Southwest Regional Partnership on Carbon Sequestration

DE-FC26-05NT42591

Phase III – Deployment Phase
Farnsworth Unit CCUS
Ochiltree, Texas

Reid B. Grigg, Ph.D.
New Mexico Institute of Mining and Technology

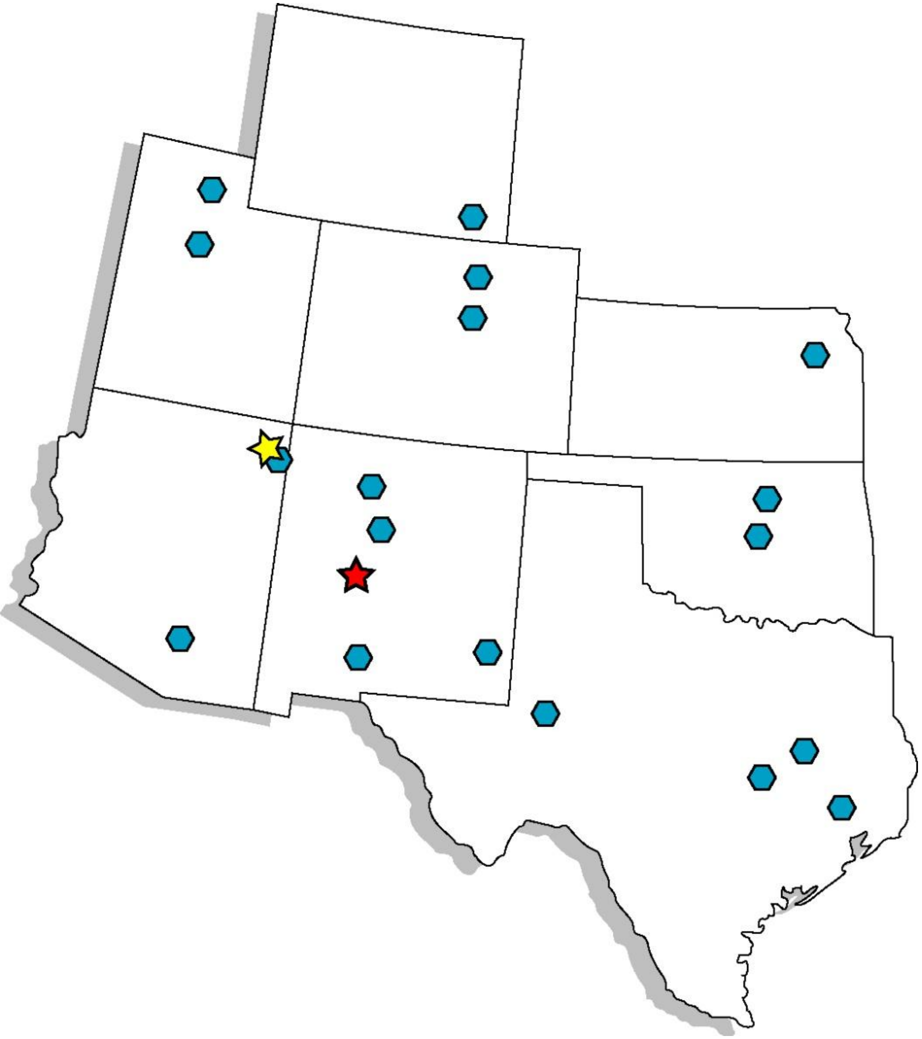
Brian J. McPherson, Ph.D.
University of Utah

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and Building the Infrastructure for CO_2 Storage

August 21-23, 2012

Acknowledgements



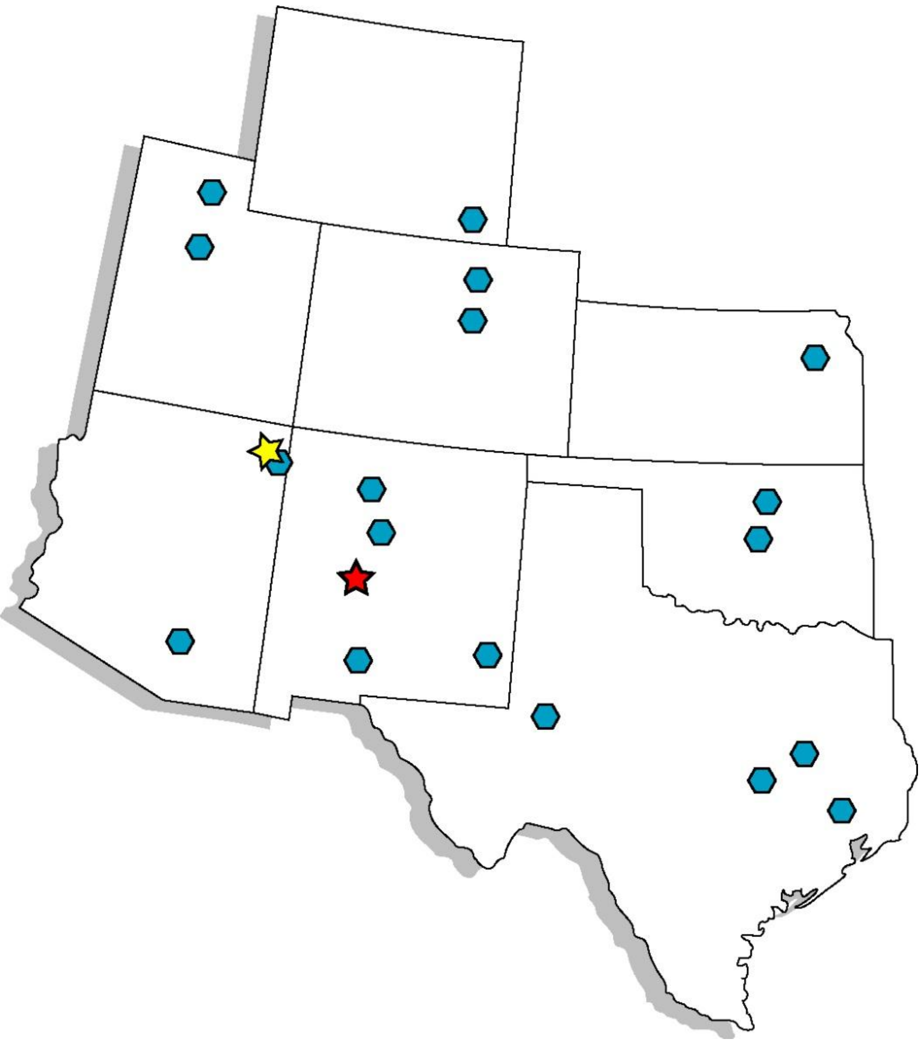
We are grateful to the Department of Energy and its National Energy Technology Laboratory for not only its financial support, but also superb technical backing of the SWP.

We also thank Chaparral Energy and the many technical partners of the SWP.

SWP Presentation Outline

- **The Southwest Partnership**
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- Phase III Technical Plan
    - What and Why
    - Field operator
    - Project Site and Key Elements
    - Collaboration benefits
    - MVA Plans
    - Simulation Plans
    - Risk Assessment Plans
- Accomplishments to Date

The Southwest Regional Partnership



In all partner states:

- major universities
- geological survey
- other state agencies
- over 50 partners

as well as

- Western Governors Association
- multiple major utilities
- multiple energy companies
- multiple federal agencies
- many other critical partners

Southwest Partners

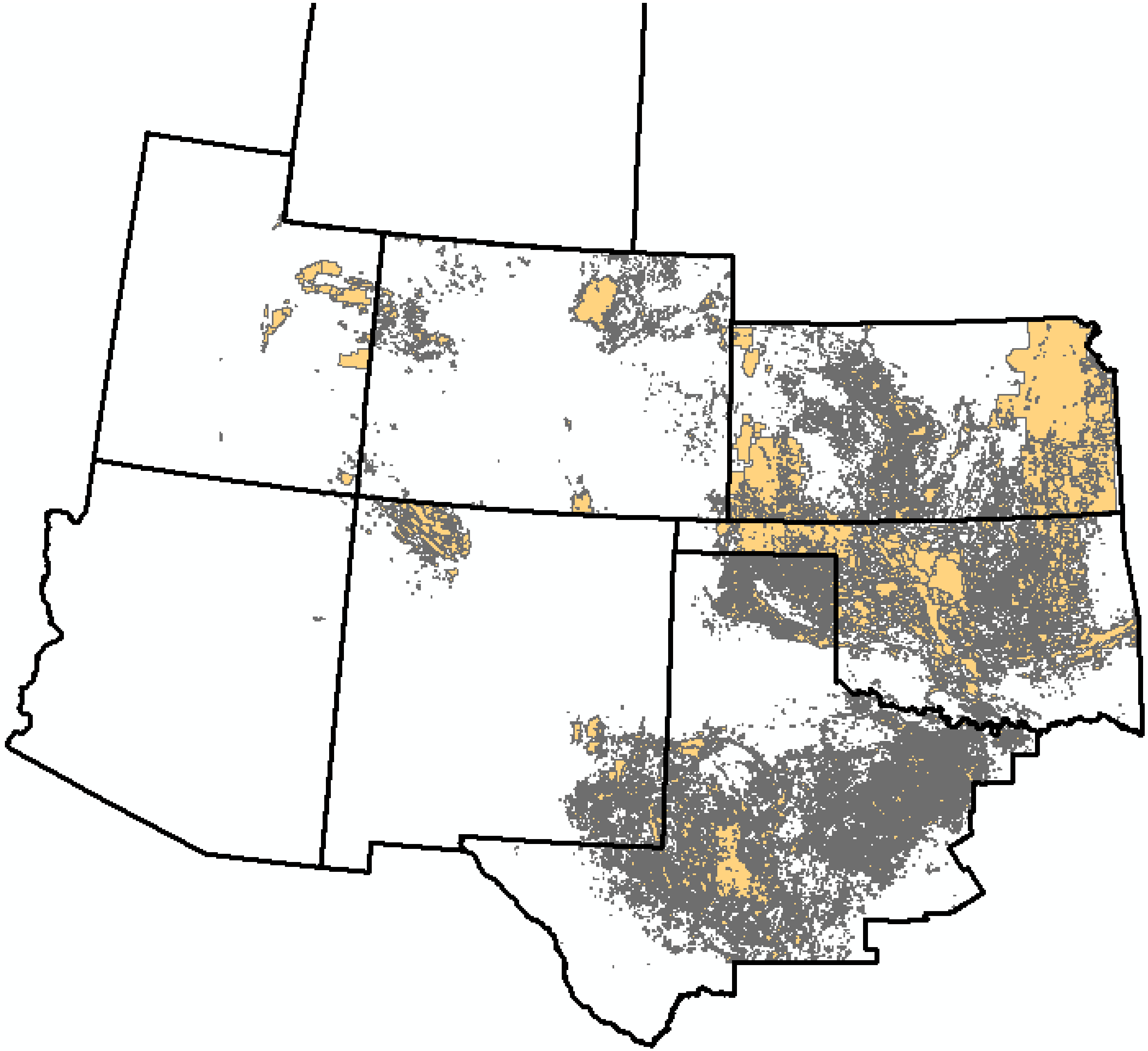
Advanced Resources International (ARI)
Applied Sciences Laboratory
Arizona Geological Survey
Arizona State University
Chaparral Energy
Chevron
Colorado Geological Survey
Colorado School of Mines
Colorado State University
ConocoPhillips
Dine College
Electric Power Research Institute (EPRI)
Energy & Geoscience Institute (EGI)
Gas Technology Institute (GTI)
Intermountain Power Agency
Interstate Oil and Gas Compact Commission
Japanese Geological Survey (AIST)
KIGAM
KinderMorgan CO_2 Company, L.P.
Los Alamos National Laboratory
Navajo Nation
Navajo Nation Oil and Gas Company
New Mexico Bureau of Geology
New Mexico Environmental Department
New Mexico Institute of Mining and Technology
New Mexico Oil and Gas Association
New Mexico Oil Conservation Division
New Mexico State University

Petroleum Recovery Research Center (PRRC)
Occidental Permian Ltd.
Oklahoma Gas and Electric
Oklahoma Geological Survey
Oklahoma State University
PacifiCorp
Public Service Company of New Mexico
Sandia National Laboratories
Schlumberger Carbon Services
Southern California Edison
Texas Tech
Tucson Electric Power Company
United States Geological Survey
U.S. Department of Agriculture
University of Missouri
University of Oklahoma
University of Utah
Utah Automated Geographic Reference Center
Utah Division of Air Quality
Utah Division of Oil, Gas, & Mining
Utah Energy Office
Utah Geological Survey
Utah State University
Waste-Management Education & Research Consortium
Western Governors' Association
Xcel Energy
Yates Petroleum Corporation

