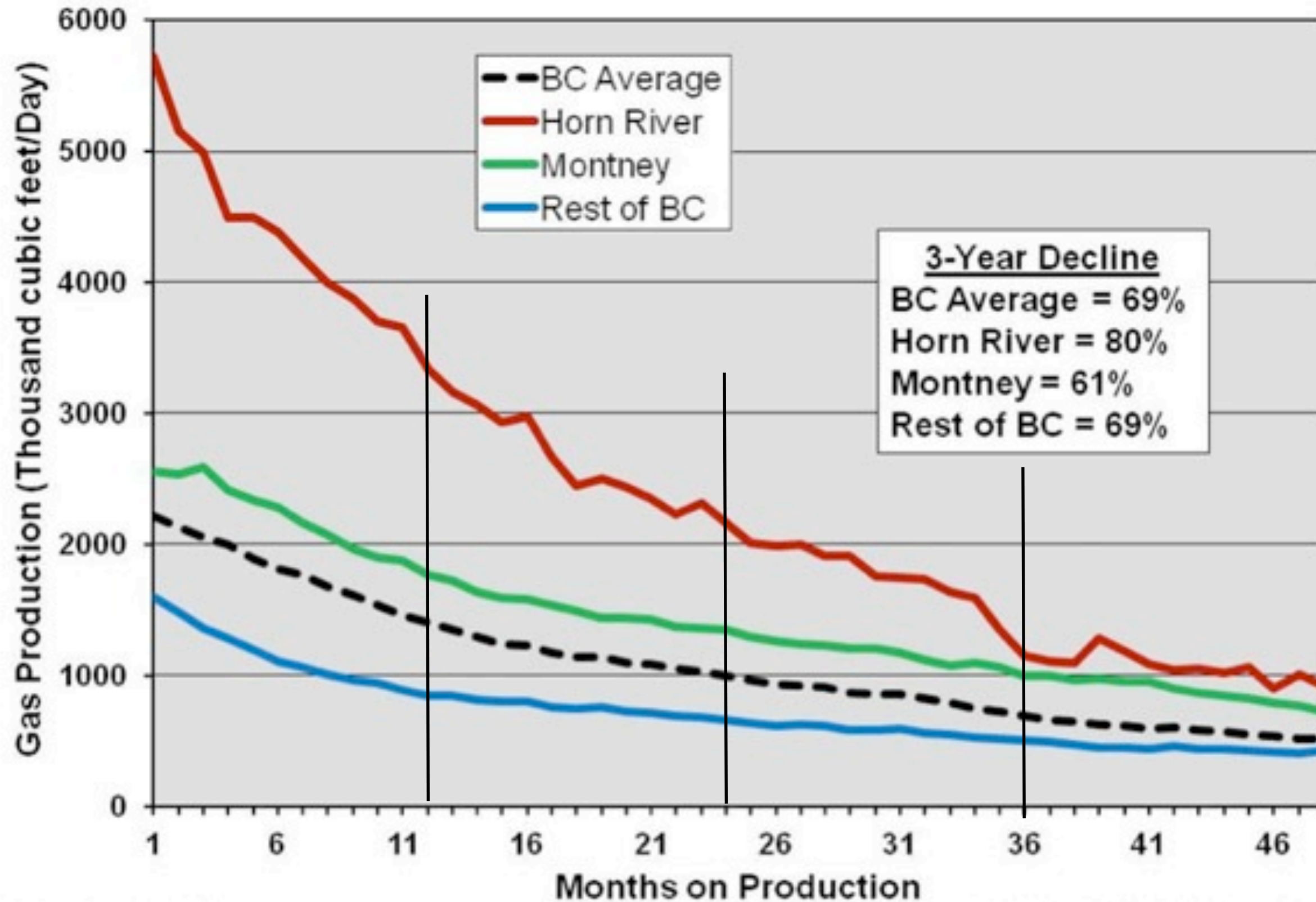




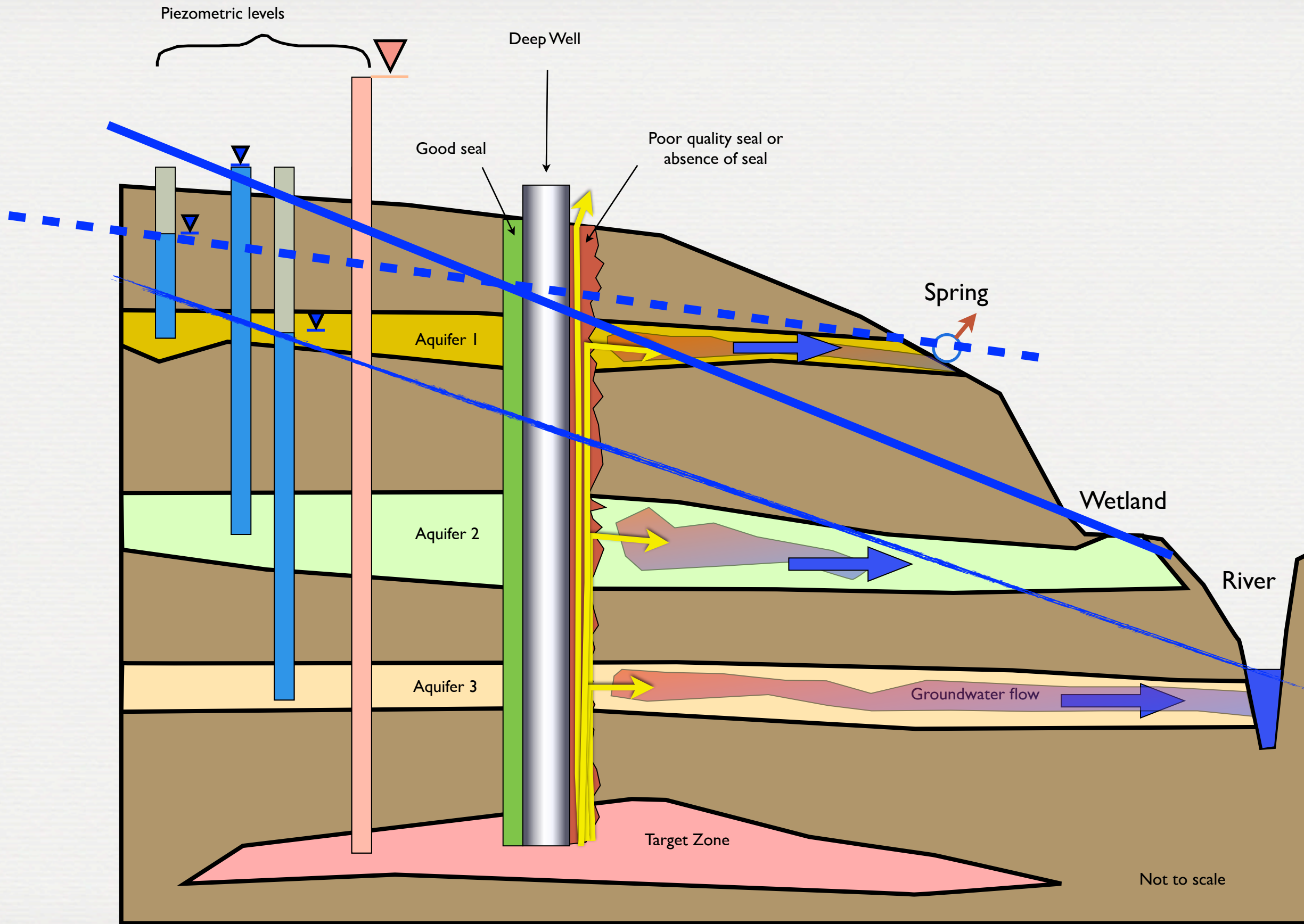
Source: USGS

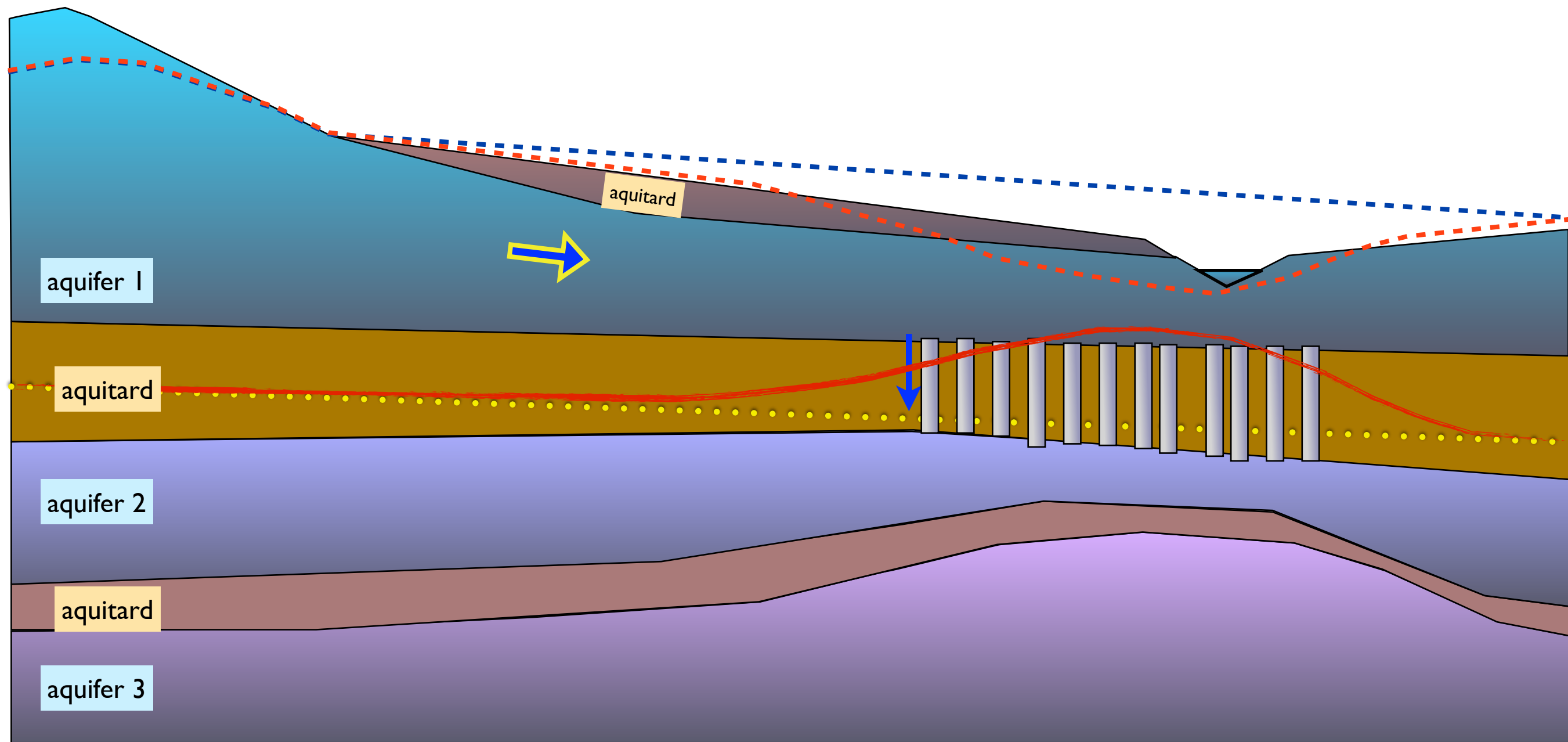
Photo: Chesapeake / Statoil

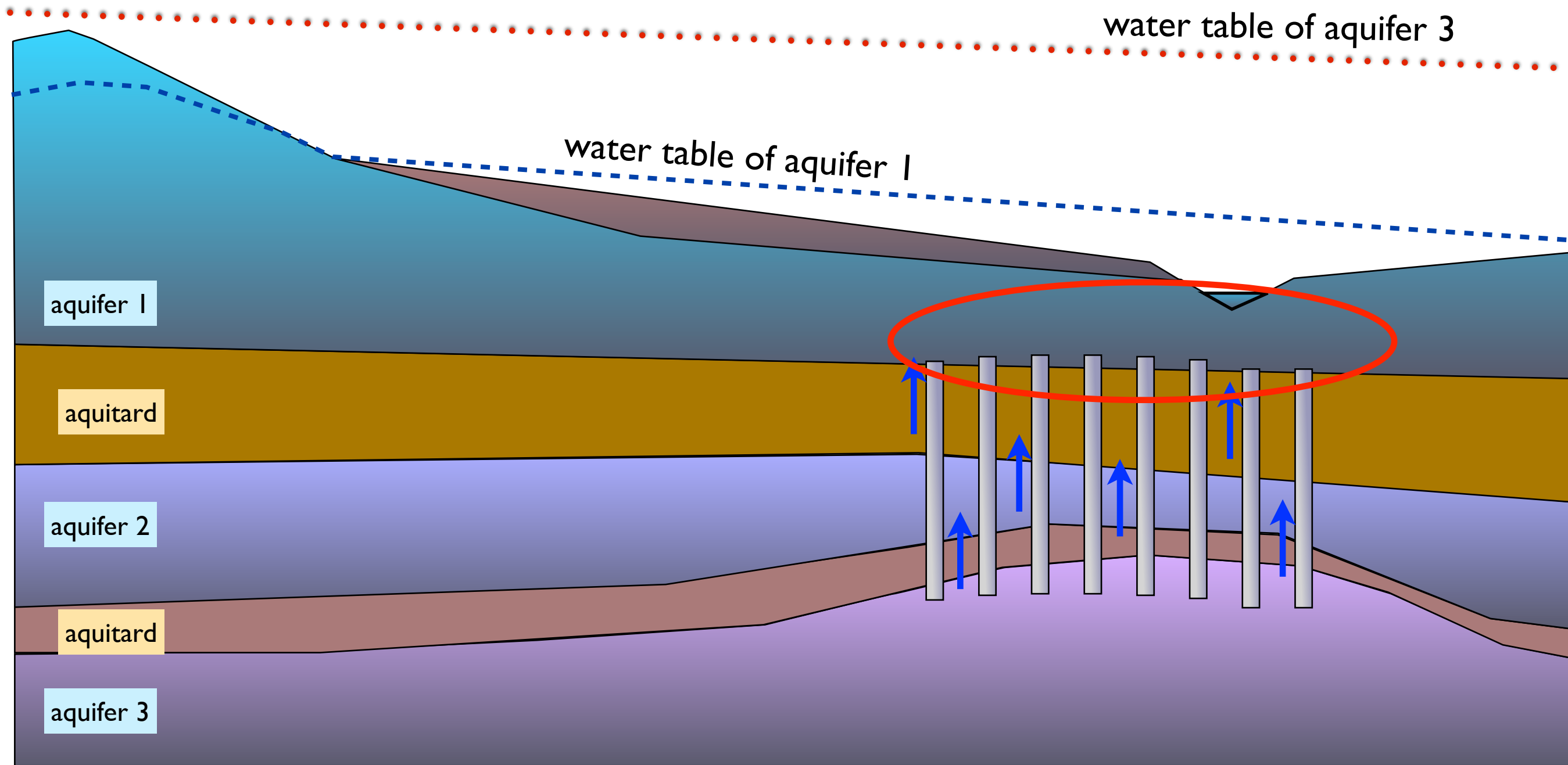
# British Columbia Type Gas Well Decline Curves by Play



