KANSAS GEOLOGICAL SURVEY
The University of Kansas

File E - Proposed Post-Injection Site Care (PISC) and Site Closure Plan

Note: This document contains Proposed Post-Injection Site Care (PISC) and Site Closure Plan information for the Kansas Small Scale Test Wellington Field. The contents were extracted from the original KGS permit document that was prepared prior to the new EPA submission format introduced to KGS on June 3rd 2014. This explains why the information in this Proposed Post-Injection Site Care (PISC) and Site Closure Plan document may contain references to figures, tables, and sub-sections in other permit sections that may not be included in this Proposed Post-Injection Site Care (PISC) and Site Closure Plan document. Therefore, to facilitate the review process, the entire original permit application has been submitted as a separate document titled "L - Other Information Required by the UIC Program Director", which also contains an Executive Summary, cover letter, application forms, complete table of contents, list of tables and figures, appendices, and a cross reference table which lists sub-sections that address all Class VI 40 CFR sections 146.82 – 146.93 requirements.

The Proposed Post-Injection Site Care (PISC) and Site Closure Plan is documented in the following section:

Table of Contents
File E: Proposed Post-Injection Site Care (PISC) and Site Closure Plan

Section 12
Post-Injection Site Care and Site Closure Plan

Facility Name:	Wellington Field Small Scale Carbon Capture and Storage Project
Injection well Location:	Latitude 37.319485, Longitude -97.4334588 Township 31S, Range 1W, Section 28 NE SW SE SW
Facility Contact:	Dana Wreath, Vice President
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12.1 Introduction

40 CFR §146.93(a) requires that the owner or operator of a Class VI well prepare, maintain, and comply with a plan for post-injection site care and site closure. 40 CFR §146.93(a)(2) requires this plan to include the following information:

(i) The pressure differential between pre-injection and predicted post-injection pressures in the injection zone(s);

(ii) The predicted position of the carbon dioxide plume and associated pressure front at site closure as demonstrated in the area of review evaluation required under §146.84(c)(1);

(iii) A description of post-injection monitoring location, methods, and proposed frequency;

(iv) A proposed schedule for submitting post-injection site care monitoring results to the director pursuant to §146.91(e); and,

(v) The duration of the post-injection site care timeframe and, if approved by the director, the demonstration of the alternative post-injection site care timeframe that ensures non-endangerment of USDWs.

The monitoring activities presented in the Testing and Monitoring Plan (Section 10) will continue during the post-injection phase to meet the post-injection site care (PISC) requirements of 40 CFR §146.93. Both direct and indirect data will be acquired during the post-injection period. Direct data will be acquired in the injection well and the monitoring wells in the Arbuckle Group, Mississippian System, and Wellington Formation at locations shown in Figure 10.1. A detailed description of the planned monitoring activities is documented in Section 10. A summary of the post-injection monitoring frequency is provided in Section 12.2.

Upon cessation of injection, the most recently acquired data and modeling results will be reviewed with respect to the most recent PISC plan. Depending on the rate and extent of plume movement observed during the injection phase, the frequency and spatial extent of the monitoring activities may be modified, and the PISC plan may be resubmitted to the EPA director for review and approval. If the preliminary plans do not need to be altered, there will be no modification to the monitoring plan and the well and sampling locations/frequencies will be maintained.

If significant differences between observed and model-simulated plume and pressure front are noted during the post-injection period, and if these differences are deemed to have the potential to alter the basis for the permit, the model will be recalibrated, and revised plume and pressure projections will be obtained. The existing post-injection monitoring plan will be reviewed along with the latest model projections, and the testing/monitoring plan will be adjusted and provided to the EPA for review to ensure accurate tracking of the plume/pressure front in support of eventual site closure. If necessary, this process of data acquisition and model refinement/projections may continue to determine whether or not the injected CO_2 poses any threat to the USDW. Once a determination of no negative impacts to the USDW is made, an application for site closure will be filed with the EPA director as outlined in Section 12.6.

