NETL Life Cycle Inventory Data
Process Documentation File

Process Name: CO_2 Sequestration Saline Aquifer Well Closure

Reference Flow: 1 piece of CO_2 Sequestration Well Closure

Brief Description: Materials of construction to plug and abandon a well for underground storage of CO_2

Section I: Meta Data

Geographical Coverage: United States **Region:** N/A

Year Data Best Represents: 2012

Process Type: Installation Process (IP)

Process Scope: Gate-to-Gate Process (GG)

Allocation Applied: No

Completeness: Individual Relevant Flows Captured

Flows Aggregated in Data Set:

☑ Process ☐ Energy Use ☐ Energy P&D ☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☐ Greenhouse Gases	☐ Criteria Air	☐ Other
Releases to Water:	☐ Inorganic	☐ Organic Emissions	☐ Other
Water Usage:	☑ Water Consumption	☐ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Plug_Type	*0 = cement retainer; 1 = cast iron bridge plug*
Drill_depth	*[m] Well depth is highly variable, depending on reservoir*

Tracked Input Flows:

Concrete, ready mix, R-5-0 [Concrete_Cement]	*[Technosphere] Concrete used for well plugs*
Cast iron part [Metal parts]	*[Technosphere] Cast iron used in well plugs*
Water [Water]	*[Resource] Water used in drilling mud*
Sodium hydroxide (100%; caustic soda)	*[Technosphere] Caustic soda used in drilling mud*
Carboxymethylcellulose (Sodium)	*[Technosphere] Carboxymethylcellulose used in drilling mud*
Barium sulphate [Non renewable resources]	*[Technosphere] Barite used in drilling mud*

Tracked Output Flows:

CO_2 Sequestration Well Closure	*Reference flow*

Section II: Process Description

Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS_Stage3_CO2_Well_Closure_CO2_Seq_2012.01.xls*, which provides additional details regarding relevant calculations, data quality, and references.

