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Critical Challenges. **Practical Solutions.**

Energy & Environmental Research Center (EERC)

DEVELOPING AND VALIDATING PRESSURE MANAGEMENT AND PLUME CONTROL STRATEGIES IN THE WILLISTON BASIN THROUGH A BRINE EXTRACTION AND STORAGE TEST (BEST) – PHASE II

DE-FE0026160

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U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration: Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 13–16, 2018

Critical Challenges. **Practical Solutions.**

This material is based upon work supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) under Award No. DE-FE0026160.

DEDICATED GEOLOGIC CO_2 STORAGE CONSIDERATIONS

- Buoyant fluid
- Large volumes = large footprint
- Regulatory compliance and costs
- Conformance and efficiency
- Access to pore space
  - Leasing, unitization/amalgamation, trespass
- Assuring permanence for certification or credits
- Risk management

Because of a host of technical, social, regulatory, environmental, and economic factors, brine disposal tends to be more accessible and generally quicker, easier, and less costly to implement compared to dedicated CO_2 storage.

Brine extraction can enable dedicated CO_2 storage and improve the geologic CO_2 storage potential of a site.

TWO COMPLEMENTARY COMPONENTS

<u>ARM Test</u>

- Reduce stress on sealing formation
- Geosteer fluid plume
- Divert pressure from leakage pathways
- Reduce area of review (AOR)
- Improve injectivity, capacity, and storage efficiency
- Validate monitoring techniques, and forecast model capabilities

<u>Brine Treatment Test Bed</u>

- Alternate source of water
- Reduced disposal volumes
- Salable products for beneficial use

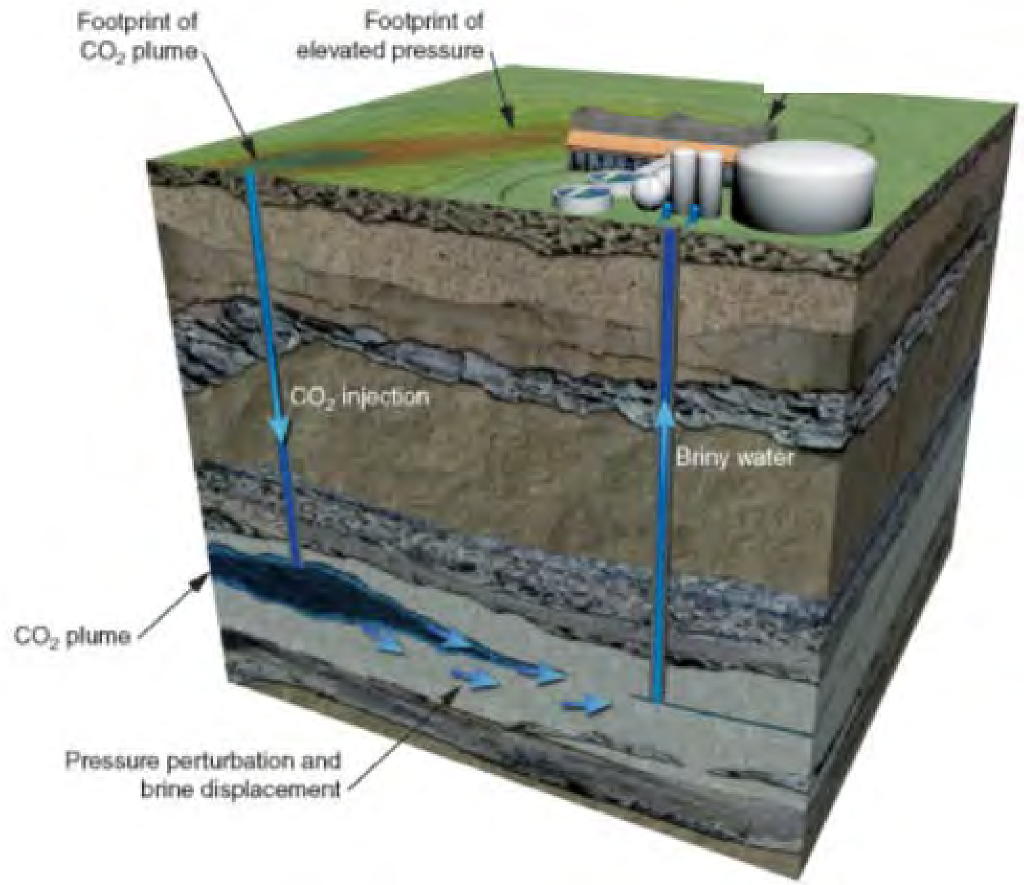
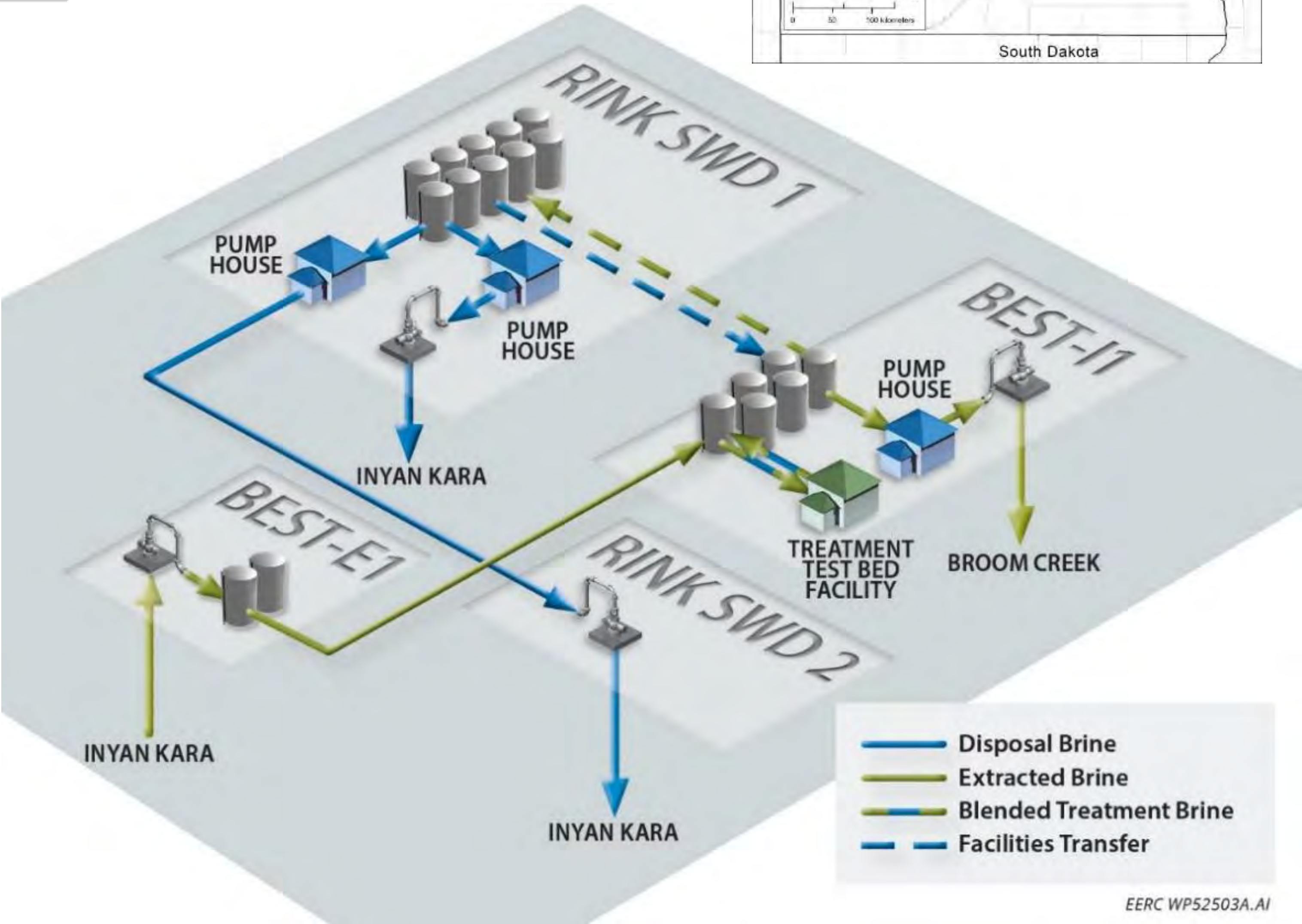


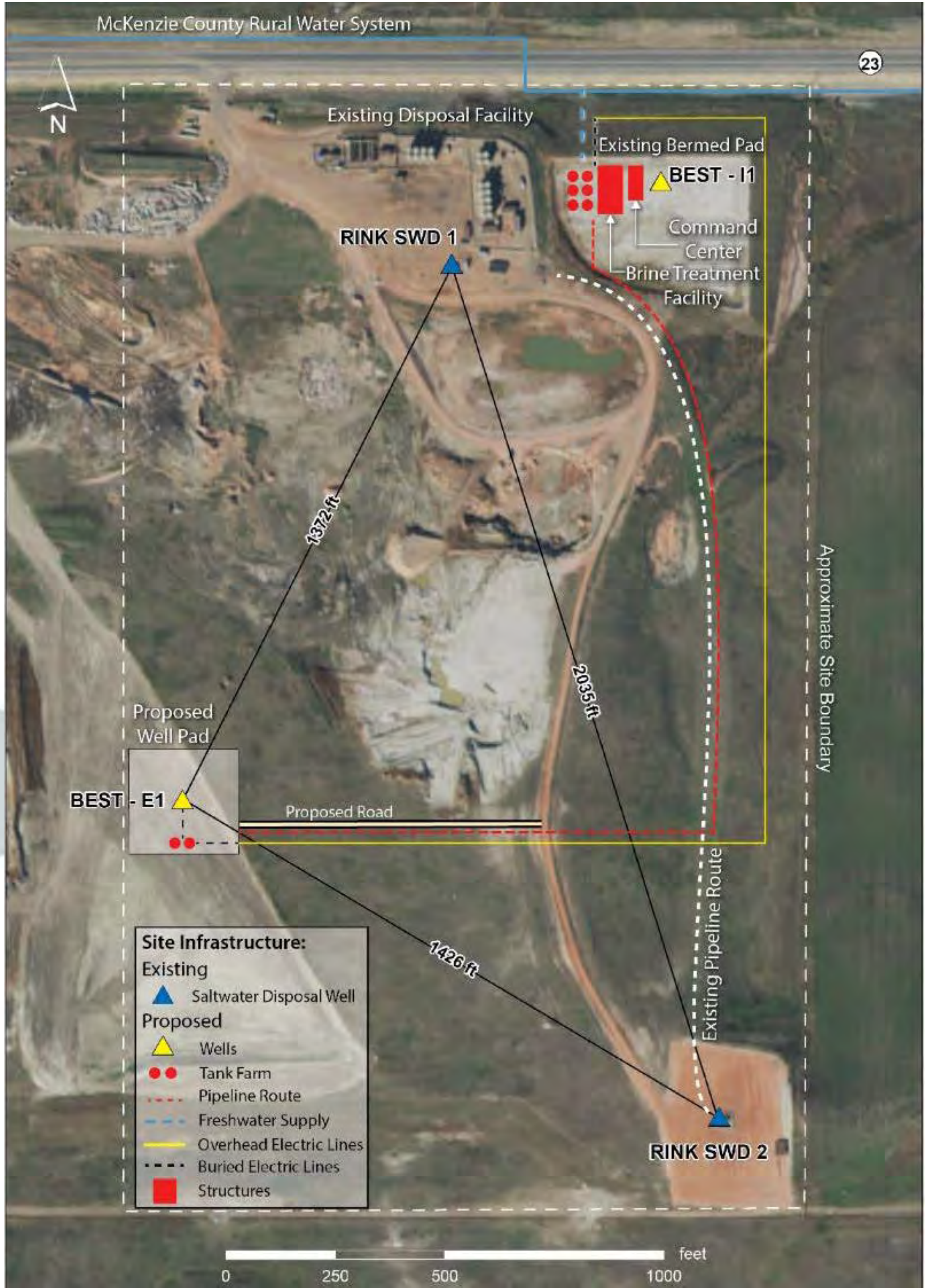
Illustration modified from Lawrence Livermore National Laboratory https://str.llnl.gov/Dec10/aines.html

ACTIVE WATER DISPOSAL SITES AS A PROXY FOR DEDICATED CO_2 STORAGE

THE SITE


RINK SWD 1
PUMP HOUSE
PUMP HOUSE
INYAN KARA
BEST-I1
PUMP HOUSE
BEST-E1
TREATMENT TEST BED FACILITY
BROOM CREEK
RINK SWD 2
INYAN KARA
INYAN KARA
Disposal Brine
Extracted Brine
Blended Treatment Brine
Facilities Transfer
EERC WP52503A.AI


Saskatchewan
Manitoba
CANADA
UNITED STATES
Williston
Minot
BEST Site
North Dakota
Grand Forks
Montana
Minnesota
Bismarck
Dickinson
Fargo
South Dakota


McKenzie County Rural Water System
23
N
Existing Disposal Facility
Existing Bermed Pad
BEST - I1
RINK SWD 1
Command Center
Brine Treatment Facility
1372 ft
2035 ft
Proposed Well Pad
BEST - E1
Proposed Road
1426 ft
Existing Pipeline Route
Approximate Site Boundary
RINK SWD 2
Site Infrastructure:
Existing
Saltwater Disposal Well
Proposed
Wells
Tank Farm
Pipeline Route
Freshwater Supply
Overhead Electric Lines
Buried Electric Lines
Structures
feet
0
250
500
1000

SITE GEOLOGY

Inyan Kara Formation (ARM Test)

- Nearshore/shallow marine sandstone
- 1568-m depth (5145 ft)
- ~120 m thick (400 ft)

Broom Creek Formation (Extracted Water Disposal)

- Eolian/nearshore marine sandstone
- 2277-m depth (7470 ft)
- ~20 m thick (65 ft)

Both formations have thick sealing units and are potential CO_2 storage targets in the Williston Basin.

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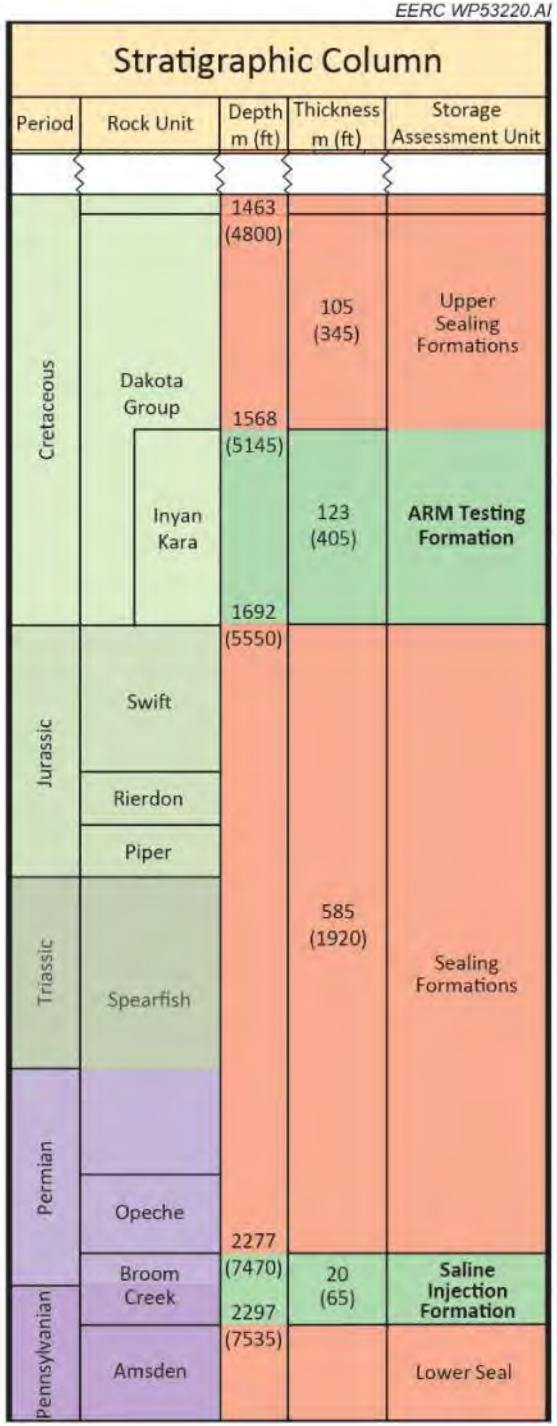
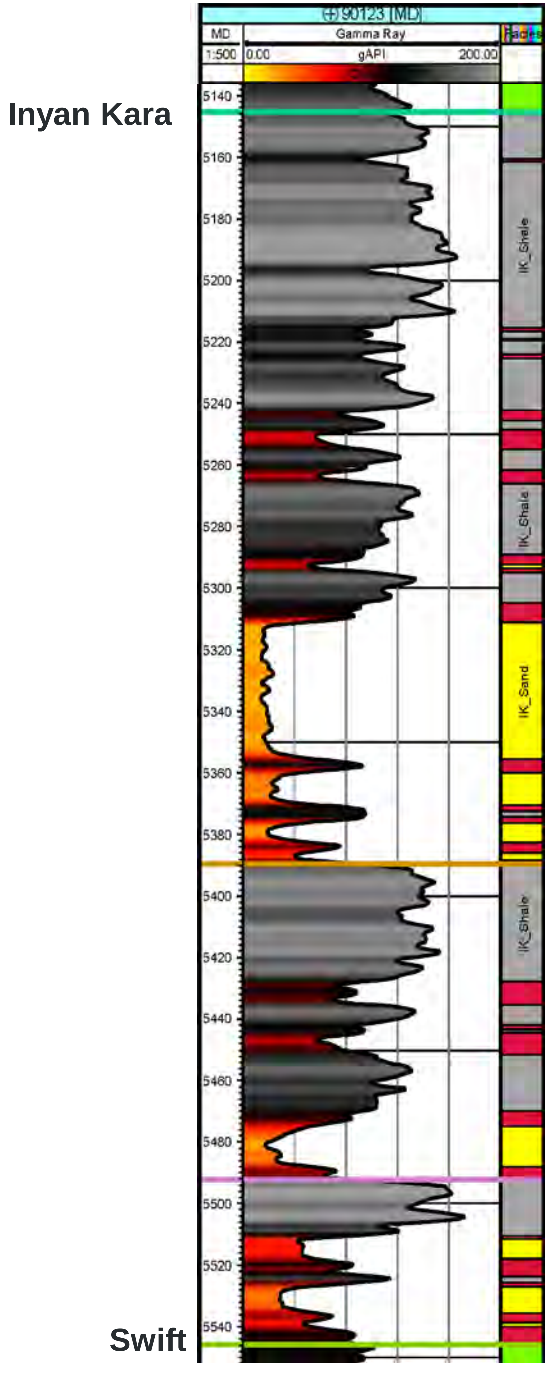
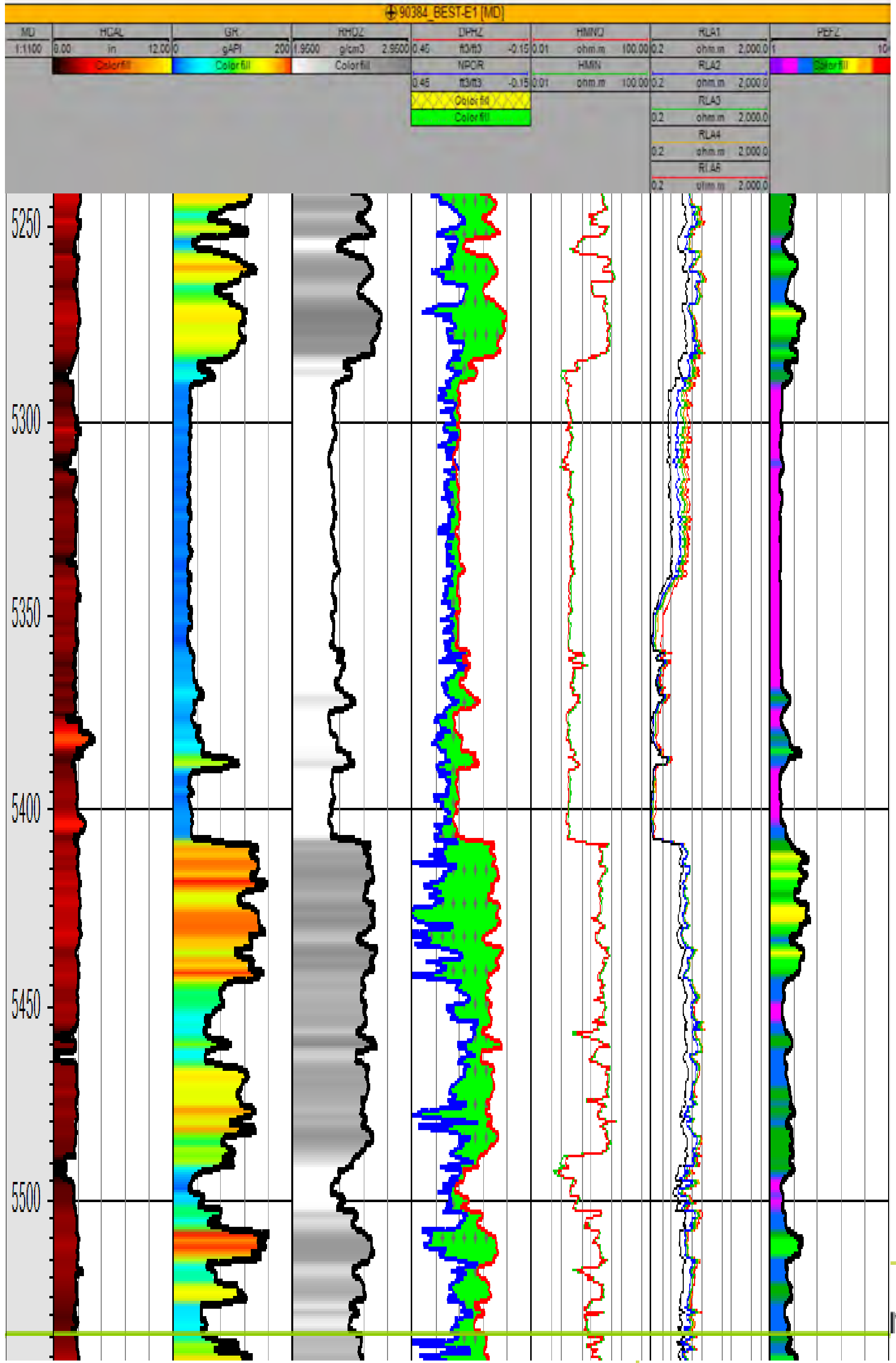
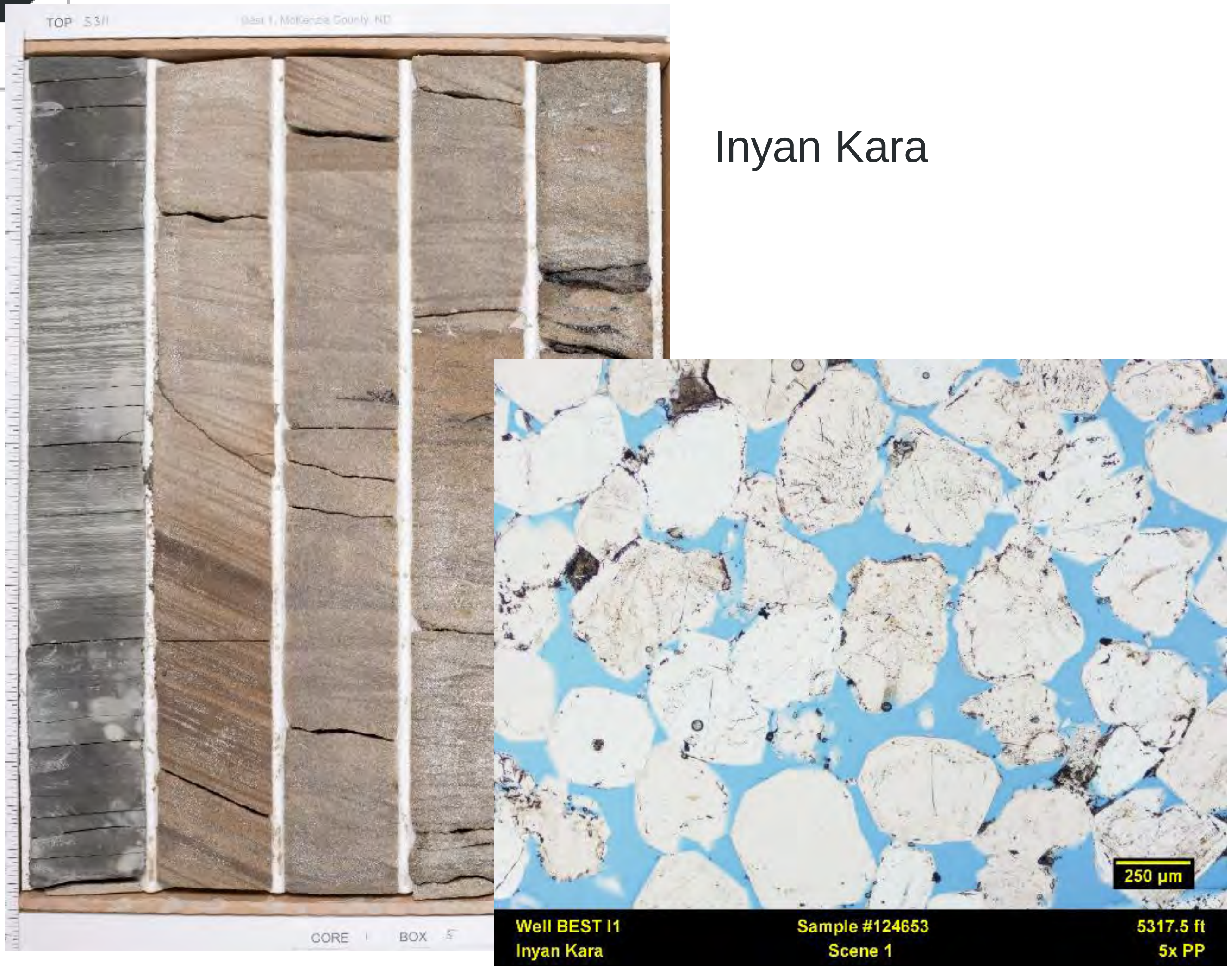