SWP Presentation Outline

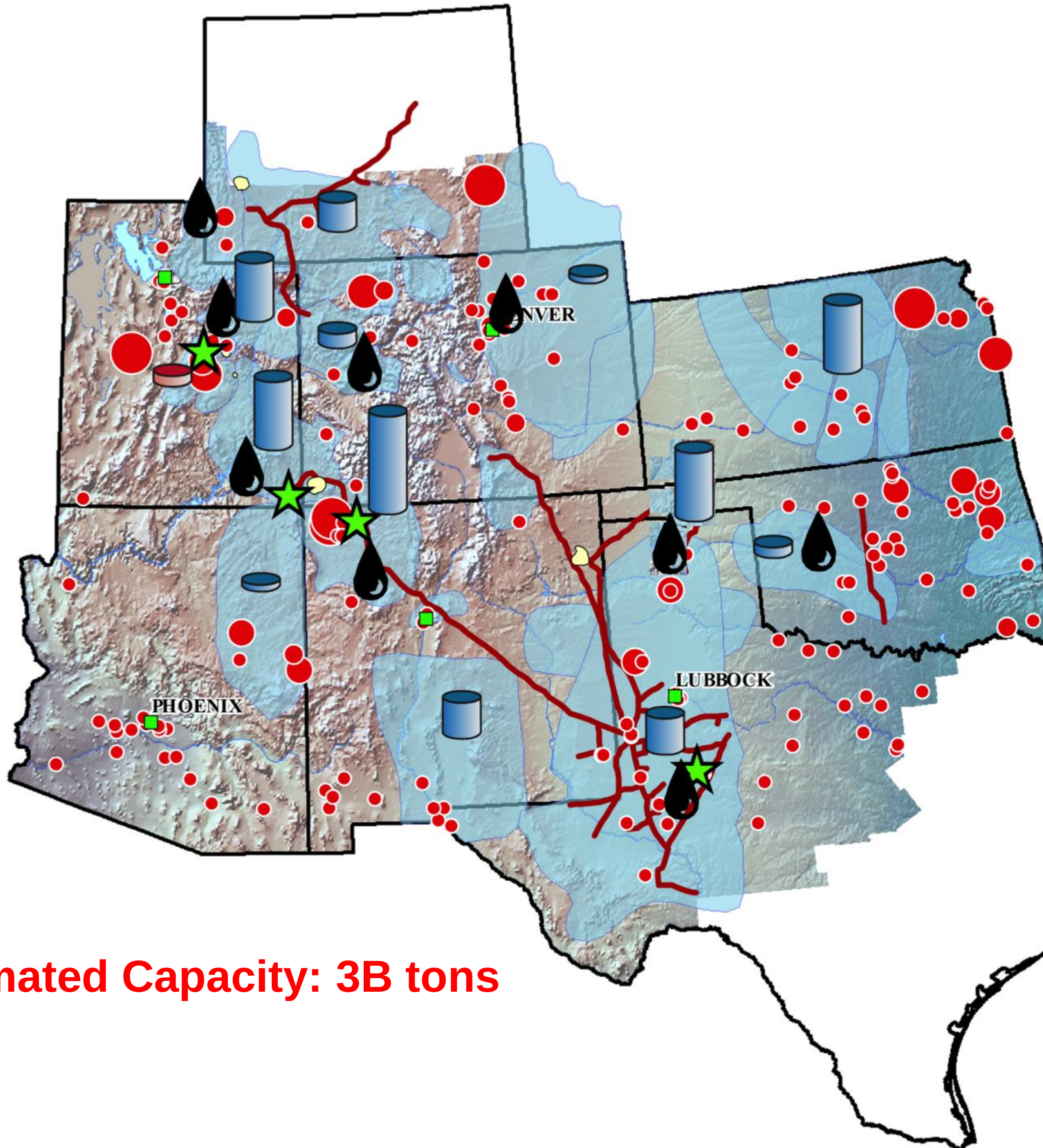
- The Southwest Partnership
- **Regional Characterization**
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- Phase III Technical Plan
  - What and Why
  - Field operator
  - Project Site and Key Elements
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

Southwest Region Oil and Gas CCUS Options



Southwest Region: Capacity Estimates

Greater SWP Saline Formation Capacities (Millions of Metric tons CO_2)	
Sequestration Target	**Capacity**
Uinta Basin	12,436
Paradox Basin	14,901
Piceance Basin	3,370
Anadarko Basin	2,319
Denver Basin	357
Green River Basin	6,387
NM & TX Permian Basins	8,399
KS & eastern CO Basins	13,329
Arizona Basins	19
San Juan Basin	20,624
Total	82,141
Initial Anadarko Estimate	~3,000



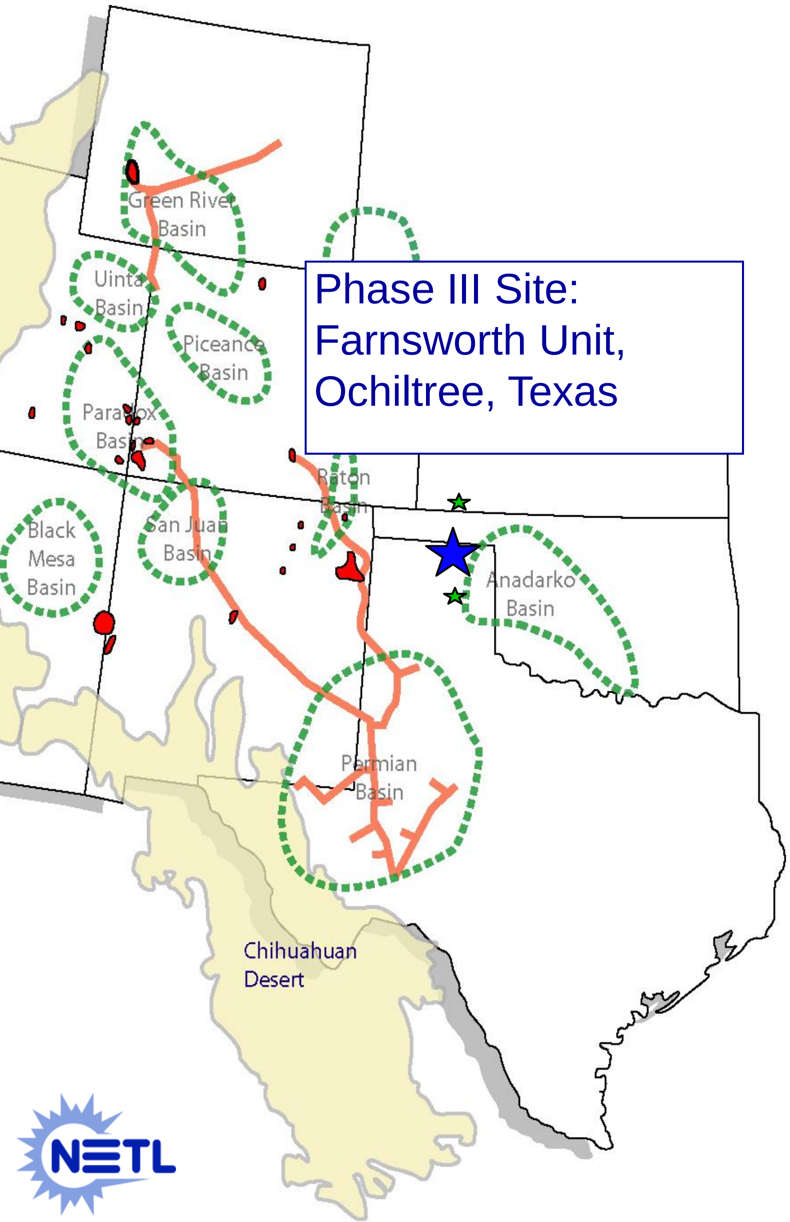
Phase III Site: Basin Initial Estimated Capacity: 3B tons

NETL

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- **Phase III Introduction**
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- Phase III Technical Plan
  - What and Why
  - Field operator
  - Project Site and Key Elements
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

SWP Phase III: Introduction



The SWP's Phase III will be a Large-Scale EOR-CCUS Sequestration Test

General Goals:

-**One million tons CO_2 injection**
-**Optimization of storage engineering**
-**Optimization of monitoring design**
-**Optimization of risk assessment**
-**"Blueprint" for CCUS in southwestern U.S.**

To date:

- site suitability evaluation completed;
- geologic characterization ongoing;
- site proposal submitted to NETL;
- cost-price (budget) evaluation beginning;
- baseline simulation models designed;
- baseline monitoring designed.

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- **Phase III General Goals and Benefits**
- Phase III Scope, Elements and Milestones
- Phase III Technical Plan
  - What and Why
  - Field operator
  - Project Site and Key Elements
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

Major Goals and Potential Benefits

- **Storage Capacity Verification**
  - The SWP is developing technologies that will support our industry partner's ability to predict and confirm CO2 storage capacity in geologic formations
  - The uncertainty or tolerance planned is ±30 % (target is ±10 %)
  - Injectivity determined from wellbore simulation models calibrated with CO2 injection from existing patterns, laboratory analysis of existing core and future core, and well-testing of characterization wells.
  - Capacity verification via 3-D simulation models and direct data, 3D-VSP, crosswell tomography, tracers, pressure and temperature, and production data.

- **Verification of Containment**
  - The SWP is refining a technological approach to confirm that 99 % of injected CO2 remains in the injection zones
  - From Phase II project results, we find that the most effective approach are geophysical (VSP) surveys, tracer monitoring, pressure and geochemical monitoring, and detailed numerical modeling.

Major Goals and Potential Benefits

- **Storage Permanence**
  - Storage permanence confirmed, including geophysical (VSP) surveys, tracer monitoring, pressure and geochemical monitoring, and detailed numerical modeling calibrated by these data.
  - Directed testing to validate that there is no impact on USCWs. Also identify risks specific to USDWs and develop associated Probability Density Functions (PDFs), quantify risks to USDWs by pressure/CO2 migration through seals; or by lateral migration of pressure/CO2; and determine conditions that minimize or eliminate the risks to USDWs.

Major Goals and Potential Benefits

- **Plume Extent and Potential Leakage Pathways**
  - The SWP will characterize and forecast potential plume extent and potential leakage pathways via geophysical surveys, tracer monitoring, pressure and geochemical monitoring, and detailed numerical modeling.
  - We will also confirm the forecasts through continuous monitoring and measurements during- and post-injection.
- **Risk Assessment**
  - The SWP has developed a comprehensive risk assessment strategy which is “Adaptive”— iterative modeling-monitoring approach for assessment of uncertainty and performance assessment: healthy/safety risks, economic and programmatic risks, and otherwise.
- **Best Practices**
  - The SWP continues to emphasize technology transfer in the form of Best Practice Manuals (BPMs) development
  - SWP personnel have already contributed much to several BPMs, including: S*imulation and Risk Assessment, Site Selection and Characterization, MVA,* and *Public Education and Outreach.*

Major Goals and Potential Benefits

- **Outreach and Education**
  - The SWP will continue successful outreach and education methods, including: focus groups with opinion leaders and decision-makers in the communities; quarterly press releases about the SWP's field progress; and collaboration with the Southwest CCS Training Center's efforts developing K-12 and University curricula, as well as professional short courses for industry and other entities.

- **Permitting Approach**
  - Regulatory efforts activities have three complementary objectives: ascertain and monitor permitting requirements as they evolve; secure any required permits for the Farnsworth Unit project; and Manual of Best Practices.

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- **Phase III Scope, Elements and Milestones**
- Phase III Technical Plan
    - What and Why
    - Field operator
    - Project Site and Key Elements
    - Collaboration benefits
    - MVA Plans
    - Simulation Plans
    - Risk Assessment Plans
- Accomplishments to Date

Project Overview and Scope of Work

The SWP project will be an Enhanced Oil Recovery (EOR) and storage deployment with

- Injection into up to 25 wells;
- Injection rates of ~ 0.2 million tonnes per year for multiple years;
- Injection in a proven sealed reservoir;
- The primary effort will be in monitoring the CO2 plume and verifying the storage capacity and permanence.

Feasibility of Approach and Schedule

Major Project Elements, Schedule and Success Factors:

BP 3 (injection period ~five years)

- Site access contract
- Baseline monitoring design and deployment: tracers, sampling etc.
- Three Characterization wells (two 1st quarter 2013, third 1st quarter 2014)
- Baseline seismic: 3D field wide, 3D-VSP, crosswell tomography. – 2013.
- Continuous monitoring: sampling etc.
- Repeat 3D-VSP and crosswell.

BP 4 (post injection, next 4 years)

- 1 million tonnes injection completed
- Continuous injection for EOR
- Continued monitoring
- Full-time monitoring begins
- Successful engineering of system
- No significant risk events induced
- Modeling of site successful

BP 5 (???? Continuous monitoring if DOE and operator agreed)

Critical Milestones

Selected Critical Milestones: Budget Period 3:

- Site Approval from the DOE
- Initial Capacity Estimate Completed
- Site Access Agreements Finalized
- All Necessary Permits Acquired
- NEPA Compliance Completed
- Start Baseline Monitoring
- Characterization wells completed
- Baseline seismic and other monitoring completed
- Continued monitoring and repeat seismic during 1 million tonnes CO2 injected.

Selected Critical Milestones: Budget Period 4:

- 1 million tonnes Injection completed
- Full-time Monitoring continued
- Updated Risk Management Framework Complete
- Updated Best Practices Manuals Completed

Selected Critical Milestones: Budget Period 5:

- Continued monitoring?

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
  - **What and Why**
  - Field operator
  - Project Site and Key Elements
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

SWP Phase 3: What and Why

- **What is the SWP and its partners planning?**
  - 1,000,000 tonnes CO2 injected and monitored
  - “blueprint” for future commercial sequestration

- **Why are we conducting this testing?**
  - many deep formations common to all basins
  - deep Jurassic- and older “clean” sandstones in all states
  - representative commercial sites

- **How are we carrying out this testing?**
  - Close collaboration among Partnership and industry
  - Concerted coordination with regulatory agencies

SWP Presentation Outline

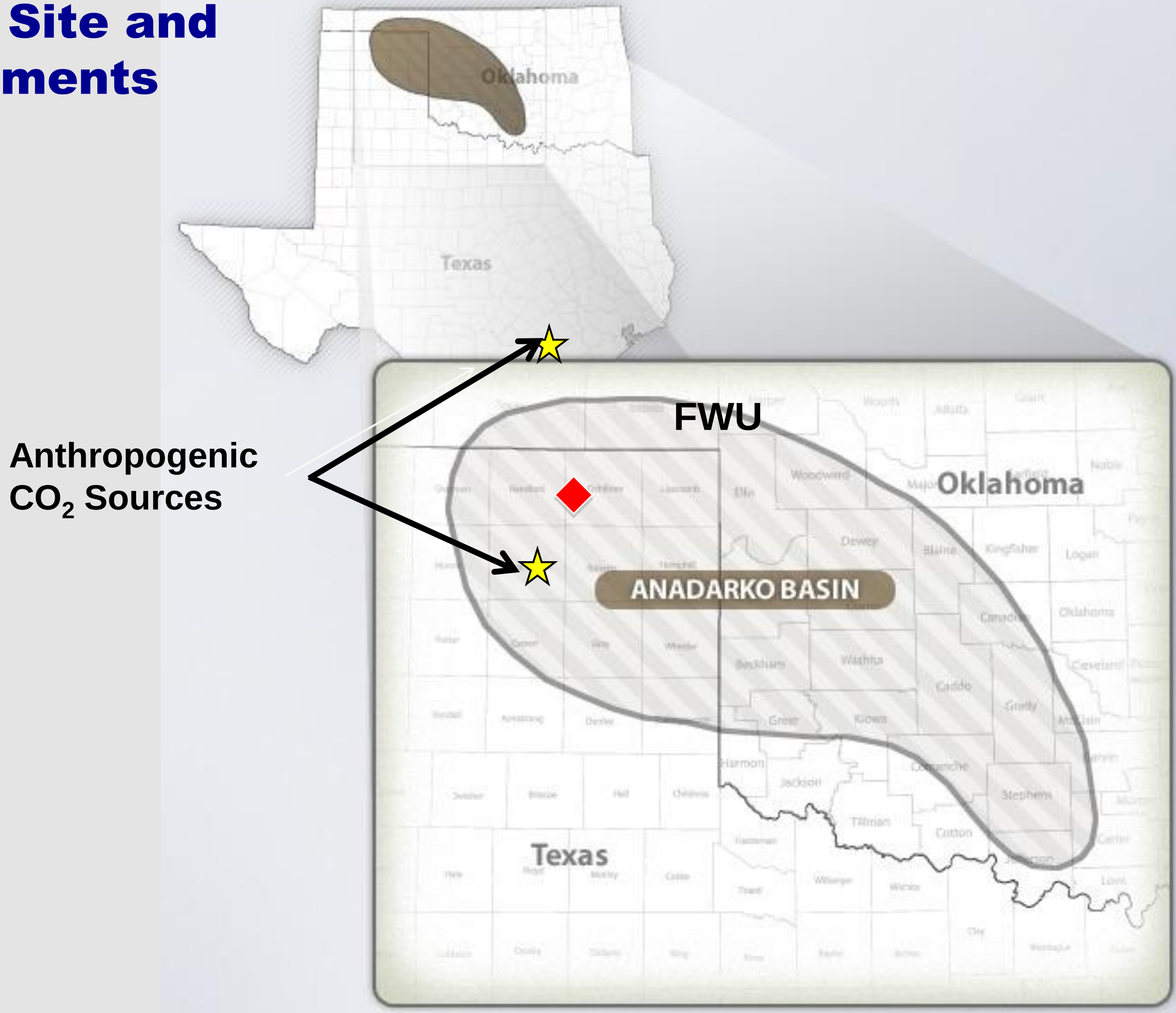
- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
  - What and Why
  - **Field operator**
  - Project Site and Key Elements
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