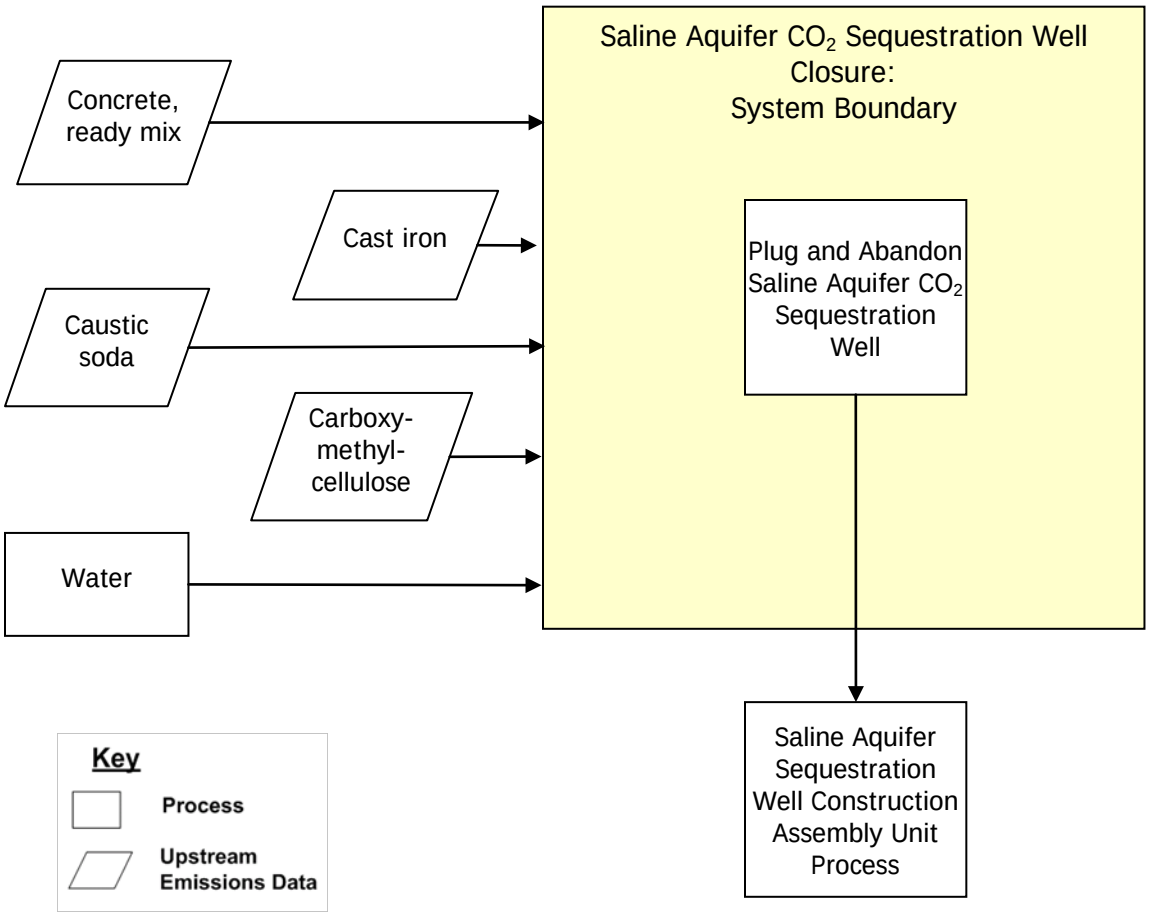
Goal and Scope

This unit process provides a summary of relevant input and output flows associated with closing a well used for underground storage of CO_2. Eight different well types are included in this unit process: stratigraphic test, injection, reservoir monitoring, above seal monitoring, groundwater monitoring, vadose zone monitoring, water production, and water disposal. There are two methods for plugging the deeper wells: cast iron bridge plug or cement retainer. Concrete and drilling fluid are used to plug the wells. The material flows of well closure are apportioned to 1 well. The reference flow of this unit process is: 1 piece of CO_2 Sequestration Well Closure.

Boundary and Description

Figure 1 provides an overview of the boundary of this unit process. Rectangular boxes represent relevant sub-processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. Water is assumed to enter the boundary of the unit process with no upstream resources or emissions. The methods for calculating these operating activities are described below.

Figure 1: Unit Process Scope and Boundary



There are eight different well types, of varying depths, that are required for CO_2 sequestration in a saline aquifer: stratigraphic test, injection, reservoir monitoring, above seal monitoring, groundwater monitoring, vadose zone monitoring, water production, and water disposal. The NETL saline aquifer storage cost model contains a representative list of possible storage formations in the United States (NETL, tbd). For each formation, the cost model calculates the depth of each well type based on the individual geologic formation characteristics. This unit process uses the average well depths from the selected list of storage formations for the calculation of plugging material. This unit process also assumes that all well types will eventually be closed.

The EPA provides guidance on plugging and abandoning wells of various types but has yet to provide specific guidance for wells that would be used for carbon dioxide sequestration, which are defined as Class VI wells (EPA, No date). This unit process uses the EPA guidance for Class II wells, defined as wells that inject fluids which are brought to the surface in connection with conventional oil or natural gas production, are used for enhanced recovery of oil or natural gas, or are used for storage of hydrocarbons (EPA, 1994). Class II guidance is a good approximation since the well depth, usage, and pressure would be similar to Class VI wells. The EPA guidance also includes options for how to implement the bottommost plug in Class II wells, which significantly changes the amount of concrete used. Both methods, either cast iron bridge plug or the use of a cement retainer (also made out of cast iron), are included in this unit process in the absence of specific guidance. Additionally, the shallow vadose zone and ground water monitoring wells are assumed to be plugged entirely with concrete.

For simplicity, the unit process assumes that there is only one underground source of drinking water (USDW) that needs to be isolated from the closed wells. The primary purpose for plugging wells prior to abandonment is to ensure that the abandoned wells do not become conduits of injection fluids (in this case carbon dioxide) or natural brines vertically into USDWs (EPA, 1994). If more USDWs were present above the closed well and there were significant salinity mismatches between the USDWs, isolation between the USDWs would also be necessary.

Figure 2 provides a schematic of well closure using the concrete retainer plug and **Figure 3** shows the alternative cast iron bridge plug. Both figures were developed using EPA guidance and data from a carbon dioxide enhanced oil recovery injection well project (API, 2008; EPA, 1994).

The inputs and outputs of this unit process are summarized in **Table 1** for the eight different well types required for saline aquifer carbon dioxide sequestration.

Figure 2: Schematic of Well Plugs using Concrete Retainer – Figure created from values in API, 2008 and EPA, 1994

