Geologic Sequestration of Carbon Dioxide

Underground Injection Control (UIC) Program Class VI Implementation Manual for UIC Program Directors

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Disclaimer

The Class VI injection well classification was established by the *Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells* (75 FR 77230, December 10, 2010), referred to as the Class VI Rule, which establishes a new class of injection well (Class VI).

The Safe Drinking Water Act (SDWA) provisions and the United States Environmental Protection Agency (EPA) regulations cited in this document contain legally-binding requirements. While the document recommends basic steps for reviewing project information, it acknowledges and is designed to accommodate potential site-specific considerations and regulatory flexibility inherent in the Class VI Rule. In several sections, this guidance document makes suggestions and offers alternatives that go beyond the minimum requirements indicated by the Class VI Rule. This is intended to provide information and suggestions that may be helpful for implementation efforts. Such suggestions are prefaced by "may" or "should" and are to be considered advisory. They are not required elements of the Rule. Therefore, this document does not substitute for those provisions or regulations, nor is it a regulation itself, so it does not impose legally-binding requirements on the EPA, states, or the regulated community. The recommendations herein may not be applicable to each and every situation.

The EPA and state decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions regarding a particular facility will be made based on the applicable statutes and regulations. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This guidance may change in the future without a formal notice and comment period.

While the EPA has made every effort to ensure the accuracy of the discussion in this document, the obligations of the regulated community are determined by statutes, regulations, or other legally-binding requirements. In the event of a conflict between the discussion in this document and any statute or regulation, this document would not be controlling.

Note that this document only addresses issues covered by the EPA's authorities under SDWA. Other EPA authorities, such as Clean Air Act (CAA) requirements to report carbon dioxide injection activities under the Greenhouse Gas Reporting Program (GHGRP), are not within the scope of this document.

Executive Summary

The United States Environmental Protection Agency's (EPA's) *Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells* (75 FR 77230, December 10, 2010), and codified in the U.S. Code of Federal Regulations [40 CFR 146.81 *et seq*.], are known as the Class VI Rule. The Rule establishes a new class of injection wells (Class VI) and sets minimum federal technical criteria for Class VI injection wells for the purpose of protecting underground sources of drinking water (USDWs).

This *UIC Program Class VI Implementation Manual for UIC Program Directors* outlines and describes recommended activities to support Class VI permitting authorities in their review and evaluation of Class VI information over the course of a Class VI project. While the document recommends basic steps for reviewing project information, it acknowledges and is designed to accommodate potential site-specific considerations and regulatory flexibility inherent in the Class VI Rule. This Implementation Manual is intended to be used by Class VI permitting authorities in conjunction with a series of technical guidance documents that support Class VI injection well permit applicants/owners or operators as they conduct required activities.

The Manual is organized into the following sections:

- Section 1, Introduction, provides an overview of the Class VI requirements and Class VI projects. It also describes the EPA-developed tools that can support the UIC Program Director.
- Section 2, UIC Program Responsibilities, describes the roles and responsibilities the UIC Program has throughout the duration of a Class VI Project, including reviewing owner or operator submittals, reporting and recordkeeping responsibilities, communicating about the project, and assuring compliance with permit conditions.
- Section 3, Pre-Permitting Considerations, describes recommended steps that the UIC Program Director can take in advance of the formal submittal of a Class VI permit application, including assisting the applicant in gaining access to the Geologic Sequestration Data Tool (GSDT) and addressing specific topics on which pre-application discussions should be focused.
- Section 4, Reviewing Pre-Construction Information, describes recommended steps to facilitate the evaluation of information submitted in a Class VI permit application, issue a draft permit, and authorize construction or conversion of an injection well.
- Section 5, Reviewing Pre-Operation Information, presents recommendations to the UIC Program for reviewing final geologic data and the results of pre-operational testing and, based on this review, authorizing operation of the Class VI well.
- Section 6, Injection Phase Review, presents recommendations for ensuring that the project is protective of USDWs during injection operations by reviewing testing and monitoring data, evaluating area of review (AoR) reevaluations, and reviewing project plan updates.
- Section 7, Post-Injection Phase Review, describes recommendations regarding how the UIC Program Director should evaluate the information that owners or operators submit during the post-injection phase, including well plugging reports, post-injection monitoring data, non-endangerment demonstrations, and site closure reports.

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Acronyms and Abbreviations

AoPI	Area of Potential Impact
AoR	Area of Review
CAA	Clean Air Act
CCS	Carbon Capture and Storage
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIL	Casing Inspection Log
CROMERR	Cross-Media Electronic Reporting Regulation
EGR	Enhanced Gas Recovery
EJ	Environmental Justice
EOR	Enhanced Oil Recovery
EPA	U.S. Environmental Protection Agency
ESA	Electronic Signature Agreement
GHGRP	Greenhouse Gas Reporting Program
GIS	Geographic Information System
GS	Geologic Sequestration
GSDT	Geologic Sequestration Data Tool
LAS	Log ASCII Standard
mg/L	Milligrams per liter
MIT	Mechanical Integrity Test
MPRSA	Marine Protection, Research, and Sanctuaries Act
NRAP	National Risk Assessment Partnership
OCSLA	Outer Continental Shelf Lands Act
PAM	Program Activity Measure
PISC	Post-Injection Site Care
ppm	Parts per Million
PWSS	Public Water System Supervision Program (under SDWA)
QA	Quality Assurance
QASP	Quality Assurance Surveillance Plan
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SNC	Significant Noncompliance
STOMP	Subsurface Transport over Multiple Phases
TDS	Total Dissolved Solids
TOUGH	Transport of Unsaturated Groundwater and Heat
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
USGS	United States Geological Survey

Definitions

Key to definition sources:

1: 40 CFR 144.3.
2: 40 CFR 146.81(d).
3: 40 CFR 144.6(f) and 144.80(f).
4: This definition was developed for the purposes of this document.
5: Class VI Rule Preamble (75 FR 77230).

Administrator means the Administrator of the United States Environmental Protection Agency, or an authorized representative.[1]

Area of Review (AoR) means the region surrounding the geologic sequestration project where USDWs may be endangered by the injection activity. The area of review is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and displaced fluids, and is based on available site characterization, monitoring, and operational data as set forth in 40 CFR 146.84.[2]

Carbon dioxide plume means the extent underground, in three dimensions, of an injected carbon dioxide stream.[2]

Carbon dioxide stream means carbon dioxide that has been captured from an emission source (e.g., a power plant), plus incidental associated substances derived from the source materials and the capture process, and any substances added to the stream to enable or improve the injection process. This subpart [subpart H of 40 CFR 146] does not apply to any carbon dioxide stream that meets the definition of a hazardous waste under 40 CFR 261.[2]

Class VI wells means wells that are not experimental in nature that are used for geologic sequestration of carbon dioxide beneath the lowermost formation containing a USDW; or, wells used for geologic sequestration of carbon dioxide that have been granted a waiver of the injection depth requirements pursuant to requirements at 40 CFR 146.95; or, wells used for geologic sequestration of carbon dioxide that have received an expansion to the areal extent of an existing Class II enhanced oil recovery or enhanced gas recovery aquifer exemption pursuant to 40 CFR 146.4 and 144.7(d).[3]

Confining zone means a geologic formation, group of formations, or part of a formation stratigraphically overlying the injection zone(s) that acts as barrier to fluid movement. For Class VI wells operating under an injection depth waiver, confining zone means a geologic formation, group of formations, or part of a formation stratigraphically overlying and underlying the injection zone(s).[2]

Corrective action means the use of Director-approved methods to ensure that wells within the area of review do not serve as conduits for the movement of fluids into underground sources of drinking water (USDW).[2]

Geologic sequestration (GS) means the long-term containment of a gaseous, liquid, or supercritical carbon dioxide stream in subsurface geologic formations. This term does not apply to carbon dioxide capture or transport.[2]

Geologic sequestration project means an injection well or wells used to emplace a carbon dioxide stream beneath the lowermost formation containing a USDW; or, wells used for geologic sequestration of carbon dioxide that have been granted a waiver of the injection depth requirements pursuant to requirements at 40 CFR 146.95; or, wells used for geologic sequestration of carbon dioxide that have received an expansion to the areal extent of an existing Class II enhanced oil recovery or enhanced gas recovery aquifer exemption pursuant to 40 CFR 146.4 and 144.7(d). It includes the subsurface three-dimensional extent of the carbon dioxide plume, associated area of elevated pressure, and displaced fluids, as well as the surface area above that delineated region.[2]

Geophysical surveys refer to the use of geophysical techniques (e.g., seismic, electrical, gravity, or electromagnetic surveys) to characterize subsurface rock formations.[5]

Injection depth waiver refers to a waiver of the Class VI injection depth requirements by the UIC Program Director pursuant to the provisions at 40 CFR 146.95.[4]

Injection zone means a geologic formation, group of formations, or part of a formation that is of sufficient areal extent, thickness, porosity, and permeability to receive carbon dioxide through a well or wells associated with a geologic sequestration project.[2]

Injectivity is the pressure differential over existing reservoir pressure required to inject a unit volume of fluid in a given unit of time. It is typically expressed as psi/bbl/day (psi per barrel per day), but can be expressed in any combination of pressure, volume, and time units.[4]

Mechanical integrity testing (MIT) refers to a test performed on a well to confirm that a well maintains internal and external mechanical integrity. MITs are a means of measuring the adequacy of the construction of an injection well and a way to detect problems within the well system.[5]

Phased corrective action refers to a provision of the Class VI Rule [40 CFR 146.84(b)(2)(iv)] afforded to Class VI injection well owners or operators to defer some identified corrective action needed within the AoR, but farther away from the injection well, until after injection has commenced, but prior to carbon dioxide plume and pressure front movement into that particular area.[4]

Plug means a watertight, gastight seal installed in a borehole or well to prevent movement of fluids; it may be mechanical or composed of cement or other materials capable of zonal isolation.[4]

Post-injection site care (PISC) means the appropriate monitoring and other actions (including corrective action) needed following cessation of injection to ensure that USDWs are not endangered, as required under 40 CFR 146.93.[5]

Pressure front means the zone of elevated pressure that is created by the injection of carbon dioxide into the subsurface. The pressure front of a carbon dioxide plume refers to a zone where there is a pressure differential sufficient to cause the movement of injected fluids or formation fluids into a USDW.[2]

Site closure means the point/time, as determined by the Director following the requirements under 40 CFR 146.93, at which the owner or operator of a geologic sequestration site is released from post-injection site care responsibilities.[2]

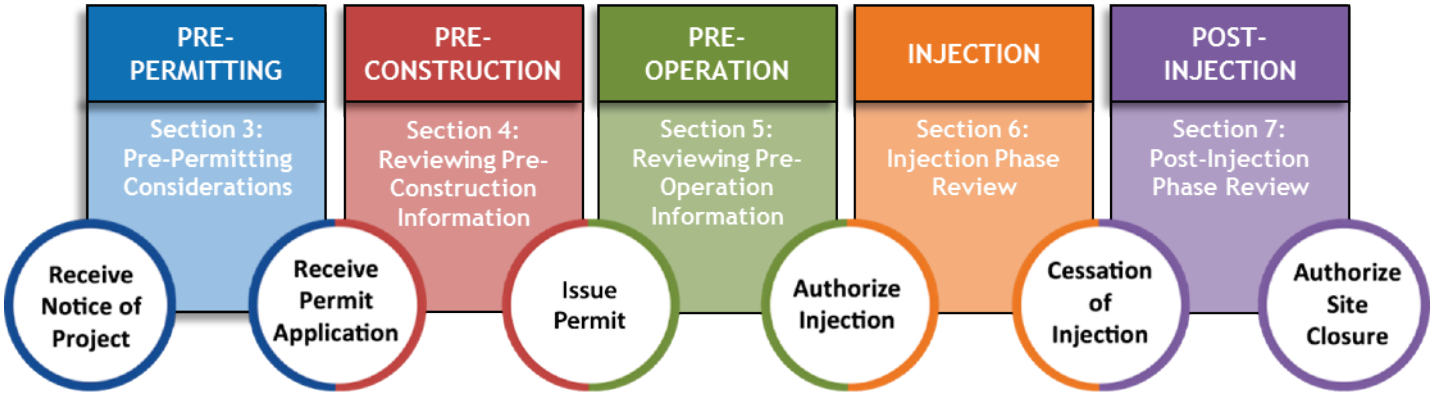
Transmissive fault or fracture means a fault or fracture that has sufficient permeability and vertical extent to allow fluids to move between formations.[2]

Underground Injection Control (UIC) Program refers to the program the EPA, or an approved state or tribe, is authorized to implement under the Safe Drinking Water Act (SDWA) and that is responsible for regulating the underground injection of fluids by well injection.[4]

UIC Program Director refers to the person responsible for permitting, implementation, and compliance of the UIC Program. For UIC programs administered by the EPA, the UIC Program Director is the EPA Regional Administrator or his/her delegatee; for UIC programs in primacy states, the UIC Program Director is the person responsible for permitting, implementation, and compliance of the state, territorial, or tribal UIC program.[5]

Underground Source of Drinking Water (USDW) means an aquifer or its portion which supplies any public water system; or which contains a sufficient quantity of groundwater to supply a public water system; and currently supplies drinking water for human consumption; or contains fewer than 10,000 mg/L total dissolved solids; and which is not an exempted aquifer.[1]

Section 1: Introduction



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1 Introduction

The United States Environmental Protection Agency's (EPA's) *Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide Geologic Sequestration (GS) Wells*, found at 75 FR 77230, December 10, 2010, and codified in the U.S. Code of Federal Regulations [40 CFR 146.81 *et seq*.], are referred to as the Class VI Rule. The Class VI Rule, promulgated under the authority of the Safe Drinking Water Act (SDWA, 42 U.S.C. §300h et al.), outlines federal requirements for the permitting, siting, construction, operation, monitoring, and site closure of Class VI injection wells, which are used to inject carbon dioxide for GS.

The UIC Program Director is responsible for ensuring that owners or operators of Class VI wells properly site, operate, monitor, and close their wells in a manner that protects underground sources of drinking water (USDWs) from endangerment. Throughout the duration of a Class VI project, permitting authorities are responsible for ensuring that:

- Class VI wells are sited and constructed such that USDWs are protected, considering site- and project-specific information collected in the pre-permitting, pre-construction and pre-operation phases;
- Class VI wells operate as planned and in compliance with the regulations as verified by testing and monitoring, in a manner that is protective of USDWs during the injection phase; and
- Post-injection monitoring is conducted until a USDW non-endangerment demonstration is made and approved by the UIC Program Director, the injection well and all monitoring wells are plugged, and the site is closed.

To achieve these goals, UIC Program Directors' activities include: reviewing Class VI permit applications; writing and issuing permits; authorizing injection; documenting decision-making; reviewing testing and monitoring data, the results of Area of Review (AoR) reevaluations, and other reports; responding to emergency situations or violations; addressing compliance issues; authorizing and approving site closure; and providing information about their oversight responsibilities to the EPA.

1.1 Document Purpose

This Implementation Manual provides guidance and procedural support to assist UIC Programs in implementing the Class VI Rule and overseeing the activities of owners or operators during the various phases of a Class VI project. Note that, given the complexity and multidisciplinary nature of Class VI projects (i.e., encompassing geology, engineering, modeling, etc.), permitting of Class VI projects will likely necessitate a team approach. In recognition that the activities and recommendations discussed in this Implementation Manual may be undertaken by UIC Program staff, through a team approach, this document refers to the "UIC Program" rather than the "UIC Program Director" unless directly referencing the regulations or specific activities for which a UIC Program Director is uniquely and individually responsible. Section 2 describes the roles of the UIC Program throughout the duration of a Class VI Project. Section 3 provides recommendations for forming a team with the necessary expertise, and Sections 4 through 7 describe the activities the UIC Program (i.e., the UIC Program Director and any team members) should perform during the various phases of a Class VI project.

The EPA encourages readers to review the Executive Summary and Sections 1 and 2 prior to receipt of a Class VI permit application. Sections 3 through 7 can be used as a reference throughout the duration of a Class VI project.

This Implementation Manual is not intended to provide an exhaustive explanation of the technical attributes of Class VI wells or how owners or operators can meet the Class VI requirements, nor does it address every situation that the UIC Program may encounter. Rather, it offers UIC Programs examples of considerations for reviewing Class VI owner or operator submittals, including where the Class VI Rule affords flexibility. In addition, references are made to other technical guidance documents that contain more specific, detailed guidance on these topics. These documents and other tools that support Class VI permitting are described in Section 1.4.

1.2 UIC Class VI Program Background

The Class VI Rule requirements at 40 CFR 146 Subpart H are tailored to the unique nature of carbon dioxide injection for GS, including the large volumes of carbon dioxide injected, the relative buoyancy of carbon dioxide, its mobility within subsurface geologic formations, and its corrosivity in the presence of water to ensure the protection of USDWs. Figure 1-1 summarizes the requirements for Class VI wells. For additional, specific information on the Class VI Rule, see the Class VI Rule and Preamble at 75 FR 77230.

Figure 1-1: Overview of the Federal Class VI Rule Requirements

The Class VI permit information requirements establish the information that owners or operators must submit to obtain a Class VI permit [40 CFR 146.82].

The minimum criteria for siting establish that Class VI wells must be located in areas with a suitable geologic system, including an injection zone that can receive the total anticipated volume of carbon dioxide and confining zone(s) to contain the injected carbon dioxide stream and displaced formation fluids [40 CFR 146.83].

The AoR and corrective action provisions require the use of computational modeling to delineate the AoR for proposed Class VI wells and the preparation of, and compliance with, an AoR and Corrective Action Plan for delineating the AoR, performing all necessary corrective action, and periodically reevaluating the AoR and amending the plan if needed [40 CFR 146.84].

The financial responsibility requirements establish that owners or operators must demonstrate and maintain financial responsibility for performing corrective action on improperly abandoned wells in the AoR, injection well plugging, post-injection site care (PISC) and site closure activities, and emergency and remedial response [40 CFR 146.85].

The injection well construction requirements specify the design and construction of Class VI wells using materials that are compatible with the carbon dioxide stream over the duration of the Class VI project to prevent the endangerment of USDWs [40 CFR 146.86].

The requirements for logging, sampling, and testing prior to operation outline activities, including logs, surveys, and tests of the injection well and formations, that must be performed before injection of carbon dioxide may commence [40 CFR 146.87].

The injection well operating requirements provide operational measures for Class VI wells to ensure that the injection of carbon dioxide does not endanger USDWs, along with limitations on injection pressure and requirements for automatic shut-off devices [40 CFR 146.88].

The mechanical integrity requirements specify continuous monitoring to demonstrate internal mechanical integrity and annual external mechanical integrity tests [40 CFR 146.89].

The testing and monitoring requirements define the elements that must be included in the required Testing and Monitoring Plan submitted with a Class VI permit application and implemented throughout the project to demonstrate the safe operation of the injection well and track the position of the carbon dioxide plume and pressure front [40 CFR 146.90].

The reporting requirements establish the periodic timeframes and circumstances for the electronic reporting of Class VI well testing, monitoring, and operating results and requirements for keeping records [40 CFR 146.91].

The injection well plugging requirements specify that a Class VI injection well must be properly plugged to ensure that the well does not become a conduit for fluid movement into USDWs in the future [40 CFR 146.92].

The post-injection site care (PISC) and site closure requirements address activities that occur following cessation of injection. The owner or operator must continue to monitor the site for 50 years following the cessation of injection, or for an approved alternative timeframe, until it can be demonstrated that no additional monitoring is needed to ensure that the project does not pose an endangerment to USDWs; following this, they must plug the injection and monitoring wells and close the site [40 CFR 146.93].

The emergency and remedial response requirements specify that owners or operators of Class VI wells must develop and maintain an approved Emergency and Remedial Response Plan that describes the actions to be taken to address events that may cause endangerment to a USDW or other resources [40 CFR 146.94].

The Class VI injection depth waiver requirements provide a process under which Class VI well owners or operators can seek a waiver from the injection depth requirements in order to inject carbon dioxide into non-USDWs that are located above or between USDWs. Including injection depth waiver provisions in a state's regulation is optional [40 CFR 146.95].

1.3 UIC Class VI Project Overview

This Implementation Manual is organized by the phases of a Class VI project, from pre-permit application activities and considerations through pre-construction, pre-operation, injection, and post-injection. Specific sections (i.e., 3 through 7) are dedicated to these Class VI project phases and may be referenced independent of other sections. Color is used in the footers and figures to facilitate navigation through the guidance sections on the various phases.

The phases of a Class VI project, as shown in Figure 1-2, include:

- The **pre-permitting phase**, when the applicant prepares the Class VI permit application. The UIC Program is encouraged to communicate with the prospective applicant as they develop the permit application to ensure that all required activities are performed and that the applicant is aware of any related approvals or permits they may need to obtain. See Section 3.
- The **pre-construction phase**, which follows the submittal of a Class VI permit application. This Implementation Manual provides recommendations for reviewing extensive geologic, modeling, hydrogeologic, engineering, and financial information about a proposed Class VI project in the permit application to confirm site-suitability, identify ways to address or mitigate uncertainties about the project, and develop a permit that protects USDWs from endangerment and allows construction of the well. See Section 4.
- The **pre-operation phase**, when the Class VI well owner or operator submits the results of required pre-operational testing, updated information about site geology, the final AoR, any needed amendments to the project plans, and information about the construction and testing of the well. This Implementation Manual provides recommendations for reviewing this information to ensure that any uncertainties

identified during the course of the permit application review have been addressed, verify site-suitability, confirm that the well was constructed or converted appropriately, and ultimately make a determination regarding authorization to inject. See Section 5.

- The **injection phase**, when Class VI well owners or operators conduct injection activities, perform testing and monitoring, and reevaluate the AoR as described in the Class VI permit and project plans. This Implementation Manual provides recommendations for reviewing this information to confirm that the well and the project are operating in compliance with the permit, the carbon dioxide plume and pressure front are behaving as predicted, and USDWs are not endangered. See Section 6.
- The **post-injection phase**, when the Class VI well owner or operator will plug the injection well, monitor the plume and pressure front, and, after demonstrating USDW non-endangerment, close the site. This Implementation Manual provides recommendations for reviewing the information submitted to verify that the project continues to be protective of USDWs and that, following site closure, the injection and monitoring wells at the site will not endanger USDWs. See Section 7.

1.4 Available Resources to Support Class VI Permitting

The EPA has developed a series of electronic tools and other resources to support permitting authorities and Class VI well permit applicants/owners or operators in understanding and implementing the requirements of the Class VI Rule.

The Geologic Sequestration Data Tool and Associated Resources

The Geologic Sequestration Data Tool (GSDT) can assist the UIC Program in organizing and retaining the large volume of material related to permit application reviews and subsequent project oversight activities. The EPA developed the GSDT to:

- Facilitate compliance with the electronic reporting requirement of the Class VI Rule at 40 CFR 146.91(e), providing reporting modules by which permit applicants/owners or operators can submit required information in an approved electronic format; and
- Support permitting authorities in tracking and managing submissions associated with Class VI reporting, including support for evaluation and oversight activities over the duration of a Class VI project.

Permitting authorities have full access to the GSDT, which allows them to access all submitted materials. They can also use the GSDT to support technical evaluations (including AoR delineation modeling), manage communications with owners or operators, and store all information related to a project. The GSDT allows permitting authorities to review and manipulate information while preserving the integrity of the original submitted data. Permitting authority users are limited to read-only access unless they are assigned to a particular project; however, no users can modify the original, time-stamped files submitted by owners or operators.

See Appendix A for a description of how the GSDT manages information and supports the needs of both permitting authorities and Class VI well permit applicants/owners or operators. See Section 3.1 for additional information on supporting permit applicants with accessing the GSDT.

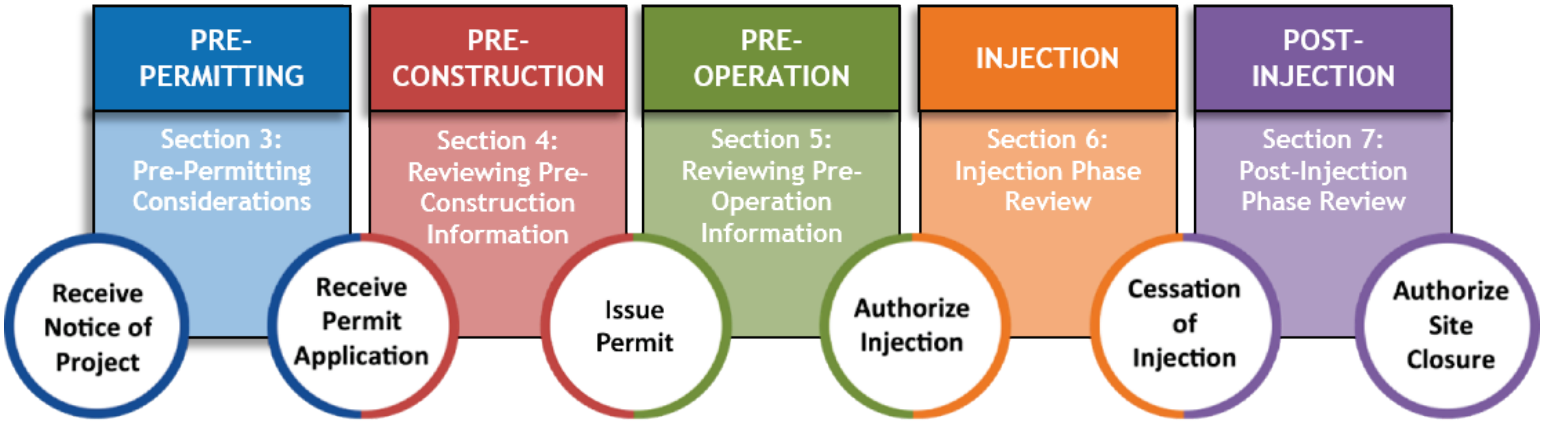

Figure 1-2: The Phases of a Class VI Project

The *UIC Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance for Owners and Operators* provides recommendations for complying with the reporting and recordkeeping requirements of the Class VI Rule. It covers electronic reporting in the context of the Class VI Program, the key components and capabilities of the GSDT's reporting modules, and how permit applicants can register to use and access the GSDT. While the primary audience for that guidance is Class VI permit applicants/owners or operators, it may also serve as a useful resource for permitting authorities. For example, it can help facilitate communicating with owners or operators who are using the GSDT or understanding the types of information that owners or operators might submit. The GSDT user guides provide additional support, with step-by-step instructions tailored to each component of the tool. The GSDT also has a resource library that contains available electronic tools, templates, and guidance (see below).

To register for a GSDT account as a permitting authority user, send an email to GSDataTool@epa.gov or request an account at https://epa.velo.pnnl.gov/gs3/.

Templates to Support Class VI Permitting

The EPA developed a series of templates to support the development of various documents associated with Class VI permitting and project oversight. These templates, for materials to be developed by both permit applicants/owners or operators and the UIC Program, can facilitate compliance with the Class VI Rule and promote consistency in Class VI permits issued nationwide. Table 1-1 presents these templates, which are available in the resource library of the GSDT.

Table 1-1: Templates to Facilitate Compliance with Federal Class VI Rule Requirements

Templates	Citation
Templates to support the submittal and evaluation of the Class VI permit application	
Narratives for permit application and associated submittals	40 CFR 146.82(a); 146.82(c)
Requests for additional information from the applicant/owner or operator and a spreadsheet to support the development of a testing and monitoring strategy	40 CFR 144; 146
Templates of Class VI permit package elements	
Permit conditions	40 CFR 144; 146
Summary of Requirements	40 CFR 146.82(a)(10); 146.88; 146.91
AoR and Corrective Action Plan	40 CFR 146.82(a)(13); 146.84(b)
Testing and Monitoring Plan	40 CFR 146.82(a)(15); 146.90
Injection Well Plugging Plan	40 CFR 146.82(a)(16); 146.92(b)
PISC and Site Closure Plan	40 CFR 146.82(a)(17); 146.93(a)
Emergency and Remedial Response Plan	40 CFR 146.82(a)(19); 146.94(a)
Quality Assurance Surveillance Plan (QASP) for testing and monitoring activities	40 CFR 146.90(k)
Well Construction Details	40 CFR 146.82(a)(11),(12)
Financial Assurance Demonstration	40 CFR 146.82(a)(14); 146.85(a)
Stimulation Program	40 CFR 146.82(a)(9)

Templates	Citation
Templates to support the issuance of a Class VI permit and required notifications	
Statement of Basis	40 CFR 124.7
Fact sheet	40 CFR 124.8
Letter for public notice of the Class VI permit application	40 CFR 124.10
Interstate coordination letter about an AoR that crosses jurisdictional boundaries	40 CFR 146.82(b)
Notification to Public Water System Supervision (PWSS) Directors about an injection depth waiver	40 CFR 146.95(b)(2)
Templates to support required reporting and notifications during the injection and post-injection phases	
Semi-annual testing and monitoring reports	40 CFR 146.91(a)
Notice of intent to plug a well and injection well plugging report	40 CFR 146.92(c),(d)
Non-endangerment demonstration narrative	40 CFR 146.93(b)(3)
Notice of intent for site closure and site closure report	40 CFR 146.93(d),(f)

Financial Responsibility Cost Estimation Tool and Checklists

To support the evaluation of cost estimates provided pursuant to 40 CFR 146.85(a)(2), the EPA developed the Cost Estimation Tool for Class VI Financial Responsibility Demonstrations. The spreadsheet-based tool estimates costs for required activities, e.g., corrective action, injection well plugging, and post-injection testing and monitoring, based on site-specific information. The cost estimates for each activity are intended to assist the UIC Program in assessing whether the financial responsibility cost estimates in the permit application are adequate, and guide discussions between the UIC Program and permit applicants during the permit application review process.

The EPA also developed a set of electronic checklists to support the evaluation of proposed financial responsibility instruments by tracking the information necessary to determine the adequacy of the financial responsibility demonstration. The Cost Estimation Tool and the checklists are available in the resource library of the GSDT. See Section 4.1.3 for additional information on evaluating financial responsibility demonstrations.

Geologic Sequestration Guidance Documents and Fact Sheets

The EPA developed a series of guidance documents and fact sheets to support Class VI well owners or operators and UIC permitting authorities in meeting the requirements of the Class VI Rule. These documents, described below, are available on the EPA's website at https://www.epa.gov/uic/class-vi-guidance-documents.

The EPA developed the following technical guidance documents to provide recommendations and considerations for meeting the Class VI Rule requirements:

- The **UIC Program Class VI Well Site Characterization Guidance** provides recommendations regarding how to perform activities that will enable an owner or operator to comply with the geologic siting requirements of the Class VI Rule.

- The **UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance** describes recommended approaches to apply computational modeling to delineate the AoR, perform corrective action at GS sites, and reevaluate the AoR.
- The **UIC Program Class VI Financial Responsibility Guidance** provides recommendations regarding demonstrating and maintaining financial responsibility for a Class VI well.
- The **UIC Program Class VI Well Construction Guidance** describes recommended procedures and materials for designing and constructing injection wells that address the unique nature of carbon dioxide injection for GS.
- The **UIC Program Class VI Well Testing and Monitoring Guidance** provides recommended approaches for meeting the testing and monitoring requirements of the Class VI Rule, including well testing, groundwater quality monitoring, and carbon dioxide plume and pressure front tracking.
- The **UIC Program Class VI Well Project Plan Development Guidance** describes the elements of the five required Class VI project plans and provides recommendations regarding how an owner or operator might consider the site-specific elements of a Class VI project in developing the plans.
- The **UIC Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance** provides recommendations to owners or operators for complying with the reporting and recordkeeping requirements of the Class VI Rule and using the GSDT.
- The **UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance** presents recommendations related to plugging the injection and monitoring wells, performing post-injection testing and monitoring, petitioning for an alternate PISC timeframe, making a non-endangerment demonstration, and closing a Class VI site.
- The **UIC Program Class VI Primacy Manual for State Directors** provides procedural support to UIC Program Directors preparing the required UIC primacy application materials to submit to the EPA for review and approval.

The EPA also developed a set of fact sheets and quick reference guides to support the UIC Program on several aspects of Class VI permitting:

- **Additional Tools for UIC Program Directors on Incorporating Environmental Justice (EJ) Considerations into the Class VI Injection Well Permitting Process**. This quick reference guide describes available tools and considerations for incorporating EJ into the Class VI permit application review and approval process.
- **Additional Considerations for UIC Program Directors on Interstate Coordination Requirements for the Class VI Injection Well Permitting Process**. This quick reference guide provides considerations for notifying other state, tribal, and territorial agencies if a Class VI AoR crosses (or comes close to) jurisdictional boundaries.
- **Additional Considerations for UIC Program Directors on the Public Participation Requirements for Class VI Injection Wells**. This quick reference guide presents a series of steps for meeting the public participation requirements of the Class VI Rule.

- **Public Participation Considerations for Geologic Sequestration Projects**. This fact sheet is designed to assist UIC Program Directors and Class VI well permit applicants/owners or operators in developing a plan to educate and engage the public on Class VI projects.

Useful Websites

The EPA compiled a list of websites that may support the UIC Program in reviewing Class VI permit applicant and/or owner or operator submittals or performing activities associated with evaluating permit applications or Class VI project data. Some of the websites may also support owners or operators as they prepare permit applications and perform activities required under the Class VI Rule. This list of EPA and other federal agency websites is presented in Appendix B.

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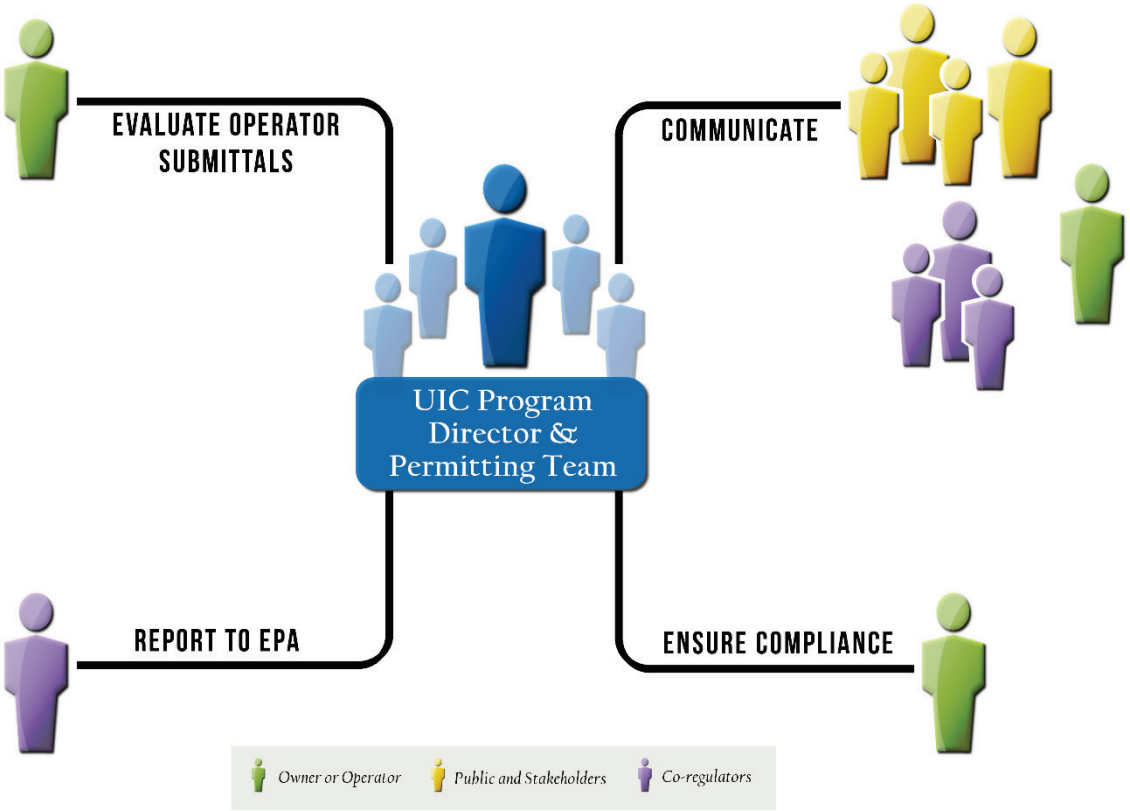
Section 2: UIC Program Responsibilities



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2 UIC Program Responsibilities

Throughout the duration of a Class VI Project, the UIC Program will likely conduct many activities and fill many roles associated with implementing the Class VI Rule. This section describes these roles, including:

- Reviewing permit applicant/owner or operator submittals and making risk-based decisions to ensure that USDWs are not endangered (see Section 2.1);
- Reporting to the EPA about Class VI permitting and projects (see Section 2.2);
- Communicating with the Class VI well owner or operator, the public, and co-regulators about Class VI projects (see Section 2.3); and
- Ensuring compliance with permit conditions and the Class VI Rule (see Section 2.4).

2.1 Reviewing/Evaluating Submittals and Decision-Making

The permitting, operation, and closure of Class VI projects are guided by a permit that includes enforceable Class VI project plans. Effective oversight of a Class VI project involves identifying the site-specific potential for endangerment to USDWs associated with the injection activity and setting permit conditions to reduce or manage this potential endangerment. Oversight during the injection and post-injection phases involves verifying, through the review of testing and monitoring data, that endangerment to USDWs is being managed (or mitigating the impacts of any unforeseen events).

The UIC Program should consider how various aspects of the site (as presented in the permit application) will ensure non-endangerment of USDWs and, following issuance of the permit, confirm this based on the testing and monitoring data that will be collected throughout all phases of the project. All the information collected and reviewed—and the documentation of that review—will collectively form a robust, defensible permit record.

The review of Class VI project information is likely to be an iterative process (See Figure 2-1). For example, it is possible that not all information needed to make a final permitting decision will be available when the permit application is submitted. Therefore, the UIC Program is encouraged to identify uncertainties to be addressed via required pre-operational testing and/or through permit conditions. Also, during the course of project operations, as testing and monitoring data are collected and AoR reevaluations are performed, the UIC Program should review this information to ensure that the project is in compliance with the permit and USDWs are not endangered—or consider whether any changes to the permit are needed. Finally, the testing and monitoring results and other geologic data collected over the duration of the project should support the eventual goal of a non-endangerment demonstration and enable the UIC Program Director to authorize the owner or operator to perform site closure activities.

While the specific activities vary based on the project phase or the type of information submitted, some basic steps should be followed throughout every phase of the project to ensure the adequate and thorough evaluation of data. These include, as described below: receiving information and confirming that it is complete, evaluating the information submitted, setting or modifying permit conditions, and documenting the evaluation.

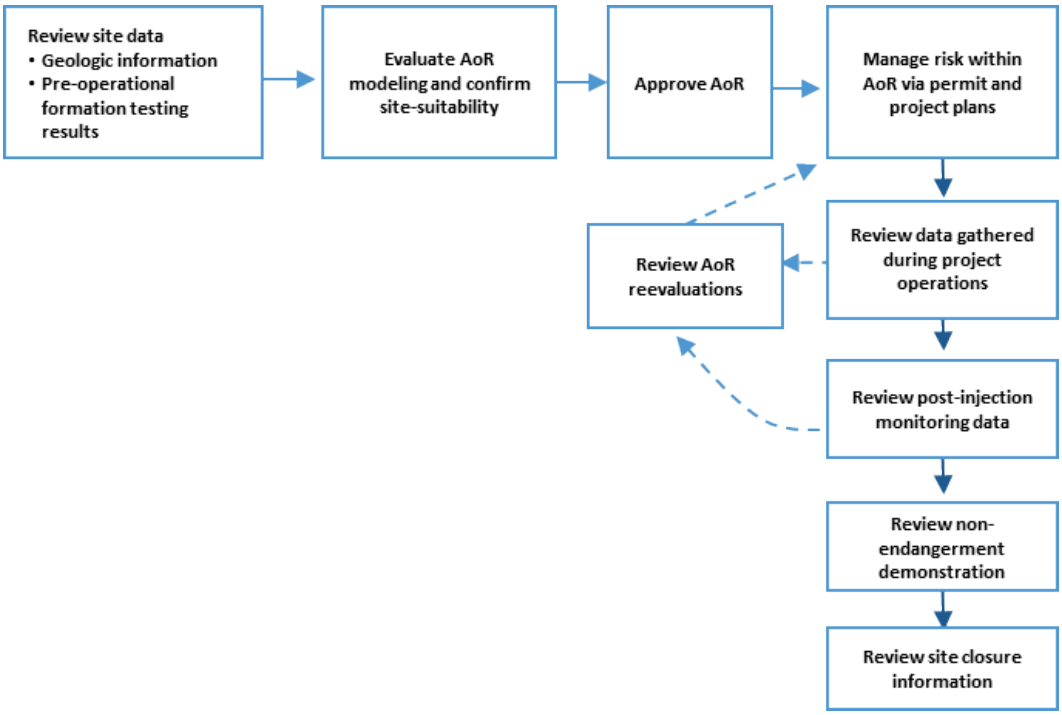

Figure 2-1: Data Evaluations and Decision-Making

Receiving Information and Confirming Completeness

The EPA encourages the UIC Program to discuss information needs with the applicant/owner or operator throughout the permit application review process and the duration of the project. Permit applicants/owners or operators should be encouraged to submit all required information electronically via the GSDT (see Section 1.4), as this will facilitate information management and review. The UIC Program should perform a completeness review to confirm that all of the required or needed information was submitted—in sufficient detail and in the right format—to inform the evaluation. If additional information or clarification is needed, the UIC Program should request the information from the owner or operator via the GSDT; this request and the responses will then become part of the permit's administrative record.

Conducting a Technical Evaluation

The UIC Program should carefully review information submitted for compliance with Class VI Rule requirements and to confirm that USDWs are not endangered.

- In the pre-construction and pre-operation phases, the UIC Program should review site-specific information to support a risk-based determination that USDWs will not be endangered by the proposed injection activity. In the pre-construction phase, the UIC Program should review the permit application to confirm that the site is suitable for carbon dioxide injection for GS or identify uncertainties to be addressed via pre-operational testing. In the pre-operation phase, the UIC Program should review updated geologic data and the results of pre-operational testing as described in the permit. This review process is similar to the initial permit application review, but is streamlined to focus on newly acquired information to confirm that identified uncertainties have been addressed and the site is suitable for GS.

- During the injection and post-injection phases, the UIC Program should review site testing and monitoring results, along with the results of AoR reevaluations or amended project plans (and, during post-injection, well plugging and site closure-related information). The purpose of these reviews is to confirm that the project continues to be in compliance with the permit or to identify needed changes to the permit to address changes from predicted site behavior. If unforeseen or emergency events occur, the UIC Program may also need to work with the owner or operator to implement appropriate remedial actions to return the project to compliance and prevent or mitigate endangerment to USDWs (see Section 2.4).

Technical evaluations should involve the input of all members of the permit application review team (see Section 3.1) and the applicant/owner or operator as needed. This approach, recommended throughout this Implementation Manual, will ensure that each aspect of the project is managed appropriately and with consideration to site-specific aspects of the project to ensure USDW protection from endangerment. This Implementation Manual recommends basic steps for performing the review and provides potential site-specific considerations.

Setting or Modifying Conditions of the Permit and Project Plans

The UIC Program should prepare a Class VI permit based on the site-specific information reviewed. Class VI permit packages will likely consist of a permit that includes a set of site- and project-specific plans, including: the required Class VI project plans, a summary of requirements, construction details, financial responsibility information, and a stimulation program (if needed). This permit package will guide well construction, injection operations, and collection of the information necessary to ensure compliance with Class VI requirements and prevent USDW non-endangerment, or, when necessary, guide steps to manage/mitigate endangerment to USDWs. Templates of each piece of the permit package, which include recommended language and places to fill in project-specific details, are available in the resource library of the GSDT. While using the templates is not required, the EPA encourages their use because they are organized to ensure that the information required by the applicable Class VI Rule requirements is included while providing the flexibility to tailor submissions to particular permits.

The permit and plans should be considered "living documents" that can be modified over the duration of the project as new information becomes available, such as during pre-operational testing, via injection or post-injection phase testing and monitoring, or as a result of AoR reevaluations.

Pursuant to the requirements at 40 CFR 124, 144 and 146, the UIC Program Director will perform a series of steps associated with issuing or modifying a Class VI permit. These include: developing Class VI permit conditions, preparing a fact sheet and/or statement of basis about the project and the evaluation, compiling an administrative record for the permitting decision, soliciting and responding to public comments, and finalizing the permit conditions, if needed based on public input.

Documenting the Evaluation

Written materials that document the review of a permit application or project data will support transparent permitting decisions and promote consistency in permitting and project oversight.

Additionally, if the permit is challenged or an enforcement action is necessary, an administrative record that contains thorough documentation of the review would support a response.

The EPA recommends that the UIC Program document the decision-making process for all Class VI permits, including evaluating Class VI permit applications, preparing Class VI permits and authorizing injection, reviewing data submitted during the injection and post-injection phases, making compliance and enforcement determinations, and modifying Class VI permits when needed. This documentation could describe: the evaluation process; any deficiencies, uncertainties, or data limitations identified in the course of the review; issues raised and discussed with the applicant/owner or operator; and how the final (or modified) permit conditions and associated plans reflect the resolution of these issues. The GSDT can support the development of the administrative record for the permitting decision; see Section 1.4 and Appendix A for additional information.

2.2 Reporting to the EPA

UIC Program Directors must report to the EPA on the status of their programs [40 CFR 144.8]. The EPA uses this information to respond to information requests and perform analyses for EPA management, the Office of Management and Budget, the U.S. Government Accountability Office, Congress, and the public.

These reports are submitted to the EPA Regional Administrator if a state agency is the permitting authority or to EPA Headquarters where the EPA is the permitting authority. This section discusses the types of reporting for which UIC Program Directors are responsible.

Compliance Reporting

Reporting on noncompliance and significant noncompliance (SNC) is required for UIC Program compliance evaluation, per 40 CFR 144.8. Instances of noncompliance to be reported include: failure to complete construction elements, modifications to schedules of compliance, failure to complete or provide compliance schedule or monitoring reports, deficient reports, noncompliance with other permit requirements, and all other instances of noncompliance. Specific information to be reported about permittees who are out of compliance with the Class VI Rule includes:

- Noncomplying permittees' names, locations, and permit numbers [40 CFR 144.8(a)(1)(ii)(A)];
- A brief description and the date of each instance of noncompliance [40 CFR 144.8(a)(1)(ii)(B)];
- The date(s) and description(s) of each enforcement action taken by the UIC Program Director [40 CFR 144.8(a)(1)(ii)(C)]; and
- The date compliance was achieved [40 CFR 144.8(a)(1)(ii)(D)].

Annual Reporting

The UIC Program Director submits annual reports to the EPA about Class VI permit review and issuance, mechanical integrity testing and remedial actions, and well inventory. The EPA tracks the following types of information on all injection wells, including Class VI wells:

- Information on permit determinations (e.g., the number of permits issued and not issued, and permit modifications) and permit file reviews;
- Enforcement actions, including administrative actions and civil and criminal actions;
- Operators of injection wells identified as being in SNC with statutory and regulatory requirements, enforcement actions against SNCs, and return of wells to compliance;
- Contamination of USDWs and well closures; and
- Wells that have remained in SNC for two or more consecutive quarters and have not been returned to compliance or have been subject to a formal enforcement action.

Annual well inventory reports are submitted in February; all remaining annual reports are submitted at the end of the federal fiscal year.

2.3 Communicating about Class VI Projects

The UIC Program Director plays a central role in communicating with a Class VI permit applicant/owner or operator, the public and interested stakeholders, and with co-regulators. See Figure 2-2.

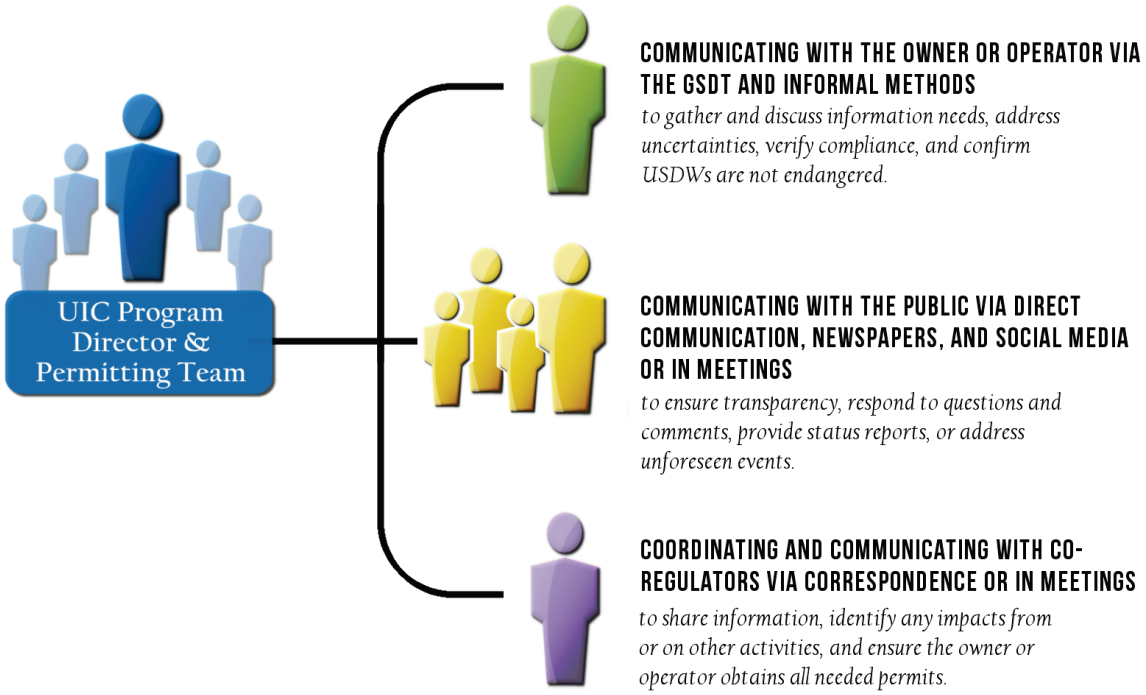

Figure 2-2: Class VI Project Communications

Proactive communication with various stakeholders is important, since GS has potentially high public interest and connections to other initiatives (e.g., carbon capture). Transparency in the permitting process and effective communication on Class VI permitting will facilitate information sharing and encourage protective projects.

Communicating with the Owner or Operator

Written and verbal communication between the UIC Program and a Class VI permit applicant or an owner or operator is a key component of setting and implementing protective permit conditions. The GSDT can support this by providing a way to share files and by serving as a record of all communications, including requests for information and the applicant's or owner or operator's response (see Section 1.4 and Appendix A). The EPA recommends that the UIC Program document all verbal communication, such as calls and meetings with the applicant, by uploading meeting notes, call logs, or other records to the GSDT.

This Implementation Manual provides specific recommendations for communication throughout the duration of the Class VI project. For example:

- *Before injection commences*, permit application reviews will necessitate communication with the applicant throughout the evaluation. The UIC Program may need to request clarifying information, hold periodic conversations or meetings with the applicant, and share draft materials in the course of performing the review and writing a draft Class VI permit.
- *During and following well construction and pre-operational testing,* interaction with the owner or operator will likely continue as the UIC Program reviews updated information and, if necessary, revises the Class VI permit or project plans.
- *During injection operations*, regular communication can help ensure that project operations are proceeding according to the permit, that testing and monitoring is being performed, and that the results confirm expectations. If an unexpected event or violation were to occur, prompt communication is essential to ensure that USDWs are not endangered and/or any impacts are mitigated.
- *Following cessation of injection*, the owner or operator and UIC Program should coordinate and communicate to ensure that well plugging activities and site closure proceed as planned. Additionally, communication with the owner or operator as post-injection monitoring is performed can help identify whether sufficient data are being generated to support a non-endangerment demonstration (see Section 7.6).

Communicating with the Public

The unique and complex nature of Class VI wells and GS highlights the importance of communicating with the public and stakeholders about these projects. Communication and outreach is important throughout the duration of a Class VI project. For example:

- *Before the permit application is submitted.* The EPA recommends that the UIC Program Director and the permit applicant provide information to the public about the proposed project and the pending permit application as early as possible in the site characterization and permit application development process. Targets of this outreach should include the public, including nearby residents and landowners. See Section 3.3 for additional information on communicating during the pre-permitting phase.

- *During the public comment period for the Class VI permit.* Public notice of the permit application is required at 40 CFR 124 (see Section 4.2). In addition to providing a copy of the draft permit and a fact sheet and/or a statement of basis, the UIC Program may conduct outreach or need to answer questions about the project. For example, the public may be interested in the geology of the site, injection technology, and how the Class VI requirements or specific permit conditions will protect USDWs from endangerment. If the applicant seeks an injection depth waiver or an expansion of the areal extent of an aquifer exemption, a separate, but related public notice is required for these actions (see Sections 4.1.11 and 4.1.12).
- *During well construction.* The period between issuance of a permit (after which the owner or operator may construct or convert the well) and commencement of injection may vary, depending on how long it takes the owner or operator to drill the well and perform pre-operational testing and the UIC Program to evaluate updated information. Providing updates on the status of well construction activities and interactions between the owner or operator and the permitting authority can keep the public informed and address any questions that may arise as the project site is developed. Furthermore, if, following the review of updated information, the permit or any project plans need to be revised, public notice of the draft revised permit is required at 40 CFR 124. During this period, the public may have questions about the reason for the modification or how the permit has changed.
- *During the injection phase*. The EPA recommends providing periodic status updates during injection operations to keep the public informed about the project. Other opportunities for communication with the public may occur during permit modifications or in the unlikely event of a violation or emergency. This communication might take the form of:
    - *Periodic updates on the status of the project.* Status reports can assure the public and stakeholders that the project is progressing as planned, that monitoring and oversight procedures are in place, and that there is no endangerment to USDWs. These updates could provide information on the location of the plume, the most recent results of water quality monitoring or well testing, or the findings of compliance reviews and recent inspections. Such reports could be timed to follow receipt and review of owner or operator submitted reports.
    - *Notice of a permit modification.* If a permit modification is required (e.g., because one or more project plans were modified following an AoR reevaluation), the public may have questions about the reason for the modification. The UIC Program should be prepared to provide information or answer questions about the AoR reevaluation process and results; what monitoring or operating data prompted any project plan revisions; and which plans or other permit conditions were revised. Public notice of non-minor permit modifications is required at 40 CFR 124 (see Section 5.2).
    - *Communication regarding a violation or emergency response.* If any event at the project results in a violation or necessitates an emergency response, the EPA encourages the UIC Program to coordinate with the owner or operator to communicate information about the situation to the public as soon as possible.

Information might include: an explanation of what occurred and whether there is evidence of USDW endangerment; a description of the responses taken; and when the well/project returned to compliance (or when a return to compliance is anticipated). If there is evidence of USDW endangerment, the UIC Program should inform customers of local water systems, nearby land owners, and the public about the event. Alternatively, if the incident did not endanger USDWs, communication can assure stakeholders that the UIC protective measures worked and that their water source was not endangered.

- *After injection has ended*. The EPA encourages the UIC Program to inform the public after the well is plugged or the site is closed to alert interested parties. At this time, the UIC Program should be prepared to provide information or answer questions about injection well plugging procedures, non-endangerment demonstrations, or the conditions that must be met to authorize the owner or operator to perform site closure activities pursuant to 40 CFR 146.93(b).

Available outreach tools include: direct communication, newspapers, and social media, such as blogs, social networks, podcasts, and webcasts. Note that outreach efforts cannot be performed in lieu of meeting the public participation requirements at 40 CFR 124. For additional information on public involvement, see the UIC Quick Reference Guide *Additional Tools and Considerations for UIC Directors on the Public Participation Requirements for Class VI Wells*.

Coordinating and Communicating with Co-Regulators

Coordination with co-regulators of other injection well classes, public drinking water utilities, and other federal, state, tribal, or local authorities may be essential at various stages of a Class VI project. Such coordination and transparency among agencies can also help the UIC Program ensure that the owner or operator applies for and receives any other permits (i.e., beyond the Class VI permit) that may be required. Below are examples of the types of coordination about a Class VI project that may be needed:

- The Class VI Rule, at 40 CFR 146.82(b), requires the UIC Program Director to notify, in writing, any states, tribes, or territories within the AoR of the Class VI project based on information provided in a Class VI permit application.
- If the project is anticipated to have an AoR that crosses (or comes close to) boundaries with other states or tribes, the UIC Program should communicate early with other UIC Programs or environmental protection officials in those states or tribes. Such officials might be affiliated with other state/tribal agencies (e.g., health departments). See the *Quick Reference Guide on Interstate Coordination Requirements* on the EPA's website for additional information.
- If the project will operate under an injection depth waiver, the Class VI Rule, at 40 CFR 146.95 requires consultation with the Directors of the Public Water System Supervision Programs of all states, territories, and tribes having jurisdiction within the AoR of the well for which an injection depth waiver is sought. The UIC Program should also inform the EPA Regional Administrator early in the process of reviewing a project's application for an injection depth waiver, as their concurrence regarding the waiver is required (40 CFR 146.95(d)). See Section 4.1.11.

- If the owner or operator applies to expand the areal extent of an existing aquifer exemption, the UIC Program should alert the appropriate EPA regional office, as the EPA must approve all aquifer exemptions, even if the state has Class VI primacy [40 CFR 144.7(d)]. Informal communication early in the process, while not required, is recommended to ensure that all parties are prepared to discuss and/or respond to the aquifer exemption application. See Section 4.1.12.
- If a pre-existing well (e.g., an injection well, a stratigraphic test well, or a site characterization well) is being re-permitted as a Class VI well, coordination with the authority that originally issued the permit for the well may help the UIC Program Director understand any previous actions taken or conditions established under a previous permit.

