Phase II Field Demonstration at Plant Smith Generating Station: Assessment of Opportunities for Optimal Reservoir Pressure Control, Plume Management and Produced Water Strategies

DE-FE0026140

Robert C. Trautz
EPRI Technical Executive
August 27, 2019

U.S. Department of Energy
National Energy Technology Laboratory

Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

Acknowledgment and Disclaimer

Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-FE0026140."

Disclaimer: "This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

Presentation Outline

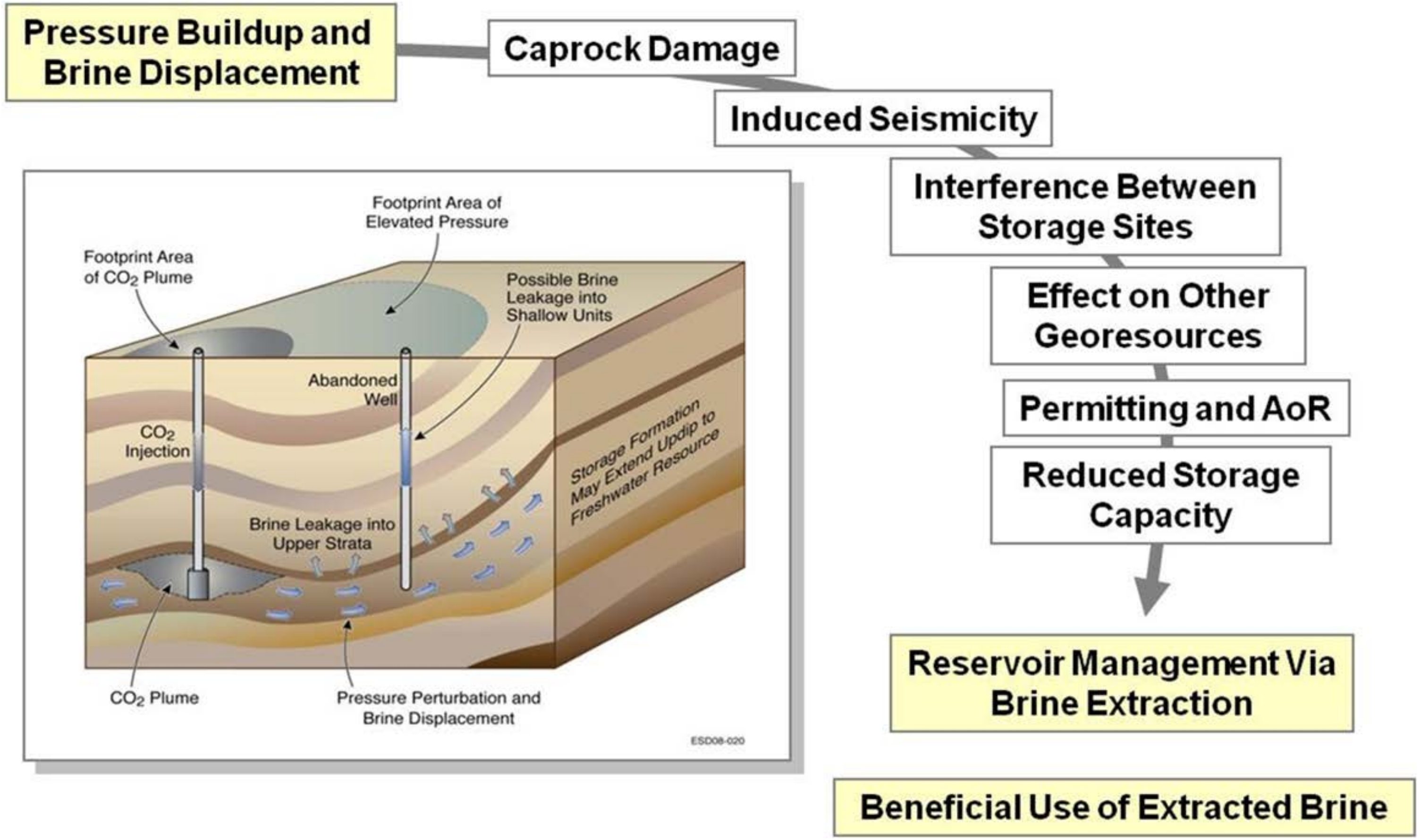
- Project Goals and Objectives
- Project Location
- Technical Objectives
- Technical Status
- Synergies
- Challenges to Date
- Project Summary

Photo showing Plant Smith in foreground and Panama City in background. Inset shows the location of Plant Smith in the Florida Panhandle (red circle).

Project Overview—Goals and Objectives

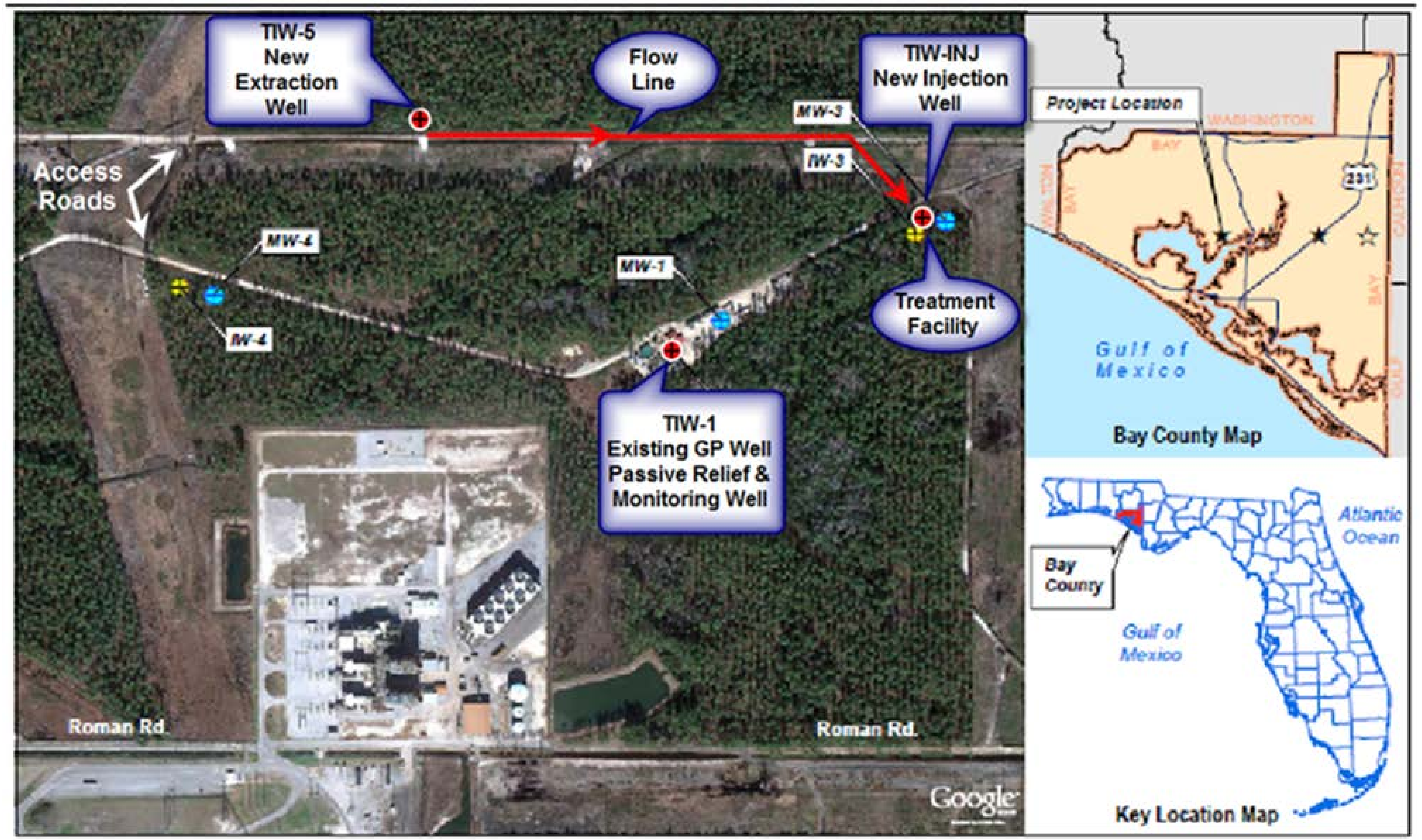
- Objective : Develop cost effective pressure control, plume management and produced water strategies for: 1) Managing subsurface pressure; 2) Validating treatment technologies for high salinity brines

Pressure management practices are needed to avoid these risks. Brine extraction is a possible remedy for reducing or mitigating risk



Plant Smith Overview

- Multiple confining units
- Thick, permeable saline aquifers
  - Eocene Series (870-2,360 ft)
  - Tuscaloosa Group (4,920-7,050 ft)
  - Represent significant CO_2 storage targets in the southeast US
- Large Gulf Power Co. waste water injection project underway (infrastructure)
- Water injection pressures will be managed as a proxy for CO_2 injection (~500k-1M gal/day)



