Experiences and Lessons Learned from the Weyburn CO_2 Monitoring Project

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Phase 1: 2000-2004

"To predict and verify the ability of an oil reservoir to securely and economically contain CO_2 (geologically)… to address the long-term migration and fate of CO_2 in a specific environment (EnCana's Weyburn, Saskatchewan EOR operation)"

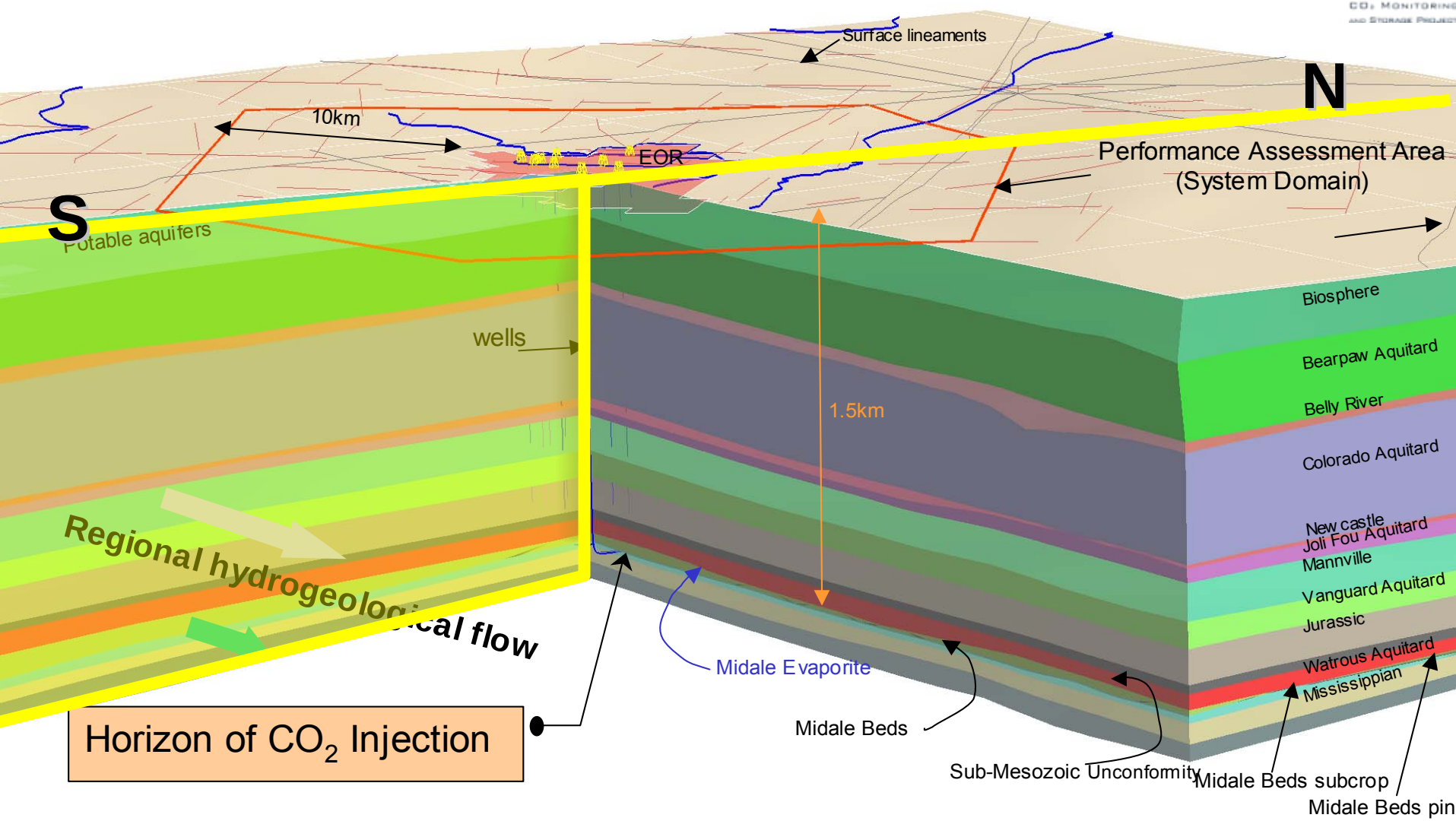
Sponsors:

- 5 governments (NRCan, US DOE, SIR, AERI, EU)
- 10 industry sponsors (Canada, USA, EU, Japan) – energy-based
- endorsed by IEA GHG R&D Programme
- $42 million (50:50 cash : in-kind)

Research Management:

- overall project management by PTRC, based in Regina, SK
- 22 S&T organizations in 6 countries
- 80+ researchers

Where is the CO_2 Stored?



Weyburn Unit Statistics

Field size
- 70 square miles

Original oil in place:
- 1.4 billion barrels

Oil recovery (pre-CO_2-EOR):
- 370 million barrels

Projected CO_2 IOR:
- 155 million barrels

Projected CO_2 stored:
- 30+ million tonnes* (gross)
- 26+ million tonnes (net)

**equivalent to removing > 5 million cars off the road for a year!*

The Source of CO_2

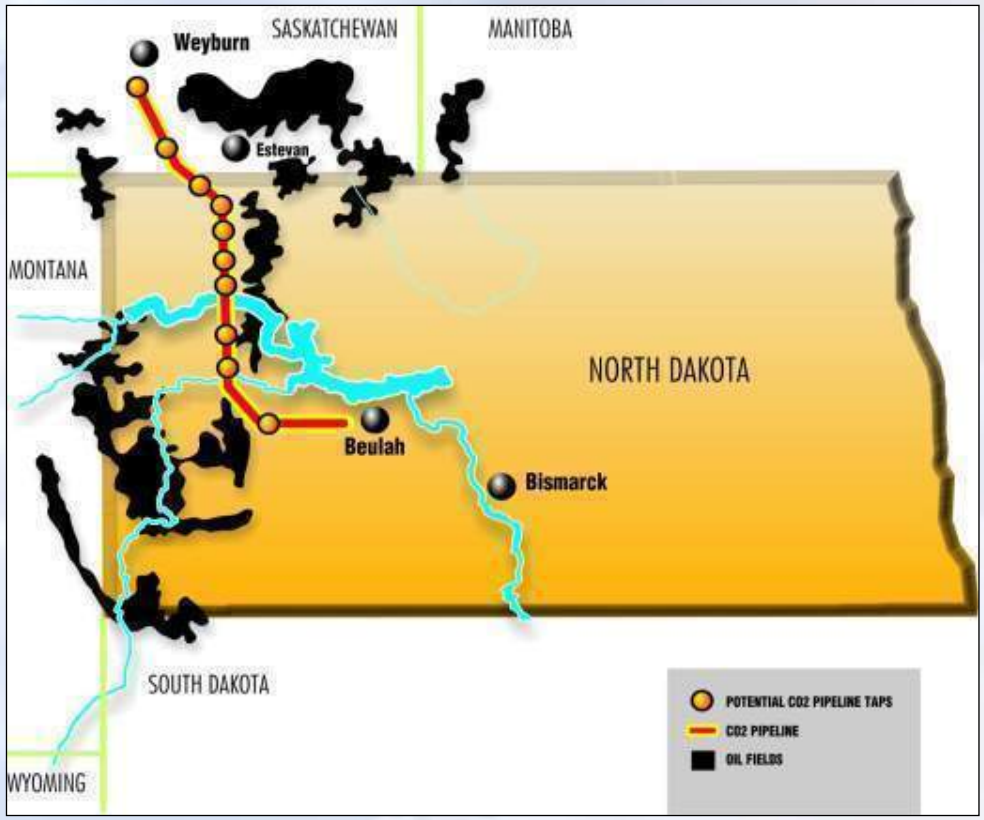
Dakota Gasification Company

- 155 mmscfd of EOR-quality CO_2 by-product of coal (lignite) gasification (over 8,000 tonnes/day); CO_2 purity 95% (less than 2% H_2S) ; trace mercaptans