# HYDROGEOLOGICAL PRINCIPLES







**DRILLING AND SEALING  
REGULATIONS TO MAKE IT SAFE**



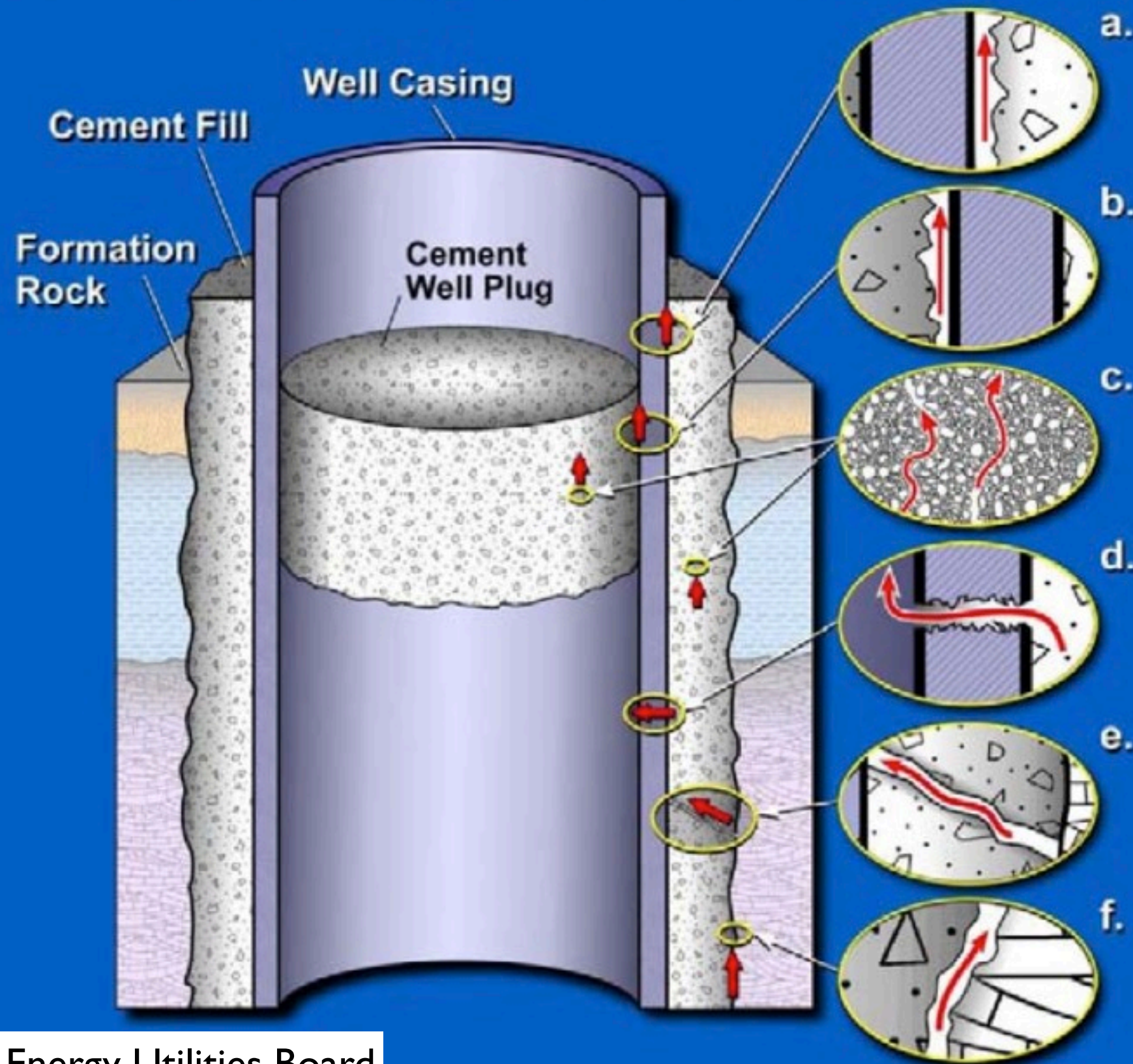
.....  
Model of a well casing after the  
cement has been poured.



**REGULATIONS TO MAKE IT SAFE**

**BUT...**

# Potential Gas Migration Paths along a Well



Source: Alberta Energy Utilities Board



## 2013 Technical Workshops

In the study's technical workshops, subject-matter experts contribute to in-depth discussions and share expertise on technical topics relevant to the study.

[Information about the upcoming technical workshop themes \(PDF\)](#)

### Analytical Chemical Methods February 25, 2013 Research Triangle Park, NC

- [Final Agenda \(PDF\)](#)
- [Final Attendees List \(PDF\)](#)
- [Workshop Participant Bios \(PDF\)](#)
- [U.S. EPA Participant Bios \(PDF\)](#)
- [Workshop Presentations](#)
- [Workshop Summary \(PDF\)](#)
- On March 25, 2013 EPA hosted a public webinar on the Analytical Chemical Methods Technical Workshop.
  - [Watch the webinar presentation](#)
  - [Get the webinar presentation slides \(PDF\)](#)

### Well Construction/Operation and Subsurface Modeling April 16-17, 2013 Research Triangle Park, NC

- [Final Agenda \(PDF\)](#)
- [Final Attendees List \(PDF\)](#)
- [Workshop Participant Bios \(PDF\)](#)
- [U.S. EPA Participant Bios \(PDF\)](#)
- [Workshop Presentations](#)
- A follow-up discussion was held on June 3, 2013 in Arlington, VA
  - [Final Agenda \(PDF\)](#)
  - [Final Attendees List \(PDF\)](#)
  - [Workshop Participant Bios \(PDF\)](#)
  - [U.S. EPA Participant Bios \(PDF\)](#)
  - [Workshop Presentations](#)
- On July 16, 2013 EPA hosted a public webinar on the Well Construction/Operation and Subsurface Modeling Technical Workshop.
  - [Watch the webinar presentation \(coming soon\)](#)
  - [Get the webinar presentation slides \(PDF\)](#)
- [Workshop Summary](#)

# **Well Integrity and Long-Term Well Performance Assessment**

**(Insights from work on CO<sub>2</sub> Sequestration)**

**Bill Carey**

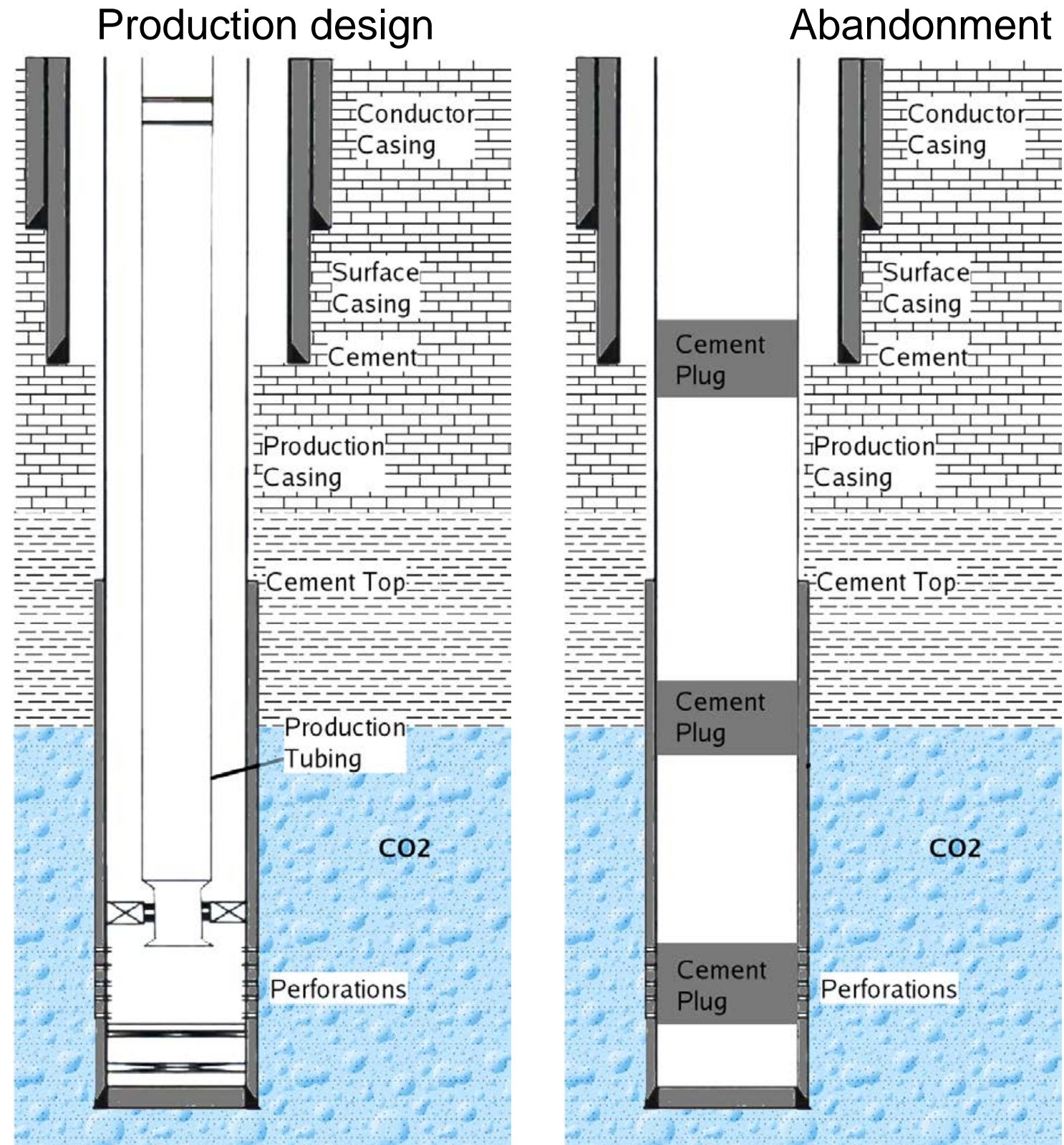
**Earth & Environmental Sciences Division  
Los Alamos National Laboratory  
Los Alamos, NM USA**

# How Is Wellbore Integrity Achieved?

- Operational measures
  - Adequate weight drilling mud
  - Monitoring pressure for gas intrusion (“gas kick”)
  - Blowout preventers
- Design measures
  - Steel
  - Portland cement
- Guidelines: API HF1 (hydraulic fracturing),



[www.theoil drum.com](http://www.theoil drum.com)



Bill Carey - EPA April 2013 Workshop

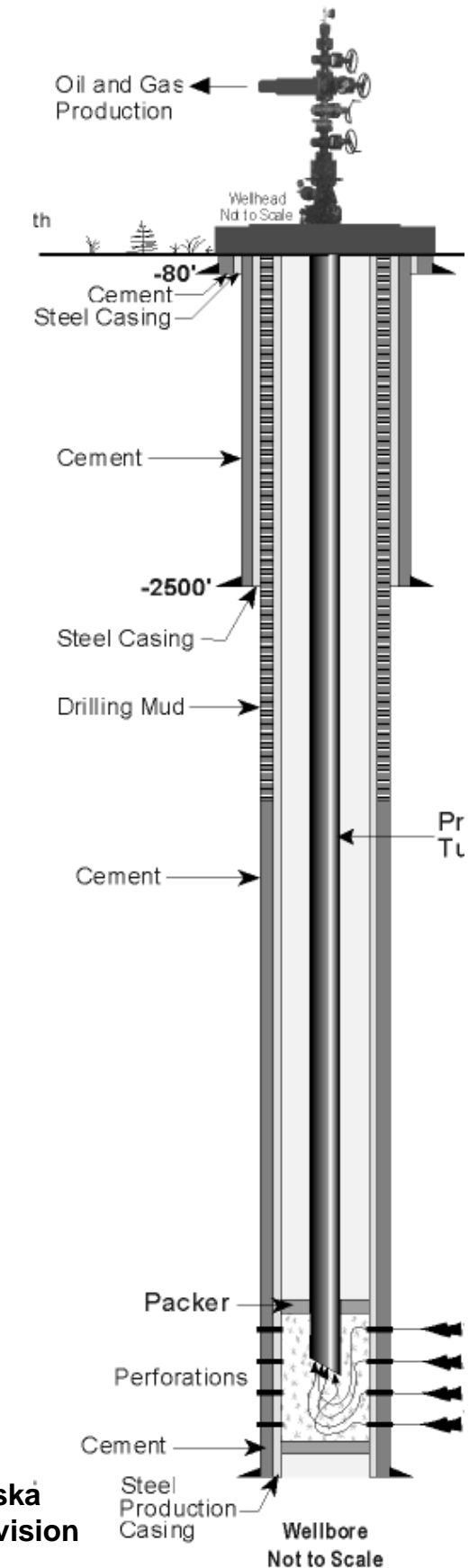
# Why do wells leak?

## Pre-Production

- Formation damage during drilling (caving)
- Casing centralization (incomplete cementing)
- Adequate drilling mud removal
- Incomplete cement placement (pockets)
- Inadequate cement-formation, cement-casing bond
- Insufficient cement coverage of well length
- Cement shrinkage
- Contamination of cement by mud or formation fluids

## Post-Production

- Mechanical or thermal stress/strain
  - Formation of micro-annulus at casing-cement interface
  - disruption of cement-formation bond
  - Fracture formation within cement
- Geochemical attack
  - Corrosion of steel casing
  - Degradation of Portland cement
    - Carbonation
    - Hydrogen sulfide
    - Sulfate attack
    - Acid attack



# Wellbore Integrity: Failure Mechanisms, Historical Record, and Rate Analysis

**Anthony Ingraffea, PhD, PE**

Cornell University

Physicians, Scientists, and Engineers for Healthy Energy (PSE)

**Renee Santoro**

Physicians, Scientists, and Engineers for Healthy Energy (PSE)

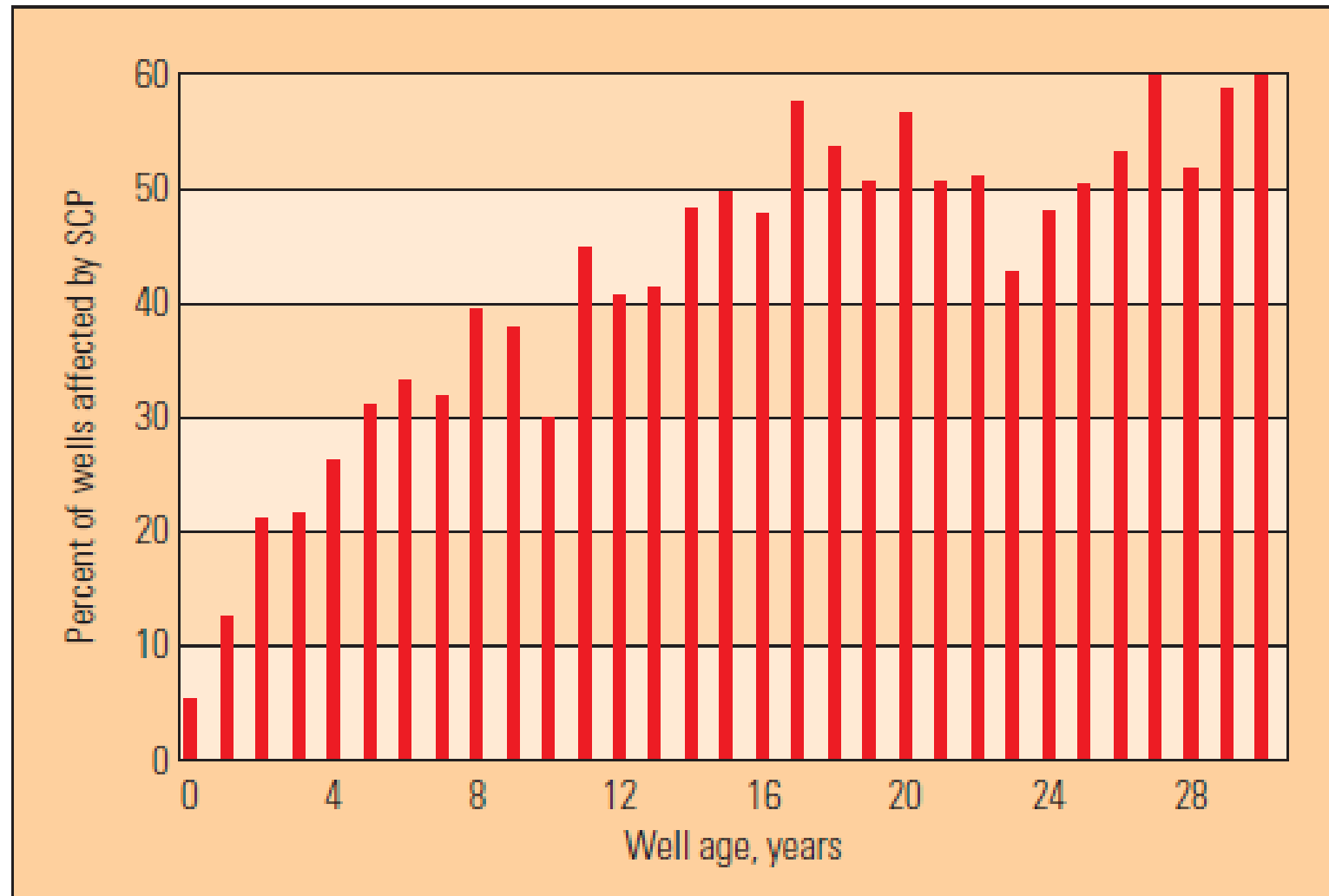
**Seth B. Shonkoff, PhD, MPH**

Physicians, Scientists, and Engineers for Healthy Energy (PSE)

University of California, Berkeley



# Industry-Reported Data On Loss of Wellbore Integrity: Offshore Wells



SCP=Sustained Casing Pressure. Also called sustained annular pressure, in one or more of the casing annuli.

