Geology & Technology Subcommittee

Carbon Capture & Sequestration

Working Group Meeting

Charleston, West Virginia

January 18, 2011

Working Group Final Report

To do list for G&T Subcommittee:

- Seismicity – further work, consider including USGS seismicity map
- Review RCSP use of MVA technology for inclusion in Final Report
- Review risk assessment for further refinement
- Improve estimate of storage volume occupied for a given amount of CO_2 in the reservoir
  - Re-visit storage volume estimates in Preliminary Report

Other items to consider:

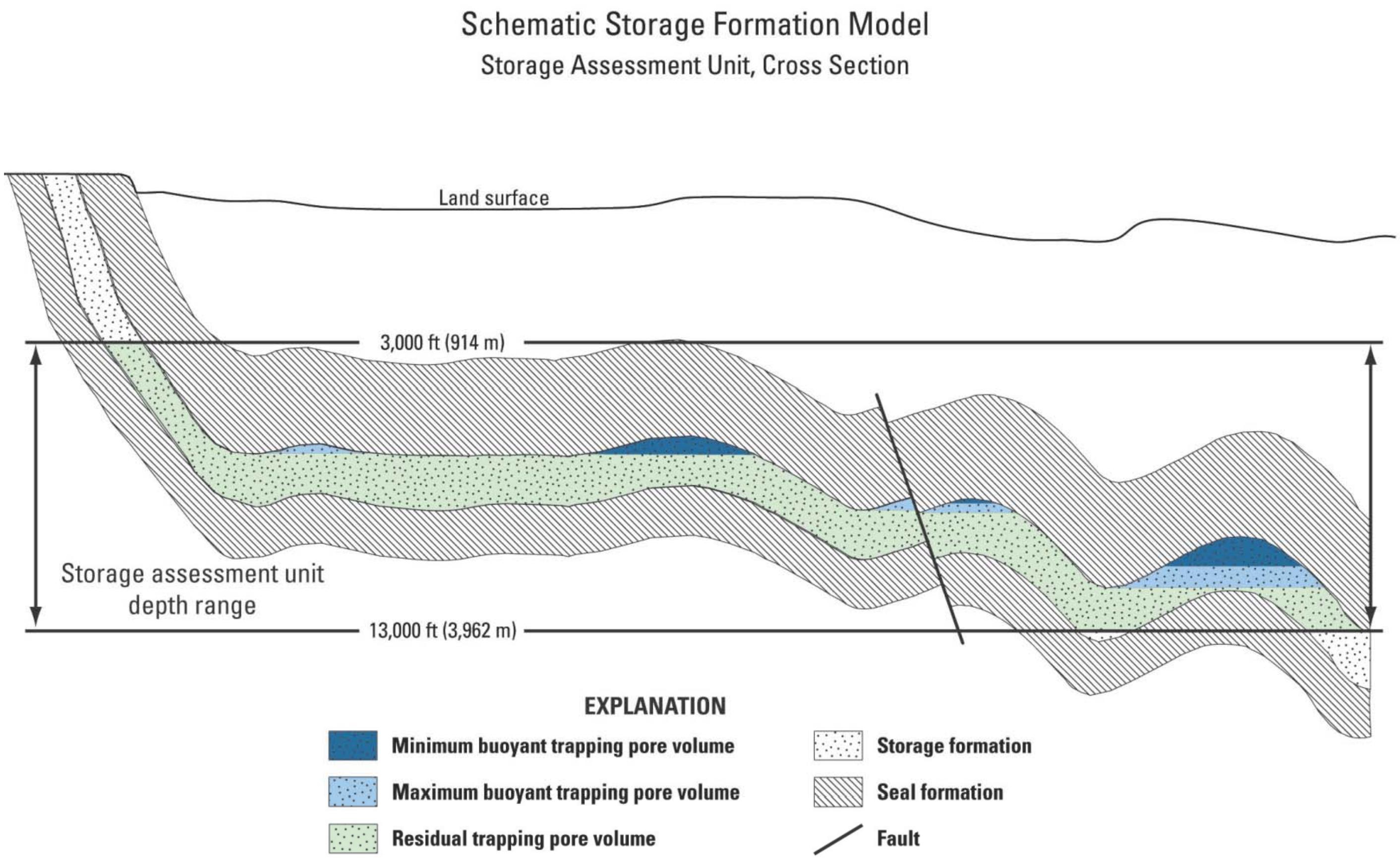
- Exporting captured CO_2 for EOR
- New UIC Class VI regulations
- Financial responsibility
- Long-term liability

Working Group Final Report

To do list for Working Group:

- Assess the economic and environmental feasibility of large, long-term carbon dioxide sequestration operations [§22-11A-6(h)(2)].
- Identify areas of research needed to better understand and quantify the processes of carbon dioxide sequestration [§22-11A-6(h)(9)].
- Outline the working group's long-term strategy for the regulation of carbon dioxide sequestration in West Virginia [§22-11A-6(h)(10)].