12.2 PISC Monitoring Activities and Schedule for Submitting PISC Results and Re-evaluation (40 CFR §146.93 [a][2][iv]) (40 CFR §146.93 [a][2][iii] and [b])

Various tools will be used to monitor, verify, and account for the injected $CO_{2,}$ and the techniques will extend into the post-injection site care timeframe. Table 12.1 presents a summary of the monitoring techniques to be employed and the monitoring schedule. Section 10 (Testing and Monitoring Plan) provides a detailed explanation of each testing and monitoring method.

Table 12.1—Schedule of monitoring activities to be conducted during the PISC phase.

Monitoring Activity	Monitoring Frequency
External MIT (temperature log)	Before closure
Corrosion	Quarterly
Pressure in Arbuckle injection and monitoring wells	Daily
InSAR	Three measurements every 20 days after cessation of injection, and decreasing incrementally to 12 months interval until closure, should closure last beyond 1 year.
USDW geochemistry	Every 6 months as specified in Table 10.7
Mississippian geochemistry	Every 6 months as specified in Table 10.7
Arbuckle geochemistry	Every 6 months as specified in Table 10.7
3-D seismic survey	Before closure

The PISC monitoring data along with any updated reservoir modeling results and any updated PISC and Site Closure Plan will be submitted bi-annually to the EPA. The contents of the these reports are specified in Section 10 (Testing and Monitoring Reporting to EPA). In the event that the monitored data deviate substantially from projections, an analysis will be conducted to explain the deviation. If necessary, the reservoir model may be recalibrated to obtain fresh projection of the future plume trajectory and pore pressures. The findings of the re-evaluation (including a potentially revised PISC and Site Closure Plan) will be submitted to the EPA within 30 days of completion of the re-evaluation. Before authorization for site closure, a demonstration will be made to the EPA director, based on monitoring and other site-specific data, that no additional monitoring is needed to ensure that the geologic storage project does not pose an endangerment to USDWs.

12.3 Alternative Post-Injection Site Care and Site Closure Timeframe (40 CFR §146.93[c])

The default timeframe for post-injection site care is 50 years. However, due to the small extent of the CO_2 plume in the subsurface for this pilot-scale project, which will result in pressures in the injection zone reverting close to pre-injection levels within three months of cessation of injection, Berexco is requesting to close the site at the end of a one-year post-injection period. This proposed post-injection site care timeframe will, however, be re-evaluated and justified to the EPA based on site-specific data obtained during the injection and post-injection phases.

The site-specific conditions that support a request for early closure are provided below in support of 40 CFR §146.93(c) (1):

- (§146.93[c][1][i])—The results of computational modeling of the project indicate that the stored CO_2 will not migrate above the primary confining zone and not spread laterally within the injection zone (Arbuckle aquifer) to any natural or artificial penetration that extends into the confining zone other than KGS 1-28 and 2-28, both of which will be constructed to Class VI (injection well) specifications. These conclusions are documented in Section 9.
- (§146.93[c][1][ii])—The results of computational modeling (Section 5.4.6) indicate that formation pressures are generally not adequate to force the CO_2-brine mixture within the Arbuckle to penetrate into the USDW. As noted from Table 9.1, a pressure increase of approximately 327 psi is required for brines in the injection interval to migrate into the USDW. As shown in Figure 5.18, the pressure drops to less than 327 psi within 100 ft of the injection well, which has been constructed per Class VI guidelines as documented in Section 8. Therefore, there are no existing or abandoned wells through which the Arbuckle brines can be expected to migrate into the USDW. As shown in Figure 6.4, there are no known or mapped faults within the AoR at the Wellington site through which the brines in the Arbuckle could migrate upward either.
- (§146.93[c][1][iii])—The predicted rate of CO_2 plume migration is minimal with a

maximum spread of approximately 1,700 ft from the injection well (Figure 9.1). Also, the plume is expected to remain confined in the injection interval within the lower Arbuckle as shown in Figures 5.11 and 5.13 and not migrate even into the middle or upper Arbuckle.

