UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF:
WP-16J

TRANSMITTED VIA EMAIL

Rory Chambers
Wabash Valley Resources, LLC
444 West Sandford Avenue
West Terre Haute, Indiana 47885
RChambers@wvresc.com

Subject: Underground Injection Control (UIC)
Class 6 Permit Applications WVCCS #1 and WVCCS #2
Permit Nos. IN-165-6A-0001 (Vermillion County) and IN-167-6A-0002
(Vigo County), Indiana (R05-IN-0001)

Dear Mr. Chambers:

Wabash Valley Resources, LLC (Wabash) submitted permit application materials as referenced above into the Geologic Sequestration Data Tool (GSDT) in April and May of 2021. EPA issued a letter to Wabash dated January 13, 2022, stating that the permit application is administratively complete per 40 C.F.R. § 124.3(c).

EPA requests additional information and seeks clarification relative to the materials. EPA is issuing the request in accordance with the regulation cited above. Please respond to the requests for additional information or clarifications within 60 days of receipt of this letter.

Should you have any questions, please contact Marc Fisher of my staff at (312) 886-4240 or (fisher.marc@epa.gov).

Sincerely,

STEPHEN JANN

Digitally signed by STEPHEN JANN
Date: 2022.09.28 09:07:13 -05'00'

Stephen M. Jann
Manager, Permits Branch
Water Division

Enclosure

ATTACHMENT A: EPA TECHNICAL REVIEW COMMENTS

Wabash Carbon Services, Permit Applications for WVCCS #1 and WVCCS #2
Permit Nos. IN-165-6A-0001 (Vermillion County) and IN-167-6A-0002 (Vigo County), Indiana (R05-IN-0001)

A. LIST OF DOCUMENTS REVIEWED

The following is a list of documents that were reviewed from the Geologic Sequestration Data Tool (GSDT). All files were located in the Submission Archive folder, Phase 1 – Pre-construction subfolder. Superseded documents in GSDT were not reviewed.

1. From the Project Info 4-28-2021 folder:
   a. 146.82a_Narrative Template.pdf
   b. ProjInfo.pdf
2. From the ProjPlan 4-28-2021-1121 folder:
   a. ERR_Template.pdf
   b. PISC_SC_Template.pdf
   c. Plugging_Template - -WVCCS - -1.pdf
   d. Plugging_Template - -WVCCS - -2.pdf
   e. ProjPlan.pdf
   f. TM_Template.pdf
3. From the AoRModeling 05-04-2021 folder:
   a. AoR_CA.pdf
   b. AoRModeling.pdf
   c. Critical - - Pressure - - Calculation.docx
   d. Oil - - and - - Gas - - List.csv
   e. All other individual files (45 total) in this folder that seem to have been incorporated in the AoR_CA.pdf document
4. From the PreOpTest 04-28-2021 folder:
   a. Proposed - - Pre-Operational - - Testing - - SVCCS1.pdf
   b. Proposed - - Pre-Operational - - Testing - - SVCCS2.pdf
   c. PreOpTest.pdf
   d. All other individual files in this folder
5. From the FinancialResp 04-28-2021 folder:
   a. CCS - - Injection - - Well - - Plugging.doc
   b. CCS - - T - - M - - Cost.pdf
   c. FinancialResp.pdf
   d. Financial - - Responsibility - - Calculation.xlsx
   e. Remediation - - Estimate - - CCS.pdf
   f. Wabash - - Trust - - Agreement 4-26-2021 - - Signed.pdf
   g. WELL - - PAD - - REMOVAL - - QUOTE.pdf
   h. Well - - Talley - - Workbook.xlsx
6. From the AlternativePISC 04-24-2021 folder:
   a. AlternativePISC.pdf