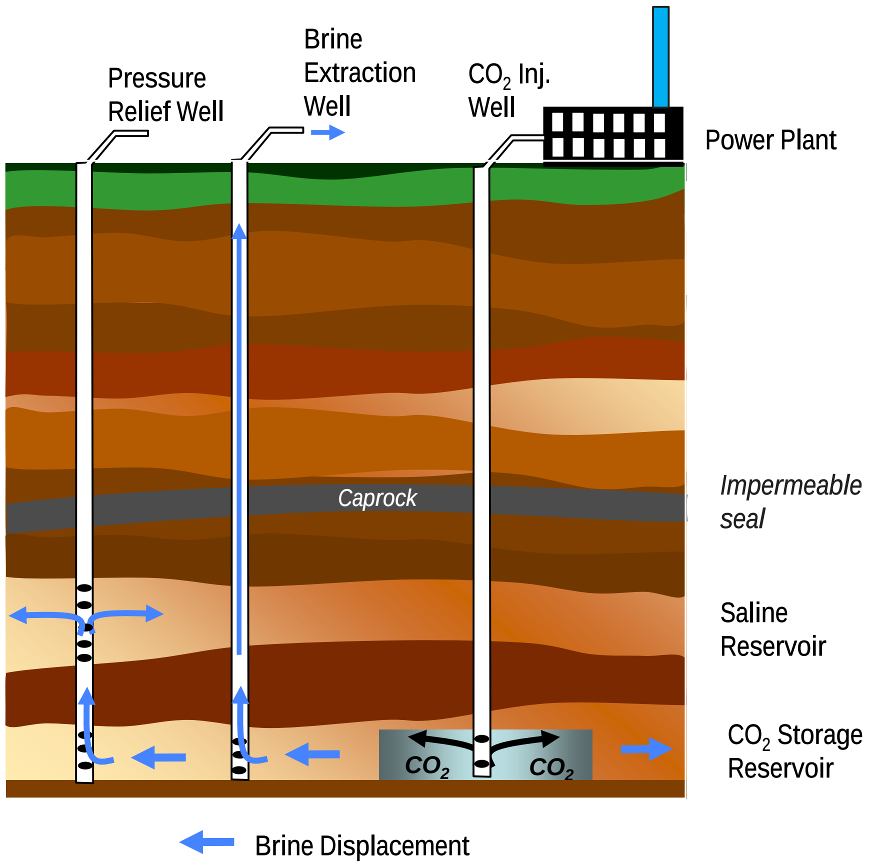
BEST project infrastructure layout showing the proposed location of the extraction well (TEMW-A), injection well (TIW-2) and flowline, and the existing passive-relief well (TIW-1)

No CO_2 injection will take place

Phase II Field Demonstration Experimental Design—Passive and Active Pressure Management

- Passive pressure relief in conjunction with active pumping can reduce pressure buildup, pumping costs and extraction volume
- Existing "pressure relief well" and "new" extraction well will be used to validate passive and active pressure management strategies

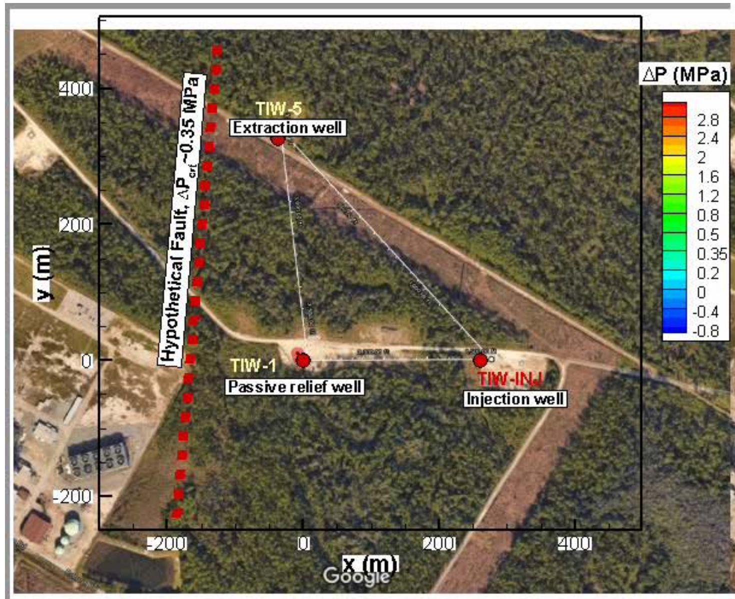
Pressure relief well has the potential to reduce extraction volume by 40%

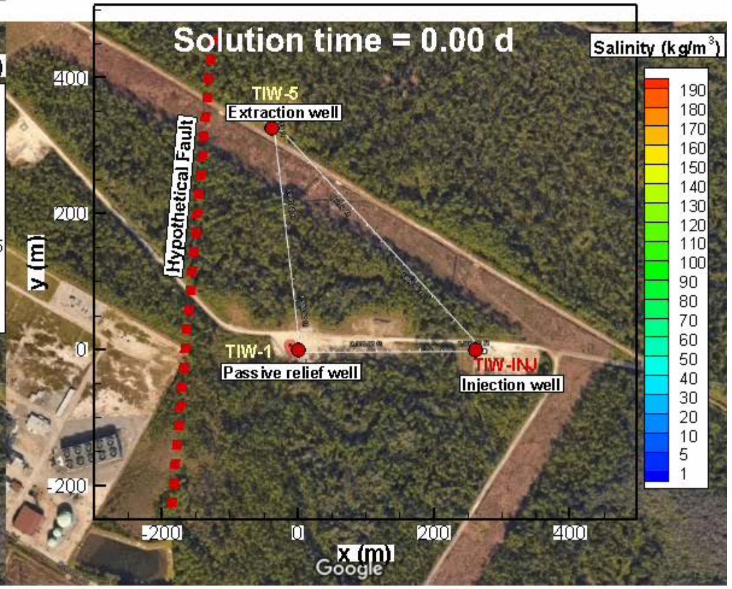


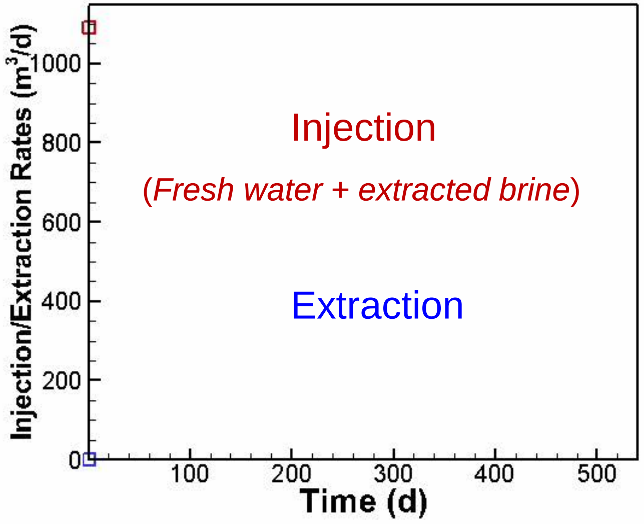
Hypothetical CO_2 storage project showing "active" extraction and "passive" pressure relief well

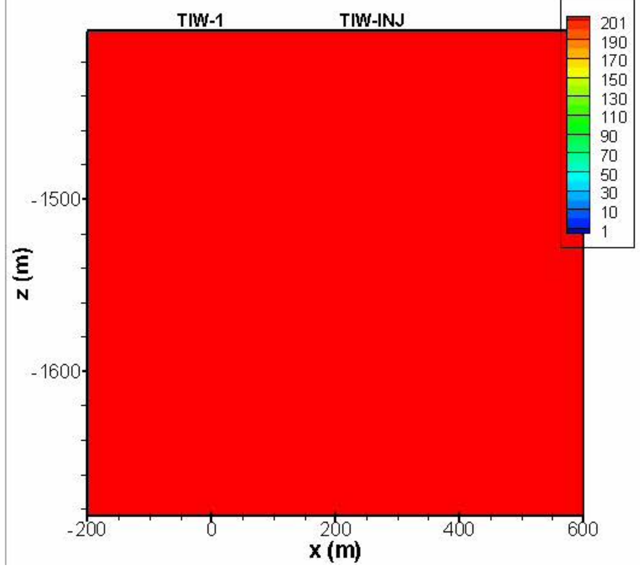
Goals of Subsurface Pressure Management Via Passive + Active Brine Extraction at Plant Smith

- Scenario—Minimize risks for injection-induced seismic events and leakage along hypothetical faults by controlling
  - Pressure buildup
  - Plume migration
- Limit the size of the Area of Review
- Limit the volume extracted
- Develop and test effectiveness of adaptive optimization methods and tools to manage overall reservoir system response









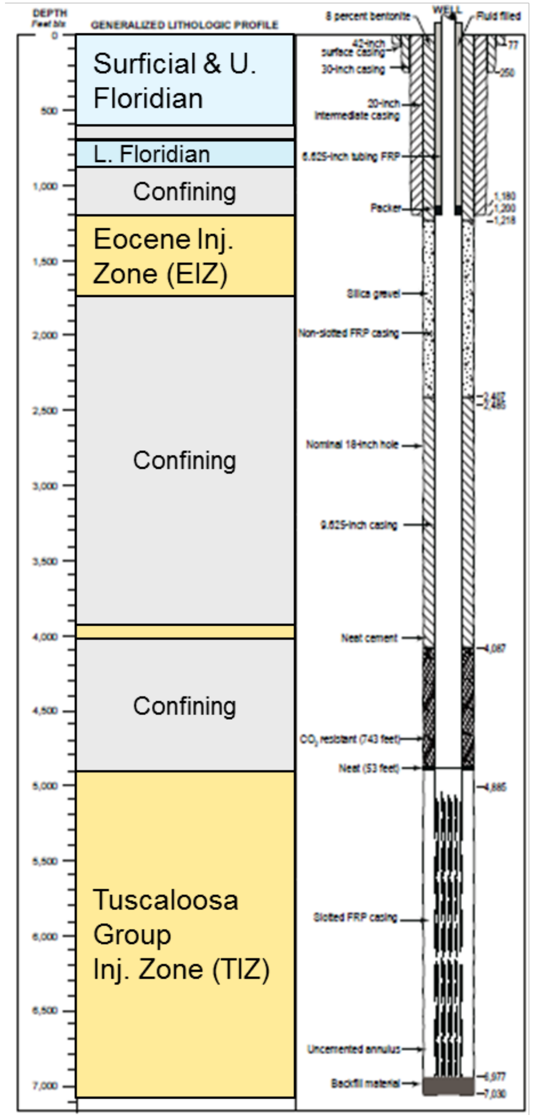
Technical Status

Injection and Extraction Wells Drilled to Total Depth

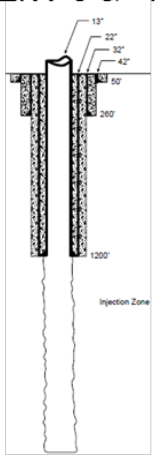
Electric rig drilling injection well TIW-2

Diesel rig drilling observation well TEMW-A

TIW-1



EIW-3 & -4



Casing and Screen Installation

←

Well screen for the 4.5 inch I.D. extraction well prior to assembly.