- (§146.93[c][iv, v, and vi])—The storage processes that were simulated include structural, hydrodynamic, solubility, and residual trapping. The model ignores storage due to capillary entrapment and mineralization, and therefore the results are expected to be on the conservative side.

  The hydrogeologic properties of the Arbuckle aquifer were derived by means of sophisticated analyses involving the construction of a geomodel using Schlumberger's Petrel modeling software. The data in the geomodel were anchored in core and log data for porosity and permeability derived at the injection well site (KGS 1-28) and the geologic characterization well (KGS 1-32). Therefore, the reservoir model is expected to realistically represent the hydrogeologic properties of the Arbuckle aquifer. However, to account for uncertainties, and to obtain conservative results, a set of nine alternative models were derived and used in the simulations by increasing and decreasing the key hydrogeologic properties by 25%. As discussed in Section 5.4, the model-based limits on maximum induced pressure and maximum extent of plume migration are based on these alternative models, which ensures some conservatism built into the projections.
- (§146.93[c][vii])—Section 4 documents in detail all of the site-specific geologic and hydrogeologic data used to develop the conceptual reservoir model of the injection zone (Arbuckle) and the confining zone (Simpson Group, Chattanooga Shale, and Pierson formation). The confining potential of the primary confining zone is extensively documented in Section 4.7.

  There are no known faults within the AoR as shown in Figure 6.4. The lack of hydraulic connection between the injection zone (Arbuckle) and the overlying formations is also documented and confirmed by the geochemical data (Section 4.6.7), which in-

dicates vastly different geochemistry in the injection zone and overlying Arbuckle and Mississippian reservoir formations. The drill-stem test (DST) data (Section 4.6.3) also indicate substantial under-pressurization in the Mississippian Formation that overlies the confining zone (Simpson/Chattanooga/Pierson), suggesting lack of transmissive features in the primary confining zone. Furthermore, the regionwide under-pressurization of the Mississippian Formation with respect to the injection zone (Arbuckle aquifer) could only exist in the absence of hydraulic conduits in the confining zone as documented in Section 7. Even if the CO_2 were to escape from the confining zone, it would be hydraulically trapped in the under-pressurized Mississippian oil reservoir above the confining zone.

- (§146.93[c][viii and ix])—No abandoned wells penetrate the primary confining zone within the AoR as shown in Figure 1.10 and Table 1.2. The only existing well within the AoR that penetrates the confining zone is the injection well (KGS 1-28), which as documented in Section 8 was constructed per Class VI specifications. The Arbuckle monitoring well (KGS 2-28), to be located approximately 300 ft northwest of KGS 1-28 and within the AoR, will also be in compliance with Class VI construction requirements as documented in Section 10. The CO_2 plume is expected to reach this well in approximately two months time.
- (§146.93[c][x])—The distance between the injection zone and the base of the USDW is in excess of 4,500 ft, as shown in Figure 1.8. There are multiple confining (shale) zones between the injection zone and the USDW as documented in Section 4.3 and Figure 1.8.

12.4 Reservoir Simulation Results Pressure Differential and Predicted Plume Position (40 CFR §146.93[a][2][i and ii])

Section 5.4.6 presents and discusses the preliminary reservoir simulation results. At the end of the nine-month injection period, the bottomhole (5,050 ft) pressure at the injection well completion is expected to increase by 442 psi (Table 5.6) but decrease rapidly with distance from