B. GENERAL COMMENTS

1. The following comment applies to most of the figures in the permit application. The resolution renders most of the legends and axis labels illegible. Please provide updated figures at a resolution that is legible both electronically and in print.
2. Please provide the boring log for Wabash #1 test hole along with a description of the drilling, sampling and logging methods.
3. Please provide a detailed injection well construction diagram for WVCCS#1 and #2.
4. Starting on page 4 under the heading "injection zone and continuing to page 5 ending with the heading "confining zones", the injection zone is identified as the Potosi Dolomite and the confining "zones" are identified as the Shakopee Dolomite, the Dutchtown Formation and the Maquoketa Group. The results of the area of review (AoR) modeling may indicate (as depicted in Figures 15 and 16) the injection zone extends above the top of the Potosi Dolomite into the Oneota Dolomite. Additionally, the Maquoketa Group along with geologic formations between the bottom of the Maquoketa and the top of the Potosi are referenced as the "confining zones". EPA will typically rely upon one "confining zone" as it relates to prevention of fluid movement and only one geologic unit is referenced. It is understood that other geologic formations/units between the bottom of the named confining unit and the top of the injection zone may inhibit fluid movement. This item relates to requests for clarification and information found later in this correspondence.
5. There is overlap and duplication of text, figures, and tables between the Narrative and the AoR modeling documents. EPA doesn't wish to cross-check all these occurrences and it is incumbent upon the applicant to ensure that changes made to the text, figures, and tables cited, will also be made to the corresponding areas of the documents.

C. PERMIT NARRATIVE AND GEOLOGIC SUMMARY

The following comments and questions are regarding the 146.82a_Narrative Template.pdf document.

1. Regarding the "Confining Zones" section, starting on page 4:
   a. Please confirm all of the geologic units that will be relied upon as part of the confining zone for this injection. The Shakopee Dolomite, Dutchtown Formation and the Maquoketa Group are the only units listed in this section (pages 4 and 5). The subsection titled "Overlying and Confining Units" on page 24 (also listed on pages 11 and 12 of the AoR and Corrective Action document) lists all of the geologic units on Table 4, page 27 (and Table 1, page 7 of the AoR document). It is stated, for instance, on page 24 that Platteville Group and the Trenton Limestone are "considered as a single confining interval because the rock properties are similar." If this is the case, include these geologic units in the list on pages 4 and 5 or explain why they are not included. To reduce confusion, confining units should refer only to those contiguous geologic formations used in the AoR modeling. Additionally, only geologic units used in the AoR modeling will be part of the "confining zone" as defined by 40 C.F.R. § 146.3 unless data suggests that other geologic units should also be included.
   b. If possible, please provide isopach maps for all geologic units in the confining zone.
   c. Please add a column to Table 4, page 27 indicating the source for the data cited in the other columns and add a row to give the cumulative thickness for the formations and for the shale thickness columns.

d. While a higher gamma ray signature is characteristic of the Shakopee and Oneota, most likely reflecting clay content, the density and density-porosity curves in Figures 2 and 3 indicate porous intervals exist in these formations as well (e.g., Huisinga well). Please explain how these formations will act as confining units given the displayed heterogeneity and porosity based on the logs in Figures 2 and 3, and how this data was used in the model.
e. Please support the statement on page 5 (last sentence in the Dutchtown Formation paragraph) that a higher neutron porosity reflects a lower clay content or revise this statement.
f. The log characters for some of the geologic units depicted on Figures 2 and 3 seem variable indicating heterogeneity. Please provide a discussion of how this heterogeneity is considered in the characterization of these units for confinement.
g. Figure 1, page 7 (and Figure 4, page 6 of the AoR document): Stratigraphic column – Please provide a site-specific stratigraphic column that identifies all geologic units, including depths to the tops of formations, from the ground surface to the injection zone. All USDW's should be identified. Also, please demark and label the injection zone and the confining zone on the cross-section.
h. Please label the isopach lines of the Shakopee in Figure 5.
i. For cross-section Figures 6 and 7, pages 9 and 10: If possible, extend the geologic interpretation up the column to the top of the Maquoketa Group to match the units identified in the model domain Figure 9, page 14.
j. The Maquoketa Shale is listed as (~312 ft), 314 ft, and 315 ft in different sections of the Narrative and in the AoR and Corrective Action Plan. Please update the estimates of the thickness of the Maquoketa for consistency.
k. Are the formations of the Maquoketa Group (Scales, Ft. Atkinson, and Brainard) differentiated at the site? Are the confining characteristics of these formations similar?

