Midwest Geological Sequestration Consortium: Annual Update

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University of Illinois - Illinois State Geological Survey
14 August 2018 – Pittsburgh, PA



MGSC

Research and Capacity Building in Capture, Utilization, and Storage

Biphasic Solvents

Large-scale Capture Pilot

Utilizing CO_2 from Coal-Fired Power Plants (algae)

Water Conservation at Power Plants

Reducing Amine-Based Aerosol Formation

Illinois Basin - Decatur Project

Illinois Industrial Sources Project

CarbonSAFE Illinois - East Basin

CarbonSAFE Illinois - Macon/Christian

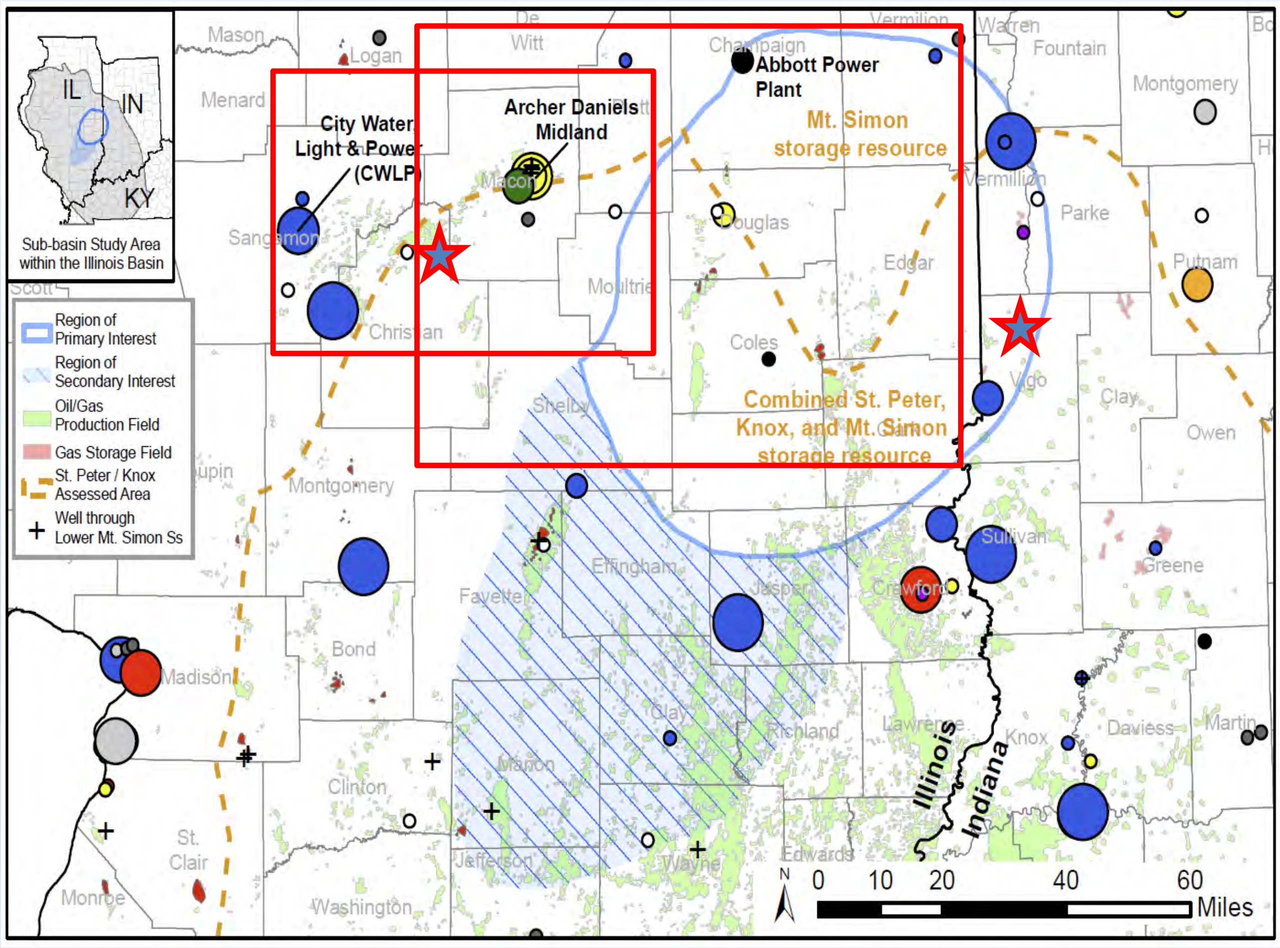
CarbonSAFE - Wabash

Cypress - ROZ

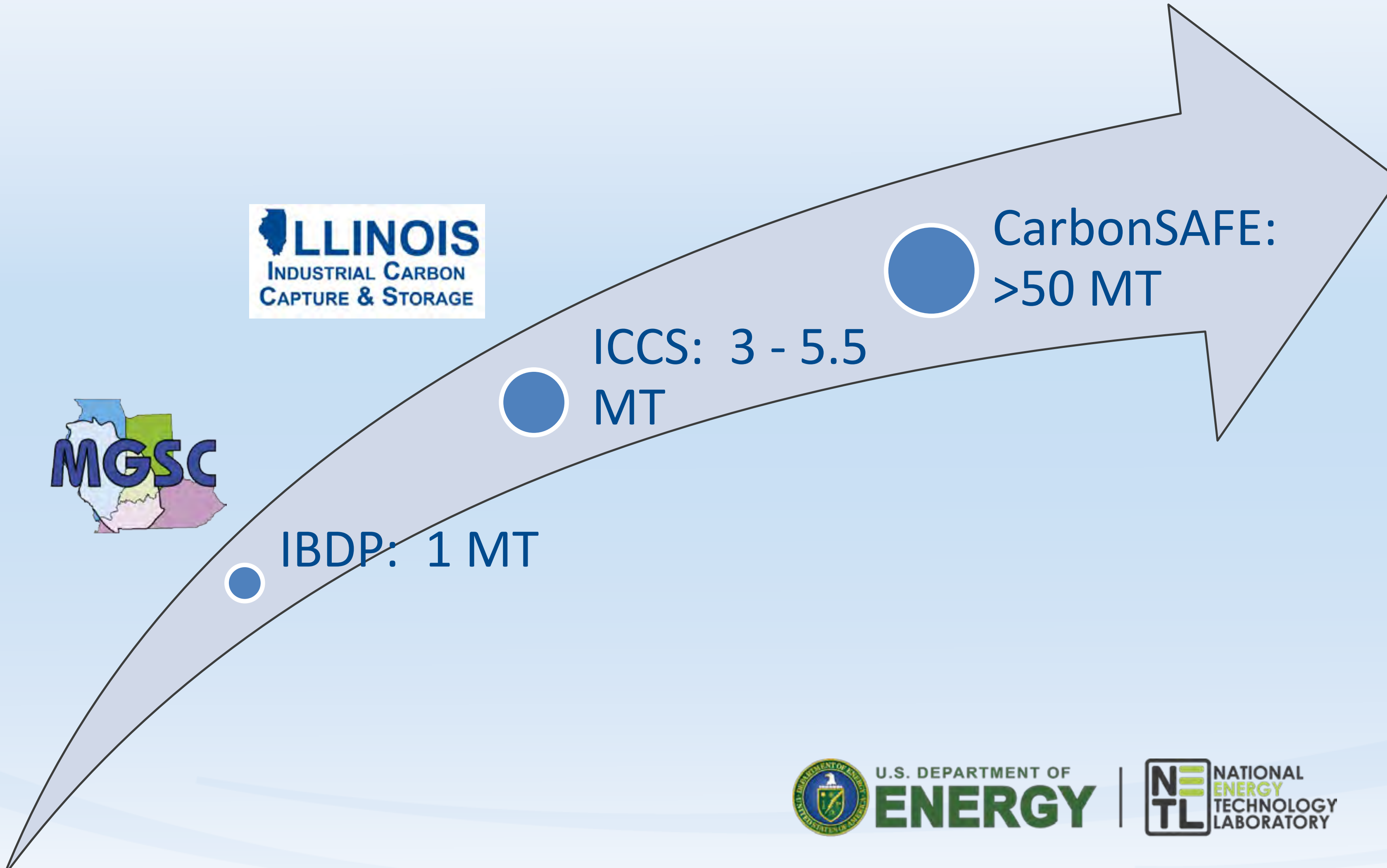
GSCO2 - EFRC

Induced Seismicity/Machine Learning

Carbon Storage Projects in the Illinois Basin



Illinois Basin Industrial CCS Progression



Current CCUS Projects 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

Contribution:

- Geologic and Social Site Characterization
- Reservoir Modeling and Risk Assessment
- MVA Development and Engineering Design
- Stakeholder Engagement

Status:

- Post-injection monitoring ends April 2020
- Conceptual site model and history matching

Illinois Industrial CCS Project

- Industrial-scale demonstration
- Volume: up to 5 million tonnes
  - 800,000+ to-date
- Injection period: 3 years (or longer)
- Injection rate: 3,000 tons/d
- Compression capacity: 2,200 tonnes/day

Contribution:

- Commercial-scale up surface and subsurface
- Intelligent Monitoring
- Class VI permitting

