



Underground Injection Control Geologic Sequestration Rule Training Workshop: Injection Well Plugging (40 CFR 146.92)

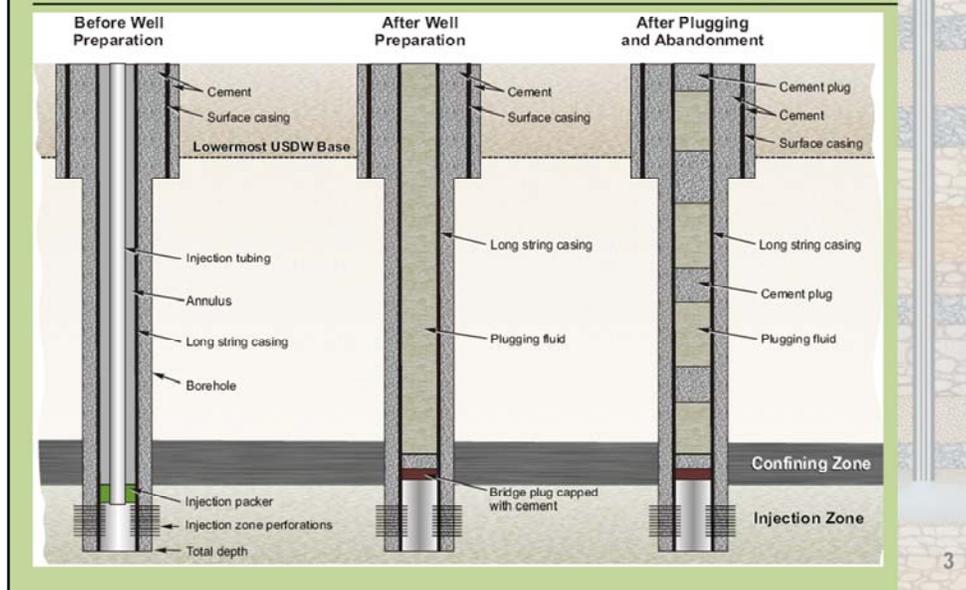
Purpose: Injection Well Plugging

- Ensure that:
 - Class VI wells are plugged and abandoned in a manner that is protective of USDWs
 - Class VI wells are plugged with injectate- and formation fluid- compatible materials

2

Following cessation of injection and when the injection well is no longer of use for monitoring at the GS project, the Class VI well must be plugged and abandoned in a manner such that they do not serve as a future conduit for fluid movement to USDWs. Plugging materials used for Class VI wells will need to be compatible with the both the injectate and formation fluids.

Class VI Injection Well Plugging



This diagram shows schematics of Class VI injection wells during different stages of plugging.

The left diagram shows a Class VI well prior to plugging. The tubing and packer are still in the well. Prior to plugging the well has been flushed with a buffer fluid, bottomhole pressure measured, and an external mechanical integrity test of the well performed.

The middle diagram shows a bottom bridge plug placed in the well. A cement retainer is often used so cement can be pumped and placed below and above the plug. Plugging fluid has been circulated in the well so this well will not be circulated with cement.

The diagram on the right illustrates the well after plugging. Cement plugs have been spotted in the well at strategic locations for protection of USDWs.

Injection Well Plugging: UIC Program Director Review

- Injection Well Plugging Plan
 - With permit application
 - No mandated periodic review of plan updates
- Notice of Intent to Plug
 - Prior to plugging activities
- Well Plugging Report
 - Following plugging activities

4

To ensure that effective methods are used for well plugging, the UIC Program Director must review, and approve, the Injection Well Plugging Plan submitted with the permit application. There is no requirement for updating the plan. However, changes in facility operations or any other data could warrant amendments, such as a significant change in wellbore configuration as a result of a workover. The Director would likely want the owner/operator to revisit and update the plan if such a change occurred. Prior to plugging, the Director will need to review the Notice of Intent to Plug and later the actual Well Plugging Report once the well is plugged.

Injection Well Plugging Plan: Purpose

- Ensures that effective methods are used for plugging



Project
Plan

40 CFR 146.92(b)

5

The regulations require the owner/operator to prepare, maintain, and comply with a Plugging Plan. The goal of the plan is to ensure that effective methods are used for plugging the injection well. Owners or operators must submit the Injection Well Plugging Plan with the permit application. Details for the plan are found in 40 CFR 146.92(b).

