INJECTION WELL PLUGGING PLAN
40 CFR 146.92(b)

Project Name: Pineywoods CCS Hub

Facility Information

Facility Name: Pineywoods CCS Hub

Facility Contact: Pineywoods CCS, LLC
14302 FNB Parkway
Omaha, NE 68154

RRC Organization Report Number: In process

Entrance Location: 30° 3'45.96"N, 94°33'14.78"W

Well Locations: Liberty and Hardin Counties, Texas

Well Name	Latitude (dms)	Longitude (dms)
PW-1	30° 2'1.24"N	94°31'16.30"W
PW-2	30° 3'45.96"N	94°33'14.78"W
PW-3	30° 6'7.27"N	94°31'27.22"W
PW-4	30° 7'58.94"N	94°31'28.79"W

Table of Contents

List of Figures

List of Tables

List of Acronyms/Abbreviations

AOR	Area of Review
Bbl	Barrel
BOP	Blow out preventer
CCS	Carbon capture and storage
CO_2	Carbon dioxide
CMG	Computer Modelling Group
DOE	Department of Energy
DAS	Distributed Acoustic Sensing
DTS	Distributed Temperature Sensing
EPA	Environmental Protection Agency
ERRP	Emergency and Remedial Response
ft	Feet

MD	Measured depth
MIT	Mechanical Integrity Test
MMcf/d	Million cubic feet/day
mg/l	Milligrams per liter
mt	Metric tons
MMt	Millions of metric tons
NU	Nipple up
t/d	Metric tons per day
t/y	Metric tons per year
TD	Total depth
TIH	Trip in hole
MMt/y	Millions metric tons per year
P&A	Plugging and abandonment
PISC	Post-Injection Site Care
PNC	Pulsed Neutron Capture Log
Ppg	Pound per gallon
psi	Pounds per square inch
psi/ft	Pounds per square inch per foot
RRC	Railroad Commission of Texas
RU	Rig up
SS	Sub-Sea
TVD	True Vertical Depth
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water

A. Introduction

Outlined in the following document is the description of the process that Pineywoods CCS, LLC will follow to plug proposed CO_2 injection wells PW-1, PW-2, PW-3, and PW-4 in accordance with the EPA's requirements under 40 CFR 146.92 and 40 CFR 146.93(e). Additionally, this plan covers Texas requirements for plugging injection wells and observation wells under 16 TAC 3.14, 5.203(k), and 76. This plan will help ensure that abandoned wells maintain integrity and will not pose a threat to USDWs and that all formations bearing usable quality water, oil, gas, or geothermal resources are protected (16 TAC 3.14(d)).

Plugging activities at an injection well will begin following the cessation of CO_2 injection in that well. However, in certain situations, Pineywoods CCS, LLC may choose to delay plugging selected injection wells and to use them, for some period of time, to monitor in-zone reservoir conditions post-injection. Texas considers a well to be inactive if it has had no disposal or other permitted activity for at least 12 months (16 TAC 3.15(a)). If delaying plugging of an injection well for more than 12 months, Pineywoods CCS, LLC will comply with 16 TAC 3.15(d) to restore the well to active operation, plug the well, or request approval from RRC of an extension for plugging an inactive well by submitting RRC Form W-3X.

A.1 Injection Well Configuration

Prior to plugging, the injection well configuration will include conductor casing, surface casing, and long string casing, all cemented to surface. The wells will also have an injection tubing string. The configuration of PW- 1 and PW-3 is shown in **Figure 41** of **the Narrative**, and configuration of PW-2 and PW-4 is shown in **Figure 42 of the Narrative**.

B. Injection Well Tests

B.1. Tests or Measures for Determining Bottom-Hole Reservoir Pressure

Bottom-hole pressure measurements will be performed and recorded throughout the injection and post-injection phases using Baker Hughes SureSENS or similar downhole pressure gauges. Pressure gauges will be placed in the injection tubing or in the deep casing string within the injection zone. These pressure-measurement devices will allow for continuous, real-time, surface readout of the pressure data. The gauges allow for operational pressures that range from 15 psi to 11,000 psi and temperatures from -99.4 to 437 degrees Fahrenheit with an accuracy of +- 0.015%. The bottom-hole reservoir pressure will be obtained using the final measurements from the pressure gauges in the injection zone after the CO_2 injection period has ended.

