EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

Updates on Integrated Carbon Capture, Utilization, and Storage (CCUS) Projects in North Dakota

January 24, 2023

Charles D. Gorecki, CEO

OUR VISION

TO LEAD THE WORLD IN
DEVELOPING SOLUTIONS
TO ENERGY AND ENVIRONMENTAL CHALLENGES.

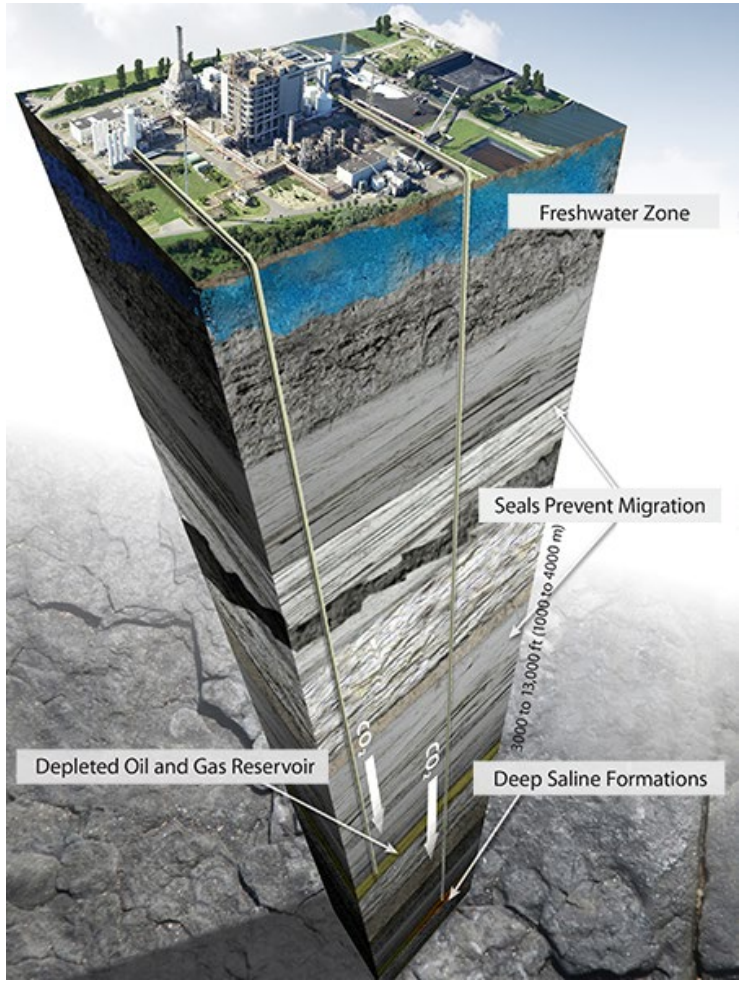
OUR FACILITIES

254,000 SQ. FT. OF FACILITIES

DIVERSE EXPERTISE

AND CAPABILITIES TO IMPACT THE WORLD

CO_2 CAN BE MANAGED



PLAINS CO_2 REDUCTION (PCOR) PARTNERSHIP

2003–2005 – PCOR Partnership: Characterization

2005–2008 – PCOR Partnership: Field Validation

2007–2019 – PCOR Partnership: Commercial Demonstration

2019–2024 – **PCOR Partnership Initiative:** Commercial Deployment

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Institute of Northern Engineering
University of Alaska Fairbanks

University of Wyoming | School of Energy Resources

EERC | University of North Dakota

PCOR Partnership PARTNERSHIP MEMBERS

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

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North Dakota Industrial Commission

UAF Institute of Northern Engineering, University of Alaska Fairbanks

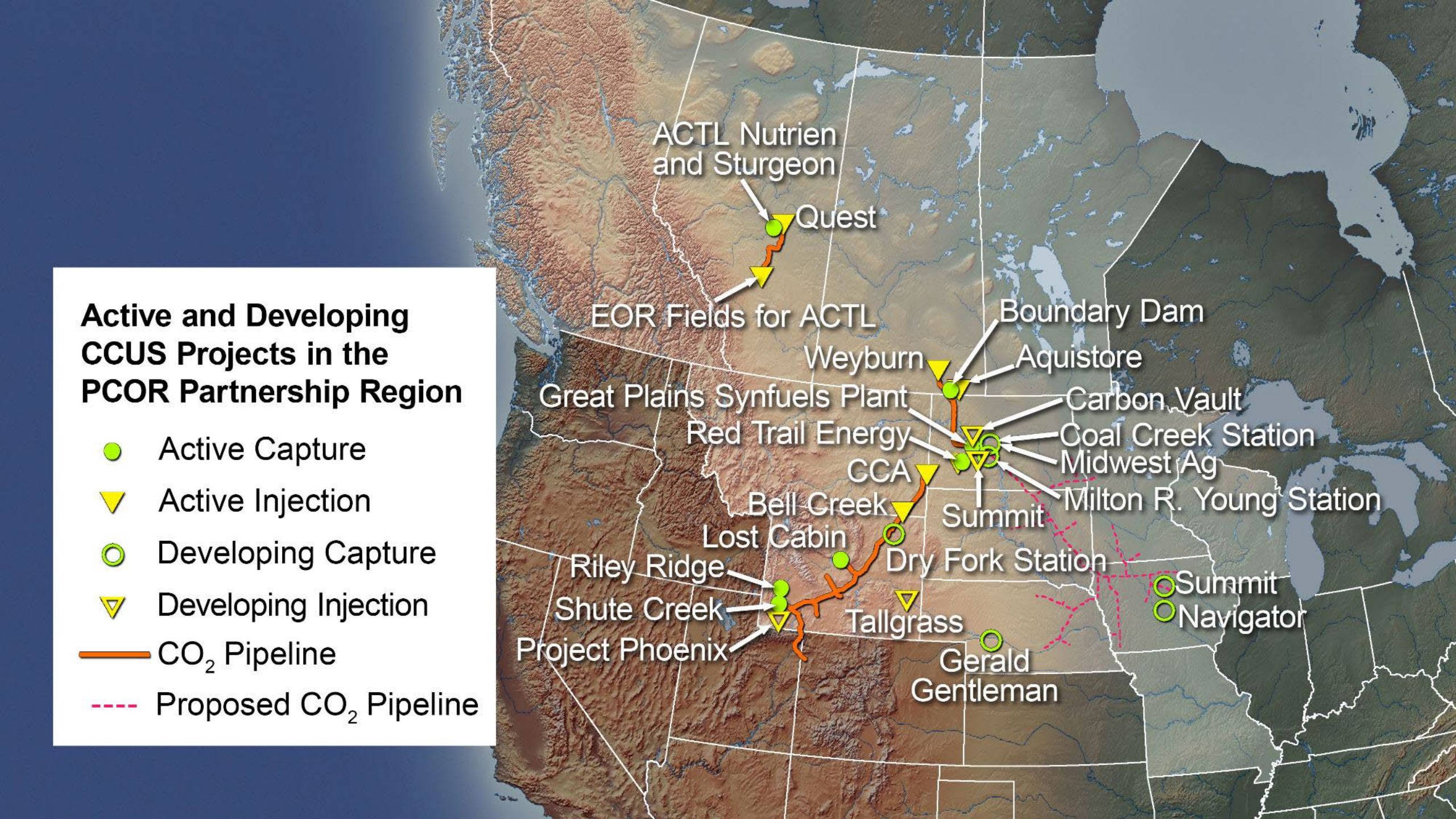
University of Wyoming, School of Energy Resources

ABENGOA BIOENERGY
ADVANCED GEOTECHNOLOGY
AES Think Big. Go Beyond.
AIR PRODUCTS
Alberta Energy
AGS ALBERTA GEOLOGICAL SURVEY
ALBERTA INNOVATES
ALLETE
ALLETE clean energy
Ameren
ACCCE AMERICAN COALITION FOR CLEAN COAL ELECTRICITY
AMERICAN LIGNITE ENERGY
Apache
Aquistore
aramco
ARCTECH Balanced Sustainable Solutions
ATCO Power
AVISTA
BAKER HUGHES a GE company
BAKKEN ENERGY
BALLANTYNE OIL • GAS • LLC
BARR
BASIN ELECTRIC POWER COOPERATIVE
BC Oil & Gas COMMISSION
BECHTEL
BillyJack CONSULTING INC.
Biorecro
BLACK & VEATCH
bluesource
BNI energy AN ALLETE COMPANY
bp
BRITISH COLUMBIA
BURNS McDONNELL
C12 Energy
CarbonAlpha
Carb.in America
CURC CARBON UTILIZATION RESEARCH COUNCIL ADVANCING FOSSIL ENERGY SOLUTIONS
CARBON VAULT
Carbon Ventures LLC
CATAHOULA RESOURCES
CERILON For a greener, cleaner future
Chevron
CCX Chicago Climate Exchange
CLASS VI SOLUTIONS
CLEARPATH
CMC RESEARCH INSTITUTES
CMG COMPUTER MODELLING GROUP LTD.
CO_2 SeQure
CO_2 SOLUTIONS
COLORADO Oil & Gas Conservation Commission
Constellation.
Continental RESOURCES
C-QUEST
CSIRO
DAKOTA GASIFICATION COMPANY A BASIN ELECTRIC POWER COOPERATIVE SUBSIDIARY
DARKVISION
DELFT INVERSION
Denbury
devon
DUCKS UNLIMITED
Ducks Unlimited Canada Conserving Canada's Wetlands
EEnergy ADAMS
Eagle Operating Inc.
EASTERN IOWA COMMUNITY COLLEGES
Elysian
ENBRIDGE
Encore Acquisition Company
energy CAPITAL Economic Development
ERCB Energy Resources Conservation Board
enerPLUS
Enhanced Oil Recovery Institute UNIVERSITY OF WYOMING
eni
Environment Canada
equinor
ES XPLORE
EXCELSIOR ENERGY
ExxonMobil
Fischer Oil and Gas, Inc.
GE
GREAT NORTHERN
GREAT RIVER ENERGY
GROUNDMETRICS
HALLIBURTON
HAM'S
HESS
Hilcorp Alaska
HITACHI Inspire the Next
HUNTSMAN
Husky Energy
HYDROGEN NATURALLY
INL Idaho National Laboratory
INDIAN LAND TENURE FOUNDATION
InnoTech ALBERTA
INTERSTATE Oil & Gas COMPACT COMMISSION
ION ENGINEERING
DNR
Jackson Walker
Kiewit
KLJ
KCRC
LIBERTY
Lignite Energy Council
Los Alamos NATIONAL LABORATORY EST. 1943
Manitoba Hydro
Manitoba Innovation, Energy and Mines
MARATHON
MarathonOil
MBI Energy Services
MEG ENERGY
Melzer Consulting
MTR MEMBRANE TECHNOLOGY & RESEARCH
metso
MIDWEST AgEnergy
MIDWEST GENERATION
Minnesota Pollution Control Agency
Minnesota power
MINNESOTA PUBLIC UTILITIES COMMISSION
Minnkota Power COOPERATIVE
MISSOURI DEPARTMENT OF NATURAL RESOURCES
MISSOURI RIVER ENERGY SERVICES
DEQ Montana Department of Environmental Quality
MONTANA BOARD OF OIL AND GAS CONSERVATION
MONTANA-DAKOTA UTILITIES CO.
MUREX PETROLEUM CORPORATION
NATIONAL COMMISSION ON ENERGY POLICY
Natural Resources Canada
Nebraska Public Power District
NESET
NSG NEUMANN SYSTEM GROUP, INC.
Nexant
NEXTSTREAM
NITEC LLC
NORTH AMERICAN COAL CORPORATION
NORTH DAKOTA'S BUILDING TRADES UNIONS
North Dakota DEPARTMENT OF COMMERCE
North Dakota Environmental Quality
NORTH DAKOTA GEOLOGICAL SURVEY
Natural Resources Trust
NORTH DAKOTA OIL AND GAS DIVISION
NORTH DAKOTA PETROLEUM COUNCIL
NDPA North Dakota Pipeline Association
NORTH DAKOTA PIPELINE AUTHORITY
North Dakota Public Service Commission
NDSU NORTH DAKOTA STATE UNIVERSITY
NorthWestern Energy
Nuverra Environmental Solutions
OXY Occidental Petroleum
OPPD Omaha Public Power District
ONEOK
OTTER TAIL POWER COMPANY
Pennsylvania Pipeline Inc.
xand Risk Management Solutions
Pacific Northwest NATIONAL LABORATORY
PACIFICORP
Peabody ENERGY
petro harvester
PETROBRAS
ptrc Petroleum Technology Research Centre
Pinnacle A HALLIBURTON SERVICE
PTTC TECHNOLOGY | CONNECTIONS
Portland General Electric
ppl
Prairie Public
Pratt & Whitney A United Technologies Company
PRAXAIR Making our planet more productive
PSC of WISCONSIN
PUGET SOUND ENERGY
RAINBOW ENERGY CENTER
RAMGEN POWER SYSTEMS
REPSOL
RESOLUTE ENGINEERING
Rockall
RPS Energy
Saskatchewan Industry and Resources
Saskatchewan Ministry of Energy and Resources
SaskPower
Schlumberger
SCOUT
seismos
SEJONG UNIVERSITY
Shell Canada Limited
Shell Cansolv
SILIXA sense the difference
SIMTECH
SOG Resources
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
South Dakota Public Utilities Commission
Spectra Energy
STATE OF WYOMING Clean Coal Technology Fund
Steiner Oil & Gas, LLC
STRATEGIC WEST ENERGY LTD.
STRYDE
SULZER
SUMMIT CARBON SOLUTIONS
SUNCOR ENERGY
TALEN ENERGY
TALLGRASS
TAQA
TC Energy
TESORO
TGS
The CETER Group, Inc.
TransAlta
Tri-Mer CORPORATION
TRI-STATE G&T A Touchstone Energy Cooperative
TUNDRA OIL & GAS
UNIVERSITY OF ALBERTA
University of Regina
Enhanced Oil Recovery Institute UNIVERSITY OF WYOMING
USGS science for a changing world
VAULT 44.01
WBI ENERGY
Weatherford
WESTERN GOVERNORS ASSOCIATION
WESTMORELAND COAL COMPANY
WHITE ROCK OIL & GAS
WHITECAP RESOURCES INC
WHITING
Woodside
DEQ WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
Wyoming INFRASTRUCTURE AUTHORITY
ITC WYOMING INTEGRATED TEST CENTER
WYOMING MINING ASSOCIATION
Wyoming Public Service Commission
Xcel Energy RESPONSIBLE BY NATURE
BKV
RITE
TERRACOH

