Observations on Class VI Permitting: Lessons Learned and Guidance Available

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Front cover: *Aerial image of Illinois agriculture infrastructure. Photograph by Joel Dexter, 2006.*

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EXECUTIVE SUMMARY

The Midwest Geological Sequestration Consortium, one of the U.S. Department of Energy's seven original Regional Carbon Sequestration Partnerships, partnered with the Archer Daniels Midland Company (ADM) and Schlumberger Carbon Services to conduct the Illinois Basin – Decatur Project (IBDP) for large-scale deep saline geologic storage of one million tons of carbon dioxide (CO_2). The IBDP was conducted at the ADM plant location in Decatur, Illinois. In addition, ADM conducts the Industrial Carbon Capture and Storage (ICCS) Project administered by the U.S. Department of Energy's Office of Fossil Energy and managed by the National Energy Technology Laboratory. The ICCS project is designed to demonstrate carbon capture and storage (CCS) at an industrial-scale facility by injecting one million tons of CO_2 annually (3,000 tons/day). The ICCS and IBDP obtained the only two Class VI permits issued to date for wells operated under the U.S. Environmental Protection Agency (USEPA) Class VI Underground Injection Control Program. The IBDP injection well was initially constructed with a Class I permit issued by the Illinois Environmental Protection Agency before the USEPA promulgated the Class VI Program. The Class I permit was then converted to a Class VI permit issued by the USEPA only after CO_2 injection had ceased. Accordingly, the Class VI permit (ADM well CCS 1) addresses only post-injection site care and site closure. This report highlights some of the important lessons learned through the permit application and issuance process for these Class VI permits as well as the four Class VI permits issued to the FutureGen 2.0 project for wells that were not constructed.

Since the USEPA promulgated the Class VI Underground Injection Control Program regulations for wells injecting CO_2 for geologic sequestration (or storage) (GS), two permits have been issued for wells that were constructed or converted, four more were issued for wells that were not constructed, and four other applications were started but not completed. All these permitting experiences from the Midwest Geological Sequestration Consortium region have yielded lessons for both the applicants and the permit reviewers and provide valuable insights for future Class VI permit applicants. Additional insights are available from the Class VI guidance documents that have been issued by the USEPA, as listed in Appendix A of this report, and from the Best Practices Manuals developed by the National Energy Technology Laboratory. Some of those are also discussed in this report.

The starting point for permitting a GS (or storage) project is the same as the starting point for designing the GS project, namely, determining the nature of the project, its objectives, and its design. A straightforward GS project aimed solely at storage of CO_2 will seek to optimize the use of supporting technologies and methodologies to achieve maximum storage with efficiency and cost-effectiveness rather than seeking to demonstrate the capabilities of a variety of testing and monitoring techniques. Projects that are truly experimental rather than commercial might still be able to obtain a Class V permit, although demonstrating that a project meets the criteria means unique experimental objectives and the inappropriateness of the Class VI requirements. It will also mean showing appropriate financial responsibility. In other cases, the USEPA should be able to scale permitting requirements to fit the size of a demonstration project.

Developing a permitting strategy and pathway requires a project management strategy that addresses CO_2 sources, volumes, rates of delivery, and desired injection rates. Meeting the storage requirements then involves identifying and characterizing sites that meet the applicable criteria and can be permitted. To be effective and efficient in obtaining a permit, it is extremely important for applicants to open communication with the permitting agency in the process of planning and developing a GS project. It is also important to maintain effective communication with the permit application reviewers throughout the permitting process. When requests for additional information are received, an applicant should assess what is requested, develop a plan for responding, and then confirm by communicating with the application reviewers that the planned response satisfies their needs.

In addition, developing and implementing an effective public engagement plan is extremely important regardless of whether any adverse public reactions are anticipated. The public that will potentially be affected should learn about a project from the project developers before hearing about it from regulators or other sources.

In the application process, it is important to reach a shared technical understanding between the applicant and reviewer on foundational information, such as geology, before proceeding to more detailed analyses and computational modeling exercises that might need to be repeated if issues remain to be resolved on the acceptability of input data and information. It is also important to maintain the focus of submitted demonstrations on what is required, thus simplifying the analyses to avoid extraneous material that will require review without contributing substantively to meeting requirements. Submitting drafts for review before formal filings can assist.

The USEPA has created the GS Data Tool (GSDT) for compliance with the electronic reporting requirements of the Class VI regulations and to assist in compiling the requisite administrative record during the application process. To be effective, applicants need to know how to make appropriate use of the GSDT without allowing it to interfere with effective communication between the applicant and reviewer.

Site characterization to comply with the regulatory requirements has two stages. These stages coincide with a two-step process for permitting that involves first, construction of the injection wells and second, operation of the wells once constructed and tested in the context of a verified site characterization. Recognizing that this two-step process will be necessary, it makes sense to plan the acquisition of additional data and information in a way that optimizes use of the two steps.

With sufficient information in hand to prepare a comprehensive threshold site characterization, the project developer will be prepared to proceed with submitting application materials sufficient to obtain a Class VI permit to drill and construct the

injection well. The preconstruction application data and information will need to be sufficient to support a permit to construct the well, but these can be supplemented with the data and information collected through the postconstruction logging and testing program. The delineation of an area of review (AoR) is a core requirement that defines the framework for many other parts of the permitting process. Applicants should discuss AoR delineation data files and formats and what information will be submitted with the permit application reviewer to be sure that these will be submitted in a manner that facilitates use and review.

Financial responsibility is another critically important part of the permitting process, and the costs to be covered by the estimates are very specifically enumerated in the regulations by reference to particular subsections. The USEPA has recognized that the covered plans and the resultant cost estimates should be developed using risk assessments and risk management plans. Although worst-case scenarios may be involved, the development of costs can weigh whether the likelihood of the event is high, medium, or low and scale response actions accordingly.

Once well construction is approved, the process will include preoperational formation testing and logging to obtain an analysis of the chemical and physical characteristics of the affected formations. Given the importance of planning properly to obtain all the information that may be needed by the permit application reviewer, it is very important to review the details of the formation testing and well logging program and procedures with the permitting authority prior to execution. Once construction and testing are completed, it may be necessary to update the information used for site characterization and AoR delineation. If substantial adjustments are made, another round of permit modification and review may also be necessary. Alternatively, a permitting process that transparently adopts an approach of delineating the AoR and establishing permit conditions that allow for uncertainties and successfully accommodate updated information and data (including new computational modeling) without requiring revisions to provide sufficient protection of underground sources of drinking water (USDWs) from endangerment should not result in a new round of administrative and public review to make major modifications.

Testing and monitoring during and after injection operations play a crucial role in Class VI compliance. An applicant should develop a plan that presents a strategy for implementing a testing and monitoring program that will achieve the two-pronged requirement to (1) verify operation as permitted and (2) protect USDWs. The testing and monitoring plan should identify measurement methods that will be sensitive enough to detect whether any identified unacceptable event is occurring or will occur and what actions should be taken in response. And the first response could be to trigger the implementation of additional monitoring, measurements, and analysis. Although the Class VI regulations actually require that an applicant provide a different testing and monitoring plan for each individual well in a multiwell project, it makes far more sense to develop project-wide plans for all aspects of a multiwell project.

INTRODUCTION

The Midwest Geological Sequestration Consortium, one of the U.S. Department of Energy's (DOE's) seven original Regional Carbon Sequestration Partnerships, partnered with the Archer Daniels Midland Company (ADM) and Schlumberger Carbon Services to conduct the Illinois Basin – Decatur Project (IBDP) for large-scale deep saline geologic storage of one million tons of carbon dioxide (CO_2). The IBDP was conducted at the ADM plant location in Decatur, Illinois. In addition, ADM conducts the Industrial Carbon Capture and Storage (ICCS) Project administered by the DOE's Office of Fossil Energy and managed by the National Energy Technology Laboratory (NETL). The ICCS project is designed to demonstrate carbon capture and storage (CCS) at an industrial-scale facility by injecting one million tons of CO_2 annually (3,000 tons/day). The ICCS and IBDP obtained the only two Class VI permits issued to date for wells operated under the U.S. Environmental Protection Agency (USEPA) Class VI Underground Injection Control (UIC) Program. The IBDP injection well was initially constructed with a Class I permit issued by the Illinois Environmental Protection Agency before the USEPA promulgated the Class VI Program. The Class I permit was then converted to a Class VI permit issued by the USEPA only after CO_2 injection had ceased. Accordingly, the Class VI permit (ADM well CCS 1) addresses only post-injection site care and site closure.

This report highlights some of the important lessons learned through the permit application and issuance process for these Class VI permits as well as the four Class VI permits issued to the FutureGen 2.0 project for wells that were not constructed. The report also draws on lessons learned from the uncompleted permit application processes for the Wellington/Berexco geologic sequestration (GS) project, the Tenaska Taylorville CCS project, and the Kevin Dome project of the Big Sky Carbon Sequestration Regional Partnership. The lessons learned by the permit applicants as well as the permit application reviewers and permit writers reflect the novelty of GS permitting under the Class VI regulations promulgated in December 2010 and the parallel challenges of developing, applying, and complying with the policies and procedures necessary to implement those regulations. Lessons learned can assist future applicants and the permit issuer to understand what is necessary and sufficient to comply with the requirements. The lessons also show how early discussions between applicants and reviewers can start permitting on the right track and how communications throughout the permitting process can avoid misunderstandings and unnecessary delays.

The report addresses the extensive guidance developed by the USEPA for the Class VI Program to assist UIC Program Directors in implementing the Class VI Program and Class VI project developers in complying with the Class VI regulations. The Class VI guidance documents address site characterization, area of review (AoR) delineation, corrective action, well design and construction, testing and monitoring, well plugging and site closure, reporting, financial responsibility, program implementation, and program primacy. Reference is also provided to the Best Practices Manuals (BPMs) initially developed by the NETL and the Regional Carbon Sequestration Partnerships in 2013, based on experience implementing the Characterization Phase and small-scale Validation Phase field projects. These manuals were then revised in 2017 to reflect lessons learned in the large-scale Development Phase field projects. The BPMs focus on essential activities common to CCS projects, including site selection and characterization, monitoring, modeling, risk assessment, field operations, and public outreach and education.

Since the USEPA promulgated the Class VI UIC Program regulations[1] for wells injecting CO_2 for GS (or storage), only six Class VI permits have been issued—all by USEPA Region 5 for projects in Illinois. Four permits issued to the FutureGen 2.0 project were never used because that project was defunded by the DOE before the wells could be drilled and constructed. The other two permits were issued to ADM for two projects being conducted at its ethanol manufacturing facility in Decatur, Illinois.[2] The CCS 1 well, in conjunction with the IBDP, originally held an Illinois EPA Class I UIC permit, which was later converted to a USEPA Class VI permit covering the post-injection site care period. From the time the first permit application for the CCS 2 well was filed on July 27, 2011, almost 3 years passed until a draft permit was issued on April 15, 2014. After a public comment period, the permit was issued on September 23, 2014, and was appealed before the final permit to drill a well was issued in December 2014. After the well was drilled and postconstruction logging and testing were conducted, modification of the permit became necessary before an authorization to inject could be issued in April 2017. The permitting process from the time of initial application to authorization to inject took almost 6 years. During that time, the USEPA was developing guidance documents for the Class VI Program and establishing a process for the review of permit applications.

After issuance of the first Class VI permits by USEPA Region 5, another application was filed with USEPA Region 7 by Berexco and processed to near completion.[3] These two experiences yielded lessons for both the applicants and the permit reviewers and provide valuable insights for future Class VI permit applicants. Additional insights are available from the Class VI guidance documents that have been issued by the USEPA, as listed in Appendix A of this report. Some of those are discussed in this report.

