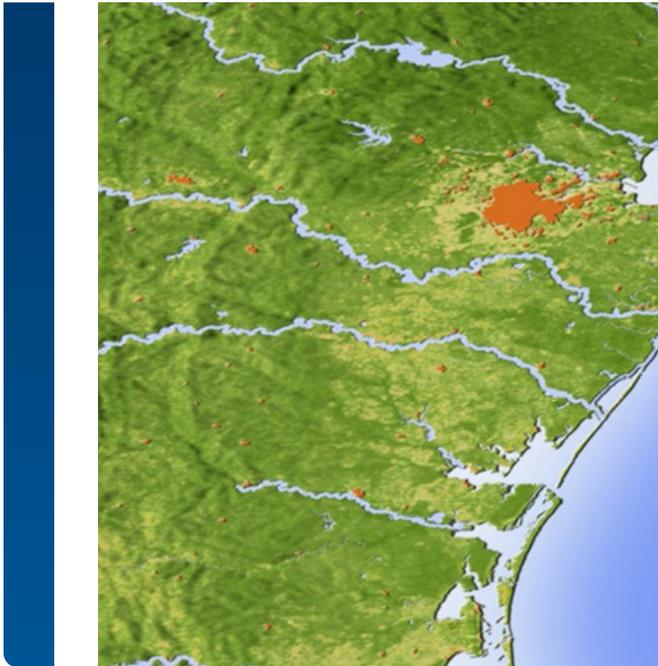


# Understanding and Determining the Area of Review for Class VI Wells



## How to leverage best-in-class planning and permitting to achieve success in carbon capture and storage

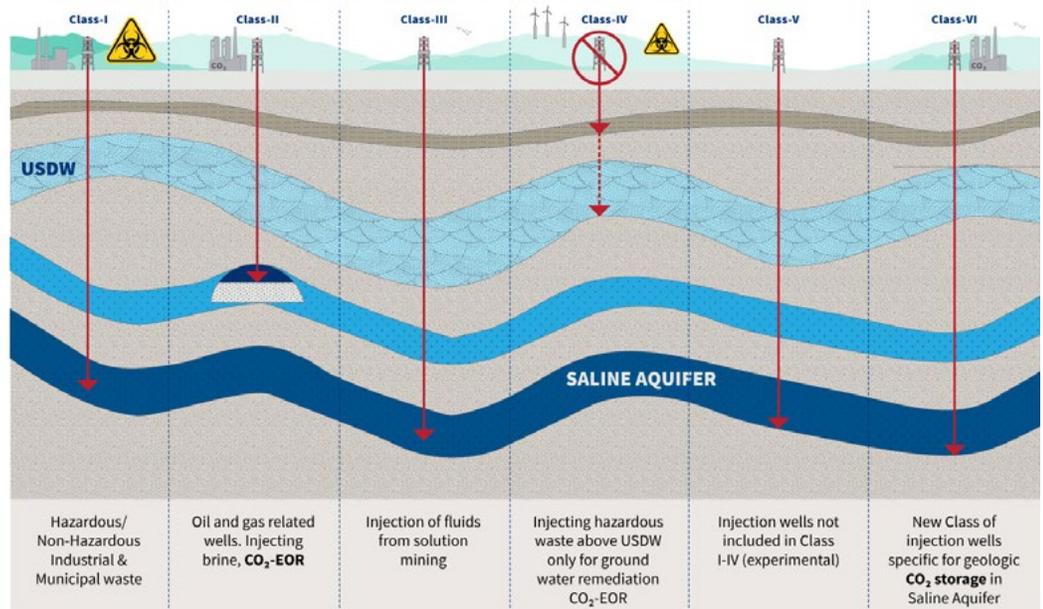
In the US, the number of Carbon Capture and Storage (CCS) projects in development is rapidly increasing, mainly due to government funding and tax incentives announced in 2022. For projects involving geological sequestration of CO<sub>2</sub> in the US, a permit to drill Class VI wells is required by the Environmental Protection Agency (EPA). One of the fundamental steps in the application process is determining the Area of Review (AoR).

### What is a Class VI Well?

Class VI is a new class of wells specific to the geological sequestration of CO<sub>2</sub>. (The other classes of well are shown in the diagram to the right.)

