

An Assessment of Geological Carbon Sequestration Options in the Illinois Basin – Phase III

DE-FC26-05NT42588

Robert J. Finley and the MGSC Project Team

Illinois State Geological Survey (University of Illinois) and
Schlumberger Carbon Services



U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the
Infrastructure for CO₂ Storage
August 21-23, 2012





Acknowledgements



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- The [Midwest Geological Sequestration Consortium \(MGSC\)](#) is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky
- Landmark Graphics software via their University Donation Program and cost share plus Petrel software via Schlumberger Carbon Services



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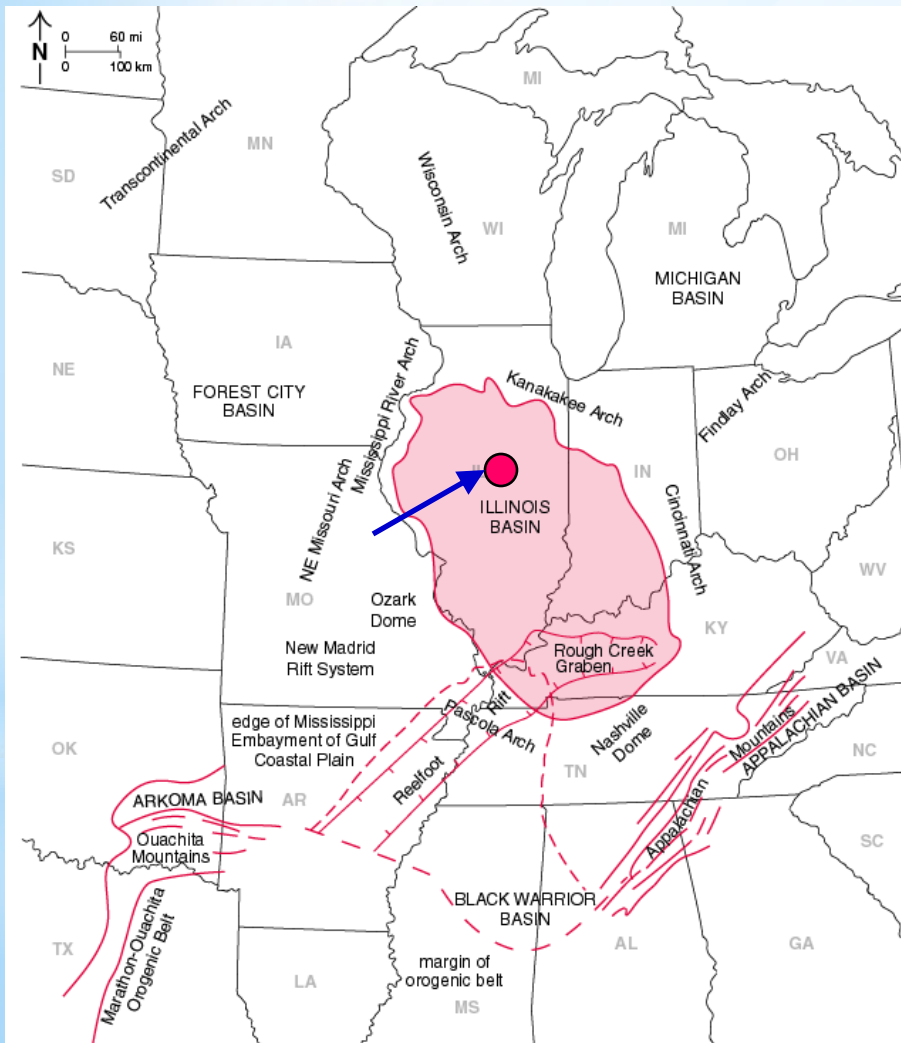




Presentation Outline MGSC Phase III: Illinois Basin-Decatur Project

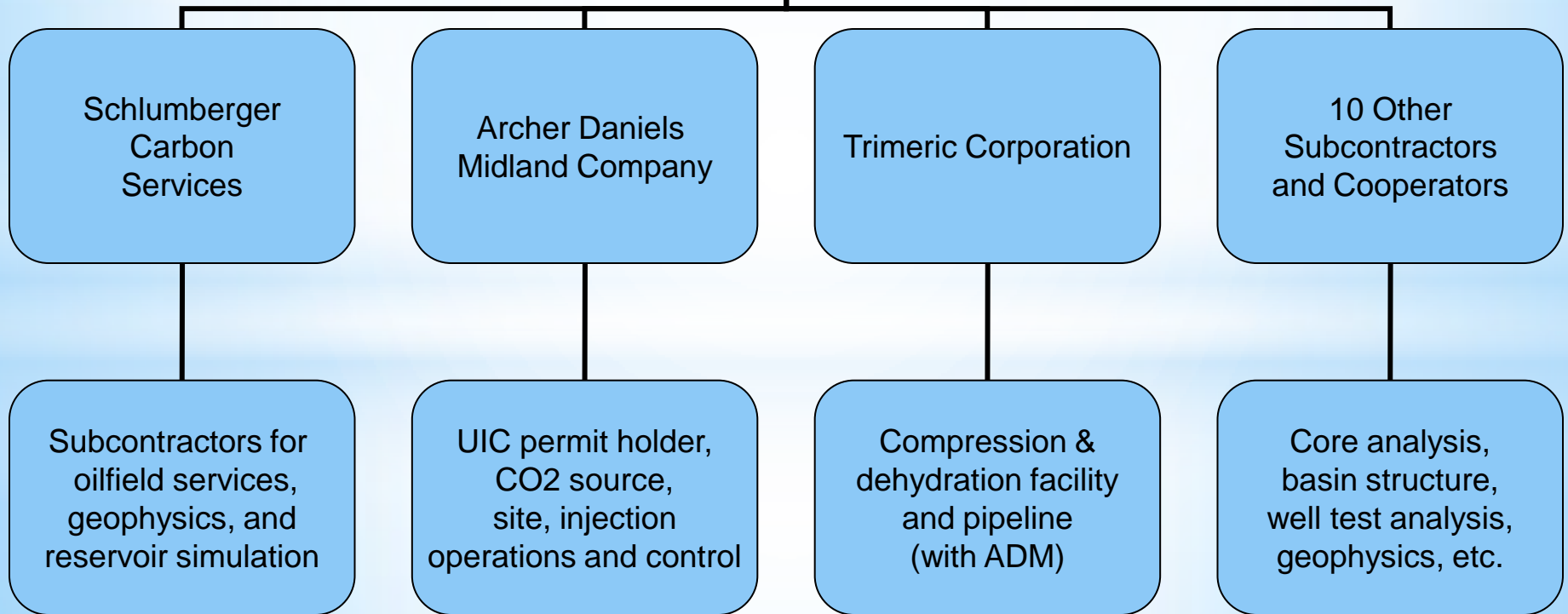
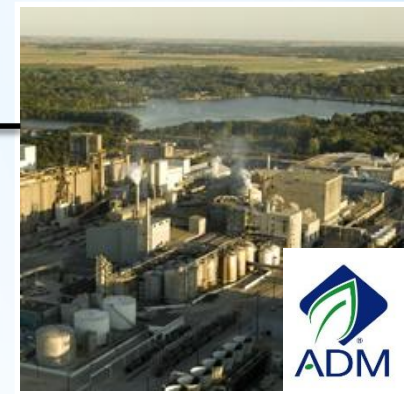
- Overview, project organization, and status
- Accomplishments and benefits
- Location and geophysical framework
- MVA and geophysical plume monitoring
- Microseismic monitoring
- Reservoir simulation
- Facilities and data collection
- Coordination with Industrial Sources project

Project Overview: Illinois Basin - Decatur Project (IBDP)



- A collaboration of the Midwest Geological Sequestration Consortium, the Archer Daniels Midland Company (ADM), Schlumberger Carbon Services, and other subcontractors to inject 1 million metric tons of anthropogenic carbon dioxide at a depth of 7,000 +/- ft (2,000 +/- m) to test **geological carbon sequestration in the Mt. Simon saline reservoir** at a site in Decatur, Illinois

Illinois Basin-Decatur Project Organization



Project Status: Operational Injection 17 November 2011

- **IBDP** fully operational 24/7
- **IBDP** is the first 1 million tonne carbon capture and storage project from a biofuel facility in the US
- Injection through fall 2014
- Intensive post-injection monitoring under MGSC through fall 2017

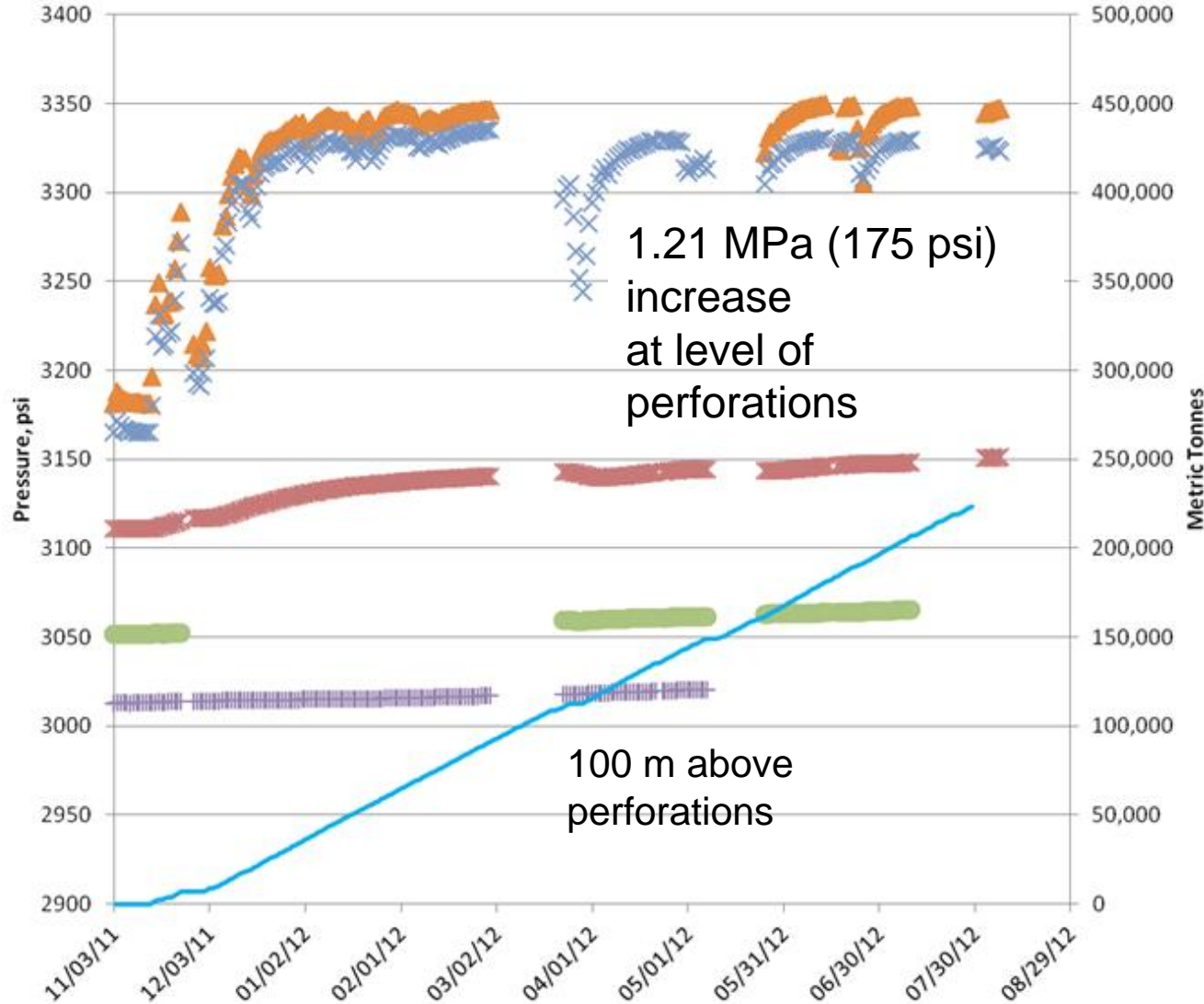
Cumulative Injection (8/17/12):
244,600 tonnes



Project Status — Verification Well Data

Illinois Basin Decatur Project
 Pressure data as observed in Verification Well #1 (VW1)
 VW1 is ~1000 ft from Injection Well CCS#1

Plotted pressure data is based on averages for each day.



CCS#1 Perforated Zone Summary

Zone #	Top	Bot
2	6982.0	7012.0
1	7025.0	7050.0

VW1 Perforated Zone Summary

Zone #	Top	Bot
11	4917.5	4920.5
10	5000.7	5003.7
9	5653.8	5557.3
8	5840.4	5843.9
7	6416.2	6419.7
6	6632.3	6635.8
5	6720.3	6723.8
4	6837.1	6840.6
3	6945.6	6949.1
2	6983.0	6985.5
1	7061.2	7064.2

- ▲ Zone 2 Pres (6983')
- × Zone 3 Pres (6946')
- * Zone 4 Pres (6838')
- Zone 5 Pres (6720')
- + Zone 6 Pres (6632')
- Calc Cumulative injected mass

Accomplishments to Recall about the IBDP

- IBDP is the first demonstration-scale (1 million tonne) US project to use carbon dioxide (CO₂) from an industrial source within the DOE Regional Carbon Sequestration Partnership (RCSP) program
- IBDP is a fully integrated demonstration, from a compression-dehydration facility and a short pipeline to delivery of supercritical CO₂ to a three-well injection and observation system on an intensely monitored site
- IBDP is the product of four years of Phase III effort, from date of funding to CO₂ in the reservoir, including site characterization, permitting, 5,424 m (17,900 ft) of drilling, reservoir geology, engineering, and geophysics, risk assessment, outreach, and baseline monitoring



Programmatic Goals and Benefits

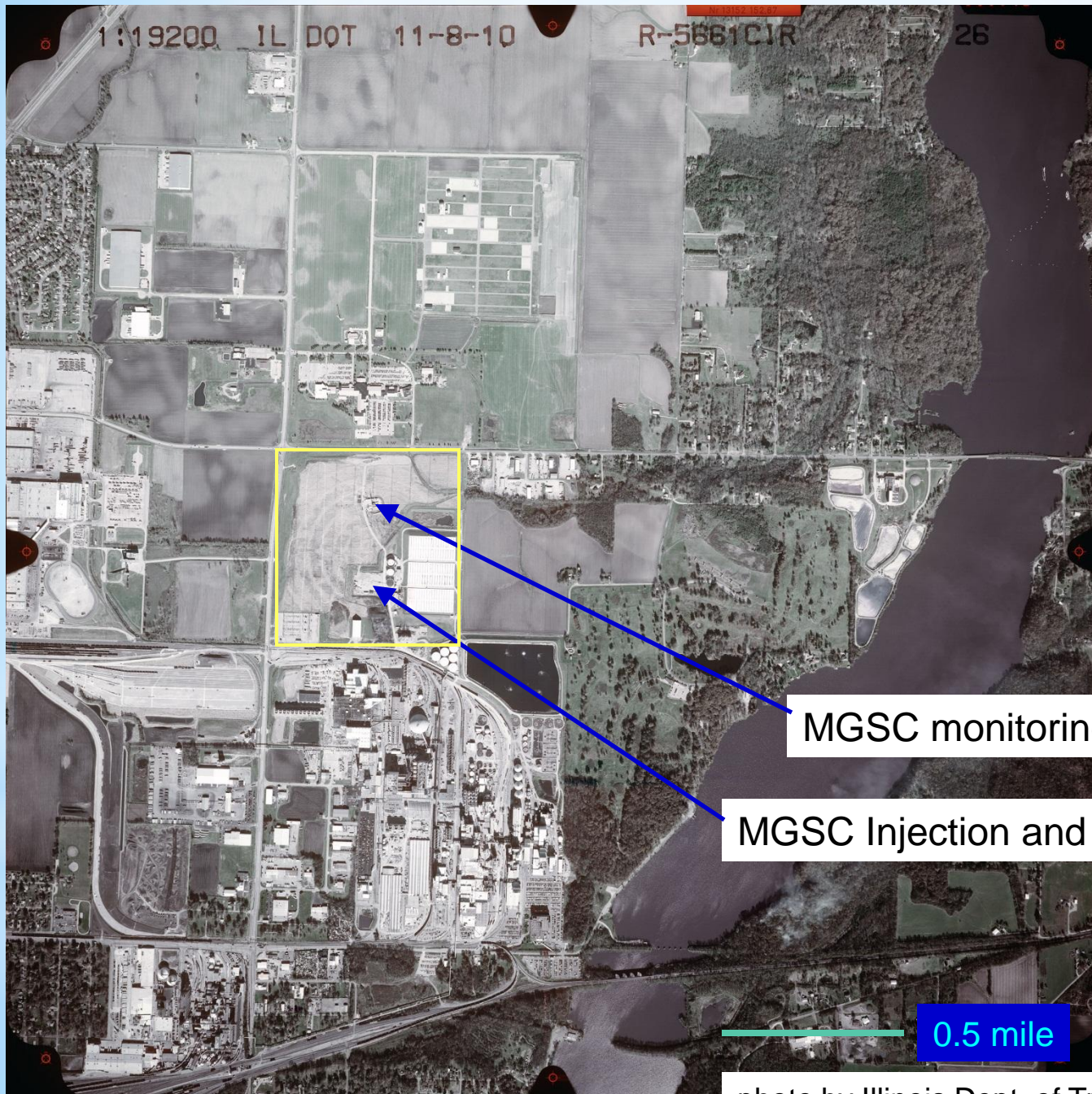
GOALS

- Validate capacity, injectivity, and containment for the largest saline reservoir in the Illinois Basin, the Mount Simon Sandstone
 - Carry out a comprehensive subsurface and surface MVA program to help validate effective storage
 - Integrate site selection, site characterization, injection operations and post-injection monitoring to verify best practices
-