A word of explanation about the role of USEPA guidance documents: As noted by the USEPA itself, the Class VI guidance documents that have been developed and published by the USEPA do not impose additional requirements beyond those contained in the Safe Drinking Water Act (SDWA) and the UIC regulations. These guidance documents are intended solely "to provide information and suggestions that may be helpful for [UIC Class VI Program] implementation efforts."[4] Furthermore, although USEPA regional offices with direct implementation authority for Class VI permitting are bound to follow the guidance, state agencies with Class VI primacy are not bound to follow the guidance and have greater flexibility to implement the binding regulatory requirements in ways that depart from the USEPA guidance.

For reference, the Class VI permit application, review, and issuance process is outlined in Appendix B along with a list of the final permit papers that have been issued for the six Class VI permits granted to date. The discussion that follows is intended to provide some insights into the process of designing and developing a Class VI GS project, preparing a permit application, and navigating the application process to the point of obtaining an authorization to inject CO_2 streams into a Class VI well. It is not intended to be a comprehensive explanation of everything needed to comply with the Class VI regulatory requirements or to provide the type of comprehensive supplementation available through the USEPA guidance listed in Appendix A, all of which should be consulted by any Class VI permit applicant. Ideally, the following discussion will supplement those requirements and guidance documents

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[1] 40 CFR § 124, 144, 145, et al. Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells; Final Rule, 75 Fed. Reg. 77230 (December 10, 2010).

[2] The first ADM injection well was constructed with a Class I UIC permit issued by the Illinois Environmental Protection Agency before the USEPA promulgated the Class VI Program and was then converted to a Class VI permit issued by the USEPA only after CO_2 injection had ceased. Accordingly, that Class VI permit (ADM well CCS 1) addresses only post-injection site care and site closure.

[3] Hildebrandt, K., B. Kobelski, and B. Bates, 2020, EPA action plan for Class VI geologic sequestration permitting, EPA—Region 7 summary of the Class VI Program permitting process for the Wellington/Berexco GS Project and lessons learned: Ground Water Protection Council 2020 UIC Meeting, San Antonio, Texas, February 18, 2020, slide 10, https://www.gwpc.org/sites/gwpc/uploads/documents/2020_UIC_Conference/GWPC_EPA_Class_VI_Presentation.pdf (accessed August 28, 2020). [Hildebrandt et al. 2020]

[4] It is useful to review the entire wording of the "Disclaimer" that appears at the beginning of each Class VI guidance document:

The Safe Drinking Water Act (SDWA) provisions and U.S. Environmental Protection Agency (EPA) regulations cited in this document contain legally-binding requirements. In several chapters 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 EPA, states, or the regulated community. The recommendations herein may not be applicable to each and every situation.

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. (USEPA, 2013, Geologic sequestration of carbon dioxide: Underground Injection Control (UIC) Program Class VI well site characterization guidance: USEPA, EPA 816-R-13-004 [May 2013]). ["Site Characterization Guidance," p. i] by providing a little more understanding of the process and options available to applicants.

PROJECT DESIGN AND PERMIT ROAD MAPPING

Determine the Nature of the Project and Its Objectives

The starting point for permitting a GS (or storage) project is the same as the starting point for designing the GS project, namely, determining the nature of the project, its objectives, and its design. The NETL BPM titled *Site Screening, Site Selection, and Site Characterization for Geologic Storage Projects* (2017d) provides valuable guidance for this step in Chapter 2, "Project Definition and Management." As noted there, "the developer should execute a project analysis consisting of at least six elements: (i) Scope, (ii) CO_2 Strategy, (iii) Evaluation Criteria, (iv) Resources, (v) Schedule, and (vi) Risk Assessment."[5] The scope consideration is the most critical threshold issue for permitting purposes.

If the sole purpose of the project is to store CO_2 in geological structures, then defining the objectives and scope will be more straightforward than will defining the objectives and scope for a project that is designed to advance the development of the technology of GS and other technologies and practices associated with GS, such as computational modeling and monitoring methods. A straightforward GS project aimed solely at storage of CO_2 will seek to optimize the use of supporting technologies and methodologies to achieve maximum storage with efficiency and cost-effectiveness.

Is the Project Experimental in Nature?

In addition to the stated objectives, the purpose of the project is likely to be reflected as well in three key considerations:

1. Volumes of CO_2 to be injected,
2. Intended duration of the project, and
3. Source(s) of the CO_2 to be injected.

For example, injecting 1,600 tons of CO_2 over a 10-day period and then 250 tons over a 5-day period, with food-grade CO_2 delivered by truck (as was done for the Frio CCS project[6]) is a project not directed primarily at GS. This is a pilot project directed at testing the technology or geology. Similar pilot projects and demonstration projects were permitted as Class V experimental wells under Guidance 83 issued by the USEPA in 2007.[7] From the time Guidance 83 was issued until the USEPA promulgated the Class VI regulations on December 10, 2010, almost all GS projects used injection wells permitted as Class V experimental wells.

Guidance 83 stated, "EPA has determined that the Class V experimental technology well subclass provides the best mechanism for authorizing pilot GS projects."[8] The preamble to the final Class VI Rule stated that, following promulgation of the rule, "only GS projects of an experimental nature (i.e., to test GS technologies and collect data) will continue to be classified, permitted, and regulated as Class V experimental technology wells."[9] Further, the preamble indicated that Class VI permits would be required only for "Class V experimental technology wells no longer being used for experimental purposes," that is, wells converted to operation as commercial-scale GS projects.[10]

Notwithstanding these indications that Class V experimental well permits should continue to be an option for pilot- and demonstration-scale projects,[11] the USEPA has shown reluctance to consider issuing Class V permits for CO_2 injection and has instead required that projects of all sizes and durations seek Class VI permits. The USEPA provided further explanation of its evolving policy on experimental CO_2 injection wells in September 2011, when the Agency announced that it would "directly implement the Class VI Program nationally" in all states and jurisdictions until an application for primacy has been granted.[12] The explanation was that "EPA expects the majority, if not all, of the wells injecting CO_2 for GS to obtain Class VI permits."[13] The explanation further stated that "the Agency anticipates that few, if any Class V experimental technology well permits will be issued under SDWA for future GS projects."[14] The reasoning behind this focused on the purported use of Class V as a temporary approach until new regulations could be written for commercial-scale injection of CO_2. Nevertheless, the door has been left open for the issuance

[5]National Energy Technology Laboratory (NETL), 2017d, Best practices: Site screening, site selection, and site characterization for geologic storage projects: U.S. Department of Energy, DOE/NETL-2017/1844. ["Site Screening BPM," p. 20]
[6] Hovorka, S., 2009, Frio brine pilot: The first U.S. sequestration test: Southwest Hydrology, Sept./Oct., p. 26–27, 31.
[7]USEPA, 2007, Using the Class V experimental technology well classification for pilot geologic sequestration projects: USEPA, UICPG No. 83, 23 p. (March 1, 2007). ["Guidance 83"]
[8]Guidance 83, p. 5.
[9]40 CFR § 124, 144, 145, et al. Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells; Final Rule, 75 Fed. Reg. 77245 (December 10, 2010).
[10]75 Fed. Reg. 77245.
[11]*See also* Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells; Proposed Rule, 73 Fed. Reg. 43492 (July 25, 2008):

> This guidance will continue to apply to pilot-projects as long as the projects continue to qualify under the guidelines for experimental wells laid out in UICPG #83. It will also remain a permitting option for future projects, as long as new projects are experimental in nature and continue to collect data and conduct research.

[12]40 CFR § 52, Approval and Promulgation of Implementation Plans; Texas; Revisions to Permits by Rule and Regulations for Control of Air Pollution by Permits for New Construction or Modification, 76 Fed. Reg. 56982 (September 15, 2011).
[13]76 Fed. Reg. 56983.
[14]76 Fed. Reg. 56983.

of future Class V experimental permits for CO_2 injection. Discussions regarding the potential availability of Class V permits for pilot or demonstration projects have led to two subjects for consideration by future projects.

First, the question of whether a project is "of an experimental nature" has focused on identifying what is novel about the project, possibly some aspect that would make it difficult to fit within the Class VI framework. The September 2011 notice states the following:

> EPA will determine, based on evaluation of project-specific information, whether a project needs to be permitted as a Class V experimental technology well because the Class VI requirements would be *technologically inappropriate* or would not adequately address the *environmental risks* of the project. In such cases, EPA will coordinate with the appropriate Class V permitting authority which may, in some cases, be the State.[15]

Accordingly, any project that wants to consider seeking a Class V permit should be prepared to make a convincing demonstration that the project is focused on advancing the knowledge and development of the technology rather than simply storing CO_2 in geologic formations.[16] Any difficulties fitting the project within the Class VI regulatory framework should also be explained with particular consideration of how environmental risks will be addressed.[17] Distinguishing the proposed project from previous projects and focusing on the specific scientific and technical questions to be answered should prove helpful in supporting such a demonstration.[18]

Additional useful information is contained in Guidance 83 itself:

- "If the project goal is to test failure scenarios, it is important that the project incorporate appropriate protections to safeguard USDWs [underground sources of drinking water] and public health (e.g., proper casing and tubing materials, sufficient logging to ensure well integrity, and adequate monitoring to detect movement of CO_2)."[19]
- "Well owners or operators should specify the objectives of the project and identify the data to be gathered; they should also demonstrate that the project meets the non-endangerment standard under the UIC Program (i.e., protection of USDWs)."[20]

Second, concerns have been raised about the extent to which a Class V permit for CO_2 injection can achieve the same level of protection as a Class VI permit, with particular concern over the ability to provide financial assurance commensurate with the Class VI requirements. Because the Class V regulations do not contain detailed regulatory language directly comparable to 40 CFR § 146.85, there has been concern whether the USEPA or a state with Class V primacy could require a Class V permittee to demonstrate and maintain financial responsibility for "the cost of performing corrective action on wells in the area of review, plugging the injection well(s), post-injection site care and site closure, and emergency and remedial response."[21] A project proponent wanting to seek a Class V permit for a pilot or demonstration project should therefore be prepared to accept comparable financial responsibility requirements included in the permit pursuant to the Director's authority to add Class V permit conditions under 40 CFR § 144.52(b)(1).[22]

Is This a Commercial-Scale Project?

The scale of a project is relevant not only in determining whether there might be any potential for Class V experimental well permitting. It should also be relevant in determining how the Class VI requirements need to be scaled to fit the project, something that the USEPA has shown some reluctance to consider in its earliest permitting actions.

Pilot-Scale Experimental Projects. There was early recognition that consideration of the size and duration of a project would be a factor in discerning whether it was intended to be experimental or commercial by nature. The USEPA recognized this in Guidance 83:

> Initially, we expect the project permit applications to request authorization to inject very small volumes of CO_2 relative to commercial-scale projects. The relatively small volumes of CO_2 injected in these initial pilot projects should minimize any potential for adverse effects on USDWs and public health due to the movement or leakage of CO_2.[23]

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[15] 76 Fed. Reg. 56983. (emphasis added)

[16] *See* Guidance 83, p. 5: "EPA's rationale for allowing the use of Class V experimental technology wells is to encourage innovation. In other words, under EPA's regulations an injection well that is being used to demonstrate a developing technology may be subject to more flexible, yet fully protective, technical standards than those designed for commercially operating facilities."

[17] *See* Guidance 83, p. 8: "A site that is deemed to be appropriate for pilot CO_2 injection may not necessarily meet future requirements for commercial-scale operations."

[18] *See* Guidance 83, p. 6–7: "EPA's regulations at 40 CFR 146.3 state that, 'experimental technology means a technology which has not been proven feasible under the conditions in which it is being tested.'"

[19] *See* Guidance 83, p. 12: "If failure scenarios are being tested, appropriate protective contingencies are encouraged . . ."

[20] Guidance 83, p. 3.

[21] 40 CFR § 146.85(c), p. 77295.

