



Midwest Geological
Sequestration Consortium

Lessons Learned from Large-scale Projects: Illinois Basin – Decatur Project

Sallie E. Greenberg, Ph.D.
Midwest Geological Sequestration Consortium
University of Illinois – Illinois State Geological Survey

5 October 2016 – Tokyo, Japan

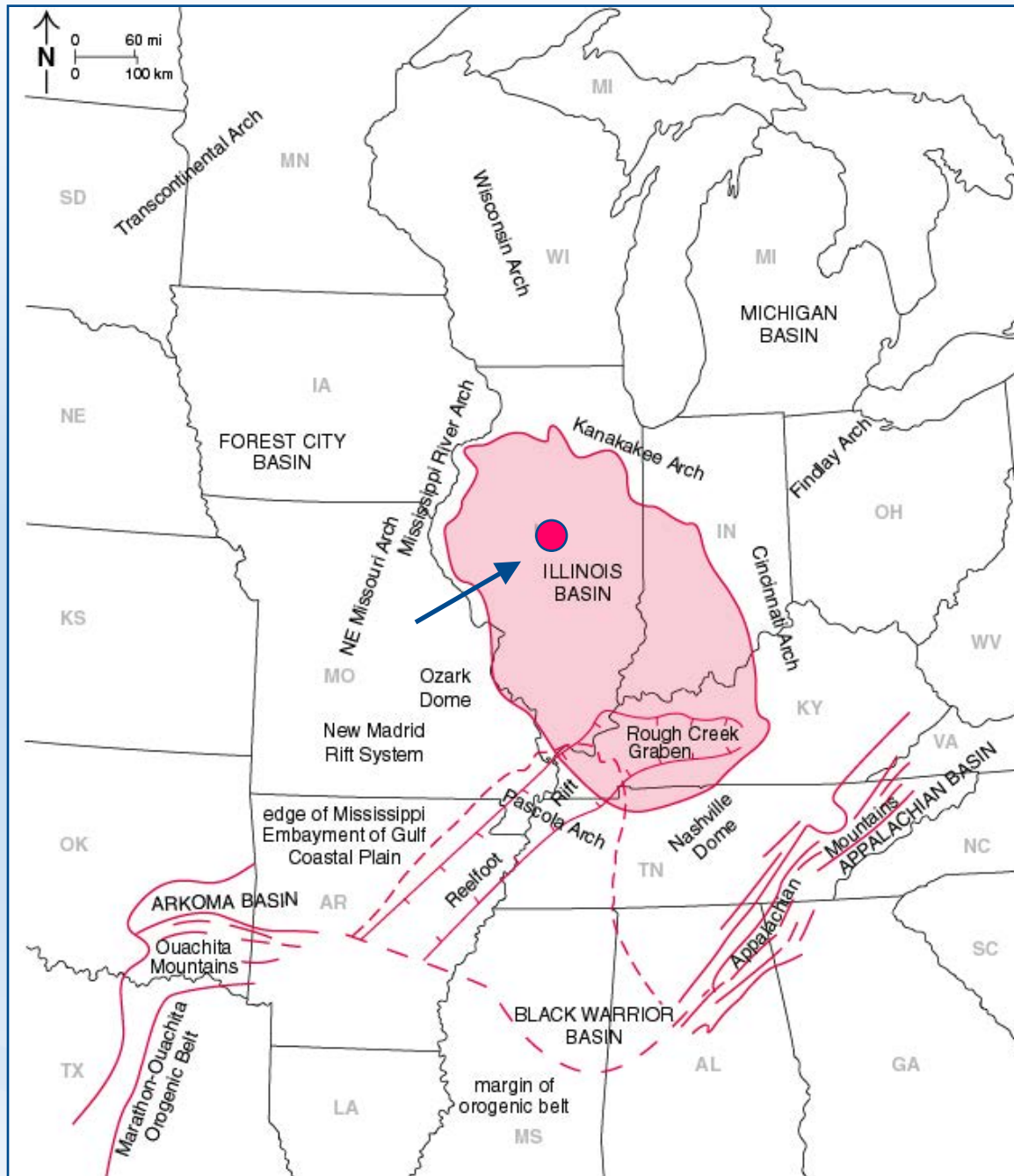


Acknowledgements

- The Midwest Geological Sequestration Consortium is funded by the U.S. Department of Energy through the National Energy Technology Laboratory (NETL) via the Regional Carbon Sequestration Partnership Program (contract number DE-FC26-05NT42588) and by a cost share agreement with the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development through the Illinois Clean Coal Institute.
- 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.



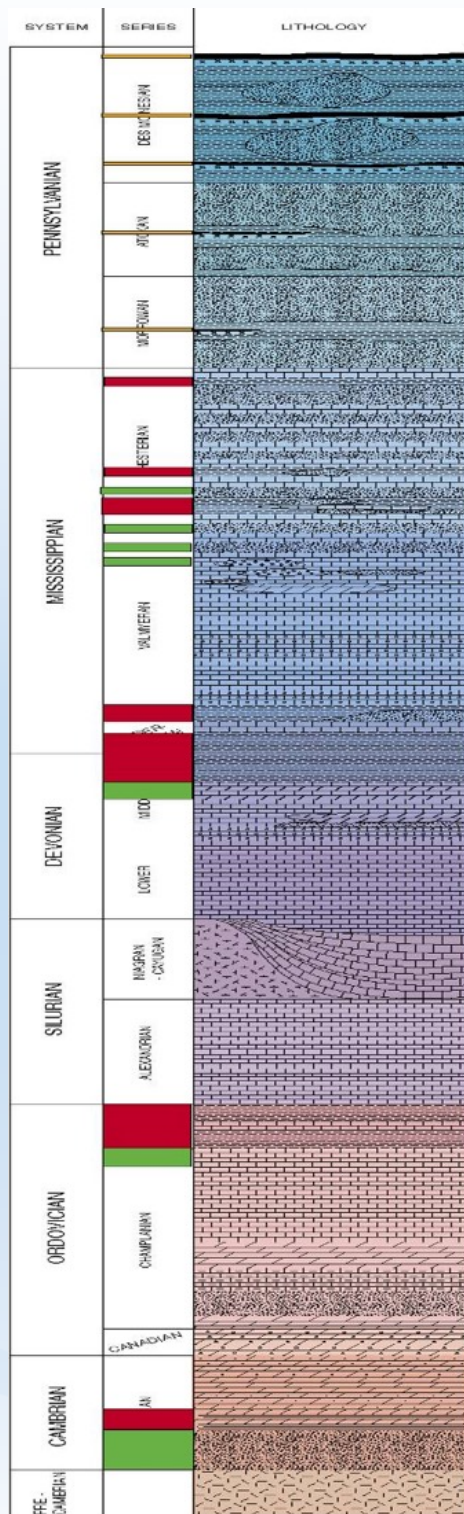
Illinois Basin – Decatur Project Scope



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 Sandstone, a saline reservoir, at Decatur, IL

- Prove injectivity and capacity
- Demonstrate security of injection zone
- Contribution to best practices

