Class VI UIC Area of Review and Corrective Action

This submission is for:

Project ID: R09-CA-0002

Project Name: Mendota BECCS Project

Current Project Phase: Pre-Injection Prior to Construction

Overview

Simulator Used for AoR delineation modeling: Eclipse

Version Used: 2018.2

Simulator Description/Documentation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Eclipse300.pdf

Total Simulation Time From Start of Injection: 70 yrs

Additional AoR Delineation Information: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Not--Applicable.txt

Description of Information Submitted: N/A

Model Domain

Coordinate System: State Plane

Horizontal Datum: NAD27

Coordinate System Units: ft

Vertical Datum: Mean Sea Level

Describe Vertical Datum: MSL

Zone: 4

FIPSZONE: 404 ADSZONE: 3351

Mesh Type: Hexahedral Cartesian

Domain Size in Global Units Specified Above

Hexahedral Cartesian

Domain Coordinates File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/AoRModeling_DomainCoord_01062020.xlsx

Angle of Inclination in X Direction: 0 Dips in the Direction of: increasing x

Angle of Inclination in Y Direction: 0 Dips in the Direction of: increasing y

Grid Size

Number of Nodes in x: 53 y: 53 z: 446

Grid Spacing: Variable

Grid File Format: Eclipse Keyword File

Grid File Description: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Eclipse--Grid.pdf

Eclipse Keyword File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Grid_Ascii_ACTNUM.GRDECL

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Grid_Ascii_COORD.GRDECL

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Grid_Ascii.GRDECL

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Grid_Ascii_ZCORN.GRDECL

Faults Modeled: No

Caprock Modeled: Yes

Image File(s) for Model Domain Grid: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Model--domain.pdf

Model Domain Comments: "0" value is used in Angle of inclination to indicate "Not Applicable".

Processes Modeled by Simulator

Reservoir Conditions:

Supercritical CO2 Conditions

Phases Modeled:

Aqueous Supercritical CO2

Aqueous Phase:

Phase Compressibility: Compressible

Compressibility Value: 0 1/psi

Phase Composition: Compositional

Aqueous Phase Components:

CO2 Water Salt

Supercritical CO2 Phase:

Phase Compressibility: Compressible

Phase Composition: Compositional

Supercritical CO2 Phase Components:

CO2 Water

Equation of State Description Including Reference: ECLIPSE 300 is a compositional finite-difference solver that is commonly used to simulate hydrocarbon production and has various other applications including carbon capture and storage modeling. The CO2STORE module accounts for the thermodynamic interactions between three phases: an H2O-rich phase (i.e.,liquid), a CO2-rich phase (i.e.,gas), and a solid phase, which is limited to several common salt compounds (e.g. NaCl, CaCl2, and CaCO3). Mutual solubilities and physical properties (e.g. density, viscosity, enthalpy, etc.) of the H2O and CO2 phases are calculated to match experimental results through a range of typical storage reservoir conditions, including temperature ranges between 12C-100C and pressures up to 60 MPa. Details of this method can be found in Spycher and Pruess (2005). Additional assumptions governing the phase interactions throughout the simulations are as follows: The salt components may exist in both the liquid and solid phases. The CO2-rich phase (i.e.,gas) density is obtained by using the Redlich-Kwong equation of state. The model was accurately tuned and modified as further described below (Redlich-Kwong, 1949). The brine density is first approximated as pure water then corrected for salt and CO2 concentration by using Ezrokhis method (Aseyev, 1992). The CO2 gas viscosity is calculated per the methods described by Vesovic et al. (Fenghour, 1990). The gas density was obtained using a modified Redlich-Kwong equation of state following a method developed by Spycher and Pruess, where the attraction parameter is made temperature dependent: P=((RT_K)/(V-b_mix))-(a_mix/(T_K^(12) V(V+b_mix))) where V is the molar volume, P is the pressure, TK is the temperature in Kelvin, R is the universal gas constant, and amix and bmix are the attraction and repulsion parameters. The transition between liquid CO2 and gaseous CO2 can lead to rapid density changes of the gas phase;the simulator uses a narrow transition interval between the liquid and gaseous density to represent the two phase CO2 region.

File with EOS Reference or Documentation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Eclipse300--Ref.pdf

Multifluid Flow Processes:

Advection Buoyancy

Non-wetting Fluid Trapping Pore Compressibility

Thermal Conditions: Isothermal

Heat Transport Processes:

Geochemistry Modeled: No

Geomechanical/Structural Deformations Modeled: No

Modeled Processes Comments: In Eclipse 300, the compressibilites of brine are based on Ezrokhis formula, which corrects the brine density for dissolved salt and CO2. Therefore, "0" is used for aquesous phase compressibility valueIn to indicate "Not Applicable".