[22] *See* CFR § 144.52(b)(1): "(b)(1) In addition to conditions required in all permits, the Director shall establish conditions in permits as required on a case-by-case basis, to provide for and assure compliance with all applicable requirements of the SDWA and parts 144, 145, 146, and 124." *See* Guidance 83, p. 13: "However, commercial-scale operations, including those that are converted from pilot projects, may have additional financial assurance requirements to ensure that issues arising from the larger CO_2 plumes, the unique nature of CO_2, and the long storage time frame are addressed."

[23] Guidance 83, p. 3. Size, however, was not considered entirely determinative: "Class V experimental technology permitting may be appropriate, as an interim measure, for CO_2 GS injection wells of a 'pilot' or 'demonstration' nature, regardless of the volumes injected" (Guidance 83, p. 6).

The USEPA further noted that "CO_2 injection for GS will eventually involve much greater volumes of CO_2, which will be stored for very long periods of time."[24] What the USEPA considered to be commercial scale was explained in the preamble to the proposed Class VI rulemaking, where the USEPA described the basis for its cost estimates:

> When analyzing costs for a commercial size sequestration project that begins in year one of the Cost Analysis, EPA assumes that the first year is a construction period, followed by 20 years of injection, followed by 50 years of post-injection site care as indicated in the proposal. The 20-year injection period reflects the assumption that a source such as a coal-fired power plant, with a potential operational lifetime of 40 to 60 years, would plan for the sequestration of only half of its emissions at a time, rather than incur those costs all at once.[25]

Scale Requirements to Fit Project. By contrast, the USEPA noted the following in the technical support document:

> the currently planned projects are only scheduled for about three to four years of injection. The typical injection rate (from one well) is up to one million tons of CO_2 per year. This can be compared to an expected full-scale future rate for a power plant of up to several million tons per year, likely involving multiple injection wells over a much longer period of time.[26]

There is in these statements an inherent recognition that the Class VI regulatory framework was designed for these larger and longer commercial-scale projects. For any project that will be operating at a smaller and shorter scale, the permit planning, application, and processing should include explicit recognition and discussion of how requirements should be tailored to accommodate the scale of the project.

According to the Nature of the Project, Develop a Preliminary Permitting Road Map Tailored to the Project Design

The DOE BPM for Site Screening explains the importance of the initial determination of the nature and design of a project. It states, "During Project Definition, the project developer establishes the scope and overall management plan for the project and establishes a set of criteria (including technical and economic criteria) that can be used to help guide subsequent stages."[27]

A critical component of this step is the development of a management strategy "that identifies CO_2 sources, volumes, rates of delivery, and target injection rates."[28] The Site Screening BPM delineates a process for identifying, screening, and characterizing potential sites through a CO_2 Storage Resource Classification System before arriving at the classification of a site as a Contingent Storage Resource. Among the factors to be used in evaluating potential storage sites is whether "the site can be permitted under all relevant Federal, state, and local regulations."[29] Although that issue lies at the heart this exercise, the evaluation of this factor actually depends on assessing a number of the other criteria, particularly the geological factors:

- Is there a single facies within a continuous vertical column of connected flow units, or does a series of stacked or amalgamated depositional compartments exist that may or may not be in flow communication?
- Are there potential faults that compartmentalize the injection zone or create closed or partly closed flow boundaries?[30]

Other factors to be used in the evaluation can be taken directly from the regulations. These require that wells be sited in areas with "a suitable geologic system," which comprises the following:

1. An injection zone(s) of sufficient areal extent, thickness, porosity, and permeability to receive the total anticipated volume of the carbon dioxide stream;
2. Confining zone(s) free of transmissive faults or fractures and of sufficient areal extent and integrity to contain the injected carbon dioxide stream and displaced formation fluids and allow injection at proposed maximum pressures and volumes without initiating or propagating fractures in the confining zone(s).[31]

If the injection zone lies above the lowermost USDW, which requires an injection depth waiver under 40 CFR § 146.95, there must also be a confining zone(s) underlying the injection zone "adequate to prevent fluid movement and pressure buildup outside of the injection zone(s)," including being "free of transmissive faults and fractures."[32] In addition, seeking an injection depth waiver will trigger specific consideration of whether the injection zone "is laterally continuous, is not a USDW, and is not hydraulically connected to USDWs; does not outcrop; has adequate injectivity, volume, and sufficient porosity to safely contain the injected carbon dioxide and formation fluids; and has the appropriate geochemistry."[33] For

[24]Guidance 83, p. 6.
[25]Federal Requirements under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells—Proposed Rule, 73 Fed. Reg. 43492, 43527 (July 25, 2008).
[26]USEPA, 2008, Geologic CO_2 sequestration technology and cost analysis: USEPA, Technical Support Document, p. 40.
[27]Site Screening BPM, p. 13.
[28]Site Screening BPM, p. 20.
[29]Site Screening BPM, p. 21.
[30]Site Screening BPM, p. 21–22.
[31]40 CFR § 146.83(a), p. 77293.
[32]40 CFR § 146.95(a)(2), p. 77302.
[33]40 CFR § 146.95(a)(1), p. 77302.

any Class VI wells, it may also become necessary to identify and characterize additional zones that are free of faults and fractures that may interfere with containment, will "impede vertical fluid movement, allow for pressure dissipation, and provide additional opportunities for monitoring, mitigation, and remediation."[34]

Communicate with the Class VI Permit Issuer

Effective communication with the agency that will be granting the Class VI permit is extremely important and should be initiated early in the process of planning and developing a GS project. This has been emphasized by the USEPA: "First Step in a GS Project: If you plan on pursuing a GS project, talk to EPA or the delegated program manager *before* either submitting an application or drilling a well!"[35] The *Class VI Implementation Manual for UIC Program Directors* notes, "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."[36] Hildebrandt et al. state, "Communication is key. . . . EPA should be talking with the applicant both prior to and during the course of the permitting process."[37] Particular emphasis is placed on communications with the permit applicant, and the applicant has a similar interest in maintaining good communications with the agency personnel who will be reviewing and writing the permit. The USEPA Implementation Manual also emphasizes the role that UIC Class VI Program Directors play in communicating with other stakeholders and the public, noting, "The unique and complex nature of Class VI wells and GS highlights the importance of communicating with the public and stakeholders about these projects."[38] And that is important for project developers and applicants to bear in mind as well—both the importance of communications with the public and the fact that UIC Program officials are urged to be proactive in making those communications. It is of the utmost importance for the project developer to make the initial public revelations about a project. If the public hears about a project from the regulators before any disclosure by the project developers, some will have a tendency to feel that secret plans were afoot, and that can be detrimental to the public acceptance of a project. As noted in the Public Outreach and Engagement section of this report, developing and implementing an effective public engagement plan is extremely important, regardless of whether any adverse public reactions are anticipated. Far too many examples exist of projects precluded by unexpected, and even inexplicable, adverse public reactions to CCS projects.

Coordinating

Perhaps the single most important statement in the USEPA Implementation Manual is the explicit recognition that "*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*."[39] Given the inherent complexity of the Class VI permitting process, which involves detailed characterization of potentially enigmatic geological settings followed by computational modeling efforts to recreate those settings and predict the future behavior of dynamic processes within those settings, close communication and step-by-step coordination are essential to efficient and successful permit development. Most important, it is critical to achieve understanding and appreciation of the needs and capabilities of both the permit applicant and its experts on the one hand and the permit reviewers and writers as well as their experts on the other hand. Crucial scientific and technical data and analyses will be presented and evaluated, and experience has shown that the potential for misunderstandings is ever present.

The permit application process involves the applicant submitting data and information sufficient to show that the applicant meets all the requisite requirements to qualify for the issuance of the permit. Understanding what is sufficient and what, if anything, needs to be clarified and how is critically important at each step in the process. Once the applicant submits something for review, the reviewers may need additional information, clarification of what has been submitted, or both. Agency reviewers of submitted Class VI application materials can respond in these instances with a "request for additional information" (an RAI, sometimes called a "notice of deficiency," or NOD), which may include a time period for responding (e.g., within 30 or 45 days).

When an applicant receives an RAI, it is important to ensure that the additional information provided is both what is necessary and only as much as is necessary. As the USEPA has emphasized, "Don't assume, ask."[40] Accordingly, the best approach to responding is to assess what is requested, develop a plan for responding, and then confirm by communicating with the application reviewers that the planned response satisfies their needs. This is not a process of showing everything you know about the scientific and technical details surrounding a proposed project, but rather a process of satisfying the permit issuer that each requisite technical requirement has

[34]USEPA, 2018, Underground Injection Control (UIC) Program Class VI implementation manual for UIC program directors: USEPA, EPA 816-R-18-001 ["Implementation Manual," p. 4-5]. Although the USEPA guidance refers to these additional zones as "additional confining zones" (Site Characterization Guidance, p. 2), the regulations do not require that the additional zones fulfill all the requirements to be "confining zones" [40 CFR § 146.83(b)]. Thus, the additional zones may be most useful in providing "opportunities for monitoring, mitigation, and remediation" (Implementation Manual, p. 3-4).
[35]Hildebrandt et al. (2020), slide 12.
[36]Implementation Manual, p. 2-5.
[37]Hildebrandt et al. (2020), slide 10.
[38]Implementation Manual, p. 2-6.
[39]Implementation Manual, p. 2-6.
[40]Hildebrandt et al. (2020), slide 10.

been satisfied. Because the permit reviewer will be compelled to review and consider everything that has been submitted, providing excessive or extraneous information can unnecessarily prolong the review process.

Lessons learned in a comparable UIC Program process are helpful here. The process through which Class I hazardous waste injection well operators demonstrate qualification for an exemption from the land disposal restrictions involves an approach similar to site characterization and computational modeling. Region 6 of the USEPA has emphasized the importance of petitioners who are demonstrating compliance with the exemption requirements to "keep the demonstration as simple as possible."[41] Region 6 has also emphasized the importance of early and frequent communication to avoid misunderstandings:

- Have a face-to-face working meeting before beginning the petition work.
- Have a face-to-face working meeting if there are significant deficiencies.[42]

It is also important to reach a shared technical understanding between the applicant and reviewer on foundational information, such as geology, before proceeding to more detailed analyses and computational modeling exercises that might need to be repeated if issues remain to be resolved on the acceptability of input data and information. That is the valuable approach reflected in the USEPA Implementation Manual statement at the beginning of this section. There is value in applicants sharing draft assessments before finalizing them for formal submission to allow for clarification and for keeping the details as simple as appropriate when finally submitted. Sharing drafts in both directions will facilitate the efficient use of resources on both ends. Another way of affording efficiency is by using a sequential process to settle foundational issues before moving to detailed analyses (e.g., computational modeling) based on inputs from those underlying analyses (e.g., geologic, geochemical, and geomechanical assessments).

Sequencing the Application Process

The classic regulatory depiction of the permit application process is detrimental to effective coordination between the permit applicant and the permitting agency for Class VI permits because it appears to preclude a beneficial sequential process. Administrative procedures for permit applications anticipate having an applicant prepare and file a comprehensive application with all the essential ingredients. When this is done, the agency application reviewer will first carry out a "completeness review" to determine whether all the necessary parts of the application have been provided.[43] Only after the application is deemed complete will the reviewer proceed to the technical review of the application to determine whether the detailed technical information, analyses, and demonstrations are sufficient to fully satisfy the requirements for a permit to be issued.

Experience has shown, however, that a different sequential process is much more effective for a process such as the Class VI permit process.[44] Preparing and filing an application with every necessary element, and doing so all at once, has a number of detrimental effects.

