



Gas Storage Technology Applicability to CO₂ Sequestration

> NorCap Seminar

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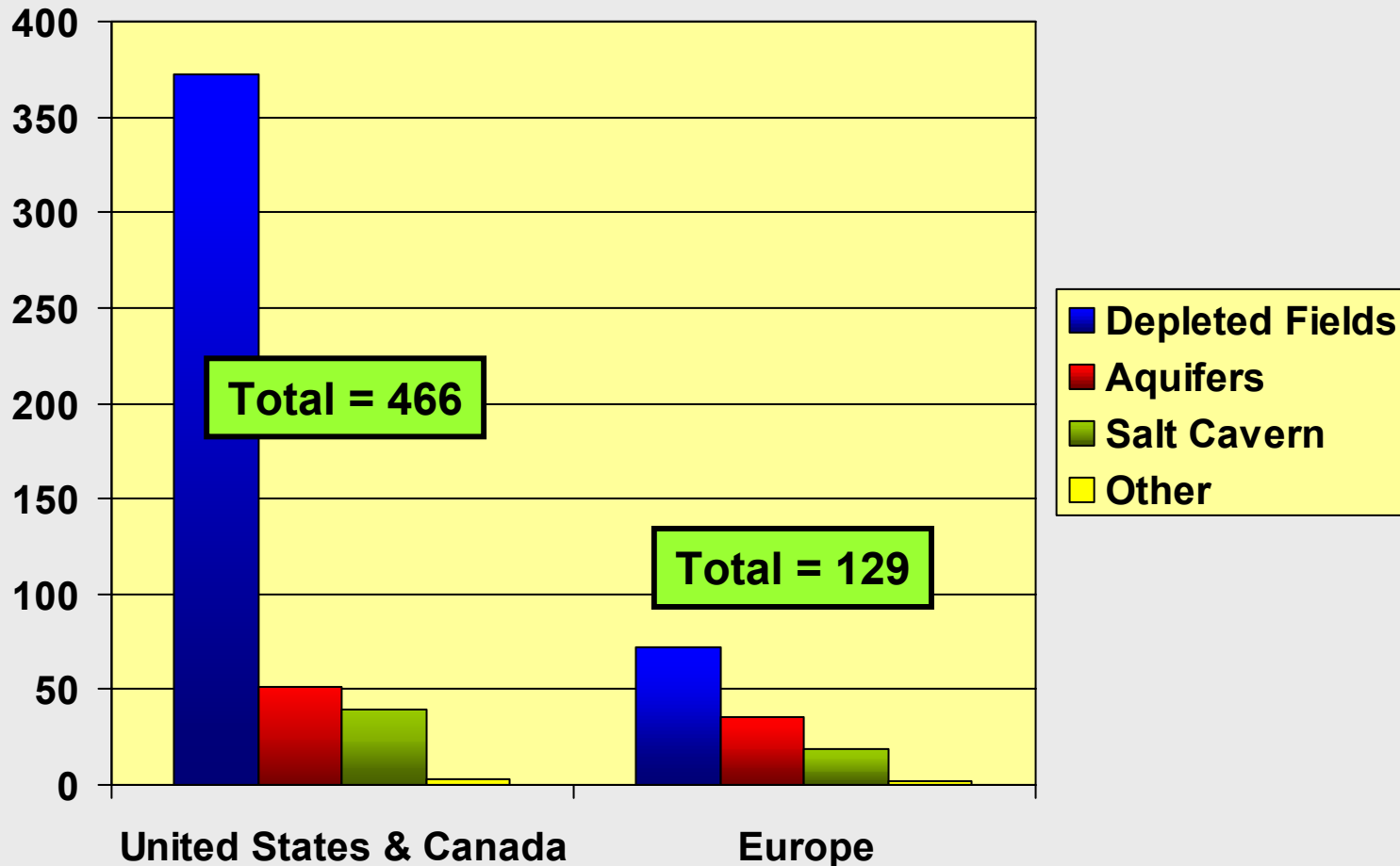
Gas Technology Institute

October 14-15, 2003

Topics

- > **Process**
- > **Conclusions**
- > **Relevant Gas Storage Technologies For Geologic CO₂ Sequestration**
- > **Summary and Recommendations**

Gas Storage Fields – Europe and United States



Process

- > **Literature Search**
- > **Interview Operators**
- > **Survey of European Operators**
 - 17 Countries
- > **Focus on Caprock Integrity, Field Monitoring, Leaks and Leak Mitigation**

24 Gas Storage Technologies With Application to CO₂ Sequestration

Inventory Verification	Gas Storage Monitoring
Pressure-Volume Techniques	Surface/Vegetation Monitoring
Reservoir Simulation	Shallow Water Well Observation
Volumetric Gas in Place Calculation	Deep Well Observation
“Watching the Barn Doors”	Well Logging
Leak Mitigation Techniques	Seismic Monitoring
Shallow Gas Recycle	Gas Metering
Aquifer Pressure Control	Gas Sampling/Analysis
Caprock Sealing	Tracer Surveys
Caprock Integrity Testing	Production Testing
Geologic Assessment	Remote Sensing
Threshold Pressure	Other Technologies
Pump Testing	Wellbore Damage Mechanisms
Flow/Shut-In Tests	Over Pressuring
Air/CO ₂ Injection	

Study Conclusions

- > **Observation Wells are the Best “Early Warning Signal” for Leak Detection**
- > **Leak Control Technology Exists For Gas Storage Reservoirs But is Not Practical for CO₂ Sequestration**
- > **Geologic Leaks in Gas Storage Reservoirs are Strongly Related to Gas Storage Structural Closure Requirements**
 - **The CO₂ Sequestration Industry Can Mitigate Risk from this Experience**
- > **Caprock Leak “Sealing” While Not Successful to Date Has Future Potential With New Technology**

Study Conclusions (continued)

- > Gas Storage Industry “*Pump Test*” Procedures Have Potential For CO₂ Field Integrity Testing**
- > Successful Monitoring of CO₂ Sequestration Projects Requires a Combination of (Available) Techniques**
 - Observation Wells, Pressure-Volume Studies, “Watching the Barn Doors”**
- > Pressure/Volume Techniques are not Always Precise Enough to Identify Gas Migration Issues During Early Stages of Gas Storage**

Study Conclusions (continued)

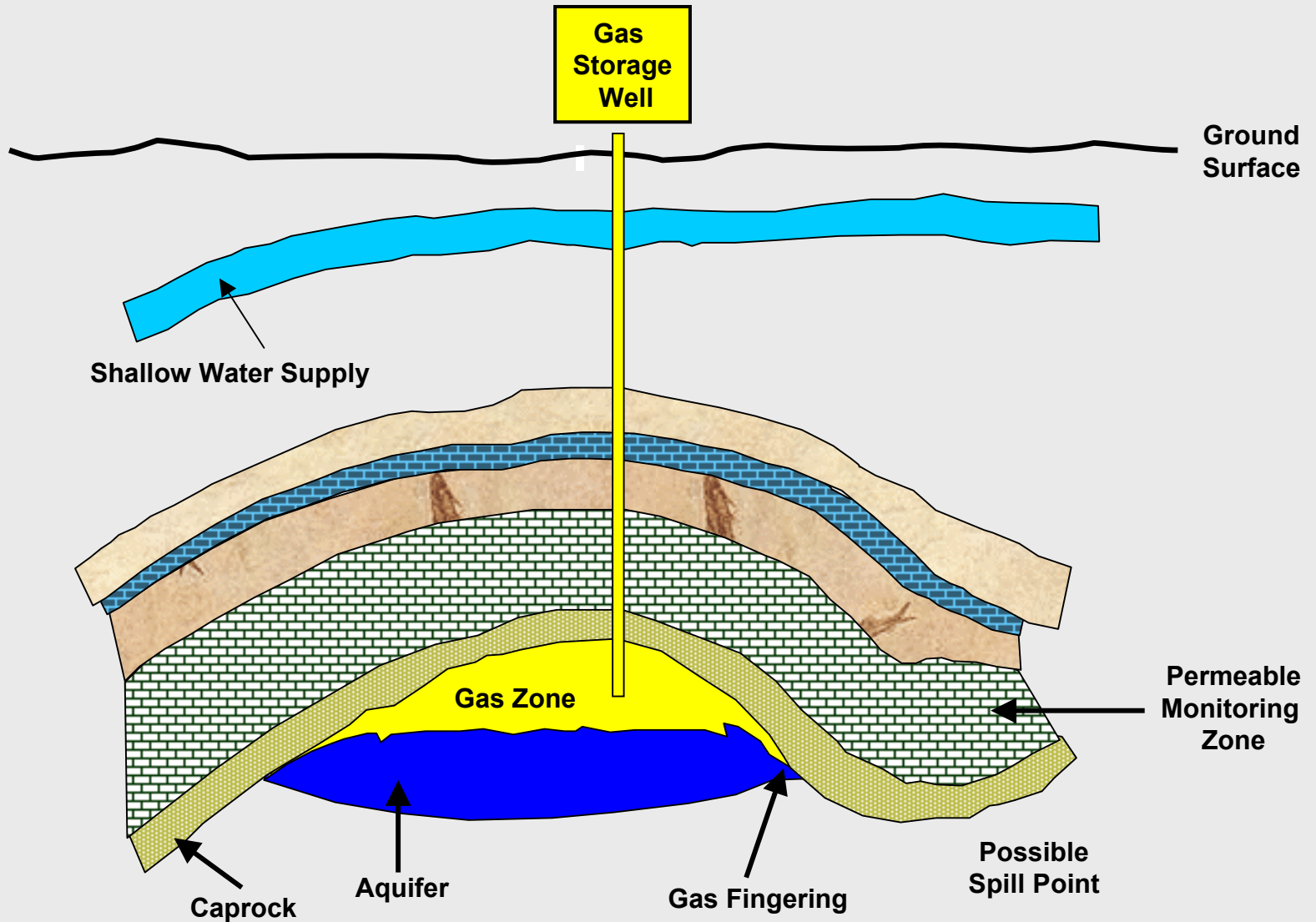
- > Small Volumes of Gas Leakage Can Manifest Itself in a Manner Disproportionate to Leak Severity (In Terms of Volume)**

