Carbon Sequestration at the Louisiana Office of Conservation

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Presentation Outline

I. Louisiana Injection and Mining Division
II. Carbon Sequestration Wells
III. Permit and Regulatory Process
IV. Permit Technical Content
V. Monitoring after a project begins
VI. Wrap up and questions

Louisiana Injection and Mining Division

What We Do

The 1974 Safe Drinking Water Act (SDWA) established national UIC Program under the EPA and charged them to:

* Establish Technical Regulations for UIC Program
* Define the Underground Source of Drinking Water (USDW)
* Establish Injection Well Classifications

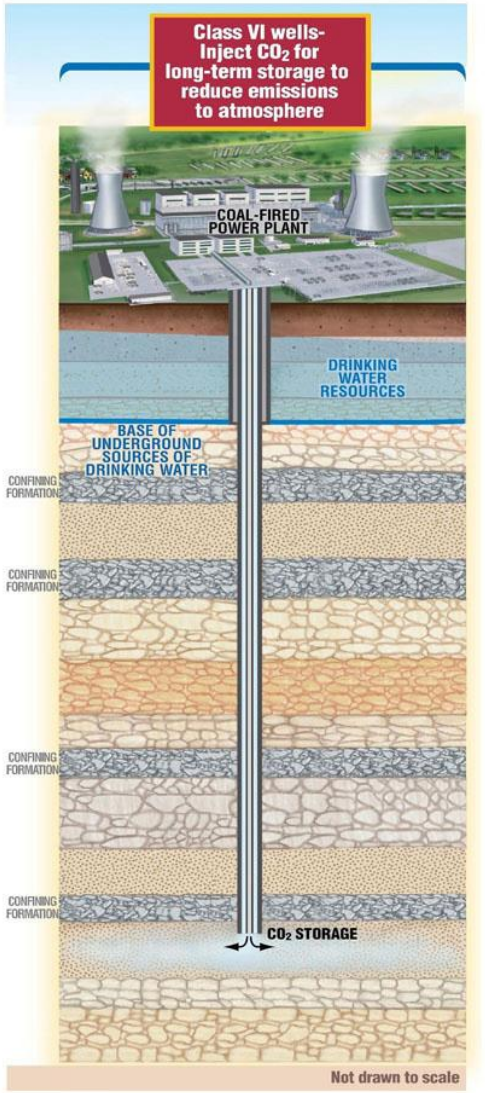
Office of Conservation was granted primacy of the UIC program in 1982.

Louisiana Injection and Mining Division

What We Do

* Regulate Class I – V wells as a Unites States Environmental Protection Agency Primacy Program
  * Seeking Class VI primacy currently
* Responsible for permitting, compliance, and enforcement for all injection wells in Louisiana
* Primary responsibility is to prevent endangerment of the Underground Source of Drinking Water from injection activities.