→

Attaching the cement basket at the bottom of the 10-inch I.D. Fiberglass Reinforced Pipe (FRP) before running the casing for the injection well

Core Samples from ~5,000 ft (~1,524 m)

Core barrel containing continuous side-wall cores

Close-up view of side-wall cores
Clay (left) and sandstone (Right)

Lower Tuscaloosa Sidewall Core Samples

- Interpreted to be fluvial sands
- Weakly consolidated to unconsolidated; interbedded with clay
- Total porosity ranges from 27 – 34 %
- Permeability ranges from 3.86E-13 to 1.52E-12 m/s (392 – 1,538 mD)

TIW-2 sidewall core sample 38; Depth 4,842 ft.

TIW-2 sidewall core sample 30; Depth 4,914 ft.

TIW-2 sidewall core sample 28; Depth 4,926 ft.

TIW-2 sidewall core sample 27; Depth 4,932 ft.

Some pebble conglomerate may be present. Some calcareous cement present.

Samples are poorly sorted to moderately well-sorted; fine to coarse grain sands

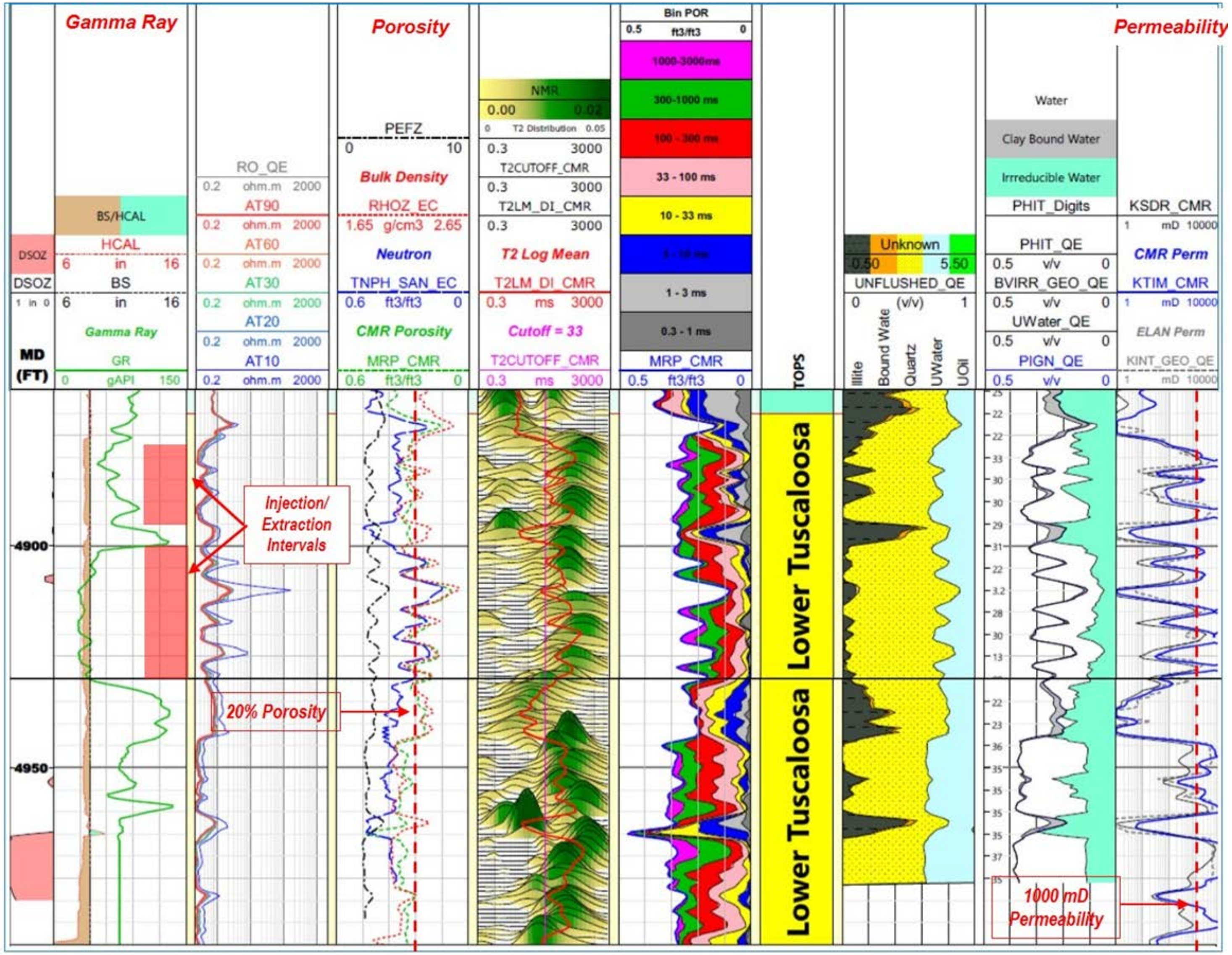
High K-feldspar content (high gamma-ray)

Correlations were used to derive layer properties because of highly unconsolidated sands

Collected and Interpreted Geophysical Well Logs

Extraction Well TEMW-A well logs for the extraction interval

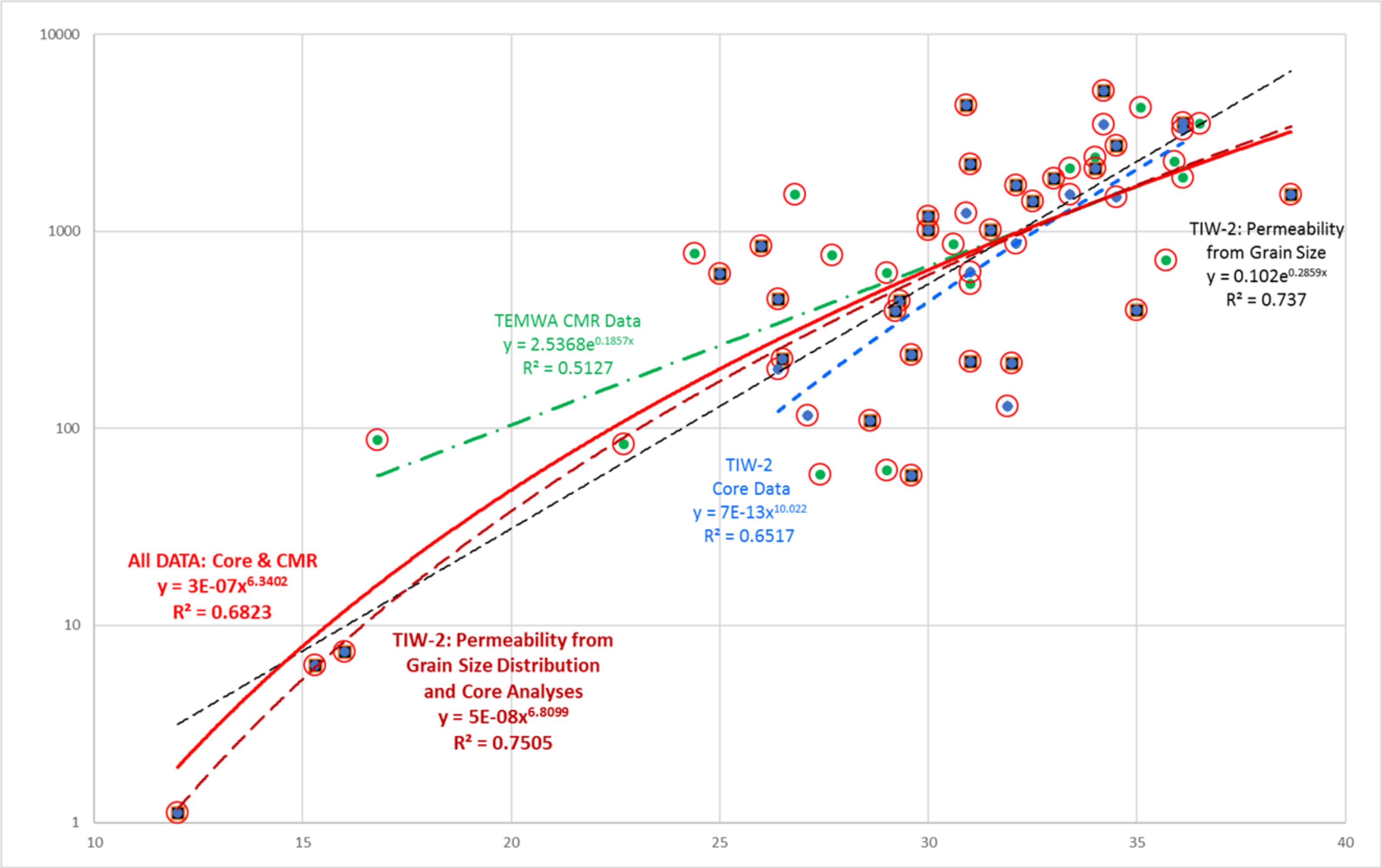
- Gamma Ray
- Density log
- Neutron porosity log
- Combinable Magnetic Resonance (CMR) porosity
- CMR permeability