Additionally, the UIC Program Director can serve as a liaison with staff in other state or federal agencies that have authority over activities that are related to or may affect or be affected by Class VI injection. Specific activities may vary by region, but might include: other injection activities that could interact with the carbon dioxide plume and pressure front; drilling associated with oil and gas exploration that may reveal new information about the geology of the area; or land use changes that could affect water needs or bring resources/populations into the AoR of the Class VI project. Likewise, the UIC Program Director may seek out the expertise of other permitting authorities to corroborate information submitted in a Class VI permit application or to ensure that a Class VI permitting decision does not interfere with or adversely impact other ongoing injection activities within the area. The EPA encourages the UIC Program Director to reach out to other regulators as needed.

The UIC Program Director can also encourage Class VI permit applicants to consider other potentially applicable statutes and regulations. UIC Programs are encouraged to communicate with these co-regulators who have authority over activities addressed under other applicable statutes, including the Clean Air Act (CAA), Resource Conservation and Recovery Act (RCRA), the Marine Protection, Research, and Sanctuaries Act (MPRSA), and the Outer Continental Shelf Lands Act (OCSLA). See Section 3.4 for information on these authorities and their implementing programs.

2.4 Ensuring Compliance with the Class VI Rule

If, during the course of the project, there is an indication that a Class VI project or injection well may be out of compliance with permit conditions or endangering USDWs, appropriate actions to prevent USDW contamination or mitigate any adverse impacts are needed. Examples of Class VI violations include a loss of mechanical integrity, an exceedance of permit limits, or an excursion of carbon dioxide or formation fluids out of the injection zone. Identifying and addressing violations in a timely manner can avoid or reduce impairment to USDWs and ensure that the circumstances that led to a violation do not recur. These situations may be identified in a variety of ways, including:

- *Reviewing project data*. Much of this review involves the comparison of testing and monitoring results to permit limits and project predictions during the injection and post-injection phases. See Sections 6.1 and 7.2.2 for additional information on reviewing testing and monitoring results. Monitoring and operational data must also be evaluated at least once every five years as part of the Class VI permit reviews required at 40 CFR 144.36(a).

- *During site inspections*, which may be performed by permitting agency staff or authorized agents to verify or witness operations, testing and monitoring, or maintenance procedures. Inspections may involve observing the injection well and monitoring wells; reviewing records to determine performance and compliance history; witnessing mechanical integrity tests (MITs), other tests of the well, workovers, or maintenance activities; or evaluating progress on required remedial procedures.
- *Based on complaints alleging improper operation or maintenance of a Class VI project*. Investigative activities should include establishing the nature and authenticity of the complaint, reviewing records and reports, contacting the owner or operator to discuss the complaint and appropriate remedial actions or responses, and inspecting the site to determine if a problem exists.

The EPA recommends that the UIC Program take the following steps to document, address, and resolve violations of a Class VI permit.

Document the violation, if one has occurred. If reviews of project information, site inspections, or complaint investigations indicate that a violation has occurred, document the nature of the violation. If the violation has endangered a USDW, require the owner or operator to take appropriate action to remove or mitigate the threat pursuant to 40 CFR 146.94(b). (See Section 6.5.2 for additional information on responding to USDW endangerment.) Proper documentation of violations is important to define the type and cause of the violation and provide a basis for any enforcement actions that may be needed. All permitting authority staff should be made aware of agency procedures for issuing notices of violation.

Determine and implement appropriate enforcement action(s), if needed. Responses may be informal (e.g., technical discussions or correspondence with the owner or operator) or formal (e.g., notices of violation, administrative orders, or judicial actions). Informal actions may be appropriate for one-time or very intermittent exceedances of a permit limit that do not affect carbon dioxide containment, compromise the integrity of the well (e.g., the triggering of a shutdown device that is not related to a loss of mechanical integrity), or endanger any USDWs. However, a pattern or trend in exceedances may be more illustrative of a problem with the Class VI project's operation and may warrant more formal actions.

Document any formal enforcement actions taken using a notice of violation, administrative order, or judicial action, and the owner or operator's response, as applicable. EPA's enforcement authority for UIC wells is contained in SDWA Section 1423. For State Programs, the specific enforcement actions available will depend on the authorities or maximum civil penalties set forth in state regulations. Select actions based on the severity of the violation, its impact on the environment, or the compliance history of the owner or operator. If appropriate, consider modifying, revoking, or suspending the UIC permit, imposing a civil penalty or fine, or initiating criminal prosecution.

Follow up on violations and enforcement actions. If a compliance schedule for implementing remedial responses is developed (see Section 6.5.2), check in periodically with the owner or operator to verify that the remedial actions are progressing and that the owner or operator is meeting all milestones. If remedial actions are not progressing, discuss this with the owner or operator or consider whether more formal or additional enforcement is needed.

Communicate with the public and other stakeholders about any investigations and their outcome. Explain the nature of the event that led to a compliance investigation, the information reviewed or tests/inspections that were performed, responses taken (including any violations or penalties), any environmental impacts, and when the well/project returned to compliance (or when a return to compliance is anticipated). For more information on public involvement and communication, see Section 2.3.

Additionally, the EPA recommends that the permitting authority document the data generated as a result of inspections or enforcement actions. This information may include: information on inspections (including the date of the inspection and the results), compliance or enforcement actions conducted, and any response and/or remedial action that resulted from inspection and enforcement actions.

Report information on noncompliance and violations to the EPA, i.e., in quarterly noncompliance reports. See Section 2.2 for additional information on the timing and requirements at 40 CFR 144.8 for reporting this information.

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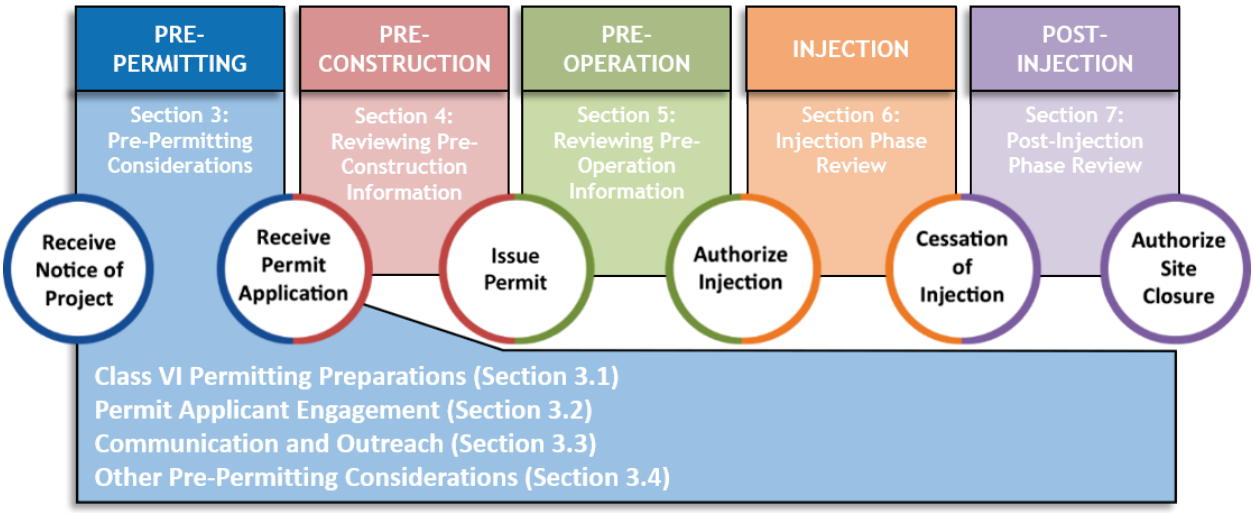
Section 3: Pre-Permitting Considerations



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3 Pre-Permitting Considerations

Coordination between the UIC Program and the permit applicant prior to submittal of the permit application is an important step for efficient and effective permitting. Early discussions will ensure that the applicant is aware of the permit application requirements at 40 CFR 146.82(a) and is able to electronically submit the permit application and other required information. These discussions may also benefit the applicant as they plan how to invest time and resources in site characterization, modeling, and other activities necessary to develop a comprehensive Class VI permit application. Such coordination may also help the UIC Program anticipate the information they will receive and review and assist the applicant in submitting all required information in the appropriate format and level of detail.

The EPA encourages prospective Class VI permit applicants to notify their Class VI permitting authority of their intent to apply for a permit. However, if the UIC Program becomes aware of a potential new project, e.g., in the course of conversations with industry representatives, through the media, or at meetings, permitting authority staff should reach out to the prospective Class VI permit applicant.

This section describes actions that the EPA recommends that the UIC Program take in advance of a formal submittal of a Class VI permit application. This section addresses: assembling the permit review team, specific topics on which pre-application discussions should be focused, recommendations for outreach and communication, and other considerations.

3.1 Class VI Permitting Preparations

Internal planning within the permitting agency can ensure an expedient response as soon as the Class VI permit application is formally submitted. This section presents recommendations for this planning step.

Assemble a permit application review team. Class VI projects are complex, and a holistic permit application review process that considers each element of the multi-faceted permit application will support the development of a protective Class VI permit and associated project plans. Assemble a team that collectively has the skills and expertise in the technical areas needed to evaluate the information in a Class VI permit application, including areas such as:

- Site characterization, e.g., geologists, hydrogeologists, geochemists, and log analysts/experts to review geologic data submitted with the permit application;
- Modeling, e.g., hydrogeologists and environmental/reservoir modelers to evaluate the models that will be used to delineate the AoR;
- Well construction and testing, e.g., well engineers, log analysts/experts, and geologists to review well construction information and the results of well testing that will be performed during construction of the injection well;
- Finance to review the financial responsibility demonstration, including cost estimates and the proposed financial instruments, e.g., UIC personnel who are familiar with financial responsibility as well as accountants and economists;
- Risk analysis to evaluate emergency and remedial response scenario probabilities and remediation cost estimates submitted with the Emergency and Remedial Response Plan; and
- Policy, legal, and regulatory expertise related to the UIC Program and the Class VI Rule to evaluate compliance with Class VI Rule requirements.

A team approach involving staff with expertise in these areas can help ensure that each piece of the permit application is evaluated on its own merit. Furthermore, effective communication among the team members will ensure that all elements of the Class VI project (i.e., well, geology, proposed operations) are complementary and that USDWs are not endangered. Sections 4 and 5 provide specific recommended cross-team consultations during the permitting process.

Given the scope of information that supports a permit application, the detailed decisions involved in the permit application evaluation process, and the potentially decades-long duration of some Class VI projects, it is likely that permitting authority staff will change over the course of the project. Documenting the review process and maintaining good records of all decisions and supporting data are important to ensure that historical knowledge of the project, justification for permit conditions, and project data are maintained and accessible following any staffing changes within the permitting agency. The GSDT can support such recordkeeping (see Appendix A).

Review available resources. As noted above, reviewing a Class VI permit application is a complex process that will involve experts across a variety of disciplines. Thus, it is important to begin assembling a review team as soon as there is indication that a permit application will be submitted. Work within the Class VI permitting agency to identify appropriate staff (see above). Ensure that all of the staff are able to make the time commitment to review materials (i.e., over several months). The EPA acknowledges that a team approach may require retaining contractor support to assist in any activities where in-house staff do not have the necessary expertise.

Also, the EPA encourages UIC Program managers to ensure that all staff on the review team have the resources they need to accomplish the review, including a GSDT account (see Section 1.4) or specialized software (e.g., to review AoR delineation modeling). Encourage team members to review GS guidance documents, GSDT user guides, or other relevant documents to become familiar with the Class VI permitting process. See Section 1.4 for a list of available tools and resources.

3.2 Permit Applicant Engagement

Working with the permit applicant early in the process will help initiate a collaborative relationship and facilitate information sharing and cooperation that will benefit the permit application review. Below are suggested ways in which the UIC Program can engage prospective Class VI permit applicants early in the permitting process.

Assisting the applicant with obtaining a GSDT account. Permit applicants should register for a GSDT account before submitting information to the EPA, to ensure that they meet the Class VI electronic reporting requirements at 40 CFR 146.91(e). Permitting authorities can direct applicants to https://epa.velo.pnnl.gov/operators, where a registration form is available for download. GSDT accounts are assigned on a per-project basis irrespective of the number of Class VI wells that will be used for injection at the proposed project. This means that the registration form only needs to be completed once for each project, and that only one set of credentials will be issued to an organization for a particular project. (It is the permit applicant/owner or operator's responsibility to ensure that only authorized individuals or their designees have access to the username and password.)

Following receipt of project-specific user credentials, each individual that will be authorized to formally submit information via the GSDT should complete, notarize, and submit a project-specific Electronic Signature Agreement (ESA). The ESA form (which contains additional

instructions regarding this process) is available for download on the operator landing page of the GSDT. As soon as they receive GSDT credentials, permit applicant users may log into the GSDT, review the user guides, and even begin populating the forms in the GSDT modules. However, information submittal is contingent on completion of the ESA process. The EPA will keep the completed ESAs on file and use them to designate authorized users for each project within the GSDT. Additional details on GSDT registration, ESAs, and designating authorized users are available in the user documentation for the GSDT.

Discussing the permit application process. The EPA recommends that the UIC Program ensure that the applicant is aware of the requirements that Class VI well permit applicants/owners or operators must meet. Encourage applicants to use the technical guidance documents for owners or operators posted on the EPA's website and other available resources such as templates available within the GSDT.

Encourage applicants to collect as much site-specific data as possible before submitting the initial Class VI permit application to facilitate the permit modification process (i.e., between conducting the pre-construction activities required at 40 CFR 146.82(a) and the pre-operation phase activities required at 146.82(c)). This type of proactive planning early in the process helps ensure that the current and potential future conditions at the proposed site have been considered and helps resolve issues related to incomplete or inaccurate information as expeditiously as possible.

If the Class VI project will eventually involve more than one injection well, the EPA recommends that the UIC Program confirm that the applicant is aware of the requirement that a separate Class VI permit application must be submitted for each Class VI well, per 40 CFR 144.33(a)(5). Note that, while the Class VI Rule precludes the use of area permits for Class VI wells, there may be ways to achieve economies of scale where certain aspects of several Class VI projects' permit applications are common. For example, the permit applicant may conduct a single site characterization study, model a single AoR that accounts for the total volume of carbon dioxide to be injected into all injection wells (even if some are planned to come online in the future), or submit common well schematics if each injection well is to have similar construction. Encourage Class VI permit applicants to consider these economies of effort and leverage the GSDT to ensure that each permit application contains all the information at 40 CFR 146.82(a) to allow for a complete review of each permit application.

Reviewing key pre-permitting considerations. Some aspects of the planned project may necessitate early discussions prior to preparation and submittal of the permit application. The paragraphs below provide some recommendations for early discussion with a prospective permit applicant related to site characterization, modeling to delineate the AoR, permitting of wells that will be converted to Class VI, and the potential need for an injection depth waiver or aquifer exemption.

Site Characterization

When possible, the EPA encourages the UIC Program to discuss planned site characterization activities with the applicant before they commence. These discussions should highlight the importance that the permit application include sufficient and site-specific geologic data. In addition to informing an understanding of the geologic suitability of the site, the geologic data provides inputs for the AoR delineation model and supports development of the Class VI project plans. Because the Class VI project plans become enforceable conditions of the Class VI permit,

any significant changes to these based on the final geologic data would require a modification of the Class VI permit before injection can be authorized [40 CFR 144.39].

If the applicant plans to use existing data about the site (e.g., data collected in the course of prior hydrocarbon exploration or other activity in the area), discussion regarding the quality and age of the available data may be beneficial. Such a discussion may also inform whether additional data (e.g., over a wider areal extent or in additional formations) might be needed to provide a complete and accurate representation of the site and provide all needed inputs for the AoR delineation model.

If the applicant plans to drill stratigraphic test wells or groundwater sampling wells that may eventually be used for carbon dioxide injection for GS, the UIC Program should inform the applicant that the wells would need to meet Class VI requirements at that point. This discussion should focus on how the stratigraphic or sampling wells might be constructed to facilitate later conversion per 40 CFR 146.81(c), i.e., by using materials that are compatible with carbon dioxide. Refer the applicant to the *UIC Program Class VI Well Construction Guidance* for additional information on carbon dioxide-compatible design.

In discussions with the applicant, the EPA encourages the UIC Program to emphasize the importance of synthesizing geologic data to inform a determination of site-suitability, i.e., that there is sufficient capacity in the injection zone to receive all carbon dioxide to be injected or that the geologic structure is suitable for GS. Encourage the applicant to consult Section 4 of the *UIC Program Class VI Well Site Characterization Guidance* and perform the level of analysis detailed in that document to facilitate the UIC Program's review of the permit application and evaluation of site-suitability.

If sufficient information is available (e.g., based on available information about the proposed site) to make a determination that additional confining zone(s) are needed, the UIC Program should discuss this with the applicant early in the site characterization process. These additional zones may be needed to impede vertical fluid movement, allow for pressure dissipation, or provide additional opportunities for monitoring, mitigation, and remediation, per 40 CFR 146.83(b). Characterization of a secondary confining zone may be needed if:

- The primary confining zone does not exhibit sufficient strength to allow injection at the proposed pressures;
- Known or suspected faults or fractures transect the primary confining zone and would interfere with containment of carbon dioxide;
- The primary confining zone is not sufficiently extensive to cover the entire maximum extent of the carbon dioxide plume and pressure front or it is not sufficiently thick and homogeneous over the entire area; or
- There is insufficient information or conflicting data about the primary confining zone.

Identifying the need for information about additional confining zone(s) as early in the permitting process as possible (ideally during pre-permit application communications) will expedite approval of the site and save resources for the applicant and the permitting authority.

The *UIC Program Class VI Well Site Characterization Guidance* provides additional recommendations on collecting and submitting geologic data.

Plans for AoR Delineation Modeling

The EPA encourages the UIC Program to discuss the applicant's planned approach for computational modeling and AoR delineation to verify that the model will meet the Class VI requirements at 40 CFR 146.84(c)(1)(i)-(iii). The AoR delineation model chosen by the permit applicant should have the capability to account for multiphase flow, the relative buoyancy of carbon dioxide, and three-dimensional geologic heterogeneity. If the applicant plans to use a proprietary model, discuss how they plan to provide sufficient information to inform a complete evaluation of their modeling activities.

A discussion of the AoR and Corrective Action module of the GSDT, including its structure and the types of information that it collects, may support the applicant's compliance with the AoR and corrective action requirements of the Class VI Rule. It may also be helpful to discuss how a prospective Class VI permit applicant can generate and document inputs to facilitate efficient and effective population of the GSDT. See the GSDT user guides for additional information on using the GSDT as part of the AoR delineation/modeling evaluation.

The UIC Program should ask the applicant about the geologic data on which the AoR delineation model will be based (e.g., distributions of rock properties). Discussing modeling needs in advance can ensure that the modeling process will be based on information of a sufficient quantity, quality, and scope (both laterally throughout the AoR and vertically through all relevant subsurface formations). Additionally, these discussions are an opportunity to emphasize the importance of consistency between the geologic information, the information used to develop the model, and the inputs used in model simulations. Designing the model with consideration to planned injection and post-injection phase monitoring can support future model validations associated with AoR reevaluations and non-endangerment demonstrations.

If the Class VI project will eventually involve more than one injection well or if other wells are in close proximity within hydraulically connected formations, the UIC Program should also discuss the merits of modeling the impact of all injection activities as part of the AoR delineation process with the applicant.

The EPA recommends that the UIC Program refer the applicant to the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance* for recommendations on performing AoR delineation modeling that will meet the requirements of the Class VI Rule.

Well Conversion and Re-Permitting

The EPA recognizes that some owners or operators may elect to use existing, previously constructed infrastructure for GS. Such infrastructure may include previously constructed injection wells (e.g., Class I, II, or V wells), stratigraphic test wells, production wells, or monitoring wells in the project area. The Class VI regulations accommodate this approach pursuant to requirements at 40 CFR 146.81(c), provided the applicant meets all applicable Class VI requirements.

To facilitate re-permitting, the UIC Program should explain to a prospective Class VI well owner or operator that they must apply for and obtain a Class VI permit, per 40 CFR 146.81(c). Such discussions should focus on what existing information about the well or the site may be used in the Class VI permit application (e.g., geologic data on an oil and gas field; construction schematics), and what information required at 40 CFR 146.82(a) will need to be prepared specifically for a Class VI permit application (e.g., project plans). Additionally, this is an

opportunity to discuss whether the construction of the well would meet the goals of 40 CFR 146.86 and can be converted and what the owner or operator must do to demonstrate that the well meets these goals.

The UIC Program should also explain that, following re-permitting, the Class VI requirements apply, and these wells will be subject to the operational, testing and monitoring, reporting, well plugging, PISC and site closure, and other requirements that apply to all Class VI wells. The EPA recommends that the UIC Program refer the applicant to the *UIC Program Class VI Well Construction Guidance* for additional information on re-permitting existing wells as Class VI wells.

Injection Depth Waivers

The requirements at 40 CFR 146.95 allow a Class VI permit applicant to seek a waiver from the Class VI injection depth requirements to allow injection into non-USDW formations while ensuring that USDWs above and below the injection zone are protected from endangerment.

The Need for Injection Depth Waivers

The injection depth waiver is a limited use option to allow for injection of carbon dioxide for GS where no alternatives exist for GS below the lowermost USDW. The waiver provisions and the additional requirements at 40 CFR 146.95 serve several purposes, including:

- Addressing concerns about local and regional geologic storage capacity limitations;
- Allowing injection into different formation types and avoiding a blanket prohibition on injection into any types of shallow formations;
- Eliminating the need to establish a minimum injection depth; and
- Ensuring that high quality water remains available in sufficient quantities to meet drinking water needs.

The additional requirements for projects operating under an injection depth waiver ensure the protection of all USDWs above and below the injection zone.

If a proposed project is in a region known to have deep USDWs, the UIC Program should work with the applicant to determine early in the site characterization process whether a USDW lies below the injection zone and, therefore, would require an injection depth waiver. Identifying USDWs may happen as part of the regional evaluation of the site in the early phases of site characterization. Otherwise, if information were to become available after the Class VI permit is issued, suggesting that previously unknown USDWs occur below the injection zone, it would be necessary for the owner or operator to apply for an injection depth waiver and modify the Class VI permit.

If the applicant intends to inject into a non-USDW formation that is above or between USDWs, the EPA recommends that the UIC Program confirm that the applicant is aware of the requirement to submit the waiver application concurrently with the Class VI permit application, and that the waiver application must contain all of the information identified at 40 CFR 146.95(a). Class VI permit applications and waiver application reports are distinct but complementary [40 CFR 146.82(d)]. That is, much of the information in the waiver application report is similar to or an expansion of information required in the Class VI permit application. However, the applicant should include the information in both submittals so that the injection depth waiver application and the permit application can each be evaluated in its entirety. The UIC Program should encourage the applicant to describe the proposed site as completely as possible, addressing USDWs above and below the injection zone—that is, it is not the EPA's intent that the permit application describes only USDWs above the injection zone and the

injection depth waiver application address those below. Rather, both documents should describe USDWs above and below the injection zone to ensure a holistic review of all pertinent information in the context of the applicable requirements.

Figure 3-1 shows how the injection depth waiver and Class VI permit application reviews are parallel. The UIC Program Director's review of the Class VI permit application should consider USDWs above and below the injection zone. The information in the waiver application report should be corroborated by geologic information and the AoR delineation modeling evaluation for the permit application review.

Information about both applications must be made available for public comment [40 CFR 124; 146.95(c)]. Requesting public input on both applications at the same time can help ensure that the public understands that the Class VI permit application involves injection under an injection depth waiver. This also offers efficiencies in evaluating public comments. The waiver application is also subject to review by the PWSS director(s) and must also be reviewed by the EPA Regional Administrator per 40 CFR 146.95(b).

If both applications meet site-suitability and other Class VI requirements, public input is addressed, and the EPA Regional Administrator concurs with issuance of the injection depth waiver, then the UIC Program Director may issue a permit and post waiver information on the EPA's website.

(Adoption of the waiver process is at the discretion of individual UIC primacy programs. If a state or tribe chooses not to make this process available to Class VI well owners or operators under their jurisdiction, the UIC Program should inform applicants that they must inject below the lowermost USDW.)

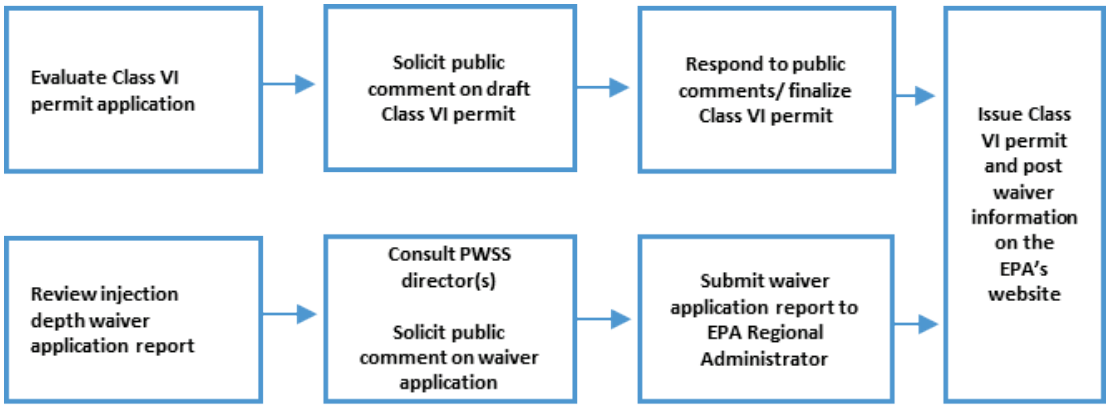


Figure 3-1: Reviewing Class VI Permit Applications and Injection Depth Waiver Applications

Aquifer Exemptions

The Class VI Rule and aquifer exemption requirements at 40 CFR 144.7(d) and 146.4(d) enable the use of aquifer exemptions for Class VI projects only in limited circumstances. Aquifer exemptions are not available for new Class VI wells or projects that are re-permitted from well classes other than Class II EOR/EGR. The Class VI Rule establishes the criteria under which

aquifer exemption expansions may be granted for owners or operators of Class II EOR/EGR wells that elect to transition to Class VI injection wells for GS.

If a Class II well owner or operator has made a decision to re-permit their well as a Class VI well and the injection zone has an existing Class II aquifer exemption, discuss the potential need to expand the areal extent of this exemption.

The UIC Program should explain the aquifer exemption application process and the information needed to demonstrate that the aquifer exemption meets the criteria at 40 CFR 146.4; and confirm that the applicant knows that they will need to apply for an aquifer exemption expansion separate from, but concurrent with, the Class VI permit. For additional information, see Section 4.1.12.

3.3 Communication and Outreach

Early communication with the public and other regulatory agencies can support awareness of the Class VI project and help meet public notification requirements. The EPA encourages the UIC Program to work with the applicant to identify information about the proposed project and in the permit application that can be shared with the public. Below are recommendations for communications and outreach related to prospective Class VI projects that the UIC Program might consider on a project-specific basis:

- Include residents and landowners near the proposed site in project-related public meetings or hearings as early as possible in the permit application development and review process. Begin to plan for the required public notification procedures at 40 CFR part 124 as well, e.g., by identifying newspapers of general circulation near the proposed site, stakeholders, etc.
- Work with the applicant to develop a communication plan that describes potentially affected parties, potential audiences, communication methods, and key messages. For more guidance on public involvement, see the EPA's UIC Quick Reference Guide *Additional Tools and Considerations for UIC Directors on the Public Participation Requirements for Class VI Wells*.
- If the applicant plans to construct additional injection wells in the future, ensure that the public is aware of planned future developments at the site, including the locations of any monitoring wells. Similarly, if the current Class VI permit application is for a new injection well at the site of an existing Class VI project, explain any relevant information about the project, e.g., compliance history.
- If, based on early information, there is reason to believe that disadvantaged communities (i.e., areas with minority populations, populations below the poverty level, or potentially vulnerable subpopulations) may be within or near the AoR of the project, the UIC Program should plan to perform an environmental justice (EJ) analysis consistent with EJ 2020 Action Agenda priorities. An EJ analysis will help identify whether any portions of the AoR encompass disadvantaged communities. The EJScreen Tool (available on the EPA's website) can support this review; for additional information see Section 1.4 and Appendix B. Where the EJ analysis indicates that the proposed site may be near disadvantaged populations that are also exposed to environmental risks, it may be appropriate to incorporate additional mitigation measures into the Class VI permit, such as monitoring in areas with identified disadvantaged communities. For additional

information, see the *UIC Quick Reference Guide - Additional Tools for UIC Program Directors Incorporating Environmental Justice Considerations into the Class VI Injection Well Permitting Process*. The Guide describes seven steps for performing an EJ analysis and mapping tools that are available to identify disadvantaged communities within the AoR of a Class VI project.

3.4 Other Pre-Permitting Considerations

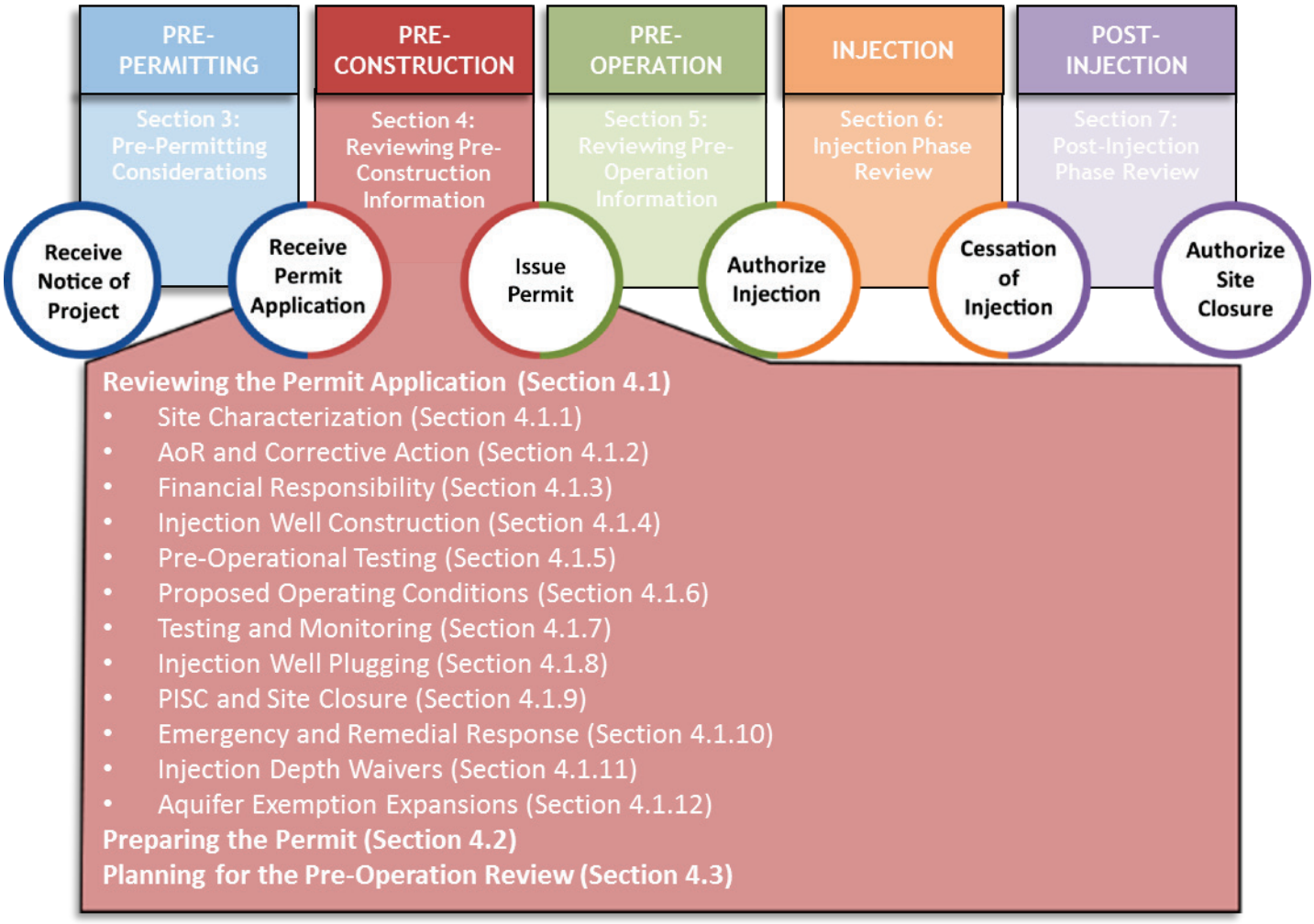
Some Class VI permit applicants may be subject to other requirements outside of the Class VI Rule. The EPA encourages the UIC Program to: ensure that the applicant is aware of these other requirements (discussed briefly below) that may apply; and work with co-regulators as needed so that permit applications under other regulatory programs are submitted and processed in a timely manner (e.g., optimally before injection is scheduled to commence). For example, a UIC Program may need to alert a Class VI permit applicant regarding the following:

- *Greenhouse Gas Reporting Program (GHGRP) Subpart RR*. GHGRP Subpart RR is complementary to UIC Class VI requirements and provides a mechanism to quantify the amount of carbon dioxide that is sequestered. Monitoring to comply with UIC Class VI requirements can provide the basis for satisfying certain GHGRP Subpart RR monitoring, reporting and verification plan requirements. For more information, see 40 CFR Part 98, Subpart RR.
- *The Conditional Exclusion under RCRA Subtitle C at 40 CFR 261.4*. If a Class VI permit applicant anticipates that the carbon dioxide stream may meet the definition of a RCRA hazardous waste, discuss the applicability of a conditional exclusion under RCRA Subtitle C at 40 CFR 261.4. The RCRA regulations conditionally exclude carbon dioxide streams that are hazardous from the definition of hazardous waste provided that the carbon dioxide stream is intended to be injected into a Class VI well and meets other specific criteria. The regulations exclude these hazardous carbon dioxide streams provided they are captured from emission sources, injected into Class VI wells for purposes of GS, and meet certain other conditions at 40 CFR 261.4(h). If the RCRA regulations are applicable, pursuant to the RCRA regulations, the applicant will need to provide the information necessary to demonstrate that the carbon dioxide streams they will be injecting will be managed in accordance with the conditions at 40 CFR 261.4(h).
- *State/Tribal Permits.* If the applicant plans to drill stratigraphic test wells or groundwater sampling wells that may eventually be used for carbon dioxide injection for GS, confirm that they are aware that they must get the appropriate permits from state/local authorities to drill any such wells.
- *Offshore Authorities.* If the well will be offshore, discuss with the applicant whether permits under the Marine Protection, Research, and Sanctuaries Act (MPRSA) or the Outer Continental Shelf Lands Act (OCSLA) are needed:
    - Under MPRSA, sub-seabed carbon dioxide injection for GS via Class VI wells, may, in certain circumstances, represent ocean dumping subject to regulation under the MPRSA. Application of the MPRSA would entail coordination of the permitting processes under SDWA and MPRSA, pursuant to MPRSA Sections 106(a) and (d).

    - Under OCSLA, Class VI wells injecting offshore (on the outer continental shelf) but within state territorial waters may be subject to requirements under the OCSLA in addition to the Class VI regulations. The Bureau of Ocean Energy Management, Regulation, and Enforcement, an agency within the Department of the Interior, administers the OCSLA.

- *Other Permits.* Discuss with the applicant any other permits that may be needed for other aspects of the facility. This may include permits under the National Pollution Discharge Elimination System Program under the Clean Water Act.

Section 4: Reviewing Pre-Construction Information



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4 Reviewing Pre-Construction Information

To apply for a Class VI permit, applicants must develop and submit to the UIC Program Director a range of geologic, hydrogeologic, modeling, engineering, and financial information about a proposed Class VI project [40 CFR 146.82(a)]. Because all of the information needed to evaluate the suitability of a proposed GS site will not be available at the time the permit application is submitted, there will likely be uncertainties regarding some aspects of the proposed site or the injection operation.

Permit Application Reviews where the Well is Converted for Class VI Injection

If the owner or operator plans to convert an existing well (pursuant to 40 CFR 146.81(c)), the permit application evaluation will incorporate elements of both the pre-construction and pre-operation phase reviews. The EPA encourages the UIC Program to consider the recommendations in Sections 4 and 5 together. See Section 3.2 for additional information.

The goal of the UIC Program's review of the permit application is to evaluate the suitability of the site based on the available information and to identify ways to address or mitigate any uncertainties about the site. Permitting decisions are technically complex and risk-based, and the UIC Program should consider how various components of the permit application and the data collected throughout all project phases will address site-specific conditions (including identified uncertainties) to ensure non-endangerment of USDWs. All the information collected and reviewed in the course of the permit application evaluation—and the documentation of that review—should collectively form a robust, defensible record of the decision.

During the pre-construction phase, Class VI permit applicants should submit the following types of information to the UIC Program as part of their Class VI permit applications:

- Site characterization information about the local and regional geology and hydrogeology (see Section 4.1.1);
- An AoR delineation based on computational modeling and information on wells in the AoR and their corrective action status (see Section 4.1.2);
- Information demonstrating financial responsibility for corrective action, injection well plugging, post-injection site care (PISC), site closure, and emergency and remedial response (see Section 4.1.3);
- Proposed well construction plans and schematics, a planned pre-operational testing program, and proposed operating data (see Sections 4.1.4 through 4.1.6);
- A series of proposed project plans presenting the applicant's approach to testing and monitoring, plugging the injection well, PISC, site closure, and addressing emergency or unforeseen events (see Sections 4.1.7 through 4.1.10); and
- Supplemental information related to injection depth waivers or aquifer exemption expansions, if applicable (see Sections 4.1.11 and 4.1.12).

Following the UIC Program's review of all information in the permit application and confirmation that the site will be protective of USDWs, a Class VI permit can be issued. See Section 4.2.

4.1 Evaluation of Pre-Construction Information

Class VI permit applications contain a wide range of information, including geologic data, an AoR delineation based on computational modeling, a financial responsibility demonstration, proposed project plans, proposed well construction plans and schematics, a planned pre-operational testing program, and proposed operating data [40 CFR 146.82(a)]. In addition, some permit applicants may need to submit supplemental information related to injection depth waivers [40 CFR 146.95] or aquifer exemption expansions [40 CFR 144.7].

All of this information is inter-related, and the information collected to meet one requirement may inform or be informed by other required submittals or analyses. Therefore, permit writers should ensure that, collectively, all of the information in the permit application is consistent and supports a determination of site-suitability. This necessitates a multi-disciplinary, team-based approach to the permit application review (see Section 3.1). Table 4-1 illustrates some of these relationships and provides examples of how they may affect the pre-construction evaluation process.

Table 4-1: Examples of Cross-Submittal Checks for Conducting Technical Evaluations of Class VI Permit Applications

Required Submittals	Recommended Cross-Submittal Checks for Evaluating the Permit Application
Site characterization data [40 CFR 146.82(a)(2),(3),(5),(6); 146.83]	• Geologic and hydrogeologic data collected during site characterization serves as, and should be consistent with, the **AoR delineation modeling** inputs. • Identified uncertainties should inform data collection during **pre-operational testing**. • **Well construction** should be suitable to, and compatible with, geologic data; the appropriate well depth should be informed by information on the depth to the lowermost USDW (unless an injection depth waiver is requested). • **Proposed operating procedures** (e.g., injection rates and volumes) should be appropriate to the storage capacity of the injection zone and the fracture pressure of the confining zone. • The **AoR delineation modeling** can be used to verify the storage capacity of the injection zone. • Monitoring locations and depths in the **Testing and Monitoring Plan** and **PISC and Site Closure Plan** should consider fluid geochemistry/mobilization of contaminants and the presence of fluid migration pathways (e.g., faults or fractures) identified via site characterization.
AoR and Corrective Action [40 CFR 146.82(a)(4),(13); 146.84]	• The AoR delineation model inputs should be consistent with and incorporate **site characterization** data and **proposed operating data**; data gaps should be addressed during **pre-operational testing**. • Monitoring locations in the **Testing and Monitoring Plan** and the **PISC and Site Closure Plan** should encompass the entire delineated AoR and be informed by the AoR delineation modeling; they should also account for all wells identified via the corrective action review. • **Financial responsibility instruments** should be adequately funded to address all needed corrective action. • AoR delineation modeling can inform the **site characterization** review, including storage capacity evaluation and an evaluation of the potential for induced seismicity. • The review of an **alternative PISC timeframe demonstration** should consider the AoR delineation modeling.

Required Submittals	Recommended Cross-Submittal Checks for Evaluating the Permit Application
Financial responsibility [40 CFR 146.82(a)(14); 146.85]	• Sufficient funds must be available to cover all needed **corrective action** and well plugging, based on the proposed **construction** of the well and the **Injection Well Plugging Plan**. • Financial instruments should be adequately funded to address vulnerabilities and/or endangerment to USDWs identified during **site characterization**, including the potential for induced seismic events. • The financial resources must also cover all activities identified in the **PISC and Site Closure** and **Emergency and Remedial Response plans**.
Proposed well construction [40 CFR 146.82(a)(11)(12); 146.86]	• The well materials should be compatible with all fluids with which they may come into contact and the design should consider the depth of all porous formations, as identified during **site characterization**. • The well's design and materials should be appropriate to the **proposed operating parameters**. • The **Injection Well Plugging Plan** should be appropriate to the well as designed and built (e.g., depth).
Proposed pre-operational testing [40 CFR 146.82(a)(8); 146.87]	• The planned formation testing should be sufficient to fill any gaps in available **site characterization** data and address key uncertainties in **AoR delineation modeling**. • The planned well testing should inform and confirm the **well construction** specifications and schematics.
Proposed operating data [40 CFR 146.82(a)(7),(9),(10); 146.83(a)(1); 146.88]	• The operating parameters should be suitable to the **site's geology**, i.e., to demonstrate that the injection zone has sufficient capacity to store the proposed carbon dioxide volumes. • The **AoR delineation** results should incorporate and support the proposed operating parameters. • The **well's construction** should be adequate to the proposed operating conditions.
Testing and Monitoring [40 CFR 146.82(a)(15); 146.89; 146.90]	• The Testing and Monitoring Plan should describe a monitoring strategy that is suitable to the **site's geology** and **proposed operating conditions** and addresses the entire **AoR**. • Appropriate well testing procedures are informed by **well construction, operating conditions**, and carbon dioxide composition as informed by **site characterization**. • Monitoring locations should consider the locations of any wells identified during the **corrective action review**. • The Testing and Monitoring Plan should collect the data needed to support a **non-endangerment demonstration**.
Injection Well Plugging [40 CFR 146.82(a)(16); 146.85; 146.92]	• The Injection Well Plugging Plan should be suitable to the proposed **well construction** and the **site geology**, including predicted composition of carbon dioxide-water mixtures. • Plugging procedures should be considered in developing **financial responsibility** cost estimates.
PISC and Site Closure [40 CFR 146.82(a)(17); 146.93]	• The PISC and Site Closure Plan should include predictions of post-injection plume movement based on the **modeled AoR**. • Post-injection phase groundwater and carbon dioxide monitoring should be an extension of activities in the **Testing and Monitoring Plan**. • The alternative PISC timeframe and criteria for the non-endangerment demonstration should be based on **AoR delineation modeling** and site-specific **geologic information**. • Post-injection monitoring and site closure activities should be considered in developing the **financial responsibility** cost estimates.

Required Submittals	Recommended Cross-Submittal Checks for Evaluating the Permit Application
Emergency and Remedial Response [40 CFR 146.82(a)(19); 146.94]	• The Emergency and Remedial Response Plan should address the risk characteristics of the site as informed by the **site characterization** (e.g., of induced seismicity) throughout the extent of the **modeled AoR.** • The **Testing and Monitoring Plan** and **PISC and Site Closure Plan** should collect sufficient data to detect all identified emergency scenarios. • **Financial responsibility** instruments should be adequately funded to address all risks and response actions identified in the Emergency and Remedial Response Plan.

The following sub-sections describe the evaluation of discrete types of program element information and the suggested outcomes of each review for the pre-construction phase evaluation. Each section describes: the types of information applicants are likely to submit and how the UIC Program can evaluate their completeness; the activities that the EPA recommends that permit writers take to evaluate the information submitted including, where necessary, discussing the information with the applicant or requesting additional or clarifying information; and the suggested outcomes or products of the review.

Because each permit application will be unique and the appropriate activities will be specific to the application being reviewed, the activities described below outline a recommended course of action to accomplish the goal of writing a protective, defensible permit. Therefore, this section also explains where the Class VI Rule affords flexibility to address site-specific circumstances and where exercising authority to request additional information per 40 CFR 146.82(a)(21) or otherwise exercising Director's discretion may be appropriate.

4.1.1 Site Characterization

Class VI permit applicants must provide extensive information about the local and regional geology and hydrogeology of the proposed site [40 CFR 146.82(a)(2),(3),(5),(6)].

The purpose of the UIC Program's evaluation of this information is to inform a determination that the Class VI well will be sited in an area with a suitable geologic system, consisting of an injection zone with sufficient capacity to receive the carbon dioxide to be injected and a confining zone that is free of transmissive faults or fractures per 40 CFR 146.83. The EPA recommends a two-phase approach to reviewing site characterization information (i.e., a review of the geologic information submitted per 40 CFR 146.82(a) and a comprehensive evaluation of that geologic information to confirm site-suitability, per 40 CFR 146.83), as described in the *UIC Program Class VI Well Site Characterization Guidance* and outlined below. The purpose of the UIC Program's review of the geologic information is to verify that the information submitted is accurate and that it provides appropriate and accurate inputs and considerations for AoR delineation modeling, well construction, and planned operation. Figure 4-1 provides an overview of the site characterization review process.

Completeness Review

Class VI permit applicants will likely submit geologic information about the site in a narrative document that describes: regional geology and hydrogeology; the thickness, mineralogy, porosity, and permeability of the proposed injection zone and overlying formations; suspected faults and fractures; geomechanical properties; seismic history; and the locations and baseline geochemistry of USDWs. This site characterization should be supported by maps, logs, cross

sections, the results of water quality sampling, and analyses of core samples. It may include a mix of published literature about the area and the results of research by the applicant. Maps and cross sections should be legible and include the names, lithologies, and depths of the injection and confining zones, and illustrate any regional structural features (e.g., folds, faults, domes, etc.). If the applicant is seeking an injection depth waiver, the site characterization should address formations below the injection zone, including the lower confining zone; see Section 4.1.11 for additional information on evaluating these projects.

The applicant's demonstration of site-suitability should be supported by research, modeling, bench top analyses, or geophysical and geologic data that are consistent with information presented elsewhere in the permit application. If, during pre-permit application discussions, an agreement was made regarding the need to characterize additional confining zones to impede vertical fluid movement, allow for pressure dissipation, and provide additional opportunities for monitoring, mitigation, and remediation, per 40 CFR 146.83(b), a UIC Program reviewer should verify that information on these additional zones is submitted.

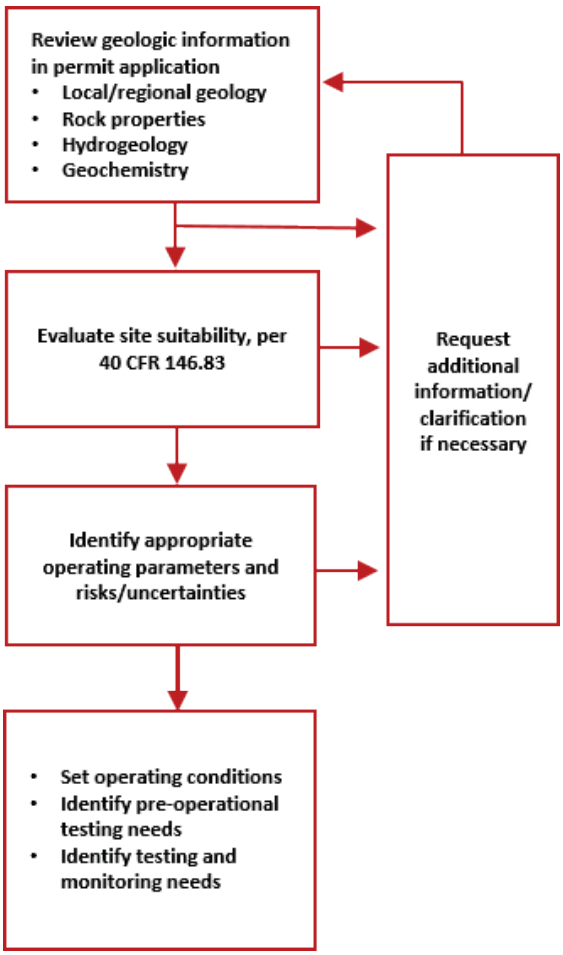

Figure 4-1: Site Characterization Review

The EPA encourages UIC Programs to perform a preliminary evaluation of the geologic information to confirm that it contains sufficient information on which to demonstrate that the site is comprised of formations that provide a suitable geologic system. During this preliminary evaluation, the permit writer should verify that the data collected and submitted are complete, that the methods used for analyses and calculations are described in adequate detail, and that quality assurance (QA) procedures are described where appropriate. Additionally, the UIC Program reviewers should confirm that secondary data are from reliable sources (e.g., federal or state agencies) and are recent and representative of the proposed site. The geologic data should represent all formations of interest, from the land surface to the injection zone (or to the lower confining zone, if the applicant is seeking an injection depth waiver). Data should be representative of the entire AoR and optimally provide some information on the general area surrounding the AoR. There should also be background information describing the regional geologic setting.

If any information is missing or is not presented in sufficient detail to inform an evaluation of site-suitability, the EPA recommends initiating a request for additional information or asking clarifying questions to inform and expedite the review.

Evaluation

Some of the geologic information submitted is fairly "straightforward," e.g., maps and cross sections, the results of testing and sampling, or research about the site to meet the requirements of 40 CFR 146.82. Conversely, some aspects of the permit application and its review reflect synthesis and integration of site-specific geologic data to support a determination of site-suitability per 40 CFR 146.83.

It may be appropriate to review the more basic information first to verify its accuracy and that it meets the Class VI Rule requirements (e.g., that faults and fractures are non-transmissive) as well as to consider how this information will inform more integrative analyses of site-suitability. Likewise, while the more comprehensive aspects of the review cannot be finalized until the geologic data are verified, the UIC Program should begin to plan for the comprehensive review early in the process to ensure that all of the required information—in appropriate types and levels of detail—will be available to support the review. Some aspects of this more comprehensive review will also need to be performed in coordination with the AoR delineation modeling review (see Section 4.1.2).

Members of the permit application review team are encouraged to work collaboratively, as appropriate, to ensure that a sufficient amount of geologic information will be collected and reviewed to support all aspects of the permit application review. Throughout the course of the review, alerting other members of the review team in a timely manner if there is concern about any aspect of the site's geology that may impact well construction or operations, or other components of the project, will benefit the comprehensive review and the schedule.

The bolded and italicized text below outlines a suggested approach that a UIC Program might employ to evaluate site characterization information, submitted by a Class VI permit applicant, to confirm that an applicant's submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Review geologic information submitted per 40 CFR 146.82(a). Review this information to confirm that the geologic site characterization is based on appropriately collected site-specific information or relevant existing data or literature about the proposed site; identify any potential site attributes that may affect its suitability for GS; and identify uncertainties to be addressed via pre-operational testing, operational changes, targeted testing and monitoring, or other permit conditions.

Review information on regional geology and geologic structure. Review the maps and cross sections that the applicant has provided to verify that they are at a scale that shows the location of the project site and places it in a regional context. Verify that the geophysical methods used to characterize the site are suitable for the geologic environment and data needs. Table 2-1 in the *UIC Program Class VI Well Site Characterization Guidance* summarizes the utility of various geophysical survey methods to various types of investigations (e.g., of porosity, thickness). Verify that the surveys were performed at a sufficient resolution such that the size of subsurface features can be distinguished. Geophysical surveys should complement, but not replace information such as logs, outcrop data, or core samples. Verify that delineation of stratigraphic units indicated by geophysical survey data is consistent with maps and well logging information.

Evaluate information on faults and fractures. Verify the extent/areal coverage of any pre-existing or public information (e.g., from the U.S. Geological Survey (USGS) or state geologic

surveys) to confirm whether or not the information is inclusive of the injection and confining zones throughout the AoR.

If information on faults is based on two-dimensional geophysical surveys, assess whether the location, geometry, depth, or displacement of the faults or fractures can be ascertained. Assess whether units juxtaposed by faulting can be determined based on geophysical surveys along with other information. If faults cannot be definitively identified or ruled out based on the images submitted, or exist but are not adequately characterized, consider requesting additional supporting information. This may include a need for higher resolution geophysical studies, updated processing and imaging from existing surveys, or information from additional sources. If the applicant does not address ambiguous features in geophysical surveys (e.g., seismic reflectors that might represent small faults), request clarifying information. Note that gravity methods are less useful than other geophysical methods for detecting small faults or faults with large displacement occurring in discrete steps; vertical faults are especially difficult to detect using surface gravity methods.

Verify that any demonstration that faults are non-transmissive is supported by adequate data and information about the site (e.g., analyses of core samples, results of geophysical surveys, pore pressure data, maps, and cross sections). Confirm that the methods for any relevant calculations (e.g., calculation of shale gouge ratio or assessment of fault slip tendency) are adequately described. Verify that the applicant's demonstration of fault stability is supported by the information submitted on downhole stresses and reflects anticipated injection pressures. Communicate any concerns about the existence of faults to the AoR delineation modeling team and to the staff reviewing the planned injection and post-injection phase testing and monitoring so that monitoring can target areas of potential concern for carbon dioxide migration.

Review information about the depth, areal extent, and thickness of the injection and confining zones. Evaluate geologic maps, cross sections, and any other maps submitted to ensure that they demonstrate that the identified confining zone extends throughout the AoR and is continuous with no pinchouts. If cross sections do not include all formations of interest (i.e., from the surface to at least the injection zone) or a sufficient extent of the preliminary AoR is not represented, request additional cross sections.

Confirm that any seismic or other geophysical data are of appropriate resolution and lateral extent to provide information on the injection and confining zones throughout the AoR. Ideally, at least two perpendicular profiles that pass close to the proposed injection well will be presented for general site description. Because two-dimensional seismic surveys are not optimal in settings where significant lateral heterogeneity is expected, three-dimensional surveys may be preferable when characterizing sites with complex or variable subsurface geology. If such surveys are performed, consider using them as a baseline for the Testing and Monitoring Plan (see Section 4.1.7).

Verify that geophysical data, core data, well logging data, and other information support consistent conclusions about the properties of the injection and confining zones. Verify that the applicant's interpretation and discussion of stratigraphy, depositional features, and environments incorporate all relevant information. If these are not representative of the entire geographic area or of all depths, incorporate the collection and analysis of additional cores or logs into the pre-operational formation testing program.

If there is variability in the thickness of the injection or confining zones, verify that this would not adversely affect storage or confinement. If the confining zone does not extend throughout the AoR or there is any uncertainty about whether it is sufficiently thick and homogeneous over the entire area, consider requesting information on an additional confining zone(s).

Review hydrologic and hydrogeologic information. Verify that information from existing data sources is reliable and accurate. For example, state water centers, water surveys, or departments of water resources or health are likely to have the most comprehensive databases of water well locations and depths. The USGS and state and local agencies may have the most complete information on USDWs and springs within the AoR.

Coverage from public sources may not be complete. Consider asking the applicant to fill in any information gaps using on-the-ground surveys or hand searches of health or environmental department records, especially if the proposed project is in a populated area.

Verify that the level of detail and the geographic scope of the available information will allow identification and characterization of all USDWs in the AoR. This submittal should also agree with any information submitted with the permit application (or that is otherwise available) on the depths, extent, and groundwater flow patterns of regional USDWs.

If there is a USDW in the AoR, coordinate with staff reviewing the Testing and Monitoring Plan to ensure that the groundwater sampling plan targets USDWs in the area. Also verify that the Emergency and Remedial Response Plan and the financial responsibility cost estimates address the potential contamination of the USDW. Communicate any updates to this information to review team staff evaluating the AoR and Corrective Action Plan.

Examine geochemical data that may have been submitted to meet the requirements at 40 CFR 146.82(a)(6). If the applicant collected fluid samples in advance of drilling the injection well (i.e., via a stratigraphic test well or in existing nearby wells) to provide baseline geochemical data, verify that they conducted a thorough geochemical analysis. A thorough suite of analyses should address basic fluid chemistry and any contaminants that could potentially be mobilized based on available information about the composition of the rock matrix and the composition of the injectate. At a minimum, the analytes should be consistent with those identified in the proposed Testing and Monitoring Plan.

Verify that fluid samples were collected using techniques that preserve downhole pressure conditions at the depths from which they were sampled or that downhole pressure and temperature estimates were available to support modeling of water chemistry speciation under conditions in the injection zone. Also verify that samples were analyzed at accredited or certified labs or at academic/university labs. If unaccredited or uncertified labs were used, it may be appropriate to request additional information about the labs to verify that they are qualified to perform the analyses (i.e., that appropriate QA controls were in place when the analyses were performed); if no information about the lab's accreditation and/or qualifications is available, consider requesting analysis/testing of new samples.

If historical geochemical data are provided, verify that the samples represent formations and locations of interest. If they do not, or the origin of the information is unclear, consider requesting that the applicant perform additional sampling to confirm the information. Also assess any available information on sampling and analytical techniques (including QA information) to verify the quality of the historical data. If data quality is in question, the values may not be

reliable for assessment of site-suitability, although they may provide some basic context for site or regional geology. If data quality is poor, consider requesting that new samples be taken, if feasible. If there has been injection or production in the area since the samples were taken, consider requesting additional or more recent analyses as part of the pre-operational formation testing program to confirm that the geochemistry has not been significantly altered as a result of these activities.

