Ensuring Integrity of Geologic Sequestration:

Integrated Application of Simulation, Risk Assessment and MVA

Presentation for AWWA

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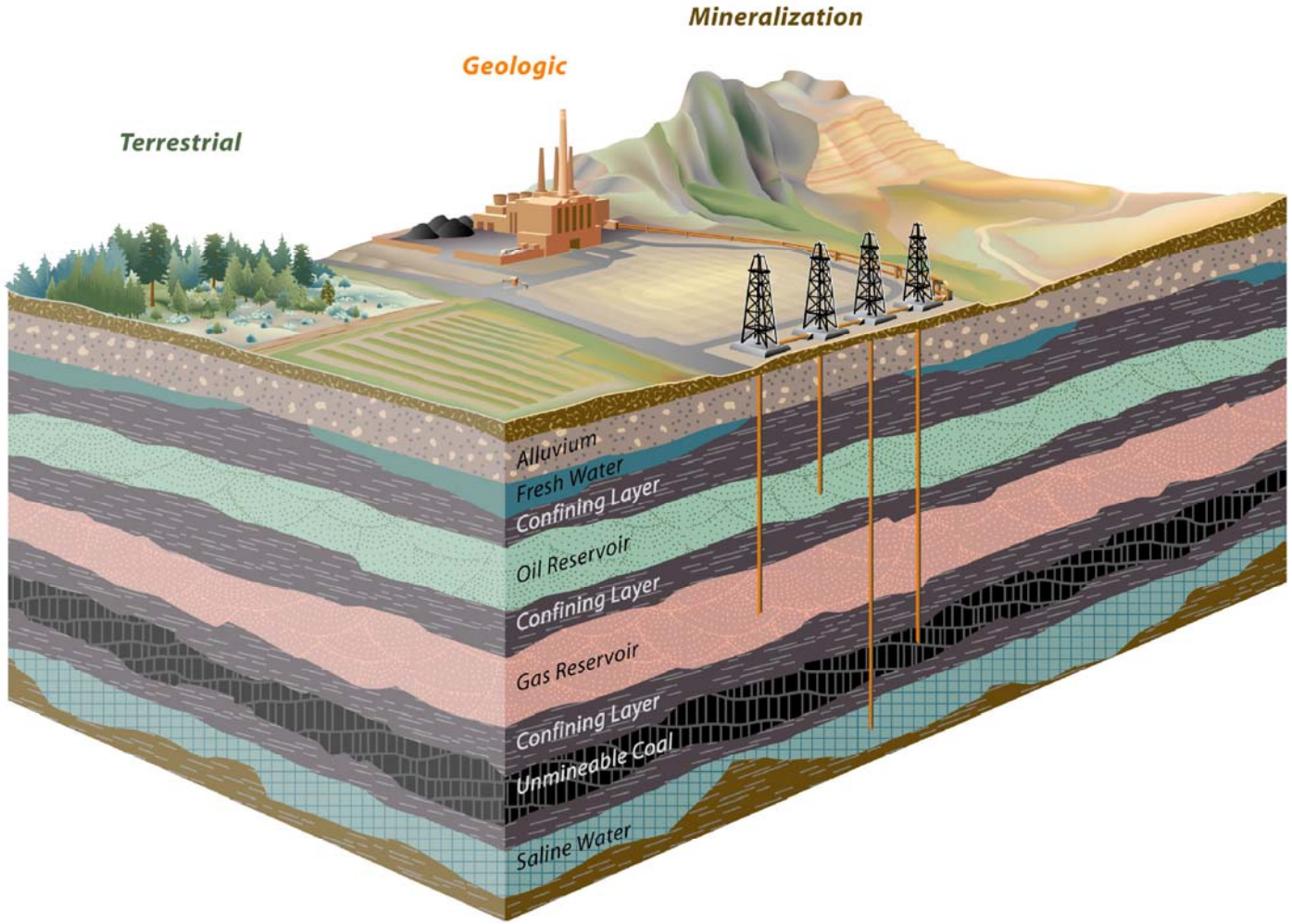
U.S. Department of Energy
National Energy Technology Laboratory
University of Utah
Many individuals...

Outline

- **Premise**
- **Site Selection**
- **Operations**
- **Site Closure**
- **Closing Remarks**

CO_2 Storage or "Sequestration"



Before carbon sequestration is implemented "commercially," it must be tested. USDWs are a primary consideration in ongoing tests.

Geological Sequestration: Integration of Monitoring, Risk Assessment, and Simulation

- ***Monitoring*** critical to ensure integrity of USDWs
- ***Simulation*** critical to ensure integrity of USDWs
- ***Quantitative Risk Assessment*** critical to ensure integrity of USDWs
- **All three are integrated and "iterative"**