Class VI well plugging plans are much like the plugging and abandonment plans required of other UIC well classes.

Sample Injection Well Plugging Plan Table of Contents

Injection Well Plugging Plan

- 1) Tests or measures to determine bottom-hole reservoir pressure
- 2) Ensure external MIT
- 3) Type and number of plugs
- 4) The placement of each plug
- 5) Type, grade, and quantity of plugging material and compatible material confirmation
- 6) Method of placement of the plugs

40 CFR 146.92(b)(1)-(6)

6

This is a sample table of contents for an Injection Well Plugging Plan that the UIC Program Director may receive. It incorporates all of the required elements of the plan that need to be reviewed.

The regulations require:

- 1) Appropriate tests or measures for determining bottom-hole reservoir pressure
- 2) Appropriate testing methods to ensure external mechanical integrity
- 3) The type and number of cement plugs to be used in the well
- 4) The placement of each plug including the calculated top and bottom depths of each plug.
- 5) The type, grade, and quantity of plugging material and confirmation the material is compatible with the carbon dioxide stream; and
- 6) The method of placement of the plugs, for example: Will the plugs be spotted or will cement be circulated from bottom to top?

A wellbore schematic may be a useful tool to illustrate many of these requirements

Owners or operators are provided flexibility in selecting plugging materials and methods, provided the materials are suitable for contact with carbon dioxide.

Notice of Intent to Plug

- Must be submitted 60 days prior to plugging for UIC Program Director to review
- Includes:
 - Time/date of plugging
 - Name/location of well(s)
 - Parties performing plugging
- If needed, submit amended Plan



40 CFR 146.92(c)

7

At least 60 days prior to plugging of a well, the owner or operator must provide the UIC Program Director with a notice of their intent (NOI) to plug. The NOI to plug should include:

- The time and date of anticipated plugging;
- The name and location of the well to be plugged; and,
- A list of which parties will be performing the plugging activities.

Any changes that have been made to the approved Injection Well Plugging Plan must be approved by the Director and incorporated into the permit prior to plugging. Any permit change is subject to the permit modification requirements, which can be found at 40 CFR 144.39 and 40 CFR 144.41, for minor permit modifications.

Plugging Report

- Submitted 60 days after plugging for the UIC Program Director to review
- Detailed account of how Injection Well Plugging Plan was implemented



40 CFR 146.92(d)

8

The owner or operator must provide the UIC Program Director with a plugging report within 60 days after plugging.

The report must be certified as accurate by the owner or operator and by the person who performed the well plugging if other than the owner/operator.

The plugging report is intended to provide the UIC Program Director with an account of the specific activities that took place during well plugging. Should any deviations from the approved plugging plan occur, these should be highlighted in the report.

The report must include the location of the well, the date the well was plugged, and details in the plugging plan, such as how the well was prepared for plugging, the materials used for plugging, depth of plugs, and methods used for plug placement.

The UIC Program Director may request additional information if sufficient detail has not been included to independently assess the quality of the well plugging. Furthermore, the UIC Program Director may require additional plugging activities, if necessary.

The owner/operator is required to retain the well plugging report for 10 years following site closure, not well closure.

Some Class VI Program Injection Well Plugging Resources

- For more information on injection well plugging, refer to:
 - Draft UIC Class VI Primacy Application and Implementation Manual
 - EPA's Class VI Web site:
<http://water.epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>

9

Some Class VI Program injection well plugging resources currently available are:

- The Draft UIC Program Class VI Primacy Application and Implementation Manual.
- EPA's Class VI website:
<http://water.epa.gov/type/groundwater/uic/class6/gclass6wells.cfm>.

There will also be guidance on this topic in the forthcoming Draft Class VI Well Plugging, PISC and Site Closure Guidance currently under development.



Now we're going to discuss something that isn't typical of most of the other UIC well classes, Post Injection Site Care or "PISC" and site closure.

Purpose: PISC and Site Closure

- Ensures that, following the cessation of injection:
 - Plume and pressure front monitoring continue
 - There is no risk of endangerment to USDWs

The Class VI PISC and site closure requirements ensure that the carbon dioxide plume and pressure front continue to be monitored following the cessation of injection and also to ensure that there is no risk of endangerment to USDWs.