After the bottom-hole pressure is determined, a buffered fluid (brine) will be used to flush and fill the well to maintain pressure control of the well. The measured bottom-hole pressure will be used to determine the proper weight brine that should be used to stabilize the well. These data may also be used to determine the blend of cement to be used to plug the well (i.e., weight range of cement to prevent leak-off into formation or flowing of well, or to prevent premature setting and curing of the cement).

B.2 Testing Method to Ensure External Mechanical Integrity

The mechanical integrity of the well will be demonstrated after CO_2 injection and prior to the plugging of the well to ensure no communication has been established between the injection zone and the USDWs or ground surface (per 40 CFR 146.92(b)(2)). Well integrity testing will include the testing outlined in **Table 1**. Specific procedures for each test are outlined in **Section C.2** below.

Table 1: Planned External Mechanical Integrity Testing

Test Description	Description	Pass	Fail	Location of Testing
Temperature Log	External formation temperature measured along the wellbore from externally mounted fiber optic cable.	No temperature anomalies found.	Temperature anomalies found.	Long String Casing; Surface to TD
Activated Oxygen Log	Pulsed neutron tool set to activated oxygen mode to determine movement of oxygen molecules (CO_2).	No oxygen detected above caprock.	Oxygen detected above caprock.	Long String Casing; Surface to Caprock
Noise Log (If Available)	Acoustic log ran to measure acoustic impedances released by flowing fluid.	No flowing noise detected.	Flowing noise detected.	Long String Casing; Surface to Caprock

B.2.1 Temperature Log Evaluation

A temperature log will be run over the entire depth of the injection well via externally mounted fiber optic cable. Data from the log will be evaluated for anomalies in the temperature curve, which would be indicative of fluid migration outside of the injection zone. This data will also be compared to the information gathered from the baseline logs performed prior to injection of CO_2 into the well. Should deviations be noted between the temperature logs performed before and after the injection of CO_2 that raise issues related to the integrity of the well casing or cement, this topic will be addressed promptly.

B.2.2 Activated Oxygen Log Evaluation

An activated oxygen log will be run over the entire depth of the injection well while injecting CO_2 to determine if there is flow of CO_2 along leakage pathways. Data from the logging run will be evaluated to determine if any oxygen is located above the caprock which would indicate leakage of CO_2. Should any issues be determined from the activated oxygen log related to the integrity of the well casing or cement, this topic will be addressed promptly.

B.2.3 Noise Log Evaluation

A noise log will be run over the entire depth of the injection well while injecting CO_2 to determine if there is flow along leakage pathways. Data from the logging run will be evaluated to determine if any flow is located above the caprock which would indicate leakage of CO_2 along a micro annulus. Should any issues be determined from the noise log related to the integrity of the well casing or cement, this topic will be addressed promptly.

C. Plugging Plan

C.1 Notifications and Reporting

Following are notifications and reporting required with plugging a well, which shall be submitted separately for each well:

- **60-Day Notification**: Pineywoods CCS, LLC will notify the UIC Program Director and RRC in writing at least 60 days prior to the plugging of an injection well. Any changes to this plan shall be submitted no later than with the notification. Texas requires this notification additionally for the plugging of an observation well that penetrates the base of usable quality water. [40 CFR 146.92(c); 16 TAC 5.203(k)(3)]

- **RRC Form W-3A**: Pineywoods CCS, LLC will submit a notice of intent to plug and abandon an injection well or observation well that penetrates the base of usable quality water on RRC Form W-3A to the RRC Houston District office and Division office in Austin at least 5 days prior to the beginning of plugging operations. The submission shall include the proposed plugging procedure, including cement formulation, and complete casing record, and work shall not commence until the proposed procedure has been approved by RRC. [16 TAC 3.14(a)(3) and 5.203(k)(3)(B)]