- > The Five Most Relevant Gas Storage Technologies Are:**
 - 1) “Watching the Barn Doors”**
 - 2) Gas Storage Observation Well Technology**
 - 3) Pump Testing Techniques**
 - 4) Caprock Sealing**
 - 5) Surface/Near Surface Monitoring**

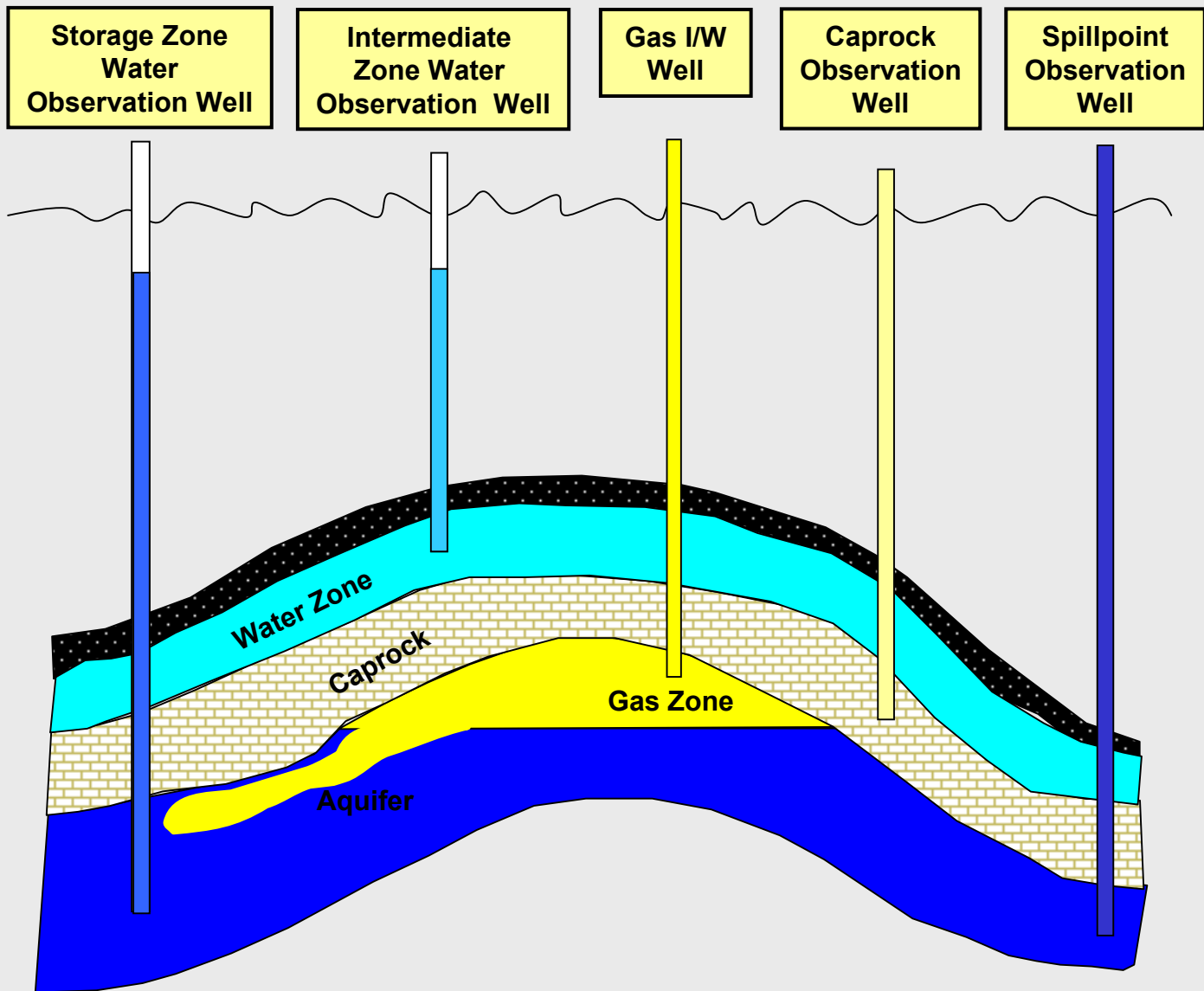
Study Conclusions (continued)

- > The CO₂ Industry Should Heed the Caution Directed at the Gas Storage Industry During its Infancy:**
 - *“Caution must be exercised in claiming that gas will never be found outside the intended area”***
- > With Only 6 Reported Gas Migration Incidents, From Operation of Approximately 600 Fields and Over 90 Years of History, Evidence is Provided That Gas Can Be Safely Stored**