Illinois Basin Stratigraphic Column



Pennsylvanian coal seams

New Albany Shale

back-up seals

Maquoketa Shale

St. Peter Sandstone

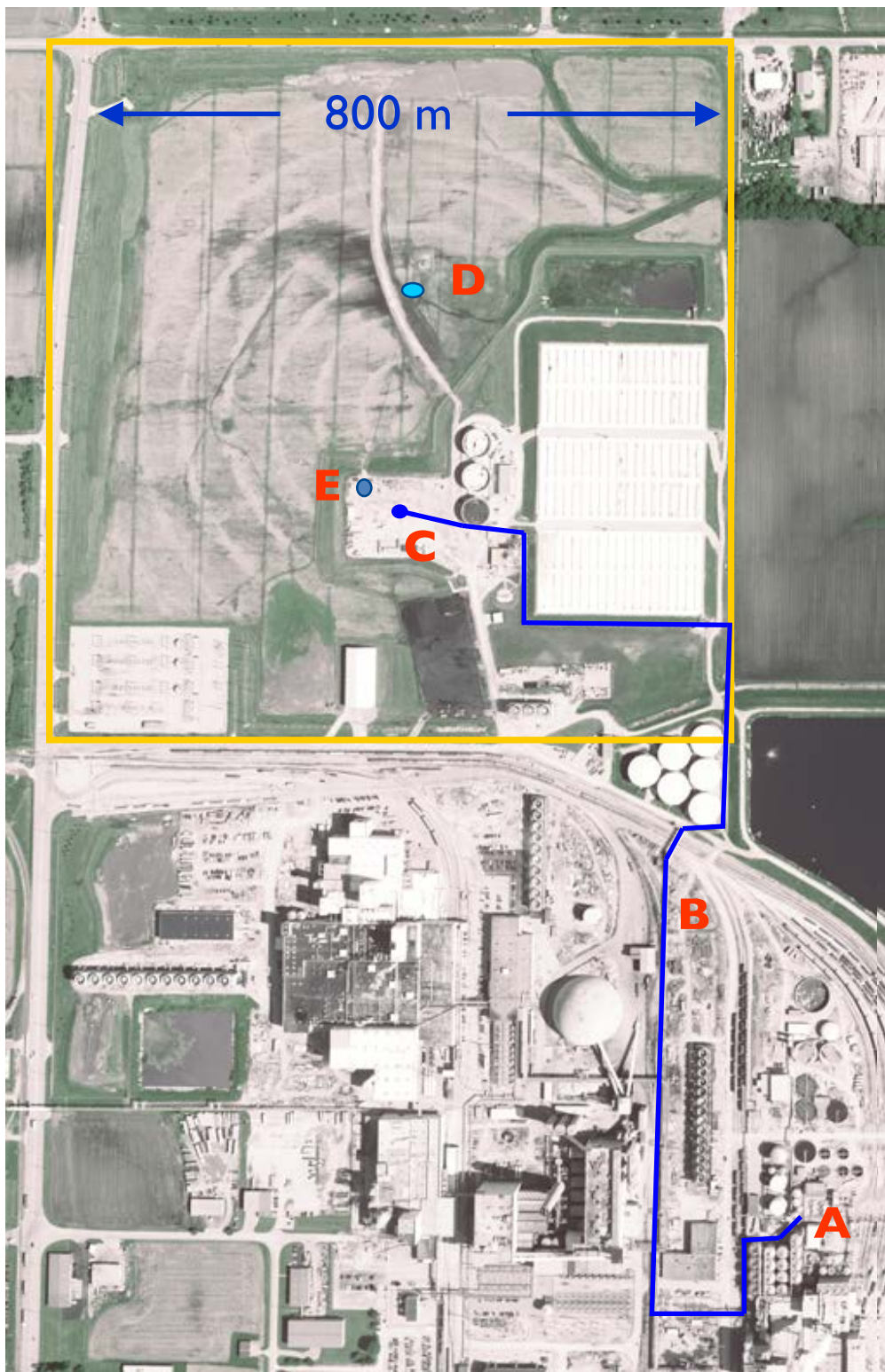
Eau Claire Shale seal

Mt. Simon Sandstone reservoir

Mount Simon Storage Capacity:

Capacity:

11 (E=0.4%) to 150 (E=5.5%) billion metric tons



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

Operational Injection: November 2011 to 2014

- **IBDP** is the first 1 million tonne carbon capture and storage project from a biofuel facility in the US
- Intensive post-injection monitoring under MGSC through 2017
- Industrial CCS Injection Monitoring through 2019



Total Injection:
999,215 tonnes

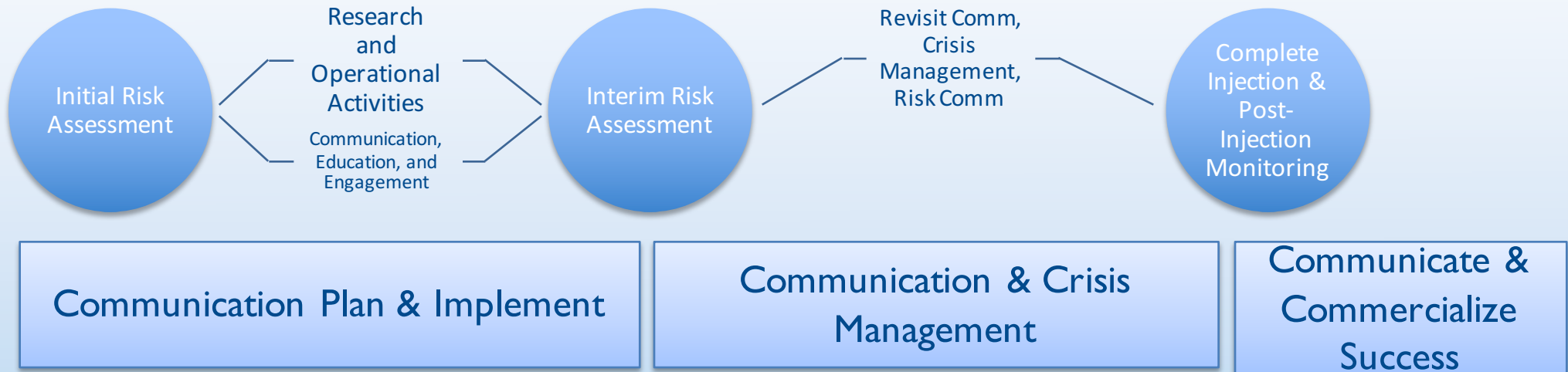
Key Operational Results – IBDP at Completion of Injection

- Mount Simon Sandstone reservoir accepted CO₂ more easily than expected resulting in quicker detection at verification well
- Upward plume growth limited by reservoir permeability stratification, as modeled, and confirmed by pressure observations
- Resulting plume believed thinner than expected and was not detected with a 3D vertical seismic profile until April 2013
- Mt. Simon 200,000 ppm brine is more corrosive than expected
- With 999,215 tonnes injected, CO₂ remains in lowermost Mt. Simon; internal reservoir heterogeneity affecting CO₂ distribution
- No CO₂ leakage or adverse impacts detected to date
- Second project (ICCS) will add opportunity to monitor two plumes