PISC and Site Closure Plan

- Describes PISC monitoring activities and their frequency
- Goals:
 - To ensure USDW protection beyond active life of the GS project
 - Gather data to support a successful non-endangerment demonstration

40 CFR 146.93(a)(1)

Project
Plan

12

The Class VI well's owner/operator is required to prepare, maintain, and comply with an injection well PISC and Site Closure Plan. The plan ensures that —prior to commencement of carbon dioxide injection— the owner or operator has approval from the Director on the procedures that will be needed after injection operations cease.

The PISC and Site Closure Plan will also help identify the appropriate types and amounts of data needed to determine that the carbon dioxide plume and pressure front do not endanger USDWs, and it will support a determination of whether conditions warrant site closure and therefore an end to PISC (i.e., there is no longer a risk of endangerment to USDWs).

PISC and Site Closure Plan Timeframe

- Timeframe for Plan must cover the entirety of PISC timeframe
- Alternative timeframe must be approved by the UIC Program Director

The PISC and Site Closure Plan must cover a timeframe that matches the duration of the PISC timeframe determined appropriate for the GS project based on site specific information. As we'll discuss later, the minimum PISC timeframe in the regulations is 50 years, though the Director may approve an alternative timeframe.

Sample PISC and Site Closure Plan Table of Contents

Post-Injection Site Care and Site Closure Plan

- 1) Pre- and predicted post-injection pressure differential
- 2) Predicted position of the CO₂ plume and associated pressure front at site closure
- 3) Post-injection monitoring plan
- 4) Proposed schedule for submitting PISC monitoring information
- 5) Duration of PISC timeframe
- 6) Site Closure Plan

40 CFR 146.93(a)

This is a sample table of contents for a PISC and Site Closure Plan that the UIC Program Director may receive.

Along with basic facility information, the PISC Plan includes:

- 1) Pressure differential between the Pre- and predicted Post-Injection Pressure
- 2) Predicted position of the carbon dioxide plume and associated pressure front at site closure which is demonstrated in the AOR evaluation
- 3) Description of the post-injection monitoring location, methods, and proposed frequency
- 4) Proposed schedule for submitting PISC monitoring results to the Director; and
- 5) The duration of PISC timeframe
- 6) The Site Closure Plan

This is adapted from the template in Appendix D of the Project Plan Development Guidance.

PISC and Site Closure Plan Updates

- No set frequency for reevaluation
- Consider:
 - Whether site care is adequate
 - Needed changes to monitoring
 - Data for non-endangerment demonstration

15

Just as with the plugging plan, the GS Rule does not set a required frequency or a schedule for the review of the PISC and Site Closure Plan during the operational phase. The UIC Program Director may require a review if any adverse events or significant deviations from predicted performance occur. At the end of operations when the pressure buildup and injection volumes are known and can be compared to predicted values, the owner/operator must submit an amended PISC/Site Closure Plan or demonstrate the existing plan is adequate. Periodic reviews of the plan during post-injection site care are also appropriate.

Considerations for determining the need for updating the post-injection site care and site closure plan include:

- Whether site care is adequate to ensure that USDWs are protected from endangerment from carbon dioxide injection activities (or provide early warning of potential endangerment);
- Whether changes to monitoring are needed, e.g., if the types or frequency of monitoring can be reduced as data indicate a post-injection stabilization of the carbon dioxide plume and the reservoir pressure buildup is insufficient to endanger USDWs; and finally
- Whether appropriate amounts and types of data are being collected to support an eventual non-endangerment demonstration, and whether making this demonstration before the 50 year PISC timeframe is appropriate.

PISC Period Timeframe

- Default is 50 years following cessation of injection
 - Can be shortened by UIC Program Director if the owner or operator makes a successful non-endangerment demonstration
 - Can be extended by UIC Program Director if the owner or operator cannot demonstrate non-endangerment and there are still risks to USDWs

40 CFR 146.93(b)(1)-(2)

16

The PISC timeframe is set at a default minimum of 50 years following the cessation of injection. The UIC Program Director has the discretion to end PISC monitoring completely, prior to the 50 year default time period, if the owner or operator can make a strong demonstration that the project will no longer pose any risk of endangerment to USDWs. At which point, authorization may be granted for site closure. Details regarding how the non-endangerment demonstration will be made on a site-specific basis must be included within the PISC and Site Closure Plan.