Site Operator: Chaparral Energy, LLC

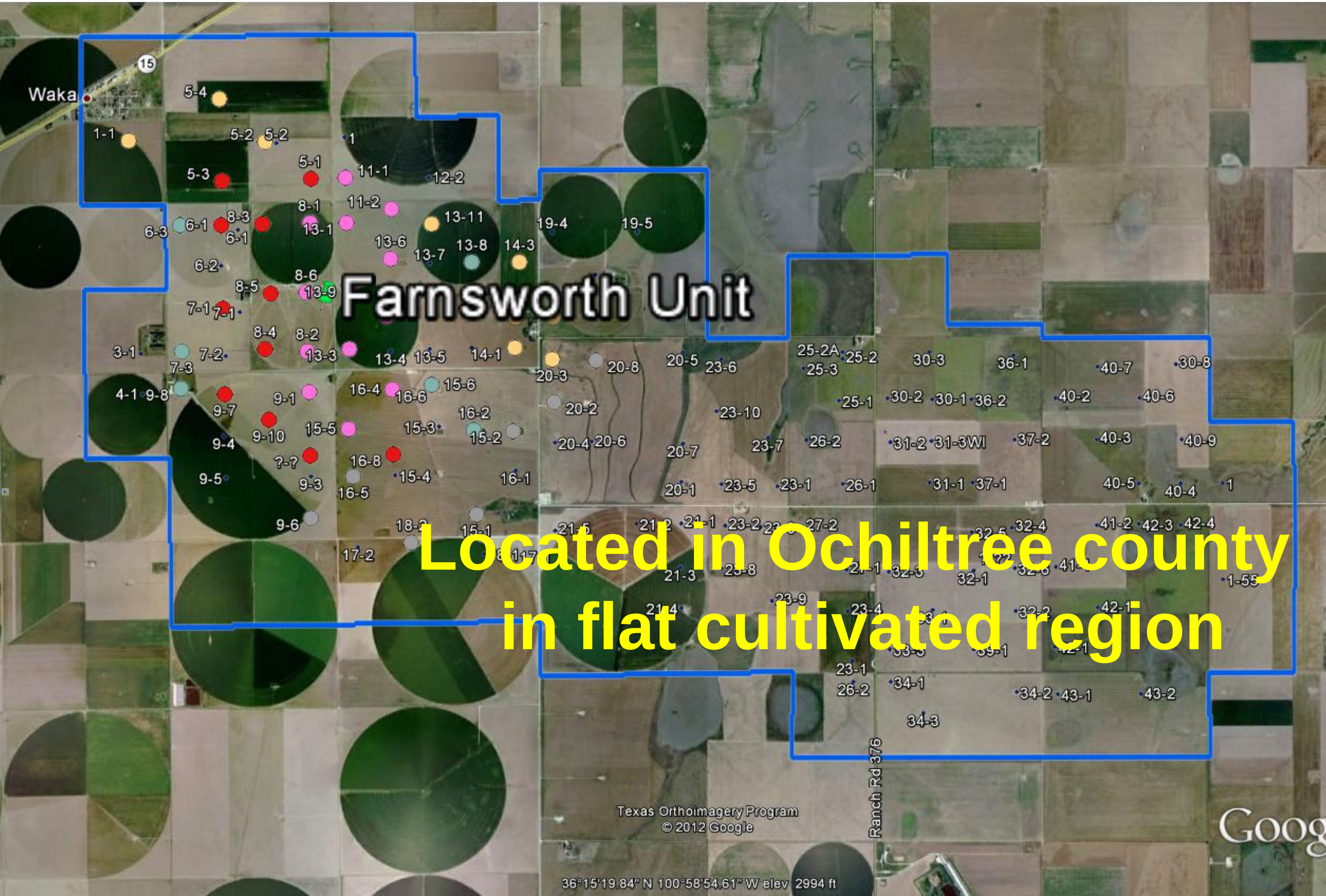
SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
  - What and Why
  - Field operator
  - **Project Site and Key Elements**
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

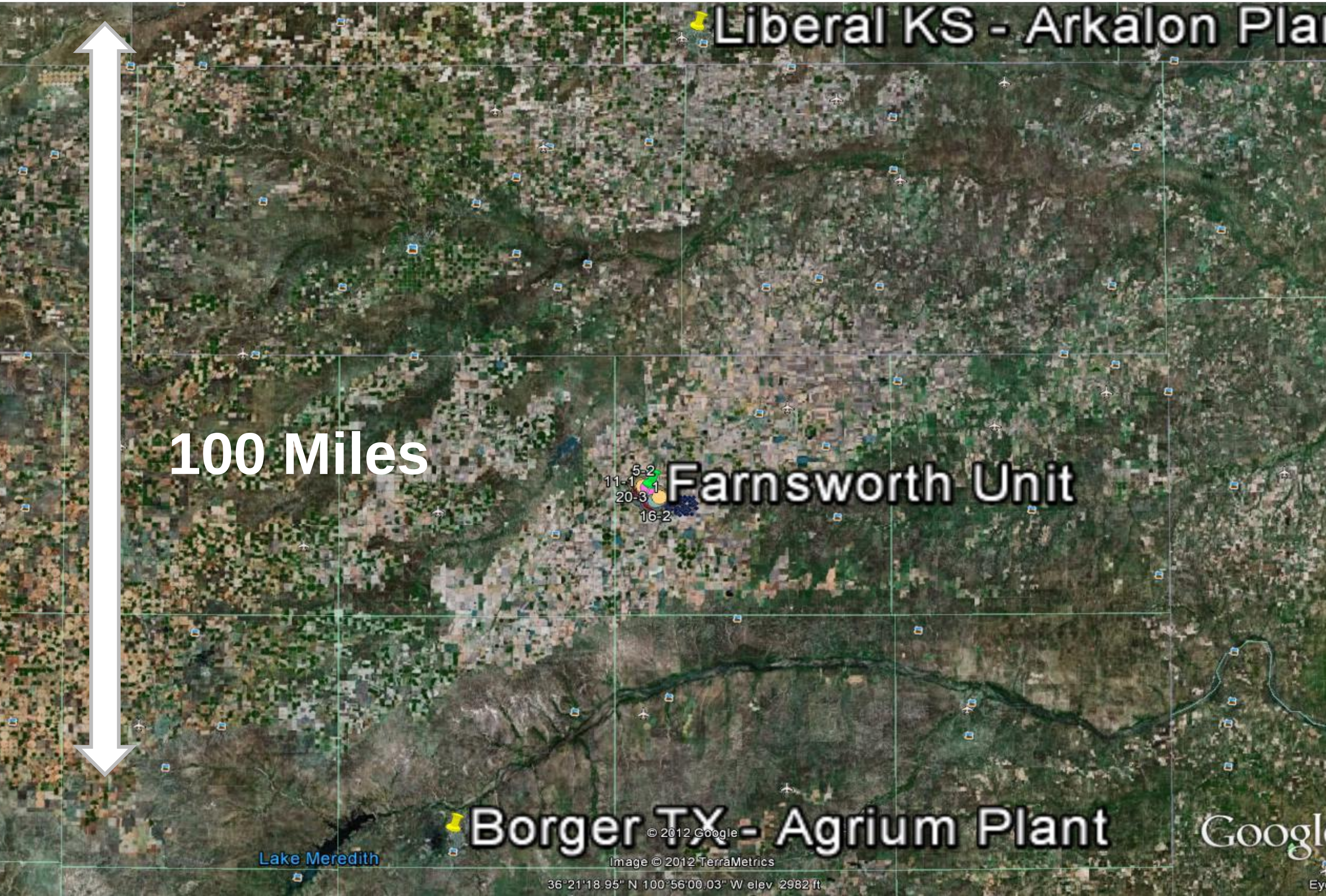
Project Site and Key Elements



Project Site and Key Elements



Project Site and Key Elements



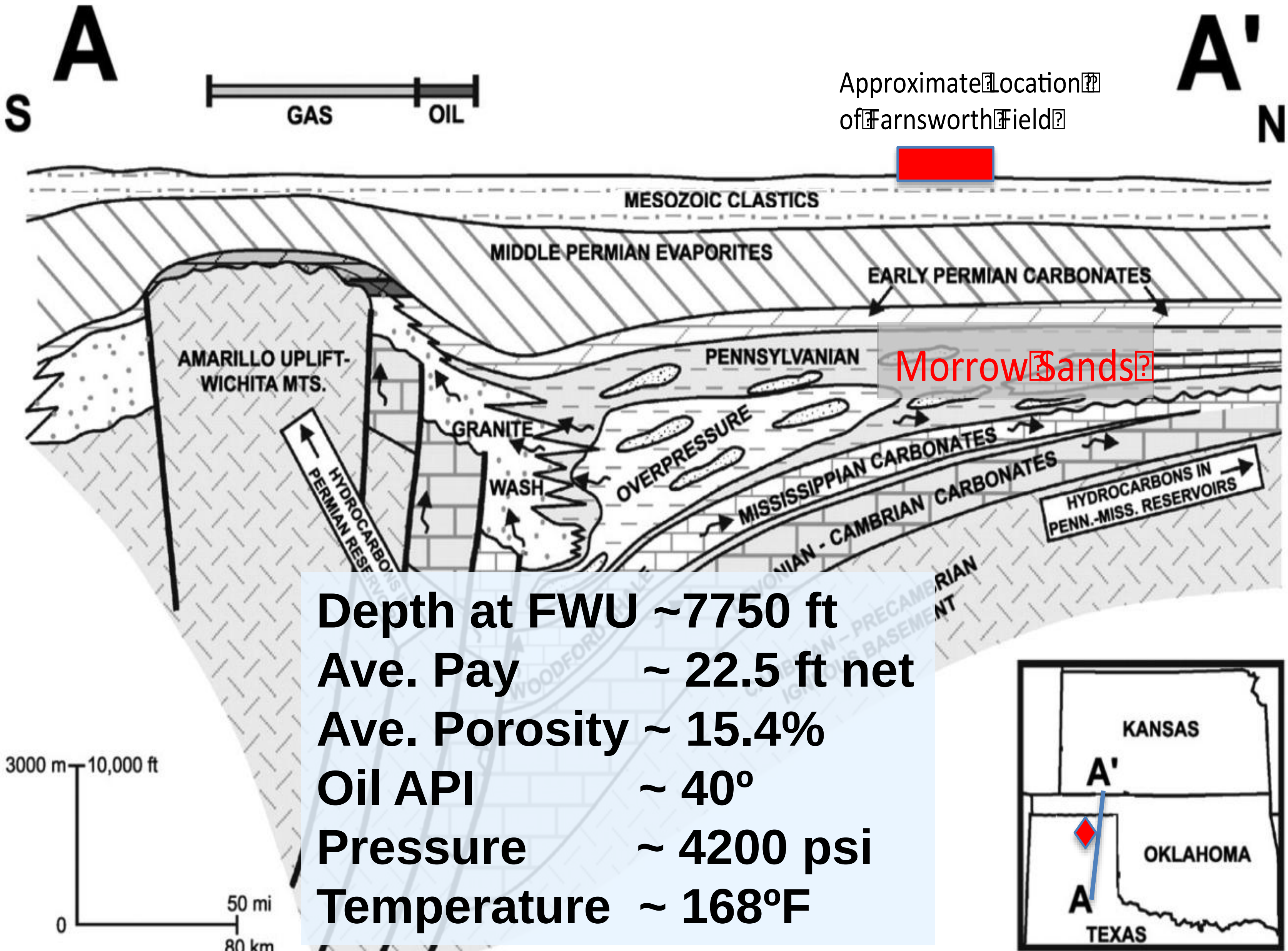
Project Site and Key Elements

CO_2 Supply:

Arkalon
Ethanol Plant
Liberal KS

Agrium
Fertilizer Plant
Borger TX

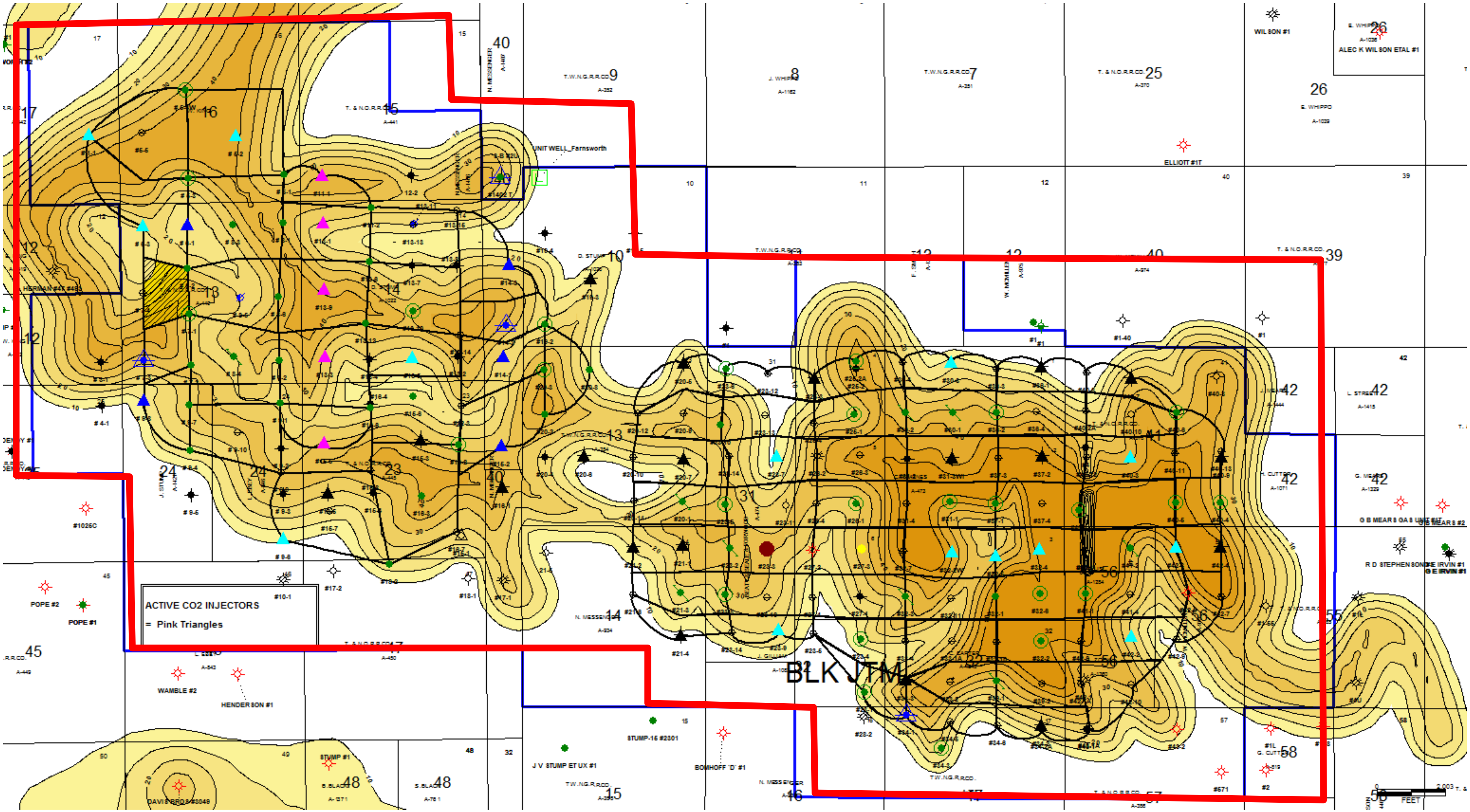
Project Site and Key Elements



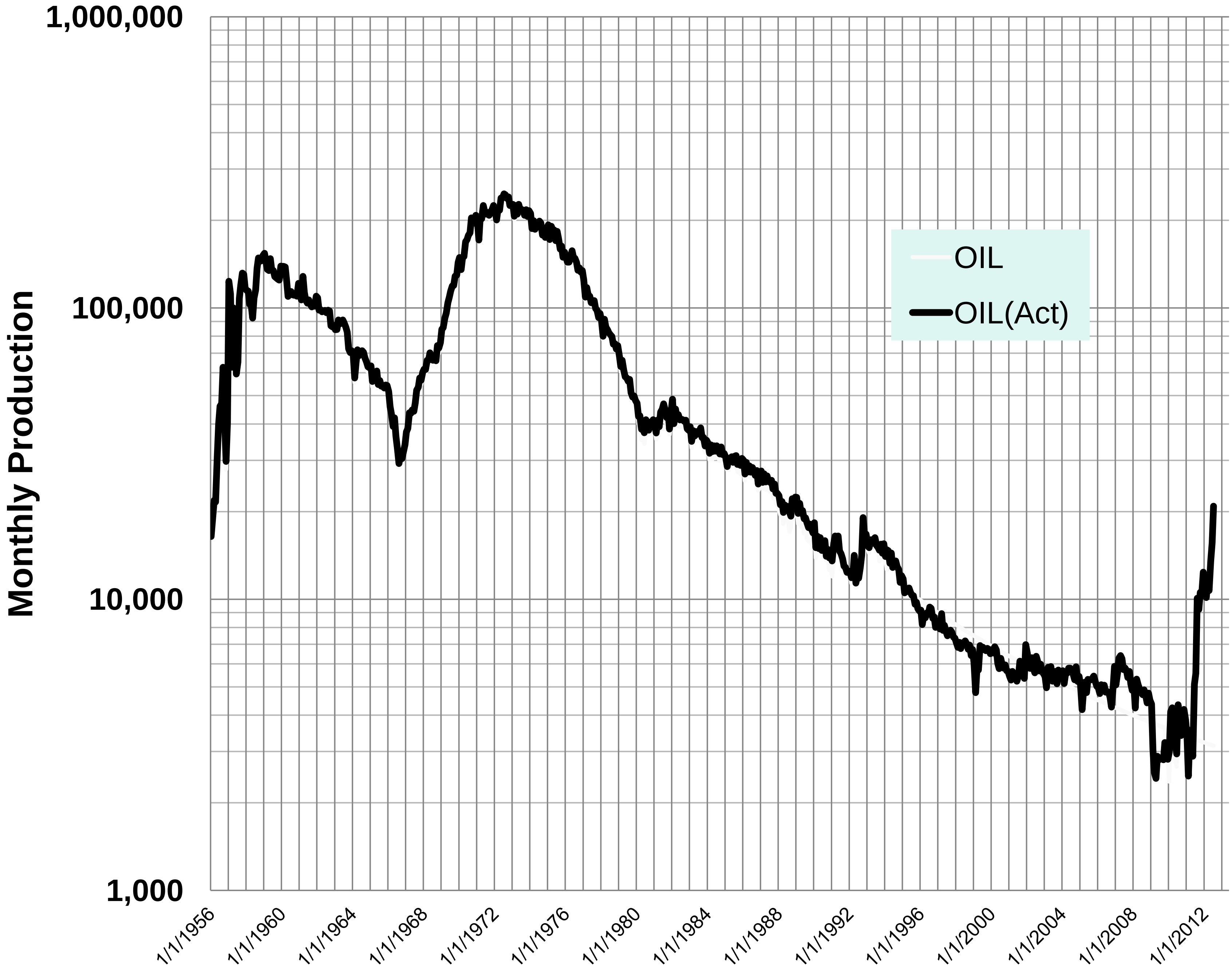
Depth at FWU ~7750 ft
Ave. Pay ~ 22.5 ft net
Ave. Porosity ~ 15.4%
Oil API ~ 40º
Pressure ~ 4200 psi
Temperature ~ 168ºF

Project Site and Key Elements

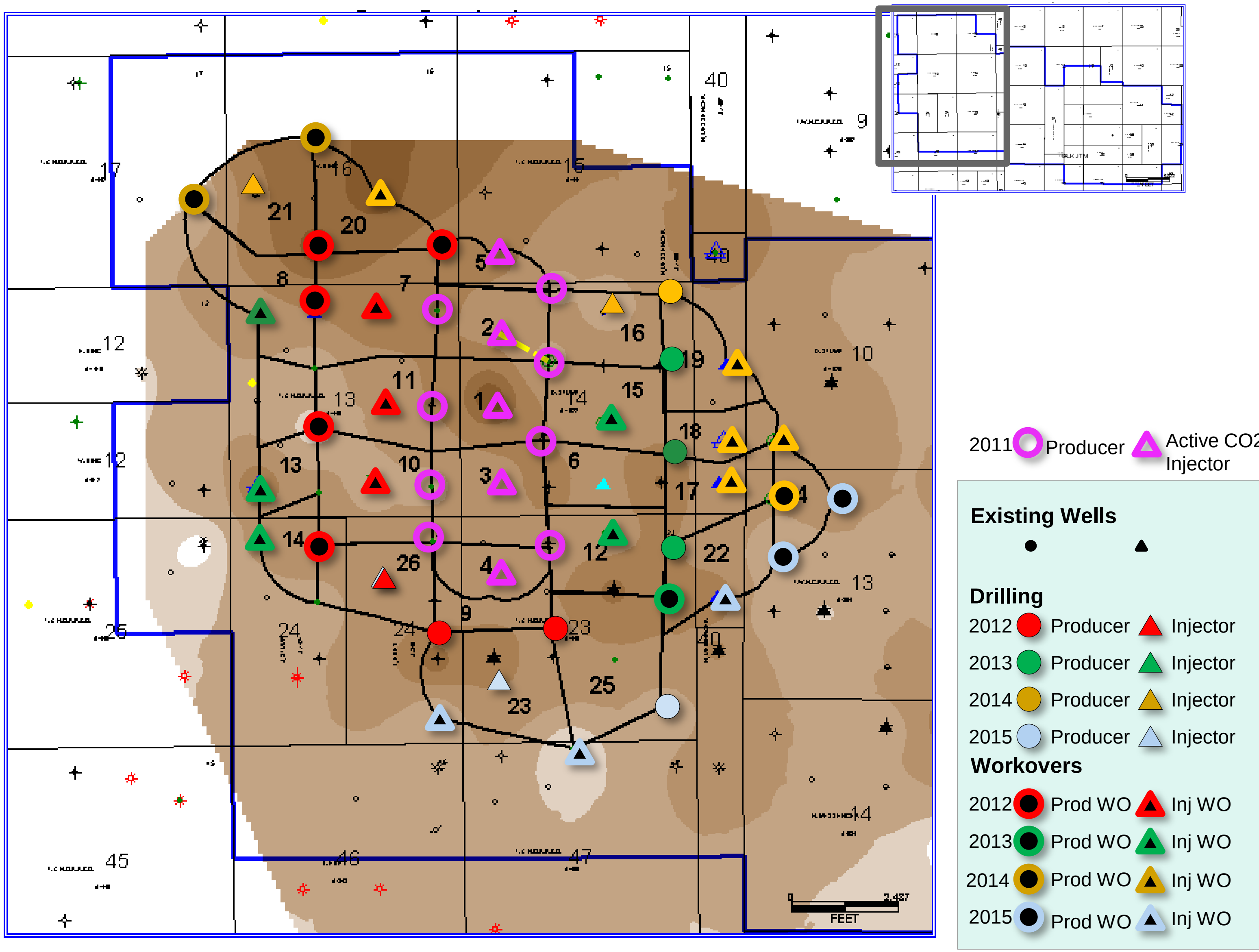
Farnsworth Unit



FWU Production 1956 - 2012



Proposed New FWU Drills and Workovers

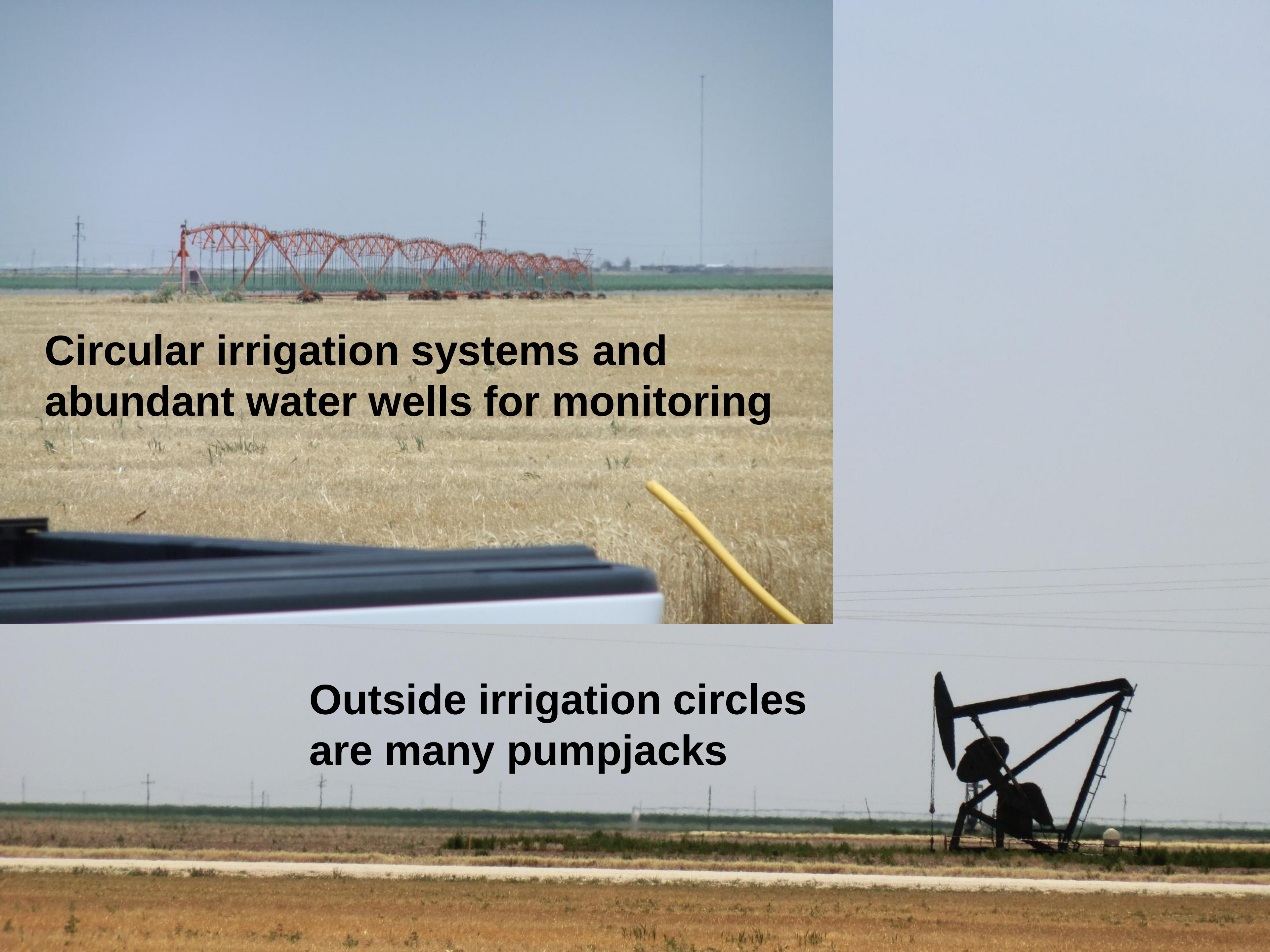


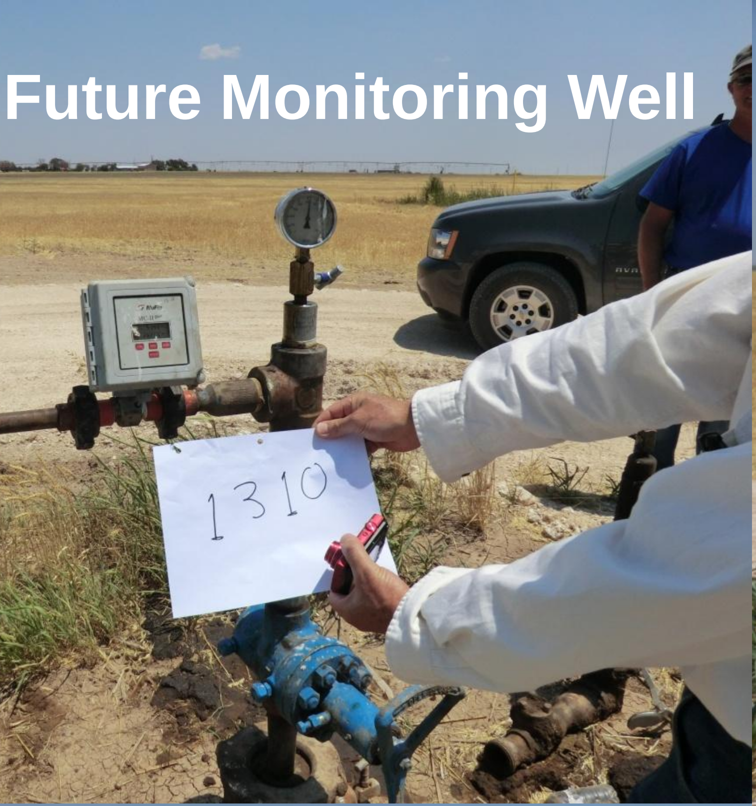
32

FWU Central Battery

FWU Central Battery

Present CO_2 injection rate: 10 million scfpd net with at least another 2 million recycled