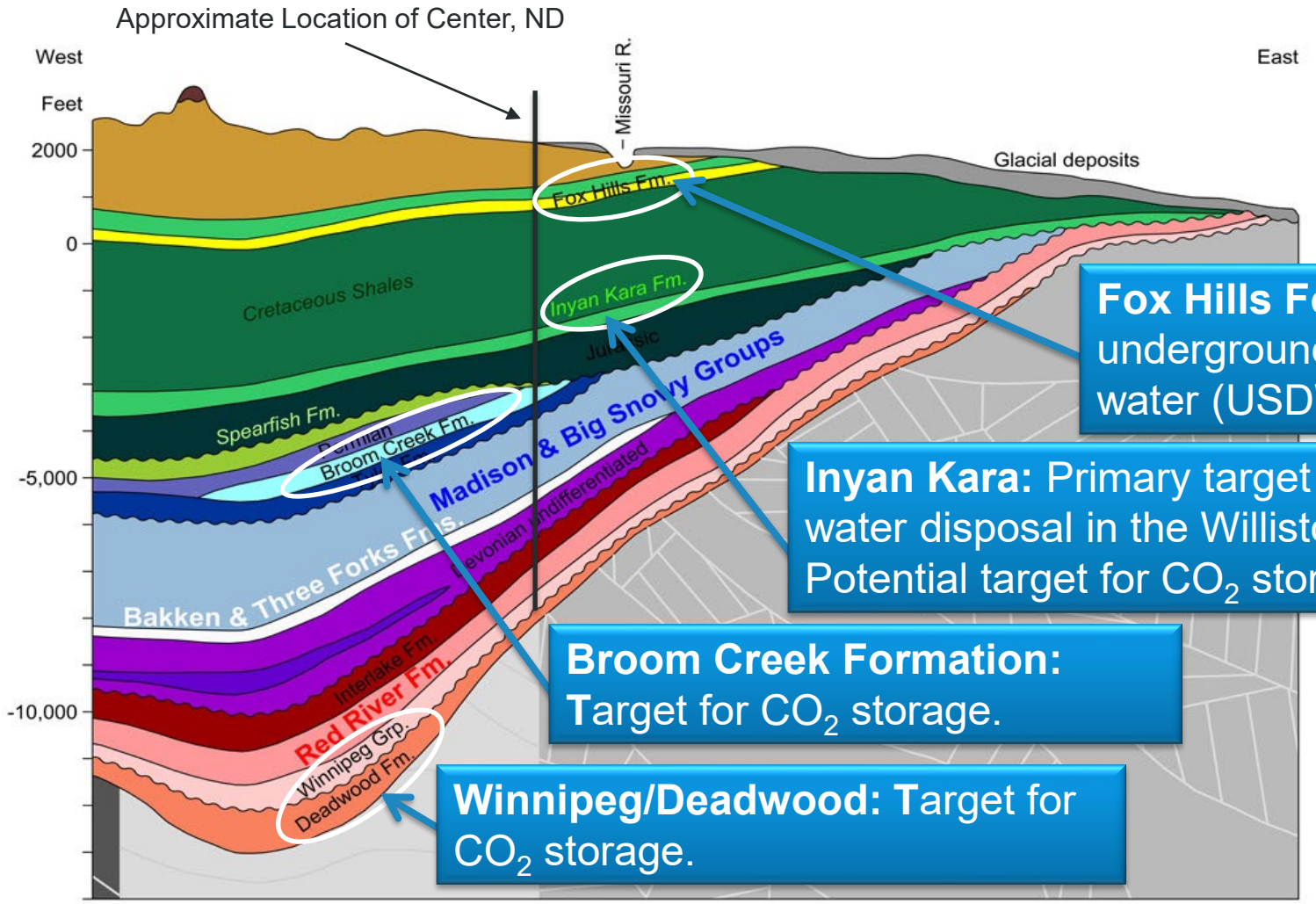
08/22

SAMPLING OF PUBLIC–PRIVATE PARTNERSHIP PROJECTS THAT THE EERC HAS PARTNERED ON WITH INDUSTRY TO ENABLE CCUS (SINCE 2003)*

* Does not include direct contract work to support commercial CCUS project development and implementation without a publicly funded component.


Active and Developing CCUS Projects in the PCOR Partnership Region
Active Capture
Active Injection
Developing Capture
Developing Injection
CO_2 Pipeline
Proposed CO_2 Pipeline
ACTL Nutrien and Sturgeon
Quest
EOR Fields for ACTL
Boundary Dam
Weyburn
Aquistore
Great Plains Synfuels Plant
Carbon Vault
Red Trail Energy
Coal Creek Station
Midwest Ag
CCA
Milton R. Young Station
Bell Creek
Summit
Lost Cabin
Dry Fork Station
Riley Ridge
Summit
Navigator
Shute Creek
Tallgrass
Project Phoenix
Gerald Gentleman

WILLISTON BASIN SALINE STORAGE OPPORTUNITIES



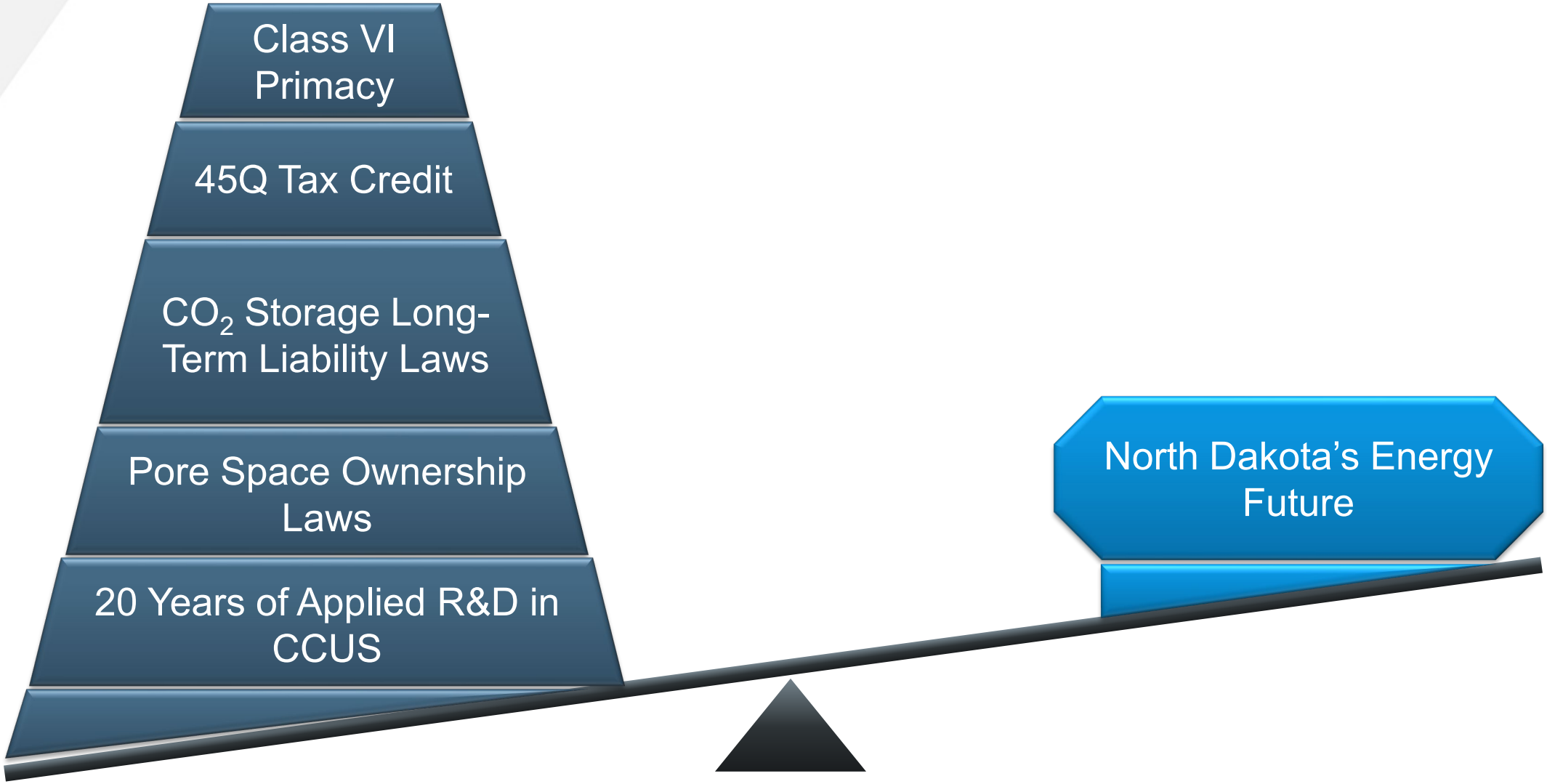
Fox Hills Formation: Lowest underground source of drinking water (USDW).