2. Regarding the "Maps and Cross-Section of the AoR section starting on page 15:
   a. EPA was able to identify three spreadsheets that list wells. The first file titled "Oil and Gas List", the second titled "Water Well List", and the third "Well Talley". In the paragraph under Table 1, page 15 it is stated, "A detailed list of *these wells* has been uploaded to the GSDT tool". Which list is this referring to? It is important that EPA has a detailed list of wells within the modeled AoR. EPA has the following comments:
      (i) Table 1 numerates a total of 61 total wells. Is this total inclusive of all wells listed in the three spreadsheets?
      (ii) EPA requires a list of wells located within the AoR. Please clearly identify on the spreadsheets which wells are within the AoR.
      (iii) For the sake of consistency, EPA requests changing the terminology on Table 1 and the spreadsheets from "plume" to "AoR". It doesn't matter how the AoRs are identified (e.g., 1 or 2, north or south, WVCCS1, WVCCS2, etc.) as long as it is consistent throughout all documents and files.
      (iv) Figure 9, page 16 should be revised to be inclusive of all the wells listed in the revised well list (Table 1 in Narrative and Table 10 in AoR_CA) denoted by type of well, and the depth of penetration.

3. Regarding the "Evidence for Faults and Fractures" section, starting on page 17:
   a. Please provide depths for the seismic reflection profiles in Figures 11, 13, and 14.
   b. It is stated that 2D seismic reflection was used to identify faults, and formation micro imager logging was used down-hole to identify fractures. Please provide more information regarding these techniques and describe how they were determined to be the best method to identify these features at the site.
   c. What criteria were used to distinguish "connected" fractures from isolated fractures?

d. Please provide detail on the depths of intervals with no fracturing and explain the methods by which this determination was made for each such geologic unit.
e. Please provide more detail on the salinities of the units tested to support the statement on page 18 that, "differences in salinity of hydrostratigraphic units were used as evidence that there is no cross-formational fluid migration."

4. Regarding the "Injection and Confining Zone Details" section:
   a. It is important to have figures available that show information and data for all geologic units from the surface to the bottom confining geologic unit. If possible, please update Figures 15, 16, and 17 to minimally incorporate the top of the Maquoketa Group to the bottom of the Potosi Dolomite.
   b. On page 21, first paragraph there is a reference to a cumulative rock thickness of over 1,900 feet comprising the "confining zone". Per comment C.1.a, make sure references to the confining zone are consistent and refer to the same zone throughout all documents submitted as part of the PA.
   c. NOTE: Comments regarding "Potosi Dolomite Well Testing" and "Permeability Estimation" are included in heading D of this letter (corresponding to similar sections in the AoR_CA document).
   d. On Figure 19, there is no caliper log in the first track with the gamma ray. The PE and NPHI log curves are nearly off-scale, leading to the conclusion that the hole might be washed-out in the tested interval. Can the porosity estimation for this interval be supported by additional well data?
   e. What matrix density was used for the DPHI and NPHI log curves?
   f. Please include a caliper, resistivity, and density log in Figures 15, 19, 21, 23, 26, 28, 30, and 33.
5. Regarding the "Overlying and Confining Units" section, starting on page 24:
   a. Please identify the geophysical logs that will be used for continuous evaluation of the injection zone and confining zones. These logs, their target formations, and the site characterization objectives, should be described in the pre-operational testing plan.
   b. Have the petrophysical analyses been calibrated to cores from the Maquoketa Group?
   c. If not, what uncertainty is there regarding the results of the petrophysical analyses and formation characteristics? Please discuss pre-operational testing plans regarding petrophysical calibration.
   d. If so, which cores from which wells were used for calibration?
6. Regarding the "Geo-Mechanical and Petrophysical Information" section, starting on page 45:
   a. Please clarify if the petrophysical analyses are calibrated to the core. If not, please discuss pre-operational testing plans regarding petrophysical calibration.
   b. How representative were the wax core samples and resulting geomechanical properties of the entire Maquoketa Group confining layer?
   c. Please provide the source of information regarding the size of the bed crossing fractures in the Shakopee Dolomite.
   d. Provide the criteria that were used to determine which natural fractures are "significant" for purposes of confinement?
   e. Due to the likely strike-slip stress regime, faults may not be resolvable on 2D or 3D seismic. If this is the case, identify the seismic data to be collected to address this as part of pre-operational testing.
   f. Please clarify the source of the estimate of hydrostatic pore pressure cited on page 47 of the Narrative.
   g. Other than data from the Illinois Basin-Decatur Project (IBDP), were cores available for comparison from other locations?

h. How is the uncertainty in measured parameters for the Maquoketa Group accounted for in the model? How does this effect the evaluation of the integrity of this confining unit?