BENEFITS

- Accessing the Mount Simon sequestration resource demonstrates its availability for other projects in the Midwest
- A three–well intensively monitored demonstration site provides a scalable model for geological carbon sequestration in a saline reservoir
- Multiple project elements incorporated to help future projects select those elements best suited to verify capacity, injectivity, and containment at other locations

MGSC Illinois Basin- Decatur Project (IBDP) Site



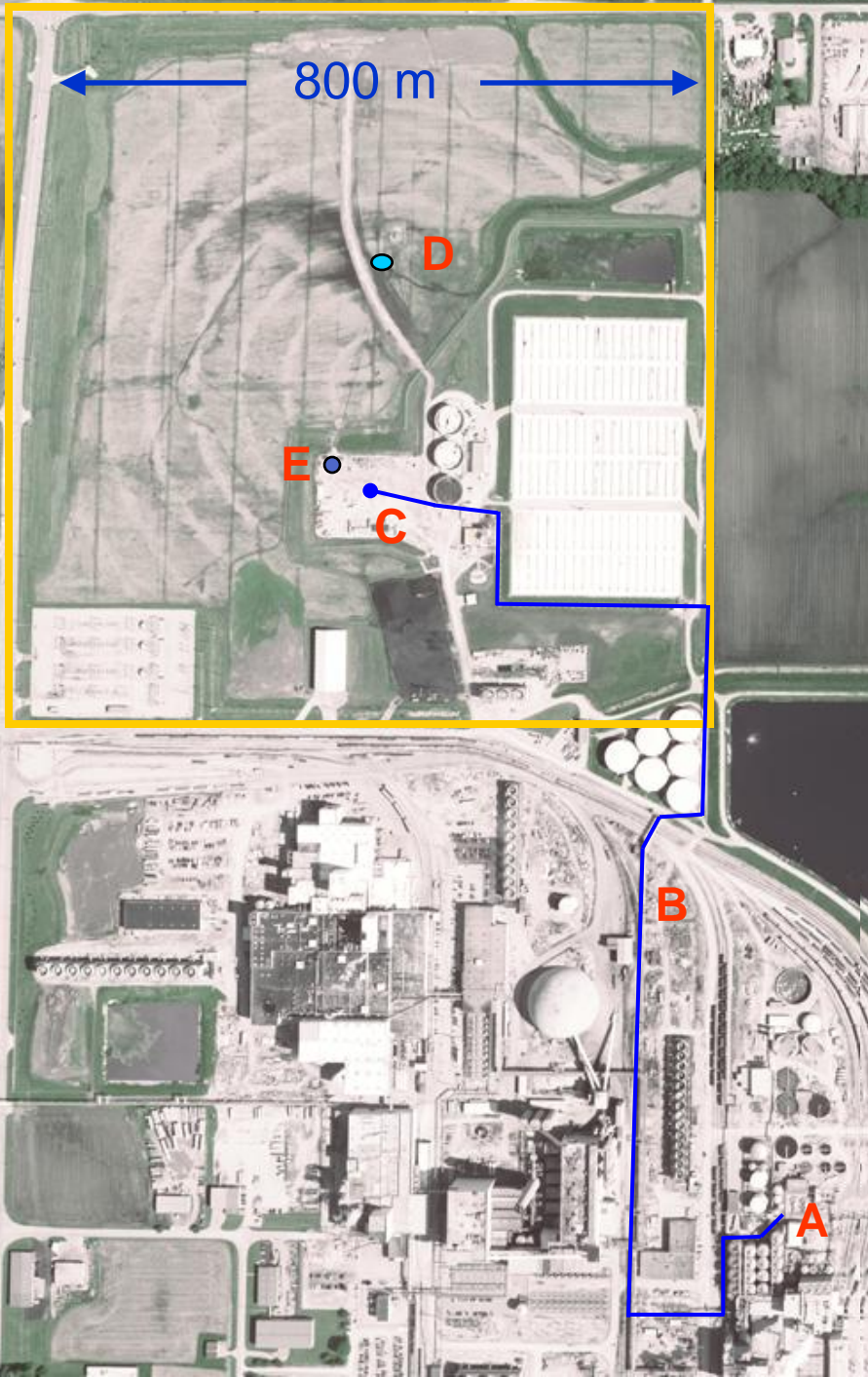
MGSC monitoring well

MGSC Injection and geophone wells

0.5 mile

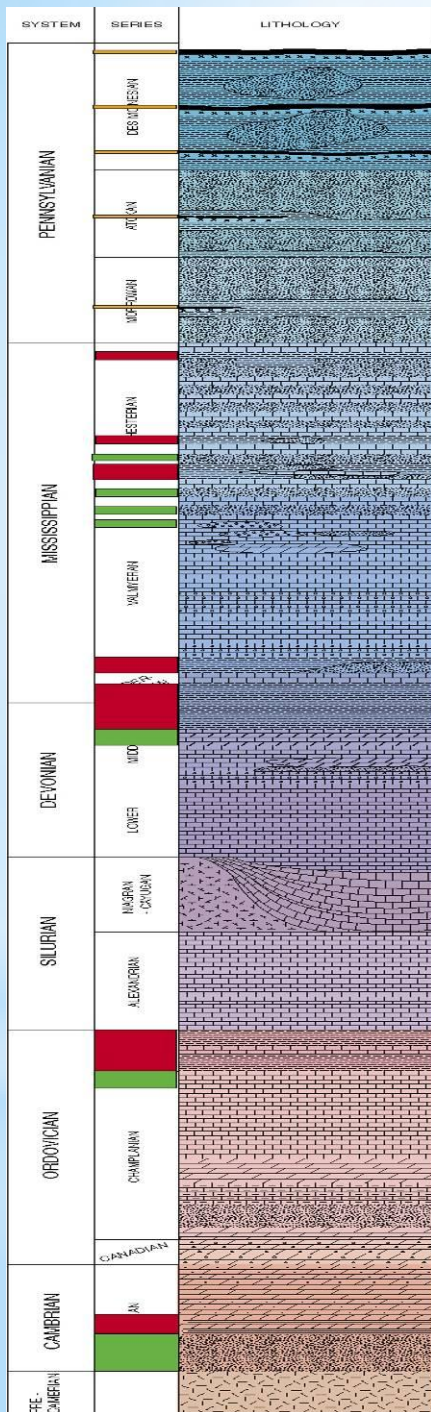
photo by Illinois Dept. of Transportation, 8 November 2010

Illinois Basin-Decatur Project Site (on ADM industrial site)



- **A** Dehydration/ compression facility location
- **B** Pipeline route (1.9 km)
- **C** Injection well site
- **D** Verification/ monitoring well site
- **E** Geophone well

Illinois Basin Stratigraphic Column



Pennsylvanian coal seams

Mississippian sandstone and carbonate oil reservoirs

New Albany Shale

back-up seals

Maquoketa Shale

St. Peter Sandstone

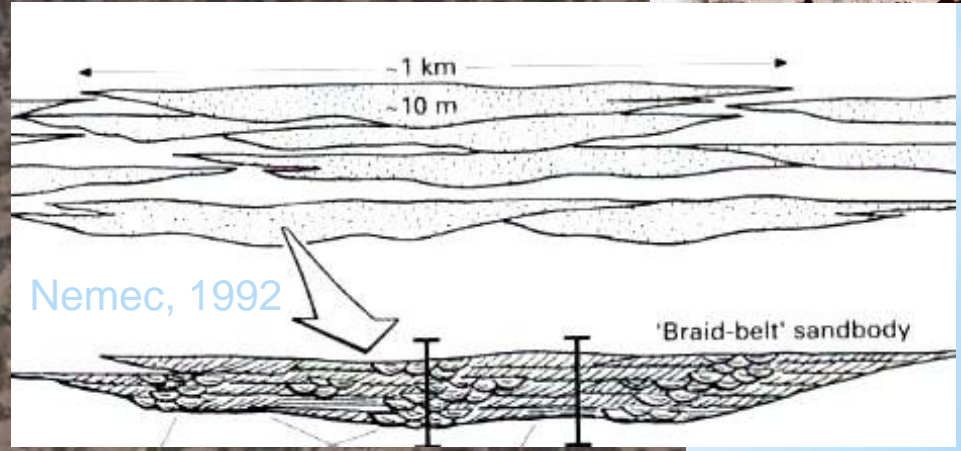
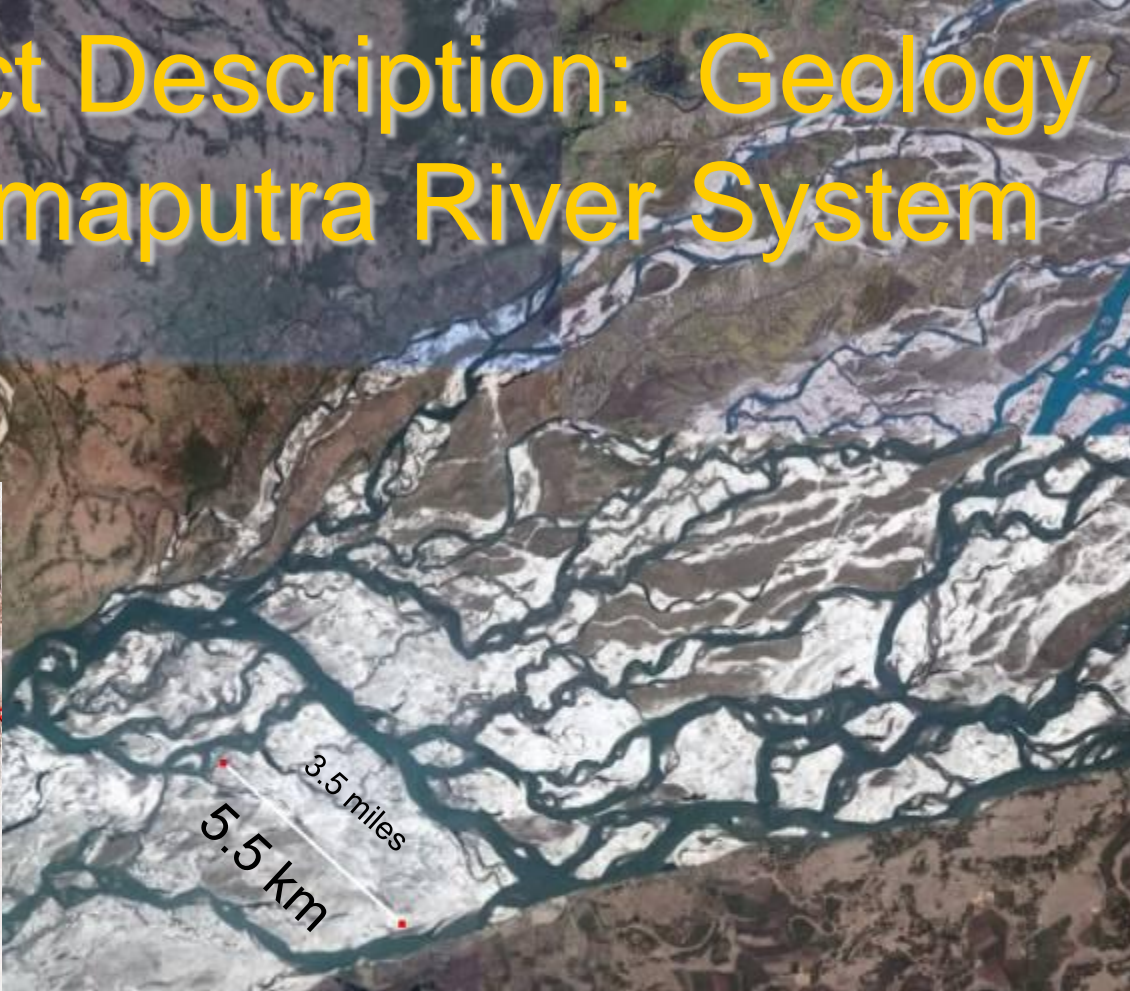
Eau Claire Shale

seal

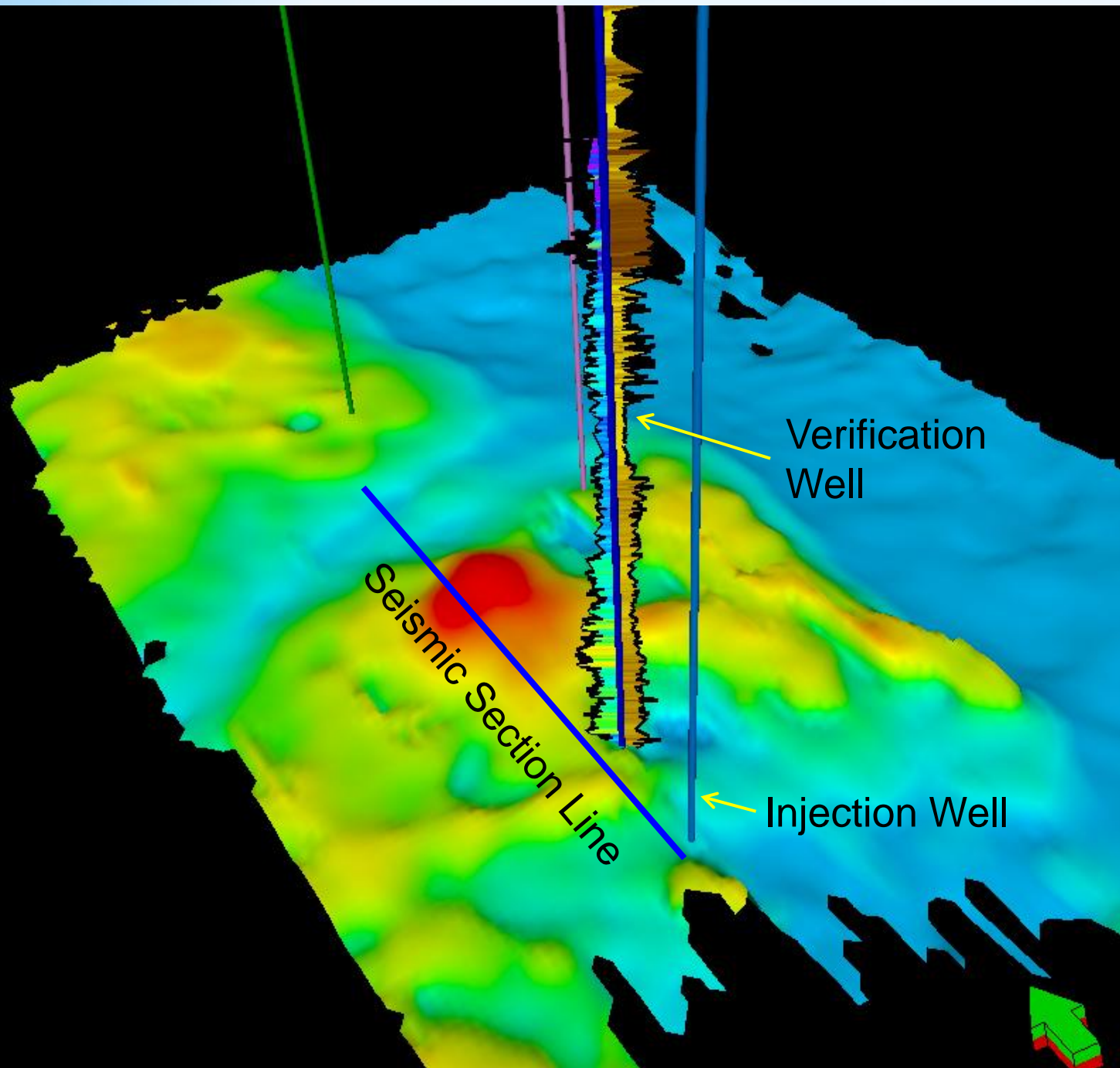
Mt. Simon Sandstone

reservoir

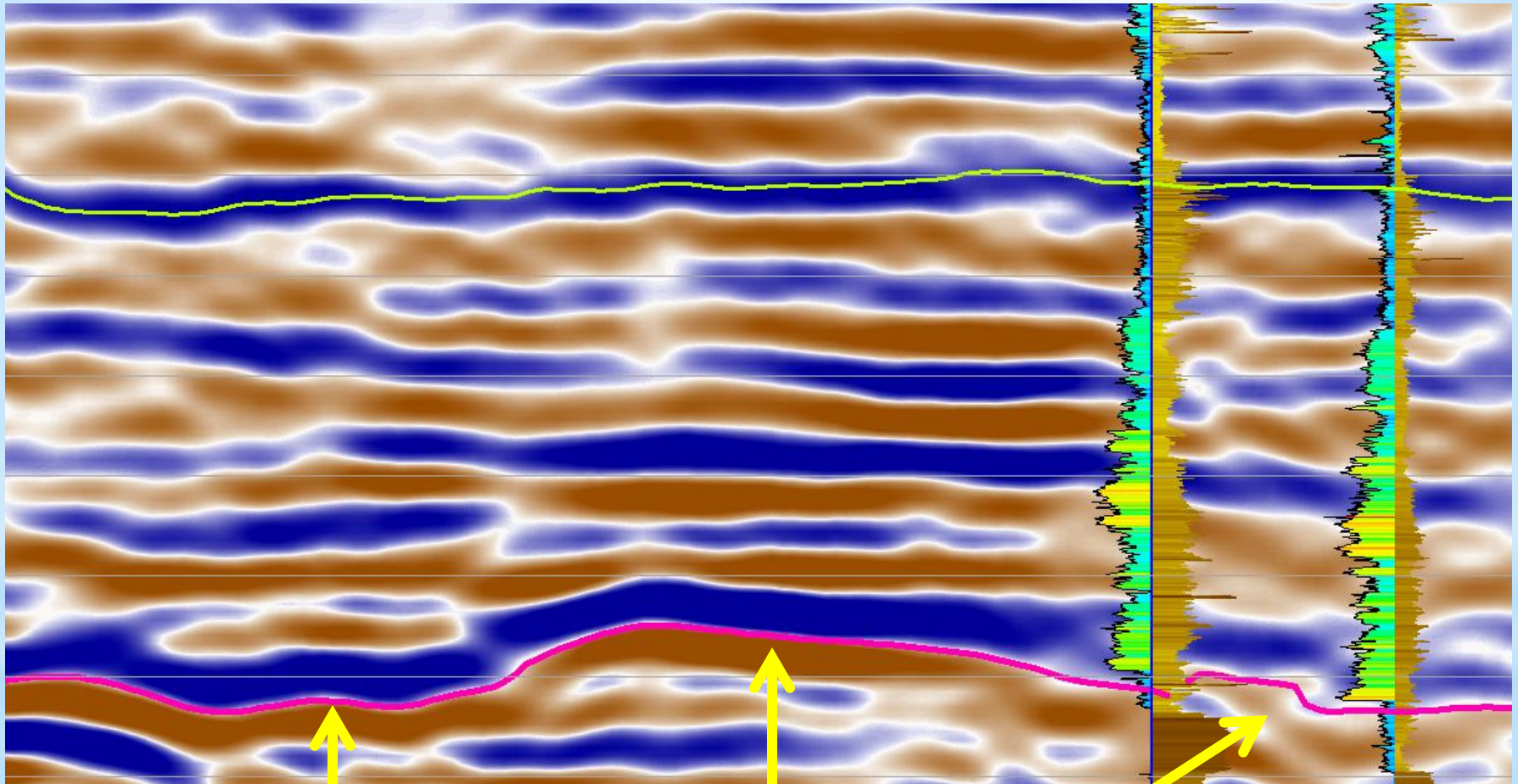
Project Description: Geology Brahmaputra River System