Circular irrigation systems and
abundant water wells for monitoring
Outside irrigation circles
are many pumpjacks



Future Monitoring Well

Future Injection Well

Submersible Pump @ Well 1312

Middle of a corn field

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
  - What and Why
  - Field operator
  - Project Site
  - **Collaboration benefits**
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- Accomplishments to Date

Chaparral and SWP Collaboration: Benefits

Anticipated benefits for SWP:

- **Active CO_2-EOR site that would be a "field lab" for evaluating efficacy of monitoring technologies and for testing and refining forecasts of CO_2 fate;**

- **Expert feedback from an experienced company who offers tangible insight regarding industry priorities and concerns with respect to CCUS (carbon capture, utilization and storage);**

- **Represents goals and requirements for testing and evaluation of CCUS;**

- **Chaparral, because of its size, is nimble and can act quickly in its decision-making (esp. compared to other companies).**

Chaparral and SWP Collaboration: Benefits

Technical benefits for SWP and its stakeholders:

- **Several monitoring/characterization wells to be drilled by SWP will (would) be completed and then used as production or injection wells and used to monitor CO_2 flow paths;**
- **Increased resolution of reservoir characterization;**
- **Direct and frequent sampling and analysis of produced fluids;**
- **New (additional) core and logs;**
- **Extensive flow testing for relative permeability;**
- **Extensive geomechanical testing for forecasting injectivity changes and other processes;**

Chaparral and SWP Collaboration: Benefits

Technical benefits for SWP and its stakeholders:

- **Independent interpretation of old and new seismic, logs, and core;**
- **Additional surface seismic: extensive VSP, crosswell, passive and/or 3D;**
- **A continuously-updated three-dimensional (3D) reservoir model (detailed facies-based geomodel for history-matching flow models);**
- **3D reservoir simulations, using models that are fully parameterized with multiphase flow of oil, CO_2, brine, and reactive chemistry;**
- **Optimized forecasts of reservoir behavior to assist with design of new patterns;**
- **Periodic snapshots of CO_2 location, forecasted by reservoir simulation and confirmed with sampling and seismic;**

Chaparral and SWP Collaboration: Benefits

Technical benefits for SWP and its stakeholders:

- **Baseline and multiple-repeat surface flux measurements;**
- **Baseline and multiple repeat reservoir and groundwater (brine compositions;**
- **Increased resolution of surface and subsurface geologic maps and cross-sections through additional mapping and new techniques;**
- **Tracer studies to determine and confirm predicted flow patterns of reservoir fluids; and GPS;**
- **Investigation of sealing behavior of overlying formations;**

Chaparral and SWP Collaboration: Benefits

“Big Picture” benefits for SWP and its stakeholders:

- **At least 1,000,000 tonnes CO_2 injection over ~five years *(meaningful commercial test)*;**
- **100% anthropogenic CO_2 *(true sequestration)***
- **Carbon accounting requested by ethanol plant source *(full “VA” in MVA”)***

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
    - What and Why
    - Field operator
    - Project Site
    - Collaboration benefits
    - **MVA Plans**
    - Simulation Plans
    - Risk Assessment Plans
- Accomplishments to Date

Phase III CCUS: MVA

Perfluorocarbon (PFC)Tracers

- PFC tracer will be injected into a selected well.
- PFC tracers detection limits approaching the part per quadrillion level.
- Soil-gas/atmosphere monitors on steel tubes are placed adjacent to injector wells, production wells and other higher leakage probability locations.
- Sampling will be employed for both directional monitoring of high leakage probability locations and area wide tracer levels.
- PFC tracers will be monitored in produced gases at selected wells.

Aqueous-Phase Tracing

- *Objective: to determine aqueous-phase flow patterns between CO_2 injection and production wells.*
- Naphthalene sulfonate tracers injected as 50-kg slugs at appropriate injection wells:
- Aqueous phase of surrounding production wells sampled periodically and analyzed.
- Tracer return-curve data processed for use in subsequent numerical simulation model calibration.

Phase III CCUS: MVA

Monitoring Activities for the FWU Sequestration Site

Surface and near-surface gas flux monitoring

Monitoring	Objectives	Equipment
❖ Soil gas flux (CO_2, CH_4) ❖ Isotope analysis	➢ Measure compositional and isotopic fluxes. ➢ Measure the total con. of CO_2 and the vertical flux of isotopes with sufficient enough to resolve diurnal variations of natural sources and isotopic shifts between natural and fossil sources. ➢ Thief zone monitoring	▪ LI-8100A Automated Soil CO_2 Flux System ▪ Picarro CO_2 and CH_4 analyzer for gas concentration and flux ▪ Gas sample bags (Tedlar) for analyses in lab

Shallow groundwater quality monitoring wells

❖ Existing water wells	➢ CO_2 leakage ➢ Identification of ground water contamination	▪ Ion chromatograph (IC) ▪ Inductively coupled plasma - mass spectrometer (ICP-MS)

Phase III CCUS: MVA

Monitoring Activities for the FWU Sequestration Site

Monitoring (production) wells

❖ Downhole P, T monit. ❖ Tracers ❖ Isotope analysis of CH_4 & CO_2 ❖ Compositional analysis of produced gases, oil, & water (all Prod. Wells)	➢ CO_2 plume tracking ➢ Caprock integrity ➢ Leakage; use isotopic mixing methods to characterize mixing and transport processes in the reservoir	▪ Pressure, temperature sensor ▪ Ion chromatograph (IC) ▪ Inductively coupled plasma - mass spectrometer (ICP-MS) ▪ Total organic carbon analyzer (TOC) ▪ Gas chromatograph for gas and oil ▪ Picarro isotope analyzer

Injection wells

❖ Downhole P, T monitoring ❖ Wellhead pressure ❖ Injection volume/rate	➢ Injectivity monitoring ➢ Operating adjustment ➢ Reservoir diagnostics to characterize boundary conditions	▪ Pressure, temperature sensors ▪ Pressure gauge ▪ Flow meter

Existing and Planned Seismic Acquisitions

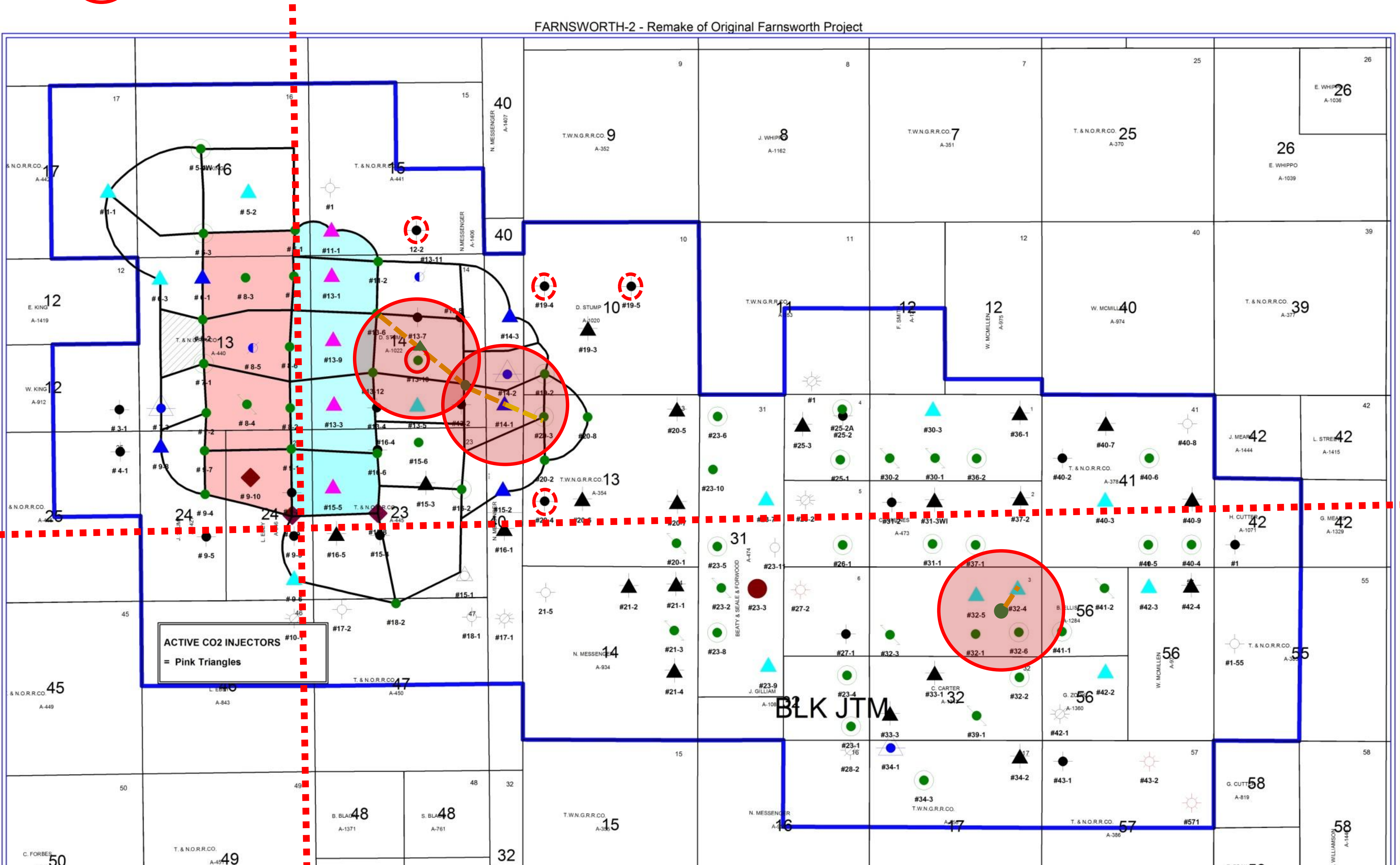
- The seismic plan calls for a variety of seismic data at several scales and resolutions
- Data will be used for characterization, modeling, and MVA purposes
  - Legacy FWU 2D Seismic lines
  - Legacy regional 3D and 4D surveys
  - 3D (4D?) UniQ Seismic Survey
  - Repeat 3D VSP’s
  - Repeat cross-well tomography
  - Passive borehole seismic

Objectives for Seismic Data

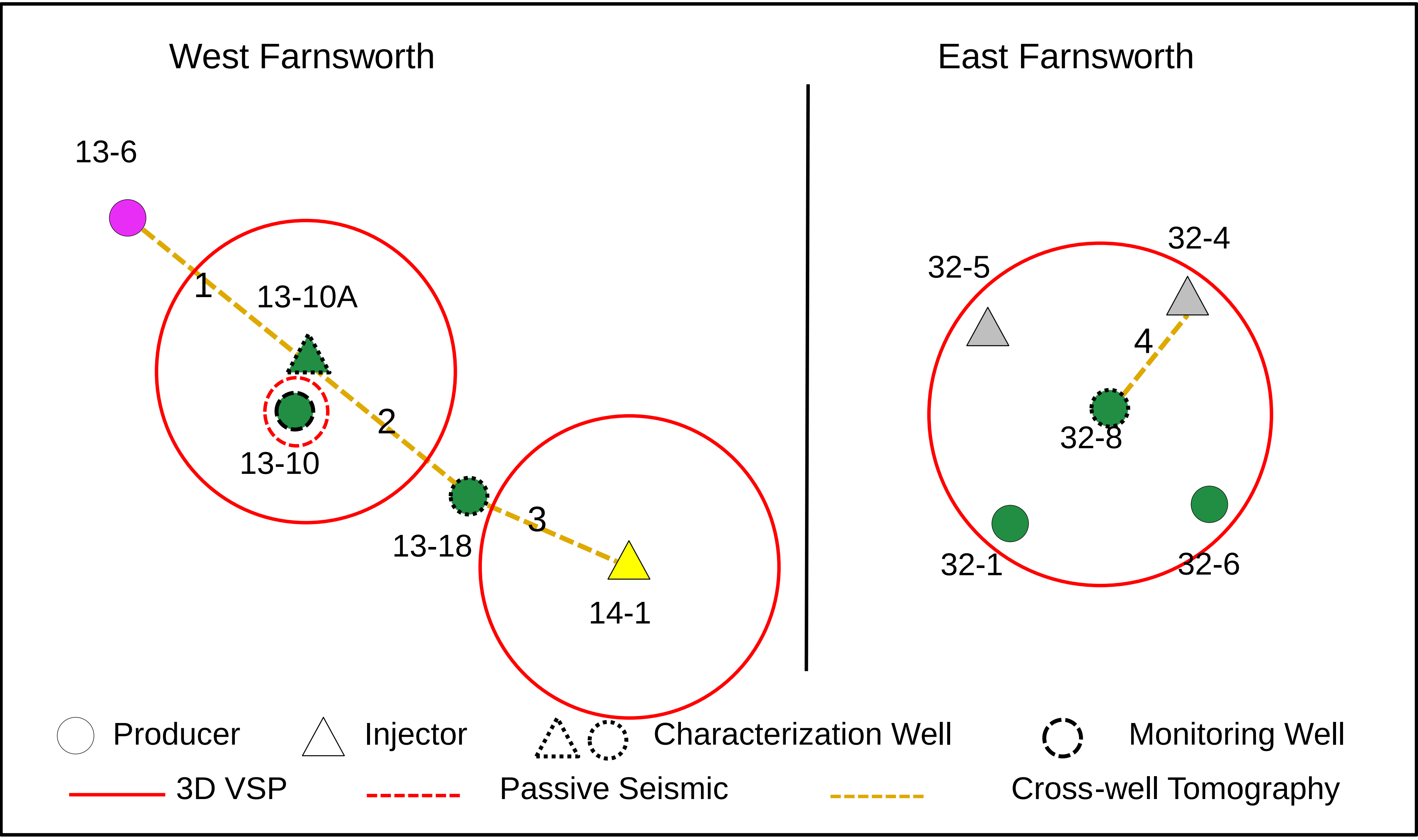
- **To improve geologic understanding**
  - 3D, VSP, cross-well, and passive seismic when combined with acquired well logs, core, and other physical data will provide a framework for a detailed facies-based geomodel that will be upscaled to improve simulation models
- **To directly monitor CO2 plume movement as patterns go from inactive through full sweep**

