COMMENT #4

Comments on Draft language for WAC 173-218: Geologic Sequestration of Carbon Dioxide

Submitted by Pacific Northwest National Laboratory Staff

B. P. McGrail, M. D. White, F. A. Spane, C. L. Davidson, E. C. Sullivan, P. E. Jagucki

ADDITIONS TO: WAC 173-218 DEFINITIONS.

"*Geologic sequestration reservoir*" means the volume of a target geologic formation that contains some or all of the injected carbon dioxide.

"*Region of Influence (ROI)*" means the areal boundary including all geologic sequestration reservoirs of the project containing 95 percent of the injected CO_2.

"S*equestration project boundary*" shall be defined as the boundary including all geologic sequestration reservoirs of the project containing 95 percent of the injected CO_2 mass 100 years post-injection, or the plume boundary at the point in time when the areal expansion is less than 1 percent per year, whichever is greater.

"*Geologic sequestration of carbon dioxide*" means the injection of carbon dioxide, usually from human activities like burning coal or oil, into subsurface geologic formations as a means of limiting release of the CO_2 into the atmosphere for a defined length of time.

GENERAL COMMENTS

1. The draft rules provide no guidance on minimum qualifying standards for geologic sequestration projects in Washington State. Minimum standards should be specified in at least several areas as follows:

    a) The sequestration project boundary shall remain within the territorial region of the United States and be greater than 10 miles away from the nearest international border.

    b) The sequestration project boundary shall not approach within 10 miles of a marine shoreline.

    c) At least 75 percent of the land area above the sequestration project boundary must reside outside a 100-year flood plain.

    d) At least 75 percent of the land area above the sequestration project boundary must be physically accessible for monitoring equipment and/or monitoring surveys.

    e) The sequestration project boundary must have low risk from significant seismic events with peak ground acceleration less than 35 percent g, with a 2 percent chance of exceedance in 50 years, or a site-specific seismic analysis demonstrating equivalent ground motion hazard.

    f) No active faults should be present within 5 miles of the nearest proposed injection well. Active faults are defined as those with Holocene fault scarps or seismic data or other documentation of historic earthquakes.

2. Ecology should reconsider requiring a Waste Discharge Permit. WAC 173-218 should provide for issuance of a geologic sequestration operating permit, which would supersede requirements under the Waste Discharge Permit program. Have all the necessary requirements provided in WAC 173-218. The current Waste Discharge Permit under WAC 173-216 is specific to industrial wastewater. For a commercial sequestration operation, it makes no sense for a utility to force fit their planned operation into a filing for an industrial waste water application. Moreover, this will trigger collection of injection fees under WAC 173-224-040. There is no category in WAC 173-224-040 presumably other than "Other" that could be applied to a CO2 sequestration project. A fee schedule is probably needed in WAC 173-218. Care needs to be exercised to ensure those fees are not sufficiently onerous to make it economically impossible to site a project.

3. The current draft does not include or specify the need for a site-specific characterization well. While the characterization information specified in the draft can be provided by surrounding local and regional wells, the feasibility of a permitted commercial operation must be determined by actual site conditions. It would make sense, therefore, that the regulations identify that an initial pilot characterization borehole may be needed at the site for assessing the feasibility of the proposed commercial operation, and to provide detailed site information about the injection reservoir(s) and caprock(s) for regulatory permitting purposes. With this regard, it would be prudent to allow a "staged" approach for the permitting application, which would allow site pilot characterization borehole studies to be performed, prior to submitting a formal/final operational permit application for the site.

4. Although elements are identified in the text discussion, the draft does not include a requirement of a proposed sequestration system design or operational plan for the commercial facility. This would include in addition to the elements identified in the draft (e.g., volumes of CO_2 injected), the number of injection wells employed, how injection wells will be operated within an operational year (e.g., cycled on vs. off periods), and how the injection will be managed over the lifetime of the facility (e.g., if multiple injection reservoirs be utilized).