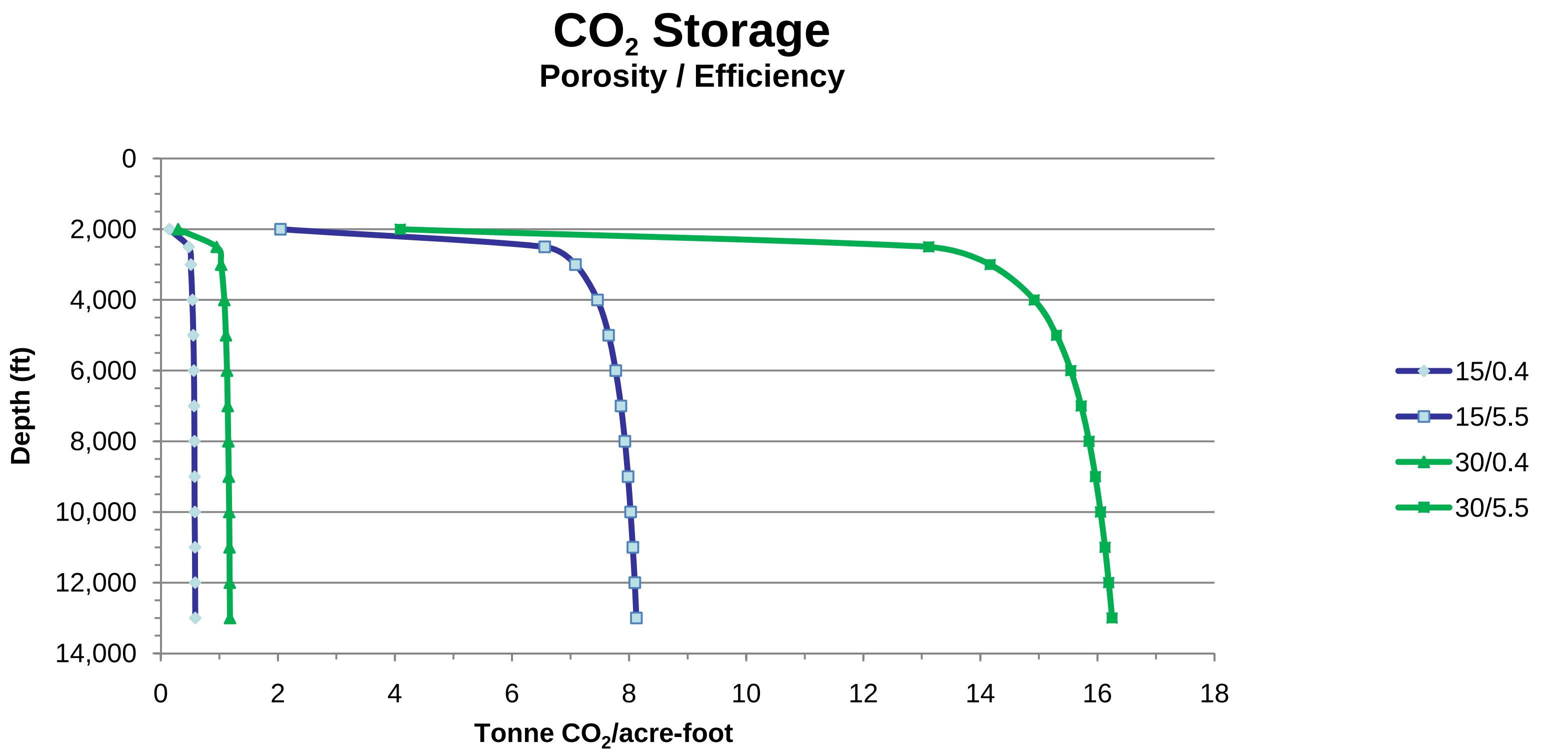
Storage Potential



- NETL released the 3rd edition of their sequestration atlas
- USGS is moving ahead with their assessment of storge potential
  - Their model is illustrated above

USGS, 2010, A Probabilistic Assessment Methodology for the Evaluation of Geologic Carbon Dioxide Storage. OFR 2010-1127.