the well as shown in Figure 5.18. As discussed in Section 9.2.1, an increase in pore pressure of approximately 327 psi is necessary for the brines in the injection zone to migrate vertically into the USDW through a natural or artificial penetration. As shown in Figure 5.18, the pressure drops to less than 327 psi within less than 100 ft of the injection well, which has been constructed per Class VI guidelines as documented in Section 8. Therefore, there are no existing or abandoned wells through which the Arbuckle brines can be expected to migrate into the USDW. Furthermore, as discussed in Section 7, the Mississippian System above the confining zone is significantly under-pressurized and therefore would act as buffer and bleed-off zones in the unlikely event that a pathway is present between the Arbuckle and the USDW. The projected pressure increase at the top of the Arbuckle (under the primary confining zone) after nine months of injection is expected to be only slightly more than 13 psi at the injection well site under the worst-case scenario (Figure 5.16). This pressure increase would be insufficient to cause migration into the USDW due to the large head differential between the Arbuckle Group and the Wellington Formation (USDW). Additionally, the pressure increase at the top of the Arbuckle is also significantly less than the entry pressure in the Chattanooga Shale of 956 psi as documented in Section 4.7.4. Therefore, the primary confining zone (Simpson/Chattanooga/Pierson) is expected to function as a competent caprock because of its lateral extent and low permeability (at the nano-Darcy level as documented in Section 4.7.3) combined with insufficient pressure build-up at the top of the Arbuckle to overcome capillary forces. The pore pressures in the injection interval are also expected to dissipate to near pre-injection levels in less than three months after cessation of injection as shown in Figure 5.17. Therefore, the aqueous phase CO_2 is not expected to penetrate into the USDW during the post-injection phase due to the large head difference between the Arbuckle and the USDW and confinement offered by the confining zone.

Modeling was also used to predict the movement of the free-phase CO_2 plume. The simulation results (Figure 5.13a–g) indicate that the free-phase CO_2 barely penetrates into the mid-Arbuckle baffle zones and does not reach the base of the confining zone. The configuration of the CO_2 plume in the injection interval at the end of one year after injection (time of proposed site closure)

is shown in Figure 12.1, which suggest that the plume (at its widest extent) will have migrated about 1,700 ft from the injection well. Although in the presence of a hypothetical pathway, CO_2 in free phase could theoretically escape into the USDW and the atmosphere through faults or artificial penetrations, there are no wells within the AoR that penetrate the confining zone except KGS 1-28 and KGS 2-28, both of which will be constructed to meet Class VI (injection well) specifications as documented in Sections 8 and 10.

With respect to escape of CO_2 via structural features, not only are there no known faults in the AoR as shown in Figure 6.4, but the pressure increase projected to occur in the injection zone will not initiate new fractures or mobilize any existing faults as documented in Sections 6.3–6.5. Furthermore, the geochemical and DST data presented in Sections 4.6.3 and 4.6.7 suggest a high level of confinement provided by the confining zone, which precludes the presence of any transmissive