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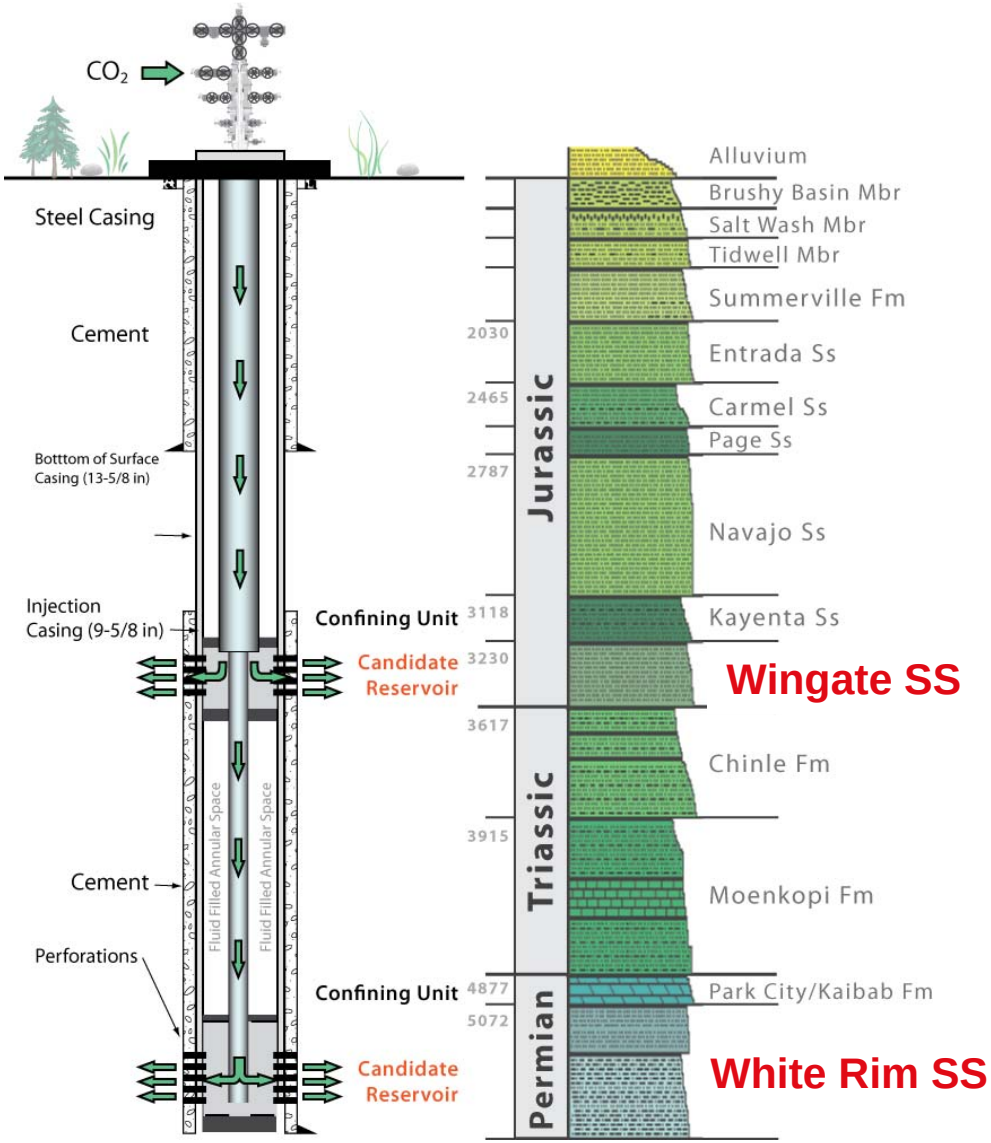
Key Considerations:

- **design and distribution of injection, monitoring and mitigation wells**
- **degree of "stacking" in stacked system**
- **depth of seals and "backup" storage reservoirs in stacked system (safety and costs)**
- **vertical and lateral distance of USDWs**
- **storage capacity**
- **presence of CO_2**
- **surface features; population**
- **mitigation options**



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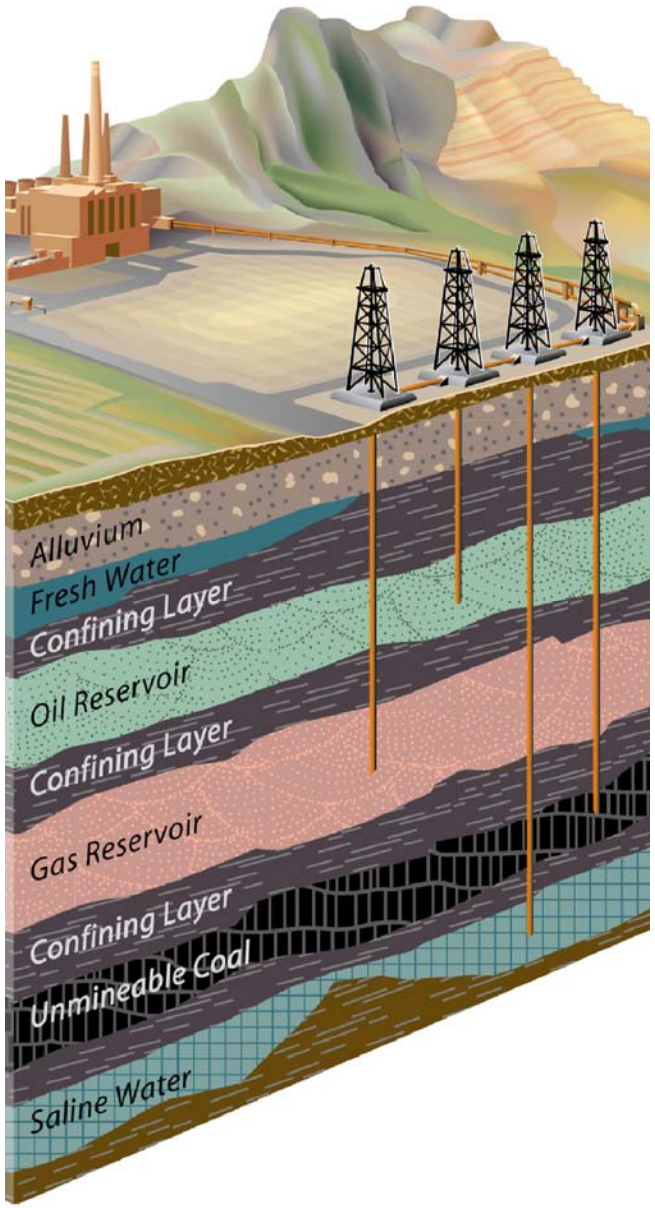