First, as noted in the preceding section, this precludes holding discussions and achieving agreement on preliminary and foundational geologic characterizations before proceeding to conduct analyses that will depend on having the correct inputs based on those characterizations. It is far more effective to share and reach a common understanding on site characterization before proceeding to the computational analyses to delineate the AoR and project CO_2 plume and pressure front behavior over the life of a project. Breaking the application presentation and review process down into sensible steps and allowing agreement to be reached on one before moving to the next is a more efficient and effective approach. As the USEPA has noted with respect to an uncompleted permit process, "Providing draft portions of the application for EPA to review and comment on prior to formal submission of the complete final application would have made the final permitting process go smoother and faster."[45]

Second, submitting everything all at once has had a historical tendency to concentrate the process of requesting additional information and responding into more massive projects. In some cases, this type of approach has resulted in long periods of suspended communication if the reviewers likewise do their work to review the entire application and all its supporting materials while compiling all the necessary RAIs for presentation back to the applicant in one combined document, along with a direction to respond within a short period of time. Experience has also shown that this type of approach loses efficiency by discarding the immediacy of getting timely

[41]Graves, B., 2017, USEPA Region 6 Update: 2017 Environmental Trade Fair & Conference, Texas Commission on Environmental Quality, Austin, May 16–17, https://carbon.americangeosciences.org/files/2021005300.pdf, slide 14 (accessed February 10, 2021).
[42]Graves (2017), slide 14.
[43]This approach is reflected in the USEPA's statement, "The EPA considers a permit application to be submitted when all associated components have been received in a way that complies with 40 CFR 146.91(e)" (USEPA, 2016, Underground Injection Control (UIC) Program Class VI well recordkeeping, reporting, and data management guidance for owners and operators: USEPA, EPA 816-R-16-005) ["O&O Reporting Guidance," p. 16]. That appears to mean that an application will not be deemed complete until each requisite permit application component has been submitted through the GSDT.
[44]The USEPA tacitly recognizes this in the following statement: "Because of the technical complexity of a Class VI permit application, the EPA expects that the permitting process will be an iterative one. Permitting authorities may need to ask clarifying questions, request additional information, or discuss the content of the application with prospective owners or operators" (O&O Reporting Guidance, p. 16).
[45]Hildebrandt et al. (2020), slide 10.

additional information while reviews of the existing, albeit insufficient, information are still fresh in the mind of the reviewer. Third, the urgency of preparing timely responses to more numerous RAIs will interfere with achieving a correct understanding of what is necessary and sufficient to satisfy the needs of the reviewer.

Using the Geologic Sequestration Data Tool Effectively

The USEPA Implementation Manual intones that 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."[46] Created to "facilitate compliance with the electronic reporting requirement of the Class VI Rule at 40 CFR 146.91(e)," the GSDT is described as also supporting the permit application process "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."[47] The GSDT was developed for the USEPA by the Pacific Northwest National Laboratory. It could be seen as a potential detriment to effective communication between Class VI permit applicants and reviewers if it were allowed to function as the only means of correspondence, but the USEPA has given no indication that such is its intended function. Rather, it is intended to serve as an electronic filing system to provide ready organization and access to communications and correspondence. There is no intent to preclude phone calls, emails, and meetings as means of communicating to share ideas or resolve questions.

To create a complete administrative record of the permit application process, the USEPA does recommend "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."[48] Recognizing this admonition, permit applicants would be smart to ensure the accuracy of their communications during the permitting process by providing their own agendas, documentation, and summaries of significant discussions and meetings. Sharing those summaries with the permit reviewers will also serve to ensure common understanding and agreement on significant points underpinning the permit application.

How Much Is Enough?

As noted, one challenge in the application process is determining how much supporting data and information and how many analyses and demonstrations are enough to satisfy the permitting requirements and reviewers without bogging down the review by submitting too much. Yet having sufficient supporting documentation is essential.[49] Effective communication and coordination between the applicant and reviewer is the key to solving this potential dilemma, and sometimes part of the challenge will be reining in the supporting expert on both ends of the exchange because those experts may be tempted to substitute their own judgments for those of the applicant and reviewer. Saving time and costs while achieving full and transparent satisfaction of supporting requirements necessitates practical management and cooperative coordination on both ends of the dialogue. Data and information overload should be avoided.

PUBLIC OUTREACH AND ENGAGEMENT

To ensure the success of a project, gaining public support for the project, or at least acceptance, is an indispensable step. This means developing and implementing a successful public outreach and engagement program. Too many projects have been hampered or terminated for failure to successfully engage with local communities and others. Important lessons have been learned from these experiences. Excellent resources are available to provide guidance in developing and implementing public engagement programs. Foremost among those is the NETL *Best Practices: Public Outreach and Education for Geologic Storage Projects*,[50] which reflects the experiences of the Regional Carbon Sequestration Partnerships with pilot and demonstration projects of a number of different types and in a variety of locations.[51] Common themes were encountered among questioning audiences:

> a lack of understanding of how CO_2 storage works due to the 'out of sight' nature of the technology, a lack of familiarity with similar storage functions already occurring in nature, and the actual performance of other geologic storage projects. Other themes include communication challenges that stem from the implementation of complex projects.[52]

[46]Implementation Manual, p. 1-4. For information about the GSDT, see https://www.epa.gov/uic/class-vi-wells-used-geologic-sequestration-co2#GSDT (accessed August 18, 2020).
[47]Implementation Manual, p. 1-4, 2-6.
[48]Implementation Manual, p. 2-6.
[49]*See* Hildebrandt et al. (2020), p. 11: "Documentation of conclusions reached by the applicant is essential (just trust me doesn't work when going out for public notification)."
[50]NETL, 2017c, Best practices: Public outreach and education for geologic storage projects: USDOE, DOE/NETL-2017/1845. ["Outreach BPM"]
[51]*See* Outreach BPM, p. 12: "Some of the development phase projects injected anthropogenic CO_2 into saline reservoirs, while others focused on storage of CO_2 in conjunction with enhanced oil recovery (EOR). The projects occurred in areas with historic and ongoing subsurface activities (e.g., oil and gas production or related injection activities) in addition to areas having little or no experience with these activities."
[52]Outreach BPM, p. 10.

The Outreach BPM provides a number of approaches for surmounting these questions. Project developers are the primary audience for the manual, but "other stakeholders may find information that will aid them in their consideration of carbon storage projects and community engagement."[53]

DEVELOPING AND IMPLEMENTING A SITE SELECTION AND CHARACTERIZATION STRATEGY DESIGNED TO FACILITATE AND EXPEDITE PERMIT APPLICATION AND ISSUANCE

Site characterization is extremely important for a number of reasons, most fundamentally because selecting a proper site is indispensable to ensuring the success of the project in storing CO_2. The purposes of site characterization are to provide the basis for selecting the best site for the project; to ensure that the injection zone will have "sufficient areal extent, thickness, porosity, and permeability to receive the total anticipated volume of the carbon dioxide stream" at the intended rate; to ensure that the confining zones have sufficient area and integrity "to contain the carbon dioxide stream and displaced formation fluids"; to ensure protection of USDWs from endangerment, in compliance with the SDWA; to ensure the ability to conduct the testing, monitoring, and data collection necessary to support effective management and operation of the project; and to allow proper closure and decommissioning once the project is completed.[54] To achieve these multiple purposes, site characterization will be conducted in a number of stages, beginning at the outset when data and information will probably be collected and analyzed for a number of different sites. As the site selection narrows to focus on a specific site, the site characterization will become more detailed, and part of the focus will require determining that the characterization data and information are sufficient to meet the regulatory requirements.

Site characterization to comply with the regulatory requirements (Regulatory Site Characterization) has two stages that coincide with the two-step process for permitting: first, construction of the injection wells and second, operation of the wells once constructed and tested in the context of a verified site characterization. Site characterization, including Regulatory Site Characterization, does not end with an authorization to inject but continues throughout the life of the project to enable compliance with requirements for verification and updating of site characterization necessary to ensure both successful operation and regulatory compliance. For permitting purposes, the focus will be on the data and information needed to comply with the Regulatory Site Characterization requirements, and this should be integrated into the site characterization program for the entire project, which will include any additional data and information collection and development desired for activities that include site selection, site characterization, risk assessment and management, project management, project operation, and closure and decommissioning.

The USEPA *Underground Injection Control (UIC) Program Class VI Well Site Characterization Guidance* is an indispensable tool for compliance with the regulations because it both reiterates the specific requirements and provides additional explanations to breathe life into the otherwise dry regulatory provisions and goes further to provide context and clarification for many of the provisions. It also provides references to many of the techniques and methodologies available for site characterization, but the guidance does assume "that readers are familiar with many of the available techniques used in geologic site characterizations and their use."[55] To obtain a more detailed introduction to the available site characterization tools and methodologies, turn to the NETL BPM for Site Screening, which also provides much more detailed guidance for the initial site identification, screening, and selection process than does the USEPA guidance.

The NETL has also developed specific tools for use in site screening and characterization through the National Risk Assessment Partnership (NRAP). For example, the "NRAP-Open-IAM is an open source Integrated Assessment Model (IAM) developed by [the] National Risk Assessment Partnership (NRAP) to perform risk assessment for geologic CO_2 storage (GCS). The goal of NRAP-Open-IAM is to extend beyond risk assessment into risk management and containment assurance."[56] The NRAP website also identifies other available tools.[57]

Engagement with the Applicable Underground Injection Control Program

As discussed in the Communicating with the Class VI Permit Issuer section, early engagement with the permit issuer is important to paving the way to efficient site characterization and demonstrating that the requisite siting criteria are satisfied. This will also facilitate any necessary discussions of various combinations of CO_2 sources and storage sites.

Availability of the Necessary Data and Information

The UIC regulations are the only definitive source for the requisite data and information to be included in a Class VI permit application. The USEPA Site Characterization Guidance is helpful for interpreting these requirements, but some discussion in the Guidance includes additional terms not defined in the regulations. It is therefore important to consult the

[53] Outreach BPM, p. 10.
[54] Site Characterization Guidance, p. 2.
[55] Site Characterization Guidance, p. 6.
[56] https://edx.netl.doe.gov/nrap/nrap-open-iam/ (accessed December 16, 2020).
[57] https://edx.netl.doe.gov/nrap/other-nrap-tools/ (accessed December 16, 2020).

Definitions section of the Guidance (p. xi–xvi) to determine which terms are taken directly from the regulations. It is also important to compare language in the Guidance with the regulations to ensure precision when assessing determinative criteria, such as what is required for "additional zones that will impede vertical fluid movement,"[58] for which the Guidance (p. 2) uses language different from the regulations at 40 CFR § 146.83(b).[59]

The first criterion for an acceptable site is the requirement for "injection zone(s) of sufficient areal extent, thickness, porosity, and permeability to receive the total anticipated volume of the carbon dioxide stream."[60] This criterion focuses on the importance of defining the project in the preliminary step discussed in the Project Design and Permit Road Mapping section of this report. In particular, it is not necessary for any one geologic storage site to be able to receive and contain the entire CO_2 stream to be produced by any one or more capture sources. Nor is there anything to prevent the storage site from receiving and containing CO_2 streams from multiple capture sources. Accordingly, the processes defining projects and characterizing sites can be coordinated to ensure that the minimum siting criteria for Class VI permitting will be met, which can be achieved by optimizing combinations of CO_2 stream sources and geologic storage sites.

The same approach can be applied to ensuring satisfaction of the criterion that the confining zones have sufficient areal extent to contain the stored CO_2. The volumes injected can be (and may need to be) adjusted to ensure sufficient confining zone coverage. The same cannot be said for ensuring the absence of transmissive faults or fractures and the presence of adequate integrity. Those siting criteria do not provide similar flexibility.

Section 146.82(a) specifies the minimum requirements for data and information that must be submitted by a Class VI permit applicant and considered by the Class VI UIC Director in demonstrating and determining that the siting criteria are met. These specifications must be viewed through the lens of the minimum siting criteria and recognized as minimum requirements that do not preclude the use of additional data and information when helpful to show that the siting criteria are met.