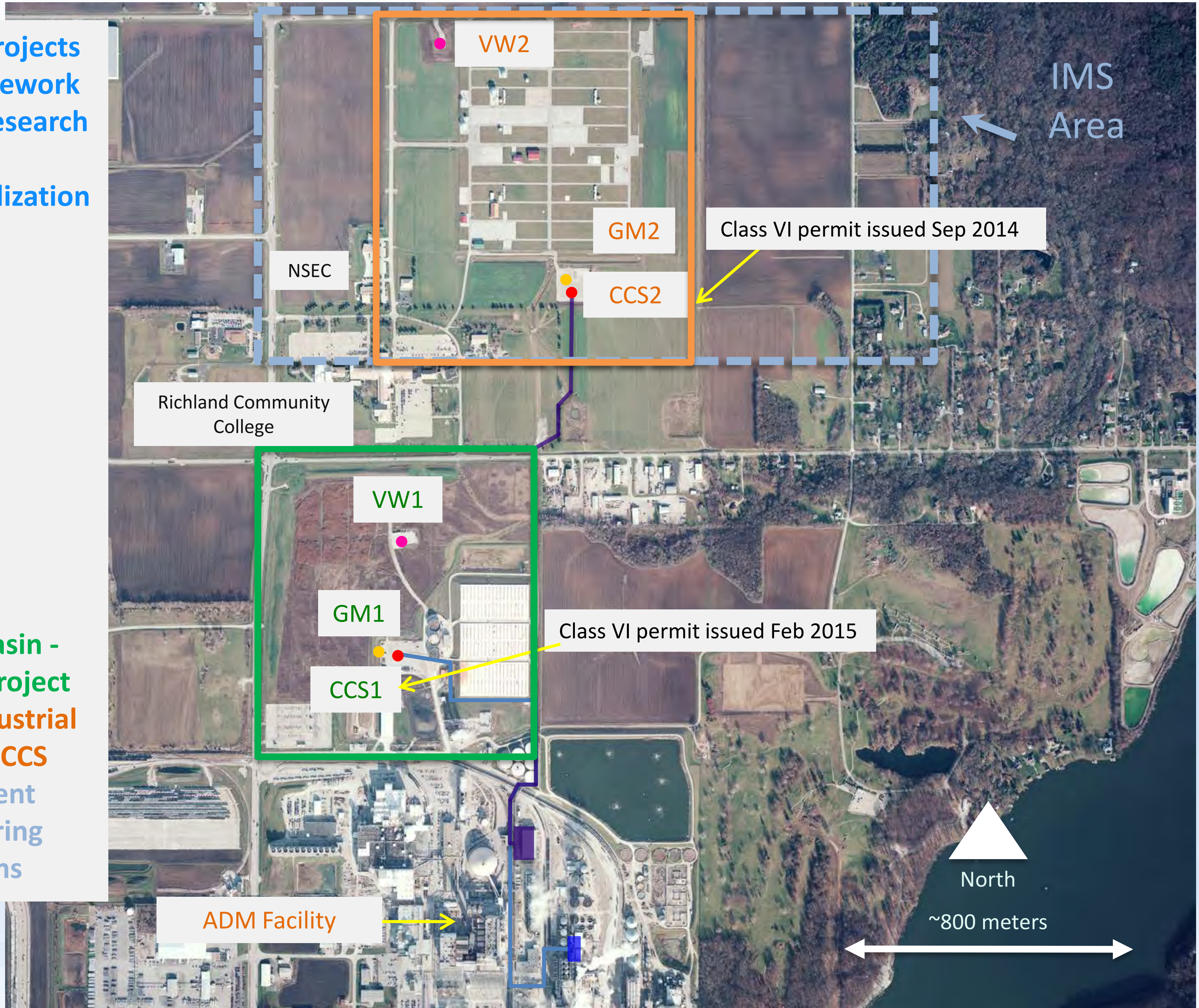
Status:

- Injection Began April 7, 2017
- Optimization of capture process
- No 45Q tax credits claimed for 2017

Establishing Injectivity, Containment, and Capacity

Illinois Basin - Decatur Project

Multiple Projects Build Framework for CCUS Research and Commercialization

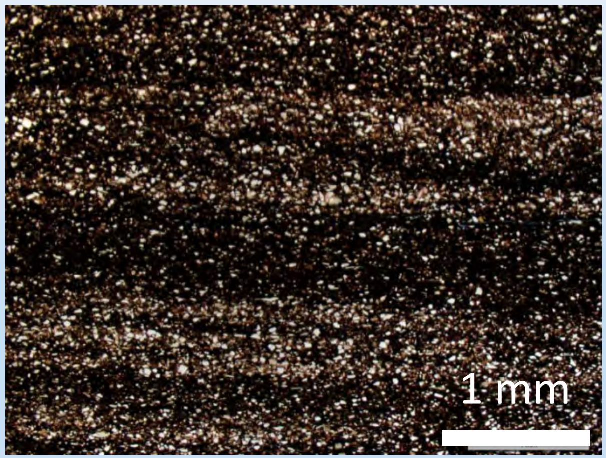


Illinois Basin - Decatur Project
Illinois Industrial Sources CCS
Intelligent Monitoring Systems

Observations from the Field

Mudstone baffle between injection zones not continuous between projects

10 cm



Zone 5

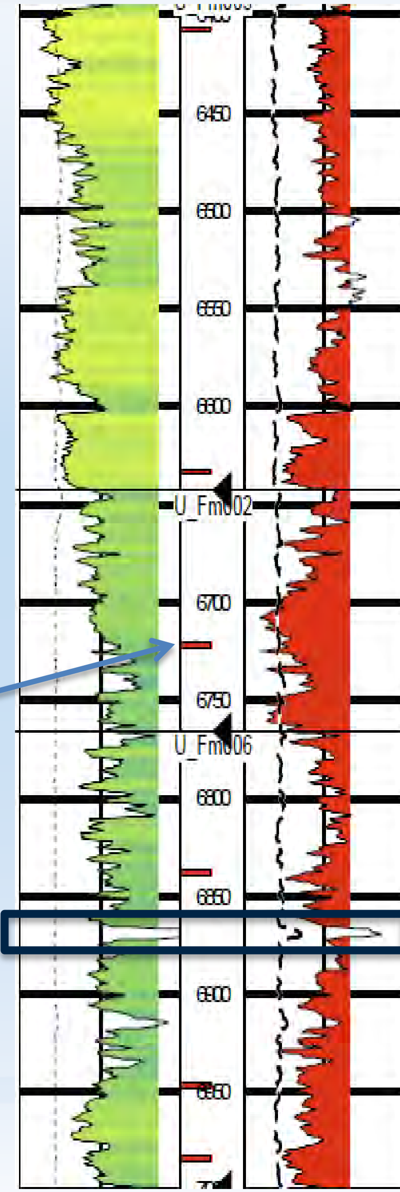
6,863-6,863.25 (2,092 m)

Porosity: 1.5%

K_v: <0.01 mD

K_h: 4.13 mD in siltstone laminae

VW1



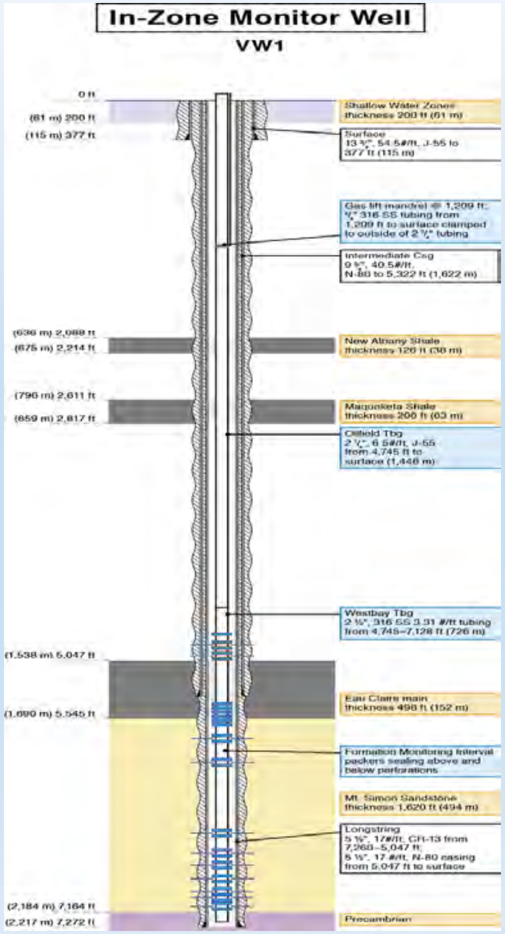
ICCS Injection Zone

Baffle

IBDP Injection Zone

Verification Well (VW1) Update

- 2010: Drilled, cased, and perforated at 11 depths in the Precambrian basement (1 zone), the Mt. Simon Sandstone (8 zones), and the Ironton-Galesville Sandstone (2 zones)
- 2011: Wireline swabbing tool used to develop well and remove all fluid in the well tubing introduced during the drilling and completion process
  - Westbay® Instruments Multilevel Monitoring and Characterization System was installed
  - 103 Westbay samples were collected from 11 rounds of sampling that occurred between June 2011 and May 2017
  - The Westbay® system removed from VW1 in May 2017 and the casing perforations were plugged with cement

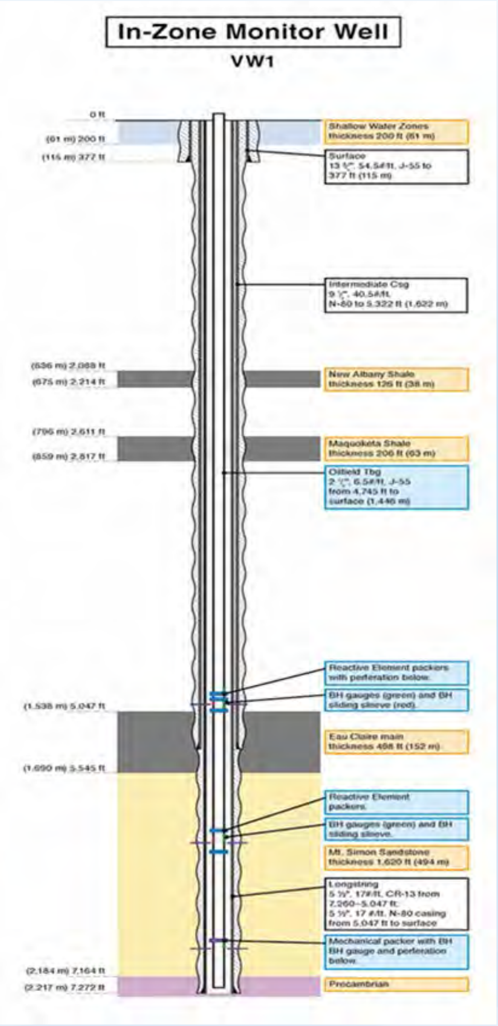


Simplified VW1 diagram, **Westbay system**, and in-zone monitoring details.