BEST-I1, BEST-E1



CORE – UNDER ANALYSIS



Inyan Kara

Broom Creek

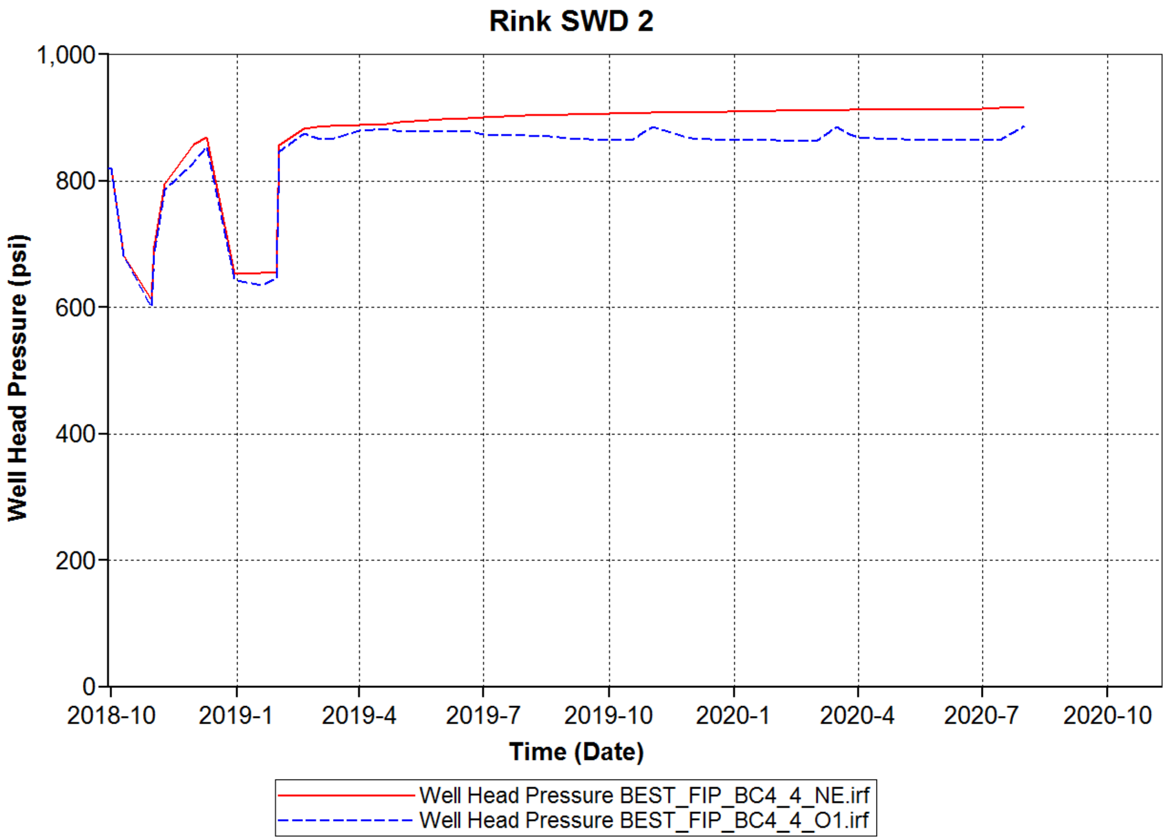
PROVISIONAL FIELD IMPLEMENTATION PLAN (FIP)

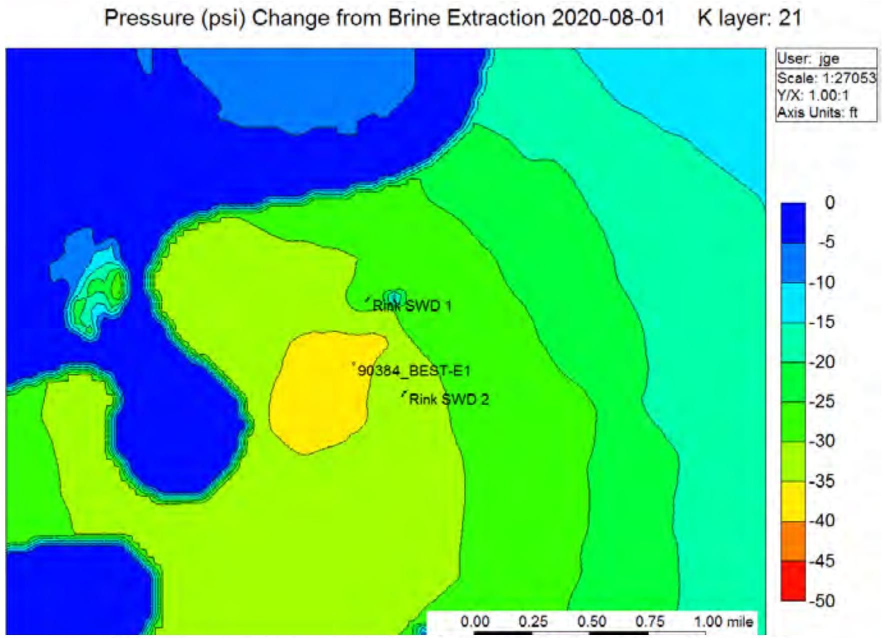
Revised to account for:

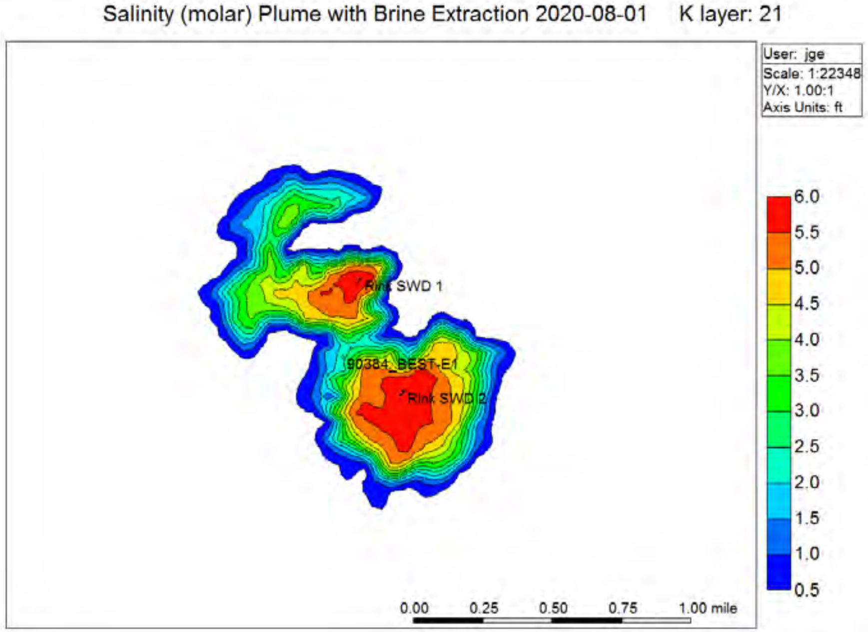
- Changes in injection rates and an additional years injection data.
- Revised implementation schedule.
- New characterization data.

BEST indicative field experimental scenario 1 (1 October 2018 – 31 July 2020) **DRAFT**							
			Description (BWPD)				
Test	Days	End date	BEST-E1	BEST-I1	RINK-1	RINK-2	Comment
	0	1-Oct-18	Stage One				Start data collection
1	10	10-Oct-18	0	0	7100	7400	Observe
2	20	30-Oct-18	-5000	5000	7100	7400	Begin interference test
3	10	9-Nov-18	0	0	7100	7400	Inject tracer
4	21	30-Nov-18	-5000	5000	7100	7400	Maximum rate test
5	10	10-Dec-18	0	0	7100	7400	Observe
6	20	30-Dec-18	0	2000	7100	5400	Rink-1 test begins
7	20	19-Jan-19	-3000	5000	7100	5400	
8	11	30-Jan-19	0	2000	7100	5400	Rink-1 test ends
9	20	19-Feb-19	0	2000	5100	7400	Rink-2 test begins
10	20	11-Mar-19	-3000	5000	5100	7400	
11	11	22-Mar-19	0	2000	5100	7400	Rink-2 test ends; interference test ends
	30	21-Apr-19	Stage Two				
12	60	20-Jun-19	-2500	2500	7100	7400	Minimum pump rate step
13	60	19-Aug-19	-4000	4000	7100	7400	Middle pump rate step
14	60	18-Oct-19	-5000	5000	7100	7400	Maximum pump rate step
15	15	2-Nov-19	0	0	7100	7400	Observe
16	120	1-Mar-20	-5000	5000	7100	7400	Long-duration test 1
17	15	16-Mar-20	0	0	7100	7400	Observe
18	120	14-Jul-20	-5000	5000	7100	7400	Long-duration test 2
19	17	31-Jul-20	0	0	7100	7400	Observe - end of extraction program
	670		-2,215,000	2,419,000	4,442,000	4,634,000	Totals. End of test.

SIMULATION RESULTS





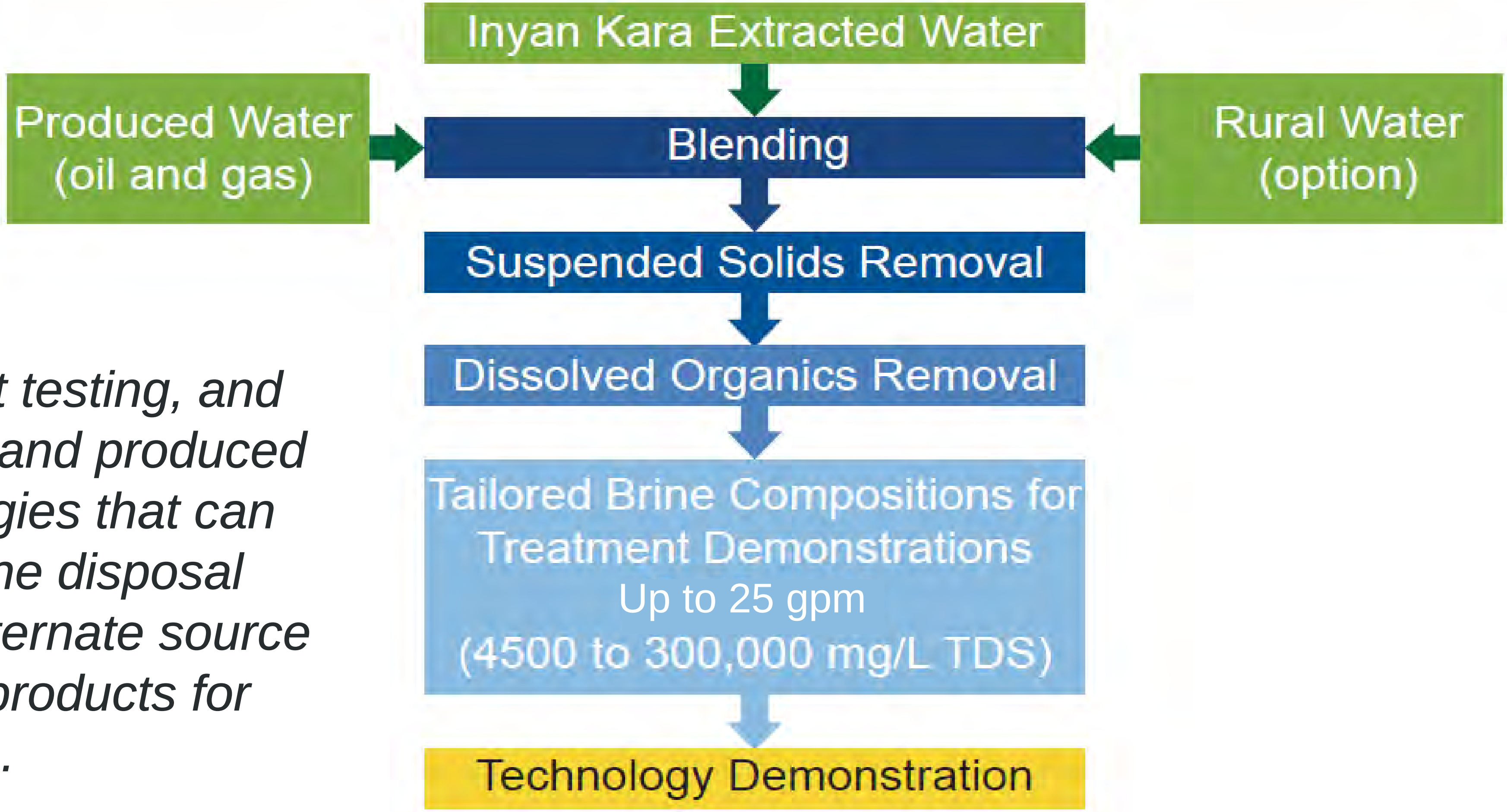


PIPELINE

INFRASTRUCTURE

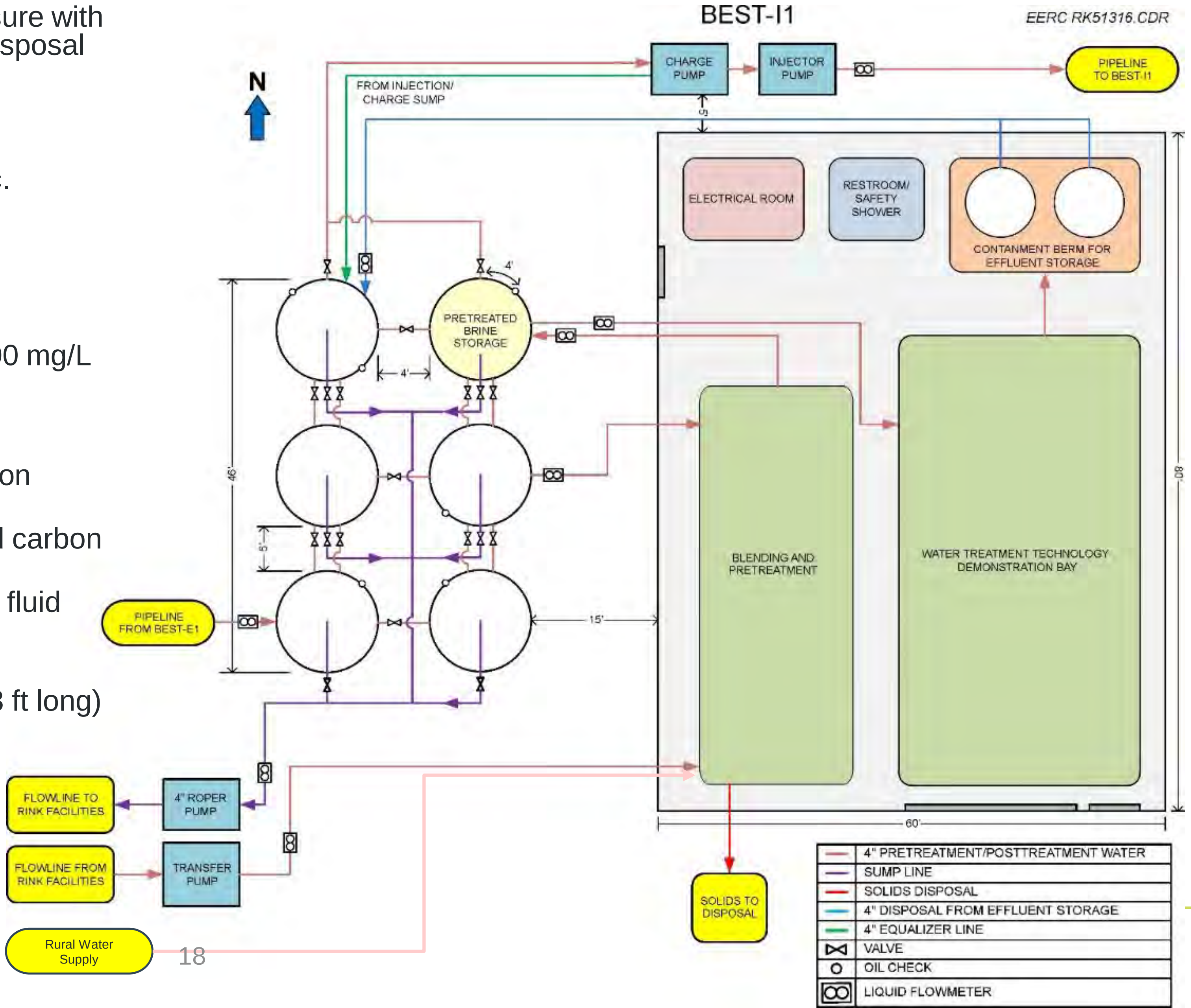
BRINE TREATMENT TEST BED

Enable development, pilot testing, and advancement of extracted and produced water treatment technologies that can meaningfully reduce brine disposal volumes and provide an alternate source of water and/or salable products for beneficial use.