Inyan Kara: Primary target for produced water disposal in the Williston Basin. Potential target for CO_2 storage.

Broom Creek Formation: Target for CO_2 storage.

Winnipeg/Deadwood: Target for CO_2 storage.

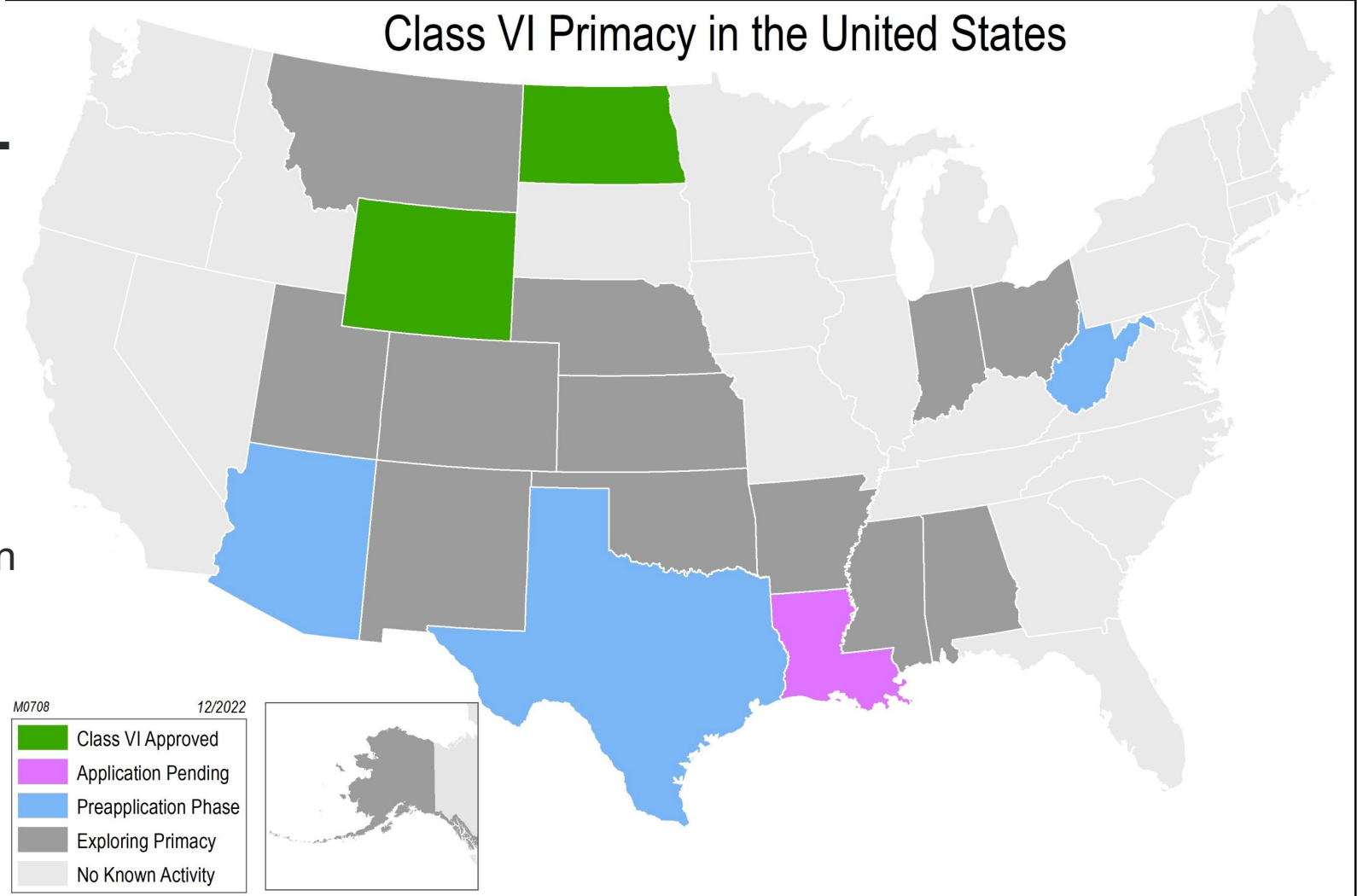
NORTH DAKOTA'S LEVERAGE



UNDERGROUND INJECTION CONTROL (UIC) Program

UIC Program Standards:

1) **Protection of USDW**
2) Injection zone
3) Confining zones (upper and lower)
4) Area of review and corrective action
5) Wellbore integrity demonstration



Class I	Class II	Class III	Class IV	Class V	Class VI
Hazardous and nonhazardous fluids (industrial and municipal wastes).	Brines and other fluids associated with oil and gas production, including CO_2 EOR.	Fluids associated with solution mining of minerals.	Hazardous or radioactive wastes. This class is banned by EPA.	Nonhazardous fluids into or above a USDW and are typically shallow.	Injection of CO_2 for long-term storage.

INCENTIVES

45Q Tax Credits

- Projects beginning construction before January 1, 2033, can claim credits for 12 years after operations begin.
- Provides for direct payment for 45Q credits.
- Tax credit for CO_2 stored in a qualified enhanced oil recovery (EOR) project: $60/tonne.
  - Tax credit from direct air capture (DAC): $130/tonne.
- Tax credit for CO_2 stored in a saline formation: $85/tonne.
  - Tax credit from DAC: $180/tonne.

West Coast LCFS Markets

- Credits trading up to $80–$220 per ton (June 2021–2022).
- Stacked with 45Q.

North Dakota Incentives

- No sales tax on capture-related infrastructure.
- No sales tax on CO_2 sold for EOR.
- No sales tax on construction of pipeline.
- Property tax-exempt for 10 years (equipment).
- Coal conversion tax: tax reduction with CO_2 capture (up to 50%).
- No sales tax on CO_2 EOR infrastructure.
- 0% extraction tax for 20 years for CO_2 EOR.

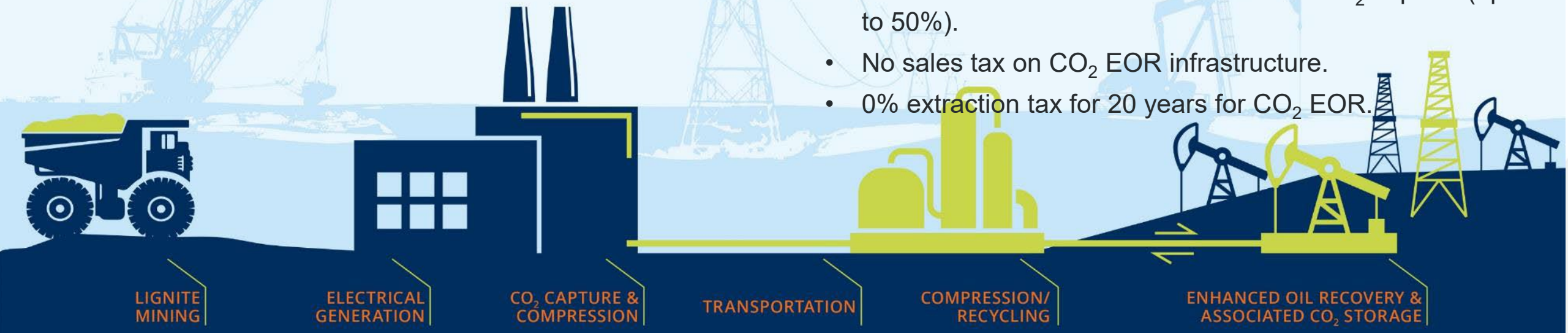


Image Credit – EERC

ANCILLARY REGULATORY MECHANISMS FACILITATE INDUSTRIAL CCUS

Carbon dioxide storage facility administrative fund ($0.01/ton): administer program.

Carbon dioxide storage facility trust fund ($0.07/ton): postinjection compliance and long-term liability.

Amalgamation of pore space (forced at 60%).

Final decision issued within 12 months of the date a submitted carbon storage facility permit (SFP) application is deemed complete.

State issues certificate of project completion (all criteria met – at least 10 years postinjection).

- Releases responsibility, regulatory requirements, and bonds.
- Transfer of title and custody to storage facility and stored CO_2 to state.
- State oversees/responsible for monitoring and managing the storage facility until such time as federal government assumes responsibility (assures site access/confidence).

State retains all authority to regulate future mineral and UIC activities.

- Preserve the integrity of storage facility (guard against recapture).

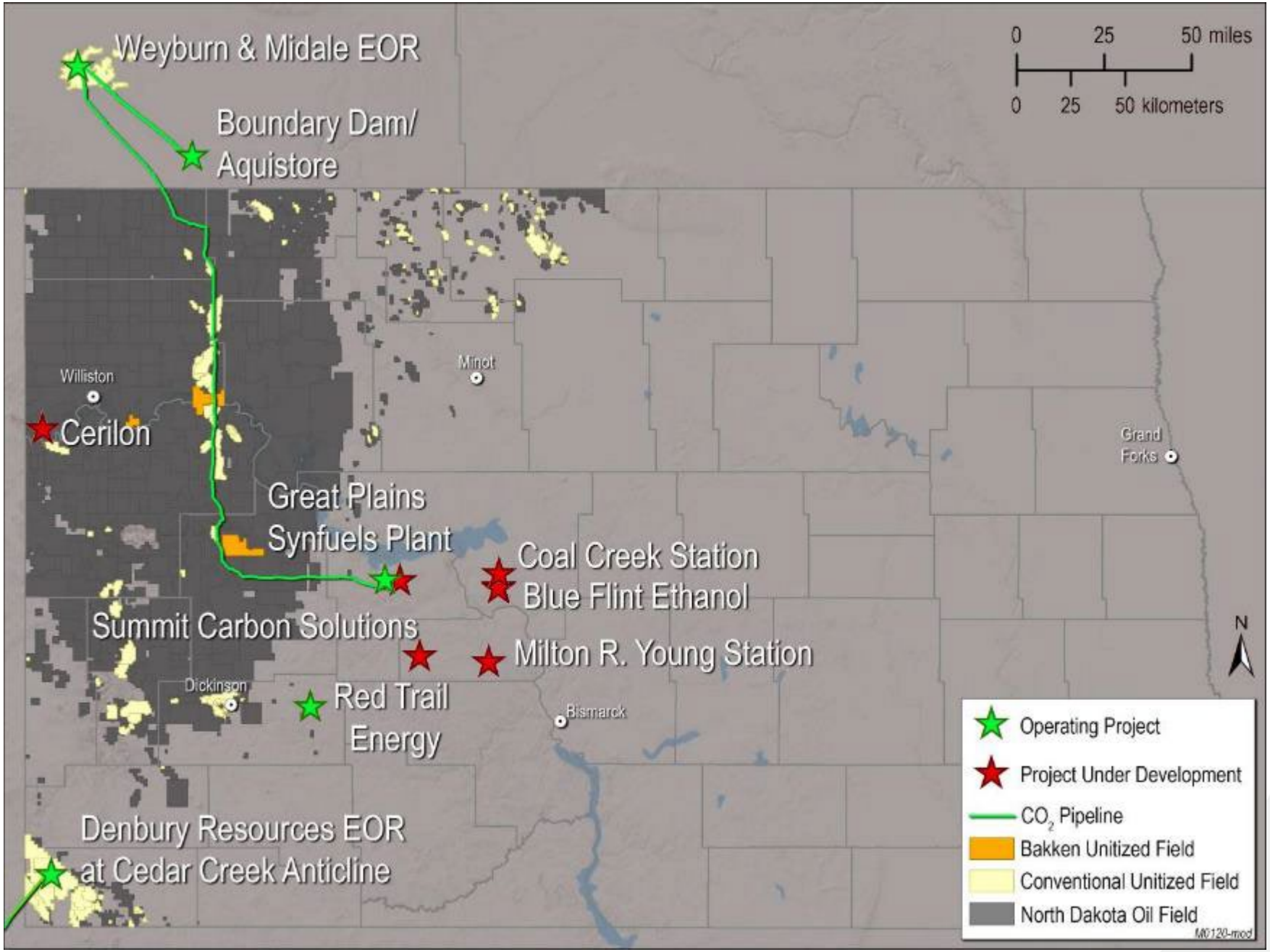
State-issued determination of storage (facilitate carbon credits, allowances, trading, emission allocations, offsets, or participation in other incentive program).