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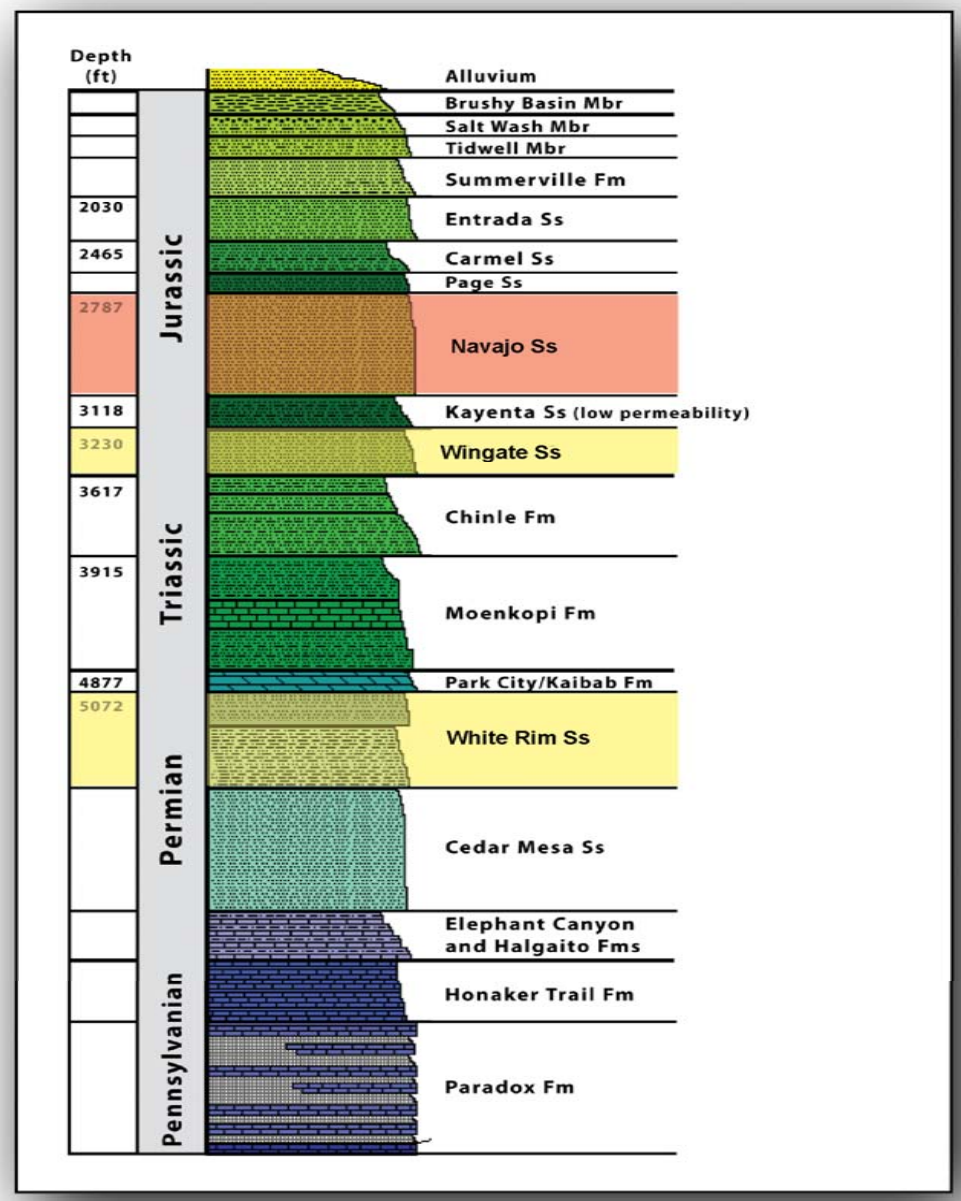

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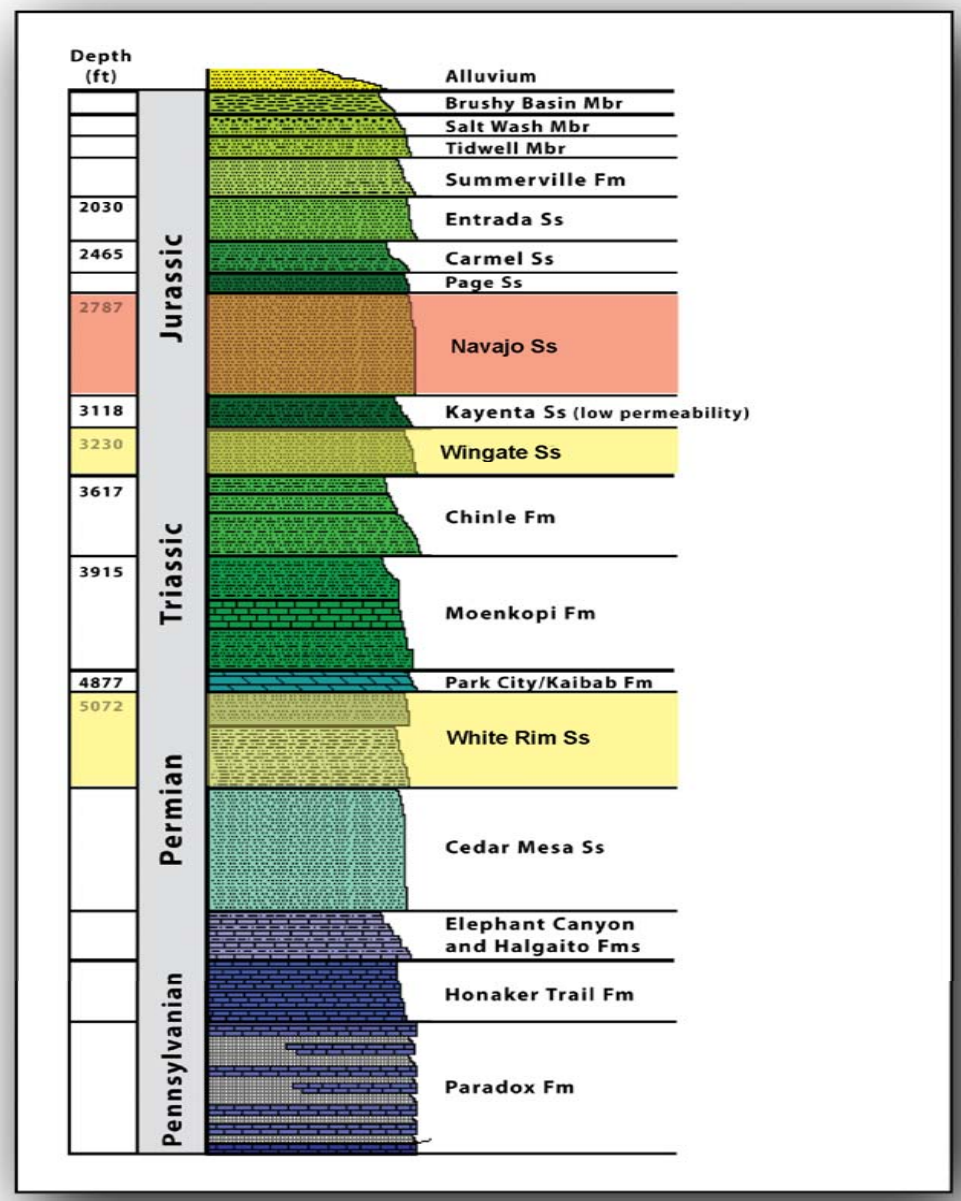