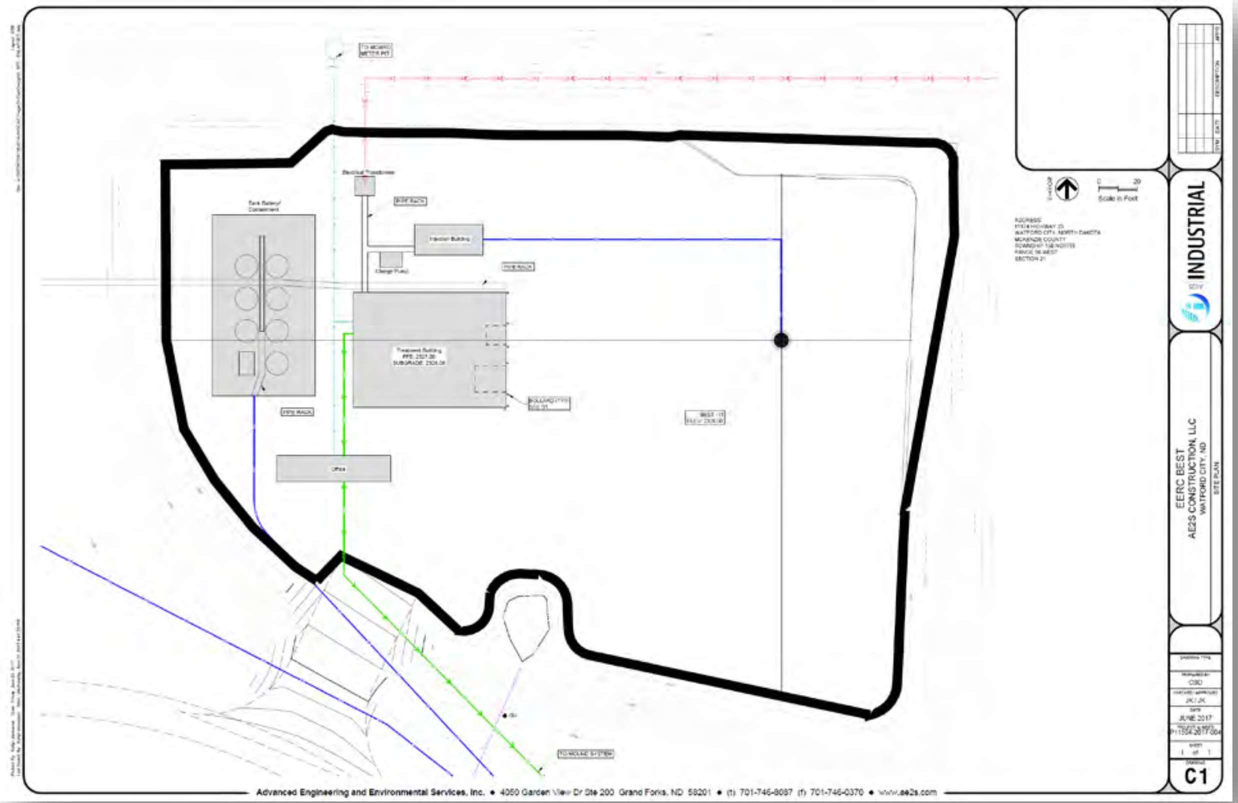


BRINE TREATMENT TEST BED

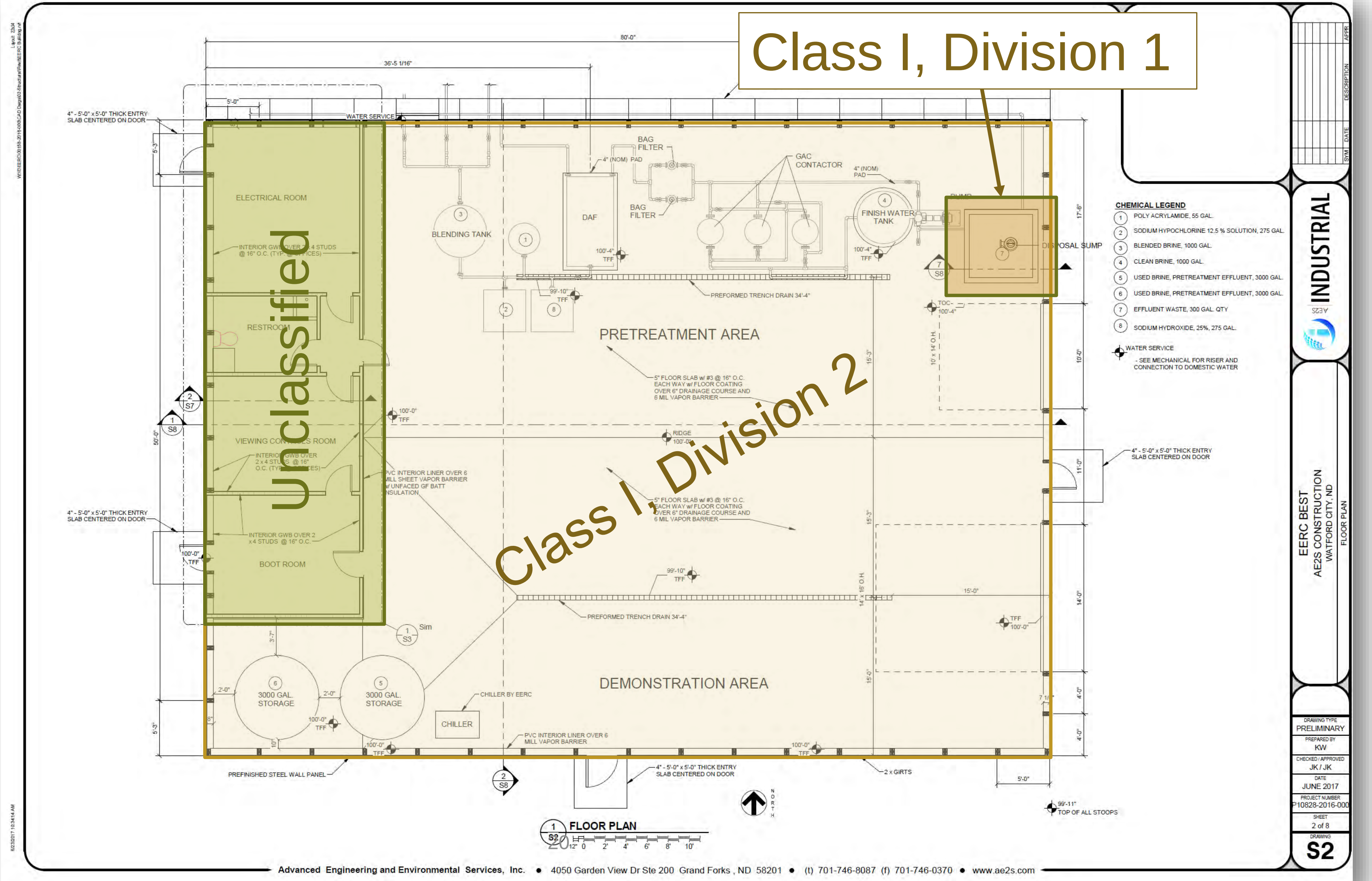
- Permanently installed heated environmental enclosure with concrete floor integrated with ARM and saltwater disposal (SWD) infrastructure
  - 30–60+-day extended-duration tests.
  - 24/7/365 operations-capable.
  - Monitoring of energy, flow, chemical usage, etc.
  - Waste management and SWD on-site.
  - Workspace, control room, restroom.
- Pilot treatment rates up to 25 gpm
- Pretreatment
  - Blending of water to target TDS level of 180,000 mg/L or tailored blends ranging between <5000 and >300,000 mg/L TDS to suit capabilities and/or limitations of selected technologies.
  - Suspended solids removal (dissolved air flotation [DAF]).
  - Dissolved organics removal (granular activated carbon [GAC]).
  - Facility could be adapted for use with alternate fluid compositions and treatment processes.
- Technology demonstration bay
  - Accommodates standard semitractor trailer (53 ft long) inside the building.
  - 300 kW electric power
  - Propane (5000-gal tank).
  - Noncontact cooling water (30 gpm).



BRINE TREATMENT TEST BED



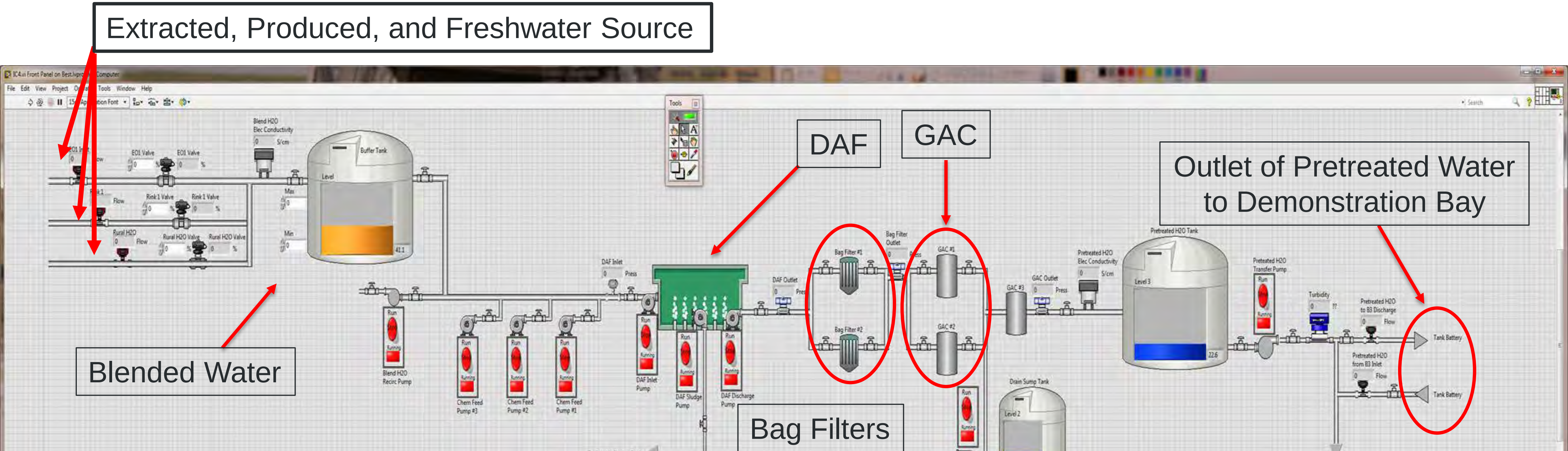
- 60 ft x 80 ft with 18-ft walls
- Two large overhead doors
- Heated environmental enclosure with air handling/exchange
- 53-ft test bay

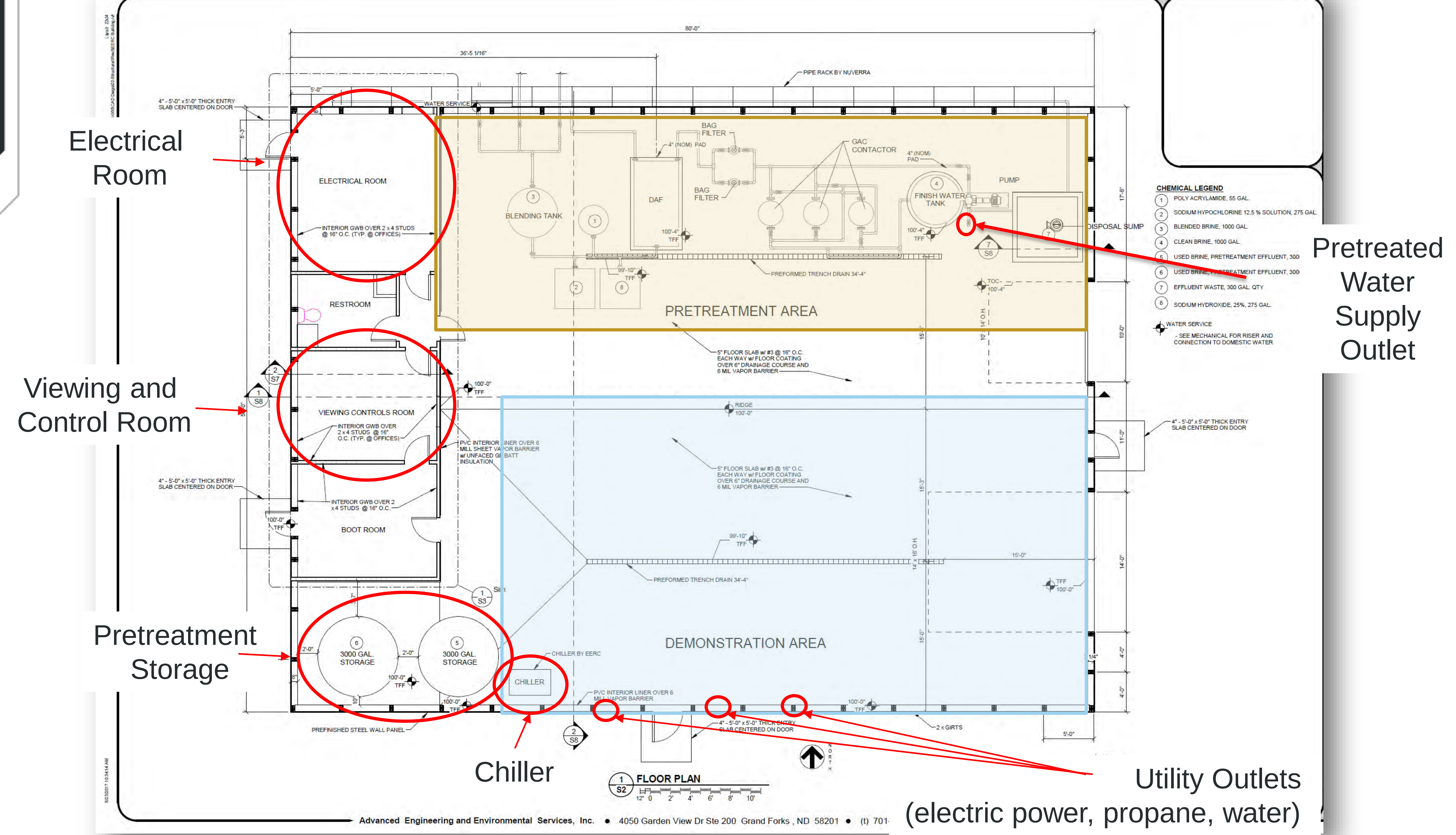


Class I, Division 1
Unclassified
Class I, Division 2
ELECTRICAL ROOM
RESTROOM
VIEWING CONTROLS ROOM
BOOT ROOM
PRETREATMENT AREA
DEMONSTRATION AREA
BLENDING TANK
DAF
BAG FILTER
GAC CONTACTOR
FINISH WATER TANK
DISPOSAL SUMP
3000 GAL. STORAGE
3000 GAL. STORAGE
CHILLER
CHILLER BY EERC
WATER SERVICE
PREFORMED TRENCH DRAIN 34'-4"
5" FLOOR SLAB w/ #3 @ 16" O.C. EACH WAY w/ FLOOR COATING OVER 6" DRAINAGE COURSE AND 6 MIL VAPOR BARRIER
PVC INTERIOR LINER OVER 6 MIL VAPOR BARRIER
4" - 5'-0" x 5'-0" THICK ENTRY SLAB CENTERED ON DOOR
PREFINISHED STEEL WALL PANEL
2 x GIRTS
99'-11" TOP OF ALL STOOPS
80'-0"
36'-5 1/16"
CHEMICAL LEGEND
1 POLY ACRYLAMIDE, 55 GAL.
2 SODIUM HYPOCHLORINE 12.5 % SOLUTION, 275 GAL.
3 BLENDED BRINE, 1000 GAL.
4 CLEAN BRINE, 1000 GAL.
5 USED BRINE, PRETREATMENT EFFLUENT, 3000 GAL.
6 USED BRINE, PRETREATMENT EFFLUENT, 3000 GAL.
7 EFFLUENT WASTE, 300 GAL. QTY
8 SODIUM HYDROXIDE, 25%, 275 GAL.
WATER SERVICE - SEE MECHANICAL FOR RISER AND CONNECTION TO DOMESTIC WATER
1 FLOOR PLAN S2
INDUSTRIAL
EERC BEST
AE2S CONSTRUCTION
WATFORD CITY, ND
FLOOR PLAN
DRAWING TYPE PRELIMINARY
PREPARED BY KW
CHECKED / APPROVED JK / JK
DATE JUNE 2017
PROJECT NUMBER P10828-2016-000
SHEET 2 of 8
DRAWING S2
Advanced Engineering and Environmental Services, Inc. • 4050 Garden View Dr Ste 200 Grand Forks , ND 58201 • (t) 701-746-8087 (f) 701-746-0370 • www.ae2s.com

BLENDING AND PRETREATMENT

- Blending of water to target TDS levels of 180,000 mg/L or other tailored blend to suit capabilities and/or limitations of selected technologies.
  - Water blending will take advantage of a combination of produced water (~300,000 mg/L TDS), extracted formation water (~10,000–100,000 mg/L TDS) and freshwater sources available on site.
- Suspended solids removal (DAF).
- Filter bags
- Dissolved organics removal (GAC).