Verify that fluid chemistry data were obtained from all appropriate formations (i.e., from at least the injection zone and the lowermost USDW above the confining zone) as close to the injection well and in as many locations in the AoR as practicable. Confirm that samples were taken at wells with a sufficient yield to represent the water chemistry of the formations to be sampled. If an insufficient geographic area (e.g., less than the extent of the AoR) is represented and data points are far from the injection well, or the chemical data are extremely limited, consider asking the applicant to conduct additional sampling. If the applicant is seeking an injection depth waiver, review geochemical information from samples taken from below the lower confining zone; see Section 4.1.11 for additional information on evaluating these projects.

If there is a concern that trace metals may be liberated due to changes in pH and affect USDWs, examine (or, if necessary, request) an analysis of formation solids in the injection and confining zones. Verify that appropriate solid phase chemical analytical techniques (i.e., EPA-approved methods) were used, or consider requesting analyses using such techniques. Coordinate with the reviewer of the Testing and Monitoring Plan to ensure that any contaminants that could potentially be liberated/mobilized are monitored as part of the groundwater monitoring program in the plan. Additionally, ensure that all of the chemicals in the baseline analysis are included as groundwater monitoring parameters throughout the duration of the project.

Review water quality sampling information to confirm the location and depth of the lowermost USDW. Verify that the reported lowermost USDW is identified based on total dissolved solids (TDS), and not on other permitting or regulatory requirements related to water resources in the area, such as aquifer usage or the depth to which surface casing must be set in oil and gas wells in the area. Section 2.3.9 of the *UIC Program Class VI Well Site Characterization Guidance* provides information on baseline geochemical characterization.

Evaluate geomechanical and petrophysical information. Verify that the applicant submitted sufficient information to characterize all required geomechanical and petrophysical parameters throughout the project area. This includes porosity, permeability, capillary pressure, and information on fractures, stress, ductility, rock strength, and in situ fluid pressures within the confining zone. Verify that the applicant presented information on and discussed the variability in measurements for the various types of geomechanical and petrophysical data. Because this information should provide the inputs for the AoR delineation modeling, coordinate with the AoR delineation modeling reviewer to verify that the inputs of the applicant's model match this information and that the inputs of the independent modeling incorporate this information. Also confirm that the modeler is aware of any changes to or uncertainties about the geologic data (see Section 4.1.2).

Ideally, any core samples that were taken (or will be taken) should be geographically distributed and of a sufficient number to represent areas close to the proposed well *and* areas that are representative of the entire AoR, accounting for any heterogeneities in the injection and confining zones. (It is likely that core samples may not be taken and analyzed until after

construction is authorized; verify that the pre-operational formation testing program will fill in any information gaps or address uncertainties. See Section 4.1.5.) If there is any indication that samples were damaged during drilling, assess whether that damage was likely to affect the analytical results. If available data are of low quality or inadequate to establish the suitability of the site, consider asking the applicant to collect and analyze new cores under the pre-operational formation testing program.

Confirm that measured permeabilities and porosities are consistent with what is known about the lithologies of the injection and confining zones and that they are reasonable values for injection and confining zones at the proposed operating conditions. Note any discrepancies between laboratory and field or well log-based values and assess whether such discrepancies are expected based on geologic and lithologic features or the methods used. If the applicant used log- and core-based porosity and permeability values to develop estimated permeability distributions, verify that the method used is fully explained and that the choices made in executing the calculations are clear and reasonable. Compare estimated values with log- and core-based values and consider the magnitude of any discrepancies and whether such discrepancies are explained. Coordinate with staff performing the AoR review to compare these data with those used in the AoR delineation. Uncertainties in estimates of formation properties (e.g., porosity, permeability) may be addressed by incorporating this information into sensitivity analyses in the AoR delineation modeling.

Verify that the method used to measure capillary pressure allows measurement at pressures and temperatures representative of the injection zone. Assess the number of samples used and verify that they are representative of any variability in lithology and that there are a sufficient number of samples to assess method variability within a lithology. Assess spatial variability and compare the values against expected pressure at the base of the confining zone should a column of separate-phase carbon dioxide develop. Also verify that measurements of ductility and rock strength are based on appropriate laboratory tests that are suitable for simulating downhole stress conditions.

Verify that information on in situ stress incorporates measurements of vertical stress, maximum horizontal stress, and minimum horizontal stress. Also verify that the applicant used appropriate methods to measure stresses (e.g., integrating density above the point of measurement to estimate vertical stress; ASTM Method D 4645-08 to measure minimum horizontal stress and maximum horizontal stress).

Verify that data submitted for any borehole logs used (e.g., fracture finder/microseismogram logs, caliper logs, or acoustic logs to detect fractures or formation testers to measure pore pressure) are complete and that measurements were taken in locations that are representative of the injection and confining zones.

If seismic data were used to obtain pore pressure estimates or used in conjunction with well logs and other data to develop porosity and permeability distributions, verify that the survey was performed at a sufficient resolution for those purposes and that data processing steps were described and are appropriate. Verify that any assumptions and uncertainties are noted.

Review information submitted on the mineralogy, petrology and lithologies of the injection and confining zones. Verify that the cores on which this information is based were collected from locations representative of the project site and that they include the injection and confining zones—or that cores will be taken as part of the pre-operational formation testing program.

Assess whether adequate core descriptions are provided and whether the cores and samples are likely to provide an indication of variability in mineralogy and overall lithologic heterogeneity that will inform the AoR delineation modeling. For example, other information, such as borehole imaging or the results of other research in the region, can be used to determine the appropriate number of samples to take.

Verify that proper analytical techniques were (or will be) used to characterize core samples. Polarized light microscopy and scanning electron microscopy may be used on thin sections, and powdered samples may be subject to X-ray diffraction. Information should include both macroscopic (hand sample for core descriptions) and microscopic (e.g., percentages of minerals present) analyses.

Note whether the mineralogy suggests any potential for release of trace metals through mineral dissolution when pH is lowered. Also take note of any likely geochemical reactions (e.g., dissolution of carbonates in or near the well or precipitation of carbonates in distal areas) that would affect injectivity, containment, and/or overall performance of the project.

Lithologic and mineralogic information based on analyzed samples should be consistent with other sources, such as information in the scientific literature, maps and cross sections prepared by the USGS or state geological surveys, and well logs. Request additional information if descriptions and analyses are incomplete, inaccurate, or not in agreement with other research.

Review the seismic history of the site and information on the presence and depths of seismic sources and seismic risk. It is likely that the applicant will rely on existing data (e.g., from USGS, the National Oceanic and Atmospheric Administration, state databases, or data generated by state seismic monitoring regimes, if the state has complete coverage) to determine the location and depth of any identified seismic sources. Confirm that the applicant used such reliable sources to compile seismic history data. Verify that the research covers the AoR of the Class VI project over an appropriate historical time period and includes sufficient information on the magnitudes and hypocenters of previous seismic events.

If the data are inconclusive or there have been earthquakes in the past, consider asking the applicant to model or otherwise determine, using documented methods, that seismic activity from identified sources will not endanger USDWs. Consider coordinating with the AoR delineation modeling reviewer to evaluate the extent of pressure increase due to injection and whether such an increase could possibly reach any faults or impact fault stability. This evaluation may also include an assessment of potential fluid migration rates if a transmissive fault were intersected by the plume and/or the area affected by the pressure increase.

Addressing Seismicity in the Class VI Permit

If there was recent seismicity near the proposed site (either natural or injection-induced), consider requiring passive seismic monitoring. The Testing and Monitoring Plan should describe a passive seismic monitoring network across the AoR that can detect seismic events.

Additionally, the Emergency and Remedial Response Plan could include an action plan to address seismic events. Several states and the EPA have developed "stoplight" approaches, in which the response varies based on the magnitude or location of the event and whether it was felt. Responses range from documenting the event to gradually shutting injection operations and investigating the event to immediately shutting the well and performing necessary corrective and/or remedial actions.

If any of the geologic or seismic data indicate a substantial likelihood of seismic activity, a fault stability analysis may be needed to demonstrate that seismic activity will not compromise subsurface containment. If there is the potential for seismic activity that may reactivate faults that transect the confining zone(s) and compromise containment, consider whether operational changes can be made and/or passive seismic monitoring can be incorporated into the Testing and Monitoring Plan to manage the risk.

Review surface air and/or soil gas monitoring data (if submitted). If surface air and/or soil gas monitoring will be required as part of the project's testing and monitoring regimen, verify that baseline data have been collected according to established methods. Verify that sampling locations have been established in locations that are representative of the entire AoR and that monitoring will provide information on any areas with potential for carbon dioxide migration (e.g., areas with faults or fractures or abandoned well bores).

Comprehensively evaluate all geologic information to determine whether it supports a demonstration of site-suitability, per 40 CFR 146.83. Section 3 of the *UIC Program Class VI Well Site Characterization Guidance* recommends approaches and analyses that applicants can perform to support this determination. This comprehensive evaluation involves reviewing all geologic data (including the information described above) along with any additional analyses, such as the AoR delineation modeling, to support a determination regarding the site's suitability for GS or to identify uncertainties about the site. Some approaches to addressing uncertainties about the site that the UIC Program may consider include: collecting additional data as part of the pre-operational formation testing program, performing sensitivity analyses as part of the independent AoR delineation modeling, adjusting operational parameters, or requiring tailored or increased monitoring during the injection and post-injection phases of the project.

As noted above, while this evaluation depends on the outcome of the geologic data review, planning for this comprehensive review should begin as soon as the permit application is received. Also, it is likely that the final determination of site-suitability will not be made until site-specific pre-operational testing is complete. See Section 5.1.1.

The paragraphs below provide recommendations for this comprehensive determination of suitability including evaluating: facies changes in the injection or confining zones, injection and confining zone structure, compatibility of the carbon dioxide stream with subsurface fluids and minerals, the storage capacity of the injection zone, and integrity of the confining zone(s).

Determine whether facies changes in the injection or confining zones may impact storage or confinement of carbon dioxide. Assess the information on the major facies present and any descriptions regarding their role in storage and confinement of carbon dioxide. Verify that facies interpretations referenced in the permit application are consistent with available geologic data for the site, including geologic and isopach maps, stratigraphic columns, well logging data, available core samples or outcrop data, and seismic data. Verify that information from all of these sources agree and support similar conclusions about the site. This information should also be consistent with the geologic site conceptual model used in the AoR delineation modeling.

Assess whether the facies interpretations are consistent with a determination that the confining zone(s) is sufficiently thick and continuous throughout the AoR to provide confinement. A confining zone of adequate lateral extent is particularly important where there are no structural traps and the carbon dioxide may migrate long distances. Take note of any indication of possible major facies changes that would provide potential preferential flow paths that could result in

movement of the plume in a particular direction or at an accelerated rate. Consider whether the data suggest that there may be high permeability zones within the confining zone that would provide a potential carbon dioxide migration pathway. If any portions of the AoR are not well characterized or the data suggest heterogeneities in the confining zone, discuss whether a secondary confining zone can be identified and, if appropriate to ensure USDW protection, request that the applicant characterize it.

Also assess whether facies interpretations are consistent with the properties of the injection zone and the injection formation as a whole. Consider the stratigraphy, degree of homogeneity or heterogeneity in lithologies, and petrophysical properties described in the permit application. Note if any features may affect migration of carbon dioxide or brine (e.g., low-permeability zones or potential preferential flow paths).

If the confining zone generally appears to be acceptable, but there are minor uncertainties about homogeneity or facies changes that may allow preferential flow paths for fluid migration, consider including targeted groundwater monitoring and carbon dioxide plume tracking in the Testing and Monitoring and PISC and Site Closure plans. If appropriate, consider requesting additional pre-operational testing (e.g., well logs or core samples for areas other than the injection well).

Examine the structure of the injection and confining zones. Examine data (including maps, cross sections, well logs, and seismic or other geophysical data) to confirm that local and regional geologic structures are conducive to GS and form an adequate confining system.

Verify that the applicant's understanding of the site's structural geology is based on a sufficient amount of data that are representative of the entire project area and encompass major features, especially where the local geology is complex. Also verify that the various data sources provide a consistent portrayal of the presence, types, sizes, and orientations of structural features. Verify that these features (e.g., dip, folds, and faults) are accounted for in, and are consistent with, the geologic conceptual model upon which the AoR delineation is based.

If a structural trap is present (e.g., fold, dome, fault trap), verify that its size and orientation are consistent with the anticipated direction and extent of plume migration. Assess this information in conjunction with AoR delineation modeling results to verify that the trap is sufficiently large to contain the proposed volume of carbon dioxide without evidence of pressure buildup that could fracture the confining zone. Steeply dipping folds or high domes may allow unacceptable stress on the confining zone from buoyant forces, while unfolded, gently-dipping sequences may allow carbon dioxide to migrate long distances. In the latter case, the AoR may be larger, and the potential effects of facies changes should be considered. If trapping is based on the presence of faults that juxtapose the injection zone with low-permeability units, verify that the stability and sealing properties of such faults have been assessed by the applicant.

Where data are incomplete or there is uncertainty regarding the geometry of the structural features or the tops and bottoms of the various units, discuss these uncertainties with the applicant. If necessary, request additional or higher resolution seismic surveys, or ask the applicant to perform additional logging (e.g., logging within wells other than the injection well) as part of their pre-operational testing procedures to refine the geologic conceptual model of the site. Also, consider incorporating additional plume monitoring in areas of concern into the Testing and Monitoring and PISC and Site Closure plans.

Assess the compatibility of the carbon dioxide stream with subsurface fluids and minerals. If the applicant's demonstration of compatibility is based on literature reviews or existing data, these data should closely reflect conditions at the site. For example, the supporting information should be based on earlier studies of the area or of geologic settings that are very similar to the proposed project site. Literature reviews may be appropriate for the pre-drilling characterization of compatibility and should be used to guide formation testing objectives for gathering information to support experimental or modeling studies.

Review the results of any geochemical or reactive transport modeling performed. Verify that the modeling inputs represent: the mineralogy of the injection formation; the results of formation fluid analyses; pressure, temperature, and pH conditions at depth; and injectate composition. Verify that the modeling allows for appropriate precipitation and dissolution reactions and that the thermodynamic and kinetic datasets used are suitable to project-specific conditions. Models should be robust, reproducible, and supported by inputs that are well documented and representative of the site. See Section 3.3.1 of the *UIC Program Class VI Well Site Characterization Guidance* for additional information on the use of modeling to evaluate carbon dioxide compatibility.

Review the results of any benchtop laboratory experiments performed. Confirm that the rock and fluid samples used in the experiments were from the site (ideally near the well) or are similar in composition to those at the site; also confirm that experimental conditions represent the downhole pressure and temperature conditions near the well. Verify that the experiments involved samples that represent any lithologic heterogeneities known to exist in the AoR. If grinding of rock samples or other changes were made to increase reaction rates so as to complete experiments in a feasible amount of time, note whether the implications of this are discussed. Verify that the experiments ran for a sufficient duration to allow the establishment of steady state conditions and that porosity and permeability changes were evaluated post-experiment using appropriate laboratory methods (see also the discussion of porosity and permeability above and Sections 2.3.4 and 2.3.5 of the *UIC Program Class VI Well Site Characterization Guidance*).

Identify whether the results of models or experiments indicate potential interactions between the injected carbon dioxide and native fluids that could affect operational parameters, plume migration, or storage capacity. For example, if potential changes in porosity and permeability (particularly in a reactive formation with a high carbonate content) could affect injectivity during the project, work with the modeling team to ensure that these changes are incorporated into the AoR delineation modeling and that storage capacity estimates and their potential effects (both positive and negative) have been explored. If mineral precipitation or dissolution could liberate trace elements of concern, consider requiring tailored testing and monitoring using appropriate analytical procedures to provide evidence of trace metal contamination of USDWs.

If there are any uncertainties about modeling or experimental results, ensure that appropriate information will be collected during pre-operational testing to provide more site-specific inputs for updating the experiments or re-running the model prior to authorizing injection. If the site is not homogeneous, verify that modeling or experimental work appropriately captured variability throughout the AoR, including information from any core and fluid samples collected from different locations within the AoR.

For information on considerations for evaluating the compatibility of the carbon dioxide stream with well materials, see Section 4.1.4.

Evaluate estimates of injection zone storage capacity. Evaluate the methods used for estimating storage capacity. See the *UIC Program Class VI Well Site Characterization Guidance* for additional information on static models or dynamic models. For site-specific estimates where the geologic data are available and numerical reservoir models are already developed for AoR delineation, dynamic methods are preferred.

Review any modeling the applicant used to estimate storage capacity. Verify that the inputs used in models to estimate storage capacity are representative of the site (e.g., injection zone properties and site-specific trapping mechanisms). Also verify that the inputs reflect the proposed operation (e.g., injection volume, rate, and duration). If the data used are not site-specific, verify that they are representative of site characteristics, particularly in settings where heterogeneity may significantly affect the performance of the project.

If a static method was used to estimate storage capacity, review the information used for consistency with other site and project information and identify any limitations (e.g., lack of heterogeneity or other unaccounted features, such as injectivity, pressure development, or effects of trapping mechanisms). Discuss these limitations with the applicant and consider whether a more refined estimate of storage capacity can be obtained prior to injection or early in the injection phase in conjunction with an AoR reevaluation (see Section 6.2). Compare the resulting storage capacity estimates to the delineated AoR (see Section 4.1.2) and any additional analysis included in the AoR delineation modeling evaluations.

Independent verification of the storage capacity estimates can be performed as part of the AoR delineation modeling. Coordinate with the staff performing the modeling evaluation so that the basis for estimating the storage capacity of the injection zone (i.e., the model inputs used) is consistent with the operational plans for the project and other geologic data submitted with the permit application. The estimated storage capacity should be greater than the total planned carbon dioxide volume, with a safety margin that is commensurate with the level of uncertainty in the estimation method or the inputs on which the estimate was based or any uncertainties about the site geology. Also confirm that the pressures predicted to occur within the geologic system will not exceed 90 percent of the fracture pressure of the injection zone. If additional injection wells are planned or there are other operations in the region injecting into or producing from the same formation or any hydraulically connected formations, confirm that storage capacity estimates incorporate any effects of such operations.

If the storage capacity of the injection zone is less than the total anticipated volume of carbon dioxide to be injected, discuss planned injection operations with the applicant and adjust the permit conditions (i.e., for injection rates and volumes) accordingly.

Evaluate the integrity of the confining zone(s). Compare the pressure distributions predicted by the AoR delineation modeling to the fracture pressure of the injection zone to verify that the proposed injection conditions will not cause an exceedance of the fracture pressure. Also verify that there is an adequate margin of safety or, if appropriate, adjust the operating conditions (e.g., injection rates or total volumes to be injected over the duration of the project).

Consistent with the intent of 40 CFR 146.83, it is important that the confining zone is sufficient to provide a barrier for fluid movement without relying on additional formations (e.g., "thief zones") to receive carbon dioxide were it to migrate out of the injection zone and into formations between the injection zone and the lowermost USDW. While such zones may provide additional protection, they should not be relied upon for confinement. If the applicant discusses such zones

without providing sufficient detail on the confining zone, request additional information about the proposed confining zone or consider recommending that the applicant characterize an additional confining zone.

Verify that the capillary entry pressure of the confining zone is greater than pressures anticipated to occur in the separate-phase carbon dioxide plume, based on proposed operating data and modeling (with appropriate safety margins, particularly in heterogeneous formations). Such determinations should be made throughout the AoR.

Assess whether information was presented to indicate that any faults within the confining zone are sealing. See Section 3.5.5 of the *UIC Program Class VI Well Site Characterization Guidance* for examples of how fluid migration along faults can occur. Verify that any faults in the area are not expected to adversely impact confinement, are identified based on site-specific data, and have been evaluated at various scales as data and samples allow (e.g., thin section, hand sample, and outcrop). Additionally, verify that any faults in the confining zone will not be reactivated under the proposed operating conditions. For example, verify that a fault stability analysis was based on reliable data and was well documented.

If the primary confining zone does not exhibit sufficient thickness or strength to allow injection at the proposed pressures and volumes with an appropriate safety margin, the UIC Program might consider one of the following options: requesting information on an additional confining zone, adjusting the operating conditions in the permit, or discussing with the applicant the need to select another site. Likewise, if there is uncertainty about the evaluation of confining zone integrity, discuss with the applicant whether additional data can be gathered during pre-operational formation testing or during injection and post-injection monitoring to target areas where fluid migration may be a concern.

Outcomes

Following the evaluation of geologic information in the permit application, the UIC Program should consider documenting the review for inclusion in the permit file. An administrative record for the permitting decision that contains documentation of the review could support a response to comments on the permit, a response if the permit were challenged, and future decisions made on the project by either the permit writer or new/different permitting authority personnel. This documentation could include the following:

- A report that confirms the suitability of the site for GS (pending the results of the pre-operational formation testing program) and describes any identified deficiencies, uncertainties, or data limitations and how these limitations or uncertainties will be addressed (e.g., via modifications to operating procedures or testing and monitoring); and
- A document that summarizes the evaluation of seismic risk, including the site-specific information reviewed and the permit conditions designed to minimize the risks associated with seismic events. This type of document is particularly recommended if there is a concern about induced seismicity in the area of the project. The EPA developed an "Injection-Induced Seismicity Decision Model" for Class II oil and gas disposal wells that can be adapted to summarize evaluations of Class VI permit applications.

Any supporting documents should be uploaded to the project's permit package area in the GSDT.

4.1.2 AoR and Corrective Action

The Class VI Rule requires owners or operators to develop and submit an AoR and Corrective Action Plan as part of their permit application [40 CFR 146.82(a)(4),(13); 146.84(b)]. The plan must document the owner or operator's compliance with the AoR delineation requirements (including the AoR delineation modeling approach), present a comprehensive strategy for AoR reevaluations over the duration of the project, and describe how any necessary corrective action will be conducted.

The purpose of the UIC Program's evaluation of the AoR delineation approach is to assess whether the AoR, as modeled, appropriately represents the area in which USDWs may be endangered by the injection operation, as specified by the Class VI Rule requirements. The delineation of the AoR relies on site characterization and proposed operational data (and the evaluation of the AoR delineation should consider this information). It also informs and supports the development and evaluation of other components of the permit application (such as the determination of site-suitability and strategies for compliance with the testing and monitoring, financial responsibility, and emergency and remedial response requirements).

The UIC Program should also review all corrective action information to ensure that all artificial penetrations that may allow fluid movement into USDWs in the AoR are identified and appropriately addressed by corrective action to ensure that they do not serve as conduits for fluid movement.

Completeness Review

Class VI permit applicants will submit a draft AoR and Corrective Action Plan, including detailed modeling information supporting the AoR delineation and information about wells in the AoR. The AoR and Corrective Action Plan should be a narrative document that describes how the AoR delineation was conducted, identifies how the input parameters for the model were selected, and presents proposed strategies for reevaluations and corrective action. Permit applicants will also submit detailed modeling data (e.g., data inputs, information on processes modeled and the simulator used, assumptions, and outputs) to support a full evaluation of the AoR delineation. The UIC Program should verify that the plan provides an accurate and complete benchmark of the initial AoR delineation process, documenting the modeling process at a sufficient level of detail and clarity. Permit applicants should also provide detailed data on the wells in the AoR, information about their condition and depth, and, if necessary, the status of corrective action.

The UIC Program should perform a preliminary assessment of the plan and the modeling information to determine whether the submitted information is sufficient to evaluate: compliance with the rule requirements for computational modeling, AoR reevaluation procedures, and corrective action. As described below, this evaluation may involve conducting semi-independent or independent computational analyses (e.g., multiphase flow simulations of the proposed injection project). Therefore, when performing the preliminary assessment, the UIC Program should ensure that the permit applicant has submitted all information necessary for the comprehensive/technical evaluation. If the applicant used a proprietary model to delineate the AoR, the UIC Program should verify that the applicant provided sufficient information, including the code assumptions, relevant equations, and other information necessary to allow an independent review of the modeling effort. If any additional information or clarification is

needed, the UIC Program may need to request additional information or clarification to inform a completeness determination.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate the AoR delineation and information on corrective action, submitted in a Class VI permit application, to confirm that an applicant's submittal meets the Class VI Rule requirements and informs the establishment of protective permit conditions.

Conduct a comprehensive technical evaluation of the AoR delineation. This evaluation of the applicant's AoR delineation modeling effort will involve a combination of qualitative and quantitative assessments. The recommendations below apply to a typical evaluation process; however, it is important to note that the evaluation process will need to be tailored to each project's specific conditions and each applicant's computational approach.

There will likely be no site-specific testing and monitoring data for model validation at this stage of a project. Therefore, the evaluation process aims at achieving three main goals:

1. An assessment of the conceptual model to verify that it is consistent with the site characterization component of the permit application (see Section 4.1.1) and that it provides an accurate representation of the geologic and operational systems.
2. An assessment of the computational/numerical model used to delineate the AoR to verify that it: accounts for all applicable chemical and physical characteristics of the injected carbon dioxide and displaced fluids; is constructed to reasonably and accurately represent the geologic and operational systems; and yields the necessary information to delineate the AoR.
3. An evaluation of the methodology used to delineate the AoR, based on the modeling results, to ensure that the AoR accurately represents the area where USDWs must be protected from endangerment.

Because every computational approach is only an approximation of an actual system, ensure that all simplifying assumptions used in the model and the AoR delineation are clearly stated. Furthermore, ensure that the modeling data and the information submitted in the AoR and Corrective Action Plan are sufficiently reproducible and accurate to ensure continuity and consistency in project operations and decision-making, given the typically long duration of Class VI projects. Recommendations for achieving these three goals are provided below.

Evaluate the conceptual model and model inputs/assumptions using qualitative methods and/or statistical evaluations (e.g., summary statistics, histograms, etc.) to verify that the model accurately represents the geologic and operational systems. If the project is to operate under an injection depth waiver, this assessment would extend to include information on the lower confining zone.

The data to evaluate include:

- Model Domain, Coordinates, Boundaries, and Other Properties: Evaluating model domain data and relevant figures (e.g., plan and cross-sectional views of the model domain) to ensure that submitted data files (e.g., grid data files) include the extent of the model in all dimensions and accurately represent the project site and injection/confining

formations, that the domain is sufficiently large to contain the predicted plume and pressure front, and that boundaries reflect the true hydrogeologic setting.

- Rock Properties: Determining whether the rock property data used in the model—such as rock type(s), porosity/permeability/rock type distributions, and constitutive relationships (e.g., relative permeability functions)—are consistent with the geologic data in the permit application. It is also important to ensure that the method for assigning the properties is clearly described and supported by relevant figures (e.g., cross-sectional/plan views of property distributions, graphs of functional forms of constitutive relationships).
- Other Structural Properties: Reviewing model inputs for any structural features that may affect containment of the plume, such as faults, folds, fractures, and permeability barriers. Ensure that all such structures identified during site characterization have been appropriately represented in the model.
- Initial Conditions: Determining if the initial conditions selected in the model accurately represent the baseline conditions established during site characterization. For example, these include the aqueous pressure, temperature, and salinity conditions in the injection formation.
- Operational System: Evaluating injection well construction and operational information to ensure that it is consistent with the relevant components of the permit application and that it incorporates any nearby injection/production operations in the injection formation.
- Model Outputs: Ensuring that the submitted data files adequately represent the extent of the plume and pressure in time-series (i.e., plan view or cross section) and that the submission includes associated images and descriptive time/location information. Other information needed to assess compliance with the rule requirements may include: certain pressure profiles (at injection and/or monitoring wells), carbon dioxide saturation profiles, an assessment of carbon dioxide partitioning into different phases (including trapped carbon dioxide) over time, and flux profiles along model boundaries.
- Sensitivity Analyses: Determining whether sensitivity analyses that are necessary to provide an understanding of model uncertainties were conducted. Note that sensitivity analyses are required to support a demonstration of an alternative PISC timeframe pursuant to 40 CFR 146.93(c)(2)(vi); see Section 4.1.9.

Assess the applicant's computational/numerical modeling effort to verify compliance with the rule requirements and appropriateness for the project. This may involve both qualitative evaluation of certain modeling aspects and independent or semi-independent quantitative modeling. Qualitative approaches used in this assessment may include evaluation of the following:

- Simulator: Ensuring that the simulator and references to equations of state present an approach consistent with the requirements of the Class VI Rule.
- Processes Modeled: Evaluating the subsurface processes in the applicant's model to verify that the model accurately accounts for all phases of the carbon dioxide and phase changes, and that the processes modeled are appropriate for the project. This may also include determining whether additional modeling approaches, such as reactive transport or geomechanical simulations, are necessary to accurately represent flow performance

over time, such as in carbonate or basalt formations where reactions with minerals may be significant.

- Model Outputs: Ensuring that the submitted output data files are consistent with the model results given in the narrative portion of the AoR and Corrective Action Plan, and evaluating AoR delineation modeling results to determine compliance with Class VI requirements, such as plume containment in the injection zone or fracture pressure limitations.
- Sensitivity Analyses: Determining whether sensitivity analyses (if used) include appropriate parameters and variabilities.

The quantitative component of the evaluation involves conducting independent or semi-independent modeling to assess the numerical/computational model used by the applicant. Note that the purpose of this effort is not to reproduce the applicant's procedures and arrive at the exact same results. Instead, the goal is to understand and evaluate the applicant's modeling activities and to confirm the general behavior of the system shown in their results. This approach would also allow additional numerical investigations/assessments, if needed. This evaluation may include the following steps:

- Identifying the Independent or Semi-independent Modeling Approach: Select methods and a tool or collection of tools that are appropriate for modeling the geologic and operational system at hand and account for the multiphase nature of carbon dioxide injection operations. Some examples of numerical simulators include Subsurface Transport over Multiple Phases (STOMP) and Transport of Unsaturated Groundwater and Heat (TOUGH). Analytical tools, such as the Area of Potential Impact (AoPI) modeling and mapping tool, may be more suitable to preliminary evaluations or understanding the general behavior of the plume and/or pressure front. More information on modeling tools is available in the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance.*
- Constructing the Model: Construct a model that accurately represents the geologic and operational system. If the applicant's conceptual model has been confirmed to accurately represent the system, it can be used for this assessment. In some instances, it may be appropriate to use a modified version of the applicant's conceptual/geologic model; for example, to test the effects of certain geologic features, include additional subsurface processes, adjust rock property distributions, or develop an upscaled model for quicker simulation times.
- Independent or Semi-independent Modeling Output and Comparison: Run simulations and produce model outputs to assess plume size/shape, reservoir pressures, carbon dioxide saturation, and other relevant parameters. It may be appropriate to analyze changes in parameter values in time or assess spatial distributions of parameter values at certain times (depending on the results submitted by the applicant). Additional analyses that can be conducted include evaluating the pressure changes within the system to confirm that it never reaches the fracture pressure value or assessing carbon dioxide trapping and dissolution. Identify any significant discrepancies between the results submitted by the applicant and results from the new simulations. It is important to note that identical distributions cannot be expected from two different simulators or with

different inputs or processes. Therefore, evaluate the results for general consistency and in the context of ensuring non-endangerment of USDWs.

Based on the results of the qualitative and quantitative evaluation, review the AoR delineation modeling proposed by the permit applicant to ensure that it meets the requirements at 40 CFR 146.84. In addition, review the calculations that estimate the critical pressure and evaluate the AoR delineation based on the extent of the plume and pressure front estimates. See the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance* for more details on methods that could be used for these calculations.

Review information on the artificial penetrations identified within the AoR. Confirm that the applicant used appropriate methods to identify all artificial penetrations throughout the AoR using database searches or other means and that the list of artificial penetrations is complete. If the list of artificial penetrations appears to be incomplete, ask the applicant to augment the list (e.g., by conducting more detailed surveys or database searches). See Section 4 of the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance* for more details on methods that can be used for identifying artificial penetrations.

If any corrective action has already been performed, evaluate whether it was conducted in a manner that will prevent the movement of fluids into or between USDWs. Available forms of corrective action include well plugging and/or remedial cementing of an improperly abandoned well. Verify that corrective action was performed using carbon dioxide-resistant materials that are appropriate to project-specific geochemical conditions and of sufficient strength.

Also, discuss with the applicant which wells will have corrective action performed prior to commencing injection to gain agreement on an appropriate schedule for phased corrective action that is based on a well's location relative to predicted plume movement or well condition (and the corrective action methods they propose to use). If there is any indication that USDWs would be endangered by a phased corrective action approach, require that all corrective action be performed prior to injection; consider planned operating conditions, the physical and chemical characteristics of the carbon dioxide stream, the number of wells that need corrective action, or the rate of movement of the carbon dioxide plume and pressure front. (See Section 2.2 of the *UIC Program Class VI Well Project Plan Development Guidance* for additional considerations regarding Director's discretion to allow phased corrective action.)

Verify that the applicant's proposed AoR and Corrective Action Plan meets the requirements of 40 CFR 146.84(b) and that it reflects the most up-to-date information on the AoR delineation and the review of corrective action information. The AoR and Corrective Action Plan incorporated into the Class VI permit will include the results of the initial AoR delineation, the methods and schedule for all planned corrective action, and the results of any corrective action that has been performed. The plan is an important enforceable condition of the permit that will be used as a benchmark to guide AoR delineation modeling for reevaluations over the duration of the project and provide procedures and a justifiable schedule for performing all remaining corrective action on deficient wells. Therefore, the plan will need to be evaluated simultaneously with both the AoR delineation evaluation and the review of corrective action procedures, as described above.

The approved plan should describe the modeling and delineation that define the permitted AoR and incorporate relevant site-specific geologic, well construction, and operational data. Depending on the amount of interaction with the applicant and revisions to the delineation

approach in the course of the permit application review, it may be significantly revised from the initial plan submitted in the permit application.

Evaluate the proposed AoR reevaluation strategy to ensure that it is appropriate to the modeled predictions, operational conditions, and anticipated monitoring schedule. Confirm that the plan describes the conditions that would warrant a change in the AoR reevaluation schedule (e.g., based on the monitoring data that will be collected under the Testing and Monitoring Plan and the PISC and Site Closure Plan, operational changes, or induced seismicity or other unanticipated events). If there are substantial uncertainties in the determinations/models in the permit application that will not be addressed by pre-operational testing activities, consider requiring more frequent reevaluations. This approach may be particularly appropriate early in the injection phase (when unexpected results are most likely to arise), followed by a reduced reevaluation frequency in the out-years of the injection phase if the carbon dioxide plume and pressure front prove to move as predicted. Verify that the AoR delineation model considers planned post-injection phase testing and monitoring to facilitate a comparison of monitoring data and model predictions.

Verify that the corrective action strategies proposed in the AoR and Corrective Action Plan describe a reasonable effort to locate all artificial penetrations in the AoR, establish the condition of each, and identify any improperly plugged wells or other artificial penetrations that may endanger USDWs. Also assess whether planned remedial techniques and materials are appropriate. If phased corrective action is approved, confirm that the plan describes a suitable schedule and that there is adequate financial responsibility coverage for all corrective action (see Section 4.1.3).

Before finalizing the AoR delineation modeling evaluation and approving the final AoR and Corrective Action Plan, confer with other members of the permit application review team to determine whether any issues identified in the course of the permit application review may necessitate a revision to the modeling approach. For example, confirm that the most up-to-date geologic information and final operating conditions match the inputs to the AoR delineation model. Ensure that data to be collected under the pre-operational formation testing program will provide geologic information to fill in any data gaps and uncertainties associated with the modeling or the plan. Also, confirm that the final findings of the AoR delineation modeling are reflected in the evaluations of storage capacity and induced seismicity (see Section 4.1.1). If site characterization and modeling investigations suggest that induced seismicity is a concern, ensure that it is addressed in the Emergency and Remedial Response Plan. Confirm, in coordination with others on the review team, that the testing and monitoring strategies proposed for the injection and post-injection phases will produce the necessary data to support AoR reevaluations and the non-endangerment demonstration. A change in the size of the AoR may also necessitate revision of the Testing and Monitoring, PISC and Site Closure, and Emergency and Remedial Response Plans.

Communicate any changes to the AoR delineation or the final plan related to corrective action to the staff reviewing financial responsibility cost estimates to ensure that sufficient resources are set aside to fund corrective action on all wells in the AoR. For example, changes to the corrective action plan (e.g., the number of wells needing corrective action, the depth of newly identified wells, or any changes to the phased corrective action schedule) may affect cost estimates. Additionally, a larger AoR may affect the number of monitoring wells that would need to be

constructed (and therefore plugged), the resources for which emergency or remedial response may be needed, or the presence of a USDW in the AoR.

If the AoR delineation evaluation for a transitioning Class II project with an existing aquifer exemption results in a larger AoR that includes areas with TDS below 10,000 mg/L, discuss with the applicant the need to expand the areal extent of the aquifer exemption and the need to coordinate an aquifer exemption request with the AoR delineation modeling.

Outcomes

Following the review of the AoR delineation, evaluation of corrective action information, and approval of the AoR and Corrective Action Plan, the UIC Program should develop information about the review for inclusion in the permit file. Relevant materials include the following:

- Permit conditions for AoR and corrective action, including the corrective action activities that must be performed prior to injection;
- The approved AoR and Corrective Action Plan as an enforceable condition of the permit;
- A map of the approved delineated AoR; and
- A report documenting the evaluation of the AoR delineation and the corrective action efforts that documents/describes:
    - The approach used for the evaluation and its results;
    - Interactions and communication with the applicant;
    - The independent modeling and the results of the effort;
    - A determination regarding the appropriateness of the modeling approach and how it complies with the Class VI Rule; and
    - Any additional information requested as part of the pre-operational testing program to address identified uncertainties at the project site.

Any supporting documents (e.g., the AoR and Corrective Action Plan and completed reports) should be uploaded to the project's permit package area in the GSDT.

4.1.3 Financial Responsibility

Class VI permit applicants must submit information to demonstrate financial responsibility for corrective action, injection well plugging, PISC and site closure, and emergency and remedial response [40 CFR 146.82(a)(14); 146.85(a)].

The purpose of the UIC Program's review of financial responsibility information is to verify that the proposed instruments are sufficiently funded to cover all applicable activities, in consideration of specific information about the project. The UIC Program should also review the financial instruments to ensure they have appropriate wording and provisions as described at 40 CFR 146.85. The goal of this review is to ensure that, in the event that owners or operators experience financial difficulties, financial resources are available for a third party (i.e., one that is retained by the EPA) to carry out activities related to closing and, if needed, remediating GS sites to ensure that USDWs are not endangered, without the use of taxpayer monies.

Completeness Review

Pursuant to 40 CFR 146.85, the permit applicant will submit cost estimates for corrective action, injection well plugging, PISC and site closure, and emergency and remedial response. Initially, as part of the permit application, applicants may submit only the cost numbers (as itemized tables and narratives about what is included in the cost estimates) and information about the types of financial instruments. (Banks, insurers, or other financial institutions may not provide the specific financial instruments until the UIC Program Director requires the instrument to be active, which may occur very late in the permitting process, i.e., close to the time that construction is authorized.)

To confirm that the submission is complete, the UIC Program should:

- Verify that the cost estimates address each of the covered activities and that the applicant plans to use one or more of the qualifying instruments at 40 CFR 146.85(a)(1) to cover the full amount of the cost estimates.
- Confirm that the applicant provided sufficient detail about what activities, equipment and materials, and assumptions about the project supported the cost estimates, along with information about the "dollar year" in which the estimate was presented and whether discounting was applied to the estimates for any activities.
- Confirm that these activities are consistent with information in other submittals, e.g., the number of wells that need corrective action as described in the AoR and Corrective Action Plan, procedures in the Injection Well Plugging Plan, the number and depth of monitoring wells in the Testing and Monitoring Plan that will need to be plugged, or potential response activities in the Emergency and Remedial Response Plan.

If any information is missing or unclear, the UIC Program should consider requesting additional information or posing clarifying questions.

Evaluation

The bolded text below outlines a suggested approach that a UIC permit writer might employ to evaluate financial responsibility cost information and draft financial instruments, submitted in a Class VI permit application, to confirm that an applicant's submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Review the applicant's cost estimates for each covered activity to verify that the costs are accurate and sufficient to cover the actual costs of contracting an independent third party to conduct the activities and all related costs. (Note that such estimates may differ from the cost to the applicant of performing these activities using the owner or operator's staff and equipment.) The EPA's Financial Responsibility Cost Estimation Tool can support this evaluation by calculating an acceptable range of costs for relevant GS activities based on information submitted with a Class VI permit application. A copy of the Cost Estimation Tool is available in the resource library of the GSDT.

- Review the cost estimate for performing corrective action to confirm that the estimate is sufficient to cover the costs of the activities outlined in the AoR and Corrective Action Plan and accounts for the number, condition, and depths of all deficient wells in the AoR. It should also address the cost of completing any proposed phased corrective action.

- Verify that the cost estimate for plugging the injection well is sufficient to cover the cost of plugging an injection well of the proposed depth, including providing adequate amounts and types of cement and plugs to seal off all relevant subsurface layers. If the applicant plans to convert the well to another use following GS activities (e.g., for EOR/EGR), confirm that the costs estimated are for the cost of plugging the injection well to the surface (see Section 4.1.8). See Section 4.1.11 for information on financial responsibility for projects operating under injection depth waivers.
- Review the cost estimate for post-injection site care and verify that the estimate properly accounts for performing groundwater monitoring and carbon dioxide plume and pressure front tracking throughout the extent of the AoR. The estimate should account for the depth and proximity of USDWs or other formations that will need to be sampled and the number, frequency, and types of post-injection testing and monitoring that are described in the PISC and Site Closure Plan.
- Review the site closure cost estimate and verify that it accounts for completing all site closure activities described in the PISC and Site Closure Plan, particularly for plugging all of the monitoring wells described in the Testing and Monitoring Plan. Note that, even if the applicant plans to convert any monitoring wells for another use, the site closure cost estimate should cover the cost to plug these wells to the surface.
- Review the cost estimate for emergency and remedial response and verify that it accounts for the presence of all potentially affected resources within the AoR, all known endangerment scenarios, and proximity to nearby USDWs, communities, residences, and drinking water systems, as described in the Emergency and Remedial Response Plan.

The Financial Responsibility Cost Estimation Tool

The EPA's Cost Estimation Tool for Class VI Financial Responsibility Demonstrations is designed to provide an "acceptable range of costs" for GS financial responsibility activities based on information submitted with a permit application. The spreadsheet-based tool requests inputs about the proposed site, e.g., well depth, planned duration of the project and PISC timeframe, and size of the AoR. Based on this, it generates a range of cost estimates for required activities, e.g., corrective action, injection well plugging, PISC and site closure and emergency and remedial response. The cost estimates for each activity are intended to be accurate enough for UIC Programs to assess whether the financial responsibility cost estimates in the permit application are likely to be adequate, and can guide discussions between the UIC Program and the applicant during the permit application review process.

If any of the cost estimates do not appear to cover all aspects of the activities they are required to cover, discuss this with the applicant and, if necessary, request updated cost estimates. Verify that cost estimates for activities that will be performed many years into the future (e.g., phased corrective action, well plugging, PISC, or site closure) are appropriately inflated. For additional information on evaluating financial responsibility cost estimates, including whether they are appropriately inflated, see Appendix C of the *UIC Program Class VI Financial Responsibility Guidance.*

Evaluate the financial instruments the applicant proposes to use. Confirm that each financial responsibility instrument is suitable to the activities it will cover. Table 4-2 presents the preferred financial instruments for each activity based on the recommendations of the *UIC Program Class VI Financial Responsibility Guidance*.

Table 4-2: Financial Instruments Recommended in the *UIC Program Class VI Financial Responsibility Guidance*

Activity	Financial Instruments
Corrective action	Trust funds, letters of credit, surety bonds, escrow accounts, and financial tests and corporate guarantees.
Injection well plugging	Trust funds, letters of credit, surety bonds, insurance, and financial tests and corporate guarantees.
Post-injection site care and site closure	Trust funds, insurance, and financial tests and corporate guarantees.
Emergency and remedial response	Insurance and financial tests and corporate guarantees. (Letters of credit and surety bonds are well-suited to emergency and remedial response during the injection phase.)

Note that the above lists are not exhaustive of all options available for each GS activity or of all considerations for evaluating the adequacy of the financial instruments. If the applicant proposes instruments that are not included in the list of qualifying instruments at 40 CFR 146.85(a)(1), determine whether these alternative instruments adequately demonstrate financial responsibility and minimize the risk of costs being passed to the public, or what assurances of solvency the applicant can provide.

Confirm that the instruments the applicant proposes to use are secure and meet the requirements for qualifying instruments at 40 CFR 146.85(a) to facilitate enforceability and prevent gaps in coverage over the duration of the project. For example:

- For trust funds, confirm that the third-party administrator has a proven track record of effective management and is financially stable, and that the agreements include a description of the acceptable ways in which the trustee can invest the fund. Verify that the conditions under which payments can be authorized are identified.
- For surety bonds, confirm that the applicant has established a standby trust to receive any funding necessary to address the cost of covered activities. Also, verify that the applicant has demonstrated the financial stability of the surety, i.e., that the surety company is tested and approved under the U.S. Department of Treasury Circular 570.
- For payment bonds, confirm that the agreement specifies that the surety company will pay the bond's face value if the applicant does not provide a substitute demonstration of financial responsibility. For performance bonds, ensure that the agreement specifies that the surety company will pay a qualified third party to complete the activities covered by the bond.
- For a letter of credit, confirm that the letter is issued by a bank or other regulated financially stable institution, requires the issuing institution to provide notice if it does not plan to reissue the letter of credit, and includes a provision for automatic renewal. Confirm that the applicant has established a standby trust to receive any funding necessary to address the cost of covered activities.
- For independent third-party insurance, confirm that the policy has a face value that is at least equal to the estimated cost of the covered GS activities. If necessary, require the applicant to provide a certificate of insurance identifying general policy information and

a statement indicating that the insurer is providing financial assurance for the insured. Also, review the third party's credit rating or most recent bond rating and calculated financial ratios. If the third-party provider does not have a top credit rating (i.e., AAA, AA, A, or BBB for Standard & Poor's or Aaa, Aa, A, or Baa for Moody's), ensure that the applicant can demonstrate the equivalency of the rating with the recommended ratings.

- For an escrow account, confirm that the escrow agent will submit statements with the value of the escrow account at least annually, has demonstrated appropriate financial stability, and received concurrence on any additional deposits or release funds. Confirm that the trust is invested according to relevant legal requirements and the established agreement. Confirm that the applicant has established a standby trust to receive any funding necessary to address the cost of covered activities. In addition, as needed, approve requests for release of excess funds or ensure that deposits of additional funds will occur if the value of the account falls below GS activity cost estimates.
- For self-insurance, confirm that the applicant has met the required financial coverage criteria and has passed the required financial steps at 40 CFR 146.85(a)(6)(v). Also, review the supporting statements provided (e.g., 10-K report, auditor's opinion on the financial data provided by the Chief Financial Officer or Federal Energy Regulatory Commission Form 2 report) and evaluate the adequacy of the audit conducted.

Verify that the proposed financial instrument(s) have protective conditions of coverage, i.e., with cancellation, renewal, and continuation provisions and other conditions identified at 40 CFR 146.85(a)(4)(i). If any aspects of the proposed instruments are determined to be insufficient or do not meet the Class VI Rule requirements for qualifying instruments, request revisions or replacements to some or all of the instruments. For additional information on financial instruments, see the *UIC Program Class VI Financial Responsibility Guidance*. Additionally, the resource library of the GSDT contains a set of checklists to support the evaluation by tracking the information necessary to determine the adequacy of the applicant's financial responsibility demonstration.

Financial Responsibility needs for Long-Duration Class VI Projects

The long duration of some Class VI projects, in particular the long post-injection timeframe, may pose challenges for securing a financial instrument for the duration of the phase or project at the time of permitting. Third-party insurance providers typically issue insurance policies for a relatively short time (e.g., 3 to 5 years), and they may not be willing to issue an insurance policy for a phase that begins ten years in the future. In these situations, it may be necessary to work with the applicant and the third-party provider to establish an instrument that is flexible enough to accommodate the specific situation while adequately meeting the financial responsibility requirements. Provisions such as cancellation and renewal notification are important to ensure adequate time to establish and approve an alternative instrument should the original instrument fail to renew for the duration of the project or phase. For phases that occur far into the future, the applicant may also establish an interim instrument to meet the financial responsibility requirements at the time of permitting if it is not possible to secure the specific instrument at that time.

Before approving the final cost estimates, coordinate with those performing other aspects of the permit application review to ensure that the final cost estimates incorporate any changes identified in the course of the review. For example, if the AoR is determined to be larger than initially modeled or predictions about plume behavior change, this may impact the costs

associated with: the number of wells that require corrective action, the number of monitoring wells that would need to be constructed (and therefore plugged), resources for which emergency or remedial response may be needed, or the presence of a USDW in the AoR.

The presence of a USDW in the AoR can significantly affect potential emergency and remedial response costs, as these must address the potential for groundwater treatment per 40 CFR 146.85(a)(2)(iv). (Although the likelihood of any Class VI project encountering an emergency or contamination event is low, all project operators need to be financially capable of addressing an emergency. As such, financial responsibility cost estimates and the value of the instruments will likely be larger than the actual costs incurred at most sites.)

Modifications to the Testing and Monitoring Plan or the PISC and Site Closure Plan in the course of permitting discussions may necessitate revisions to the monitoring well plugging cost estimates. For example, the addition of more or deeper monitoring wells or increases to the length of the post-injection monitoring phase (or modifications to the alternative PISC timeframe) can affect the PISC cost estimate. Changes to the injection well's construction may affect the cost of well plugging. The final approved cost estimates should reflect any such changes to the project.

Outcomes

Following the review, the EPA recommends that the UIC Program develop the following financial responsibility information and upload it to the project's permit package area in the GSDT:

- Permit conditions for financial responsibility, including:
    - The type and value of the financial instrument(s) for all required activities based on the approved cost estimates;
    - Requirements to maintain financial resources for each activity until the relevant phase of the operation is complete or site closure is completed; and
    - A schedule for adjusting cost estimates and revising the financial instrument(s);
- A description of the enforceable financial responsibility conditions of the Class VI permit that includes: a summary of cost estimates by activity; copies of the instrument(s) to be used; and a pay-in schedule (if applicable); and
- A report summarizing the evaluation of the applicant's financial responsibility determination. The report might address the independent evaluation of whether the cost estimate is complete and sufficient and an evaluation of the language in the financial instruments.

4.1.4 Injection Well Construction

Class VI permit applicants must submit proposed schematics and construction procedures for the injection well [40 CFR 146.82(a)(11),(12); 146.86].

The purpose of the UIC Program's evaluation of well construction information is to ensure that the injection well will be constructed in a manner that is appropriate to planned operations, is compatible with the carbon dioxide and subsurface chemistry, and will maintain integrity throughout its duration. Reviewing proposed injection well construction plans is necessary to ensure that the proposed well materials and cement have adequate strength and design

appropriate to the site-specific conditions; and to confirm injectate and formation fluid compatibility.

In addition, the EPA recommends reviewing the procedures for constructing monitoring wells with similar considerations for subsurface conditions to ensure that the monitoring wells will not become conduits for fluid movement. See Section 4.1.11 for additional information on evaluating the construction of wells for projects operating under injection depth waivers.

Completeness Review

Class VI permit applicants will submit proposed injection well construction procedures and schematics. The submittal will likely be in the form of a narrative document with associated schematics that describes how the applicant will construct the injection well to meet the goals of 40 CFR 146.86.

The UIC Program should perform a preliminary review of the proposed construction procedures to verify that they provide a sufficient level of detail to inform an evaluation. The applicant should describe the materials and cement to be used and demonstrate that they are compatible with the injectate and formation fluid geochemistry; the construction procedures should also identify the depths of the injection zone, any production zones, any formations with USDWs and other water-bearing formations.

The applicant should demonstrate that the proposed well materials, including casing, tubing, and cement, have sufficient strength to withstand the forces to which they will be subjected. The cementing plan should be sufficiently detailed to demonstrate that a continuous cement sheath will be provided from the injection zone to the surface. The locations of the packer and perforation intervals should be indicated. The applicant should also demonstrate that the well will be equipped with a continuous injection (i.e., injection rate and pressure) and annulus monitoring system, safety valves, and shut-off devices as required at 40 CFR 146.88(e).

If the applicant plans to convert an existing well to a Class VI well, confirm that they have provided information to demonstrate that the well was engineered and constructed to meet the requirements at 40 CFR 146.86(a) to ensure protection of USDWs (per 40 CFR 146.81(c)). They should submit as-built schematics; the results of tests performed during the well's construction; recent MIT results; and other information demonstrating the mechanical integrity, material strength and compatibility, and corrosion resistance of the well.

If any information is missing or is not presented in sufficient detail to inform an evaluation of the well construction or conversion plan, consider the need to request the missing information or send the applicant clarifying questions to inform the review.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate well construction information, submitted in a Class VI permit application, to confirm that an applicant's submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Ensure that the materials planned for all well components are compatible with the planned injectate and formation fluids that may be encountered, and that they can resist corrosion for the duration of the project. Compare the chemical resistances of all proposed well materials to the chemical composition of any fluids with which they may come into contact, including the

injectate (based on information provided in the permit application), formation fluids (based on any available geochemical data as informed by the site characterization), and resultant mixtures of carbon dioxide and subsurface fluids. Standard construction materials, such as carbon steel and Class G or H cement, may be adequate above the packer if the injectate is dry, i.e., containing less than 50 parts per million (ppm) water. However, if the injectate contains greater than 50 ppm water, corrosion-resistant materials should be used for any components that will contact the injectate, such as casing, tubing, packer, and cement. If sulfide, sulfate, or nitrate is present in either the injectate or formation fluids, confirm that well materials that will contact these fluids are resistant to those chemicals. Consider requiring cement additives or non-Portland cements to increase cement resistance if any of the following conditions are present in the injection well: wet carbon dioxide; high temperatures; presence (or potential presence) of sulfate, nitrate, or sulfide; or high flow rates of formation fluids (containing injected carbon dioxide) contacting the exterior of the well.

If the chemical resistance of any material is in doubt, request that the applicant provide certifications from the manufacturers of those materials or the results of corrosion tests, or consider specifying more frequent, ongoing corrosion testing during the injection phase (this should be described in the Testing and Monitoring Plan). If any of the materials are not compatible with the fluids they will contact over the duration of the project, require that the applicant resubmit construction plans that include materials with the appropriate chemical resistance.

Compare the inside diameter of the casing to the diameter of all equipment that is proposed to be lowered into the well for purposes of logging, monitoring, sampling, or performing workovers as described in the proposed operating plan or Testing and Monitoring Plan. If any piece of equipment is not small enough to fit in the well casing without getting stuck, require the logging equipment to be changed or a larger casing be installed. If the well is proposed to be constructed at an angle departing from vertical, compare the radius of curvature of the well to the length of each piece of equipment. If a deviated well is proposed, consult with the team reviewing geologic information and the AoR delineation modeling reviewer to ensure that the well's design is being considered in their reviews.

Review the strength of all proposed well materials to ensure that they can resist all of the forces they will encounter. These forces include burst pressure, collapse pressure, axial loading, compressive forces during installation, thermal stresses, and cyclic stresses caused by cycling injection on and off. For example, compare formation (external) pressure to collapse strength of the materials. Verify that formation pressures are based on, or are consistent with, the geologic characterization or ensure that this information will be collected as part of the pre-operational well testing program. Also, compare the planned injection pressure to the burst strength of the well materials and verify that the tensile strength of all well materials is adequate to sustain anticipated axial loads. If injection will not be continuous, consider the effects of cyclic changes in stress and temperature on well components. If the permit will include gradual shutdown procedures (see Section 4.1.6), verify that these procedures are appropriate to known information about the well's strength.

If it is not clear what stresses the well materials will experience, consider asking the applicant to provide stress calculations or models for the well component(s). If the well materials are not capable of resisting the stresses they will experience during the project, request that the applicant

propose stronger, alternative materials. Section 2.4 of the *UIC Program Class VI Well Construction Guidance* contains more details on stresses to consider in this review.

Review the proposed cementing procedures to ensure that they will provide a continuous sheath of cement from the bottom of each casing string to the surface. Ensure that the cement for the long-string casing will extend into the injection zone. Review the cementing plan to confirm that the cement will ensure external mechanical integrity across all fluid-containing zones in the well bore, especially the injection zone and any USDWs. Verify, in consultation with the reviewer of the geologic information, that all such fluid-containing zones are identified in well schematics and addressed in the cementing plan. Ensure that the surface casing extends below the depth of the lowermost USDW (unless an injection depth waiver is requested).

If necessary, require that cement additives be used. Cement additives may be necessary to ensure chemical compatibility, reduce cement loss, improve resistance to cyclic stress, or increase strength.

If cement staging is proposed, review the cementing plan to ensure that the cement will provide a continuous sheath for the length of the casing. If necessary, ask the applicant to provide information to support these reviews. Verify the necessity of staged cementing by comparing the weight of the cement column to the fracture pressure of relevant subsurface formations. Check records of nearby wells for records of lost cement to determine depths at which stage intervals might be necessary. Review the cementing plan to verify proper setting of each stage, proper bonding between the stages, and that cement ports will not be plugged by prior stages of cementing. Verify that the cement staging plan includes proper procedures, such as temperature logs, to locate each stage in order to form good bonding between stages and confirm that these are documented in the pre-operational well testing program. Refer to Section 2.5.1 of the *UIC Program Class VI Well Construction Guidance* for additional information on staged well cementing.

If the cementing plan as submitted will not provide a sheath of cement covering the entire casing length and provide external mechanical integrity to the well as required at 40 CFR 146.86(b), ask the applicant to submit a revised plan that includes proper cementing procedures.