Recompletion VW1: Installing the Baker Intelligent well system

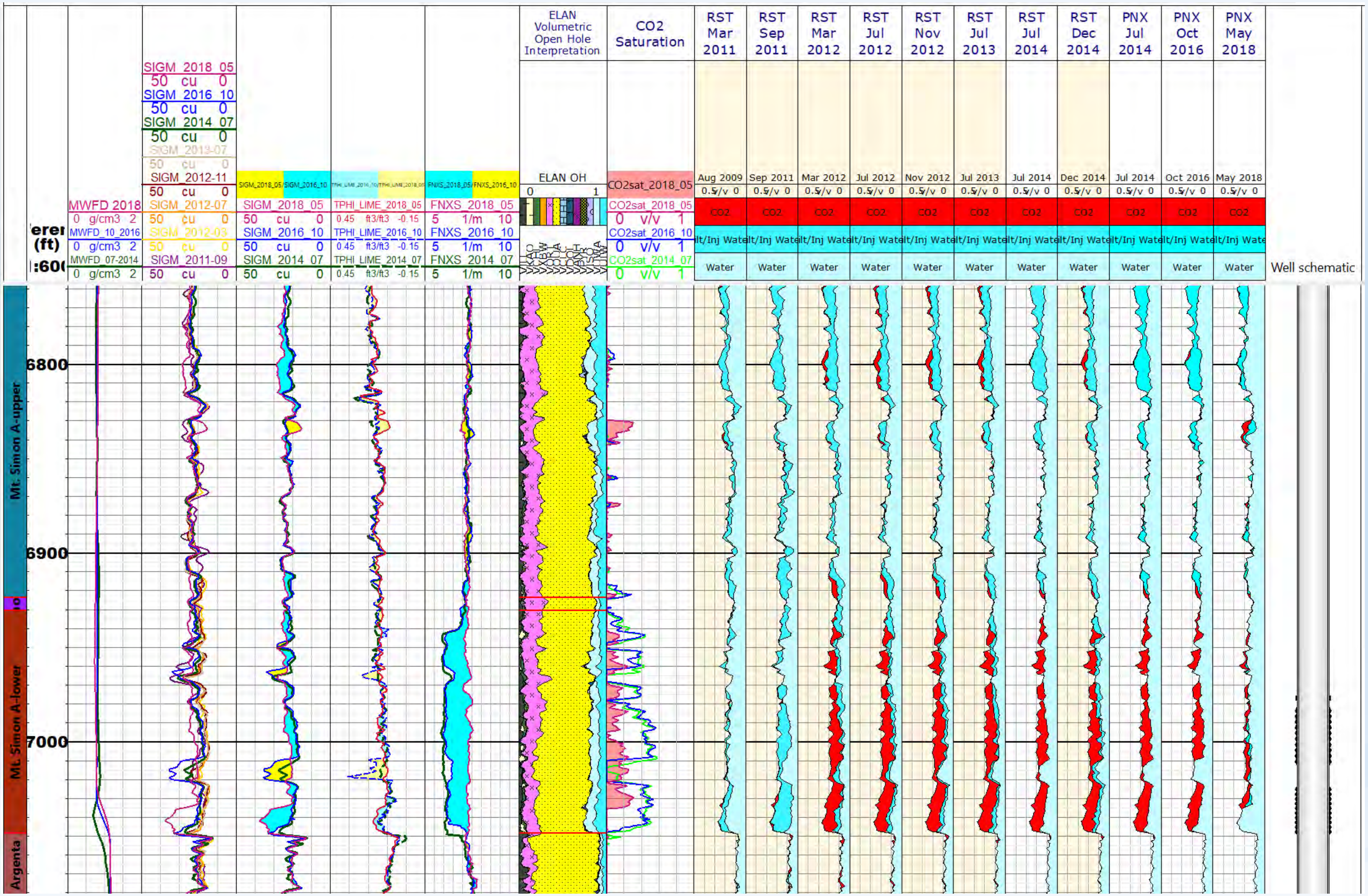
- June 2017 - Perforated at 3 new depths. Ironton-Galesville Sandstone (1 zone) and Mt. Simon Sandstone (2 zones)
- After swabbing, Schlumberger installed the Baker Hughes Intelligent completion
- September 2017 - Purging and sampling completed
- May 2018 - Compliance sampling
- Formation pressures/temperatures currently monitored remotely
- Formation fluids are collected using a Kuster™ Flow-Thru Sampler (FTS)

VW1 Zone	Formation	Depth m (ft)	Date of post-Baker installation purging, compliance sampling (liters (barrels) of fluid purged prior to sampling)
BH-1	Mt. Simon	2,127.5-2,128.4 (6,980-6,983)	N/A
BH-2	Mt. Simon	1,951.3-1,954.4 (6,402-6,412)	8/22-25/2017, 9/13/2017, 2,226 L (53 bbls)
BH-3	Ironton-Galesville	1,513.0-1,517.9 (4,964-4,980)	9/1-12/2017, 9/12/2017, 7,350 L (175 bbls)

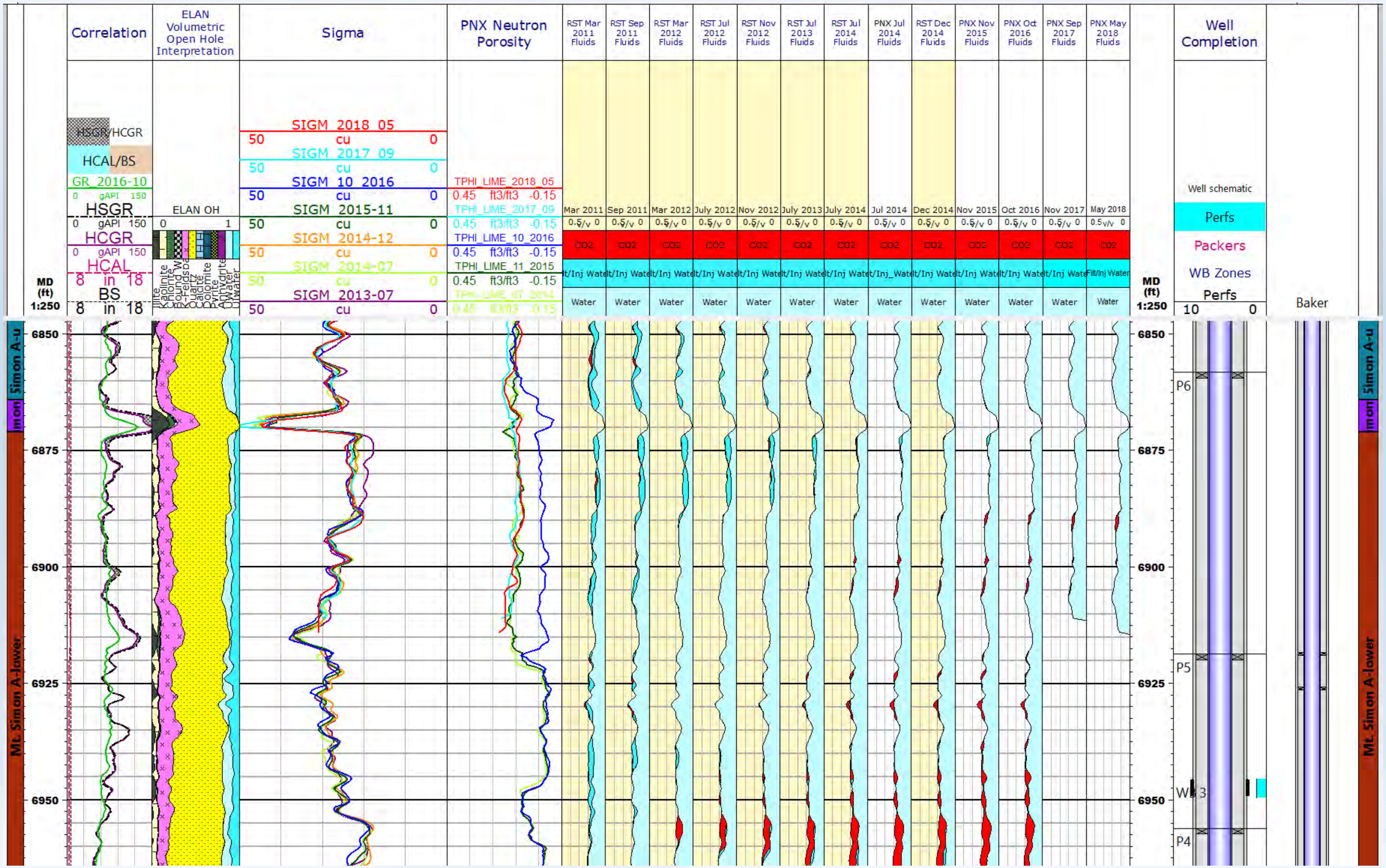


Simplified VW1 diagram, **Baker Hughes** system, and in-zone monitoring details.