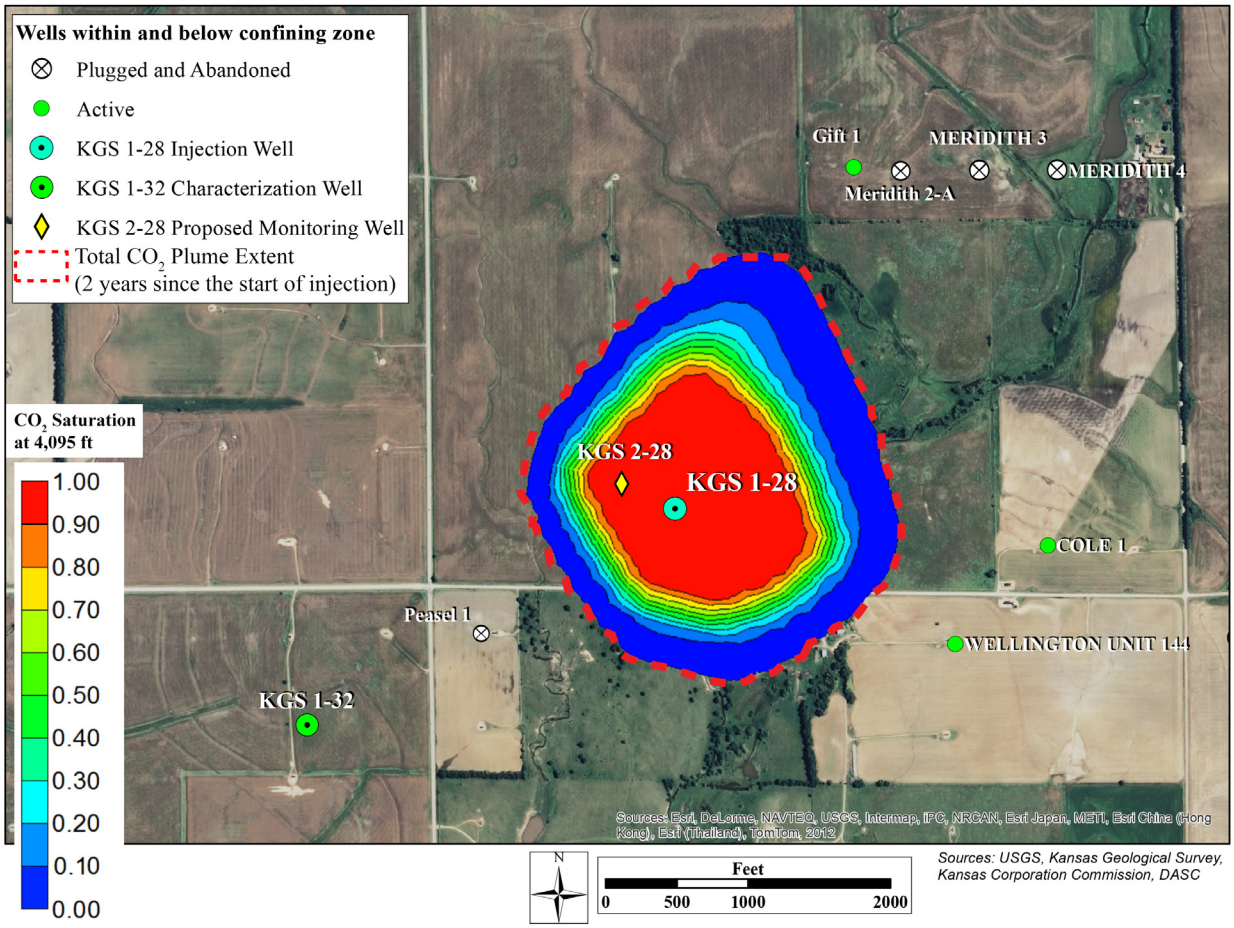

Figure 12.1—Extent of plume migration at the end of one year after cessation of injection for the alternative model resulting in the largest extent of plume migration (k-1.25/phi-0.75).

fractures in the primary confining zone. An analysis of fractures in the confining zones, documented in Section 4.7.5, suggests the absence of communicative fractures in the confining zone.

12.5 Criteria for Demonstration of Alternative Post-Injection Site Care Timeframe. (40 CFR § 146.93 [a][2][v] and [c][2])

Care has been taken to ensure acquisition of quality data and to promote careful processing of the acquired data. The geophysical logs were acquired and analyzed by reputable vendors, such as Weatherford and Schlumberger. Laboratory tests to estimate formation properties, such as permeability/porosity and rock elasticity/strength, were conducted by certified laboratories, such as Weatherford Laboratories. Data synthesis and interpretation were conducted by professional staff at KGS who are experts in their field and by professionally certified external consultants. All technical analyses have been checked and documented and are available for review and reproduction by the EPA.

The geo and reservoir models developed for the project are based on the carefully processed core and geophysical data. The reservoir model is also based on available field data, such as injection tests. However, a set of alternative conceptual models were also developed in order to incorporate conservatism in the simulation results. QA/QC measures to be implemented while conducting testing and monitoring activities during the pre-injection, injection, and post-injection phases are documented extensively in Section 10. All analyses and QA/QC for project data meet and will continue to meet the following required standards:

(i) All analyses and tests performed to support the demonstration will be accurate, reproducible, and performed in accordance with the established quality-assurance standards;