Post-Injection Activities (Since November 2014)

- Post-injection near surface and deep monitoring
- Post-injection modelling and data evaluation
 - 3D Surface Seismic Survey – 2015
 - Post-injection VSP (permit interim period) – 2015
 - RTAC to Well Watcher Migration - 2016
 - Recomplete VWI – 2016
 - Final static and dynamic models – 2016
 - Near-surface monitoring analysis and recommendations - 2016
 - Passive/active monitoring project (US-Norway) – 2016-2017
 - Peer-reviewed articles, technical and final reports
- Knowledge and data sharing best practices
- Preparing IBDP site for long-term commercial viability
- Permit monitoring for ADM Industrial CCS project

IBDP Risk Assessment and Project Uncertainties



2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

Geologic Uncertainty
Operational Uncertainty
Regulatory Uncertainty
Social Uncertainty

Regulatory Uncertainty

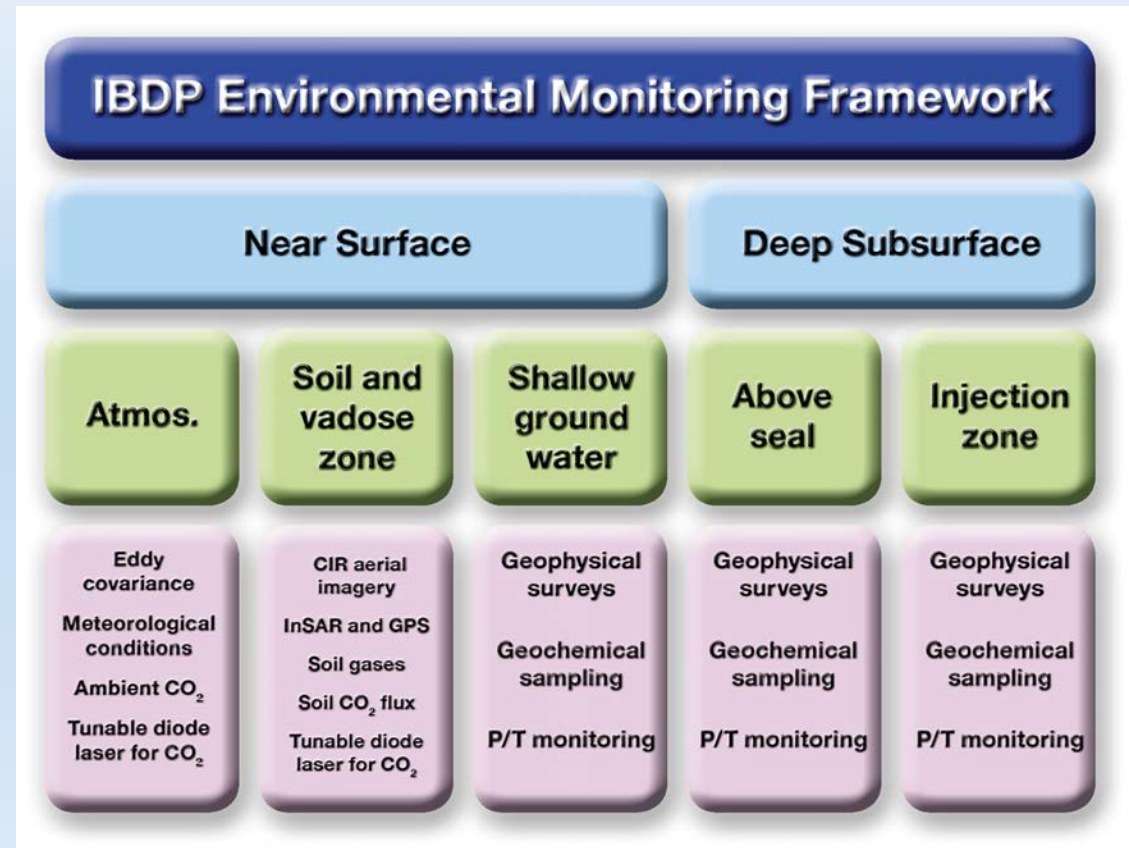
Change in Scope
Long-term Funding
Challenges in Knowledge Sharing
Complacency Potential
Institutional Memory Loss