*Diagram showing the different EPA permitting classifications of carbon capture and storage wells and the different ground strata into which the well injects.*

### CARBON CAPTURE | TRANSPORT | UTILIZATION | STORAGE OVERVIEW OF EPA INJECTION PERMIT CLASSES FOR CO<sub>2</sub> INJECTION (CLASS-II/VI)



## Why do we need an Area of Review?

The Area of Review (AoR) refers to the region surrounding a CCS project where underground sources of drinking water (USDWs) could be affected by the injection of CO<sub>2</sub> into deep geological formations.

Drinking water could be endangered if there is a vertical leakage pathway between the CO<sub>2</sub> injection zone and the USDW.

Additionally, drinking water can be negatively impacted by the movement of CO<sub>2</sub> through changes in pH or acidity, contamination by trace impurities, including mercury or hydrogen sulfide, or the leaching of metals and organics.

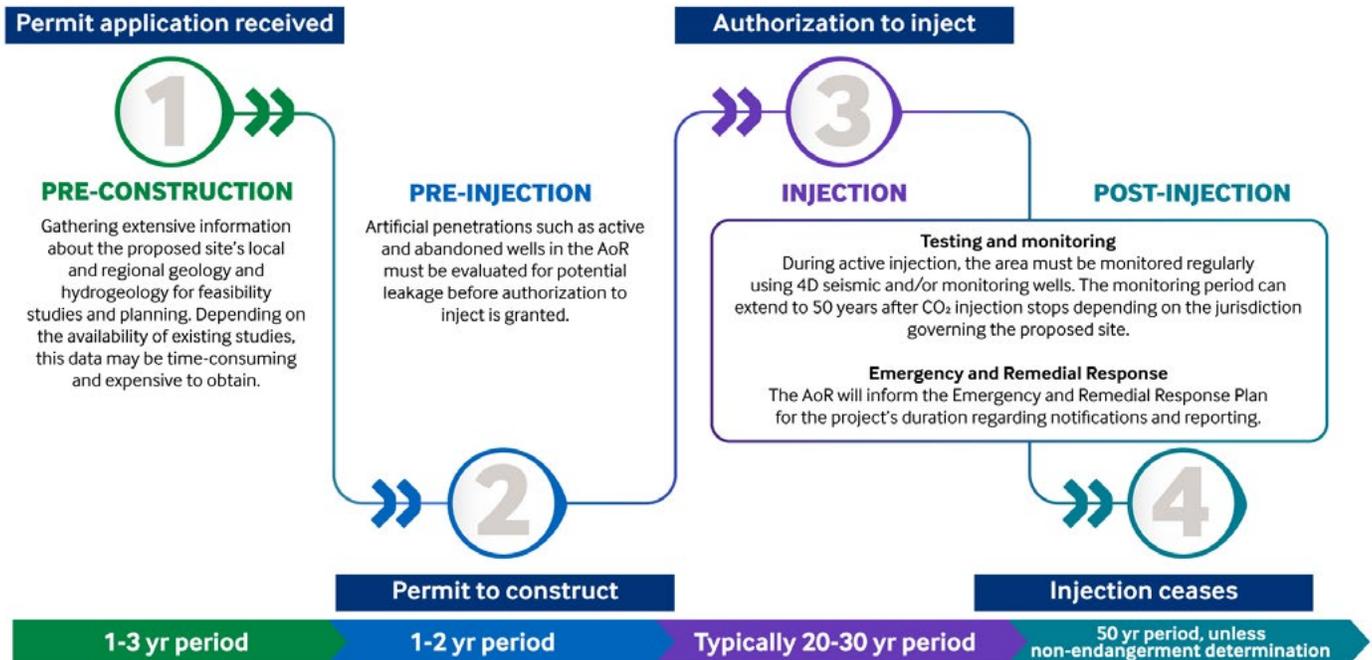
If non-potable water, such as brine, moves up into a USDW because of the increased pressure in an underlying geological formation (or reservoir) due to the injection of CO<sub>2</sub>, the USDW could become contaminated.

## What project considerations do the AoR impact?

The AoR sets the boundary area for Class VI permitting and will impact several factors.

1. Site characterization – Gathering extensive information about the proposed site's local and regional geology and hydrogeology for feasibility studies and planning. Depending on the availability of existing studies, this data may be time-consuming and expensive to obtain.
2. Corrective action – Artificial penetrations such as active and abandoned wells in the AoR must be evaluated for potential leakage before authorization to inject is granted.
3. Testing and monitoring – During active injection, the area must be monitored regularly using 4D seismic and/or monitoring wells. The monitoring period can extend to 50 years after CO<sub>2</sub> injection stops depending on the jurisdiction governing the proposed site.
4. Emergency and Remedial Response – The AoR will inform the Emergency and Remedial Response Plan for the project's duration regarding notifications and reporting.