Determine What Additional Information Will Need to Be Acquired to Obtain the Final Permit and Authorization to Inject, Recognizing That It May Be Necessary to Stage This Process

The requirements of section 146.82(a) provide the initial checklist of data and information to be provided with the permit application and that must be obtained in some manner if not already available. For each required item that is not already available, a plan must be developed for obtaining the additional information necessary to provide the basis for site characterization, AoR delineation, and permit application, all steps that must be conducted in coordination to support the permit application. In identifying the necessary data and information to support the demonstration that the siting criteria are met, two additional demonstration requirements in section 146.82(a) should be kept in mind. The first is also inherent in the 146.83(a)(2) criteria, namely the requirement that along with information on "the location, orientation, and properties of known or suspected faults and fractures that may transect the confining zone(s) in the area of review," the applicant must provide "a determination that [any such faults or fractures] will not interfere with containment."[61] This is tantamount to saying, as in 146.83(a)(2), that the confining zones must be demonstrated to be "free of transmissive faults or fractures" and have "sufficient areal extent and integrity."[62] The second additional requirement is more independent and includes "a determination that [any] seismicity will not interfere with containment" based on an assessment of seismic history and seismic sources for the area where the site is located.[63]

Consider Potential Alternative Approaches Tailored to the Amount of Information Available

Under all circumstances, Class VI permitting is a two-step process with an initial successful application resulting in issuance of a Class VI permit to construct, but not to operate, the well. Operation of the well will be approved only after (1) construction of the well has been completed with the filing of an approved completion report and (2) conduct of the required well logging and testing and the approved preoperational formation testing program have been completed and the results reviewed to determine what changes must be made to the permit conditions and plans. Approval to operate—typically in the form of an authorization to inject—is issued only after any necessary permit and plan revisions have been completed and issued as part of the final permit approval. Recognizing that this two-step process will be necessary, it makes sense to plan the acquisition of additional data and information in a way that optimizes use of the two steps. Thus, it might be beneficial to defer acquisition of data and information in the deep subsurface as part of the well construction, logging, and formation testing process after the initial construction permit is issued. Applicants should work with the Class VI UIC Program Director to determine the requisite data and information necessary to obtain the permit to construct with the understanding that the operation will not commence until any necessary additional data and information are obtained, analyzed, and

[58]Site Characterization Guidance, p. 63.
[59]Site Characterization Guidance, p. 2.
[60]40 CFR § 146.83(a)(1), p. 77293.
[61]Site Characterization Guidance, p. 2.
[62]40 CFR § 146.83(a)(1), p. 77293.
[63]Site Characterization Guidance, p. 3; 40 CFR § 146.82(a)(3)(v), p. 77292.

used to finalize the permit conditions and plans. The USEPA recognizes this approach by recommending that applicants discuss "data gaps and uncertainties that will be addressed through the formation testing program and other activities conducted after well construction/conversion, but before receiving authorization to inject.[64]

As summarized in the Site Characterization Guidance, the following information must be submitted after construction of the well and prior to receiving authorization to inject:

- Any relevant updates to the information on the geologic structure and hydrogeologic properties of the proposed storage site and overlying formations, based on data obtained during logging and testing of the well [40 CFR § 146.82(c)(2)];
- Information on the compatibility of the carbon dioxide stream with fluids in the injection zone(s) and minerals in both the injection and the confining zone(s) [40 CFR § 146.82(c)(3)];
- The results of formation testing [40 CFR § 146.82(c)(4)]; and
- All available logging and testing program data on the well required by 40 CFR § 146.87 [40 CFR § 146.82(c)(7)].[65]

Data Collection for Site Characterization

Although the USEPA "encourages owners or operators to collect as much site-specific data as possible before submitting the initial Class VI permit application,"[66] that may not be the most cost-effective allocation of resources. Applicants should determine the most efficient approach for obtaining all the necessary data and information, recognizing that at least two stages will be necessary. This process may include the consideration of drilling one or more test wells.

Test Well Options

Anytime a project is considering drilling a borehole for any purpose, the project should give further consideration to all options for potential future use of the borehole. The USEPA specifically recognizes that "a stratigraphic well may need to be drilled in some cases" and notes that it may be desirable to consider using the stratigraphic well as the injection well.[67] The potential use of any stratigraphic well either as an injection well or as a monitoring or observation well should definitely be considered and incorporated into the plan for both well construction and acquisition of all necessary data and information, and the timing and staging should consider the ultimate use of the borehole as well as other factors.

SUBMITTING PRECONSTRUCTION APPLICATION MATERIALS

With sufficient information in hand to prepare a comprehensive threshold site characterization, the project developer will be prepared to proceed with submitting application materials sufficient to obtain a Class VI permit to drill and construct the injection well. Whenever the USEPA will be issuing the permit, the applicant needs to register with the USEPA Regional office early in this process to gain access to the GSDT,[68] which has materials that should be considered and used as appropriate in the application process.

The USEPA has identified the required Class VI permit application components as follows:[69]

- Basic project information: 40 CFR § 146.82(a)(1), (20)
- Site characterization information: 40 CFR § 146.82(a)(2)–(3), (5)–(6)
- Proposed AoR and Corrective Action Plan and associated modeling data: 40 CFR § 146.82(a)(4), (13)
- Financial responsibility demonstration: 40 CFR § 146.82(a)(14)
- Injection well construction data: 40 CFR § 146.82(a)(9), (11), (12)
- Proposed preoperational testing program: 40 CFR § 146.82(a)(8)
- Proposed operating data: 40 CFR § 146.82(a)(7), (10)
- Proposed Testing and Monitoring Plan: 40 CFR § 146.82(a)(15)
- Proposed Injection Well Plugging Plan: 40 CFR § 146.82(a)(16)
- Proposed PISC (Post-injection Site Care) and Site Closure Plan: 40 CFR § 146.82(a)(17), (18)
- Proposed Emergency and Remedial Response Plan: 40 CFR § 146.82(a)(19)
- Any other information requested by the UIC Program Director: 40 CFR § 146.82(a)(21)

The specific GSDT reporting modules that relate to these components are identified as follows:[70]

- Project Information Tracking (for submitting and organizing general project data and permit applications)
- AoR and Corrective Action
- Financial Responsibility Demonstration

[64]O&O Reporting Guidance, p. 17.
[65]Site Characterization Guidance, p. 3.
[66]Site Characterization Guidance, p. 3.
[67]Site Characterization Guidance, p. 3.
[68]*See* O&O Reporting Guidance, p. 9: "The GSDT is for authorized users only and requires registration in compliance with the EPA's Cross-Media Electronic Reporting Regulation (CROMERR) and 40 CFR 144.32(a), under which UIC permit applications or other submittals by corporations must be signed by 'a responsible corporate officer or other authorized personnel."
[69]O&O Reporting Guidance, p. 15.
[70]O&O Reporting Guidance, p. 8.

- Preoperational Testing
- Project Plan Submissions
- Alternative PISC Time Frame Demonstration
- Injection Depth Waivers and Aquifer Exemption Expansions
- Nonendangerment Demonstration
- Injection and Post-injection Phase Reporting
- Information Request (for responding to permitting authority requests for additional information)

Site Characterization Information

The USEPA wants the site characterization to be presented as a narrative that "should integrate the information specified under 40 CFR 146.82(a)(2)–(3) and (5)–(6) to demonstrate a clear and data-driven understanding of the site and show how the site meets the criteria at 40 CFR 146.83."[71] This narrative should be "incorporated into the 40 CFR 146.82(a) narrative template, available in the Project Information Tracking module of the GSDT."[72] The preconstruction application data and information will need to be sufficient to support a permit to construct the well, but it can be supplemented with the data and information collected through the postconstruction logging and testing program. In addition, the site characterization narrative should be fully consistent with the other portions of the permit application and "should support the other site-specific aspects of the permit application, such as the proposed well construction procedures, the injection and post-injection phase testing and monitoring strategies, the Emergency and Remedial Response Plan, etc."[73]

Area of Review and Corrective Action

Area of Review Delineation

The AoR delineation is primarily intended to identify the area within which USDWs might potentially be endangered by injection operations, but the delineation also defines the area where corrective action on artificial penetrations that extend into the confining zone might be necessary, contributing to the evaluation of potential emergency and remedial responses might be necessary as inputs to determining financial responsibility cost estimates, identifying areas to be addressed in project-specific testing and monitoring strategies, and providing a focus for supporting alternative PISC time frame demonstrations and closure demonstrations. The USEPA wants applicants to submit a narrative that "describes procedures for delineating the AoR by using computational modeling, addressing all deficient artificial penetrations within the AoR, and reevaluating the AoR periodically throughout the life of the project."[74] Data and information that support the delineation of the AoR are not part of the AoR and Corrective Action Plan and should be submitted separately with this narrative rather than being incorporated in the plan. All the supporting information, "(e.g., computational modeling data such as simulator information and model input, assumptions, output, etc., and the tabulation of wells in the AoR) can all be submitted using the AoR and Corrective Action module."[75] Applicants should discuss data files and formats and what information will be submitted with the permit application reviewer to ensure that these will be submitted in a manner that facilitates use and review.

The USEPA also "recommends that applicants work with their permitting authority to identify the best approach for submitting project-specific modeling information; this will also help the permitting authority determine the most efficient and effective process to evaluate this information."[76] This information should include what models will be used before actually conducting the modeling because the applicant should understand how the application reviewers intend to conduct their review of the computational modeling, including in particular whether the reviewer plans to seek to recreate the modeling by using the same or some different models. The reviewer is not required to try to replicate the modeling or to make it possible for others to do so.[77] Nevertheless, it may be more difficult if proprietary models are used[78] and the reviewer wants to replicate the delineation,[79] unless specific arrangements are made to facilitate the reviewer's use of the models. Such arrangements are likely to be easier where open source models are used. The USEPA's specific recommendations on

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[71] O&O Reporting Guidance, p. 16.
[72] O&O Reporting Guidance, p. 16.
[73] O&O Reporting Guidance, p. 17.
[74] O&O Reporting Guidance, p. 19.
[75] O&O Reporting Guidance, p. 18.
[76] O&O Reporting Guidance, p. 18.
[77] *In re Archer Daniels Midland*, 17 E.A.D. 380 (2017); *In re FutureGen Industrial Alliance, Inc.*, 16 E.A.D. 717 (2015).
[78] The USEPA does explicitly recognize the appropriateness of using proprietary models:

> The EPA recognizes that some Class VI permit applications may rely on proprietary models, software, or inputs. Users should submit only non-proprietary information with the GSDT. The AoR and Corrective Action module does not necessitate user submittal of actual models or code—only the parameters, assumptions, results, and other supporting information that will allow the permitting authority to fully evaluate the AoR delineation are required. (O&O Reporting Guidance, p. 20)

[79] USEPA, 2013, Geologic sequestration of carbon dioxide: Underground Injection Control (UIC) Program Class VI well area of review evaluation and corrective action guidance: USEPA, EPA 816-R-13-005, p. 48:

> EPA recommends that this permit application submittal include all necessary information for the UIC Program Director to evaluate the AoR delineation results and replicate the computational modeling exercise if he or she elects to do so, as well as all model input and output data and files. ["AoR Guidance"]

the supporting material to be submitted with the delineation are presented in the AoR Guidance.[80]

Delineation of the AoR includes determination of the pressure front, which is fairly straightforward unless the injection is overpressurized relative to the USDW. The USEPA has provided examples of "methods to estimate an acceptable pressure increase for overpressurized reservoirs" in the AoR Guidance.[81]