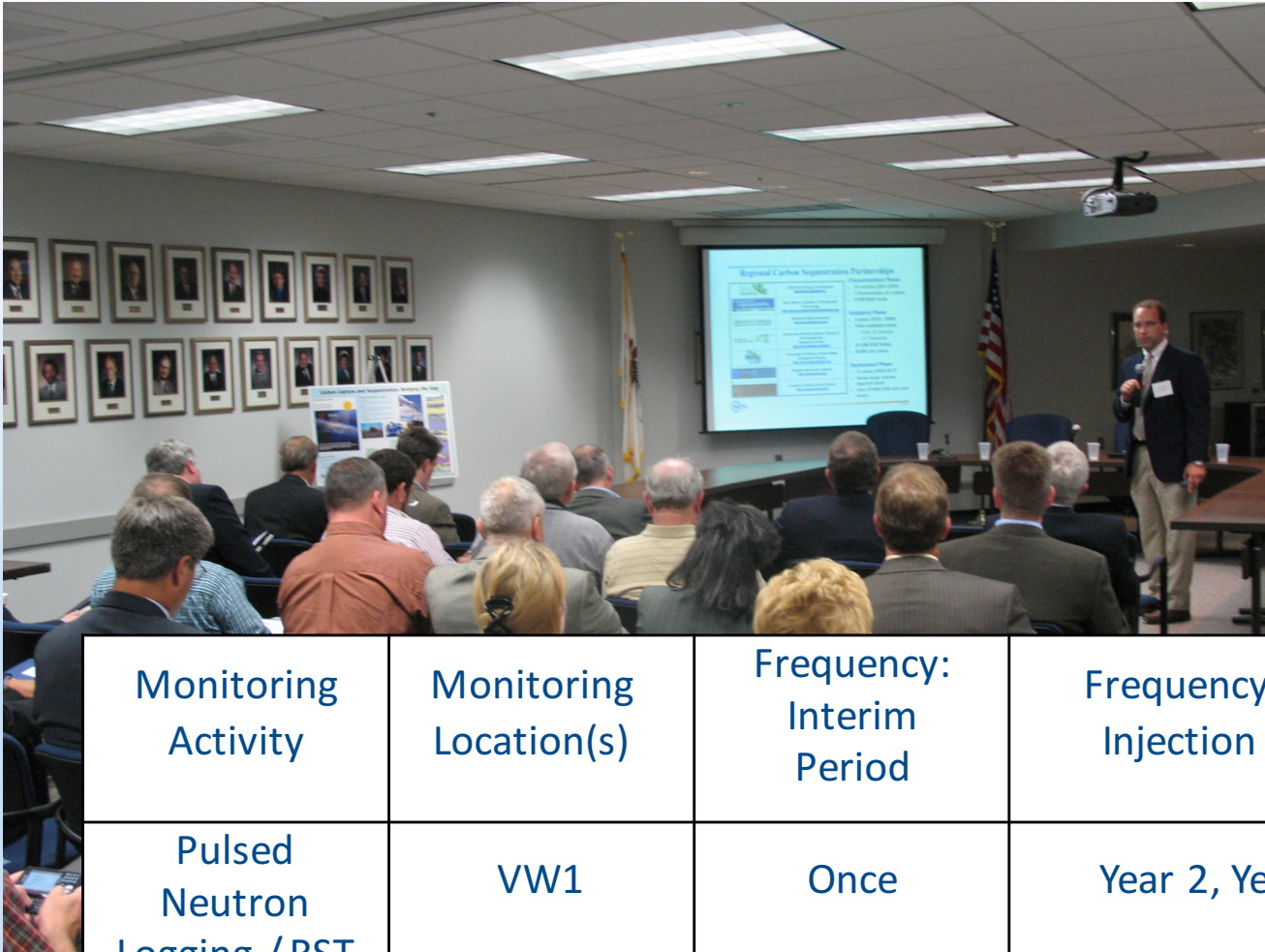
Regulatory Uncertainty

Funding Uncertainty
Transferring Knowledge
Sharing Data
Maintaining Capacity
Finishing Strong

Post-injection Monitoring – Locke and Collaborators

- Near-surface comparison with baseline
- Regulatory compliance for the IBDP PISC
- Recommendations for commercial-scale MVA operations based on IBDP experiences





Permitting
 IL EPA UIC Class I
 to
 US EPA UIC Class VI

Monitoring Activity	Monitoring Location(s)	Frequency: Interim Period	Frequency: CCS2 Injection Phase	Frequency: CCS2 Post- Injection Phase
Pulsed Neutron Logging / RST	VW1	Once	Year 2, Year 4	Year 1, Year 3, Year 5, Year 7, Year 10
Fluid Sampling	VW1	Once	Year 1-3 : Annual Year 4-5 : None	None
Pressure/ Temperature Monitoring	VW1	Continuous	Year 1-3 : Continuous Year 4-5 : None	None

Recompletion of VWI Monitoring Well

Westbay System

Flexible, industry-tested design offers Superior Performance

OVERVIEW
The Westbay System is a completely versatile, multilevel monitoring technology that allows testing of hydraulic conductivity, monitoring of fluid pressure and collection of fluid samples from multiple zones within a single borehole. Designed for reliability and flexibility, the Westbay System can accommodate a wide variety of borehole conditions including diameter, depth, temperature and chemistry considerations.

Westbay System advantages

- obtain measurements and samples at any number of discrete locations along a single borehole
- collect samples without purging
- designed for long-term monitoring
- engineered to operate at great depths
- reduced drilling and installation costs, with minimal site disturbance
- removable probes allow for convenient calibration and servicing
- built-in deflatable G/AC procedures

WELL COMPLETIONS
Westbay Systems are engineered with a unique, customizable casing system. The casing system is available in two sizes (MP78 and MP92) and manufactured from plastic or stainless steel to fit various borehole dimensions and operational requirements. Hydraulically-inflated packers and/or backfill provide engineered seals between monitoring zones, preventing unwanted flow and cross-contamination. Valved ports in the zones provide access for monitoring, sampling and hydraulic testing.

Westbay Systems can be installed in a number of different ways to suit geologic conditions, drilling methods, and project objectives.

Completion methods include:

- packers in open borehole
- packers through temporary casing
- packers in a cased well
- direct backfill

WESTBAY SYSTEM PROBES
A variety of probes are available for use in the Westbay System. Reliable, accurate, portable wireline-operated probes can be lowered into the casing system and used to:

- measure groundwater pressure
- test hydraulic parameters
- collect samples in-situ
- perform system specific tests

SAMPLING PROBES
Westbay Systems offer the unique ability to collect discrete fluid samples at formation pressure. For sample collection the probe and sample container are lowered to the desired depth, where the sample is collected into the container. The probe and container are then retrieved to the surface for further analysis.

Westbay System sampling allows you to:

- collect samples with minimal disturbance and without repeated purging
- maintain samples at formation pressure
- monitor pressure during sampling
- document quality assurance

1 PACKERS

- Engineered seal in a range of borehole sizes
- No dedicated inflation lines
- Controlled hydraulic inflation with record of pressure and volume
- Quality control tests to confirm performance at any time after installation

2 MEASUREMENT PORT

- For fluid pressure measurements, fluid sampling and low-k testing

3 PUMPING PORT

- For purging, hydraulic conductivity testing, and quality control testing.

For more information, visit www.bactechtechnology.com

Advancing Reservoir Performance

REPACKer™ Reactive Element Packers

Baker Hughes

HCM-Plus Hydraulic Sliding Sleeve
Baker Hughes intelligent well systems flow control valves

© 2010 Baker Hughes Intellectual Property. All Rights Reserved.

The Baker Hughes Inforce HCM™-Plus downhole valve provides remote and reliable isolation of a specific interval. It reduces costs and minimizes production downtime by allowing production or injection from the wellbore to be altered without intervention from the surface. This product is compatible with oil- or water-base control fluids.

The hydraulically balanced piston yields high shifting forces to overcome scale and debris, and it requires two control lines per HCM-Plus valve. A third port is included on the valve as part of the closed line circuit. This port reduces the number of lines required to operate a multizone system.

Hydraulic pressure applied from the surface shifts the HCM-Plus valve to the open or closed position. If a hydraulic operation cannot be performed, the HCM-Plus valve has an integral shifting profile for mechanical operation.

The Baker Hughes testable control line jam nut fittings are some of the most widely used hydraulic connectors available in the market.

Applications

- Multiple zone production or injection wells requiring remote operations to isolate a specific zone when choking is not required

Benefits

- Intervention not required to open or close the valve
- Cost-effective, remote valve operation
- Reliable, simple design with proven technology and built-in flexibility

Features

- Balanced piston design to open and close the valve at deep setting depths
- Simple surface procedures for valve actuation
- Non-elastomeric sealing technology isolated during flowing operations for high-performance sealing from tubing to annulus
- Testable control line jam nut fittings
- Control line bypass allows multiple valves, sensors, or chemical injection valves to be run as part of an intelligent well system
- Internal profiles allow placement of flow control devices
- Integral profile for secondary mechanical shifting
- Water- or oil-base control line fluid compatible

- Option 1 – Retain Westbay
- Option 2 – Schlumberger IntelliZone
- Option 3 – Baker Hughes Intelligent
- Option 4 – Drill new well

Two Fluid Sampling and Four Pressure Zones

Research priorities:

- Monitor injection of multiple plumes within Mt. Simon in order to **determine and observe reservoir response** via pressure, temperature, geophysical, geomechanical, and geochemical means.
- **Demonstrate and test monitoring equipment and methodologies** for deployment at the near and deep subsurface through a comprehensive MVA program.
- **History match and determine plume development response** through active and passive seismic monitoring in order to further understand reservoir microseismic response

Project management priorities:

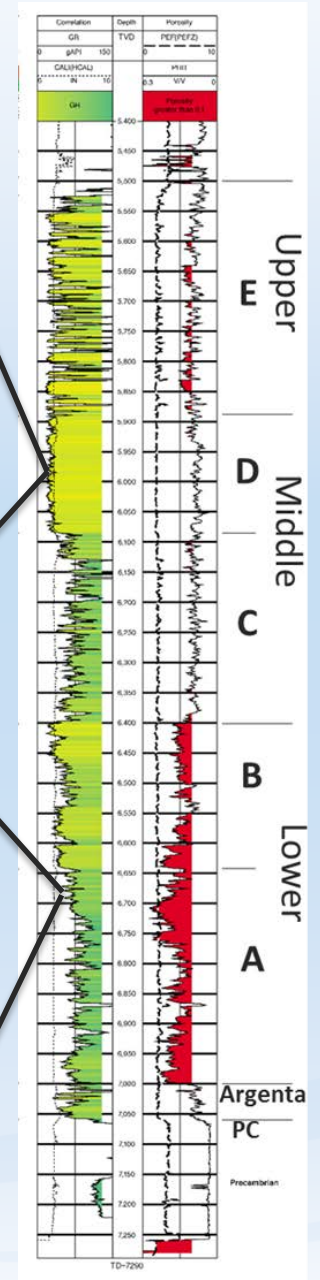
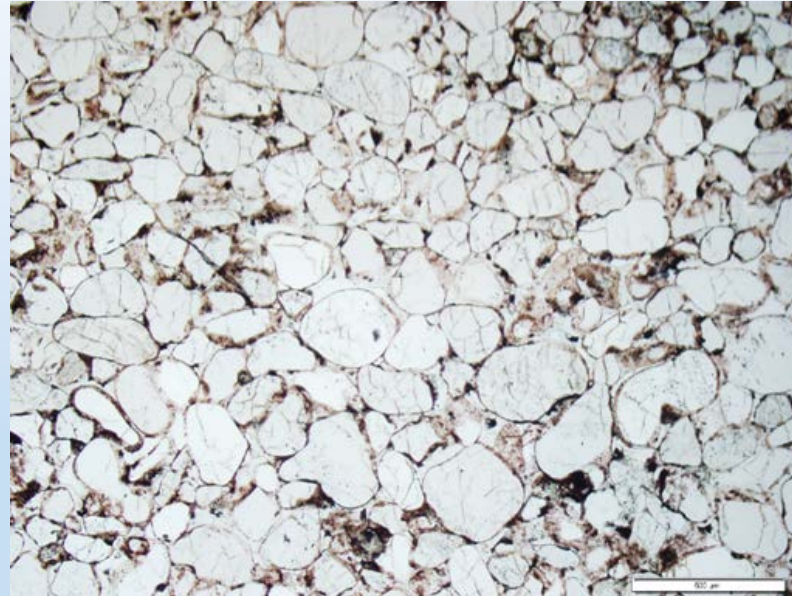
- **Deliver project on-time and within budget**
- **Reduce short- and long-term risk to project**

Permit priorities:

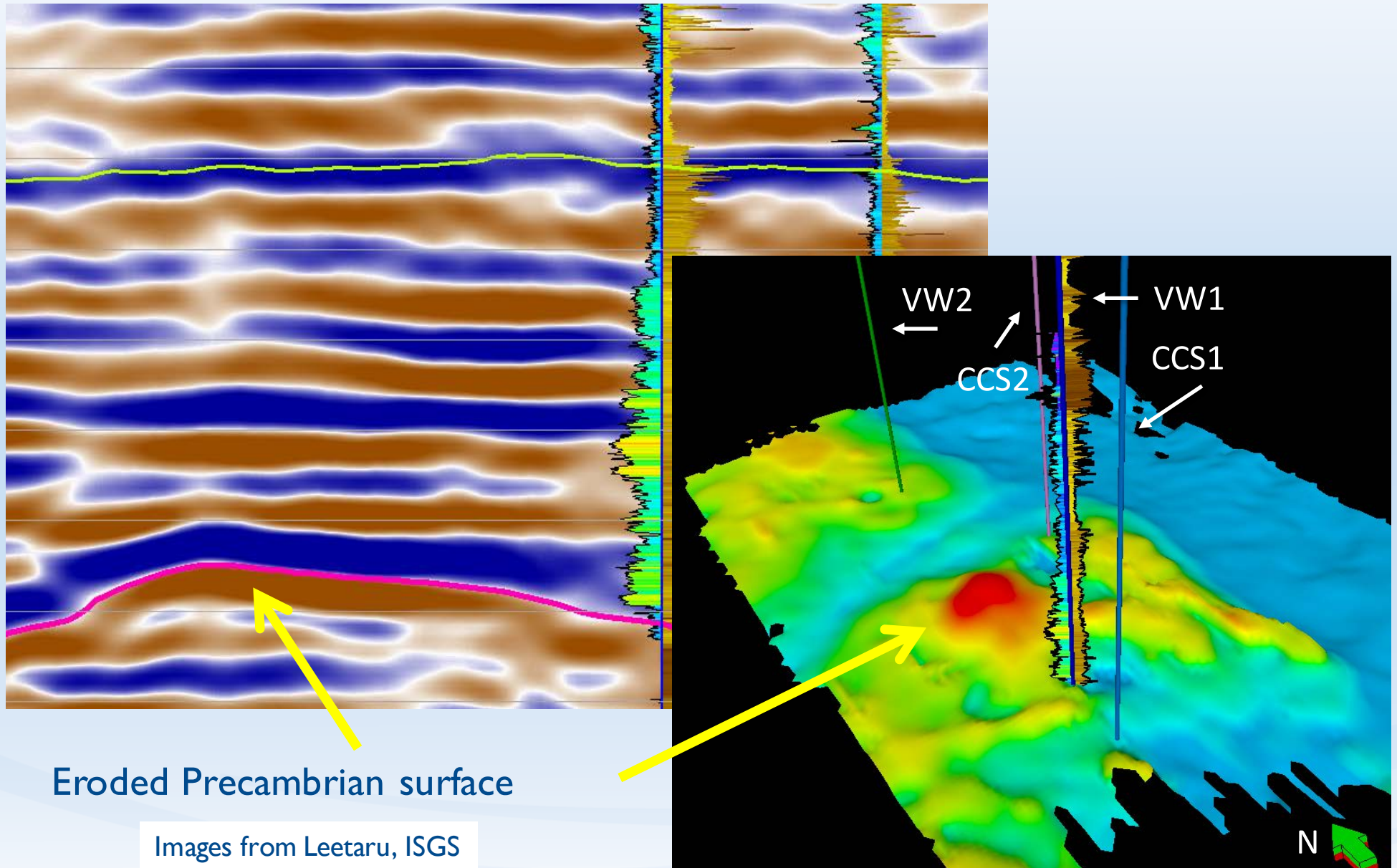
- **Perform Injection phase monitoring by fluid sampling** in two zones (one in Mt. Simon and one in Ironton/Galesville)
- **Perform continuous pressure and temperature monitoring**
- **Conduct direct and indirect plume monitoring**

Refined view of Lower Mt. Simon Depositional and Diagenetic History - Freiburg and Collaborators