ELECTRIC POWER RESEARCH INSTITUTE

Porosity/Permeability Correlations for Geologic Model

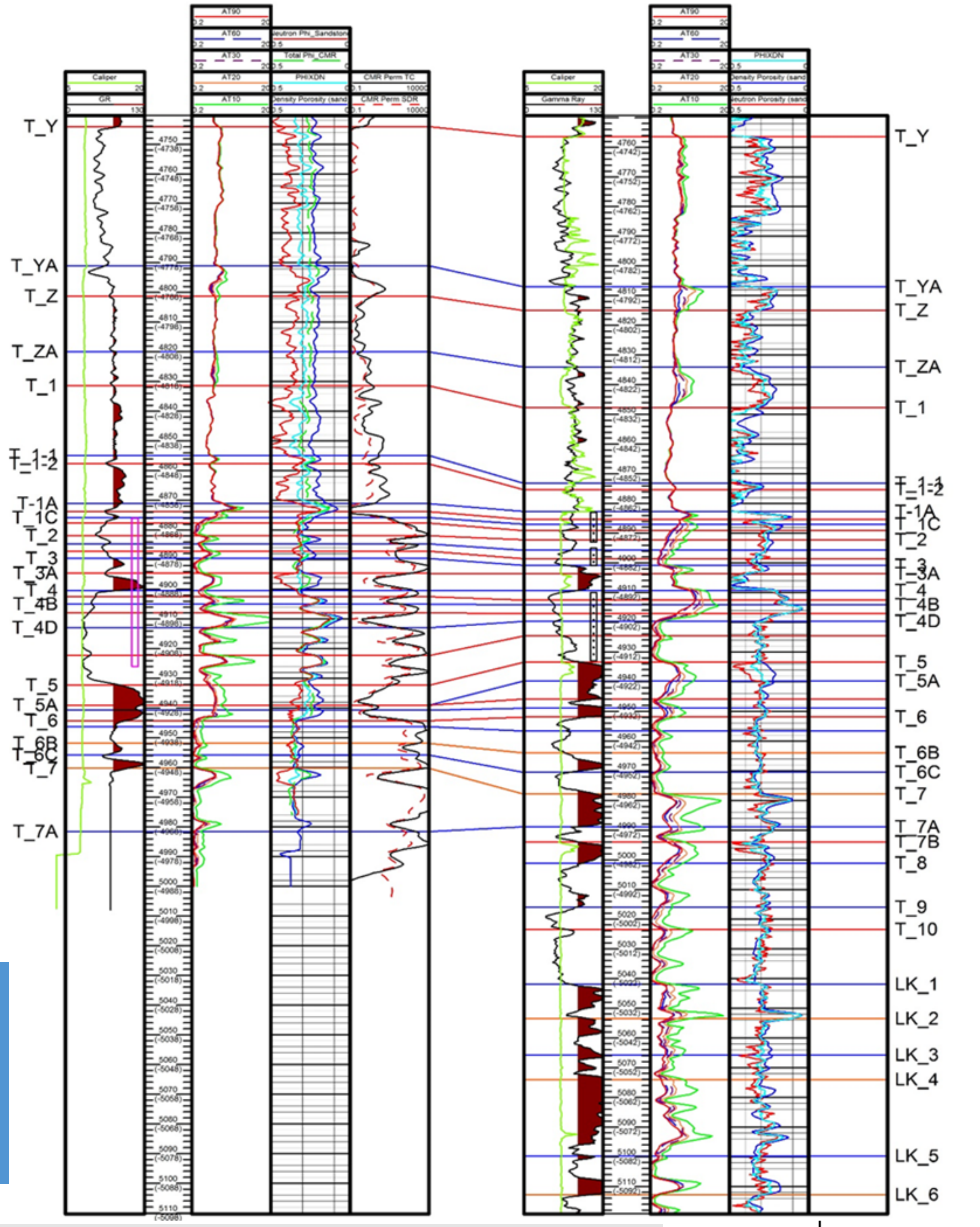
- TIW-2: Routine Core Analysis & MICP = Blue Diamond
- TIW-2: Permeability from Grain-Size Distribution = Black Square
- TEMW-A CMR Data = Green Circle
- “All Data”(combines CMR data points with core-derived data) = Red Ring



Unconsolidated core resulted in heavy reliance on correlations and logs to populate geomodel

Static Geologic Model

- Geomodel contains 86 layers
  - Top depth is 1449.8 m (4,756.4 ft); Base depth is 2,133.6 m (7,000 ft)
- 41 model layers for the Lower Tuscaloosa and upper sands of the Lower Cretaceous Undifferentiated
- 45 layers for the Lower Cretaceous Undifferentiated sandstones
- Single porosity and permeability value was selected as representative of the model layer for each well
  - Porosity obtained from geophysical logs
  - Permeability from a variety of sources: direct measurement of sidewall core samples, extrapolated from measured grain size distribution of core samples; from the CMR log
- Porosity and permeability varies for each model layer in each well in the geomodel



Geologic data confirm that the sand layers of the proposed injection/extraction interval are continuous between all three wells

Reservoir Simulation for Test/Well Design

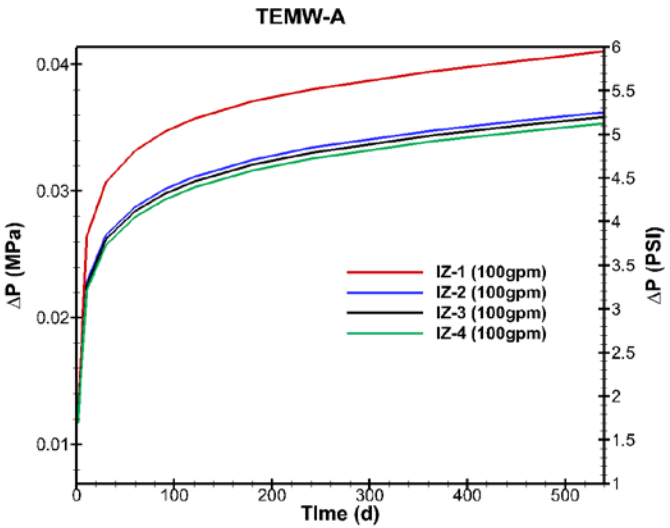
	Thickness (m)	Top depth (m)	Porosity	Perm (mD)
Confining Zone: Tuscaloosa Marine Shale	46.3296	1403.2992	0.24	0.2
Confining	15.5448	1449.6288	0.2	0.1
Lower Tuscaloosa - Sandstone ("Pilot Sand") - Confining	11.8872	1465.1736	0.2	12
Confining	11.2776	1477.0608	0.2	0.5
Potential Injection Zone 1	3.3528 2.1336	1488.3384 1491.6912	0.26 0.31	**190** **800**
Confining	2.4384	1493.8248	0.15	0.5
Potential Injection Zone 2	7.3152	1496.2632	0.32	**1300**
Confining	5.7912	1503.5784	0.27	7
Potential Injection Zone 3	7.9248	1509.3696	0.325	**2625**
Confining	7.0104	1517.2944	0.27	10
Potential Injection Zone 4	4.572 2.1336 5.7912	1524.3048 1528.8768 1531.0104	0.3 0.29 0.32	**600** **550** **1060**
Confining	3.6576	1536.8016	0.12	0.5

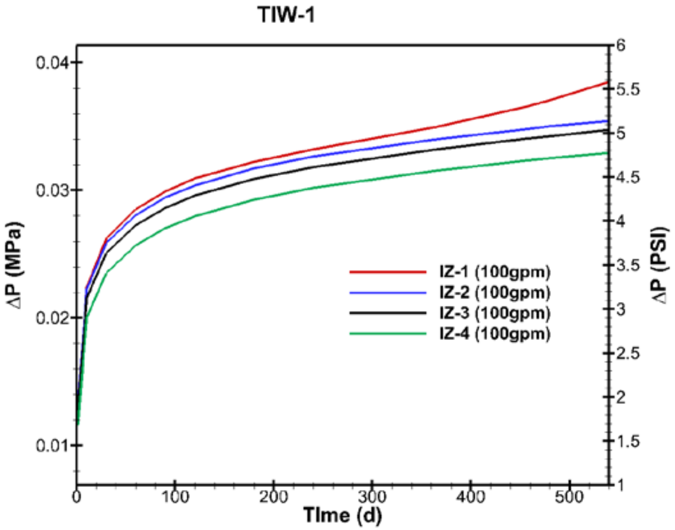
- Assessed four individual injection zone options:

1. Base case geological model for 100 gpm and 200 gpm injection rates
2. Reduced confining layer permeability values by a factor of 10 for 100 gpm injection rate
3. Reduced injection layer permeability values by a factor of 10 for 100 gpm injection rate
4. Combination of iz1 and iz2