- currently ~ 80% is contracted to companies operating CO_2-EOR operations in SE Saskatchewan, Canada

- 95 mmscfd (5000 tonnes/day) contracted and injected at Weyburn

- EnCana injects 150 mmscfd (33% recycle) as of December 2005

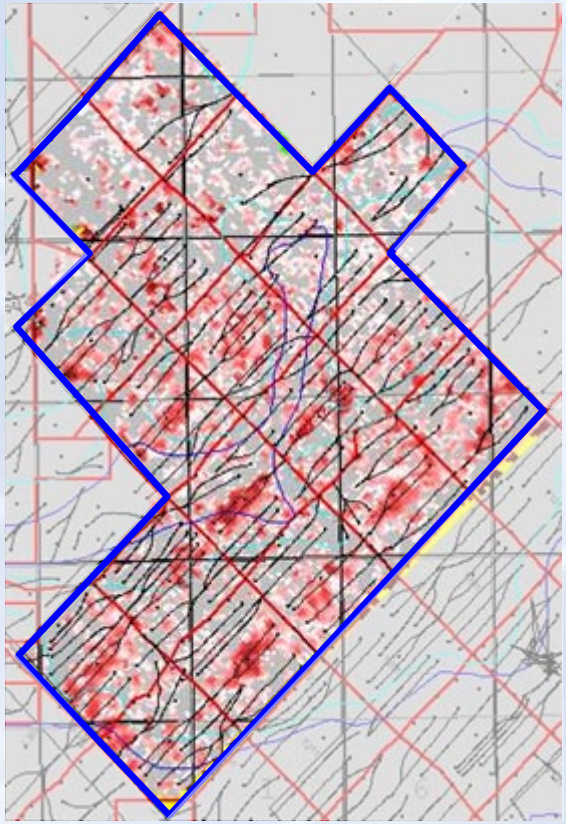


A comprehensive, internationally peer-reviewed data set

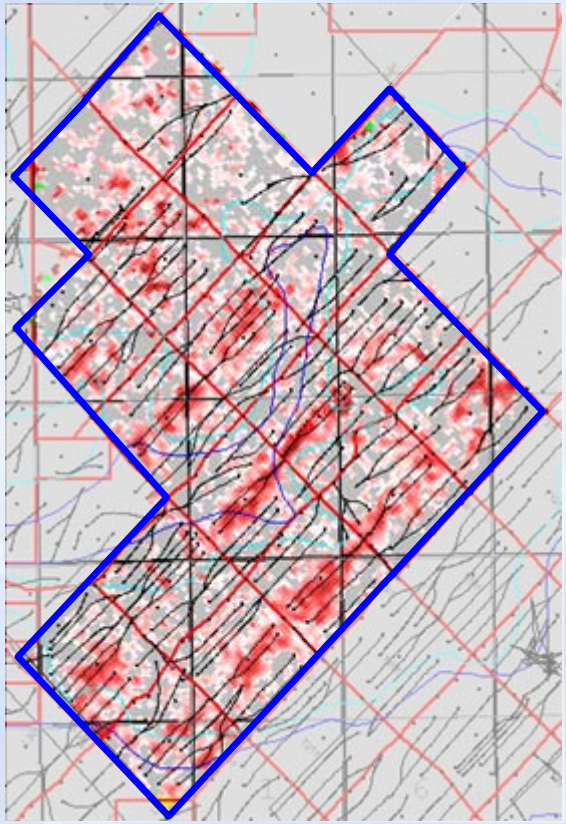
- Baseline monitoring survey (geophysical, geochemical, surface) in July 2000 (pre-injection)
- CO_2 injection began in September 2000 in 19 of 75 planned patterns
- R&D program focused on the first 19 patterns (Phase 1a)
- Regular monitoring surveys completed (quarterly, annually)
- Expert review led by IEA GHG in mid-2003 to make course adjustments and plan for Final Phase
- Expert review of Final Phase Technical Program led by IEA GHG in early 2006