Storage Space

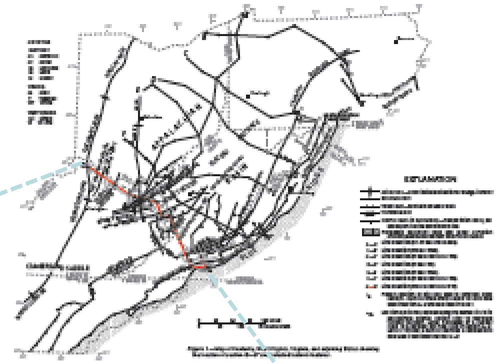


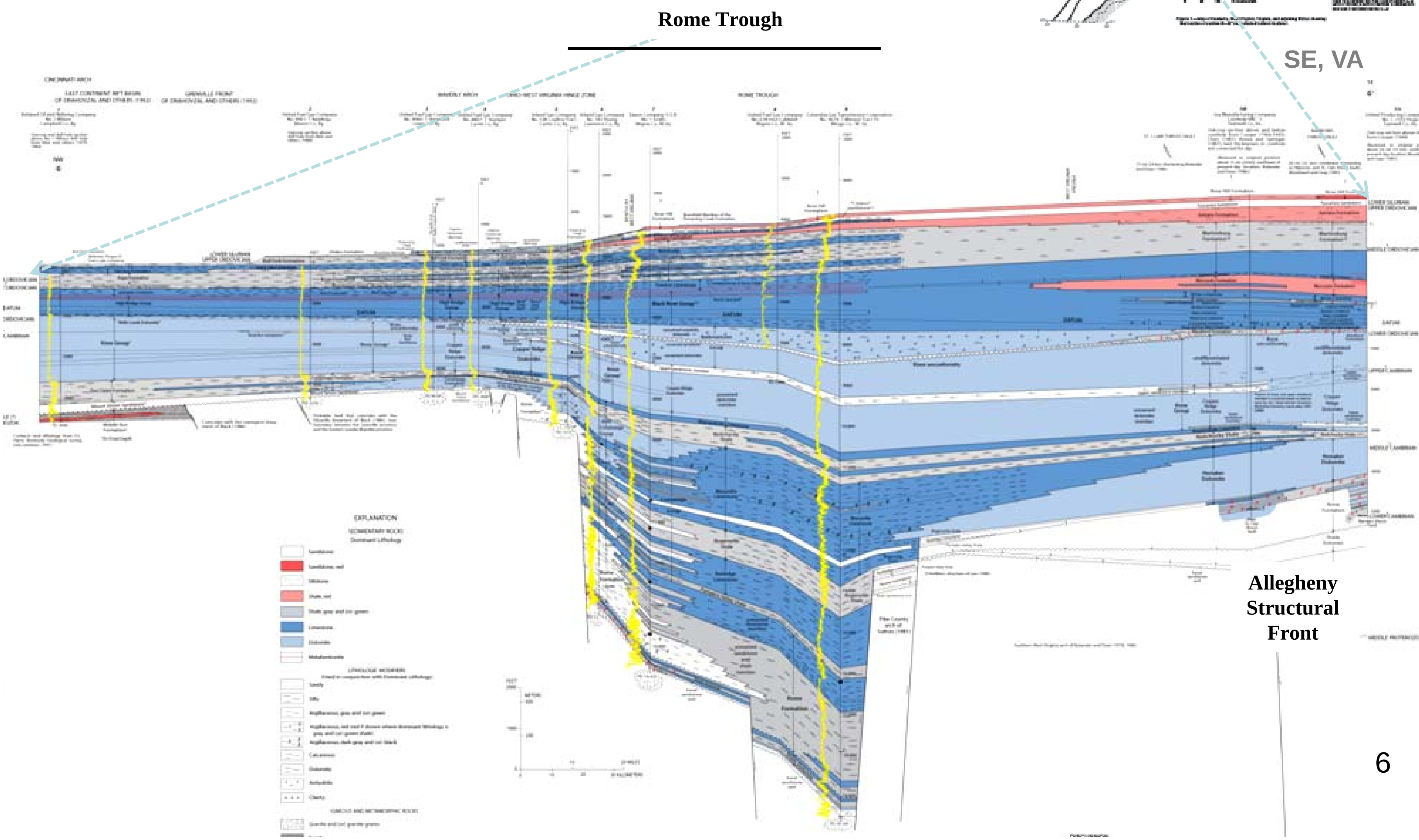
- For any given depth, storage efficiency is critical
  - Efficiency values used here from NETL's Atlas 3rd edition, found at:

  http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasIII/index.html
- Illustrates potential importance of efficiency – but what mechanisms, if any, can be used to improve efficiency?
  - Some research suggest production of formation waters can increase storage efficiency/control storage area
    - LLNL active reservoir management: https://str.llnl.gov/Dec10/pdfs/12_10.4.pdf
    - Surdam, R.C. et al, 2009, An integrated strategy for carbon management combining geological CO_2 sequestration, displaced fluid production, and water treatment. Wyoming State Geological Survey, Challenges in Geological Resource Development No. 8.
  - Some research suggest co-injection of formation waters can increase storage efficiency
    - Ran Qi, LaForce, T.C. and Blunt, M.J, 2009, Design of carbon dioxide storage in aquifers. International Journal of Greenhouse Gas Control, v. 3. pp 195-205

#6 – Assess Feasibility of CO_2 Sequestration…

Stratigraphic Cross-Section





West Virginia:
CO_2 Storage Resource Potential

	Atlas Second Edition (2008)			Atlas Third Edition (2010)		
		Low	High		Low	High
Sources	30			26		
Emissions	102.1			99		
Oil & Gas		1,353	1,353		1,830	1,830
Coal		177	177		320	500
Saline		3,343	13,463		4,480	17,930
TOTAL		4,873	14,994		6,630	20,260
Years Injection		47	146		66	204

All emission and storage values are in Million Metric Tons.
Coal means unmineable coal.

- Estimates of Storage Efficiency have changed
  - Saline: from 1% - 4% in 2008 to 0.4% - 5.5% in 2010
  - Coal: from 28% - 40% in 2008 to 21% - 48% in 2010 for overall storage efficiency
- Oil & Gas storage potential based on production estimates
  - Assume 100% efficiency for pressure depleted reservoir volume

West Virginia:
Change in CO_2 Storage Resource Potential

	Atlas Second Edition (2008)		Atlas Third Edition (2010)		
	Low	High		Low	High
Change in Sources			-13.3		
Change in Emissions			-3.0		
Oil & Gas - % of Total	27.8	9.0		27.6	9.0
Coal - % of Total	3.6	1.2		4.8	2.5
Saline % of Total	68.6	89.8		67.6	88.5
% Change in TOTAL				36.1	35.1
% Increase in Injection Years				40.4	39.7

- Slight increase in Coal storage potential along with slight decrease in Saline storage potential.
- Significant increase in overall storage potential.
- Significant increase in potential injection time span