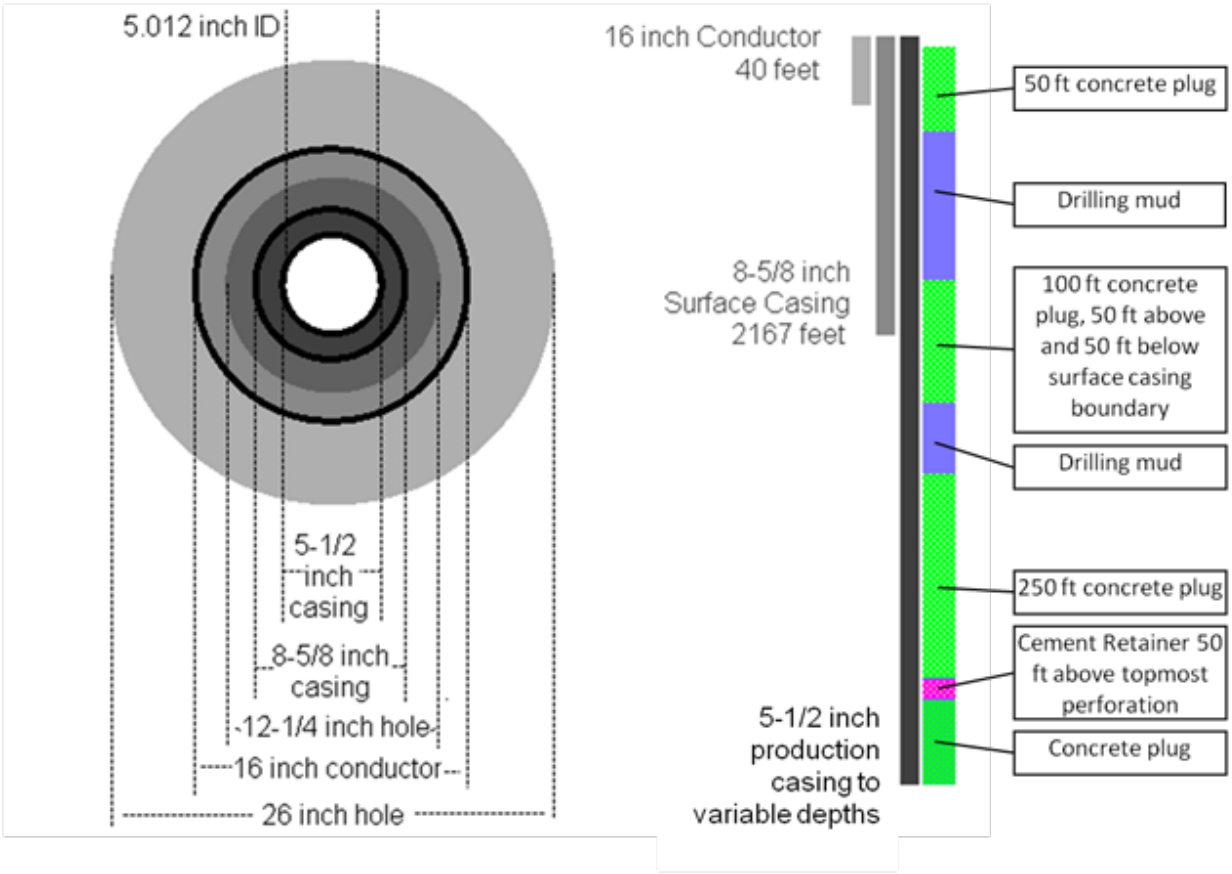


Figure 3: Schematic of Well Plugs using Cast Iron Bridge Plug - Figure created from values in API, 2008 and EPA, 1994