Modeling Sensitivity Studies Were Used to Select the Test Interval

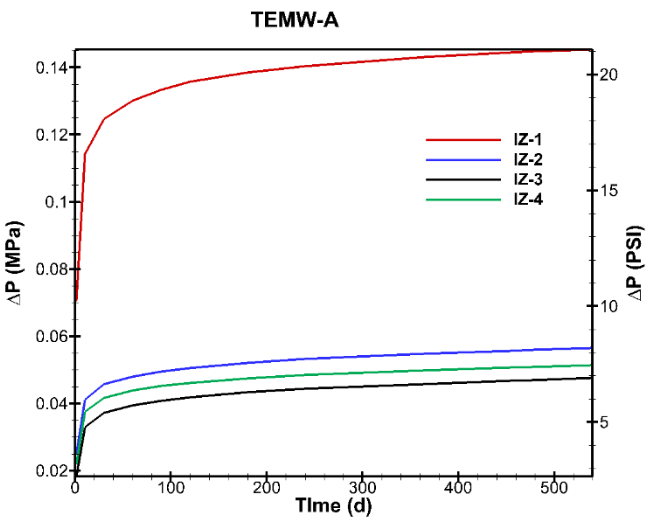
PSI
325
5.4

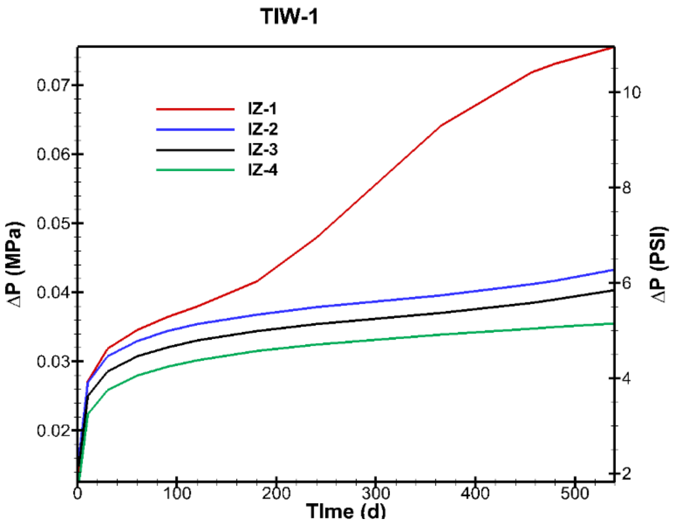




Base case

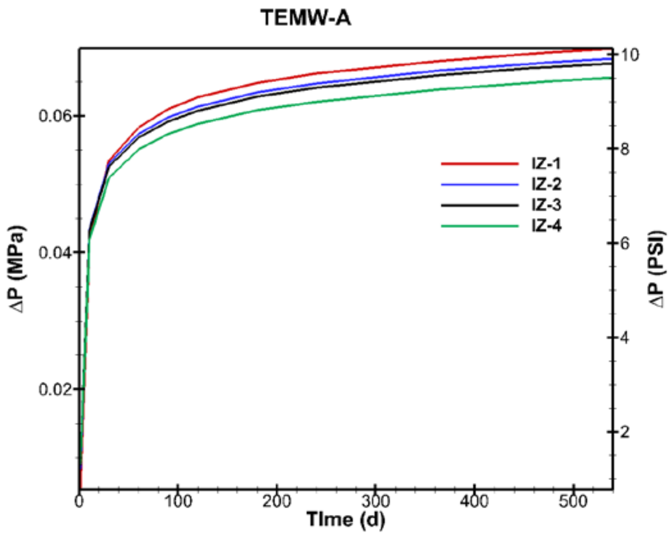
PSI
384
20

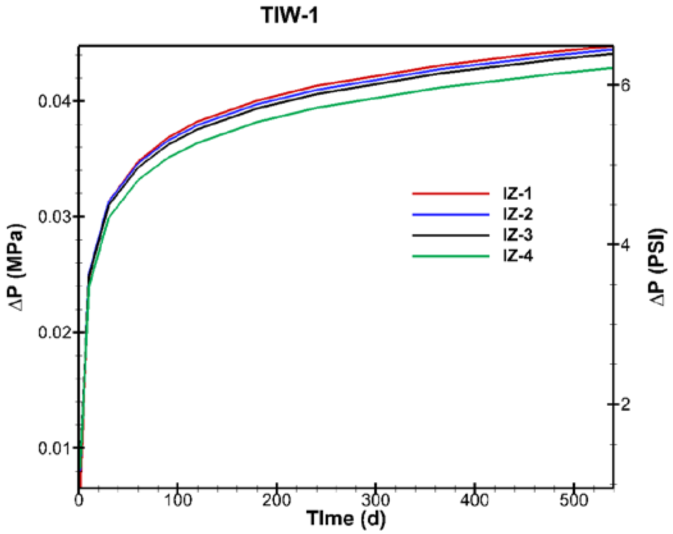




Confining unit 10x perm reduction

PSI
2,546
9.4





Injection zone 10x perm reduction

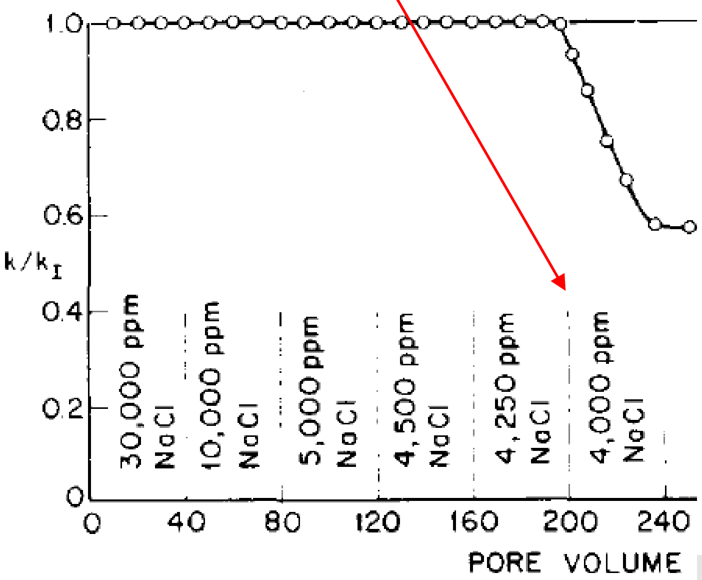
Permeability Impairment Near Wells May Occur through Different Mechanisms

- Will initially focus on fine particle release near the injector as a result of very low-salinity water injected into the Lower Tuscaloosa brine reservoir, low-consolidated and with a high clay content
- Bacterial growth
- Clay swelling
- Scale formation (deposition of precipitates due to incompatibility of injected water and host rock fluid)

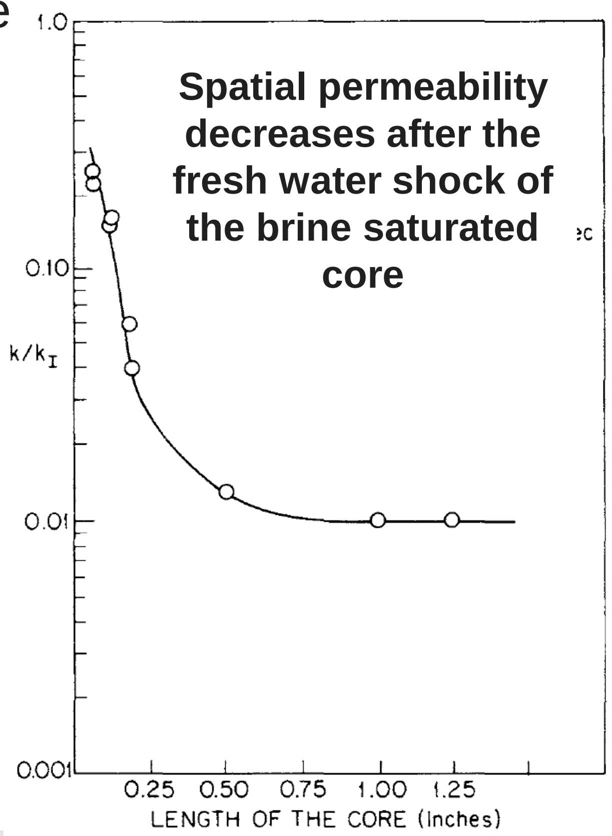
Well-known phenomenon, reported in laboratory and field studies:

E.g., Khilar and Fogler (1983)'s core flood experiments in Berea sandstone, showing significant permeability damage

Permeability starts to decrease at a critical salt concentration, as a function of velocity, pH, T

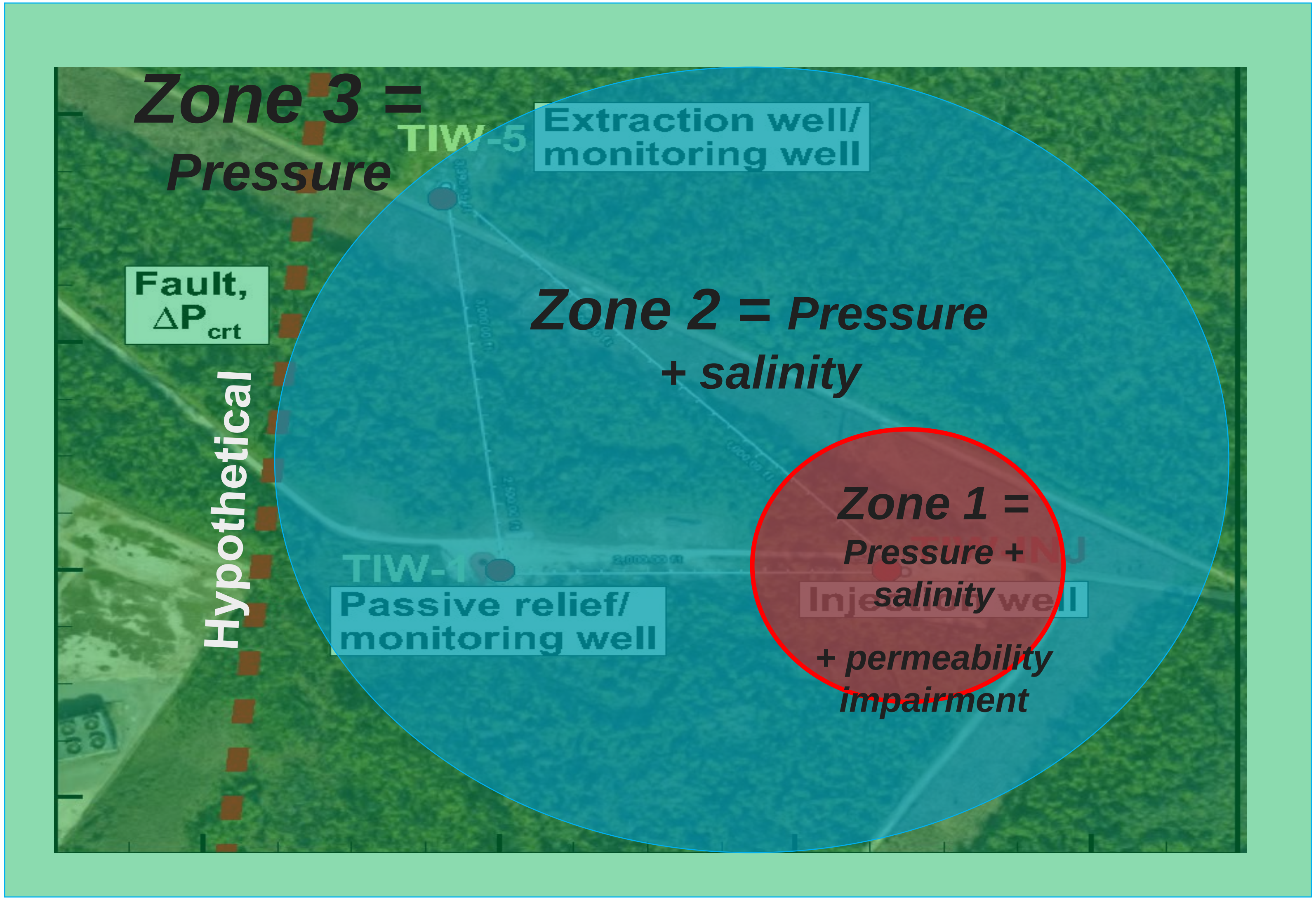


Spatial permeability decreases after the fresh water shock of the brine saturated core