Electrical Room
Viewing and Control Room
Pretreatment Storage
Chiller
Pretreated Water Supply Outlet
Utility Outlets (electric power, propane, water)
80'-0"
36'-5 1/16"
PIPE RACK BY NUVERRA
WATER SERVICE
ELECTRICAL ROOM
INTERIOR GWB OVER 2 x 4 STUDS @ 16" O.C. (TYP. @ OFFICES)
RESTROOM
VIEWING CONTROLS ROOM
BOOT ROOM
3000 GAL. STORAGE
3000 GAL. STORAGE
CHILLER
CHILLER BY EERC
BAG FILTER
GAC CONTACTOR
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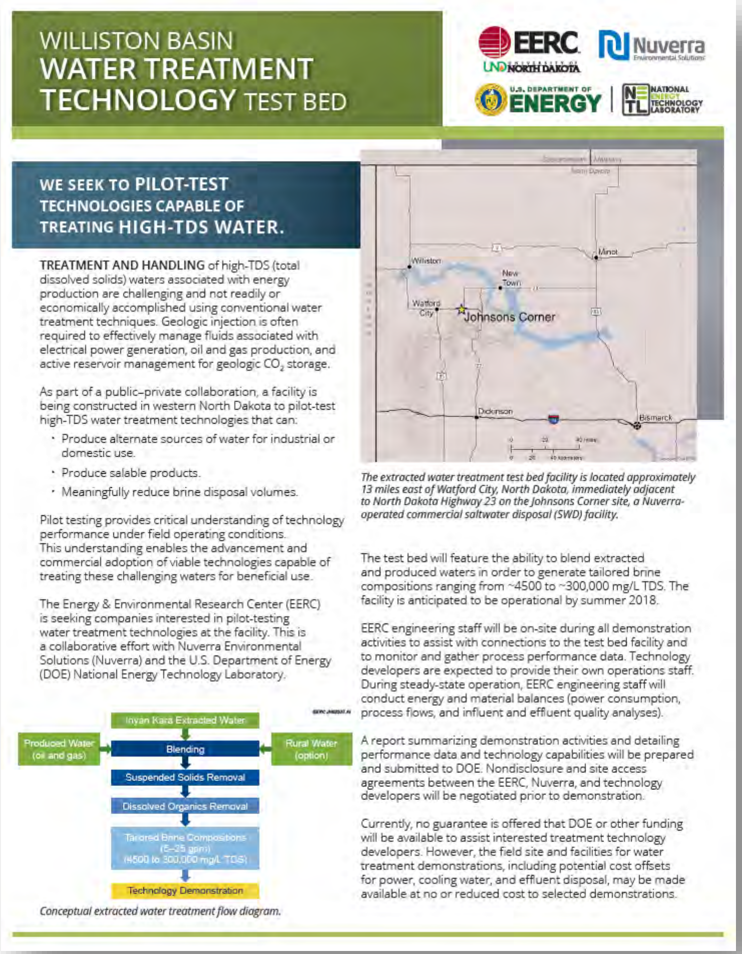
6 USED BRINE, PRETREATMENT EFFLUENT, 300
7 EFFLUENT WASTE, 300 GAL. QTY
8 SODIUM HYDROXIDE, 25%, 275 GAL.
WATER SERVICE
- SEE MECHANICAL FOR RISER AND CONNECTION TO DOMESTIC WATER
FLOOR PLAN
NORTH
Advanced Engineering and Environmental Services, Inc. • 4050 Garden View Dr Ste 200 Grand Forks, ND 58201 • (t) 701


OUTLET

TECHNOLOGY PROVIDER CONTACTS

- The EERC and EPRI collaborated with NETL to jointly develop a list of potential technology providers, a treatment technology-screening questionnaire, project fact sheets, and a technology demonstration screening and selection process.
  - NETL approved questionnaire and the screening and selection process in February 2018.
  - The EERC and EPRI are collaborating on engagement of potential brine treatment technology providers .
  - Technology providers were contacted and provided with the project fact sheets and questionnaire between April and June 2018.
- Several technology providers responded with questions, and three (out of 20) responded to the questionnaire.
  - Engagement is ongoing.



WILLISTON BASIN
WATER TREATMENT
TECHNOLOGY TEST BED

WE SEEK TO PILOT-TEST TECHNOLOGIES CAPABLE OF TREATING HIGH-TDS WATER.

TREATMENT AND HANDLING of high-TDS (total dissolved solids) waters associated with energy production are challenging and not readily or economically accomplished using conventional water treatment techniques. Geologic injection is often required to effectively manage fluids associated with electrical power generation, oil and gas production, and active reservoir management for geologic CO_2 storage.

As part of a public–private collaboration, a facility is being constructed in western North Dakota to pilot-test high-TDS water treatment technologies that can:

- Produce alternate sources of water for industrial or domestic use.
- Produce salable products.
- Meaningfully reduce brine disposal volumes.

Pilot testing provides critical understanding of technology performance under field operating conditions. This understanding enables the advancement and commercial adoption of viable technologies capable of treating these challenging waters for beneficial use.

The Energy & Environmental Research Center (EERC) is seeking companies interested in pilot-testing water treatment technologies at the facility. This is a collaborative effort with Nuverra Environmental Solutions (Nuverra) and the U.S. Department of Energy (DOE) National Energy Technology Laboratory.

The extracted water treatment test bed facility is located approximately 13 miles east of Watford City, North Dakota, immediately adjacent to North Dakota Highway 23 on the Johnsons Corner site, a Nuverra-operated commercial saltwater disposal (SWD) facility.

Conceptual extracted water treatment flow diagram.

The test bed will feature the ability to blend extracted and produced waters in order to generate tailored brine compositions ranging from ~4500 to ~300,000 mg/L TDS. The facility is anticipated to be operational by summer 2018.

EERC engineering staff will be on-site during all demonstration activities to assist with connections to the test bed facility and to monitor and gather process performance data. Technology developers are expected to provide their own operations staff. During steady-state operation, EERC engineering staff will conduct energy and material balances (power consumption, process flows, and influent and effluent quality analyses).

A report summarizing demonstration activities and detailing performance data and technology capabilities will be prepared and submitted to DOE. Nondisclosure and site access agreements between the EERC, Nuverra, and technology developers will be negotiated prior to demonstration.

Currently, no guarantee is offered that DOE or other funding will be available to assist interested treatment technology developers. However, the field site and facilities for water treatment demonstrations, including potential cost offsets for power, cooling water, and effluent disposal, may be made available at no or reduced cost to selected demonstrations.

<ins>Technology Providers Contacted by EERC</ins>

- ABR Process Development
- AE_2S, Inc.
- Caloris Thermal Process Technology
- Encon Evaporators
- Illinois State Geological Survey
  - University of Illinois at Urbana-Champaign
- Los Alamos National Laboratory
- Mantra Energy Alternatives
- MGX Minerals
- NETL
- Nuverra Environmental Solutions, Inc.
- Oasys Water
- Ohio University
  - Russ College of Engineering and Technology
- RTI International
- RWL Water
- GE Global Research
- Slipstream ZLD
- University of Pittsburgh
  - Department of Civil and Environmental Engineering

MAJOR ACCOMPLISHMENTS TO DATE (ARM)

- All design, permitting, and bonding complete.
- Drilled two new wells (BEST-E1 and BEST-I1).
  - Extraction well and extracted water injection well.
  - Conducted DST in Broom Creek interval.
  - Casing conveyed pressure/temperature gauge installed in BEST-E1.
- Collected new characterization data
  - 190 feet of core representing Inyan Kara and Broom Creek Formations.
  - Well logs.
  - Laboratory analysis ongoing.
  - Completed an update to field implementation plan (FIP).
- Installed water handling infrastructure (pipeline, pumps, tanks, monitoring equipment, etc.).
- Utilities installed.

MAJOR ACCOMPLISHMENTS TO DATE (TEST BED)

- Water treatment test bed demonstration facility constructed and internals fitted.
- Pretreatment equipment installed
- Utilities hookups complete.
- Initiated solicitation of water treatment demonstrations.

FUTURE ACTIVITIES

- Complete core testing
  - XRD, XRF, porosity, permeability,etc.
  - Fluid compatibility testing
- Update geologic models and field implementation plan (FIP).
- Complete wells (Perforate, acidize, test well, and install ESP).
  - BEST-E1 - Inyan Kara interval
  - BEST-I1 - Broom Creek and potentially Amsden intervals
- Install suspended gauges and conduct spinner survey in offset RINK SWD wells.
- Initiate FIP
- BSEM baseline survey and tracer injection.
- Shake down systems.
- Select and demonstrate water treatment technologies.

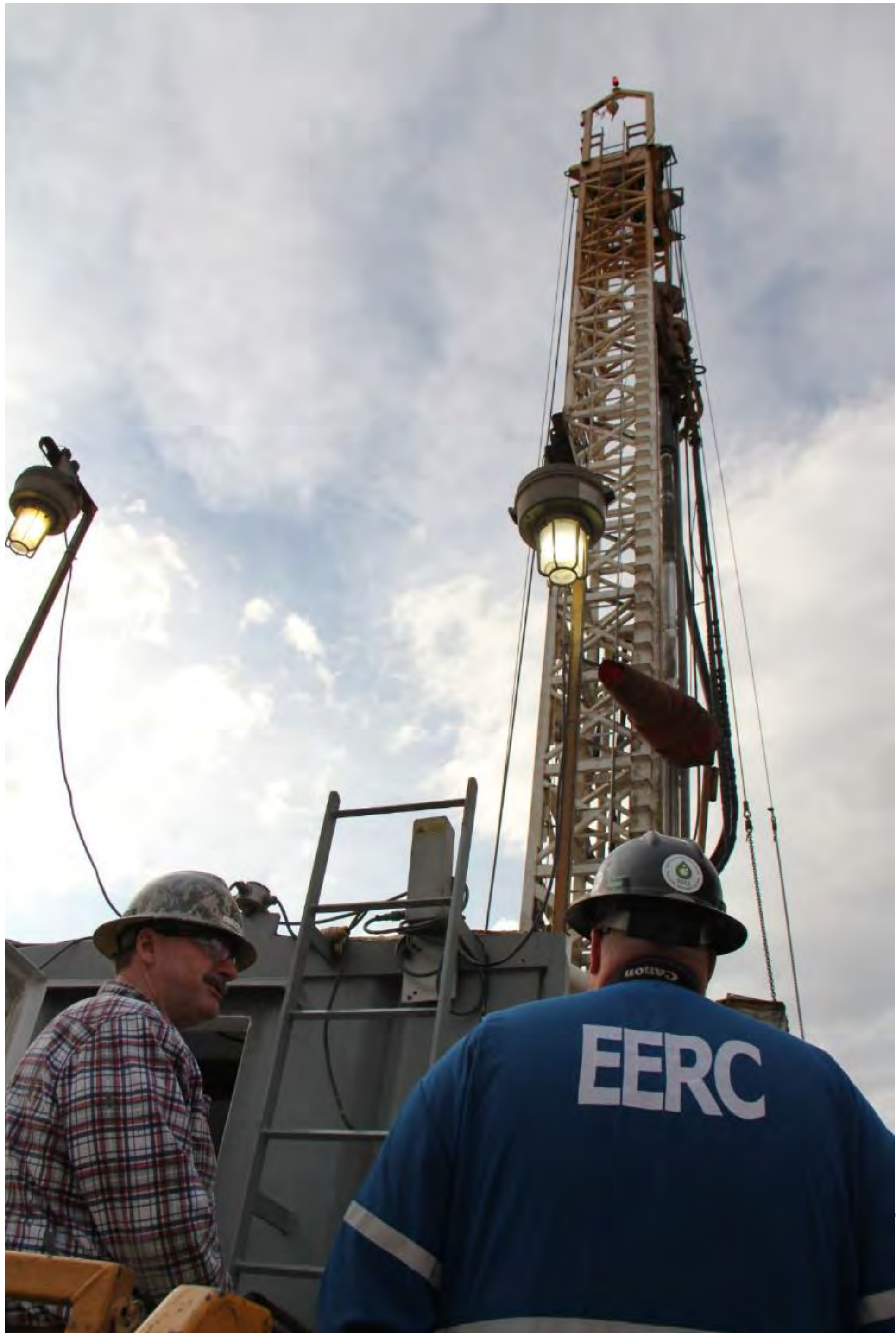
Operational Fall 2018

CHALLENGES & LESSONS LEARNED

Infrastructure installation is nearly complete; major research activities will initiate fall 2018.

- Flexibility to adapt operations and ARM to evolving operational and commercial conditions is critical for success.
- Designs cannot fully account for the real world. Have contingency plans in place and use them, be adaptive as conditions change
- Manage risk, cost, and objectives
- Hands-on involvement with drilling and construction pays dividends. Communicate with stakeholders regularly and often.
- Mother nature! (winter construction delays; some infrastructure has sustained wind damage; temporary brine storage (100ºF to -50ºF).
- Potential for fluid interactions, scaling, and TNORM.

- Geology can be unpredictable – may need to complete Amsden interval to achieve extraction target.
- Water treatment of target 180,000 mg/L TDS is challenging and generally not commercially economic.
- Field demonstration can be a technical, logistical and financial challenge for many technology providers lacking the strong market pull from a yet emerging industry.



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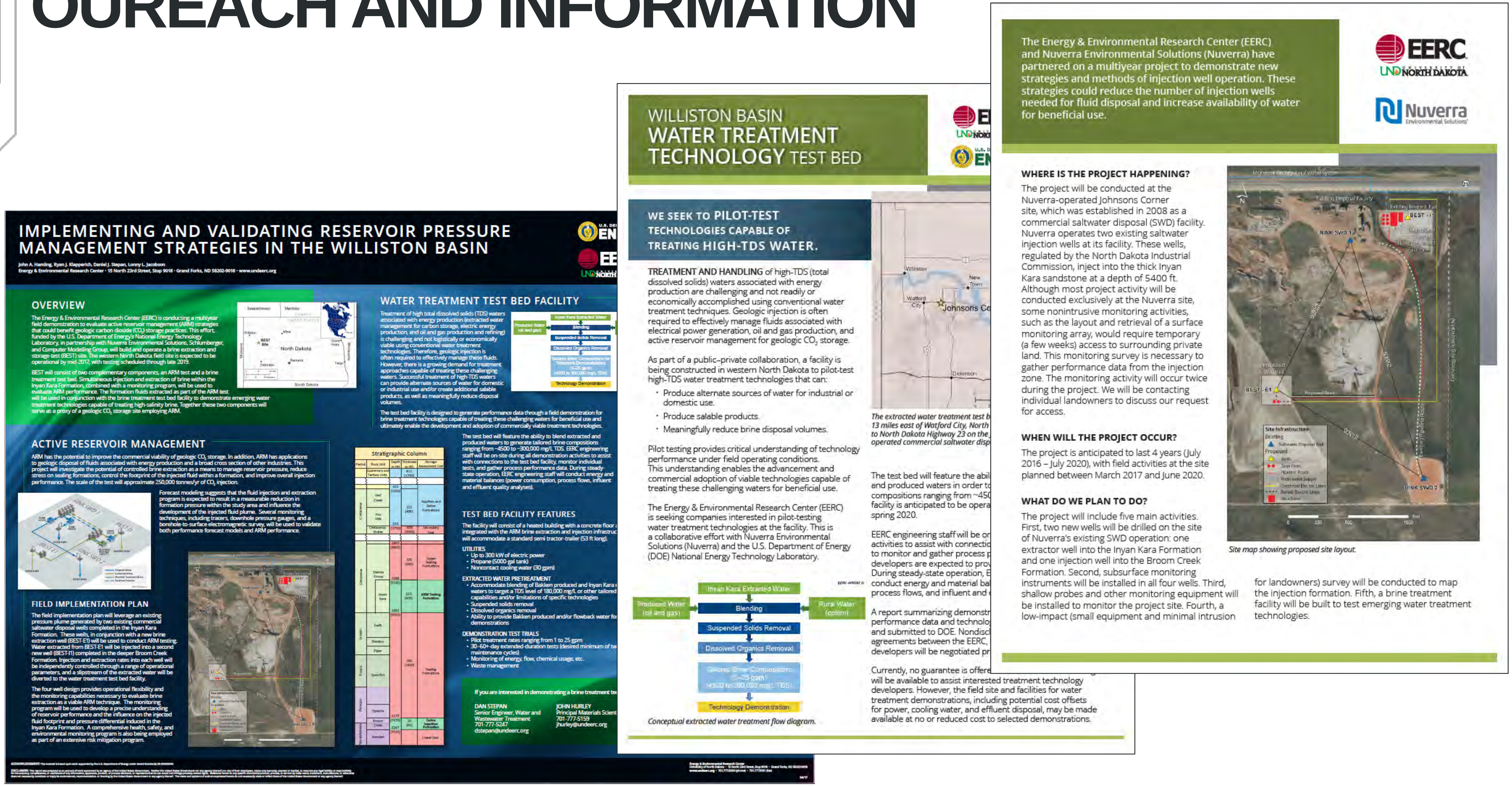
SYNERGY OPPORTUNITIES

- Opportunity to advance understanding of the impact of ARM on CO_2 injection operations.

- Opportunity to adapt facility to demonstrate water treatment technologies for multiple industries.
  - Produced water treatment and use
  - Industrial or municipal wastewater
  - Other chemical treatments
  - Formation effects (e.g. homogenization and filtering)

- Collaboration with EPRI-led Florida project.
  - e.g., technology vetting, complementary ARM test program, knowledge-sharing, etc.

OUREACH AND INFORMATION



SITE TOUR - IEAGHG RISK AND MODELING NETWORK MEETING

THANK YOU!

CONTACT INFORMATION

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701.777.5181 (fax)

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Assistant Director for Integrated Projects
jhamling@undeerc.org

APPENDIX

SUPPLEMENTAL SLIDES

TECHNICAL STATUS

Phase I – Complete

- Regional characterization
- Site screening and feasibility study
- Site selection
- Geologic modeling
- Reservoir simulation resulting in ARM schema
- Site infrastructure design and field implementation plan

Phase II – Under Way

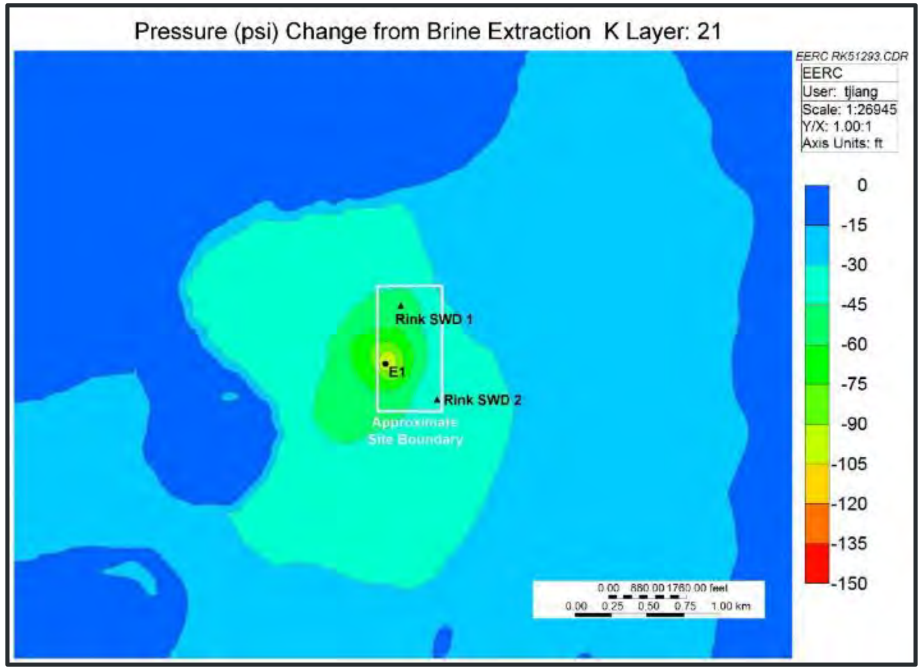
- ARM site preparation
  - Permitting
  - Well drilling
  - Surface infrastructure installation
  - Site characterization/model updates
- Test site preparation
  - Permitting
  - Test bed facility installation
  - Solicitation of treatment technologies
- ARM operations
  - Injection/extraction testing
  - Monitoring, verification, and accounting (MVA) implementation
  - Model updates/history matching
- Test bed treatment operations
  - Facility shakedown/training
  - Long-term performance evaluations
- ARM site closeout
  - ARM site decommissioning
  - Finalization of ARM test results/ data
- Brine treatment test bed site closeout
  - Treatment test bed decommissioning
  - Finalization of test bed results/ data

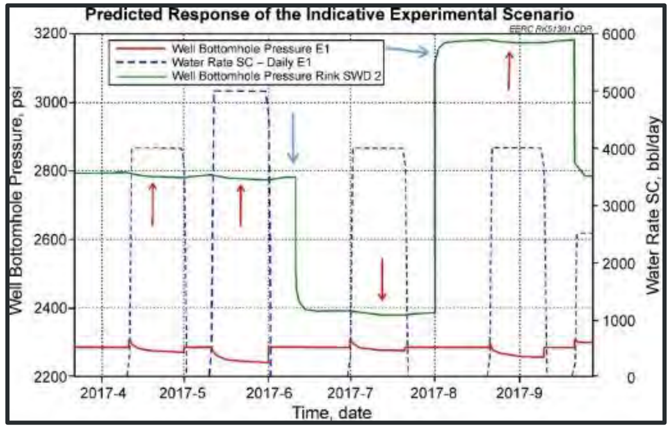
BRINE EXTRACTION FOR PRESSURE MANAGEMENT