- About 5% of wells fail soon
- More fail with age
- Most fail by maturity

Ingraffea et al., EPA April 2013 Workshop

^ Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.

Brufatto et al., *Oilfield Review*, Schlumberger, Autumn, 2003

# Recent Operator Performance in the Pennsylvania Marcellus Play: Results of Survey

1,609 wells drilled in 2010.  
97 well failures.  
6% rate of failure.

1,972 wells drilled in 2011.  
140 well failures.  
7.1% rate of failure.

1,346 wells drilled in 2012  
120 well failures.  
8.9% rate of failure.

Consistent with previous industry data, and not improving.

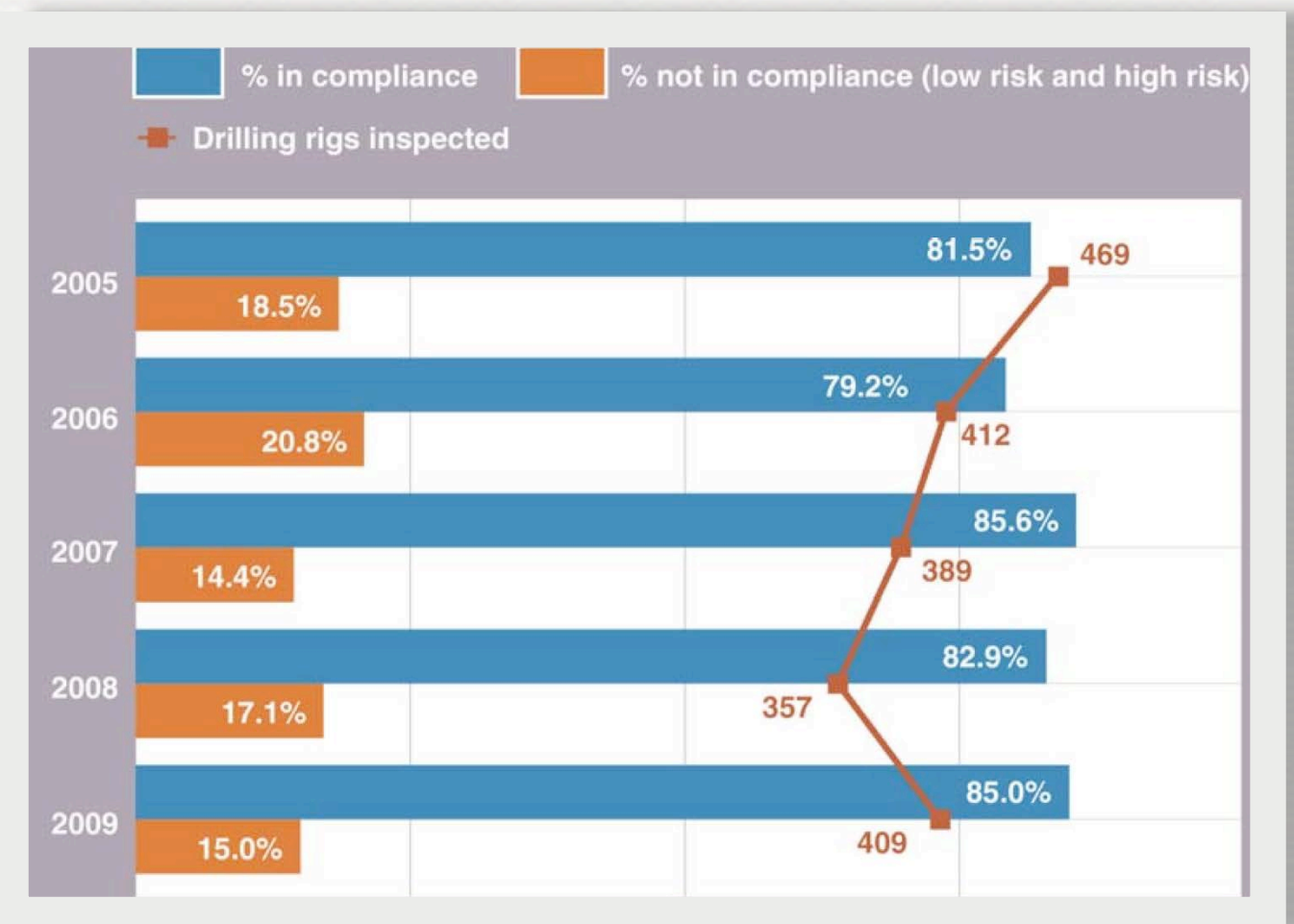
(GWS note: well failure = leaky well )

Ingraffea et al., EPA April 2013 Workshop

# MEASURES IN PLACE.. BUT THINGS CAN GO WRONG

- “Ten casing failures occurred at the enhanced heavy oil recovery operations in northeast Alberta, resulting in cross flow from the producing zone into another formation.”

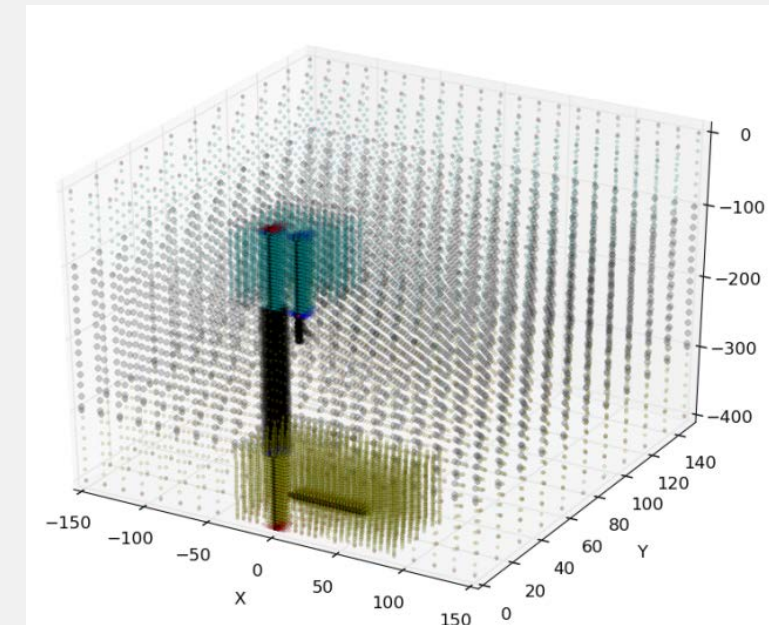
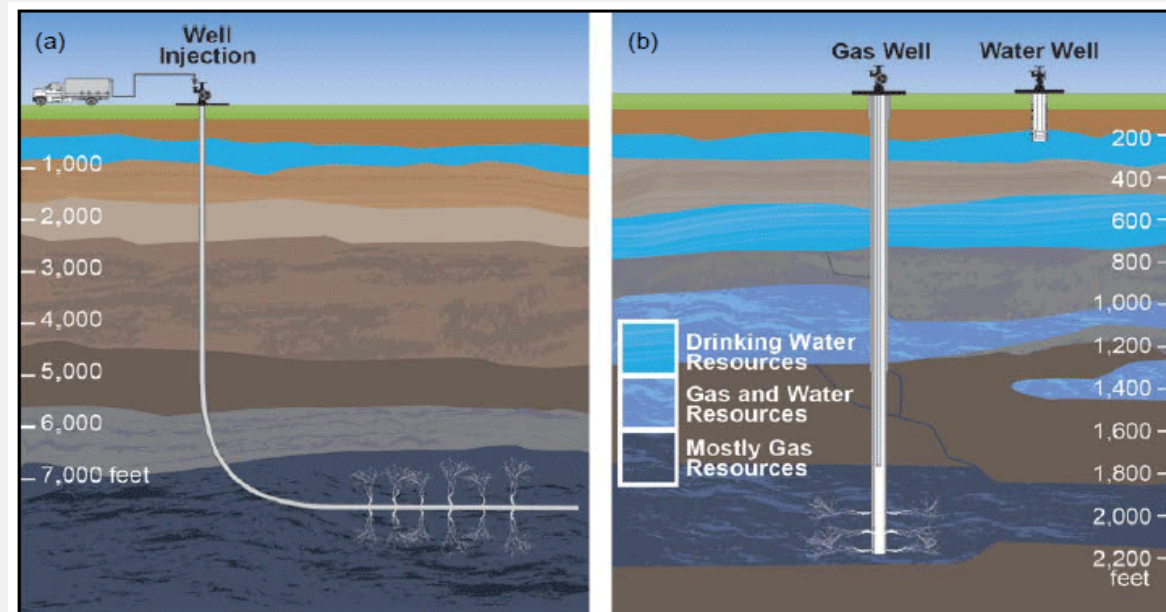
Alberta Energy Resources Conservation Board (ERCB), “Field Surveillance and Operations Branch Provincial Summary 2009” (2010)



# Modeling of Leakage in Potential Failure Scenarios in Shale Gas Systems

*Technical Workshop Series:*

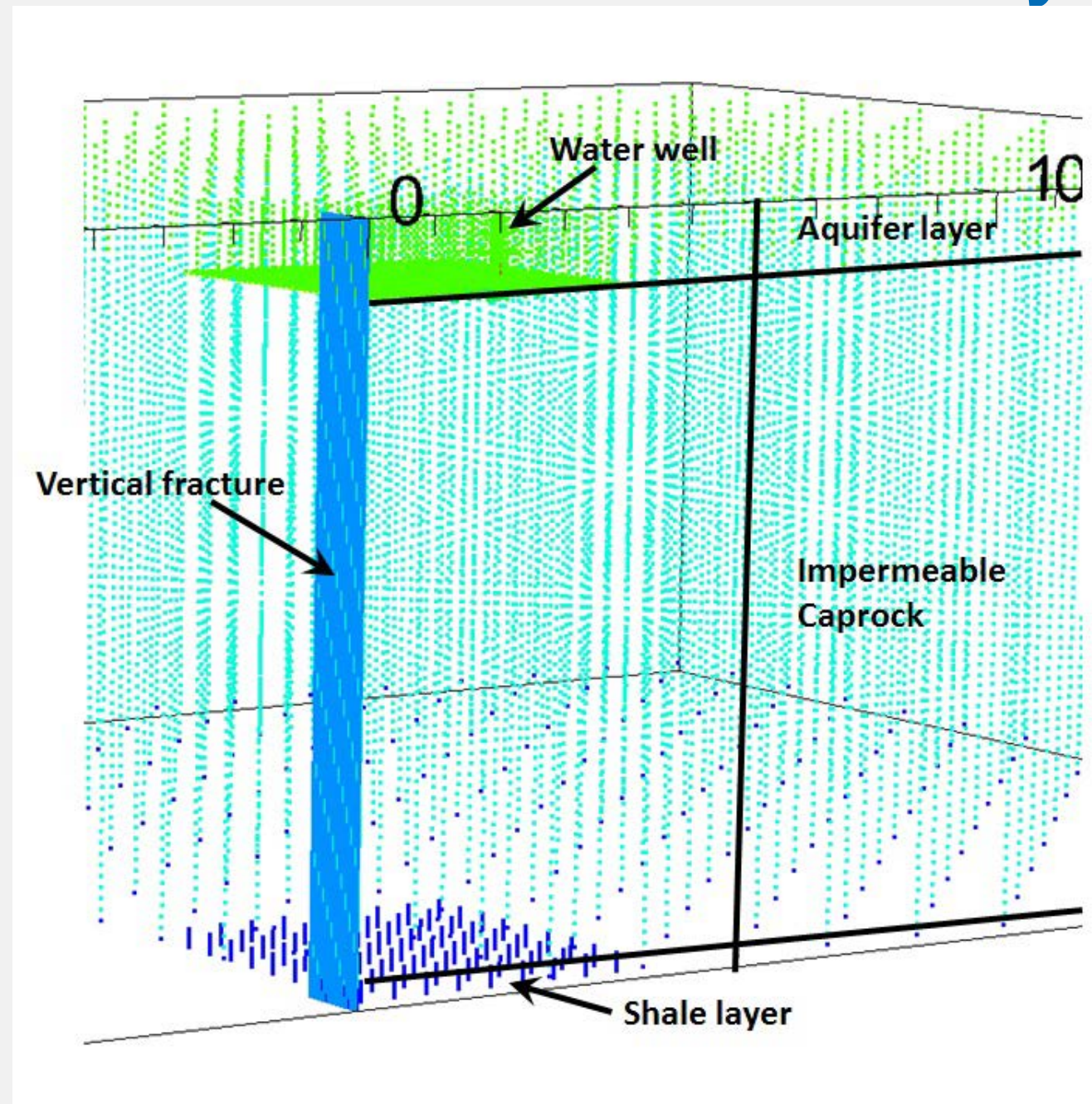
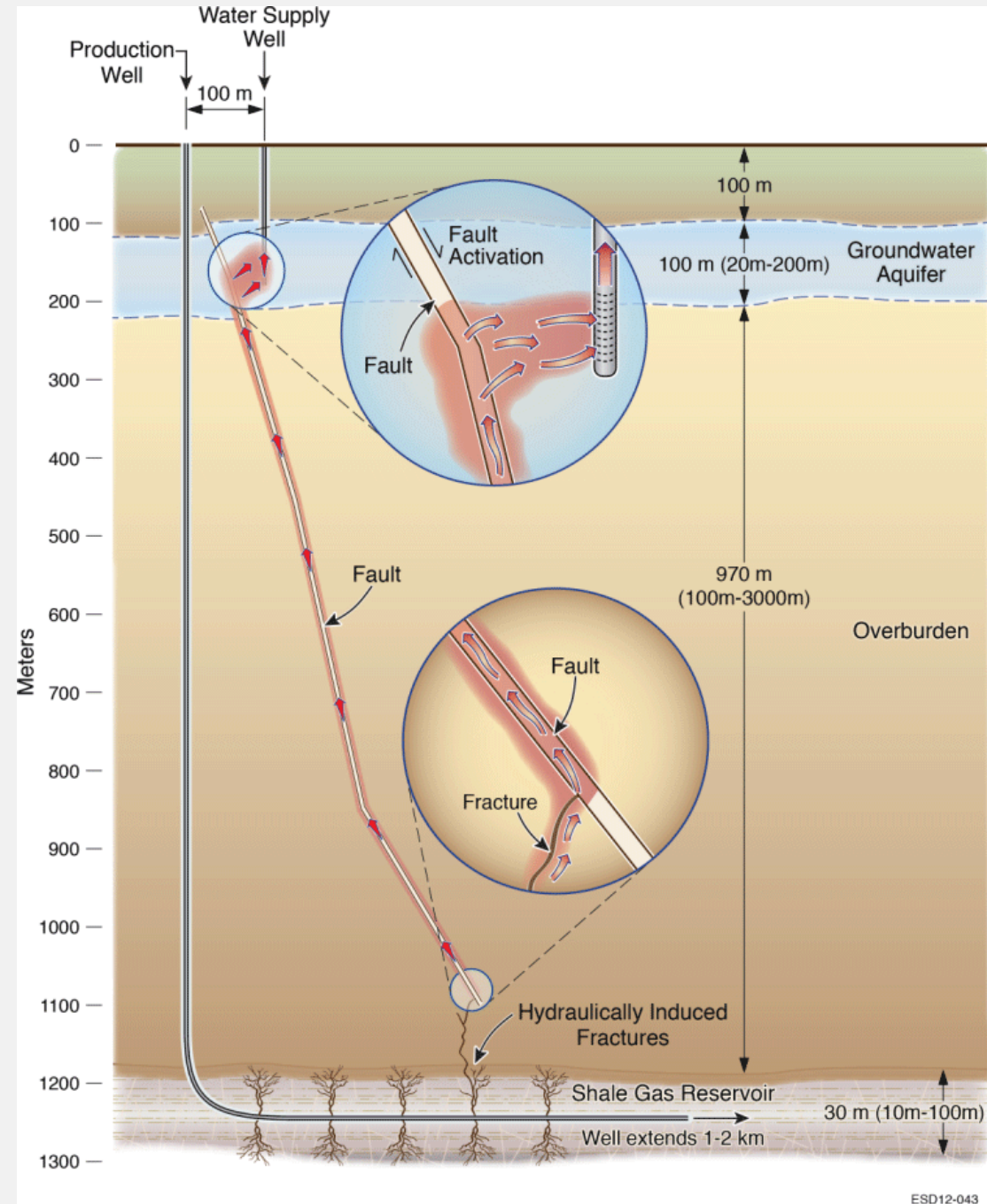
*Well Construction/Operation and Subsurface Modeling*