NORTH DAKOTA CCUS ACTIVITY

Approved permits:
- Red Trail Energy (RTE)
- Minnkota (Milton R. Young Station)

Pending permits:
- Great Plains Synfuels Plant
- Blue Flint Ethanol

8-month Review and Approval Process

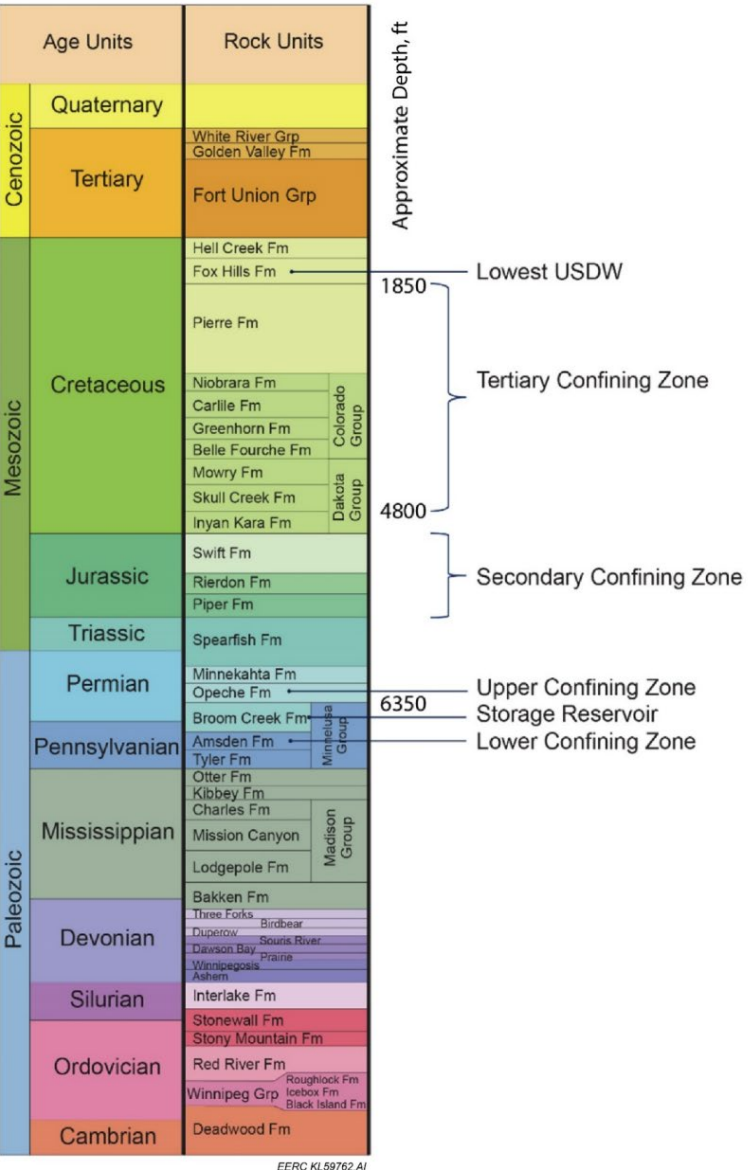


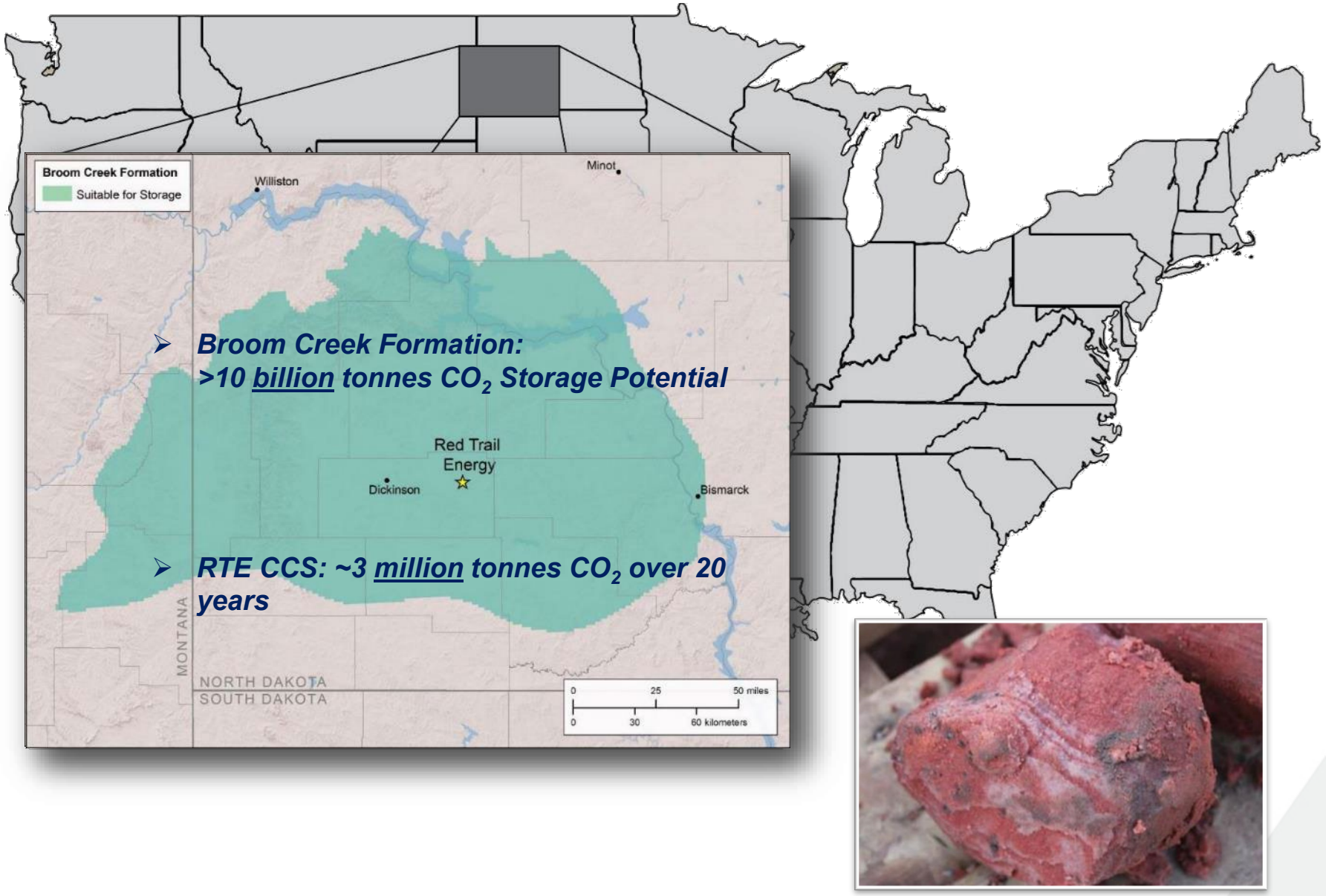
RED TRAIL ENERGY

- RTE announced June 16, 2022 as the official start date of carbon capture and storage (CCS) operations.
- RTE is capturing 100% of CO_2 from the fermentation process and is injecting approximately 500 metric tons of CO_2 per day into the Broom Creek Formation.
- Approximately 82,000 tons stored as of December 31, 2022.

RTE

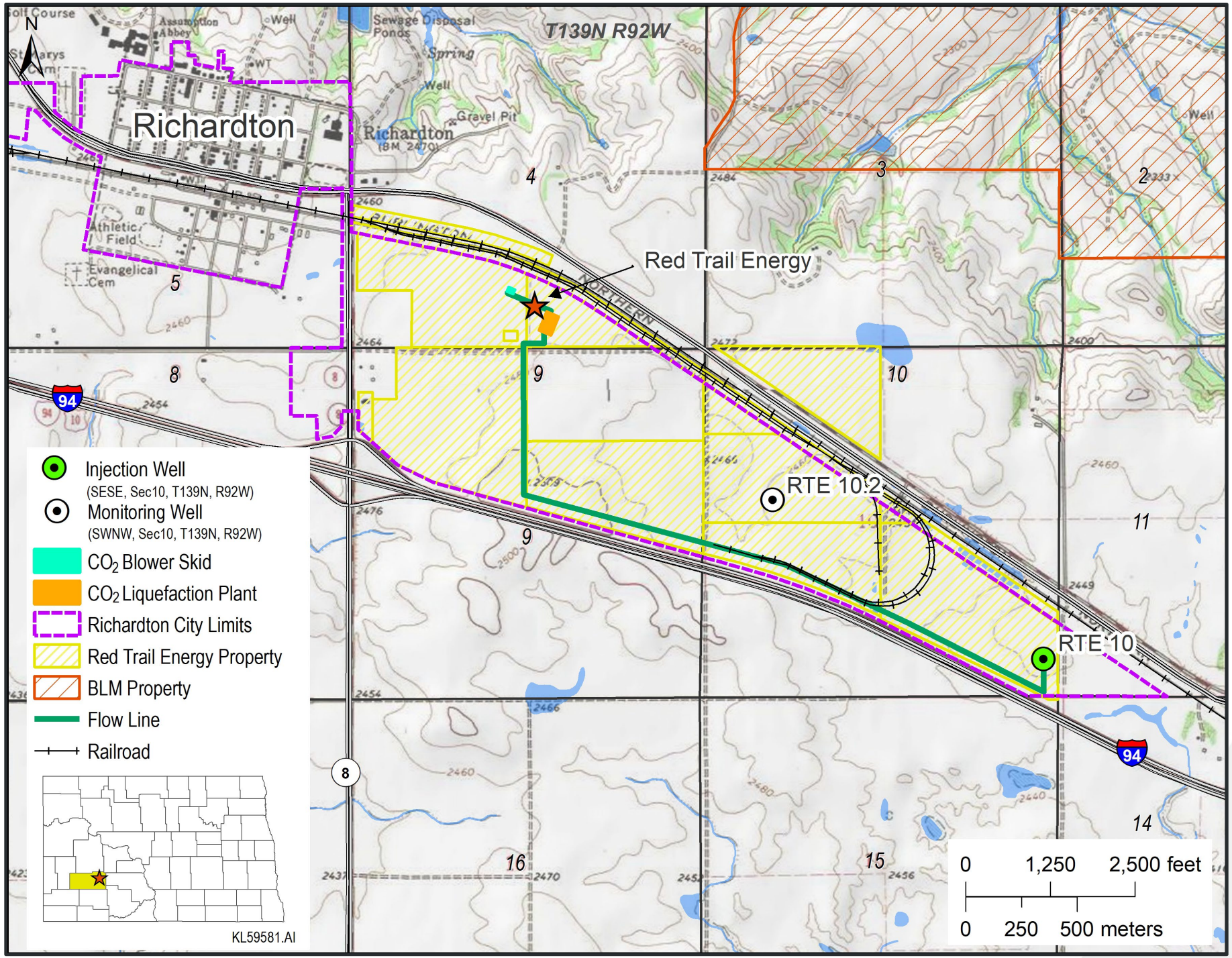
Images Credit: Red Trail Energy





- ***Broom Creek Formation: >10 billion tonnes CO_2 Storage Potential***
- ***RTE CCS: ~3 million tonnes CO_2 over 20 years***