The PISC timeframe may also be extended by the UIC Program Director if after 50 years the Director determines that USDWs may still become endangered by the carbon dioxide plume and/or pressure front. Records collected during the PISC period must be retained by the owner or operator for 10 years following site closure. After this retention period, the records must be provided to the Director, who will designate a location where the records will be retained.

PISC Period Timeframe (cont'd.)

- Alternative PISC Timeframe
 - At the Director's discretion, the owner or operator may propose an alternative PISC timeframe with the permit application

40 CFR 146.93(b)(1)-(2)

17

At the Director's discretion, the owner or operator may propose an alternative PISC timeframe with the permit application. The owner or operator must provide a demonstration that this timeframe will not result in endangerment of USDWs.

Demonstration of Alternate PISC Timeframe

- Demonstration must consider and document:
 - Computational modeling results
 - Pressure decline predictions
 - Rate of carbon dioxide plume migration
 - Carbon dioxide chemical trapping processes
 - Rate of carbon dioxide trapping

40 CFR 146.93(c)(1)

18

The UIC Program Director has the discretion to allow an alternative PISC timeframe, whether shorter or longer than 50 years. The Director will want to consult with EPA prior to approving an alternative PISC timeframe.

The owner's or operator's demonstration for an alternative PISC timeframe must include consideration and documentation of 11 items listed in 40 CFR 146.93(c)(1):

- The results of computational modeling from the AoR delineation.
- The predicted timeframe for pressure decline within the injection zone, and any other zones, such that formation fluids may not be forced into any USDWs and/or the timeframe from pressure decline to pre-injection pressures.
- The predicted rate of carbon dioxide plume migration within the injection zone and the predicted timeframe for plume stabilization.
- A description of the site-specific processes that will result in carbon dioxide trapping including immobilization by capillary trapping, dissolution, and mineralization at the site. This information must be verified using the results of laboratory analyses, research studies, and/or field or site-specific studies.
- The predicted rate of carbon dioxide trapping in the immobile capillary phase, dissolved phase, and/or mineral phase. Again, this information must be verified using the results of laboratory analyses, research studies, and/or field or site-specific studies.

Demonstration of Alternate PISC Timeframe (cont'd.)

- Demonstration must consider and document:
 - Characterization of the confining zone(s)
 - Conduits for fluid movement
 - Description of well construction and quality of plugs
 - The distance between the injection zone and USDWs

40 CFR 146.93(c)(1)

19

The owner/operator demonstration for an alternative PISC timeframe must ALSO include consideration and documentation of:

- A characterization of the confining zone(s) including a demonstration that it is free of transmissive faults, fractures, and micro-fractures and of appropriate thickness, permeability, and integrity to impede fluid (e.g., carbon dioxide, formation fluids) movement.
- The presence of potential conduits for fluid movement including planned injection wells and project monitoring wells associated with the proposed geologic sequestration project or any other projects in proximity to the predicted/modeled, final extent of the carbon dioxide plume and area of elevated pressure.
- A description of the well construction and an assessment of the quality of plugs of all abandoned wells within the area of review.
- The distance between the injection zone and the nearest USDWs above and/or below the injection zone.
- Any additional site-specific factors required by the Director.

Non-Endangerment Demonstration

- Based on monitoring data and modeling
- UIC Program Director reviews prior to authorizing site closure
- Analysis and discussion of risk of endangerment to USDWs
 - How risk changed over time
 - Future risk outlook

40 CFR 146.93(b)

20

The frequency of PISC monitoring and the types of monitoring that must be performed are determined by the risk of endangerment to USDWs. If a reduction in risk is demonstrated, the frequency of PISC monitoring may decrease.

The owner/operator must submit relevant monitoring data used in the non-endangerment demonstration. Monitoring data are integral to the determination of plume migration rates and risk to USDWs and must include both direct and indirect data on the position and rate of movement of the carbon dioxide plume and pressure front.

The owner or operator is required to provide a written quantitative analysis and discussion of any risk of endangerment to USDWs, including how the risks have changed over time and how they may persist in the future. This demonstration will ideally provide enough information to the UIC Program Director so that he or she is able to make a determination of whether a reduction in PISC monitoring frequency, or an end to PISC, is acceptable at that time. The Director may independently assess this quantitative analysis, underlying data, and relevant assumptions.