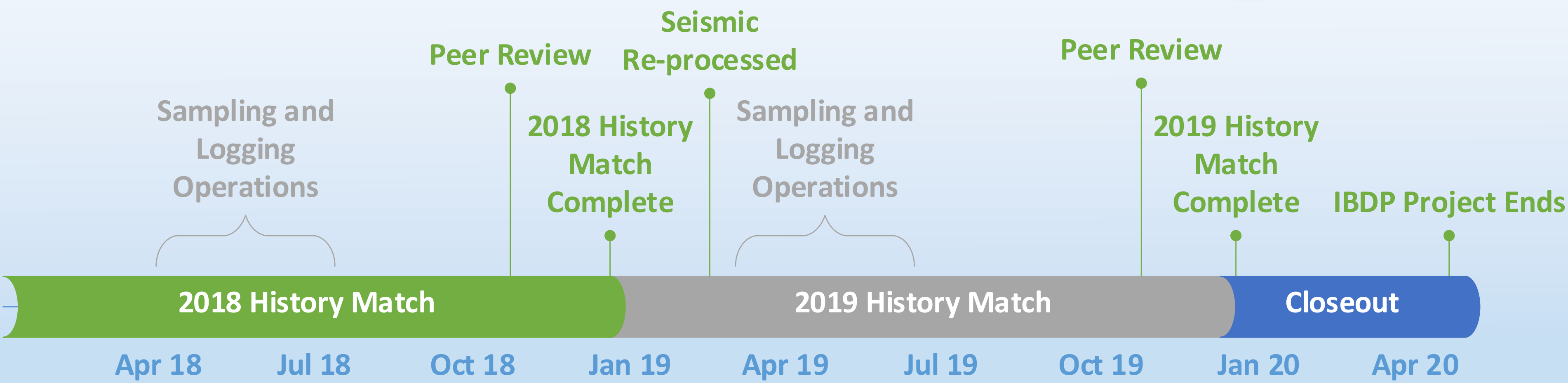
CCS1 PNX Image

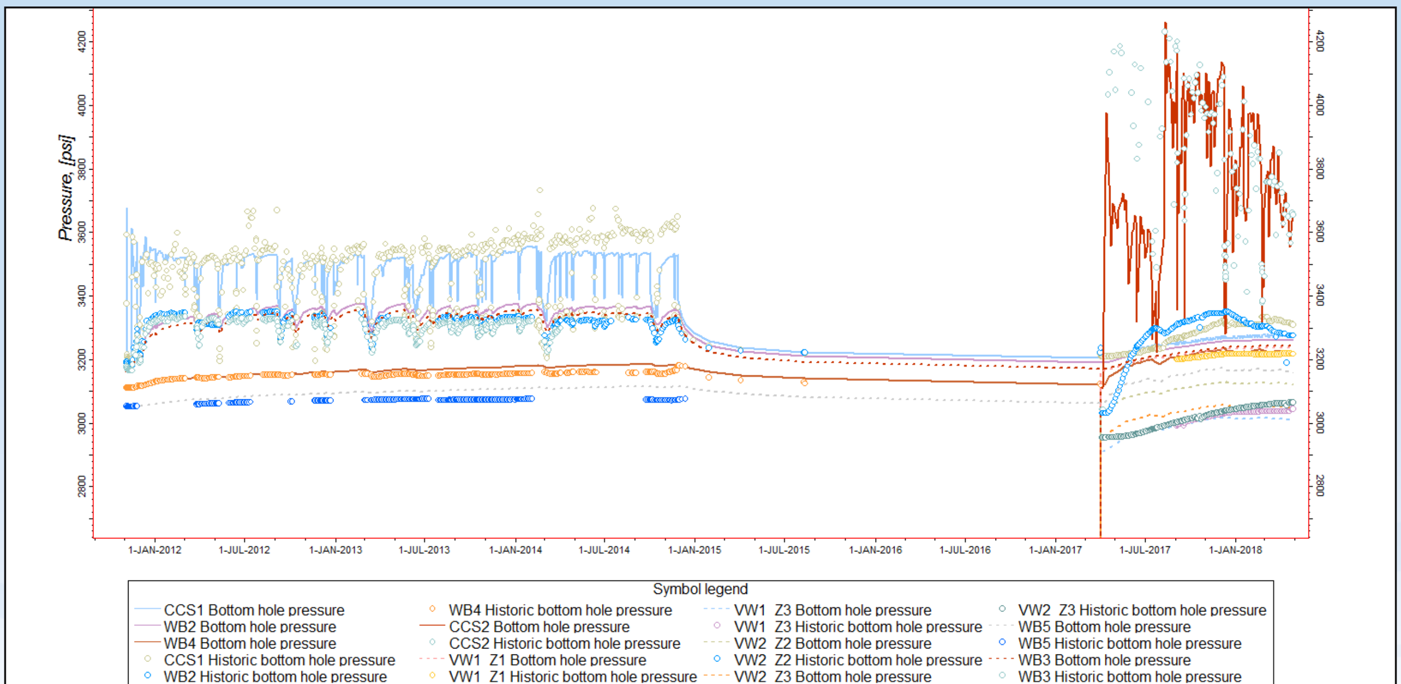


VW1 PNX Image

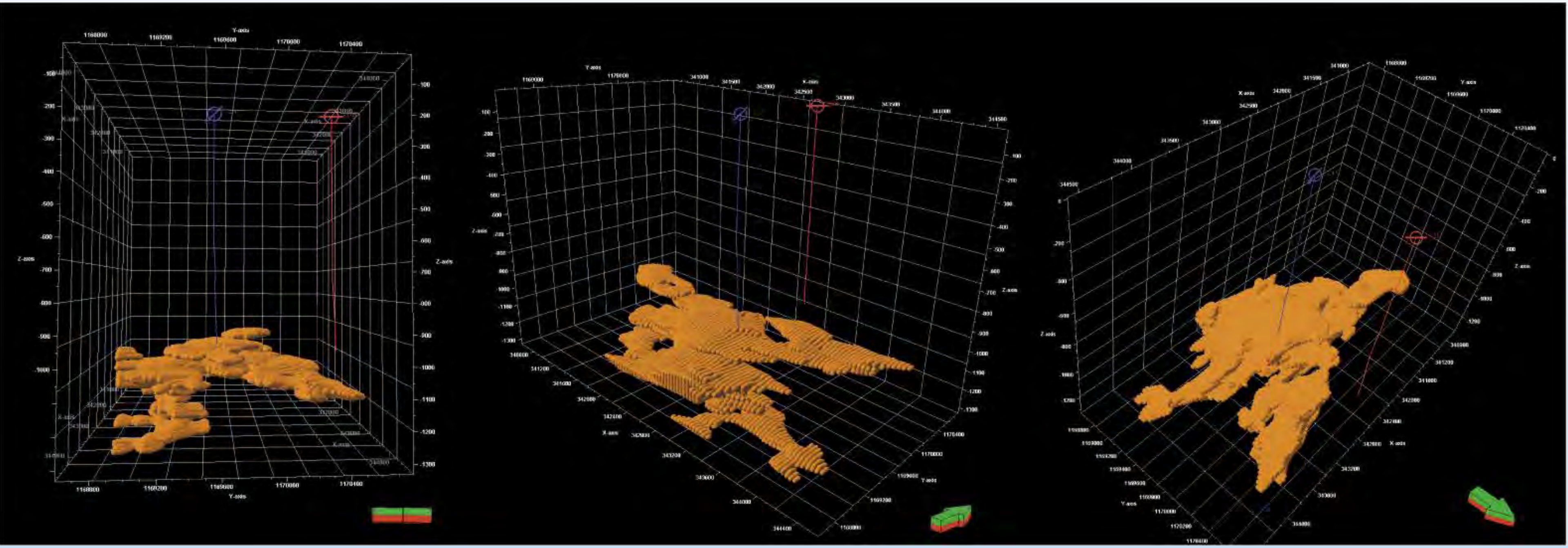


Modeling and History Matching Update





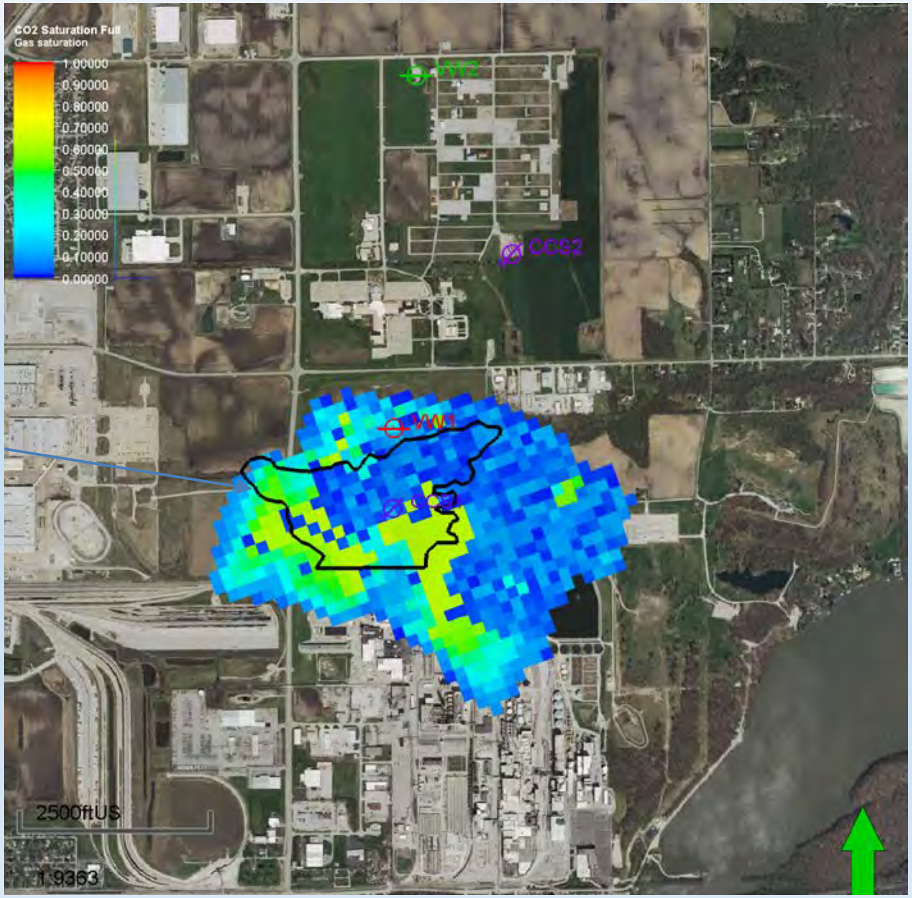
2018 Model provides greater understanding of plume



2019 modeling is expected to include:

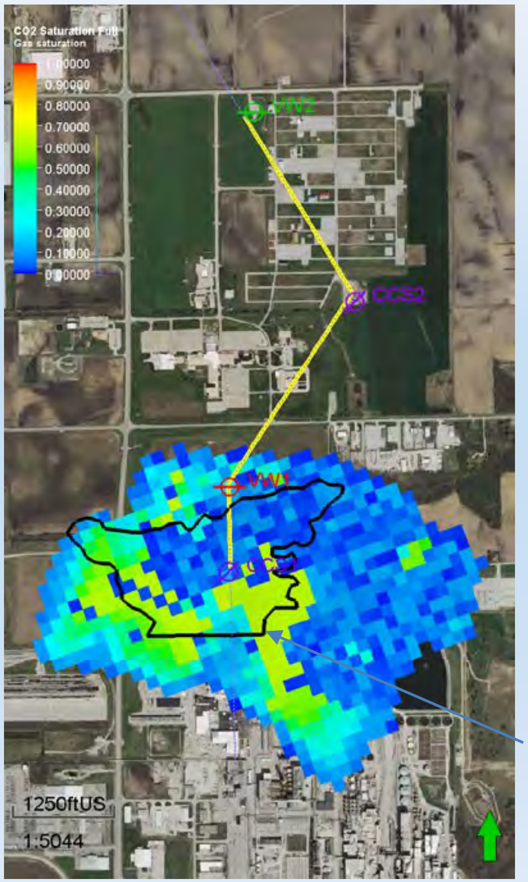
- Temperature analysis.
- Latest pressure, pulsed neutron, and log data.
- Incorporate newest seismic processing.
- A more thorough and complex set of faults.

