6.0 Injection Well Plugging Plan

This chapter describes the injection well plugging plan the Alliance will implement in compliance with 40 CFR 146.92 after CO_2 injection has ceased and injection well monitoring activities have been completed. This plan applies to each of the four injection wells. Section 6.1 describes the tests that will be completed prior to plugging the injection wells. The details for plugging and abandoning the wells are provided in Section 6.2, including the methods and materials used to plug each injection well. Section 6.3 provides a list of references for sources cited in this chapter.

6.1 Injection Well Tests

The UIC Class VI permit regulations require that data be collected prior to plugging an injection well. Specifically, the bottom-hole pressure must be determined and the mechanical integrity of the well casing must be confirmed before proceeding to plug and abandon the well (40 CFR 146.92(a)). The procedures that will be used to generate these data, as required in 40 CFR 146.92(b), are described in the following sections.

6.1.1 Tests or Measures for Determining Bottom-Hole Reservoir Pressure

Bottom-hole pressure measurements will be used to determine the pressure required to squeeze the cement from the well casing into the injection reservoir. In addition, these data will be used to determine the need for well control equipment. The weight of brine required to prevent the well from flowing will be calculated using this information. The pressure measurements will also be used to determine the formulation of cement to be used to plug the well (i.e., cement-setting retardants may need to be added to the cement to prevent premature setting and curing of the cement).

Bottom-hole pressure measurements will be performed and recorded throughout the duration of the project. Pressure gauges will be placed in the injection tubing or within the deep casing string within the injection zone, and these pressure-measurement devices will allow for continuous, real-time, surface readout of the pressure data. The bottom-hole reservoir pressure will be obtained using the final measurements from the pressure gauges in the injection zone after the injection of CO_2.

After the bottom-hole pressure is determined, a buffered fluid (brine) will be used to flush and fill each well to maintain pressure control of the well. The bottom-hole pressure will be used to determine the proper weight of brine that should be used to stabilize each well.

6.1.2 Injection Well Testing to Ensure External Mechanical Integrity

The mechanical integrity of each well must be demonstrated after CO_2 injection and prior to the plugging of the well to ensure conduits between the injection zone and the USDWs or ground surface have not developed. External mechanical integrity will be evaluated by performing temperature logging on the injection well, as described in Section 5.3.2.

The temperature log will be run over the entire depth of each injection well. Data from the logging run will be evaluated for anomalies in the temperature curve, which would be indicative of fluid migration outside of the injection zone. These data will also be compared to data from the logs performed

prior to injection of CO_2 into the well. Deviations between the temperature logs performed before and after the injection of CO_2 may indicate issues related to the integrity of the well casing or cement.

6.2 Plugging Plan

Each injection well casing will be plugged with cement and 6 percent water gel spacers to ensure that the well does not provide a conduit from the injection zone to the USDW zone or ground surface. As discussed in Chapter 4.0, two types of well completion designs are being considered: one with a perforated-cased horizontal lateral, the other with an open, uncased horizontal lateral. The procedures for plugging and abandoning both types of horizontal CO_2 injection wells are very similar, whether they are a cased and perforated completion or an open-hole completion. However, cement volumes will differ depending upon the total depth and horizontal length of the well. Table 6.1 summarizes the plugging plans for each type of well completion and describes intervals that will be plugged and the materials and methods that will be used to plug the intervals.

For both well completion designs, the portion of the well corresponding to the injection zone will be plugged using CO_2-resistant cement with a retainer method. Class A well cements are formulated in accordance with API Specification 10A (API 2010) standards and are similar to ASTM Type I Portland cements (ASTM C465, ASTM 2010). CO_2-resistant cement is formulated with the addition of pozzalan or other materials that reduce production of calcium hydroxide and calcium silicate hydrate, that weaken cements in the presence of CO_2. The cement retainer will be set at a depth of 3,900 ft, at the contact between the Eau Claire Formation and the Mount Simon Sandstone, and will be constructed of corrosion-resistant materials. Depending upon the horizontal length and well construction, approximately 450 to 1,475 sacks of CO_2-resistant cement will be used to plug the injection interval (this includes a 10 percent excess volume to be squeezed through the perforations into the Mount Simon Sandstone).