7. Regarding the "Seismic History" section, starting on page 51:
   a. Please provide the source of the data represented on Tables 10 and 11 and on Figures 38 and 39.
   b. Please provide a clearer legend for Figure 38 and add Map ID #40 to the map.
   c. The narrative on page 58 states that the "relative risk of the site is considered minimal." The word "minimal" is a relative term; please provide a more detailed qualitative description supported by criteria. There is reference to a percent probability that peak acceleration as a percent of gravity will occur at the proposed injection well locations. Figure 40 is a generic earthquake hazard map of the United States. None of the citations in the text appear to be related to Figure 40. Either provide an explanation as to how Figure 40 relates to the data cited or provide additional figures that depict the probability of peak acceleration versus percent gravity.
   d. EPA requests that the seismic evaluation address whether the geologic system is free of faults and fractures and is capable of receiving and containing the volumes of CO_2 proposed to be injected. Please provide a discussion of the potential for induced seismicity, its causes, and probability of occurrence as a result of this injection.
8. Regarding the "Hydrologic and Hydrogeologic Information" section, starting on page 59:
   a. Please provide a stratigraphic column showing all underground sources of drinking water (USDW) in both unconsolidated and bedrock aquifers. It is assumed that all USDWs are above the Maquoketa Group confining zone. In the column, please depict the top of the Maquoketa Group.
   b. We recommend adding discussion of the USDWs (unconsolidated and bedrock) present in east central Illinois for context as well.
   c. Include a discussion of which USDWs are utilized by which communities, homes, and businesses within the AoR for each injection well.
   d. Please revise Figures 41 through 46, which are illegible in print and electronically.
   e. Figure 46, page 68 depicts the 10,000 mg/l total dissolved solids (TDS) boundary for the Silurian-Devonian carbonate bedrock aquifer system in Indiana. These data are from 1994 or prior. Is there more recent data/maps that depict this boundary? If so, please present it.
   f. If possible, show the D-D' cross-section line on a map for reference.
   g. Figure 47: Please indicate the Wabash #1 test hole location on this figure and resubmit.
   h. Please confirm that there are no USDWs below the injection zone. Please provide a discussion of the water bearing characteristics of the bedrock units below the Potosi Dolomite injection zone and their current or potential use as a USDW.
   i. Is there a reason to believe that the reactions documented by Palmer (1991) that form solution channels in the Mississippian carbonates will not significantly impact formation permeability of the confining zone?
   j. How did this information inform the interpretation of model dissolution which estimated a 2.2% decrease in mineral volume?
   k. Please provide information about the TDS content of the Silurian, including the source of the value, and any pre-operational testing that is planned to confirm this and provide the baseline data required at 40 C.F.R. § 146.82(a)(6).
   l. In addition to the average water well depth referenced on page 80, please explain the data that were used to identify USDWs in the AoR.
   m. Please provide a stratigraphic column that shows the lowermost USDW formation (Bainbridge/Salina/Silurian).
   n. Which equation was used for the calculations in equations 9 and 10?

o. Considering the formulas are intended to determine Cl^- concentrations based on known TDS content, and known TDS is necessary in determining the appropriate equation, why is this considered to be an appropriate method of estimating TDS?

9. Regarding the "Geochemistry" section, page 70:
   a. Please clarify the relevance of the logs in Table 2 to this section.
   b. The application stated that full diameter core and sidewall core were not collected over all intervals. Please update the section to state the intervals that did not have available core data.
   c. WCS states that there is, "considerable regional understanding of the geochemistry of fluids and rock lithology within the Illinois Basin. (Narrative pg. 71)" Please provide citations or descriptions of the geochemistry of intervals where core data was unavailable.
   d. The discussion of pre-operational testing in the narrative indicates that no coring will be performed at WVCCS2 given its proximity to core collection sites. Given that the reservoir is most likely a highly heterogeneous carbonate, please consider collecting at least rotary side wall cores at WVCCS2 to calibrate petrophysical calculations and reduce overall uncertainty.
   e. Is XRD data available for any formations other than the Oneota Dolomite and Shakopee Dolomite?
   f. If XRD data is not available on formations in addition to the Oneota Dolomite and Shakopee Dolomite, are there plans to perform this (or similar) analysis of the injection and confining zones during pre-operational testing?
   g. Will cores from the Potosi Dolomite close to the proposed injection site be compared to the cores from southwest Missouri once they are available?
   h. Is there other information that can confirm that the outcrop is indicative of formation characteristics at the proposed injection site?
   i. Please include references to Table 12 where applicable.
   j. Please provide the laboratory analysis report for the swab samples obtained in the injection zone (Potosi Dolomite) along with a description of the sampling methods employed and a copy of the chain of custody documentation.
10. Regarding the "Site Suitability" section, page 75:
   a. Describe the "early testing" referenced on page 75 that took place resulting in a permeability of 2,400 mD and explain how this value is representative of the planned injection zone.
   b. Please clarify what is meant by the statement on page 75 that "The usage of the much lower value of 2,400 mD ensures that no limitation on injection capacity will be encountered."
   c. During lab scale testing, were injection zone pressures and temperatures used? If not, are these expected to change the CO_2 – injection zone lithology interaction?
   d. Please clarify why carbonate mineral dissolution is expected to be less during injection operations than during modeled scenarios.
   e. Please clarify that any updated information about the transmissivity of faults or fractures gathered during pre-operational vertical seismic profiling will be incorporated into the evaluation of confining zone suitability.