ELECTRIC POWER RESEARCH INSTITUTE

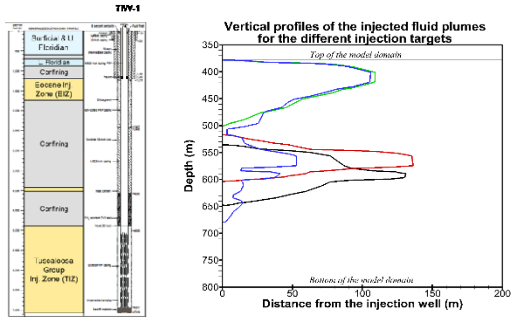
Development of a Zonal Multiphysics Modeling Approach for Computational Efficiency



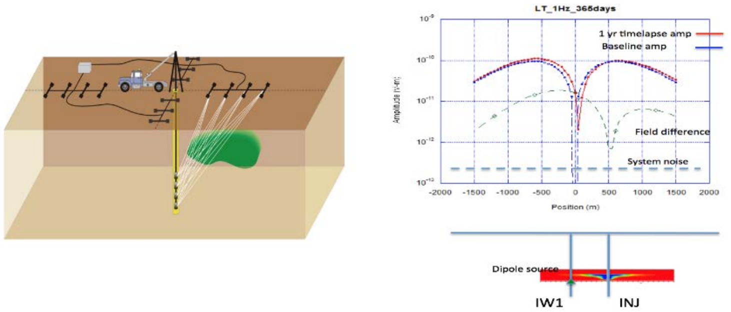
- Each zone captures the relevant physics
- Zone 1 takes into account the permeability impairment near the well
- Computational time expected to reduce orders of magnitude
- Can allow optimization and inverse modeling using numerical model

Monitoring – Inversion for Pressure & Salinity

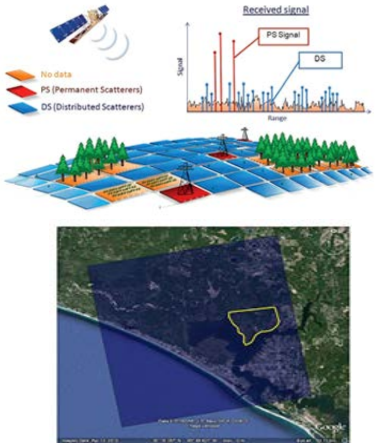
- **Borehole -** Continuous and time-lapse (discrete) borehole measurements of fluid pressure, flow rate, temperature, and electrical conductivity will be used to provide high-resolution, ground-truth, direct measurements at discrete locations (1D).



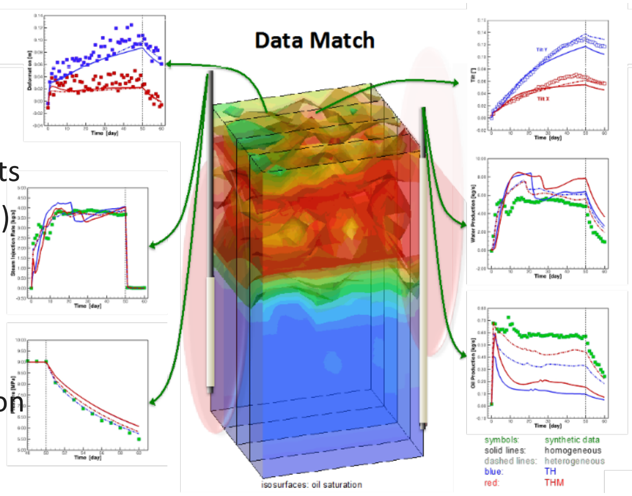
- **EM** - Time-lapse crosswell and borehole-to-surface EM will provide indirect measurements of the higher resistivity injected ash pond water with spatial resolutions in 2D and 3D approaching several meters to tens of meters, respectively.



- **InSAR** - InSAR will be used to map surface deformations resulting from subsurface pressure increases over 16 day intervals



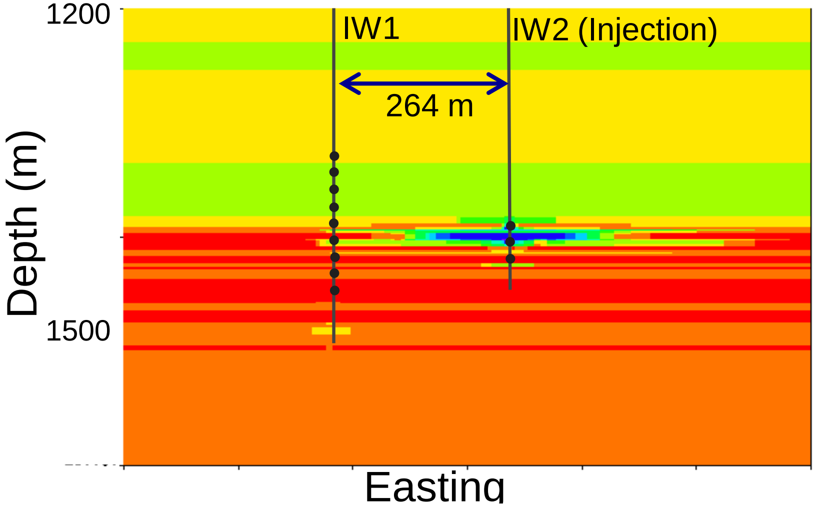
Joint Inversion - We will use LBNL's powerful inverse modeling and parameter estimation tool iTOUGH (in its parallel version MPiTOUGH2) for the automated joint inversion of hydrological, large-scale geophysical (EM) data, and surface deformation data.

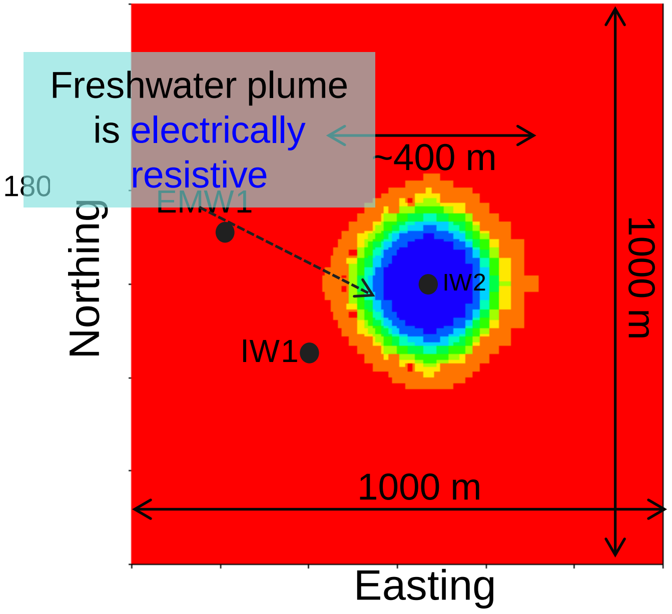


EPRI ELECTRIC POWER RESEARCH INSTITUTE

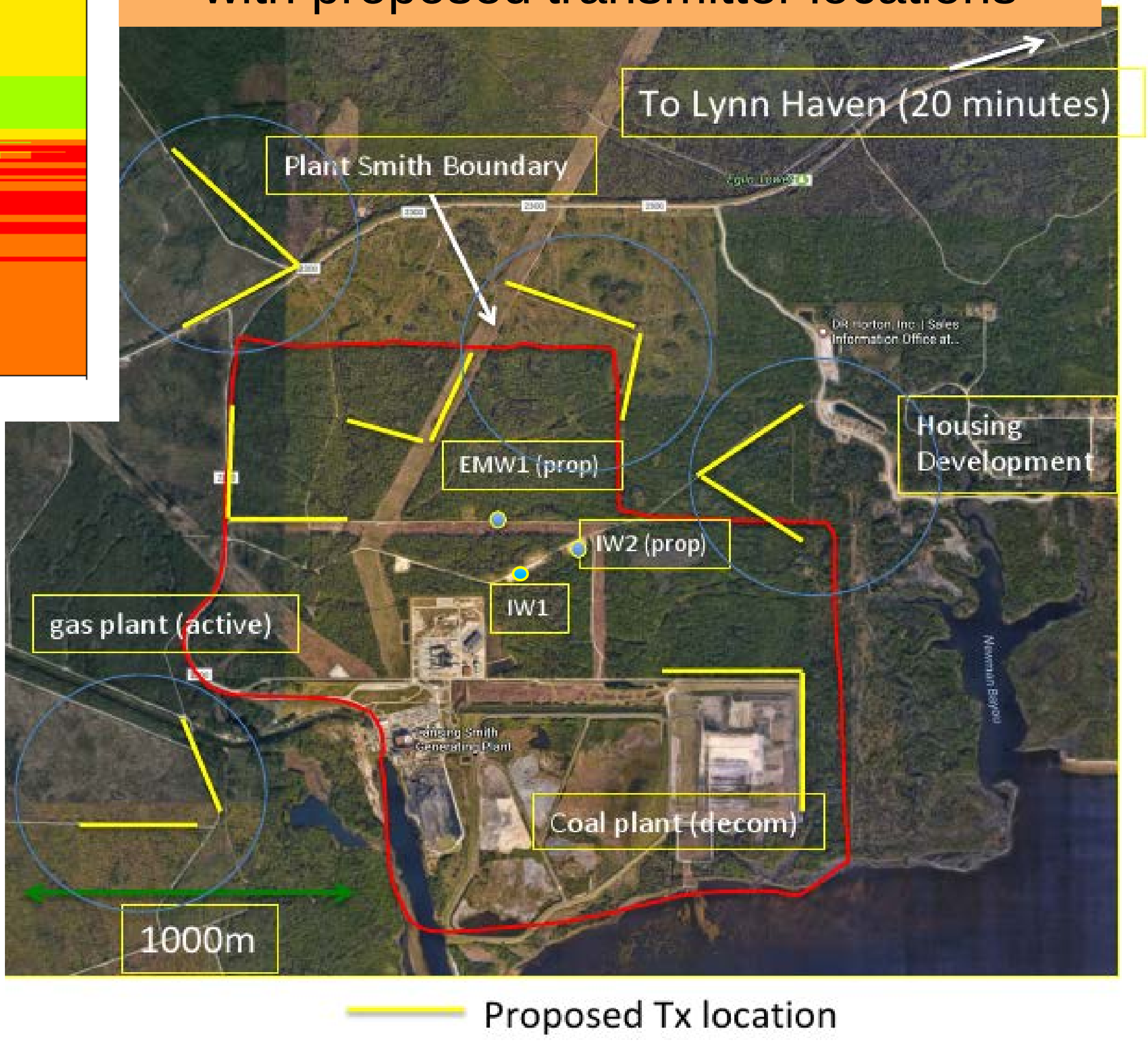
Plume Monitoring Using Controlled-Source Electromagnetics