Review the submitted well schematics to ensure proper placement of the perforations and packer. Ensure that the proposed perforations are entirely within the proposed injection zone. Verify that the packer is set within the confining layer and will be constructed of material that is compatible with carbon dioxide and carbon dioxide-water mixtures.

Check that the well will be equipped with safety valves and shut-off devices and verify that these devices will be linked to the continuous injection and annulus monitoring system and are designed to shut-in when injection or annulus pressures exceed specified parameters, as described in the operating conditions of the permit. See Section 4.1.6 for additional information about gradual or immediate shutdown of the well. If the well is offshore, verify that the construction plans include downhole shut-off devices. Consider requiring downhole shut-off devices for any onshore wells that have one or more of the following risk factors: high temperature, high pressure, presence of hydrogen sulfide, proximity to populated areas, or high likelihood of damage to the wellhead. Wells without downhole shut-off devices should have surface shut-off devices. Confirm with other members of the review team that activation of these devices is tied to operating requirements and that appropriate responses are described in the Emergency and Remedial Response Plan. Check that pressure gauges and flow meters have

adequate range and sensitivity to properly measure the planned flow rates and pressures. Confirm that the location of the devices is appropriate (e.g., bottomhole versus wellhead) to yield useful information.

If an existing well is to be re-permitted as a Class VI well, ensure, in consideration of requirements at 40 CFR 146.81(c), that the applicant has demonstrated the mechanical integrity, material strength, and material compatibility/corrosion resistance of the well, the ability of the well to accommodate testing and workover equipment, and that appropriate remedial actions have been or will be taken to address any deficiencies. Particular attention is needed to assess the condition of the well materials and cement at or above any USDWs, given the requirement at 40 CFR 146.86(a) that Class VI wells must be constructed to protect all USDWs. Below the lowermost USDW, there is less potential for unacceptable fluid movement to USDWs, so additional flexibility, e.g., the presence of cement across certain intervals, may be appropriate.

This evaluation will likely involve reviewing existing information about the well to ensure that it satisfies the requirements at 40 CFR 146.86(a) or to identify additional testing or repair that may be needed, given that injection pressures and volumes will likely be increased following re-permitting as a Class VI well. For example:

- Consult recent well logs and internal MIT results to verify that the well has retained its original integrity. If recent well logs or MIT results are not available, logs and MITs may need to be performed as part of the pre-operational well testing program.
- Review cementing records and external MIT results to ensure that the cement will prevent migration of all fluids out of the injection zone or between formations. While continuous cement to the surface is not required in converting wells, all subsurface layers containing fluids, such as water or hydrocarbons, should be isolated with cement.
- Review material strength and compatibility in the same manner as with new wells (see above). If any well materials are incompatible with carbon dioxide or the anticipated composition of carbon dioxide-water mixtures, request that they be replaced.

If it cannot be demonstrated that the well has the ability to maintain both internal and external mechanical integrity (i.e., to ensure that the well meets the requirements at 40 CFR 146.81(c)), the well should be repaired and retested. If the well cannot be satisfactorily repaired to meet the requirements, it cannot be used for Class VI injection.

Outcomes

Following review of information related to the Class VI well, the UIC Program should develop:

- Permit conditions for well construction that include:
    - Casing of suitable, carbon dioxide-compatible materials;
    - The name of the formation (i.e., the lowermost USDW) to which the surface casing must be cemented and the name of the injection zone to which the long-string casing must be cemented;
    - Construction details, e.g., open hole diameters and intervals, casing specifications, and tubing and packer specifications;
    - Cement materials and volumes and cement emplacement procedures (e.g., circulation of cement, if appropriate);

    - Continuous injection pressure, rate, volume, and temperature and annulus pressure monitoring devices and automatic shut-off systems; and
    - Any conditions for construction relevant to operating under an injection depth waiver to ensure that USDWs above and below the injection zone are protected.
- A summary of the enforceable construction conditions of the Class VI permit;
- Final approved well construction schematics;
- A document that identifies any deficiencies in the proposed construction plan and how the UIC Program worked with the applicant to address these, including additional testing or data collection to be performed during well construction; and
- Documentation of the evaluation that the applicant provided sufficient information on which to approve certain components of an existing injection well and a description of these components (if applicable).

Any supporting documents should be uploaded to the project's permit package area in the GSDT.

4.1.5 Pre-Operational Testing

Permit applicants must submit a proposed pre-operational formation and well testing program that describes how they will test the well and analyze the chemical and physical characteristics of the injection and confining zones [40 CFR 146.82(a)(8); 146.87].

The purpose of the UIC Program's review of the proposed pre-operational testing program is to confirm that all tests required at 40 CFR 146.87 are planned and designed to collect the information needed to verify that the well is properly constructed; gather information on subsurface formations and fluid geochemistry; and address identified uncertainties. The UIC Program should also confirm that the pre-operational formation testing program, as proposed, will provide information to support the setting of operating conditions of the permit, provide inputs for modeling to delineate the final AoR (or confirm the assumptions on which the preliminary AoR delineation modeling was based), and establish a baseline for parameters that will be measured during the injection and post-injection phases.

Completeness Review

The Class VI permit applicant's proposed pre-operational formation and well testing program will likely be a narrative description of the specific well and geologic tests that the applicant plans to perform to meet the requirements of 40 CFR 146.87.

The UIC Program should perform a preliminary review of the proposed pre-operational formation and well testing program to verify that it describes the specific testing procedures that will be performed, including their timing relative to well construction (i.e., before installation of surface casing and long-string casing). During this review, the UIC Program should confirm that the applicant documented QA procedures (e.g., water quality sampling protocols and custody procedures for core collection and analysis) and provided information about the qualifications of log and core analysts.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate planned pre-operational testing information, submitted by a Class VI permit applicant, to confirm that the applicant's submittal meets the Class VI requirements and informs the establishment of protective permit conditions.

Verify that the applicant plans to conduct all tests needed to evaluate that the well is properly drilled and constructed. Confirm that the applicant plans to employ the best available techniques (as described in industry standard practices and technical guidances) and perform a full suite of logs and tests. Available logs and tests include: deviation checks, cement evaluation, caliper, cement bond, and temperature logs and video inspections. Confirm that the tests are planned to be performed at appropriate phases of well construction (i.e., after the cement for each casing string has been emplaced and allowed to set for the appropriate amount of time). Confirm that internal and external MITs are planned; arrange to witness these tests as necessary.

If the well has already been constructed (i.e., it is to be converted from an existing injection well or a stratigraphic test well), request that the applicant provide documentation of prior logs, MITs, or other tests to inform a demonstration that the well was engineered and constructed to meet the goals of 40 CFR 146.86. Additionally, confirm that the well has mechanical integrity, and that approving the well's construction is appropriate and will not allow injection of carbon dioxide that will endanger USDWs. See the *UIC Program Class VI Well Construction Guidance* for additional information on pre-operational well testing methods.

Additionally, consider the merits of requesting that the applicant tests deep monitoring wells (i.e., those that penetrate the confining zone) prior to project operation, in a similar manner to the pre-operational testing performed on the injection well.

Verify that the pre-operational formation testing plan includes all logs necessary to evaluate and understand the subsurface geology of the injection and confining zones, including their thicknesses, lithologies, porosities, and permeabilities. These logs include resistivity, spontaneous potential, porosity, gamma ray, and fracture finder logs. Evaluate the proposed testing in consultation with reviewers of the site's geology and the AoR delineation modeling to ensure that any identified uncertainties about site-specific conditions will be addressed. Section 4 of the *UIC Program Class VI Well Site Characterization Guidance* provides additional information on pre-operational formation testing methods.

Confirm that the applicant plans to take cores of the injection and confining zones. If the applicant proposes to submit information on cores previously taken near the injection well, confirm that they represent the properties of the injection and confining zones near the well and provide sufficient and representative information on their porosities, permeabilities, petrologies, and mineralogies to inform the geology review, AoR delineation modeling evaluation, and an assessment of the potential for mobilization of contaminants. Additionally, if there is evidence of heterogeneity (or uncertainty as to the homogeneity of the injection or confining zones), consider whether it would be beneficial to use the discretion afforded at 40 CFR 146.87(b) to request that additional cores be taken and analyzed to characterize the site geology as thoroughly as possible. If necessary to fully characterize the site, consider whether to request that cores be taken from layers in addition to the injection and confining zones and analyzed.

Confirm that the applicant plans to determine fracture pressure and analyze the physical and chemical characteristics of the injection and confining zones and the fluids within these formations. Ensure that the chemical analytes in the fluid analyses will provide sufficient data to assess the compatibility of the well with formation fluids, particularly when the carbon dioxide mixes with formation waters, and to fully characterize subsurface geochemistry and fluid chemistry. Verify that pressure fall-off tests and injectivity tests will provide sufficient data to evaluate that the proposed operations are suitable or to set the injection pressure limit in the permit. Confirm that a step-rate test to determine fracture pressure will be conducted under the appropriate conditions.

Evaluate any additional testing that is necessary to ensure the integrity of the confining zone and protection of USDWs. Additional testing may include seismic monitoring to determine if seismic activity may impact the confining zone. Monitoring may also be appropriate to determine whether there are faults that might be activated by injection activities. If surface air and/or soil gas monitoring is identified as part of an approach to monitor for potential carbon dioxide leaks, determine whether this is feasible given site conditions.

If an injection depth waiver is requested, confirm that sufficient formation testing is planned to provide adequate fracture pressure and geochemical data on the confining zones above and below the injection zone. Also ensure that testing of the well during construction will address the need to protect USDWs above and below the injection zone.

Review a QASP or other documentation of QA procedures that address the sampling and analysis of fluids or logging procedures in the pre-operational formation testing program. Verify that the appropriate parameters will be measured, including pH, temperature, pressure, and conductivity. Evaluate the equipment the applicant plans to use to conduct the tests (e.g., subsurface pressure gauges).

Before approving the pre-operational well and formation testing program, consult with other members of the review team, including the individuals reviewing the geologic information, to determine if there are significant uncertainties or data gaps about the site that could be addressed through well or formation testing. Additionally, confirm that the modelers have complete data inputs to characterize site geology and geochemistry in the model. If any such information is missing or incomplete, consider how the pre-operational formation and well testing program can address the data gaps or uncertainties.

Outcomes

Following review and approval of the pre-operational testing program, the UIC Program should incorporate the following information into the permit file:

- Permit conditions for pre-operational testing that must be performed prior to authorizing injection, including requirements to report the results within 60 days after completion of the injection well;
- A pre-operational testing program as an enforceable part of the Class VI permit (if applicable); and
- Documentation of any reviews/evaluations that resulted in changes to or confirmed the appropriateness of the applicant's proposed pre-operational testing.

Any supporting documents (e.g., the pre-operational testing program) should be uploaded to the project's permit package area in the GSDT.

4.1.6 Proposed Operating Conditions

Permit applicants must submit information on the proposed injection well operating conditions [40 CFR 146.82(a)(7),(9),(10); 146.88].

The purpose of the UIC Program's review of the proposed injection pressure, annulus pressure, and planned down-hole shut-off systems is to ensure that injection rates and volumes are appropriate to the site geology (considering any uncertainties identified in the course of site characterization) and the well's construction.

Completeness Review

The applicant's proposed operating procedures will likely be a narrative document supported by tables and equipment schematics that identifies the proposed injection rates and pressures, the total volume of carbon dioxide to be injected over the duration of the project, and the physical and chemical characteristics of the carbon dioxide stream. The applicant should also present information about the proposed annulus pressure and the fluids to be used to fill the annulus between the casing and tubing. If the applicant proposes that the annulus pressure be less than the injection pressure, the UIC Program should confirm that they provided information to support the need for this condition. If well stimulation is anticipated, the applicant should also submit proposed stimulation procedures.

The UIC Program should perform a preliminary review of the proposed operating procedures to verify that the applicant provided information at a sufficient level of detail to inform an evaluation. During this review, the UIC Program should:

- Confirm that the permit application includes information demonstrating how the operating procedures were developed. For example, a reviewer should ensure that the maximum injection pressure is based on the fracture pressure of the injection zone (or any available information on fracture pressure) and that annulus pressure is suitable to the well's design and will not impact the well's integrity or induce formation fractures.
- Confirm that information about the carbon dioxide stream is based on chemical analyses that were performed pursuant to appropriate QA procedures and represent the source of the carbon dioxide.

If any information is missing or is not presented in sufficient detail to inform an evaluation of the proposed operations, the UIC Program should consider the need to request the missing information or send the applicant clarifying questions to inform the review.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate planned operational information, submitted by a Class VI permit applicant, to confirm that an applicant's submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Review the proposed maximum injection pressure to confirm that it is no more than 90 percent of the fracture pressure of the injection zone. If information on the fracture pressure of the injection zone is pending the completion of formation testing, the draft permit conditions will

need to be reviewed and finalized before injection commences (see Section 5.1.5). If the proposed maximum fracture pressure is greater than 90 percent of the fracture pressure of the injection zone, require a change in the injection pressure to ensure compliance with 40 CFR 146.88(a). If there is uncertainty about the geologic characterization of the site or concerns about induced seismicity, consider whether setting an injection pressure that is less than 90 percent of the fracture pressure of the injection zone is appropriate. Also confirm that the well is designed to be of suitable strength to withstand anticipated pressures and maintain mechanical integrity.

Review the proposed volume of carbon dioxide to be injected. Confirm, in consultation with others on the permit application review team, that the injection zone has adequate capacity to receive the total anticipated volume of carbon dioxide (see 40 CFR 146.83(a)(1)) and that the confining zone is appropriately characterized and demonstrated to contain the carbon dioxide (see 40 CFR 146.83(a)(2)). This review should be coordinated with the geologic site characterization evaluation and the AoR delineation modeling review.

Review the proposed annulus pressure to ensure that it is greater than the injection pressure. If the applicant proposes that the annulus pressure be less than the injection pressure, verify that this is necessary by confirming that an annulus pressure above the injection pressure could impact the well's integrity or fracture the formation. Compare the annulus pressure to the burst pressure of the casing and the collapse pressure of the tubing and the formation fracture pressure. If the annulus pressure is close to any of these values, consider either requiring stronger tubular materials or reducing the required annulus pressure to a positive value that will not exceed the rated strength of the well casing or tubing or fracture the formation. If the proposed annulus pressure is not greater than the injection pressure and there is no danger to the well integrity caused by raising the pressure, require the annulus pressure to be increased to a pressure greater than the injection pressure. Also, verify that the fluid with which the applicant proposes to fill the annulus between the casing and tubing is compatible with all well components and is non-corrosive.

If well stimulation is anticipated, review the proposed procedures to ensure that well integrity will be maintained and that the confining zone will not be fractured. Compare proposed stimulation pressures to well material strength and formation fracture pressures and compare the composition of any stimulation chemicals proposed to the chemical resistance of the well materials. If it appears that any proposed stimulation procedures might harm the well or fracture the confining layer, require that the stimulation plan be revised or do not allow stimulation. If it is not clear whether stimulation procedures might damage the well or confining layer, consider requesting modeling of the stimulation activity and resultant fracture patterns or increased monitoring of pressure and other variables with appropriate safeguards during stimulation.

Review information about the physical and chemical characteristics of the carbon dioxide stream. Verify, in consultation with others on the permit application review team, that there are no concerns related to potential interactions with subsurface fluids based on available information about their geochemical composition or implications for the suitability of the well materials. If the carbon dioxide is anticipated to contain any hazardous components, work with the applicant to determine whether they plan to meet applicable requirements under RCRA related to obtaining a conditional exclusion from the definition of hazardous waste under 40 CFR 261.4(h); see Section 3.4.

Consider including injection well shutdown procedures in the permit's operating conditions. The Class VI Rule requires, under certain circumstances, that operators immediately cease injection. However, there may be circumstances where immediately ceasing injection could pose greater endangerment potential (i.e., by placing additional stresses on the well) than a gradual reduction in the injection rate over a number of hours or days. Describing the gradual shutdown procedures in advance can help ensure expeditious implementation of a shutdown process that is appropriate to the well's construction and the situation if the need arises. Either the operating conditions or the Emergency and Remedial Response Plan should specify under what circumstances immediate vs. gradual shutdowns would be employed and the specific procedures to be followed. Consult with the engineer reviewing the well's design to confirm that installation of required automatic shut-off equipment is planned.

Before establishing the operating conditions in the permit, confer with other members of the permit application review team to determine whether any issues identified in the course of the review may necessitate revisions. For example, verify that any revised information about the site's geology (i.e., fracture pressure, injection zone storage capacity, seismic history, or the presence of faults or fractures) does not affect the assumptions on which limits on injection pressures or the total carbon dioxide volumes are based. Also, verify that the proposed well construction materials can withstand the stresses that will be imposed by injection at anticipated pressures and the planned well testing procedures. Verify that the proposed injection pressure and volumes are consistent with the inputs of the AoR delineation modeling (or are revised as needed based on adjustments in the approved final AoR delineation model) and any analyses of geologic suitability (particularly storage capacity estimates). Section 4 of the *UIC Program Class VI Well Construction Guidance* provides additional information on operating requirements for Class VI wells.

Incorporating Project-Specific Startup Procedures

As with shutdown procedures, there may be situations where gradual startup of injection could help address site-specific uncertainties, e.g., pressure at the well immediately after the start of injection. A gradual or "step-wise" startup of injection could help manage pressure development and ensure that the project does not violate any permit conditions during this period. Consider specifying a schedule (i.e., a number of days or weeks) over which injection rates would gradually increase to permitted levels. Increased monitoring and reporting of operating data or other parameters during the first few days of injection can help verify that startup was successful. Alternatively, reporting of initial monitoring results in advance of the first semi-annual report can help to confirm that the project is operating as anticipated.

Outcomes

Following the evaluation and approval of operating requirements, the UIC Program should develop the following:

- Permit conditions for injection well operation, including:
    - Injection limits, including maximum injection pressure and maximum and average daily injection volume and rate limits;
    - The source, location, and percentages of constituents in the carbon dioxide stream;
    - Prohibition of injection between the outermost casing and the well bore;

    - A requirement that a positive pressure be maintained on the annulus and mechanical integrity be maintained at all times;
    - Requirements for the use and maintenance of an automatic warning and automatic shut-off system; and
    - Procedures for gradually shutting down the well and situations where the owner or operator must cease injection (if appropriate).
- A summary of the enforceable operating requirements in the Class VI permit; and
- Documentation of any reviews/evaluations that resulted in changes to the applicant's proposed operating conditions or confirmed the appropriateness of the operating limits.

Any supporting documents should be uploaded to the project's permit package area in the GSDT.

4.1.7 Testing and Monitoring

The Class VI Rule requires Class VI permit applicants to develop and implement a comprehensive testing and monitoring plan for their projects that includes injectate monitoring, corrosion monitoring of the well's tubular, mechanical, and cement components, mechanical integrity testing, pressure fall-off testing, groundwater quality monitoring, carbon dioxide plume and pressure front tracking, and, at the UIC Program Director's discretion, surface air and/or soil gas monitoring [40 CFR 146.82(a)(15); 146.89; 146.90].

The purpose of the UIC Program's evaluation of the applicant's proposed Testing and Monitoring Plan is to ensure that the testing and monitoring procedures will be appropriate to planned operations, the well's construction, and site-specific geologic conditions. The UIC Program should ensure that the Testing and Monitoring Plan is designed to generate information over the duration of the project to:

- Demonstrate that the well is maintaining mechanical integrity, the site is operating as planned, and the carbon dioxide plume and pressure front are behaving as predicted;
- Provide essential points of comparison for modeled predictions, allowing for validation of the AoR delineation model and helping to address uncertainties during AoR reevaluations; and
- Form the basis of the non-endangerment demonstration that must be made before the owner or operator may proceed with site closure.

The UIC Program should also ensure that planned monitoring locations, methods, frequencies, parameters, etc., contribute to a comprehensive, tailored strategy for evaluating the performance of the project against modeled predictions and determining how other required activities will be implemented.

See the *UIC Program Class VI Well Testing and Monitoring Guidance* for additional information on testing and monitoring procedures for Class VI projects; also see the *UIC Program Class VI Well Project Plan Development Guidance* for additional information on evaluating Testing and Monitoring Plans.

Completeness Review

Class VI permit applicants will submit a draft Testing and Monitoring Plan, which will likely be in the form of a narrative document that describes the proposed testing and monitoring activities, and be accompanied by any supplemental materials related to or supporting the plan. Ideally, the Testing and Monitoring Plan should explain the purpose of each proposed activity and how its results will contribute to the data needs of the project to inform review of the plan and justify associated permitting decisions. The applicant must also submit a Quality Assurance Surveillance Plan (QASP) for all testing and monitoring activities, per 40 CFR 146.90(k).

The UIC Program should perform a preliminary review of the draft Testing and Monitoring Plan to verify that it provides a sufficient level of detail to inform an evaluation. For example, the plan should describe the methods to be used to perform all required testing and monitoring. The testing frequency, parameters/detection limits, and locations should be clearly described, and the monitoring locations should be representative of the entire delineated AoR in three dimensions. Furthermore, the UIC Program should verify that the plan includes a proposed schedule for all testing and monitoring, ideally with specific dates on or by which various tests will be performed each year. If any information is missing or is not presented in sufficient detail to inform an evaluation of the Testing and Monitoring Plan, the UIC Program should consider the need to request the missing information or send the applicant clarifying questions.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate a Class VI permit applicant's proposed Testing and Monitoring Plan, to confirm that the submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

It is important to note that the post-injection phase groundwater, plume, and pressure front monitoring in the PISC and Site Closure Plan (see Section 4.1.9) is an extension of the injection phase testing and monitoring, and the results from both monitoring programs contribute to the non-endangerment demonstration that the applicant must perform pursuant to 40 CFR 146.93(b). The EPA recommends that the review of the injection and post-injection phase testing and monitoring be done concurrently. To facilitate this type of review, the EPA developed a spreadsheet-based template to summarize a testing and monitoring strategy that complies with 40 CFR 146.90(d) and (g), and that includes baseline, injection, and post-injection activities. The template, which is available in the resource library of the GSDT, can serve as a point of discussion between the applicant and the UIC Program. Figure 4-2 presents an overview of the content of the template (and examples of some, but not all, types of monitoring that could be employed). For additional information and considerations for reviewing testing and monitoring results, see Section 6.1.

Review the proposed plan to ensure that all of the testing and monitoring activities that are required in the Class VI Rule are included and are appropriate to site-specific geologic and operating conditions. Throughout the course of the review, consider how the Testing and Monitoring Plan will be implemented over the duration of the project (particularly for long-term projects), and whether any aspect of the plan would need to be modified to address anticipated changes to the site or operations. Discuss with the applicant whether incorporating the deployment of future monitoring technologies into the plan (e.g., bringing additional monitoring wells online after injection commences) may be appropriate. If so, incorporate a deployment

schedule into the plan to avoid the need for future modifications of the plan and permit. The plan should include specific, quantitative triggers for increasing or decreasing monitoring frequency or adjusting other aspects of the testing and monitoring program.

Review plans to analyze the carbon dioxide stream. Verify that the parameters for which the carbon dioxide stream will be analyzed—and the associated analytical procedures—are consistent with those analyzed by the applicant to meet the requirement to characterize the carbon dioxide stream per 40 CFR 146.82(a)(7)(iv). Ensure that these analyses will provide the necessary information for any components of the testing and monitoring strategy that may rely on them—for example, if the owner or operator plans to use a certain constituent of the carbon dioxide stream to help track the migration of the plume, it should be included in the carbon dioxide stream analysis at an appropriate level of precision. If the applicant anticipates that the source of the carbon dioxide will vary over the duration of the project, more frequent carbon dioxide stream analyses may be necessary, and flexibility may be needed to revise the analytical parameters (and associated QA procedures) in the plan.

Verify that all planned well testing is appropriate to the well's construction and the proposed operating conditions. The Testing and Monitoring Plan must include plans for quarterly corrosion monitoring; continuous recording of injection pressure, rate, and volume to evaluate internal mechanical integrity; and annual external MITs, including an approved tracer survey (such as an oxygen-activation log) or a temperature or noise log [40 CFR 146.90(b),(c),(e)]. Confirm that corrosion monitoring will be performed using materials representative of the casing, tubing, and packer. If the applicant proposes the use of alternative MITs, evaluate these in the context of the planned construction of the injection well and inform the applicant that the MIT must be approved by the EPA Administrator [40 CFR 146.89(g)]. If appropriate to ensure that an adequate amount of corrosion monitoring is performed, consider requesting that the plan include performing casing inspection logs. Available logging techniques include caliper log, electromagnetic thickness survey, pipe analysis survey, or ultrasonic imaging surveys.

Ensure that the plan includes the sampling and recording frequencies for all continuous monitoring methods. In addition, ensure that the proposed operational monitoring program will detect any triggers for responses specified in the Emergency and Remedial Response Plan (e.g., exceedances of annulus or injection pressures).

Confirm that the applicant plans to conduct a pressure fall-off test at least once every five years. Any procedures for pressure fall-off tests that are specified in the Testing and Monitoring Plan should be consistent with the needs of Class VI projects; standardized procedures used for other well classes may not be appropriate.

Figure 4-2: Examples of Class VI Groundwater Monitoring and Plume and Pressure Front Tracking Activities

Monitoring Category/ Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage or Depth	Frequency (Baseline)	Frequency (Injection Phase)	Frequency (Post-Injection)
Groundwater Monitoring Above Confining Zone *[40 CFR 146.90(d)]*	USDW	Fluid sampling					
	Formation above confining zone	Fluid sampling					
Indirect Monitoring Above Confining Zone *[40 CFR 146.90(d)]*	Formation above confining zone	2D seismic survey					
Direct Plume Monitoring *[40 CFR 146.90(g)]*	Injection zone	U-tube fluid sampling					
Indirect Plume Monitoring *[40 CFR 146.90(g)]*	Multiple zones	3D seismic survey					
	Injection zone	Continuous active-source seismic monitoring					
		Cross-well tomography					
Direct Pressure Front Monitoring *[40 CFR 146.90(g)]*	Injection zone	Pressure monitoring					
Indirect Pressure Front Monitoring *[40 CFR 146.90(g)]*	Injection zone	InSAR with continuous GPS					
Other Related Monitoring *[40 CFR 146.90(i)]*	Multiple	Passive seismic monitoring					

Evaluate the applicant's groundwater quality monitoring. Confirm that planned groundwater monitoring is sufficient to ensure non-endangerment to USDWs throughout the delineated AoR, considering site-specific conditions, baseline conditions, AoR delineation modeling results, operational parameters, and the presence of artificial penetrations in the AoR. Monitoring wells should be located in the predicted direction of plume movement and in the vicinity of any known or potential fluid migration pathways for carbon dioxide or mobilized fluids. Also, the groundwater monitoring plan should include sampling and analysis for TDS or any contaminants of concern (e.g., mercury or hydrogen sulfide) that could be mobilized. Also confirm that samples will be taken at appropriate depths. In general, the EPA recommends that owners or operators sample in the first reasonably permeable formation above the confining zone (i.e., the first formation from which fluids can be extracted at appreciable volumes for sampling and analysis). Sampling in other zones, such as shallow USDWs used as drinking water sources, can help to demonstrate that USDWs are protected. If the applicant is requesting an injection depth waiver, confirm that the first USDW below the injection zone will be monitored.

Review the schematics of the monitoring wells to ensure that they are sited and constructed such that they will not corrode or provide a conduit for fluid movement that could endanger USDWs. It may be appropriate for those reviewing the injection well construction information to also evaluate the monitoring wells' construction to ensure that the monitoring well materials are suitable to the anticipated composition of the carbon dioxide and carbon dioxide-water mixtures. Ensure that the owner or operator has made arrangements to access the monitoring wells, particularly in cases where the project is anticipated to last for many years.

Because groundwater quality data will eventually support the demonstration of non-endangerment, consider whether the groundwater monitoring plan will collect a sufficient amount of data at/with appropriate locations, methods, frequencies, and parameters to inform the demonstration. If the applicant proposes an alternative PISC timeframe, consider whether the proposed groundwater monitoring frequency will ensure the collection of sufficient data to support the non-endangerment demonstration. To allow comparison of injection and post-injection phase water quality to baseline conditions, sampling and analysis methods and target parameters should be consistent with those used to collect baseline data, either submitted with the permit application or to be gathered during pre-operational testing (see Section 4.1.5). In addition to the direct groundwater sampling required by 40 CFR 146.90(d), indirect methods such as seismic surveys may also be used to monitor conditions above the confining zone.

Review plans for tracking the extent of the carbon dioxide plume and pressure front. Verify that plans for carbon dioxide plume and pressure front tracking include the use of both direct methods for tracking the pressure front within the injection zone [40 CFR 146.90(g)(1)] and indirect geophysical techniques to track the extent of the carbon dioxide plume unless, based on site-specific geology, such methods are not appropriate [40 CFR 146.90(g)(2)]. Where possible, a strategy consisting of both direct and indirect plume and pressure front tracking methods is recommended to facilitate comparisons with modeled predictions, allow early identification of unanticipated subsurface behavior or potential impacts to USDWs, and provide data to support a non-endangerment demonstration.

Direct carbon dioxide plume monitoring is performed via geochemical sampling in monitoring wells in the injection zone, while direct pressure front monitoring may be achieved using downhole pressure transducers. As with groundwater monitoring, direct plume and pressure front monitoring strategies should reflect site-specific characteristics and AoR delineation model

predictions. For example, the frequency and timing of sampling in the injection zone should be sufficient to capture the arrival of the plume at specified monitoring locations at the arrival times predicted by the model. Analytical parameters and methods used for injection zone fluid monitoring should be appropriate for the subsurface fluids described during site characterization. Indirect geophysical methods to monitor the plume and pressure front may include seismic, electrical, gravity, electromagnetic, or other techniques. If the applicant submits a plan that does not include indirect plume tracking methods, evaluate the site-specific geology to verify that such methods are not appropriate.

Review plans for surface air and/or soil gas monitoring (if applicable). The rule affords the UIC Program Director discretion at 40 CFR 146.90(h) to require surface air and/or soil gas monitoring to detect movement of fluid that could endanger USDWs within the AoR. The need for this monitoring may be informed by or considered to address uncertainties identified during the geologic characterization of the site, e.g., in areas where there may be potential for carbon dioxide movement to the surface. If surface air and/or soil gas monitoring is needed, the applicant may be able to demonstrate that monitoring employed under Subpart RR of 40 CFR Part 98 meets the requirements for the Class VI Testing and Monitoring Plan (additional information on Subpart RR monitoring is presented in Section 3.4).

Review any additional monitoring proposed by the applicant. Additional monitoring that an applicant may propose includes passive seismic monitoring, the use of tracers, or surface deformation measurement techniques (such as satellite-based elevation measurements or tiltmeters). If, based on site-specific conditions, additional monitoring is needed to sufficiently assess the behavior of the Class VI project, address uncertainties identified during site characterization, or protect USDWs from endangerment, request that the plan include appropriate additional monitoring using the authority provided at 40 CFR 146.90(i).

Verify that the plan includes a QASP that describes the standard procedures and practices that will be employed to ensure data quality for all testing and monitoring procedures. The QASP should describe sampling methods; sample handling and custody; analytical methods; quality control; instrument/equipment testing, inspection, and maintenance; data management, e.g., recordkeeping and tracking practices; and data review, verification, and validation procedures. The QASP does not need to re-state monitoring timing, frequency, location, analytes, etc. (except specifically in the context of quality assurance) or other information that is included in the Testing and Monitoring Plan. Verify that all of the testing activities, analytes, etc., included in the QASP are consistent with the body of the Testing and Monitoring Plan.

Discuss whether any issues or changes identified by others on the permit application review team might necessitate changes to the Testing and Monitoring Plan. Most significantly, the locations, frequencies, and analytical parameters tested pursuant to the Testing and Monitoring Plan should allow comparisons against baseline data and/or modeled predictions to support an evaluation of project operations, confirm modeled predictions of the carbon dioxide plume and pressure front movement, and contribute to AoR reevaluations and a non-endangerment demonstration. Therefore, the Testing and Monitoring Plan should be reviewed in conjunction with, and in consideration of, the AoR delineation modeling effort and associated reviews, e.g., a demonstration of an alternative PISC timeframe.

Additionally, changes to the well construction and operating conditions from those described in the initial permit application may have implications for corrosion testing, continuous monitoring,

and mechanical integrity testing procedures. Concerns about seismicity or uncertainties about the seismic history of the site raised during site characterization may also necessitate the inclusion of passive seismic monitoring.

Outcomes

Following the evaluation and approval of the Testing and Monitoring Plan, the UIC Program should incorporate the following information into the permit file:

- Permit conditions for testing and monitoring and MITs;
- The approved Testing and Monitoring Plan as an enforceable condition of the permit;
- An approved QASP that addresses all activities in the Testing and Monitoring Plan;
- Approved plans for construction of all monitoring wells; and
- A report documenting the review of the Testing and Monitoring Plan, including how the approved plan addresses any identified deficiencies in the proposed plan or uncertainties about the site, supports AoR reevaluations and the non-endangerment demonstration, and considers what is known about site geology and the behavior of the carbon dioxide plume and pressure front.

Any supporting documents (e.g., the Testing and Monitoring Plan, the QASP, and any reports documenting the review) should be uploaded to the project's permit package area in the GSDT.

4.1.8 Injection Well Plugging

Class VI permit applicants must submit a plan to plug the injection well in a manner that protects USDWs [40 CFR 146.82(a)(16); 146.92].

The purpose of the UIC Program's evaluation of the proposed Injection Well Plugging Plan is to ensure that the proposed materials and procedures for injection well plugging are appropriate to the well's approved construction and the site's geology and geochemistry. This evaluation is important to ensure that the injection well will not serve as a conduit for fluid movement that could endanger USDWs following cessation of injection.

Completeness Review

The draft Injection Well Plugging Plan will likely be a narrative document with associated schematics that describes how the applicant will plug the injection well in accordance with the requirements at 40 CFR 146.92.

The UIC Program should perform a preliminary review of the draft Injection Well Plugging Plan to verify that it provides information at a sufficient level of detail to inform an evaluation. For example, the plan should describe the plugs and the cement to be used and demonstrate that they are compatible with the injectate, formation fluid geochemistry, and subsurface geology. Plugging schematics should identify the depths of the injection zone, any production zones, any formations with USDWs, and other water-bearing formations. The method of plug placement and preliminary cement volume calculations should also be included. If any information is missing or is not presented in sufficient detail to inform an evaluation of the Injection Well Plugging Plan, the UIC Program should consider the need to request the missing information or send the applicant clarifying questions to inform the review.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate the proposed Injection Well Plugging Plan, submitted by a Class VI permit applicant, to confirm that the submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Confirm that the proposed Injection Well Plugging Plan meets the requirements at 40 CFR 146.92. The review should be done in coordination with reviewing the well's construction and schematics.

Verify that the proposed plugs and cement are suitable to the injectate and formation fluid geochemistry, including any geochemical changes anticipated during the injection phase as informed by an evaluation of geochemistry. Also verify that the plugging is appropriate to the planned construction of the well, e.g., to the sizes and depths of the various casing strings.

Review the Injection Well Plugging Plan against data on subsurface formations to verify that the placement of the plugs and cement are at appropriate depths. Consider the depths of the injection zone, any production zones, any formations with USDWs and other water-bearing formations, or other geologic features.

Review the cement calculations to confirm that the planned cement is sufficient to cover all relevant hydrocarbon- or water-bearing formations. Check that the plug placement procedures are adequate to properly clean the well bore, prevent contamination of the plugging fluid, allow proper fluid stability, and allow for sufficient setting time.

While not required under the Class VI Rule, evaluating monitoring well plugging procedures in conjunction with the same considerations for the review of the Injection Well Plugging Plan will help ensure that the monitoring wells will be plugged in a manner that is appropriate to the subsurface geochemical conditions of the Class VI project and ensure USDW protection.

Conversion of the Class VI Well Following Injection

If the applicant intends to convert the injection well to use it for another purpose following cessation of Class VI injection (e.g., to another UIC well class or a monitoring or production well), it may be appropriate to address this in the Injection Well Plugging Plan. For example, if the well will be used for injection into another, shallower formation, such as for enhanced oil or gas recovery (EOR/EGR), the Injection Well Plugging Plan should describe how the well would be plugged from the carbon dioxide injection zone to the hydrocarbon-bearing formation in a way that ensures proper cementing across any intervening porous or water-bearing formations. The plan should also describe procedures for plugging the well to the surface to address the possibility that the planned EOR/EGR operation does not commence or the applicant experiences financial difficulties and is unable to continue the injection operation (in this event, sufficient financial resources would be needed to plug the well, and the financial responsibility cost estimates for well plugging to the surface must be adequate). If the applicant plans to convert the injection well to a monitoring or production well, the Injection Well Plugging Plan should describe how this conversion would be implemented, including flushing the well and removing or changing equipment; procedures for eventual plugging per 40 CFR 146.92 must also be described in the Injection Well Plugging Plan.

Before approving the final Injection Well Plugging Plan, consult with other members of the permit application review team to determine whether any questions identified in the course of other aspects of the permit application review may necessitate a revision to the plan. In particular, verify that the final Injection Well Plugging Plan is consistent with the well's approved construction. Additionally, any revised information about the site's geology (e.g., the

depth of subsurface water- and hydrocarbon-bearing formations) and changes to, or uncertainties about, the predicted composition of carbon dioxide-water mixtures may affect the appropriateness of well plugging procedures.

If the applicant is requesting an injection depth waiver, confirm that the proposed well plugging will protect USDWs above and below the injection zone. If any aspects of the proposed Injection Well Plugging Plan change based on the review, alert the staff reviewing the financial responsibility cost estimates that the estimates to plug the well may need to be revised.

For additional information on evaluating Injection Well Plugging Plans, see the *UIC Program Class VI Well Project Plan Development Guidance*. See Section 2 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* for additional information on Class VI injection well plugging procedures.

Outcomes

Following the review and approval of the Injection Well Plugging Plan, the UIC Program should develop and upload the following to the project's permit package area in the GSDT:

- Permit conditions for injection well plugging and requirements for advance notice of, and reporting following, plugging the injection well;
- The approved Injection Well Plugging Plan as an enforceable condition of the permit; and
- A report documenting the review of the Injection Well Plugging Plan that describes any deficiencies identified, issues raised and discussed with the applicant, and how the final plan addresses these issues.

4.1.9 Post-Injection Site Care and Site Closure

Class VI permit applicants must submit a PISC and Site Closure Plan that outlines the proposed post-injection monitoring strategies and how non-endangerment of USDWs will be ensured throughout the PISC phase [40 CFR 146.82(a)(17); 146.93]. The applicant may also submit a demonstration of an alternative post-injection site care timeframe per 40 CFR 146.82(a)(18).

The purpose of the UIC Program's review of the PISC and Site Closure Plan is to ensure that planned post-injection phase activities are appropriate to the project and address known uncertainties or data gaps. If the applicant submitted a demonstration of an alternative PISC timeframe, the UIC Program should evaluate the demonstration to ensure that it is suitable to the site-specific conditions, of an appropriate duration, and informed by modeling predictions.

The UIC Program can also use the review as an opportunity to ensure, in coordination with the owner or operator, that the PISC and Site Closure Plan includes appropriate monitoring to validate modeled predictions, inform AoR reevaluations during the post-injection phase, and demonstrate non-endangerment. For additional information on evaluating the PISC and Site Closure Plan, see the *UIC Program Class VI Well Project Plan Development Guidance*.

Completeness Review

The draft PISC and Site Closure Plan should be a narrative document that describes how the applicant will meet the requirements at 40 CFR 146.93, including performing post-injection groundwater monitoring and plume and pressure front tracking, plugging the monitoring wells, and closing the site. It should be supported by maps and cross sections depicting the plume and

pressure front and schematics showing how the monitoring wells will be plugged. The applicant should also submit a QASP or otherwise provide QA procedures for post-injection phase testing and monitoring; for example, by incorporating the necessary information about post-injection monitoring into the Testing and Monitoring Plan's QASP.

If the applicant submits a demonstration of an alternative PISC timeframe as part of the permit application, the UIC Program should verify that it includes the specific technical information required to support an alternative PISC timeframe demonstration at 40 CFR 146.93(c). This may include a combination of new files and references to other components of the permit application, as applicable and appropriate.

Additionally, the UIC Program should perform a preliminary review of the draft PISC and Site Closure Plan to verify that it provides information at a sufficient level of detail to inform an evaluation. For example, the plan should describe the methods the applicant will use to perform all required post-injection testing and monitoring, a schedule for performing all planned testing, analytes/detection limits, and locations that are representative of the entire delineated AoR. The plan should also describe how monitoring wells will be plugged, and include schematics and a description of plugging and cementing procedures. If any information is missing or is not presented in sufficient detail to inform an evaluation of the PISC and Site Closure Plan, consider the need to request the missing information or send the applicant clarifying questions about the plan.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate a Class VI permit applicant's proposed PISC and Site Closure Plan, to confirm that the submitted information meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Verify that the predictions of pressure decline and fluid movement in the PISC and Site Closure Plan are consistent with AoR delineation modeling, reflecting site characterization and proposed operating data. The Class VI Rule requires that the plan describe the pre- and post-injection pressure differential and the predicted position of the carbon dioxide plume and associated pressure front at site closure [40 CFR 146.93(a)(2)(i),(ii)]. Verify that this information is incorporated into the plan and that it is consistent with the outputs of the modeling performed for AoR delineation as verified by those reviewing the AoR information.

Reducing Monitoring Frequency during PISC

It is possible that, as pressures decline and the plume and pressure front begin to equilibrate and plume movement slows, less frequent monitoring may be needed. If any decreases in monitoring frequency are proposed, it may be appropriate for the PISC and Site Closure Plan to identify specific quantitative triggers that would result in decreased monitoring activities or frequency. For example, the plan may specify that the frequency of certain monitoring activities could decrease from monthly to semi-annually when pressure (as measured at a certain location) returns to a certain percent above baseline levels. Providing this level of specificity would allow the applicant to reduce the monitoring frequency without needing to amend the plan (and possibly modify the permit). If such triggers are specified, baseline measurements should be taken as part of the pre-operational testing procedures.

Review the applicant's plans for post-injection monitoring. The Class VI Rule does not specify monitoring methods that must be used during the post-injection phase; instead, the monitoring program should be tailored to the project-specific characteristics, identified risks, and data needs for the non-endangerment demonstration. The EPA anticipates that, in many cases, post-injection monitoring activities will be an extension of

those performed during the injection phase (and described in the Testing and Monitoring Plan). Although, the agency acknowledges that the Class VI regulations are designed to accommodate new technologies or site-specific monitoring changes (e.g., frequency) on a project-specific basis. (See Section 4.1.7 for additional information on evaluating testing and monitoring strategies for Class VI projects.) Verify that the post-injection monitoring strategy is suitable to track the location of carbon dioxide and other mobilized constituents within the injection zone, track fluid pressures, and monitor the integrity of monitoring wells and former injection wells. As with injection phase monitoring, this monitoring should target any areas of potential USDW endangerment identified in the site characterization process and reflect any contaminants of concern that may be mobilized as a result of geochemical changes. If surface air and/or soil gas monitoring or passive seismic monitoring will be required during the injection phase, consider whether this should continue during part or all of the post-injection monitoring phase.

Verify that the proposed injection and post-injection phase testing and monitoring programs will, as an overall strategy, generate a sufficient amount of data to support AoR reevaluations and a non-endangerment demonstration. This is particularly important if the applicant submits a demonstration of an alternative PISC timeframe. If the applicant plans to request an alternative PISC timeframe, ensure that they understand that the PISC and Site Closure Plan will need to include the collection of a sufficient amount of monitoring data on which to base a non-endangerment demonstration. Because there will be fewer years over which to collect data, more frequent groundwater monitoring or plume and pressure front tracking may be appropriate to ensure collection of sufficient data to validate modeled predictions of pressure decline and reductions in the rate of plume movement. For example, verify that a sufficient number of monitoring samples will be taken at appropriate locations and the number of geophysical surveys will generate a sufficient amount of data on which to base a non-endangerment demonstration. Verify that the QASP addresses all post-injection testing and monitoring activities.

Review the alternative PISC timeframe demonstration if the applicant submits one. Evaluate the information provided to ensure that an alternative timeframe would be protective of USDWs, according to the requirements at 40 CFR 146.93(c). Verify that the demonstration agrees with predictions of plume and pressure front movement in the AoR delineation model. However, note that 40 CFR 146.93(c)(2) contains additional requirements for alternative PISC timeframe demonstrations that are not specified for AoR delineations, such as the use of sensitivity analyses to address key areas of uncertainty. Also verify that the geologic data on which the demonstration is based agree with the site characterization component of the permit application, the planned operating data, the physical and chemical characteristics of the carbon dioxide stream, and predicted interactions between carbon dioxide and formation fluids.

If the alternative PISC timeframe demonstration is not sufficient, does not meet the requirements and criteria at 40 CFR 146.93(c), or the modeling effort does not appropriately address uncertainty, discuss these findings with the permit applicant. Options may include:

Plans for Carbon Dioxide Production and the PISC Timeframe

If the applicant plans to eventually produce the carbon dioxide from the formation, they may base a demonstration that an alternative PISC timeframe is appropriate on subsurface pressure reductions associated with withdrawal of the carbon dioxide. Such a demonstration would be acceptable; however, PISC will need to continue until the carbon dioxide is withdrawn and reductions in pressures and the rate of plume movement are observed.

- Discussing the information submitted and revising the alternative PISC timeframe demonstration during the pre-construction phase; or
- Using the 50-year default PISC timeframe and relying on operational and monitoring data generated during the injection or post-injection phases to support a stronger demonstration, at a later time, that an alternative timeframe is appropriate. A future change to the PISC timeframe may necessitate an amendment to the PISC and Site Closure Plan.

For additional information on the alternative post-injection site care timeframe, see Section 3.2.2 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance*.

Encourage the applicant to submit proposed non-endangerment demonstration criteria. While there are no requirements for providing the criteria for the non-endangerment demonstration with the permit application, describing and agreeing upon the criteria that will be used for the non-endangerment demonstration reduces future uncertainty. This can also help ensure that the operator plans to collect the types and amounts of data that are needed to inform a demonstration that site closure is appropriate (per 40 CFR 146.93(b)(3)), particularly if an alternative PISC timeframe is anticipated.

The Class VI Rule does not specify the content of the non-endangerment demonstration. However, the EPA recommends that the non-endangerment demonstration address: available groundwater and plume monitoring data; comparison of monitoring data to model predictions; evaluation of the carbon dioxide plume and reservoir pressure; and an evaluation of any unanticipated events that occurred during the project. See Section 3.4 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* for additional information on non-endangerment demonstrations.

In coordination with the applicant, identify specific criteria on which the non-endangerment demonstration would be made and ensure that the criteria can be supported by the data the applicant proposes to collect during injection and post-injection testing and monitoring. For example, verify that the monitoring data will be able to be compared with baseline data on fluid chemistry collected during the site characterization process and validate modeled predictions of plume and pressure front behavior. Consider specifying these criteria—and what will happen if a demonstration of non-endangerment cannot be made—in the PISC and Site Closure Plan. Additionally, ensure that baseline data have been, or will be, collected prior to commencing injection.

Review plans for monitoring well plugging and site closure. Confirm that the applicant proposes to use proper plugs and cement in all monitoring wells and that they are of suitable construction and at appropriate depths. As with injection well plugging, the monitoring well plugging plans should consider the depth of water and hydrocarbon-bearing formations, subsurface geochemistry, and the predicted composition of carbon dioxide-water mixtures. Review the schematics of the monitoring wells' construction and plugging concurrently to ensure consistency.

Confirm that the plan describes site closure and site restoration activities. These may include removing all surface equipment and restoring the site to its prior condition (e.g., planting vegetation).

Before approving the final PISC and Site Closure Plan, discuss the plan with other members of the permit application review team to determine whether any issues identified in the course of the permit application review may necessitate changes to the plan. For example, changes to operating procedures or updated geologic information may affect predictions of pressure decline and the position of the plume. Additionally, the non-endangerment demonstration criteria or evaluation of a demonstration of an alternative PISC timeframe should reflect any changes to the evaluation of site geology and the findings of the AoR delineation modeling, account for the approved operating conditions, and reflect data to be gathered during injection and post-injection phase testing and monitoring. Monitoring well plugging procedures should reflect any revised information about the site's geology and predictions about the composition of carbon dioxide-water mixtures.

As with injection-phase testing and monitoring, ensure that the proposed post-injection monitoring program will detect any triggers for responses specified in the Emergency and Remedial Response Plan.

If any aspects of the PISC and Site Closure Plan change based on the review, alert the staff reviewing the financial responsibility cost estimates that the estimates for PISC and/or site closure may need to be revised.

Outcomes

Following the review and approval of the PISC and Site Closure Plan and related information, the UIC Program should develop the following information:

- Permit conditions for PISC and site closure;
- The approved PISC and Site Closure Plan as an enforceable condition of the permit;
- An approved QASP for all post-injection testing and monitoring activities;
- A report documenting the review of the PISC and Site Closure Plan that summarizes the review process and how the approved plan addresses any uncertainties about the site and ensures non-endangerment of USDWs; and
- A report that documents the alternative post-injection site care timeframe review, including how the information provided meets the criteria at 40 CFR 146.93(c)(1) and (2) and supports the determination that an alternative post-injection site care timeframe is appropriate.

Any supporting documents (e.g., the final PISC and Site Closure Plan) should be uploaded to the project's permit package area in the GSDT.

4.1.10 Emergency and Remedial Response

The Class VI Rule requires owners or operators to develop and maintain an Emergency and Remedial Response Plan that describes actions to be taken to address events that could potentially cause endangerment to a USDW during the construction, operation, and PISC phases of a project [40 CFR 146.82(a)(19); 146.94].

The purpose of the UIC Program's evaluation of the Emergency and Remedial Response Plan is to ensure expeditious and appropriate responses to protect USDWs from endangerment should an emergency event occur. The UIC Program should ensure that procedures are in place to address

the potential endangerment to all identified resources near the well, based on site-specific information including site geology, the extent of the AoR, and operating conditions.

Completeness Review

The draft Emergency and Remedial Response Plan should be a narrative document supported by maps and images that describes how the permit applicant will meet the requirements at 40 CFR 146.94, including how they plan to address any potential emergency or unforeseen event at the well and all resources within the AoR.

The UIC Program should perform a preliminary review of the draft Emergency and Remedial Response Plan to verify that it provides information at a sufficient level of detail to inform an evaluation. For example, the plan should describe all potentially impacted resources throughout the geographic extent of the AoR and include detailed and event-specific procedures to address emergency events. It should also identify response personnel and include a plan to communicate with the public. If any information is missing or is not presented in sufficient detail to inform an evaluation of the Emergency and Remedial Response Plan, the UIC Program should consider the need to request the missing information or send the applicant clarifying questions about the plan.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate a Class VI permit applicant's proposed Emergency and Remedial Response Plan to confirm that the submittal meets the requirements of the Class VI Rule and informs the establishment of protective permit conditions.

Review the proposed Emergency and Remedial Response Plan to ensure that it meets the requirements at 40 CFR 146.94, it accounts for all risks identified within the AoR, and that planned responses will be adequate for mitigating any adverse events that may arise. Some considerations include the following:

- Confirm that, for all resources throughout the approved AoR, the Emergency and Remedial Response Plan identifies potential risk scenarios and adverse events. Special consideration should be given to events with the highest potential of occurring or that may have the highest impacts.
- Verify that planned response activities are appropriate to the risk scenarios and their potential impacts. While the specific details of response planning are not included in the Class VI Rule, the EPA recommends that, for each scenario identified, the plan describe: the anticipated severity of the event, the phase during which the event could occur (i.e., injection and/or post-injection phases), proposed avoidance measures, detection methods, and response actions, including the personnel and equipment that would be employed.
- Confirm that response equipment and trained personnel are available to respond to adverse events. The plan should include contact information for response personnel, a communications plan, and a description of staff training and exercise procedures.

For additional information on evaluating Emergency and Remedial Response Plans, see the *UIC Program Class VI Well Project Plan Development Guidance*.

Before approving the final Emergency and Remedial Response Plan, discuss whether any issues identified by others on the permit application review team may necessitate a revision to the plan. For example, changes reflected in the final approved extent of the AoR may impact what resources should be addressed in the Emergency and Remedial Response Plan. Any uncertainties or new information about the site's geology may necessitate consideration of additional carbon dioxide migration or groundwater contamination scenarios. Concerns about seismic history, the presence of faults in the AoR, or induced seismicity may impact the final procedures for responding to seismic activity. See Section 4.1.11 for additional information on emergency and remedial response planning for projects operating under injection depth waivers.

Confirm that the Testing and Monitoring and PISC and Site Closure plans include procedures for quickly detecting situations that may endanger USDWs, particularly where there is uncertainty about any aspects of the project. Communicate any changes to the final Emergency and Remedial Response Plan to staff reviewing financial responsibility cost estimates to ensure that sufficient resources are set aside for emergency actions.

Outcomes

Following review and approval of the Emergency and Remedial Response Plan, the UIC Program should develop the following information for inclusion in the permit file:

- Permit conditions for emergency and remedial response;
- The approved Emergency and Remedial Response Plan as an enforceable condition of the permit; and
- A report documenting the review of the Emergency and Remedial Response Plan that describes any deficiencies identified, issues raised and discussed with the applicant, and how the final plan addresses these issues.

Any supporting documents (e.g., the Emergency and Remedial Response Plan and any reports documenting the review) should be uploaded to the project's permit package area in the GSDT.

4.1.11 Injection Depth Waivers

Class VI permit applicants seeking to inject above the lowermost USDW must submit a request for an injection depth waiver [40 CFR 146.82(d); 146.95(a)]. The injection depth waiver provisions of the Class VI Rule afford flexibility to allow injection into non-USDW formations while ensuring that USDWs above and below the injection zone are protected from endangerment where the lowermost USDW is very deep.

Figure 4-3 illustrates the type of geologic setting under which injection depth waivers would be necessary. The panel on the left presents a "typical" Class VI injection scenario (i.e., where an injection depth waiver would not be needed) and the panel on the right shows injection into a non-USDW that lies above the lowermost USDW, where an injection depth waiver could be needed to allow injection at that site.

The purpose of the UIC Program's evaluation of an injection depth waiver application is to ensure that USDWs above and below the injection zone are protected from endangerment if the project operates under an injection depth waiver. The UIC Program should work with the owner or operator to consider, on a site-specific basis, the implications, benefits, and challenges associated with GS, water availability, and USDW protection where an injection depth waiver is

being considered. Following the review, the UIC Program Director will forward information to the EPA Regional Administrator, who must concur on the issuance of an injection depth waiver [40 CFR 146.95(d)].

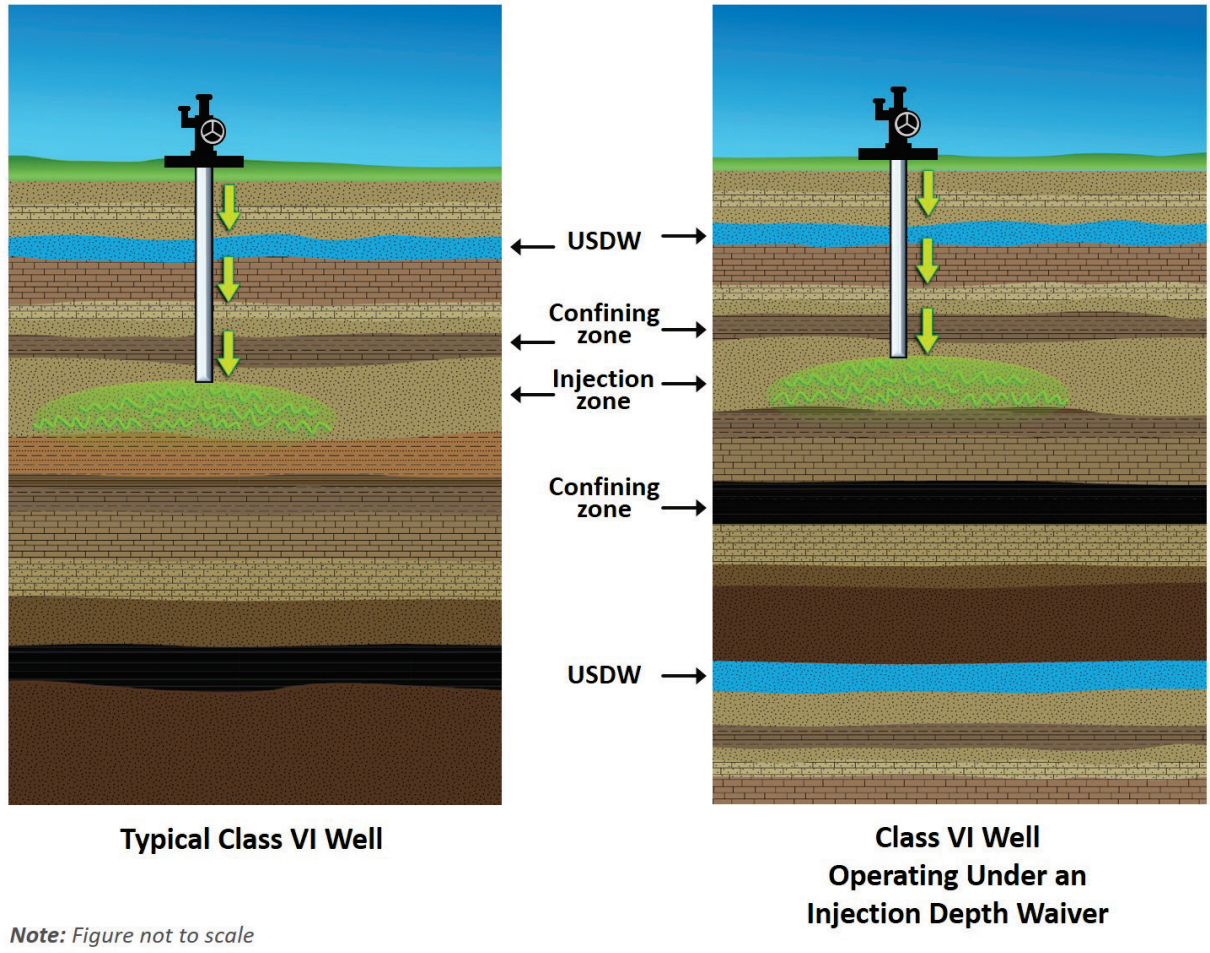

Figure 4-3: Geologic Scenarios for Injection Depth Waivers

Completeness Review

Class VI permit applicants seeking an injection depth waiver will likely submit a narrative report that addresses each element at 40 CFR 146.95. The report should include information on the upper and lower confining zones; the storage capacity of the injection zone; information on drinking water resources and water supply needs and plans for securing alternative water resources or treating USDWs; and hydrocarbon or mineral resource exploitation. The waiver application should be supported by maps, logs, model outputs, and other relevant data.