D. AREA OF REVIEW, MODELING, AND CORRECTIVE ACTION PLAN

The following pertain to the AoR_CA.pdf document.

1. Regarding the "Model Background" and "Site Geology and Hydrology" sections, pages 2 through 13:
   a. Please provide an explanation of how geologic units between the bottom of the Maquoketa Group and the top of the Potosi Dolomite were incorporated into the model:
      (i) How were the shale layers used in the model?
      (ii) Were other units used as flow inhibitors? If so, how were they incorporated into the model.
      (iii) Please provide an explanation as to the validity of using a cumulative shale thickness for units from different geologic formations.
   b. How was the dip angle and direction of the geologic units determined?
   c. Please provide the internal lookup tables used to define gas properties vs. pressure.
   d. Please update Figure 9, page 14, so that the labels for the test hole, and proposed injection wells are discernable.
   e. For Figures 11 and 12, pages 18 and 19:
      (i) Please add demarcation lines for the bottom of the Maquoketa Group and the top of the Potosi Dolomite.
      (ii) If possible, please label the intermittent shale units if they are relied upon in the model.
      (iii) Please update Figure 11 of Wabash Line 1000 to show the same scale as Figure 12.
      (iv) If possible, please provide depths in feet on the y-axis in addition to time.
   f. The thicknesses of the shale layers in the Trenton Limestone and the St. Peter Sandstone are 3.5 ft thick. Is there research that the applicant can cite that supports the addition of these relatively thin shales to the cumulative total "confining unit?"
   g. Many of the shales used as the confining unit are in limestone formations, which are likely porous and not effective seals. Is it reasonable to assume that the confining zone consists of only the 592.5 ft of shale?
2. Regarding the "Model Domain" section, pages 13 through 20:
   a. This section mentions the use of "47 vertical layers" and "241 layers." Please explain the difference between the referenced numbers of vertical layers.
   b. How was the 22-mile square model domain area determined and why it is appropriate?
3. Regarding "Porosity and Permeability" section, pages 14 through 19:
   a. Were the "in situ" tests referenced in paragraph 2, page 15, the step rate test (SRT), the pressure fall-off test (FoT), and multi-rate test (MRT) referenced in the preceding paragraph 1? If not, please provide a description of the "early in situ" test conducted.
   b. Please describe the relationship of the length of the screened interval with regard to the representativeness of the SRT, FoT, and MRT results to the entire thickness of the injection zone.
   c. Please clarify the specific types of "longer well testing" mentioned in the "Potosi Dolomite well testing" section.
   d. A fluid representative of the injection fluid is typically used to perform well tests. Please describe how the use of freshwater in these tests yields representative results when compared to a supercritical CO_2 fluid. The description should include but is not limited to the following elements: geochemistry and reactive transport effects, and fluid-dependent permeability alteration.
   e. Please specify the depth(s), rock type, and facies in which the permeability measurements were obtained.
   f. It is stated in the last paragraph of page 15 that core and thin sections from Decatur, Illinois were "calibrated" to the well logs from Wabash #1. If Lucia's rock classes are applied to the Potosi Dolomite for the Wabash project, then the method of the "calibration" conducted needs to be described.