- Diagenetic controls on reservoir properties
- Depositional interpretation



Refining Understanding of Precambrian Structure using 3D Seismic Volume – McBride, Leetaru, and Collaborators



Eroded Precambrian surface

Images from Leetaru, ISGS

Gaining insights into microseismic activity

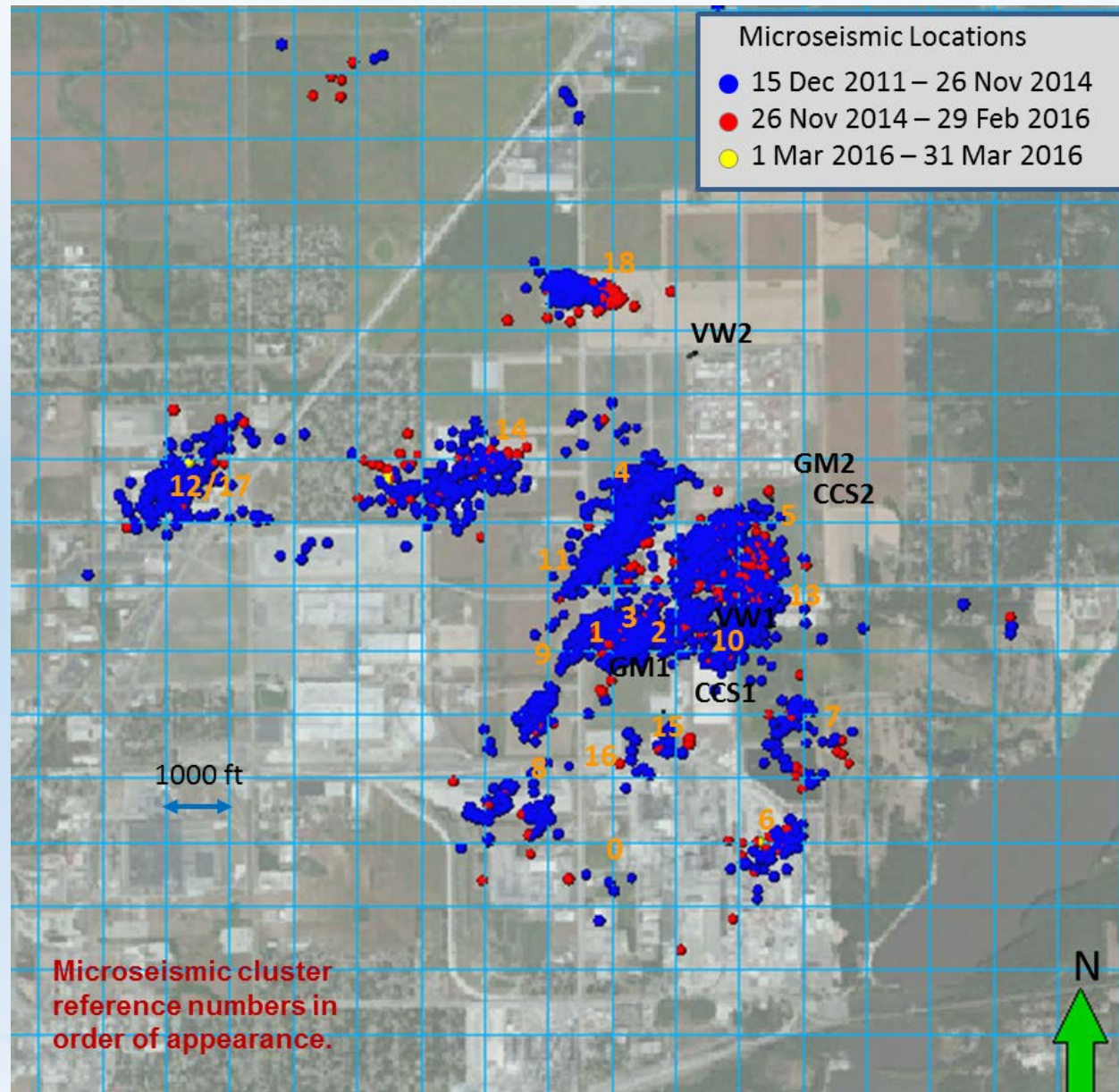


Image provided by Schlumberger Carbon Services

Gaining insights into microseismic activity

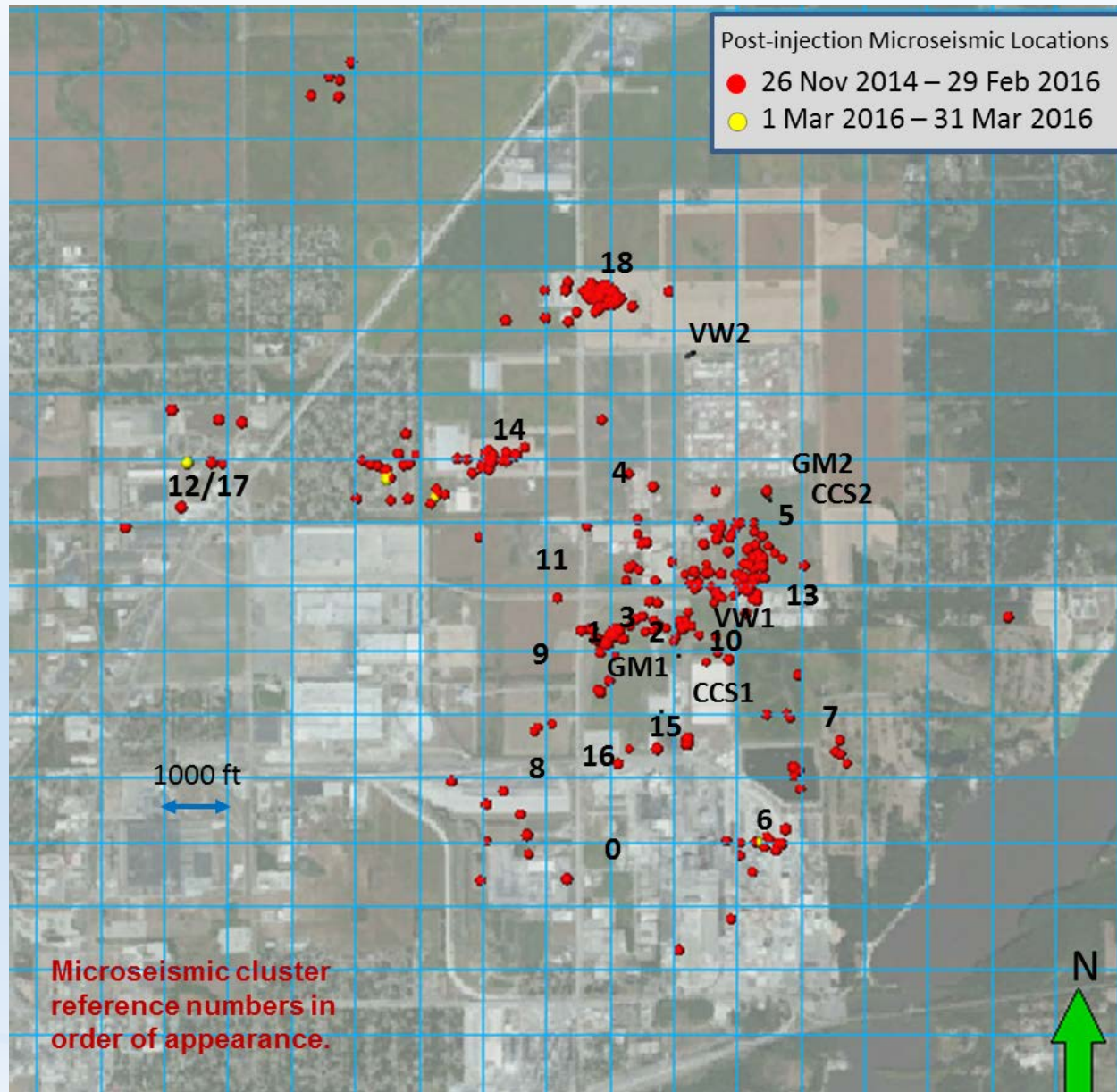