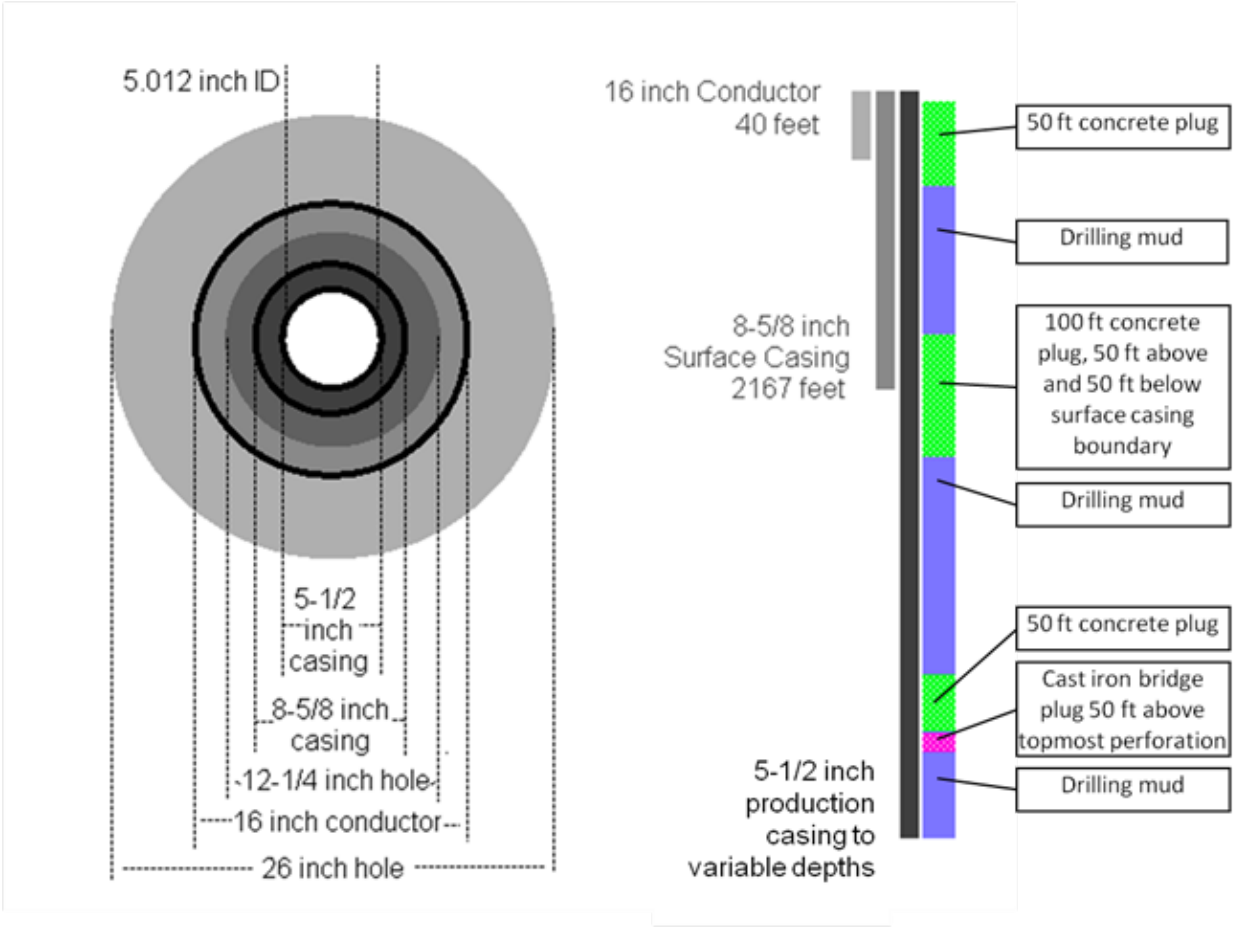


Table 1: Unit Process Input and Output Flows

Flow Name	Strat Test	Injection	In-Reservoir Monitoring	Above Seal Monitoring
Inputs				
Concrete, ready mix, R-5-0 [Concrete_Cement]	4607.10	4607.10	4607.10	4607.10
Cast iron part [Metal parts]	77.88	77.88	77.88	77.88
Water [Water]	26650.18	25573.37	24496.57	23837.58
Sodium hydroxide (100%; caustic soda) [Inorganic intermediate products]	367.14	352.30	337.47	328.39
Carboxymethylcellulose (Sodium) [Organic intermediate products]	379.38	364.05	348.72	339.34
Barium sulphate [Non renewable resources]	12164.52	11673.01	11181.51	10880.71
Outputs				
CO_2 Sequestration Well Closure	1.00	1.00	1.00	1.00
Flow Name	Groundwater	Vadose Zone	Water Production	Water Disposal
Inputs				
Concrete, ready mix, R-5-0 [Concrete_Cement]	4607.10	368.57	4607.10	4607.10
Cast iron part [Metal parts]	0.00	0.00	77.88	77.88
Water [Water]	0.00	0.00	25573.37	25573.37
Sodium hydroxide (100%; caustic soda) [Inorganic intermediate products]	0.00	0.00	352.30	352.30
Carboxymethylcellulose (Sodium) [Organic intermediate products]	0.00	0.00	364.05	364.05
Barium sulphate [Non renewable resources]	0	0	11673.01	11673.01
Outputs				
CO_2 Sequestration Well Closure	1.00	1.00	1.00	1.00

* **Bold face** clarifies that the value shown *does not* include upstream environmental flows.

Embedded Unit Processes

None.

References

API. (2008). *Summary of Carbon Dioxide Enhanced Oil Recovery (CO2 EOR) Injection Well Technology*. A. P. Institute, from http://www.api.org/~/media/Files/EHS/climate-change/Summary-carbon-dioxide-enhanced-oil-recovery-well-tech.ashx

EPA. (1994). Plugging and Abandoning Injection Wells. Environmental Protection Agency Retrieved September 11, 2012, from http://www.epa.gov/r5water/uic/r5guid/r5_04.htm

EPA. (No date). Geologic Sequestration Class VI Wells. Environmental Protection Agency Retrieved September 11, 2012, from http://water.epa.gov/type/groundwater/uic/class6/gsclass6wells.cfm

NETL. (tbd). *Saline Storage Cost Model*. National Energy Technology Laboratory. Pittsburgh, PA.

Section III: Document Control Information

Date Created: September 11, 2012

Point of Contact: Timothy Skone (NETL), Timothy.Skone@NETL.DOE.GOV

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Original/no revisions

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