## Major Stages for a Class VI UIC Well Permitting Project



## CO<sub>2</sub> plume and CO<sub>2</sub> pressure and their impact on the AoR

The CO<sub>2</sub> plume is the free-phase CO<sub>2</sub> boundary. It is the dispersing volume of CO<sub>2</sub> in geological formation. Modeling the size of the potential CO<sub>2</sub> plume is relatively straightforward once sufficient geological data has been gathered through site surveys and 3D seismic and operational data.

Under pressure – this is where it gets complex!

However, calculating the potential size of the pressure front caused by the injection of CO<sub>2</sub> is much more complex. The pressure level required to lift brine into a USDW must be calculated. The size of the pressure front can also be significantly larger than the plume size.

EPA guidance for calculating the pressure front  
The Environmental Protection Agency (EPA) does not prescribe a specific method for calculating the pressure front, but their guidelines refer to two formulas:

$$\Delta P_c = 1/2g\xi(z_u - z_i)^2 \quad \xi = \rho_i - \rho_u / z_u - z_i$$

[Thornhill et al., 1982.](#), (equation 1), which states that the pressure increase in the reservoir is equal to the pressure in the USDW plus the hydrostatic pressure of your fluid column minus the original pressure in your injection zone.

The second equation, offered by the EPA ([Nicot et al. and Bandilla et al. 2012](#)), (equation 2), is

$$\Delta P_{if} = P_u + \rho_i g(z_u - z_i) - P_i$$

and represents a set of assumptions that look at linear varying fluid density along a freely transmissive pathway that connects the injection zone to a USDW.

## Special considerations: Variables

The variables in the equations used to calculate the critical pressure for the AoR are foremost and can dramatically alter its size.

### Pressure of injection zone

Injecting into an over-pressurized reservoir could result in a smaller pressure needed to lift brine into the USDW, resulting in a larger pressure zone. An underpressurized reservoir has more buffer before critical pressure is reached.

### Density of the fluid in the injection zone

Fluid that is not very saline or dense means that you have less weight working in your favor, pushing back the injection.

### Heat

In the Thornhill equation, the mathematics will decrease the calculated value in hot reservoirs, resulting in a larger AoR. This consideration is especially applicable to the Gulf of Mexico.

## Why these equations don't always yield the "best" result

The variation in AoR sizes when using the same data set highlights the need for a thorough understanding of physics behind the equations proposed by the EPA. There are assumptions embedded in the formulas that may not apply to a specific project. One assumption is that there are freely transmissive pathways from the injection zone to a nearby USDW. The pathway could be an orphan well with a wellbore – no cement or drilling mud, only air. In this case, nothing prevents that fluid from migrating up to the USDW. Given the number of abandoned wells in the US, ensuring the AoR covers the wells that could impact the project while not being too large to become onerous is a challenge in some areas of the US.



## Why the smallest AoR isn't always the smartest

Based on the discussion above, many project owners might ask themselves, or their permitting team, why they shouldn't just choose the formula that yields the smallest AoR. It would be the cheapest option, at least in the short term, which could get the project started faster.

This question is especially relevant for small exploration companies focused on flipping a project to the highest bidder early in the project lifecycle.

However, selecting a too-small AoR (based solely on reducing the costs of site characterization, corrective action and monitoring) could result in increased risk.

The risk factors are operational, contractual and reputational risk, resulting in:

- a leak beyond the AoR boundary due to not correcting artificial penetrations, such as wellbores
- temporary closure of the site until corrective action is taken following a leak
- breach of contract as the facility is no longer able to accept CO<sub>2</sub> for injection from clients
- increased scrutiny or the inability to obtain additional permitting approvals post-incident
- new legislation and stricter permitting requirements that delay or derail future CCS projects.

## How to make sure your project has the right sized AoR

Depending on the project's location, geology and hydrology, your team's technical specialists may find it helpful to consider alternatives to the methods referred to in the EPA guidelines when defining and "right-sizing" CCS project AoR. We consider the needs of a successful project as well as the needs of the permitting process. Our team of permitters have had projects approved using alternative methods for delineating the AoR and can advise you on the most appropriate approach for your project.



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