CO_2 Plume Saturation Top Down View

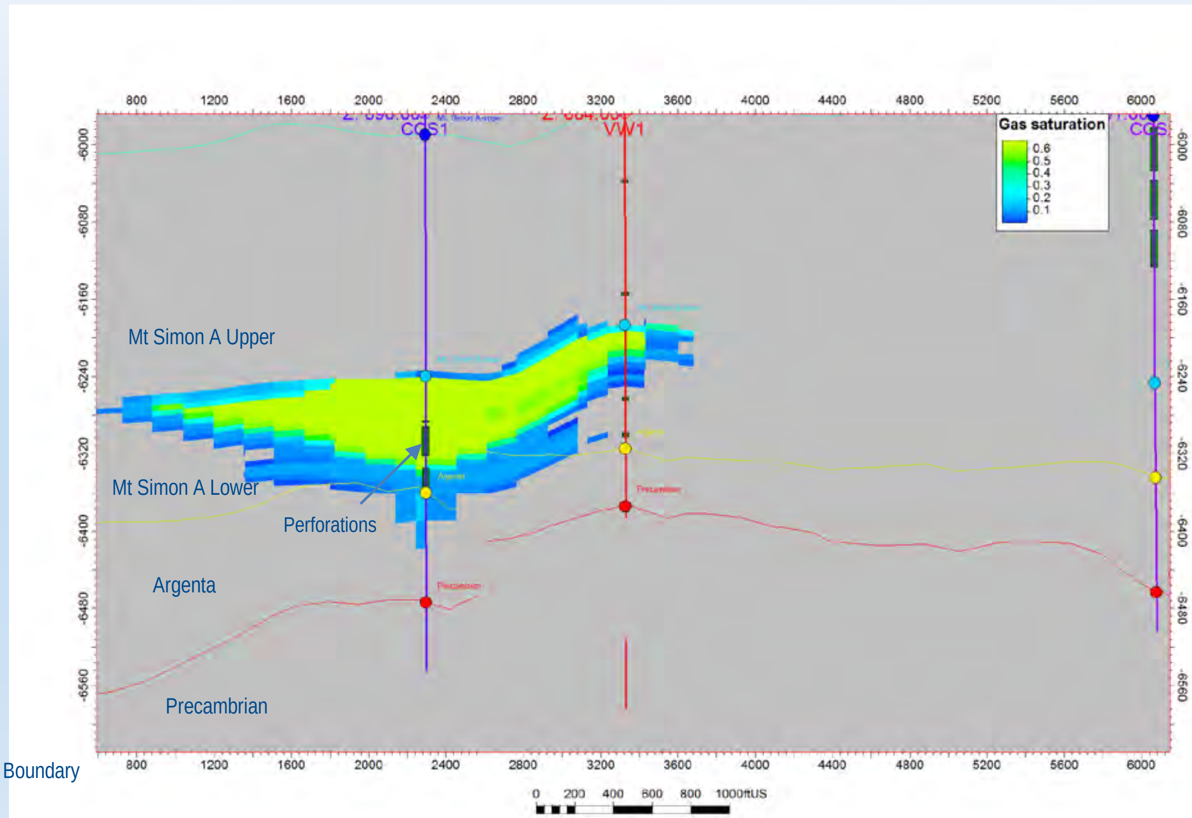


NRM Boundary

CO_2 Plume Saturation Cross Section View



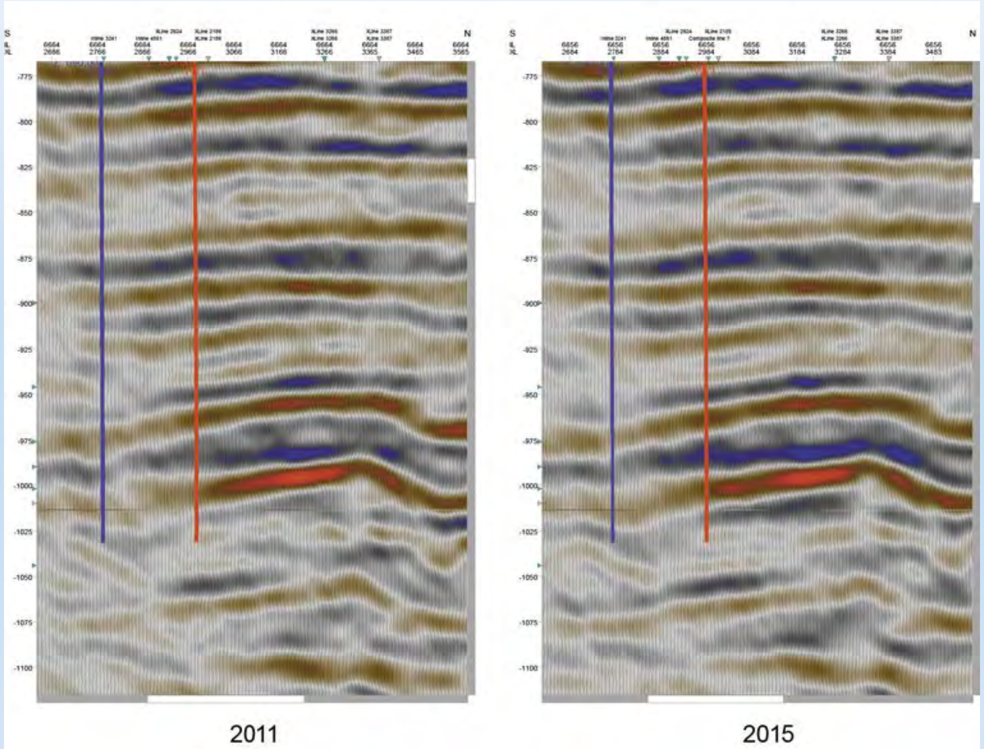
NRM Boundary



Vertical Exaggeration 5X

Taking another look at 3D seismic data

- Pre-migrated 3D seismic data showed differences in 2015 compared with 2011
- May see an indication of faulting which correlates with microseismic activity
- May not see reservoir heterogeneities with oversmoothed seismic
- Recommendation to reprocess for due diligence
- Determine if conducted inversion again now that more wells for groundtruthing



Microseismic External Review (Septemeber 2017)

The recommendations identified by the experts can be classified into three broad categories:

- Category 1: Work required for the successful completion of IBDP.
- Category 2: Future work focused on applied-strategic research opportunities
- Category 3: Future work focused on the completion of a fully-coupled seismic, geomechanical, and fluid flow model

- Category 1 recommendations:
  - Compile a summary of the existing seismic/microseismic data collection and geomechanical modeling efforts of the IBDP;
  - Conduct targeted reviews of interpretations of the existing seismic/microseismic data;
  - Document the current status of the microseismic modeling efforts and identify data gaps/needs;
  - Develop Microseismic conceptual site model (CSM); and
  - Prepare final report and peer-reviewed publication summarizing the microseismic research results of the IBDP.

Further clarification of microseismic locations

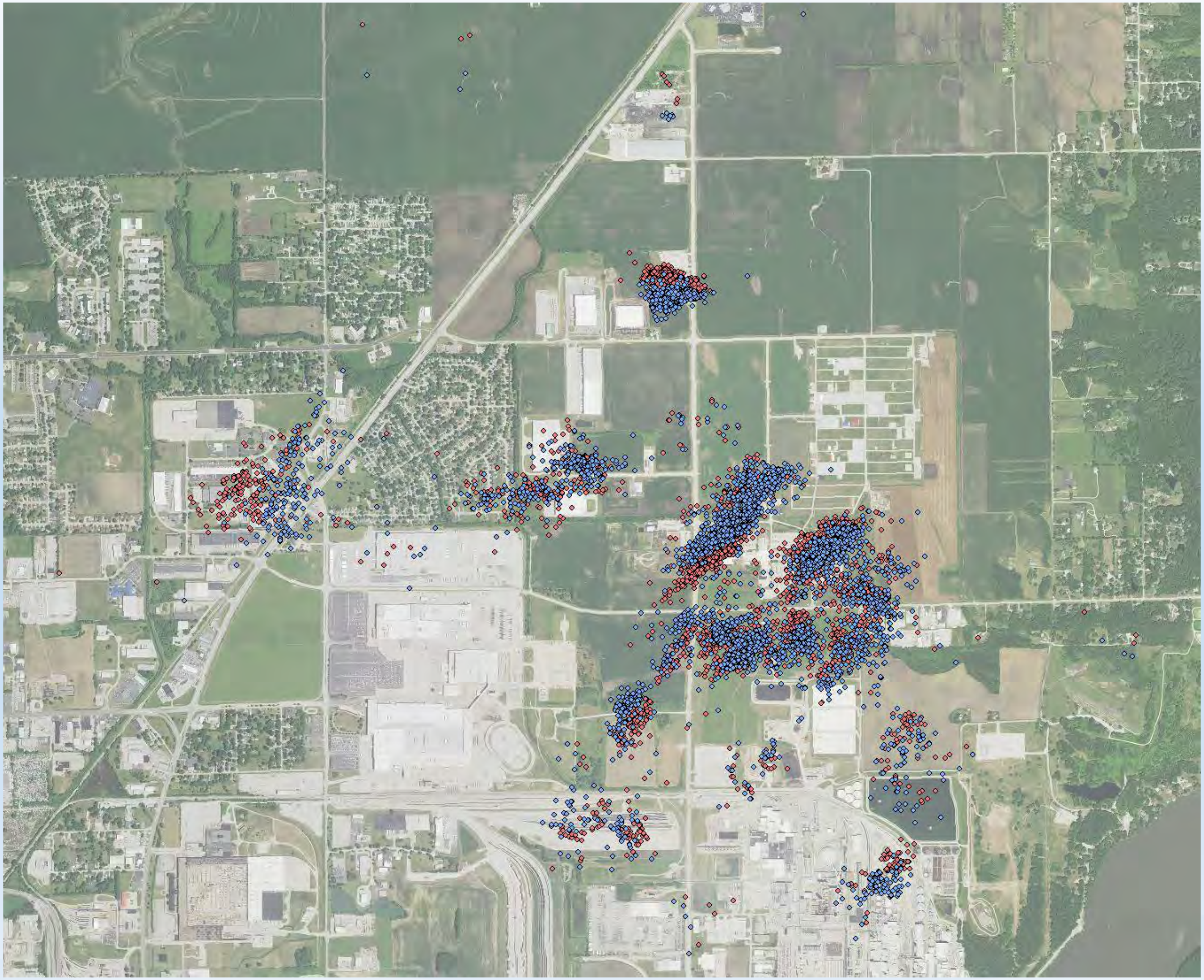
- Location changes occurred when:

- New surveys of well head locations were added along with a correction to the depth of one of the CCS#1 geophones