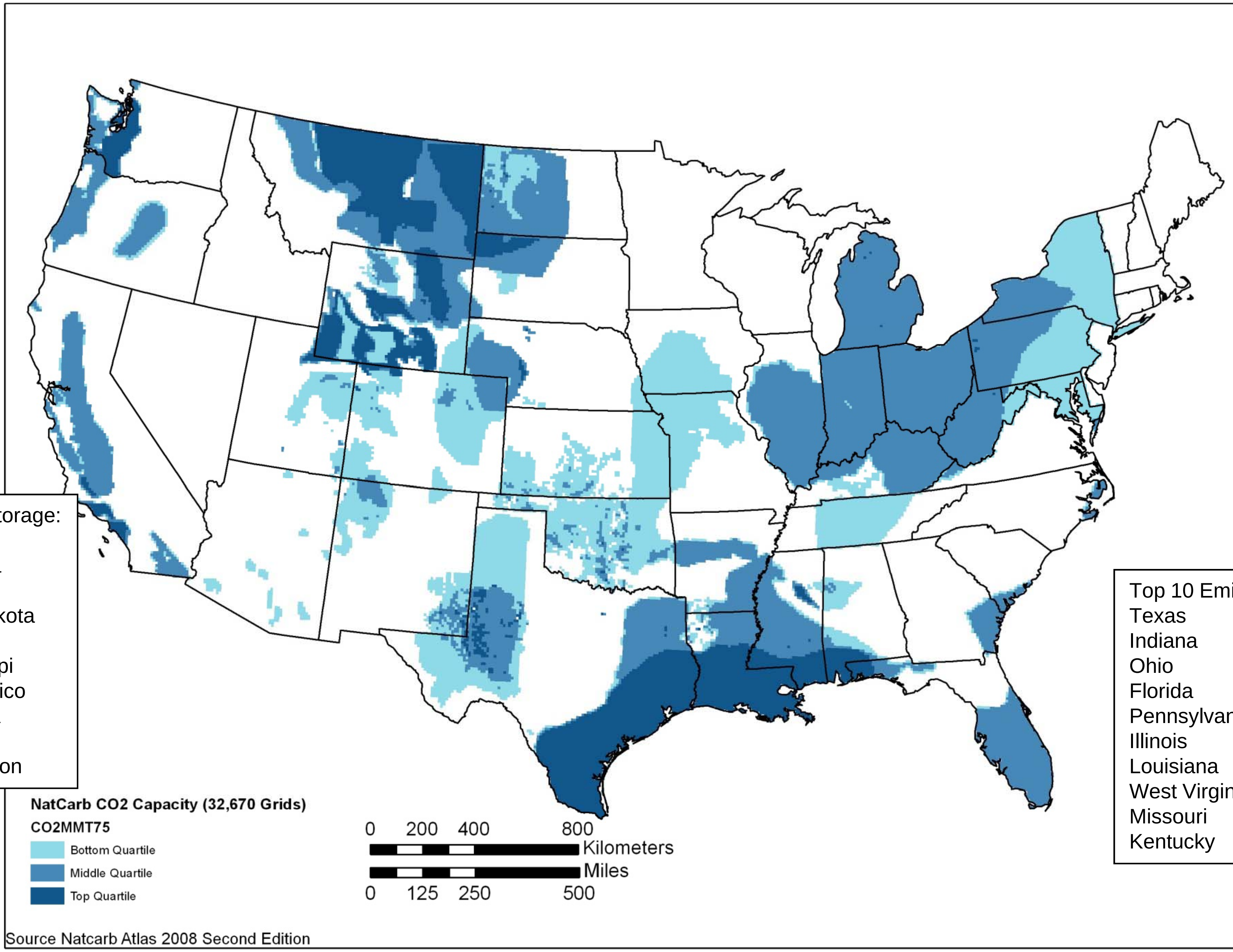
Appalachian Basin:
CO_2 Storage Resource Potential

	Atlas Second Edition (2008)			Atlas Third Edition (2010)		
		Low	High		Low	High
Sources	569			539		
Emissions	483.6			476		
Oil & Gas		7,833	7,833		15,780	15,780
Coal		696	696		660	980
Saline		18,350	73,932		17,050	68,270
TOTAL		26,879	82,462		33,490	85,030
Years Injection		55	170		72	182

New York, Ohio, Pennsylvania and West Virginia
All emission and storage values are in Million Metric Tons.
Coal means unmineable coal.

- Storage potential estimates are a resource value that have yet to be proven
- New York, Ohio, Pennsylvania and West Virginia have:
  - 14% of the sources
  - 15.3% of the emissions
  - 2.6% of the low estimated storage potential (0.6% of the high estimate)

CO_2 Storage Resource Potential – 3rd Edition



Top 10 Storage:
Texas
Louisiana
Montana
North Dakota
Wyoming
Mississippi
New Mexico
California
Colorado
Washington

Top 10 Emissions:
Texas
Indiana
Ohio
Florida
Pennsylvania
Illinois
Louisiana
West Virginia
Missouri
Kentucky

Oil & Gas

Coalbed Methane (CBM)

Marcellus Shale

Trenton-Black River

There are other formations with oil & gas potential. A geologic column for West Virginia is also posted in the Preliminary Report.