The injection depth wavier application is a separate submittal from the Class VI permit application. Because the permit application and the waiver application report serve different purposes, the applicant must, per 40 CFR 146.95(a), include a demonstration in the injection depth waiver application that is complete and provides the appropriate context (i.e., describes confinement above and below the injection zone). However, the waiver application report may

reference background information in the permit application, provided it is readily available to the reviewer and its relevance to the injection depth waiver is clearly explained in the waiver application report.

The UIC Program should perform a preliminary review to verify that the waiver application includes all of the information required at 40 CFR 146.95(a) and that it is based on the site-specific geology, modeling, and operational data described in the Class VI permit application, with information and data about the lower confining zone at the same level of detail as information in the Class VI permit application. If information provided in the waiver application about the injection zone, the modeled AoR, planned construction, or planned testing and monitoring does not agree with the Class VI permit application, the UIC Program should discuss any discrepancies with the applicant and consider requesting that the waiver application and/or the permit application be revised accordingly.

Evaluation

The review of the injection depth waiver application should parallel the review of the Class VI permit application. However, where injection depth waivers are sought, this information will be evaluated in the context of protecting USDWs above *and* below the injection zone.

In addition to evaluating the injection depth waiver application, permitting authorities must consult with the Directors of the PWSS Programs of all states, territories, and tribes, having jurisdiction within the AoR, about the proposed waiver; notify the public; and forward the injection depth waiver application to the EPA Regional Administrator for approval, per 40 CFR 146.95(b) and (c) and as described below.

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate a Class VI injection depth waiver application, to confirm that an applicant's submittal meets the requirements of the Class VI Rule and to inform: a decision on whether to grant an injection depth waiver, and the establishment of permit conditions that protect USDWs above and below the injection zone.

Review the injection depth waiver application. The elements defined at 40 CFR 146.95(b)(1) that the UIC Program Director must document in referring the injection depth waiver to the EPA Regional Administrator are described below. A list of websites and databases that could support the review of information required at 40 CFR 146.95 (b) and (c) is available in the resource library of the GSDT.

- **Review information on the integrity of the upper and lower confining zones** [40 CFR 146.95(b)(1)(i)]. Review the geologic maps, geophysical survey results, geomechanical data (including information on faults and fractures), and permeability and porosity data that were submitted to confirm the presence of laterally continuous, impermeable confining units above and below the injection zone. Verify that adequate data have been submitted, including appropriate data collection/testing methods, number of samples, etc., to characterize confining zones above and below the injection zone.
- **Evaluate the suitability of the injection zone** [40 CFR 146.95(b)(1)(ii)]. Consider whether the injection zone outcrops within the AoR or is hydraulically connected to a USDW above or below the injection zone that could be impacted by the injection. Verify that the injection zone is laterally continuous based on maps, cross sections, and geophysical survey results, and whether confining units above and below it form a clear

separation between the injection zone and any other formations. Evaluate whether porosity and permeability data support a determination that the injection zone will be suitable for the proposed injection activities and will not allow for unacceptable pressure buildup. Review analyses of formation solids and fluid geochemistry to verify that dissolution or precipitation reactions will not affect injectivity or liberate contaminants.

- **Evaluate the capacity of the geologic formation to sequester carbon dioxide,** considering information submitted on the availability of alternative sites, including their capacity, depth, and location [40 CFR 146.95(b)(1)(iii)]. Review the information submitted by the applicant to ensure that it is consistent with other information about the proposed site provided elsewhere in the injection depth waiver application and in the Class VI permit application, including storage capacity estimates as confirmed by the independent AoR delineation modeling. (The applicant's modeling must also demonstrate that USDWs above and below the injection zone will not be endangered as a result of fluid movement, per 40 CFR 146.95(a)(3).) If alternative injection zones below the lowermost USDW exist, discuss with the applicant whether such formations are more suitable than injection zones above or between USDWs. See Section 4.1.1 for additional information on evaluating confining zone integrity, the suitability of the injection and confining zones, and storage capacity estimates.
- **Verify that the applicant's proposed Emergency and Remedial Response Plan addresses all risks** in the AoR, including any endangerment to USDWs below the injection zone. Also, **review the financial responsibility demonstration** to ensure that the applicant has sufficient resources to respond to potential endangerment to USDWs below the injection zone, including the cost of securing alternative water resources or treating USDWs in the event of contamination [40 CFR 146.95(b)(1)(iv)]. This evaluation should consider the applicant's description of how the Testing and Monitoring Plan and other plans will ensure protection of USDWs above and below the injection zone.
- **Evaluate information regarding community needs, demands, and supply from drinking water resources** and planned needs, and potential and/or future use of USDWs and non-USDWs in the area [40 CFR 146.95(b)(1)(v),(vi),(vii)]. Confirm that the applicant provided information on all drinking water supplies within the AoR. Verify that projections of future uses of USDWs and non-USDWs consider anticipated land use changes over the duration of the Class VI project and that the information provided is consistent with other geologic data presented in the injection depth waiver application and the Class VI permit application. Note that some information that could support an evaluation of water resources (e.g., related to public or private drinking water wells) may not be publicly available for the applicant to access; if so, consider whether UIC Program staff should request this information from the appropriate agency as part of the waiver evaluation.
- **Evaluate information submitted related to any planned or potential hydrocarbon or mineral resource exploitation** near the proposed site [40 CFR 146.95(b)(1)(vii)] to determine if there are any plans to drill through the formation to access resources above or beneath the proposed injection zone(s). Consider mineral rights leases in formations above and below the injection zone, information on current (and potential future) resource exploitation, and whether such activities could provide potential conduits for fluid migration to USDWs.

- **Evaluate the applicant's proposed plan for securing alternative water resources or treating USDWs** in the event of contamination [40 CFR 146.95(b)(1)(viii)]. Verify that the submitted plans for obtaining alternative drinking water resources are technologically and economically feasible and include adequate quantities of water to address current and projected needs. These plans should be reflected in the Emergency and Remedial Response Plan.

Review the construction plans for the well to confirm that it will be protective of USDWs above and below the injection zone, as required at 40 CFR 146.95(f)(2). Confirm that the casing and cement are designed to prevent movement of fluid into unauthorized zones, including USDWs, above and below the injection zone [40 CFR 146.95(f)(2)(ii)]. Verify that any penetrations through the upper or lower confining zone will be plugged or cased and cemented with materials that are compatible with injected and native fluids. Also confirm that the surface casing will extend below any USDWs that lie above the injection zone and be cemented to the surface [40 CFR 146.95(f)(2)(iii)]. See Section 4.1.4 above for additional information on reviewing the construction of Class VI wells.

If the information presented in the waiver application supports a determination that operating under an injection depth waiver will be protective of USDWs above and below the injection zone, initiate consultations and notifications as described below. If there is inadequate information in the application, work with the applicant to determine whether additional information can be provided or to identify other suitable injection zones.

Consult with the Directors of the PWSS Programs of all states, territories, and tribes having jurisdiction within the AoR of a well for which an injection depth waiver is sought per 40 CFR 146.95(b)(2). The purpose of this communication is to ensure that water system interests are considered in a waiver application review. While there is no required format or process for the consultation, a recommended template of a letter to a PWSS Director is available in the resource library of the GSDT. Respond to any questions from the PWSS Directors about the project. These questions may cover topics such as: how potential contamination has been considered and expeditious responses will be ensured, the relationship of the injection well to all public water systems and USDWs, or the composition or volumes of carbon dioxide to be injected. Document the results of the consultation.

Notify the public that an injection depth waiver application has been submitted per 40 CFR 146.95(c). The public notification of the injection depth waiver can occur concurrently with notification of the Class VI permit application; however, the notice should make it clear that the site, if permitted, would be operating under an injection depth waiver. Include information on the depth of the injection zone; the location of the well; the name and depth of all USDWs; a map of the AoR; the names of any public water supplies affected, reasonably likely to be affected, or served by USDWs in the AoR; and the results of the consultation with the PWSS Director(s). Evaluate and respond to all public comments about the injection depth waiver.

Provide all relevant information to the EPA Regional Administrator for concurrence regarding the injection depth waiver. Provide the results of the evaluation of the information listed in 40 CFR 146.95(b)(1), documentation of the PWSS Director consultation, and responses to public comments on the proposed waiver. The EPA Regional Administrator will review all of the information about the project collected during the waiver application and the public notice process and make a final decision regarding the waiver [40 CFR 146.95(d)].

If necessary to support a determination regarding the protectiveness of injection above or between USDWs, the EPA Regional Administrator has the authority to request that additional

information be provided [40 CFR 146.95(d)(1)]. If the EPA Regional Administrator requests additional information, ask the permit applicant for more details. If substantially more or different information is provided and the EPA Regional Administrator requests re-initiation of the public notice process, notify the public of the revised waiver application.

Based on the information provided, the EPA Regional Administrator will provide written concurrence or non-concurrence regarding the waiver. Four outcomes of the review of the injection depth waiver application are possible:

1. If the EPA Regional Administrator concurs with the waiver (and all other aspects of the permit application are acceptable), prepare a draft Class VI permit that identifies the proposed injection zone and includes additional permit conditions for projects operating under injection depth waivers related to well construction and testing and monitoring (see the "outcomes" discussion below for additional information).
2. If the application for a waiver is acceptable in most respects, e.g., the site is generally suitable, but there are deficiencies in the waiver application report (e.g., insufficient data or detail are present to support a determination), work with the applicant to determine whether the waiver application can be updated and resubmitted for approval. Discuss the specific information needs with the owner or operator to determine whether the waiver application can be updated (and, if so, which portions require revision). Re-initiation of the public notification process may be necessary, as determined by the EPA Regional Administrator.
3. If available information indicates that another suitable injection formation exists, the owner or operator may apply for a Class VI permit to inject into that formation. In such cases, the owner or operator would need to resubmit a Class VI permit application, providing specific information about the alternate formation.
4. If an injection depth waiver application is denied because, based on the review, injection above or between USDWs would endanger USDWs and there is no suitable target injection formation for which a waiver would not be required or other injection options exist, then a Class VI permit cannot be issued at the proposed site.

An injection depth waiver may not be issued without written concurrence by the EPA Regional Administrator [40 CFR 146.95(d)(2)].

Outcomes

Following the evaluation of the injection depth waiver application, the UIC Program should develop the following information:

- Permit conditions related to operation under the injection depth waiver, such as:
    - Conditions for designing the casing and cement to prevent fluid movement into unauthorized zones, including USDWs, above and below the injection zone [40 CFR 146.95(f)(2)(ii)], including surface casing that extends through the base of the lowest USDW above the injection zone and is cemented to the surface [40 CFR 146.95(f)(2)(iii)];
    - Conditions for additional direct monitoring during the injection and post-injection phases in the first USDW above and the first USDW below the injection formation [40 CFR 146.95(f)(3)(i); 146.95(f)(4)(i)];

- Conditions for additional indirect monitoring during the injection and post-injection phases unless, based on site-specific geology, such methods are not appropriate for the specific site [40 CFR 146.95(f)(3)(ii); 146.95(f)(4)(ii)]; and
- Other conditions that may be necessary, based on site-specific geology, to ensure protection of USDWs above and below the injection zones [40 CFR 146.95(f)(5)], which may include:
  - Injection pressure limits that address the fracture pressures of the confining zones above and below the injection zone;
  - Additional monitoring that may be necessary to identify endangerment of USDWs;
  - Injection well plugging conditions that are necessary to protect USDWs above and below the injection zone; or
  - Emergency and remedial response considerations for impacts on public water supplies affected, likely to be affected, or served by USDWs in the AoR and plans for securing alternative resources or treating USDWs in the event of contamination.

- A report documenting the evaluation of the injection depth waiver application that describes any identified deficiencies or concerns with the waiver application, how uncertainties are being addressed, and a determination that the site is suitable for operating under an injection depth waiver;
- Documentation of consultation with applicable PWSS Director(s), including a copy of the letter and/or other materials sent to the PWSS Director and any information related to the waiver submitted by the PWSS Director(s);
- Information related to public notice of the waiver application, including a copy of the public notice, a record of any public comments received, and the responses to those comments; and
- Information related to documenting the EPA Regional Administrator's evaluation, including copies of all materials submitted to the EPA Regional Administrator and a copy of the EPA Regional Administrator's concurrence with issuance of the waiver.

Any supporting documents or materials related to the injection depth waiver review and any reports documenting the review should be uploaded to the project's permit package area in the GSDT.

4.1.12 Aquifer Exemption Expansions

Class II well owners or operators injecting into an exempted aquifer who have made a decision to transition from Class II to Class VI and anticipate that the carbon dioxide plume and pressure front will expand beyond the area covered by an existing Class II aquifer exemption will need to apply to expand the areal extent of the aquifer exemption. The aquifer exemption requirements in the Class VI Rule afford Class VI permit applicants an opportunity to assess and select a suitable GS site in areas where oil and gas recovery has occurred while also protecting USDWs (i.e., formations/aquifers afforded SDWA protection). By regulation, expansions of the areal extent of

aquifer exemptions are only available and can only be granted to owners or operators of Class II wells with existing aquifer exemptions prior to re-permitting as Class VI.

An owner or operator seeking an aquifer exemption expansion must define the areal limits of the expanded aquifer exemption per 40 CFR 144.7(d)(1) and submit information to support a determination that the proposed Class VI aquifer exemption meets the criteria at 40 CFR 146.4(d).

The purpose of the UIC Program's evaluation of an aquifer exemption application is to ensure, based on site-specific information, that an appropriately sized area is exempted such that the carbon dioxide plume and pressure front remain within the exempted area. The review of the request to expand the areal extent of a Class II aquifer exemption could also take place concurrently with review of an injection depth waiver request (if applicable). This approach can help ensure that the aquifer exemption determination considers the most up-to-date information about the proposed project.

Completeness Review

Class II well owners or operators seeking to expand the areal extent of their approved aquifer exemption will apply for an aquifer exemption expansion; this application is a separate submittal from the Class VI permit application. It should be in the form of a narrative that describes the delineated area of the expansion, supported by geologic maps and model outputs and a description of how the aquifer exemption meets the criteria at 40 CFR 146.4.

The UIC Program should perform a preliminary review to confirm that the aquifer exemption application is based on the same or a similar delineation modeling, geologic, and operational data as those on which the Class VI permit application is based. Additionally, the UIC Program should verify that the demonstration that the aquifer exemption meets the criteria at 40 CFR 146.4 includes a description of the water quality analyses to determine the TDS of the aquifer to be exempted and that evaluations of current and future use of the aquifer are based on a thorough review of state and/or local water supply data or other appropriate sources.

Evaluation

The bolded and italicized text below outlines a suggested approach that a UIC Program might employ to evaluate information submitted to request an expansion of the areal extent of a Class II aquifer exemption, to confirm that an applicant's submittal meets the requirements of the Class VI Rule and that the expanded aquifer exemption is appropriate.

Verify that the proposed expanded area of the aquifer exemption is complementary to and based on the same information used to delineate the Class VI AoR. It is likely that the applicant will use the AoR delineation modeling performed pursuant to 40 CFR 146.84 to delineate the aquifer exemption area. If this is the case, the modeling should account for all geologic data, operational conditions, and any other injection activities (i.e., related to Class II wells); see Section 4.1.2. If the aquifer exemption delineation is based on other modeling or analyses, compare the lateral and vertical extent of the delineated area of the aquifer exemption expansion to ensure that it encompasses, at a minimum, the entire geographic extent of the approved Class VI AoR.

Confirm that the proposed aquifer exemption meets the criteria at 40 CFR 146.4(d). An owner or operator seeking to expand the areal extent of an existing aquifer exemption should submit information to support a determination that the proposed area of the expanded aquifer exemption meets all of the following criteria: it does not currently serve as a source of drinking water; the TDS content of the groundwater is more than 3,000 mg/L and less than 10,000 mg/L; and it is not reasonably expected to supply a public water system.

Verify that the aquifer is not currently a source of drinking water. The EPA interprets water that currently serves as a source of drinking water to include water that is being withdrawn at the time of the aquifer exemption request and water that will be withdrawn in the future by wells that are in existence at the time of the request. Confirm that the applicant evaluated information on all public water suppliers and private wells across the entire AoR for the Class VI well and the area delineated per 40 CFR 144.7, accounting for any anticipated population or land use changes. Verify that the information reviewed is consistent with information from municipal water systems' websites, the Safe Drinking Water Information System (SDWIS), and county or state health department records of drinking water wells. If the applicant is also seeking an injection depth waiver, the information submitted for the aquifer exemption should match the information submitted per 40 CFR 146.95(a).

Confirm that the TDS is more than 3,000 mg/L and less than 10,000 mg/L. This should have been established for the previously exempted areas of the aquifer; TDS information for the expanded area should be consistent with information on formation fluids gathered as part of the Class VI permit application process or that will be collected under the pre-operational formation testing program. Verify that this information is available and that sampling and testing was (or will be) performed properly, i.e., tested in a certified laboratory or using proper QA protocols or pursuant to the Class VI QASP. Also confirm that any reported TDS levels are consistent with other information provided as part of the Class VI site characterization performed per 40 CFR 146.82(a)(6). If there is any uncertainty regarding whether the samples are representative of the entire expanded area (i.e., if there is variability), consider requesting that additional sampling be performed. If the TDS concentration in the proposed aquifer exemption expansion area is lower than 3,000 mg/L, an expansion of the areal extent of an aquifer exemption cannot be granted because it would not meet the requirement that the TDS content be greater than 3,000 mg/L.

Review information to confirm that the aquifer is not reasonably expected to supply a public water system. This determination will likely be related: to water use demands/plans and to the presence of economically valuable mineral, hydrocarbon, or geothermal energy resources (per 40 CFR 146.4(b)(1)). Verify that the applicant provided sufficient information about hydrocarbon recovery in the area of the expansion to support a determination that this criterion was met.

Verify that all three criteria at 40 CFR 146.4(d) are met; if one or more of the criteria is not met, an aquifer exemption expansion may not be granted. However, injection of carbon dioxide at a volume that remains within the previously exempted area may be acceptable, provided all other applicable Class VI requirements are met. Modified operations may be needed to ensure that the carbon dioxide remains within the originally exempted area, and appropriate limits should be specified in the Class VI permit.

Review and Approval of Aquifer Exemptions

An expansion of the areal extent of an aquifer exemption for a Class VI project constitutes a substantial revision to a state's approved primacy program and requires an EPA rulemaking and revision of 40 CFR 147 [40 CFR 145.32]. All aquifer exemptions must be approved by EPA, even if the state has Class VI primacy.

Where the state has Class VI primacy, the state UIC Program Director must, following the review of information related to the aquifer exemption, submit a program revision to the EPA region. This review is separate from the review of the Class VI permit application. However, because the supporting information is related, EPA recommends that the UIC Program Director review the aquifer exemption and Class VI permit application at the same time. The state will perform the following activities:

- Review the information in the aquifer exemption application.
- Issue public notice of the proposed exemption. This is recommended, since an expansion to an aquifer exemption for the purposes of GS may be of interest to the public.
- Submit documentation of the review and any other documents required by EPA to the EPA Region.

Once the EPA Region has received information from the state, EPA will evaluate the state's revised program submission, issue a public notice that EPA has received an aquifer exemption, prepare the aquifer exemption rulemaking, and publish notice in the *Federal Register*.

EPA recommends that publication of the *Federal Register* notice about the aquifer exemption be timed to coincide with public notice of the draft Class VI permit (pursuant to requirements at 40 CFR 146.82(a) and 124.10). This would allow a single outreach process so that the public could review materials and submit comments on both actions at the same time.

See the *UIC Program Class VI Primacy Manual for State Directors* for additional information about revising state primacy programs.

Outcomes

Most of the products of the aquifer exemption review at the pre-construction stage will likely be documentation associated with the primacy revision process required for aquifer exemption approvals. Information the state will produce will likely include:

- A report documenting the review of the aquifer exemption, including the evaluation that the expanded areal extent of the aquifer exemption is at least as large as the Class VI AoR and that the aquifer exemption meets the criteria at 40 CFR 146.4(d); and
- Documentation associated with the aquifer exemption review, including:
    - The completeness review;
    - Correspondence with the EPA Regional Administrator; and
    - Information related to public notice of the aquifer exemption and any public comments received.

4.2 Preparing the Permit

In addition to conducting a technical review of the permit application (as described in Section 4.1), a permit writer should perform the following steps in support of a permit decision. Some of these steps may be conducted concurrent with the technical evaluation while others will necessarily follow chronologically after the conclusion of the technical evaluation.

Finalize the Environmental Justice (EJ) assessment. If any portions of the AoR are in disadvantaged communities, compare maps of the AoR to maps of known disadvantaged communities and facilities that may adversely affect those communities. If the EJ analysis indicated that the proposed site may be near disadvantaged communities that are also exposed to environmental risks, confirm that any appropriate mitigation measures (e.g., additional monitoring) are included in the Class VI permit. See Section 3.3 for additional information on performing EJ analyses.

Develop draft Class VI permit conditions based on the preliminary site and project data submitted with the permit application. Include permit conditions to ensure that the owner or operator will meet all of the requirements of the Class VI Rule. As described earlier, the EPA developed a template for permit text that can be accompanied by a set of enforceable project-specific plans. Using the template will promote consistency among Class VI permits issued nationwide and facilitate the use of this Implementation Manual, which is organized in consideration of this approach. The templates of the Class VI permit (i.e., the main body and the associated enforceable plans) reflect the Class VI requirements and the recommendations in this Implementation Manual. These are available in the resource library of the GSDT. States may develop other template formats; however, the Class VI requirements and the recommendations about the content of the permit still apply.

The permit should also set conditions for reporting and recordkeeping required at 40 CFR 146.91. Identify what must be included in semi-annual reports. Require the owner or operator to report the results of MITs or workovers within 30 days. Identify situations that require "emergency" reporting and activities for which the owner or operator must provide advance notice. Require the owner or operator to submit all reports in an electronic format via the GSDT and identify recordkeeping requirements. See the *UIC Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance for Owners and Operators* for additional information on electronic reporting.

Additionally, the permit should include general permit conditions that address modification, revocation, reissuance, termination, or transfer of permits; severability and confidentiality conditions; and duties and requirements of the permit, e.g., duty to comply, penalties for violations, duty to mitigate, operation and maintenance, duty to provide information, inspection and entry, and signatory requirements.

Prepare a fact sheet and/or statement of basis summarizing the project and the evaluation of the permit application. The EPA recommends that the permit writer develop both a fact sheet and a statement of basis about the permitting decision. The statement of basis [40 CFR 124.7] is a way to document the technical review, identify protective permit conditions, and explain the rationale for the regulatory agency's decision-making.

The fact sheet is a public document that explains the permit in lay terms, per 40 CFR 124.8(b). Templates are available in the resource library of the GSDT. Include a brief description of the

facility, the injectate, the basis for the draft permit conditions, and how the permit writer determined the appropriate conditions. For example, describe the geology, the AoR, USDWs and the injection and confining zones, planned construction of the well, planned operating and monitoring requirements, and plans for plugging the well and performing post-injection monitoring. Explain that a draft permit has been issued, identify where people can obtain a copy of the draft permit, and provide a contact person in the permitting agency.

Compile all information supporting the administrative record for the permitting decision. The administrative record should include the permit (incorporating all of the enforceable project plans), reports that document the review of the permit application (e.g., the AoR delineation modeling evaluation report, induced seismicity report, and financial responsibility report), references that the permit application review team consulted during the technical review, and documentation of all communications with the applicant (including email communications, call logs, and summaries of meetings).

The GSDT can facilitate this process because it is a repository of all the documents associated with the permit application. Identify the materials that are to be included in the administrative record and copy or move them into the permit package area for the project. Personal evaluation files, notes, drafts, etc., that are not part of the administrative record can be stored elsewhere in the GSDT for future reference.

Finalize the draft permit for public notice and comment. Publish a notice in a newspaper of general circulation near the project site that describes the project, explains the comment submission procedures and deadlines, provides information about planned public hearings, and provides information about where to receive additional information. If an injection depth waiver application and/or aquifer exemption expansion request has been submitted, the EPA recommends providing notice of this concurrently with notice of the permit application, if possible. A sample public notice of a Class VI permit application is available in the resource library of the GSDT. Hold one or more public hearings and document all input provided.

Conduct outreach to stakeholders, including any tribes, in or near the AoR. The unique nature of Class VI wells and GS highlights the importance of communicating with the public and among states, tribes, and territories about pending Class VI projects. See Section 2.3 above. Effective communication can ensure transparency in the permitting process, encourage coordination and information sharing, and promote safe, protective projects. In addition to providing a copy of the draft permit and a fact sheet and/or statement of basis, consider providing outreach or be prepared to answer questions from the public about the characteristics of the site, injection technology, the relationship of the well to all nearby public water systems and USDWs, and how public safety and potential contamination have been considered in the development of permit conditions. If any portions of the AoR are in disadvantaged communities, the EPA encourages conducting enhanced public outreach activities to these communities. If the AoR crosses (or comes close to) boundaries with other states, territories or tribes, notify appropriate officials in those jurisdictions (e.g., UIC program or environmental protection officials), per 40 CFR 146.82(b). A template of a letter that can accomplish this required notification is available in the resource library of the GSDT.

Consider posting materials relevant to the permit application online, if possible. For additional information on public outreach, see the UIC Quick Reference Guide *Additional Tools and*

Considerations for UIC Directors on the Public Participation Requirements for Class VI Wells, and the *Fact Sheet on Public Participation Requirements*.

Review public comments, including testimony at public hearings; prepare responses; and develop a responsiveness summary document.

Finalize Class VI permit conditions, if needed based on the public process, and issue a Class VI permit. Consistent with the regulations, the permit should specify that the applicant is authorized to construct or convert the injection well, but may not commence injection until authorized in writing to do so and that they must meet any new or revised conditions in the permit based on the final geologic data that are collected pursuant to 40 CFR 146.82(c). Identify the final geologic and well data that must be submitted and approved before injection will be authorized, e.g., as-built well schematics, pre-operational testing results, demonstration of mechanical integrity, completion of all required corrective action on wells in the AoR, updated financial responsibility information, submittal of final geologic data, AoR delineation modeling, and project plans. Templates with recommended language are available in the resource library of the GSDT. If the determination is positive, update the project status in the GSDT to show that the project is in the pre-operation phase.

4.3 Planning for the Pre-Operation Review

As described above, the Class VI Rule is designed to address the fact that not all of the information needed to evaluate the suitability of a proposed GS site will be available at the time of a Class VI permit application. The information required at 40 CFR 146.82(a), and described in this section, will be collected and submitted before the well is constructed or converted and, accordingly, it will be based on preliminary information.

To address the uncertainties inherent in the pre-construction information (as described in Section 4.2), 40 CFR 146.82(c) requires the collection of information that confirms the assumptions on which the permit determination was based. After the permit is issued, the owner or operator will construct the well and perform the required pre-operational testing. The data collected will augment the regional geologic and hydrogeologic information with data specific to the direct vicinity of the well, e.g., based on cores and sampling during drilling.

The EPA recommends that the UIC Program communicate with the owner or operator while the well is constructed and formation testing is being performed. This can help ensure that all of the information that will be needed to address all uncertainties is collected. If witnessing of any tests (e.g., MITs, logging, sampling, or testing of automatic alarms and shut-off systems) is anticipated, make appropriate arrangements with the owner or operator.

As Section 5 describes, the UIC Program Director will receive additional information for review, generated by a Class VI permit applicant/owner or operator to confirm site-suitability, before the UIC Program Director can authorize injection. The EPA recommends that UIC Programs review Section 5 before the owner or operator submits information required at 40 CFR 146.83(c) to become familiar with, and plan for, the review.

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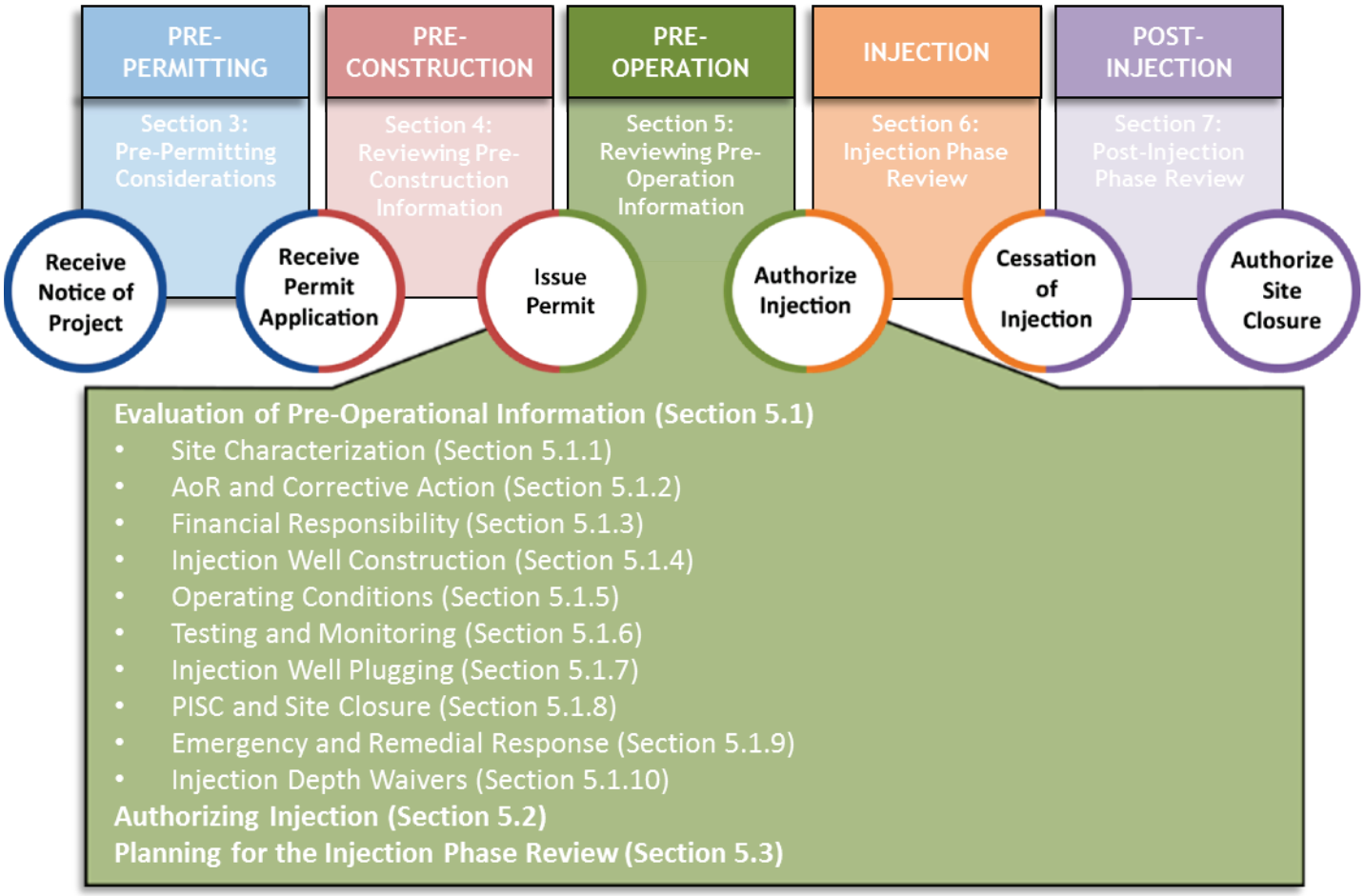
Section 5: Reviewing Pre-Operation Information



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5 Reviewing Pre-Operation Information

Following receipt of the Class VI permit, the owner or operator will construct or convert their well and perform the pre-operational well and formation testing required at 40 CFR 146.87. Class VI well owners or operators must submit the results of all required pre-operational formation testing, updated information about site geology, the final AoR, any needed amendments to the project plans, and information about the construction and testing of the well [40 CFR 146.82(c)].

The primary goal of the pre-operation phase review is to ensure that any uncertainties identified during the course of the permit application review have been addressed. The newly acquired information should strengthen the basis on which the determination of site-suitability was made. Any remaining uncertainties should be addressed by appropriate risk mitigation methods, e.g., by planning targeted monitoring to detect carbon dioxide migration or setting operating limits to ensure confinement of the injected carbon dioxide.

The UIC Program should also confirm that the injection well was constructed to maintain mechanical integrity throughout the duration of the project (particularly in light of information about subsurface geochemistry) and is equipped to monitor injection operations and shut-in if needed.

Pre-Operation Reviews for Converting Existing Wells

If the owner or operator converted an existing well (and has completed some or all of the formation testing required at 40 CFR 146.82(c) and 146.87), the permit application may include some of this information. The EPA encourages the UIC Program to consider the recommendations in this section during the permit application review. See Section 3.2 for additional information.

In general, the pre-operation phase review should parallel the initial permit application review. However, this review will likely be streamlined to focus on newly acquired information, particularly information that has changed based on the results of pre-operational testing or other pre-operational activities.

During the pre-operation phase, a UIC Program is likely to receive the following types of information submitted by the owner or operator (per 40 CFR 146.82(c)) for the UIC Program's evaluation:

- Updated geologic information based on the results of pre-operational formation testing (see Section 5.1.1);
- A final AoR delineation based on computational modeling and the status of corrective action on wells in the AoR (see Section 5.1.2);
- Updated financial responsibility information that reflects any changes to the Corrective Action, Injection Well Plugging, PISC and Site Closure, or Emergency and Remedial Response Plans (see Section 5.1.3);
- As-built well construction specifications and any revisions to the proposed operating data (see Sections 5.1.4 and 5.1.5);
- Updates to the Testing and Monitoring Plan, Injection Well Plugging Plan, PISC and Site Closure Plan, and Emergency and Remedial Response Plan (see Sections 5.1.6 through 5.1.9); and

- In addition, some owners or operators may need to submit updated information related to injection depth waivers [40 CFR 146.95]. See Section 5.1.10.

This section provides guidelines and recommendations for how the UIC Program should review the information submitted to confirm compliance with 40 CFR 146.82(c) and verify the suitability of the site. It describes the types of pre-operational information owners or operators will likely submit, how the UIC Program can evaluate the submitted information to ensure USDW protection, and the outcomes or products of the review.

Following the review of well construction information and the results of pre-operational formation and well testing that confirm site-suitability and proper well construction/conversion, the UIC Program Director can authorize injection. See Section 5.2.

5.1 Evaluation of Pre-Operation Information

Following construction or conversion of their well and pre-operational testing, Class VI well owners or operators must submit the results of all required pre-operational well and formation testing, updated information about site geology, the final AoR, any needed amendments to the project plans, and information about the construction and testing of the well [40 CFR 146.82(c)].

The UIC Program should evaluate this information to confirm the assumptions on which the permit application, the AoR delineation modeling, or other information that supported the Class VI permit were based. The newly acquired information should strengthen the basis on which the determination of site-suitability was made. Any remaining uncertainties should be addressed by appropriate risk mitigation methods to form a robust, defensible permit record. Table 5-1 presents some examples of how the newly acquired information can inform various aspects of the pre-operation phase review.

The following sub-sections provide guidelines and recommendations for how the UIC Program should review, and where necessary, discuss the information with the owner or operator or request additional or clarifying information, to confirm compliance with 40 CFR 146.82(c) and verify the suitability of the site, focusing on how pre-operational formation testing program results can address uncertainties; make a risk-based determination and issue a modified permit if necessary to ensure protection of USDWs; and authorize injection operations. Each permit application is unique and the appropriate activities will be specific to the application being reviewed. Therefore, the activities described in the sections below outline a recommended course of action to accomplish the goal of evaluating pre-operational information to ensure that the final permit conditions are protective of USDWs.

Table 5-1: Examples of how Pre-Operational Submittals can Inform Considerations for Issuing Authorization to Inject at a Class VI Well

Required Submittals	Recommended Cross-Submittal Checks and Considerations
The final AoR and the status of corrective action on wells in the AoR [40 CFR 146.82(c)(1),(6)]	• A larger AoR may affect: the need for additional corrective action, the areal scope of injection and post-injection phase testing and monitoring, resources to be addressed in the Emergency and Remedial Response Plan, and financial responsibility needs. • Revised estimates of the time for plume and pressure front movement to slow/cease may necessitate revisions to the alternative PISC timeframe and the PISC and Site Closure Plan; financial responsibility needs for PISC may also be affected. • Changes in the estimated speed or direction of plume and pressure front movement may affect the placement of monitoring wells and plume and pressure front tracking activities. • If any planned corrective action is not complete, financial responsibility cost estimates may need to be adjusted.
Updated geologic information about the site [40 CFR 146.82(c)(2)]	• The presence of additional fluid-containing or porous formations or geologic features that could allow fluid movement to USDWs should be addressed in injection and monitoring well construction and plugging. • Additional faults/fractures or other geologic features that could be pathways for fluid movement or carbon dioxide leakage should be addressed in the injection and post-injection testing and monitoring plans. • The presence of additional USDWs in the AoR should be addressed in the injection and post-injection phase testing and monitoring programs, the construction and plugging of injection and monitoring wells, and the Emergency and Remedial Response Plan; additional financial resources may be needed to cover associated activities. • New geologic information may affect AoR delineation modeling inputs and, therefore, the size/shape of the AoR. • Increased seismic activity should be addressed in the Testing and Monitoring Plan and Emergency and Remedial Response Plan.
Carbon dioxide compatibility information [40 CFR 146.82(c)(3)]	• Updated information about carbon dioxide-formation fluid compatibility may impact carbon dioxide trapping mechanisms, estimates of plume and pressure front behavior, or storage capacity estimates (and the injection volume limits). • Any anticipated geochemical changes that could affect the compatibility of the injectate with well materials should be addressed in the construction/conversion and plugging of injection and monitoring wells.
Formation testing results [40 CFR 146.82(c)(4)]	• Logging and testing data should confirm the assumptions on which AoR delineation modeling, site-suitability, and storage capacity estimates (and permitted injection volumes) are based. • Updated fracture pressure calculations based on formation testing results may necessitate modified injection pressure limits. • Updated information about formation fluid properties may affect storage capacity estimates (and volume limits), AoR delineation modeling inputs, and predictions of plume and pressure front migration. • New information about subsurface geochemical reactions may necessitate inclusion of additional geochemical parameters in the Testing and Monitoring and PISC and Site Closure plans.

Required Submittals	Recommended Cross-Submittal Checks and Considerations
Final well construction procedures; logging and testing data and MIT results [40 CFR 146.82(c)(5),(7),(8)]	• The as-built well specifications should be reviewed before approving well construction/conversion; they may inform approval of monitoring well construction. • Any divergences from the approved well construction procedures should be addressed in the Injection Well Plugging Plan; these may also affect financial responsibility needs. • Logging and testing results and the results of MITs should be reviewed to confirm that the well was constructed or converted properly.
Plan amendments or alternative PISC timeframe updates [40 CFR 146.82(c)(9)]	• Amendments to the AoR and Corrective Action, PISC and Site Closure, or Emergency and Remedial Response plans may affect financial responsibility needs. • All amended plans should be checked for needed consistency changes in other plans. • A change to the alternative PISC timeframe may affect financial responsibility needs for PISC and emergency and remedial response.

5.1.1 Site Characterization

Following the required pre-operational testing, owners or operators must submit: the results of formation testing [40 CFR 146.82(c)(4); 146.87], updates to information on the geologic structure and hydrogeologic properties of the injection zone and overlying formations [40 CFR 146.82(c)(2)], and information on the compatibility of the carbon dioxide stream with fluids in the injection zone and minerals in the injection and confining zones [40 CFR 146.82(c)(3)]. This pre-operational data augments the regional geologic and hydrogeologic information on which the permit application was based to include data specific to the direct vicinity of the well, e.g., based on cores and water samples taken during drilling. This information should also address the key data gaps or uncertainties identified in the initial permit application review, as described in Section 5.1 above.

The purpose of the UIC Program's review of the geologic information collected during the pre-operation phase is to assess whether final geologic data are consistent with and confirm the data that were submitted with the permit application. The UIC Program should review this information to ensure that appropriate assumptions are made in the AoR delineation modeling and other analyses, particularly where supporting data were not available when the Class VI permit application was submitted.

Completeness Review

Following completion of formation testing, owners or operators will submit the testing results and any updated geologic information to the UIC Program.

The EPA anticipates that the pre-operational formation testing results will include a combination of graphs/figures, log results, tabular data, and third party materials such as log analyst reports. The UIC Program should:

- Verify that the owner or operator performed all testing required at 40 CFR 146.82(c) and 146.87, including any additional logging or testing that may have been identified as necessary during the initial permit application review;
- Verify that cores and samples were properly collected and that the submission includes the log analyst's report required at 40 CFR 146.87(b);
- Confirm that all parameters specified in the approved pre-operational formation testing program were analyzed and that all QA protocols were followed;

- Confirm that samples were taken at all locations and depths/formations specified in the approved pre-operational formation testing program (including any additional confining zones that may be needed to ensure confinement or containment of the carbon dioxide); and
- Verify that the specified analytical techniques were used and that all chemical analyses were performed at certified or accredited labs following the protocols in the approved QASP.

Identification of Additional USDWs

If pre-operational testing identifies the presence of additional USDWs above the injection zone (e.g., if water sampling in deep formations indicates that any formations below the previously identified lowermost USDW are less than 10,000 mg/L), groundwater sampling in the Testing and Monitoring and PISC and Site Closure plans should target all USDWs and the Emergency and Remedial Response Plan should identify appropriate responses to potential contamination of any USDW. Also, the AoR delineation modeling should address all USDWs and the well's construction should protect all USDWs. If any previously unidentified USDWs below the injection zone are detected, the owner or operator would need to obtain an injection depth waiver in order to inject carbon dioxide into the injection zone identified in the permit. See Section 4.1.11.

The EPA recommends that changes to the geologic information be submitted as a narrative document that meets the requirements at 40 CFR 146.82(c). The descriptive material should be a synthesis of the pre-operational formation testing results that highlights any changes to the understanding of the site since the initial permit application review. Ideally, it will address the uncertainties identified in the permit application and provide additional evidence to demonstrate that the site meets the suitability criteria at 40 CFR 146.83.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate site characterization information, submitted by a Class VI well owner or operator, to confirm that information submitted meets the requirements of the Class VI Rule; confirm that the permit conditions are protective; and facilitate authorization to inject.

Review the results of logs performed during drilling to evaluate formation properties (e.g., resistivity, spontaneous potential, porosity, gamma ray, and fracture finder logs). Verify that logging results support consistent findings about subsurface stratigraphy and that they corroborate other geologic data provided in the original permit application or collected via pre-operational testing. Examine information on the depth, thickness, porosity, permeability, and lithology of the injection and confining zones to assess whether it is consistent with information in the initial permit application (including parameters used in AoR delineation modeling). Verify the locations of any USDWs and any hydrocarbon-containing zones. If there are any inconsistences with information available at the time of the initial permit application, assess whether such differences affect site-suitability. For example, if the confining zone exhibits greater permeability than initially predicted, verify that it will still provide adequate containment. If the injection zone is less porous or permeable than indicated by initial data, assess whether storage capacity estimates might need to be revised and whether operating at the approved injection pressure can proceed without the potential for fracture. If multiple confining zones are needed to ensure confinement or containment of the carbon dioxide, verify that the intervening layers between the primary and additional confining zones will impede vertical fluid movement, are free of faults and fractures, and will allow pressure dissipation.

If additional logs in other wells were requested as part of the permit application review (e.g., to support facies analyses or evaluate the integrity of the confining zone), evaluate the results of these logs to determine whether they confirm assumptions about site-suitability. If well stimulation was performed, verify that the confining zone was not fractured as a result of stimulation.

Review analyses of whole cores or sidewall cores of the injection and confining zones. Confirm that information about porosity, permeability, petrology, and mineralogy based on core analyses is consistent with other submitted information on the injection and confining zones. If any information based on this analysis conflicts with geologic data submitted prior to construction, evaluate its impact on site-suitability and operational parameters. For example, consider the effects of porosity and permeability on storage capacity and the permitted total volume of carbon dioxide to be injected or the effects of rock strength on injection pressure limits.

In any new information on the mineralogy, petrology, or lithology of the injection and confining zones affects the understanding of injectivity or containment, or if it suggests any potential for release of trace metals through mineral dissolution, confirm that these considerations are incorporated into the Testing and Monitoring Plan (e.g., via appropriate groundwater testing parameters) and as inputs to the AoR delineation model.

Review information on formation fluids in the injection zone. Examine the data provided (including temperature, pH, conductivity, reservoir pressure, and static fluid level or other physical and chemical characteristics of the formation fluids) to determine if they agree with information in the permit application, match AoR delineation modeling outputs, and address any uncertainties identified in the permit application review. If information about the physical and chemical characteristics of the formation fluids is not consistent with information used in the evaluation of compatibility with the carbon dioxide stream, assess whether revisions to the original compatibility assessment are warranted (or review any updates provided by the owner or operator). Verify that the physical and chemical characteristics of the formation fluid are consistent with the inputs of the AoR delineation modeling; confirm that the model reviewer is aware of any changes that may affect the modeling inputs. Assess whether new information about formation fluids indicates the need for any additional protective measures for USDWs (e.g., changes to operating limits or to monitoring parameters/frequencies in the Testing and Monitoring and PISC and Site Closure plans).

If, based on geochemical analysis of formation solids and/or fluids, there is a concern that trace metals may be liberated as a result of interactions with carbon dioxide and affect USDWs, coordinate with the reviewer(s) of the Testing and Monitoring and PISC and Site Closure plans to ensure that any contaminants that could be liberated/mobilized are addressed in the groundwater monitoring program.

Review information about the fracture pressure of the injection and confining zones. Review the fracture pressure data (e.g., determined via a step rate test) to verify that the test was performed properly and the fracture pressure was calculated accurately. If the pressure gauges used for the test were not deployed at the bottom of the well, verify that proper correction factors were used.

Review information on the hydrogeologic characteristics of the injection zone. Verify that a pressure fall-off test and either a pump test or injectivity test were performed, that proper testing

and analytical procedures were followed (e.g., that surface gauges were properly corrected to obtain bottom-hole pressure), and that the testing parameters are based on the operating conditions in the permit (e.g., injection pressures). If pressure fall-off tests suggest the presence of faults or fractures near the well bore, determine whether these may be transmissive and could impact confinement. If the results of pressure fall-off tests indicate the presence of newly identified faults or fractures that were not considered in the permit application review, communicate this to the AoR delineation modeling team and to the staff reviewing the planned injection and post-injection phase testing and monitoring to ensure that monitoring will target areas where there is a potential for carbon dioxide migration.

Verify that the results of hydrogeologic testing are consistent with other geologic data. For example, compare transmissivity values calculated from the pressure fall-off test to injection zone permeability values determined from cores.

Review the results of any additional testing requested during the permit application review. In addition to the examples cited above, this may include additional or higher resolution geophysical surveys to evaluate the depth, areal extent, and thickness of the injection and confining zones or to explore alternate interpretations of the geologic site conceptual model. Review the results of any surface air and/or soil gas monitoring (if required) that may be appropriate to provide a longer-term baseline against which future results could be compared. If any of this information does not corroborate the initial geologic data or address uncertainties, consider revising the permit conditions.

Review updates to the geologic site characterization based on pre-operational formation testing results. The results of the formation testing will support the comprehensive evaluation as described in Section 4.1.1 and the *UIC Program Class VI Well Site Characterization Guidance*. Owners or operators must submit updates to the information on the geologic structure and hydrogeologic properties of the injection zone and overlying formations based on the results of pre-operational formation testing [40 CFR 146.82(c)(2)]. If an injection depth waiver was approved for the project, encourage the owner or operator to include any information relevant to the waiver, including the results of pre-operational formation testing below the lower confining zone, as part of these updates (see Sections 4.1.11 and 5.1.10 for additional information on waivers). Evaluate this information to confirm that the site is suitable for carbon dioxide injection, per 40 CFR 146.83 and in the context of the comprehensive evaluation of site-suitability (as described in Section 4.1.1).

- Assess whether newly acquired information confirms that ***facies interpretations about the injection and confining zones*** are consistent with the descriptions in the permit application. Verify that the confining zone(s) is sufficiently thick and continuous throughout the AoR to provide confinement. Confirm that the injection zone will provide adequate storage. If sampling and analyses of cores from locations in addition to the injection well were requested to evaluate facies in heterogeneous settings or structural features, evaluate the results of these analyses to determine whether they address uncertainties about the site and confirm assumptions about site-suitability.
- Review the results of any logging within wells other than the injection well and whether they confirm that ***the structures of the injection and confining zones*** are conducive to GS and form an adequate confining system. Also, consider whether additional monitoring

is needed in any areas to address uncertainty; if so, verify that such monitoring has been incorporated into the Testing and Monitoring and PISC and Site Closure plans.

- If any fluid sampling results vary from the assumptions used in geochemical or reactive transport modeling to demonstrate the ***compatibility of the carbon dioxide stream with subsurface fluids and minerals***, verify that the owner or operator has updated the model(s) accordingly. Verify that the modeling results confirm assumptions about injectivity, appropriate operational parameters, etc. Identify whether the results of models or experiments indicate potential compatibility issues that could affect operational parameters, plume migration, carbon dioxide trapping mechanisms, or storage capacity. For information on considerations regarding evaluating the compatibility of the carbon dioxide stream with well materials, see Section 5.1.4.

Class VI Projects with Aquifer Exemptions

If an aquifer exemption expansion was approved for the project (see Section 4.1.12), newly acquired information should continue to support the basis for approving the aquifer exemption. Specific considerations include:

- The delineated lateral and vertical extent of the aquifer exemption expansion should encompass, at a minimum, the entire approved, final Class VI AoR (see Section 5.1.2).
- The results of geochemical sampling should confirm that the TDS content of the injection zone is between 3,000 and 10,000 mg/L (see Section 5.1.1).
- Any additional available information should support the determination that the aquifer does not currently serve as a source of drinking water.

If the EPA denied the aquifer exemption, the UIC Program should work with the owner or operator to ensure that the injected carbon dioxide will remain within the confines of the previously approved Class II exemption, e.g., by limiting injection rates or total allowable volumes of carbon dioxide in the Class VI permit.

- If ***estimates of injection zone storage capacity*** change based on pre-operational formation testing results, determine whether adjusting the injection rates and volume limits in the permit is necessary. If any revisions to the geochemical modeling or storage capacity estimation modeling were requested to address uncertainties identified during the permit application review, verify that the updated models incorporate all site-specific data collected during pre-operational testing.
- Compare the fracture pressure to assumptions on which the evaluation of ***confining zone integrity*** was based and to the distribution of pressures in the AoR as predicted by modeling. If information indicates that injection pressures will exceed the fracture pressure of the confining zone or 90 percent of the fracture pressure of the injection zone, consider adjusting operating limits in the permit or requesting information on additional confining zones. See Section 4.1.6 for additional information on using fracture pressure data to set operating limits.

Review any updated information about seismic activity at the site. If there has been recent natural or anthropogenic seismic activity at the site, review information collected since the permit was issued to determine whether the frequency or intensity of such events has increased. Also consider whether any newly acquired data indicate an increased risk that seismic activity may reactivate faults and compromise containment. Options to address seismic risk in the permit include: operational changes (e.g., reduced injection rates), incorporation of passive seismic

monitoring into the Testing and Monitoring Plan (if it is not already included), and addressing the potential for induced seismicity in the Emergency and Remedial Response Plan.

Notify other members of the review team of any relevant changes to geologic information that may affect other aspects of the review (such as evaluating the AoR delineation modeling) or necessitate revising permit conditions or the plans, as described above. See Section 4.1.1 for additional information on evaluating geologic information about the site.

Outcomes

Following the evaluation of final geologic information and pre-operational formation testing results, the UIC Program should consider documenting the review for inclusion in the permit file. This documentation could be informed by reports developed during the permit application review and may include:

- A description of how the results of pre-operational formation testing addressed deficiencies, uncertainties, or data limitations identified during the pre-construction review of geologic information or confirmed assumptions on which the permit decision was based; and
- Any updated information relevant to the evaluation of seismic risk, if necessary, to incorporate any newly acquired information about the potential for induced seismicity, recent seismic events, or revised permit conditions designed to minimize the risks associated with induced seismic events.

The revised reports and any supporting documentation should be uploaded to the project's permit package area in the GSDT.

5.1.2 AoR and Corrective Action

Following the required pre-operational testing, owners or operators must submit: the final AoR delineation [40 CFR 146.82(c)(1)], the status of corrective action on wells in the AoR [40 CFR 146.82(c)(6)], and any amendments to the approved AoR and Corrective Action Plan [40 CFR 146.82(c)(9)].

The purpose of the UIC Program's evaluation of the final AoR, any changes to the AoR and Corrective Plan, and the status of corrective action is to ensure that the AoR appropriately represents the area where USDWs may be endangered due to injection and that all potential conduits for fluid movement that could endanger USDWs in that area are identified and addressed. The primary focus of the UIC Program's evaluation should be to assess whether the data collected during pre-operational testing address the information gaps and/or uncertainties identified during permitting and support the assumptions used and the approach taken during computational modeling. Therefore, the UIC Program should review this information in close coordination with the review of the pre-operational testing results (see Section 5.1.1).

Completeness Review

Owners or operators will submit the final AoR delineation (including detailed modeling data to support the delineation), the amended AoR and Corrective Action Plan (if needed), and the status of corrective action. Similar to the proposed plan submitted during the pre-construction phase, the amended plan is expected to be a single narrative document, while the detailed modeling data will likely include a combination of modeling input and output data, short text descriptions, formulae, GIS data/maps, etc. The EPA anticipates that some of the data will be the same as

those used for the initial AoR delineation, while other components of the submission will reflect updated information or new data generated during the pre-operation phase.

The UIC Program should perform a preliminary assessment of the amended AoR and Corrective Action Plan and the final AoR, including the supporting modeling information. The following activities are recommended to ensure that the amended plan is complete:

- Identify the changes made to the AoR delineation, any key updates of the modeling data, and the revisions that have been made to the plan.
- Verify that all changes and amendments are documented comprehensively and consistently. For example, the final AoR delineation should be presented consistently throughout the AoR and Corrective Action Plan and other project submittals.
- Determine whether the submitted information is sufficient to evaluate compliance with the requirements for computational modeling and AoR delineation with an appropriate level of detail and clarity.

Demonstration that no updates to the AoR and Corrective Action Plan are needed

In some instances (e.g., for a well-characterized site with substantial data available in the pre-construction phase), the pre-operational testing data may fully support the existing, approved AoR delineation, and no amendments may be needed to the plan. In those cases, the owner or operator should submit a description of how the new data confirm and support the approved AoR delineation and the strategy used to determine this. The corrective action status and any relevant updates to the detailed modeling data supporting the final AoR delineation would still be required in those cases.

If any additional information or clarification is needed, consider sending one or more sets of questions/requests until a determination of completeness can be made.

Evaluation

The following recommendations apply to a generic new project and the evaluation process will need to be tailored to each project's specific conditions and each owner or operator's computational approach. For example, in most cases, it is anticipated that no operational testing and monitoring results will be available for model verification/calibration during the pre-operation phase, because injection has not yet begun. However, at some sites, there may be data from historical or nearby injection operations that could also be used to support the AoR delineation process.

Similar to the process used during the pre-construction phase, the evaluation of the final AoR delineation should involve a combination of qualitative and quantitative assessments. The goals of this evaluation include:

1. Verifying that all relevant new information has been appropriately considered in the delineation of the final AoR and identifying areas where new information supports the previous approaches/assumptions.
2. Ensuring that the updated conceptual/geologic model and model inputs are consistent with pre-operational testing results, and evaluating how the newly available information addresses the data gaps/uncertainties associated with the existing AoR delineation.

3. Assessing whether the updated computational/numerical model used to delineate the final AoR complies with 40 CFR 146.84, that it is constructed to reasonably and accurately represent the geologic and operational systems, and that it yields the information necessary to delineate the AoR.
4. Confirming that the methodology used to delineate the AoR (based on the modeling results) is a conservative and reasonable approach to ensure that the AoR accurately represents the area where USDWs may be endangered.
5. Ensuring that all simplifying assumptions are clearly stated, documented, and justified, as are the methods used for integrating new information into the modeling approach.

The bolded text below outlines a suggested approach that a UIC Program might employ to achieve these goals. This approach will help to: confirm that the final AoR delineation meets the requirements of the Class VI Rule; confirm that the permit conditions are protective in light of the pre-operational testing results; and facilitate authorization to inject.