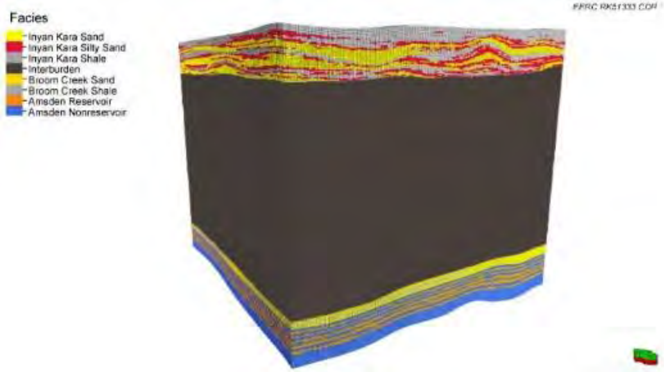
- Incremental cost
  - Wells and infrastructure
  - Operating and energy
- Disposal of extracted brine
  - Treatment and discharge
  - Reinjected into a <u>different</u> suitable geologic formation
- Efficiency losses
  - bbl_{out} > incremental bbl_{in}
- Complicates project
- Additional health, safety, and environmental risk

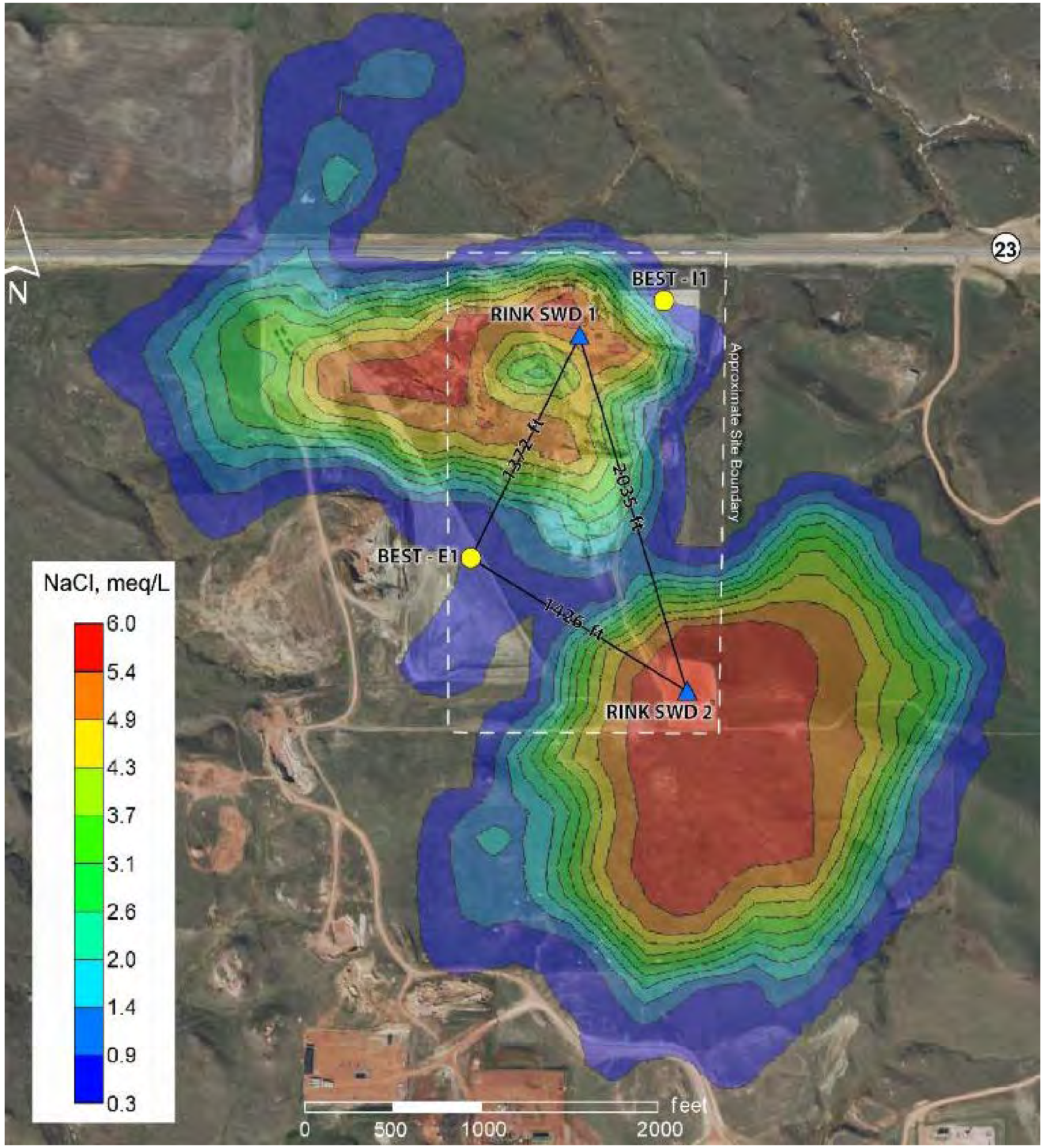
Brine extraction can enable dedicated CO_2 storage and improve the geologic CO_2 storage potential of a site.

THE DESIGN (BALANCE)









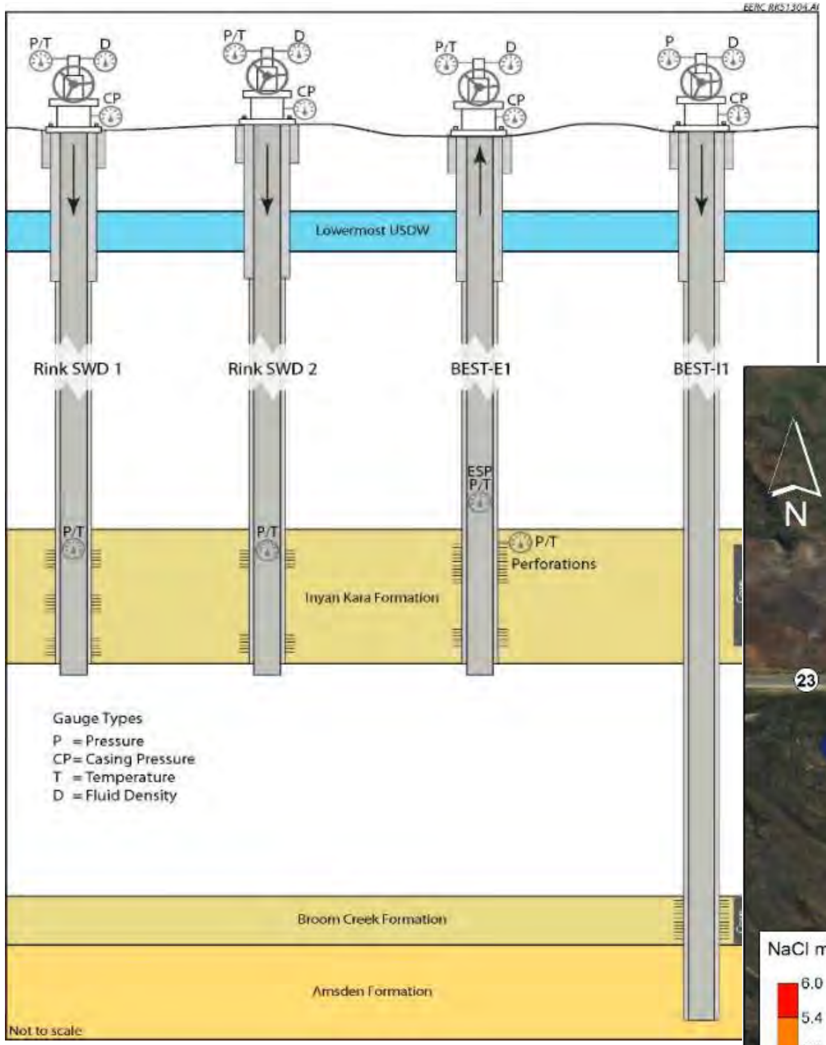
MVA PROGRAM

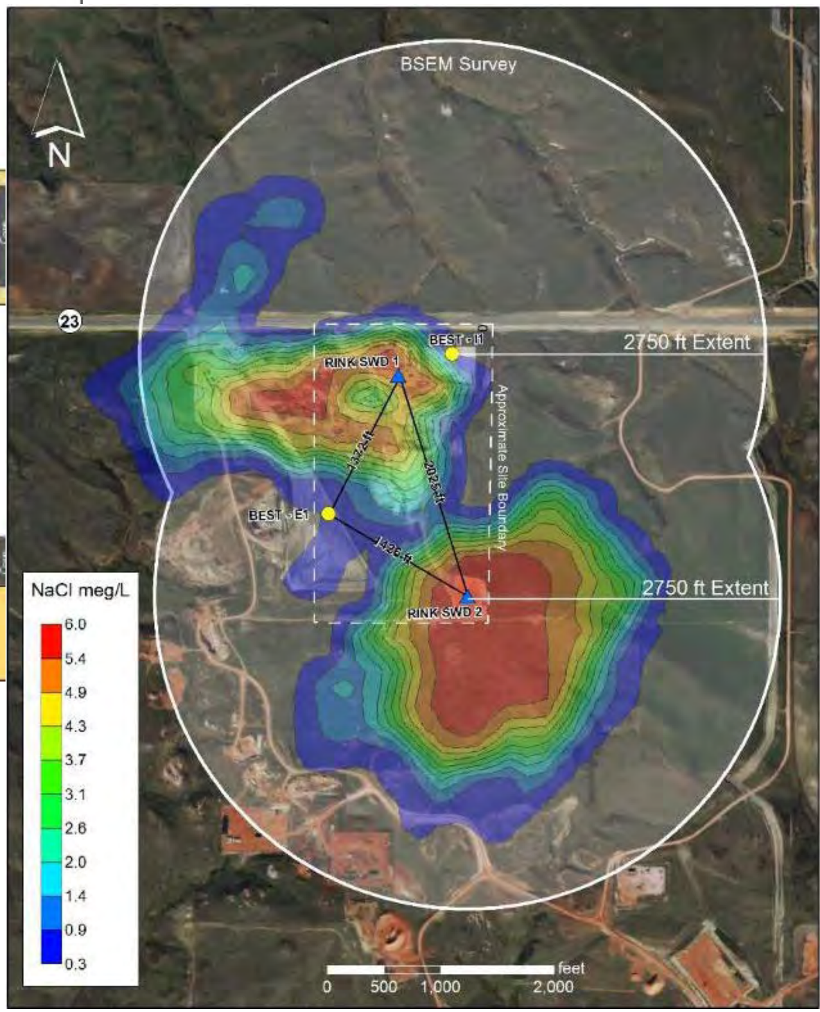
<u>Reservoir Surveillance</u>

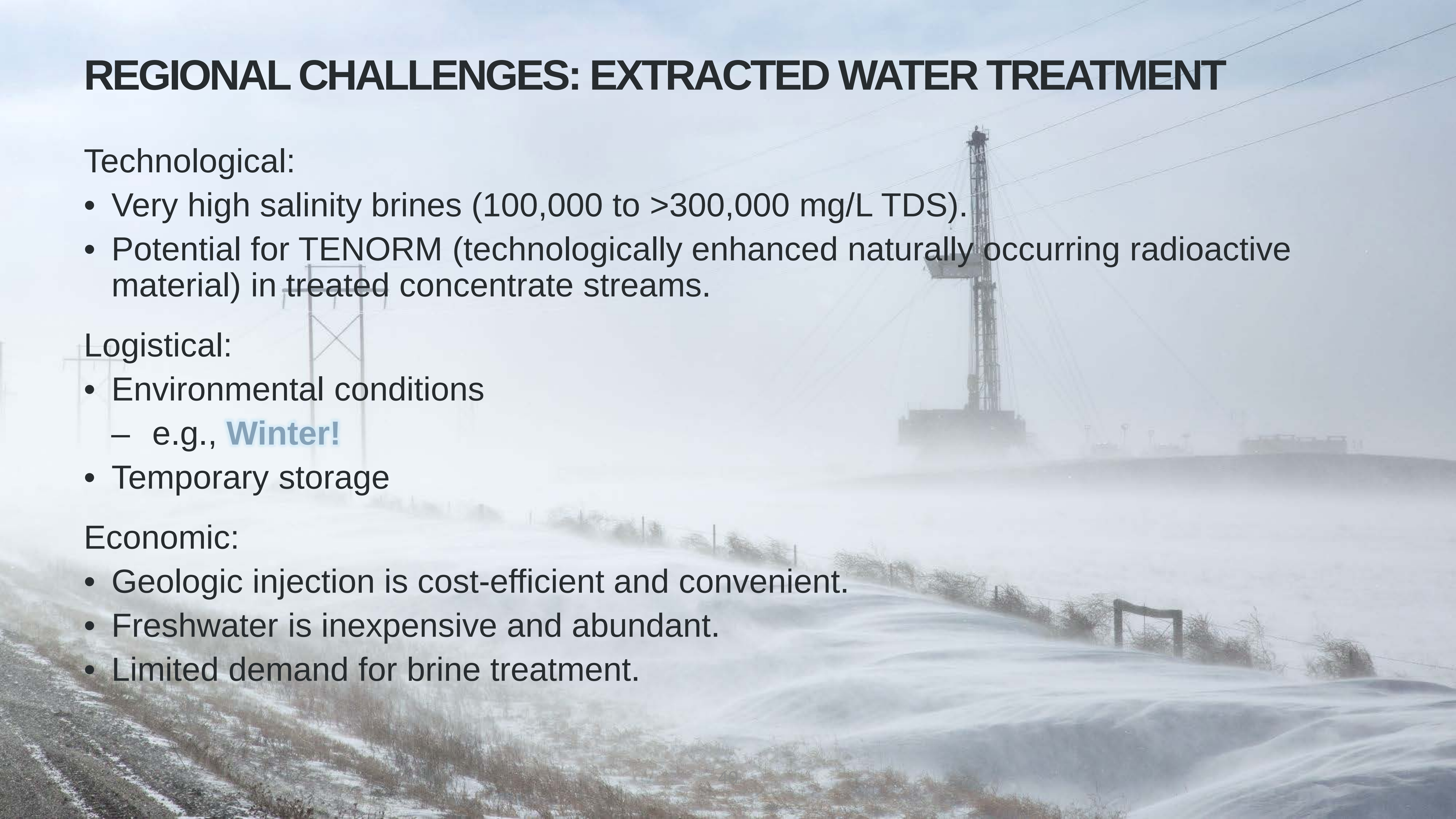
- Well evaluation
  - Logging, coring, testing
- Borehole to surface electromagnetic (BSEM)
- Active reservoir surveillance
  - Pressure, temperature, flow rates, fluid density
- Tracer survey
- Fluid sampling

<u>Safety and Performance</u>

- Tank and pipeline monitoring and response plans
- Dual containment pipeline
- Flow and density meters
- Power and chemicals
- Pipeline monitoring
- High-level/low-level shutdown
- Remote sensing







REGIONAL CHALLENGES: EXTRACTED WATER TREATMENT

Technological:

- Very high salinity brines (100,000 to >300,000 mg/L TDS).
- Potential for TENORM (technologically enhanced naturally occurring radioactive material) in treated concentrate streams.

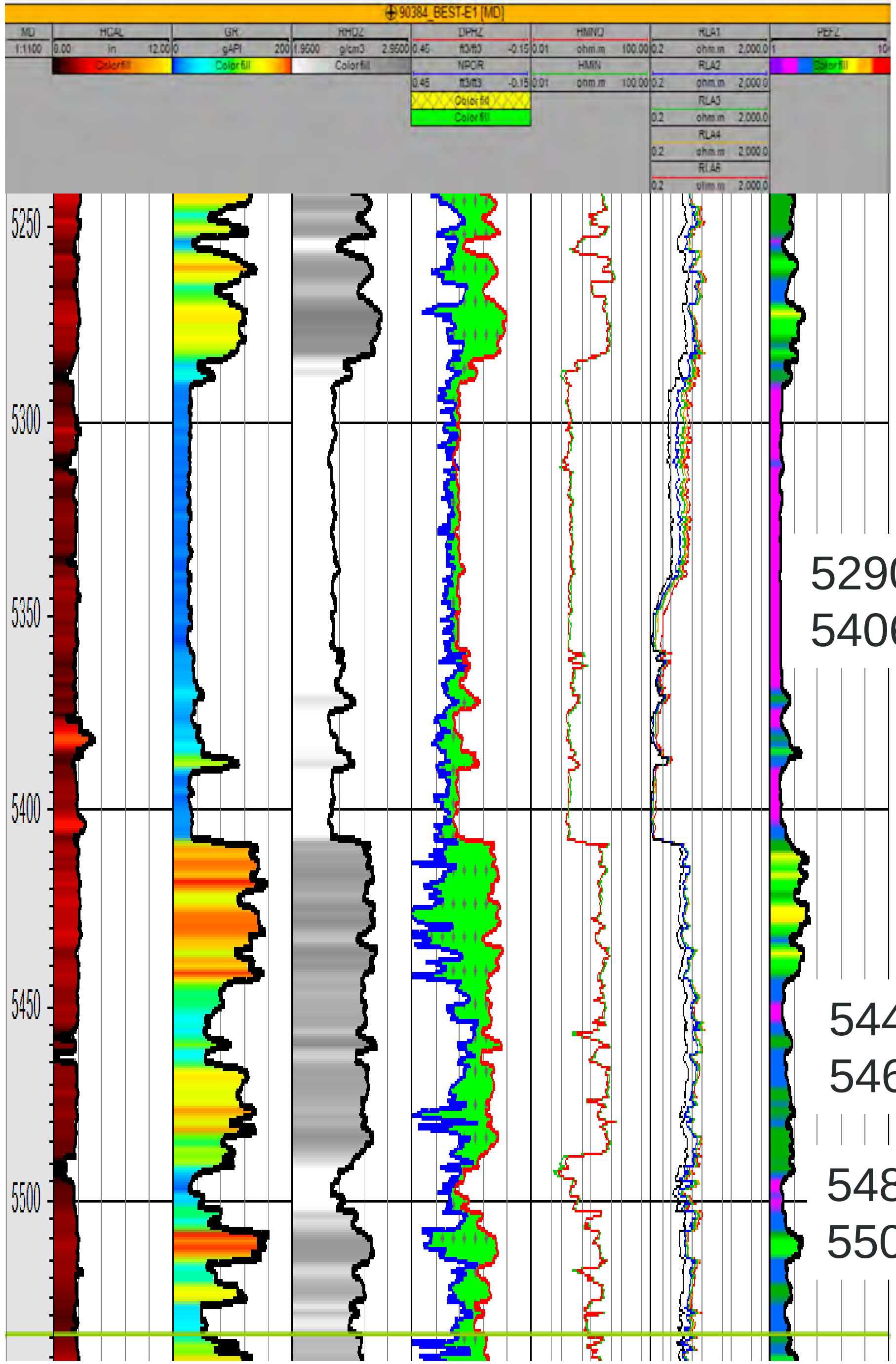
Logistical:

- Environmental conditions
  - e.g., **Winter!**
- Temporary storage

Economic:

- Geologic injection is cost-efficient and convenient.
- Freshwater is inexpensive and abundant.
- Limited demand for brine treatment.