Topography
on the
Unconformity
Impacts CO₂
Distribution



Precambrian Topography Deflects CO₂



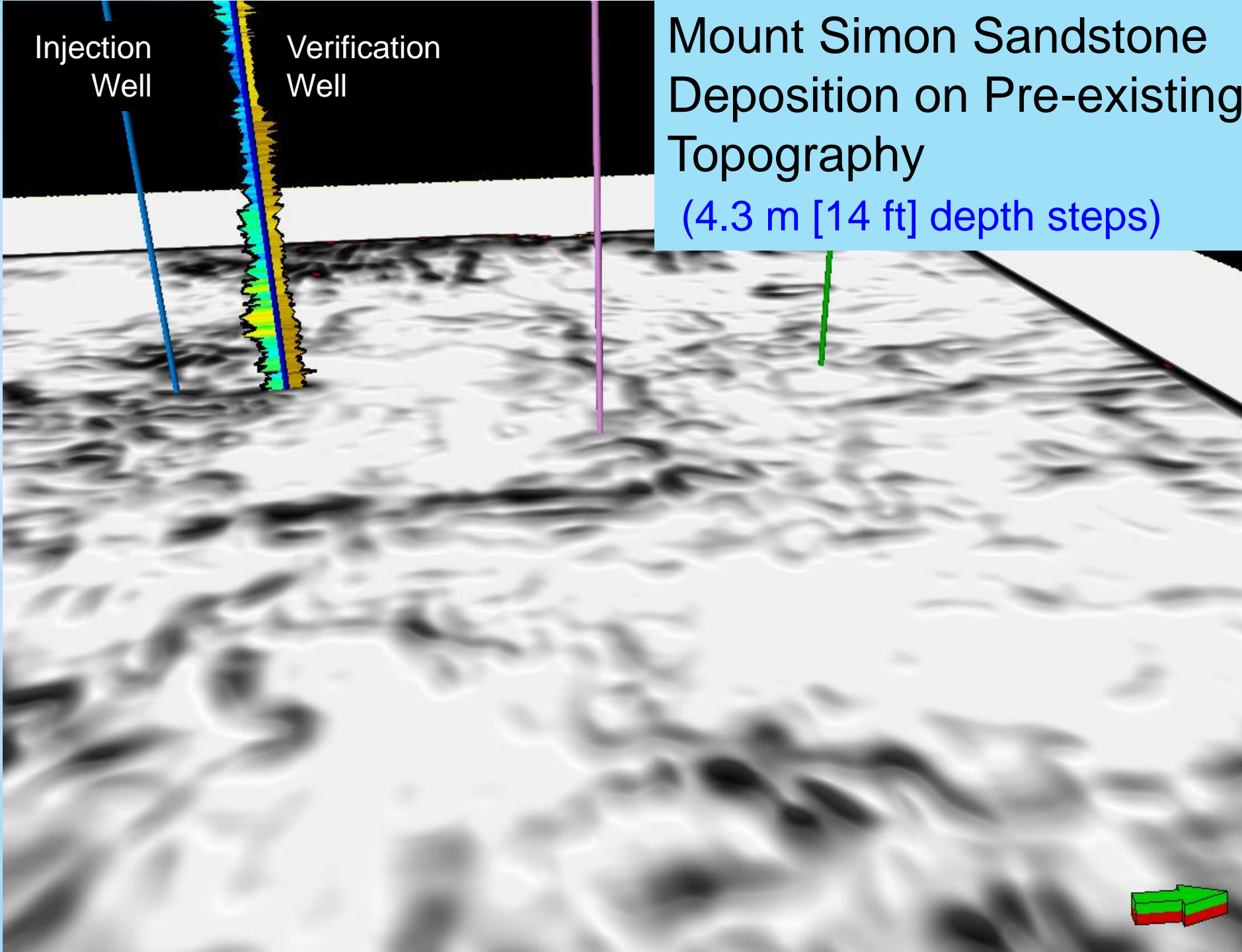
Valley eroded into Precambrian

Precambrian High

Injection
Well

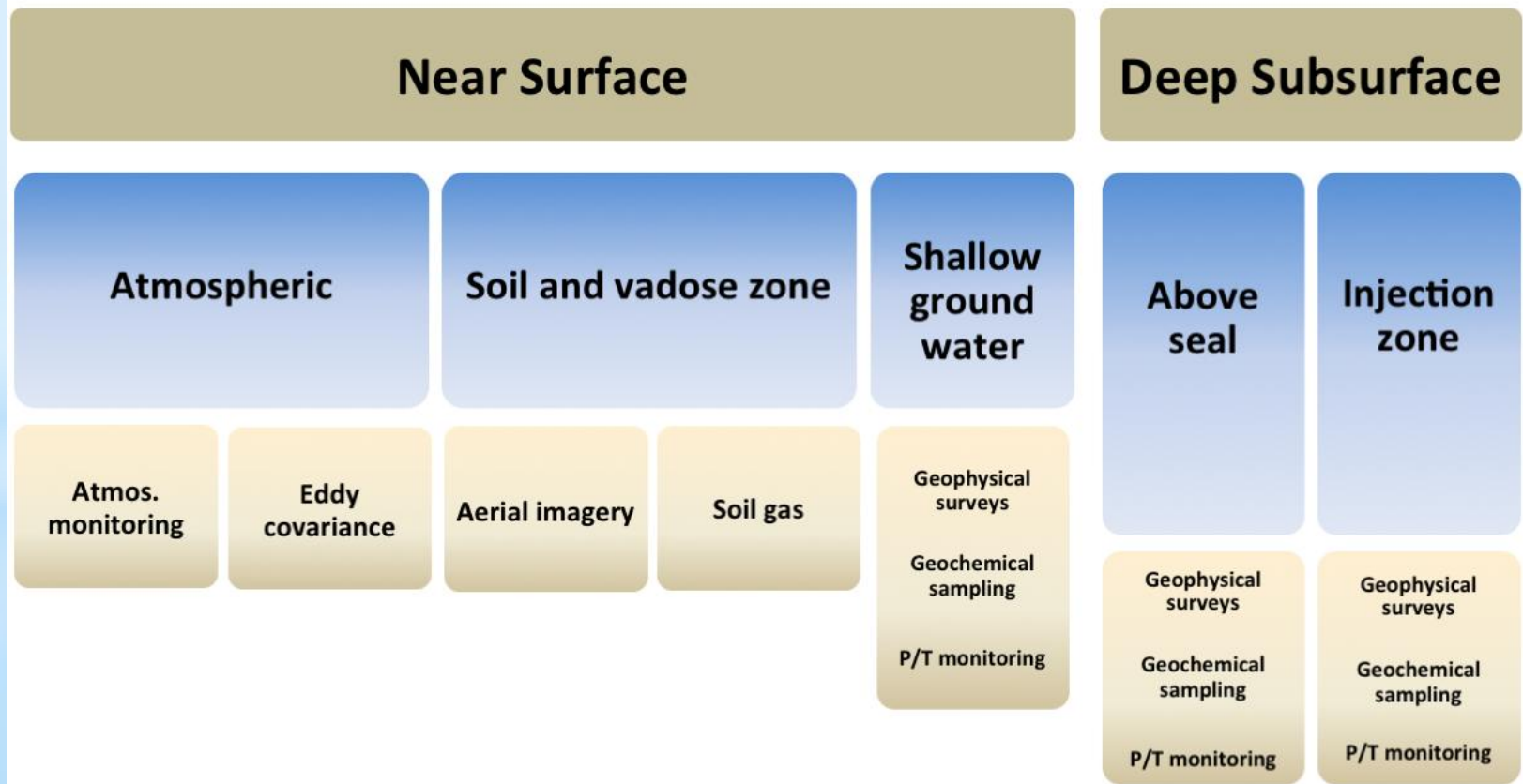
Verification
Well

Mount Simon Sandstone Deposition on Pre-existing Topography (4.3 m [14 ft] depth steps)



Monitoring, Verification and Accounting

Example Environmental Monitoring Framework





Groundwater



Surface deformation

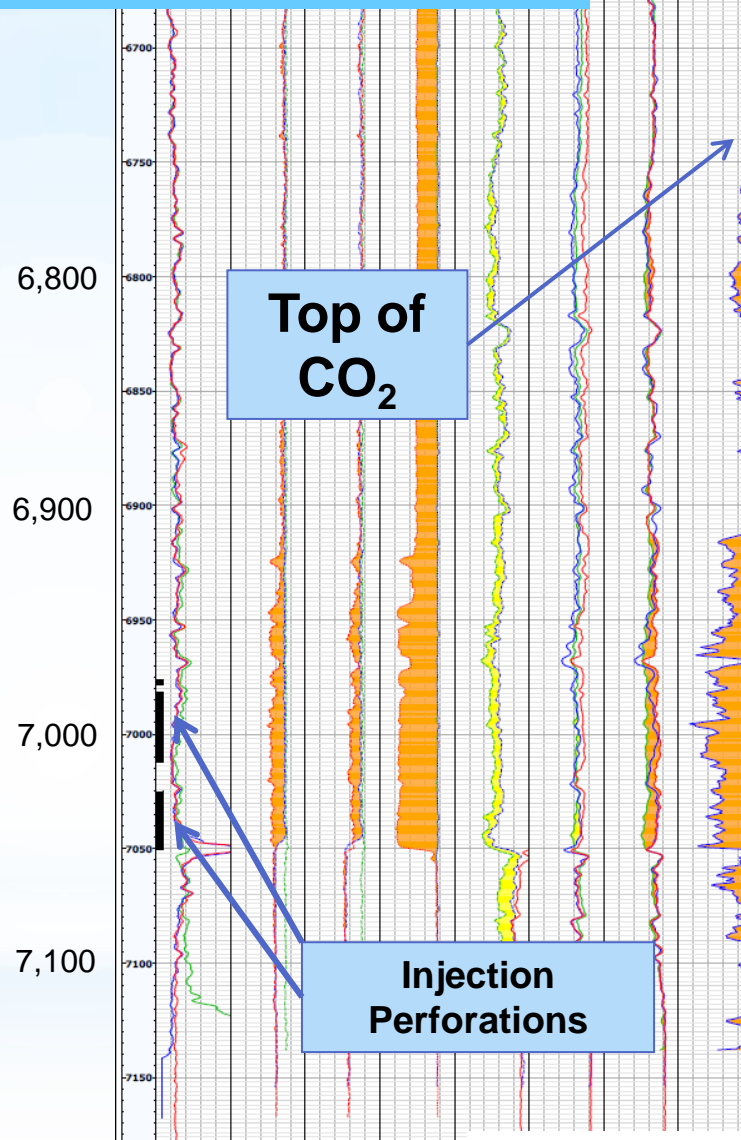


Soil flux



Eddy Covariance

Injection Well Drilled to 2,190 m (7,230 ft) (2009)



RST*
Log

Logged March 1, 2012 with ~75,000 tonnes metric tons injected

*Reservoir Saturation Tool



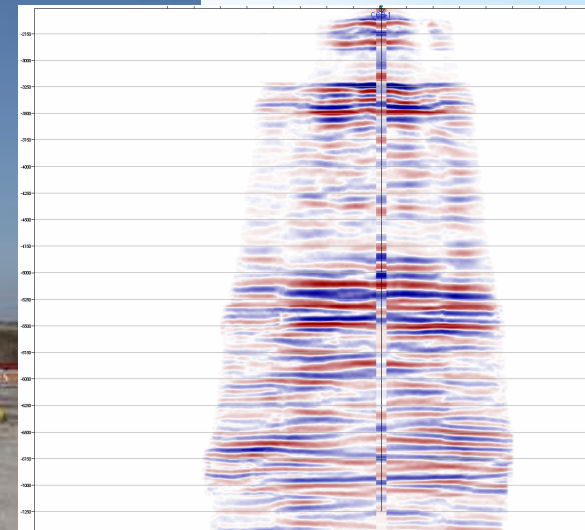
from Schlumberger Carbon Services

Geophone Well Completed November 2009

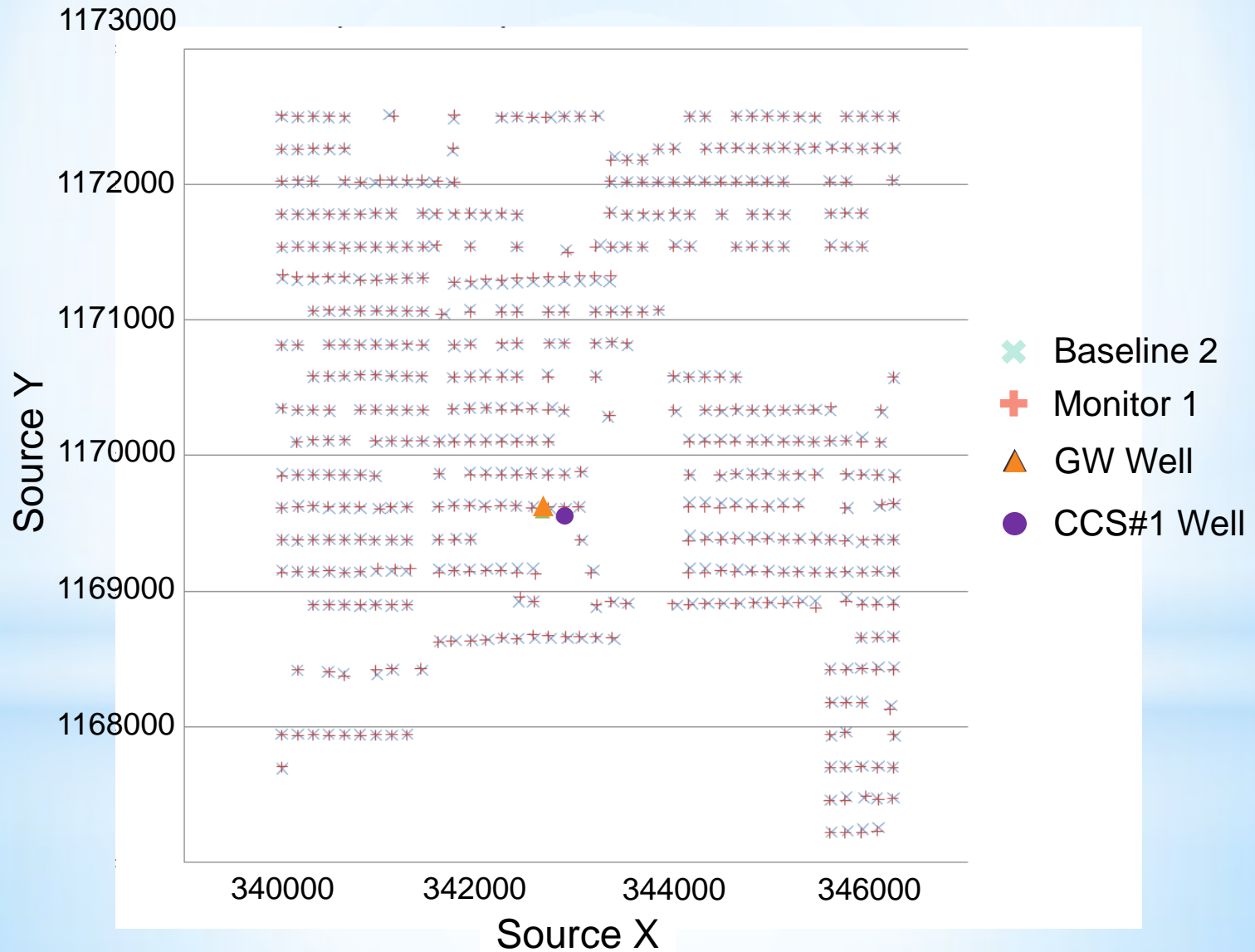
Geophone in special carrier
strapped to 3.5 inch (8.9 cm)
tubing