Crosswell EM configuration





Surface-to-borehole EM configuration with proposed transmitter locations

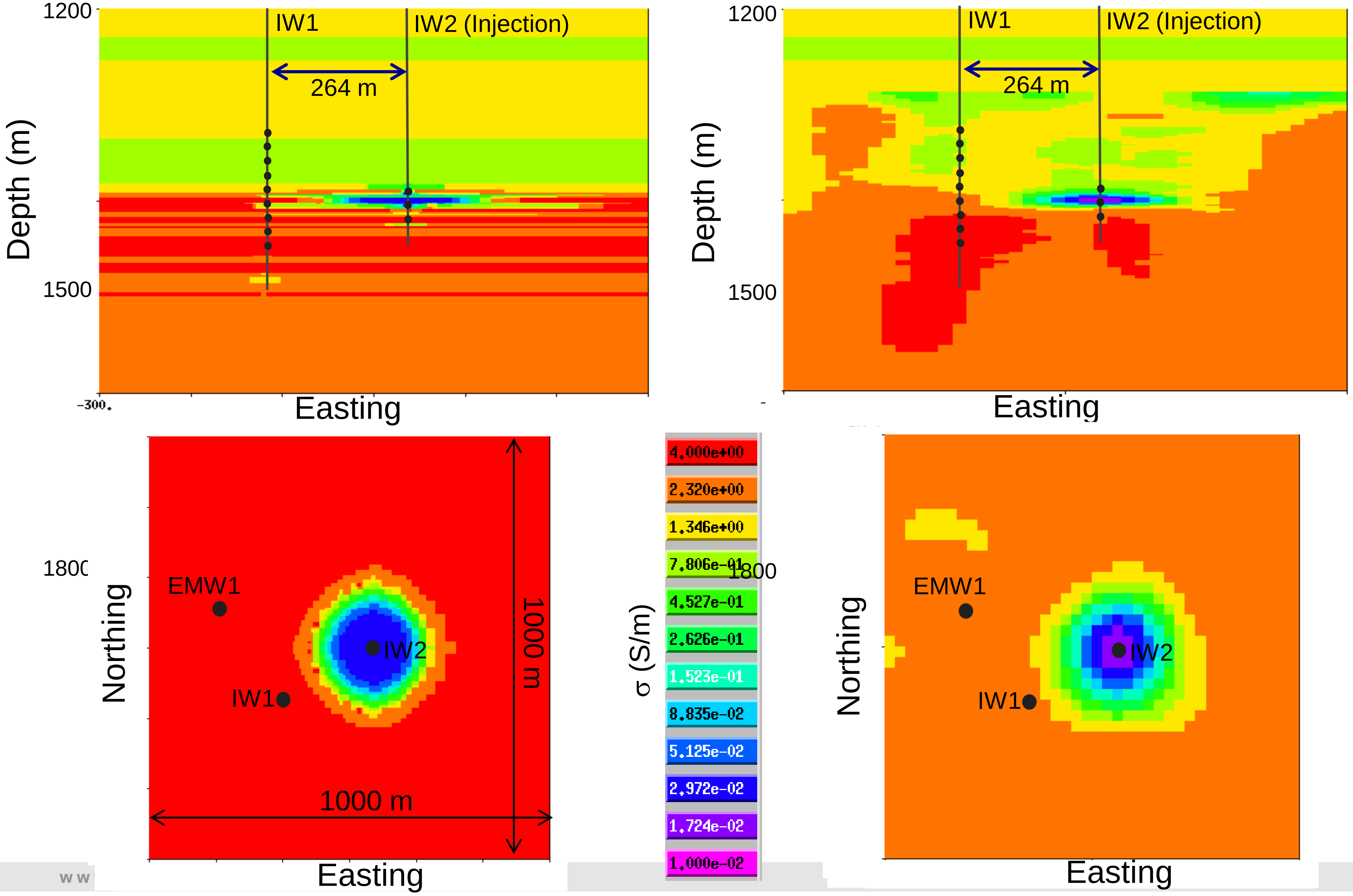


ELECTRIC POWER RESEARCH INSTITUTE

3D EM Inverse Modeling for Plume Monitoring

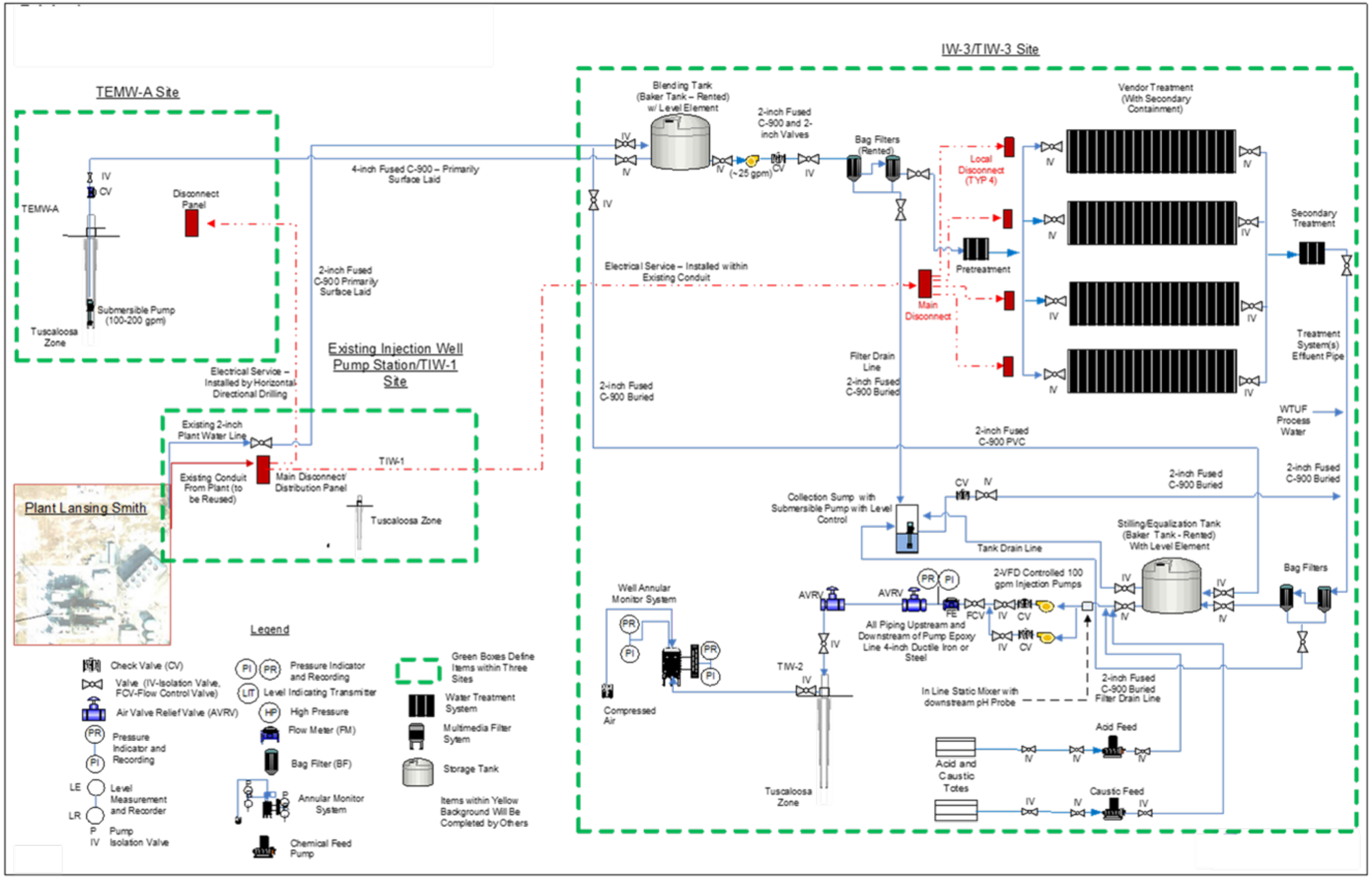
True plume contours

Reproduced through inverse modeling



Synergy Opportunities

- EERC and EPRI are hosting Water treatment user facilities
- EERC facility is open for business
- EPRI Water Treatment User Facility Design is 60% Complete