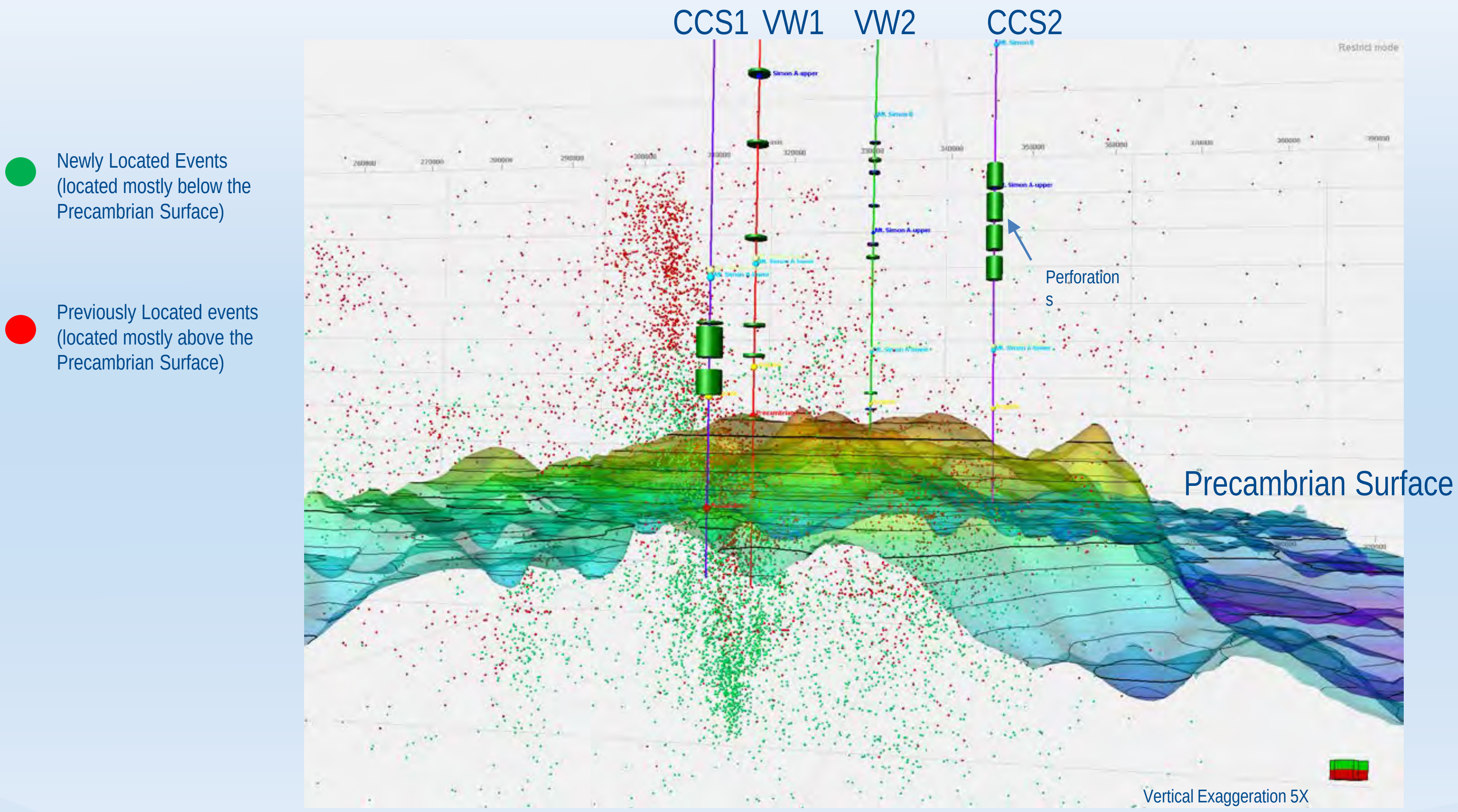
- The largest change was to the depth of the microseismic events placing them deeper by about 150 to 400 feet.

- Previously about 50% of events in Precambrian, now 80+% in Precambrian

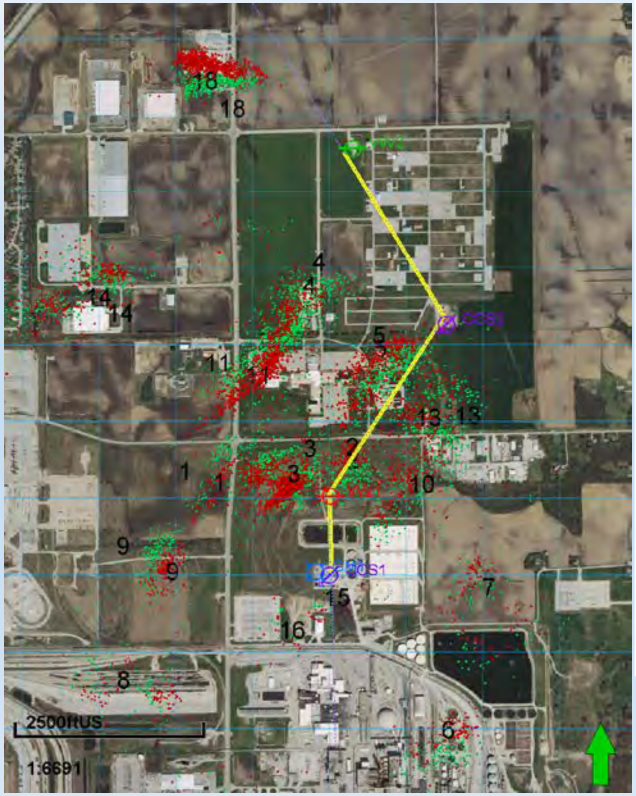
Comparison of IBDP Microseismic Event Catalogues 2017 (RED) vs 2018 (BLUE)

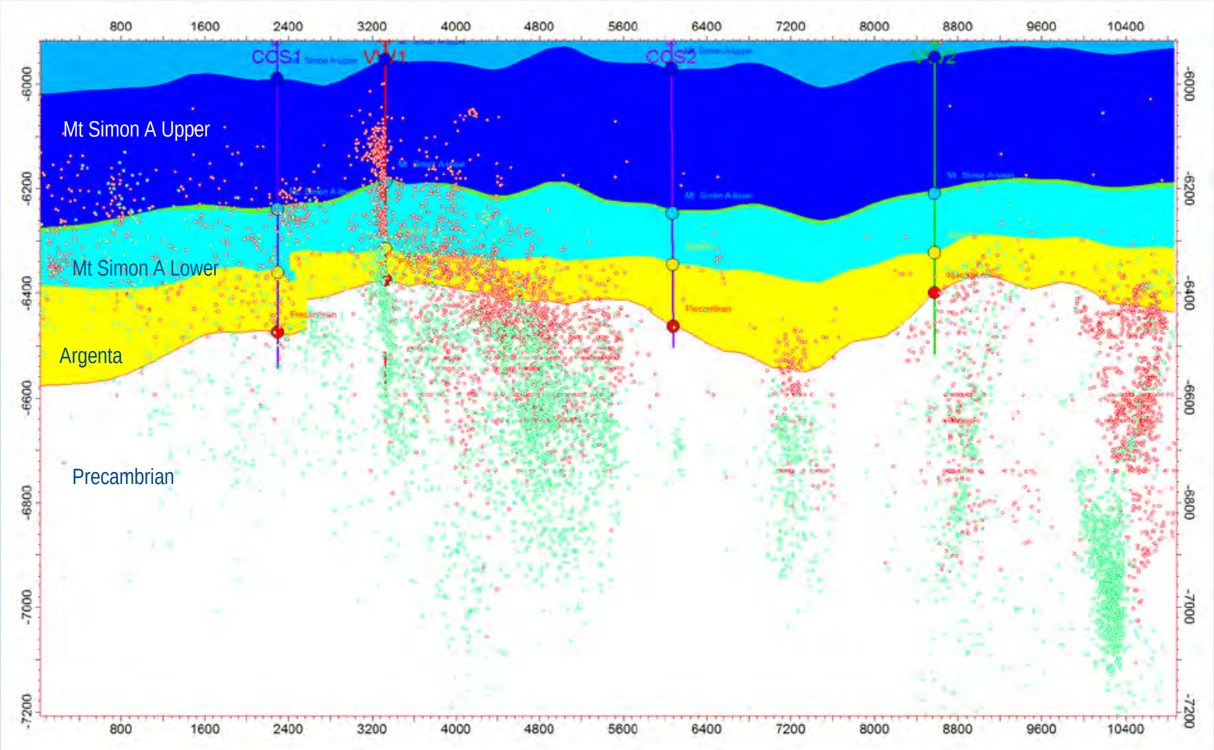


3D Looking North: Microseismic Events Newly and Previously located



2D Map and Cross Section: Microseismic Events Newly and Previously located





Events Projected 5000ft from Cross Section line

Vertical Exaggeration 5X

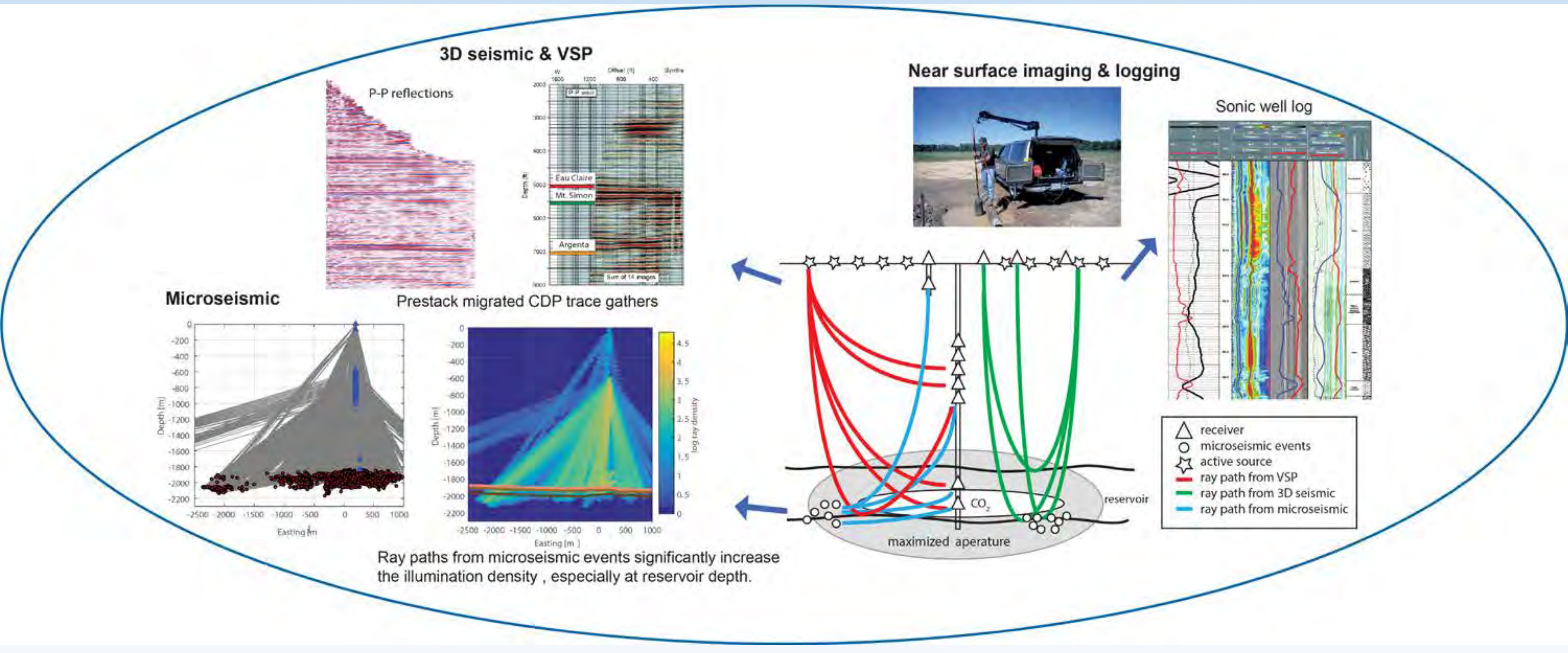
New Located Events (located mostly below the Precambrian Surface)