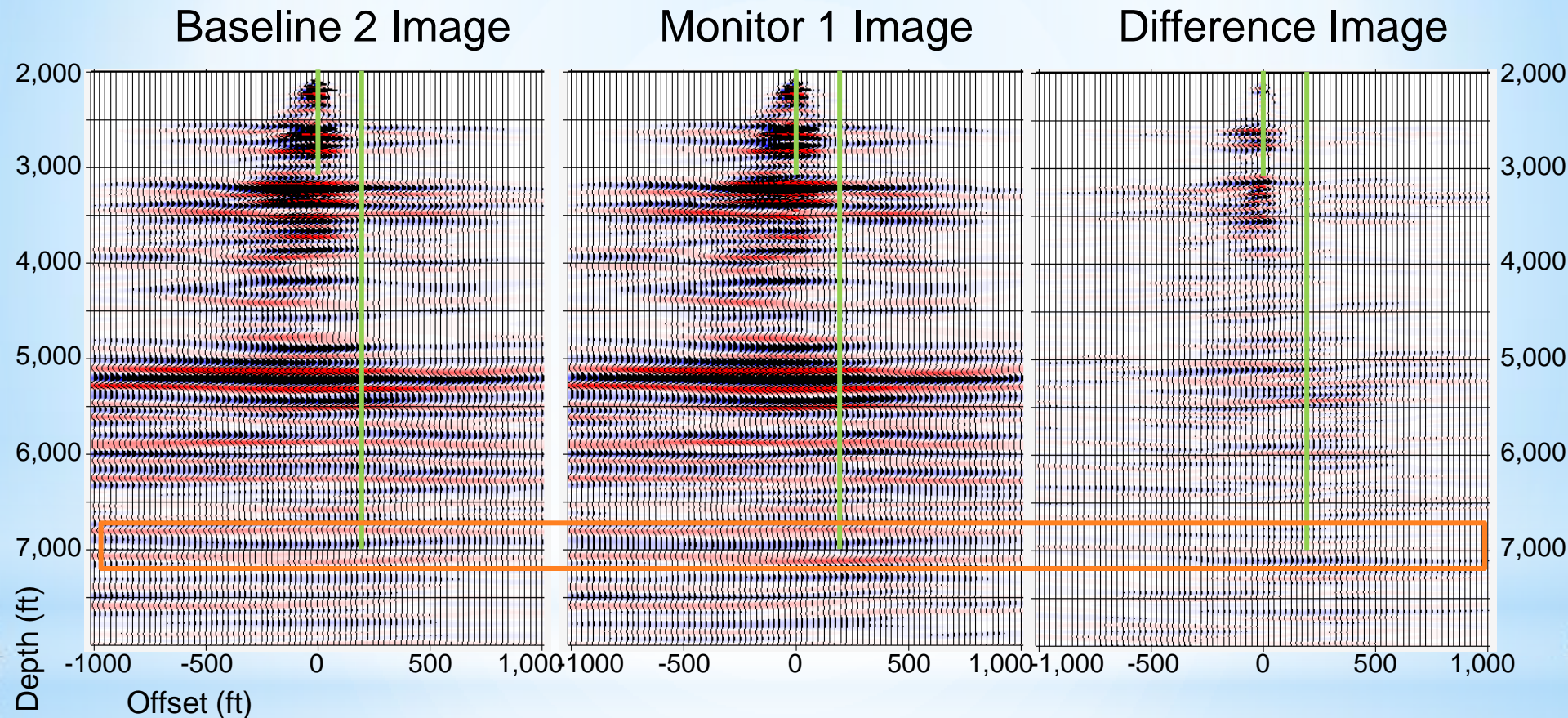
Injection Well



Baseline 2 and Monitor 1 : Map of Co-located Shot Points

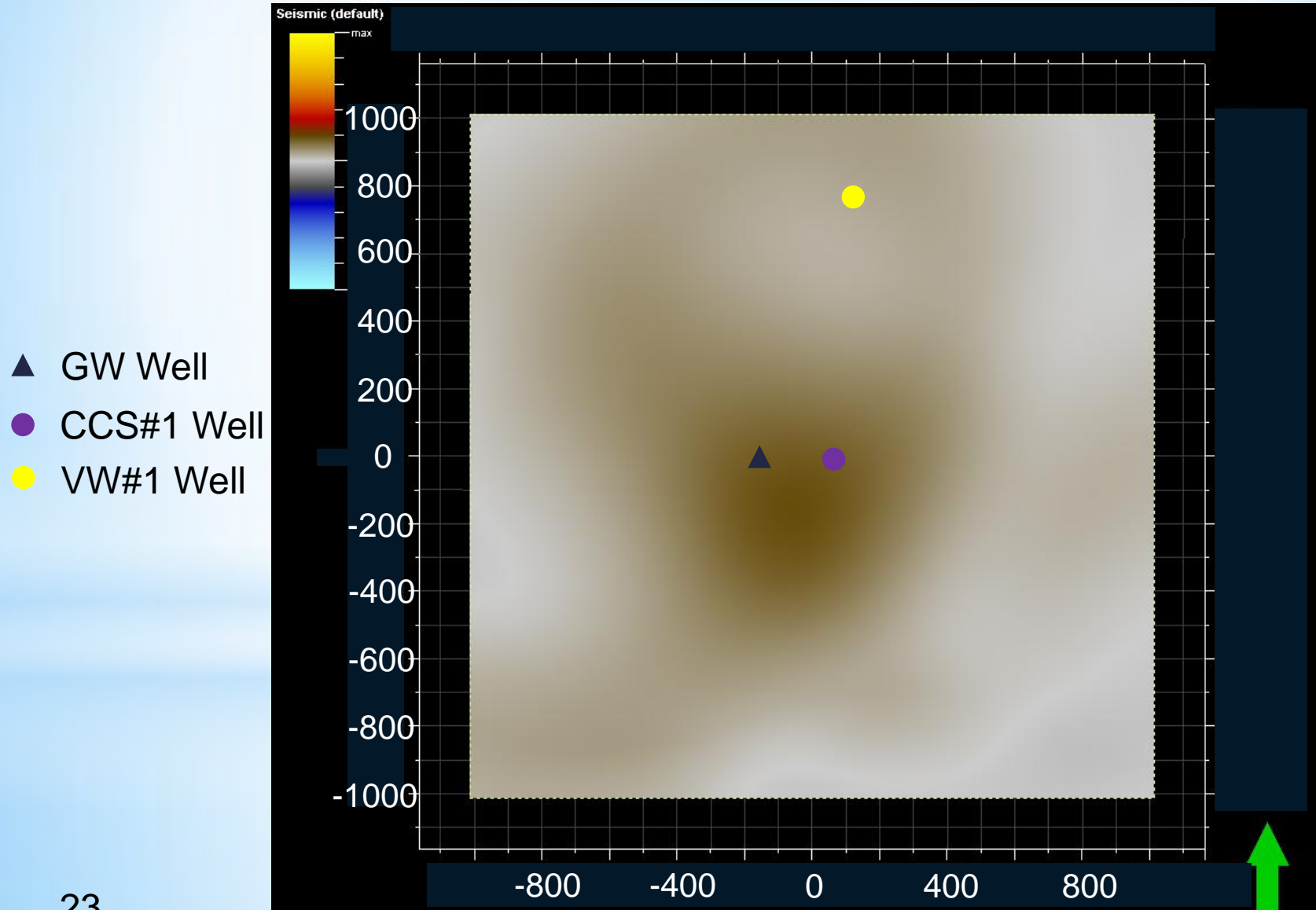


Time-lapse 3D VSPs: Final Migrated Image of Cross-Equalized Data

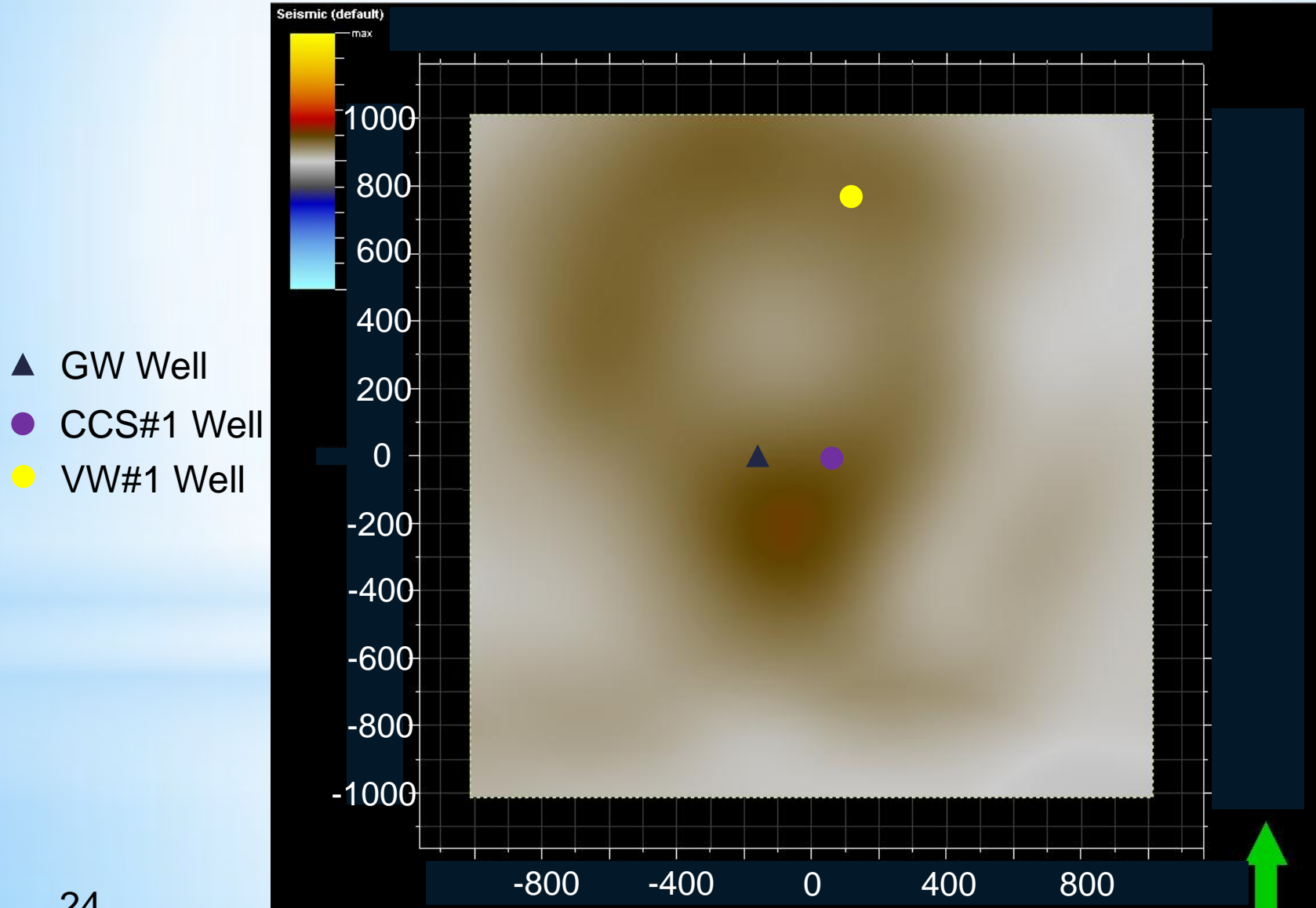


- Shown above in the left two panels is a west-east image section
- Rightmost panel is the difference of the two
- The input to migration is the processed and cross-equalized, notch filtered upgoing data

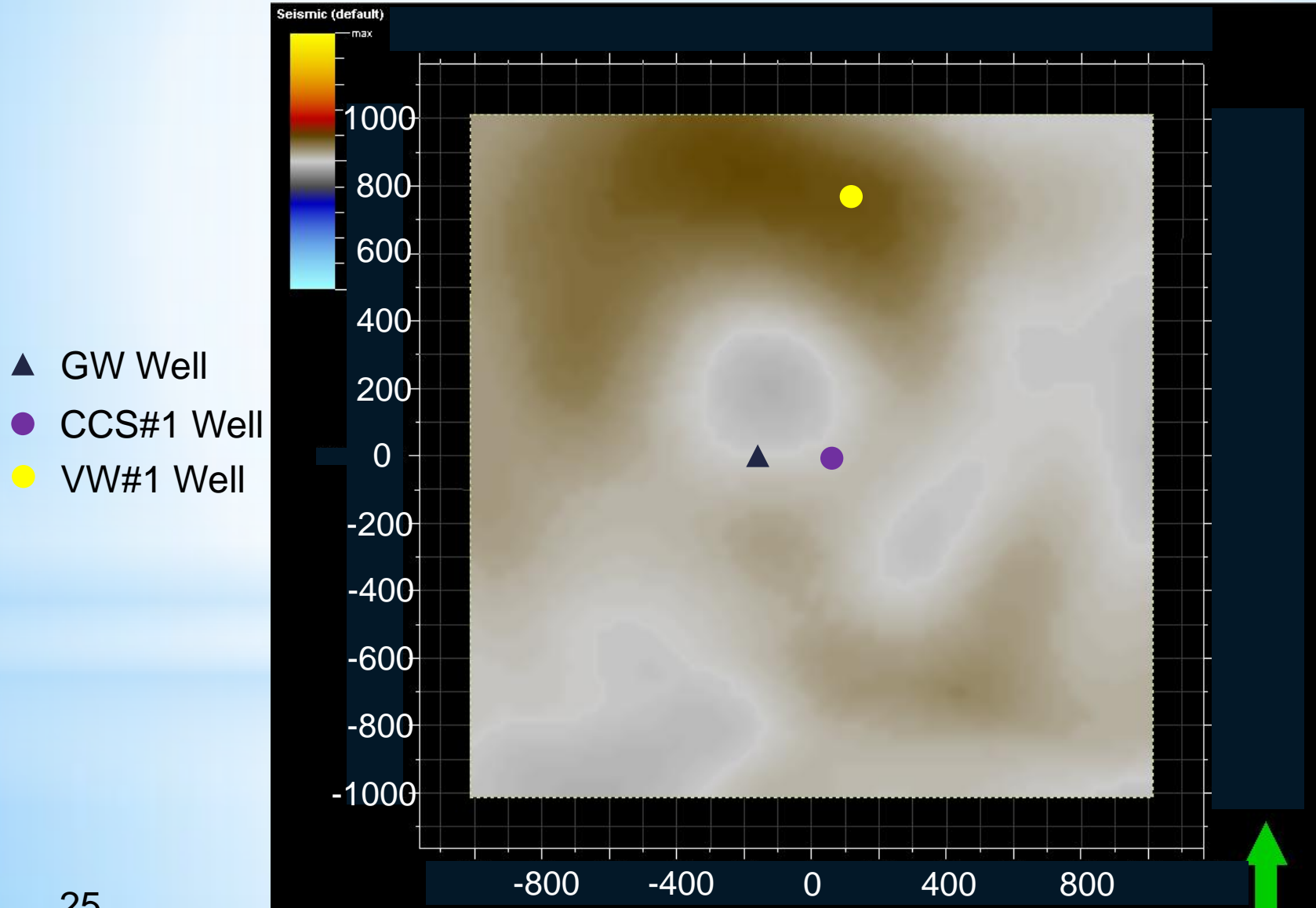
Baseline 2 Amplitude Depth Slice at 6,950 ft



Monitor 1 Amplitude Depth Slice at 6,950 ft



Difference Amplitude Depth Slice at 6,950 ft



First Post-Injection 3D VSP Survey Not Definitive

- One repeat survey has been undertaken with about 70,000 tonnes injected
- Differences directly attributable to the CO₂ injection are difficult to identify
- The associated time-lapse signal may be below the noise levels in the data at the volume injected
- The CO₂ may be in a thinner interval than predicted
- Repeat location accuracy of vibroseis sources may need to be improved