Carbon Sequestration Wells



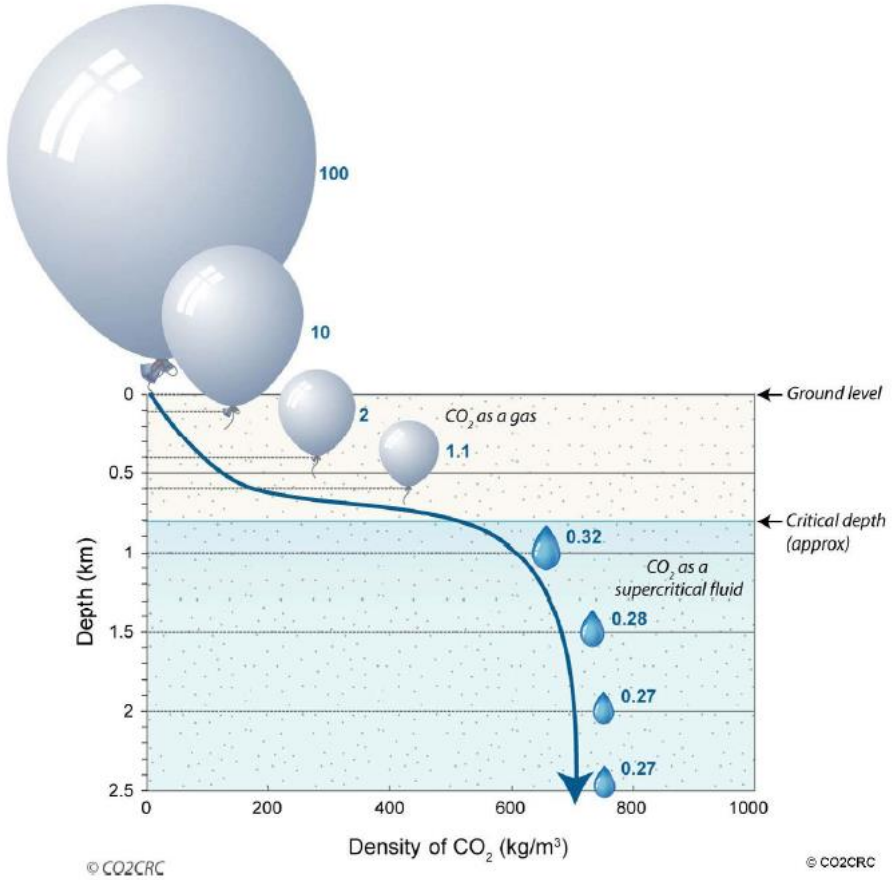


Figure A-26: Density of Carbon Dioxide as a Function of Depth.
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Regulatory Process

Pre-construction

- Site characterization
- AOR modeling
- Financial responsibility
- Well construction
- Proposed operating data and pre-injection testing
- Proposed project plans

Permit To Construct

Pre-injection

- Review revisions to plans (site characterization, corrective action, etc)
- Confirm background data is collected
- Verify adherence to Permit to Construct

Permit To Inject

Injection

- Review operating, monitoring, and testing data
- AOR updates at least every five years
- Annual financial responsibility updates
- Enforcement and compliance
- Permit modification

Injection Ceases

Post-injection

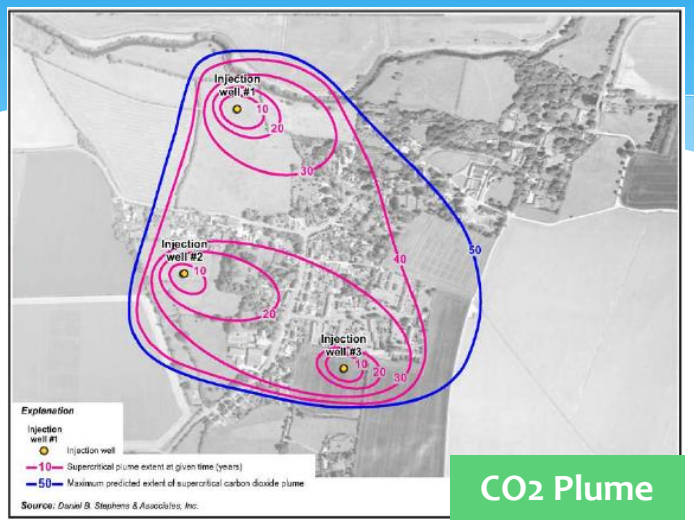
- Well P&A
- Post-injection site monitoring
- Emergency and remedial response
- Project and financial responsibility updates
- Non-endangerment demonstrations
- Site closure

Permit Technical Content

Area of Review (AOR)

* "the region surrounding the *geologic sequestration project* where USDWs may be endangered by the injection activity, and is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected *carbon dioxide stream* and displaced fluids, and is based on available site characterization, monitoring, and operational data as set forth in §§3615.B. and 3615.C." - LAC 46.XVII.3601.A
* **AOR = Plume Extent + Pressure Front**
* Pressure front is extent of sufficient pressure to force injection zone fluid into the USDW
* Must be reevaluated at least every five years, or when monitoring and operational conditions warrant
* Updates must incorporate monitoring data and any changes in operating conditions
* **Importance of a fully characterized AOR cannot be overstated**