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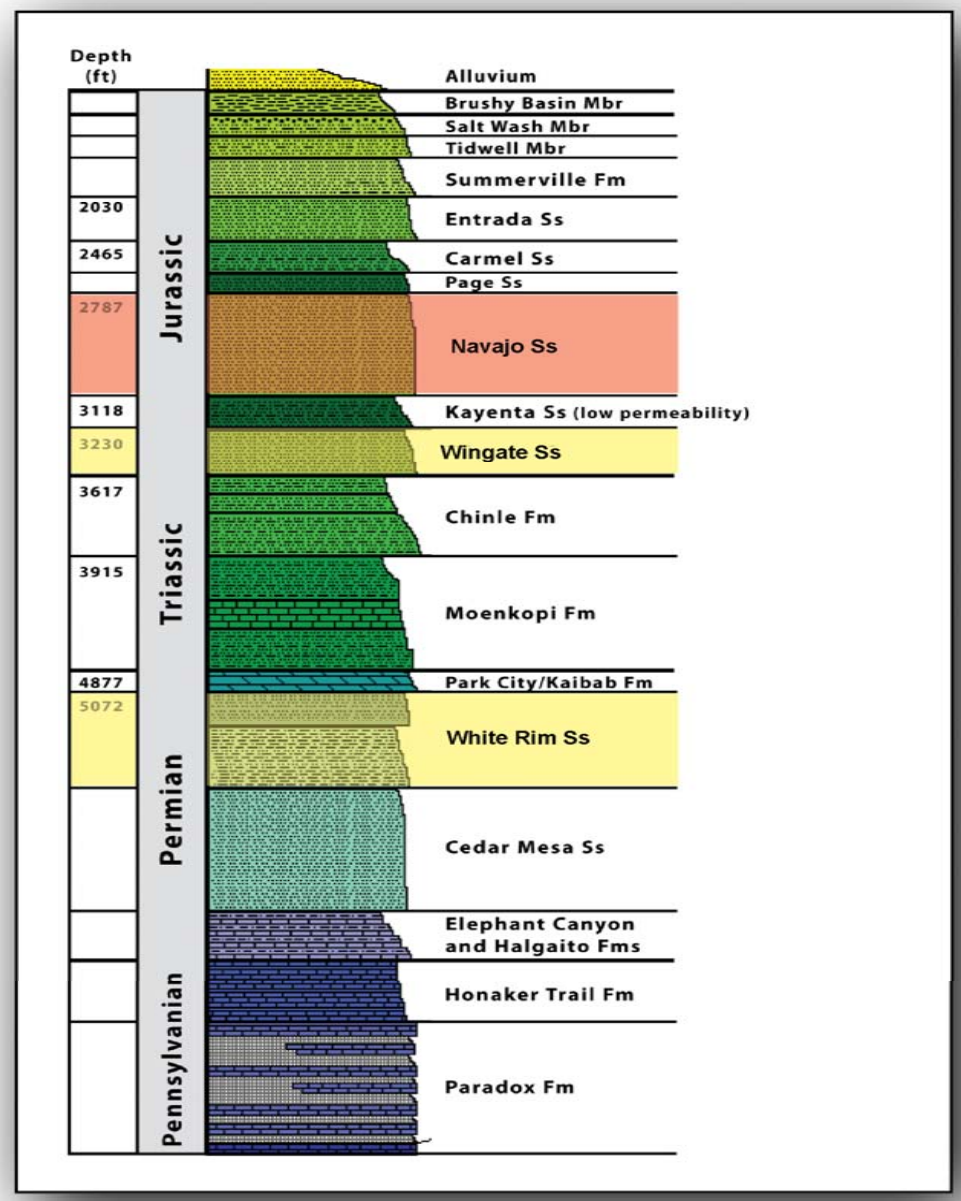

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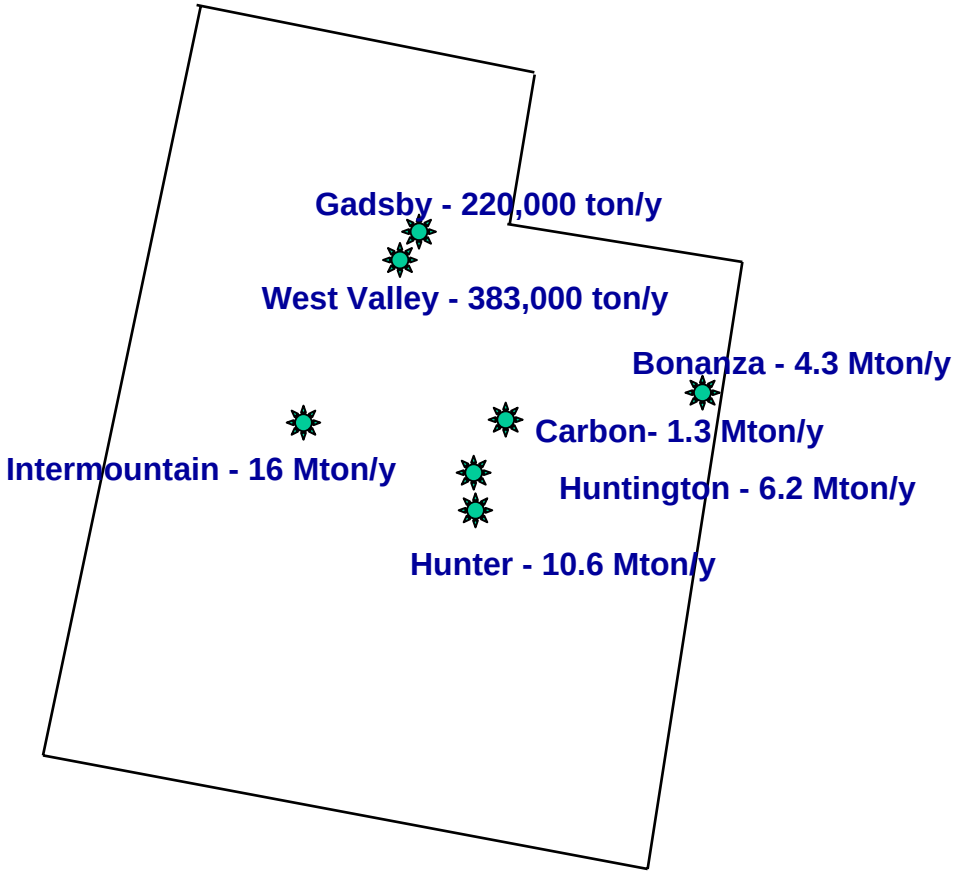

EXAMPLE: Utah Emissions & Capacity

Sources : **40 million tons CO_2 per year**

Utah's CO_2 Sinks and Capacities:

Oil and Gas Reservoirs: **1400 million tons**

Un-mineable Coal Seams: **120 million tons**

Deep Saline: **500 million tons minimum**

Storage capacity in Utah is equivalent to over 50 years of its emissions!