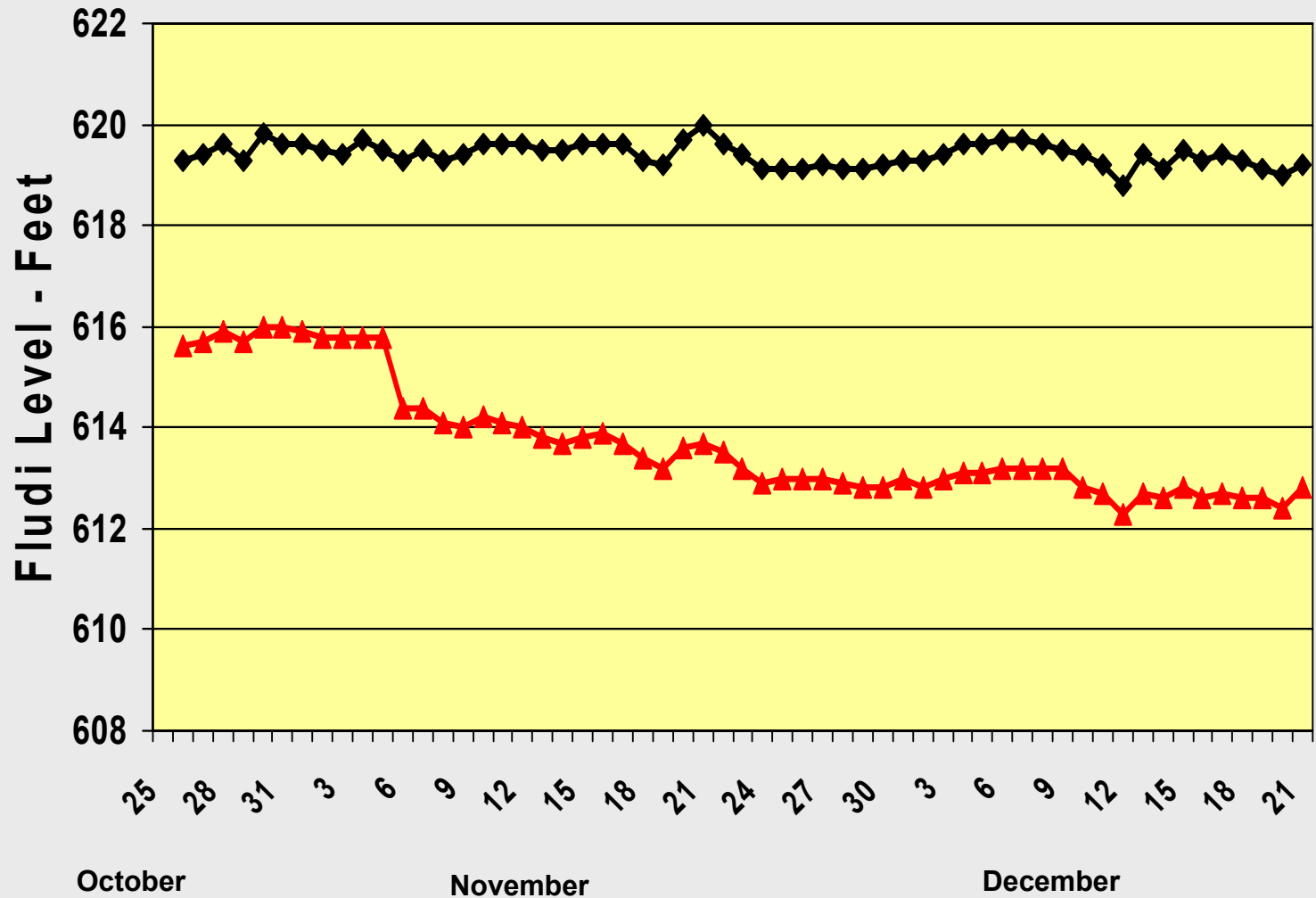
Storage System Definitions



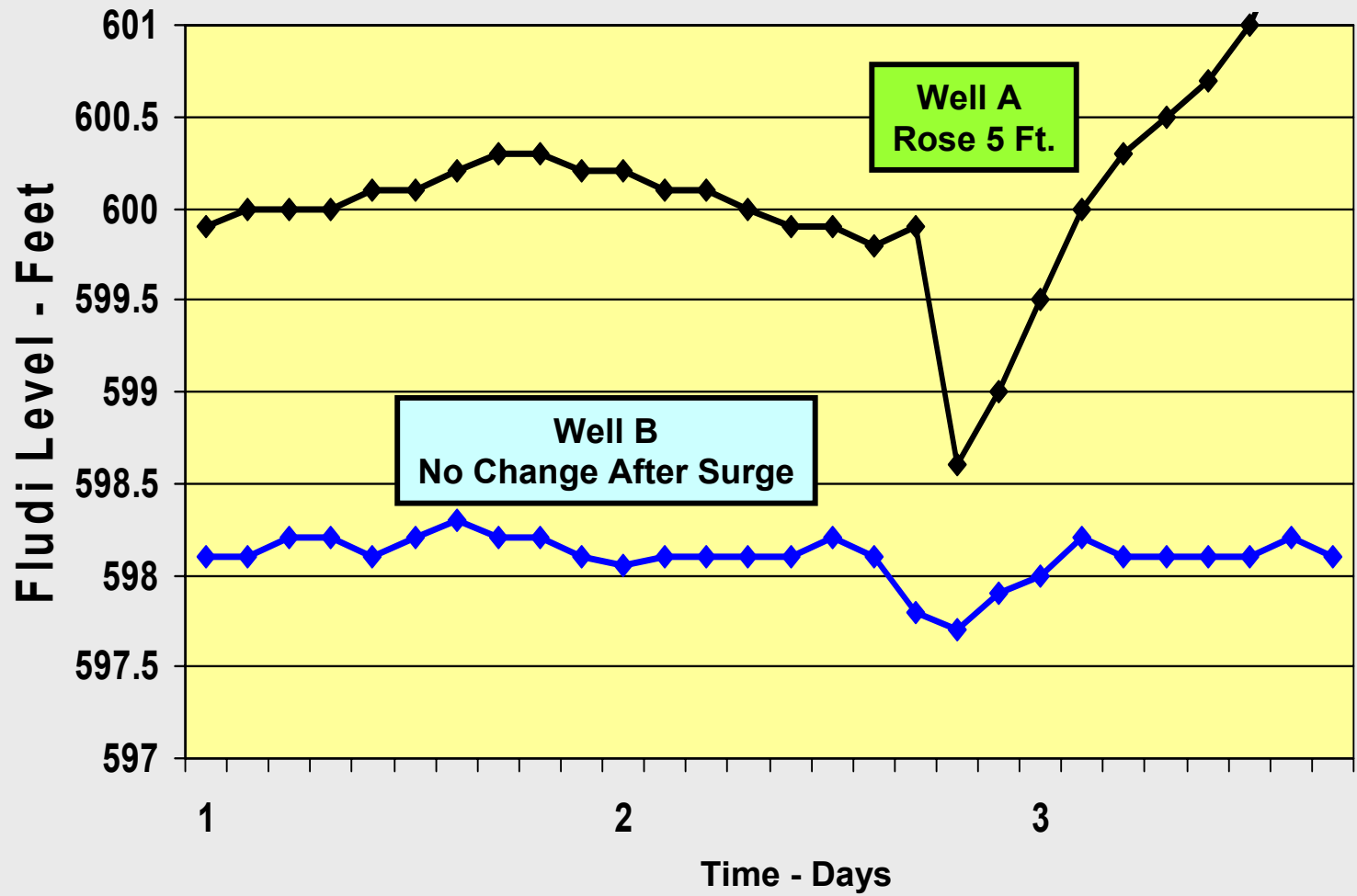
Observation Wells



Observation Well Data



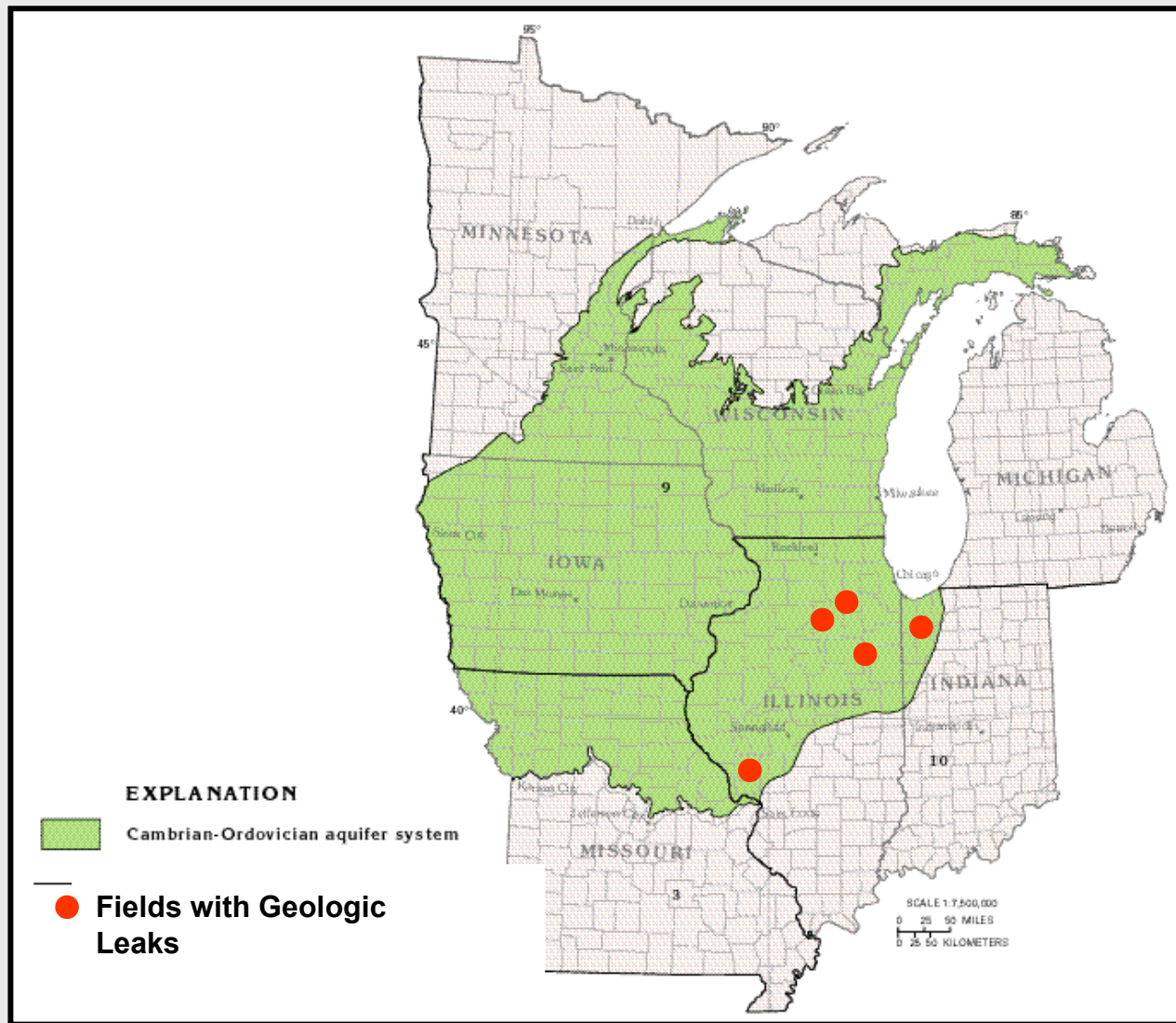
Observation Well Data – Earthquake Response