- **Well Plugging Report**: Within 30 days of plugging an injection well, Pineywoods CCS, LLC will submit a well plugging report using RRC Form W-3 to the UIC Program Director and RRC Houston District. Texas requires this report additionally for the plugging of an observation well that penetrates the base of usable quality water. [40 CFR 146.92(d); 16 TAC §5.203(k)(4)]

C.2 Plugging Procedures

All injection and observation wells will be plugged following the schedule outlined in **Section D.4 of PISC and Site Closure**. A generalized summary of the plugging and abandonment approach for each CO_2 injection well and each observation well (except shallow groundwater wells) is as follows:

- After the life cycle of the well is complete, bottom hole measurements will be made from downhole gauges to determine bottomhole reservoir pressure and necessary fluid density, and the well will then be flushed with a kill weight brine fluid (40 CFR

§146.92; 16 TAC 5.203(k)(2)). A minimum of three tubing volumes will be injected without exceeding fracture pressure.

- The well will undergo mechanical integrity testing (MIT) to ensure internal and external mechanical integrity prior to commencement of P&A operations (40 CFR §146.89, 40 CFR §146.92; 16 TAC 5.203(k)(2)). If a mechanical integrity issue is encountered, remedial activities will be completed prior to proceeding with P&A activities.
- All casing in the wells will be cemented to the surface during construction (40 CFR §146.86) and will not be retrievable at abandonment.
- Before commencing plugging activities, ensure all materials are compatible with CO_2 and formation fluids. Final cement formulation will be without volume extenders and in compliance with 16 TAC 3.14(d)(4).
- Upon permanent conclusion of the lifecycle of wells, the tubing and packer will be removed.
- After removal of the tubing and packer, the balanced-plug placement method will be used to plug the well. If, after flushing, the tubing and packer cannot be released, an electric line with tubing cutter will be used to cut off the tubing above the packer, and the packer will be left in the well. The cement retainer method will be used for plugging the injection formation below the abandoned packer.
- All of the casing strings will be cut off at least 3 feet below the surface, below the plow line (16 TAC 3.14(d)(8)). A blanking plate with the required permit information will be welded to the top of the cutoff casing.
- All surface features associated with the plugged well and well-pad will be removed.

Shallow groundwater wells will be plugged in accordance with 16 TAC 76.104.

The methods and materials described in this part are based upon current understanding of the geology at the site and the current well designs. If necessary, the plan will be updated to reflect the latest well designs. Any changes to the plan will be submitted at least 60 days prior to the plugging of the well and approved by the UIC Program Director prior to commencing plugging activities.

The following procedure includes mechanical integrity tests and operations to place a solid column of cement in the necessary intervals to total depth. To further ensure no communication from the injection zone to the USDW zone or ground surface, the injection well casing will be plugged with cement.

1. Upon receiving approval from RRC after submission of Form W-3A (see **Section C.1** above), mobilize rig and field staff to the facility and rig up. All CO_2 pipelines will be marked and noted with rig supervisor prior.
2. Conduct and document a safety meeting to identify site-specific occupational hazards.
3. Record bottom hole pressure from down hole gauge and calculate kill fluid density.
4. Open up all valves on the vertical run of the tree and check pressures.
5. Test the pump and line to 2,500 psi. Fill tubing with kill weight brine (9.5 ppg or determined by bottom hole pressure measurement). Bleeding off occasionally may be necessary to remove all air from the system. Test casing annulus to 1000 psi and monitor as

in annual MIT. If there is pressure remaining on tubing, rig to pump down tubing and inject two tubing volumes of kill weight brine. Monitor tubing and casing pressure for 1 hour. If both casing and tubing are dead, then nipple up blowout preventers (NU BOP's). Monitor casing and tubing pressures.