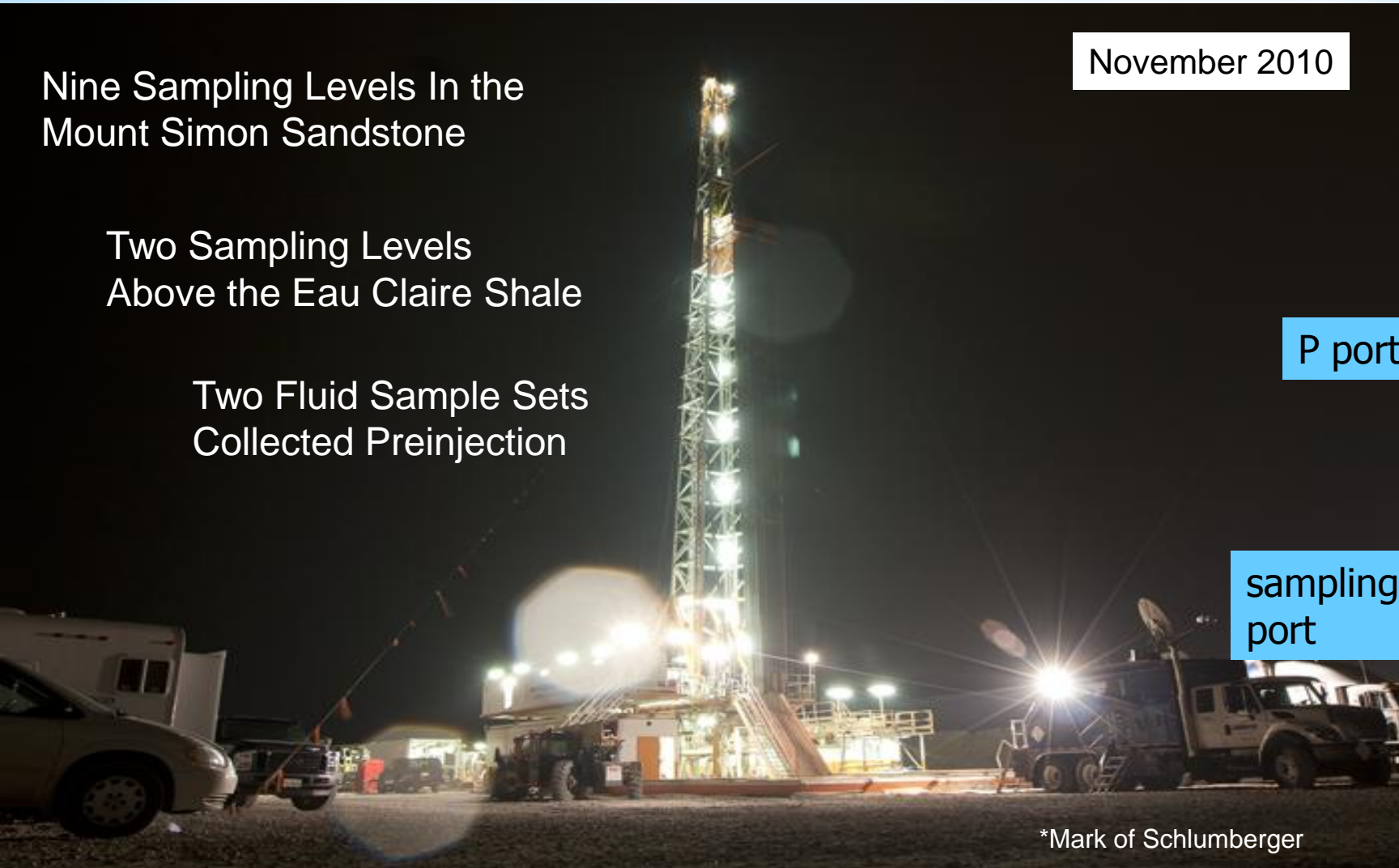
Schlumberger Westbay* System First-in-the-World Deployment at 2,200 m+ for Eleven Sampling Levels

Nine Sampling Levels In the Mount Simon Sandstone

Two Sampling Levels Above the Eau Claire Shale

Two Fluid Sample Sets Collected Preinjection

November 2010



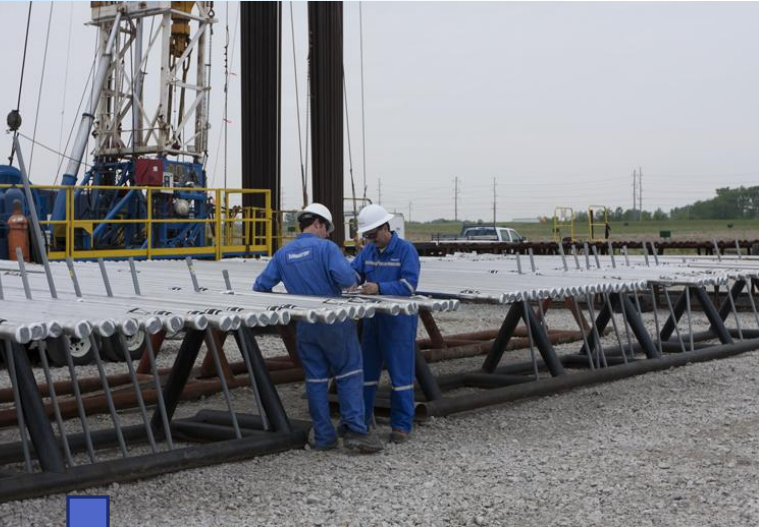
P port

sampling port



*Mark of Schlumberger

Westbay Installation and Sampling



June-August 2011

Water Quality Comparison

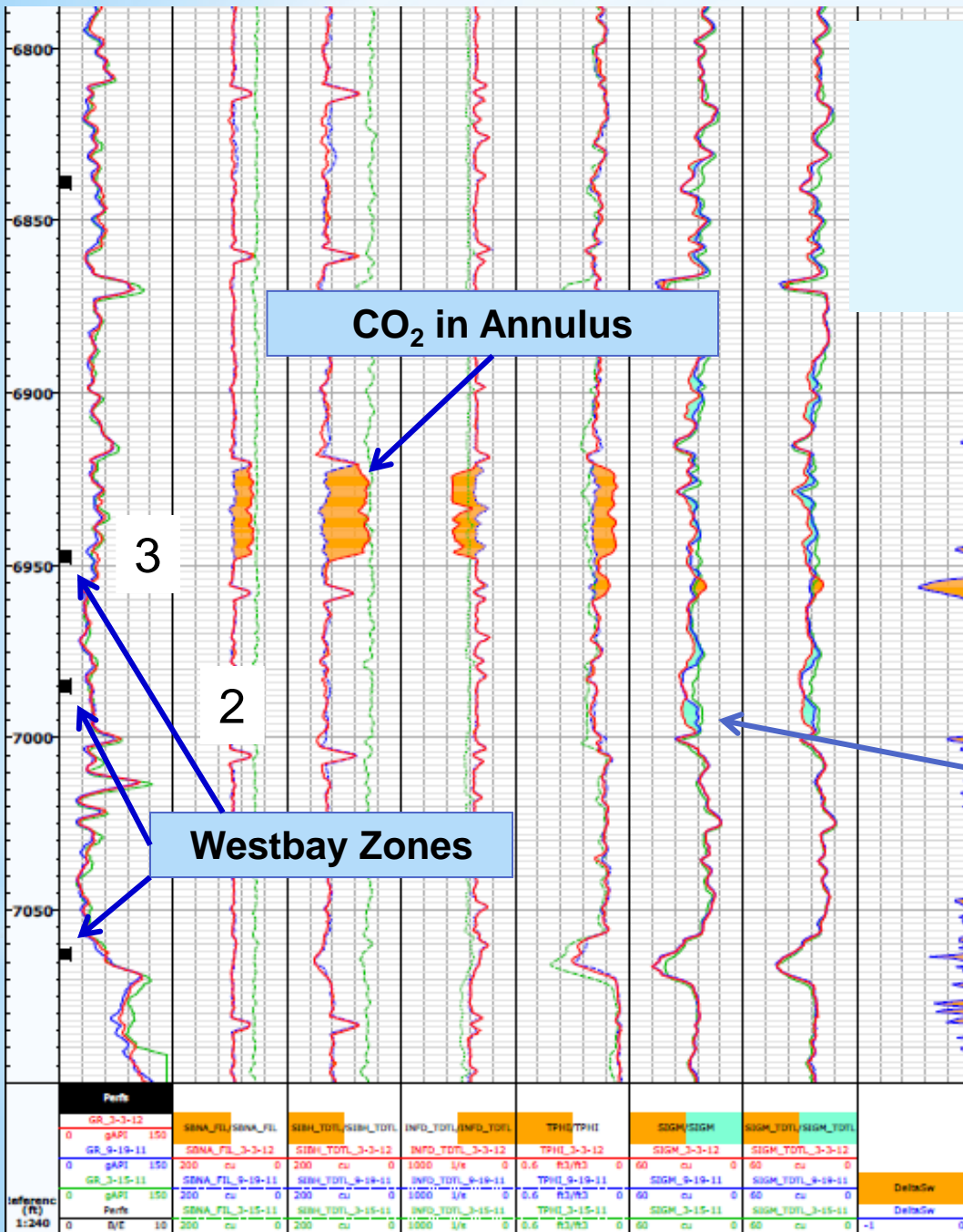
Constituent	Shallow Groundwater	Ironton-Galesville	Mt. Simon (injection formation)
Conductivity (mS/cm)	1.5	80	170
TDS (mg/L)	1,000	65,600	190,000
Cl ⁻ (mg/L)	170	36,900	120,000
Br ⁻ (mg/L)	1	180	680
Alkalinity (mg/L)	380	130	80
Na ⁺ (mg/L)	140	17,200	50,000
Ca ²⁺ (mg/L)	100	5,200	19,000
K ⁺ (mg/L)	1	520	1,700
Mg ²⁺ (mg/L)	50	950	1,800
pH (units)	7.2	6.9	5.9

- Shallow groundwater (16 well average)
- Ironton-Galesville (2 zone average; swab only)
- Mt. Simon (9 zone average)

Verification Well RST

Logging

March 3, 2012

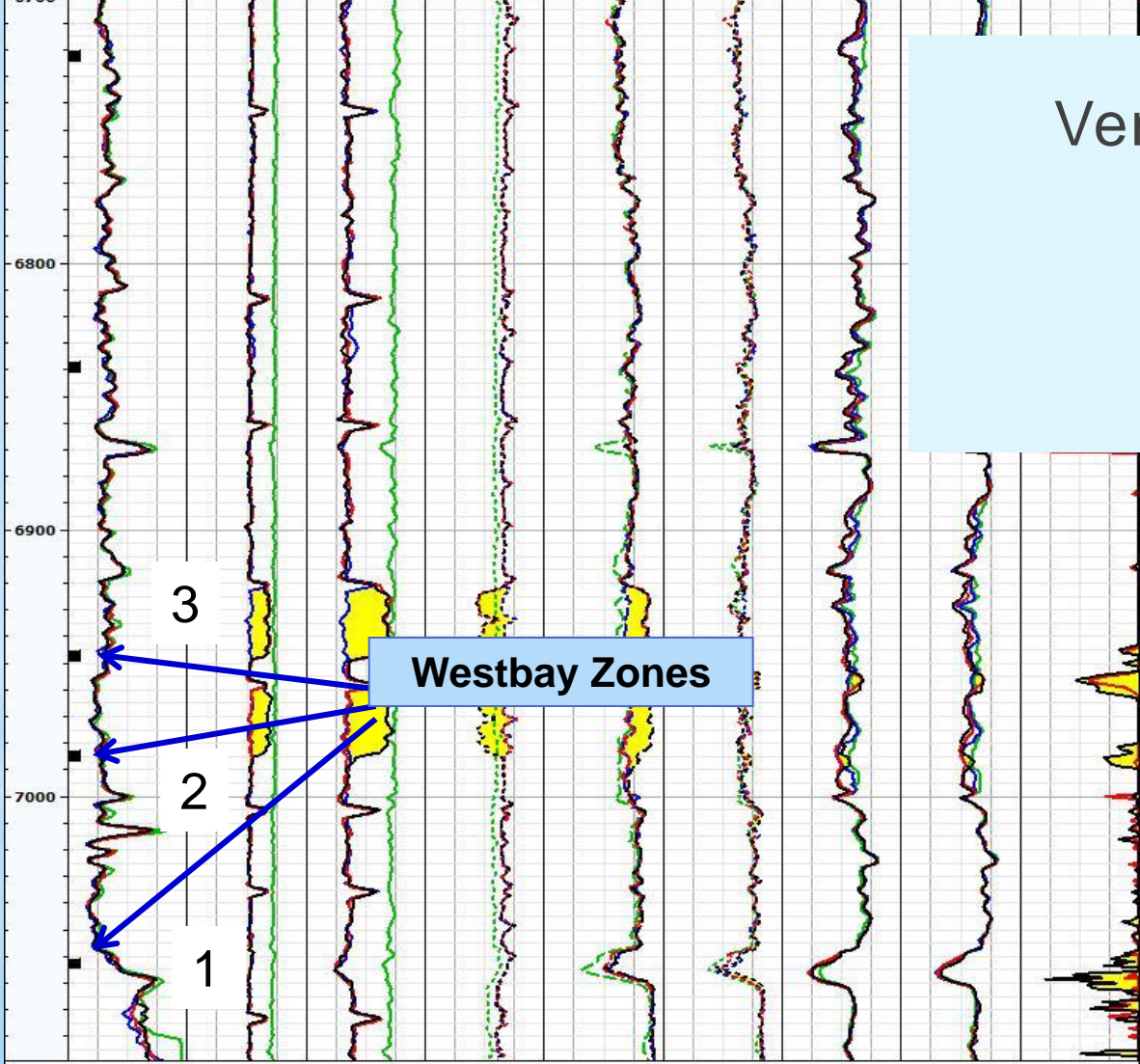


CO₂ in Reservoir

Non-CO₂ Fluid Movement

Westbay Zones 2 and 3 equivalent to lower and upper perforations, respectively

Perfs		A_FIL_7-12/SBNA_FIL		TDTL_7-12/SIBH_TDTL		TDTL_9-11/INFO_TDTL		TPHL_7-12/TPHL_9-11		PHIC_7-12/PHIC_9-11		SIGM_7-12/SIGM_9-11		TDTL_7-12/SIGM_TDTL	
0	B/E 10														
GR_7-12		SBNA_FIL_7-12		SIBH_TDTL_7-12		INFO_TDTL_7-12		TPHL_7-12		PHIC_7-12		SIGM_7-12		SIGM_TDTL_7-12	
0	gAPI 150	200 cu 0	0	200 cu 0	0	1000 1/s 0	0	0.6 m3/m3 0	0	0.6 R3/R3 0	0	60 cu 0	0	60 cu 0	
GR_3-12		SBNA_FIL_3-12		SIBH_TDTL_3-12		INFO_TDTL_3-12		TPHL_3-12		PHIC_3-12		SIGM_3-12		SIGM_TDTL_3-12	DeltaSw_7-12
0	gAPI 150	200 cu 0	0	200 cu 0	0	1000 1/s 0	0	0.6 m3/m3 0	0	0.6 R3/R3 0	0	60 cu 0	0	60 cu 0	
GR_9-11		SBNA_FIL_9-11		SIBH_TDTL_9-11		INFO_TDTL_9-11		TPHL_9-11		PHIC_9-11		SIGM_9-11		SIGM_TDTL_9-11	DeltaSw_7-12
0	gAPI 150	200 cu 0	0	200 cu 0	0	1000 1/s 0	0	0.6 m3/m3 0	0	0.6 R3/R3 0	0	60 cu 0	0	60 cu 0	-1
GR_3-11		SBNA_FIL_3-11		SIBH_TDTL_3-11		INFO_TDTL_3-11		TPHL_3-11		PHIC_3-11		SIGM_3-11		SIGM_TDTL_3-11	DeltaSw_3-12
0	gAPI 150	200 cu 0	0	200 cu 0	0	1000 1/s 0	0	0.6 m3/m3 0	0	0.6 R3/R3 0	0	60 cu 0	0	60 cu 0	-1 v/v 0