RED TRAIL ENERGY SITE LAYOUT



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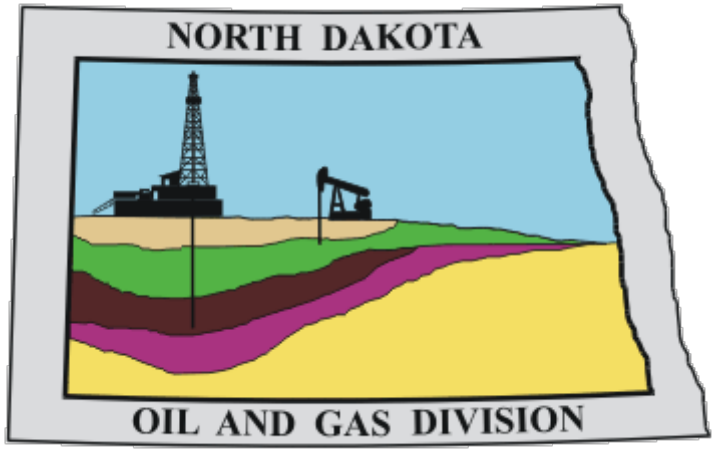
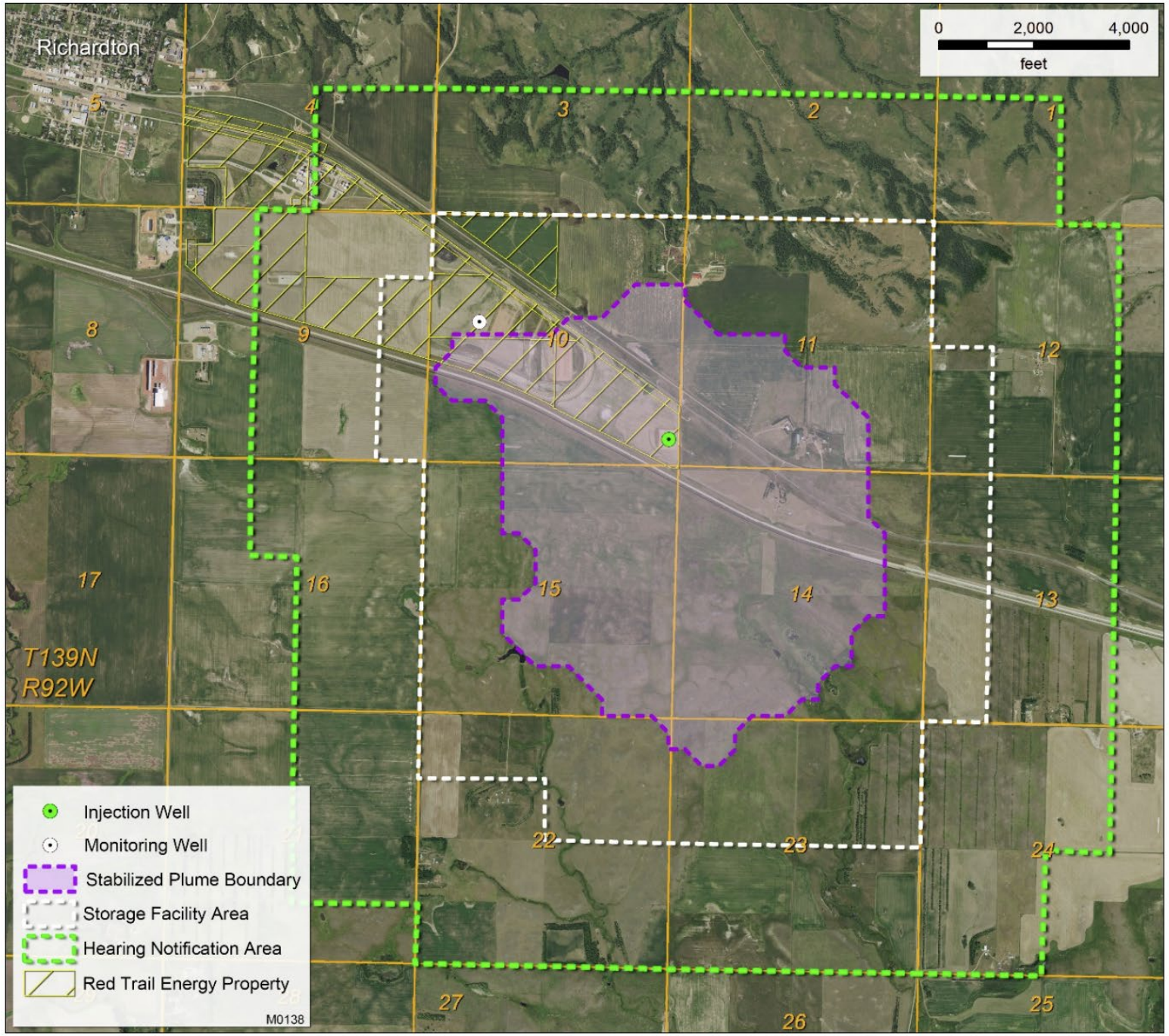
RTE NORTH DAKOTA SFP

Monitoring Type	RTE Monitoring Program	Target Structure/Project Area
Analysis of Injected CO_2	Compositional and isotopic analysis of the injected CO_2 stream	Wellhead
CO_2 Flow Line	DTS/DAS and distributed strain sensing (DSS)	Capture facility to the wellsite
Continuous Recording of Injection Pressure, Rate, and Volume	Surface pressure/temperature gauges and a flowmeter installed at the wellhead with shutoff alarms	Surface-to-reservoir (injection well)
Well Annulus Pressure Between Tubing and Casing	Annular pressure gauge for continuous monitoring	Surface-to-reservoir (injection well)
Near-Surface Monitoring	Groundwater wells in the AoR, dedicated Fox Hills monitoring wells, and soil gas sampling and analyses	Near-surface environment, USDWs
Direct Reservoir Monitoring	Wireline logging, external downhole pressure and temperature gauges, and DTS/DAS fiber optic cable	Storage reservoir and primary sealing formation
Indirect Reservoir Monitoring	Time-lapse geophysical surveys, gravity surveys, inSAR and passive seismic measurements.	Entire storage complex
Internal and external mechanical integrity	Tubing-casing annulus pressure testing (internal) DTS/DAS fiber optic cable, ultrasonic imager tool (USIT) (external)	Well infrastructure
Corrosion Monitoring	Flow-through corrosion coupon test system for periodic corrosion monitoring.	Well infrastructure



- Supplemental U.S. Department of Energy (DOE)–PCOR Partnership monitoring activities integrated with RTE's SFP.
  - SFP ensures safe storage and compliance.
  - SFP requires a periodic testing and monitoring plan.

RED TRAIL ENERGY STORAGE FACILITY AREA



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MONITORING CO_2 SATURATION AND PRESSURE

Analyze historical InSAR.

Build and install reflective monuments to improve surface signal.

Surface expression of injection operations.

InSAR

SASSA

Autonomous units for recording SOV, vibroseis, and passive noise.

Parameter testing to optimize autonomous sourcing.

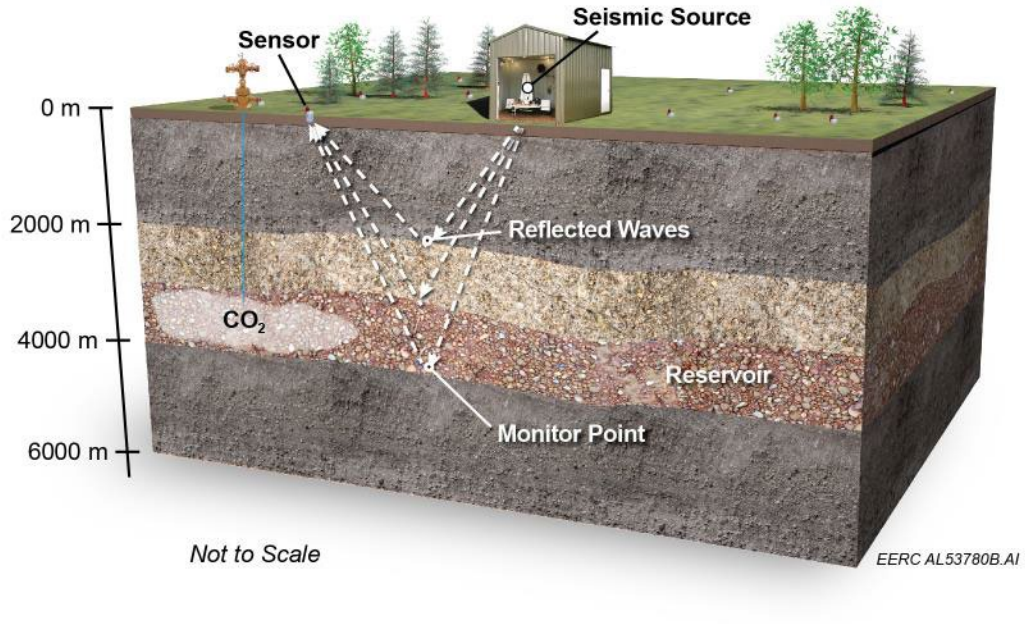
Fiber-Optic Systems

DAS and DSS systems sense changes related to saturation and pressure.

Record vibroseis for VSP (3D and walkaway).

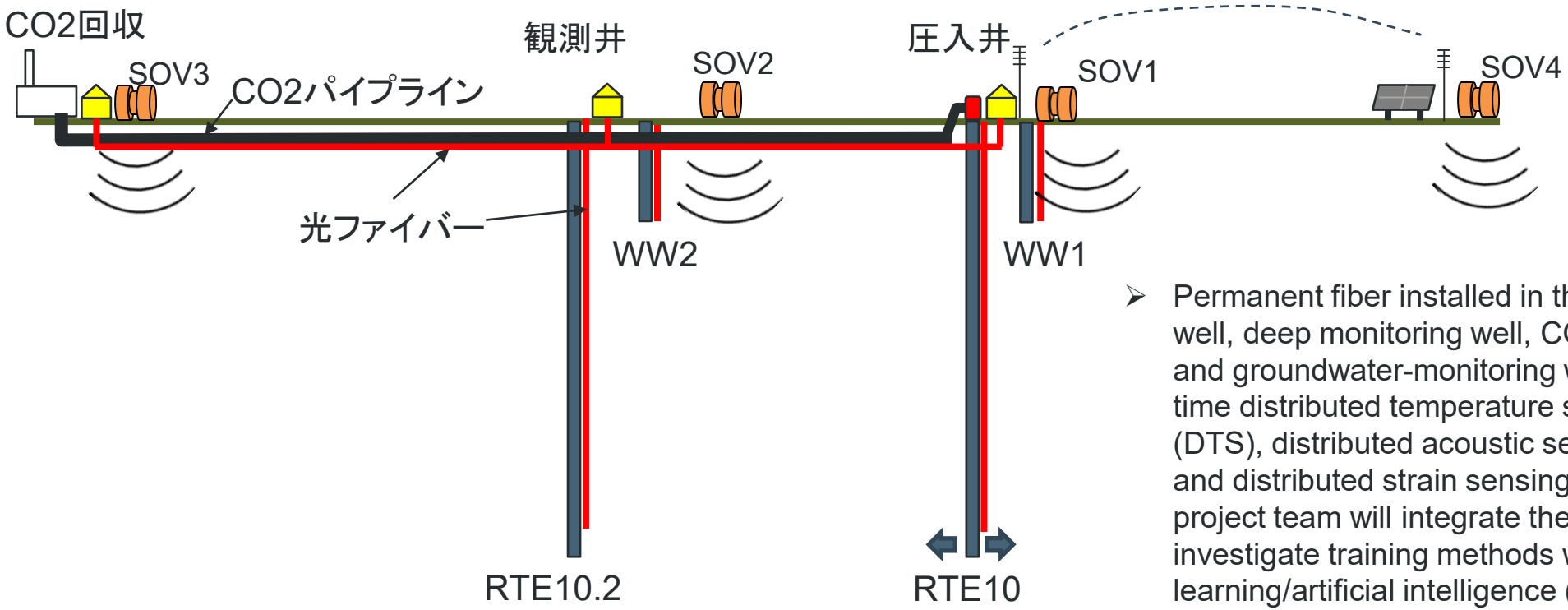
Record strain and passive noise.