Challenges/Lessons Learned

- Drilling
  - Well costs higher than expected in Florida
    - Non-competitive market
    - Special Florida injection well regulations contribute to costs
  - Weather delays – Hurricane Michael
  - Mechanical delays
- Contracting – never goes as quickly as hoped or planned
  - Unit price with cost not-to-exceed drilling contract with stipulated penalties is providing cost protection
- Technical
  - Injection/formation water compatibility impacts on design
  - Unconsolidated sediments have a unique set of laboratory challenges

Accomplishments

- Geo-static and reservoir models were updated and used to select the final test zone and screened interval length
  - Log interpretation, core analysis and model updates took less than 50 days to complete
- Extraction well was completed and the screen was installed from 4,876 – 4,936 ft
- Injection well was drilled to a total depth of 7,010 ft; casing installation is pending
- 60% design complete on the water treatment user facility
- EM modeling studies show it should have sufficient sensitivity to image plume in cross-well and surface to borehole configurations (Mike Wilt poster)

Project Summary

- Next Steps
- BP3 plans include:
  - Casing installation, perforation and hydraulic tests
  - Final design and installation of the water treatment user facility
  - Equipment commissioning
  - 6 months of injection followed by 12 months of injection and extraction
- BP4 plans include:
  - Site restoration
  - Final reporting

Photographs of existing Gulf Power wellfield. Photos clockwise from upper left: Eocene Injection well EIW-4; graveled access road; pump station under construction; cleared and permitted drilling pad location for future well

Together…Shaping the Future of Electricity

Appendix

Benefit to the Program

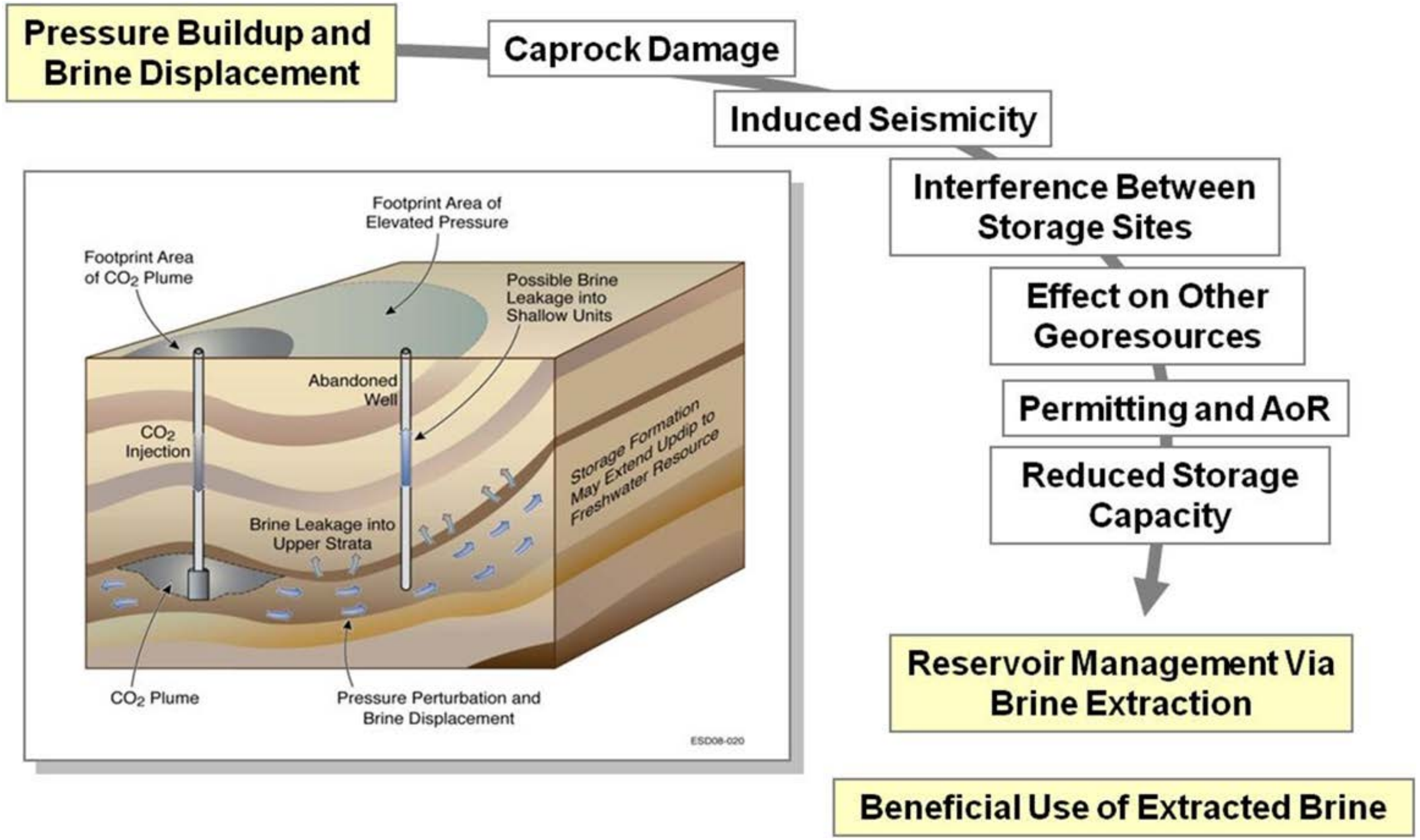
- Program Goals
  - Develop cost effective pressure control, plume management and produced water strategies that can be used to improve reservoir storage efficiency and capacity, and demonstrate safe, reliable containment of CO_2 in deep geologic formations with CO_2 permanence of 99% or better.
- Benefit Statement

  The project will…
  - Use optimization methods and smart search algorithms coupled with reservoir models and advanced well completion and monitoring technologies to develop strategies that allocate flow and control pressure in the subsurface.
  - Address the technical, economic and logistical challenges that CO_2 storage operators will face when implementing a pressure control and plume management program at a power station and increase our knowledge of potential storage opportunities in the southeast region of the U.S.
  - Contribute to the development cost effective pressure control, plume management and produced water strategies that can be used to improve reservoir storage efficiency and capacity, and demonstrate safe, reliable containment of CO_2 in deep geologic formations with CO_2 permanence of 99% or better.
  - And the operational experiences of fielding a water management project at a power station can be incorporated into DOE best practice manuals, if appropriate.

Project Overview—Goals and Objectives

- Objective : Develop cost effective pressure control, plume management and produced water strategies for: 1) Managing subsurface pressure; 2) Validating treatment technologies for high salinity brines

Pressure management practices are needed to avoid these potential risks. Brine extraction is a possible remedy for reducing or mitigating risk



Organization Chart

NETL
DOE Project Manager
Bruce Brown

EPRI
Project Manager
Robert Trautz, PI
Dr. Laura Chiaramonte, Geo.

Southern Company
Consulting Geologist
Dr. Richard Esposito, RG

Energy to Serve Your World™

ARI
Geology & Testing Services
Michael Godec, Dir.
Robin Petrusak, Geo.
Dave Riestenberg, Geo.

Advanced Resources International, Inc.

CH2M
Envir. Compliance, Design & Drilling Coordinator
Lisa Drinkwater, Eng.
Jeff Lehnen, FL PG

LBNL
Reservoir Simulation
Dr. Jens Birkholzer, Dir.
Dr. Adullah Cihan, Res.Eng.
Dr. Kurt Nihei, Geophysics
Dr. Jonny Rutqvist, Geomech.

EPRI
Water Treatment
Dr. Abhoyjit Bhown, Eng.
Jeffery Preece, Eng.

Gulf Power
Site Host and Site Contracting Agent
Mike Markey, Geo.
Robert Jernigan, Eng.

A SOUTHERN COMPANY

Gantt Chart

Phase II Project Schedule

Description	Start Date	End Date	Dur. Mos.
	9/1/2016		
Task 1: Project Management and Planning			Ongoing
Sub-recipient & vendor contracting	9/1/2016	8/31/2017	12
Revise Project Management Plan and Project Data Factsheet	10/1/2018	10/31/2016	1
Task 2: Permit Development and Compliance Reporting			
Prepare, submit and receive approved NEPA, UIC and other permts	10/1/2016	10/31/2017	13
UIC Compliance reporting	7/15/2018	2/28/2021	31
Task 3: Well Field Infrastructure Development, O&M and Closure			
Prepare final design/specs/bids for wells and surface infrastructure	10/1/2016	7/31/2017	10
Install wells and infrastructure	7/15/2018	7/14/2019	12
Inject water, operate and maintain infrastructure	7/15/2019	1/15/2021	18
Reclaim sites	1/15/2021	2/28/2021	1.5
Task 4: User Treatment Facility Development, O&M and Closure			
Prepare final design/specs/bids for treatment infrastructure	5/1/2017	4/15/2019	6
Install infrastructure	4/15/2019	9/15/2019	5
Treat saline water, validation sampling, operate and maintain infrastruct	1/1/2020	6/30/2019	6
Reclaim treatment facility	10/1/2020	10/31/2020	1
Task 5: Pressure Optimization and Produced Water Strategies			
Update Static Geologic Model	7/15/2018	3/31/2019	12
Final design of the field demonstration test	10/1/2017	7/14/2019	21
Development of adaptive management methods	1/1/2017	12/31/2018	24
Implementation and testing of adaptive pressure management method	5/15/2019	1/15/2021	20
Task 6: Site Characterization/Monitoring Program			
Reservoir characterization	7/15/2018	10/15/2019	15
Monitoring program	7/15/2018	1/15/2021	30
Task 7: Final Data Processing and Reporting			Ongoing
Compile, analyze and tabulate data	7/15/2018	4/15/2021	33
Evaluate performance of optimization and reservoir models	11/1/2019	4/30/2021	6
Final report	2/1/2021	8/31/2021	6