Permit Technical Content



CO_2 Plume

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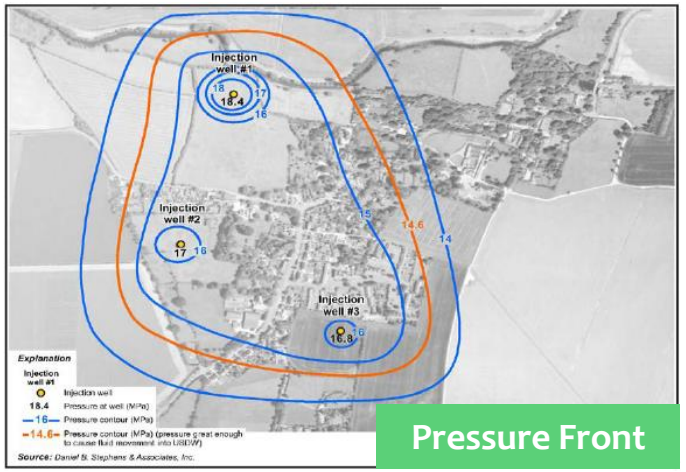
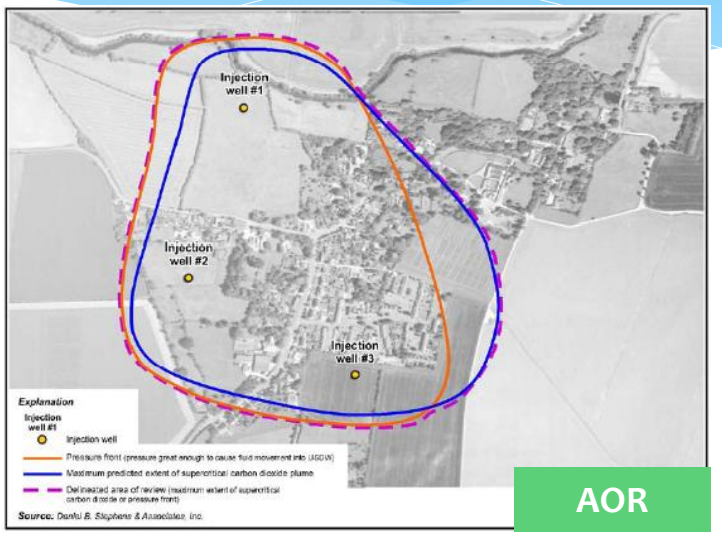


Pressure Front

=



AOR

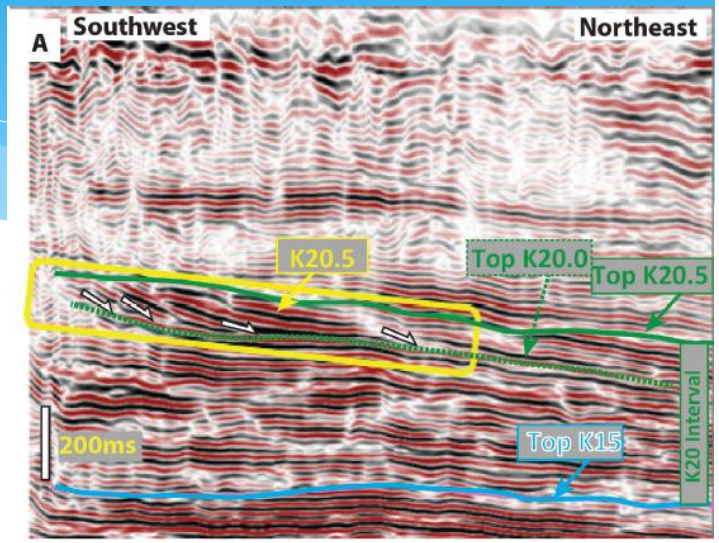
Modified from EPA , "Underground Injection Control (UIC) Program Class VI Well Area of Review Evaluation and Corrective Action Guidance"

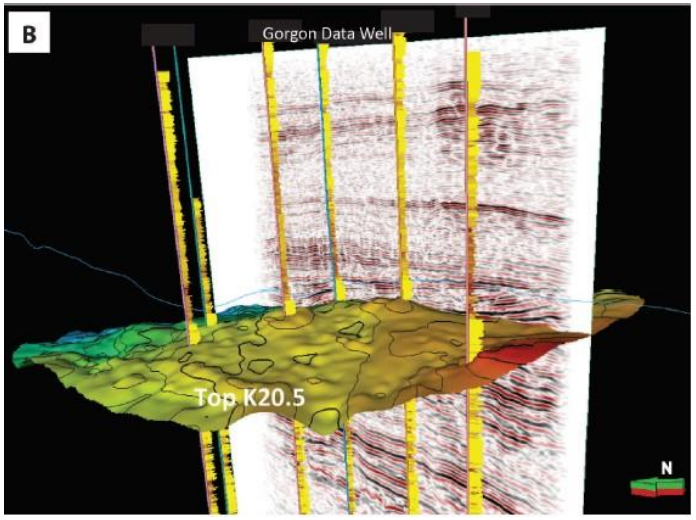
* Theoretical AOR based on max extent of multiphase CO_2 plume **AND** maximum extent of pressure effects