Parameter testing to optimize recording.



The project team will investigate the integration of these data sets into automated-predictive decision-making.

光ファイバーによるCO2モニタリング



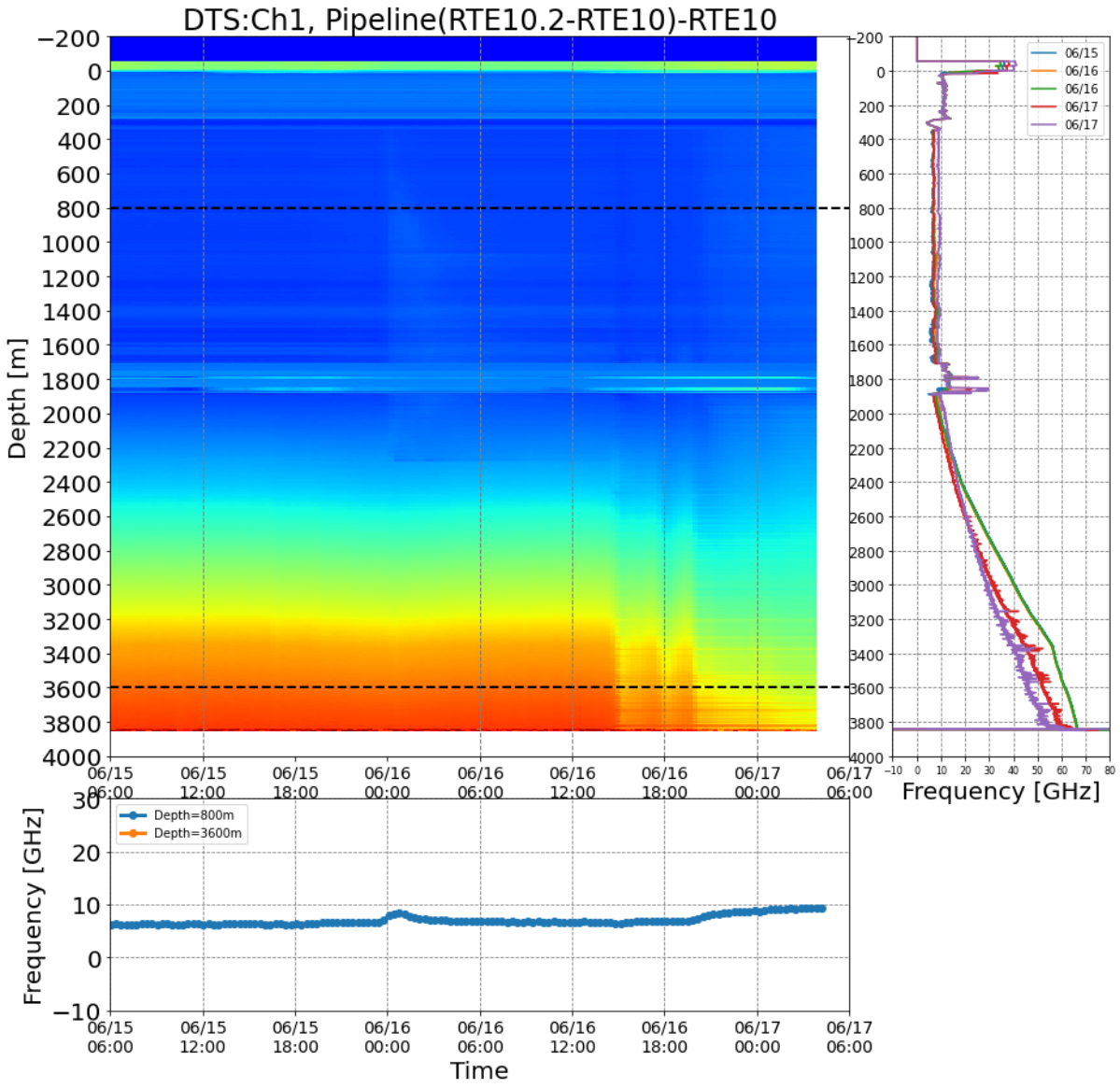
- Permanent fiber installed in the injection well, deep monitoring well, CO_2 flowline, and groundwater-monitoring wells for real-time distributed temperature sensing (DTS), distributed acoustic sensing (DAS), and distributed strain sensing (DSS). The project team will integrate these data and investigate training methods with machine learning/artificial intelligence (ML/AI) for predictive decision-making.

Credit: Takayuki Miyoshi at RITE

DAS（音響計測）	CO2プルームの広がり把握（DAS/VSP）
DSS（ひずみ計測）	坑井健全性、貯留層/遮蔽層安定性監視、CO2挙動監視
DTS（温度計測）	坑井周辺のCO2挙動監視（坑井健全性）

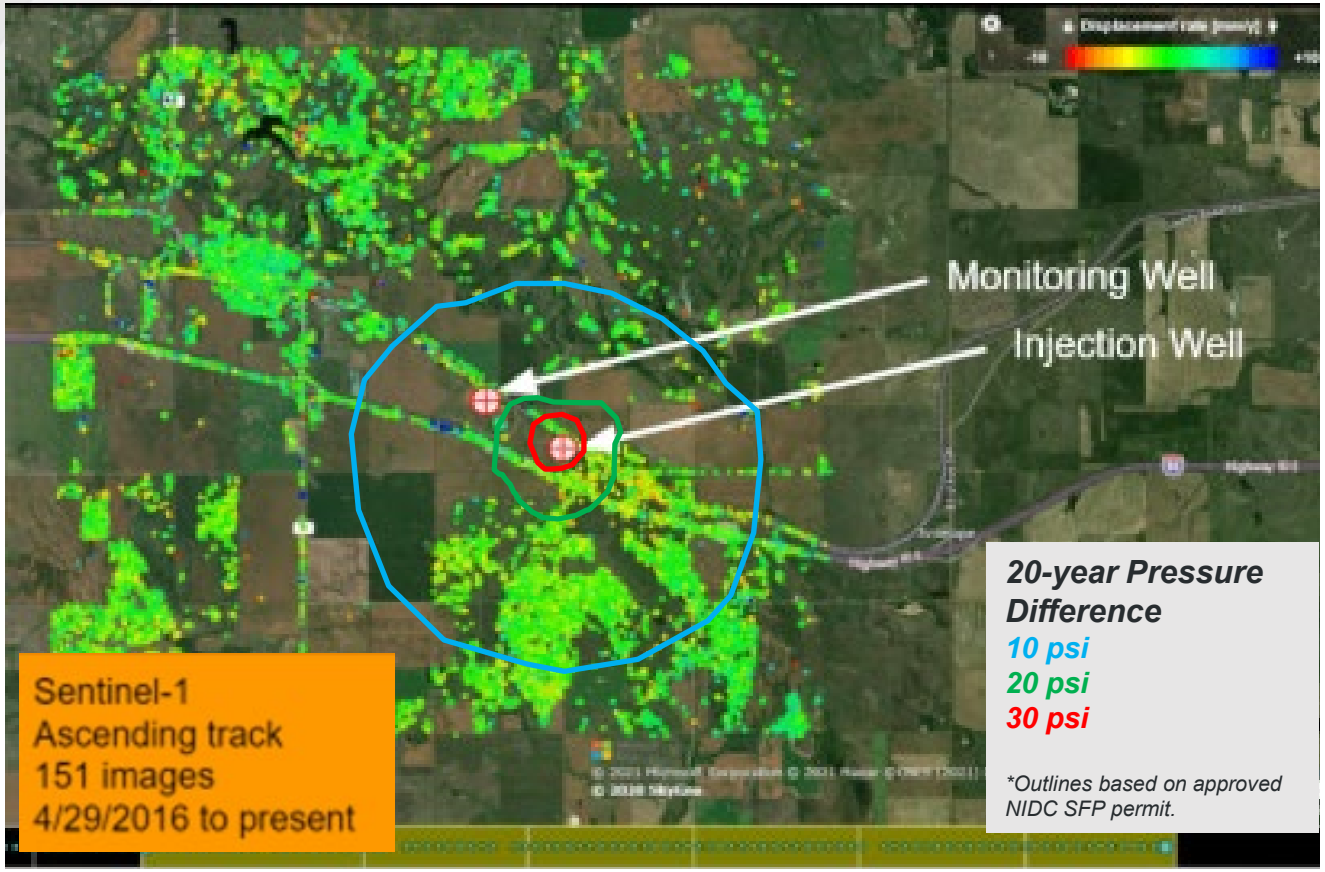
DISTRIBUTED FIBER-OPTIC STRAIN AND TEMPERATURE

- DTS and DSS calibrated with casing-convey pressure/temperature gauges.
- DTS will continuously monitor temperatures for wellbore integrity.
- DSS will continuously measure and monitor stress changes related to reservoir changes and integrate with other pressure data.



INTEGRATED GEOMECHANICAL MONITORING

InSAR



- Integration between injection data, InSAR, and DSS.
- High-frequency (weekly) data and AI/ML-ready.