Rock Properties and Constitutive Relationships

Porosity/Permeability Model

Single Porosity

Porosity Distribution: Heterogeneous

Porosity included in Eclipse Keyword File: Yes

Porosity Variable Name in Eclipse Keyword File: POR

File Describing how Porosity was Determined and Assigned to Numerical Model: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Porosity--from--Narrative.pdf

Image Files for Porosity Distributions: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Porosity--image_r1.pdf

Permeability Distribution: Heterogeneous

Permeability included in Eclipse Keyword File: Yes

Permeability Variable Name in Eclipse Keyword File: PERMX, PERMY, PERMZ

File Describing how Permeability was Determined and Assigned to Numerical Model: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Permeability--from--Narrative.pdf

Image Files for Permeability Distributions: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Permeability--image_r1.pdf

Number of Rock Types Modeled: 2

Description of Rock Type Selection and Assignment: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Rock--types.pdf

Rock Type Distribution Data File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/SATNUM.zip

Image Files for Rock Type Distribution: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Rock--types--image_r1.pptx

Rock Type #1

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000002 1/psi

Compressibility included in Eclipse Keyword File: Yes

Compressibility Variable Name in Eclipse Keyword File: ROCK

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Table

Tabular Format File for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/GSF.pptx

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Relative--perm--and--capillary--pressure.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Table

Tabular Format File for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/WSF.TXT

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/WSF.pptx

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Table

Tabular Format File for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/GSF.TXT

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Type #2

Rock Compressibility: Pore

Rock Compressibility Distribution: Single Value

Compressibility Value: 0.000002 1/psi

Compressibility included in Eclipse Keyword File: Yes

Compressibility Variable Name in Eclipse Keyword File: ROCK

Constitutive Relationships

Aqueous Saturation vs. Capillary Pressure: Table

Tabular Format File for Aqueous Saturation vs Capillary Pressure: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Relative--perm--and--capillary--pressure-----Rock_Type2.pdf

Aqueous Trapped Gas Modeled: No

Hysteresis other than non-wetting fluid trapping: No

Aqueous Relative Permeability: Table

Tabular Format File for Aqueous Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/WSF-----Rock_Type2.TXT

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/WSF--

---Rock_Type2.pptx

Hysteresis other than non-wetting fluid trapping: No

Gas Relative Permeability: Table

Tabular Format File for Gas Relative Permeability: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/GSF-----Rock_Type2.TXT

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/GSF-----Rock_Type2.pptx

Hysteresis other than non-wetting fluid trapping: No

Porosity and Permeability Reduction Due to Salt Precipitation

Rock Properties Comments: The details of the Petrophysical work is presented in the Narrative

Boundary Conditions

Attach Boundary Conditions Description File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/boundary--conditions.pdf

Initial Conditions

Initial Phases in Domain: Aqueous

Initial Aqueous Pressure: Varying with Depth, Temperature, and Salinity

Initial Aqueous Pressure: 4211 psi at Reference Elevation: -9505 ft

Initial Temperature: Varying with Depth

Initial Temperature: -6350 F at Reference Elevation: -6350 ft Gradient: 0.0146 deg F/ft

Initial Salinity: Spatially Constant

Initial Salinity: 25000 ppm

Initial Condition Comments: Initial temperature given at two reference points defines the initial temperature in between. 137.5 F at -6350 ft 249.7 F at -13350 ft See Section 2.7 in Attachment B (AoR and Corrective Action Plan) for the reservoir pressure and temperature gradient obtained from nearby oil and gas fields.

Operational Information

Number of Injection Wells: 1

Injection Well #1

Well Direction: Vertical

Location: X: 1600305.8 Model Units Y: 520689.2 Model Units

Wellbore Diameter: Constant

Wellbore Diameter: 9.625 in

Well Screen Interval Provided as: Single Interval

Elevation of Top of Screened Interval: -9400 Elevation of Bottom of Screened Interval: -9620 ft

Mass Rate of Injection: 0.35 MMT/yr

Total Mass of Injection: 7 MMT

Fracture Gradient: 0.65 psi/ft

Maximum Injection Pressure: 5677.4 psi Elevation Corresponding to Pressure: -9505 ft

Description of How Fracture Gradient and Maximum Injection Pressure were Determined File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/frac--pressure--and--gradient.pdf

Composition of Injectate: Pure CO_2

Injection Schedule Provided as: Single Injection Period

Injection Start Date: 01/01/2023 Stop Date: 01/01/2043

Number of Production/Withdrawal Wells: 0

Operational Information Comments: See Section 2.8 of Attachment B for the details of operational information.