In addition, the owner or operator may also submit modeling results in support of the non-endangerment demonstration, in order to assess the risk posed to USDWs. Modeling may be used to estimate the phase-state and degree of trapping of carbon dioxide over time and future plume migration. Modeling results, including sensitivity analyses, may be used to demonstrate that plume migration rates are negligible, based on available site characterization, monitoring, and operational data.

Notice of Intent for Site Closure

- Submitted at least 120 days prior to site closure for UIC Program Director to review
 - Shorter notification period allowed at UIC Program Director's discretion

40 CFR 146.93(d)

21

The owner or operator must notify the UIC Program Director in writing at least 120 days prior to site closure and cessation of PISC activities. Any changes to the PISC and Site Closure Plan must also be submitted at this time and will be evaluated by the Director as discussed previously. A shorter notification period may be allowed at the discretion of the Director.

Activities to occur prior to site closure include, but may not be limited to, plugging all monitoring wells; submitting a site closure report; and recording a notation on the deed to the facility property or other documents that the land has been used to sequester carbon dioxide. Site closure would proceed according to the approved PISC and Site Closure Plan.

Site Closure Report

- Submitted within 90 days of authorization of site closure for UIC Program Director to review
- Includes:
 - Documentation of plugging activities
 - Information on composition and volume of CO₂ stream
 - Survey plat

40 CFR 146.93(f)

22

A site closure report must be submitted within 90 days of the UIC Program Director's authorization of site closure. The purpose of the report is to document appropriate closure procedures, as well as information concerning injection well operation, which may be of interest to future land owners and planners.

The report must:

- Document proper injection well plugging and monitoring well plugging;
- Include records reflecting the nature, composition, and volume of carbon dioxide stream; and,
- Contain a copy of a survey plat that has been submitted to the local zoning authority designated by the Director.

PISC and Site Closure: UIC Program Director Review

- Post-Injection Site Care and Site Closure Plan
 - With permit application
- Non-endangerment Demonstration and Notice of Intent for Site Closure
 - Prior to authorizing site closure
- Site Closure Report
 - Following site closure activities



23

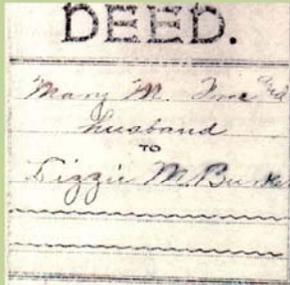
The UIC Program Director reviews the PISC and Site Closure Plan with the permit application. The Director has the discretion to require any additional information necessary to support this Plan.

Prior to authorizing site closure, the Director will review the non-endangerment demonstration and the notice of intent for site closure.

The site closure report is reviewed following all site closure activities.

Site Closure Record Retention

- Records must be retained by the owner or operator for 10 years following site closure, then provided to the UIC Program Director



- Notation on facility property deed
- Any other steps required by UIC Program Director

40 CFR 146.91(f)(4) & 146.93(g)-(h)

24

Records collected during the PISC period must be retained by the owner or operator for 10 years following site closure. After this retention period, the records must be provided to the UIC Program Director, who will designate a location where the records will continue to be retained.

Each owner or operator of a Class VI injection well must record a notation on the deed to the facility property that notes that the land has been used for GS, the name of the agency with which the survey plat was filed, the volume of fluid injected, the time period of injection, and the injection zone(s). These requirements ensure that the site was properly closed and that proper notifications have been made for future landowners.

EPA recommends that the UIC Program Director confirm that submitted information is both accurate and complete.