Existing and Planned Seismic Acquisitions

3D VSP | Passive | Cross-well | UNIQ (3D) | Legacy 2D



Existing and Planned Seismic Acquisitions



Existing and Planned Seismic Acquisitions

- **Legacy 2D Data** will provide additional velocity model information and tie-ins to Anadarko Structure
- **3D VSP Data** will leverage the proven ability of walkaway VSP's to image CO_2 plumes with a more data rich 3D grid, which should enhance areal measurements
  - Repeats and multiple flood patterns imaged will provide MVA and simulation control data
- **Cross-well Data** will provide details along ideal flow paths for location of the plume and potentially density of the plume
  - Repeats and multiple flood patterns imaged will provide MVA and simulation control data
- **Passive Seismic Data** 1-2 boreholes will have permanently installed geophone arrays used for passive seismic monitoring
  - Passive seismic can indirectly monitor movement of the pressure front through the reservoir by recording micro-earthquakes
- **UNIQ 3D Survey** Allows for dynamic allocation of seismic bins and formation of arrays and bins after acquisition
  - Can drastically reduce attenuation such as regionally seen in the Anadarko basin due to thick (1000' plus) weathered zone and anhydrite layers

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
  - What and Why
  - Field operator
  - Project Site
  - Collaboration benefits
  - MVA Plans
  - **Simulation Plans**
  - Risk Assessment Plans
- Accomplishments to Date

Simulation Plans:
Integrated Modeling – MVA – Risk Assessment

monitoring surveys continuous, with initial frequency established by site selection process…

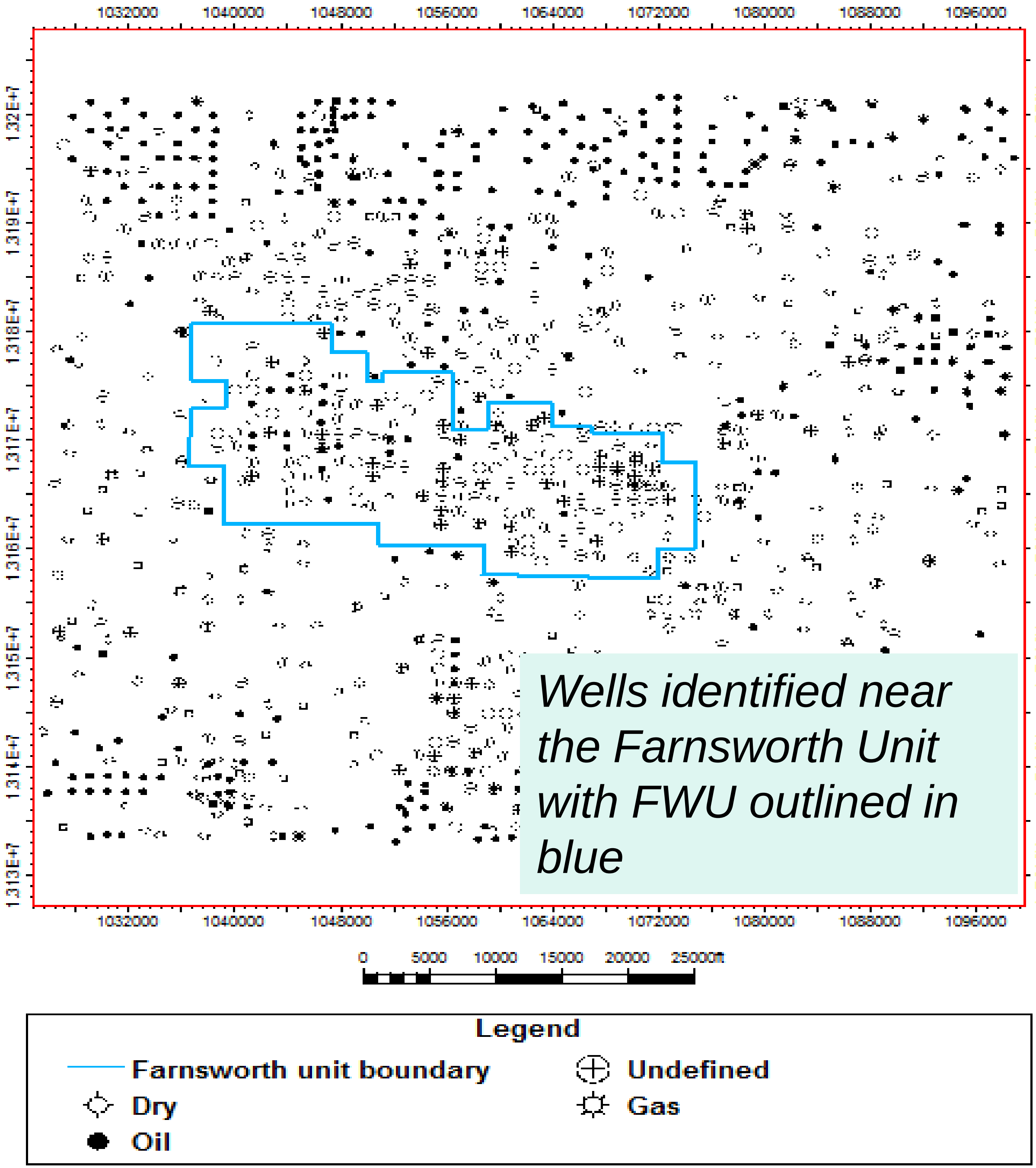
…as more monitoring and characterization data gathered, *model resolution increases*

…as model resolution increases, simulation results used to guide *improvement of monitoring design*

…as model results and monitoring design become more effective, uncertainty associated with probability of FEPs will decrease, *PDFs better defined, and risk profiles (values) better resolved*

…as risk profiles become better defined, injection design and engineering can be modified to *improve and optimize - risk reduced*

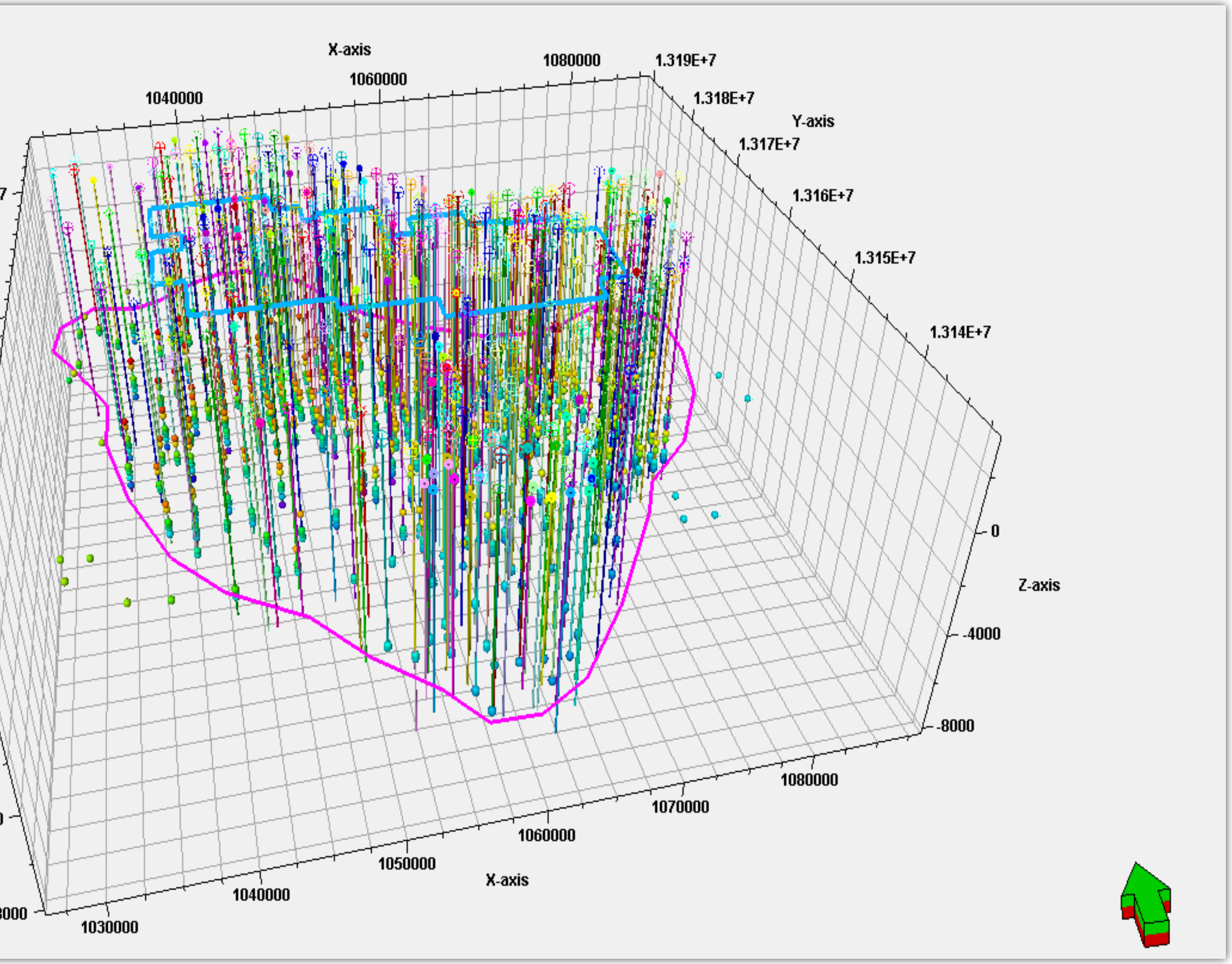
…as risk profiles better defined and risks reduced, monitoring strategy can be tailored to reflect more focus on areas of greater relative risk *(devote fewer resources to areas of lower risk)*



Simulation Goals

- Improved monitoring design
- Facilitate meaningful capacity estimation
- Facilitiate storage accounting and verification
- Improved quantification of risk elements

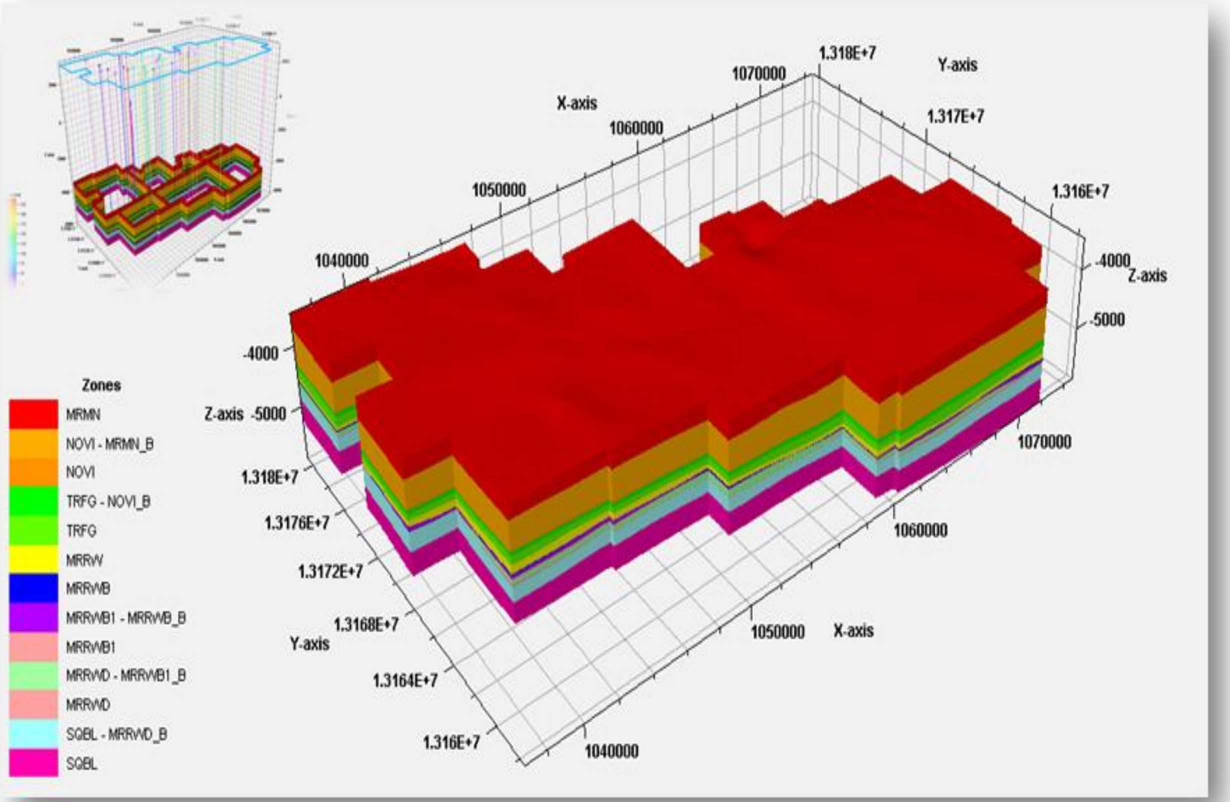
Simulation Goals



Location of wells with the formation top picks. Vertical exaggeration is 2x.