Previously Located events (located mostly above the Precambrian Surface)

Collaboration between US (ISGS and BEG) and Norway (NORSAR and SINTEF)

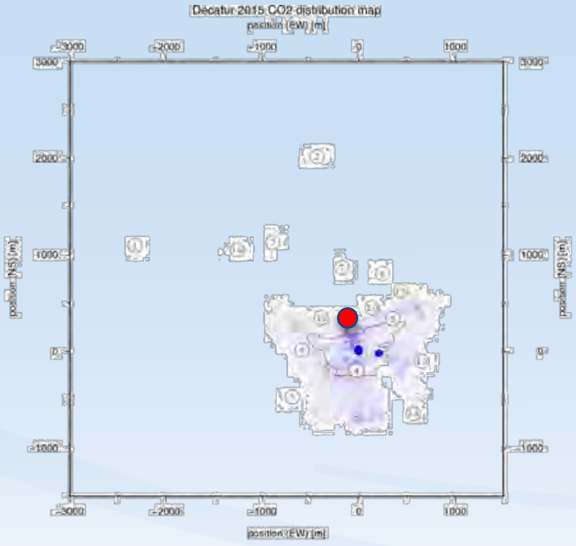
- Develop a unique seismic data analysis methodology to allow for higher resolution monitoring of the injected CO_2 for monitoring and verification.

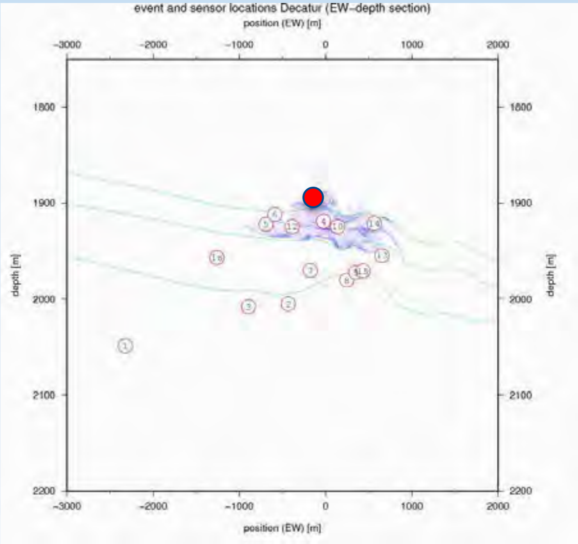
- Repeat 3D and Vertical Seismic Profiling data are combined with microseismic event data to jointly illuminate changes in and around the injection volume.

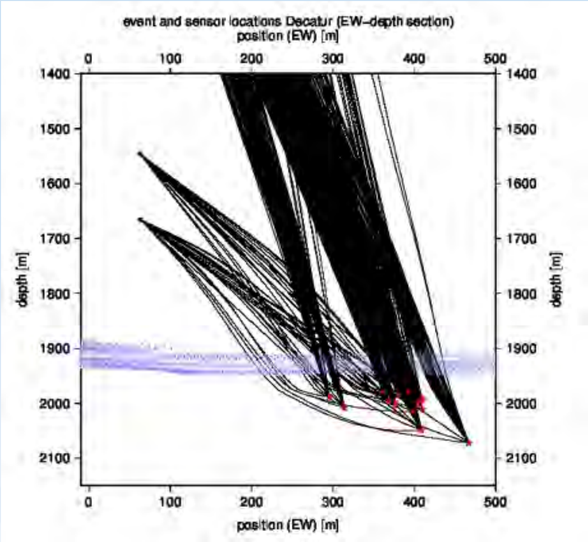


Main findings

- Analysis of temporal relationship between VSP, 2D, and 3D active seismic surveys, CO_2 injection and occurrence of repeating microseismic events.
- Multiplets (similar, repeating microseismic events) have been identified and could be used to extract medium properties.
- Due to the limited temporal resolution no temporal changes of attenuation could be resolved.
- The distribution of passive seismic sources compared to the modeled CO_2 plume together with ray tracing results suggest a limited sampling of the reservoir but may be sufficient for the attenuation/velocity inversion procedure.



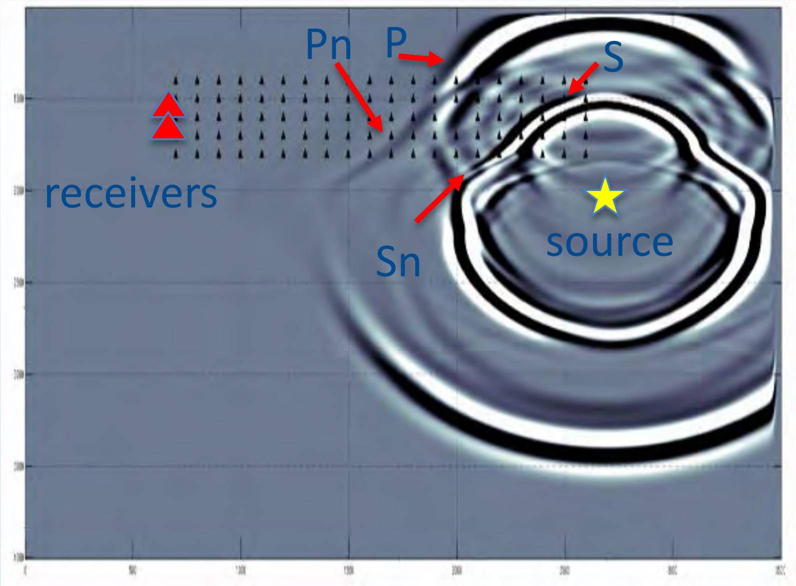




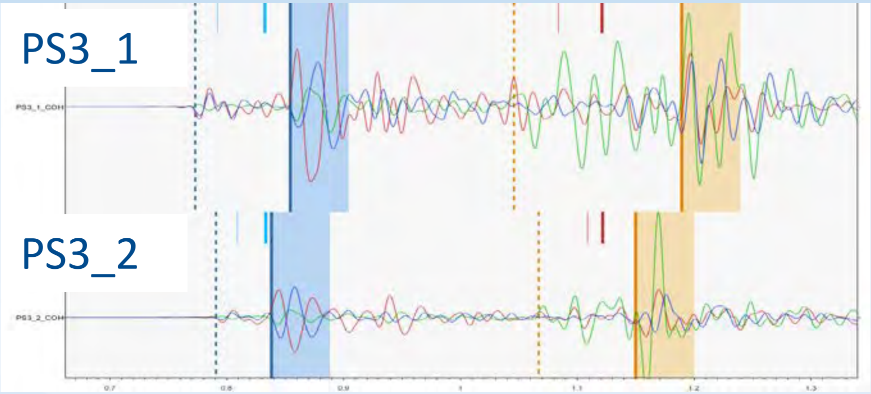
Waveform modeling

- Finite-difference waveform modeling can capture the complexity of the observed waveform very well.
- This allows us to better contrain the location of microseismic events

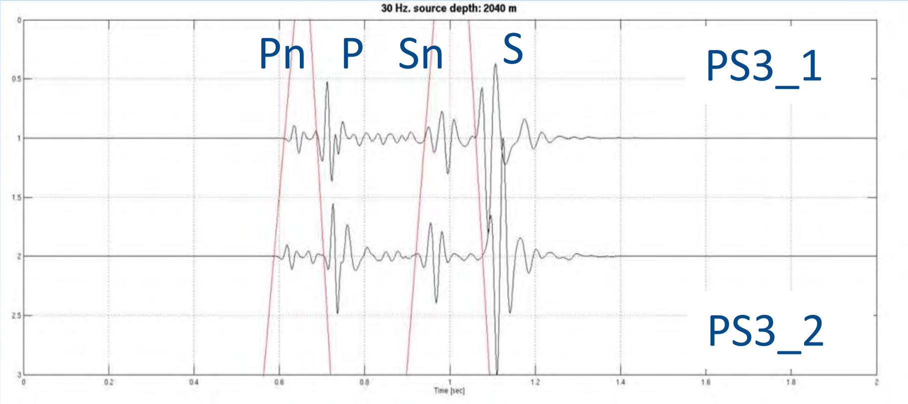
Snap-shot of wave propagation



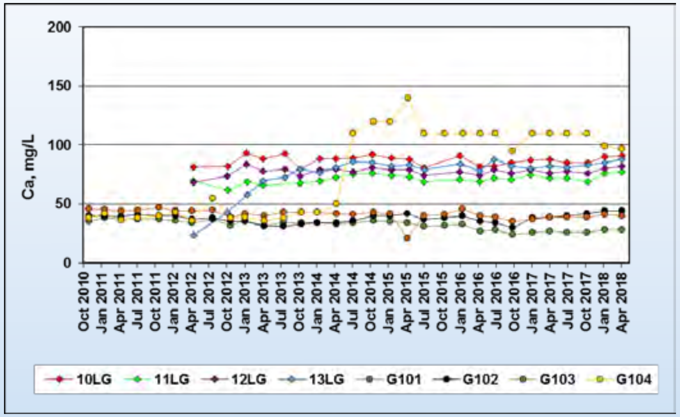
Observed waveform example at the deepest two sensors