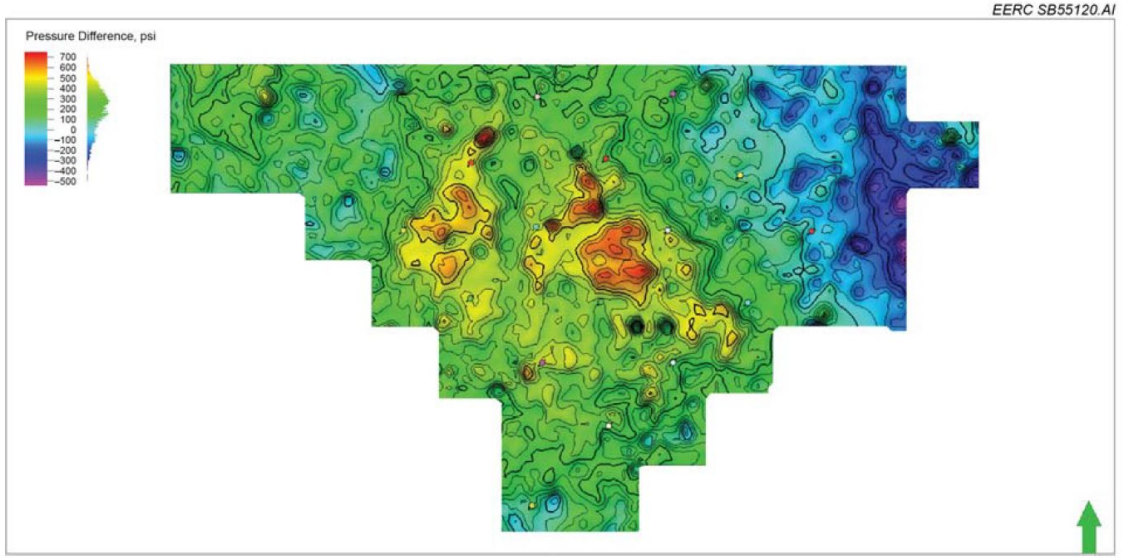
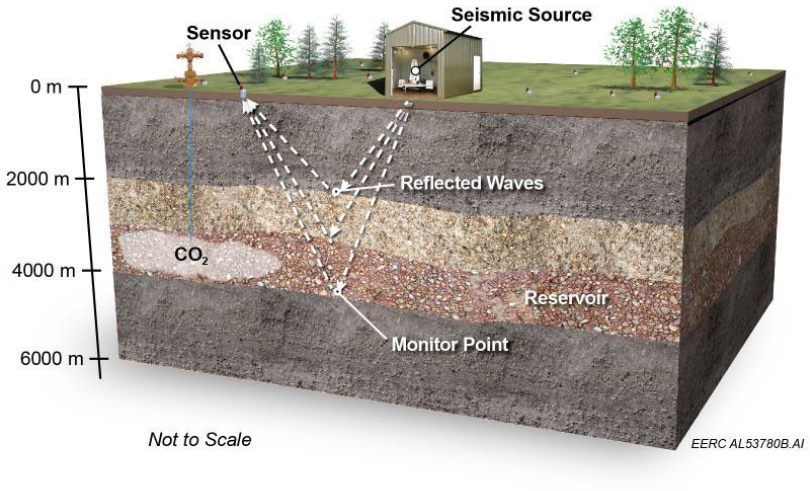


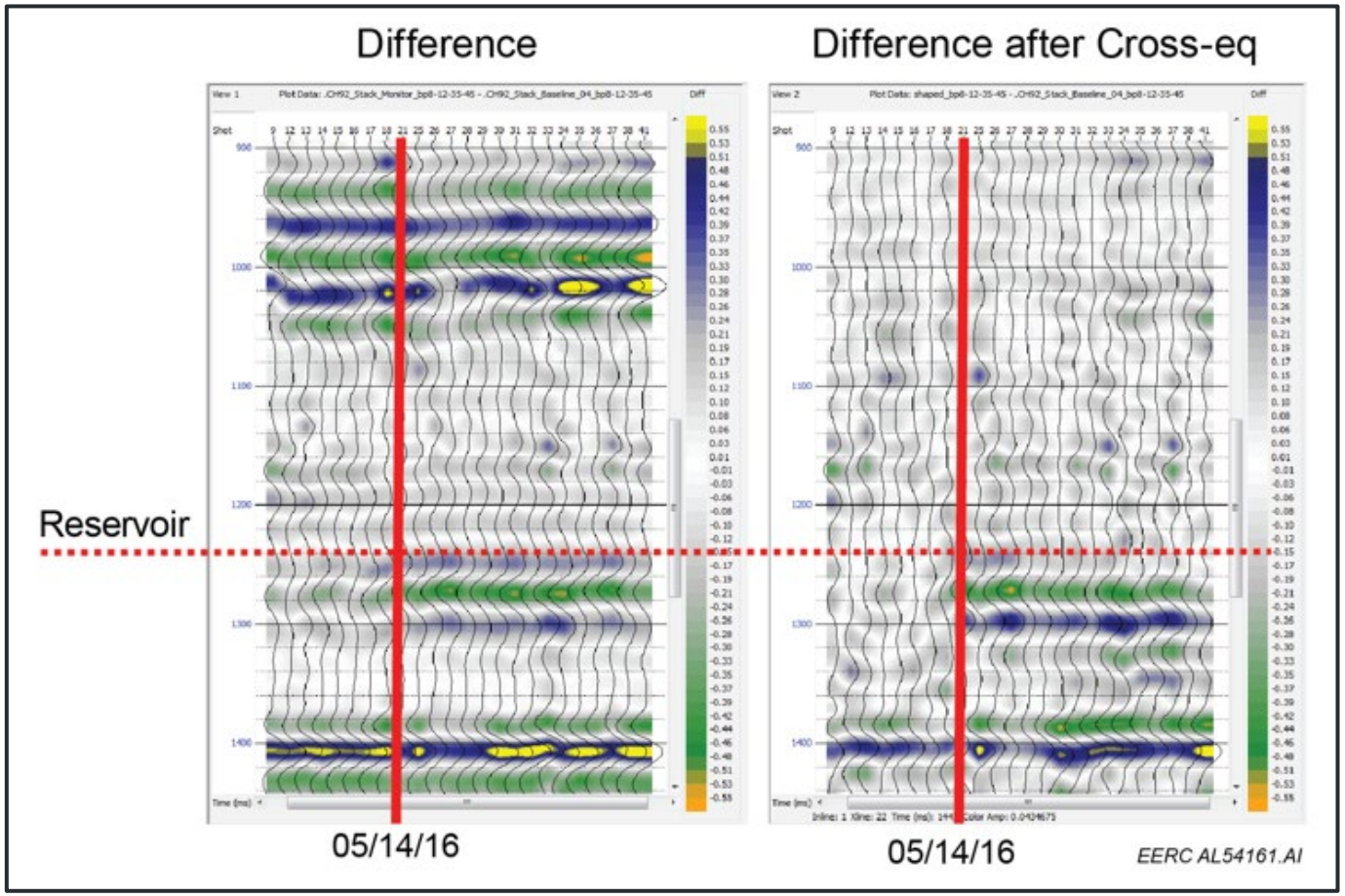
Fig. 14. Reservoir pressure differences between September 2015 and December 2016 inverted from measured InSAR data.

SCALABLE AUTOMATED SPARSE SEISMIC ARRAY (SASSA)

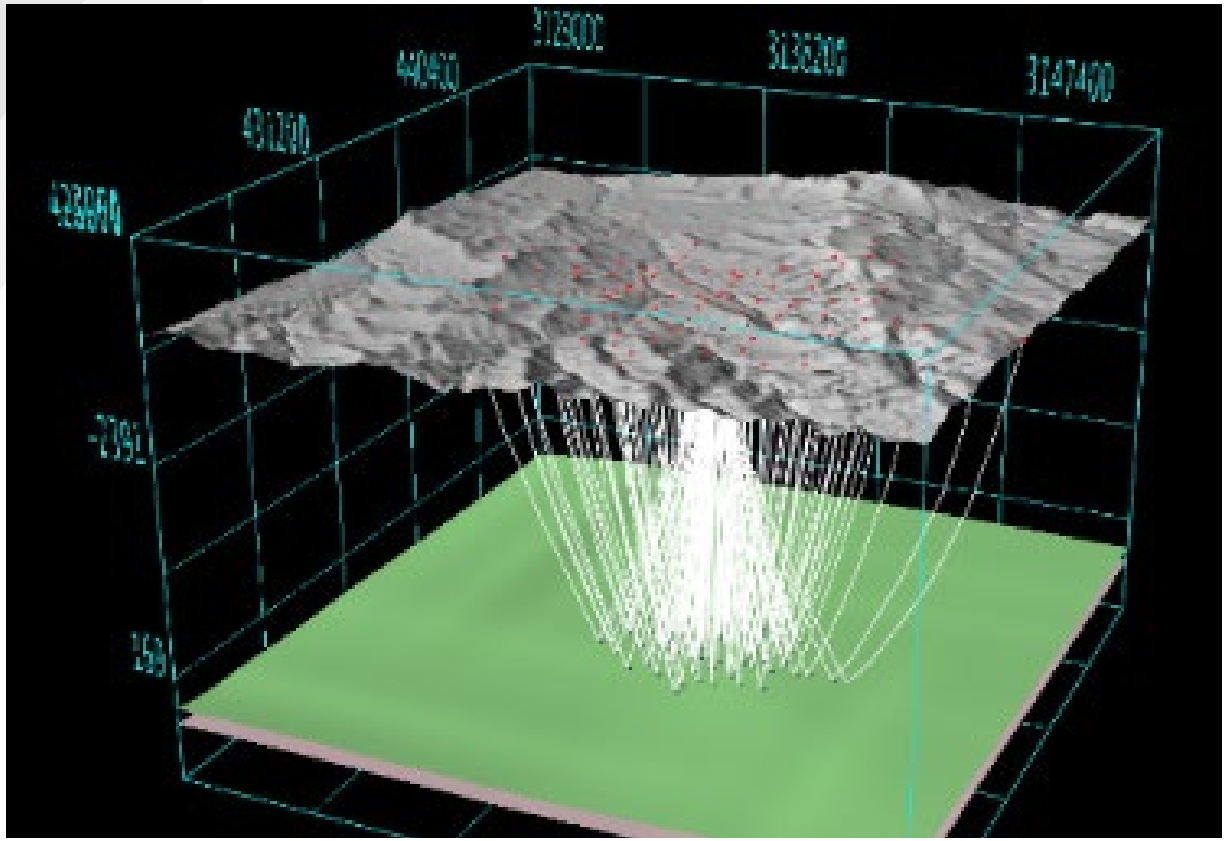
- Monitoring of strategically located subsurface discrete locations for understanding plume extents.
- Single-fold weekly reflection changes indicate change in CO_2 saturation.
- Integrate with dynamic reservoir simulations.