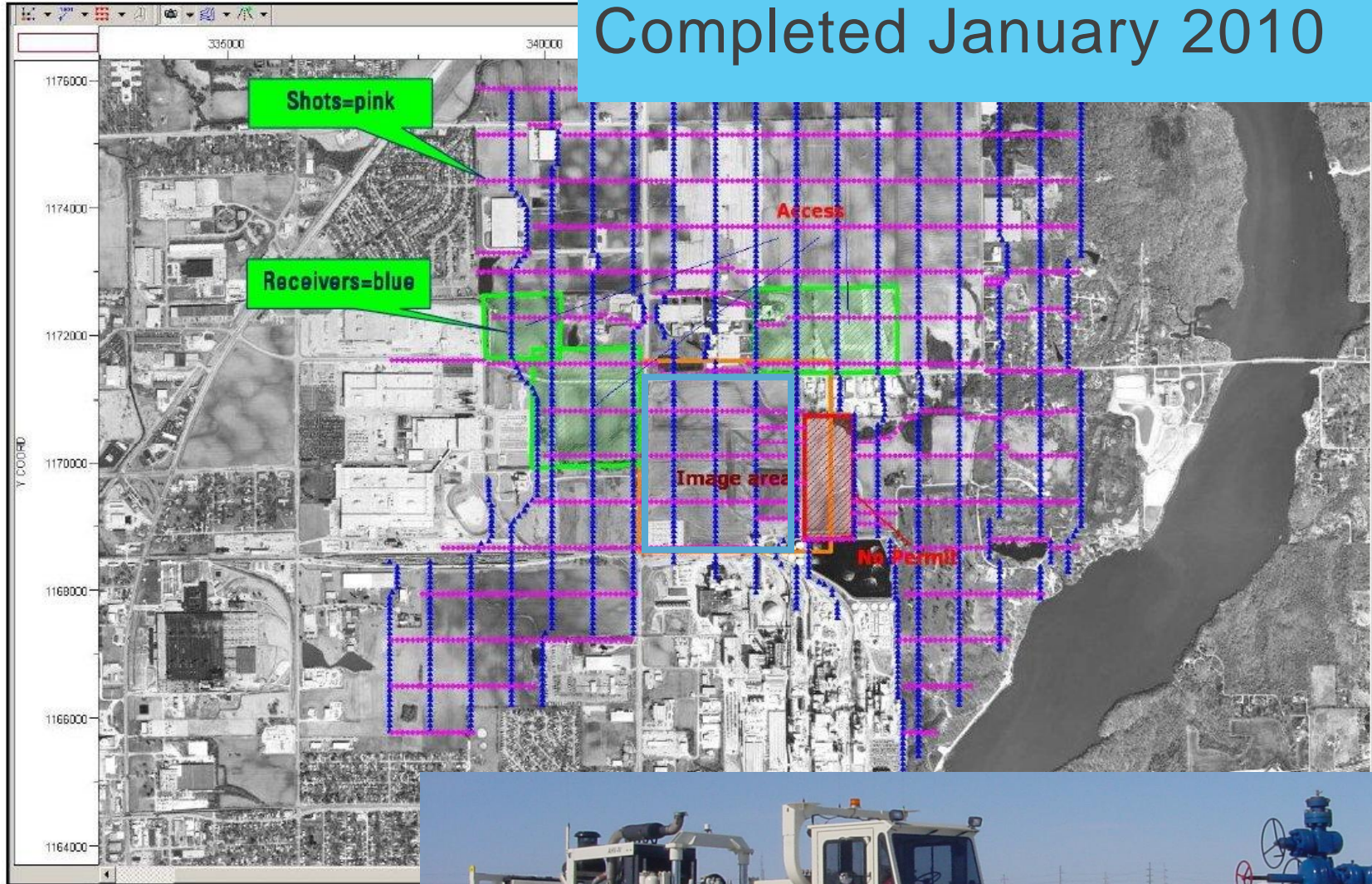
Verification Well RST Logging

July 13, 2012

CO₂ in Reservoir

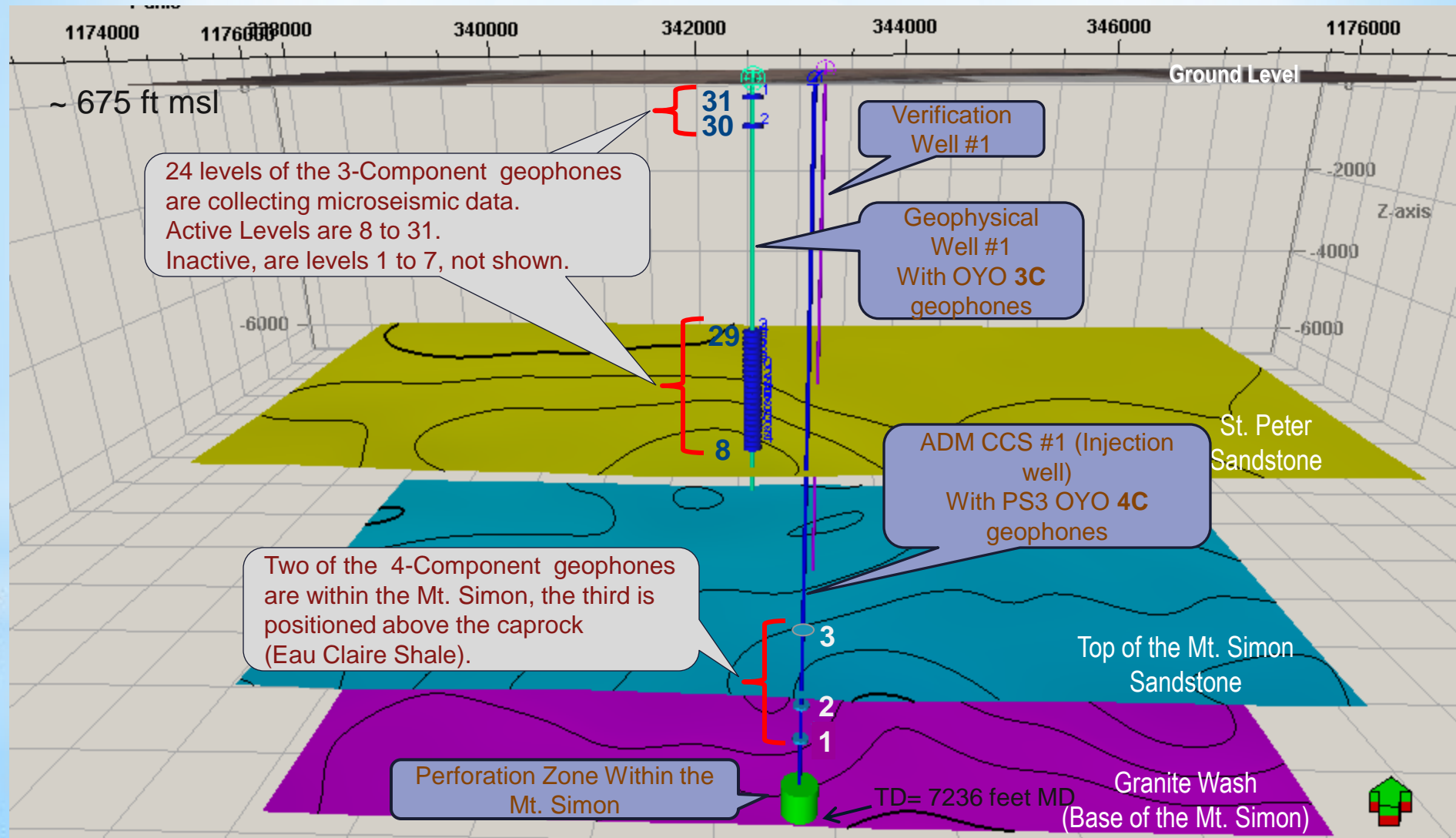
Westbay Zones 2 and 3 equivalent to lower and upper perforations, respectively

Baseline 3D Geophysical Survey Completed January 2010



Geophones, wells, and reservoir details

From Schlumberger Carbon Services

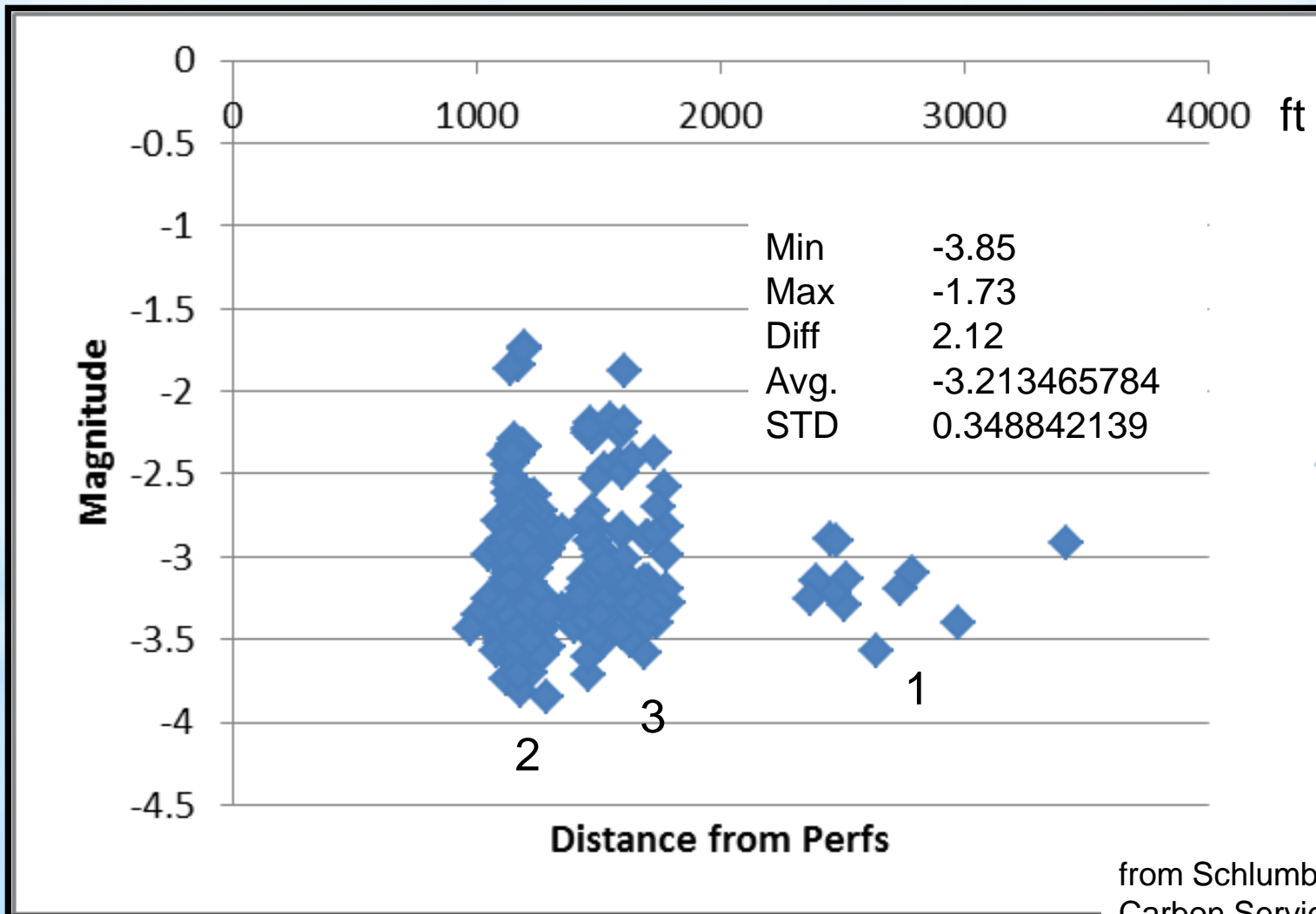




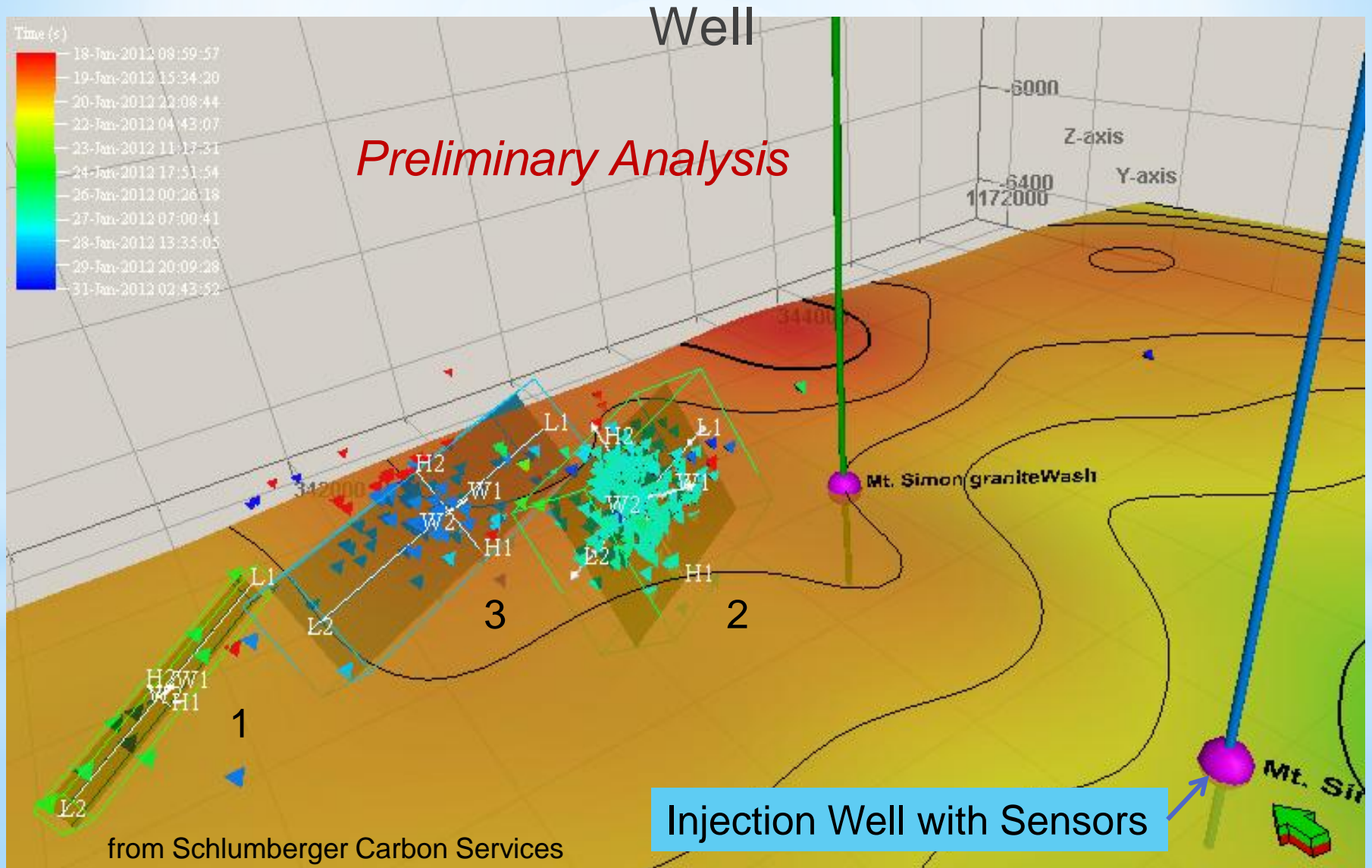
Multicomponent
Geophones¹
Installed on
Tubing String in
Injection Well

¹Schlumberger PS³ System

Microseismic Magnitude vs. Distance from Injection Well



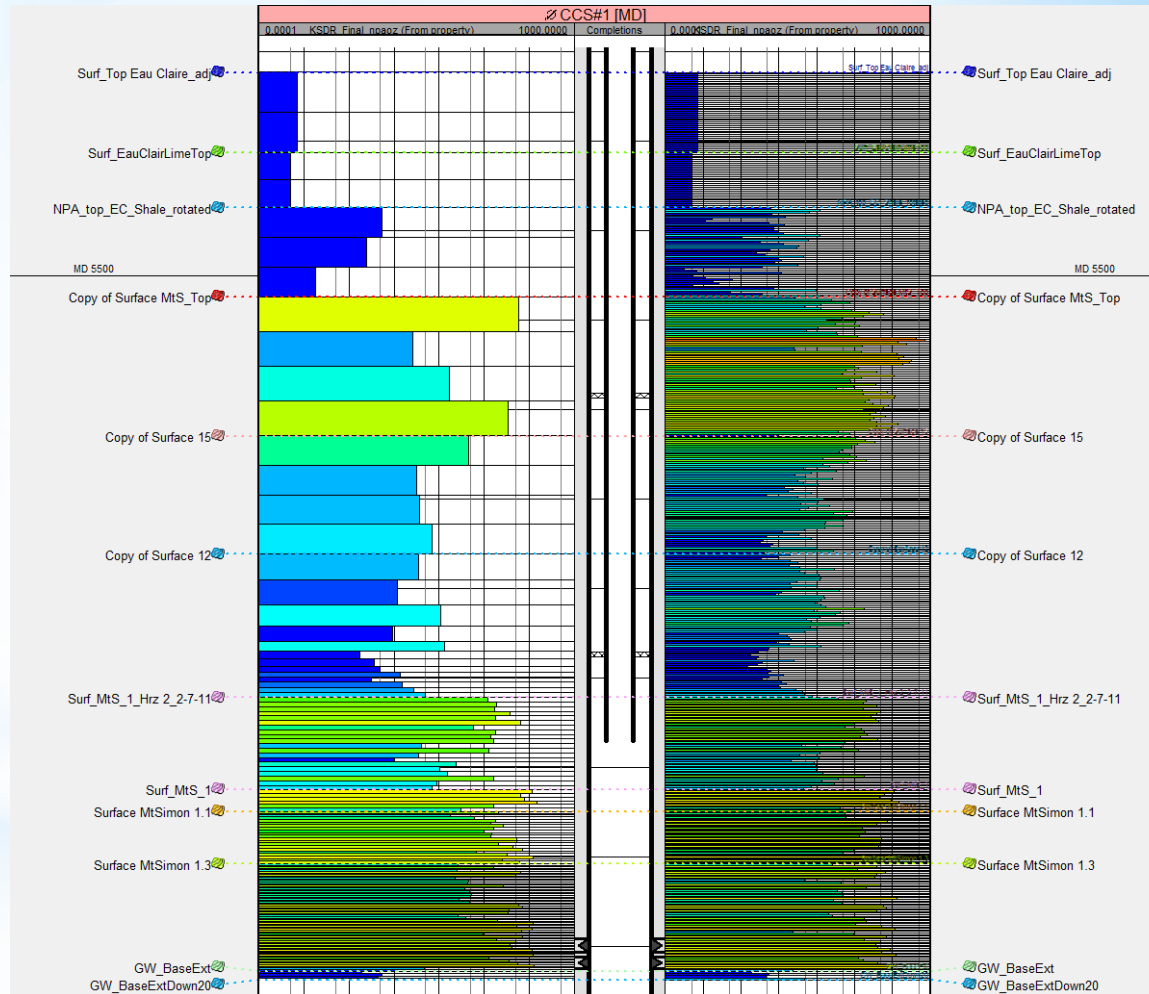
Microseismic Events Recorded NW of Verification



Reservoir Simulation Development

- Reservoir Model:

- Eclipse 2011.2
- 20 x 20 mile coverage
- ~ 3M Cells, 143 x 143 x148
- Cell Horizontal Dimensions are from 5 ft and 50 ft at wells to 1500 ft at the model boundaries
- Cell Vertical Dimensions from 3 ft to 30 ft
- Infinite acting boundary conditions