Some Class VI Program PISC and Site Closure Resources

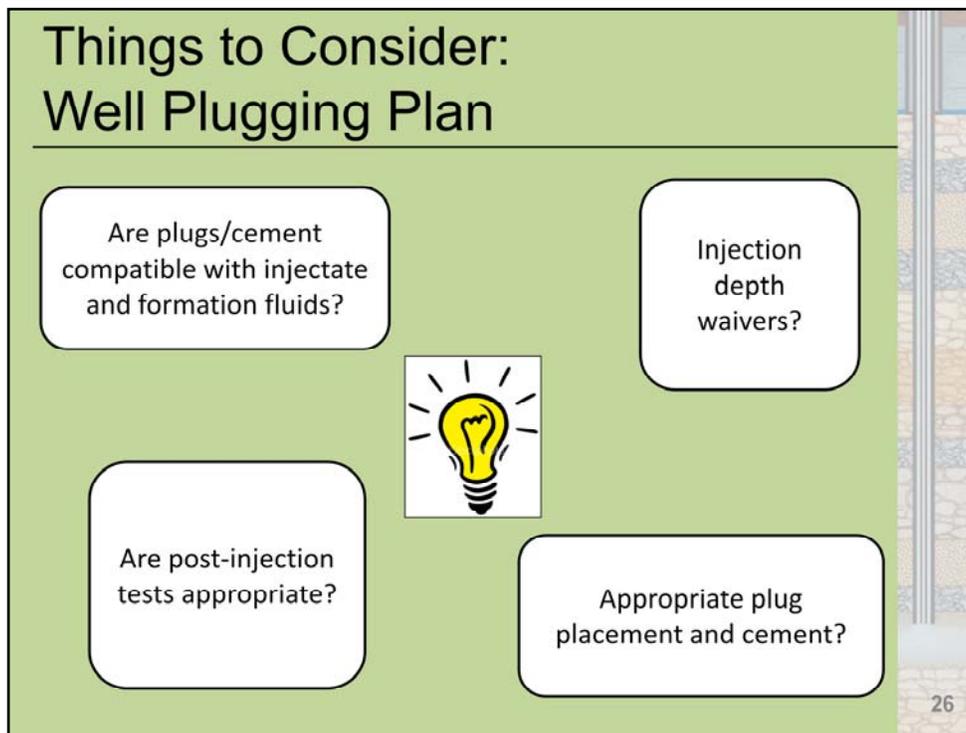
- For more information on PISC and site closure, refer to:
 - Draft UIC Class VI Primacy Application and Implementation Manual
 - EPA's Class VI Web site: <http://water.epa.gov/type/groundwater/uic/class6/gsclass6wells.cfm>

25

Class VI Program PISC and site closure resources that are currently available or will be available in the future are:

- The Draft UIC Program Class VI Primacy Application and Implementation Manual.
- And EPA's Class VI website:
<http://water.epa.gov/type/groundwater/uic/class6/gsclass6wells.cfm>.

These topics will also be covered in the Forthcoming Draft UIC Class VI PISC and Site Closure Guidance currently under development.



The UIC Program Director will review the operator's well plugging plan to ensure that it is complete and adequate to ensure that USDWs are protected. Questions that the Director will want to consider while reviewing the Injection Well Plugging Plan include:

1. Are the plugs and cement that the owner or operator proposes to use compatible with the injectate and formation fluid geochemistry?
2. Are proposed post-injection tests (e.g., MITs, bottom-hole reservoir pressure tests) sufficient to characterize the well and formation pressures?
3. Is the proposed placement of the plugs and cement appropriate based on the presence and depth of USDWs within the AoR or the presence of any other geologic features?
4. If injection depth waivers are allowed, does the proposed Injection Well Plugging Plan protect USDWs both above and below the injection zone?

Additional Discussion Questions (if needed):

1. What are the best industry standards to consider when taking into the account the unique properties of carbon dioxide?
2. Are any new technologies being considered that take into account the unique properties of carbon dioxide?

Things to Consider: PISC and Site Closure Plan

Do predictions match modeling and site data?



Will monitoring provide early warning of USDW endangerment?

Are all potential risks addressed?

27

The UIC Program Director will evaluate the proposed PISC and Site Closure Plan to verify that all required elements are present and that they account for all site-specific conditions to ensure that USDWs are protected from endangerment. For example:

1. Are predictions of pressure decline and fluid movement consistent with AoR modeling and do they accurately reflect geologic and operating data?
2. Is the proposed carbon dioxide plume and pressure front tracking appropriate to the predicted changes in subsurface conditions during post-injection?
3. Is the proposed post-injection monitoring (e.g., ground water quality monitoring) adequate to provide early warning of USDW endangerment?

Open Discussion

We'll open the floor for questions, experience sharing, comments on the slides, etc.

28

You are free to ask questions, provide examples of your experiences to date, or provide comments on the slides.

Discussion Questions (if needed):

1. Are there any features (chemicals, isotopic ratios) unique to the injected carbon dioxide that could be tested for and used to further examine the possibility of carbon dioxide leakage?
2. What type of additional review/questions may be appropriate if the owner or operator proposes an alternative post-injection site care timeframe?