**Matt Freeman, LBNL**

EPA-Research Triangle Park • April 17, 2013

# Conceptual Model Building: Scenarios: Fault/Fractures Pathway



Annotated view of the various zones of the simulated system. Colors denote different material types.

# GENERAL CONCLUSIONS (2013 WORK)

- Work in progress - More studies required
- EPA report release scheduled in 2014

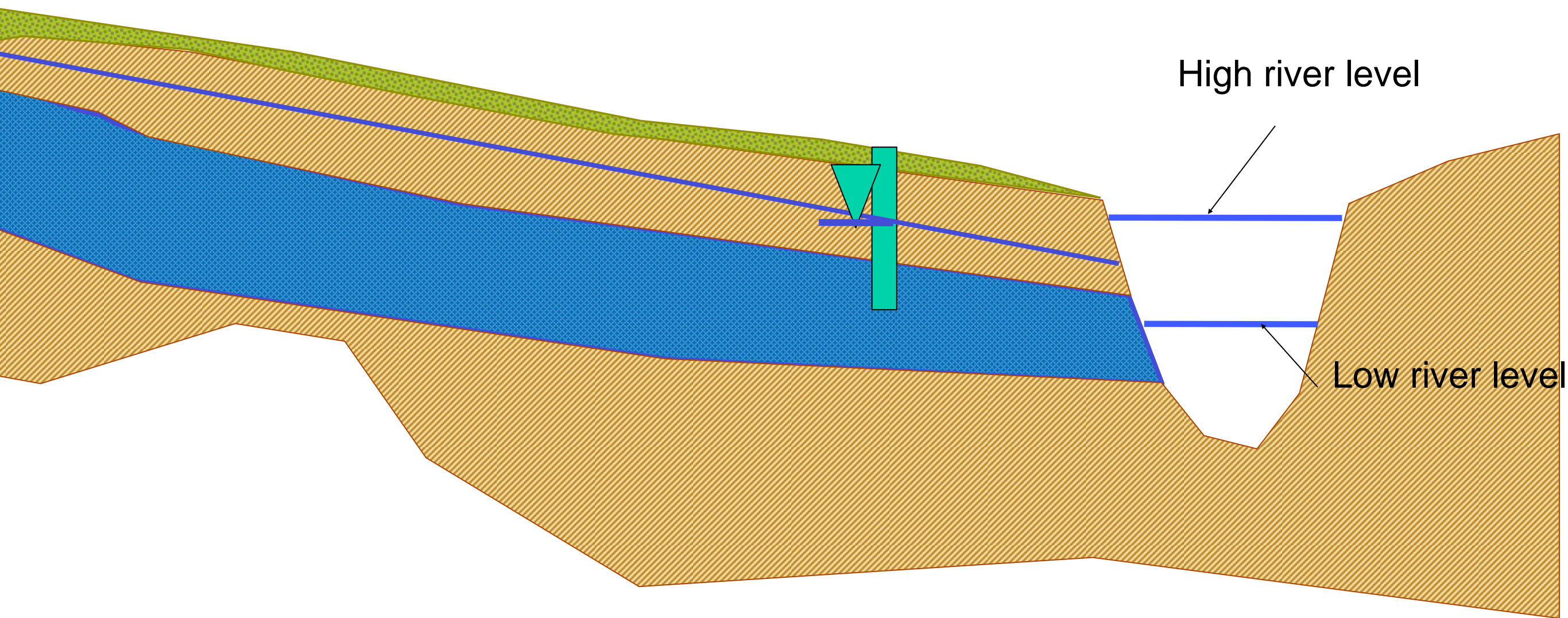
**100% OF WELLS ARE SEALED**

**FOREVER**

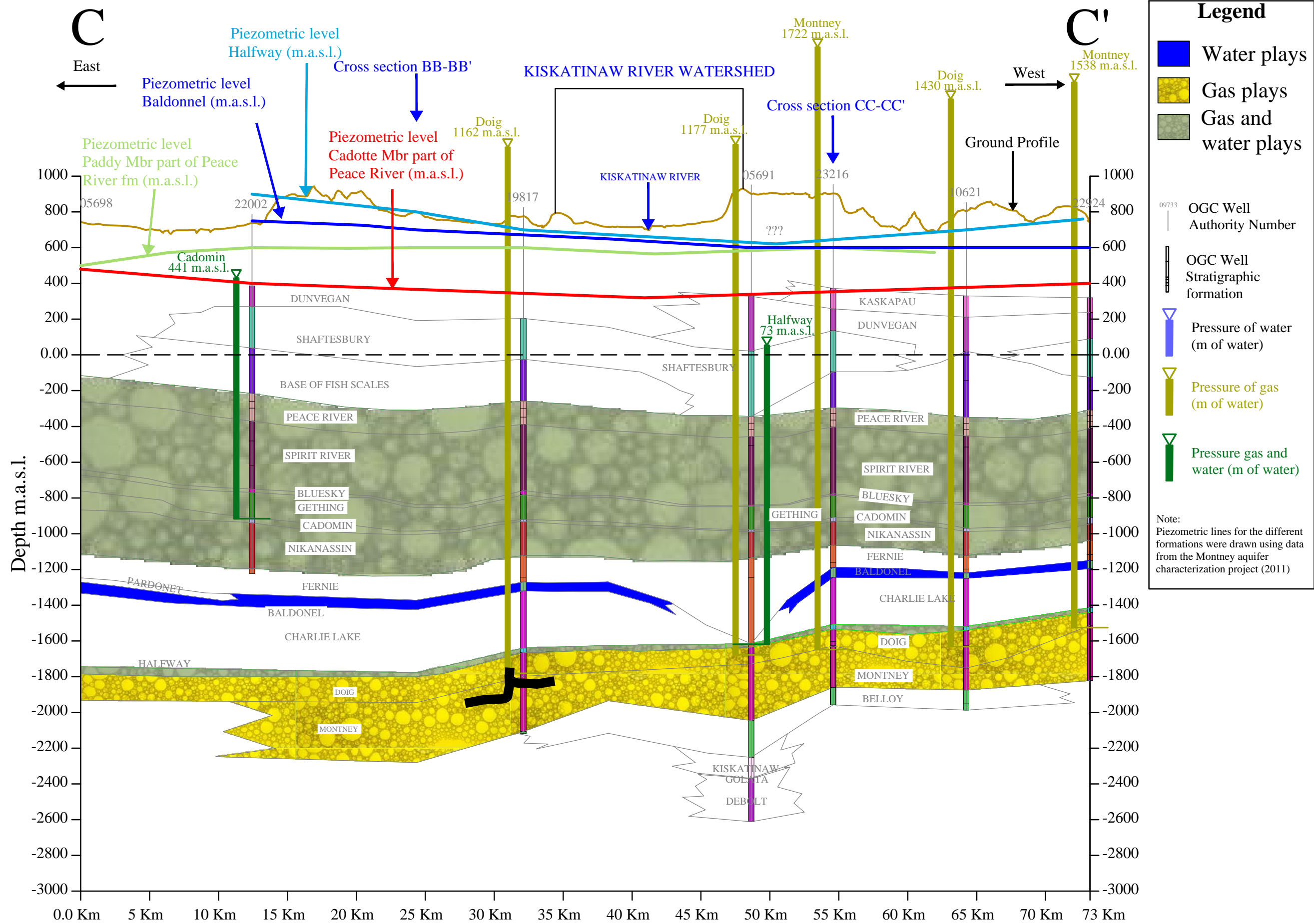
**???**

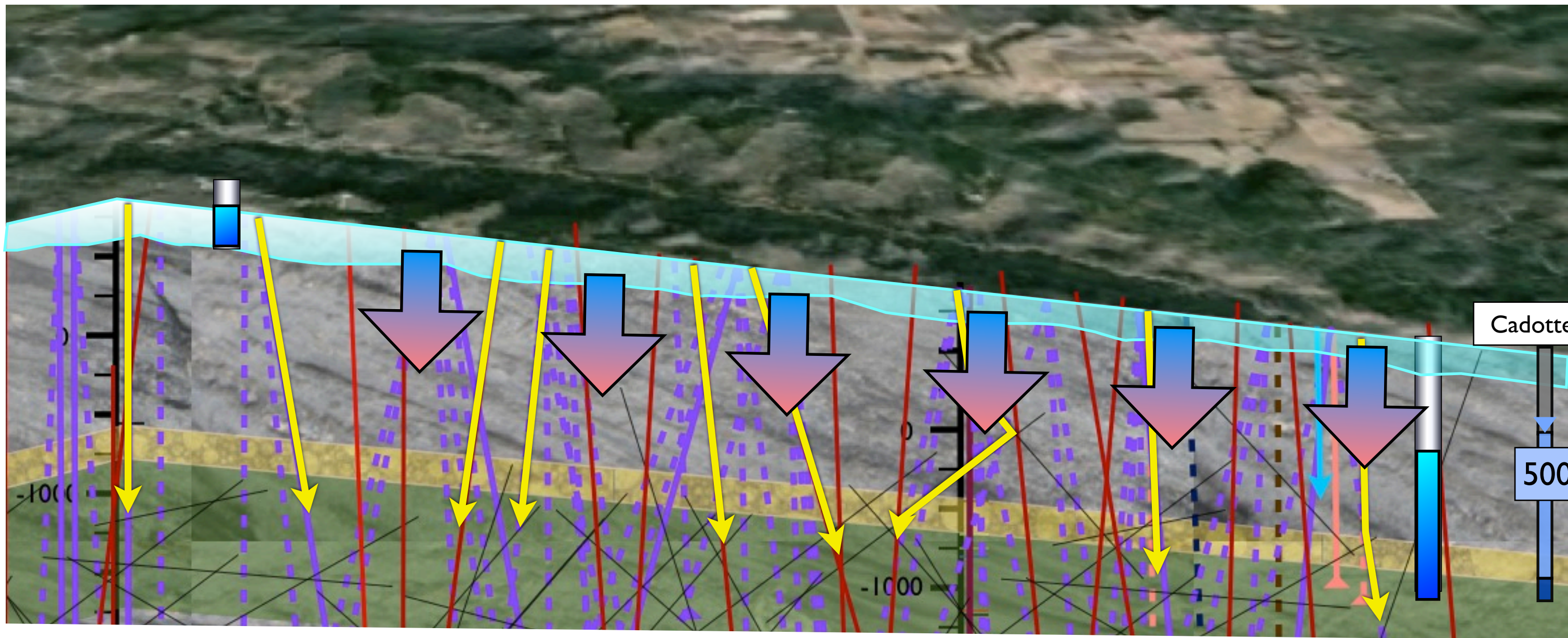
**WHY IS THIS SO IMPORTANT?**



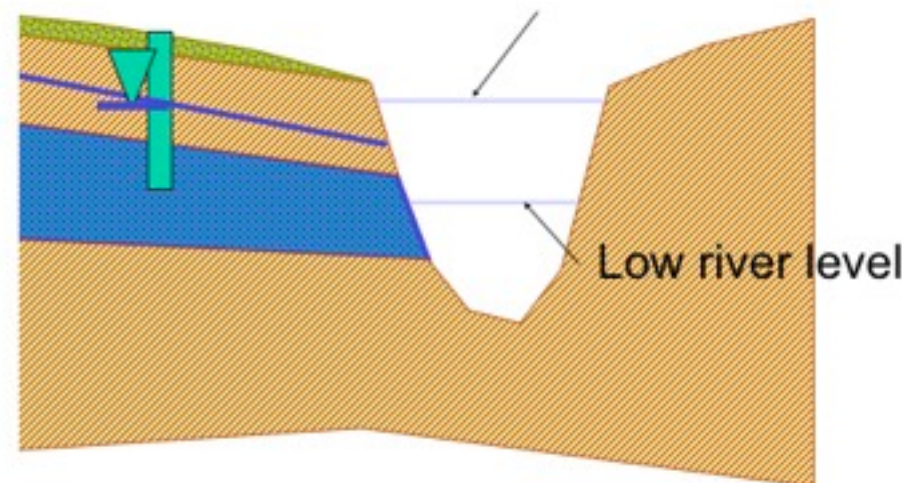


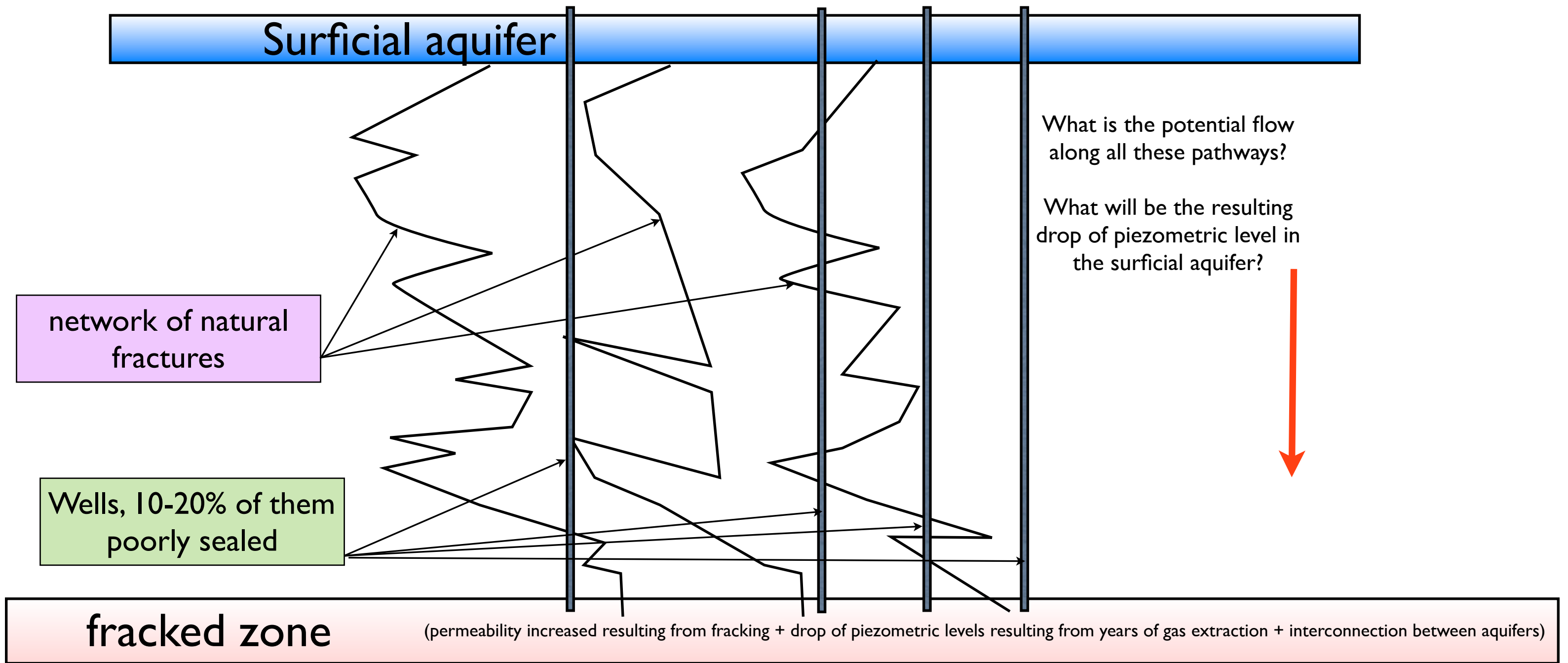
Aquifers provide flow and temperature control!