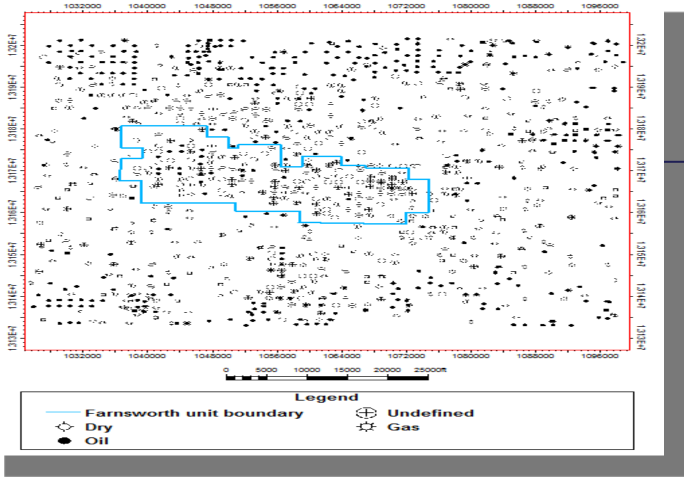
- Improved monitoring design
- Facilitate meaningful capacity estimation
- Facilitiate storage accounting and verification
- Improved quantification of risk elements

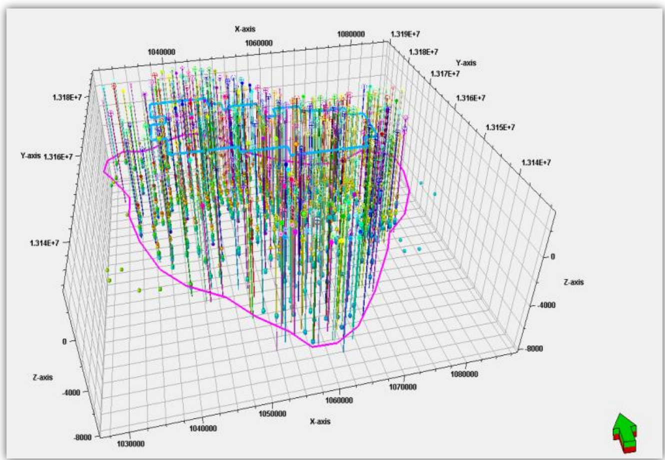
Simulation Goals

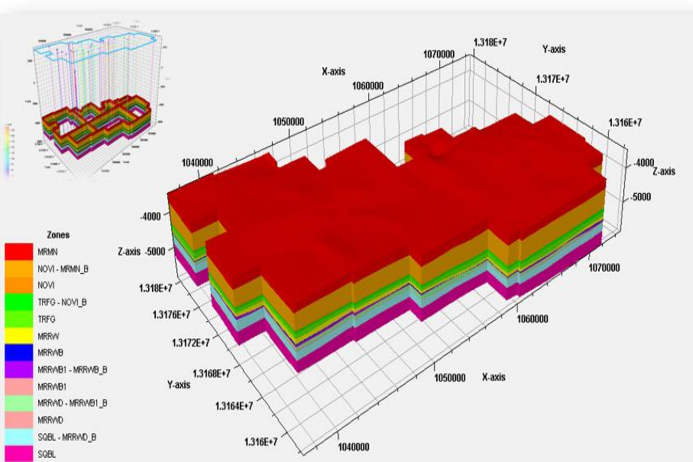


Stratigraphic distribution of geologic formations within the Farnsworth Unit boundary. Vertical exaggeration 2x

- Improved monitoring design
- Facilitate meaningful capacity estimation
- Facilitiate storage accounting and verification
- Improved quantification of risk elements







Simulation Codes Used by SWP

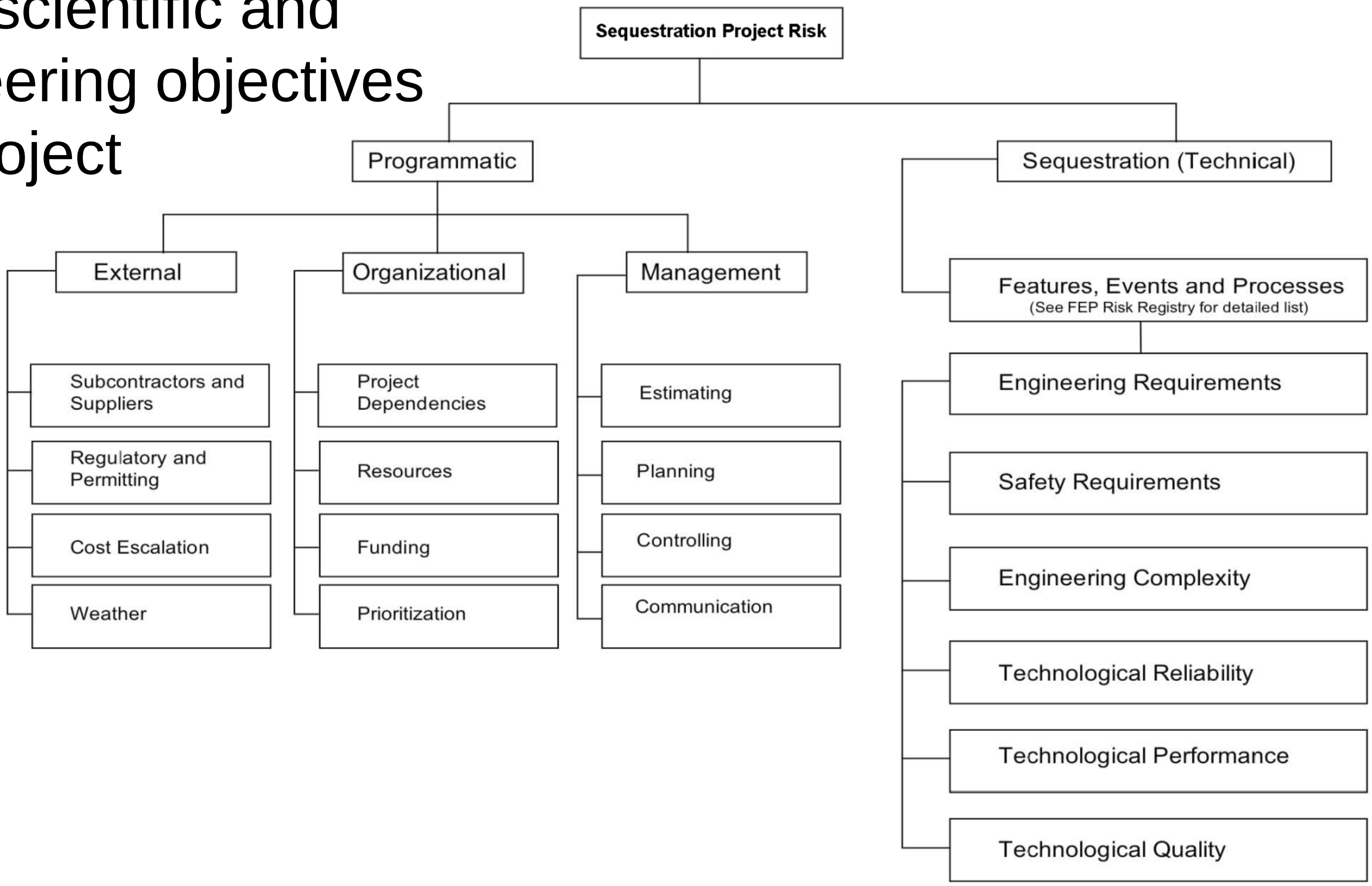
Reservoir Simulator:	**Developer**
STOMP	PNNL
TOUGHREACT	LBNL
Eclipse	Schlumberger
Geochemist's Workbench	University of Illinois
PFLOTRAN	LANL
Nexus	Halliburton
For System Integration, Risk Assessment and Accounting:	
VELO	PNNL
CO2-PENS	LANL

SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- **Phase III Technical Plan**
  - What and Why
  - Field operator
  - Project Site
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - **Risk Assessment Plans**
- Accomplishments to Date

Risk Assessment Plans

- Programmatic risks that impede project progress or cost
- Technical risks inherent to the scientific and engineering objectives of a project



Potential risk pathways are being identified

- Features, events, and processes (FEPs)
  - leaky wellbores or faults for features,
  - injection pressure increases or earthquakes for events, and
  - gravity-driven CO_2 movement or residual saturation trapping for processes.
- From FEPs, consequences are identified.

Risk assessment : iterative procedure

- Initial info from site characterization and modeling, used to develop meaningful models

- Monitoring provides feedback
  - Deep gives early warning
  - Near-surface helps quantify impact and reduce risk

- Updated models provide updated risks

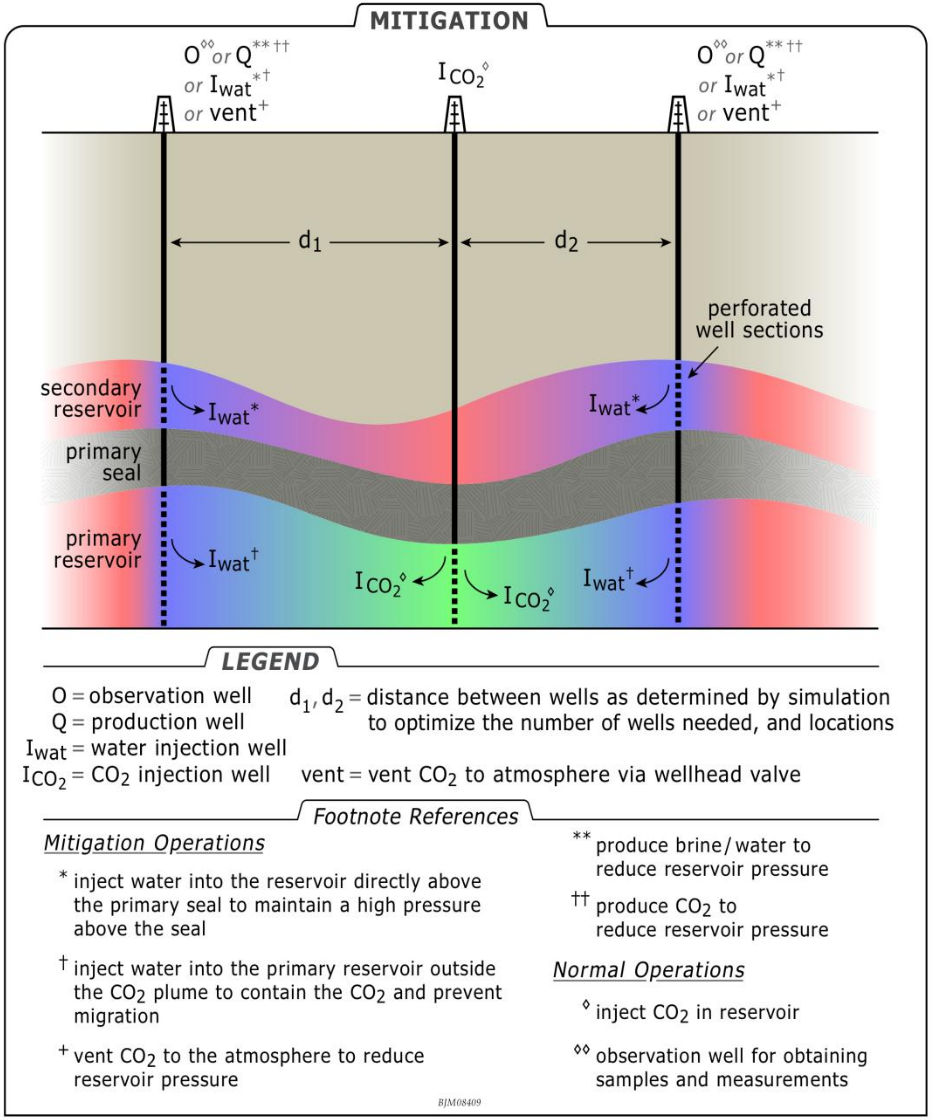
General Mitigation Planning

The basis of ongoing mitigation plans involve:

(1) integration of monitoring technologies at appropriate scales in reservoir models, for optimized design of monitoring deployments

(2) integration of unique or site-specific risk elements (e.g., FEPs) in reservoir models, for optimized calculation of risk probabilities

Reservoir models will include (1) and (2) to be more adept at formulating mitigation plans.



SWP Presentation Outline

- The Southwest Partnership
- Regional Characterization
- Phase III Introduction
- Phase III General Goals and Benefits
- Phase III Scope, Elements and Milestones
- Phase III Technical Plan
  - What and Why
  - Field operator
  - Project Site
  - Collaboration benefits
  - MVA Plans
  - Simulation Plans
  - Risk Assessment Plans
- **Accomplishments to Date**

Accomplishments to Date

- Site suitability evaluation completed;
- geologic characterization ongoing;
- site proposal submitted to NETL;
- cost-price (budget) evaluation beginning;
- baseline simulation models designed;
- baseline monitoring designed.

Wrap-up: Future Plans

- Complete site approval and access.
- Refine design of storage monitoring
- Complete NEPA
- Continue baseline monitoring and characterization
- Measure baseline CO_2 and CH_4 fluxes (if any) in the field, as a means of evaluating hydraulic communication in the Farnsworth area
- Continue simulation development and increase resolution of risk assessment

Many thanks!