Facility where main CO_2 pipeline enters Weyburn field from Beulah, ND

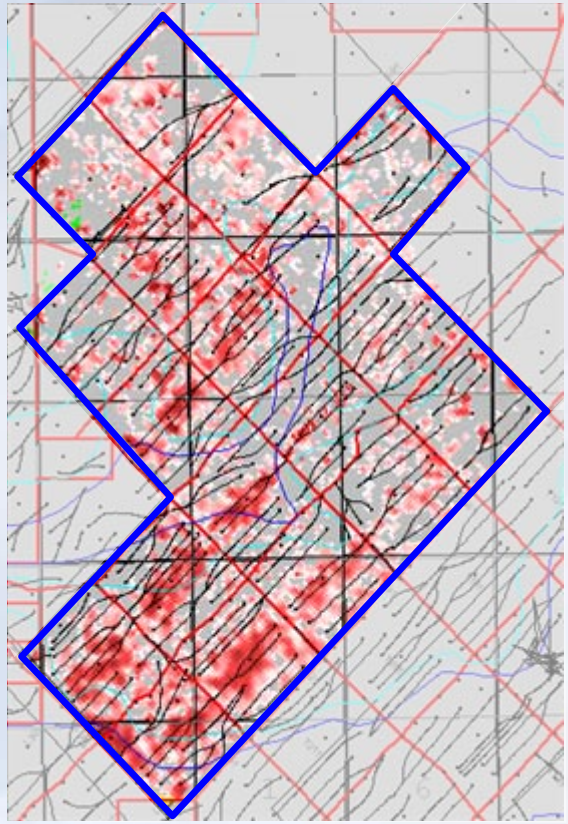
Tracking CO_2 Movement: Seismic surveys (Baseline to 2004) – Phase 1



Baseline - 2001



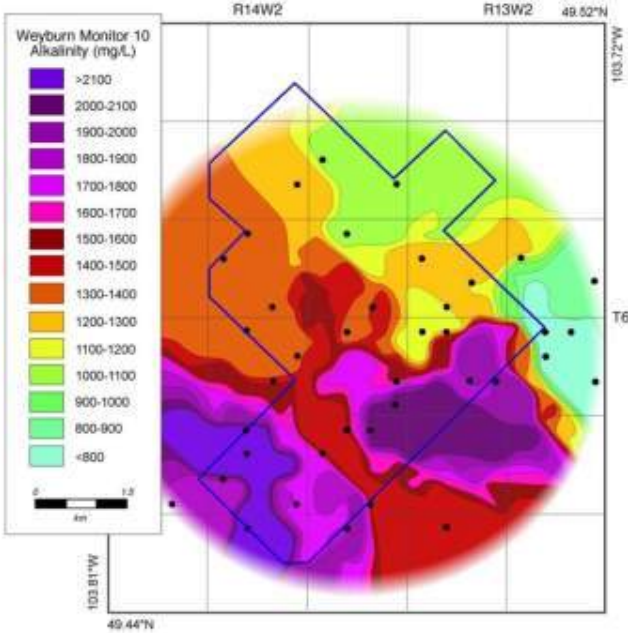
Baseline - 2002



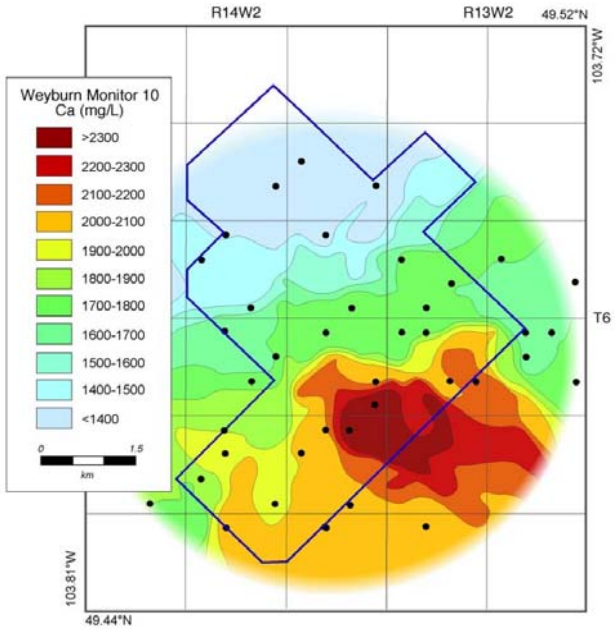
Baseline - 2004

Tracking CO_2 Chemistry: Fluid Monitoring Surveys (Phase 1)