6. If the well is not dead or the pressure cannot be bled off of tubing, RU slickline and set plug in lower profile nipple below packer. Circulate tubing and annulus with kill weight fluid until well is dead. After the well is dead, nipple down tree, NU BOPs, and perform a function test. BOPs should have appropriately sized single pipe rams on top and blind rams in the bottom ram for tubing. Test pipe rams and blind rams to 250 psi low, 3,000 psi high. Test annular preventer to 250 psi low and 3,000 psi high. Test all Texas Iron Works (pressure valve), BOP's choke and kill lines, and choke manifold to 250 psi low and 3,000 psi high. NOTE: Make sure casing valve is open during all BOP tests**.** After testing BOPs, pick up tubing string and unlatch seal assembly from seal bore. Rig slick line and lubricator back to well and remove plug from well. Rig to pump via lubricator and circulate until well is dead.
7. Pull out of hole with tubing laying it down. NOTE: Ensure that the well is over-balanced so there is no backflow due to formation pressure and there are at least 2 well control barriers in place at all times.
8. Pull seal assembly, pick up work string, and trip in hole (TIH) with the packer retrieving tools. Latch onto the packer and pull out of hole laying down same.
    a. ***Contingency:*** If unable to pull seal assembly, RU electric line and make cut on tubing string just above packer. Note: Cut must be made above packer at least 5-10 ft measured depth (MD). If unable to pull the packer, pull the work string out of hole and proceed to the next step. If problems are noted, update cement remediation plan (if needed) and execute prior to plugging operations.
9. Confirm the well's mechanical integrity by performing one of the external mechanical integrity tests listed in **Table 1**.
    a. Temperature log:
        i. Using fiber optic interrogator, take temperature data along the wellbore.
        ii. Compare tests against both baseline and annual tests.
    b. Activated Oxygen log:
        i. Rig up logging company.
        ii. Log down from surface to caprock using pulsed neutron tool in activated oxygen mode.
        iii. Pull out of hole.
        iv. Rig down logging company.
        v. Evaluate activated oxygen log.
    c. Noise log (if available):
        i. Rig up logging company.
        ii. Run in hole to TD.
        iii. Log up from caprock to surface.
        iv. Pull out of hole.
        v. Rig down logging company.
        vi. Evaluate noise log.
10. If issues arise from external mechanical integrity test, address appropriately.

11. TIH with work string to total depth (TD). Keep the hole full at all times. Circulate the well and prepare for cement plugging operations.
12. The lower section of the well will be plugged using CO_2-resistant cement from TD in the Vicksburg Interval to around 500 ft above the top of the Anahuac Formation. This will be accomplished by placing plugs in 500 ft incremental lifts and using specific cement design outlined in **Section C.3.** It is anticipated that 6 plugs of 500 feet in length will be necessary. No more than two plugs will be set before cement is allowed to set and plugs verified by setting work string weight down onto the plug.
13. Circulate the well and ensure it is in balance. Place tubing 500 ft. below the lowest identified base of USDW. Mix and spot 500 ft balanced plug in 5.5" casing. Pull out of plug and reverse circulate tubing. Repeat this operation until a total of 5 plugs have been set and 500 ft above the top of the USDW has been reached. If plugs are well balanced, then the reverse circulation step can be omitted until after each third plug. Lay down work string while pulling from well. If the rig is working daylights only then pull 10 stands and rack back in derrick and reverse tubing before shutting down for night. After waiting overnight, trip back in hole and tag plug and continue. After the required plugs have been set, pull tubing from well and shut in for 12 hours. TIH with tubing and tag cement top. Pull tubing back out of well. Nipple down BOPs and cut all casing strings below plow line (min 3 feet below ground level). Trip in well and set final cement plug. Lay down all work string, etc. Rig down all equipment and move out. Clean cellar to where a plate can be welded with well name onto lowest casing string at 3 feet.
14. The procedures described above are subject to modification during execution as necessary to ensure a plugging operation that protects worker safety and is effective to protect USDWs, and any significant modifications due to unforeseen circumstances will be described in the Well Plugging Report. Complete plugging forms and send in with charts and all lab information to the regulatory agency as required by permit. The plugging report shall be certified as accurate by Pineywoods CCS, LLC and plugging contractor and submitted as described above in **Section C.1**. A reference schematic for the plugging protocol mentioned above is shown in **Figure 1.**