5. The injection zone is referred to as the "target formation" and "injection reservoir" interchangeably within the draft discussion. It is recommended that a zone identified for CO_2 injection be uniformly referred to as the "target formation" throughout the draft. Additionally, the draft discussion addresses only an individual target formation or zone, when multiple formations may be utilized at a particular site.

6. While the monitoring program (page 6) calls for monitoring water-quality parameters to ensure integrity of shallower aquifer systems, the regulations should specifically identify monitoring of pressure responses immediately above the injection reservoir horizon. In – reservoir monitoring might also be done subject to issues associated with deep monitoring wells.

7. Regarding the issue of a requirement for monitoring wells, in particular deep monitoring wells - both Region V and Ohio EPA have explicitly stated concerns with deep monitoring wells being nothing more than additional risk for leakage. This is one of the reasons they don't force hazardous waste injection facilities to have monitoring wells.

8. The writeup does not appear to provide for a staged implementation, which is very important to the applicant and should be to EFSEC as well. Stage 1 should include well installation and

characterization, and Stage 2 should include the injection operating phase and closure/post closure. Permitting guidelines are needed for both stages, with simpler streamlined guidelines for Stage 1.

9. The draft does not address issues associated with multicomponent gas streams that are produced from fossil power plants. There needs to be some specifications provided on CO2 purity that would qualify under an operating permit. Should a utility propose injecting a CO2 stream outside those specifications, additional information would be needed in their application. Of particular importance is H_2S for IGCC type plants and SO_x for PC or oxy-combustion plants.

SPECIFIC COMMENTS #1 (EDITED TEXT IN RED)

WAC 173-218-XXX Specific requirements for Class V wells used to inject carbon dioxide for permanent geologic sequestration.

(1) Class V wells used to inject carbon dioxide for geologic sequestration are not rule authorized and must obtain a state waste discharge permit under chapter 173-216 WAC State waste discharge permit program or chapter 173-226 WAC Waste discharge general permit program.

Comment [BPM1]: ee General Comments. There are very significant problems with a Waste Discharge Permit requirement.

(2) Class V wells used to inject carbon dioxide for geologic sequestration may directly discharge into an aquifer only if:

(a) The aquifer contains "naturally non-potable ground water" as defined in WAC 173-200-020(18) and is deeper than any potable ground water within the project area;

(b) operators have obtained a permit under the state waste discharge permit program or the waste discharge general permit program establishing enforcement limits which may exceed the ground water quality criteria, as allowed under WAC 173-200-050(3)(b)(vi); and operators are in compliance with all conditions of their state waste discharge permit or their waste discharge general permit.

Permit Application

The application for a discharge permit authorizing the injection of carbon dioxide for geologic sequestration shall include information supporting the demonstration required by WAC 173-200-050(3)(b)(vi) and the following:

(1) A current site map showing the *sequestration project boundary*, the location and well number of all proposed CO_2 injection wells, including any subsurface observation wells and the location of all other wells including cathodic protection boreholes and the location of all pertinent surface facilities within the *sequestration project boundary*;

(2) A technical evaluation of the proposed project, including but not limited to, the following:

(a) The name of the *target formation(s)*;

(b) The name, description, and average depth of the *target formation(s)*;

(c) A geologic and hydrogeologic evaluation of the *target formation(s)*, including an evaluation of all existing information on all geologic strata overlying the *target formation(s)*, including the immediate caprock containment characteristics and all designated subsurface monitoring zones. The evaluation shall include any available geophysical data and assessments of any regional tectonic activity, local seismicity and regional or local fault zones, and a comprehensive description of local and regional structural or stratigraphic features. The evaluation shall focus on the proposed *target formation(s)* and a description of mechanisms of geologic confinement, including but not limited to rock properties, regional pressure gradients, structural features, and absorption characteristics with regard to confinement of CO_2 within the sequestration project boundary. The evaluation shall also identify any productive oil and natural gas zones occurring stratigraphically above, below, or within the *target formation(s)* and all water-bearing horizons known in the immediate vicinity of the *target formation(s)*. The evaluation shall include a

method to identify unrecorded wells that may be present within the project boundary. The evaluation shall include exhibits and plan view maps showing the following:

(i) All wells, including but not limited to, water, oil, and natural gas exploration and development wells, and other man-made subsurface structures and activities, including coal mines, within one mile of the *sequestration project boundary*;

(ii) All manmade surface structures that are intended for temporary or permanent human occupancy within one mile of the *sequestration project boundary*;

(iii) Any regional or local faulting;

(iv) An isopach map of the proposed *target formation(s)*;

(v) An isopach map of the primary and any secondary containment barrier;

(vi) A structure map of the top and base of the *target formation(s)*;

(vii) Identification of all structural spill points or stratigraphic discontinuities controlling the isolation of stored CO_2 or associated fluids;

(viii) An evaluation of the potential displacement of in situ water and the potential impact on groundwater resources, if any; and

(ix) Structural and stratigraphic cross-sections that describe the geologic conditions of the *target formation(s)*.

A licensed geologist or engineer shall conduct the geologic and hydrogeologic evaluation required under this paragraph. As appropriate, existing geologic, geophysical, or engineering data available within the *sequestration project boundary* may be incorporated into the evaluation;

(d) A review of the data of public record for all wells within the *sequestration project boundary*, which penetrate the reservoir or primary and/or secondary seals overlying the *target formation(s)*, and those wells that penetrate the *target formation(s)* within one half mile, or any other distance as deemed necessary by the department, of the *sequestration project boundary*. This review shall determine if all abandoned wells have been plugged in a manner that prevents the movement of CO_2 or associated native fluids from the *target formation(s)*. A geologist or engineer shall conduct the review required under this paragraph;

(e) The proposed sequestration project boundary shall be calculated using numerical simulation[1,2,3,4,5,6] of CO_2 injection into each proposed target formation. Numerical simulators

---

[1] ECLIPSE, Schlumberger (http://www.slb.com/content/services/software/reseng)

[2] TOUGH, Lawrence Berkeley National Laboratory (http://www-esd.lbl.gov/TOUGH2/index.html)

[3] STOMP, Pacific Northwest National Laboratory (http://stomp.pnl.gov)

for modeling the geologic sequestration of carbon dioxide shall include but not be limited to the following capabilities:

(i) multifluid flow through variably saturated geologic media;

(ii) nonisothermal environments;

(iii) supercritical and subcritical CO_2 environments;

(iv) aqueous phase, comprising liquid water, dissolved CO_2, and dissolved salt;

(v) gas phase, comprising water vapor and CO_2;

(vi) reactive transport for the chemical system comprising water, CO_2, salt and minerals of the *target formation(s)*, considering porosity and permeability alteration with precipitation and dissolution;

and shall include but not be limited to the following *target formation(s)* hydrologic and transport properties:

(i) porosity

(ii) compressibility

(iii) intrinsic permeability or hydraulic conductivity

(iv) aqueous and gas relative permeability versus saturation functions

(v) aqueous and gas saturation versus capillary pressure functions

(iv) thermal conductivity and specific heat

(vi) equilibrium and kinetic reactions

(f) The proposed maximum bottom hole injection pressure to be utilized at the reservoir. The maximum allowed injection pressure, measured in psig, shall be no greater than 80 percent of the formation fracture pressure as determined by a step-rate test or other method approved by the department. The *target formation(s)* shall not be subjected to injection pressures in excess of the calculated fracture pressure even for short periods of time. Higher operating pressures may be allowed if approved in writing by the department. The application, if approved by department, shall be subject to any conditions established in the permit;

~~(g) The proposed maximum long-term *target formation* pressure and the necessary technical data to support the proposed *geologic sequestration target formation* storage pressure request.~~

Comment [BPM2]: This request reads like a single parameter but there really is no such thing. Pressure varies in space and time – this request does not provide useful data to evaluate a project.