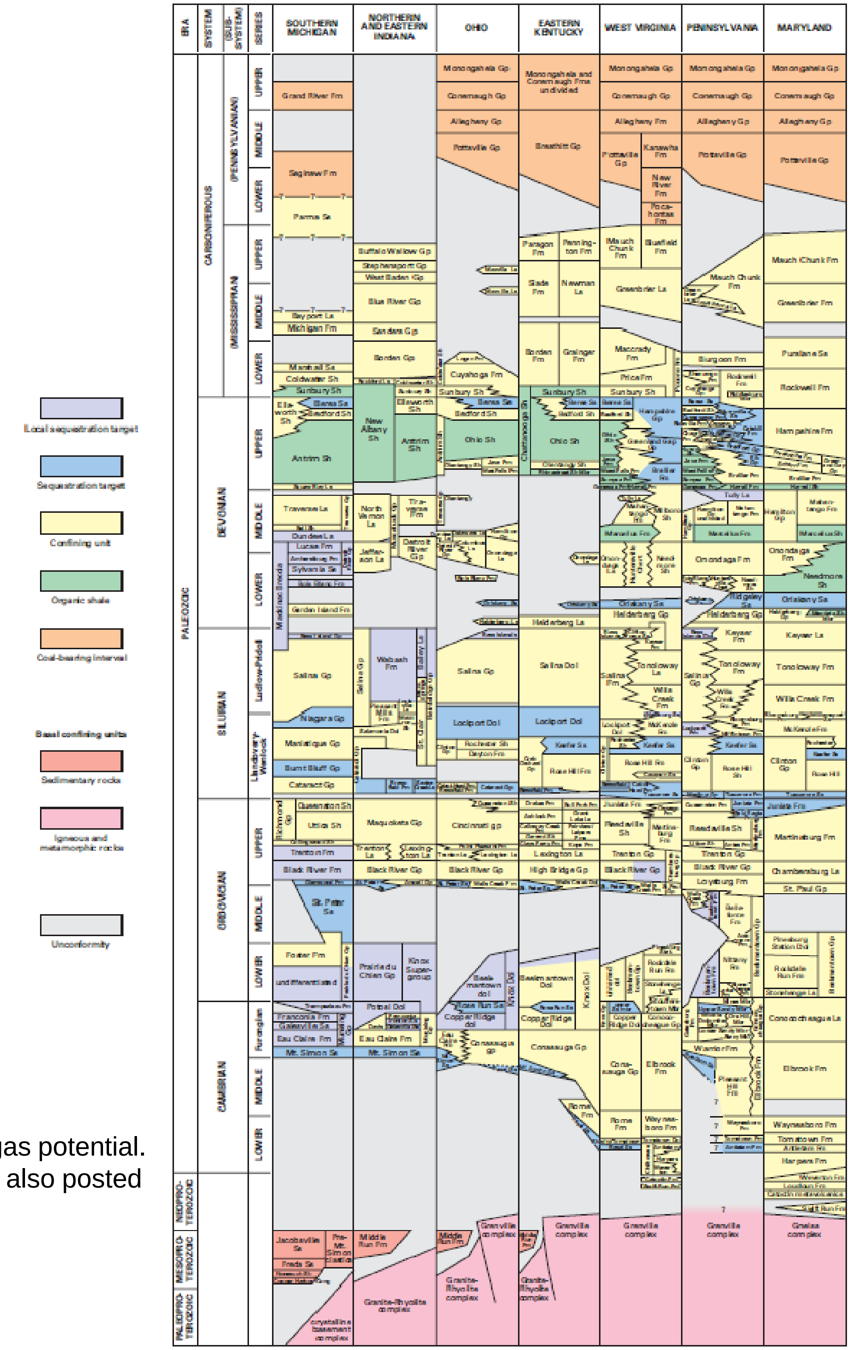


Figure 5.—Stratigraphic correlation and CO_2 sequestration characterization chart of geologic units in the MRCSP region.