Assess the completeness of the pre-operational testing data incorporated into the AoR delineation to ensure that all available relevant information collected pursuant to 40 CFR 146.87 and the permit has been used to support the process. The relevant data are expected to include, at a minimum: information on rock properties, such as porosity, permeability, and constitutive relationships (i.e., capillary pressure-saturation-relative permeability); injection and confining zone geochemistry; geomechanical characteristics of the injection and confining zones; and in situ fluid pressures and temperatures. See Section 5.1.1 for additional information on evaluating pre-operational formation testing data.

Assess the conceptual/geologic model and model inputs to evaluate the data/information used in the model. For example, qualitative methods and/or statistical evaluations (e.g., summary statistics, histograms, etc.) could be used to verify that the updates accurately represent the newly available data. Confirm that the updates are supported by all relevant new information. For a detailed description of the evaluation process for various model input categories, see Section 4.1.2.

Review the owner or operator's computational/numerical modeling effort to verify compliance with the rule requirements, assess consistency with the approach described in the approved AoR and Corrective Action Plan, and evaluate appropriateness for the project. This may involve both qualitative evaluation of certain modeling aspects and independent or semi-independent quantitative modeling. In addition to the recommendations provided in Section 4.1.2, determine whether any updates to the modeled subsurface processes, such as inclusion of any geochemical reactions, are necessary based on new information.

Assess the owner or operator's methodology for delineating the AoR to ensure that it represents the area where USDWs may be endangered. Confirm that an acceptable approach was used to determine the critical pressure (see the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance*) and that the associated calculations are based on appropriate, site-specific values collected during pre-operational testing (e.g., pressure in various formations, salinity, etc.).

Review the status of corrective action in the AoR. Confirm that the owner or operator used appropriate methods to identify all artificial penetrations throughout the final AoR using database searches or other means, and that the list of artificial penetrations is complete. If the list

of artificial penetrations appears to be incomplete, ask the owner or operator to augment the list (e.g., by conducting more detailed surveys or additional well record searches).

Evaluate whether corrective action conducted on all previously determined and/or newly identified wells was completed in a suitable manner, e.g., using carbon dioxide-resistant materials. If phased corrective action was approved as part of the AoR and Corrective Action Plan, confirm that the owner or operator is conducting corrective action based on the pre-determined schedule. In particular, verify that any corrective action that the permit requires to be completed prior to commencement of injection has been performed using appropriate methods and materials.

Verify that the amended AoR and Corrective Action Plan reflects the most up-to-date information on the AoR delineation and corrective action. When evaluating the final AoR delineation and corrective action status, as described above, also review the changes made to the narrative plan to ensure that the plan accurately reflects all relevant information. The plan should present the final AoR delineation, describe how the delineation is supported by the newly collected data, and contain any necessary updates to the procedures for corrective action (including phased corrective action, if appropriate) and AoR reevaluation. It should provide an accurate and complete benchmark for future AoR reevaluations and corrective action, with a sufficient level of detail and clarity. See Section 4.1.2 for more information on evaluating the AoR and Corrective Action Plan.

Periodically confer with other members of the review team throughout the evaluation process, and before approving the final AoR and the amended AoR and Corrective Action Plan. Ensure that any issues identified during the review of the information submitted under 40 CFR 146.82(c) are considered by the team and that the final AoR is incorporated into any updates to other project plans or permit conditions.

Outcomes

Following the review of the final AoR delineation, the amended AoR and Corrective Action Plan, and the status of corrective action, the UIC Program should revise information in the permit file as needed. These materials may include the following:

- Revised permit conditions for AoR and corrective action, if needed;
- Documentation of any corrective action performed since the permit was issued and of any remaining corrective action activities that must be performed under a phased approach, if appropriate (and the schedule for those activities);
- The approved amended AoR and Corrective Action Plan, if needed, as an enforceable condition of the permit;
- An updated map of the approved AoR delineation, if needed; and
- A report documenting the evaluation of the AoR and corrective action submissions, highlighting newly incorporated information about the site and any updates to the independent modeling evaluation approach and results.

The AoR and Corrective Action Plan and any supporting documents should be uploaded to the project's permit package area in the GSDT.

5.1.3 Financial Responsibility

Class VI well owners or operators must update their financial responsibility cost estimates annually or when any of the specified project plans have been updated [40 CFR 146.85(c)(2)]. Given the likelihood that one or more project plans will change during the pre-operation phase, it is possible that an updated cost estimate may be needed during this phase.

The purpose of the UIC Program's review of updated financial responsibility information is to confirm that the cost estimates for corrective action, injection well plugging, PISC, site closure, and emergency and remedial response are adjusted as needed to address any changes to the covered activities that were identified during the pre-operation review. For additional information, see the *UIC Program Class VI Financial Responsibility Guidance*.

Completeness Review

The owner or operator will submit updated cost estimates for corrective action, injection well plugging, PISC, site closure, and/or emergency and remedial response. These updates must reflect adjustments for inflation (if it has been at least one year since the instruments were approved), per 40 CFR 146.85(c)(2). Additionally, for any covered activities for which a change is necessary based on new information collected during the pre-operation phase, the owner or operator must submit revised cost estimates to ensure that the financial instruments will be adequately funded.

The UIC Program should verify that any changes to covered activities described in the Class VI project plans are addressed in the cost estimate updates. These may include: the number of wells that need corrective action as described in the AoR and Corrective Action Plan, the number of monitoring wells that need to be plugged following post-injection monitoring or site closure activities described in the PISC and Site Closure Plan, or potential response activities identified in the Emergency and Remedial Response Plan.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate updated financial responsibility cost information and/or revisions to financial instruments submitted by a Class VI well owner or operator to: confirm that the submittal meets the requirements of the Class VI Rule; confirm that the permit conditions are protective; and facilitate authorization to inject.

Review any revised cost estimates in the context of amendments to the AoR and Corrective Action, Well Plugging, PISC and Site Closure, or Emergency and Remedial Response plans. If updated information impacts any of the activities for which financial responsibility is needed (which may result in increases or decreases to the cost estimates), verify that the cost estimates are appropriately updated and accurate. See Section 4.1.3 for additional information on the EPA's Cost Estimation Tool, which can facilitate this review. Below are examples of how updated information about the site may impact financial responsibility cost estimates:

- If the reevaluated AoR is larger than what was delineated in the initial permit application and encompasses additional wells that need corrective action, the cost estimate for corrective action will need to be adjusted. A larger AoR may encompass additional resources that were not identified and addressed in the Emergency and Remedial

Response Plan. It may also impact the number or depth of monitoring wells that would need to be constructed (and therefore plugged).

- If computational modeling results or other information indicate that a longer PISC timeframe may be necessary before an owner or operator could demonstrate non-endangerment, additional resources will need to be available to cover a longer post-injection testing and monitoring phase.
- If the injection well's construction differs from what was described in the original plan, this may affect the cost to plug the well.
- If pre-operational testing identifies the presence of additional USDWs in the AoR, the cost estimates for emergency and remedial response will need to be sufficient to address potential contamination of those USDWs. Also, if monitoring within these USDWs necessitates more or deeper monitoring wells, PISC and site closure costs may need to be adjusted to cover the increased monitoring well plugging costs.
- If any new information about subsurface formations impacts the well plugging methods or materials to be used, additional financial resources may be needed to plug the injection and/or monitoring wells.

Review any adjustments to the cost estimates to account for inflation if it has been at least a year since the financial instruments were established or last updated, as required at 40 CFR 146.85(c)(2). This may be needed, given the time needed to construct the well and perform all required pre-operational testing.

Review any changes to the financial instruments. If the owner or operator submits revised financial instruments, confirm that the instruments are suitable to the activities they cover, are adequately funded, and contain required language and conditions of coverage as described at 40 CFR 146.85(a). Verify that financial instruments for all activities are in force and fully funded prior to authorizing injection. If initiation of any instruments was to be deferred until injection commenced, verify that these are in place. Confirm that all applicable milestones in any pay-in schedules have been met. See Section 4.1.3 for additional information on evaluating financial instruments.

Outcomes

The UIC Program should revise the permit or other materials as needed following the review of updated financial responsibility information, including:

- Permit conditions for financial responsibility (if applicable);
- Final, fully-funded financial responsibility instruments with appropriate text/conditions to cover all required activities related to corrective action, well plugging, PISC, site closure, and emergency and remedial response;
- An updated description of the enforceable financial responsibility conditions of the permit (if applicable); and
- A report on the evaluation of the owner or operator's financial responsibility cost estimates.

The revised financial responsibility instruments and any supporting materials should be uploaded to the project's permit package area in the GSDT.

5.1.4 Injection Well Construction

To demonstrate proper construction or conversion and testing of the well, the Class VI Rule requires owners or operators to submit information on final injection well construction procedures [40 CFR 146.82(c)(5)], all available logging and testing program data on the well [40 CFR 146.82(c)(7)], the results of MITs on the injection well [40 CFR 146.82(c)(8)], and information on the compatibility of the carbon dioxide stream with the materials used to construct the well [40 CFR 146.82(c)(3)].

The purpose of the UIC Program's evaluation of information on how the injection well was built and the results of well testing is to confirm that the well was engineered and constructed to meet the requirements at 40 CFR 146.86(a). The UIC Program's evaluation will ensure that the well's construction is appropriate for planned operations and conditions so that it will maintain integrity throughout its life and not become a conduit for fluid movement that could endanger a USDW.

Completeness Review

Owners or operators will submit the final construction procedures to the UIC Program Director. The submittal will likely be in the form of a narrative document that describes how the injection well was constructed, accompanied by "as-built" schematics and specifications that show the final construction of the well along with cementing records. The specifications should indicate the location of all casing strings and cement, along with the location of the packer and perforated intervals. The schematics should illustrate the shut-off system and any continuous monitoring equipment installed to demonstrate internal mechanical integrity per 40 CFR 146.89 and 146.90.

The owner or operator will also submit the results of logging and testing program data on the well, internal and external MIT results, and information on the compatibility of the carbon dioxide stream with the well materials. The pre-operational testing results will likely include a combination of narrative information (such as log analyst reports), graphs/figures, tabular data, and log results in Log ASCII Standard (LAS) format. Confirm that all required tests were performed and that the results include appropriate analyses and discussions to support a determination that the well is of suitable construction, has mechanical integrity, and that corrosion will not impact well integrity.

Owners or operators who converted their wells should submit post-conversion schematics, the results of any additional tests that were requested in the course of the permit application review, and documentation that any needed repairs were performed.

Evaluation

The UIC Program should review information on the well to confirm that construction or conversion of the well took place as planned and that the construction is suitable based on updated geologic data and the results of pre-operational testing. Certain newly acquired information, e.g., about the compatibility of the carbon dioxide stream with the well materials or the location of fluid-containing/porous formations, may also impact proper monitoring well construction and should be considered in reviewing amendments to the Testing and Monitoring Plan (see Section 5.1.6).

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate as-built well construction information, to confirm that an owner or operator's submittal meets the requirements of the Class VI Rule; confirm that the well was constructed in a manner that is protective of USDWs, and that the permit conditions are appropriate to the well's construction; and facilitate authorization to inject.

Compare the as-built schematics and construction procedures to those submitted with the permit application and the approved injection well construction plan. Verify that the well was constructed as planned, including the use of proper lengths and diameters of casing and acceptable materials and cement (i.e., of sufficient strength and corrosion-resistance). Note and document any divergence from the approved construction plans, schematics, and procedures in the permit.

If there are changes from the approved construction plan, confirm that the well was constructed in a manner that will maintain mechanical integrity and prevent migration of fluids into unauthorized zones, as informed by the most up-to-date geologic information. If any of the changes might result in the inability of the well to prevent fluid migration or maintain mechanical integrity, verify that remedial actions were or will be performed (and identify the anticipated timing of such remediation). Confirm that continuous monitoring and recording devices to demonstrate internal mechanical integrity were installed, per 40 CFR 146.88(e) and that the well is equipped with shutoffs and safety devices that are linked to final operating limits (see Section 5.1.5).

If the well is deviated at all from vertical, compare the radius of curvature to the length of monitoring instruments described in the Testing and Monitoring Plan to ensure that the instruments will not become lodged in the bend of the well casing. Likewise, if the diameter of the well is different from what was planned, confirm that instruments required for testing, monitoring, and well workovers will fit in the well.

Review the results of logs run during well drilling and construction to evaluate whether the well was properly constructed. Verify that all well logs (e.g., caliper, cement evaluation, temperature, and cement bond) were conducted properly and as described in the permit. Review logs used to determine cement placement and verify that the emplaced cement is continuous and that no channels that would allow unacceptable fluid migration exist. Examine logging records to verify that the depths of well perforations are properly located within the injection zone. Examine cement bond logs to determine the quality of the cement. Independently evaluate the well properties if necessary to achieve a complete understanding of the suitability of the well.

Review cementing records to ensure that cement was circulated to the surface. If cement was not returned to the surface or logs indicate missing or thin cement in any areas, determine whether

the existing cement is adequate to ensure that there will be no fluid migration along the well bore for the duration of the Class VI project. If the cement is not adequate to prevent migration of fluids, determine if additional cement placement (e.g., through tremie pipes) could provide adequate cement to prevent fluid migration; if so, consider requesting that this be performed.

Review caliper logs and video inspections to evaluate the condition and placement of all well components. Verify that the packer is seated within the confining zone immediately above the injection zone. Ensure that the casing strings were installed as described in the construction plans, and that the casing size is sufficient to accommodate the necessary logging and workover equipment that will be needed to test the well during project operations. Evaluate the condition of the casing. If conditions are observed that indicate the casing cannot maintain its integrity for the duration of the project, require (or confirm) that appropriate repairs are made. Verify that the well was constructed using materials that are of sufficient strength to withstand anticipated stresses for the duration of the Class VI project. If well stimulation was performed, review post-stimulation documentation to verify that the well and cement were not impacted or compromised as a result of stimulation. If any well components were damaged, confirm that the necessary repairs were or will be made (and the anticipated timing of such repairs).

Review the results of formation testing and analyses of geochemical samples taken to verify that the assumptions on which well construction plans were based are accurate and that there are no concerns about the compatibility of the well construction materials with the carbon dioxide stream. If any variations have the potential to affect well integrity or cause premature corrosion of the well, discuss with the owner or operator whether any changes to the well materials or cement are needed. If geochemical analyses indicate that the subsurface geochemistry is significantly different than the assumptions on which the approved construction procedures were based, verify (or consider requesting a demonstration) that the well materials are compatible with formation conditions. Also, consider whether more frequent corrosion monitoring or MITs may be appropriate. (For information on the compatibility of carbon dioxide with formation fluids and minerals, see Section 5.1.1.)

Verify that the well has mechanical integrity. Examine the results of the pre-operational external MIT to ensure proper cementing. Review the results of the annular pressure test or other internal MIT to verify proper casing installation. If it appears that the well cannot maintain integrity for the duration of the project, require that appropriate repairs are made (or confirm that they have been successfully completed).

Additionally, if the permit included conditions to test deep monitoring wells (see Section 4.1.5), confirm that the tests were performed as required by the permit and verify that the wells were constructed as proposed and have mechanical integrity.

Verify that any needed remedial actions for wells that were converted pursuant to 40 CFR 146.81(c) were performed as planned and that all information necessary to demonstrate that the well was engineered and constructed to meet the requirements at 40 CFR 146.86(a) is present. Confirm that the owner or operator performed any needed replacement or remediation of any components or materials. Also, review information about any new materials that were installed to ensure compatibility with the injectate and formation fluids. Examine construction records to ensure proper procedures and adequate cement setting times. Review cement evaluation logs to verify proper cement placement. Evaluate post-remediation internal and external MITs to ensure

that the well has mechanical integrity. See Section 4.1.4 for additional information on evaluating the construction of converted wells.

Consider whether any newly acquired information about the project impacts the appropriateness of the well's construction. For example:

- If geologic testing revealed the presence of additional USDWs or porous formations, confirm that the well was cemented across these zones.
- Confirm that the well shut-in procedures are appropriate based on the most up-to-date information about the site or changes to planned operations.
- Verify that the approved well construction is suitable to the final operating conditions, e.g., related to the materials' strengths versus anticipated pressures.

Also, communicate any changes to the well's construction to reviewers of the Injection Well Plugging Plan and the well testing components of the Testing and Monitoring Plan and of financial responsibility information. For detailed information on the construction of Class VI wells, refer to the *UIC Program Class VI Well Construction Guidance*.

Outcomes

Following the review of as-built well construction specifications and pre-operational well testing results, the UIC Program should develop and upload the following to the project's permit package area in the GSDT:

- Final, as-built well construction specifications and schematics that describe all required casings, cement, safety and shutoff devices, and monitoring gauges;
- Revised permit conditions (if applicable);
- Documentation of the review of final schematics, including any divergence from the procedures that were approved with the initial permit, and an evaluation that the procedures and materials used ensure USDW protection;
- Documentation of the review of pre-operational well testing results; and
- An evaluation of the procedures employed to convert the well (if applicable), and documentation that the well was converted in compliance with 40 CFR 146.81(c).

5.1.5 Operating Conditions

Based on the outcomes of their pre-operational testing, owners or operators may submit updates to their planned operating conditions (e.g., injection pressure). It is anticipated that changes to the understanding of the site could impact appropriate operating limits and, if so, this should be addressed in the permit.

The purpose of the UIC Program's review of planned operations is to ensure that the injection rates and volumes in the permit are suitable to the site-specific geology and other project characteristics, particularly in light of pre-operational testing results, to ensure that injection operations will not endanger USDWs.

Completeness Review

Class VI well owners or operators may submit updated information about operating procedures, such as the proposed injection rates and pressures, annulus pressure, and the total volume of

carbon dioxide to be injected over the duration of the project. The updated information will likely be a narrative description supported by graphs or tables that highlight changes to the relevant operating parameters. The UIC Program should verify that any updated information is adequate to inform an evaluation, i.e., the information should be similar in content and level of detail to the operating information submitted with the initial permit application.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate updated operating information, submitted by a Class VI well owner or operator, to confirm that the submittal meets the requirements of the Class VI Rule; confirm that the permit's operating conditions are appropriate to final geologic and well construction information; and facilitate authorization to inject.

Confirm that the maximum allowable injection pressure in the permit is appropriate based on pre-operational formation testing results. Review step rate tests performed after well construction and the results of other logs to verify that information provided in the permit application related to the fracture pressure of the injection and confining zones is correct. If the calculated fracture pressures of the injection and confining zones differ from the assumptions on which injection rates and pressures in the Class VI permit were based and, as a result, the injection pressure exceeds 90 percent of the fracture pressure of the injection zone, revise the permit conditions accordingly. If there is/are any uncertainty or inconsistencies in calculated fracture pressures within the injection or confining zones, consider whether the maximum injection pressure limit may need to be revised to less than 90 percent of the fracture pressure of the injection zone. Verify that any revised information about the site's geology (i.e., seismic history, potential interactions with subsurface fluids or well materials, or the presence of faults or fractures) does not affect the assumptions on which the injection pressure limits in the permit are based.

Confirm that the total permitted volume of carbon dioxide to be injected is appropriate. Consult with others on the permit application review team (including those reviewing site geology and the AoR delineation modeling) to confirm that there are no changes to the estimated storage capacity of the injection zone or the properties of the confining zone, and that the site can receive and contain the total volume of carbon dioxide to be injected.

Confirm that the permitted annular pressure is acceptable in light of pre-operational testing results. Consider whether any change to the annulus pressure is necessary in light of final well construction (e.g., the strength of the casing and tubing), formation fracture pressure, or injection pressure.

If the owner or operator revises any of the planned operating conditions (e.g., the total volume of carbon dioxide to be injected or the carbon dioxide source/composition), inform other members of the review team—including reviewers of the AoR delineation modeling and well construction—of the changes. Confirm that the well is equipped with shutoffs and safety devices that are tied to final operating limits. See Section 4 of the *UIC Program Class VI Well Construction Guidance* for additional information on Class VI well operating conditions.

Outcomes

Following the evaluation of operating requirements in the context of formation and well testing results and other information, develop or update the following:

- Final operating limits in the permit to reflect any needed changes to maximum injection pressure, volume, or annulus pressure limits;
- The summary of the enforceable operating conditions of the Class VI permit (if applicable); and
- Documentation of any reviews that resulted in changes to or confirmed the operating limits in the permit.

Any final materials should be uploaded to the project's permit package area in the GSDT.

5.1.6 Testing and Monitoring

Owners or operators must submit an amendment to the Testing and Monitoring Plan if needed to address newly identified information gathered via pre-operational testing or other pre-operation phase activities [40 CFR 146.82(c)(9)].

The purpose of the UIC Program's review of any amendments to the Testing and Monitoring Plan is to ensure that the testing and monitoring procedures remain appropriate to planned operations, the well's construction, site-specific geologic and hydrologic conditions, and the predicted behavior of the carbon dioxide plume and pressure front based on final AoR delineation modeling. The UIC Program should also ensure that planned testing and monitoring will generate the data necessary to demonstrate that the project is not endangering USDWs, provide the necessary input data for AoR delineation modeling reevaluations, and provide data points on which the non-endangerment demonstration will be based.

Verifying that the strategy described in the amended Testing and Monitoring Plan is based on the most up-to-date understanding of the site is essential to ensuring that sufficient data will be generated to demonstrate compliance (with the permit conditions and the Class VI Rule) and to inform decision-making at project milestones.

Completeness Review

An amendment to the Testing and Monitoring Plan will likely be in the same format as the approved Testing and Monitoring Plan, with changes made to address the results of pre-operational testing or any other new information about the site. Optimally, the owner or operator will highlight any changes to the testing and monitoring strategy, including explaining the purpose of any new monitoring methods and how the results will be used.

The UIC Program should perform a preliminary review of the amended Testing and Monitoring Plan to verify that it provides a sufficient level of detail to inform an evaluation. For example, it should describe any newly added testing and monitoring methods, including testing frequency, parameters, detection limits, and locations or depths. These should be representative of the most up-to-date AoR delineation and reflect the presence of any newly identified USDWs or other formations of interest identified through pre-operational testing. If any information is missing or is not presented in sufficient detail to inform an evaluation of the Testing and Monitoring Plan, the UIC Program should consider requesting the missing information or asking clarifying questions. See Section 4.1.7 for additional information on reviewing the completeness of the Testing and Monitoring Plan. Confirm that the owner or operator has updated the QASP if the amended Testing and Monitoring Plan includes any new testing or analytical methods.

Evaluation

The UIC Program should review the amended Testing and Monitoring Plan to confirm that it appropriately reflects all relevant new or updated information about the site. For example:

- Confirm that the plan includes changes to the planned carbon dioxide stream analyses (e.g., analytes or sampling frequency) that are needed to address updated information about the carbon dioxide composition or source.
- Confirm that planned well testing (e.g., corrosion testing, MITs, or continuous monitoring of operational parameters) reflects the most up-to-date information on project operations, well construction, carbon dioxide stream composition and source, and the compatibility of the carbon dioxide stream with well materials.
- Verify that planned groundwater sampling or other above-confining-zone monitoring reflects the most up-to-date information on site characteristics. For example, if formation testing data indicate that mobilization of additional constituents is possible, verify that the groundwater monitoring program includes monitoring for these constituents. If any new USDWs were identified during pre-operational testing, verify that the final plan includes monitoring to ensure that these USDWs are not endangered. Confirm that sampling locations, depths, and frequencies are appropriate based on the most up-to-date computational modeling results. For example, the monitoring strategy may need to be adjusted if the predicted direction of plume movement is substantially different compared to previous expectations or if any new pathways for potential carbon dioxide leakage have been identified.
- Verify that all monitoring wells that need to be installed prior to commencing injection are in place and properly constructed. Review as-built schematics in the context of any updated information about the compatibility of the carbon dioxide stream with well materials (see Section 5.1.4 for similar considerations regarding injection well construction).
- Confirm that plume and pressure front monitoring strategies are appropriate based on the most up-to-date geologic information, planned operational procedures, and computational modeling results. Monitoring locations/depths, spatial coverage, and frequencies should be appropriate to the most up-to-date AoR delineation, predictions of plume and pressure front behavior, and any new information about endangerment to USDWs within the AoR. For example, if predicted plume arrival times at certain monitoring locations have changed, the monitoring schedule may need to be adjusted to ensure that sufficient data are collected to compare with those predictions.
- Confirm that any surface air monitoring and/or soil gas monitoring (if required) remains appropriate based on the results of updated geologic information. The plan should incorporate any revisions to monitoring locations or frequencies that are needed based on the results of baseline testing or information on potential carbon dioxide leakage pathways.
- Review any additional testing and monitoring included in the plan.

- Request and review a revised QASP if any testing or monitoring activities (or the associated QA/QC needs) change. Verify that the QASP describes standard procedures and practices to ensure data quality for all testing and monitoring procedures.

The *UIC Program Class VI Well Project Plan Development Guidance* provides additional information on evaluating Testing and Monitoring Plan amendments. See the *UIC Program Class VI Well Testing and Monitoring Guidance* for additional information on testing and monitoring procedures for Class VI projects.

Outcomes

Following review and approval of the amended Testing and Monitoring Plan, the UIC Program should incorporate the following information into the permit file:

- Updated permit conditions for testing and monitoring and MITs, if modifications are needed based on the pre-operation phase review;
- The approved amended Testing and Monitoring Plan as an enforceable condition of the permit;
- A final, approved QASP that addresses all testing and monitoring activities in the amended Testing and Monitoring Plan;
- Approved construction schematics for all monitoring wells; and
- Follow-up reports or other materials documenting the evaluation, focusing on changes to the plan and highlighting how uncertainties or data limitations were addressed.

The Testing and Monitoring Plan, the QASP, and any associated materials should be uploaded to the project's permit package area in the GSDT.

5.1.7 Injection Well Plugging

Owners or operators must submit any amendments to the approved Injection Well Plugging Plan that are needed to address newly acquired information following pre-operational testing [40 CFR 146.82(c)(9)].

The purpose of the UIC Program's review of the amended Injection Well Plugging Plan is to confirm that the materials and procedures described in the plan are appropriate in light of the well's final construction and any new information about the site's geology and geochemistry, particularly regarding compatibility with the subsurface environment at the site. This review will ensure proper plugging of the injection well to prevent it from becoming a conduit for fluid movement that could endanger USDWs after well plugging.

Completeness Review

An amended Injection Well Plugging Plan should be similar to the approved plan. That is, it will likely be a narrative document that includes well schematics and describes how the owner or operator will plug the injection well in accordance with the requirements at 40 CFR 146.92. The plan should highlight and explain any changes that are needed to address modifications to the well's construction, as documented in the construction specifications (see Section 5.1.4), or new information about subsurface geochemistry based on the results of pre-operational formation testing and the compatibility of well materials with subsurface fluids and the injectate. See

Section 4.1.8 for additional information on reviewing the completeness of the Injection Well Plugging Plan.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate an amended Injection Well Plugging Plan to: confirm that the owner or operator's submittal meets the requirements of the Class VI Rule; confirm that the permit conditions for well plugging remain appropriate in light of information on the well's final construction and other site information; and facilitate authorization to inject.

Review the amended Injection Well Plugging Plan in the context of new information. The review should be done in coordination with reviewing information on the final injection well construction (or conversion) and pre-operational testing results. For example:

- If any aspects of injection well construction varied from the approved procedures, verify that the types and amounts of cement and plugs in the final Injection Well Plugging Plan reflect these changes;
- If any new information is available about the injectate or formation fluid geochemistry (including any anticipated geochemical changes that could affect the compatibility of the injectate with well materials), confirm that the plugging materials and cement described in the Injection Well Plugging Plan are suitable to those conditions; or
- If pre-operational formation testing reveals the presence of any additional USDWs, other fluid-containing or porous formations, or other geologic features that could allow fluid movement that could endanger USDWs, confirm that the plan includes plugs and cement at appropriate depths and that the calculated quantity of cement is sufficient to cover all relevant formations.

If any aspects of the Injection Well Plugging Plan change based on the review, alert the staff reviewing the financial responsibility cost estimates that the estimates to plug the well may need to be revised. Note that changes to the procedures in the Injection Well Plugging Plan may also need to be reflected in the monitoring well plugging procedures; for this, coordinate with the reviewer of the PISC and Site Closure Plan as appropriate.

See Section 4.1.8 for additional information on addressing conversion of the injection well for another purpose following cessation of carbon dioxide injection for GS. This conversion should be addressed in the Injection Well Plugging Plan.

For additional information on evaluating amended Injection Well Plugging Plans, see the *UIC Program Class VI Well Project Plan Development Guidance*. See Section 2 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care and Site Closure Guidance* for additional information on Class VI injection well plugging procedures.

Outcomes

Following the review of the amended Injection Well Plugging Plan, the UIC Program should develop and upload the following to the project's permit package area in the GSDT:

- Updated permit conditions for injection well plugging (e.g., procedures and materials) and associated notifications, if necessary;
- The approved amended Injection Well Plugging Plan as an enforceable condition of the permit; and
- Follow-up reports about any aspects of the review of the Injection Well Plugging Plan that have changed since the permit application review.

5.1.8 Post-Injection Site Care and Site Closure

Owners or operators must submit any amendments to the PISC and Site Closure Plan or updates to the alternative PISC timeframe demonstration that are needed to address information gathered during pre-operational testing [40 CFR 146.82(c)(9)].

The purpose of the UIC Program's review of PISC and Site Closure Plan amendments is to ensure that any needed revisions are made to address information gathered during the pre-operation phase, so that protection of USDWs is ensured following injection operations. In particular, the UIC Program should ensure that the plan encompasses post-injection testing and monitoring throughout the entire AoR for a sufficient duration (as informed by the most up-to-date computational modeling results), reflects any changes in predicted behavior of the carbon dioxide plume and pressure front, and includes monitoring well plugging procedures that are appropriate based on the current understanding of the site. The review of the amended PISC and Site Closure Plan should be closely linked to reviews of the amended AoR and Corrective Action Plan, Testing and Monitoring Plan, and Injection Well Plugging Plan (as discussed in Sections 5.1.2, 5.1.6, and 5.1.7, respectively).

Completeness Review

An amendment to the PISC and Site Closure Plan will likely be a narrative document (supported by maps, cross sections, and well schematics) that is similar in format and content to the approved plan in the Class VI permit. Any changes relative to the approved plan that address newly acquired information should be highlighted and explained, either in the plan or in supporting documentation.

The owner or operator should also submit an updated QASP to address any new testing and monitoring procedures or parameters. A single QASP that covers injection and post-injection phase testing and monitoring may be acceptable. The UIC Program should verify that the QASP addresses all post-injection testing and monitoring. Section 4.1.9 provides additional information on reviewing the completeness of the PISC and Site Closure Plan.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate the amended PISC and Site Closure Plan to: confirm that the owner or operator's submittal meets the requirements of the Class VI Rule; confirm that the permit conditions for post-injection site care are appropriate based on updated well and site-specific information; and facilitate authorization to inject.

Verify that the predictions of post-injection phase plume and pressure front behavior are consistent with the most up-to-date computational modeling results. If the results of pre-operational formation testing necessitate revisions to the AoR delineation modeling (see Section

5.1.2), any associated changes to the estimates of the pre- and post-injection pressure differential, the predicted position of the carbon dioxide plume and pressure front at site closure, or other relevant parameters should be reflected in the amended PISC and Site Closure Plan. Changes to operating procedures or updated geologic information may also affect predictions of plume and pressure front behavior.

Review the proposed post-injection testing and monitoring program. In general, the testing and monitoring methods used in the post-injection phase will likely be an extension of the injection phase testing and monitoring methods. Thus, any changes to the strategies in the Testing and Monitoring Plan may need to be reflected in this part of the PISC and Site Closure Plan. Verifying that the strategy described in the amended PISC and Site Closure Plan is based on the most up-to-date understanding of the site is essential to ensuring that sufficient data will be generated to demonstrate compliance with the permit conditions and the Class VI Rule and to inform decision-making at project milestones. For example, consider the following in reviewing the amended PISC and Site Closure Plan:

- If new pathways for potential carbon dioxide movement (e.g., additional faults, fractures, or other pathways) have been identified, verify that post-injection monitoring will target these areas;
- If any new USDWs are identified during pre-operational testing, verify that the final plan includes monitoring to ensure that these USDWs are not endangered;
- If formation testing data indicate that mobilization of additional constituents is possible, confirm that the groundwater monitoring program in the PISC and Site Closure Plan includes monitoring for these constituents;
- If the most up-to-date computational modeling results indicate that the predicted speed, direction, or extent of plume and pressure migration have changed, verify that the spatial and temporal coverage of plume and pressure front tracking methods are appropriate considering the new information; and
- Verify that the locations/depths, spatial coverage, and frequencies of post-injection phase testing and monitoring are appropriate to the most up-to-date AoR delineation, predictions of plume and pressure front behavior, and any new information about endangerment to USDWs within the AoR.

If the plan includes provisions to decrease monitoring parameters or frequencies during the post-injection phase, confirm that any quantitative triggers specified to reduce monitoring (or the baselines against which they would be compared) remain accurate based on the current understanding of the site and model predictions.

If any new monitoring activities are included in the amended plan, confirm that they are addressed in an updated QASP.

Review the alternative PISC timeframe demonstration in the context of new information (if applicable). If new information about the site is relevant to any of the criteria for an alternative PISC timeframe demonstration at 40 CFR 146.93(c), revisit the basis of the demonstration. In particular, any changes to the geologic understanding of the site based on formation testing, predicted interactions between carbon dioxide and formation fluids (based on geochemical analyses), or any changes to planned operating procedures (or the physical and chemical

characteristics of the carbon dioxide stream) may affect the trapping mechanisms and the overall behavior of the carbon dioxide plume and pressure front. When evaluating updates to the alternative PISC timeframe demonstration, also consider predictions about the rate or extent of carbon dioxide movement and/or the timeframe for pressure decline after injection ceases, changes to the understanding of the confining zone characteristics, the number/quality/location of conduits for fluid movement that could endanger a USDW in the final AoR, and the presence of any newly identified USDWs. Review this information and discuss it with the owner or operator as needed to confirm that the assumptions on which the predictions of the alternative timeframe are based remain accurate and the PISC timeframe is protective of USDWs. See Section 4.1.9 above for additional information.

Review the non-endangerment demonstration criteria in light of newly available information. If the PISC and Site Closure Plan included non-endangerment demonstration criteria, confirm that any changes to planned monitoring activities, computational modeling results, or information about potential conduits for fluid movement that could endanger USDWs are reflected in the non-endangerment demonstration criteria described in the amended plan. Also, confirm that a sufficient amount and types of baseline data to which future monitoring results will be compared were collected and documented during pre-operational testing. Coordinate with the reviewers of the Testing and Monitoring Plan and the AoR and Corrective Action Plan to ensure that sufficient information will be available at the end of the post-injection phase of the project to make a non-endangerment demonstration.

Review plans for monitoring well plugging and site closure. Any amendments made to the Injection Well Plugging Plan to address new information about the site (e.g., on subsurface geochemistry that could affect the compatibility of the injectate with well materials) should be considered for potential modifications to the monitoring well plugging procedures and materials. See Section 4.1.8. Verify that any other proposed site closure activities described in the plan are appropriate in light of newly collected information.

For additional information on evaluating amended PISC and Site Closure plans, see the *UIC Program Class VI Well Project Plan Development Guidance*. Section 3 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care and Site Closure Guidance* provides additional information on PISC for Class VI projects.

Outcomes

Following review of the amended PISC and Site Closure Plan and related information, the UIC Program should revise information in the permit file as needed, including the following:

- Permit conditions for PISC and site closure (if necessary);
- The approved amended PISC and Site Closure Plan as an enforceable condition of the permit;
- A final, approved QASP that addresses all testing and monitoring activities in the amended PISC and Site Closure Plan (if necessary, and if the owner or operator develops separate QASPs for injection and post-injection testing and monitoring);
- Any applicable updates to the conditions that must be met to demonstrate that the site does not pose an endangerment to USDWs; and

- Any revisions to the alternative PISC timeframe, including a report documenting the evaluation of the alternative PISC timeframe demonstration based on the results of newly available information.

The final PISC and Site Closure Plan and any associated supporting materials should be uploaded to the project's permit package area in the GSDT.

5.1.9 Emergency and Remedial Response

Following pre-operational testing, owners or operators must amend the Emergency and Remedial Response Plan if necessary to address updated information [40 CFR 146.82(c)(9)].

The purpose of the UIC Program's review will be to ensure that the amended Emergency and Remedial Response Plan includes any revisions that are necessary to address newly available information, such as changes to site operations, additional resources in an expanded AoR, or the presence of previously unidentified USDWs.

Completeness Review

The amended Emergency and Remedial Response Plan will likely be a narrative document that is similar in format and content to the approved plan in the permit. The amended plan should include any changes that are needed to address newly available or updated information about the site. This may include changes to the size of the AoR or the presence of additional resources or risks for which response procedures are needed. See Section 4.1.10 for additional information on reviewing the completeness of Emergency and Remedial Response Plans.

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate an Emergency and Remedial Response Plan amendment to: confirm that the owner or operator's submittal meets the requirements of the Class VI Rule; verify that the permit conditions related to emergency response are protective; and facilitate authorization to inject.

Review the amended Emergency and Remedial Response Plan to ensure that it addresses any newly identified risks or resources. For example:

- If the size or shape of the delineated AoR changes based on newly acquired information, the Emergency and Remedial Response Plan should address risk to all resources and infrastructure throughout the final, approved AoR;
- If updated geologic information or modeling investigations suggest that there is a potential for induced seismicity, the Emergency and Remedial Response Plan should address induced seismicity;
- If pre-operational geochemical testing identifies additional USDWs within the AoR, the Emergency and Remedial Response Plan should address potential carbon dioxide or other fluid movement into these USDWs; and
- If updated information about the geologic characteristics of the site indicate the presence of additional pathways for fluid movement, the Emergency and Remedial Response Plan should describe any associated carbon dioxide leakage or groundwater contamination scenarios and identify responses.

Confirm that the amended Emergency and Remedial Response Plan meets the requirements at 40 CFR 146.94 and that planned responses will be adequate for mitigating any adverse events that could arise during injection and through the PISC phase. See the *UIC Program Class VI Well Project Plan Development Guidance* for additional information on evaluating amended Emergency and Remedial Response plans.

Outcomes

Following the review and approval of the amended Emergency and Remedial Response Plan, the UIC Program should develop the following information and upload it to the project's permit package area in the GSDT:

- Revised permit conditions for emergency and remedial response, if appropriate;
- The approved amended Emergency and Remedial Response Plan as an enforceable condition of the permit; and
- Follow-up reports about any aspects of the review that have changed since the permit application review, highlighting how any uncertainties or data limitations were addressed.

5.1.10 Injection Depth Waivers

It is possible that additional geologic information collected during pre-operational testing may be relevant to the injection depth waiver determination or waiver-specific permit conditions. Additionally, such information could strengthen and support the demonstration of site-suitability and the appropriateness of an injection depth waiver. Thus, while there is no specific requirement to update the injection depth waiver application following construction of the well, it is anticipated that owners or operators may submit updated geologic information, required by 40 CFR 146.82(c)(2), that is relevant to the injection depth waiver, including the results of pre-operational formation testing below the injection zone.

Where an injection depth waiver is needed to allow injection into the identified injection zone, the UIC Program should review this in the context of newly acquired or updated geologic information collected during pre-operational testing, the reevaluated AoR, and the final construction of the well. The purpose of the UIC Program's evaluation is to confirm that all permit conditions are appropriate and that the Class VI project will be protective of USDWs. The EPA expects that this evaluation would be closely linked to the review of updated geologic information (see Section 5.1.1) and the AoR reevaluation (see Section 5.1.2).

Completeness Review

The EPA recommends encouraging the owner or operator to include in the updated geologic information any information relevant to the injection depth waiver—including information on the lower confining zone and USDWs below the injection zone—highlighting any newly acquired information. If necessary to ensure protection of USDWs above and below the injection zone, the UIC Program should consider requesting that the owner or operator submit this information, pursuant to 40 CFR 146.95(f)(5).

Evaluation

The bolded text below outlines a suggested approach that a UIC Program might employ to evaluate any updated information about the injection depth waiver to: confirm that the owner or operator's submittal meets the requirements of the Class VI Rule; confirm that the permit

conditions remain protective of USDWs above and below the injection zone; and facilitate authorization to inject.

Verify that updated geologic data confirm the information on which the injection depth waiver application and its approval were based, particularly regarding USDWs and other formations below the injection zone. Consider operations under an injection depth waiver in the context of the current understanding of the site (e.g., the results of formation testing or updated computational modeling). Modify the Class VI permit conditions or project plans if necessary to address any remaining uncertainties. For example:

- Review the results of fluid sampling and analysis on all formations, including USDWs, below the injection zone and in the context of potential adverse reactions between the carbon dioxide stream and formation fluids or the well. If there is potential for mineralization or liberation of trace metals that may endanger USDWs, consider whether additional groundwater monitoring parameters should be specified in the Testing and Monitoring Plan and PISC and Site Closure Plan. If fluid analysis indicates the potential for adverse reactions between the carbon dioxide stream and well materials in formations below the injection zone, modify the corrosion monitoring or MIT conditions in the permit, as appropriate.
- Verify that the injection and confining zones are still suitable for receiving and confining the total volume of carbon dioxide to be injected based on the current understanding of the site and any newly acquired geologic, geomechanical, geochemical, or lithologic data about the injection and confining zones. For example, if the estimated total storage capacity of the injection zone has changed, consider whether it is necessary to modify the total permitted volume of carbon dioxide. If there is any change in information about the injectivity of the injection zone or the integrity of the confining zone, consider modifying the injection rate or pressure limits in the permit.
- Verify that the AoR reevaluation incorporates all available data about the lower confining zone and USDWs below it, and that no movement of the carbon dioxide plume or pressure front into unacceptable zones is predicted to occur. If necessary, request and review updates to the computational model and/or an amended AoR and Corrective Action Plan that incorporates consideration of the lower confining zone based on newly acquired information.
- Verify that the amended Emergency and Remedial Response Plan and the most up-to-date demonstration of financial responsibility address any newly identified risks to USDWs below the injection zone.
- If, based on other aspects of the pre-operation phase review, revisions to the injection and/or post-injection phase testing and monitoring strategies are necessary, determine whether permit conditions for monitoring below the injection zone are also needed. If so, verify that these have been incorporated into the amended Testing and Monitoring Plan and PISC and Site Closure Plan, as appropriate.

Verify that the well was constructed properly and confirm that it will allow injection operations that are protective of USDWs above and below the injection zone. Confirm that the casings were constructed to prevent movement of fluid into all unauthorized zones, including USDWs, above and below the injection zone. Review cement logs and the results of other pre-

operational well tests to confirm the proper placement of cement. If the well was constructed differently than described in the original well construction plan, verify that the procedures and materials described in an amended Injection Well Plugging Plan are appropriate to protect USDWs below the lower confining zone. See Section 5.1.4 for additional information on evaluating the construction of the well.

If the owner or operator drilled test well bores to obtain logs and cores for geologic characterization below the injection zone, verify that they were plugged and sealed to prevent fluid movement.

Coordinate with U.S. EPA Headquarters staff as needed so that notice of the waiver can be posted on the EPA's Office of Water website, per 40 CFR 146.95(e). Provide information about the depth of the injection zone; the location of the well; the name and depth of all USDWs; a map of the AoR; the names of any public water supplies affected, reasonably likely to be affected, or served by USDWs in the AoR; and the date on which the waiver was issued.

Outcomes

Following the review of updated information related to the injection depth waiver, revise relevant information in the permit file as needed, including the following:

- Revised permit conditions to conduct direct and indirect testing and monitoring below the injection zone during the injection and post-injection phases or other accommodations to address operation under an injection depth waiver (e.g., related to injection pressure limits or well plugging conditions), if necessary;
- Follow-up to any reports that documented the initial evaluation of the injection depth waiver application, highlighting any changes or clarifications based on pre-operational formation testing results or updated geologic information;
- Documentation of any additional consultation with the applicable PWSS Director(s), e.g., in light of new information or to address questions or issues raised by the public;
- Copies of any public comments received on the waiver; and
- Information about the waiver that was posted on the EPA's website.

Any materials related to the injection depth waiver review should be uploaded to the project's permit package area in the GSDT.

5.2 Authorizing Injection

Issuing authorization to inject will likely involve similar activities to those performed to prepare the initial Class VI permit that allowed construction or conversion of the well (see Section 4.2). UIC Programs should implement the following steps:

Revise the Class VI permit conditions as needed to address any changes in the understanding of the site. As described throughout this section, it is likely that any needed changes to permit conditions will result from: an evaluation of pre-operational testing results and revised geologic characterization data and/or any updates to previously submitted information to reflect information that was not available at the time the permit application was submitted. Incorporate any changes that are needed based on the reviews described in Section 5.1 into the Class VI permit language.

Modification of UIC permits is addressed at 40 CFR 144.39 and 144.41:

- 40 CFR 144.39 identifies the conditions under which permit modifications are needed. For Class VI permits, these include (but are not limited to): any permit changes that are necessary based on AoR reevaluations, amendments to any Class VI project plan, or any permit modification that is necessary based on a review of testing and/or monitoring results conducted in accordance with permit requirements. Permit modifications under 40 CFR 144.39 require additional public notification as described at 40 CFR 124. When a permit is modified, only the conditions subject to modification are reopened [40 CFR 144.39]. Note that, pursuant to 40 CFR 144.39, if the permit is revoked and reissued, the entire permit is reopened, subject to revision, and reissued for a new term.
- 40 CFR 144.41(h) presents examples of minor permit modifications for Class VI permits, which include revising any Class VI project plans where the modifications merely clarify or correct the plan. Minor permit modifications may be implemented without preparing a draft permit or soliciting public comment.

Incorporate the amended project plans as enforceable conditions of the permit (if needed). See Sections 5.1.6 through 5.1.9 for additional information on reviewing the amended project plans in the context of pre-operational testing results and other information the owner or operator submitted pursuant to 40 CFR 146.82(c).

Conduct additional outreach per 40 CFR 124, if appropriate. For example, if the AoR delineation changes and is determined to impact additional disadvantaged communities in areas that were not identified at the time of the initial permit development, communicate with representatives of these communities and provide outreach materials (see Section 3.3 for additional information on EJ considerations). If the final AoR delineation crosses boundaries with other states, territories, or tribes, notify appropriate officials (e.g., UIC Program or environmental protection officials). See 40 CFR 146.82(b) and the template of a letter that can help accomplish this notification, which is available in the resource library of the GSDT.

Finalize the draft modified permit for notice and comment, if necessary. Soliciting public comment is required if the updated information about the site necessitates more than minor modifications to the permit [40 CFR 144.39(a)]. For example, public notice and comment would be needed if the delineated AoR changes or calculations of fracture pressure necessitate a change in the approved injection pressure. See above for additional information on permit modifications. Develop a fact sheet and/or statement of basis and compile materials for the administrative record for the permitting decision (see Section 4.2 for additional information on using the GSDT to compile and organize permit files). Highlight how the permit has been modified, particularly how any changes address information acquired during pre-operational testing and updated geologic information. Publish a notice in a newspaper and post all relevant materials online, if possible [40 CFR 124.10(c)(2)(i)]. Provide an updated permit along with a summary of the revisions to the initial permit and why the permit conditions changed, i.e., based on site-specific data or the results of geologic testing. Hold a public hearing or hearings and document all input provided. Prepare responses to all public comments and develop a responsiveness summary document.

Revise the Class VI permit conditions, if needed based on the public process, and **issue authorization to inject for the Class VI well.** The permit should identify the date on which injection may commence. The authorization to inject may be a follow-up letter or other

communication to the permittee that the permit is effective on a specific date. Change the project status in the GSDT to show that the project is in the injection phase.

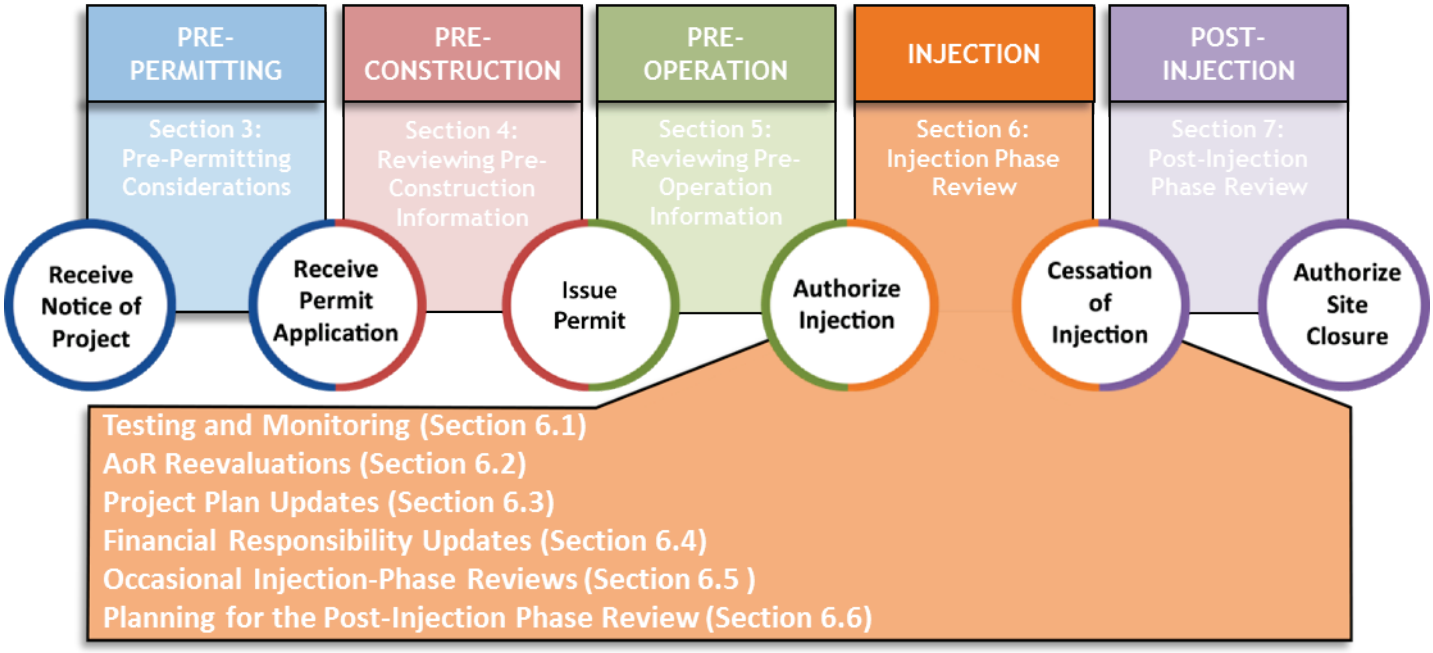
5.3 Planning for the Injection Phase Review

After injection is authorized, the owner or operator will begin to inject carbon dioxide and perform required testing and monitoring. The information the owner or operator will generate and submit to the UIC Program should demonstrate that the project is operating within permitted limits and that the well maintains mechanical integrity. Monitoring data should: demonstrate that the plume and pressure front are behaving as predicted; confirm that USDWs are not endangered; and validate modeled predictions or identify the need for appropriate responses. Consistent with the regulations at 40 CFR 146.84, 146.90, 146.92, 146.93, and 146.94, the owner or operator will periodically reevaluate the AoR and update the project plans as needed to ensure that the permit and plans are tailored to site-specific conditions and the behavior of the project.

During the injection phase, the UIC Program should evaluate the testing and monitoring results, AoR reevaluations, and updated project plans submitted by the owner or operator to confirm that the project is performing as predicted or, if necessary, work with the owner or operator to implement appropriate actions to return the project to compliance and prevent or mitigate endangerment to USDWs.

Section 6 provides recommendations for how the UIC Program can evaluate the information submitted and coordinate with the owner or operator throughout the injection phase of a Class VI project. The EPA recommends that the UIC Program review Section 6 at the time injection is authorized and consult the section throughout injection operations.

Section 6: Injection Phase Review



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6 Injection Phase Review

During the injection phase, Class VI well owners or operators will conduct injection activities and perform testing and monitoring as described in the permit and project plans. The information generated and submitted by the owner or operator should demonstrate that the well is maintaining integrity and the carbon dioxide plume and pressure front are behaving as predicted. Reviewing data on project performance or the position of the plume and pressure front can validate modeled predictions or identify the need for appropriate responses. Data generated during injection phase activities will inform the need for AoR reevaluation and the demonstration of non-endangerment.

The goal of the UIC Program's review of information during this phase should be to confirm that the Class VI well and the Class VI project are operating as planned and in compliance with the permit, and that USDWs are not endangered. This information should be evaluated in consideration of the findings of the site characterization and permit application review, particularly with respect to any identified uncertainties about the site.

The UIC Program will likely receive and evaluate the following types of information during the injection phase:

- The results of testing and monitoring required at 40 CFR 146.90 (see Section 6.1);
- Information associated with AoR reevaluations, including updates to the AoR and Corrective Action Plan (see Section 6.2);
- Updates to the other project plans including, at a minimum, the Testing and Monitoring Plan and the Emergency and Remedial Response Plan. The owner or operator may also submit an updated Injection Well Plugging Plan or PISC and Site Closure Plan during this phase (see Section 6.3);
- Updated financial responsibility information (see Section 6.4); and
- Occasional notifications associated with workovers, emergency events, or adverse financial conditions, if necessary (see Section 6.5).

This section presents recommendations for how the UIC Program can evaluate the submitted information. Each subsection below describes the types of information owners or operators will submit, followed by considerations for reviewing the information to verify compliance or identify appropriate follow-up actions (e.g., discussions with the owner or operator or requests for additional or clarifying information). Because each project is unique and the specific information submitted by the owner or operator will vary, the appropriate activities will be specific to the project; thus, the activities described below outline a recommended course of action to accomplish the goal of evaluating injection phase information to ensure that USDWs are protected.

6.1 Testing and Monitoring

Throughout the injection phase, owners or operators must perform all testing and monitoring specified in the approved Testing and Monitoring Plan and submit the results to the EPA [40 CFR 146.90]. Owners or operators will also submit 30-day advance notifications of some testing and monitoring activities, as required by 40 CFR 146.91(d); see Section 6.5.1.

While the specific considerations for each type of required testing and monitoring will vary (as explained in the subsections below), the recommended approach to evaluating the submitted information is the same (see Figure 6-1). The UIC Program should:

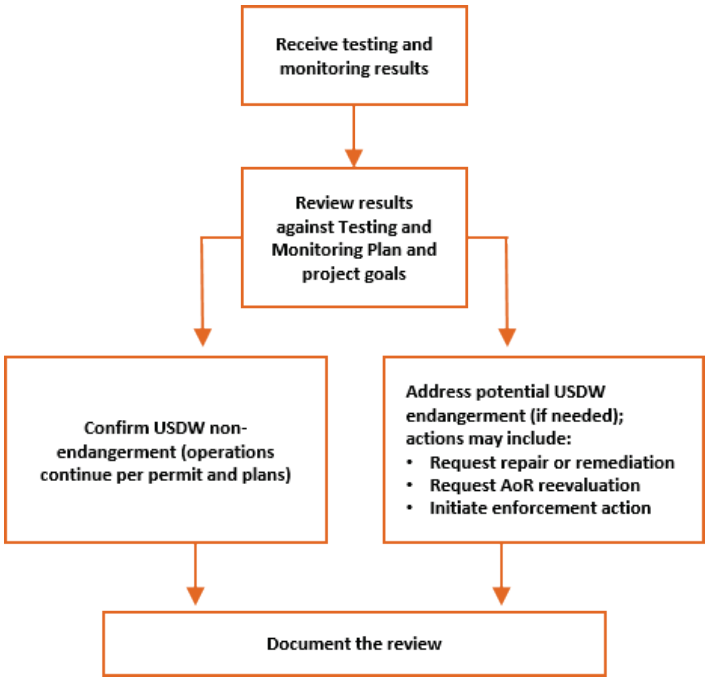


Figure 6-1: Reviewing Testing and Monitoring Results

- Confirm that the owner or operator has submitted all required information, i.e., as specified in the Testing and Monitoring Plan;
- Verify that the Class VI well is operating within the conditions of the permit and confirm that there is no evidence of USDW endangerment;
- Identify and discuss any exceedances or unexpected measurements that may provide evidence of endangerment or contamination and request appropriate responses, including well repairs or remediation, an AoR reevaluation, or additional monitoring;
- If there is any indication of noncompliance with the Class VI permit, determine whether a formal or informal enforcement action is appropriate (see Section 2.4); and
- Document the review.

Each subsection below describes, for each type of required testing or monitoring, the types of information that Class VI well owners or operators may submit and suggestions for UIC Programs to consider when reviewing the information to verify permit compliance and identify, where appropriate, any follow-up actions.

6.1.1 Characteristics of the Carbon Dioxide Stream

Class VI well owners or operators must analyze the physical and chemical characteristics of the carbon dioxide stream [40 CFR 146.90(a)]. The purpose of the UIC Program's review of information about the carbon dioxide stream is to confirm that its composition remains consistent with the permit and the information on which predictions of no adverse interaction between the injectate and well materials or formation fluids were based. Changes to the carbon dioxide stream could have implications for well integrity or subsurface geochemical reactions (e.g., reactions that could cause mineralization or alter the corrosivity of the injectate).

Owners or operators may submit the following information about the carbon dioxide stream as part of their semi-annual reports:

- Tabulations and/or plots of analytical results for each sampling event during the reporting period for the suite of parameters specified in the Testing and Monitoring Plan;

- Any changes to the physical, chemical, and other relevant characteristics of the carbon dioxide stream from the proposed operating data, per 40 CFR 146.91(c)(1);
- Compilations of previous results to facilitate evaluation of temporal trends; and
- Descriptions of the sampling methodology and copies of original laboratory reports.