g. Based on the Permit Narrative and Geologic Summary document, it is assumed that within the AoR the spatial distribution of porosity values in the confining zone and injection zone is relatively uniform. Confirmation of this assertion is constrained by a lack of available data. Pre-operational testing at both injection wells should be conducted to determine site-specific porosity values once the core is retrieved. These data should be used in the modeling parameters.
h. Please describe or provide a citation for the method used in determining secondary porosity by subtracting sonic porosity from the total porosity.
i. A correlation is made between the Potosi Dolomite encountered in Wabash #1 to the Potosi Dolomite "…in Illinois, Indiana and Kentucky have injected millions of gallons of liquid waste…" Is there data to support this claim or is it anecdotal? Supplying data regarding the vuggy, secondary porosity of the Potosi from other sites (e.g., logs, core data, citations correlating mud loss to vugs, etc.) and directly relating them to the Wabash site will provide evidence that the assumptions made regarding the porosity estimates are valid.
j. If possible, please provide a map showing the other locations injecting into the "vugular" carbonates, specifically noting those that inject in the Potosi Dolomite and providing proof that the formation is vugular at those locations.
k. It is noted that porosity and permeability data was calculated and upscaled from the well path to the 3D model domain using the arithmetic averaging method.
   (i) Does this include the arithmetic averaging of wellbore-measured petrophysical properties over each zone/layer, and extrapolation of such properties to the entire modeled domain? If so, was a single value used per zone/layer for such properties?
   (ii) Please elaborate on the arithmetic averaging method used in this scenario.
   (iii) Additionally, please confirm the use of a homogeneous or heterogeneous reservoir property distribution per zone/layer.
l. Figures 11 and 12 have illegible color bars with the units of measure apparently set to "U". Please update the figures color bar and units of measure. Also, "Well 2 South" is depicted in yellow. Please choose a different color so the location of the proposed well stands out.
m. What is the time step of the model and how was it selected?

4. Regarding the "Constitutive Relationships and Other Rock Properties section, page 19:
   a. Please explain how the 8% median porosity for the Potosi Dolomite was derived.
   b. Please explain why certain functions were used for each of the rock types used in the STOMP model (e.g., "Nisku Formation #2" for dolomite and limestone).
5. Regarding the "Boundary Conditions", the "Initial Conditions", the "Operational Information", and the "Fracture Pressure and Fracture Gradient" sections, pages 20 and 21:
   a. Please define the bottom boundary of the model and explain why it was established as a no-flow boundary, including the relevant geologic data to support this.
   b. The initial conditions in Table 5 were established at a depth of 4,500 ft MSL. The perforation intervals for Injection Wells 1 & 2 in Table 6 are above 4,500 ft MSL. Please explain how the initial conditions at a depth of 4,500 ft MSL are representative of the perforation intervals in Injection Wells 1 & 2.
   c. In the Narrative, the discussion of "Operational Procedures" cites a supercritical CO_2 density of 712 Kg/M3. Please explain how this was derived.
   d. Please add the reference elevation and pressure gradient to Table 5.
   e. The calculated fracture gradient and maximum injection pressure values are listed in Table 7, not Table 4 as documented. Please revise this sentence accordingly.
   f. Please tabulate all SRT tests and corresponding test details to clearly demonstrate the nature of such tests and the results.
   g. What injection fluid will be used in the pre-operational mini-frac and SRT?