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		Symbol	Formation	Thickness	Comments
MESOZOIC	CRETACEOUS	Km	Mancos Shale, *Ferron Sandstone Member* *Tununk Shale Member*	0-440	Hogbacks of the Ferron Sandstone form the west and east flanks of the structure
		Kd	Dakota Sandstone	50	
		Kcm	Cedar Mountain	500	Exposed at the crest of the surface anticline
	JURASSIC	Jm	Morrison, *Brushy Basin Member* *Salt Wash Member*	730	
		Js	Summerville	140	
		Jct	Curtis	170	
		Je	Entrada	448	
		Jc	Carmel	380	Basal decollement, Arapien equivalent
		Jgc	Glen Canyon Group, *Navajo Sandstone* *Kayenta Fm* *Wingate Sandstone*	780	Navajo Sandstone produced 4.7 BCF of CO_2 Wingate tested CO_2 and water
	TRIASSIC	Trc	Chinle	230	
		Trmt	Moenkopi, Torrey Member	600	
		Trms	Moenkopi, Sinbad Limestone	70	Sinbad Limestone tested CO_2
		Trmbd	Moenkopi, Black Dragon Member	350	
PALEOZOIC	PERMIAN	Ppc	Park City	130	Shows of CO_2
		Pwr	White Rim Sandstone	780	Shows of CO_2
		Pu	Lower Permian undifferentiated	540	
	PENNSYLVANIAN	IPu	Pennsylvanian undifferentiated	600-1200	Show of CO_2 and 17% methane in EDP 1 well
	MISSISSIPPIAN	Mu	Upper Mississippian undifferentiated	550-1000	
		Mm	Madison Limestone	500	
	DEVONIAN	D	Devonian undifferentiated	150	
	CAMBRIAN	C	Cambrian undifferentiated	270	

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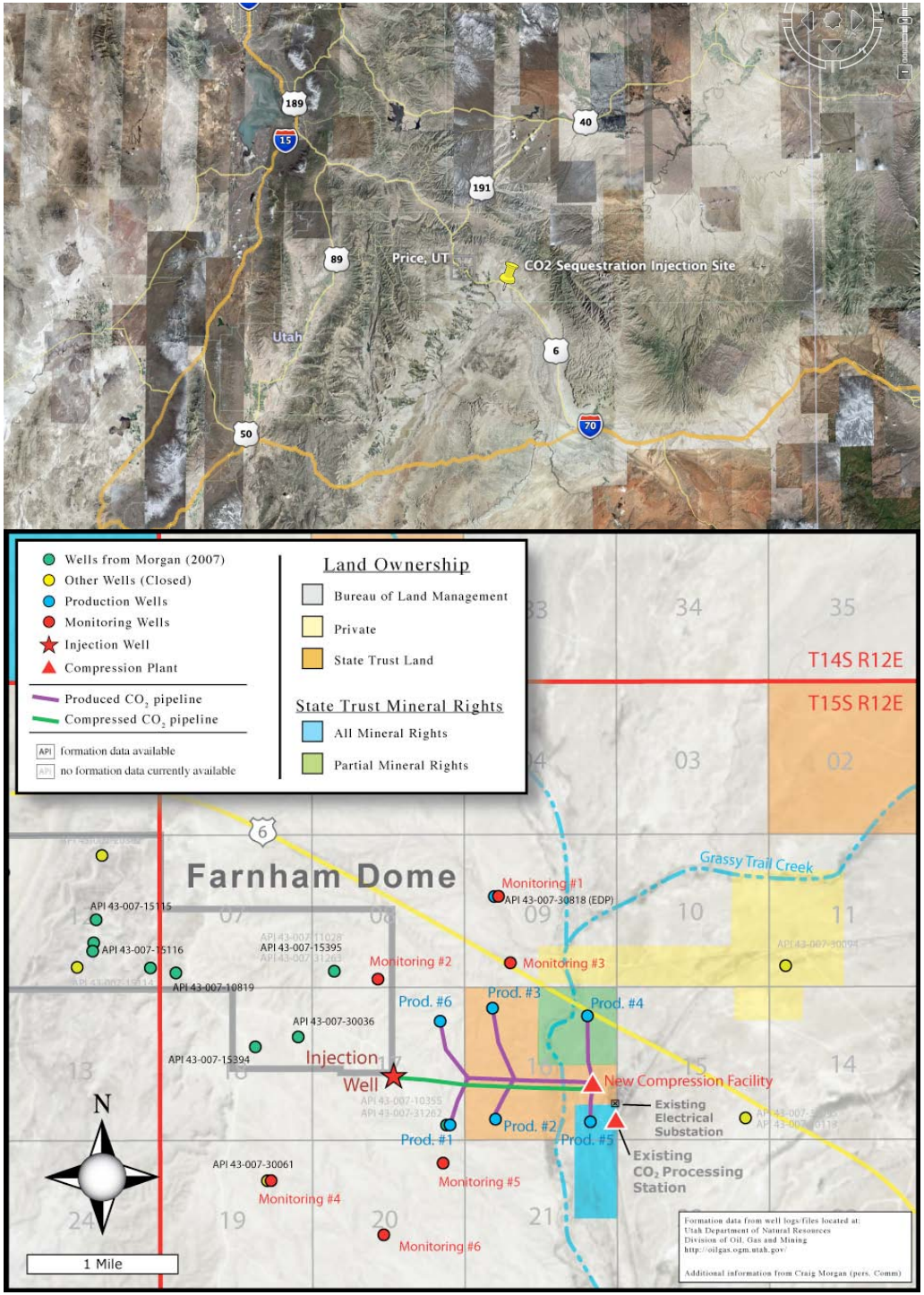