Potential Sequestration

Unmineable Coal Seams

Upper Devonian Sandstones

Devonian Organic Shales

Oriskany Sandstones

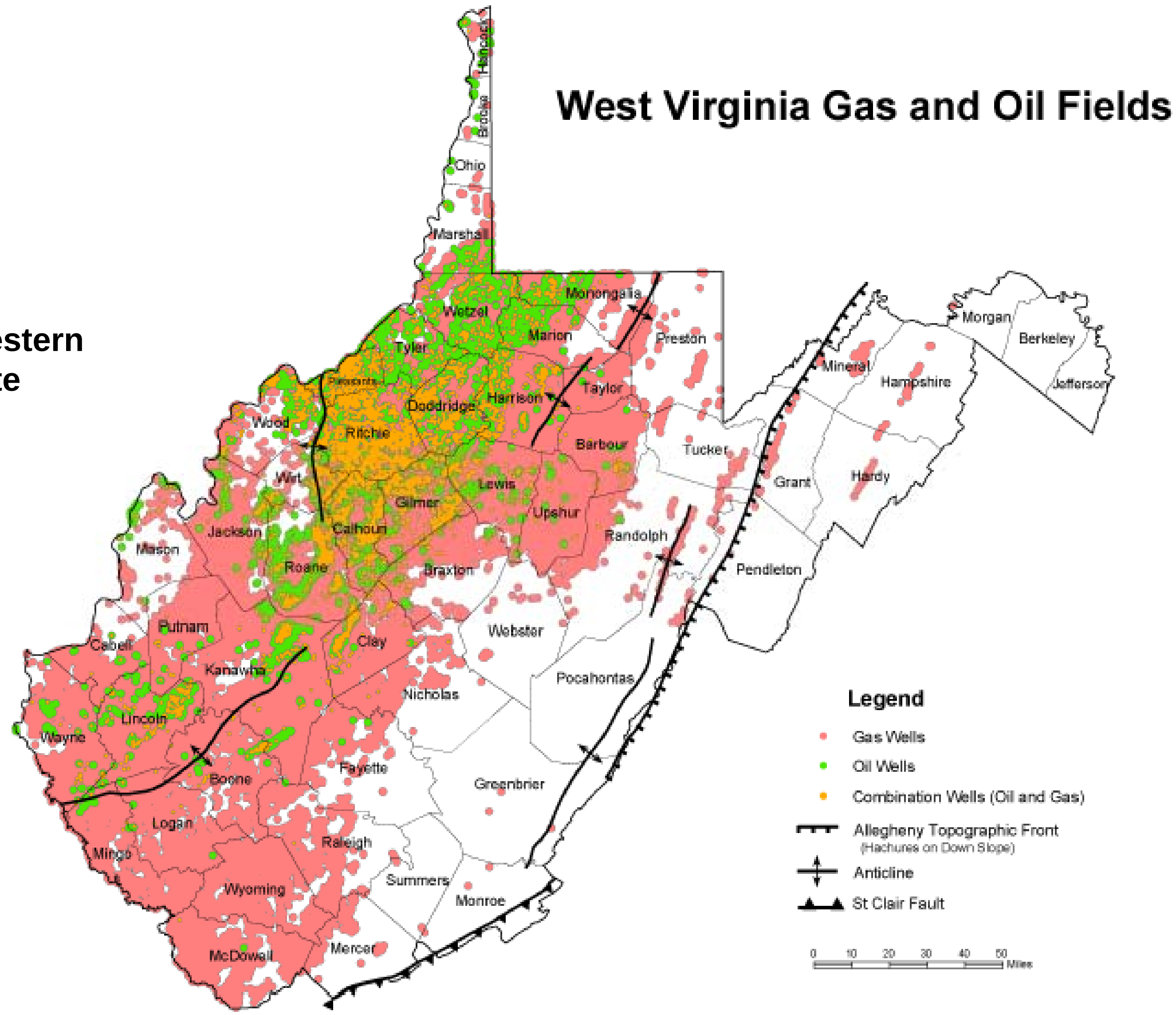
Medina/Tuscarora Sandstone

Rose Run Sandstone
Copper Ridge Dolomite

Conasauga Sandstone

Rome Sandstones

Primarily in western part of the State



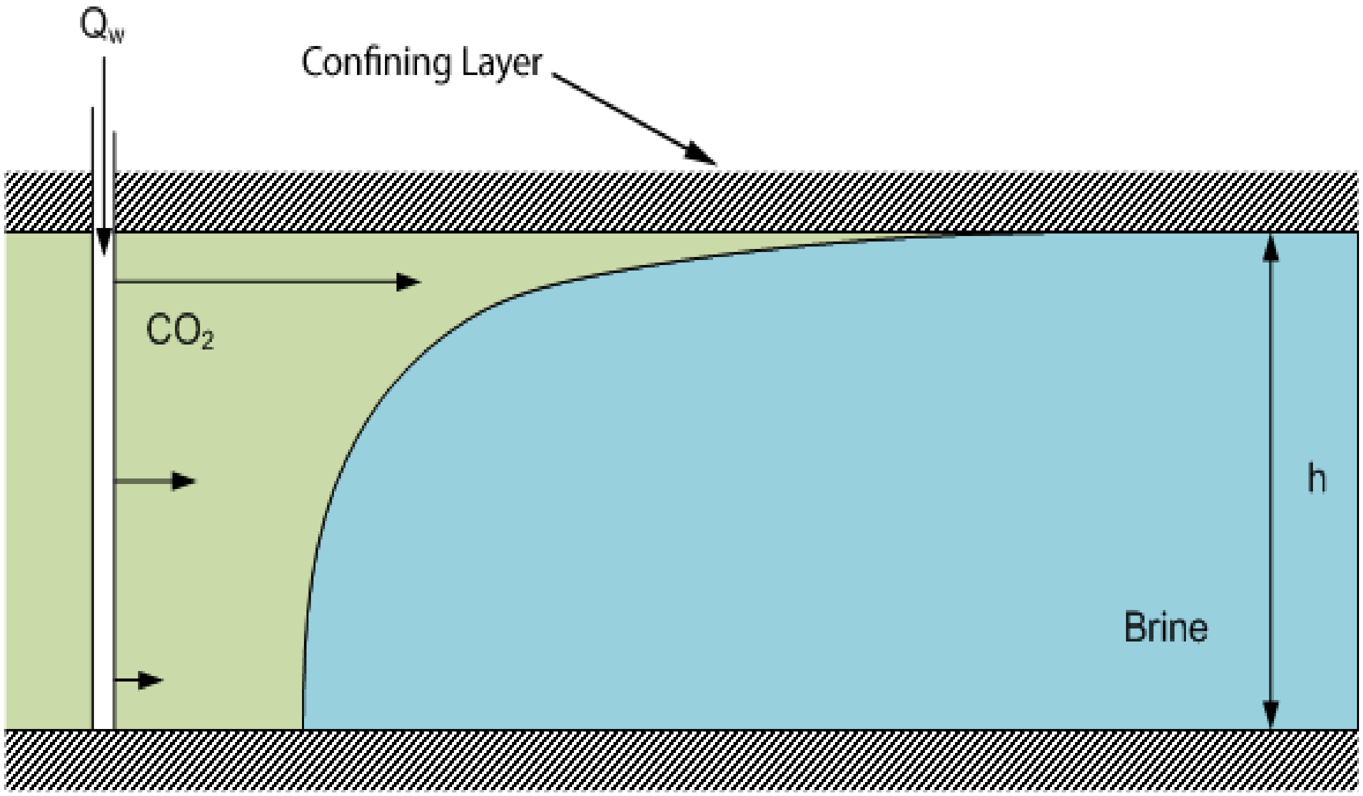
Potential distribution of CO_2 storage reservoirs. Saline reservoirs may be found outside the oil & gas field area illustrated here.