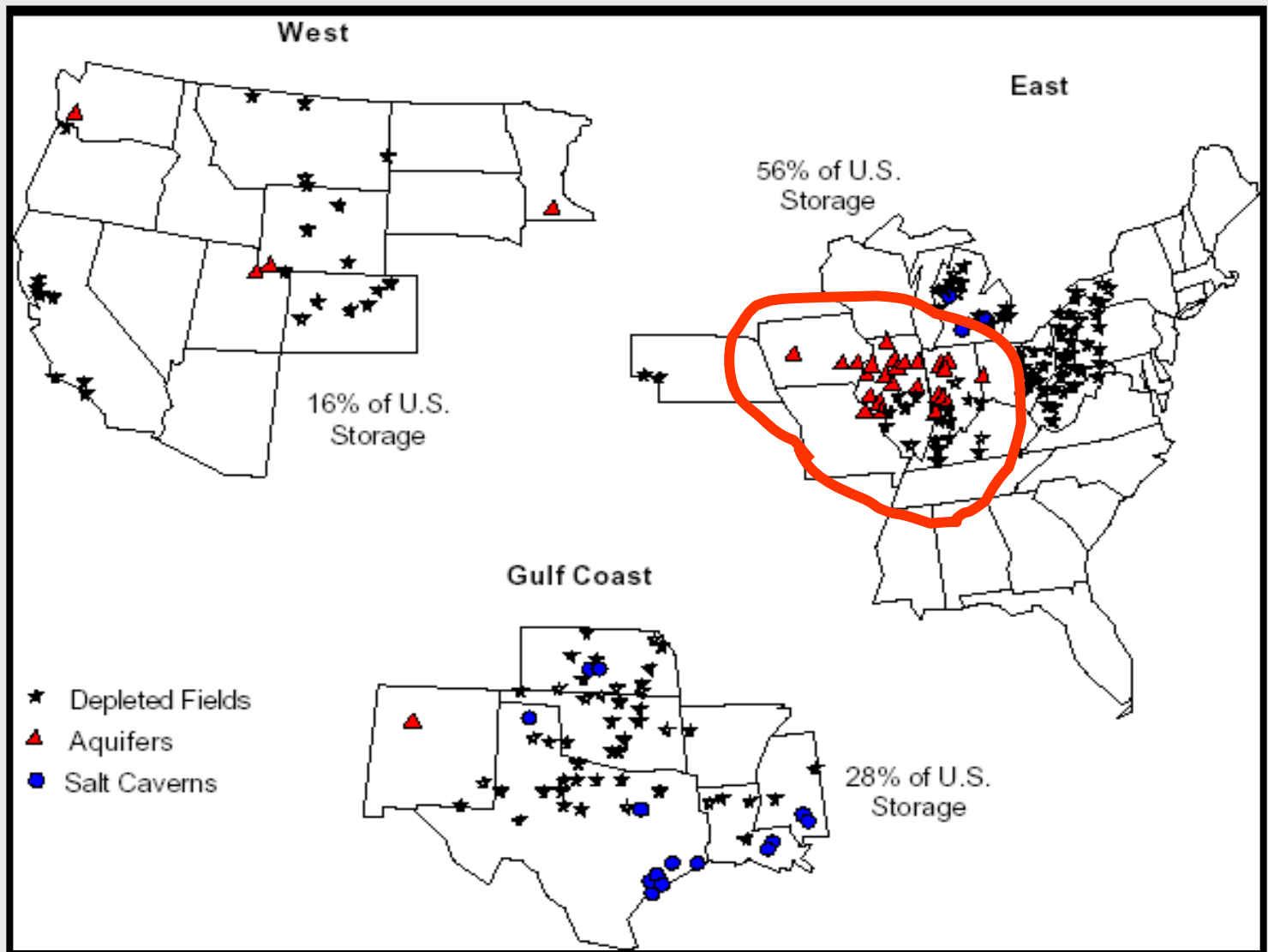
Gas Storage Fields With Some Type of Leak

Field Type & Location	Type of Leak	Remedial Action Taken
Aquifer – Midwest U.S.	Caprock	Aquifer Pressure Control
Aquifer – Midwest U.S.	Caprock	Shallow Gas Recycle
Aquifer – Midwest U.S.	Caprock	Field Abandoned
Aquifer Storage – Wyoming U.S.	Wellbore Leak	Wellbore Remediation
Salt Cavern – Kansas, U.S.	Wellbore Leak	Wellbore Remediation
Depleted Gas Field, Canada	Wellbore Leak	Wellbore Remediation
Depleted Gas Field, W. Virginia, U.S.	Casing Leaks	Wellbore Remediation
Depleted Field, California, U.S.	Improperly Plugged Well	Re-Plug Old Well
Aquifer – Indiana, U.S.	Reservoir Too Shallow	Abandon Field
Russian Fields	No Data	

Mt. Simon Aquifer

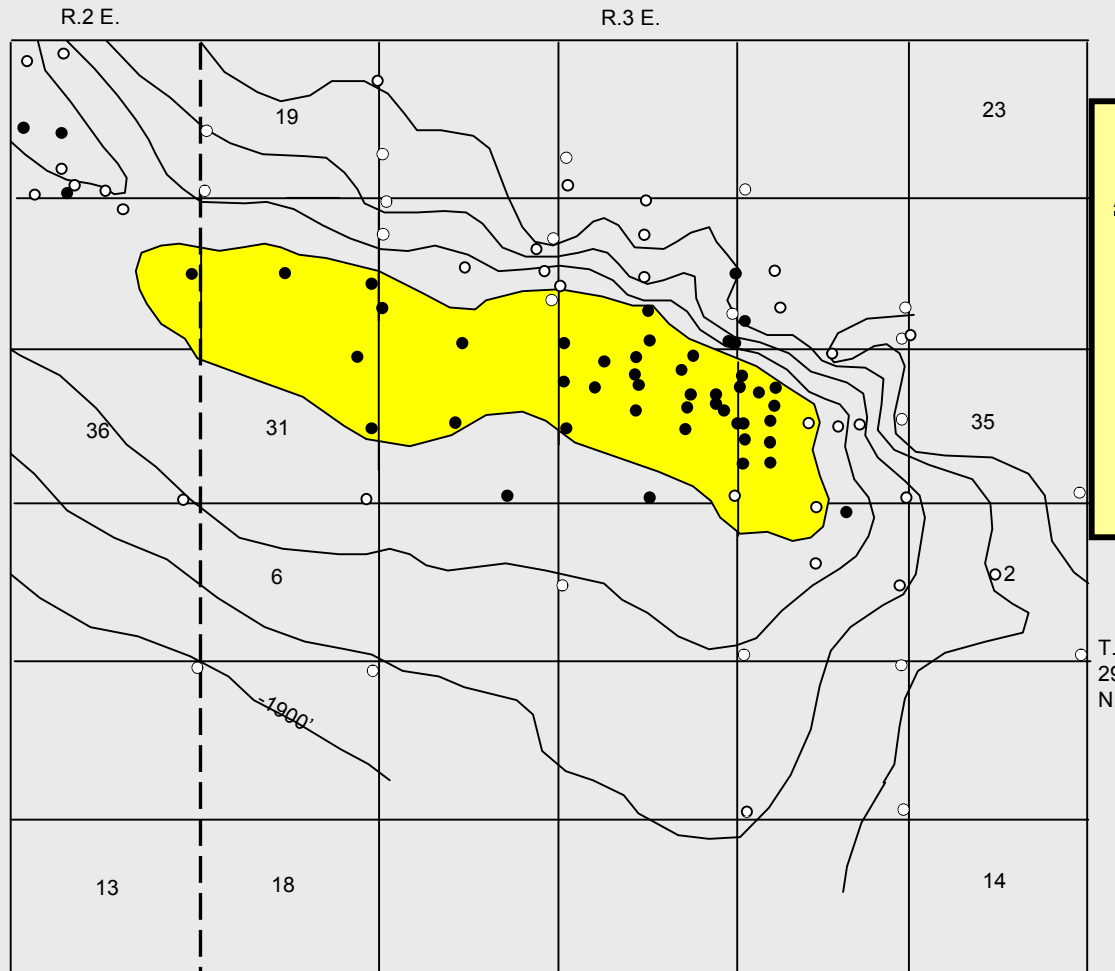


U.S. Gas Storage Fields



Geologic Leaks and Structure

Structure Map (Top of Mt. Simon Sandstone)