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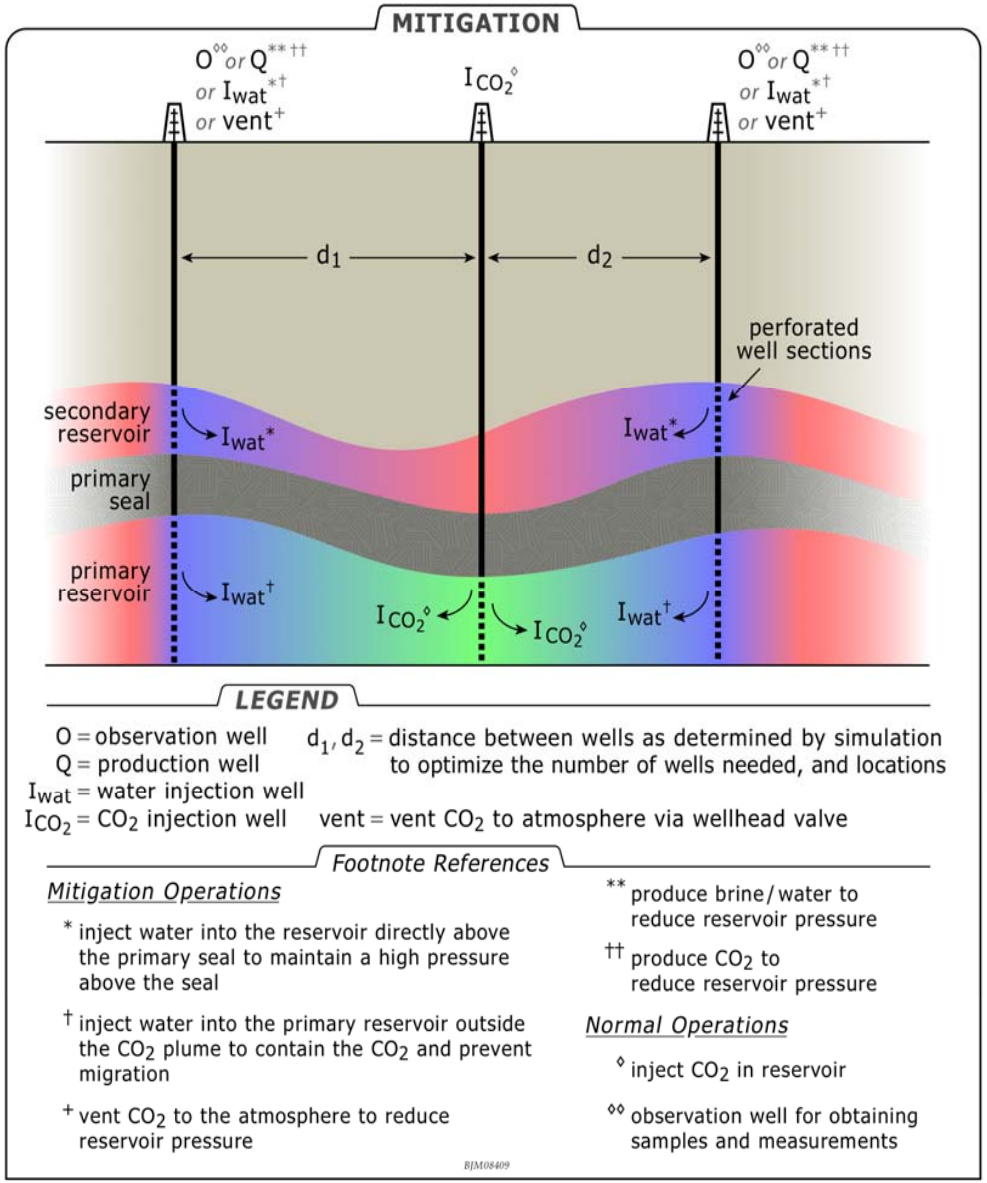

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Site Selection

Candidate Sites Characterized and Monitored –

- initial and boundary conditions for models established
- data density - amount of geological / hydrologic data available
- establish initial (baseline) presence of CO_2

Candidate Sites Modeled –

- Establish criteria / ability to verify containment and capacity ("VA")
- verify containment and capacity
- Footprint (size) of monitoring required
- frequency of monitoring surveys required
- data from monitoring and characterization used to parameterize models
- uncertainty associated with all processes quantified
- identify best mitigation options

Candidate Sites' Risk Evaluated –

- uncertainty estimated from models and simulation results used to develop probability density function of each risk feature / event / process (FEP)
- consequence (usually in $ or other) of a FEP multiplied by its probability to quantify risk
- **Site with best (least) risk profile is selected**

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Site Selection and Operations

Candidate Sites Characterized and Monitored –

- initial and boundary conditions for models established **(updated)**
- data density - amount of geological/hydrologic data available **(continuous gathering of data)**
- establish initial (baseline) presence of CO_2

Candidate Sites Modeled –

- Establish criteria/ability to verify containment and capacity ("VA")
- verify containment and capacity **(refine)**
- Footprint (size) of monitoring required **(updated)**
- frequency of monitoring surveys required **(updated)**
- data from monitoring and characterization used to parameterize **(refine)** models
- uncertainty associated with all processes quantified **(refined)**
- identify best mitigation options **(update)**

Candidate Sites' Risk Evaluated –

- uncertainty estimated **(refined)** from models and simulation results used to develop probability density function of each risk feature / event / process (FEP)
- consequence (usually in $ or other) of a FEP multiplied by its probability to quantify risk **(updated)**
- Site with best (least) risk profile is selected