High river level





Surficial aquifer

What is the potential flow along all these pathways?  
 What will be the resulting drop of piezometric level in the surficial aquifer?

network of natural fractures

Wells, 10-20% of them poorly sealed

fracked zone

(permeability increased resulting from fracking + drop of piezometric levels resulting from years of gas extraction + interconnection between aquifers)

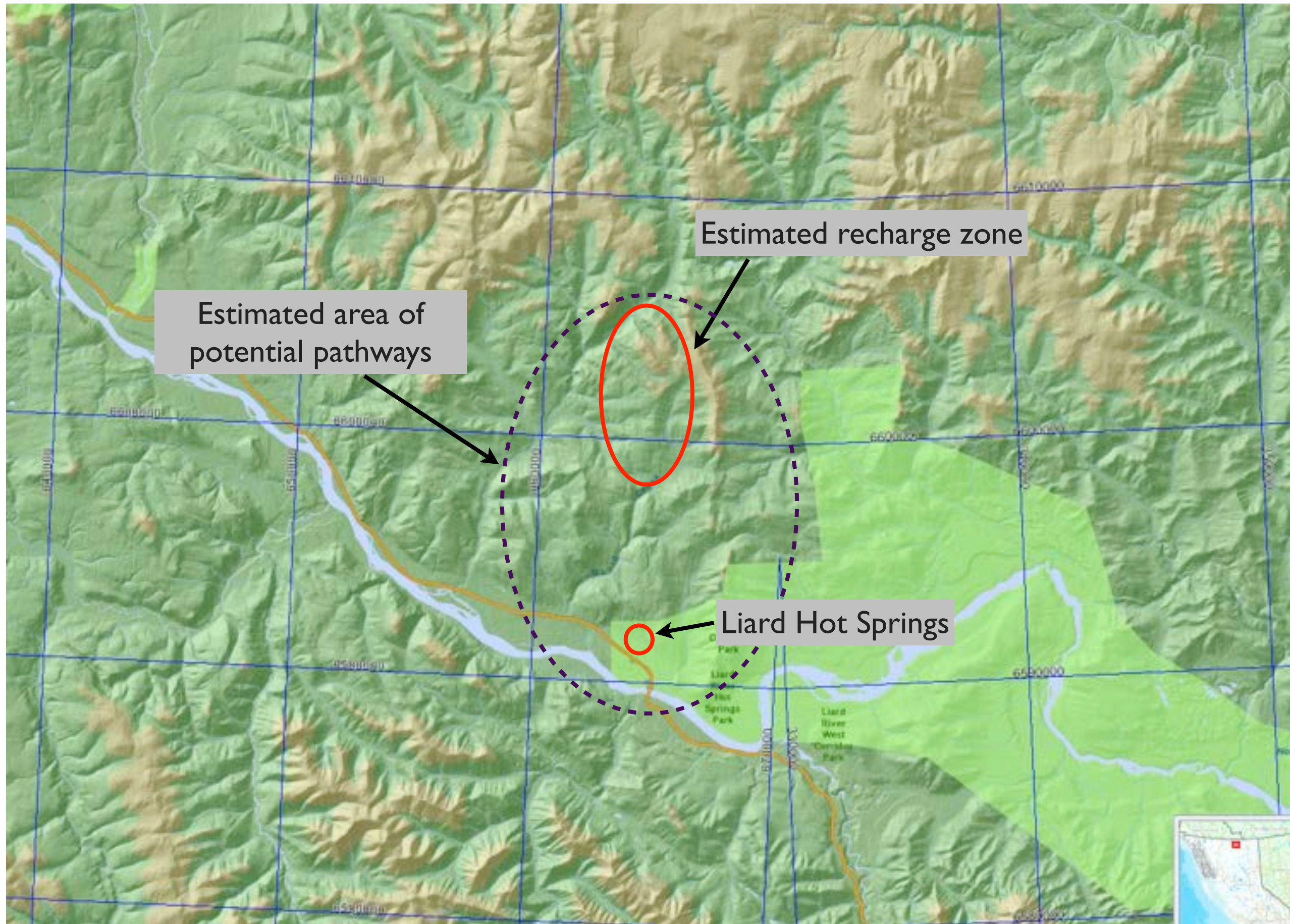
## **Modeling the impacts of shale gas extraction on groundwater and surface water resources**

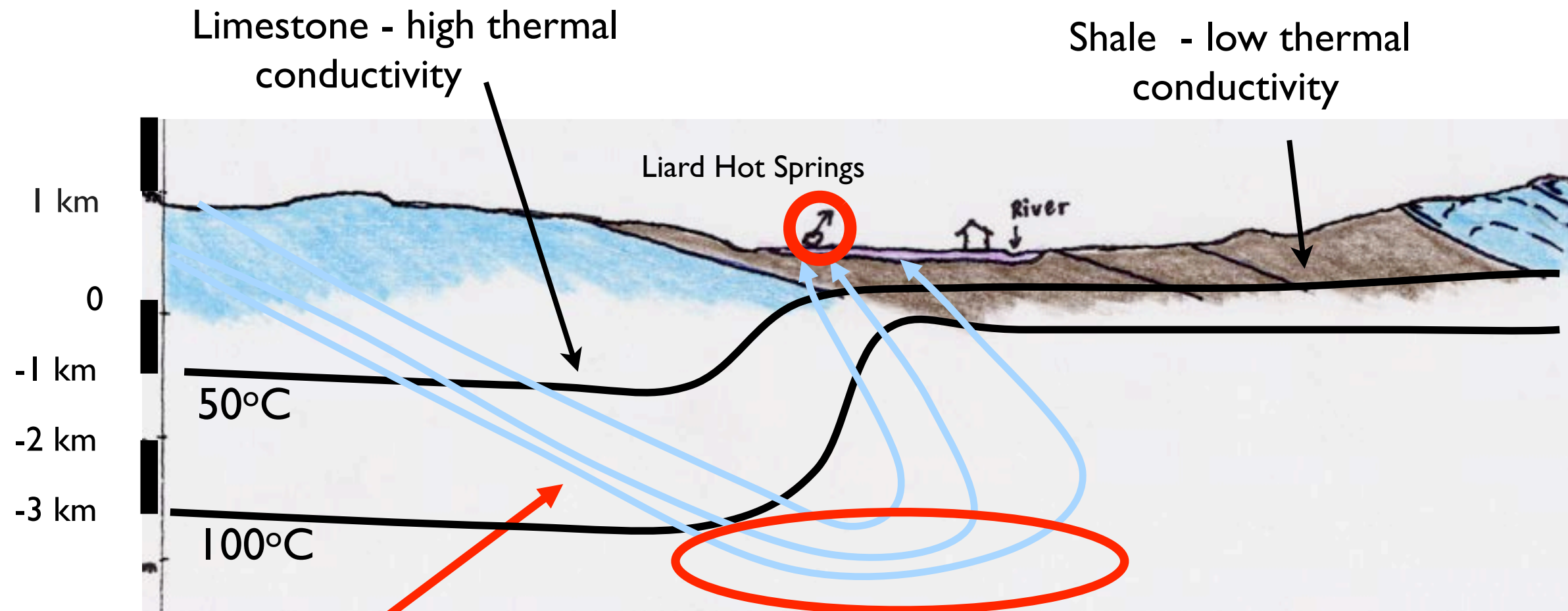
**Romain Chesnaux<sup>1#</sup>, Lucie Dal Soglio<sup>2</sup>, Gilles Wendling<sup>3</sup>**



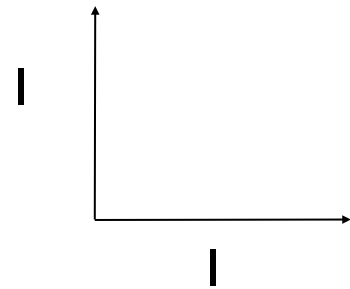
- Modeled drawdown range: 0.6 m to 0.9 m after 3 to 5 years
- Effects:
  - permanent and irreversible
  - could be devastating for watersheds and their ecosystems
- Debate needed with more modeling results from academia and industry

**NATURAL PATHWAYS  
(SHOWN BY HOT SPRINGS)**





Possible Flow Paths



Geochemistry

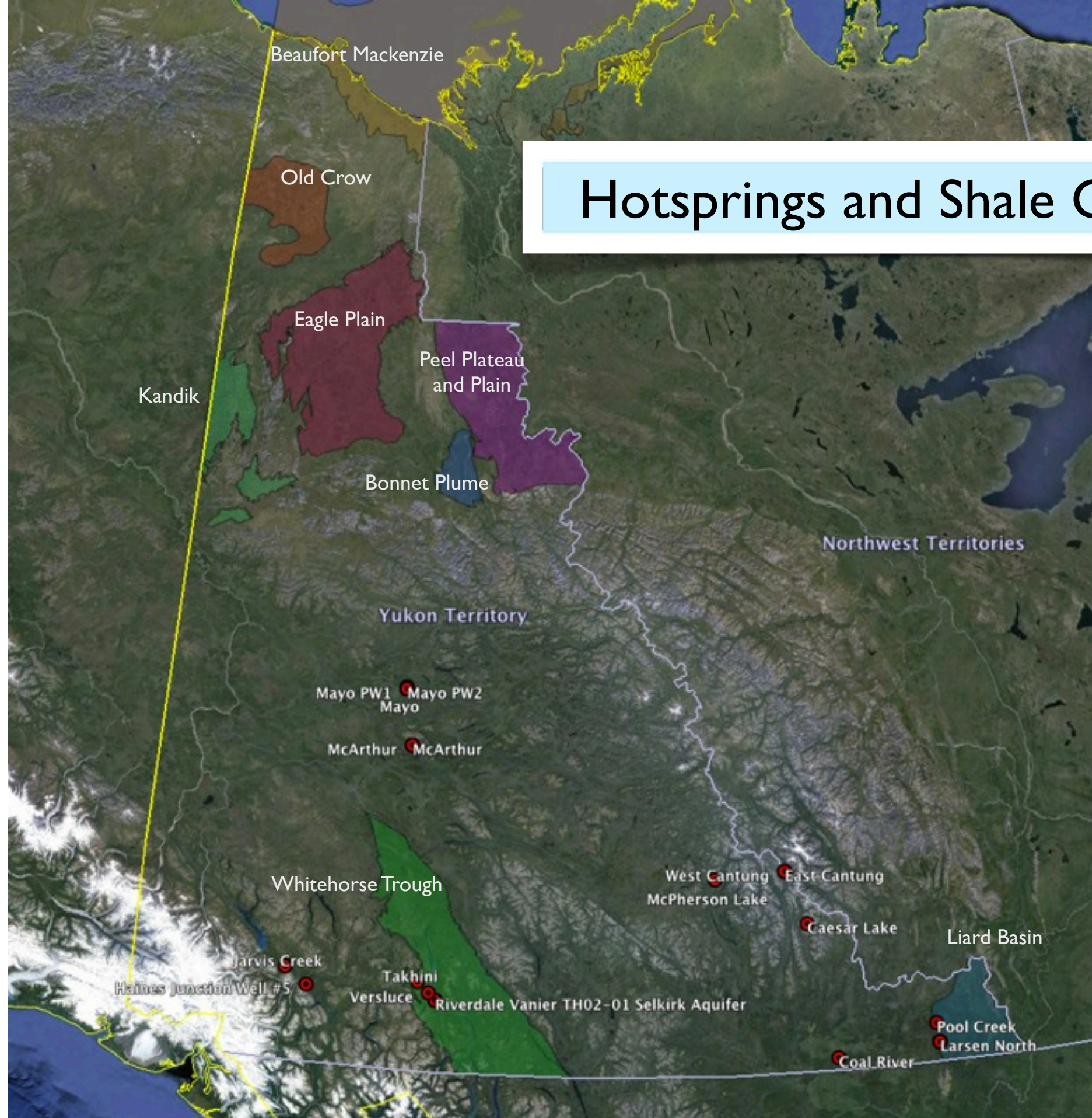
temp. max.: 120 °C

approx. depth: 3.4 km

(Grasby and al. 2001)