Storage Potential Impact on Costs

Porosity and Permeability

- Permeability
  - Controls injectivity and number of wells required to sequester a given amount of captured CO_2
  - Monitor wells required for each injection well
    - Above and within injection zone
  - Spare injection capacity to accommodate injection well maintenance
- Porosity
  - Storage capacity restricted by efficiency
  - Net height of injection zone (also impacts injectivity)
  - Reservoir architecture – distribution of porosity and permeability
  - All directly impact areal extent of CO_2 plume
- Production of formation fluids (waters)
  - Maintain injectivity, influence pressure
  - Potential to increase storage efficiency
  - Add costs: permits, operations, water treatment/disposal

Storage Potential Impact on Costs



Q_w – Injection rate: permeability, number of injection wells.
h – height of injection zone: reservoir architecture, porosity & efficiency, injectivity.

- Diagram illustrates density difference between formation waters and CO_2 on development of CO_2 plume.
- Preliminary research suggests co-injection of water and CO_2 may better utilize the full height of the reservoir

Diagram source – Sean McCoy, CMU

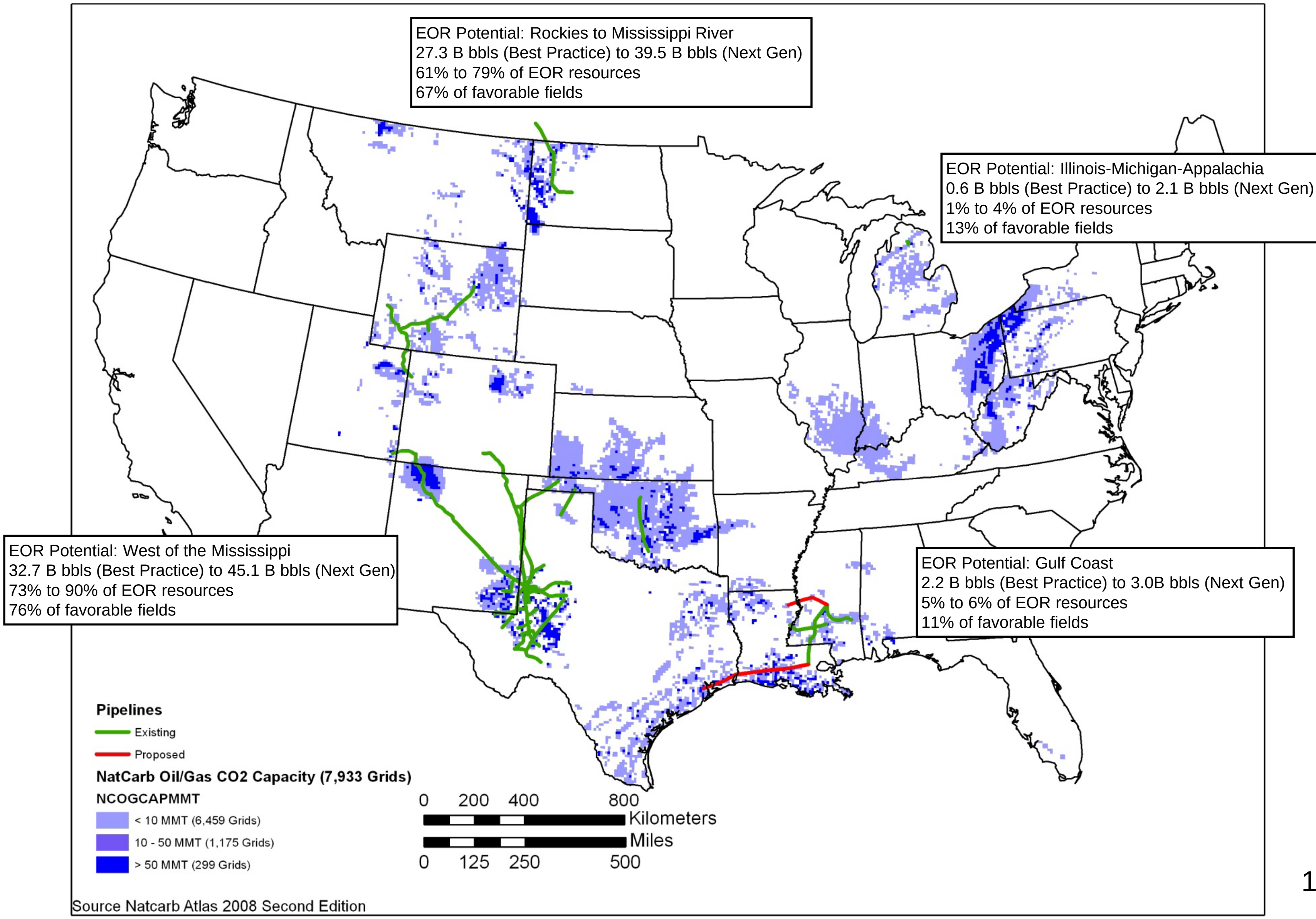
CO_2 - EOR

- A market mechanism for deployment of CCS technology
- Potential for CO_2-EOR to consume all of the CO_2 captured over the first two decades
  - Assuming all captured CO_2 is delivered to EOR projects
- ARI-NRDC study
- Potential to accelerate deployment:
  - Three years to characterize and build saline storage operations
    - Maybe longer: four years for saline gas storage development
    - An exploration component to developing saline storge – success factor
    - EPA assumes a 25% success rate in establishing saline storage reservoirs
  - 8 months to 18 months to begin CO_2 injection for EOR project
    - But several years to establish positive cash flow
- Possible option for West Virginia to export captured CO_2
  - Competition with other states
  - Look at Appalachian/Mid-West opportunities

CO_2 - EOR

- Permian Basin EOR fields in production decline due to tight supply of CO_2
- EOR production growing overall with expansions in Wyoming and Gulf Coast
- EOR projects sensitive to cost of CO_2
- CO_2 single largest expense over life of EOR project
- Cost of CO_2 sensitive to cost of capture and transportation
- CO_2 cost > $35/tonne can stress EOR economics
- CO_2 costs tied to price of oil
- Actual cost of CO_2 is confidential business information

Oil & Gas Field Sequestration Potential



ARI report for NETL: Storing CO_2 and Producing Domestic Crude Oil with Next Generation CO2-EOR Technology. Jan 2009

EPA Class VI Rules

- EPA UIC Class VI rules published in the Federal Register in December, 2011.
- These rules cover all of the items listed in Article 11A, §22-11A-4: General powers and duties of the secretary with respect to carbon dioxide sequestration.
- These rules cover most of the items listed Article 11A, §22-11A-5: Permit application requirements and contents; permit application fees.
  - Class VI rules not concerned with pore space ownership
  - Class VI rules do not discuss fees
  - Limited discussion on public review of application/permit; refer to 40 CFR §124.10
  - Class VI rules not concerned with overall field, permit tied to injection wells, not to field the entire field.