C.3 Information on Plugs

Table 2 presents the intervals that will be plugged and the materials and methods that will be used to plug the intervals. The portion of the well corresponding to the injection zone will be plugged using Schlumberger's EverCRETE or similar CO_2-resistant cement with a retainer method. Cement plugging will begin below the injection zone at the top of the Vicksburg formation. The entire injection zone, the Frio Formation, will be plugged using EverCRETE cement in 500 ft. intervals (starting with one initial 300 ft interval). Plugging will continue in 500 ft intervals until 500 ft. above the confining unit, the Anahuac, where Class A cement will be used for the remaining 500-ft interval plugs. Plugging will continue in 500 feet intervals until 500 feet above the top of the USDW. A final 500 ft. plug will be placed to the surface. Cement volumes were calculated by volumetric calculations. (Example: Assuming 9.625-inch 47 lb/ft casing; [500 feet x 0.399 ft^3ft^{-1} x 1.1 excess]/ 1.11ft^3/sack = 197 sacks)

Table 2. Plugging Details

Plug	Diameter of boring which plug will be placed (inches)	Inner Diameter of casing which plug will be placed (inches)	Depth to bottom of tubing or drill pipe (feet)	Sacks of cement to be used	Slurry volume to be pumped (bbl)	Weight of Slurry (ppg)	Calculated top of plug (feet)	Bottom of plug (feet)	Type of cement	Method of emplacement
Plug #1	12.25	8.525	7,300	118	23.3	15.8	7,000	7,300	EverCRETE	Balance
Plug #2	12.25	8.525	7,000	197	38.8	15.8	6,500	7,000	EverCRETE	Balance
Plug #3	12.25	8.525	6,500	197	38.8	15.8	6,000	6,500	EverCRETE	Balance
Plug #4	12.25	8.525	6,000	197	38.8	15.8	5,500	6,000	EverCRETE	Balance
Plug #5	12.25	8.525	5,500	197	38.8	15.8	5,000	5,500	EverCRETE	Balance
Plug #6	12.25	8.525	5,000	197	38.8	15.8	4,500	5,000	EverCRETE	Balance
Plug #7	12.25	8.525	4,500	185	38.8	15.8	4,000	4,500	Class A	Balance
Plug #8	12.25	8.525	4,000	185	38.8	15.8	3,500	4,000	Class A	Balance
Plug #9	12.25	8.525	3,500	185	38.8	15.8	3,000	3,500	Class A	Balance
Plug #10	12.25	8.525	3,000	185	38.8	15.8	2,500	3,000	Class A	Balance
Plug #11	12.25	8.525	2,500	185	38.8	15.8	2,000	2,500	Class A	Balance
Plug #12	12.25	8.525	2,000	185	38.8	15.8	1,500	2,000	Class A	Balance
Plug #13	12.25	8.525	1,500	185	38.8	15.8	1,000	1,500	Class A	Balance
Plug #14	12.25	8.525	1,000	185	38.8	15.8	500	1,000	Class A	Balance
Plug #15	12.25	8.525	500	185	38.8	15.8	0	500	Class A	Balance

The pressure used to squeeze the cement will be determined from the bottom-hole pressure data measured before beginning the plugging and abandonment process. A maximum pressure threshold of 90% of the determined reservoir fracture pressure for the Frio Sandstone will be utilized to constrain pressure increases during the cement injection process. If it appears that the injection pressure will exceed the 90% fracture pressure threshold and the total amount of cement has not been pumped into the injection zone, cement pumping will cease. Then, the tubing will be removed from the cement retainer to allow the pressure to return to static condition. After allowing the pressure to decline, the tubing will be re-strung through the cement retainer, and cement pumping will be attempted again. A rapid increase in pressure on the tubing would indicate that the Frio perforations have been sealed with cement, and no additional cement will be added to the zone or plug.

Cementing operations will continue to plug the wellbore. Cement will be pumped in 500 ft intervals (197 sacks for EVERCRETE, 185 Sacks for Class A) using a balance method. This will ensure efficient cement placement and prevent tubing from sticking in the cement column. **Figure 1** shows the details of the injection well after plugging and abandonment.

After the remainder of the casing has been filled with cement, the casing sections will be cut off approximately 5 ft below surface and a steel cap will be welded to the top of the deep casing string. The cap will have the well identification number, the Class VI UIC well permit number, and the date of plug and abandonment inscribed on it. Soil will be backfilled around the well to bring the area around the well back to pre-well-installation conditions. This area will then be planted with natural vegetation.