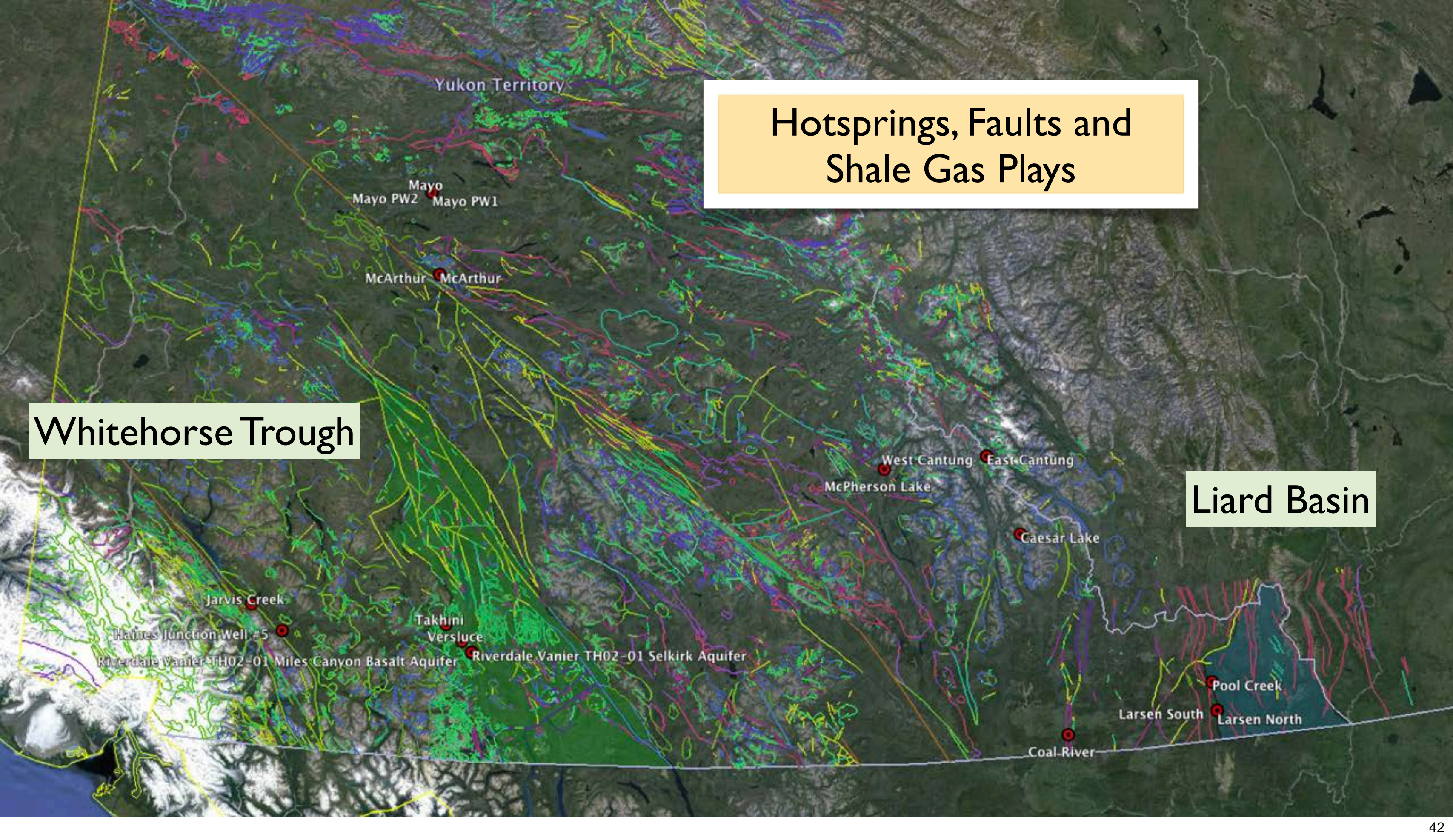
# Hotsprings and Shale Gas Plays



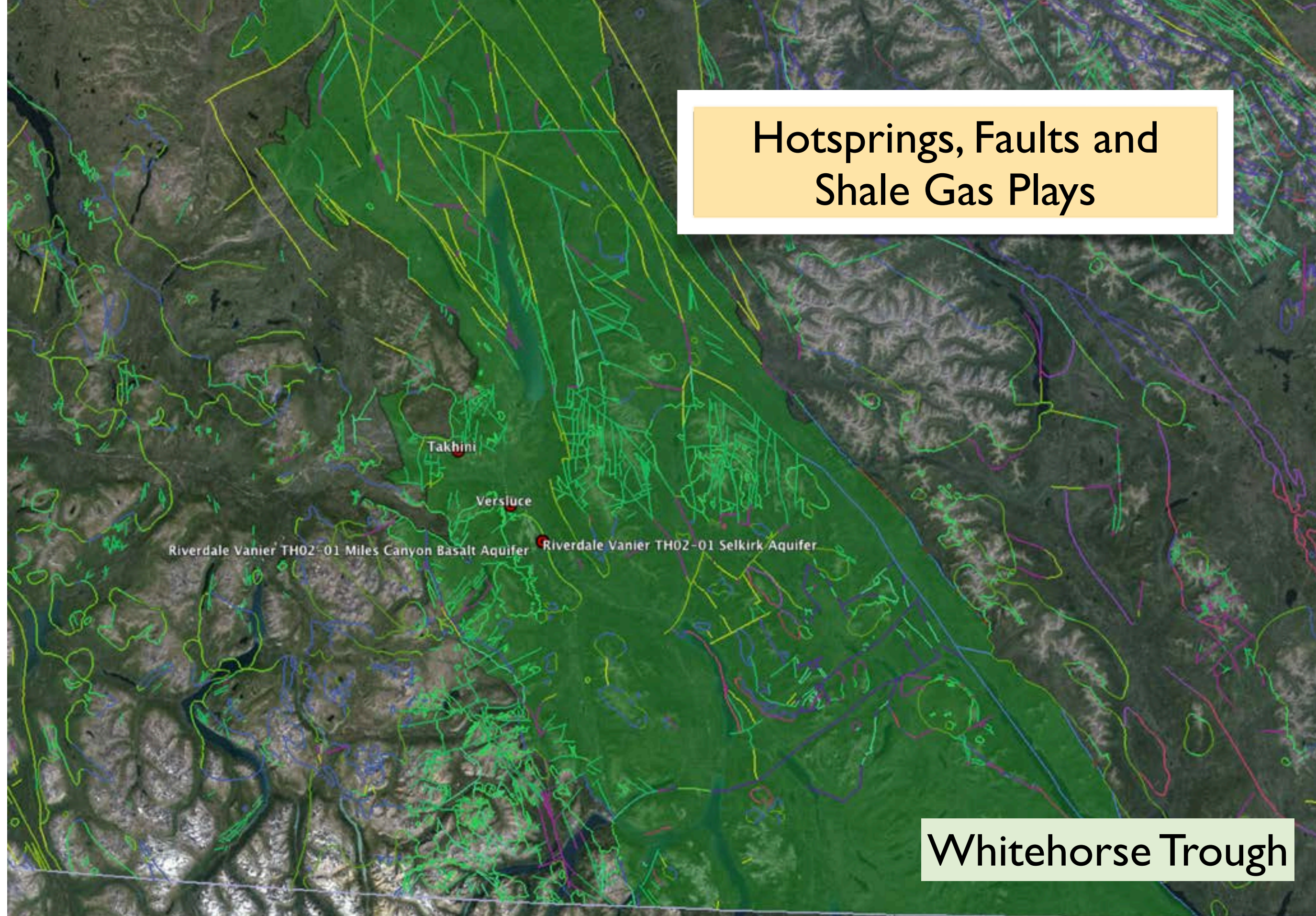
# Hotsprings, Faults and Shale Gas Plays

Whitehorse Trough

Liard Basin

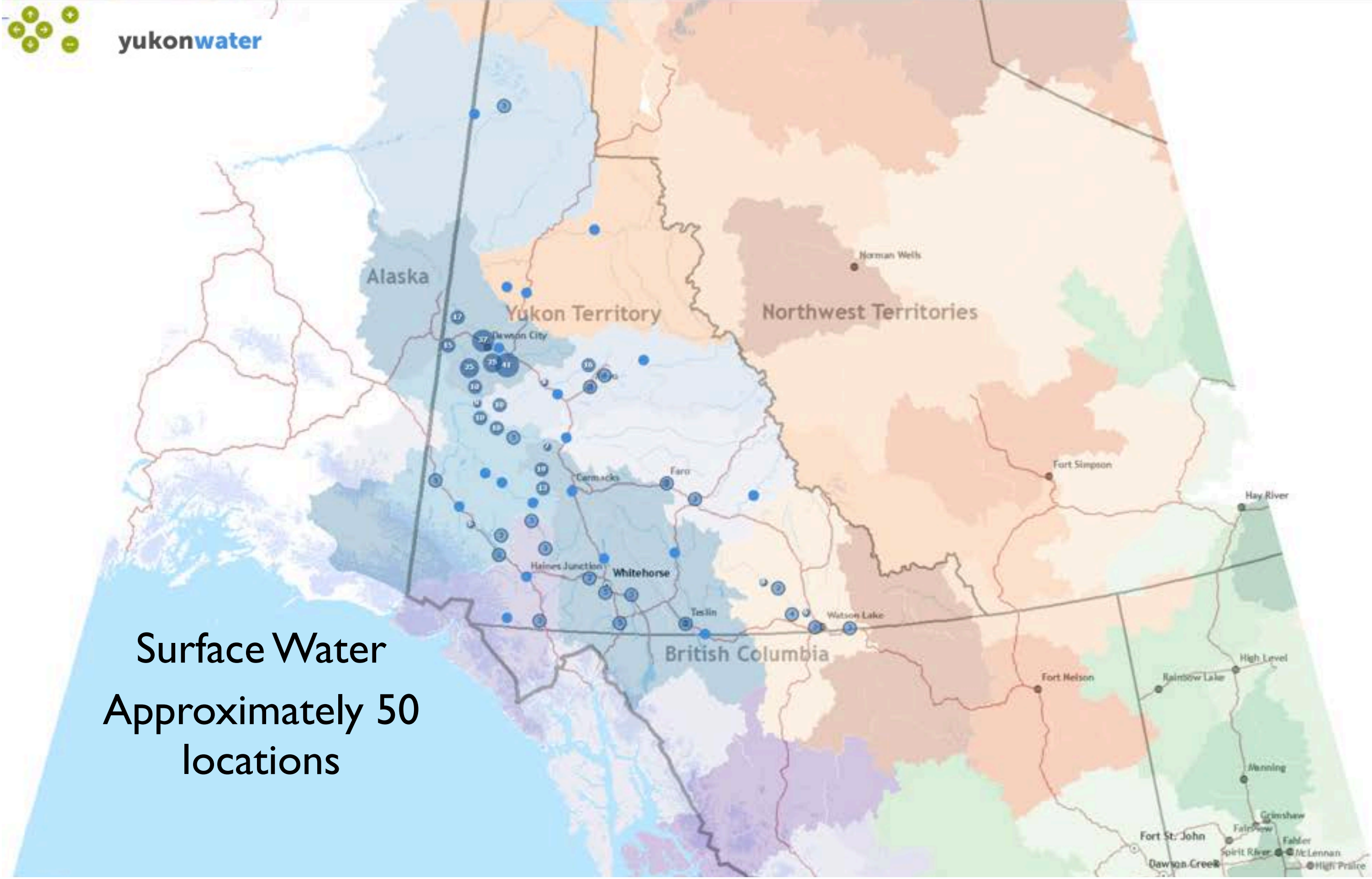


# Hotsprings, Faults and Shale Gas Plays



Whitehorse Trough

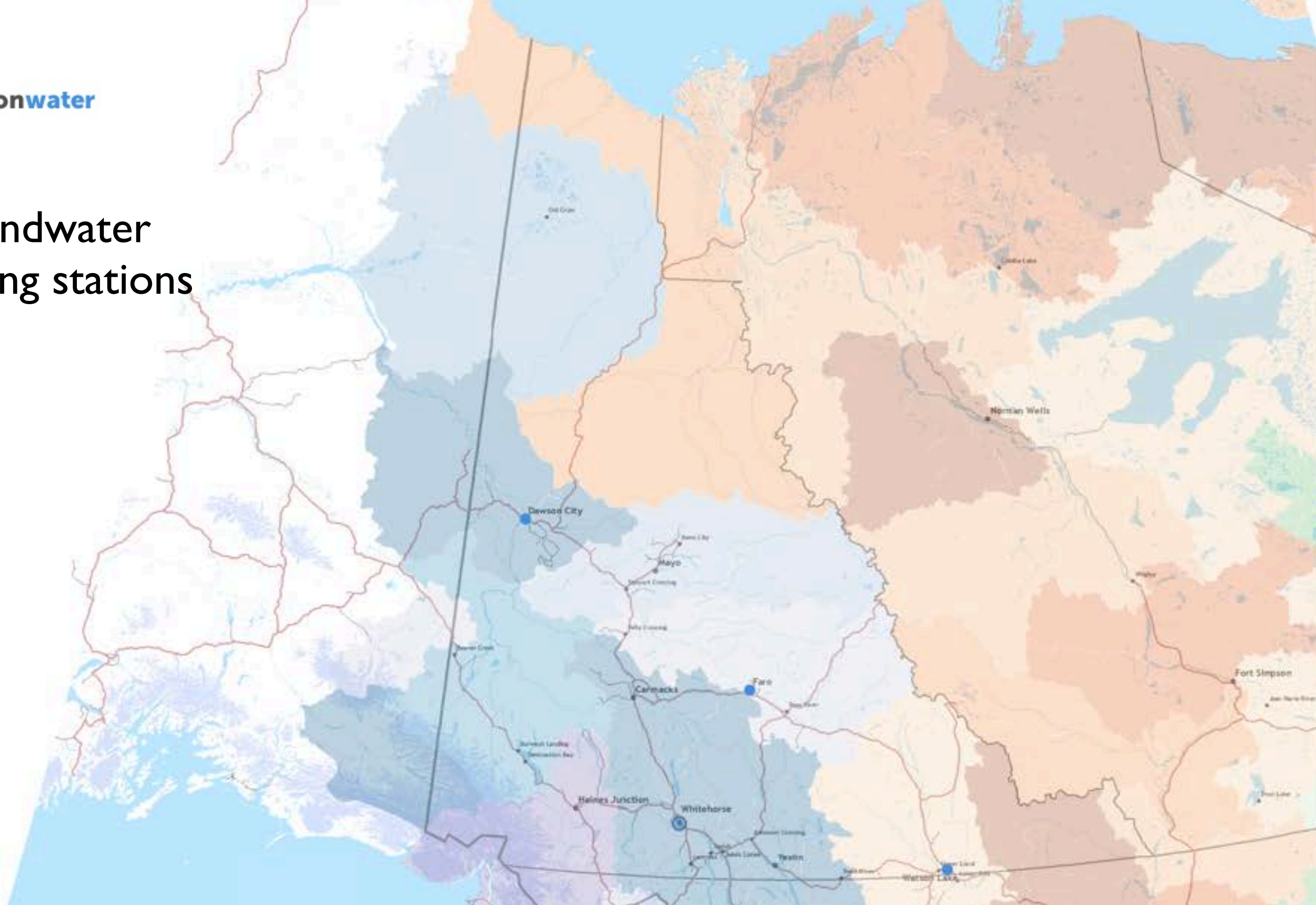
# WHAT IS BEING MONITORED IN THE YUKON?