For more information, access:

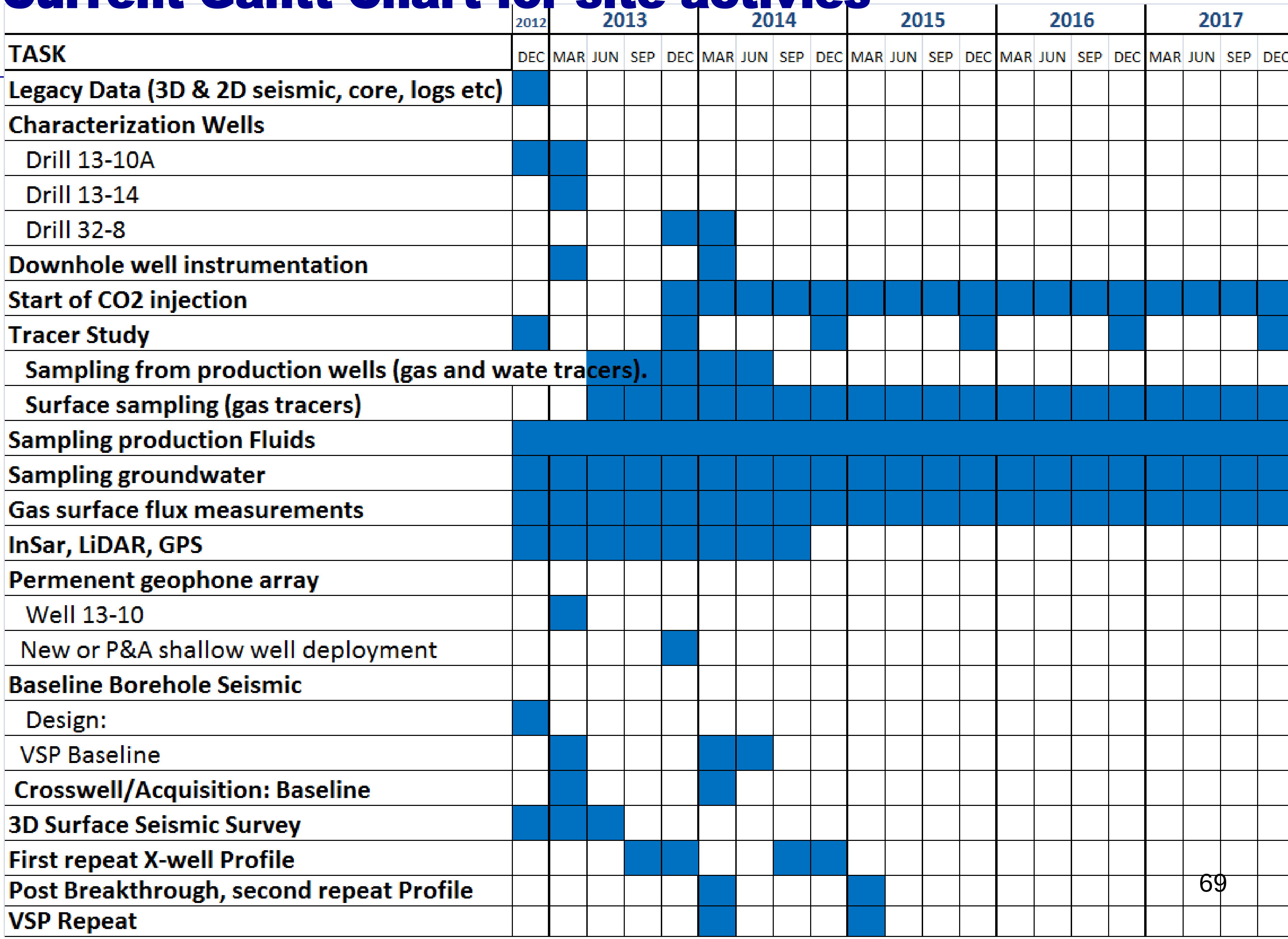
http://swpartnership.org

Support of Local Politicians

- Because FWU is in an area of active hydrocarbon production, public perception tends to be very positive and supportive

- Being in an existing CO_2 EOR project, including additional monitoring only improves the public perception of injection.

Current Gantt Chart for site activies

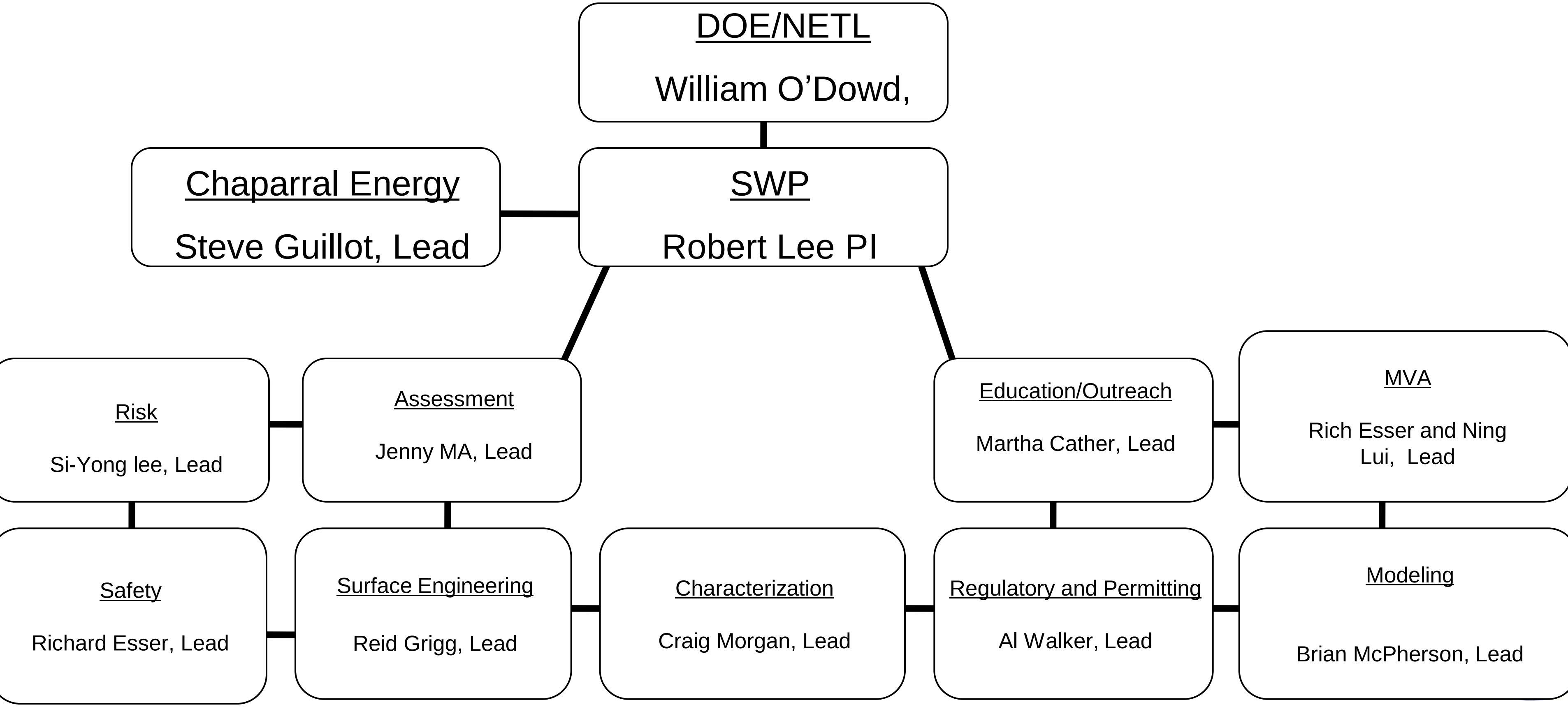


#	Task Description BP3	2,012	2,013				2,014				2,015				2,016				2,017			
		DEC	MAR	JUN	SEP	DEC	MAR	JUN	SEP	DEC	MAR	JUN	SEP	DEC	MAR	JUN	SEP	DEC	MAR	JUN	SEP	DEC
1	**Refine Regional Characterization**																					
1.1	Refine regional storage capacity																					
1.2	Give evidence of potential storage capacity.																					
1.3	Updates for data bases/NATCARB																					
1.4	Extended regional characterization																					
1.5	Interpartnership participation																					
2	**Public Outreach and Education**																					
2.1	Develop and implement outreach plan.																					
2.2	Update and expand the SWP website periodically.																					
2.3	Develop & publish quarterly internet newsletter.																					
2.4	Assess public knowledge & understanding.																					
2.5	Collaborate with National Outreach efforts.																					
3	**Permits & NEPA requirements**																					
3.1	Verify/define mineral/pore space rights																					
3.2	Provide documentation of site access agreements.	* Site access agreement																				
3.3	Environmental questionnaire and EA or EIS	* Cultivated and ~60 years of petroleum production (CX?)																				
3.4	Conduct surveys/obtain permits																					
3.5	UIC permit (field operator)	*UIC Class II well permits				*																
3.6	Define/obtain water rights																					
3.7	Ground water/surface water impacts																					
3.8	Assume all wells and liability (field operator)	* As EOR project operator assumes liability																				
3.9	National Historic Preservation Act																					
4	**Initial Field Sampling & Legacy Data**																					
4.1	Literature review																					
4.2	Outcrop/well sampling																					
4.3	Available legacy data																					
4.4	Existing seismic survey																					
5	**Well Drilling and Completion**																					
5.1	Characterization Wells		* First Char. Well completed				*All Char. Wells completed															
5.2	Shallow Monitoring Wells (if appropriate																					
5.3	Injection Formation Monitoring Well(s																					
5.4	Coring/Logging/Monitoring																					
6	**Infrastructure Development**																					
7	**Procurement of CO_2**																					
8	**CO_2 Transportation and Injection Operations**																					
8.1	Utilize existing site facilities for transportation																					
8.2	Utilize existing & new injection wells																					
9	**Injection Monitoring and Modeling**																					
9.1	Surface, Near-Surface, and USDW Characterization.																					
9.2	Subsurface Characterization																					
9.3	Seismic Surveys		*Baseline surveys																			
9.4	Determination of sites for characterization well																					
9.5	Characterize & analyze target reservoir and seals																					
9.6	Reservoir model development and refinement																					
9.7	Risk assessment	* Initial Assessment framework																				
9.8	(MVA/MRV) plans and program for all activities	*Design finalized					*All MVA in place															
9.9	Well integrity monitoring																					
9.10	Safety training program																					
10	**Site Closure**																		All wells in hands of CELLC*			

Team Selection and Budget

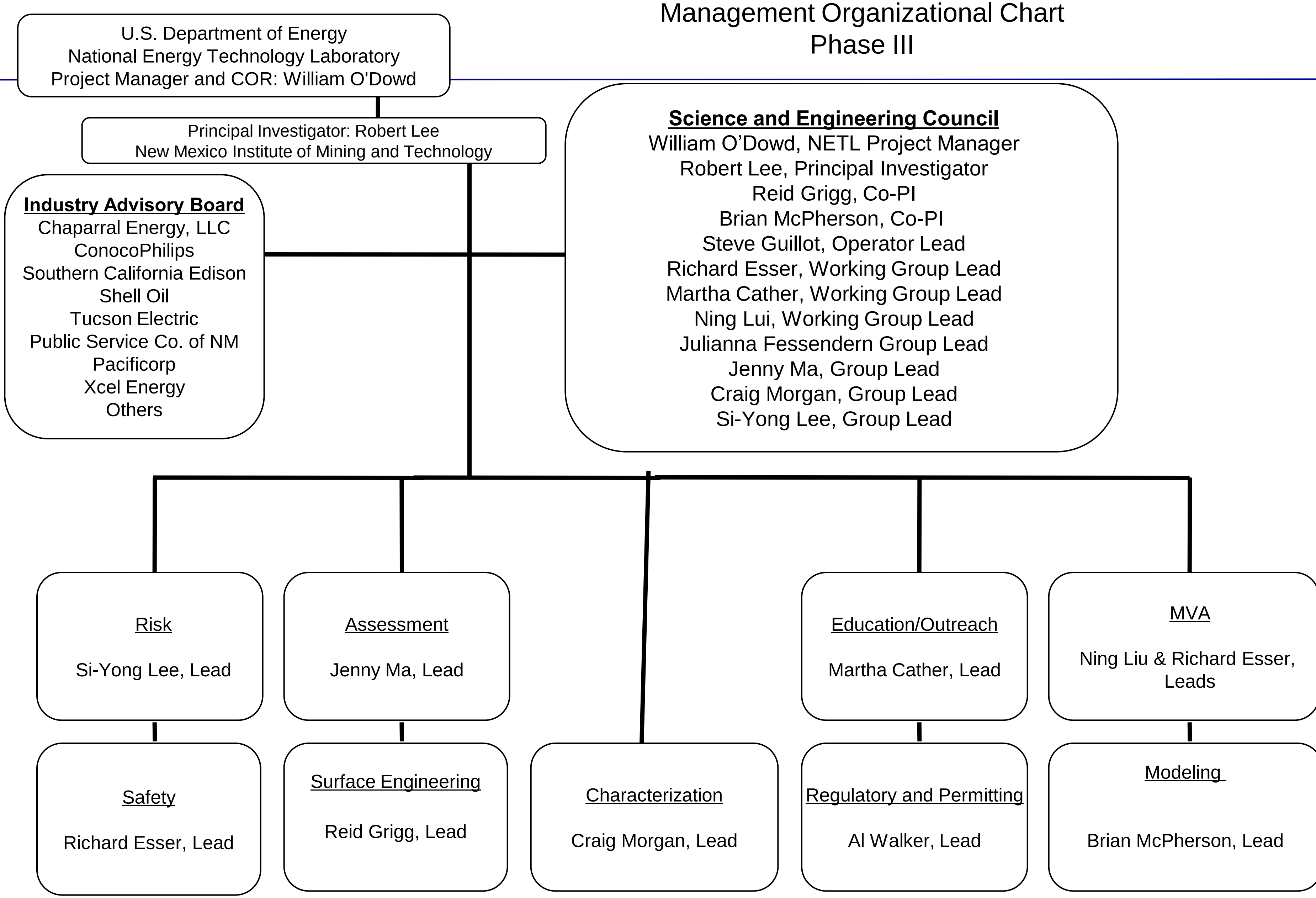
- Workgroup leader selection based on Phase 2 project experience
- All group leaders led workgroups for 3 previous successful projects
- Budget breakdown also based on this experience:

~15% of federal budget dedicated to field operations
~85% of federal budget dedicated to science (measurements/analysis)



Southwest Regional Partnership on Carbon Sequestration

Management Organizational Chart
Phase III



Wrap-up: Key Findings and Lessons Learned (Phase II)

- Oil/gas fields can play an important monitoring role in deep saline sequestration ops

- In all cases, it is difficult to predict geomechanical processes

- In all cases, it is difficult to predict induced or triggered seismicity

- CO_2 Diffusivity not = Hydraulic Diffusivity

Wrap-up: Key Findings and Lessons Learned (Phase II)

Too many specific lessons to list. A specific sub-list, for sake of example, focuses on microseismicity:

- Microseismicity - both natural and induced - occurs just about everywhere
- Most seismic/microseismic events are associated with:
- pre-existing faults
- low permeability zones

(3) Microseismicity can aid in identifying geologic features like "critically-stressed" faults

(4) Induced seismicity can be controlled through effective reservoir/injection engineering

(5) Careful and effective site characterization and selection are keys to successful microseismicity management