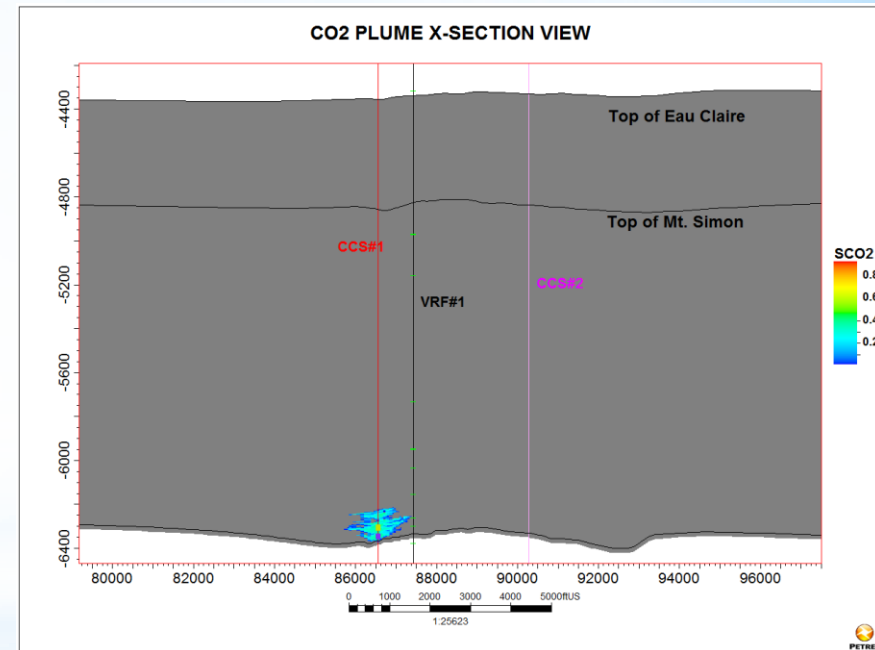
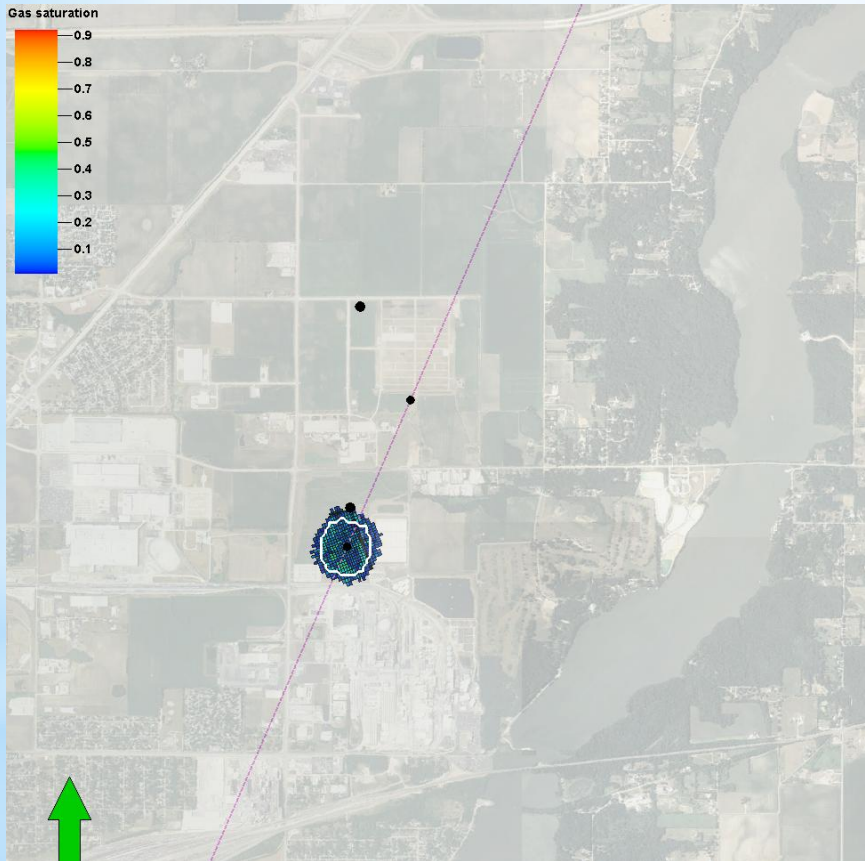
from Schlumberger Carbon Services

Reservoir Model

Static Model

IBDP - CO₂ Plume & Pressure Pulse Evolution

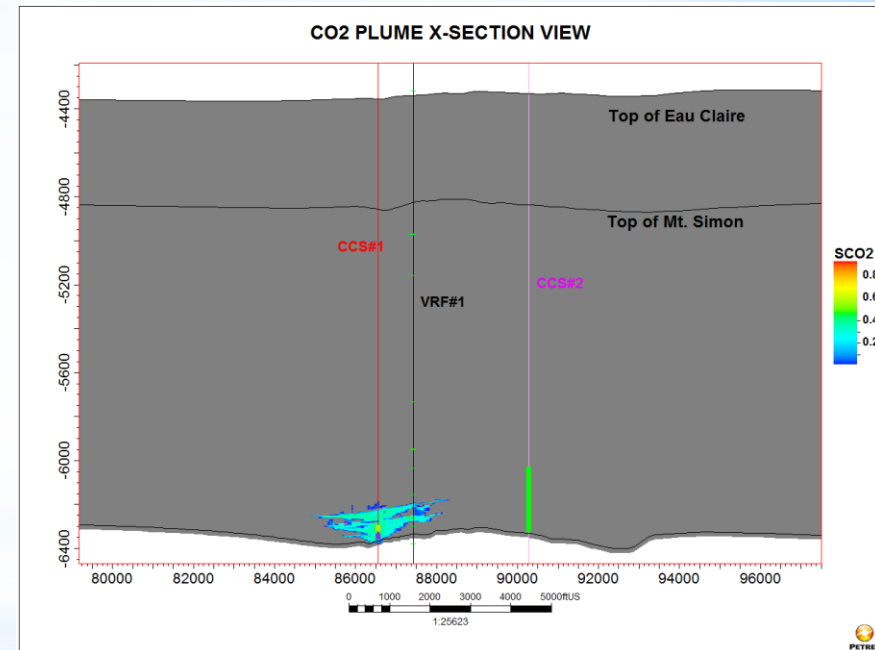
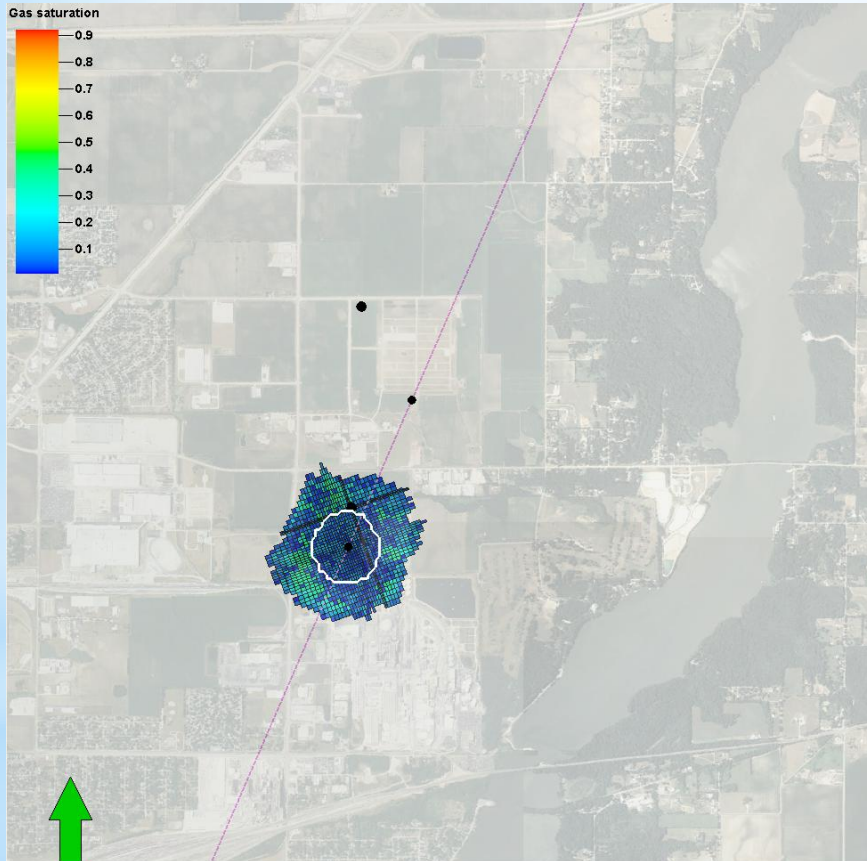
March 2012



from Schlumberger Carbon Services

IBDP - CO₂ Plume & Pressure Pulse Evolution

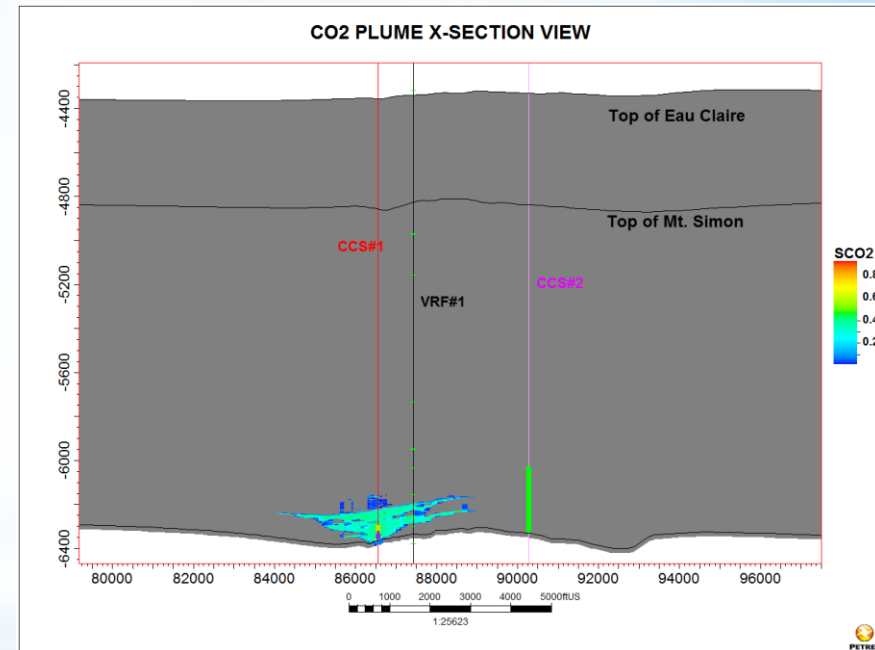
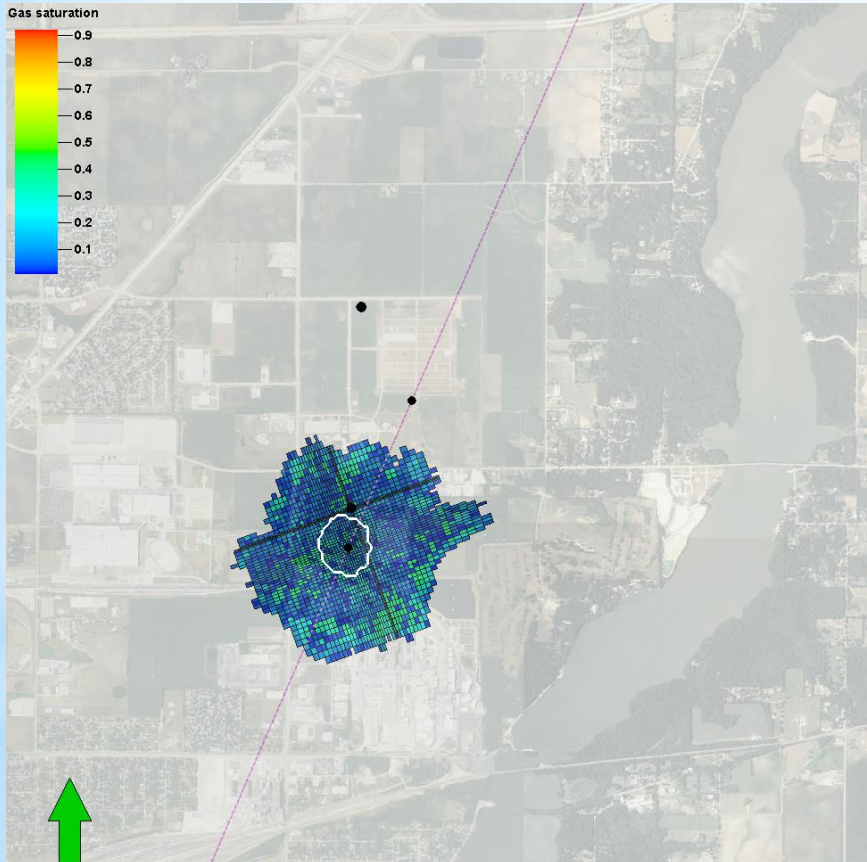
2013



from Schlumberger Carbon Services

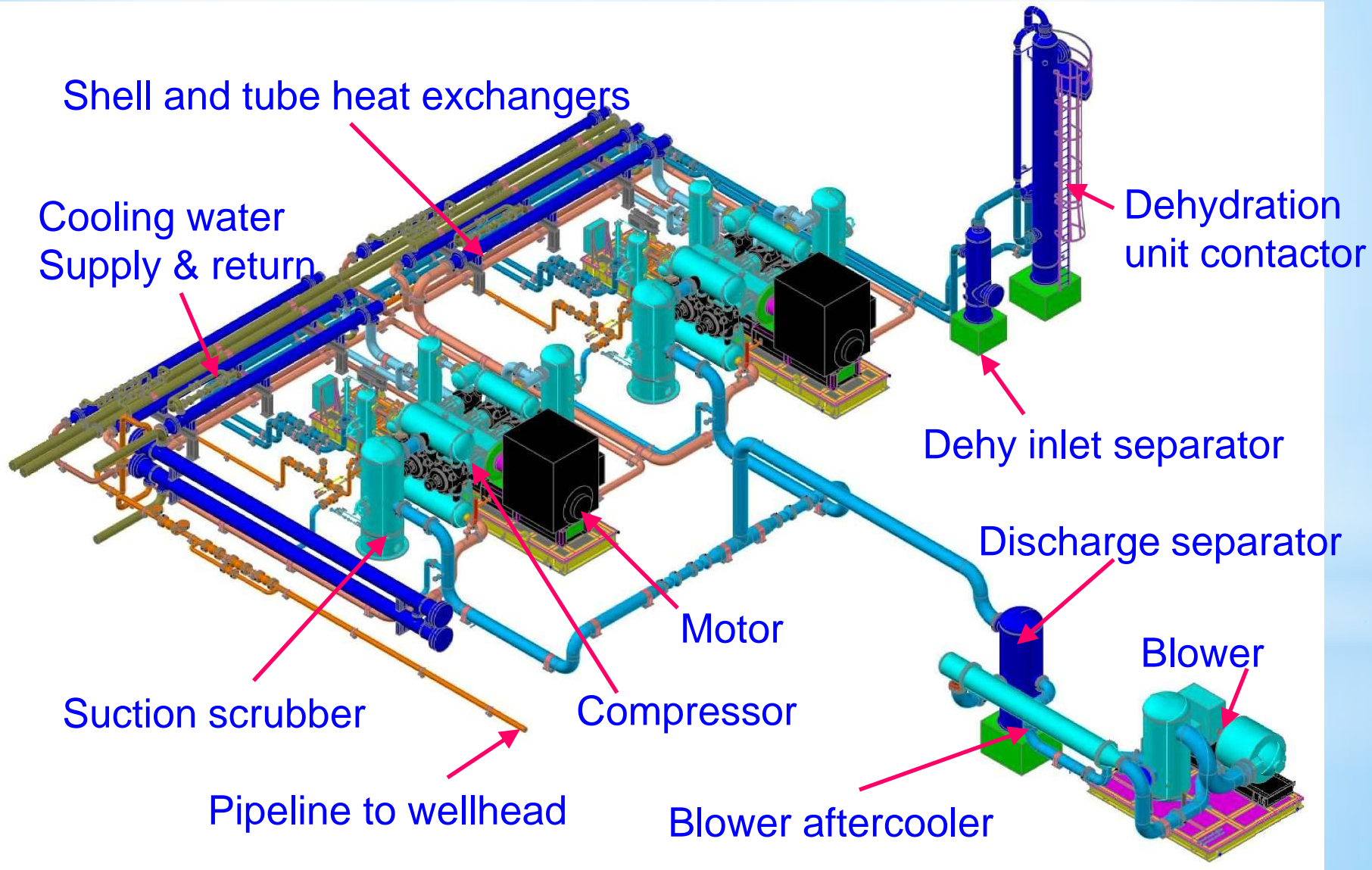
IBDP - CO₂ Plume & Pressure Pulse Evolution