Permit Technical Content

Site Characterization

- Informs the design and calibration of CO_2 plume models
- Geologic maps - structure, cross-sections, isopachs, fault plane, etc.
  - Account for regional geology, area of review (AOR), and hydrology
  - Characterize structure, stratigraphy, lithology, and faulting for confining and injection zones
- Reservoir characteristics - mineralogy, porosity, permeability, capillary pressure, formation fluid, etc.
  - May initially be based on offset wells but must be verified by well logs and coring within the AOR and from the injectors
  - Data collection via stratigraphic test wells
  - Strategic core collection

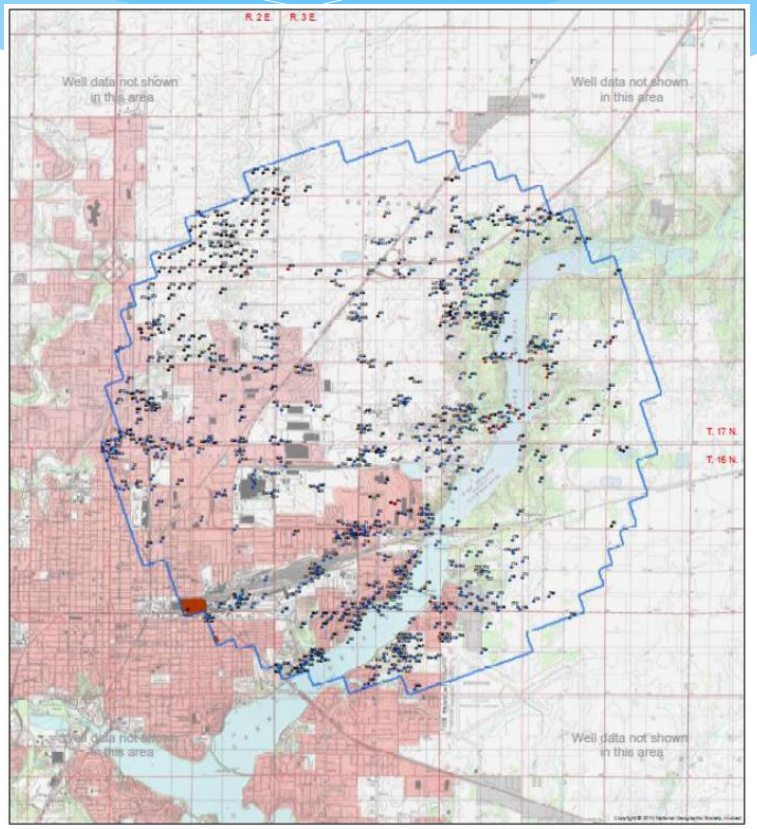




Modified from Barranco et al, 2013.

Permit Technical Content

* Archer Daniels Midland – Decatur, IL
  * Injection zone: Mt. Simon sandstone
  * Upper confining zone: Eau Claire basal shale overlain by limestone and siltstone
  * Lower confining zone: granitic basement
  * Injection interval avg. porosity = 22% and avg. permeability = 25 mD
  * CCS #2 perfs: 6630-6825' MD
  * AOR area = 34.17 square miles; r ≈ 3.30 miles
  * 1,065 wells within AOR; the only wells to penetrate upper confining zone are associated with the CCS project