BEST-E1

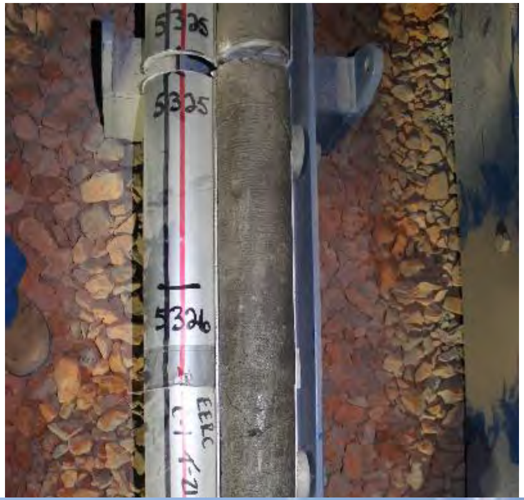


5290 – 5406

5443 – 5465

5484 – 5506

DRILLING PICTURES







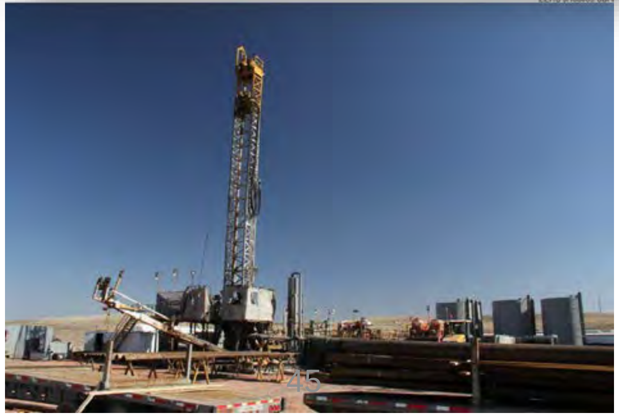


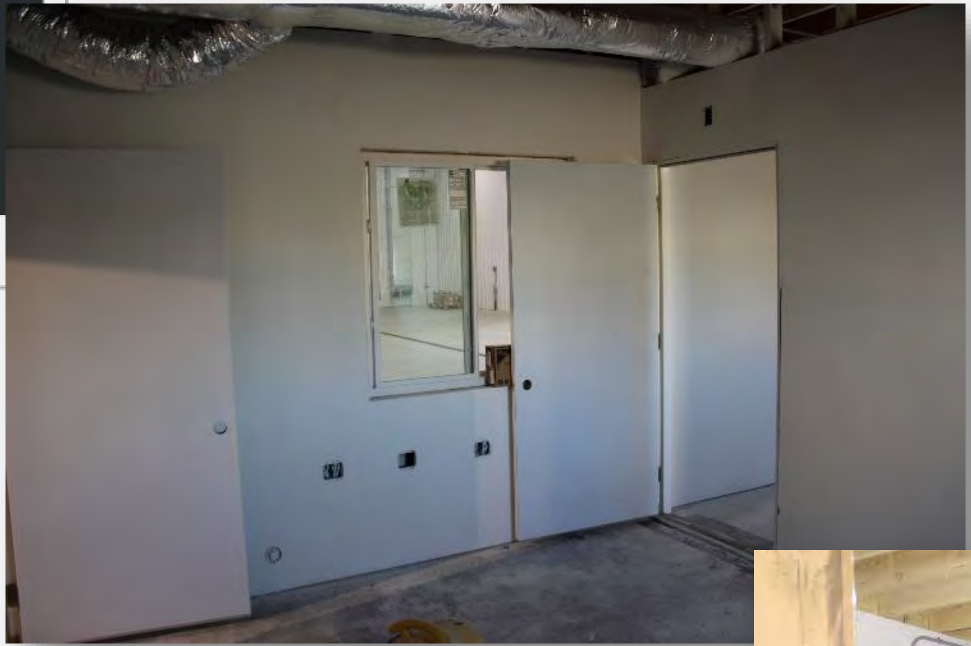
East



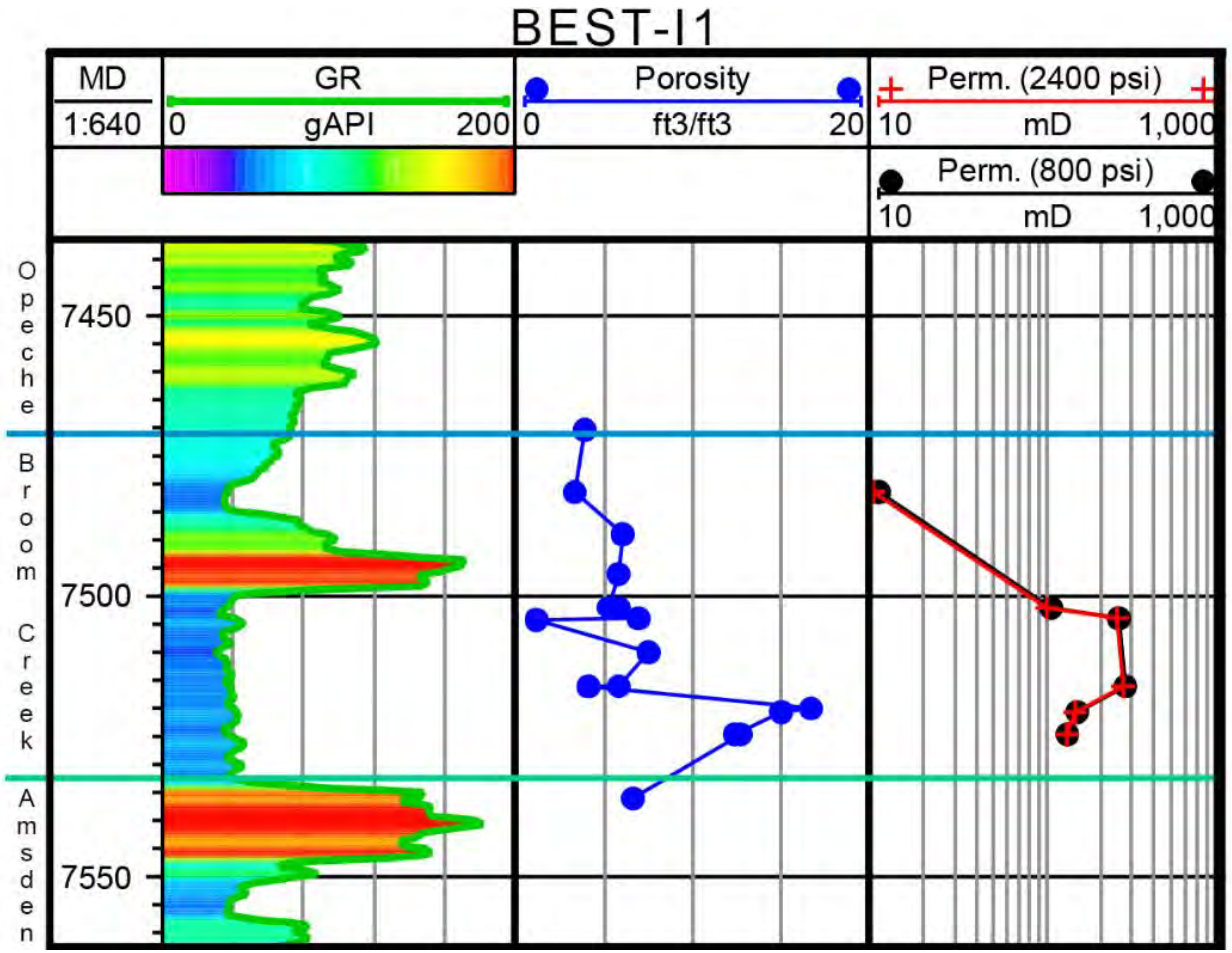


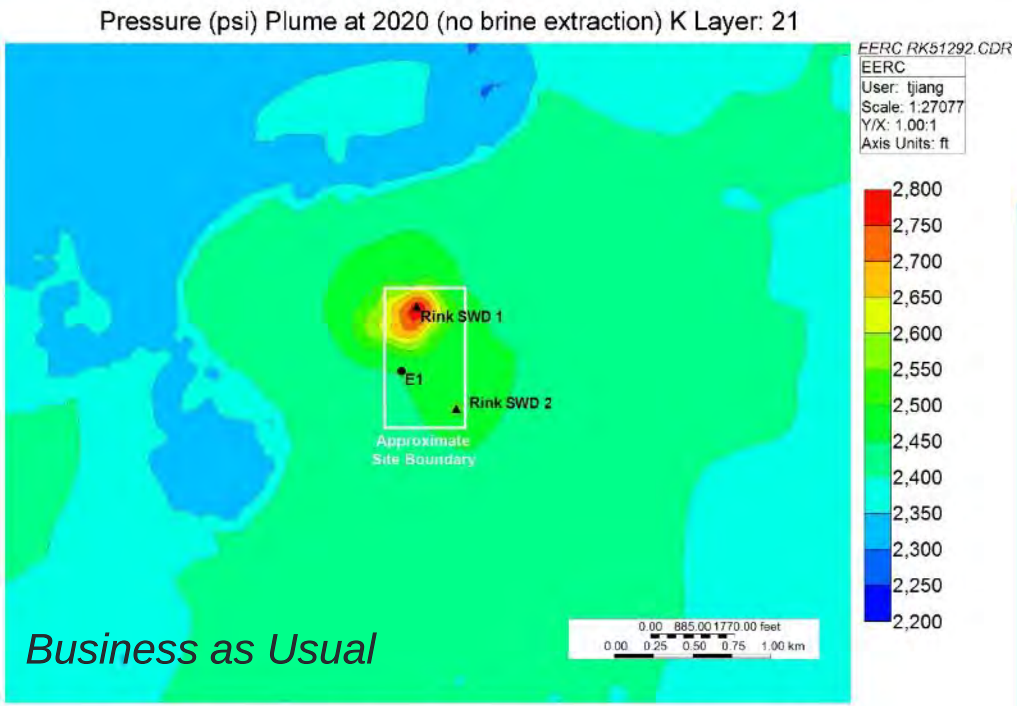


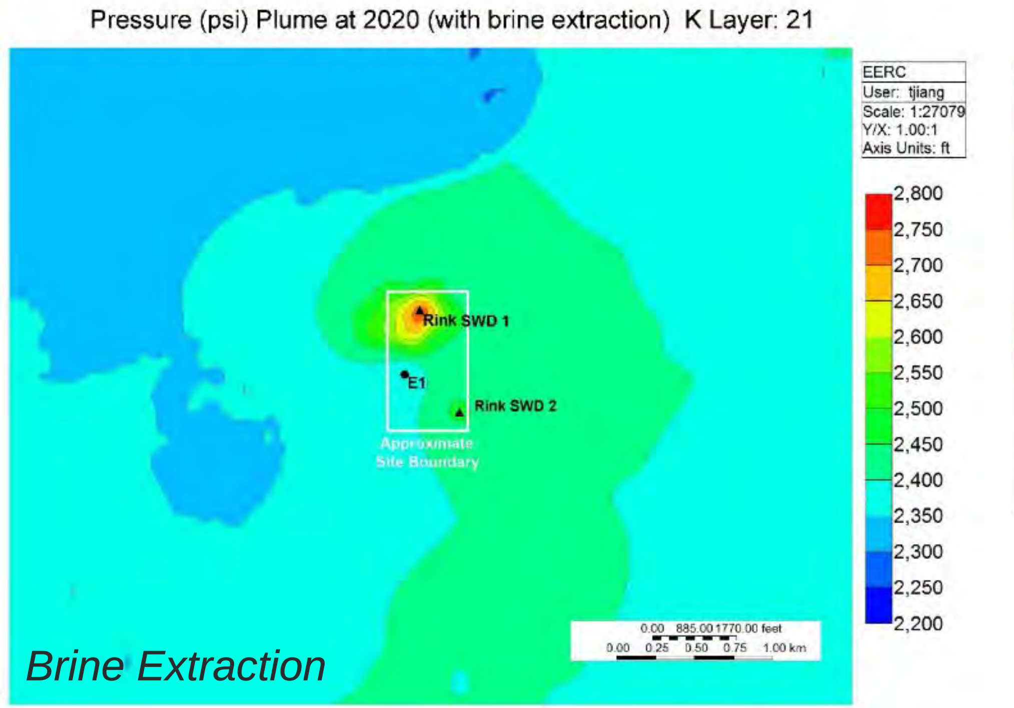


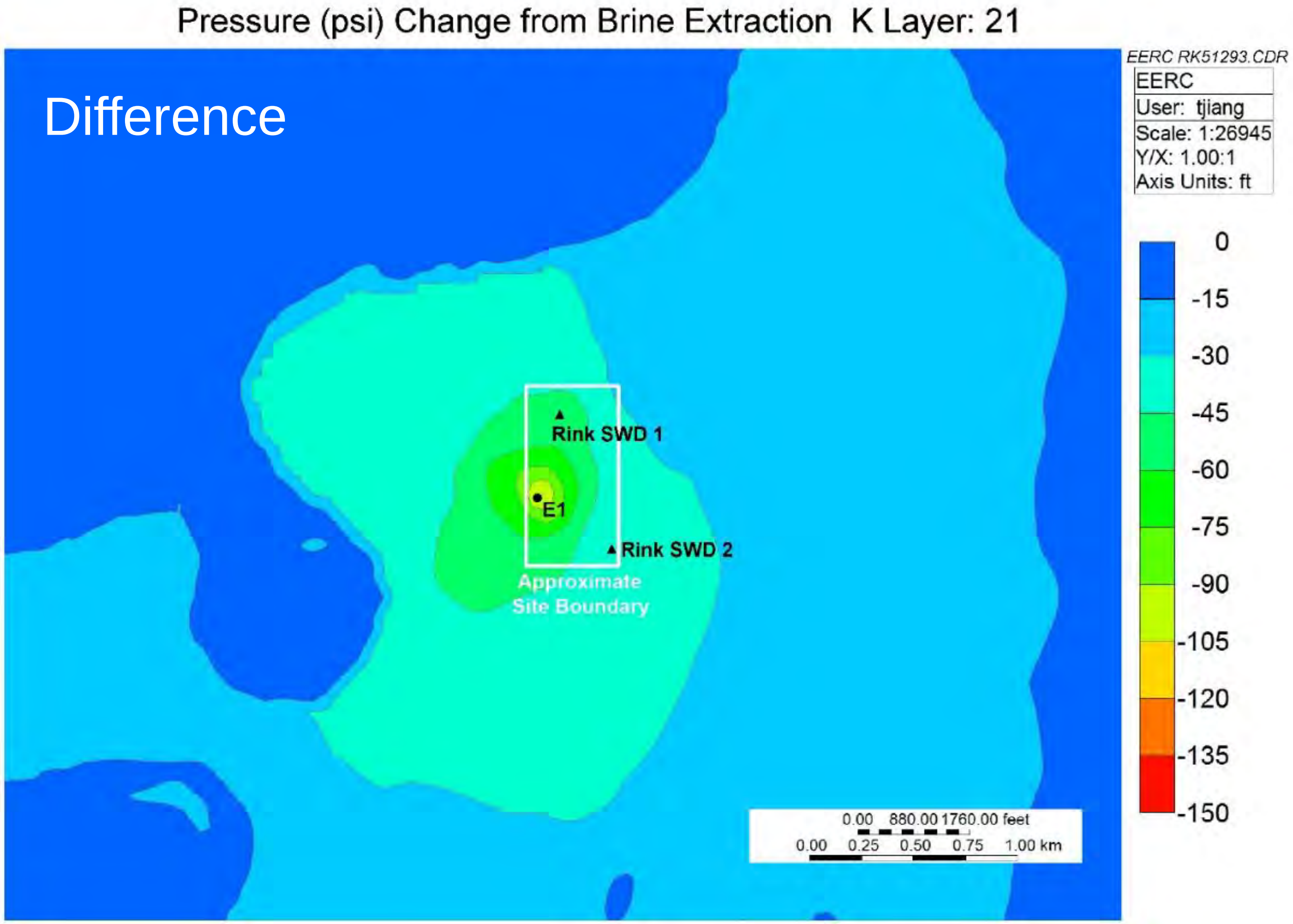


BROOM CREEK CORE TESTS

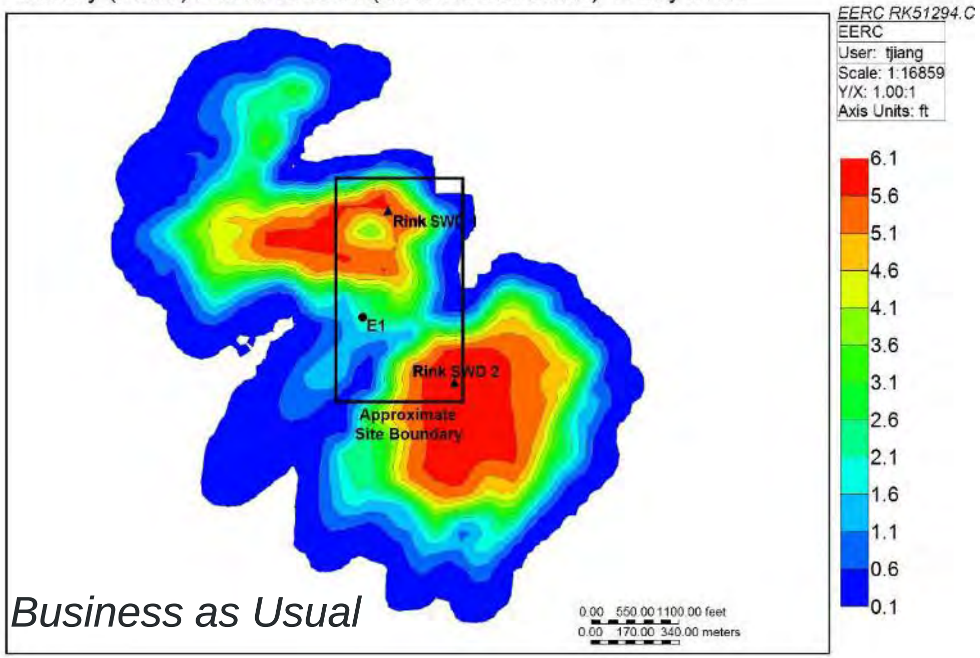



Pressure (psi) Plume at 2020 (no brine extraction) K Layer: 21
EERC RK51292.CDR
EERC
User: tjiang
Scale: 1:27077
Y/X: 1.00:1
Axis Units: ft
2,800
2,750
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Rink SWD 1
E1
Rink SWD 2
Approximate
Site Boundary
0.00 885.00 1770.00 feet
0.00 0.25 0.50 0.75 1.00 km
Business as Usual

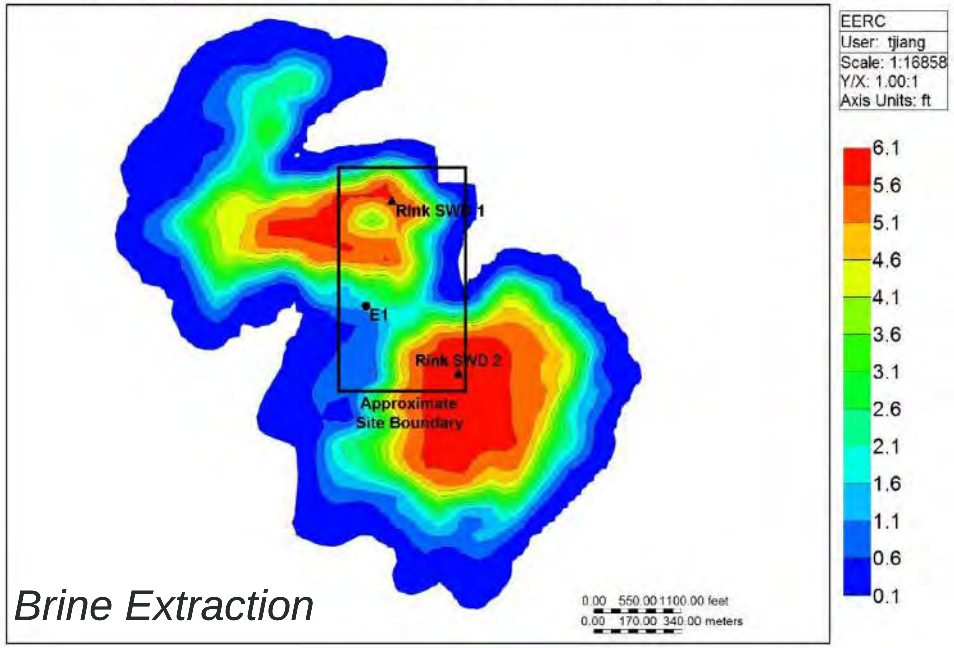

Pressure (psi) Plume at 2020 (with brine extraction) K Layer: 21
EERC
User: tjiang
Scale: 1:27079
Y/X: 1.00:1
Axis Units: ft
2,800
2,750
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
Rink SWD 1
E1
Rink SWD 2
Approximate
Site Boundary
0.00 885.00 1770.00 feet
0.00 0.25 0.50 0.75 1.00 km
Brine Extraction


Pressure (psi) Change from Brine Extraction K Layer: 21
Difference
EERC RK51293.CDR
EERC
User: tjiang
Scale: 1:26945
Y/X: 1.00:1
Axis Units: ft
0
-15
-30
-45
-60
-75
-90
-105
-120
-135
-150
Rink SWD 1
E1
Rink SWD 2
Approximate
Site Boundary
0.00 880.00 1760.00 feet
0.00 0.25 0.50 0.75 1.00 km