6. Regarding the "Computation Modeling Results" section, pages 21 through 28
    a. The lateral extent of the CO_2 plume extends to year 62 (the end of the simulation period). It is understood that the maximum lateral extent is relatively constant between years 16 and 62, however it is recommended that this section is clarified regarding the timing of maximum lateral extent cessation.
    b. Please explain the significance of a 1% CO_2 saturation cutoff used to determine the extent of the CO_2 plume for delineating the AoR.
    c. Regarding Figure 13, page 22: It is noted that this figure is important to demonstrate the results of the computational modeling.
        (i) Please explain the early changes in slope (i.e., at year 12) demonstrated by the curves in Figure 13.
        (ii) Please explain the increase in plume distance predicted to occur after approximately year 52 for the y-direction, and after year 59 for the North Well. The model predicts plume stability after approximately year 22 until this occurs.
    d. Please clearly label the color bar and define units of measure in Figures 14, 15, and 16.
    e. What is the maximum bottom hole pressure as referenced in the discussion of "Model Calibration and Validation?"
    f. Was sensitivity analysis conducted on grid geometry and petrophysical properties? Please explain why or why not.
    g. Please include discussion as to why there are no significant differences between the 4 models.
7. Regarding the "AoR Delineation" section, pages 29 through 32:
    a. Please show the calculation for critical pressure.
    b. Please explain why the reservoir zone is assumed to extend to the base of the Maquoketa Group, causing the Trenton Limestone pressure and depth to be used in the calculation.
    c. Please show the 63.4 psi contour in a figure within the AoR CA narrative.
    d. Please describe and map the areal extent over which pressures will increase as a result of injection, even if they are below the calculated critical pressure.
    e. Additionally, please confirm that the predicted pressure increase as a result of CO_2 injection does not exceed 90% of the fracture pressure for the injection or confining zones.
    f. Please provide a map showing the maximum extent of the area of elevated pressure and the maximum extent of the 1% saturation CO_2 plume to identify the "delineated AoR" that accounts for both elements of the AoR definition for Class VI wells.
    g. For Figures 14 through 19, pages 23 through 29: please indicate the depths of the bottom of the confining zone (Maquoketa Group) and top of the injection zone (Potosi Dolomite) for the cross-sectional figures.
    h. Figures 15 through 18: A review of the depths of the CO_2 plume depicted on these figures indicates that it may extend above the proposed injection zone (Potosi Dolomite) and into the Oneota Dolomite. Please provide an explanation as to the potential/likelihood of this occurrence.
    i. Please confirm that the AoR will be recalculated in the pre-injection phase once additional site characterization data is acquired.
8. Regarding the "Corrective Action" section, pages 33 through 35:
    a. As EPA commented in C.2.a above (Table 1 in Narrative), the well data depicted on Table 10, page 33 should be revised to include the list of wells along with all pertinent information (location, depth, type, etc.). EPA was able to identify three files in GSDT: Oil-and-Gas-List.csv, Water-Well-List.xlsx, and Well Talley.xlsx. EPA believes that these files should be combined and presented in Table 10 (and Table 1 of the Narrative).

Since the application claims that no wells exist which penetrate the confining zone, it is important that the pertinent data to support this claim be clearly depicted in the narrative sections of the application.

b. Figure 20, page 34: Please revise these figures in accordance with comment C.2.a.v (regarding Figure 9 in Narrative).

9. Regarding the "Reevaluation Schedule and Criteria" section, pages 35 through 38:
   a. Please define what "other sources" referenced on the first darkened bullet on page 35 will be used in reevaluation.
   b. Please explain how 2D and 3D seismic will be used to track CO_2 plume migration. The discussion should include but not be limited to uncertainties with seismic processing and imaging (especially fluid discrimination in carbonates), and seismic acquisition timeframe. Providing references regarding a similar workflow would be beneficial.
   c. Please explain the statistical methods that will be used to correlate the modeling results with measured monitoring data.
10. Regarding the "Triggers for AoR Reevaluations Prior to the Next Scheduled Reevaluation" section, 37 and 38:
   a. What is the significance of three (3) standard deviations from the average for pressure and temperature measurements?
   b. Please clarify what is determined to be "statistically significant," as mentioned in the Exceeding Established Baseline Hydrochemical/Physical Parameter Patterns discussion. Additionally, please clarify what is meant by "significant" in the Compromise in Injection Well Mechanical Integrity discussion.
   c. The following triggers should be added:
      (i) If the arrival time of the pressure front at the deep monitoring well and/or when pressure and plume data recorded at the deep monitoring well differs significantly from model projections.
      (ii) A change in modeled direction of pressure front movement or vertical and lateral plume distributions detected by means other than the monitoring well.
      (iii) Indication of competing injection projects within the same injection formation that have the potential to influence and/or interact with the AoR for these permits.

E. PRE-OPERATIONAL TESTING PLAN

The following comments and questions are regarding the Proposed Pre-Operational Testing WVCCS1.pdf and the Proposed Pre-Operational Testing WVCCS2.pdf documents.

1. It is stated on page 2, paragraph 5, and on page 4, paragraph 3 that whole core samples will be gathered in the intermediate and the long string sections of the hole for WVCCS#1. Additionally, it is stated that the core will be obtained at 2,600 feet MD and 3,354 feet MD for the intermediate string and that core samples for the long string will be based upon data from Wabash #1, overlapping the "highly vugular zones that are the targets for injection", between approximately 4,500 feet MD and 4,700 feet MD. EPA has the following requests regarding coring at the two injection well locations:
   a. A continuous core of the Wabash #1 test hole wasn't obtained. The permit application files refer to refinement of data that will be obtained during the construction of WVCCS #1 and #2. EPA requests that a continuous core of the confining unit that will be relied upon for containment (ostensibly the Maquoketa Group) and of the injection zone (Potosi Dolomite and potentially the lower section of the Oneota Dolomite) be conducted, in addition to the downhole testing outlined in Tables 2 through 7 for both injection wells.