Artificial Penetration Evaluation

The regulations require an applicant to "identify all penetrations, including active and abandoned wells and underground mines, in the area of review that may penetrate the confining zone(s)."[82] The search for penetrations is to be conducted using "methods approved by" the Class VI UIC Program Director. The USEPA has identified methods and sources of information available for identifying artificial penetrations.[83] With approval discretion granted to the Director, the method to be used for this identification is one on which the applicant and reviewer should reach agreement, and what is appropriate will be governed by site-specific circumstances, including specifically any oil and gas production history in the area. Once identified, each well must be evaluated to determine to the extent possible "each well's type, construction, date drilled, location, depth, record of plugging and/or completion, and any additional information the Director may require."[84] This evaluation is directed at determining which wells have the potential "to serve as a conduit for fluid movement."[85] Specifically, the regulations call for the applicant to determine "which abandoned wells in the area of review have been plugged in a manner that prevents the movement of carbon dioxide or other fluids that may endanger USDWs, including use of materials compatible with the carbon dioxide stream."[86] The USEPA's guidance describes a two-step process:

> The first step is to review whatever records are available, as outlined in section 4.3.1, for information relevant to proper plugging. The second step is to perform physical tests on wells that are suspect or for which no records are available.[87]

Corrective Action

Once wells in the AoR have been identified and evaluated, applicants "must perform corrective action on all wells in the area of review that are determined to need corrective action."[88] Methods for performing corrective action are described in the AoR Guidance.[89] The AoR and Corrective Action Plan must include a schedule for completing corrective action and describe the following:

> what corrective action will be performed prior to injection and what, if any, portions of the area of review will have corrective action addressed on a phased basis and how the phasing will be determined; how corrective action will be adjusted if there are changes in the area of review; and how site access will be guaranteed for future corrective action.[90]

As noted, the regulations provide the option (if approved by the UIC Program Director) of phased corrective action (i.e., deferring corrective action for those wells that are not expected, based on modeling and site-specific information, to be impacted by the carbon dioxide plume or pressure front for several years).[91]

Area of Review and Corrective Action Plan

The USEPA wants "the AoR and Corrective Action Plan [to] be provided as a single PDF file, uploaded to the AoR and Corrective Action module" in the GSDT.[92] Although a template is provided to ensure that all the relevant parts are provided, "applicants are encouraged to tailor their plans to the needs of their particular projects."[93]

Financial Responsibility Demonstration

Meeting the Class VI financial responsibility requirements is a two-step process that begins with developing and supporting the cost estimates for the elements that must be covered according to 40 CFR § 146.85(a)(2):

- Corrective action,
- Injection well plugging,
- Post-injection site care and site closure, and
- Emergency and remedial response.

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[80] AoR Guidance, p. 48.
[81] AoR Guidance, p. 42–43.
[82] 40 CFR § 146.84(c)(2), p. 77294; AoR Guidance, p. 50.
[83] AoR Guidance, p. 52–56.
[84] 40 CFR § 146.84(c)(2), p. 77294.
[85] AoR Guidance, p. 57.
[86] 40 CFR § 146.84(c)(3), p. 77294.
[87] AoR Guidance, p. 57.
[88] 40 CFR § 146.84(d), p. 77294.
[89] AoR Guidance, p. 62–66.
[90] 40 CFR § 146.84(b)(2)(iv), p. 77294.
[91] 40 CFR § 146.84(b)(2)(iv), p. 77294.
[92] O&O Reporting Guidance, p. 19.
[93] O&O Reporting Guidance, p. 19.

Ultimately, the cost calculations “must be sufficient to address endangerment of underground sources of drinking water” as determined through risk-based estimates.[94] Applicants are required to provide cost estimates based on “the costs to the regulatory agency of hiring a third party to perform the required activities,” that is, someone “not within the corporate structure” of the applicant.[95] If necessary, the cost estimates may be supported by “supplemental materials, such as engineering reports.”[96]

It is noteworthy that the costs to be covered by the estimates are very specifically enumerated in the regulations by reference to particular subsections. Thus, the cost estimate must cover the cost of “corrective action,” which expressly includes the following:

> on all wells in the area of review that are determined to need corrective action, using methods designed to prevent the movement of fluid into or between USDWs, including use of materials compatible with the carbon dioxide stream, where appropriate. [40 § CFR 146.84(d)]

It does not require including the cost of delineating the AoR or of periodically reevaluating the delineation, identifying additional artificial penetrations for evaluation, and designing corrective actions for those penetrations, as appears to be assumed by the Financial Responsibility Guidance.[97]

Estimating the cost of injection well plugging is fairly straightforward and consistent with the UIC Program requirements for other classes of injection wells. Guidance for this is available in the Class VI guidance documents and at http://www.epa.gov/uic/financial-responsibilities-underground-injection-well-owners-or-operators. Post-injection site care and site closure are also addressed in the guidance documents, and the most important consideration for PISC is the recognition that the scope and costs of testing and monitoring activities covered will be reduced as PISC proceeds.[98]

To date, the largest component of financial responsibility cost estimates has been the emergency and remedial response plans. As the USEPA has recognized, these plans and the resultant cost estimates should be developed using risk assessments and risk management plans:

> EPA envisions that each plan will be site-specific and risk-based, and depend on a variety of factors, including the nature of any movement of carbon dioxide or other fluids, the presence of USDWs, and what, if any, impacts could result from carbon dioxide movement into unintended zones, carbon dioxide leaks, or ground water or surface water contamination.[99]

Even if the approach is one of considering worst-case scenarios, an “Emergency and Remedial Response Plan may also consider whether the likelihood of the event is high, medium, or low, and tier the actions in the plan accordingly.”[100]

The second step in meeting the financial responsibility requirements is to provide the necessary financial instruments to provide assurance that funds are available if the permittee defaults on responsibilities to implement the actions covered by the cost estimates if and when necessary. It is particularly important to be aware that different combinations of instruments can be used and that the combinations used can be varied over time, given that the financial responsibility demonstration must be updated every year.[101] It is also important to note that the financial responsibility need not be finalized until the permit is ready to be issued because the cost estimates will vary throughout the application process as plans are modified in response to emerging data and technical information and in response to the negotiations between the applicant and the permit issuer.[102]

Injection Well Construction, Testing, and Operation

The Class VI regulations detail a number of specific requirements for well construction or conversion that are generally performance based and oriented toward protecting USDWs from endangerment. In most cases, these are further discussed and clarified in the USEPA’s guidance document for well construction.[103] There are, however, some situations

[94] 40 CFR § 146.85(a)(3), p. 77294.

[95] 40 CFR § 146.85(c)(1), p. 77295.

[96] O&O Reporting Guidance, p. 21.

[97] USEPA, 2011, Underground Injection Control (UIC) Program Class VI financial responsibility guidance: USEPA, EPA 816-R-11-005, p. C-4:

> While the Class VI Rule contains no specific requirement to demonstrate financial responsibility for AoR reevaluations, it will be necessary to update the AoR models to ensure that all wells that need corrective action are identified. The cost of this element derives from paying an expert (or team of experts) to set up, run, and interpret a site-specific simulation model. [“FR Guidance”]

[98] 40 CFR § 146.93(b)(2), p. 77300.

[99] USEPA, 2012, Underground Injection Control (UIC) Program Class VI well project plan development guidance: USEPA, EPA 816-R-11-017, p. 52. [“Plan Guidance”]

[100] Plan Guidance, p. 52–53.

[101] *See* FR Guidance, p. 43:

> Since financial conditions for independent third party firms and GS owners or operators are highly variable, it is important that the UIC Program Director determine the completeness and accuracy of the demonstration annually, as required by the Rule at 40 CFR 146.85(a)(5)(i).

[102] *See* O&O Reporting Guidance, p. 21:

> Because banks, insurers, or other financial institutions may not provide the specific instruments until the applicant is prepared to purchase them, the initial permit application may only contain information about the types of financial instruments to be used rather than the instruments themselves.

[103] USEPA, 2012, Underground Injection Control (UIC) Program Class VI well construction guidance: USEPA EPA 816-R-11-020. [“Well Construction Guidance”]

where the USEPA's guidance documents fail to accurately reflect the provisions and requirements of the regulations. Accordingly, it is always wise to refer back to the regulations, especially in circumstances where the guidance indicates that a practice or approach is prohibited, regardless of whether it would be fully protective of USDWs. The well construction guidance discussion of what is required for wells being converted from another class or use to serving as a Class VI well is one example of inconsistency between regulations and guidance.

Existing Well Conversion

When the USEPA finalized the well construction guidance, a new section was added that had not appeared in the draft guidance published for public comment. That new section contained statements that appeared to be presented as statutory or regulatory requirements but could only have been intended as recommendations or suggestions because those items are not requirements of the Class VI Rule. Thus, the "final" Well Construction Guidance appears to impose additional mandatory requirements that are not prescribed by the rule and could serve to disqualify substantial numbers of wells that are in full compliance with the Class VI regulations and would provide all of the necessary protections for USDWs. For example, the Well Construction Guidance presents this statement on page 37: "To demonstrate zonal isolation, an owner or operator must demonstrate, at a minimum, that the surface casing has intact cement from the bottom of the lowermost USDW to the surface." Yet this is not a required element of the Class VI Rule. Similarly, although the Well Construction Guidance states that "the long-string casing must be cemented from the production zone into the confining layer," the regulations do not in fact contain this requirement.[104]

By using mandatory terminology in these statements, the Well Construction Guidance fails to provide an accurate picture of what is required. It indicates instead that a well lacking these elements cannot be re-permitted by a UIC Program Director as a Class VI well even where the well complies with the applicable requirements of sections 146.81(c) and 146.86(a). In other places, the well construction and other guidance documents seemingly state as mandatory requirements approaches that should be treated as recommendations instead—places where UIC Class VI Directors actually have discretion to approve other approaches that are equally protective of USDWs.

Formation Evaluation and Postconstruction Logging

Although the regulations require that applicants develop and submit a "pre-operational formation testing program to obtain an analysis of the chemical and physical characteristics of the injection zone(s) and confining zone(s), and that meets the requirements at § 146.87,"[105] the USEPA guidance documents do not offer much more than what is stated in the regulations. To be sure, the regulations are very specific in identifying the testing and logging to be conducted in conjunction with well construction. Yet flexibility is also provided by including authorization to use "any alternative methods that provide equivalent or better information and that are required by and/or approved of by the Director."[106] The USEPA does provide that it "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."[107]

More extensive guidance on formation evaluation and well logging is available from the NETL *Best Practices: Operations for Geologic Storage Projects*.[108] That discussion addresses formation evaluation, well logging, mud logging, geophysical logging, and coring, as well as hydrologic and geomechanical testing. Given the importance of planning properly to obtain all the information that may be needed by the permit application reviewer, it is very important to review the details of the formation testing and well logging program and procedures with the permitting authority prior to execution.[109]

Monitoring and Testing Plan

The principal testing and monitoring requirement for Class VI is as follows: "The owner or operator of a Class VI well must prepare, maintain, and comply with a testing and monitoring plan to verify that the geologic sequestration project is operating as permitted and is not endangering USDWs."[110] The heart of this plan should be the "description of how the owner or operator will meet the [applicable testing and monitoring] requirements of this section" before and during the injection period.[111] As noted in the preamble to the final Class VI Rule, "these plans [should] be tailored to the GS project."[112] The USEPA "acknowledge[d] the importance of flexibility" and adopted an approach that "will allow for site specificity and selection of the most appropriate monitoring technologies."[113]

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[104]Well Construction Guidance, p. 37.
[105]40 CFR § 146.82(a)(8), p. 77293.
[106]40 CFR § 146.87(a)(5), p. 77297.
[107]Implementation Manual, p. 5-4.
[108]NETL, 2017b, Best practices: Operations for geologic storage projects: USDOE, DOE/NETL-2017/1848, p. 55–60. ["BPM for Operations"]
[109]*See*, for example, the BPM for Operations, p. 57:

> It is important to note that a provision in the U.S. EPA Class VI UIC permit indicates that regulators can request information about the geologic properties of sealing formations. Therefore, it is recommended that regulators be contacted during the development of a coring program. It is also recommended that [the] volume of sample needed for laboratory analysis also be factored into the decision on the specific type of coring method to be used.