- This Working Group has discussed/recommended that West Virginia establish primacy for Class VI wells.

EPA Class VI Rules

- Class VI rules, though not prescriptive, are extensive.
- If you call it sequestration a Class VI permit is required.
- If you call it EOR a Class II permit is required
  - Provisions for converting Class II permits to Class VI
  - If Director considers EOR operations a risk to USDW can require conversion to Class VI
- Any well drilled during site characterization can not be converted to Class VI
  - These wells considered strat tests
  - Can be utilized as monitoring wells
- Class VI permit application requires:
  - Area of Review (AoR) and corrective action plan
  - Monitoring and testing plan
  - Injection well plugging plan
  - Post-Injection Site Care (PSIC) and site closure plant
  - Emergency and remedial response plan

EPA Class VI Rules

- Financial Responsibility required to get permit:
  - Corrective Action – remediation of existing wells
  - Injection Well Plugging
  - Post-Injection Site Care & Site Closure
  - Emergency & Remedial Response
- Financial instruments will be effective prior to operations
  - Trust Fund, Letters of Credit, Surety Bonds, Insurance, Escrow Account
  - Financial Test & Corporate Guarantees
    - Recommended owner/operator tangible net worth of $100 million
  - If EPA is “Director” then can ‘t be beneficiary of instruments, set-up stand-by trust
    - If state is “Director” is can be a beneficiary (?)
    - Primacy can increase control over financial responsibility funds (?)
- Beginning injection operations is a two-step process:
  - Apply for permit and get approval to drill Class VI injection well(s)
  - Incorporate data from drilling Class VI injection into AoR model and other relevant plans and present to Director
  - Receive final approval to begin injection operations

EPA Class VI Rules
Items not covered

- Overall storage site & operations
  - A site permit is included in this Working Group's recommendations
- Monitoring Wells
  - Required by Class VI rules, number depends on approved plans
  - Permitted by state
  - Financial responsibility covered by PISC & site closure
- Site characterization process
  - An exploration effort for saline reservoirs
  - EPA assigns a 25% success factor
  - Play concept – assemble large acreage block, far more than needed
  - Permits needed during site characterization

EPA Class VI Rules
Items not covered

- Production of formation fluids
  - May be necessary to control reservoir pressure
  - May be necessary to control plume
  - Co-injection of water may increase storage efficiency
    - Use portion of produced waters, dispose or treat remainder
  - Another layer of operations
  - More permits: producing wells and water disposal wells
    - How to permit water disposal wells: Class I, II or V?
  - Increased capital and operating expenses
    - Potential for sales of treated (potable) water
- Other financial responsibilities to consider
  - Surface facilities
  - Other typical business coverage

EPA Class VI Rules
MVA

- Monitoring wells required (direct methods)
  - Above and into injection zone
  - Geochemistry, pressure
- Indirect methods
  - Seismic, electrical, gravity, electromagnetic
- Post-Injection monitoring
  - VSP and Cross-Well seismic
  - Electromagnetic surveys, electrical resistance tomography, microgravity surveys
- These technologies suggest locations from which to monitor the CO_2 plume

Questions