Evaluation

In reviewing information about the physical and chemical characteristics of the carbon dioxide stream, the EPA recommends that the UIC Program implement the following activities:

- Review the information submitted to verify that it reflects the requirements of the Testing and Monitoring Plan. For example, verify that appropriate analytical parameters and methods were used, that the testing was performed on schedule and at the specified frequency, and that all QA protocols were followed.
- Evaluate the results of the analyses of the carbon dioxide stream (i.e., composition and the concentrations of any impurities or water content) and compare the results to permitted values.
- Compare the results against any previously reported results to identify any significant changes in the physical and chemical characteristics of the carbon dioxide stream composition over time.

During this review, the UIC Program should consider the following to ensure compliance with the permit:

- If any impurities in the injectate render it a hazardous waste, discuss the implications related to the RCRA conditional exclusion for carbon dioxide in GS activities and assist the owner or operator in coordinating with the RCRA Program regarding the conditional exclusion under 40 CFR 261.4(h), if one has not been certified within the last year (see Section 3.4);
- If any changes in the physical or chemical characteristics of the carbon dioxide stream could potentially lead to unwanted interactions with well components (particularly where exceedances or inconsistencies are ongoing), consider requiring the owner or operator to perform an internal MIT to confirm that there were no adverse impacts on the well;
- If any changes in the physical and chemical characteristics of the carbon dioxide stream could potentially lead to unwanted interactions with formation solids/fluids, consider requiring the owner or operator to modify the water quality monitoring parameters in the Testing and Monitoring Plan; and
- If trends in testing results indicate that the injectate regularly contains impurities that are not listed in the permit or are present in excess of permitted amounts, this may constitute a violation of the permit (see Section 2.4).

6.1.2 Continuous Monitoring Data

Owners or operators must demonstrate internal mechanical integrity by continuously monitoring injection pressure, injection rate, injected volume, pressure on the annulus between the tubing and long-string casing, and annulus fluid volume [40 CFR 146.89(b); 146.90(b)].

The purpose of the UIC Program's review of operating data is to ensure that the Class VI project is operating as planned and within permitted limits and that the well is maintaining internal mechanical integrity.

The owner or operator may submit the following results of continuous monitoring in a tabular and/or graphical form in a PDF file, spreadsheet, or database file, as part of the semi-annual report:

- Injection rate, volume, and pressure measurements;
- Monthly maximum, minimum, and average values for injection rate, carbon dioxide volume (mass), injection pressure, and annular pressure;
- Monthly annulus fluid volume added; and
- Total volume (mass) injected each month and cumulative carbon dioxide volume (mass) injected for the project.

The owner or operator should also note and explain any divergences from the testing protocols described in the approved Testing and Monitoring Plan or any exceedances of a permit limit.

Evaluation

In reviewing continuous monitoring data submitted by the owner or operator, the EPA recommends that the UIC Program implement the following activities:

- Confirm that measurements were taken using approved equipment (i.e., as specified in the approved well schematics/the Testing and Monitoring Plan) and recorded at the frequencies specified in the permit. Also verify that measuring instruments have been regularly calibrated according to the QASP. Compare the reported operating data to the limits set forth in the permit and to expected values presented in the Testing and Monitoring Plan to ensure compliance with the Class VI permit.
- Confirm that injection pressures did not exceed 90 percent of the fracture pressure of the injection zone (or a lower injection pressure set as a permit condition) and that they are consistent with values used as inputs in computational modeling. If pressure gauges are not located downhole, verify that proper corrections were made to determine bottom-hole pressure.
- Compare the volume (mass) of carbon dioxide injected to the permitted values and to the overall project volume goals, including estimates of the storage capacity of the injection zone. Examine any calculations of carbon dioxide volume based on the injection rate and verify that proper corrections for bottom-hole temperature and pressure were applied. Sections 3.2 and 3.3 of the *UIC Program Class VI Well Testing and Monitoring Guidance* contain additional information on pressure and flow rate monitoring.
- Evaluate the amount of fluid added to the annulus. If the amount added is excessive (i.e., a greater volume than can be attributed to pressure and temperature changes), consider requiring an MIT to verify well integrity (i.e., to confirm that the annulus is not compromised or leaking fluid).

The UIC Program should consider the following to ensure that USDWs are protected from endangerment:

- Discuss potential reasons for the variances with the owner or operator. If necessary, require follow-up testing to determine the cause of any variances from predicted values or permit conditions;
- If there is a significant divergence over permitted injection pressures (or a pattern of exceedances), consider whether testing to ensure that the injection or confining zone were not fractured or adjustments to the AoR delineation modeling to predict the impacts of higher injection pressures is needed;
- If the injection rate or pressure exceeded permit limits during the reporting period, verify that the owner or operator provided a description of the event(s), including the cause of the exceedance, the duration of the exceedance, and the owner or operator's response;
- If any permit conditions were exceeded, issue a notice of violation and begin discussions with the owner or operator about how to prevent future occurrences. If operating conditions that meet permitted limits cannot be restored, issue a notice to cease injection until the situation can be remedied; and
- If operating data indicate that the project is proceeding differently than the inputs on which computational modeling for delineating the AoR were based (particularly if significantly higher volumes of carbon dioxide are injected), this should trigger an AoR reevaluation (see Section 6.2).

6.1.3 Corrosion Monitoring Results

Owners or operators must perform quarterly corrosion monitoring [40 CFR 146.90(c)] and, if required by the UIC Program Director, perform casing inspection logs (CILs).

The purpose of the UIC Program's review of corrosion monitoring information is to confirm that there are no indications of well material corrosion that could compromise the well's integrity. This is important for Class VI projects, given the potential corrosivity of wet carbon dioxide injectate or of carbon dioxide-water mixtures where an injectate mixes with fluids in the subsurface.

The owner or operator may submit the following information in the semi-annual report:

- Measurements of mass and thickness loss in any corrosion coupons or loops and any assessment of additional corrosion, including pitting, in corrosion coupons or loops (as tabular data or a PDF file, spreadsheet, or database files); and
- The results of any CILs performed, including information about:
    - The measured CILs and comparison to previous logs;
    - The thickness of the casing (referencing the original casing thickness); and
    - The locations of any detected anomalies such as pits, scratches, and splits.

Evaluation

In reviewing corrosion monitoring results, the EPA recommends that the UIC Program implement the following activities:

- Confirm that corrosion monitoring was performed at least quarterly and that any required CILs were performed on schedule. Verify that the corrosion monitoring parameters and techniques used are consistent with those required by the Class VI Rule and described in the approved Testing and Monitoring Plan.
- If the owner or operator used corrosion coupons, verify that the coupon composition is appropriate for the well component(s) being tested (e.g., consisting of the same material as the casing and tubing). Confirm that the coupons were subjected to conditions representative of downhole conditions (e.g., placed downhole or within the injection line) for a duration that will yield relevant results. If the owner or operator used corrosion loops, verify that the temperature of the corrosion loop was controlled to simulate well conditions (otherwise, because corrosion rate increases with temperature, the results may be artificially low). Review the reported measurements of mass and thickness loss in any corrosion coupons or loops used, as well as any information on the nature of the corrosion that is taking place (e.g., localized or general attack, presence of pitting or cracking).
- If the owner or operator performed a CIL, verify that the test was performed properly, using tools and procedures described in the Testing and Monitoring Plan. Review the results of the CIL, such as reported thickness of the casing and the locations of anomalies such as pits, scratches, or splits. If the owner or operator used an alternative method to monitor corrosion, verify that the procedures used were consistent with those described in the approved Testing and Monitoring Plan.
- For all methods of corrosion monitoring, compare the results to any previously reported results that are available to identify any changes in the rate and/or nature of corrosion over time. Based on this information, assess whether the results indicate that that corrosion rates are within acceptable ranges.

During a review of the corrosion monitoring results, the UIC Program should consider the following to ensure that the well is in compliance:

- While target corrosion rates of 1 mil per year or less (or approximately 25 μm per year) are common in wells used in the oil industry, determining acceptable corrosion rates for wells at Class VI projects necessitate consideration of site-specific factors, such as subsurface conditions and well materials.
- The nature and location of corrosion is also important; a relatively higher rate of generalized metal loss may be less significant than a lower rate of localized corrosion, and certain well components may be more or less susceptible to different types of corrosion.
- If the information submitted suggests that unanticipated and/or unacceptable levels of corrosion may be occurring in any well components, initiate discussions with the owner or operator and request follow-up testing or repairs of the well, if necessary.

6.1.4 Groundwater Quality Monitoring

Periodic monitoring of groundwater quality above the confining zone(s) is required at 40 CFR 146.90(d). Owners or operators of projects that are operating under an injection depth waiver must also monitor in the first USDWs above and below the confining zones, per 146.95(f)(3)(i).

Reviewing the results of groundwater monitoring can reveal geochemical changes that result from leaching or mobilization of heavy metals and organic compounds, or from fluid displacement.

The purpose of the UIC Program's review of groundwater quality data is to identify whether there is evidence of the migration of carbon dioxide and/or other fluids out of the injection zone that may endanger USDWs and identify appropriate responses or mitigation activities.

Owners or operators may submit the following types of information in the semi-annual reports:

- Tabulations of all analytical results for all chemical constituents analyzed, for each sampling event during the reporting period at each monitoring well;
- Previous results to facilitate evaluation of temporal trends;
- Maps and graphs in a geographic information system (GIS)-compatible format to support model validation; and
- Supporting information, including analytical data and interpretive analyses (e.g., using Piper or Stiff diagrams, time series graphs, or isopleth maps).

If the owner or operator supplemented their direct groundwater sampling with other above-confining-zone monitoring methods (such as well logging or geophysical techniques) they will also submit the results of these activities in their semi-annual reports.

Evaluation

In reviewing the results of groundwater quality monitoring, the EPA recommends that the UIC Program implement the following activities:

- Verify that samples were collected according to the schedule identified in the approved Testing and Monitoring Plan, taking into consideration any phased monitoring described in the plan (e.g., phased installation of monitoring wells), and that the parameters monitored are consistent with those identified in the plan.
- Verify that samples were collected and analyzed from all monitoring locations and intervals identified in the approved Testing and Monitoring Plan. Also verify that procedures such as well purging, instrument calibration, sample collection and handling, and quality assurance measures were carried out as described in the Testing and Monitoring Plan and the QASP. Confirm that samples were analyzed for all of the parameters specified in the Testing and Monitoring Plan using approved analytical methods. If applicable, verify that appropriate preservation of in situ conditions (e.g., pressure, temperature) was maintained to ensure that the results are representative of subsurface conditions. If additional above-confining-zone monitoring methods are used to supplement direct fluid sampling, review the results for consistency with the results of the groundwater analyses.
- Compare the analytical results with the baseline results collected during the site characterization process, as well as to any applicable predictions from the AoR delineation model or expectations stated in the Testing and Monitoring Plan. Also compare the results with previously reported data to identify trends that may indicate the movement of carbon dioxide and/or other fluids out of the injection zone. See the Interpretation subsection of Section 4.3 of the *UIC Program Class VI Well Testing and*

Monitoring Guidance for a description of trends that may indicate unintended fluid migration. However, keep in mind that these trends may have other causes and may not necessarily indicate leakage and/or migration.

During their review of the groundwater quality monitoring results, the UIC Program should consider the following to confirm non-endangerment of USDWs:

- If any excursions or trends indicate potential leakage or fluid migration out of the injection zone, initiate discussions with the owner or operator and request follow-up actions as needed. This may include additional testing or implementation of the Emergency and Remedial Response Plan.
- Review any analyses or documentation of trends provided by the owner or operator and, if necessary, discuss these or request that the owner or operator explain their cause.

6.1.5 External MITs

Owners or operators must perform annual external MITs, per 40 CFR 146.89 and 146.90(e). The purpose of the UIC Program's review of MIT results is to verify that the well is maintaining mechanical integrity and the injection system is operating as intended, or to identify integrity issues that may indicate a possible loss of containment that could endanger USDWs.

Owners or operators must submit the results of external MITs within 30 days of each test [40 CFR 146.91(b)]. Depending on the type of test(s) performed, submissions may include the following information:

- Graphs (e.g., temperature vs. depth from temperature logs);
- Supporting data in spreadsheets or databases; and/or
- Log results (e.g., in LAS format) accompanied by narrative interpretations of the logs.

Evaluation

In reviewing MIT data, the EPA recommends that the UIC Program implement the following activities:

- Confirm that the owner or operator performed the MITs using the methods and procedures specified in the approved Testing and Monitoring Plan.
- Verify that necessary test conditions were met for a particular MIT (e.g., a sufficient shut-in period for temperature logs). Also review reported instrument calibration and other quality assurance-related procedures for consistency with the QASP. If the MIT results (especially from temperature and noise logs) are ambiguous or there are unresolved anomalies, discuss the potential need for the owner or operator to re-test the well using another method.

The UIC Program should consider the following to ensure that the well will not become a conduit for fluid movement:

- If proper testing procedures were not followed, request that the owner or operator re-test the well.
- If it is confirmed that the well lacks external mechanical integrity or is otherwise out of compliance with the Class VI permit, pursuant to 40 CFR 146.88(f), require the owner or

operator to cease injection until the cause of the mechanical integrity loss has been determined and remedied. Ensure that the owner or operator completes follow-up activities (e.g., performing remedial action on the well) and, if necessary, implements procedures specified in the Emergency and Remedial Response Plan (see Section 6.3).

- If there is concern that carbon dioxide may have leaked from the well, discuss with the owner or operator whether additional above-confining-zone testing or monitoring may be appropriate.

6.1.6 Pressure Fall-Off Test Results

Class VI well owners or operators must perform a pressure fall-off test at least once every five years [40 CFR 146.90(f)] unless more frequent testing is specified in the Testing and Monitoring Plan.

The purpose of the UIC Program's review of pressure fall-off data is to confirm that reservoir pressures are consistent with predicted pressures and modeling inputs. The evaluation should also confirm the geologic information on which the site characterization is based and verify that projects are operating properly and that pressures within the injection zone are responding as predicted.

Owners or operators will submit the results of pressure fall-off testing within 30 days of the test if required by the UIC Program Director [40 CFR 146.91(b)(3)]. (Otherwise, the results may be provided as part of the semi-annual reports.) These submissions may include the following information:

- Narrative summaries that describe any changes to formation characteristics of the near-well bore environment and any indication of fluid leakage during the test;
- Supporting information, including tabular data and/or the outputs from commercial software used to analyze the data;
- Trend data comparing new test results with previous results; and/or
- Other supporting information, including: measured injection rates and pressures from the test well and any offset wells; plots of observed pressure, time, and change in pressure as a function of time; any temperature anomalies and whether they correspond to pressure anomalies; and calculated formation characteristics (i.e., transmissivity, well skin factor).

Evaluation

In reviewing pressure fall-off testing results, the EPA recommends that the UIC Program implement the following activities:

- Confirm that the pressure fall-off testing was performed using the procedures specified in the approved Testing and Monitoring Plan, that the testing was performed on schedule, and the results were reported as specified in the plan.
- Verify that, during the test, a sufficient shut-in period elapsed and pressure stabilization was achieved. Confirm that the owner or operator measured the pressure prior to beginning the test and verified that it was not changing and that the injection was shut off for the duration of the test. At sites where multiple wells are injecting into the same zone, review the procedures related to offset wells (e.g., whether injection was halted or held

constant at the offset wells). Also review reported gauge calibration records and other quality assurance-related items against the QASP, and verify that the quantitative methods used to analyze the results were consistent with the Testing and Monitoring Plan.

- Compare the resolution of the pressure fall-off test results to the sensitivity of the gauges used. Evaluate the methods used to account for multiphase effects and the assumptions made by the owner or operator when interpreting the results. To assess whether there have been any changes in the near-well bore environment, compare the test results to the results of any previous pressure fall-off tests and to the formation characteristics (e.g., permeability, transmissivity) reported with the geologic data used in the AoR delineation model.

During their review of pressure fall-off data, the UIC Program should consider the following to confirm compliance with the permit:

- If proper testing procedures were not followed, discuss with the owner or operator the potential need to re-test the well and submit the new results;
- If any aspect of the test results (e.g., anomalous pressure drops) suggest the possibility of fluid migration, initiate discussion with the owner or operator and request further testing, if appropriate; and
- If changes in formation characteristics have been identified, discuss the potential need to reevaluate the AoR to reflect the new values with the owner or operator.

6.1.7 Plume and Pressure Front Tracking Information

Owners or operators must track the carbon dioxide plume and pressure front using direct and indirect methods [40 CFR 146.90(g)]. The purpose of the UIC Program's review of plume and pressure front tracking information is to confirm that the carbon dioxide plume and pressure front are behaving as predicted (i.e., to validate the AoR delineation model) or identify any evidence of unintended carbon dioxide or formation fluid migration out of the injection zone and/or potential USDW endangerment.

Owners or operators will submit the results of both direct and indirect methods for tracking the pressure front within the injection zone and tracking the extent of the carbon dioxide plume unless indirect methods were not included in the Testing and Monitoring Plan based on a UIC Program Director decision pursuant to 40 CFR 146.90(g)(2). Owners or operators may submit the following types of information in the semi-annual report:

- A narrative summary that presents the results of all required tests/surveys, supported by maps, graphs, and monitoring data in tables;
- Monitoring data in a GIS-compatible format to allow data matching with the AoR delineation model;
- Comparisons of monitoring results to modeled predictions or to previous monitoring or survey results (to illustrate trends); and
- An assessment of whether any monitoring results indicate fluid movement into USDWs.

Evaluation

In reviewing the results of plume and pressure front tracking, the EPA recommends that the UIC Program implement the following activities:

- For each plume and pressure front monitoring activity, confirm that the measurement(s) or test(s) were conducted according to the schedule described in the approved Testing and Monitoring Plan. Also review the method(s) chosen (e.g., seismic, electrical, gravity) and specific procedures used for consistency with both the Testing and Monitoring Plan and the QASP. If the information submitted indicates that tests or measurements were not completed as described in the Testing and Monitoring Plan, initiate discussions with the owner or operator and, if necessary, request repeat or additional testing.
- For direct pressure monitoring, confirm that all pressure transducers have adequate sensitivity to measure the expected pressure increases caused by injection and that they were calibrated according to manufacturer's recommendations and/or industry standards. If pressure gauges are not placed downhole, review calculations to determine whether bottom-hole pressures have been properly calculated. Where fluid sampling from the injection zone is used to directly monitor the carbon dioxide plume, compare the results of this monitoring with baseline data, previously reported data, and predictions from the AoR delineation model to confirm that the plume and pressure front are behaving as predicted and/or identify any trends that may indicate that the rate and direction of plume movement are not as predicted.
- For indirect geophysical methods, verify that the instruments were properly placed and georeferenced. Verify that interpreted results are consistent with other monitoring data, such as directly measured data (e.g., pH, temperature, pressure, saturation).
- Compare the results of direct pressure front tracking against any threshold values for the pressure front established in the Testing and Monitoring Plan. Also compare the data to predictions of plume and pressure front locations based on AoR delineation modeling. If measurements have been collected from one or more zones above the confining zone, evaluate the results for possible indications of fluid migration (e.g., an increase in pressure above the confining zone).
- For indirect methods, compare the results against baseline surveys and other previous surveys, and any additional monitoring data that have been submitted since the last survey was conducted. In addition, review the assumptions made during data processing and other information used to constrain the interpretation of the results.

The UIC Program should consider the following about plume and pressure front behavior to ensure compliance with the permit:

- If the submitted information includes unexplained anomalies or ambiguous results, or indicates the possibility of fluid migration, initiate discussions with the owner or operator. As necessary, consider the need for follow-up testing or monitoring activities to ensure the protection of USDWs (pursuant to 40 CFR 146.90(i)).
- If the results suggest that the locations of the plume and/or pressure front do not agree with modeled predictions, this may trigger one of the criteria for an AoR reevaluation established in the AoR and Corrective Action Plan.

- If results indicate that fluid migration or pressure increases may be endangering USDWs, work with the owner or operator to initiate response procedures as described in the Emergency and Remedial Response Plan.

6.1.8 Surface Air and/or Soil Gas Monitoring

If surface air and/or soil gas monitoring is required as part of the Testing and Monitoring Plan, pursuant to 40 CFR 146.90(h), the owner or operator will submit the results along with other testing and monitoring results.

The purpose of the UIC Program's review of surface air and/or soil gas monitoring is to confirm that there were no results that might indicate fluid migration out of the injection zone and/or USDW endangerment.

The owner or operator will submit the results of any required surface air and/or soil gas monitoring in their semi-annual reports. The owner or operator may submit the following information:

- A narrative description of the monitoring results;
- Descriptions of any significant changes in carbon dioxide levels compared to background levels or any detection of carbon dioxide migration that may impact a USDW; and
- Supporting images, maps, or spreadsheets or databases of all available surface air and soil gas monitoring data from each sampling location and depth, including any background data and QA/QC samples.

Evaluation

In reviewing surface air and/or soil gas monitoring data, the EPA recommends that the UIC Program implement the following activities:

- Verify that any required surface air and/or soil gas monitoring was performed according to the schedule in the approved Testing and Monitoring Plan. Review measurement procedures (e.g., instrument calibration, vacuum-volume purge tests, sample probe purging, sampling rates) and analytical procedures for consistency with the Testing and Monitoring Plan and the QASP.
- Compare the surface air and/or soil gas monitoring results to background/baseline data and other expectations as described in the Testing and Monitoring Plan. Also consider previous monitoring results from the sampling site(s) to identify trends that may indicate carbon dioxide leakage to the surface. However, keep in mind that carbon dioxide detection above background levels in surface air and/or soil gas does not necessarily indicate USDW endangerment; for example, it may reflect changes in near-surface carbon dioxide levels that are unrelated to the Class VI project.

The UIC Program should consider the following when reviewing the monitoring results to ensure compliance and USDW protection:

- If specified procedures were not followed or there are unexplained data gaps, initiate discussions with the owner or operator and evaluate the need for re-sampling/re-analysis and re-submission of the results; and

- If the results indicate elevated surface air and/or soil gas carbon dioxide levels, initiate discussions with the owner or operator and request additional follow-up work or remedial actions as necessary to ensure the protection of USDWs.

6.1.9 Other Required Monitoring

A Class VI permit may include additional monitoring if, pursuant to 40 CFR 146.90(i), the UIC Program Director determined that such monitoring was necessary.

The purpose of the UIC Program's review of this monitoring data is to confirm that the results satisfy the intended purpose. For example, the UIC Program should evaluate the information submitted to determine compliance with the prohibition of fluid movement into USDWs per 40 CFR 144.12, and confirm that the monitoring/approach is appropriate to site-specific conditions. The UIC Program should also review the monitoring information to ensure that it confirms predictions of site behavior and/or supports updating or refinements to the AoR delineation modeling.

The specific information submitted and the timing of the submittal will depend on the testing and monitoring performed, but owners or operators may submit the following information:

- A narrative description of the monitoring results;
- A discussion of any changes or trends in the results;
- Maps, graphs, and monitoring data in tables (accompanied by historical data to illustrate trends) to support the monitoring data; and/or
- If passive seismic monitoring is required, information on the magnitude and location/depth of hypocenters of any microseismic activity or earthquakes, along with information about whether the event was felt (i.e., per USGS data).

Evaluation

While reviews of the results of additional testing and monitoring will be site-specific and depend on the nature of the activities performed, a general strategy may be followed. This section briefly explains several potential examples and activities that the EPA recommends that the UIC Program implement:

- Verify that the testing or monitoring was performed on the schedule set in the Testing and Monitoring Plan and that procedures (sampling, data collection, analytical methods, etc.) were consistent with the Testing and Monitoring Plan and the QASP. If specified testing/monitoring or quality assurance procedures were not followed, or if there are unexplained data gaps, initiate discussions with the owner or operator regarding re-sampling/testing, if necessary.
- Compare the results against any expected or threshold values included in the Testing and Monitoring Plan or predictions established by computational modeling, permit conditions, or other expectations.
- If the owner or operator performed passive seismic monitoring, review information about the magnitude and location/depth of seismic events, particularly any that were felt events, where applicable. Confirm that appropriate responses, e.g., applicable threshold-based

responses in the Emergency and Remedial Response Plan, were performed (see Section 4.1.10).

In evaluating the results of this monitoring, the UIC Program should consider the following, which may have implications for compliance:

- If any monitoring results indicate the possibility of a carbon dioxide leak or fluid migration out of the injection zone/through the confining zone, USDW endangerment, or any other unexplained anomalies, establish appropriate follow-up actions. These may include additional monitoring/testing (either with the same or a different method), revisions to the Testing and Monitoring Plan, an AoR reevaluation, or remedial action as described in the approved Emergency and Remedial Response Plan.
- If there is an indication that the frequency or intensity of seismic activity is increasing over time, consider modifying the operating parameters (e.g., injection rates or pressures) in the permit.

6.2 AoR Reevaluations

Class VI well owners or operators must reevaluate the AoR delineation throughout the duration of the project [40 CFR 146.84(e)] and, if necessary, update the AoR and Corrective Action Plan based on the results of the AoR reevaluation. Owners or operators must reevaluate the AoR at a frequency set in their approved AoR and Corrective Action Plan or when warranted based on certain conditions, such as following significant changes in site operations, monitoring results that deviate from computationally predicted behavior, or availability of new site-specific data that may impact modeling predictions. See Figure 6-2.

AoR reevaluations may result in two potential outcomes, with different submittals made by the owner or operator:

1. A technical demonstration that the existing AoR and Corrective Action Plan is adequate, supported by project monitoring data; or
2. An amended AoR and Corrective Action Plan with a modified AoR delineation and a revised corrective action strategy (or a demonstration that the existing corrective action strategy continues to ensure protection of USDWs).

The purpose of the UIC Program's review of information associated with AoR reevaluations is to ensure that all new and relevant observed/measured

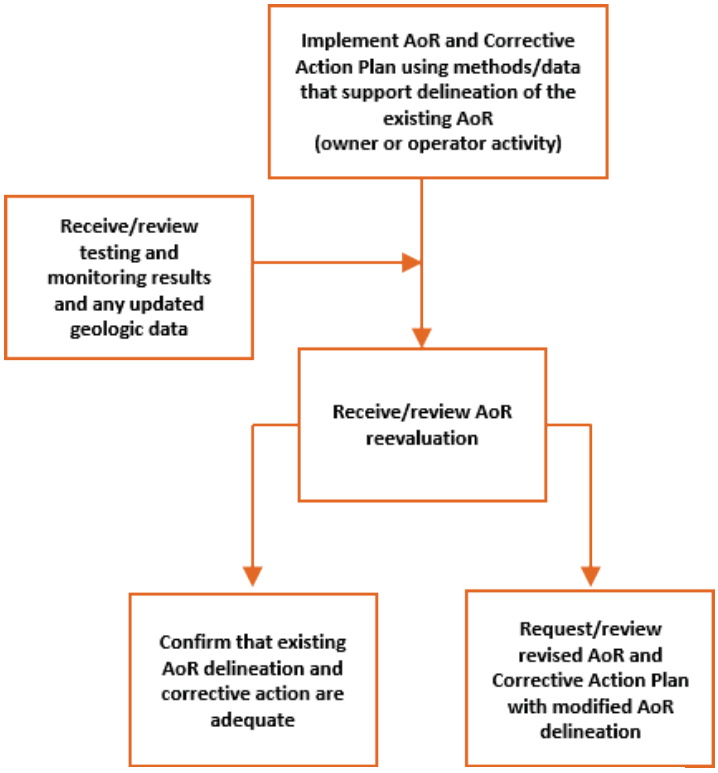


Figure 6-2: AoR Reevaluations

project data support the existing AoR or that, if necessary, a new AoR is delineated to more accurately represent the area where USDWs may be endangered. Reviewing this information is analogous to the pre-construction and pre-operation phase reviews of the AoR delineation, although it will focus on data collected during project operations.

The goal of evaluating these submittals is the same as that described in Section 4.1.2 for the initial AoR delineation: to assess (in light of any new data) whether the AoR appropriately represents the area in which USDWs may be endangered by the injection activity, and to ensure that all artificial penetrations that may allow fluid movement into USDWs in the AoR are identified and addressed by corrective action. For additional information on AoR reevaluations, see the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance*.

Completeness

Depending on the progress of the project, owners or operators will either submit a demonstration that the existing AoR is adequate or a revised AoR and Corrective Action Plan.

Owners or operators may use a variety of approaches to demonstrate that the existing AoR is adequate. However, the EPA expects that such a demonstration will, at a minimum, involve comparison of the most up-to-date monitoring and operational data and other site-specific information to the computational predictions that supported the existing, approved AoR delineation. Owners or operators might also evaluate the agreement between the inputs used to delineate the existing AoR and the measured/observed project data or they might conduct additional computational modeling with updated, calibrated input parameters and show that this results in the same AoR.

The UIC Program should identify the approach taken by the owner or operator and examine the updated information to ensure that all necessary submissions/changes have been made to support the demonstration. The submission should account for all testing and monitoring, site characterization, and/or operational data used in the analysis and clearly reference the source of this information. If the owner or operator employed a new modeling approach and predictions used in the analysis have not been submitted previously, the permit writer should verify that the data associated with the predictions are also submitted to the GSDT along with a confirmation that they resulted from the same simulation (e.g., with the same initial conditions, simulation time, etc.) used for delineating the existing AoR.

If the owner or operator is submitting a revised AoR and Corrective Action Plan as a result of the reevaluation, the EPA expects that a detailed description of the reevaluation activities and the results that triggered a new delineation of the AoR will be submitted as part of this process. The UIC Program should confirm that:

- The submission sufficiently describes the inconsistencies found during the reevaluation;
- The necessary changes to the existing modeling data in the GSDT or the new data (e.g., associated with the calibration of the model) have been submitted and that they support the technical evaluation;
- An updated corrective action strategy has been provided, if needed; and
- A revised narrative plan, including all required components (as informed by 40 CFR 146.84), has been submitted.

Evaluation

The specific aspects of the technical review of AoR reevaluations during the injection phase will depend on the types of information and materials submitted by the owner or operator. The bolded text below outlines a suggested approach for reviewing the injection phase AoR information. This approach will help to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit; confirm that the AoR is appropriately protective; and ensure that the submitted reevaluation sufficiently addresses identified uncertainties associated with the existing AoR delineation to confirm USDW non-endangerment.

Review the demonstration that the existing AoR is adequate (if the owner or operator submits one). Identify the parameters used in the owner or operator's analysis to demonstrate conformity between the predicted and observed data (e.g., between the computationally predicted plume and pressure behavior and the plume and pressure front tracking results). Ensure that the data used in the analysis incorporates all the relevant data that have become available since the existing AoR delineation was approved (including the results of monitoring collected throughout the AoR). The demonstration should reflect the results from all relevant activities covered by the Testing and Monitoring Plan, as well as any newly available geologic data that the owner or operator may have collected (e.g., from new logs run at nearby wells). Pressure profiles at given locations (e.g., at injection or monitoring wells) over time are expected to be one of the key parameters of comparison between predicted and observed data. However, in addition to pressure data, it is important to ensure that the results of operational monitoring are also consistent with the operational input data used in the modeling effort, and to confirm that the observed plume migration agrees with predicted behavior. When conducting this evaluation, refer to the monitoring results submitted with the semi-annual reports (see Section 6.1) to ensure that the data used in the demonstration are accurate and complete.

If the AoR does not Change during the Reevaluation

In some cases, the revised plan may only need to include a new corrective action strategy or related information, with no changes made to the existing AoR. For instance, the AoR reevaluation may have been triggered by testing and monitoring results that indicate fluid migration out of the injection zone/into a formation above the confining zone formation through a newly identified abandoned well. While the reevaluation in this case confirms that the existing AoR is adequately delineated, a revised corrective action strategy should be incorporated into the AoR and Corrective Action Plan and evaluated by the UIC Program.

This demonstration should also include assessments of compliance with regulatory requirements and validation of AoR delineation modeling predictions, and compliance with the permit (e.g., pressure limits to ensure that injection does not initiate or propagate fractures in the confining zone). Assessments of agreement between the predicted and observed trapping values for different mechanisms are also important, particularly to ensure that the alternative PISC timeframe, if one has been approved, remains adequate. Furthermore, the demonstration should include an assessment of the adequacy of the existing corrective action plan by confirming that the previously identified corrective action needs are still accurate and were addressed.

The EPA expects that the conformity between predicted and measured project behavior will, at a minimum, be based on graphical examination of the data for the chosen parameters. For example, these graphical evaluations may include plots comparing observed and predicted pressure values at a certain location, or a comparison of the predicted plume extent at certain times to corresponding 3D seismic survey results and/or plume arrival data at specific

monitoring locations. In addition to comparing data directly, evaluations may also include comparisons of ranges and medians of integrated parameter values, or comparison of cumulative distribution functions. Confirm that the data used in these graphical examinations are correct and complete. This may be best achieved by developing plots of reported monitoring data (see Section 6.1) over time and comparing them to plots provided in the detailed discussion of the monitoring results. If the conformity is supported by a statistical analysis, in addition to confirming the accuracy and completeness of the data used, also evaluate the statistical methods to ensure they are suitable and correctly implemented.

If new/updated geologic data is available, assess whether it affects the AoR delineation (e.g., if it is relevant to the porosity, permeability, or relative permeability of key formations, the depth or extent of the confining zone, the pressure at the bottom of the lowermost USDW, etc.). If it does, evaluate whether it is consistent with the inputs used in the existing AoR delineation model. For example, it might be appropriate to develop plots of the data used in the model (e.g., a layer-by-layer distribution of mean parameter values and standard deviations) and compare those to the new information.

If the owner or operator conducted any additional computational modeling to demonstrate that the new information does not affect the existing AoR, identify the method used (e.g., whether the owner or operator used the original model or a new approach) and evaluate its accuracy by, for example, using the independent model developed to evaluate the existing AoR delineation. Any relevant testing and monitoring results and other new information should be integrated into the independent model, and/or the model parameters should be calibrated using the new data to support simulations assessing the impact on the AoR.

Review the revised AoR and Corrective Action Plan (if one was submitted). Ensure that the approach used to delineate the new AoR complies with the requirements under 40 CFR 146.84 and that it accounts for all new site characterization, operational, and testing and monitoring information. The EPA expects that a detailed description of the AoR reevaluation and its results warranting a new delineation of the AoR will be submitted as part of the revised plan, to achieve consistency and continuity in documenting project decisions. Conduct an evaluation of this submission, similar to the evaluation of the demonstration that the existing AoR is adequate, to confirm the need for a revised plan and/or a new AoR delineation.

If the owner or operator submitted an updated AoR and Corrective Action Plan, review the following:

- The reevaluation approach and the identified inconsistencies that warranted the delineation of the new AoR;
- The delineation of the new AoR (including the computational modeling and delineation method); and
- Any corrective action status/updates, including any updates to the phased corrective action schedule (or the owner or operator's demonstration that no update is needed).

Review and confirm that all proposed or performed corrective action relies on methods that are consistent with the testing and monitoring results (e.g., geochemical data). If phased corrective action is being implemented, evaluate the schedule in light of the new AoR delineation and computational modeling results.

If any unexpected carbon dioxide movement, fluid migration out of the injection zone, or emergency events have occurred since the last AoR reevaluation, discuss with the owner or operator the possible need to revise the reevaluation schedule or triggers for reevaluations.

Review a new AoR delineation (if one was submitted). Evaluate all of the updates/changes made to the modeling data and confirm that:

- They represent parameters for which inconsistencies have been identified. For example, if the reevaluation identified an inconsistency between newly available data for relative permeability in the injection zone and the values used in the existing AoR delineation, confirm that the AoR delineation reflects the most up-to-date data.
- The updates/changes reflect the adjustments, within reasonable limits (depending on the parameter used), determined via model calibration procedures to achieve an acceptable agreement between model predictions and the collected testing and monitoring data. Such model calibration procedures should focus on the parameters that have been identified as the most sensitive parameters during sensitivity analyses. If the same numerical model that supported the existing AoR delineation is being updated, a sensitivity analysis should already have been conducted during the delineation process identifying these parameters. Model calibration procedures should also include the model outputs that are most affected by these key parameters. At a minimum, it is expected that model calibration would involve an iterative optimization process resulting in an updated conceptual model and input parameters (e.g., inverse modeling). Additional information on model calibration can be found in the *UIC Program Class VI Well Area of Review Evaluation and Corrective Action Guidance.*

For these assessments, the EPA recommends using a combination of qualitative and quantitative procedures similar to the procedures described in Section 4.1.2. As part of the quantitative approach, conduct independent or semi-independent computational modeling that also accounts for the calibration of model parameters. Follow these general steps:

- Assess the conceptual/geologic model and model parameters to verify that they are consistent with all available data (i.e., including any newly acquired geologic information, testing and monitoring, and operational information), and that they provide an accurate representation of the geologic and operational systems.
- Assess the computational/numerical model to verify that it accounts for all applicable chemical and physical characteristics of the injected carbon dioxide and displaced fluids; that it is constructed to accurately represent the geologic and operational systems based on the measured data; and that its outputs are consistent with the measured/observed monitoring results.
- Evaluate the methodology used to delineate the modified AoR, based on the new modeling results, to ensure that the AoR accurately represents the area where USDWs may be endangered and parameter values used in the delineation are consistent with the most up-to-date field measurements.
- Determine if any additional artificial penetrations are present in the new AoR and verify that the owner or operator has taken actions to evaluate the conditions of these new wells and perform any needed corrective action. If phased corrective action was approved,

verify that the phasing plan remains appropriate based on the most recent plume/pressure trajectory from the updated model or monitoring results.

- Confirm that the new AoR delineation process and the status of corrective action are documented in the narrative portion of the revised AoR and Corrective Action Plan. Determine if the frequency for future reevaluations included in the revised plan is sufficient, or whether more frequent reevaluations are necessary (e.g., due to some significant deviations identified during the current reevaluation process).
- Identify the other project plans that might need to be amended, such as the Testing and Monitoring Plan or PISC and Site Closure Plan (e.g., to include monitoring in new areas of the AoR or expanded geophysical monitoring that encompasses a wider area, or to identify more frequent monitoring) and the Emergency and Remedial Response Plan (e.g., to address additional resources in an expanded AoR). See Section 6.3 for more information on project plan updates and Section 5.2 for information on modifying the Class VI permit.

Review information on any newly-performed corrective action (i.e., under an approved phased corrective action schedule). Confirm that the owner or operator performed all phased corrective action on schedule and used appropriate/approved methods and carbon dioxide-resistant materials.

Outcomes

To ensure that the area where USDWs may be endangered due to the injection activity is accurately delineated and to support future site closure decisions, the UIC Program should develop the following:

- An updated AoR and Corrective Action Plan that is an enforceable condition of the Class VI permit;
- A modified permit that incorporates the amended plan; and
- A report documenting the technical evaluation process as described above to support a determination regarding whether revising the project plans (and potentially modifying the Class VI permit) are needed.

6.3 Project Plan Updates

Class VI well owners or operators must submit amended Testing and Monitoring and Emergency and Remedial Response Plans within one year of an AoR reevaluation or submit information to demonstrate that no amendments to the project plans are needed [40 CFR 146.90(j)(1); 146.94(d)(1)]. Project plan revisions may also be triggered by significant changes to the facility (e.g., addition of new injection wells) or as required by the UIC Program Director.

The purpose of the UIC Program's evaluation of the updated plans is to confirm that they address the entire AoR delineated as part of the most recent reevaluation and address any relevant risks to the site. In particular, the UIC Program should ensure that the amended plans are appropriate to operations, the well's construction, and the most up-to-date understanding of the behavior of the site, as informed by the most recent testing and monitoring and AoR delineation modeling results.

As described in Section 6.2 above, AoR reevaluations may also trigger revisions to the AoR and Corrective Action Plan [40 CFR 146.84(e)(4)]. In addition, revisions to the project plans may necessitate an update to the financial responsibility cost estimates and financial instruments. See Section 6.4 for additional information about reviewing these updates.

Completeness

Project plan updates will likely be narrative documents that are similar to the approved project plans that are enforceable conditions of the Class VI permit; they may be supported by supplemental information (e.g., GIS files or other materials). Changes should reflect the monitoring, operating, or modeling activities that need to be revised based on the findings of the AoR reevaluation or other event that triggered the plan revision. If applicable, owners or operators should also submit an updated QASP for all testing and monitoring procedures (e.g., as part of a revised Testing and Monitoring Plan or PISC and Site Closure Plan). See Section 4.1 for additional information on evaluating the completeness of Class VI project plans.

If any changes are needed and either a revised plan was not submitted or the appropriate changes were not included in the revised plan, the UIC Program should consider requesting that the owner or operator update the plan and submit a revised version. Alternatively, in some cases, the owner or operator may make a justification that no plan updates are needed; this should be a technical demonstration based on site-specific data.

Evaluation

If the owner or operator submits one or more updated project plans, reviewing the updated plans will entail a process similar to the review of the initial plans submitted with the permit application (see Section 4.1 for specific considerations). However, reviews during this phase will focus on operating data and monitoring data generated since the last review/update of the plans, the most recent AoR reevaluation, and any aspects of the project that have changed since the plans were last approved.

If the owner or operator submits a demonstration that no updates to one or more project plans are needed, the UIC Program should review geologic data and the most recent AoR reevaluation to confirm that there have been no changes at the facility (or divergences from predicted values) that would warrant revision of any of the plans. The demonstration should show how operating data (e.g., injection pressures, volumes, rates) and monitoring data (e.g., position of the carbon dioxide plume and pressure front and groundwater quality data) confirm there have been no significant changes at the site.

The bolded text below outlines a suggested approach for reviewing updated project plans that a UIC Program might employ. This approach will help to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit, and that the amended plans are protective in light of the most recent site data and the approved AoR.

Review the updated Testing and Monitoring Plan or the owner or operator's demonstration that no update to the plan is needed. If revised modeling delineates a larger or differently shaped AoR, or monitoring indicates that the carbon dioxide plume is moving at a rate or in a direction other than was predicted, verify that the amended Testing and Monitoring Plan includes an expanded groundwater monitoring well/pressure monitoring network, more frequent/extensive geophysical surveys, or other appropriate methods to track the plume/pressure front to ensure that USDWs are not being endangered.

If groundwater monitoring indicates leaching/mobilization of metals or organics, or impairment of a USDW has occurred, verify that the plan includes analysis of groundwater for additional parameters or analytes or more frequent analyses as needed to provide early indication of possible USDW endangerment. Likewise, if any of the physical or chemical characteristics of the carbon dioxide stream have changed, additional analytical parameters may be appropriate.

If MIT results or corrosion monitoring data identify changes to the injection well that could potentially endanger USDWs, confirm that any needed modifications to the well testing regime (e.g., to corrosion monitoring or MIT frequency or methods) are incorporated into the plan.

If new, more site-suitable testing and monitoring methods for use at the Class VI project become available, discuss with the owner or operator the merits of incorporating them into the Testing and Monitoring Plan.

Review the updated Injection Well Plugging Plan if any updates to the plan are submitted during the injection phase. Formal periodic reviews and amendments to the Injection Well Plugging Plan are not required during the injection phase. However, data on the chemistry of the carbon dioxide plume and formation fluids, well testing results, operational data, or significant changes to the facility may indicate that changes to the planned plugging techniques are necessary. If so, discuss with the owner or operator the need to eventually update the Injection Well Plugging Plan, including the merits of doing this during a current plan update cycle to ensure consistency across all the approved plans, or waiting until a future date. If a plan update is needed at a specific time, request an updated plan pursuant to 40 CFR 146.92(b).

If an updated Injection Well Plugging Plan is submitted during the injection phase, review the procedures and materials described in the plan to ensure that they are suitable to subsurface and carbon dioxide chemistry, operational data, and other aspects of the project based on recent testing and monitoring results. Cross-check the plan against information from monitoring and well logs, as appropriate. See Section 7.1 for additional information on reviewing the updated Injection Well Plugging Plan.

Review the updated PISC and Site Closure Plan if one is submitted. The Class VI Rule does not require formal periodic reviews and amendments to the PISC and Site Closure Plan during the injection phase; however, the owner or operator may choose to do so at any time [40 CFR 146.93(a)(4)]. If any changes in facility operations, monitoring results, or operational data warrant changes to other Class VI project plans, ask the owner or operator to consider updating the PISC and Site Closure Plan, particularly if the changes involve a permit modification.

Changes to the PISC and Site Closure Plan may be needed if monitoring indicates that the carbon dioxide plume is moving at a rate or in a direction other than was predicted, or pressures within the injection zone vary from modeled predictions. Additionally, changes may be appropriate if injection-phase AoR reevaluations indicate that predicted post-injection pressure differentials or the position of the carbon dioxide plume and pressure front will differ from those on which the plan was based. Additionally, if any changes to the injection-phase Testing and Monitoring Plan are needed (e.g., parameters or monitoring locations), the EPA recommends revising the post-injection monitoring strategy accordingly and concurrently with updates to the Testing and Monitoring Plan. If the owner or operator submits a revised plan that includes revisions to the PISC timeframe, evaluate the request in the context of available monitoring and operating data to determine whether a shorter (or longer) PISC timeframe is appropriate. Encourage the owner or operator to submit information that meets all of the criteria at 40 CFR 146.93(c) to demonstrate

that the alternative timeframe is protective of USDWs. See Section 7.2.1 for additional information on reviewing updated PISC and Site Closure plans and specific considerations for the review.

As part of the revisions to the PISC and Site Closure Plan, the owner or operator may submit changes to the non-endangerment demonstration criteria. The criteria should be based on monitoring and operational data that verify modeled predictions about the behavior of the carbon dioxide plume and pressure front and confirm USDW non-endangerment (see Section 4.1.9 for additional information on identifying criteria for non-endangerment demonstrations).

Review the updated Emergency and Remedial Response Plan or the owner or operator's demonstration that no update to the plan is needed. If revised modeling delineates a larger/differently shaped AoR that includes new resources/infrastructure or if recent (or planned) land use changes brought new resources or infrastructure near or into the AoR, consider requesting that the Emergency and Remedial Response Plan be revised to address such changes. If there has been a need to implement emergency procedures at the site, discuss the response with the owner or operator and consider asking them to incorporate any lessons learned into an amended Emergency and Remedial Response Plan.

Discuss with the owner or operator whether there have been any changes to available responding personnel (including updated contact information), training, or communications and notification procedures, or newly developed procedures that are not in the approved plan. If changes have occurred, verify that the Emergency and Remedial Response Plan includes this updated information.

Outcomes

Following review and approval of the amended plans, the UIC Program should develop the following information for inclusion in the permit file:

- Updated plans as enforceable conditions of the Class VI permit;
- A modified Class VI permit that incorporates the amended plans. See Section 5.2 for additional information on modifying Class VI permits;
- Documentation of the review to support the administrative record for a permit modification (if one is needed to incorporate the revised plans) or justify and explain to stakeholders and the public that testing and monitoring data and modeling indicate that the project is operating as planned and there is no evidence of endangerment to USDWs and, therefore, no changes to the plans are needed; and
- Periodic public updates on the status of the project. Consider providing status reports to reassure the public and stakeholders that the project is progressing as planned and that there is no endangerment to USDWs.

6.4 Financial Responsibility Updates

Per 40 CFR 146.85(c)(2),(3), the owner or operator must update the cost estimates for covered activities annually or within 60 days of revising the AoR and Corrective Action Plan, the Injection Well Plugging Plan, the PISC and Site Closure Plan, or the Emergency and Remedial Response Plan. Cost estimate updates may also trigger revisions to third-party financial instruments, pursuant to 40 CFR 146.85(c)(4).

The purpose of the UIC Program's review of these updates is to confirm that sufficient resources remain available to ensure USDW protection without requiring the use of public funds to perform any of the covered activities.

Completeness

The owner or operator will submit cost estimates for any remaining corrective action and updates to the estimates for plugging the injection well, PISC and site closure, and emergency and remedial response. They may also need to submit updated financial instruments (e.g., renewed insurance policies or financial instruments with updated face values) or proposed language for any financial instrument(s) they plan to purchase.

Verify that the updated cost estimates reflect any changes to the covered activities and that the owner or operator plans to use one or more of the qualifying instruments at 40 CFR 146.85(a)(1) to cover the full amount of the cost estimates. Confirm that the updates were submitted on time; a delay in receiving updates to the financial instruments and cost estimates could serve as an indication that the owner or operator may no longer be able to meet the financial responsibility requirements.

Reviewing Annual Submittals Associated with Self-Insurance

Owners or operators who use self-insurance to demonstrate financial responsibility must submit a report of their bond rating and financial information annually [40 CFR 146.85(a)(6)(v)]. If the owner or operator fails to submit an updated report of their bond rating and financial information at the end of each fiscal year, then they may no longer qualify to use self-insurance as a financial instrument. The annual reports should be reviewed to confirm the owner or operator's continued eligibility for self-insurance. If self-insurance is no longer viable, the owner or operator will need to establish an alternative financial instrument within 60 days of the end of the fiscal year.

Evaluation

The text below outlines a suggested approach for reviewing updated financial responsibility information that a UIC Program might employ to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit, and confirm that adequate financial resources are available to address the covered activities.

Verify that the cost estimates submitted by the owner or operator have been accurately adjusted for inflation relative to the prior year's cost estimates. If any changes to the Class VI project (e.g., related to changes to the size or shape of the AoR resulting from an AoR reevaluation) impact the covered activities, discuss with the owner or operator whether this may result in increases or decreases in the cost estimates and therefore necessitate changes to the value of the financial instrument(s). If so, request updated cost estimates and evaluate these. See Section 4.1.4 for additional information on the EPA's Financial Responsibility Cost Estimation Tool, which can support the evaluation of the cost estimates.

If the costs for any activity have increased, request that the owner or operator provide evidence that the value of the financial instrument has increased accordingly. If the cost estimate for any activity decreases, provide written approval to the owner or operator to reduce the face value of the financial instrument.

Release the owner or operator from financial instruments as activities are completed, e.g., as all corrective action is complete. Provide written authorization for the owner or operator to withdraw the financial instrument.

Outcomes

To ensure that adequate financial resources are in place to address all Class VI activities, develop or document the following:

- Permit conditions and/or a summary of the enforceable financial responsibility conditions that reflect any updates to the cost estimates or changes to the instruments;
- Copies of the financial instruments or documentation that any new or updated financial instruments are active or in force;
- Any documentation releasing the owner or operator from a financial instrument following completion of specific activities; and
- A report documenting the review, including the review of cost estimate updates and any adjustments for inflation; additional financial responsibility instruments obtained; or activities that have been completed.

6.5 Occasional Injection-Phase Reviews

In addition to the information that must be submitted by all owners or operators at a schedule defined in the permit, owners or operators may also need to submit certain information to respond to occasional or unanticipated events. These events include additional testing (beyond that described in the Testing and Monitoring Plan) or workovers, emergency events, or adverse financial conditions experienced by the owner or operator or the issuer(s) of the financial instruments.

The purpose of the UIC Program's evaluation of this information is to ensure that USDWs are protected, or identify appropriate actions to address endangerment and the implications for project operations or updates to the permit (including the Class VI project plans). The UIC Program is encouraged to discuss the activity or event with the owner or operator.

6.5.1 Workovers, Stimulation, or Other Well Tests

During the injection phase, an owner or operator may submit notices related to workovers, stimulation, or other well tests. The bolded text below describes activities that the UIC Program may need to take to review the information submitted to ensure that all work is planned and executed in a manner that protects both the integrity of the well and USDWs.

Review advance notices of planned workovers, stimulation, MITs, or non-routine testing. Verify that proper procedures will be followed, including gradual well shutdown procedures according to the permit conditions (see Section 4.1.8).

- Review any descriptions of the work that the owner or operator submits with the notification to ensure that all work on the well will be performed such that fluids will be confined to the injection zone and that precautions are in place to avoid damage to the well or to mitigate the impacts of any damage.
- If the owner or operator provides notice of workovers or MITs less than 30 days in advance of the planned activity as required at 40 CFR 146.91(d), coordinate with the owner or operator to determine the feasibility of witnessing the tests. If witnessing is not feasible, confirm whether or not witnessing the test will impact the permitting authority's

ability to review the planned work. If witnessing the test is essential, work to identify dates that work for both parties.

If appropriate or necessary, arrange to witness the work or activity. Select the personnel who will witness the work and coordinate with the owner or operator for those personnel to be present.

Review the post-workover or testing reports, which must be submitted within 30 days of the activity [40 CFR 146.91(b)]. Verify that the work was performed as planned and consider the following:

- If there is evidence or an indication of well damage or integrity issues, discuss the situation with the owner or operator and identify needed responses, such as additional MITs.
- If there is evidence of unacceptable fluid movement, discuss the situation and appropriate responses with the owner or operator. These may include additional rounds of monitoring to detect excursions of carbon dioxide or formation fluids. Update the project plans if needed.
- If a violation has occurred, take appropriate informal or formal enforcement actions (see Section 2.4).

6.5.2 Emergency Response

While the goals of proper siting, construction, and operation of a Class VI project are to prevent the occurrence of an emergency or adverse event, quick and effective response is vital for mitigating the effects of such an event, if one should occur.

The Class VI Rule requires owners or operators to report, within 24 hours, any evidence of endangerment to a USDW [40 CFR 146.88(f)(3); 146.91(c); 146.94(b)(3)], including:

- Any evidence that the carbon dioxide plume or pressure front may endanger a USDW;
- Any noncompliance with a permit condition;
- Any malfunction of the injection system;
- Any triggering of a shut-off system or a loss of mechanical integrity; or
- A release of carbon dioxide to the atmosphere or biosphere.

Initial information about these events or evidence of endangerment to a USDW, as required at 40 CFR 146.91(c), may be:

- Reported via emergency "24-hour notices" from the owner or operator about an accident or adverse event;
- The subject of public inquiries or comments about the facility; or
- Based on inspections or reviews of monitoring data (e.g., that increased levels of carbon dioxide or mobilized metals were detected outside the injection zone or in a USDW).

The EPA anticipates that emergency notifications (e.g., immediate/24-hour) will be initiated by phone or email and followed up by formal electronic submittals via the GSDT to comply with 40 CFR 146.91(e).

The Class VI Rule does not specify the content of the notifications; however, given the need for timely reporting, the EPA anticipates that they will take the form of a brief letter to the UIC Program Director describing: what happened, the time and date of the event, any immediate actions the owner or operator may have taken, and initial information on any impacts to the well or the environment. Depending on the nature of the emergency, it may also be appropriate to notify (or ask the owner or operator to notify) local water systems, government agencies, etc.

The UIC Program should communicate with the owner or operator during the event to ensure that responses are taken to expeditiously mitigate risk(s) and return the project to compliance. The bolded text below describes activities that the UIC Program may need to take, based on the specific nature of the event, to support the owner or operator in returning the project to compliance and ensuring that USDWs are protected.

Work with the owner or operator to identify and implement an appropriate response. The response will be site- and situation-specific and depend on a variety of factors. These may include: whether there was damage to the injection well or any monitoring wells; whether there was any unacceptable movement of carbon dioxide or other fluids (and, if so, the extent of movement); the presence of USDWs or water supplies within the AoR and their proximity to an event; and what, if any, impacts could (or did) result from the event.

Responding to emergency events should be guided by and follow established permit conditions or the procedures in the approved Emergency and Remedial Response Plan. Work with the owner or operator to verify that the appropriate immediate actions were taken and to develop solutions. For example:

- Verify that the owner or operator has shut down the well, if necessary. The shutdown should be conducted as described in the permit, including the implementation of gradual shutdown procedures, if appropriate.
- Begin discussions with the owner or operator to determine the cause of the event, identify remedies to be taken (as outlined in the Emergency and Remedial Response Plan), and set a timeline for resolving the problem and returning the well to service.
- Where the response will take months or years to implement (e.g., groundwater remediation), develop a compliance schedule that describes required activities and a timeline for their completion, and provide this to the owner or operator. Verify that the owner or operator meets the milestones in the compliance schedule as the response proceeds.

Maintain open communication with the owner or operator throughout the response to confirm that all necessary steps are being taken to prevent or mitigate contamination. This might include requesting updates on the status of the project, the remedial effort, and any testing or monitoring performed (and documentation of the results).

Initiate an enforcement action, if necessary. If the event caused or was a result of a violation (e.g., failure to maintain integrity of the well or an excursion of injectate or formation fluids into a USDW), determine what enforcement actions are appropriate. (Failure to implement the Emergency and Remedial Response Plan would also constitute a violation of the permit.) Note that some events described in an Emergency and Remedial Response Plan (e.g., the triggering of an automatic shutdown device where the integrity of the well was not compromised) may not

constitute a violation. See Section 2.4 for additional information on enforcement associated with Class VI permits.

Require follow-up monitoring or testing to confirm that remedial actions were successful and no USDWs were impacted. For example, if there was a loss of mechanical integrity, require internal and/or external MITs (i.e., pursuant to 40 CFR 146.88(f)(4)) or cement logs to verify that repairs to the well are complete. Arrange to witness MITs or other testing before the well is returned to service, if necessary. If there are indications that injectate or other fluids may have migrated out of the injection zone, consider the need for monitoring of USDWs or other formations. If a seismic event occurred, discuss the magnitude and location of the event with the owner or operator to determine whether additional monitoring stations may be needed. Check in with the owner or operator periodically to verify that milestones in a compliance schedule are being met.

Authorize the owner or operator to resume injection. After remediation is complete and the owner or operator demonstrates that the well has integrity and/or that USDWs are not endangered, inform the owner or operator that they may resume injection. UIC Program Directors also have discretion at 40 CFR 146.94(c) to allow injection to resume prior to remediation if the owner or operator demonstrates that the injection operation will not endanger USDWs. This determination will be site- and situation-specific, and should consider the extent of the contamination and proximity of USDWs or water supplies. For example, if movement of formation fluids or injectate was limited and no groundwater-based water systems or private water wells are near the migration pathway, it may be appropriate to allow injection to recommence, provided the owner or operator monitors water quality in the area.