(ii) Estimation techniques will be appropriate and EPA-certified test protocols will be used where available;

(iii) Reservoir model will be appropriate and tailored to the site conditions, composition of the carbon dioxide stream, and injection and site conditions over the life of the geologic storage project;

(iv) Reservoir model will be reviewed to ensure that it is in conformance with newly acquired monitoring and geophysical data;

(v) Reasonably conservative values and modeling assumptions will be used and disclosed to the director whenever values are estimated on the basis of known, historical information instead of site-specific measurements;

(vi) An analysis will be performed to identify and assess aspects of the alternative post-injection site care timeframe demonstration that contribute significantly to uncertainty. Sensitivity analyses will be conducted to determine the effect that significant uncertainty may contribute to the modeling demonstration.

(vii) The quality-assurance and quality-control measures specified in Section 10 will address all aspects of the demonstration; and,

(viii) Any additional criteria required by the director.

12.6 Site Closure Activities (40 CFR §146.93 [d-g])

Prior to authorization of site closure, Berexco will submit to the director for review and approval a demonstration, based on monitoring and other site-specific data, that no additional monitoring is needed to ensure that the geologic storage project does not pose a danger to USDWs. If the demonstration cannot be made (i.e., additional monitoring is needed to ensure that the geologic storage project does not pose a danger to USDWs), an updated PISC plan will be submitted to the director to continue post-injection site care until a demonstration can be made and approved by the director.

The following activities will be carried out before requesting site closure:

- A 3-D seismic survey will be acquired over the area of approximately one square mile. The new 3-D data will be interpreted and compared with the baseline survey (that has already been acquired and discussed in Section 4.8) to detect the presence of CO_2 outside the expected plume containment area as modeled by reservoir simulation studies.
- The non-seismic MVA data and its analyses conducted during the post-injection phase

will be integrated with the newly acquired 3-D seismic data to validate the absence of CO_2 outside the containment strata, thus confirming that future leakage risks are minimal to non-existent.

- All monitoring data and other site-specific data will be accounted for and used in the simulation model to demonstrate to the EPA in the form of a report that the pressures have abated, that the plume growth has slowed, and that no additional monitoring is needed to ensure that the storage project does not pose a danger to USDWs. If the EPA does not approve the demonstration, an amended plan will be submitted to the director for continuing PISC until a demonstration of safe site closure is made and approved by the director.

Berexco will notify the EPA Region 7 director of its intent to close the site at least 120 days before the closure date. Any revisions to the PISC and Site Closure Plan will accompany the notice. Once the EPA has approved closure of the site, all monitoring wells included in the permit application may be plugged. The Arbuckle injection well (KGS 1-28) and potentially the Arbuckle monitoring well (KGS 2-28) will be abandoned in accordance with the plan described in Section 11. The Wellington shallow USDW monitoring wells will be plugged following standard industry practices. The Arbuckle geologic characterization well (KGS 1-32) will be plugged in accordance with procedures used for KGS 2-28. A site closure report will be prepared within 90 days of closure and submitted to the EPA director, documenting the following:

- plugging of the injection and USDW monitoring wells,
- location of the sealed injection well on a plat of survey that has been submitted to the local zoning authority. A copy of the plat also will be submitted to the EPA regional office,
- notifications of closure to state and local authorities,
- records documenting the nature, composition, and volume of the injected CO_2,
- all pre-injection, during injection, and post-injection monitoring records,
- certifications to the Region 7 program director that all geologic injection and storage

activities have been completed in accordance with the Post-Injection Site Care and Site Closure Plan.

Berexco will record the following information in a notation to the property deed on which the injection well (KGS 1-28) was located:

- that the property was used for CO_2 storage,
- the name of the agency with which the survey plat was filed as well as the address of the EPA Region 7 office that received a copy of the plat survey,
- the volume of fluid injected,
- the formation into which the fluid was injected,
- the period over which the injection occurred.

All PISC records will be retained by Berexco for a period of 10 years, after which the records will be delivered to the EPA director for retention.