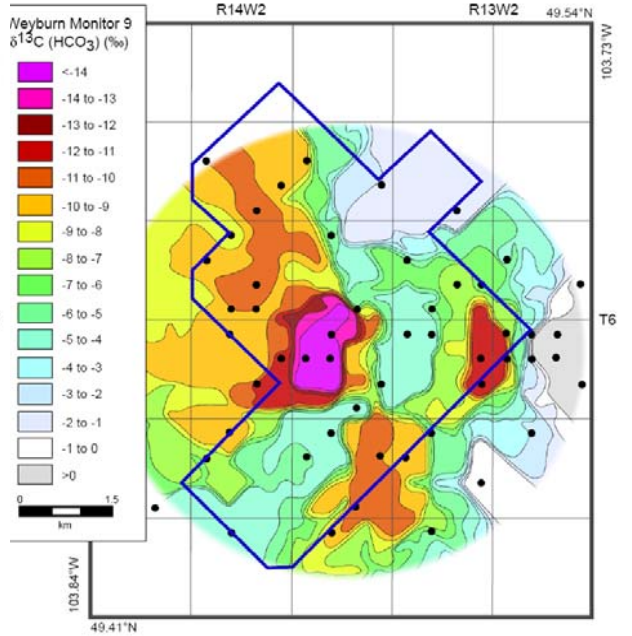
Monitor 10 (03-2004)



Total Alkalinity (mg/L)



Ca^{+2} (mg/L)



$\delta^{13}C_{HCO3}$ (‰)

Competing Reactions: $CO_2 + H_2O \leftrightarrow H^+ + HCO_3^- / CO_2 + Ca^{2+} + H_2O \leftrightarrow 2H^+ + CaCO_3 / CO_2 + H_2O + CaCO_3 \leftrightarrow Ca^{2+} + 2HCO_3^-$