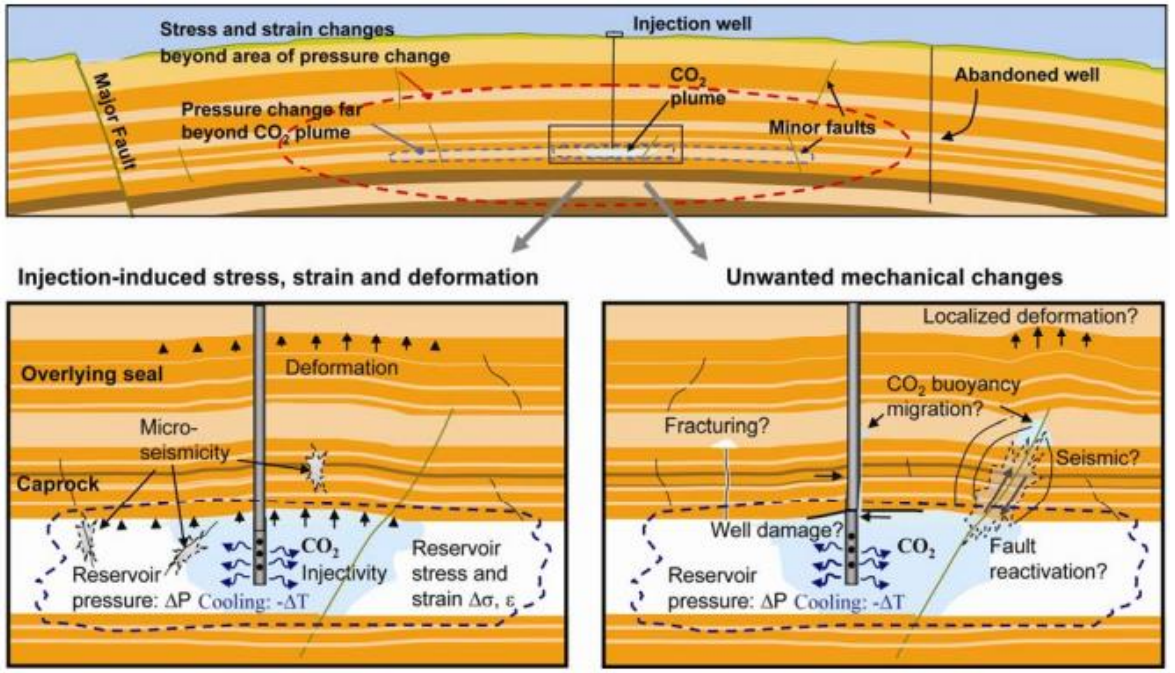
Modified from "Area of Review and Corrective Action Plan for ADM CCS#2 — Modified January 2017"

Permit Technical Content

* Computational Modeling
  * **Static/geologic model** – geologic structure, lithology, stratigraphy, porosity and intrinsic permeability distribution, reservoir characteristics, etc.
  * **Reservoir simulation** – models the flow of the multiphase CO_2 plume through the pore space. Accounts for CO_2 phase transition (supercritical/liquid/gas), CO_2 dissolution with brine and oil, density and thermal effects, etc.
    * *Reactive transport modeling* – mineral dissolution and precipitation, effects of trace constituents in the CO_2 stream (e.g., H_2S, So_x), mineralization as a trapping mechanism; may be required
  * IMD will use CMG GEM but no particular modeling software is required – RESQML file submissions and detailed technical report
  * IMD will review the inputs and approach but will not reconstruct the model
  * Must be updated **at least every five years** or as warranted by operating and monitoring conditions

Permit Technical Content

* Geomechanical studies
  * Important for determining maximum surface injection pressure (MASIP)
  * **Fractures** – fracture finder, caliper, video, acoustic logs, etc.
  * **Ductility** – triaxial load test on core sample
  * **In situ stress regime**



Modified from Rutqvist, 2012.

* Geomechanical risks
  * Fractures leading to loss of containment
  * Fault activation
  * Induced seismicity that can be felt at the surface
  * Localized deformation
  * Mechanical damage to injector

Permit Technical Content

Geophysical Characterization	SEISMIC						GRAVITY		ELECTRICAL/EM			MAGNETIC
	2D	3D	VSP	3D-VSP	Cross-well	Borehole microseismic	Aerial & surface gravity	Borehole gravity	Natural source	Controlled source	ERT	Aerial & surface magnetic
Near borehole and shallow subsurface			W	W	W	W		W		W		
Field-wide subsurface studies	W	W		W		P	W		W	W		W
Stratigraphy	W	W	W	W	W		W	W	P	P	W	P
Thickness	W	W	W	W	W			W			W	
Structure 0 - 100 m				P		P	P		P	P	P	P
Structure 100 m - 1 km	W	W		W	W	W	P	P	P	P	W	P
Structure > 1km	W	W		W	P	W	W	P	W	W	P	W
Fault/fracture	W	W		W	W	W	P		W	W	P	
Porosity							P	W	W	W	W	
Pore pressure	P	W	P		P							
Abandoned wells											W	W

Modified from EPA , "Underground Injection Control (UIC) Program Class VI Well Site Characterization Guidance"

W = well suited (already in use for site characterization with good results)
P = potential (could be used, but better alternatives available or results lack desired resolution)