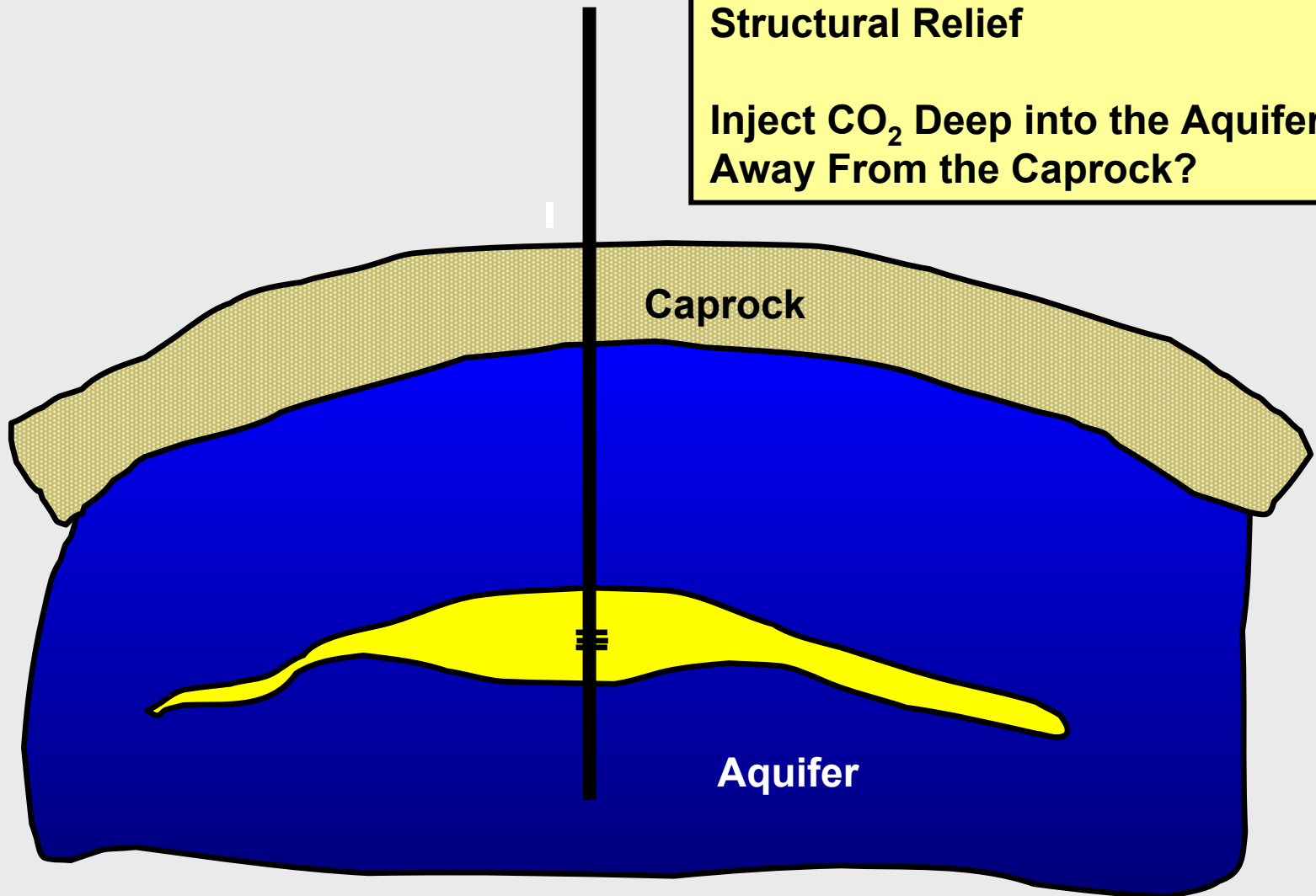
Midwest U.S. Aquifer Gas Storage Field

- Caprock Leak
- Steep NE Flank is Area Of Suspected Leak Due To Steep Flank

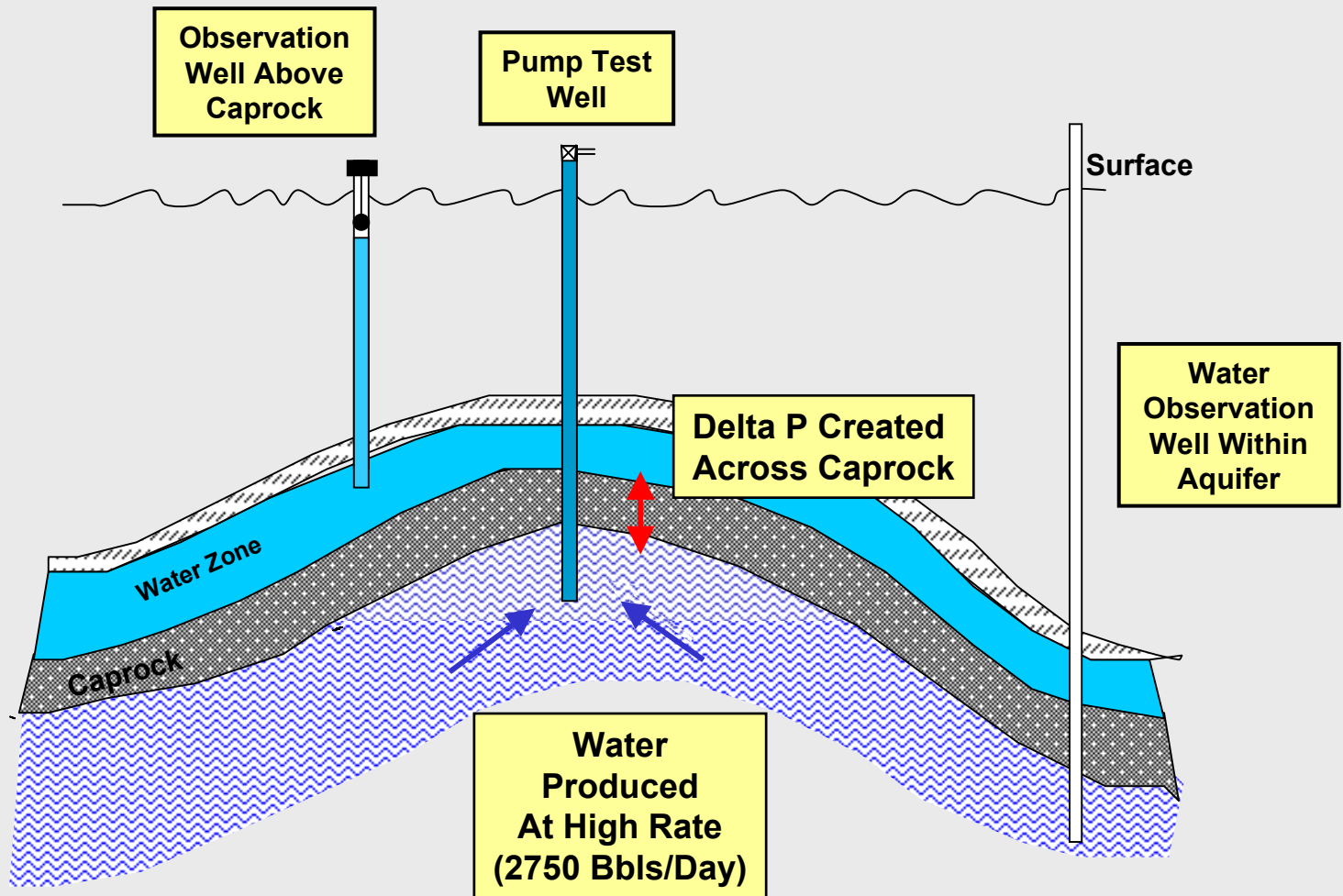
Caprock Leak - Risk Mitigation

Store in Areas With Minimal Structural Relief

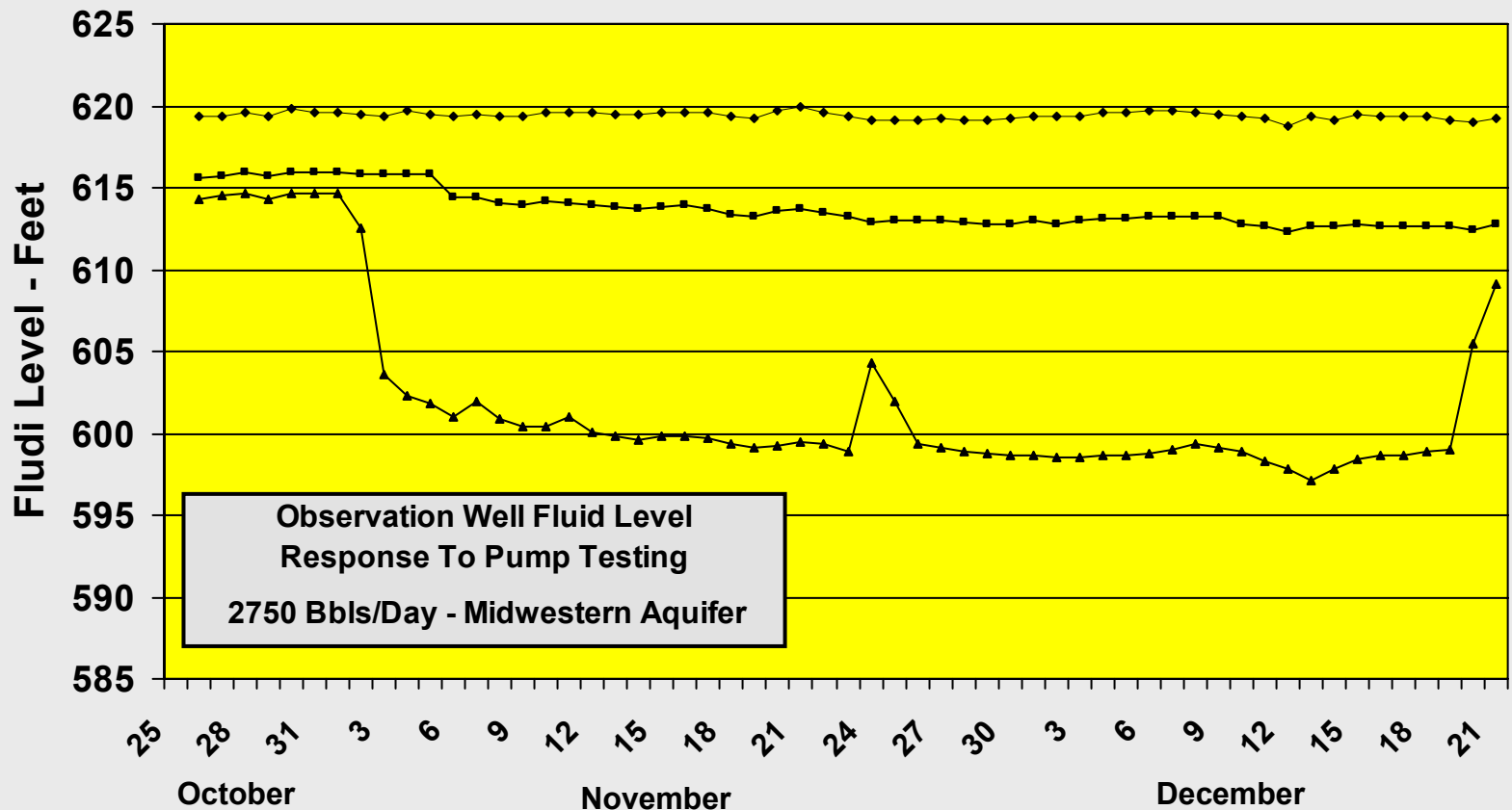
Inject CO₂ Deep into the Aquifer Away From the Caprock?