2014



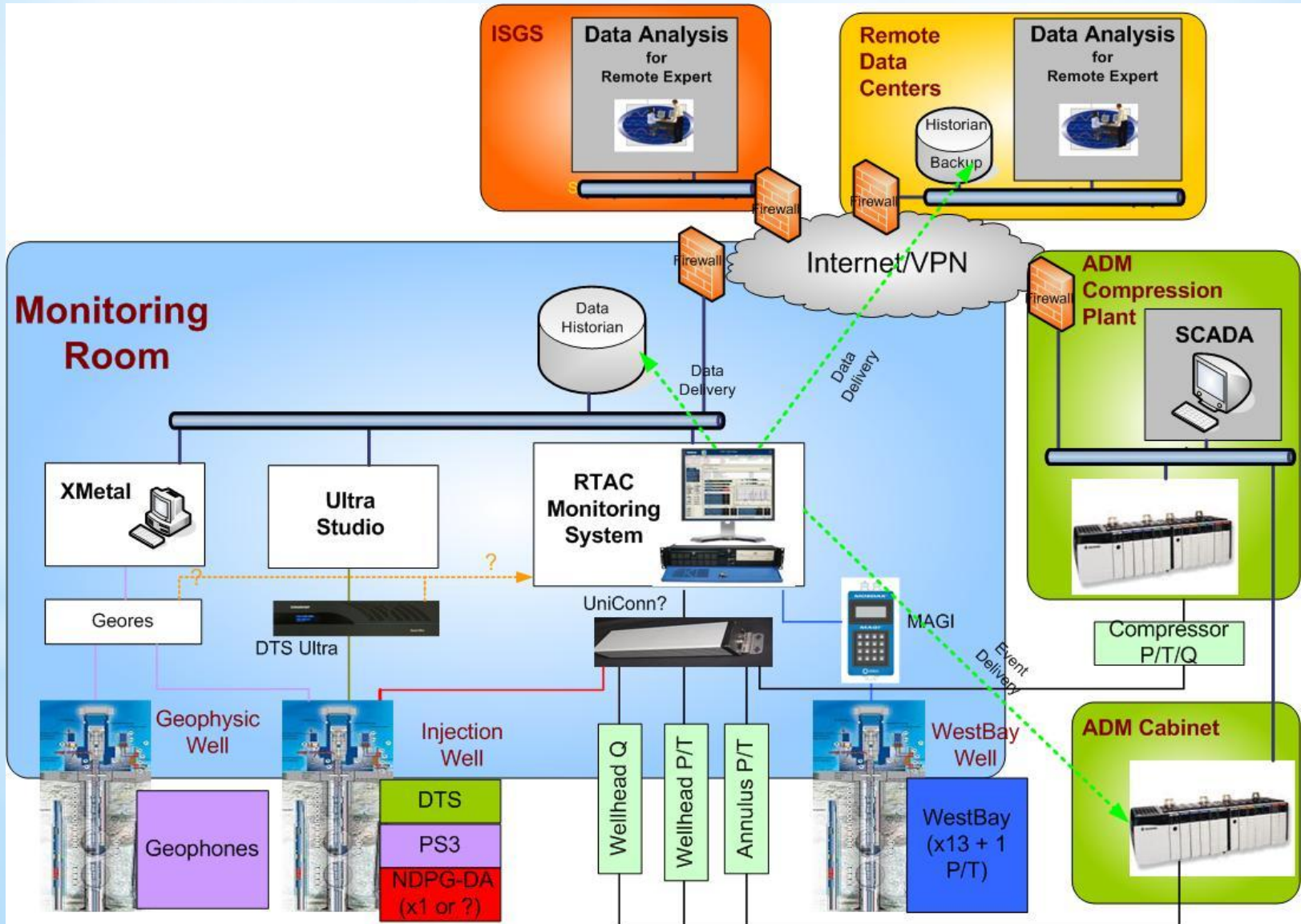
from Schlumberger Carbon Services

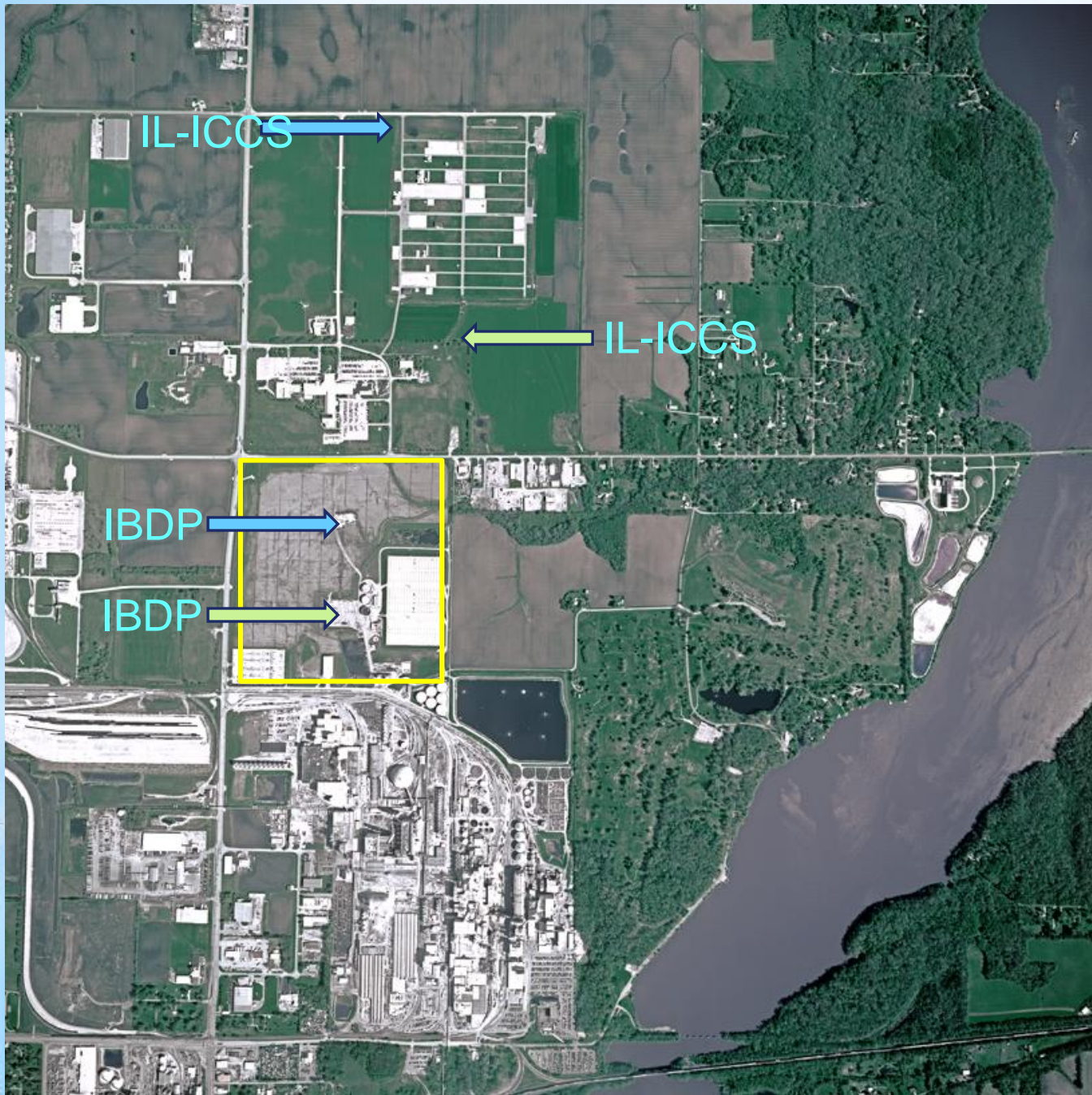
Dual 550 TPD Reciprocating Compressors with Glycol Dehydration



Data Collection System

courtesy Schlumberger Carbon Services

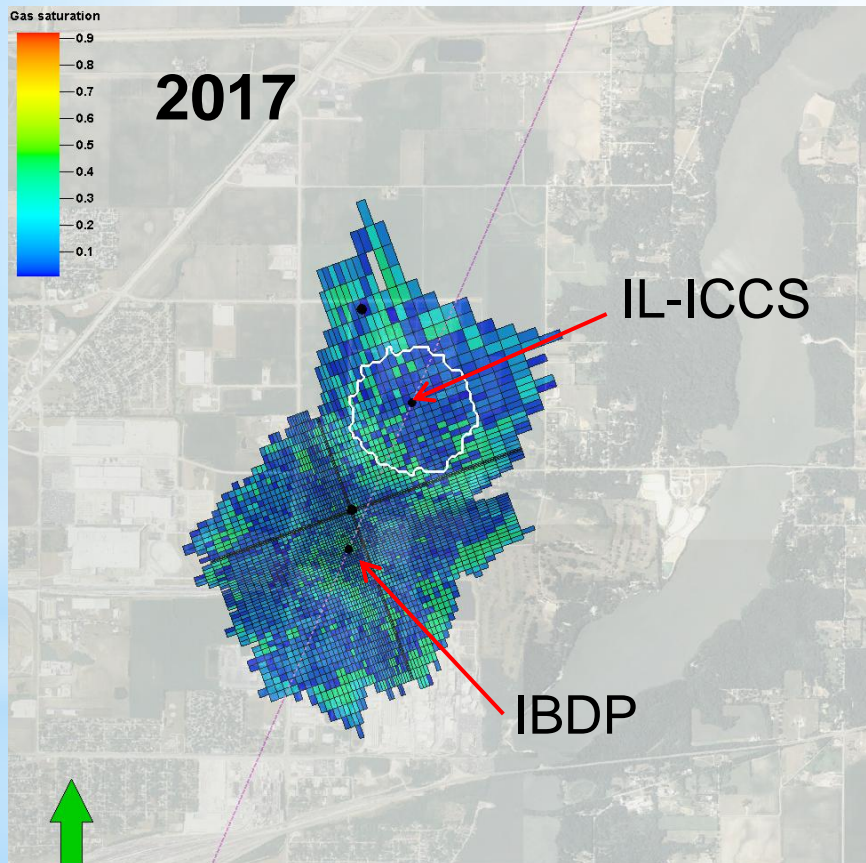




Industrial
Carbon
Capture and
Storage (ICCS)
Wells Currently
in UIC Class VI
Permit Process



Illinois Industrial Carbon Capture and Storage (IL ICCS) Project will Prove CCS at Scale



- Commercial scale operations of one million metric tons per year will be achieved
- Will build on the leading-edge technology of the Illinois Basin - Decatur Project by expanding injected volumes
- Will add an education and training component through Richland Community College, National Sequestration Education Center
- **IBDP** and **IL ICCS** will be a first in the world to assess two injected carbon dioxide plumes in the same reservoir that resemble volumes derived from a commercial coal-fired power plant



Summary

- After four years of site specific work, the IBDP went operational on 17 November 2011 with cumulative injection of 244,600 tonnes (to 17 August 2012) into the Mount Simon Sandstone
- Expectations of capacity, injectivity, and containment in the Mount Simon Sandstone are being met
- Permitting and remediating a lost circulation zone were the biggest time and cost impacts on the project to date
- Injection will continue through Fall, 2014 and a follow-up phase of project environmental monitoring will extend through 2017

2012 MIDWEST CARBON SEQUESTRATION SCIENCE CONFERENCE

The Midwest Geological Sequestration Consortium (MGSC), one of the US Department of Energy Regional Carbon Sequestration Partnerships, the Sequestration Training and Education Program (STEP), and Schlumberger Carbon Services are hosting a knowledge sharing event at the Illinois Basin-Decatur Project (IBDP).

SAVE THE DATE!

September 17 - 19 2012
Champaign, IL USA

This 2-day event features:

A full day of presentations on the IBDP 1-million tonne saline reservoir injection demonstration, including geology, geophysics, environmental monitoring, outreach/education, and compression/infrastructure. A visit to the Project site at the Archer Daniels Midland Company in Decatur, Illinois will be offered.

A STEP developed educational opportunity will be available to all attending.

Networking opportunities including an opening mixer, conference reception and dinner, and meeting lunches.



Schlumberger
Carbon Services



ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



Midwest Geological
Sequestration Consortium
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ILLINOIS STATE
GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

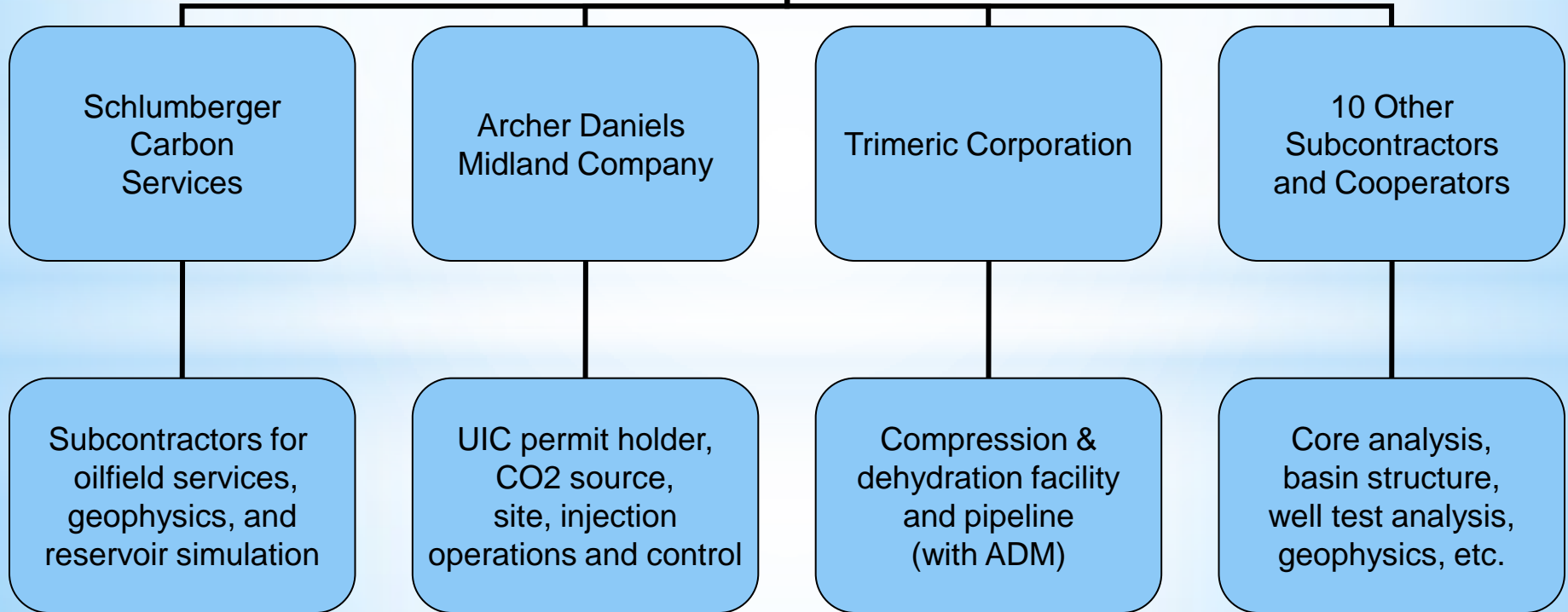
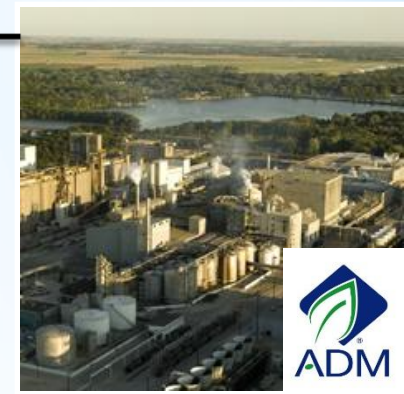
Photo credits: Daniel Byers

Appendix

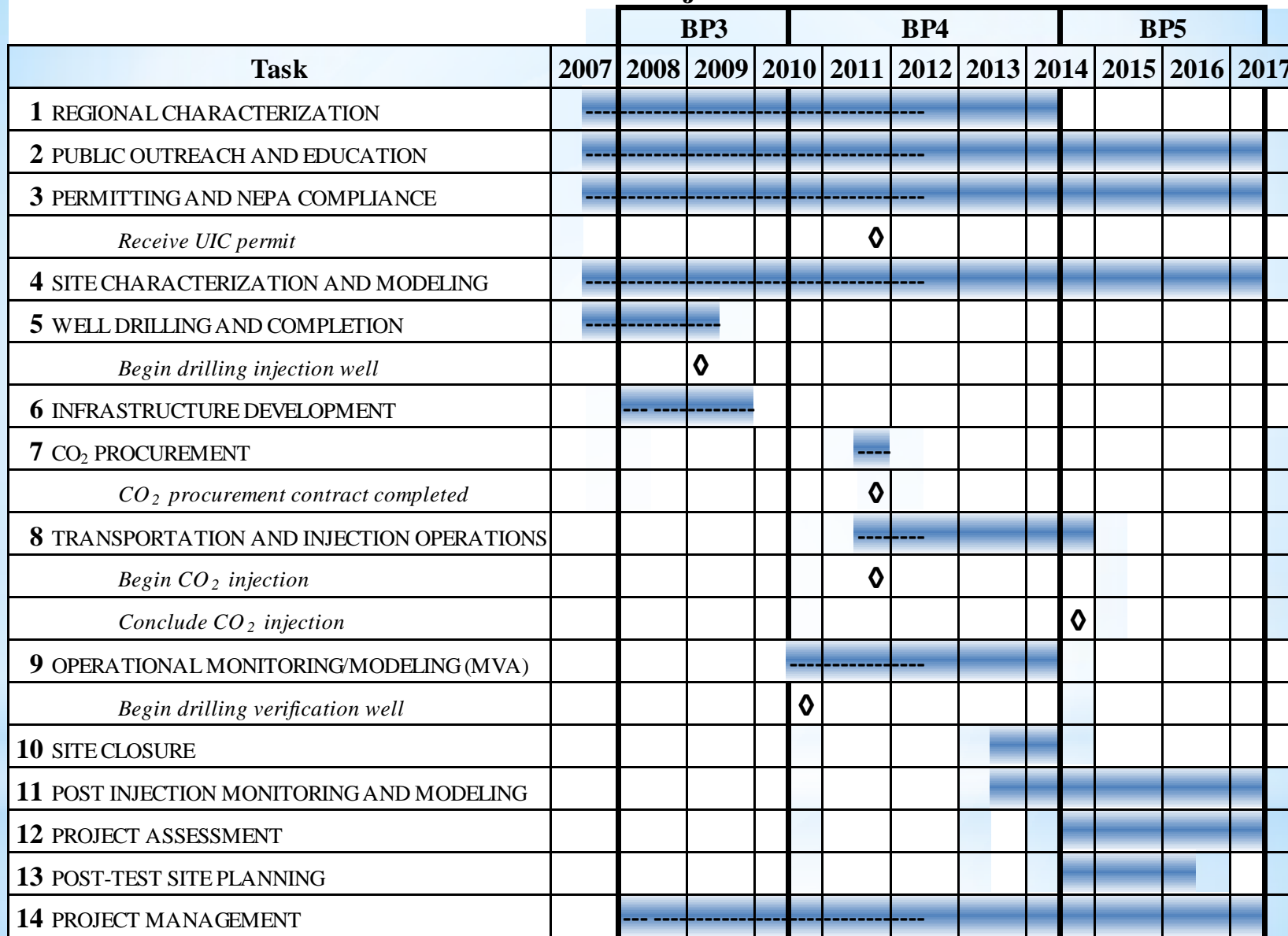


Illinois Basin-Decatur Project Organization

Illinois State Geological Survey



MGSC Phase III Project Gantt Chart



Duration of task
 Work completed to date
 Milestone



Selected Bibliography

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