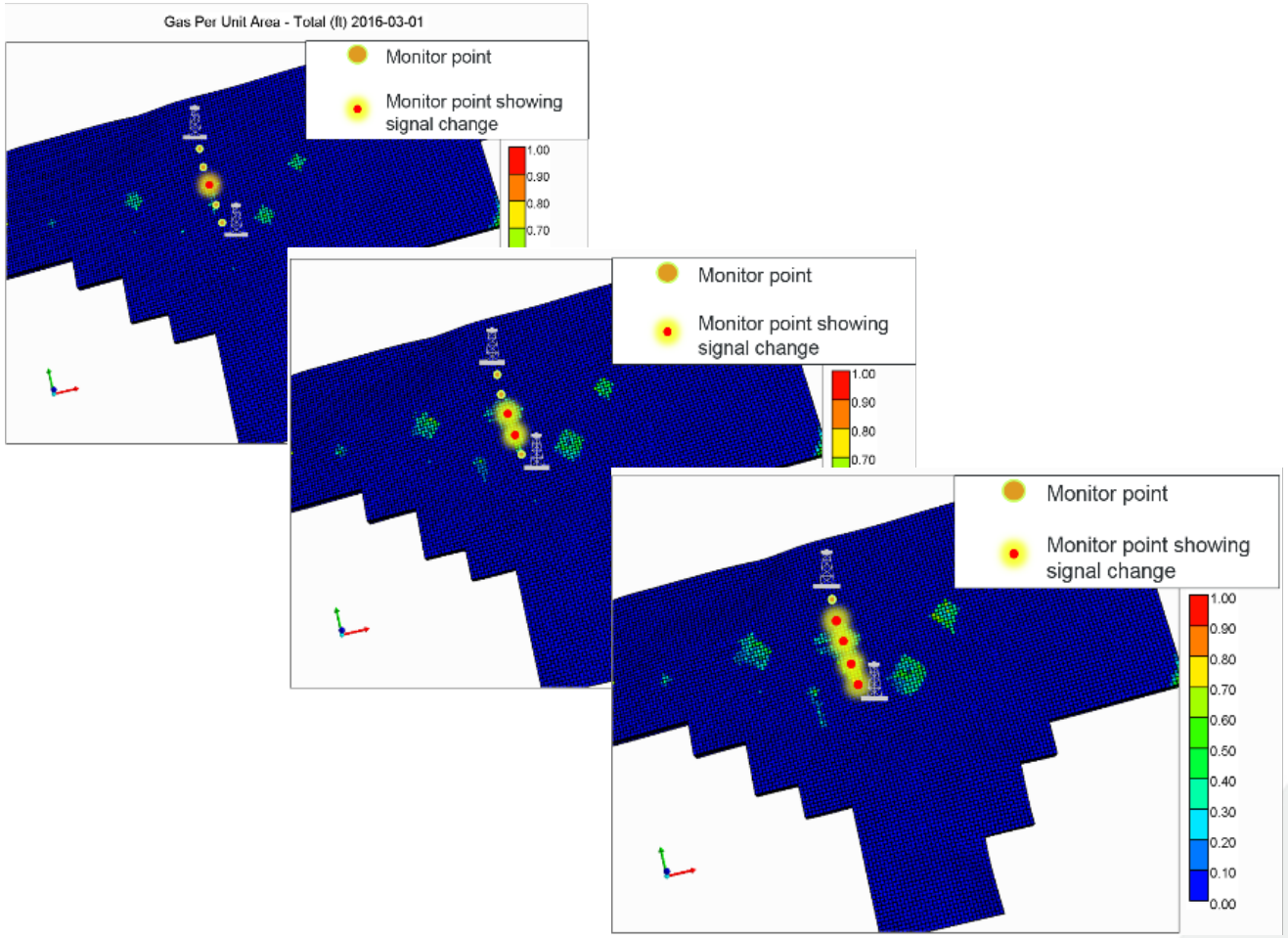


Bell Creek Oil Field, MT – SASSA Example



SASSA



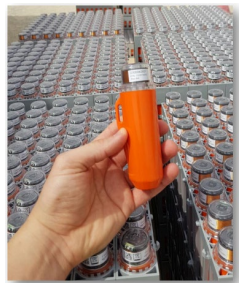

Gas Per Unit Area - Total (lt) 2016-03-01
Monitor point
Monitor point showing signal change
1.00
0.90
0.80
0.70
Monitor point
Monitor point showing signal change
1.00
0.90
0.80
0.70
Monitor point
Monitor point showing signal change
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

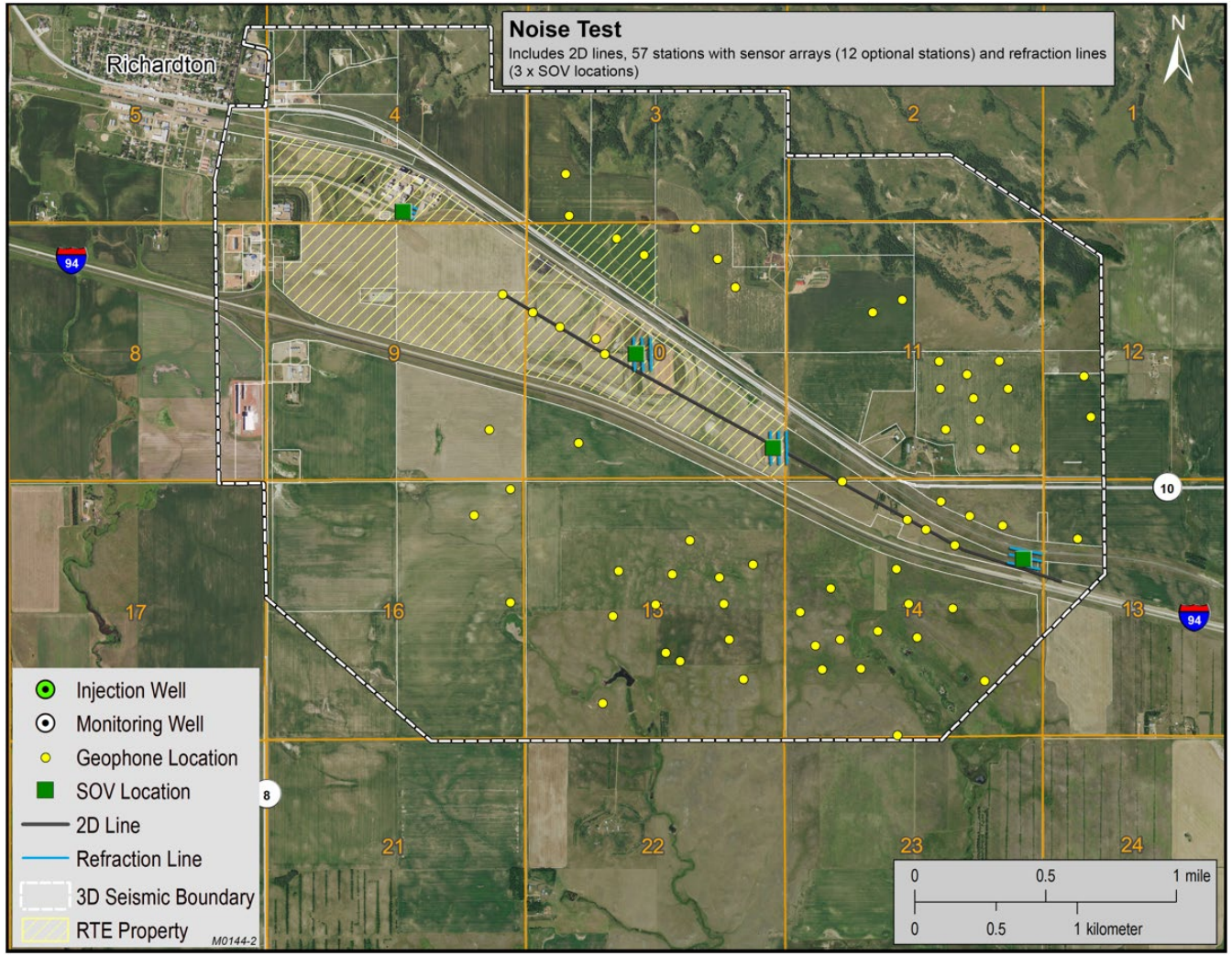
SASSA PLANNING – NOISE TEST

Enhancing and optimizing cost-effective methods that reduce surface impact, lower HSE risk, and allow for safer storage.

- Deployment of a sparse array of geophones at strategic locations for monitoring the injected CO_2 plume.
- RITE's SOV source will be recorded with the sparse array on a daily/weekly basis.

- 96 Zland 3C nodes to be deployed for noise characterization and SASSA baseline.
- 20 Geospace GSX-C nodes for demonstration of on demand remote harvesting.
- 750 Stryde nodes deployed in high-density arrays for noise characterization and monitoring phase of SASSA.

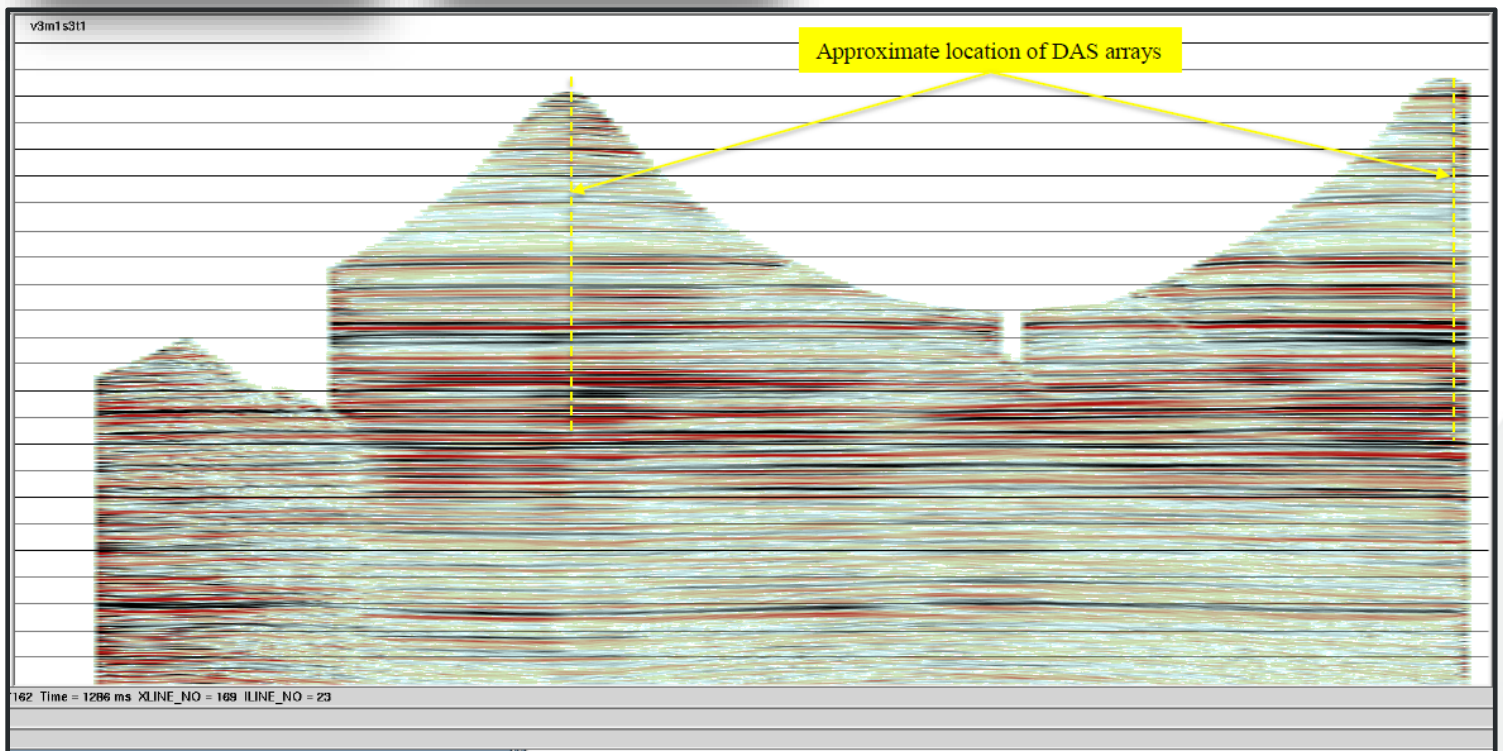




*https://**www.dmr.nd.gov**/oilgas/seismic/permitfiles/970304.pdf*

HIGH-FREQUENCY VERTICAL SEISMIC PROFILES

- Four SOVs are installed in sheds for protection.
- Each SOV includes a geophone installed beneath the foundation to capture source signature.
- Maximum ground force is 15 tonnes.



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SUSTAINABLE MONITORING

- Ensure safe storage and regulatory compliance.
- Robust risk-based sustainable monitoring plan to meets storage goals.
- Allows for adaptations to the monitoring plan.
- Track the movement of CO_2 and assure permanence for geologic storage.
- Provide measurements of downhole and reservoir conditions for real-time decision-making and process optimization.
- Decrease the cost and uncertainty in measurements and satisfy regulations.
- Provide long-term postinjection monitoring.

Be good stewards of the land...

PCOR PARTNERSHIP INITIATIVE MISSION:

Accelerating Commercial Deployment of CCUS in the Region

Charles Gorecki, CEO
cgorecki@undeerc.org
701.777.5355 (phone)

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)

THANK YOU

Critical Challenges. Practical Solutions.

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DISCLAIMER

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BEST

Cooperative Agreement No. DE-FE0026160

DOE PCOR Agreement #: DE-FE0031838
DOE BEST Agreement #: DE-FE0026160
Red Trail Energy (MSA) Agreement #: None

NDIC LRP (PCOR) Agreement #: FY20-XCI-226

NDIC OGRC (PCOR) Agreement Number #: G-050-C-096