Request an AoR reevaluation, if appropriate. If the event indicates that the carbon dioxide plume or pressure front are not moving as predicted, consider requesting an AoR reevaluation. Also request that the Class VI project plans be evaluated and updated, if needed (e.g., revising the Emergency and Remedial Response Plan to incorporate lessons learned during the event). See Section 6.3. The financial responsibility cost estimates may need to be updated accordingly.

Consider communicating to stakeholders, including customers of local water systems, nearby land owners, and the public about the event. If a water supply was endangered or contaminated as a result of the event, work with the water system operator or state drinking water authorities to ensure that appropriate actions are taken to protect public health. Alternatively, if the incident did not endanger USDWs or public health, communication is important to reassure stakeholders that UIC protective measures worked and that their water supply was protected. See Section 2.3 for additional information on communicating about Class VI projects.

Document the event. The EPA recommends documenting the event. This can provide a record that an appropriate response was taken or, if necessary, support the administrative record for future permitting actions (e.g., if any modifications to the permit or plans are needed based on the event or outcomes), or support an enforcement action (see Section 2.4). A summary report of the incident may address: what happened, including when it was discovered and the cause, if known; what responses or remedial action(s), including activities specified in the Emergency and Remedial Response Plan, were conducted; any impacts to USDWs; and the date that injection resumed.

6.5.3 Notification of Adverse Financial Conditions

The owner or operator must notify the UIC Program Director of adverse financial conditions that may affect their ability to carry out injection well plugging and post-injection site care and site closure. [40 CFR 146.85(d)] These may include bankruptcy of the owner or operator or a third-party provider, suspension or revocation of a trustee, or failure of the issuing institution to renew a letter of credit. If the owner or operator provides notification of any adverse financial conditions, the UIC Program should perform the following activities to ensure that adequate financial resources are available:

- Initiate discussions with the owner or operator and/or the financial institution to address the issue;
- If a new financial instrument is proposed and determined to be sufficient, provide written approval of the new financial instrument and release the owner or operator from the previous financial instrument; and
- Verify that the owner or operator establishes other financial assurance within 60 days after such an event.

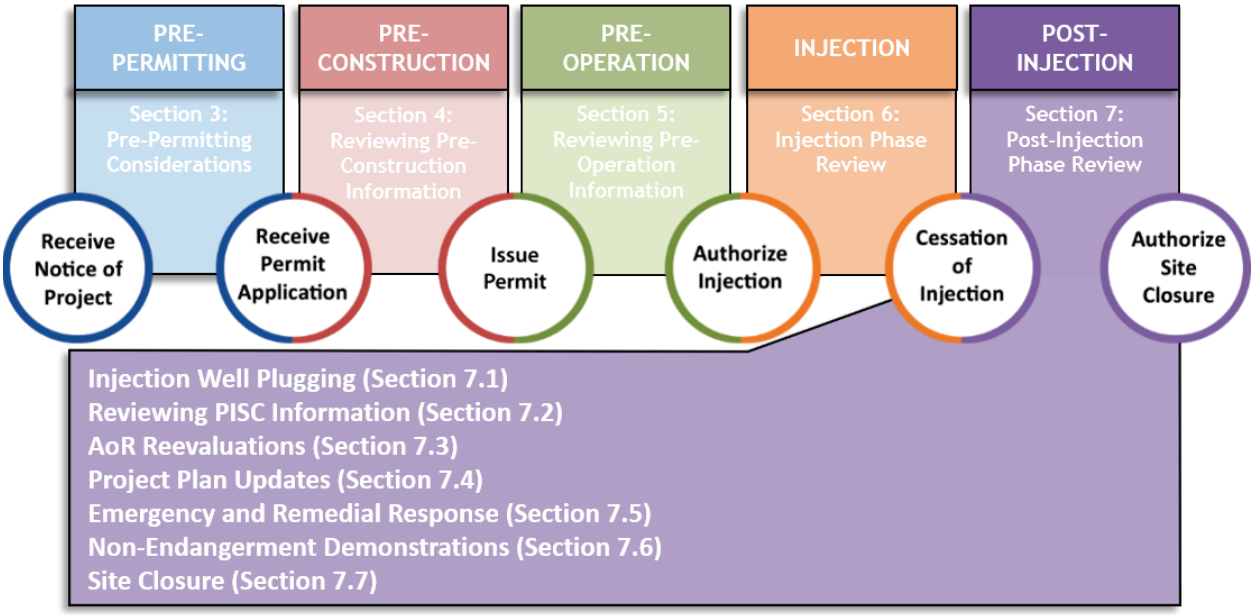
6.6 Planning for the Post-Injection Phase Review

The activities and reviews described in this section will continue for as long as the owner or operator injects carbon dioxide for the purpose of GS. Following cessation of injection, the owner or operator will continue to monitor the site to ensure that the project complies with permit conditions or that any unforeseen USDW endangerment is identified and mitigated. Information about groundwater quality, the performance of the carbon dioxide plume and pressure front, and the results of any other required monitoring will also support the non-endangerment demonstration that must be made before the owner or operator may be authorized to perform site closure activities per 40 CFR 146.93(b).

During the post-injection phase, the UIC Program will receive information related to plugging the injection well, post-injection monitoring results, a non-endangerment demonstration, and site closure-related information to confirm that the project continues to be protective of USDWs and that, following site closure, the site will not endanger USDWs.

Section 7 presents recommendations for how the UIC Program can confirm that all required post-injection activities are performed and review the information that is submitted to ensure that the Class VI project remains in compliance until site closure is complete.

Section 7: Post-Injection Phase Review



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7 Post-Injection Phase Review

During the post-injection phase, after injection has ceased, Class VI well owners or operators will conduct monitoring to confirm project behavior over time. While the potential for endangerment of USDWs will likely decrease during this phase (i.e., as trapping mechanisms continue to immobilize the carbon dioxide and subsurface pressures decline), continued monitoring of the site, per 40 CFR 146.93(a),(b), is necessary to ensure continued project compliance with the permit, confirm USDW protection, and address any identified USDW endangerment. Generating, evaluating, and discussing site data can also ensure collection of the amounts and types of information necessary for demonstration of non-endangerment and authorization of site closure. Also during this phase, the owner or operator must plug the injection and monitoring wells to ensure they will not become conduits for fluid movement that could endanger USDWs [40 CFR 146.92(b); 146.93(e)], and restore the site to pre-operation conditions [40 CFR 146.93(e)].

The goal of the UIC Program's review of the information submitted during the post-injection phase is to verify that the project continues to be protective of USDWs and that, following site closure, the site will not endanger USDWs. Specifically, the UIC Program should confirm that all post-injection phase milestones are met, including proper plugging of the injection and monitoring wells, a demonstration of non-endangerment to USDWs, and closure of the site.

During this phase, the UIC Program will likely receive and evaluate the following types of information:

- Information related to plugging the injection well (see Section 7.1);
- Post-injection site care information, including amendments to the PISC and Site Closure Plan and the results of post-injection testing and monitoring (see Section 7.2);
- AoR reevaluations (see Section 7.3);
- Emergency and Remedial Response Plan amendments or financial responsibility updates (see Section 7.4);
- Information associated with emergency events and associated responses (see Section 7.5);
- A non-endangerment demonstration (see Section 7.6); and
- Site closure notifications and documentation, including information on plugging of the monitoring wells (see Section 7.7).

This section presents recommendations for how the UIC Program can confirm that all required information is generated and submitted, and evaluate this information to ensure that the project continues to be protective of USDWs. Many of the evaluations during this phase are analogous to injection-phase activities (e.g., reviewing testing and monitoring data, AoR reevaluations, and project plan updates), and this section focuses on what is likely to be unique to the post-injection phase. The reader is encouraged to review Section 6 as needed.

Each subsection below describes the types of information owners or operators are anticipated to submit and considerations for reviewing the information (e.g., discussing the information with the owner or operator or requesting clarifying information, if necessary) to verify permit compliance as well as identifying appropriate follow-on actions to ensure USDW protection.

Because each project is unique and the specific information submitted by the owner or operator will vary, the appropriate activities will be specific to the project. Thus, the activities described below outline a recommended course of action to accomplish the goal of evaluating post-injection phase information to ensure that USDWs are protected.

7.1 Injection Well Plugging

Class VI well owners or operators must implement the approved Injection Well Plugging Plan, pursuant to 40 CFR 146.92(b) during the post-injection phase. The timing of well plugging will be site- and project-specific; however, the activities to be performed to plug the well will be the same. Proper plugging of injection wells is necessary to ensure that the wells do not serve as conduits for fluid movement into USDWs following cessation of injection and site closure. See Section 2 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* for additional information on plugging Class VI injection wells.

Completeness

UIC Program activities associated with injection well plugging should include reviewing the following information related to plugging the injection well:

- An amended Injection Well Plugging Plan if any changes have been made to the approved plan [40 CFR 146.92(b)]. The amended plan will likely be of a similar format to the approved plan that is included in the existing Class VI permit (see Section 4.1.8).
- A notice of intent to plug the well, which must be submitted at least 60 days prior to plugging unless a shorter timeframe is approved [40 CFR 146.92(c)].
- A well plugging report, which must be submitted within 60 days of plugging the well [40 CFR 146.92(d)] and that will likely consist of a narrative document, supported by schematics or other images.

Evaluation

The bolded text below outlines a suggested approach for reviewing injection well plugging information. This approach will help to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit, and confirm that the well was plugged in a manner that will prevent USDW endangerment.

Review any amendments to the Injection Well Plugging Plan that the owner or operator submits in advance of plugging activities to ensure that it includes all the required elements at 40 CFR 146.92(b) and addresses the current conditions of the well. The review should focus on any changes to the well or other aspects of the project since the plan was approved. For example, if the owner or operator has become aware of any debris or lost tools that need to be removed, ensure that provisions are included for their removal. Review the calculation of fluid weight proposed for well flushing to ensure that it is based on the most recent downhole data. Review the proposed plugging materials and buffer fluids to be sure they are compatible with the most recent analyses of formation fluids (i.e., based on any chemical changes that may have resulted from interactions between formation fluids and the injectate). Modify the Class VI permit to incorporate the revised Injection Well Plugging Plan. See Section 5.2 for additional information on modifying Class VI permits.

Review the notice of intent to plug the well. Discuss the timing of well plugging with the owner or operator. If witnessing the plugging is necessary or appropriate, assign personnel to witness the plugging and schedule this with the owner or operator.

Review the injection well plugging report, which the owner or operator will submit following plugging activities, to confirm that all actions were completed as described in the approved Injection Well Plugging Plan and in a way that is compliant with the requirements at 40 CFR 146.92. Review records to confirm that tubing and all debris were removed from the well. Confirm that the fluid weight used for plugging operations was calculated using measured bottom-hole pressure. Verify that an MIT was performed and appropriate remedial action was taken to repair the well or cement across any zones where fluid movement did or could occur. Review information about the plugging materials that were used and confirm that they are compatible with downhole conditions and the location of plugs, and that they match the approved plan (or that any divergence from the plan is justified). Review cementing records and any tests performed to verify that appropriate cement strength was obtained.

Note any challenges the owner or operator encountered during plugging and confirm that adequate responses were taken. If it is not clear that the plugs were properly placed and are adequate to prevent fluid migration, additional information or testing may be needed. If testing indicates deficiencies in the plugs or the plugging procedures, confirm that the owner or operator performed remedial action to correct any deficiencies and retested the well.

Converting Injection Wells to Post-Injection Monitoring Wells

The EPA acknowledges that injection wells may be converted to monitoring wells during the PISC phase. If an owner or operator plans to convert the injection well to a monitoring well, the EPA encourages the UIC Program to discuss the conversion process with the owner or operator and consider the following:

- Tubing and debris should be removed and the well should be flushed before monitoring equipment is installed.
- Any remedial actions that may be necessary prior to installation of monitoring equipment, i.e., to address zones of weakness in the cement.
- Whether any packers will need to be replaced or if additional packers will be needed to isolate the zones to be monitored.
- The monitoring equipment to be installed should be capable of providing accurate measurements and collecting the data that are needed throughout the post-injection monitoring period.
- Proper procedures should be in place to confine fluids to the injection zone during the conversion process.

7.2 Reviewing Post-Injection Site Care Information

The primary activities occurring during the post-injection phase will be associated with testing and monitoring to track the carbon dioxide plume and pressure front and demonstrate that the project is in compliance with the permit and the Class VI Rule. During this phase, the UIC Program will likely receive the following information:

- An amended PISC and Site Closure Plan or a demonstration that no amendment to the plan is needed, per 40 CFR 146.93(a)(3); and
- The results of testing and monitoring performed pursuant to the approved PISC and Site Closure Plan and 40 CFR 146.93(a),(b).

Section 3 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* provides detailed information on post-injection site care.

7.2.1 PISC and Site Closure Plan Amendments

Class VI well owners or operators must amend the PISC and Site Closure Plan at the end of the injection phase or demonstrate that no amendment to the plan is needed [40 CFR 146.93(a)(3)]. The owner or operator may also amend the plan at any time during the post-injection phase, pursuant to 40 CFR 146.93(a)(4).

The purpose of the UIC Program's review of the amended PISC and Site Closure Plan is to verify, before post-injection site care begins, that the activities in the plan reflect the most up-to-date understanding of the site. In particular, the review should focus on the most recent AoR delineation modeling, carbon dioxide plume and pressure front behavior, and any additional information needed to support the non-endangerment demonstration (e.g., information on plume trapping). The UIC Program should also work with the owner or operator throughout the review to ensure that the planned post-injection monitoring will generate the data needed to inform a non-endangerment demonstration. See Section 4.1.9 for additional information on evaluating PISC and Site Closure plans.

Completeness

The amended PISC and Site Closure Plan will likely be a narrative document similar in format to the approved plan in the Class VI permit and must include all of the required elements described at 40 CFR 146.93(a). If any aspects of the testing and monitoring strategy have changed, the owner or operator may also submit an updated QASP.

If the owner or operator submits an alternative PISC timeframe demonstration as part of the plan amendment, the UIC Program should verify that the request includes sufficient information on which to base an evaluation, e.g., addressing all of the criteria at 40 CFR 146.93(c).

If any changes to the PISC and Site Closure Plan are needed and either an amended plan was not submitted or the changes were not adequately addressed in the amended plan, the UIC Program should consider requesting that the owner or operator update and resubmit the plan. A justification that no updates to the plan are needed should be a technical demonstration based on site-specific data.

Evaluation

An amended PISC and Site Closure Plan will likely include the same activities that were described in previously approved versions of the plan. As such, the evaluation of any amendments submitted after cessation of injection should focus on any changes necessary to address new information that arose during site operations.

The bolded text below outlines a suggested approach for reviewing PISC and Site Closure Plan amendments. This approach will help to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit, and confirm that PISC activities will ensure that USDWs are protected from endangerment.

Review the predicted post-injection pressure differentials and the position of the carbon dioxide plume and pressure front. Confirm that these predictions, as described in the amended PISC and Site Closure Plan, reflect the most recently modeled predictions of carbon dioxide plume and pressure front behavior (i.e., based on the findings of the most recent AoR reevaluation).

Evaluate any changes to the post-injection monitoring strategy. Verify that the proposed monitoring activities will allow for a comparison of results over time, ideally with monitoring continuing at the same locations/depths/extents and addressing the same analytes as during the injection phase. However, these monitoring activities should also be designed to capture the expected system behavior (as predicted by the AoR delineation modeling) and changes (e.g., monitoring of the carbon dioxide plume at points along its predicted trajectory or monitoring of trapping) during the post-injection phase. If groundwater monitoring during the injection phase identified leaching/mobilization of metals or organics, groundwater contamination, or plume excursions, determine whether analysis of groundwater for additional analytes is needed during post-injection monitoring. If new, more site-suitable testing and monitoring methods have become available, discuss with the owner or operator the merits of incorporating these into the PISC and Site Closure Plan. Any revisions to the fluid sampling/pressure monitoring network or the extent of geophysical surveys should encompass the entire extent of the current, approved AoR. Confirm that the owner or operator has updated the QASP, if necessary, to address new or additional testing and monitoring activities.

The owner or operator may propose reducing the scope or frequency of monitoring activities as the post-injection phase progresses. Any planned reductions should be informed by monitoring results, supported by AoR delineation modeling predictions, and linked to site-specific quantitative criteria. For example, the plan could include provisions for reducing the frequency of pressure monitoring at a location once pressures reach a specified level relative to baseline levels as demonstrated during pre-operational testing.

Review plans to plug the monitoring well(s). Confirm that the planned monitoring well plugging activities and materials remain appropriate based on any recent information about subsurface conditions, particularly the presence of potentially corrosive carbon dioxide-water mixtures.

Evaluate an updated or new alternative PISC timeframe demonstration (if applicable). If the owner or operator proposes an updated or new alternative PISC timeframe as part of the PISC and Site Closure Plan amendment, encourage them to submit information that meets all of the criteria at 40 CFR 146.93(c) to demonstrate that the alternative timeframe is appropriate and protective of USDWs. The evaluation of a proposed alternative PISC timeframe should focus on the results of the current AoR delineation modeling of pressure front and plume migration and immobilization of the plume due to site-specific trapping mechanisms and available monitoring data. Some specific considerations to support a decision that the project will no longer pose an endangerment to USDWs at the end of the post-injection phase include:

- The modeling results should demonstrate system-wide pressure levels and trends (e.g., decline) such that, at the end of the proposed alterative PISC timeframe, the project will no longer pose an endangerment to USDWs;
- The predicted results should demonstrate carbon dioxide plume immobilization by site-specific trapping mechanisms (e.g., structural trapping, capillary trapping, and mineralization) or a migration rate that is declining such that there is no potential for fluid movement into USDWs at the end of the proposed PISC timeframe; and
- All potential conduits within the AoR should be identified, characterized, and addressed and the proposal to revise the timeframe demonstrates that the conduits will not pose an endangerment to USDWs.

Consider meeting with the owner or operator to discuss the information that should be submitted and how best to conduct the analyses needed to demonstrate that an alternative PISC timeframe is appropriate. See Section 4.1.9 for additional information on evaluating proposed alternative PISC timeframes.

Outcomes

Following review and approval of the amended plan, the UIC Program should develop the following information for inclusion in the permit file:

- An updated PISC and Site Closure Plan as an enforceable part of the Class VI permit (if needed);
- A modified Class VI permit that incorporates the amended plan, if needed. See Section 5.2 for additional information on modifying Class VI permits; and
- Documentation of the review to support the permit's administrative record.

7.2.2 Post-Injection Monitoring

After injection has ceased, the owner or operator must implement the PISC and Site Closure Plan, which includes performing monitoring to track the position of the carbon dioxide plume and pressure front and ensure that USDWs are not endangered [40 CFR 146.93(a),(b)]. As noted earlier, post-injection testing and monitoring will likely be an extension of the injection phase testing and monitoring; see Section 6.1 for additional information on reviewing testing and monitoring results.

The purpose of the UIC Program's review of this information is to confirm that the owner or operator is in compliance with the PISC and Site Closure Plan and other permit conditions, or to identify the need for follow-up actions to address any endangerment to USDWs. The UIC Program is encouraged to discuss the results of post-injection testing and monitoring with the owner or operator in the context of an eventual non-endangerment demonstration to confirm that appropriate types and amounts of data are being collected throughout the post-injection phase to support this demonstration.

More information about PISC monitoring requirements and recommendations for meeting those requirements can be found in the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance*.

Completeness

The specific information the owner or operator submits and the timing of reporting will depend on the testing and monitoring provisions of the approved PISC and Site Closure Plan. However, the UIC Program will likely receive the following types of information:

- The results of groundwater quality monitoring (and potentially other above-confining-zone monitoring), including analytical results for each sampling event during the reporting period at each monitoring well;
- Plume and pressure front tracking information, including the results of all required tests/surveys;
- The results of any required MITs or corrosion testing of monitoring wells; and/or

- The results of any other required activities, e.g., surface air/soil gas monitoring and/or passive seismic monitoring.

The results should be accompanied by a synthesis that interprets the results. The report may describe any evidence of fluid migration out of the injection zone and/or into USDWs, compare results to modeled predictions, and identify trends in the context of previous results.

Evaluation

The bolded text below outlines a suggested approach for reviewing post-injection monitoring results. This approach will help to confirm that the owner or operator's submittals meet the requirements of the Class VI Rule and the permit, and confirm that USDWs are not endangered.

Verify that all testing and monitoring was performed as planned, i.e., on schedule using approved methods, equipment, and procedures; that samples were taken at all required locations and depths; and that proper QA protocols were applied. If the information submitted indicates that any tests or measurements were not completed as described in the approved PISC and Site Closure Plan and the QASP, a discussion with the owner or operator and/or a request for repeat or additional testing may be necessary.

Review the testing and monitoring results, including any submitted interpretations of the data. Confirm that:

- The plume and pressure front are tracked as permitted;
- Sufficient data are generated to inform future project decisions;
- The plume and pressure front location are consistent with the predicted behavior; and
- There have been no excursions of carbon dioxide or formation fluids out of the injection zone or any evidence of endangerment to USDWs.

Where applicable, this evaluation can be achieved by comparing the results to baseline data and/or to previous results from the injection and post-injection phases, along with the predictions of the system behavior.

Consider the overall trends in subsurface pressures. In most cases, sustained decreases in fluid pressures will be expected over time during the post-injection phase, unless there are other injection activities operating in the same formation. However, the rate of fluid pressure decline, which depends on the site-specific hydrogeologic properties of the injection zone and overlying formations, may not be steady within particular zones due to heterogeneity in the subsurface. Confirm that pressure measurements represent system-wide behavior and are consistent with the predicted pressure changes during this phase. Identify changes in any trends or deviations from predicted behavior and evaluate whether the results indicate the possibility of carbon dioxide or other fluid migration out of the injection zone, and whether reevaluation of the AoR is needed.

Also consider the trends in the behavior of both the separate-and dissolved-phase carbon dioxide plume. In general, most of the injected carbon dioxide is expected to remain as a separate-phase plume subject to both pressure- and/or buoyancy-driven migration. Confirm that plume monitoring results provide system-wide information (both spatially and temporally) that is consistent with, and complementary to, the AoR delineation modeling predictions. Review information on trapping mechanisms identified via monitoring data and their relevant/quantitative significance in the immobilization of the plume, and confirm that these

observations are consistent with the AoR delineation modeling predictions. Identify any deviations in the monitoring data from the predicted behavior and evaluate whether the results indicate the possibility of fluid migration out of the injection zone or USDW endangerment, and if a reevaluation of the AoR is necessary.

Review the results of other monitoring activities, such as monitoring above the confining zone, surface air/soil gas monitoring, and/or passive seismic monitoring, to confirm confinement of the injected carbon dioxide in the injection zone. Also review the results of periodic mechanical integrity and corrosion testing of the monitoring wells. For additional information on testing and monitoring for Class VI projects, see Section 6.1 and the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance*.

Note whether any anticipated milestones or benchmarks established in the PISC and Site Closure Plan have been reached, as these would support a demonstration of a decreased potential for endangerment to USDWs. Alternatively, if there is not a general trend of pressure decline or other results are not consistent with modeled predictions, discuss with the owner or operator whether additional monitoring or an amendment of the PISC timeframe may be needed. In addition, consider the testing and monitoring results in the context of the non-endangerment demonstration. For example, verify that data collection is tailored to meet any specific non-endangerment criteria established in the PISC and Site Closure Plan.

Based on the results of the review, consider whether the following activities may be appropriate to ensure compliance with the Class VI Rule and any related permit conditions:

- If warranted based on changes in site conditions, request that changes to monitoring frequency, methods, and/or locations or depths be incorporated into an amended PISC and Site Closure Plan.
- Request that the owner or operator reevaluate the AoR if any AoR reevaluation criteria were triggered or to incorporate new information to better predict the actual behavior of the carbon dioxide plume and pressure front.
- If monitoring results suggest the possibility of unintended movement of carbon dioxide or other fluids, or if there is concern that a monitoring well is experiencing degradation or a loss of mechanical integrity, initiate communication with the owner or operator and request additional testing to identify the source of the issue, followed by appropriate actions, such as remediation of monitoring wells or former injection wells.
- If the owner or operator is out of compliance with the Class VI permit, assess the situation, determine if a violation or USDW endangerment occurred, and if necessary, issue a violation (see Section 2.4). Work with the owner or operator to initiate response procedures as described in the Emergency and Remedial Response Plan if results indicate that fluid migration or pressure increases may be endangering USDWs (see Section 7.5).

Outcomes

The EPA recommends that the UIC Program document the review of testing and monitoring results and any follow-up actions taken. Materials that can support a robust permit record and promote consistency and continuity in project-related decision-making include:

- A report that documents the review of all monitoring data, including whether the monitoring was performed in a manner consistent with the approved PISC and Site

Closure Plan, whether the results confirm predictions about the carbon dioxide plume and pressure front, or whether the results indicate any evidence of USDW endangerment; and

- Documentation of any identified deficiencies or concerns and how they were resolved, including whether a revision to the PISC and Site Closure Plan is needed, AoR reevaluation criteria were triggered, or any remedial responses were necessary (and how these were performed and the issue was resolved).

Note also that, following retention of PISC monitoring records (for 10 years following site closure, pursuant to 40 CFR 146.93(h)), the owner or operator must deliver these records to the UIC Program Director. The UIC Program Director must then designate a location for these records to be retained thereafter.

7.3 AoR Reevaluations

Reevaluations of the AoR and reviews of the AoR and Corrective Action Plan will continue throughout the post-injection phase. As in the injection phase, the purpose of the UIC Program's review of information associated with post-injection AoR reevaluations is to verify that predictions of plume and pressure front movement are accurate based on information collected via post-injection testing and monitoring. Reviewing this information is analogous to the injection phase review of AoR reevaluations, but focuses on post-injection phase monitoring results.

The bolded text below outlines a suggested approach for reviewing post-injection phase AoR reevaluations. This approach will help to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit, and ensure that the AoR delineation is based on the most up-to-date information to prevent USDW endangerment.

Review all new and relevant project data generated from monitoring activities to ensure that the information is consistent with the modeling predictions and supports the existing AoR delineation. Reevaluations of the AoR must continue over the duration of the Class VI project, including the post-injection phase, to ensure that the area where USDWs may be endangered is delineated accurately [40 CFR 146.84(e)]. Post-injection phase AoR reevaluations will involve a comparison of newly collected data to the computational predictions that supported the existing, approved AoR delineation, similar to those conducted during the injection phase (as discussed in more detail in Section 6.2).

It is likely that, following cessation of injection, the area of increased pressure will reduce in size as pressures dissipate (unless there are other operations affecting the pressure in the formation); however, the separate-phase plume is expected to continue its migration until trapping mechanisms cause immobilization. The EPA anticipates that it is unlikely the area that may be endangered by the project will increase during the post-injection phase (if the existing AoR delineation was verified with monitoring data during the injection phase). However, in addition to plume movement and pressure changes, post-injection phase reviews of AoR reevaluations will also focus on verifying predicted trapping mechanisms (i.e., the type of trapping mechanism and their relative effects).

For projects where new information confirms and supports the existing AoR, the EPA expects that the owner or operator will submit a demonstration that the current AoR and predictions about plume/pressure front movement adequately represent the system behavior. If any monitoring data or other information about the project indicate a need to update the AoR

delineation and/or amend the AoR and Corrective Action Plan, consider discussing this with the owner or operator.

Review an amended AoR and Corrective Action Plan (if one is submitted). Similar to the corresponding injection phase activities, the focus of reviewing any amendments to the AoR and Corrective Action Plan will be to ensure that the new AoR delineation complies with 40 CFR 146.84 and accounts for all new, relevant project information. In addition to the amended plan, the EPA expects that the owner or operator will submit an analysis of the AoR reevaluation and whether its results warrant a new delineation and/or amendment of the plan. Review the amended plan to confirm that it accounts for the most recent testing and monitoring results or other site- or project-specific information. See Section 6.2 for additional information on AoR reevaluations and reviewing amendments to the AoR and Corrective Action Plan.

7.4 Project Plan Updates

In addition to the AoR and Corrective Action Plan, the owner or operator may update the Emergency and Remedial Response Plan and submit annual updates to the financial responsibility cost estimates and financial instruments in the post-injection phase. The owner or operator may also submit amendments to the Injection Well Plugging Plan or the PISC and Site Closure Plan during this phase; see Sections 7.1 and 7.2.1 for further information on evaluating amendments to these plans.

The UIC Program's evaluation of these amendments and updates should focus on information collected via post-injection testing and monitoring, with the goal of ensuring that USDWs are not endangered, that the project is in compliance with the permit, and that the project is progressing toward meeting the criteria for a non-endangerment demonstration.

The bolded text below outlines a suggested approach for reviewing post-injection phase plan updates. This approach will help to confirm that the owner or operator's submittals meet the requirements of the Class VI Rule and the permit, and confirm that planned activities will protect USDWs from endangerment.

Review any proposed amendments to the Emergency and Remedial Response Plan or the owner or operator's demonstration that no amendment to the plan is needed. This review should be similar in scope to reviews of injection-phase amendments to the plan (see Section 6.3), focusing on the presence of any new resources/infrastructure within the AoR or any updates to response personnel or procedures.

Review any updates to the financial responsibility cost estimates and instruments to ensure that they will cover all required activities, e.g., all remaining post-injection testing and monitoring (considering frequency, spatial coverage, etc.) and site closure. If the injection well has been plugged, release the owner or operator from financial responsibility for injection well plugging activities. Verify that the updated cost estimates reflect inflation or any changes to the project (e.g., related to changes to the size or shape of the AoR). Discuss with the owner or operator whether this may result in increases or decreases in the cost estimates and corresponding changes in the value of the financial responsibility instruments. Note that the requirements for updating or replacing financial responsibility instruments, as described in Section 6.4, continue to apply during this phase of the project.

Following review and approval of the amended plans, **incorporate the amended plans into the Class VI permit** and modify the permit. See Section 5.2 for information on modifying the Class VI permit.

7.5 Emergency and Remedial Response

During the post-injection phase, events requiring an emergency or remedial response may involve excursions of the carbon dioxide plume and pressure front or other fluid movement. (Because the injection well will generally be plugged or converted for monitoring, mechanical integrity losses will be less likely.) The owner or operator must notify the UIC Program Director of any evidence of endangerment to a USDW within 24 hours [40 CFR 146.91(c), 146.94(b)(3)].

As with injection-phase events, the owner or operator's responses to emergency events should be guided by the approved Emergency and Remedial Response Plan and the permit. The UIC Program should discuss any events with the owner or operator to confirm that they have investigated the cause/impact of an event and initiated the appropriate response (if needed). On a project-specific basis, one of the following may be necessary: an AoR reevaluation and amendment to any of the Class VI project plans (see Sections 7.2.1 and 7.4); or an enforcement action if the event caused or was the result of a violation and impacted the integrity of the well and/or resulted in USDW endangerment (see Section 2.4).

The EPA encourages the UIC Program to communicate often with the owner or operator during these types of events to ensure that identified remedial actions are being taken and that they are successful in addressing the event. Additionally, communicating with/providing outreach to stakeholders and the public about the event and any impacts may be appropriate. For additional information, see Section 6.5.2.

7.6 Non-Endangerment Demonstrations

Before the owner or operator can be authorized to perform site closure activities, they must submit a demonstration, based on monitoring and other site-specific data, that the Class VI project does not pose an endangerment to USDWs [40 CFR 146.93(b)(3)]. Pursuant to 40 CFR 146.93(b)(2), the owner or operator may submit this demonstration before the end of the 50-year PISC timeframe or the end of an approved alternative PISC timeframe. Owners or operators may do this regardless of whether an alternative PISC timeframe is in place. Additional information on non-endangerment demonstrations is available in Section 3.4 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care and Site Closure Guidance*.

The purpose of the UIC Program's review of the non-endangerment demonstration is to confirm, based on all available monitoring and other site-specific data, that no additional monitoring is needed to ensure that the project does not pose an endangerment to USDWs.

Completeness

The non-endangerment demonstration should reference or summarize all relevant monitoring data—including trends and interpretations—on which the demonstration is based. It should also include a discussion of modeling results (e.g., following the last AoR reevaluation) and any other information necessary to assess, confirm, and validate the owner or operator's analysis. The demonstration should also present information to confirm that there are no conduits for fluid movement.

The UIC Program should verify that the data on which the non-endangerment demonstration was based reflect all relevant testing and monitoring results throughout the injection and post-injection phases to provide an accurate representation of current subsurface conditions and trends over time.

Evaluation

The bolded and italicized text below outlines a suggested approach for reviewing non-endangerment demonstrations. This approach will help to confirm that the owner or operator's submittal meets the requirements of the Class VI Rule and the permit, and confirm that there is no endangerment to USDWs from the carbon dioxide plume and pressure front.

Review groundwater monitoring data to verify that there is no USDW contamination that may be attributed to the Class VI project and that there is no evidence of fluid mobilization as a result of injection or interactions between the injectate and formation fluids. Verify that data from monitoring wells completed above the primary confining zone, within any USDWs that were monitored, or in the vicinity of any known leakage pathways demonstrate favorable trends in observed geochemical monitoring results. Compare recent data with baseline geochemical data and trends in monitoring data through the duration of the project, taking into account anything known about natural variability and surface influences.

Verify that the carbon dioxide plume and pressure front are behaving as predicted and that pressures within the subsurface are dissipating. Information about the movement of the carbon dioxide plume and dissipation of the pressure front should be based on a combination of in situ injection zone measurements, the results of geophysical surveys and/or other indirect monitoring techniques, and computational modeling results.

- Examine ***data from in situ pressure monitoring*** and/or any other indirect monitoring to determine whether pressures have declined to a level such that they no longer pose an endangerment to USDWs (e.g., to pre-operation conditions) and they are consistent (both spatially and temporally) with the approved AoR delineation modeling results. In cases where elevated pressures are sustained (e.g., if other operations are affecting pressures in the formation), review the pressure levels in light of their potential to drive fluids into unauthorized formations and the presence of potential conduits in the area affected by the injection (e.g., the AoR, if it is reevaluated and/or verified by the monitoring data).
- Evaluate ***plume monitoring results*****,** including direct measurements in the injection zone using monitoring wells combined with any geophysical survey results, to ensure that the separate-phase carbon dioxide is migrating as predicted (both laterally and vertically) and verify the trapping mechanisms (e.g., structural trapping, capillary trapping, and mineralization) and their effects (e.g., the estimated trapped fraction of the carbon dioxide). If the plume is predicted to continue migrating at a slow rate (i.e., it would take a significantly long period—on the order of thousands of years—for the plume to reach a potential receptor), confirm the predicted/estimated migration rate and verify that there are no other potential receptors along the plume trajectory.
- Review the results of the most recent ***AoR delineation modeling*** (e.g., AoR reevaluation). If any new computational modeling activities were conducted specifically for the non-endangerment demonstration, evaluate these efforts in a manner similar to that used to review AoR reevaluations during the injection phase (see Section 6.2).

While the owner or operator need not demonstrate that the plume has completely stopped moving, the non-endangerment demonstration should provide evidence, based on monitoring data, that the plume and pressure front are behaving as predicted and they will not pose any endangerment to USDWs and, therefore, no further monitoring is needed.

Confirm that there are no potential conduits for fluid movement in the vicinity of the project (e.g., active and abandoned wells, faults, or fractures). Verify that the analyses conducted to identify potential conduits (e.g., aeromagnetic surveys or records reviews) encompassed the maximum extent of the carbon dioxide plume and pressure front. Where conduits were identified, confirm that the owner or operator has demonstrated that none pose an endangerment to a USDW based on plugging records or MITs, assessments that faults or fractures are not transmissive to USDWs, or distance to USDWs.

Discuss the results of the evaluation with the owner or operator. Based on the review of the non-endangerment demonstration, three outcomes are possible (see Figure 7-1):

1. The non-endangerment demonstration supports a determination that the plume and pressure front no longer pose an endangerment to USDWs and additional monitoring is not needed. See Section 7.7 for more information on site closure.
2. Additional sampling data, more robust modeling, or additional analysis of results is needed to support a stronger demonstration of non-endangerment. If this outcome is indicated (and sufficient data exist at this point in the post-injection phase), work with the owner or operator to identify these needs and update the non-endangerment demonstration accordingly.

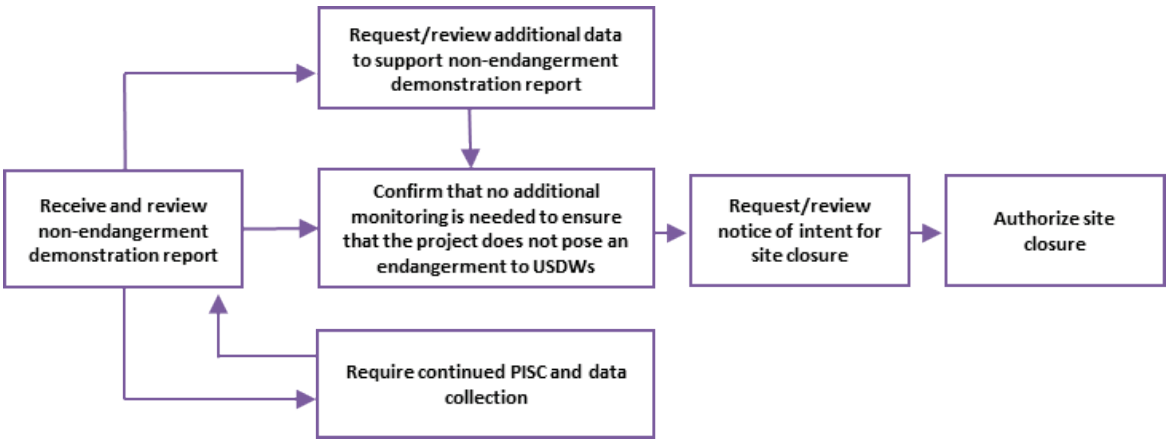

Figure 7-1: Reviewing Non-Endangerment Demonstrations

3. Monitoring or modeling data indicate that the carbon dioxide plume and pressure front continue to pose a potential endangerment to USDWs. If this outcome is indicated, request that the owner or operator continue to perform post-injection monitoring. If necessary to ensure protection, a UIC Program Director may require monitoring to continue beyond the previously established PISC timeframe [40 CFR 146.93(b)(4)]. If appropriate, consider asking the owner or operator to amend the PISC and Site Closure Plan, e.g., to modify the monitoring strategy, including increasing or decreasing the frequency at which monitoring is performed and results are submitted. Modify the Class VI permit if needed (see Section 5.2).

Outcomes

The EPA encourages the UIC Program to prepare the following materials to document the review of the non-endangerment demonstration and the outcome of the evaluation:

- A report that describes the information reviewed; and
- Documentation regarding whether:
    - The non-endangerment demonstration complies with the requirements under 40 CFR 146.93 and established permit conditions;
    - The UIC Program Director approves the non-endangerment demonstration;
    - Any additional actions, monitoring, or modeling are required of the owner or operator to protect USDWs from endangerment; and
    - The owner or operator may proceed to closing the site pursuant to 40 CFR 146.93(e).

7.7 Site Closure

After non-endangerment has been demonstrated and approved by the UIC Program Director, a final site closure process is initiated pursuant to 40 CFR 146.93(d) and (e). During this process, the owner or operator submits a notice of intent to close the site for review and approval by the UIC Program Director. Following approval, the owner or operator closes the site as described in the approved PISC and Site Closure Plan and submits a site closure report to the UIC Program Director (see Figure 7-1).

Proper site closure is necessary to ensure that all monitoring wells are plugged appropriately to prevent them from serving as conduits for fluid migration and to restore the Class VI project site for other uses. The documentation associated with site closure is needed to ensure that future land owners and planners will be made aware that carbon dioxide is stored in the subsurface and help authorities impose appropriate conditions on subsequent drilling activities that may penetrate the injection or confining zone(s).

Completeness

During the post-injection phase, Class VI well owners or operators will submit a notice of intent for site closure and a site closure report to the UIC Program Director. Site closure notifications must be submitted at least 120 days prior to closure unless the UIC Program Director allows for a shorter notice period [40 CFR 146.93(d)]. The site closure notification will likely be a letter that includes information about the facility, contact information for site personnel, and the projected site closure date. At the time of the notification, the owner or operator must also provide an amended PISC and Site Closure Plan if any changes have been made to the approved plan [40 CFR 146.93(d)].

Owners or operators must submit a site closure report within 90 days of site closure [40 CFR 146.93(f)]. The report will describe the pre-plugging activities and the plugging procedures performed on all monitoring wells. It should also contain a copy of a survey plat that was submitted to the local zoning authority and document other required notifications to state, local, and tribal authorities.

Evaluation

The bolded text below outlines a suggested approach for reviewing information related to site closure. This approach will help to confirm that the owner or operator's submittals meet the requirements of the Class VI Rule and the permit, and confirm prevention of USDW endangerment.

Review the notice of intent for site closure. Consult with the owner or operator prior to the actual closure of the site so that a general understanding of the process is clear to everyone involved. Verify that all site closure activities will be completed by the closure date. If witnessing of monitoring well plugging or other closure activities is necessary, assign the appropriate personnel to witness the activities and schedule this with the owner or operator.

If the owner or operator submits amendments to the PISC and Site Closure Plan, review the information provided to ensure that the owner or operator plans to close the site in a manner that meets the requirements of 40 CFR 146.93. See Sections 4.1.9 and 7.2.1 for additional information on evaluating the PISC and Site Closure Plan.

If the injection well was converted to a monitoring well, ensure that the owner or operator will plug the well in the manner described in the approved Injection Well Plugging Plan [40 CFR 146.92].

Authorize the owner or operator to proceed with site closure after confirming that the notice of intent for site closure addresses any outstanding questions and that the owner or operator will proceed in a manner pursuant to 40 CFR 146.93(e) and the conditions of the Class VI permit.

Review the site closure report to verify that all activities were conducted according to the procedures described in the approved PISC and Site Closure Plan. Specifically:

- Verify that all monitoring wells were properly plugged as described in the approved plan.
- Review the results of any MITs performed on the monitoring wells prior to their plugging and confirm that appropriate remedial measures were taken to address any problems that were identified.

- Verify that tubing, other equipment, and debris were removed from the monitoring wells prior to plugging.
- Confirm that plugs are located as described in the PISC and Site Closure Plan and emplaced to prevent fluid migration between formations.
- Ensure that cement used for plugging is compatible with formation fluids and with carbon dioxide or carbon dioxide-water mixtures if the monitoring well penetrates the injection zone.
- Evaluate whether proper cement setting times were allowed and proper cement strength was obtained. If any monitoring wells were not properly plugged, request that the owner or operator perform remedial measures and/or retest the well.
- Confirm that the site was restored as described in the approved PISC and Site Closure Plan.
- Verify that all equipment slated for removal was removed and that any pits used for drilling have been properly filled.
- Confirm that vegetation has been replanted and any landscaping described in the plan has been accomplished.

Verify that the owner or operator performed all site closure-related notifications required at 40 CFR 146.93(f) and (g).

- Confirm that the required plat of the injection site was included in the site closure report and submitted to the appropriate land zoning authority.
- Verify that the location of the injection well is correctly indicated on the plat; the locations of the monitoring wells may also be helpful. Be sure that locations are documented with respect to permanently surveyed benchmarks.
- Verify that the owner or operator notified all appropriate state, local, tribal, and territorial agencies with authority over drilling activities, and that the notification included all of the information required at 40 CFR 146.93(f). This required information includes the location of the well, the nature of the injection activities, information about the carbon dioxide stream, and recent maps of the carbon dioxide plume position.
- Verify that the owner or operator recorded a notation on the deed to the facility property, and any other documents normally reviewed during a title search, that the site was used for injection of carbon dioxide. If any of the notifications required at 40 CFR 146.93(g) were not provided, request that the owner or operator complete and submit them to the appropriate parties and provide a copy to the Class VI permitting authority.

Confirm that the owner or operator is aware of their recordkeeping responsibilities. Many records must be retained for ten years following site closure [40 CFR 146.91(f)]. These include:

- Data collected to support the permit application;
- Data on the nature and composition of all injected fluids; and

- Well plugging reports, post-injection site care data (including, if appropriate, data and information used to develop the demonstration of the alternative PISC timeframe), and the site closure report.

If appropriate, require the owner or operator to deliver the records to the UIC Program Director at the conclusion of the retention period [40 CFR 146.91(f)(2)] or retain records for longer than 10 years after site closure [40 CFR 146.91(f)(5)].

Release the owner or operator from remaining financial responsibility after all site closure activities have been completed. Inform the owner or operator that, while they have been released from regulatory compliance and the Class VI permit, they are still responsible for any remedial actions necessary if USDWs should become endangered as a result of the injection activity. The owner or operator may also be liable to lawsuits and remedies under RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). See Section 4 of the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* for additional information.

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Appendix A

The Geologic Sequestration Data Tool

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The GSDT

Storage and Access to Class VI Project Data

The GSDT supports the collection, preservation, and evaluation of project-related information and the development of an administrative record for each Class VI permit. The flow and use of information in the GSDT is outlined below:

- Permit applicants/owners or operators use topic-specific **reporting modules** to upload and submit information (see "Permit Applicant/Owner or Operator Reporting Modules" below). Reporting modules are launched from a centralized **operator landing page**.
- Information submitted by the applicant/owner or operator is saved in read-only format in the **administrative record area** of the GSDT. In compliance with the EPA's Cross-Media Electronic Reporting Regulation (CROMERR), users cannot modify these original, time-stamped files.
- Each time information related to a Class VI project is submitted, designated users receive an **automatic email alert**, which includes a PDF that summarizes the contents of the submittal and provides links to the location where the submitted information is stored. The PDF summary also highlights any information that has changed since the last submission.
- The permit writer and other members of the permitting authority team can access copies of the submitted files, save them to the **permit package area** of the GSDT, and collaboratively edit them as needed during the course of evaluating submittals (e.g., to annotate with questions, copy text to create reports, or add permit numbers to project plans). They can also launch the reporting modules directly to help them see the context of the original submittals.
- The permitting authority can request additional information, ask clarifying questions, or initiate other formal communications with the permittee via the **Information Request module**. The module facilitates the transmittal of information requests from the permitting authority to the permit applicant/owner or operator and the submission of responses. Because the communications take place within the GSDT, all requests and responses are automatically retained for inclusion in the permit's administrative record.
- The permitting authority can use the GSDT to organize the **administrative record** for the permit by saving files in the designated area. Any file associated with a project can be included, including original submittals, correspondence with the applicant/owner or operator, UIC Program Director-generated reports, and elements of the permit package.
- When a project milestone is reached (e.g., issuance of a permit), the permit writer can **change the project phase** (e.g., from the pre-construction phase to the pre-operation phase). The GSDT then generates a new area within the project's file structure to facilitate collection and review of information associated with the next project phase.
- The GSDT's **resource library** contains various tools, templates, guidance documents, and other materials that can be used to support the permitting authority's activities through the duration of a Class VI project.

The GSDT allows for project-specific access control to ensure the integrity of information in the GSDT while allowing for information sharing among permitting authorities. By default, registered permitting authority users will have read-only access to all materials (across all projects) to facilitate transparency and information sharing. Users can be granted higher levels of access on a project-by-project basis, if they need to create or edit materials for those projects. In contrast, permit applicant/owner or operator users can only access materials that they have submitted and information requests sent to them by their permitting authority.

GSDT Permitting Authority Capabilities

Permitting authority users access the GSDT via a set of web-based dashboards, which provide users with flexibility to manage work on their assigned Class VI projects. These include user dashboards (which allow individual users to manage work and navigate the site) and project dashboards (to manage information related to each Class VI project).

Permitting authority users seeking access to the GSDT should send an email to GSDataTool@epa.gov or request an account at https://epa.velo.pnnl.gov/gs3/ to begin the registration process. Figure A-1 illustrates the GSDT capabilities and resources available to permitting authorities relative to those available to permit applicants/owners and operators.

Permitting Authority Dashboards

Upon logging onto the GSDT, permitting authority users arrive at their user dashboard, which serves as a personalized landing page. The dashboard helps users navigate throughout the GSDT and keep track of relevant information. It provides links to useful information and pages, including:

- The Class VI projects (and associated files) to which the user has been invited (e.g., as a permit writer/project manager or team member) and pending invitations to additional projects.
- Recently edited documents or other materials chosen as "favorites," for easy access to frequently viewed items.
- The overall file structure for the GSDT, with read-only access to all projects.
- User account settings (for changing a password, etc.).
- A resource library (for user documentation, templates, etc.).
- The owner or operator landing page, so that permitting authority users can launch the reporting modules.

Additional capabilities available to permitting authority users include task assignment/ management and support for computational evaluation tools.

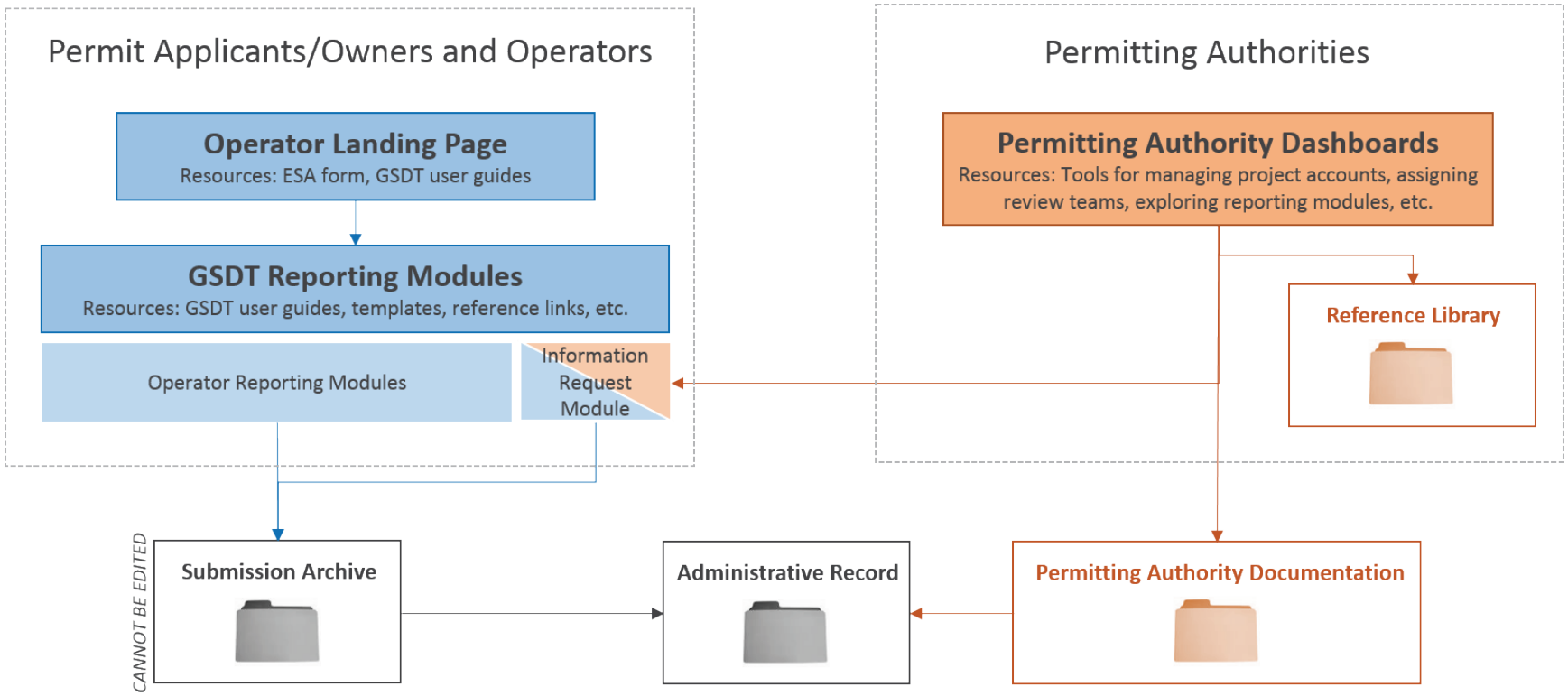

Figure A-1: Schematic of GSDT Capabilities and Resources for Permit Applicants/Owners or Operators and Permitting Authorities

Project Dashboards

The GSDT is designed so that each Class VI project has its own dashboard. Project dashboards are created automatically in the GSDT when a new project is created. These dashboards serve as centralized landing pages for each project.

Project dashboards allow easy access to all information and activities related to the project, including:

- The project file structure, which includes both permit applicant/owner or operator submissions and files created or added by the permitting authority team.
- A list of project team members and their roles.
- A summary of recent project updates, such as new content, new users, etc.
- Special capabilities for project manager (permit writer) users, such as project milestone tracking.

For additional information on navigating the dashboards and using the GSDT, see the GSDT user guides for permitting authorities.

Permit Applicant/Owner or Operator Reporting Modules

To facilitate the efficient submittal of required information, permit applicants/owners or operators interact with the GSDT via a set of reporting modules that reflect the Class VI Rule requirements. Permit applicants/owners or operators access the modules through a centralized operator landing page.

The GSDT provides the following capabilities to facilitate use of the modules and support compliance with the Class VI Rule:

- The reporting modules consist of structured electronic forms that reflect the Class VI Rule requirements. Within the modules, applicants/owners or operators provide information via a combination of selections (with check boxes, radio buttons, drop-down menus, etc.), direct entry into text fields, and file uploads.
- Some modules contain templates (e.g., for the various Class VI project plans) to help users ensure that they have included all the necessary information to fulfill the Class VI Rule requirements while providing flexibility to tailor submissions to their project.
- Each reporting module has a user guide that describes the specific technical procedures necessary to populate and submit data. These user guides can be downloaded from within the modules and be accessed from the operator landing page of the GSDT.
- Most modules are designed to be used during multiple Class VI project phases. This allows owners or operators to return to modules that they have already populated and provide updated information when necessary, while avoiding the need for duplicative submissions.

See the *UIC Program Class VI Well Recordkeeping, Reporting, and Data Management Guidance for Owners and Operators* for additional information on use of the GSDT by permit applicants and permittees. That guidance describes electronic reporting in the context of the Class VI Program, the key components and capabilities of the owner or operator modules of the GSDT, and how permit applicants can register to use and access the GSDT. Step-by-step instructions for using each module can be found in the GSDT user guides.

Appendix B

Useful Websites

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Useful Websites

The websites below provide tools and information that can support the UIC Program Director in reviewing permit applicant/owner or operator submittals or performing activities associated with developing a Class VI permit or supporting documents as part of a Class VI permit record. Some of the sites below are also referenced in the UIC Program guidance documents for owners or operators.

EPA UIC Program Websites

The EPA's GS Guidance page includes all of the draft and final technical guidance documents for implementing the Class VI Rule. See https://www.epa.gov/uic/class-vi-guidance-documents.

The GSDT can be accessed at https://epa.velo.pnnl.gov/.

A list of Regional UIC contacts and links to state UIC contacts is available on the EPA's UIC page at https://www.epa.gov/uic.

Information on plugging monitoring wells is provided in the *UIC Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance* and the EPA Region V's "Guidance on Plugging and Abandoning Injection Wells," which is available at https://www.epa.gov/sites/production/files/2015-09/documents/r5-deepwell-guidance4-plugging-abandoning-injection-wells-19941222.pdf.

The EPA's financial responsibility resources are available at http://www.epa.gov/uic/financial-responsibilities-underground-injection-well-owners-or-operators.

Other EPA Websites

Information about water systems is available on the EPA's Safe Drinking Water Information System (SDWIS) at http://www.epa.gov/enviro/facts/sdwis/search.html.

Information on reporting under subpart RR of the Greenhouse Gas Reporting Program is available at https://www.epa.gov/ghgreporting.

Information and guidance related to EJ, including the EPA's environmental justice screening and mapping tool are available at https://www.epa.gov/environmentaljustice.

The EPA's Drinking Water Mapping Application to Protect Source Waters (DWMAPS), an online mapping tool to support updating of state source water assessments and protection plans, is available at https://www.epa.gov/sourcewaterprotection/dwmaps.

The EPA public involvement policy and public involvement web pages provide resources designed to assist in addressing community issues. See https://www.epa.gov/international-cooperation/public-participation-guide.

An index of EPA-approved laboratory methods can be found at https://www.epa.gov/dwanalyticalmethods.

A listing of state laboratory certification programs is available on the EPA's website at http://water.epa.gov/scitech/drinkingwater/labcert/statecertification.cfm.

U.S. Department of Energy Websites

DOE's Office of Fossil Energy provides news and information about research related to Carbon Capture and Storage (CCS) and best practices documents. Information is available at http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research.

Information on the TOUGHREACT reactive transport model is available from the Lawrence Berkeley National Laboratory at http://esd.lbl.gov/TOUGHREACT/.

Information on STOMP is available from the Pacific Northwest National Laboratory at http://stomp.pnnl.gov/.

The National Risk Assessment Partnership (NRAP) develops risk assessment tools for geologic sequestration. Information about NRAP and its resources is available at https://www.netl.doe.gov/research/coal/crosscutting/national-risk-assessment-partnership.

U.S. Geological Survey Websites

USGS maintains a variety of tools that can support reviews of geologic information in Class VI permit applications and injection depth waiver applications. Some examples include:

- The USGS Earthquake Hazards Program database, available at http://earthquake.usgs.gov/hazards/qfaults/.
- Groundwater information including groundwater use, aquifers, and water quality data, available at http://water.usgs.gov/ogw/data.html.
- USGS's Hydrologic Investigations Atlas Series, available at http://pubs.usgs.gov/ha/ha730.
- Data on water use by county is available at http://water.usgs.gov/watuse/.
- The Land Cover Institute databases of land use are available at http://landcover.usgs.gov/urban/intro.php.