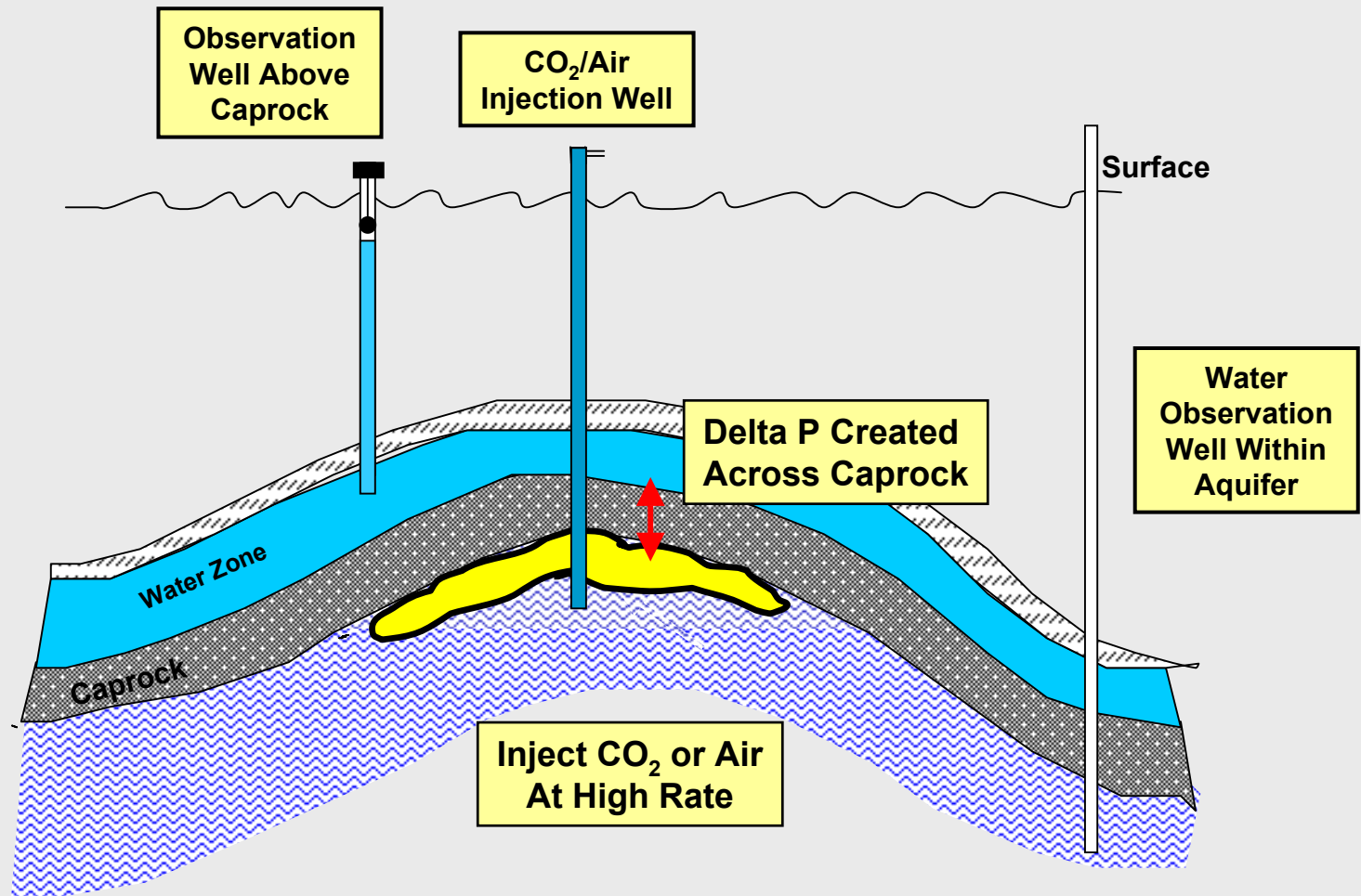
“Pump Test” For Caprock Integrity



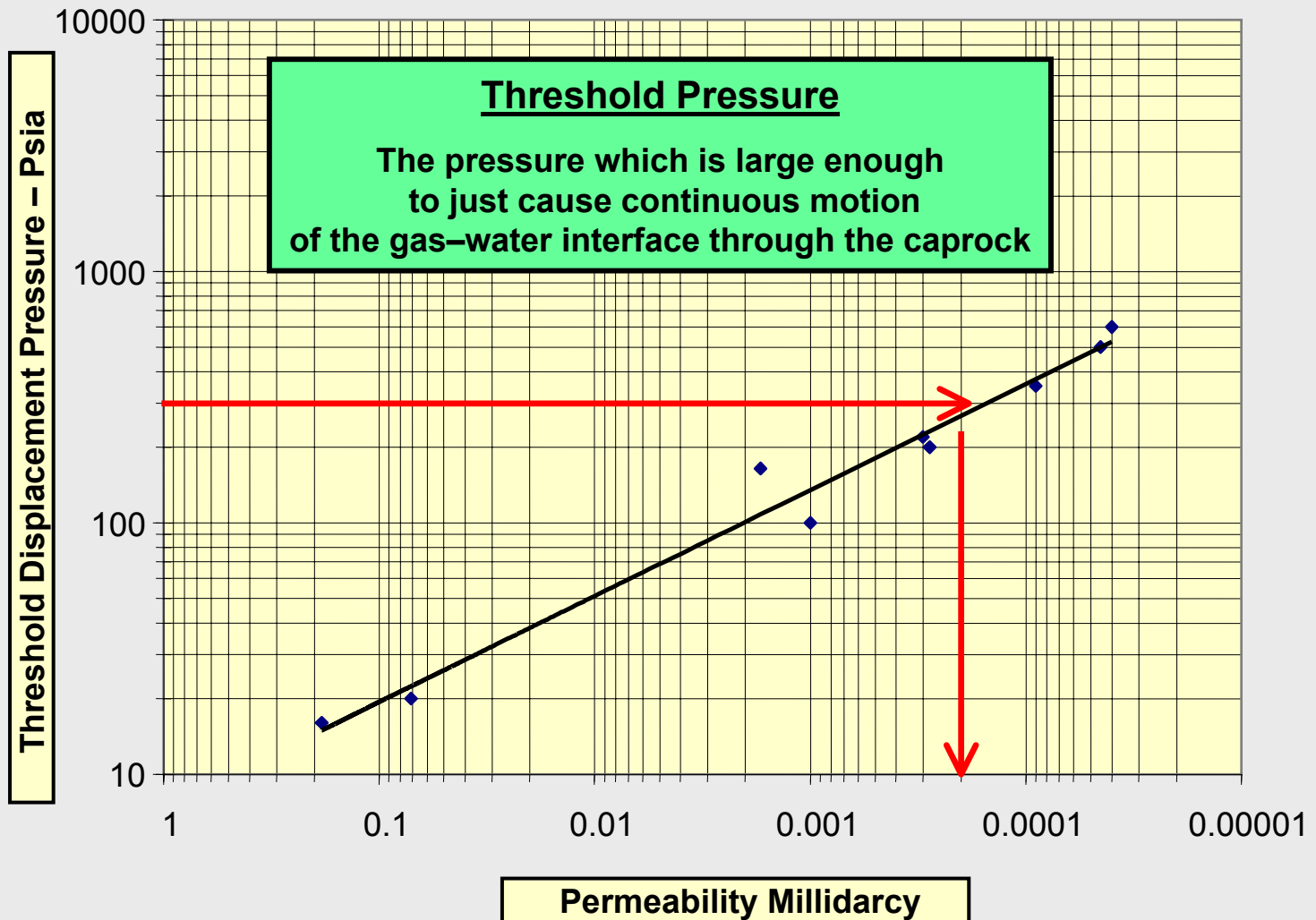
Observation Well Data During Pump Test Mt.Simon Aquifer Midwestern U.S.