The pressure used to squeeze the cement will be determined from the bottom-hole pressure data measured before beginning the plugging and abandonment process. However, the injection pressure of the cement will not exceed the fracture pressure of the Mount Simon Sandstone. If it appears that the injection pressure will exceed the fracture pressure and the total amount of cement has not been pumped into the injection zone, cement pumping will cease and the tubing will be removed from the cement retainer to allow the pressure to return to static conditions. After allowing the pressure to reduce, 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 perforations have been sealed with cement, and no additional cement will be added to the zone or plug.

Figure 6.1 shows the details of cased injection wells after plugging and abandonment. Figure 6.2 shows the design for an uncased horizontal injection well closure.

After the remainder of the casing has been filled with cement, the casing sections will be cut off approximately 5 ft bgs, and a steel cap will be welded to the top of the deep casing string. The cap will have the well identification number, the UIC Class VI 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 grade. This area will then be planted with natural vegetation.

Table 6.1. Intervals to Be Plugged and Materials/Methods Used

Zone of Interest	Depth	Formation	Plugging Method	Plug Description	
Description	Cemented Interval	Name	Description	Type	Quantity
Perforated Interval (2,500 ft lateral)	3,900 – 7,004	Mt. Simon	Retainer	EverCRETE CO_2-Resistant or similar	666 sacks (15% Excess)
Retainer Plug	3,100 – 3,900	Various	Balanced Plug	EverCRETE CO_2-Resistant or similar	150 sacks
Gel Spacer	1,800 – 3,100	Various	Balanced Plug	6% freshwater gel	48.2 bbl
Intermediate Plug	1,500 – 1,800	Various	Balanced Plug	Class A Neat	53 sacks
Gel Spacer	700 – 1,500	Various	Balanced Plug	6% freshwater gel	30 bbl
Surface Plug	0 – 700	Various	Balanced Plug	Class A Neat	124 sacks
Perforated Interval (1,500 ft lateral)	3,900 – 6,004	Mt. Simon	Retainer	EverCRETE CO_2-Resistant or similar	450 sacks (15% Excess)
Retainer Plug	3,100 – 3,900	Various	Balanced Plug	EverCRETE CO_2-Resistant or similar	150 sacks
Gel Spacer	1,800 – 3,100	Various	Balanced Plug	6% freshwater gel	48.2 bbl
Intermediate Plug	1,500 – 1,800	Various	Balanced Plug	Class A Neat	53 sacks
Gel Spacer	700 – 1,500	Various	Balanced Plug	6% freshwater gel	30 bbl
Surface Plug	0 – 700	Various	Balanced Plug	Class A Neat	124 sacks
Open Hole Interval (2,500 ft lateral)	3,950 – 7,004	Mt. Simon	Retainer	EverCRETE CO_2-Resistant or similar	1,500 sacks (30% excess)
Retainer Plug	3,100 – 3,900	Various	Balanced Plug	EverCRETE EverCRETE CO_2-Resistant or similar CO_2-Resistant or similar	150 sacks
Gel Spacer	1,800 – 3,100	Various	Balanced Plug	6% freshwater gel	48.2 bbl
Intermediate Plug	1,500 – 1,800	Various	Balanced Plug	Class A Neat	53 sacks
Gel Spacer	700 – 1,500	Various	Balanced Plug	6% freshwater gel	30 bbl
Surface Plug	0 – 700	Various	Balanced Plug	Class A Neat	124 sacks
Open Hole Interval (1,500 ft lateral)	3,900 – 6,004	Mt. Simon	Retainer	EverCRETE CO_2-Resistant or similar	1,200 sacks (30% Excess)
Retainer Plug	3,100 – 3,900	Various	Balanced Plug	EverCRETE CO_2-Resistant or similar	150 sacks
Gel Spacer	1,800 – 3,100	Various	Balanced Plug	6% freshwater gel	48.2 bbl
Intermediate Plug	1,500 – 1,800	Various	Balanced Plug	Class A Neat	53 sacks
Gel Spacer	700 – 1,500	Various	Balanced Plug	6% freshwater gel	30 bbl
Surface Plug	0 – 700	Various	Balanced Plug	Class A Neat	124 sacks