Surface Water  
Approximately 50  
locations

yukonwater

# 7 groundwater monitoring stations



Presentation to the Select  
Committee on Hydraulic Fracturing

September 26, 2013  
9:00 am

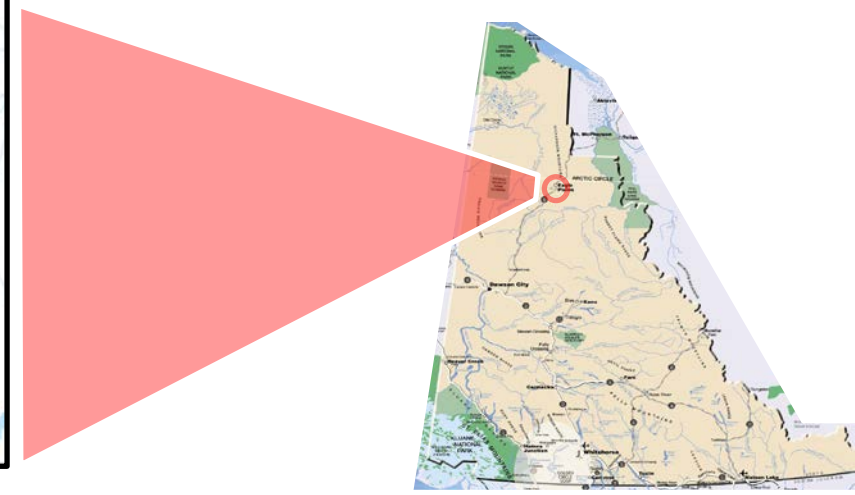


# Water Monitoring Network

## Eagle Plain Basin



- New water monitoring sites added in August 2013:
  - McParlon Creek
  - Dalglish Creek
  - Glacier Creek
- To be added this fiscal:
  - Eagle River

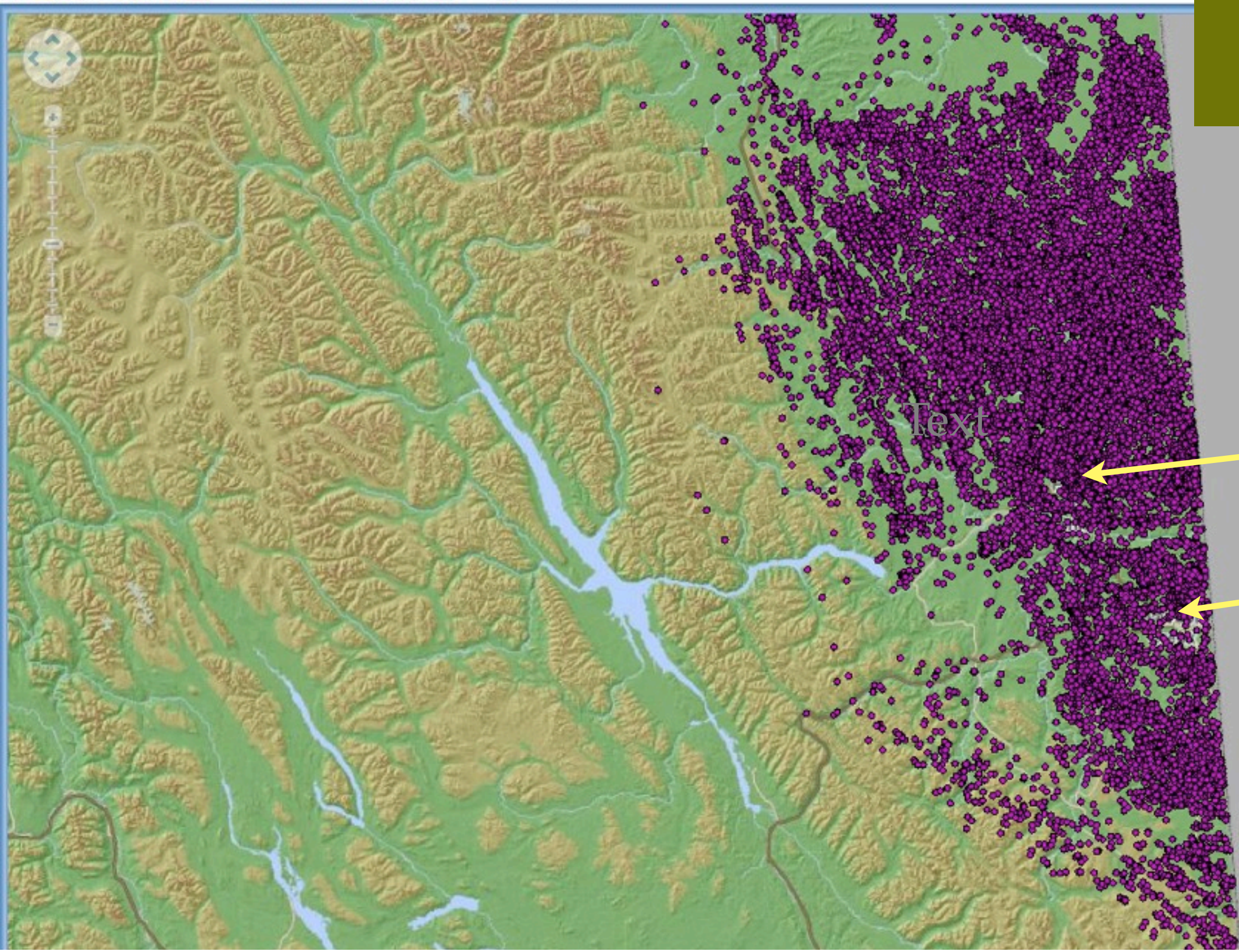


# WHAT WE SHOULD KNOW



**WHAT IS COMING?**

**(I.E. FULL BUILT-OUT PLAN)**

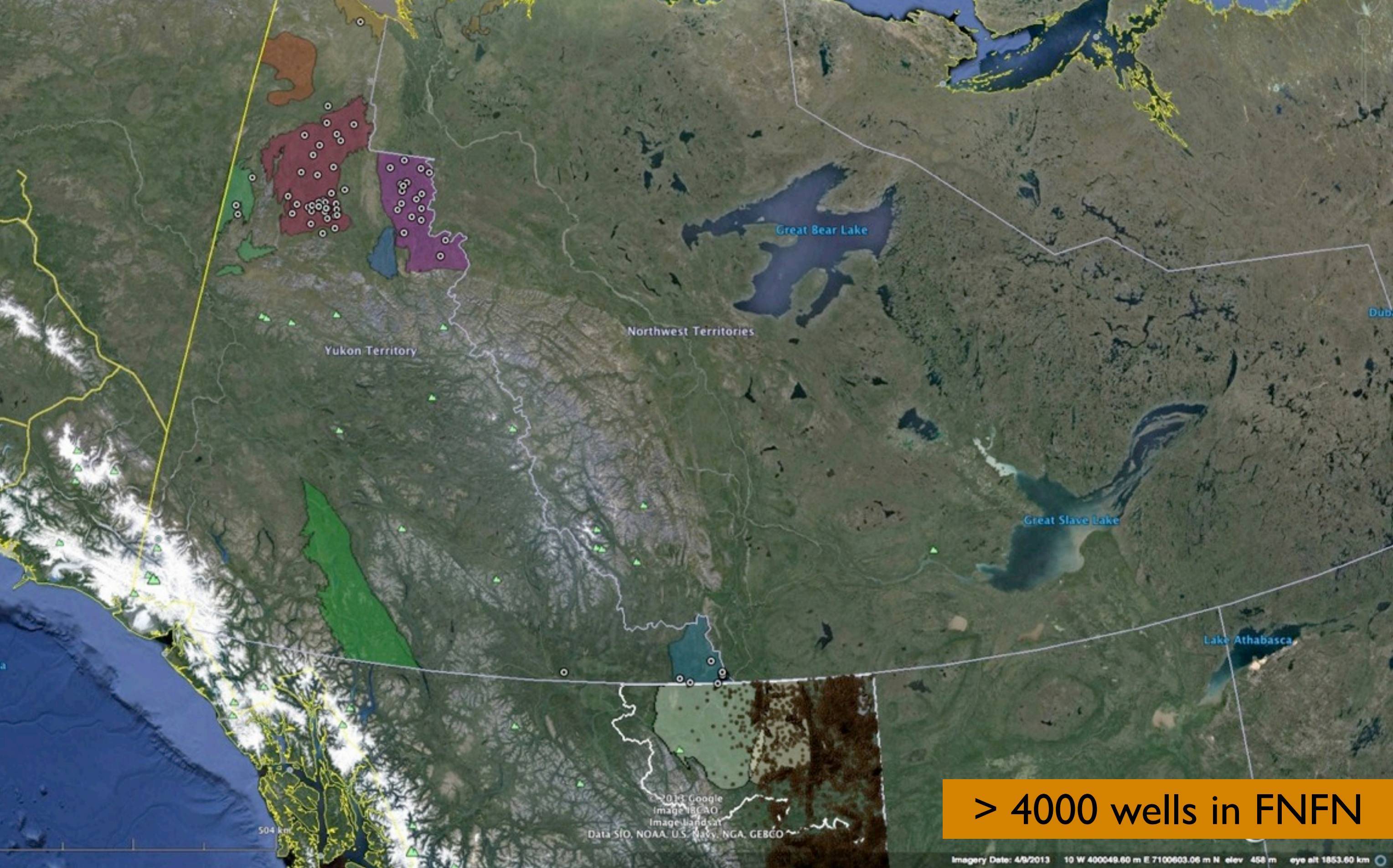


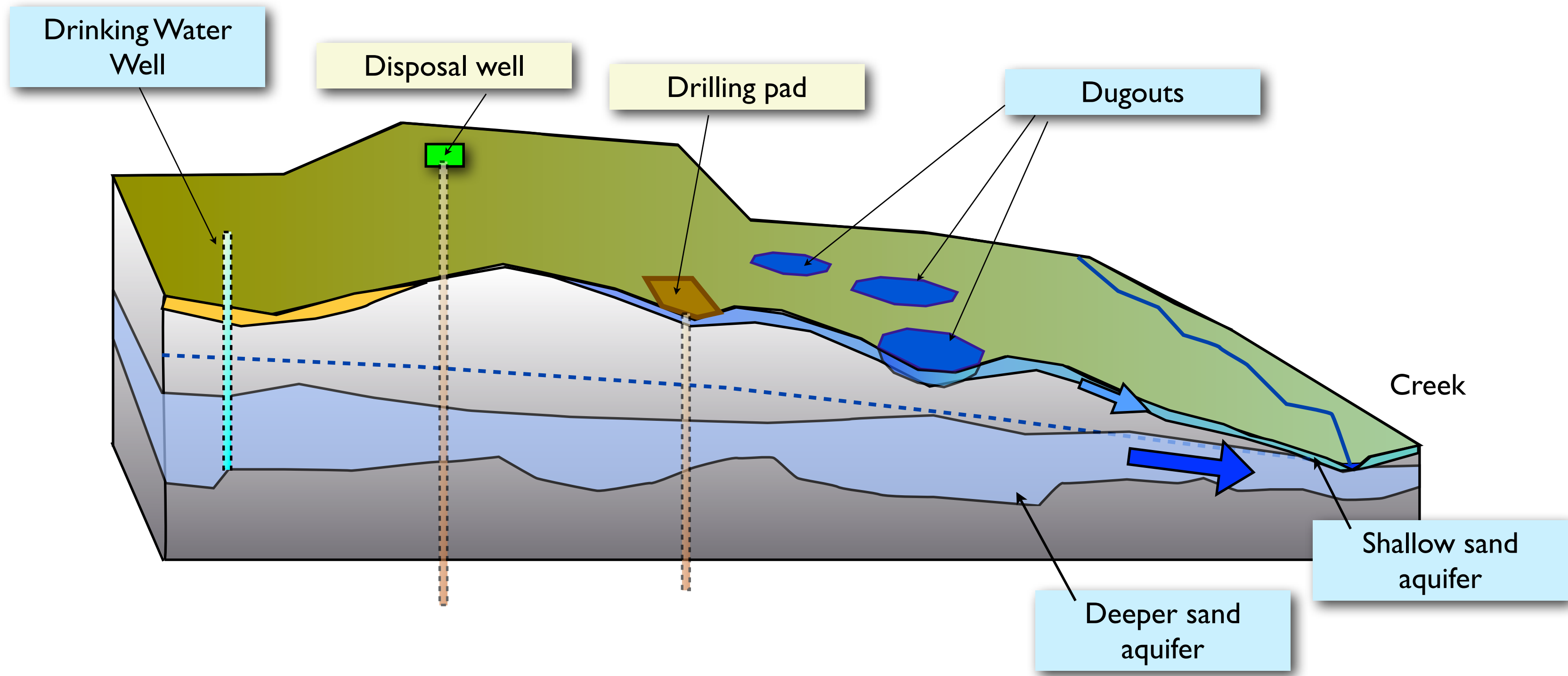
NE BC  
over 31 000 O&G Wells  
(source: National Energy Board)