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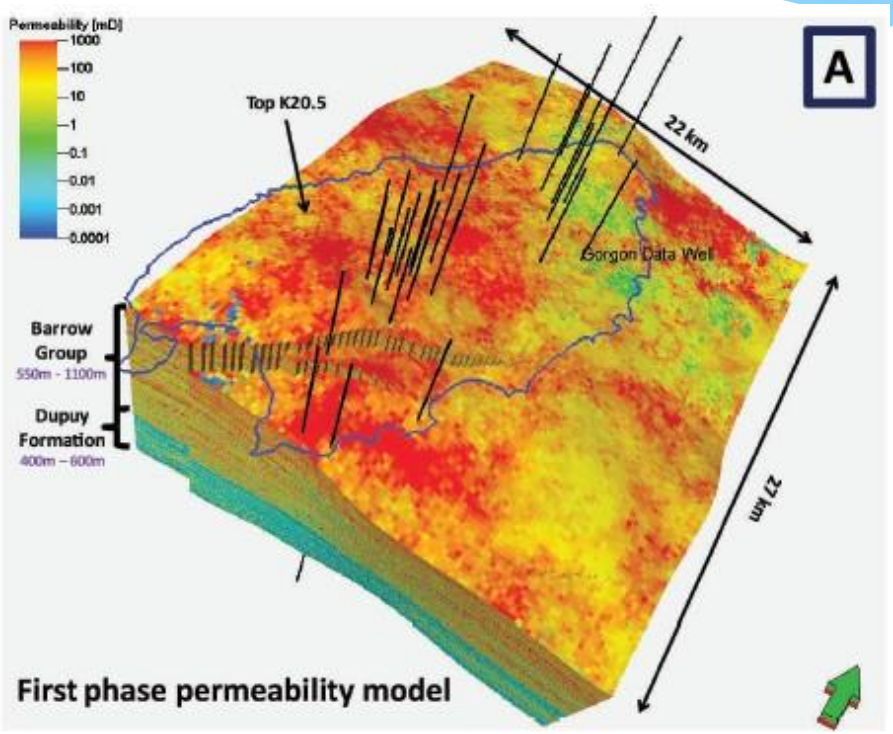

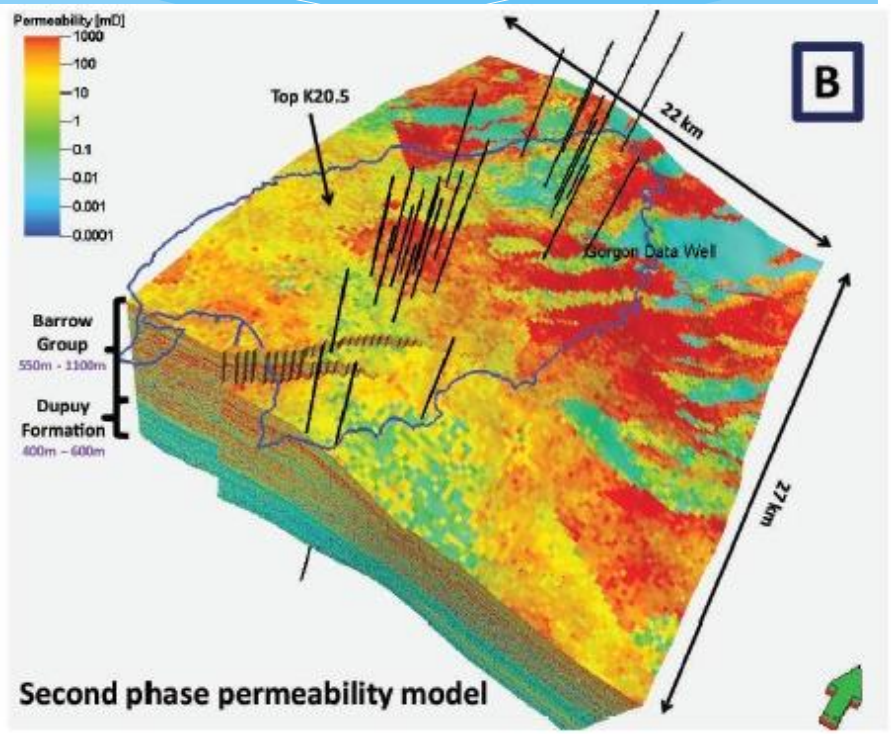

Modified from Barranco et al, 2013.