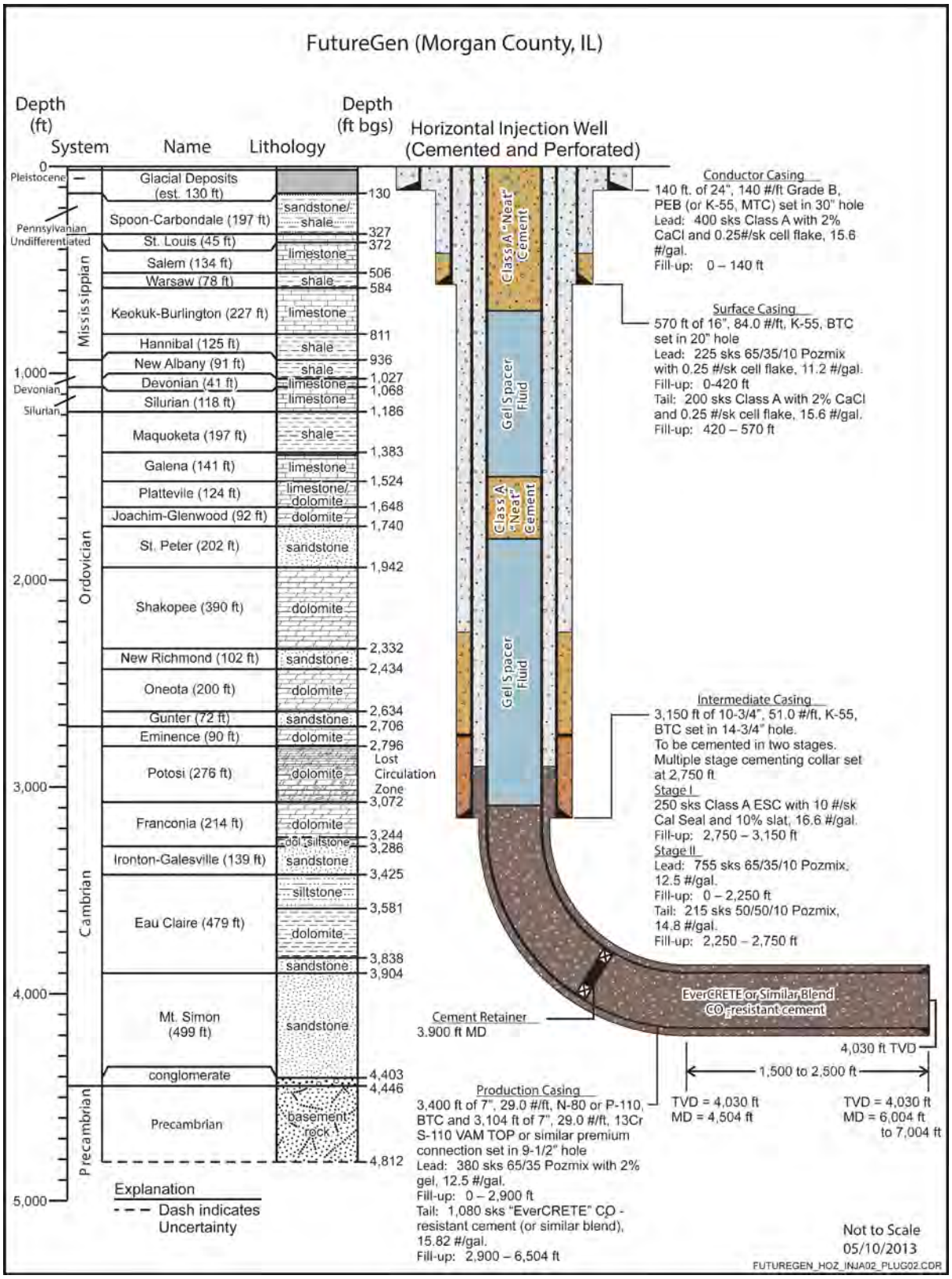

Figure 6.1. Diagram of Cased Injection Well After Plugging and Abandonment

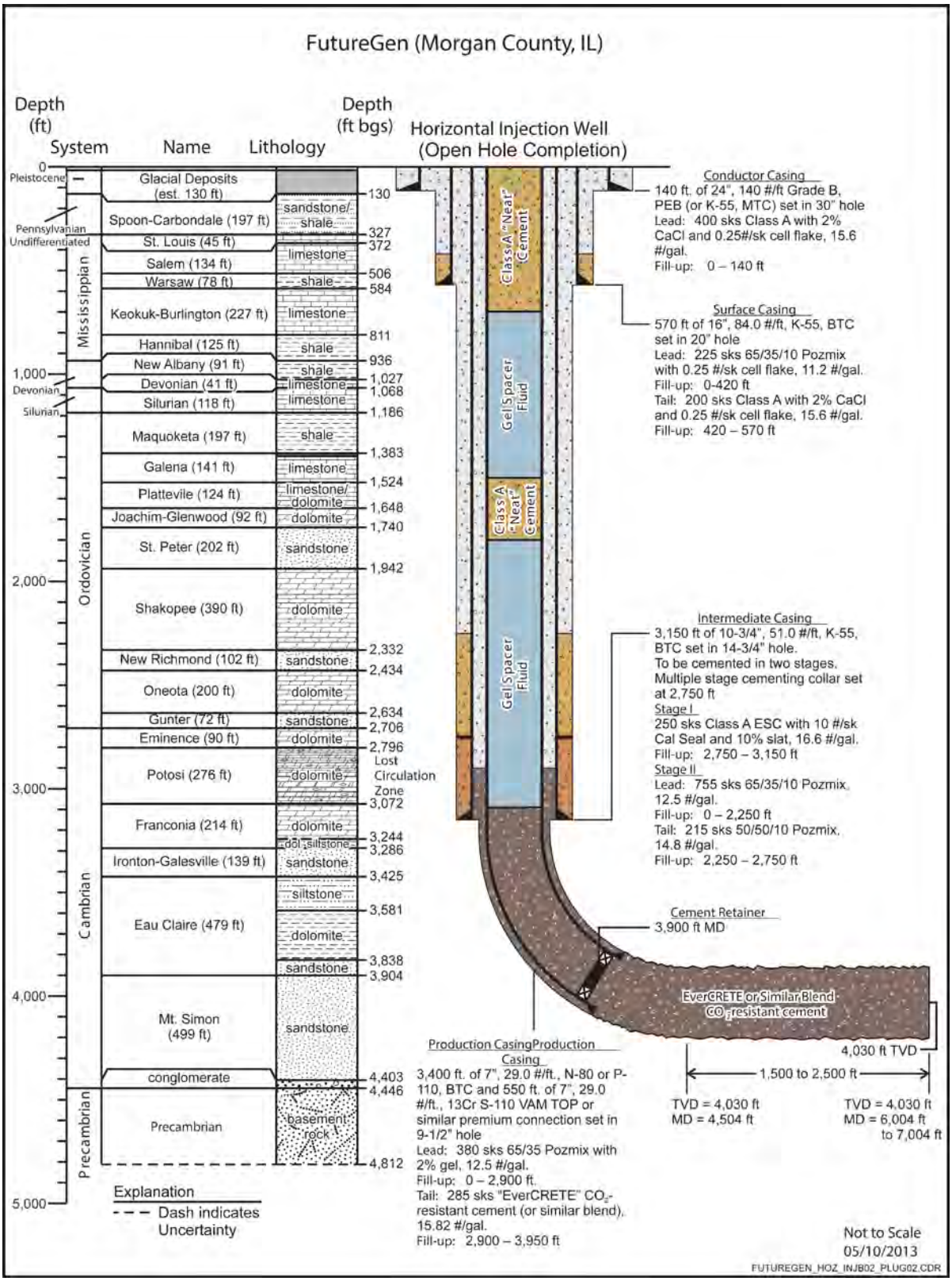

Figure 6.2. Diagram of Non-Cased Injection Well After Plugging and Abandonment

The methods and materials described in this plan are based upon current understanding of the geology at the site and current well designs. If necessary, the plans will be updated to reflect the latest well designs. These new designs, materials, and methods will be described in the Notice of Intent to Plug submitted at least 60 days prior to the plugging of the well.

After the completion of the plugging activities, a plugging report will be submitted to the UIC Program Director describing the methods used and test performed on the well during plugging. This report will be submitted to the UIC Program Director within 60 days of completing the plugging activities.

6.3 References

40 CFR 146.92. Code of Federal Regulations, Title 40, *Protection of Environment*, Part 146, "Underground Injection Control Program: Criteria and Standards," Section 92, "Injection well plugging."

American Petroleum Institute (API). 2010. *Specification for Cements and Materials for Well Cementing.* ANSI/API Specification 10A, Twenty-fourth edition, Washington, D.C. Available at: http://www.api.org/publications-standards-and-statistics.aspx.

American Society for Testing and Materials (ASTM). 2010. *Standard Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements.* ASTM C465, 10th edition, Englewood, Colorado.