[110]40 CFR § 146.90, p. 77298.
[111]40 CFR § 146.90, p. 77298.
[112]75 Fed. Reg. 77259.
[113]75 Fed. Reg. 77259.

Intended Flexibility and Adaptability

Thus, the applicant should develop a plan that presents a strategy for implementing a testing and monitoring program that will achieve the two-pronged requirement to (1) verify operation as permitted and (2) protect USDWs. That plan should be based on the site characterization and site-specific risk assessment and should identify the purpose for each testing or monitoring technique, explain how it fits that purpose, and show that the combination of techniques included in the strategy will achieve the mandated objectives when implemented in accordance with the strategy.[114]

To facilitate the development and implementation of an acceptable testing and monitoring plan, applicants will need useful information about the various available and developing techniques, the circumstances under which those techniques have been found to be most effective, whatever limitations have been identified, and how they might be used most effectively in combination with other techniques to provide an effective and cost-efficient program for an individual project. The USEPA's Testing and Monitoring Guidance[115] does a much better job of addressing the first two of these points but largely fails to provide the latter. The information on availability of techniques and examples of their use is also provided by some other sources,[116] but the critically necessary information on how to use combinations of techniques effectively is less available. One valuable tool is available from the DOE NETL National Risk Assessment Partnership in the form of its DREAM tool, which "was developed to assist in [the] design of effective and efficient GCS leakage monitoring networks."[117]

Strategy and Plan Development

The initial step in testing and monitoring plan development should be to use the information available to characterize the site and delineate the AoR as the area of the GS project[118] where there is a potential that USDWs might be endangered by the GS project. The testing and monitoring plan presents the strategy for ensuring that the injected CO_2 streams, pressure front, and displaced fluids remain within the defined GS project and AoR and that the GS project does not endanger USDWs. Importantly, this does not require that the plan include techniques designed to identify the exact size, shape, and location of the CO_2 plume or that the project operator "track the migration" of the plume, pressure front, or both on any real-time basis even if that were truly possible and affordable.[119] It does necessitate an understanding of the potential full three-dimensional "extent" of both and the use of methods to ensure that neither extends beyond the current projection, including using an iterative process and strategy to double-check those projections and make adjustments as necessary.[120]

Risk assessment should identify the events or series of events that might lead to endangerment of a USDW. Such events could, for example, include exceeding the permitted area or magnitude of elevated pressure, exceeding the permitted area of future migration or thickness of a two-phase plume, having a confining system that is not as impermeable or extensive as thought, or experiencing well integrity problems.

The testing and monitoring plan should identify measurement methods that will be sensitive enough to detect whether any identified unacceptable event is occurring or will occur and what actions should be taken in response. And the first response could be to trigger the implementation of additional monitoring, measurements, and analysis. To show that the plan will be effective, an operator should demonstrate through characterization and modeling that the proposed testing and monitoring plan would detect events that might lead to endangerment of USDWs. The plan should also be able to detect nonconformance of fluid migration and pressure response in the injection zone that might indicate the start of a chain of events potentially leading to endangerment of USDWs. Class VI Program Directors should not prescribe a cookie-cutter monitoring scheme that operators can substitute for conducting a site-specific assessment and showing how the proposed testing and monitoring plan will be effective.

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[114] NETL, 2017a, Best practices: Monitoring, verification, and accounting (MVA) for geologic storage projects: USDOE, DOE/NETL-2017/1847, p. 14:

> MVA programs need to be flexible and site-specific to adapt to the inherent variability and heterogeneity of geologic systems. MVA plans also tend to change in scope as a project progresses from the pre-injection phase to the post-injection phase. For all these reasons, MVA plans need to be tailored to site-specific geologic conditions and operational considerations. ["MVA BPM"]

[115] USEPA, 2013, Underground Injection Control (UIC) Program Class VI well testing and monitoring guidance: USEPA, EPA 816-R-13-001. ["Testing and Monitoring Guidance"]

[116] MVA BPM; Yonkofski, C., C.L. Davidson, L.R. Rodriguez, E.A. Porter, S.R. Bender, and C.F. Brown, 2017, Optimized, budget-constrained monitoring well placement using DREAM: Energy Procedia, v. 114, p. 3649–3655; Bacon, D.H., C.M. Yonkofski, C.F. Brown, D.I. Demirkanli, and J.M. Whiting, 2019, Risk-based post injection site care and monitoring for commercial-scale carbon storage: Reevaluation of the FutureGen 2.0 site using NRAP-Open-IAM and DREAM: International Journal of Greenhouse Gas Control, v. 90, article no. 102784.

[117] Accessible through https://edx.netl.doe.gov/nrap/dream-2/ (accessed August 25, 2020).

[118] According to 40 CFR § 146.81(d), p. 77292, the geologic sequestration project is essentially 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."

[119] MVA BPM, p. 54. *See also* p. 12:

> Subsurface monitoring of CO_2 storage projects includes monitoring the evolution of the dense-phase CO_2 plume, assessing the area of elevated pressure caused by injection, and measuring to determine that both pressure and CO_2 are within the expected and acceptable areas and migrating in a way that does not damage resources or the integrity of the storage.

[120] *See* MVA BPM, p. 15:

> The location of the injected CO_2 plume in the storage complex can also be inferred, via monitoring, to satisfy operating requirements under the Environmental Protection Agency's (EPA) Underground Injection Control (UIC) Class VI and GHG Reporting Programs to ensure that potable groundwater and ecosystems are protected.

Importance of Phasing and Staging

There is no requirement that the testing and monitoring plan list or adopt all the testing and modeling techniques that are deemed appropriate for consideration, with the expectation that all will be initiated from day one and throughout the life of the project. It is quite possible—and indeed most likely and desirable—that the plan will identify different techniques to be used at different stages of the process and with different frequencies in each of those stages. In addition, the strategy could identify a technique to be used to monitor for certain events that, if detected, would trigger a subsequent phase involving the implementation of additional steps to further investigate and evaluate what has been observed.

The role of triggers in a comprehensive plan is very important and not well recognized in USEPA guidance. If an unexpected measurement is made (outside the range of expected variability), this could trigger a set of additional measurements and analyses. In some cases, the unexpected measurement might indicate material risk to the project; in others it might be a completely benign miscalculation during initial characterization. The testing and monitoring plan should anticipate the appropriate follow-up work, which could be outlined in the plan.

Principal Reliance on Proven Techniques

In UIC Program experience that predates Class VI, injection pressure and rate were relied on heavily to assess performance. This strong and historically reliable tool should be the featured approach for Class VI as well. If the injection rate and injection pressure are deviating from their expected values or from past history, this should be reported and further evaluated. The pressure response to the injected volume is a key tool in management for all kinds of reservoirs operated for both production and storage.

Logging is deservedly a well-known workhorse for all kinds of reservoir management and can be highly useful in monitoring CO_2 in a reservoir and characterizing the key parameters of CO_2 saturation and thickness. Tools such as a reservoir saturation tool and sonic logging can be used in single runs or improved greatly by use in time lapse. These can be used in perforated wells and in boreholes or unperforated zones (good leakage detection). Unperforated boreholes could be desired because they are durable and the fluid in which the logging tool is run remains constant; operators should justify their decisions with respect to the value of pressure and fluid data. Production and injection logging are effective, relatively low-cost tools that can be used to see where fluids are accessing perforations.

Assessing flow distribution among perforations and sand intervals can be vital to assessing whether a GS project is performing as anticipated in the permit. Thus, it is important to design carefully and provide justification for the perforation strategy. Perforation over too many zones could result in dilution of the signal below detection. Too many perforations could allow all the fluid to preferentially enter the highest permeability zone. Modeling and assessment strategies should use evaluations and calculations that optimize not only well placement but also perforation.

Limitations of Geochemical Techniques

In the deep subsurface, geochemical detection of anomalies is not a very effective technique because fluid flow is slow (and diffusion even slower). Density and viscosity separation could easily isolate much of a leaked fluid from groundwater flow paths. A large plume could develop in zones above the confining system with no impact on geochemistry. That is why oil and gas exploration does not rely on using geochemistry. The oil and gas can be trapped and provide minimal indication that could be observed in any overlying, underlying, or laterally equivalent aquifer. It is better to test the trap itself for free-phase fluids. Carbon dioxide would be expected to behave similarly. Some dissolved plume-type assessments rely on gradient to drive transport, but sufficient gradient may not exist in the deep subsurface. Induced gradient toward water or hydrocarbon producers might be used to advantage, if they exist. In some regions, subsurface gradients are natural or formed by human interactions. Wherever present, these should be considered in the monitoring design.

Geochemistry is not useful in the evaluation of plume thickness. Once CO_2 arrives, the accessible wellbore will be filled with CO_2 because of its higher mobility. Plume thickness and saturation may be better history match parameters than CO_2 arrival (breakthrough). Saturation and thickness changes over time will provide a more robust cross-check on plume evolution. Plume thickness and saturation can be measured by various logging or geophysical techniques that are not described fully in the USEPA guidance.

Project-wide Planning Is Best

The Class VI regulations actually require that an applicant provide a different testing and monitoring plan for each individual well in a multiwell project. Because area permits are not allowed, the presumption is that applicants must provide a separate testing and monitoring plan for each well. Under this approach, if a site has five injection wells, the operator could be required to provide five plans. Not only would that be cumbersome for both the operator and the permit application reviewer, but it would also be counterproductive in the ultimate effort to protect USDWs because of the potential for inconsistencies and overly narrowly focused plans. Accordingly, the permitting authority should not only recognize the potential for plans to be developed on a project-wide basis but also provide the strongest possible encouragement to use that approach.

Low Utility of Air and Soil Monitoring

Surface or soil gas monitoring, or both, might conceivably be required by a permit, but must be "based on potential risks to USDWs within the area of review."[121] The goal of any monitoring should be to ensure that injected CO_2 streams remain confined in the subsurface and do not endanger USDWs. Surface air or soil gas monitoring would impose substantial costs, and the results of such monitoring would be subject to a host of confounding factors. Moreover, such monitoring would be aimed at leakage of CO_2 all the way to the surface, which—in the case of any properly permitted Class VI project—would by definition be an extraordinarily low-probability scenario. Accordingly, such requirements should not be imposed.

SUBMITTING POSTCONSTRUCTION AND PREOPERATION MATERIALS

Following construction of the well and completion of the preoperational formation testing and well logging program, the Class VI permitting process enters a second full round of review by the permit writer. As described in the USEPA Implementation Manual, the focus is as follows:

> 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.[122]

The following information will be submitted by the applicant for review:

- Updated geologic information based on the results of preoperational formation testing;
- A final AoR delineation based on computational modeling and the status of corrective action on wells in the AoR;
- 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;
- As-built well construction specifications and any revisions to the proposed operating data;
- Updates to the Testing and Monitoring Plan, Injection Well Plugging Plan, PISC and Site Closure Plan, and Emergency and Remedial Response Plan; and
- Updated information related to injection depth waivers, if applicable.

As with the other information required during the permit application process, the USEPA will require that this information be submitted through the GSDT. The reporting process is also similar; like the permit application, the USEPA recommends that owners or operators submit the following:

1. A narrative summarizing the changes to site characterization, strategies for site operation, etc., as a result of preoperational testing results (compiled into a single file and submitted using the Project Information Tracking module of the GSDT).
2. Specific, detailed information required by certain Class VI Rule provisions (submitted using other GSDT modules, which are tailored to the applicable rule requirements).[123]

Review of the postconstruction information and data submitted may also prompt further rounds of RAIs[124] that will be received and responded to through the GSDT. That additional process is described in the O&O Reporting Guidance[125] and in the Implementation Manual.[126]

The most critical information relates to site characterization and the AoR.[127] Significant changes to the geologic assessments of the injection and confining zones and other subsurface formation[128] may necessitate redoing the AoR delineation through a new round of computational modeling. If that is necessary, then it is also likely that the Class VI permit and the approved project plans will need to be modified and taken back through the process of having the permit authority issue a draft permit and conduct a public review and comment process (and possibly a public hearing) before issuing a final, revised permit and an authorization to inject.