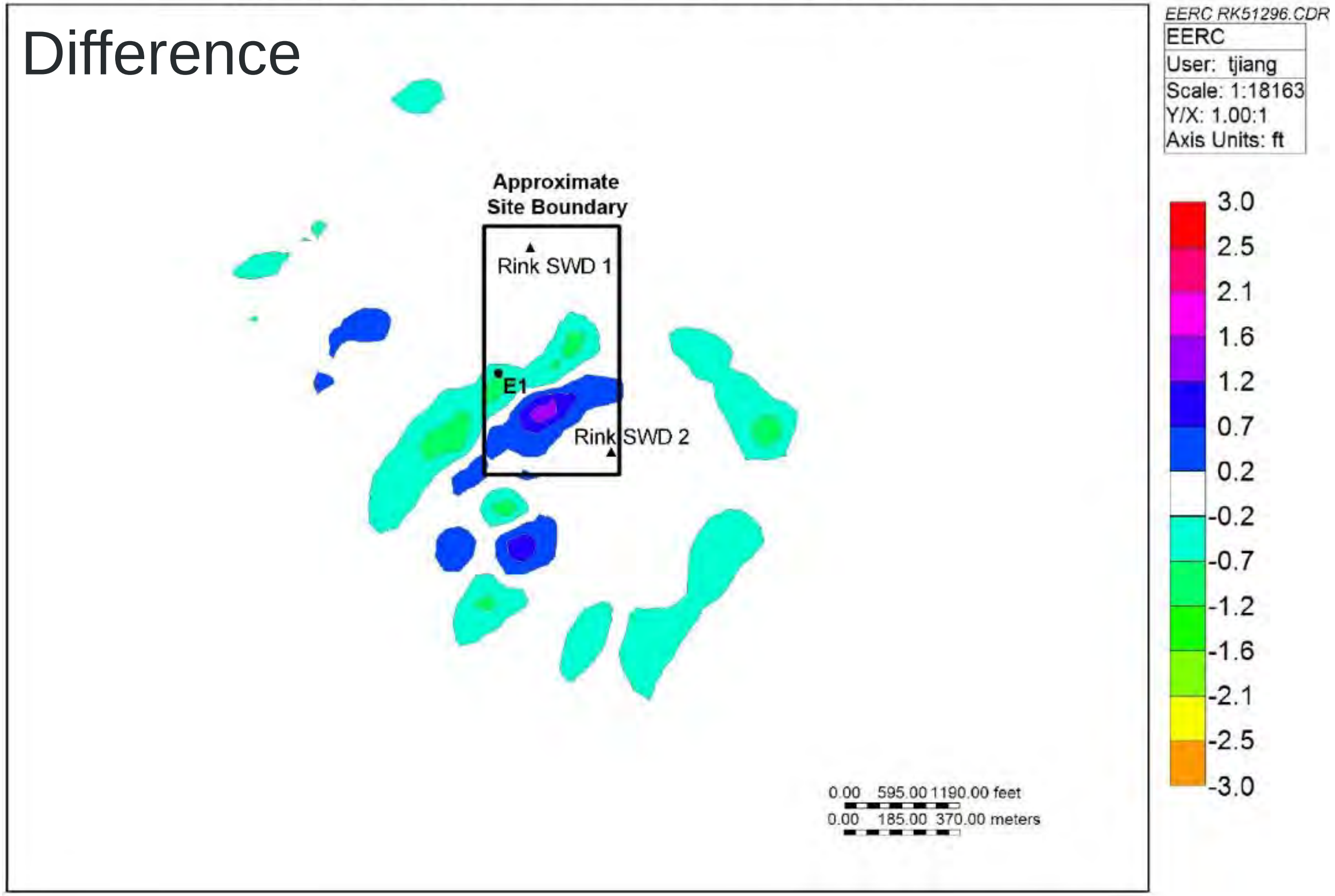
Salinity (molar) Plume at 2020 (no brine extraction) K Layer: 21



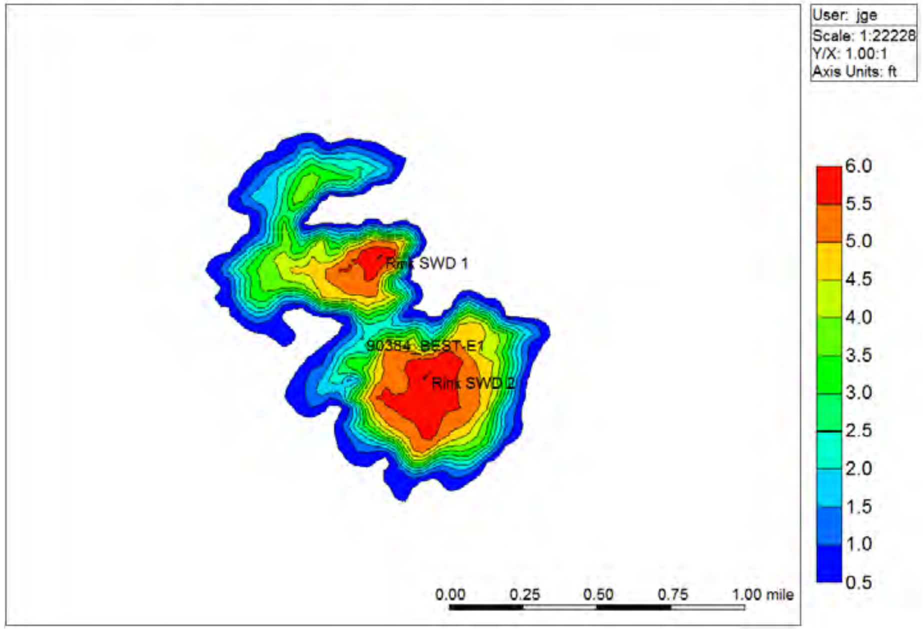
Salinity (molar) Plume after Brine Extraction K Layer: 21



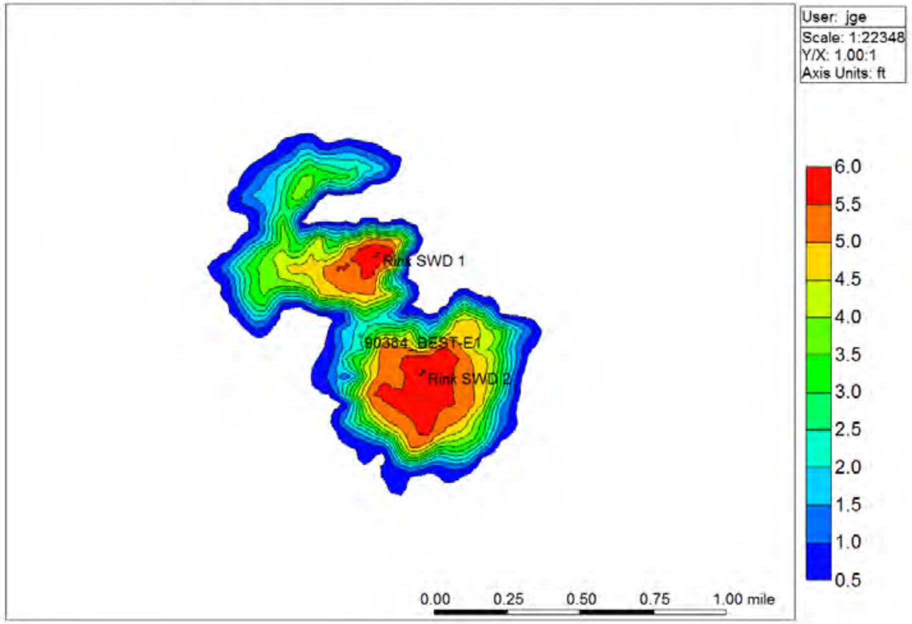
Salinity (molar) Change from Brine Extraction K Layer: 21



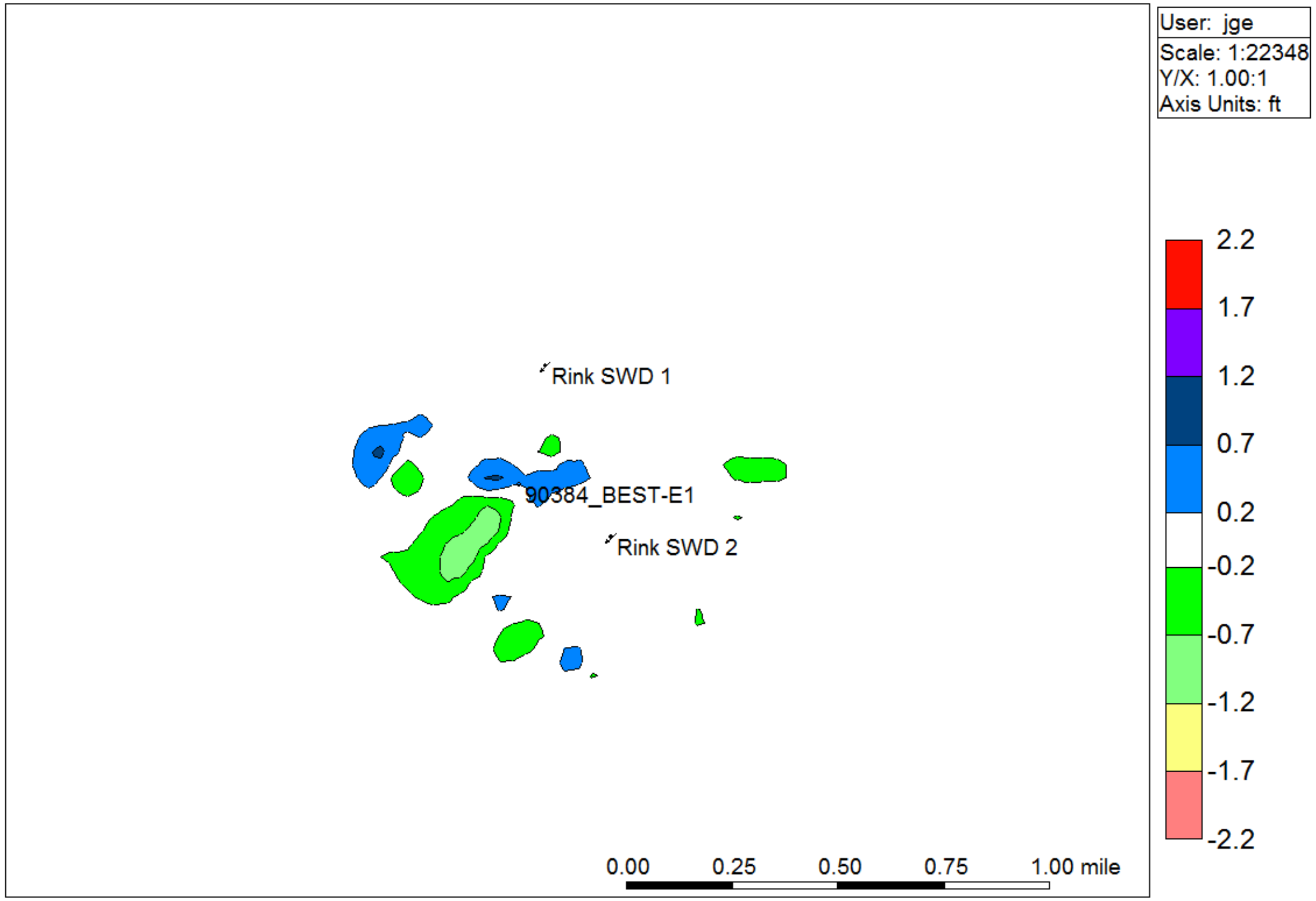
Salinity (molar) Plume without Brine Extraction 2020-08-01 K layer: 21



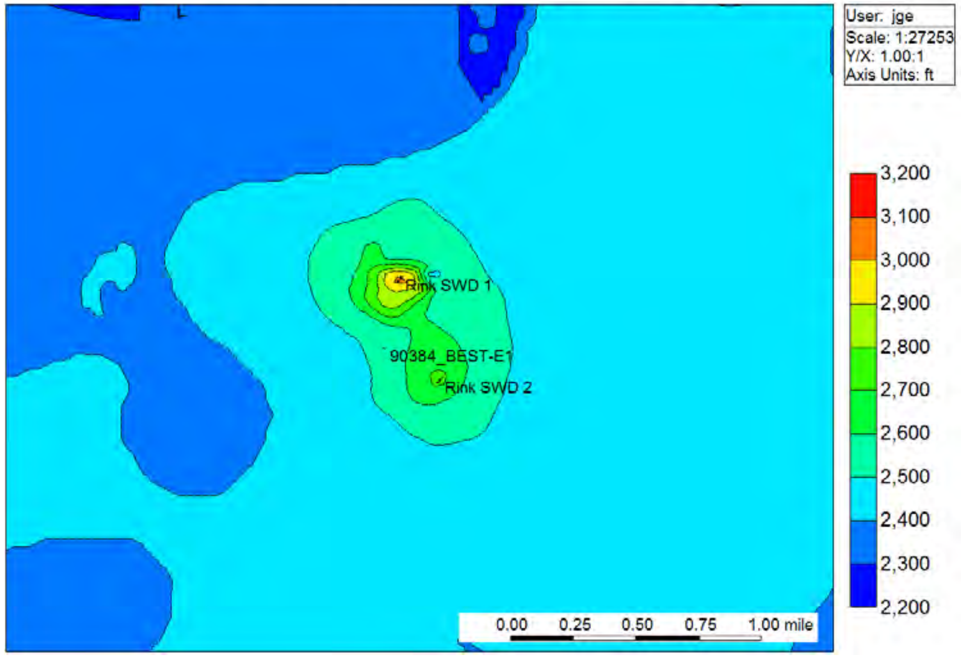
Salinity (molar) Plume with Brine Extraction 2020-08-01 K layer: 21



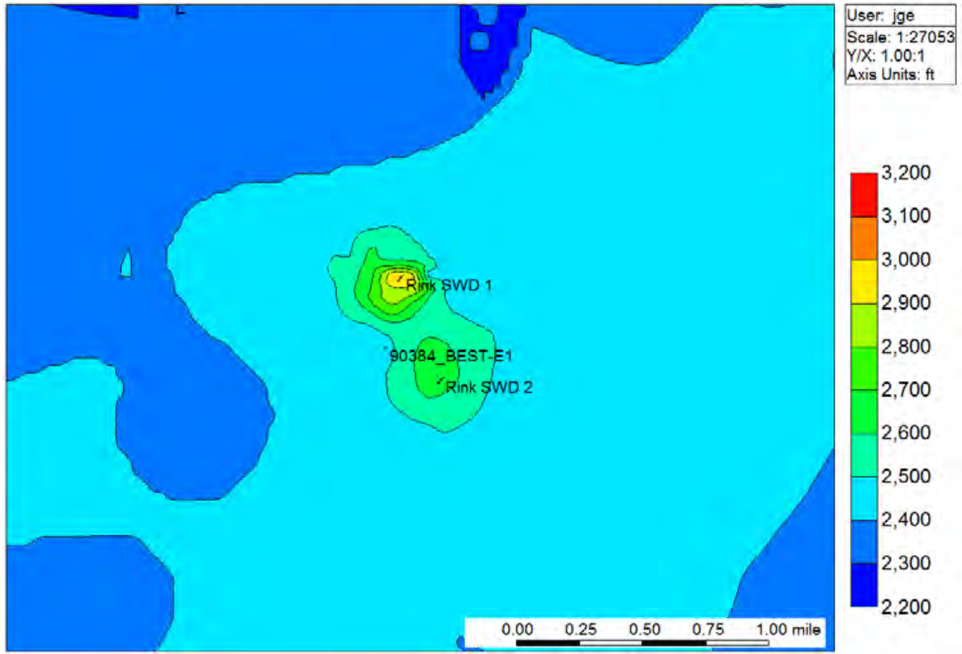
Salinity (molar) Change from Brine Extraction 2020-08-01 K layer: 21



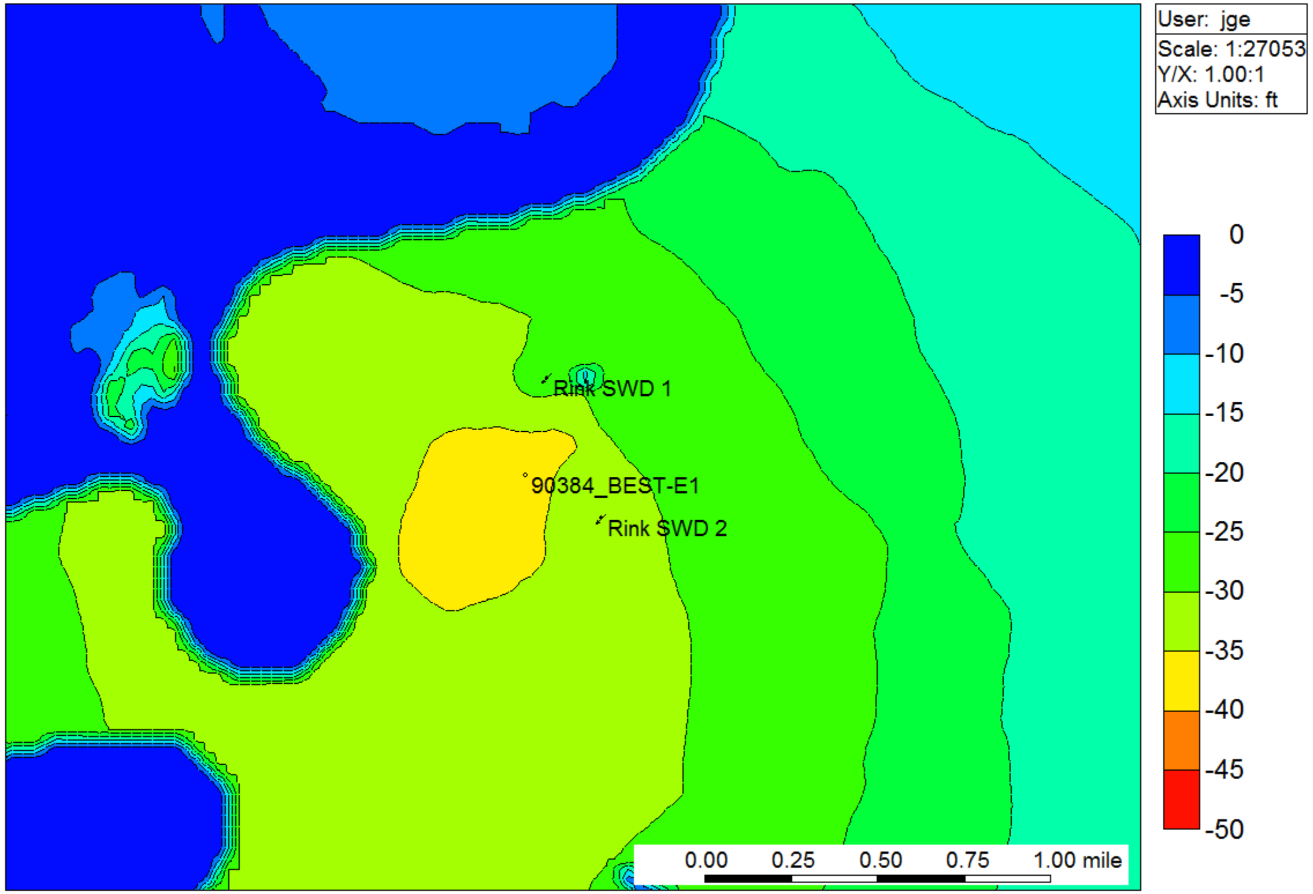
Pressure (psi) Plume without Brine Extraction 2020-08-01 K layer: 21



Pressure (psi) Plume with Brine Extraction 2020-08-01 K layer: 21



Pressure (psi) Change from Brine Extraction 2020-08-01 K layer: 21



TREATMENT TECHNOLOGY SELECTION PROTOCOL

- Screening criteria
  - Ability to produce a beneficial use effluent or product at reasonable operating costs based on target influent water quality
  - Enable successful operation of other technologies (i.e., pretreatment)
  - Provide a relatively high yield of treated water or product
  - Significantly reduce the volume of fluids requiring disposal
  - Not produce hazardous by-products

- Ranking factors
  - Treatment costs (40%)
  - Readiness level (30%)
  - Safety considerations (20%)
  - Waste generation (10%)

SOLICITING BRINE TREATMENT TECHNOLOGIES

- NETL, EPRI, and the EERC are coordinating efforts to define water treatment goals and solicit technologies for pilot testing.
  - Cooperatively developed vendor questionnaire and selection criteria
- The North Dakota and Florida facilities will provide unique water treatment scenarios but will have similar operational capabilities.
- North Dakota test bed is anticipated to be operational by fall 2018.
- Site access agreements will be negotiated between host site operator, EERC, and brine treatment technology provider.
- Knowledge-sharing workshop tentatively scheduled for fall 2018.