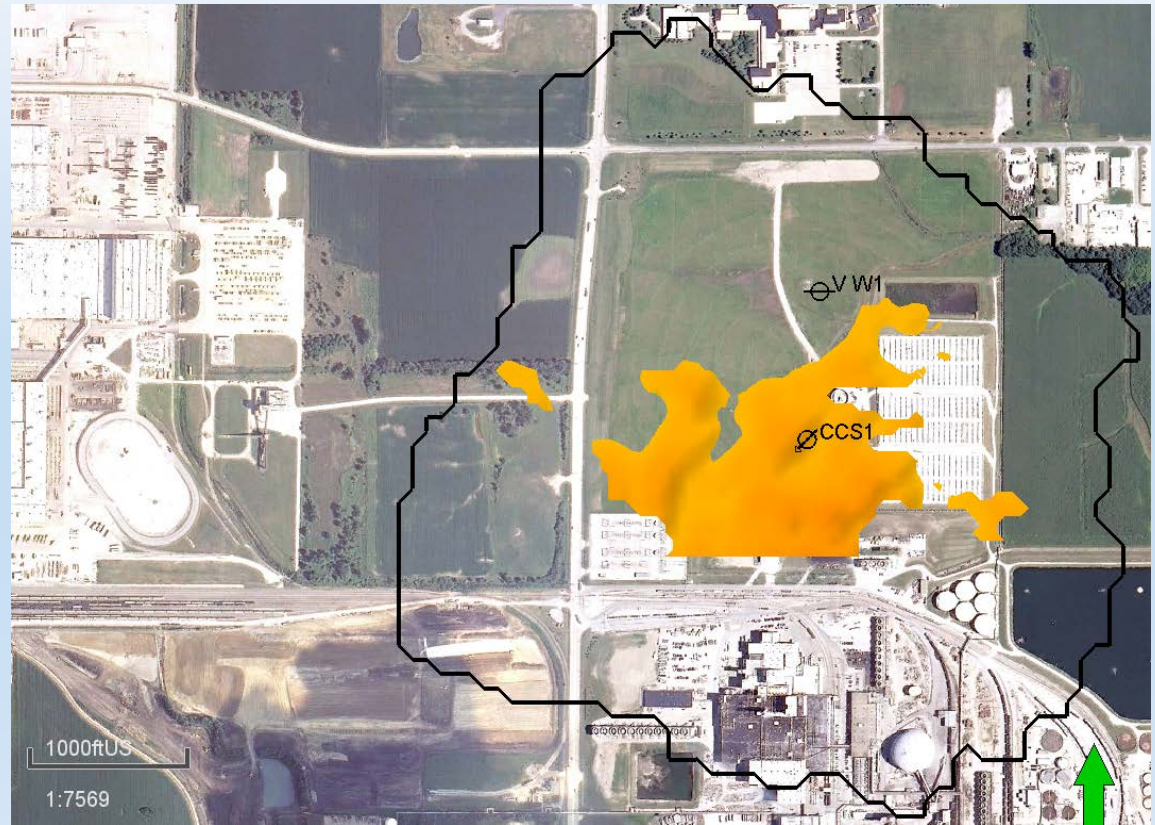


Image provided by Schlumberger Carbon Services

Integration of Modeling Efforts

- Concurrent IBDP Modeling Efforts:
 - Geologic (static)
 - Reservoir simulation
 - Geomechanical
 - Coupled hydro-mechanical



Preliminary consolidated time-lapse attribute interpretation (orange) and outline of modeled plume (black polygon) in Q1 2015.

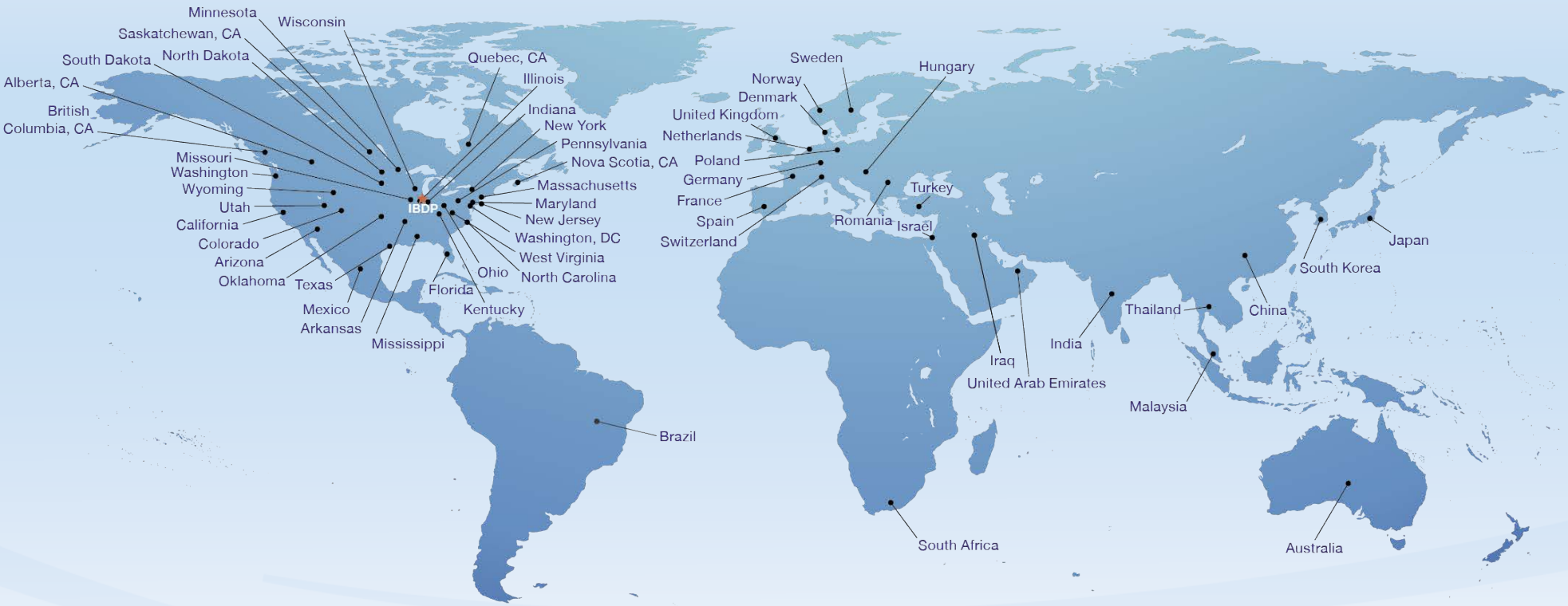
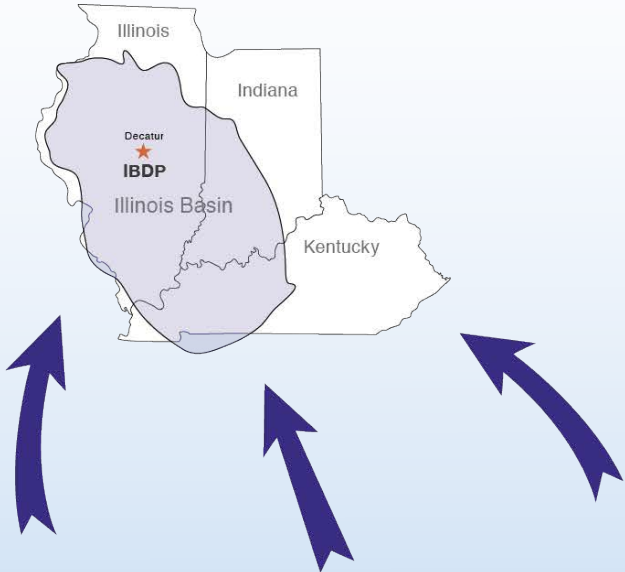
By the numbers:

- A million tonnes stored and...
- More than **17,000 feet** of wells have been drilled
- More than **800 feet** of core have been collected
- Near-surface groundwater monitoring efforts have resulted in more than **50,000 analyses**
- For basin-scale modeling, we will use **1,020,000 CPU-hours** of XSEDE supercomputing resources.
- More than **700 visitors from 29 countries** have been to IBDP
- Over **180 publications** and **435 presentations**
- More than **100 people at least 10 organizations** have worked together to make this project a success



XSEDE is an NSF-sponsored supercomputer network

Global Participants Attending STEP-IBDP Events



Global STEP Education and Outreach Events



*All International STEP Activities Were Paid From Non-Contract Funds

CCS in Decatur, IL USA

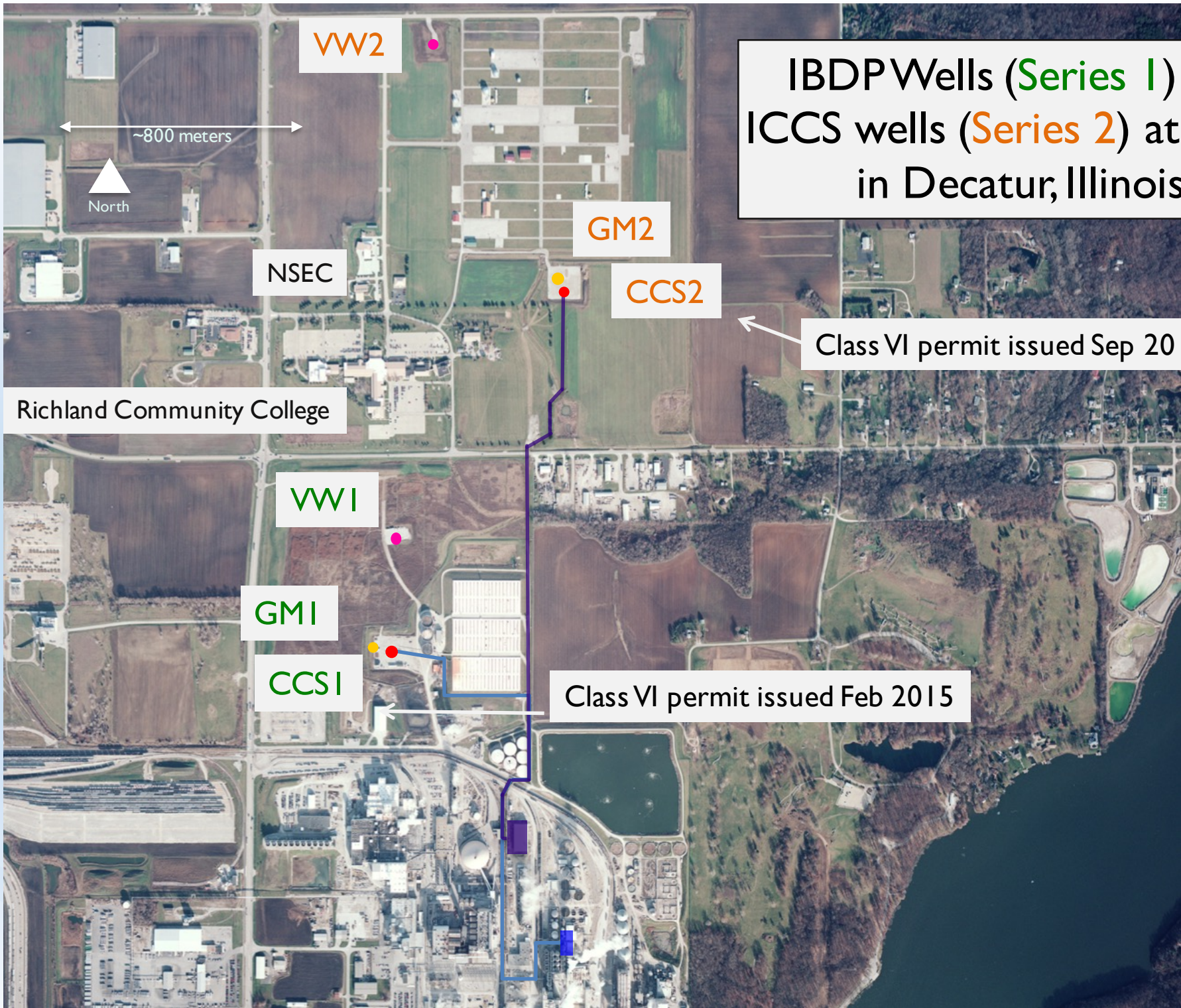


Illinois Basin – Decatur Project

- Large-scale demonstration
- Volume: 1 million tonnes
- Injection period: 3 years
- Injection rate: 1,000 tonnes/d
- Compression capacity: 1,100 tonnes/day
- Status: Post-injection monitoring

Illinois Industrial CCS Project

- Industrial-scale
- Volume: 5 million tonnes
- Injection period: 3 years
- Injection rate: 3,000 tons/d
- Compression capacity: 2,200 tonnes/day
- Status: Pre-injection monitoring



IBDP Wells (**Series 1**) and ICCS wells (**Series 2**) at ADM in Decatur, Illinois

Class VI permit issued Sep 2014

Class VI permit issued Feb 2015

VW2

GM2

CCS2

NSEC

VW1

GM1

CCS1

Richland Community College

~800 meters

North



Midwest Geological
Sequestration Consortium