Reservoir Models – structural framework, facies modeling, porosity and permeability models, history matching,

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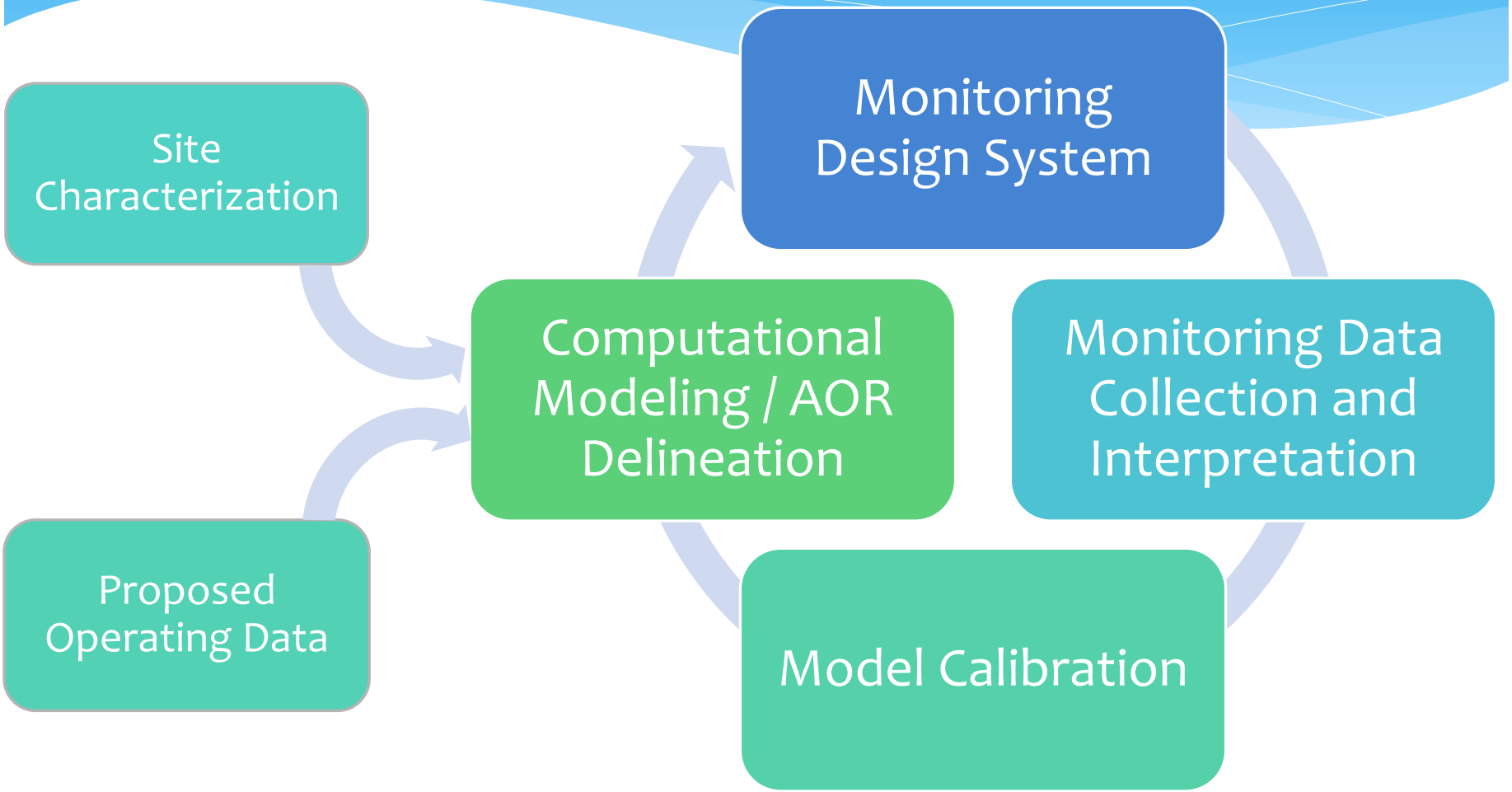
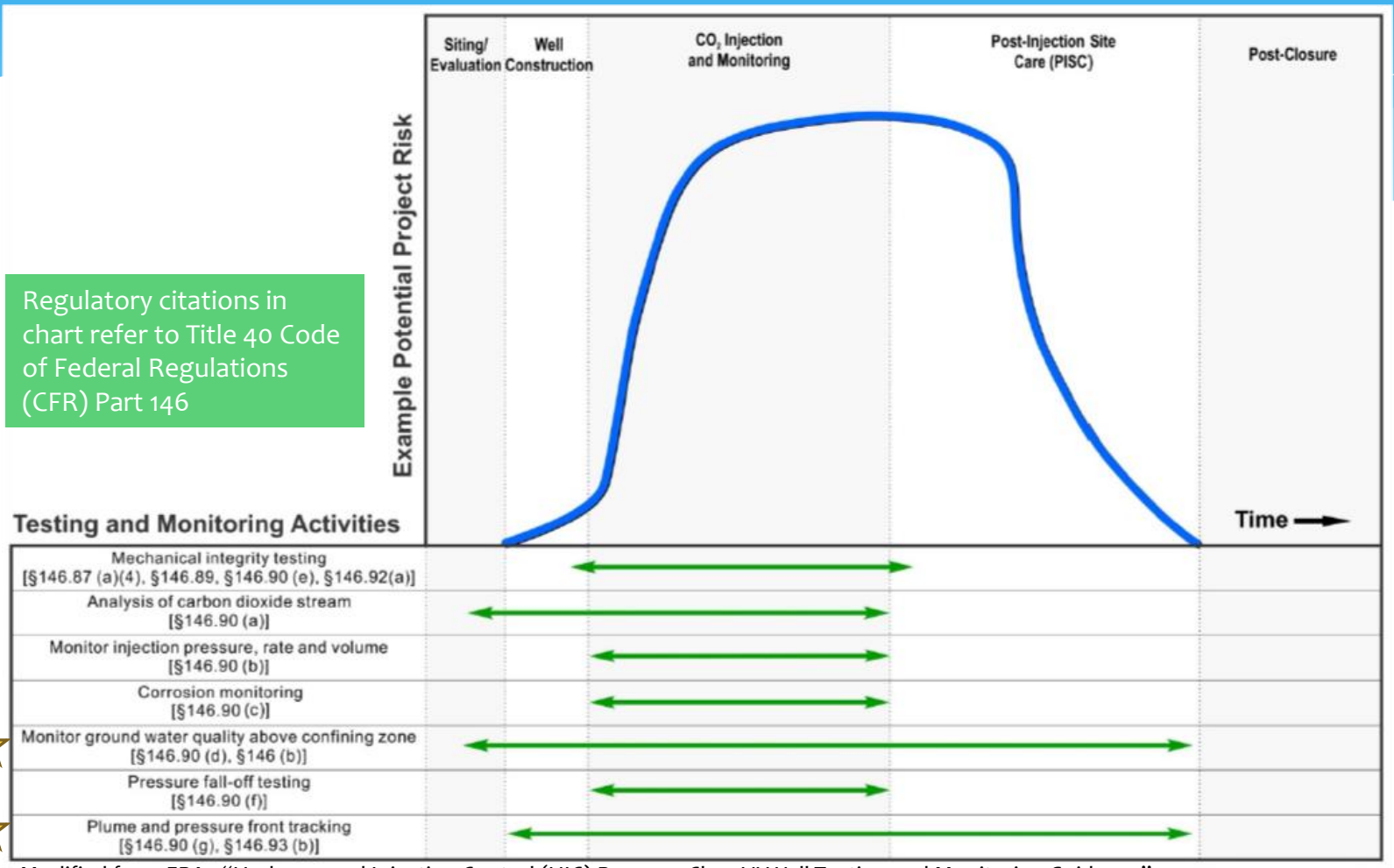


Monitoring After a Project Begins

Regulatory citations in chart refer to Title 40 Code of Federal Regulations (CFR) Part 146



Modified from EPA , "Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance"

Monitoring After a Project Begins

* Groundwater Quality Above the Confining Zone
  * Testing to detect changes in groundwater chemistry that may indicate loss of containment; compare to baseline data collected during site characterization
  * Regulations require "periodic" sampling but EPA recommends quarterly
* Plume and Pressure Front Tracking
  * Results necessary for model comparison and verification
  * *In situ fluid pressure monitoring* – e.g., pressure transducers in monitoring wells
  * *Indirect geophysical monitoring* – seismic, gravity, electromagnetic, electrical
  * *Groundwater geochemical monitoring* – detection of CO2 plume in monitoring wells; adjusted sampling procedures for high temp/pressure conditions
  * *Computational modeling* – part of required AOR updates
* Surface Air/Soil Gas Monitoring
  * May be required to detect movement of CO_2 leakage
  * Incorporates baseline data but other technologies may be approved

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Questions?

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Useful Links
Louisiana Regulations for Injection and Mining
Office of Conservation - Injection & Mining
EPA Class VI Wells
Gulf Coast Carbon Center
Groundwater Protection Council