Continuous cores should also be obtained from any other geologic units/formations that will be relied upon for confinement.

b. Please provide a description of the coring method to be conducted and the core diameter.
c. Pre-injection testing requirements will be outlined in the draft permit, should it be issued by EPA.

2. Please refer and respond to earlier EPA statements regarding pre-injection testing, in this letter above at C.5.a and c, C.7.a and e, C.9.k, C.10.d and f, C.11.e, D.3.g, and D.5.g.

F. TESTING AND MONITORING PLAN

The following requests and questions are regarding the TM_Template.pdf document.

1. The results of the STOMP model predict that the pressure front will reach the proposed locations of FM1 and FM2 within 3 to 4 years, and the dissolved CO_2 plume at approximately 12 years after the commencement of injection. Please provide justification that one injection zone monitoring well per injection well is sufficient to monitor both the dissolved CO_2 plume and the pressure front.
2. Please provide justification for the number and location of monitoring points above the confining zone.
3. Please revise Figure 1, page 4. Remove the oil/gas wells and the water wells and add the locations for the 6 injection zone monitoring wells, the 4 confining zone monitoring wells, and the 10 proposed ground water monitoring wells.
4. The Quality Assurance and Surveillance Plan (QASP) was not included in the permit application review materials. Please provide a copy of the plan. Elements of the plan will be incorporated as appropriate to the monitoring section of the draft permit should the application be approved.
5. Please provide a new summary table of the monitoring wells to be used for the injection zone, confining zone, and the USDWs. The table should include the well identification, purpose, proposed total depth, length of screened interval, elevations of the top and bottom of the screens, the name of the geologic formation containing the screened interval, and relative coordinate location to the injection wells.
6. Please provide detailed well construction diagrams for the injection zone monitoring wells, the confining zone monitoring wells, and the USDW monitoring wells. These diagrams should include pipe material, diameters, materials, along with borehole diameters.
7. Please provide a description of the monitoring well drilling and logging method to be used. Also include a description of how it will be determined when the depth of the monitoring well is within the formation to be monitored.
8. As per C.1.g, above, please provide a revised stratigraphic column in this document.
9. How was (or will) the exact locations and depths of all monitoring wells be determined? Provide a description and rationale segregated by type.
10. How were the well off-sets for the confining zone monitoring wells determined?
11. Where will the CO2 stream be sampled as stated on page 5?
12. Please describe the procedure for maintenance of the permanent downhole temperature and pressure transducers, should they be found to be out of tolerance based upon the results of the downhole gauge monitoring described on page 7.
13. Please resubmit Figure 2, page 10 with better resolution. All system components need to be discernable and clearly labeled.

G. POST-INJECTION SITE CARE AND SITE CLOSURE PLAN (PISC)

The following requests and questions are regarding the PISC_SC_Template.pdf document.

1. Please include demarcation of the tops of the geologic units/formations on Figures 1 through 4, pages 2 through 4.
2. Please include the updates for Figure 5, page 5 per comment F.3.
3. Please update Tables 1 through 6, pages 6 through 9 per comment F.1.
4. The proposed alternative post-injection site care (PISC) period of 4 years is inadequate for the collection of data regarding the long-term stability of the CO_2 and pressure front and to validate/calibrate the model. Figure 13, page 22 of the AoR narrative shows that the model doesn't predict asymptotic pressure front readings until after Year 20 and it shows growth in the modeled front through Year 62. Please address these issues in order to further support a PISC period of less than 50 years. Owners and operators may also petition for a reduction of the PISC monitoring and care period per 40 C.F.R. §146.93(a)(4).

H. EMERGENCY AND REMEDIAL RESPONSE PLAN

The following requests and questions are regarding the ERR_Template.pdf document.

1. Please provide an explanation as to how Figure 1, page 3 depicts resources and infrastructure to be covered in the Emergency and Remedial Response Plan (ERRP).
2. The intended purpose of the ERRP per regulation is to mitigate site conditions and well operation/testing to prevent movement of all fluid (not just brine and CO_2 as stated on page 7) into USDWs. Please revise the plan accordingly.
3. Please add a triggering event section for movement of fluid out of the injection zone.