WILLISTON BASIN WATER TREATMENT TECHNOLOGY TEST BED

EERC UND UNIVERSITY OF NORTH DAKOTA · Nuverra Environmental Solutions · U.S. DEPARTMENT OF ENERGY · NATIONAL ENERGY TECHNOLOGY LABORATORY

WE SEEK TO PILOT-TEST TECHNOLOGIES CAPABLE OF TREATING HIGH-TDS WATER.

TREATMENT AND HANDLING of high-TDS (total dissolved solids) waters associated with energy production are challenging and not readily or economically accomplished using conventional water treatment techniques. Geologic injection is often required to effectively manage fluids associated with electrical power generation, oil and gas production, and active reservoir management for geologic CO_2 storage.

As part of a public–private collaboration, a facility is being constructed in western North Dakota to pilot-test high-TDS water treatment technologies that can:

- Produce alternate sources of water for industrial or domestic use.
- Produce salable products.
- Meaningfully reduce brine disposal volumes.

Pilot testing provides critical understanding of technology performance under field operating conditions. This understanding enables the advancement and commercial adoption of viable technologies capable of treating these challenging waters for beneficial use.

The Energy & Environmental Research Center (EERC) is seeking companies interested in pilot-testing water treatment technologies at the facility. This is a collaborative effort with Nuverra Environmental Solutions (Nuverra) and the U.S. Department of Energy (DOE) National Energy Technology Laboratory.

The extracted water treatment test bed facility is located approximately 13 miles east of Watford City, North Dakota, immediately adjacent to North Dakota Highway 23 on the Johnsons Corner site, a Nuverra-operated commercial saltwater disposal (SWD) facility.

Conceptual extracted water treatment flow diagram.

The test bed will feature the ability to blend extracted and produced waters in order to generate tailored brine compositions ranging from ~4500 to ~300,000 mg/L TDS. The facility is anticipated to be operational by summer 2018.

EERC engineering staff will be on-site during all demonstration activities to assist with connections to the test bed facility and to monitor and gather process performance data. Technology developers are expected to provide their own operations staff. During steady-state operation, EERC engineering staff will conduct energy and material balances (power consumption, process flows, and influent and effluent quality analyses).

A report summarizing demonstration activities and detailing performance data and technology capabilities will be prepared and submitted to DOE. Nondisclosure and site access agreements between the EERC, Nuverra, and technology developers will be negotiated prior to demonstration.

Currently, no guarantee is offered that DOE or other funding will be available to assist interested treatment technology developers. However, the field site and facilities for water treatment demonstrations, including potential cost offsets for power, cooling water, and effluent disposal, may be made available at no or reduced cost to selected demonstrations.

EMERGING BRINE TREATMENT TECHNOLOGIES

- Treatment technologies for high-salinity brines continue to evolve, but few have been tested at the commercial scale.
- Most technologies fall into several main categories:
  - Evaporation/distillation (mechanical vapor recompression)
  - Evaporation/crystallization (low- pressure, low-temperature evaporation)
  - Membrane treatment (reverse osmosis, forward osmosis, membrane distillation)
  - Freezing-based treatment

BRINE TREATMENT TEST BED OPERATIONS

- Shakedown testing of all pretreatment equipment prior to pilot tests.
- Selected technologies connected to the test bed facility – electric, propane, cooling water (EERC assistance to ensure safety requirements are satisfied).
- Technology vendors to provide operations staff, with assistance by EERC staff.
- During steady-state operation, EERC staff will conduct energy and material balances (power consumption, process flows, influent and effluent quality analyses).
- Extended operating periods (60+ days) to identify maintenance requirements and any operational issues.
- Operations will be scheduled to coincide with preferable operational windows (weather, ARM test program, etc.) where possible.

Top-ranked technologies may receive operating cost offsets.

OPERATIONS

- Shakedown testing of all pretreatment equipment prior to pilot tests.
- Selection and scheduling of treatment technology, negotiate site access agreements.
- Mobilize technology demonstration to site.
- Treatment technology connected to the test bed facility – electric, propane, cooling water, influent/effluent water, etc.
  - EERC assistance to ensure health, safety, environmental and operability.
- Treatment technology demonstration providers will operate their treatment equipment; the EERC will operate the treatment test bed facility in coordination with the treatment technology demonstrator.
- During steady-state operation, EERC staff will conduct energy and material balances (power consumption, process flows, influent and effluent quality analyses).
- Extended operating periods (60+ days) to identify maintenance requirements and any operational issues.
- Operations will be preferentially scheduled to coincide with optimal operational windows (weather, ARM test program, etc.) when possible.
- Effluent and treated water will be blended and reinjected where possible; waste streams unable to be reinjected will be disposed of at an authorized facility.

Top-ranked technologies may benefit from cost offsets.

BRINE TREATMENT TEST BED – POTENTIAL SYNERGY

- Technology providers are indicating limited resources and incentives for technology development and for CCUS and oil and gas brine treatment demonstrations.

- Facility could be readily adapted for use with alternate fluid compositions or treatment processes.
  - Alternate water sources trucked and offloaded at site
  - Blending of alternate fluid chemistries for demonstration of water or chemical treatment processes
  - Test beds for other fluid conditioning or treatment processes

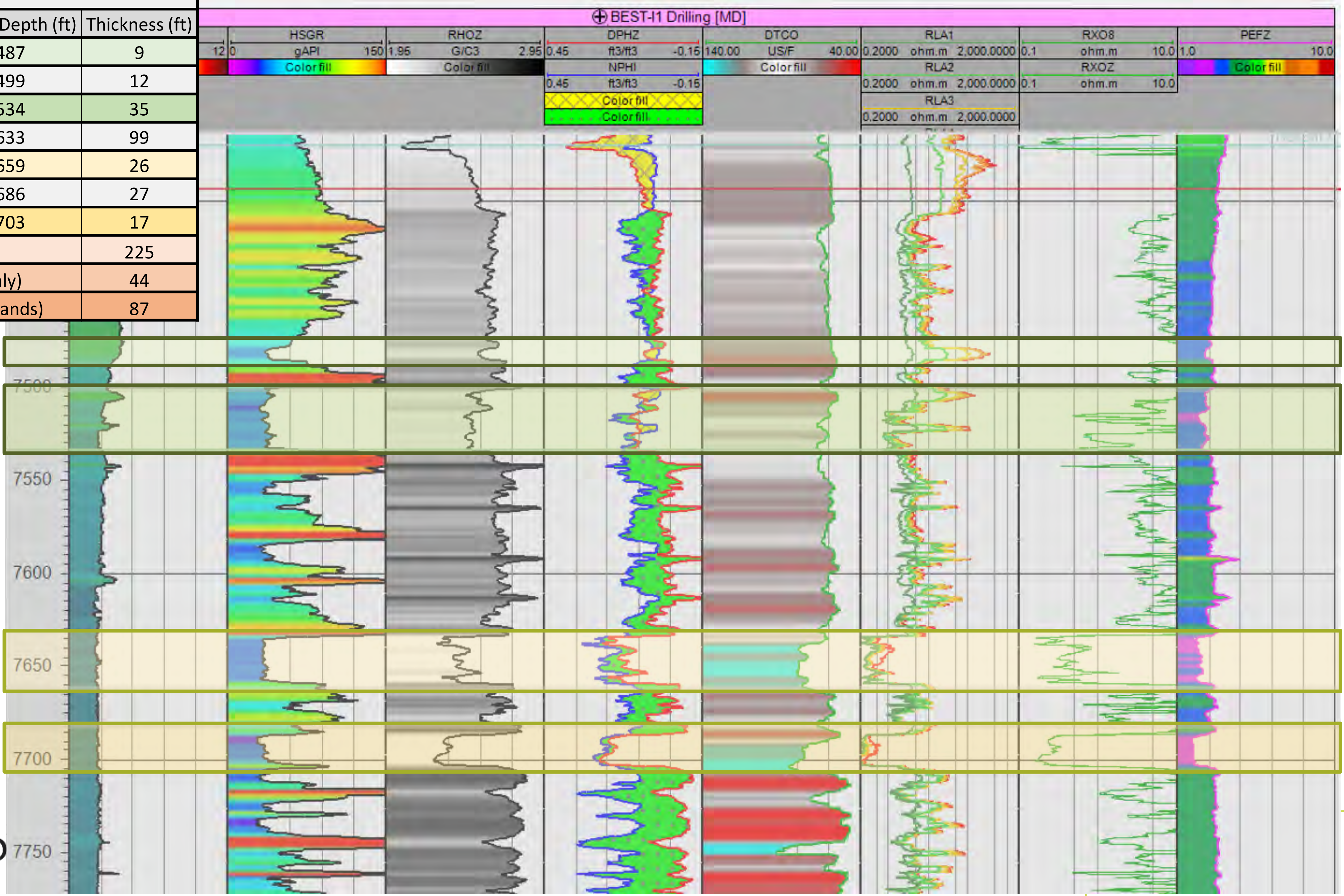
- Flexibility of the system makes it ideal for demonstrating a wide variety of technologies.
  - Oil and gas fluid conditioning (e.g., emulsion breaking, corrosion, scale inhibitors, fluid compatibility testing, etc.) and produced water treatment
  - Electric power generation wastewater treatment
  - Industrial and municipal waste and water treatment
  - Mineral resource recovery
  - Agricultural water treatment
  - Geologic conditioning and homogenization as a means of water pretreatment
  - Synergistic opportunities with other federal, state, or industry groups
  - Benchmarking the economic and technical limits of water treatment technologies (e.g., MVR)

PROJECT SUMMARY

- The EERC is finalizing construction of all infrastructure for the BEST program.
  - Wells drilled, pipeline installed, electrical service installed, test bed building constructed.
    - ♦ Complete wells and initiate MVA program
    - ♦ Pretreatment system being assembled; building is being outfitted.
    - ♦ Plumbing of ARM and treatment systems.
  - ARM infrastructure and treatment technology test bed are anticipated to be fully operational by fall 2018.
  - Continue engagement with technology providers.

BEST-I1 Recommended Completion Intervals

BEST-I1 Completion			
Interval	Top Depth (ft)	Bottom Depth (ft)	Thickness (ft)
Upper Broom Creek	7478	7487	9
Interburden	7487	7499	12
Lower Broom Creek	7499	7534	35
Interburden	7534	7633	99
Amsden 1	7633	7659	26
Interburden	7659	7686	27
Amsden 2	7686	7703	17
Gross Thickness (All Units)			225
Net Thickness (Broom Creek Sands Only)			44
Net Thickness (Broom Creek + Amsden Sands)			87



Upper BC Sand

Lower BC Sand

Amsden 1

Amsden 2

APPENDIX
REQUESTED SLIDES

PRESENTATION OUTLINE

- Technical Status
  - Overview
  - Active Reservoir Management (ARM) Installations
  - Brine Treatment Test Bed Installations
- Major Accomplishments
- Future Activities
- Lessons Learned
- Synergistic Opportunities
- Summary

BENEFIT TO THE PROGRAM

This project is expected to result in the development of engineering strategies/approaches to quantitatively affect changes in differential formation pressure and to monitor, predict, and manage differential pressure plume movement in the subsurface for future CO_2 saline storage projects. Additionally, the brine treatment technology evaluation is expected to provide valuable information on the ability to produce water for beneficial use. The results derived from implementation of the project will provide a significant contribution to the U.S. Department of Energy's (DOE's) Carbon Storage Program goals. Specifically, this project will support **Goals 1 and 2** by validating technologies that will improve reservoir storage efficiency, ensure containment effectiveness, and/or ensure storage permanence by controlling injected fluid plumes in a representative CO_2 storage target. Geologic characterization of the target horizons will provide fundamental data to improve storage coefficients related to the respective depositional environments investigated, directly contributing to **Goal 3**. In addition, this project will support **Goal 4** by producing information that will be useful for inclusion in DOE best practices manuals.

PROJECT OVERVIEW

GOALS AND OBJECTIVES

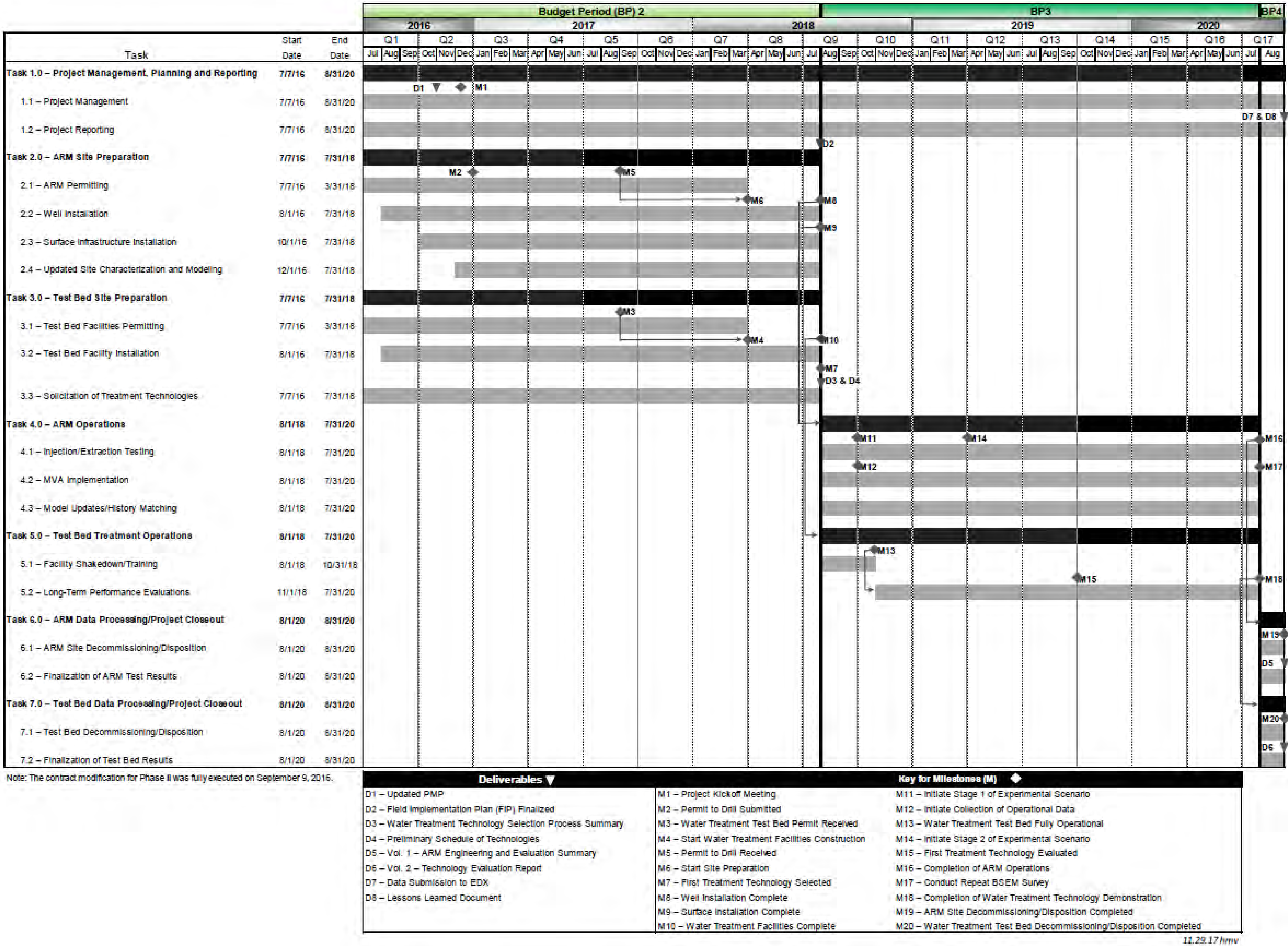
- Confirm efficacy of the ARM approaches developed during Phase I
  - Formation pressure
  - Predicting and monitoring plume movement
  - Validating pressure and brine plume model predictions

- Implement and operate a test bed facility for the evaluation of selected brine treatment technologies applicable to ARM for CCUS

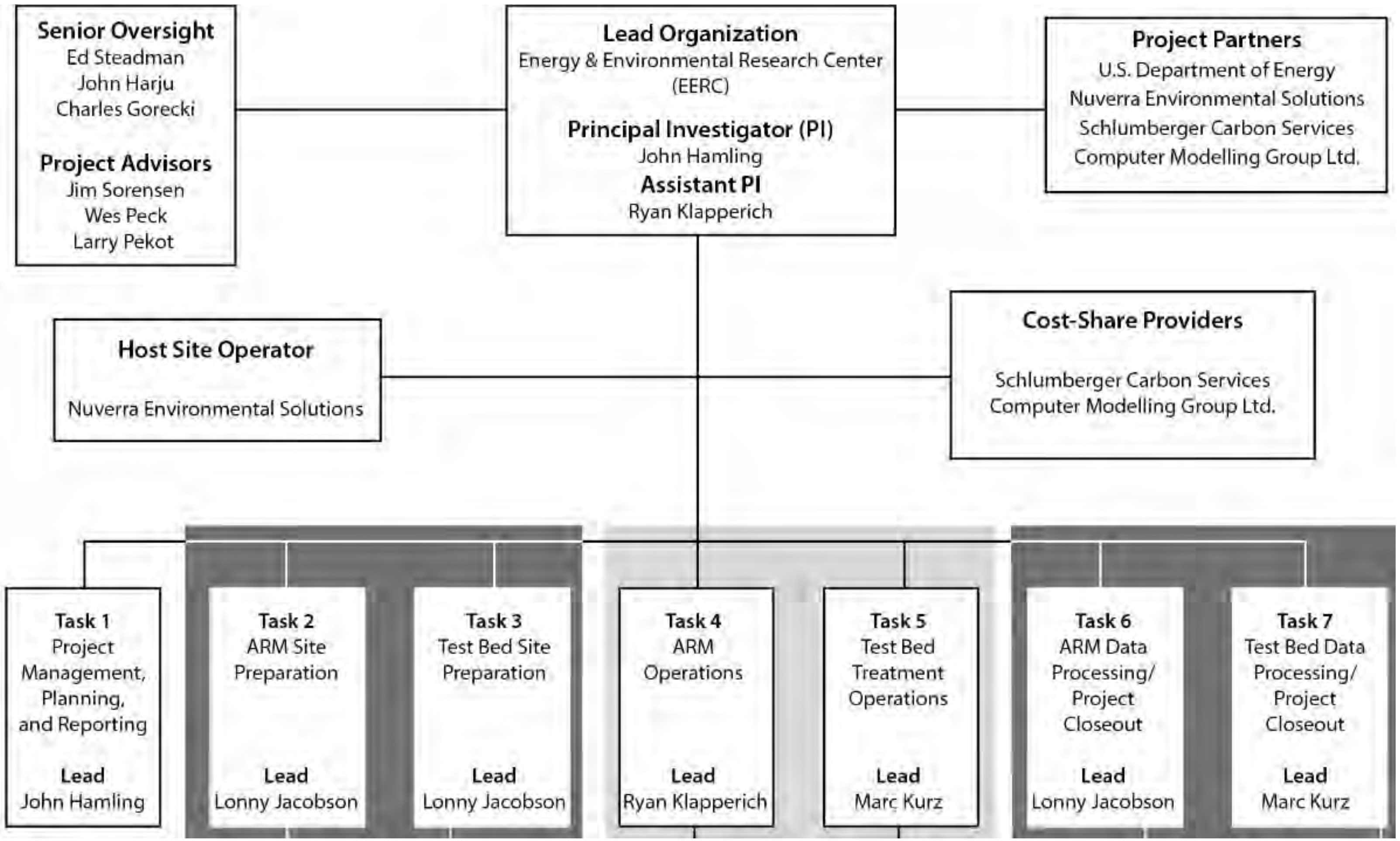
Three development stages over 48 months

1. Site preparation and construction
2. Site operations including ARM and extracted brine treatment technology testing and demonstration
3. Project closeout/decommissioning and data processing/reporting

Gantt Chart, Deliverables, and Milestones



ORGANIZATION CHART



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