Fort St John

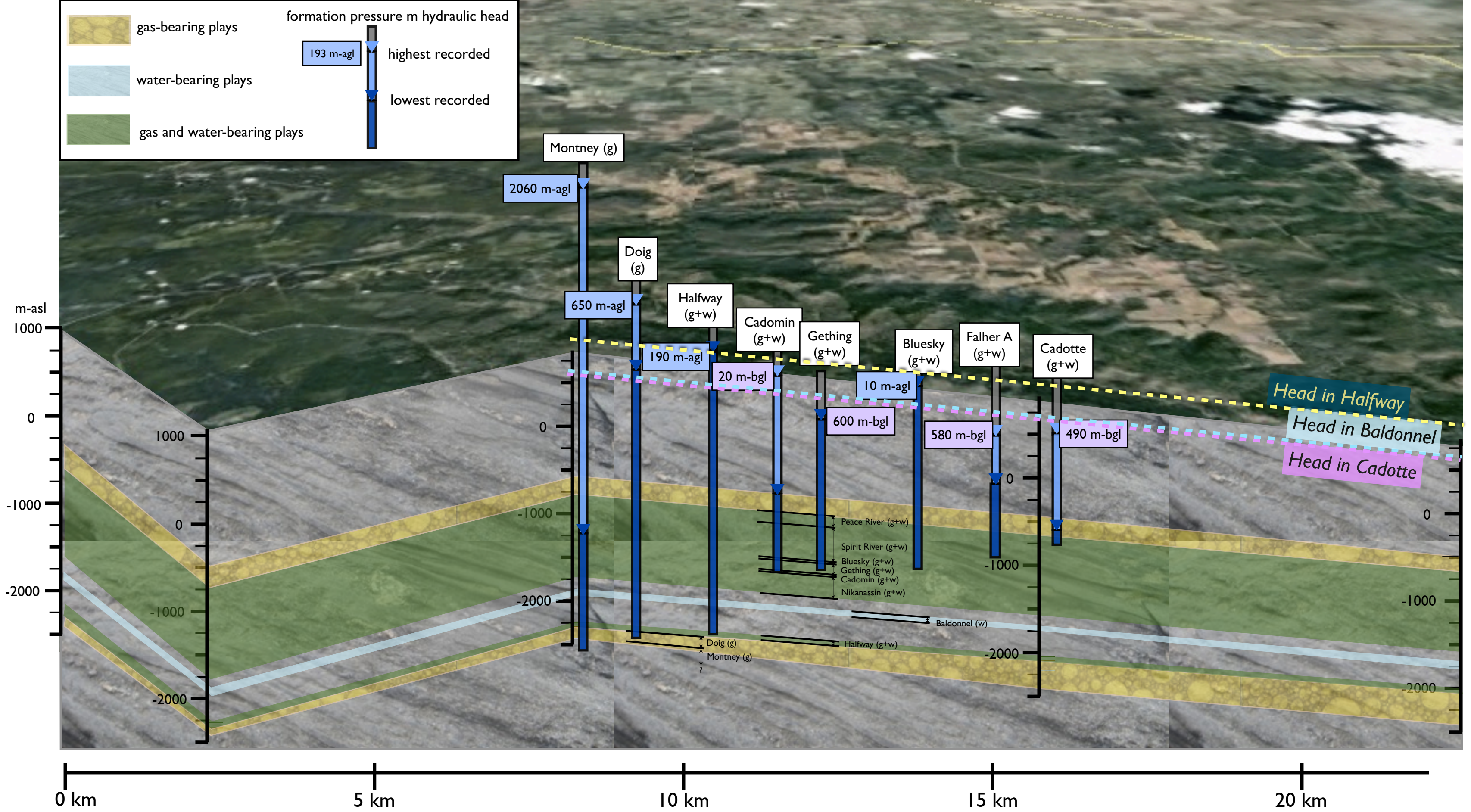
Dawson Creek

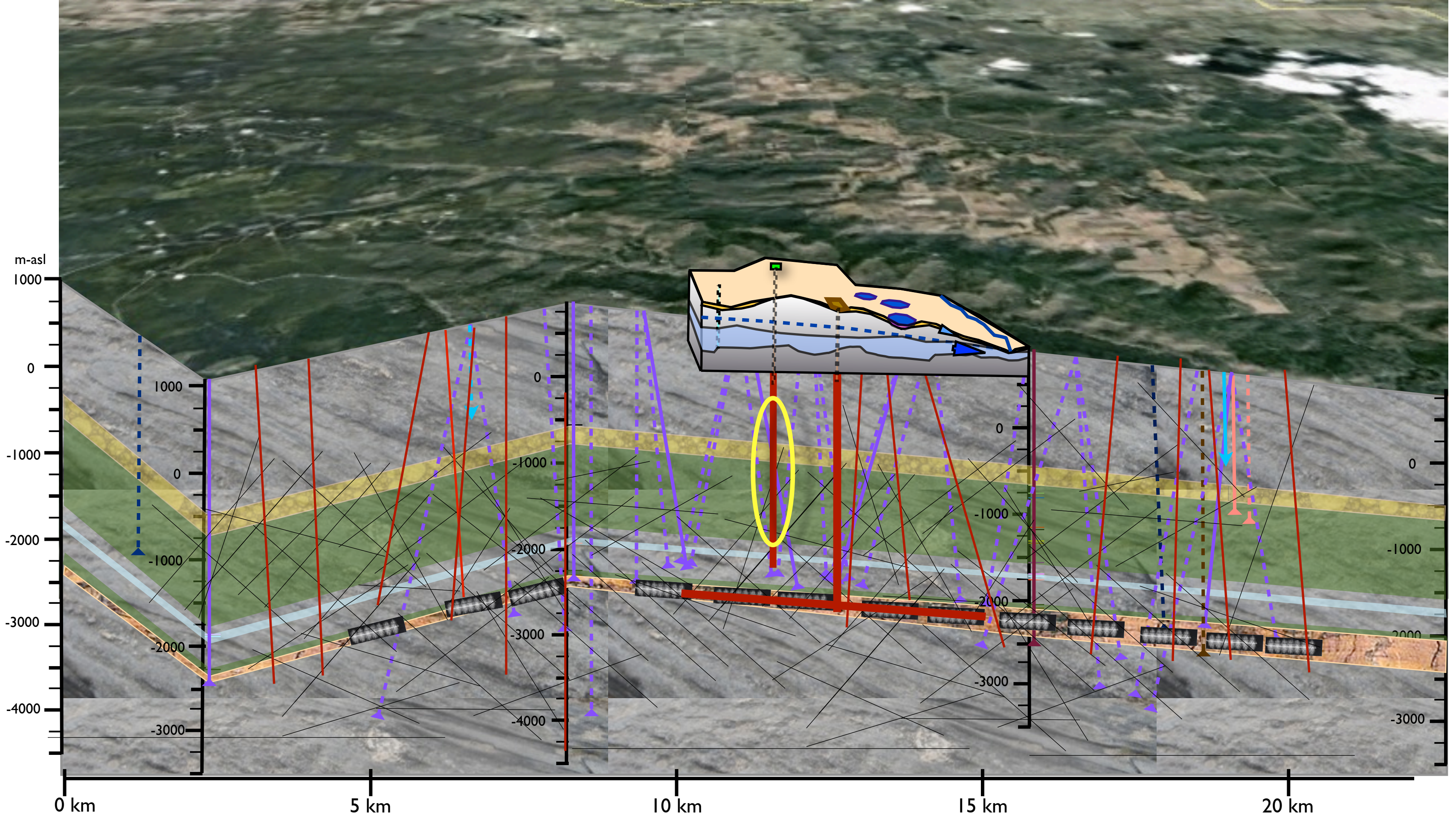






Conceptual image of groundwater dynamic and connection to surface water





**OTHER COMMENTS**  
**TAKE HOME MESSAGES**

EFFECTS COULD TAKE TIME TO BE  
OBSERVED: YEARS, DECADES

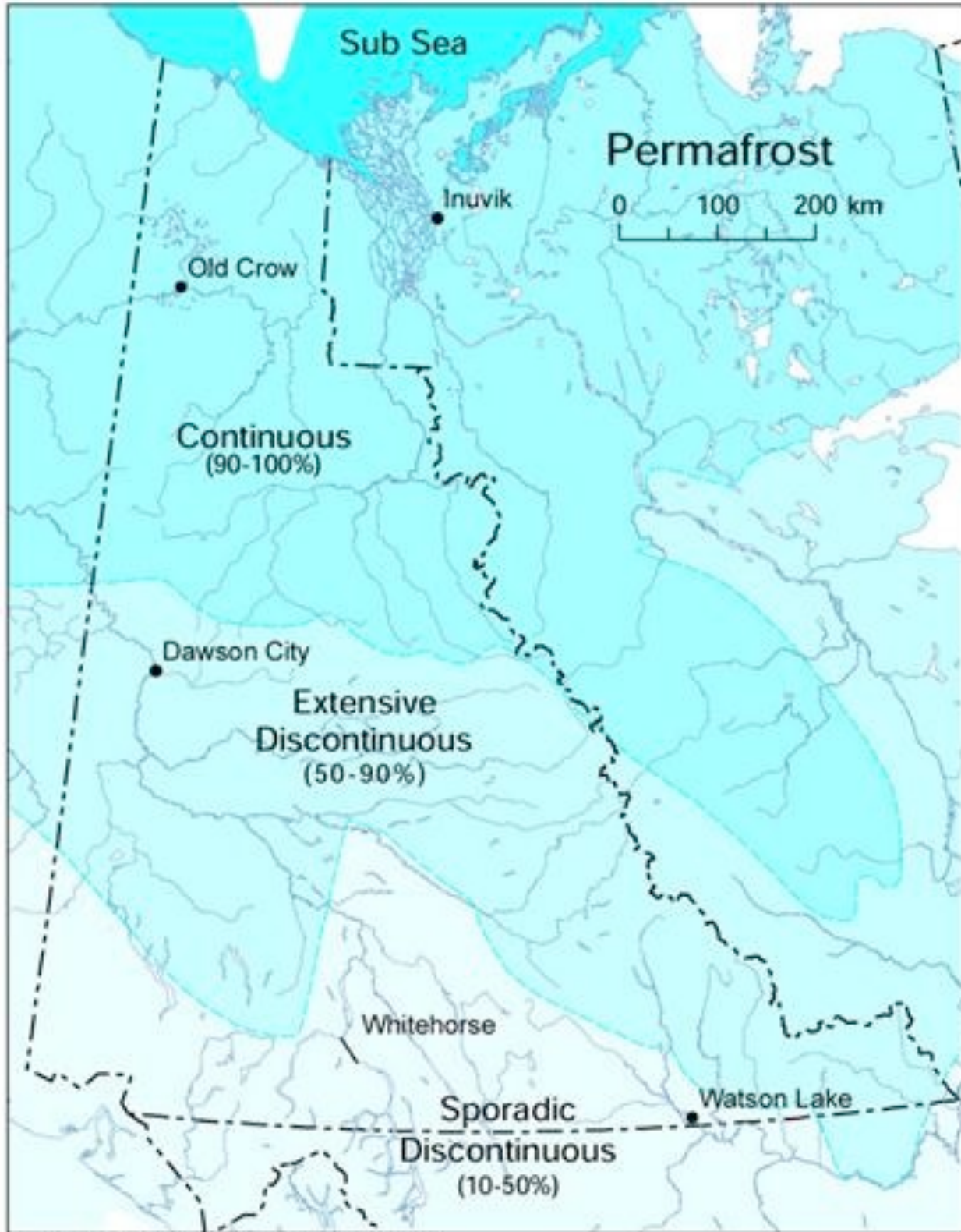


# CUMULATIVE EFFECT

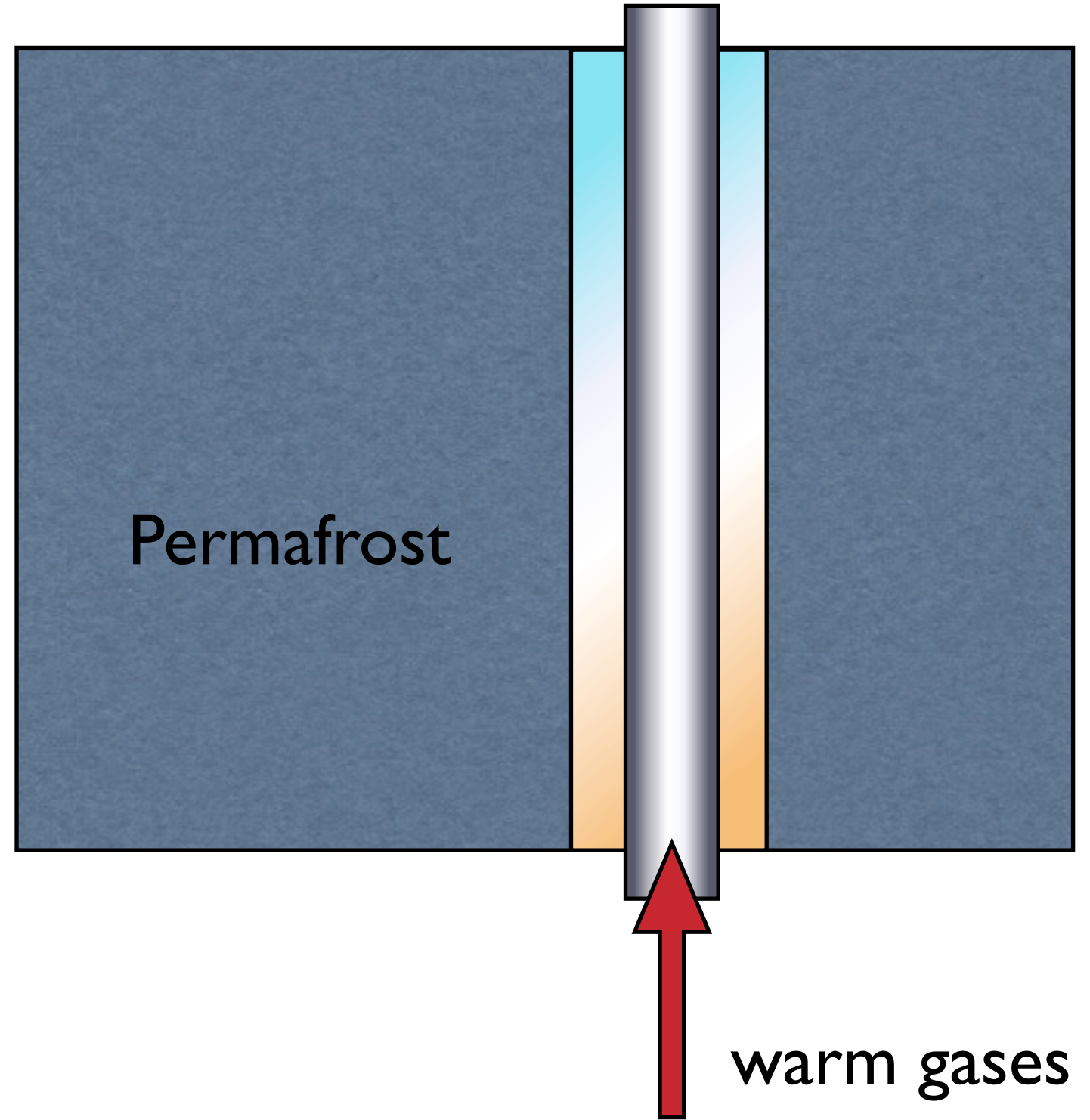
# O&G WELLS IN WESTERN CANADA

**Over 0.5 million wells!!!**

- 385 000 in Alberta
- 113 000 in Saskatchewan
- 31 000 in BC
- 8 000 in Manitoba



Department of Environment Map ID: GIS2003-028-05



VERY SENSITIVE ENVIRONMENT

**100% OF WELLS ARE SEALED**

**FOREVER**

**ARE WE SURE ???**

WHAT WILL HAPPEN TO  
WATER  
IF IT IS NOT THE CASE ?

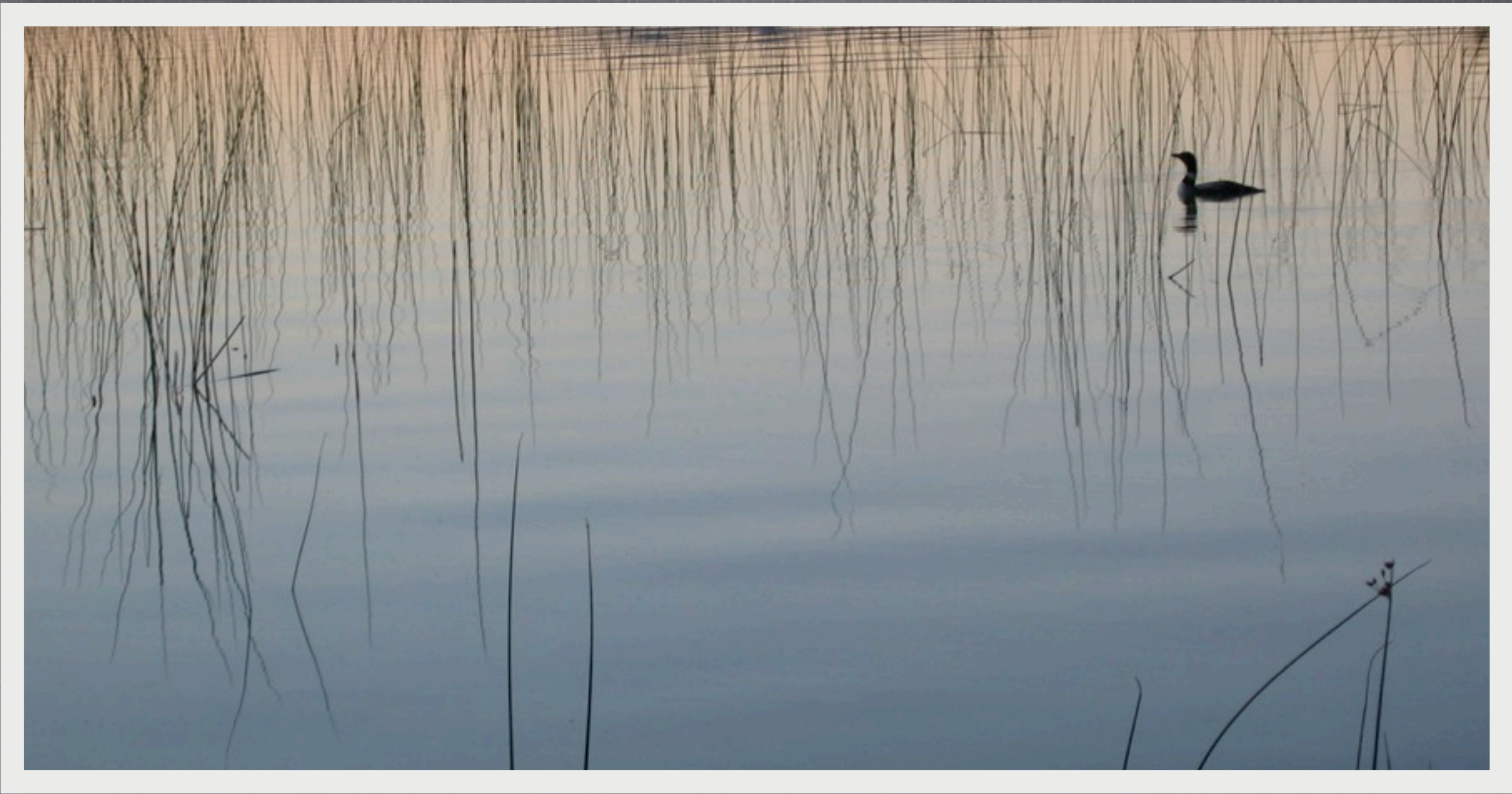


Photo: Gilles Wendling

**THANK YOU**