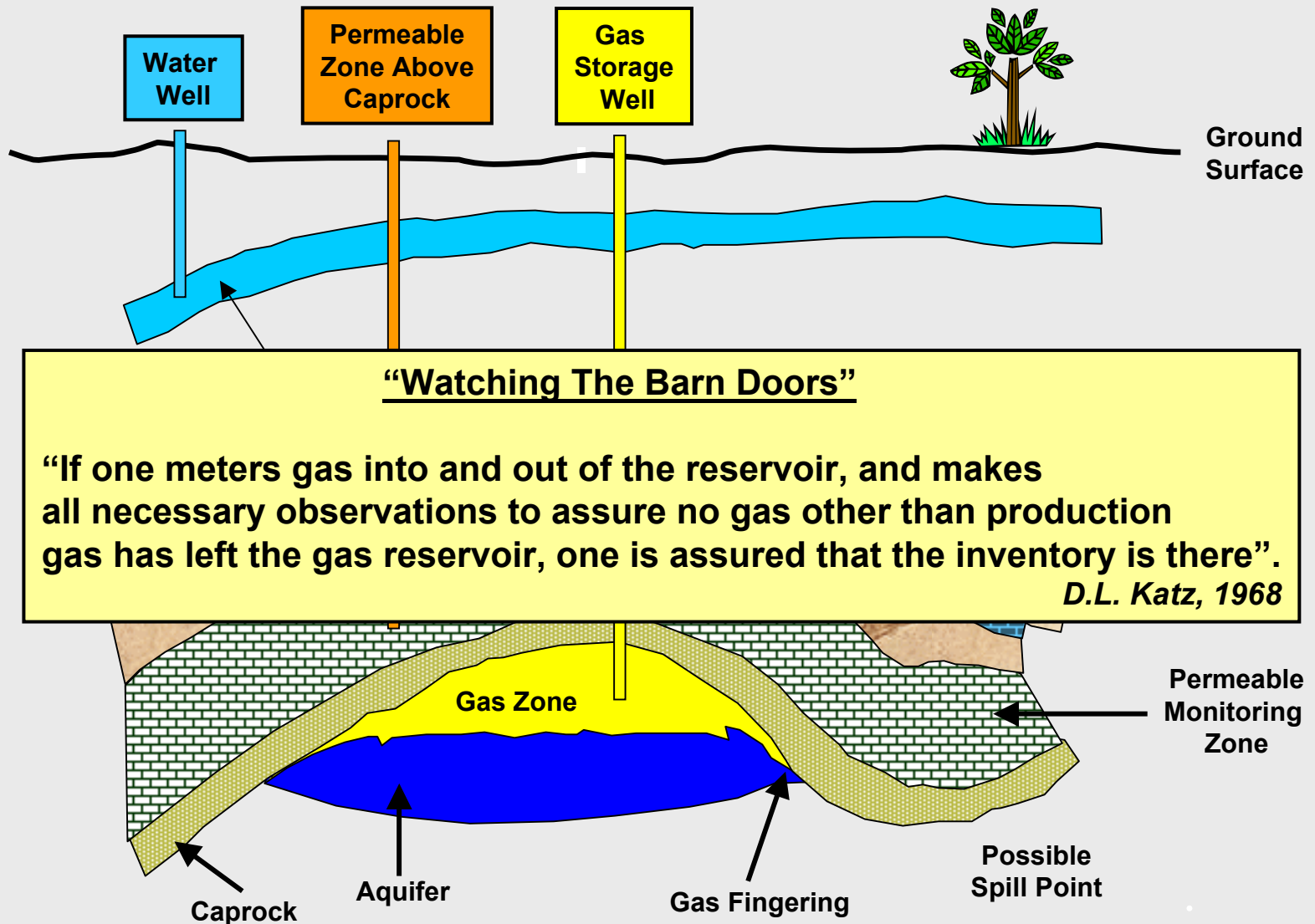
Custom “Pump Test” For Caprock Integrity For CO₂ Sequestration



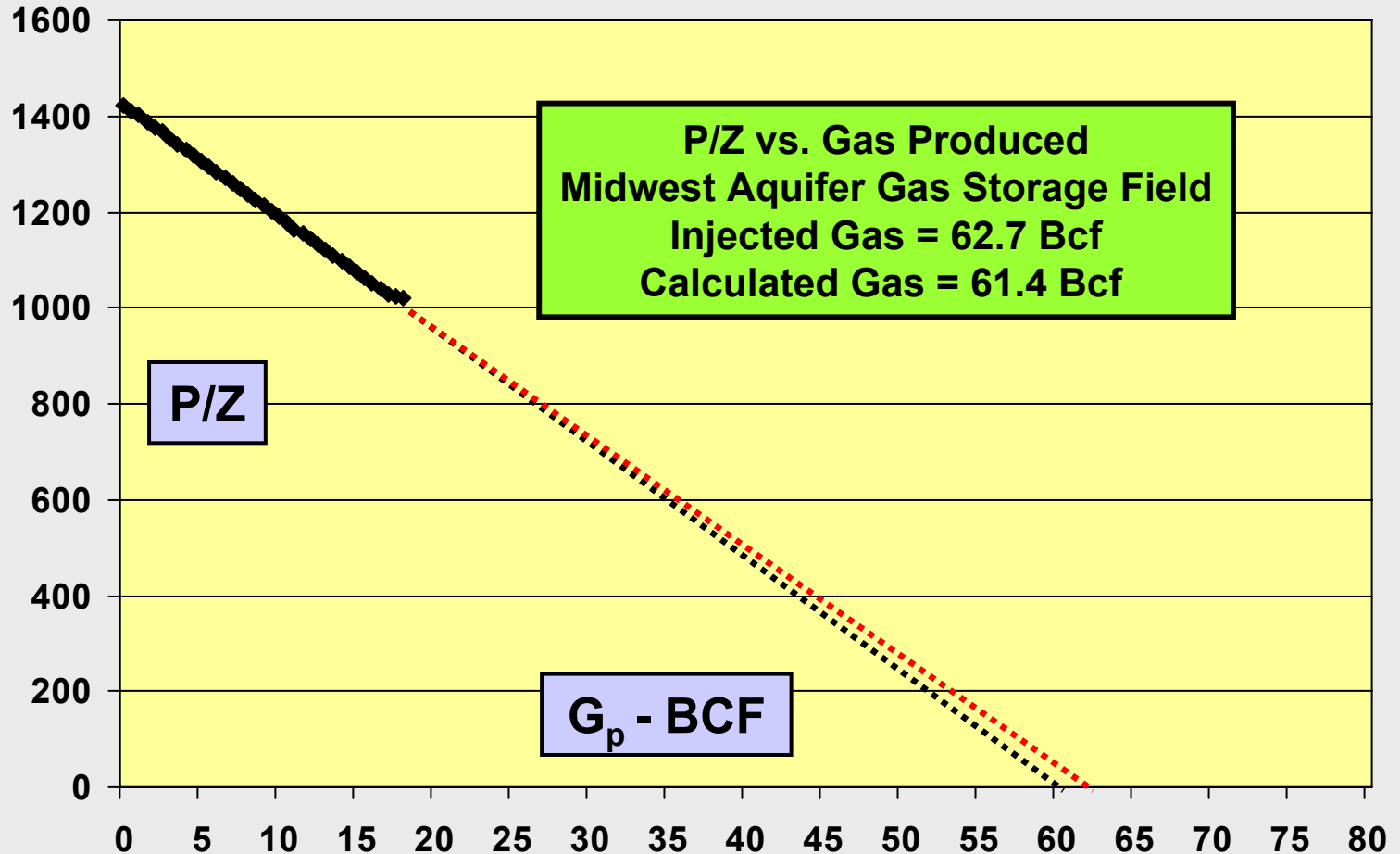
Caprock Threshold Displacement Pressure Versus Water Permeability