[4] NUFT, Lawrence Livermore National Laboratory (http://www.llnl.gov/IPandC/technology/software/softwaretitles/nuft.php)

[5] FEHM, Los Alamos National Laboratory (http://www.ees5.lanl.gov/fehm)

[6] PFLOTRAN, Los Alamos National Laboratory (https://software.lanl.gov/pflotran)

(3) The *sequestration project boundary*, determined by utilizing all available geologic and reservoir engineering information, and the projected response and storage capacity of the geologic sequestration target formation;

(4) A detailed description of the proposed project public safety and emergency response plan. The plan shall detail the safety procedures concerning the facility and residential, commercial, and public land use within one mile, or any other distance as deemed necessary by the department, of the *sequestration project boundary*. The public safety and emergency response procedures shall include contingency plans for CO_2 leakage from any well, flow lines, or other permitted facility. The public safety and emergency response procedures also shall identify specific contractors and equipment vendors capable of providing necessary services and equipment to respond to such CO_2 injection well leaks or loss of containment from CO_2 injection wells or the *geologic sequestration reservoir(s)*. These emergency response procedures should be updated as necessary throughout the operational life of the permitted storage facilities.

(5) A detailed worker safety plan that addresses CO_2 safety training and safe working procedures at the facility;

(6) A corrosion monitoring and prevention plan for all wells and surface facilities;

(7) A leak detection and monitoring plan for all wells and surface facilities. The approved leak detection and monitoring plan shall address:

(a) Identification of potential release to the atmosphere;

(b) Identification of potential degradation of all groundwater resources; and

(c) Identification of potential migration of CO_2 into any overlying oil and natural gas reservoirs.

(8) A geologic sequestration target formation leak detection and monitoring plan utilizing subsurface observation wells to monitor any movement of the CO_2 volume outside of the permitted *sequestration project boundary*. This may include the collection of baseline information of CO_2 background concentrations in groundwater, surface soils, and chemical composition of in situ waters within the *target formation(s)*. The approved subsurface leak detection and monitoring plan shall be dictated by the site characteristics as documented by materials submitted in support of the application with regard to CO_2 containment and address:

(a) Identification of potential leakage pathways to the atmosphere;

(b) Identification of potential migration pathways groundwater resources; and

(c) Identification of potential migration pathways of CO_2 into any overlying oil and natural gas reservoirs.

SPECIFIC COMMENTS #2

1. Permit Application

   a) "designated monitoring zones" are not clearly defined anywhere.

   b) "The evaluation shall also identify any productive oil and natural gas zones occurring stratigraphically above, below, or within the geologic sequestration target formation and all water-bearing horizons known in the immediate vicinity of the geologic sequestration target formation." *A distinction should be made here between potable and non-potable reservoirs. The applicant should identify the deepest potable aquifer above the sequestration project boundary.*

   c) Part 8 – Delete the word "any". It is not possible to meet this standard. I think it would really be preferable to not mandate monitoring wells per se but allow the applicant to propose a monitoring program that is protective of drinking water and human health. Section also refers to singular target formation when multiple formations may actually be used.

2. Please consider the following paragraphs for the types of geological and other data being required for sequestration projects in other states:

   a) Provide a topographical map (or other map if a topographical map is unavailable) on a scale not smaller than four hundred feet to the inch, prepared by a Registered surveyor, extending one mile beyond the sequestration project boundaries and depicting the facility and each of its intake and discharge points; each of its hazardous waste treatment, storage or disposal facilities, including but not limited to neutralization ponds, segregating or mixing tanks, and any solid waste disposal areas on site; each well where fluids from the facility are injected underground, including but not limited to known mines, mineral deposits, and other oil and gas reserves; and those wells, springs, wetlands and other surface water bodies, and drinking water wells listed in public records or otherwise known to the applicant within a quarter mile of the facility property boundary. If the well is or is to be located within the excavations and workings of a mine, the map shall also include the location of such mine, the name of the mine, and the name of the person operating the mine.

      a. Drilling and completion records including:
         a. Daily reports;
         b. Driller's log or record of strata;
         c. Casing and tubing records: pipe tallys;
         d. Detailed screen and liner setting;
         e. Cement records;
         f. Details of centralizers, scratchers, and other such equipment; and,
         g. Engineering drawings of:
            i. Well completion;
            ii. Packer assembly and setting; and,
            iii. Well head, parts list.