Integrated Workflow of Monitoring, Risk Assessment, and Simulation

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*

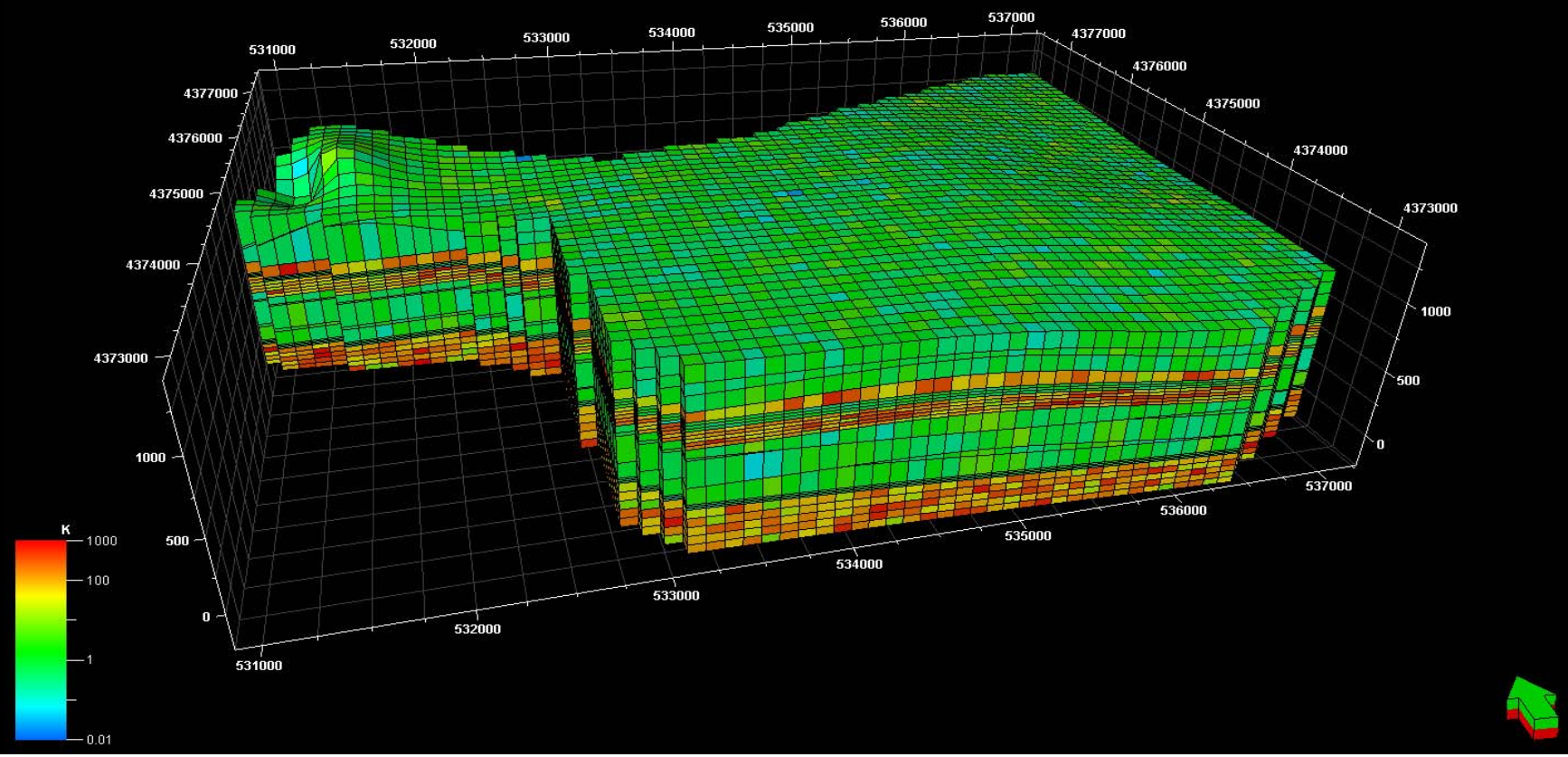
…as **model results and monitoring design become more effective,** uncertainty associated with probability of FEPs will decrease, *PDFs better defined, and risk profiles (values) better resolved*

…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)*

Not only is the workflow integrated, but the tools are also integrated on a <u>practical</u> level:

Example: scale model grid resolution (density) and size to the resolution of monitoring technologies; *example: subsurface resolution of seismic imaging techniques and areal size of surveys*



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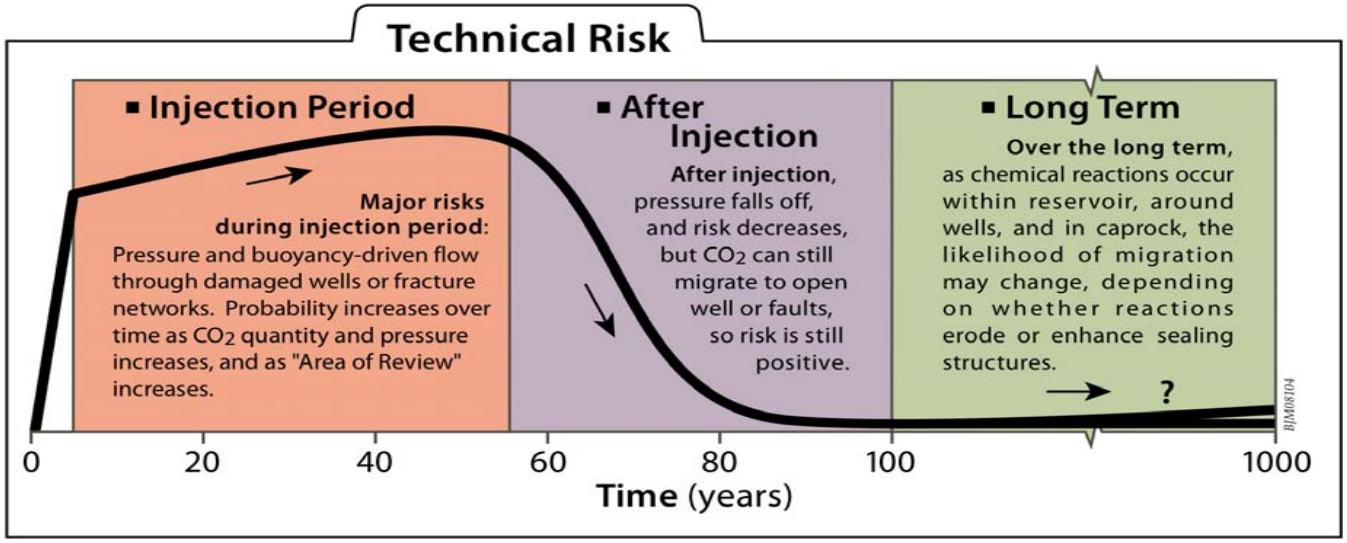
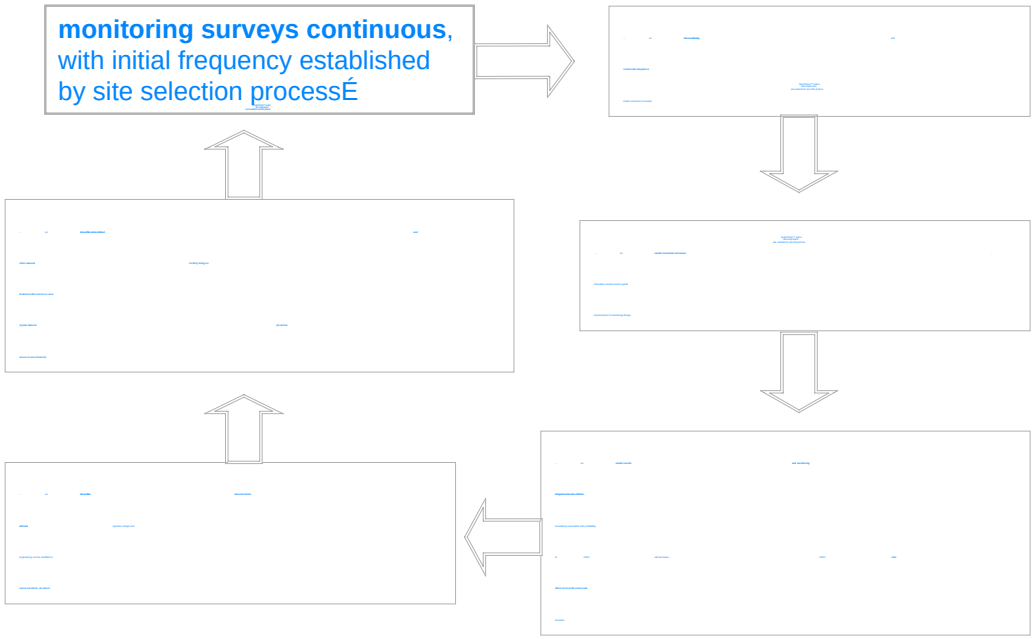