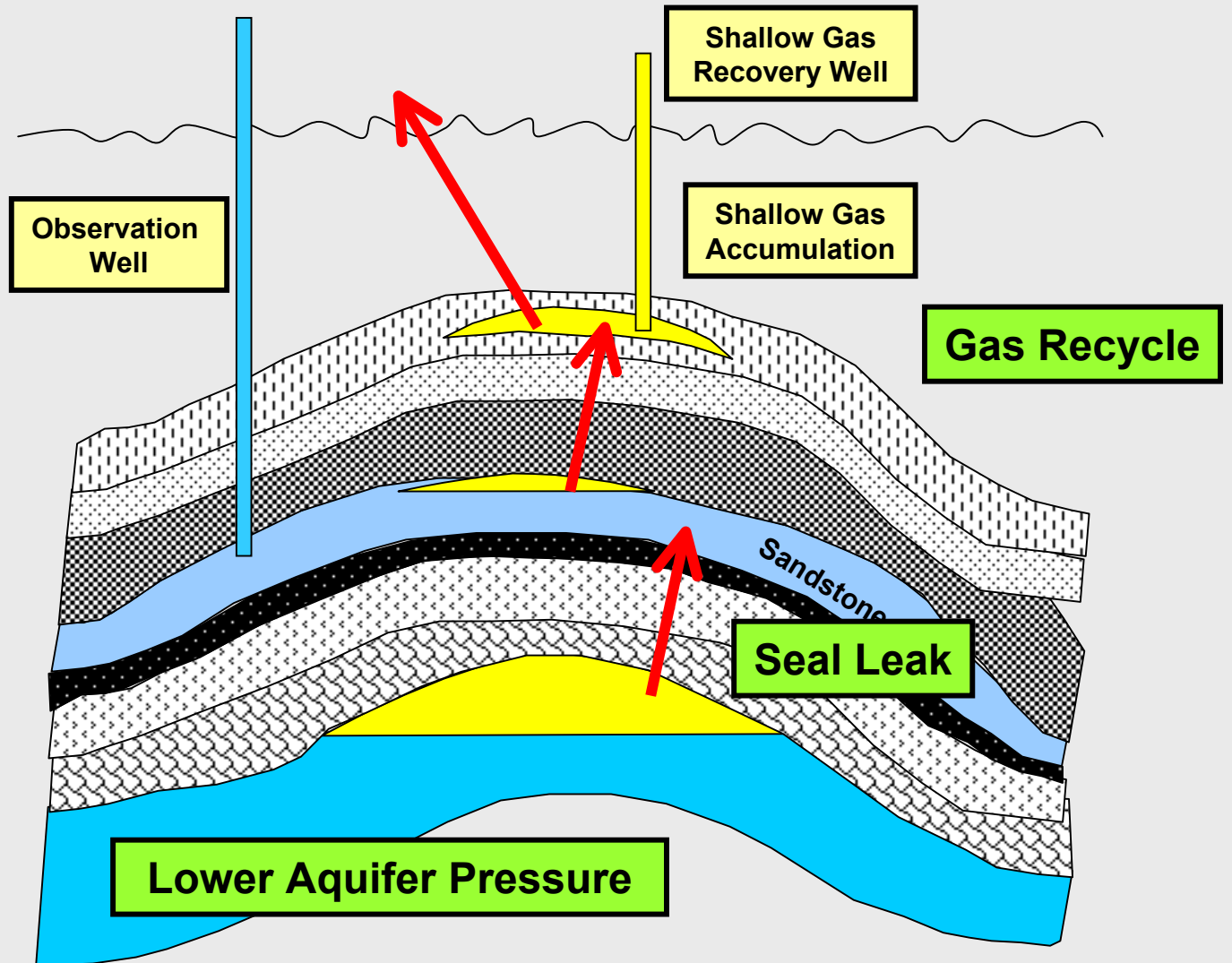
Inventory Verification



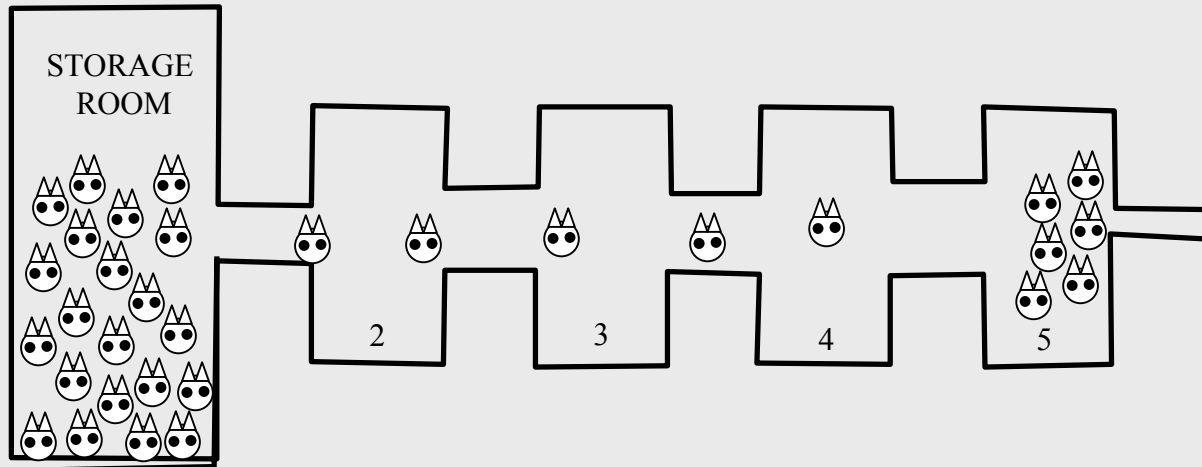
Pressure Volume Techniques For Inventory Verification



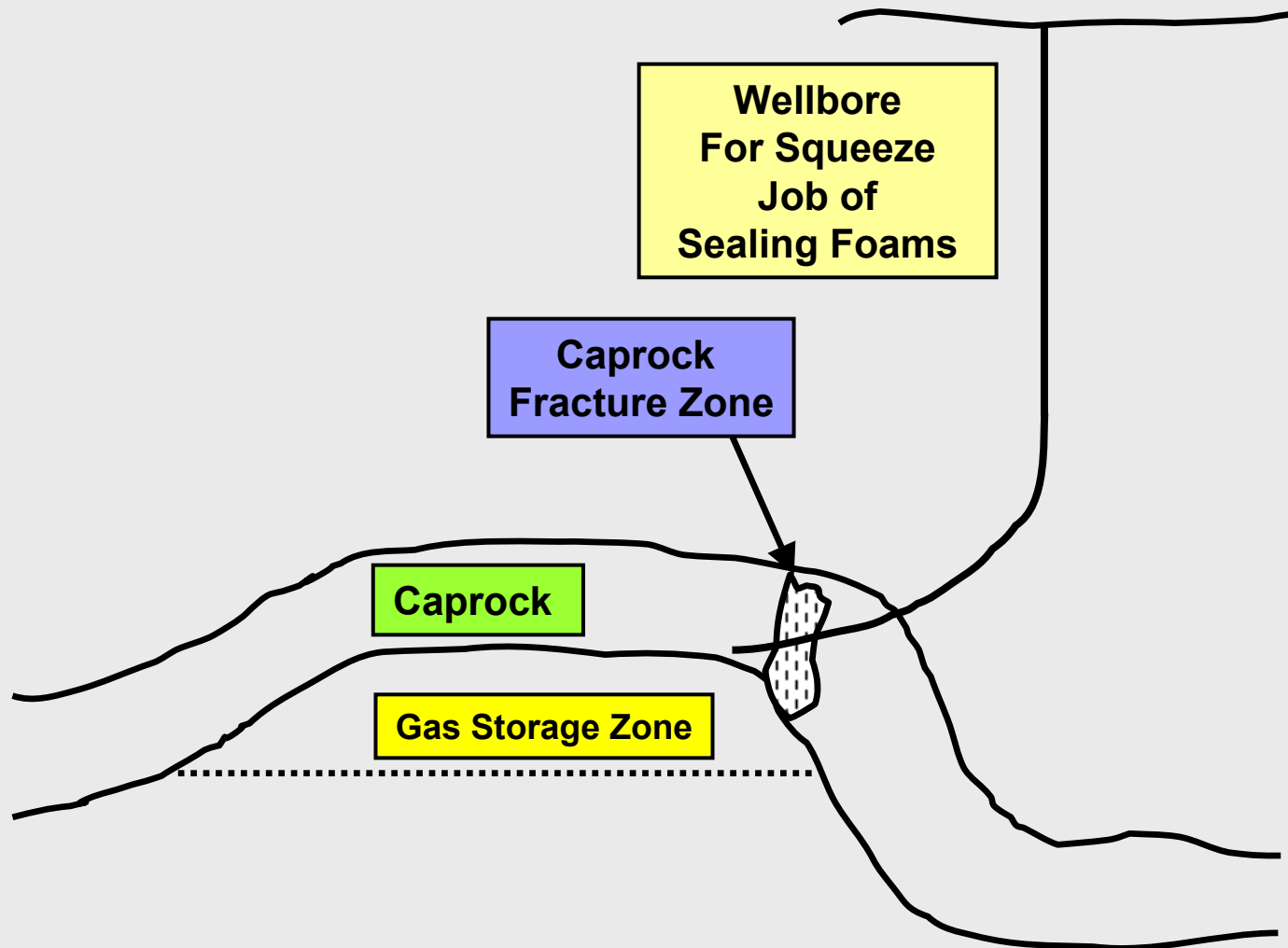
Leak Control Technology



“Cats (*Katz*) and Doors” Analogy For Gas Leakage



Caprock Leak Sealing



Summary and Recommendations

- > **Safe Storage Has Been Demonstrated**
- > **Valuable Storage Techniques and Procedures Exist and Are Applicable to CO₂ Sequestration**
- > **Areas For Further Research By the CO₂ Sequestration Industry Include:**
 - Observation Well Response
 - Pump Testing Procedures Specific To CO₂ Sequestration
 - Technology Integration for Locating and Sealing Geologic Leaks