Model Output/Results

Provide file name and corresponding spatial location for each file: Currently there is no monitoring well included in the simulation work. After the collection of site-specific data (characterization well, 3D seismic survey, etc.), monitoring point will be determined and added to the reservoir modeling and the simulation results will be reported accordingly in the next phase.

Time-Series File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-

1650/BHP--at--injector.pdf

Provide file name and corresponding variable and time stamp for each file: Attached pdf includes the snapshot of plume- and pressure-based AoRs and the 2D profiles of CO2 gas saturation along the SW-NE direction at selected times.

Snapshot File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/AoRs.pdf

Provide file name and corresponding description of surface for each file: Water flow rate from reservoir to Garzas is shown in the attached surface flux file.

Surface Flux File: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Inter-region--Flow-----Reservoir--to--Garzas.pdf

AoR Pressure Front Delineation

Lowermost USDW:

Name of Lowermost USDW: Garzas

Water Density: 1000 kg/m^3 at Elevation: -1415 ft

Location of Measurement for Density: 0

Temperature: 0 F at Elevation: 0 ft

Location of Measurement: 0

Pressure: 701 psi at Elevation: -1415 ft

Location of Measurement: 0

Salinity: 0 ppm at Elevation: 0 ft

Location of Measurement: 0

Elevation of bottom of USDW: 0 ft

Injection Zone:

Name of Injection Zone: Panoche

Water Density: 1002 kg/m^3 at Elevation: -9505 ft

Location of Measurement: 0

Temperature: 0 F at Elevation: 0 ft

Location of Measurement: 0

Pressure: 4211 psi at Elevation: -9505 ft

Location of Measurement: 0

Salinity: 0 ppm at Elevation: 0 ft

Location of Measurement: 0

Elevation of top of Injection Zone: 0 ft

Method of Estimating Critical Pressure: Other

File Describing Critical Pressure Estimation: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Critical--pressure--calc--01072020.pdf

Estimated Critical Pressure: 3.5 psi

Delineated AoR:

Shapefile or KML File Showing Delineated AoR: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/dP_AoR_3.5psi_after_20yr_injection.zip

AoR Pressure Front Delineation Comments: Currently there is no direct measurement available for density, temperature, pressure, and salinity. "0" is used to indicate "Not Applicable". See Section 4 of Attachment B for the details of pressure-based AoR delineation.

Corrective Action

File with Location of All Penetrations within AoR: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Wells--in--2.5--miles--AOI.csv

File with Location of Wells Requiring Corrective Action: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Wells--corrective--action.csv

Corrective Action Comments: There are no wells in the AoR that penetrate the Moreno shale (secondary confinement layer). There are two wells within a 2.5-mile radius of Mendota_INJ_1 (BB Co 1 and Amstar 1) that do penetrate the Moreno shale and may require remediation. Final remediation plans for these wells will be informed by updated plume simulations after site-specific data are acquired. More information is available in Attachment B.

Area of Review and Corrective Action Plan [40 CFR 146.82(a)(13) and 146.84(b) or applicable state requirements]

Are you making an Area of Review and Corrective Action Plan submission at this time?: Yes

Reason for Project Plan Submission: Permit application submission

Project Plan Upload

Attach the Area of Review and Corrective Action Plan: https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Att--B-----AoR--CA--Plan.pdf

https://epa.velo.pnnl.gov/alfresco/service/velo/getFile/no_wiki/shared/Submissions/R09-CA-0002/Phase1-PreConstruction/AoRModeling-09-22-2021-1650/Att--B-----AoR--CA--Plan_92121.pdf

Appendices and Supporting Materials Upload

Area of Review Reevaluation [40 CFR 146.84(e) or applicable state requirements]

Minimum fixed frequency of AoR reevaluation: 5 Years

Are you making an Area of Review reevaluation submission at this time?: No

Reevaluation Background

Reevaluation Materials

Please upload your amended AoR and Corrective Action Plan on the previous tab.

Complete Submission

Authorized submission made by: Rebecca Hollis

Comments regarding this submission: Submitting revised application attachments per EPA Information Request #7.

For confirmation a read-only copy of your submission will be emailed to: rhollis@cleanenergysystems.com