After site closure, risks to USDWs should drop off dramatically.

However, the same integrated monitoring, modeling and risk assessment will continue!



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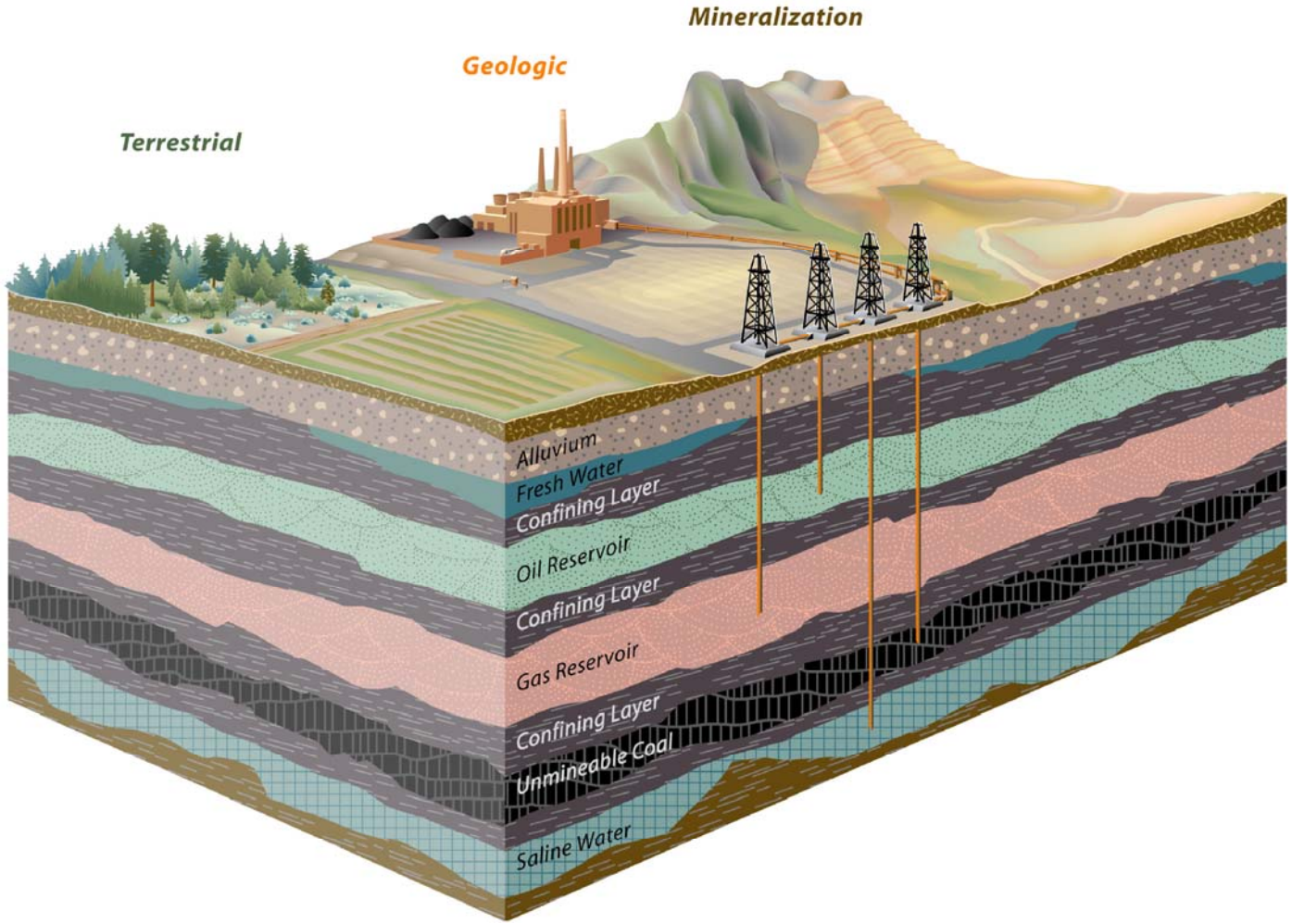

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Effective Integration Maximizes Integrity of Future Commercial-Scale Geologic Sequestration

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