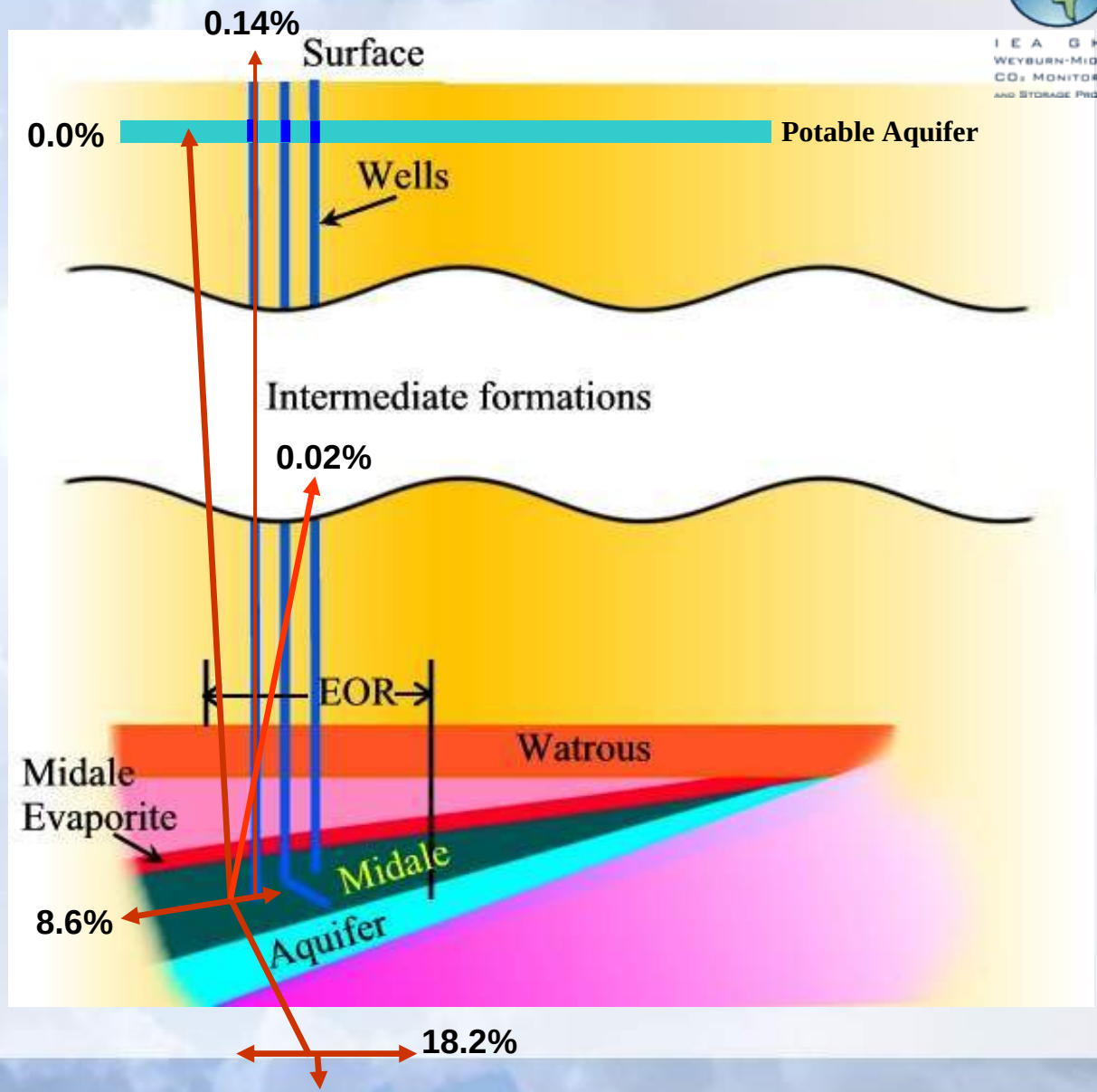
Summary of Phase 1 Results

Geological "container" at Weyburn is effective:

- Primary carbonate and secondary shale seals are highly competent
- Hydraulic separation between adjacent aquifers

Migration of CO_2 outside the EOR area at 5000 years post-injection:

- 26.8% (7 million tonnes) moves outside the EOR area but remains within region



Why pursue a Final Phase (2005-2008) project?

"Encourage the widespread use of technologies required for the design, implementation, monitoring and verification of a significant number of CO_2 geological storage projects in Canada and the USA"

- Build a Best Practices Manual (BPM) as a practical, technical guide for design and implementation for CO_2 storage associated with EOR
- Influence the development of clear, workable regulations for CO_2 storage, building upon existing, effective regulatory frameworks
- Influence the development of an effective public consultation process
- Influence the development of effective public policy to seed the development of a large, economic CO_2 supply and infrastructure, and a mechanism for monetizing credits for CO_2 storage

IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project

Best Practices Manual – Final Phase

Protocols for:

- ***Storage site selection***
- ***Monitoring and verification of stored CO_2***
- ***Well-bore integrity monitoring and remediation***
- ***Long-term risk assessment and risk management***
- ***Maximizing economic CO_2 storage capacity***

Overarching Principles: Address gaps in IPCC CCS Report and facilitate good public policy development to ensure widespread deployment of long-term CCS

ptrc
Petroleum Technology Research Centre

Conclusions (for now)

- Based on preliminary results, the natural geological setting appears to be highly suitable for long-term CO_2 geological storage
- The Project has arguably the most complete, comprehensive, peer-reviewed data set in the world for CO_2 geological storage
- An effective, international team of high-quality researchers has been established
- Strong international leadership has been demonstrated by Canada and the USA in CO_2 geological storage R&D through continued financial and managerial support
- International credibility and recognition have been achieved through recognition by the IEA GHG R&D Programme and the Carbon Sequestration Leadership Forum
- Best Practices Manual development will assure integration across the Technical and Policy Programs during the Final Phase