If the AoR delineation is significantly different[129] and larger or reshaped to include area not previously within the AoR, the applicant will also be required to conduct a supplemental search and to identify and evaluate any additional artificial

[121] 40 CFR § 146.90(h)(1), p. 77299.
[122] Implementation Manual, p. 5-1.
[123] O&O Reporting Guidance, p. 34.
[124] *See* Implementation Manual, p. 5-10: "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."
[125] O&O Reporting Guidance, p. 33–43.
[126] Implementation Manual, p. 5-1–5-32.
[127] *See* AoR Guidance, p. 48: "The final delineated AoR based on computational modeling is submitted to the UIC Program Director prior to receiving authorization to inject [40 CFR 146.82(c)(1)]."
[128] *See* Implementation Manual, p. 5-4:

> 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.

[129] *See* Implementation Manual, p. 5-3, Table 5-1: "New geologic information may affect AoR delineation modeling inputs and, therefore, the size/shape of the AoR."

penetrations. Revisions to the corrective action plan will be required as necessary to address any new artificial penetrations needing corrective actions.

Given the importance of the AoR delineation to all other aspects of the permitting process and the potential delays that could be caused by a new full round of administrative processing required to complete modification of the permit and plans, it is particularly important to conduct the initial AoR delineation with full consideration of the uncertainties that could be involved in the site characterization and geologic assessment of the subsurface. Having a larger than necessary AoR delineated when full evaluation of the preoperational formation testing and well-logging program has been completed should avoid the need for permit modification.[130] Significantly, USEPA guidance recognizes that reviewing the AoR delineation at this stage is focused on ensuring the protection of USDWs—the objective is "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."[131]

In particular, any further changes in the delineation of the AoR within the permit and plans is something that should be deferrable until the next reevaluation of the AoR is conducted using the initial rounds of operational information and data. Taking this approach should be discussed with the permit authority throughout the preconstruction review stage. It is disconcerting that USEPA guidance documents almost appear to presume that permit modification and another full round of administrative and public review will be necessary for every Class VI permit. Specifically, the USEPA states that "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."[132] Thus, the first anticipated step in this process involves "revis[ing] the Class VI permit conditions as needed to address any changes in the understanding of the site."[133] With respect to potential changes to the AoR, the guidance almost appears to presume the need for modification:

> 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.[134]

Two important concepts must be understood to place these statements in their proper context. The first concept is the "delineation of the AoR," which is defined in 40 CFR § 146.84(a) as "the region surrounding the geologic sequestration project where USDWs may be endangered by the injection activity."[135] Accordingly, the heart of the delineation process is making sure that the delineated AoR fully encompasses the entire area "where USDWs may be endangered" by a Class VI project.[136] The next sentence of section 146.84(a) helps in understanding the delineation process because it states, "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 is based on available site characterization, monitoring, and operational data."[137] What is critically important here is that the AoR is delineated *using* computational modeling; it is not delineated *by* the computational modeling. It is also delineated using the other types of information and data identified. It is essential that the delineated AoR not be too small, but there is no danger from its being too large. Accordingly, an applicant can consciously decide to oversize the AoR to account for potential uncertainties that might yield different modeling outputs or to account for other uncertainties in site characterization.

The second important concept is "setting permit conditions." The USEPA states, "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."[138] By reference back to the earlier statement, one permit condition will establish the maximum injection pressure. Although the USEPA indicates that updated information might "necessitate a change in the approved injection pressure,"[139] this would be true only if the updated information indicated that the injection pressure in the permit was set too high. If the updated information would justify a higher injection pressure, then it is not at all necessary to change the permit condition that establishes the maximum injection pressure. Instead, the applicant could choose to accept the permit condition as set, and that condition would still "reduce or manage this potential endangerment."[140] Thus, the updated information does not trigger a need to modify the permit conditions only if the conditions would fail to be sufficiently protective without change.

[130] *See* Implementation Manual, p. 5-3, Table 5-1: "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."
[131] Implementation Manual, p. 5-11.
[132] Implementation Manual, p. 5-30.
[133] Implementation Manual, p. 5-30.
[134] Implementation Manual, p. 5-31.
[135] Implementation Manual, p. x.
[136] 40 CFR § 146.84(a), p. 77293.
[137] 40 CFR § 146.84(a), p. 77293.
[138] Implementation Manual, p. 2-1.
[139] Implementation Manual, p. 5-31.
[140] Implementation Manual, p. 2-1.

In sum, a permitting process that transparently adopts an approach of delineating the AoR and establishing permit conditions that allow for uncertainties and successfully accommodate updated information and data (including new computational modeling) without requiring revisions to provide sufficient protection of USDWs from endangerment should not result in a new round of administrative and public review to make major modifications. In addition, changes could be made to the AoR and corrective action plan (or any other plan) "where the modifications merely clarify or correct the plan, as determined by the Director."[141] Such minor modifications could, for example, explain how the approved plans served to account for any updated information.

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[141] 40 CFR § 144.41(h), p. 77289.

APPENDIX A: FINAL CLASS VI GUIDANCE DOCUMENTS AND QUICK REFERENCE GUIDES

FINAL CLASS VI GUIDANCE DOCUMENTS

1. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Site Characterization Guidance (PDF) (192 p., 4 MB, May 2013, EPA 815-R-13-004)
2. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Area of Review Evaluation and Corrective Action Guidance (PDF) (96 p., 4 MB, May 2013, EPA 816-R-13-005)
3. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Testing and Monitoring Guidance (PDF) (142 p., 5 MB, March 2013, EPA 816-R-13-001)
4. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Construction Guidance (PDF) (58 p., 1 MB, May 2012, EPA 816-R-11-020)
5. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Plugging, Post-Injection Site Care, and Site Closure Guidance (PDF) (73 p., 3 MB, December 2016, EPA 816-R-16-006)
6. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Well Project Plan Development Guidance (PDF) (104 p., 2 MB, August 2012, EPA 816- R-11-017)
7. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Financial Responsibility Guidance (PDF) (127 p., 924 K, July 2011, EPA 815-R-11-005)
8. Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Primacy Manual for State Directors (PDF) (167 p., 1 MB, April 2014, EPA 816-B-14-003)
9. Geologic Sequestration of Carbon Dioxide: Underground Injection Control Program Class VI, Recordkeeping, Reporting, and Data Management Guidance for Owners or Operators (PDF) (84 p., 3 MB, September 2016, EPA 816-R-16-005)
10. Geologic Sequestration of Carbon Dioxide: Underground Injection Control Program Class VI Implementation Manual for UIC Program Directors (PDF) (212 p., 5 MB, January 2018, EPA 816-R-18-001)
11. Using the Class V Experimental Technology Well Classification for Pilot Geologic Sequestration Projects (PDF) (23 p., 460 K, March 2007)
12. Geologic Sequestration of Carbon Dioxide: Draft Underground Injection Control (UIC) Program Guidance on Transitioning Class II Wells to Class VI Wells (PDF) (93 p., 1 MB, December 2013, EPA 816-P-13-004)
13. Key Principles in EPA's Underground Injection Control Program Class VI Rule Related to Transition of Class II Enhanced Oil or Gas Recovery Wells to Class VI (PDF) (2 p., 317 K, April 23, 2015)
14. Frequently Asked Questions: Class VI and Subpart RR Reporting (PDF) (2 p., 162 K, September 2016, EPA 816-U-16-001)

QUICK REFERENCE GUIDES

Quick Reference Guides on Class VI Program Implementation (accessed March 4, 2021)

Geologic Sequestration of Carbon Dioxide—UIC Quick Reference Guide: Additional Tools for UIC Program Directors Incorporating Environmental Justice Considerations into the Class VI Injection Well Permitting Process (PDF) (12 p., 457 K, June 2011, EPA 816-R-11-002)

The purpose of this Quick Reference Guide is to provide UIC Program Directors with additional tools to incorporate environmental justice considerations into the Class VI permit application review and approval process.

Geologic Sequestration of Carbon Dioxide—UIC Quick Reference Guide: Additional Considerations for UIC Program Directors on Interstate Coordination Requirements for the Class VI Injection Well Permitting Process (PDF) (10 p., 69 K, June 2011, EPA 816-R-11-003)

The purpose of this document is to provide additional considerations for UIC Program Directors on Interstate Coordination Requirements for the Class VI Injection Well Permitting Process. Notification of specific agencies at the State, Tribal, and Territorial level (by the UIC Program Director) regarding the receipt of a Class VI injection well permit application should afford such entities an opportunity to provide input on any relevant activities in the permit application review process.

Geologic Sequestration of Carbon Dioxide—UIC Quick Reference Guide: Additional Considerations for UIC Program Directors on the Public Participation Requirements for Class VI Injection Wells (PDF) (14 p., 407 K, June 2011, EPA 816-R-11-001)

The purpose of this document is to present a series of steps for achieving the public participation requirements of the Class VI Rule.

APPENDIX B: U.S. ENVIRONMENTAL PROTECTION AGENCY PERMIT PROCESS OUTLINE

The U.S. Environmental Protection Agency (USEPA) uses its Geological Sequestration Data Tool (GSDT) to manage communications with permit applicants in order to develop and manage a comprehensive administrative record, consisting of all documents and communications supporting permitting decisions.

I. PERMIT APPLICATION PROCESS

A. Here are the specific types of information that must be submitted to USEPA during the permit application process:
   1. Site characterization and preinjection logging and testing
   2. Area of review (AoR) delineation using "computational modeling" and identification of artificial penetrations in the AoR, assessment of the integrity of any penetrations "that may penetrate the confining zone(s)," and plans for corrective action on any faulty wells
   3. Injection depth waiver (if necessary)
   4. Well construction and operation
   5. Logging and testing program after construction and before injection
   6. Financial responsibility demonstration
   7. Testing and monitoring plan for implementation during the injection operations
   8. Post-injection site care (PISC) plan
   9. Alternative PISC time frame demonstration
   10. Well plugging and abandonment plan
   11. Site closure plan, including nonendangerment demonstrations
   12. Emergency and remedial response plan

II. PERMITTING STAGES

A. Permit application—all communications through the GSDT
   1. Completeness review
   2. Notice of completeness
   3. Technical review
   4. USEPA notices of deficiency (NODs) or requests for additional information (RAIs)—could be multiple rounds
   5. Submissions of additional information by applicant

B. Draft permit or notice of intent to deny the application or terminate the permit [40 CFR § 124.9(b)(2)]
   1. Draft permit and attachments
   2. Statement of basis or fact sheet [40 CFR § 124.9(b)(3)]

C. Public notice and requests for comments—opportunity to request hearing
   1. Comment period
   2. Hearing if request is granted

D. Issuance of the final permit to construct the well(s)
   1. Drilling and completion
   2. Preoperational testing and logging
   3. Submit final construction and completion report and any necessary revisions to permit application and plans

E. Potential need for permit amendment

F. Authorization to inject

III. PERMIT DOCUMENTATION

A. Permit

B. Attachments
   1. Summary of requirements
   2. AoR and corrective action plan
   3. Testing and monitoring plan and quality assurance and surveillance plan (QASP)
   4. Well plugging plan
   5. PISC and site closure plan
   6. Emergency response and remediation plan
   7. Construction details
   8. Financial responsibility demonstration
   9. Stimulation program