      ii. Geophysical logs:
         a. Final prints of all logs run on each well;
         b. Interpretation of logs by a qualified person; and,

c. Directional or inclinational survey.

iii. Testing records:

a. Well testing:

i. Static fluid level;

ii. Bottom hole temperature and pressure;

iii. Injectivity test result; permeability determination; reservoir limits and storage;

iv. Spinner or tracer surveys; and,

v. Casing testing results.

b. Laboratory testing results:

i. Cores for permeability;

ii. Cores for compatibility;

iii. Cores for porosity;

iv. Analysis of formation water;

v. Descriptive core analysis and sieve analysis.

b) Provide the following geologic information as indicated:

i. Provide maps and cross sections indicating the general vertical and lateral limits of all underground sources of drinking water within the sequestration project boundary, their position relative to the injection formation and the direction of water movement where known, in each underground source of drinking water. Geologic description of aquifer units including: name, age, depth, thickness, lithology, and TDS (Ave.);

ii. Depth to base of potable quality groundwater;

iii. Depth to base of potentially useable groundwater

iv. Depth to base of non-potable groundwater;

v. Generalized maps and cross sections illustrating the regional geologic setting;

vi. Lithology of injection and confining intervals;

vii. Lithostatic pressure gradient (use 1.0 psi/ft) of the injection interval;

viii. Fracture pressure (psig) (show how derived) of the injection interval;

ix. Average porosity of the injection interval;

x. Permeability (millidarcies) of the injection interval;

xi. Results of the formation testing program including an analysis of the chemical, physical, and radiological characteristics of each target formation;

xii. Maps and cross-sections showing the location of seismic areas, flood hazard areas, carbonate formations that result in caverns, and underground mines, both active and inactive;

xiii. Bottom hole temperature and pressure and,

xiv. The results of the pump test and injectivity tests

1. 1st Page; Additions to WAC173-218 Definitions: Modify Caprock definition to read: " …'Caprock' means the geologic formation that has sufficiently low permeability and lateral continuity to prevent the upward migration of injected carbon dioxide."

2. 2nd Page; Permit Application, Item 2(c), Third Sentence: Following the phrase "…..and absorption characteristics" add "or geochemical reaction/mineralization processes with regard to …..".

3. 3rd Page; Permit Application, Item 2(f): Modify the following:
   a) change the maximum allowed injection pressure from 90 to 80% of the minimum threshold injection reservoir fracture pressure.

   b) for establishing the minimum threshold injection reservoir fracture pressure, change "step-rate test" to "mini-frac injection test" or "multiple-stage, minimum threshold fracture injection test".

4. 5th Page; Geologic Sequestration Well Standards, Item 6: Modify "All geologic data including: logs, surveys, cuttings and cores ……" to "All geologic data including: logs, surveys, and geologic descriptions of cuttings and cores……"

5. 5th Page; Geologic Sequestration Well Standards, Item 7(d): Comment: while wireline surveys for casing integrity/corrosion assessment are common assessment tools, annual pressure testing of injection wells would be a significant cost and time requirement for an operational commercial facility. This requirement is not reflected in other similar, permitted injection well regulations. It is recommended that injection well-casing pressure testing be required over a much larger regulatory periods (e.g., 5 to 10 years), unless warranted or indicated by wireline casing integrity/corrosion survey results.

6. 6th Page; Permit Terms and Conditions, Item 5(c): "Continuous monitoring of pressure on annulus between tubing and long-string casing" assumes that an injection packer-tubing-string would be used inside of the cemented casing string. For cases where a cemented casing-string is set to immediately above the injection reservoir, a packer-tubing-string system would not be employed and no open annulus would be available for monitoring of pressures.

7. 7th Page; Closure: Comment: operational plants may be required to sequester only a percentage of the CO_2 emissions produced at the plant to meet State regulations. This may mean from an operational perspective that CO_2 emissions are sequestered only during periods of the year, and that off-cycle, sequestration periods may exceed the draft specified 90-day period that triggers implementation of a closure plan. It is recommended that a larger time period (e.g., 180-days) be utilized as the criteria for implementing a facility closure plan.