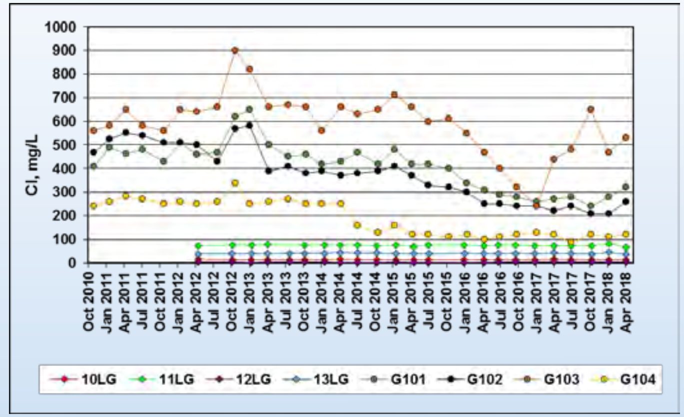
Modeled waveform



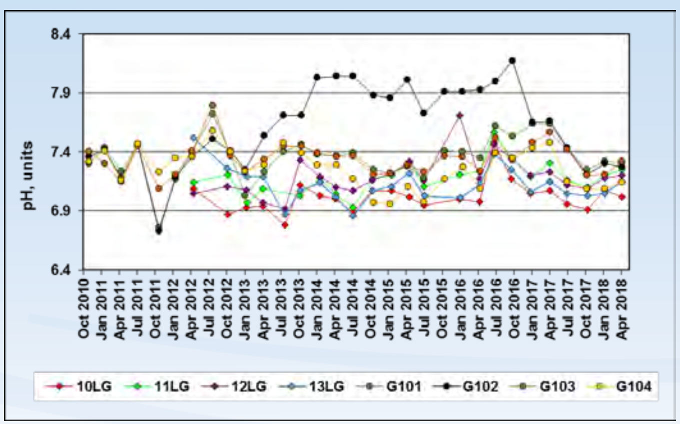
MVA Results: Interpretations of shallow groundwater data



- Calcium concentrations range from 21 to 140 mg/L
- Groundwater data suggests the Upper Glasford (avg Ca concentration = 159 mg/L) and Pennsylvanian (avg Ca concentration = 46 mg/L) strata are in moderate hydraulic communication



- Chloride concentrations in groundwater ranged from 90 to 900 mg/L
- The decreasing chloride trends observed suggests no brine intrusion into shallow groundwater



- pH values have ranged from 6.7 to 8.2
- No apparent decreasing trends in pH values, suggesting injection activities have not impacted shallow groundwater quality

Partnering with NETL for Comparison of CO_2 Detection Methods Tested in Shallow Groundwater Monitoring

In July 2018, the ISGS team collaborated with National Energy Technology Laboratory (NETL), Pittsburgh, PA

Used existing shallow monitoring well, 08S, to measure the concentration of CO_2 with a CarboQC beverage carbonation meter by monitoring temperature and pressure changes and calculating the P_{CO2} based on the ideal gas law

Installed a non-dispersive infrared (NDIR) CO_2 sensor that measures CO_2 by determining an equilibrium concentration

NDIR sensor system is equipped with a data logger and telemetry and will provide the real-time measurement of concentrations of dissolved CO_2 in a shallow groundwater environment

IBDP Cost Analysis

- Infrastructure (capture and transport) conduct by Trimeric, report available later this year.
- Subsurface and monitoring - in progress
  - Developed methodology for analysis
  - Costs analyzed from invoices for federal share of funding
  - Cost/benefit for MVA
  - Present at GHGT and invited IJGCC paper

IBDP Environmental Monitoring Framework

Near Surface			Deep Subsurface	
Atmos.	**Soil and vadose zone**	**Shallow ground water**	**Above seal**	**Injection zone**
Eddy covariance	CIR aerial imagery	Geophysical surveys	Geophysical surveys	Geophysical surveys
Meteorological conditions	InSAR and GPS	Geochemical sampling	Geochemical sampling	Geochemical sampling
Ambient CO_2	Soil gases	P/T monitoring	P/T monitoring	P/T monitoring
Tunable diode laser for CO_2	Soil CO_2 flux			
	Tunable diode laser for CO_2			

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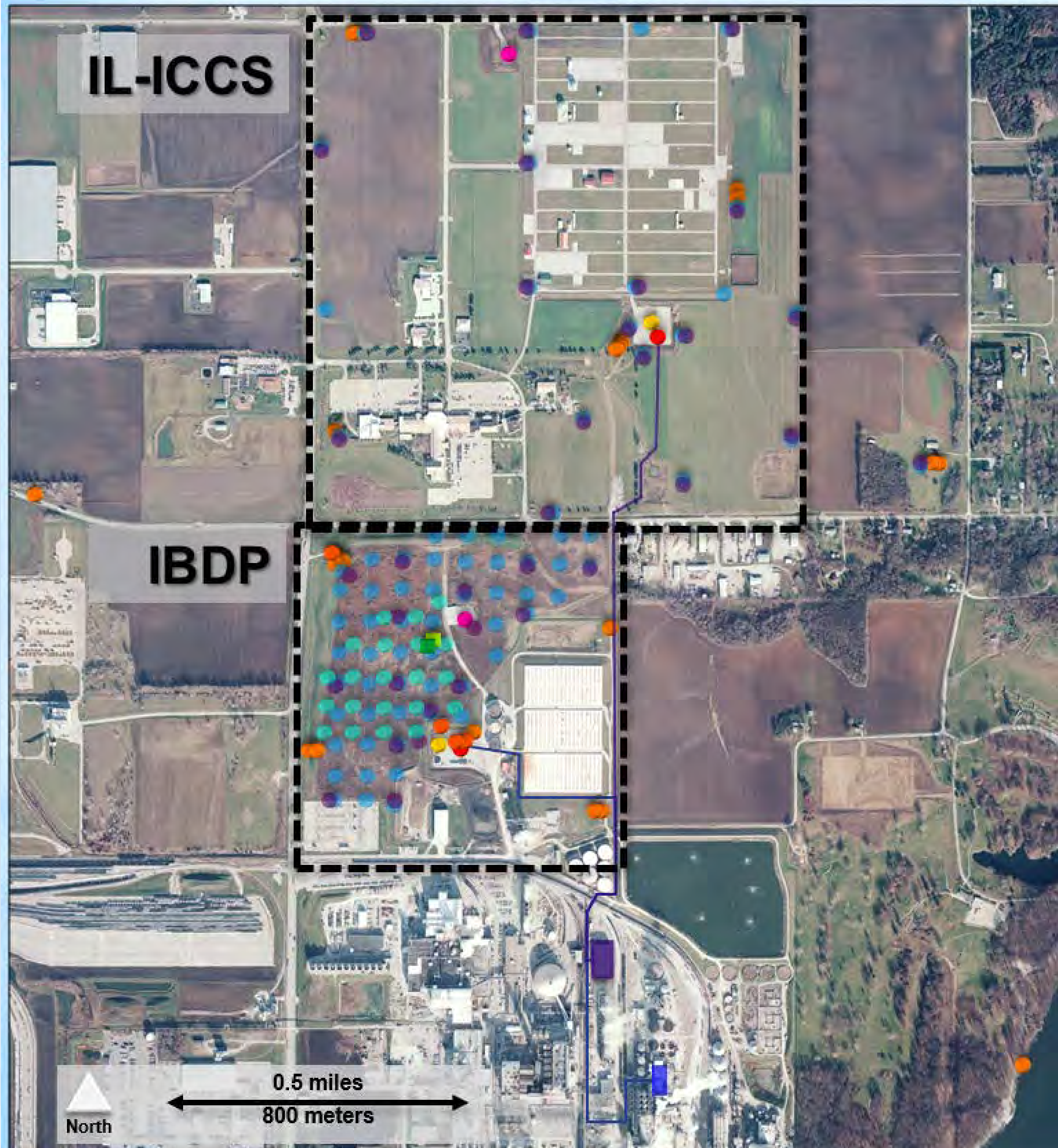
Environmental Monitoring Framework

Near Surface		Deep Subsurface		
Atmos.	**Soil and vadose zone**	**Shallow ground water**	**Above seal**	**Injection zone**
Eddy covariance Meteorological conditions Ambient CO_2 Tunable diode laser for CO_2	CIR aerial imagery InSAR and GPS Soil gases Soil CO_2 flux Tunable diode laser for CO_2	Geophysical surveys Geochemical sampling P/T monitoring	Geophysical surveys Geochemical sampling P/T monitoring	Geophysical surveys Geochemical sampling P/T monitoring

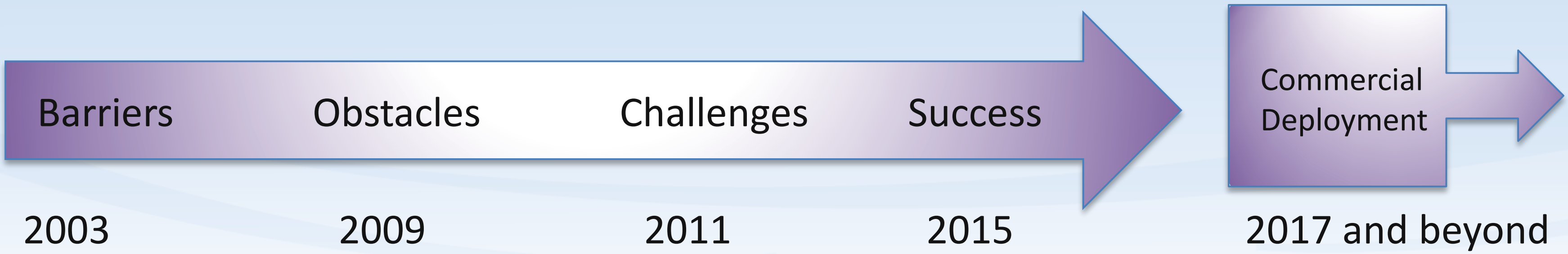


Monitoring Summary

- Injection wells (2)
- Verification wells (2)
- Geophysical wells (2)
- Compliance wells (4)
- Research wells (24)
- Soil gas points (35)
- Soil flux points (145)
- Eddy covariance station (1)
- Continuous GPS station (1)
- InSAR artificial reflectors (21)

What We've Learned:

- Carbon capture and storage from biofuel sources in deep saline reservoirs can be conducted safely
- Research and scale-up demonstration projects can lead directly to industrial-scale or commercial-scale projects
- The Mt. Simon Sandstone is a viable and important deep saline storage resource for the US
- Establishment of an MVA baseline is critical to characterize site and reduce project risk, but needs to be revisited on a regular basis
- Permitting can be time intensive and should not be underestimated as a potential project risk
- Economy of scale learnings essential to commercial CCS deployment



MGSC and IBDP Future Steps

- Active interest from partners within region to pursue CCUS
- Compliance phase of post-injection monitoring – April 2020 (tied to start of ADM Industrial CCS Sources project)
- Address microseismic research review recommendations
- Reprocess seismic
- Final integration and completion of geologic and reservoir models (2019)
- Knowledge sharing and capacity building
- Publication of IBDP technical papers
- Publication of IBDP project experience and learnings book

Acknowledgements

- The Midwest Geological Sequestration Consortium is funded by the U.S. Department of Energy through the National Energy Technology Laboratory via the Regional Carbon Sequestration Partnership Program (contract number DE-FC26-05NT42588)
- The MGSC is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky
- CarbonSAFE Illinois projects are funded by the U.S. Department of Energy through the National Energy Technology Laboratory

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