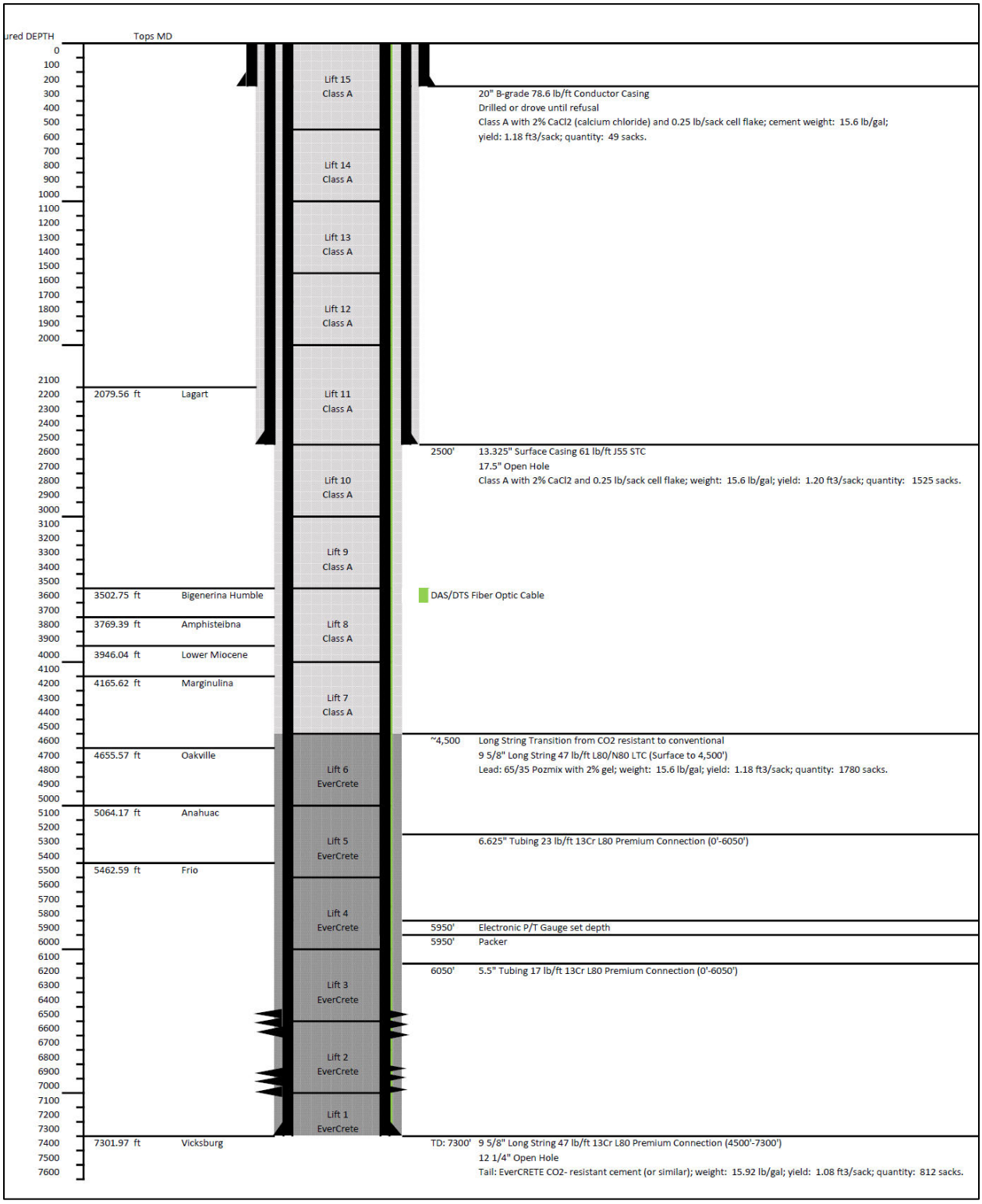

Figure 1. Diagram of the Injection Well After Plugging and Abandonment