GROUND WATER/GEOCHEMICAL MONITORING ABOVE THE CONFINING ZONE - Injection Phase

40 CFR 146.90(d):
Testing and monitoring associated with geologic sequestration projects must, at a minimum, include periodic monitoring of the ground water quality and geochemical changes above the confining zone(s) that may be a result of carbon dioxide movement through the confining zone(s) or additional identified zones including:
(1) The location and number of monitoring wells based on specific information about the geologic sequestration project, including injection rate and volume, geology, the presence of artificial penetrations, and other factors; and
(2) The monitoring frequency and spatial distribution of monitoring wells based on baseline geochemical data that has been collected under 146.82(a)(6) and on any modeling results in the AoR evaluation required by 146.84(c).

UIC Program Class VI Well Testing and Monitoring Guidance:
The primary purpose of this monitoring is to identify potential injectate migration and/or native fluid displacement from the injection zone by detecting potential geochemical changes due to the introduction of the injectate or displaced formation fluids above the primary confining zone(s). EPA recommends that the geochemical monitoring be conducted in the first formation overlying the confining zone that has a sufficient permeability to support collection and analysis of ground water samples. However, the decision regarding which formation(s) to monitor will be based on site-specific conditions and will be determined in consultation with the UIC Program Director. The UIC Program Director may determine that monitoring ground water quality (or pressure) within

Instructions: **Please fill in the red items** in the table below and **answer** the questions listed in the column "Questions for Permit Applicant".

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - Baseline	Frequency - DOE Active Injection Startup (Years 1-3)	Frequency - DOE Active Injection (Years 4-5)	Frequency - Commercial Injection (Years 6-20)	Questions for Permit Applicant	Responses to Questions
Ground Water Monitoring Above Confining Zone [40 CFR 146.90(d)]	Surficial aquifers	Fluid sampling	Local landowner wells Locations of wells?	Approx. 10 point locations Depth of sampling intervals?	3 events	Quarterly	Annually	Annually	• The permit application lists this monitoring method as "under consideration." Will shallow aquifer sampling be carried out during the injection phase? • What are the locations of the private wells that will be used for sampling? Has the location of the project-installed well been finalized, as indicated in the November 2013 communication? The location information for these wells may need to be finalized for the permitting process. • What arrangements have been made to ensure access to these wells for the lifetime of the project? • Which target parameters will be selected for analysis at these wells and what is the justification for selecting these parameters? Also, if any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that USDWs may be affected by injection activities.	
			Project-installed well Location of well?	1 point location Depth of sampling interval?						
	St. Peter	Fluid sampling	Lowermost USDW monitoring well Location of well?	1 point location Depth of sampling interval?	3 events	Quarterly	Annually	Annually	• Has the location and depth of this well been finalized, as indicated in the November 2013 communication? The location information for these wells may need to be finalized for the permitting process. • What arrangements have been made to ensure access to this well for the lifetime of the project? • Which target parameters will be selected for analysis at these wells and what is the justification for selecting these parameters? Also, if any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that USDWs may be affected by injection activities.	
	Ironton	Fluid sampling	ACZ early-detection monitoring well Location of well?	1 point location Depth of sampling interval?	3 events	Quarterly	Semi-annually	Annually	• Has the location and depth of this well been finalized, as indicated in the November 2013 communication? The location information for these wells may need to be finalized for the permitting process. • What arrangements have been made to ensure access to this well for the lifetime of the project? • Which target parameters will be selected for analysis at these wells and what is the justification for selecting these parameters? Also, if any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that USDWs may be affected by injection activities.	

GROUND WATER/GEOCHEMICAL MONITORING ABOVE THE CONFINING ZONE - Post-Injection Phase

Instructions: **Please fill in the red items** in the table below and **answer** the questions listed in the column "Questions for Permit Applicant".

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - PISC	Questions for Permit Applicant	Responses to Questions
Ground Water Monitoring Above Confining Zone [40 CFR 146.90(d)]	Surficial aquifers	Fluid sampling	Local landowner wells Locations of wells?	Approx. 10 point locations Depth of sampling intervals?	Every 5 years	• The permit application lists this monitoring method as "under consideration." Will shallow aquifer sampling be carried out during the PISC phase? Also, if any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that USDWs may be affected by injection activities.	
			Project-installed well Location of well?	1 point location Depth of sampling interval?			
	St. Peter	Fluid sampling	Lowermost USDW monitoring well Location of well?	1 point location Depth of sampling interval?	Every 5 years	• If any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that USDWs may be affected by injection activities.	
	Ironton	Fluid sampling	ACZ early-detection monitoring well Location of well?	1 point location Depth of sampling interval?	Every 5 years	• If any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that USDWs may be affected by injection activities.	

PLUME MONITORING - Injection Phase

40 CFR 146.90(g):
Testing and monitoring associated with geologic sequestration projects must, at a minimum, include testing and monitoring to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure (e.g., pressure front) by using:
(1) Direct methods in the injection zone; and
(2) Indirect methods (e.g., seismic, electrical, gravity, or electromagnetic surveys and/or down-hole carbon dioxide detection tools), unless the Director determines, based on site-specific geology, that such methods are not

Instructions: Please complete the yellow highlighted cells and fill in the red items in the table below and answer the questions listed in the column "Questions for Permit Applicant".

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - Baseline	Frequency - DOE Active Injection Startup (Years 1-3)	Frequency - DOE Active Injection (Years 4-5)	Frequency - Commercial Injection (Years 6-20)	Questions for Permit Applicant	Responses to Questions
Plume Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Fluid sampling	Single-level monitoring wells Locations of wells?	2 point locations Depth of sampling intervals?	3 events	Annually	Annually	Every 2 years	• Have the locations and depths of these wells been finalized, as indicated in the November 2013 communication? The location information for these wells may need to be finalized for the permitting process. • What arrangements have been made to ensure access to these wells for the lifetime of the project? • Which target parameters will be selected for analysis at these wells and what is the justification for selecting these parameters? Also, if any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that the plume is not behaving as expected.	
			Multi-level monitoring well Location of well?	1 point location with multiple sampling intervals Depth of sampling intervals?	3 events	Quarterly	Semi-annually	Annually	• Has the location and depth of this well been finalized, as indicated in the November 2013 communication? The location information for this well may need to be finalized for the permitting process. • What arrangements have been made to ensure access to this well for the lifetime of the project? • Which target parameters will be selected for analysis at these wells and what is the justification for selecting these parameters? Also, if any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that the plume is not behaving as expected.	
		VSP survey			Once	None	None	None		
Plume Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Pulsed neutron capture logging or determination of reservoir CO2 saturation			Once after well completion	Annually	Annually	Annually	• Please provide a description of the strategy that will be employed to track the plume using the data generated from each of these monitoring activities and how each activity will contribute to an overall monitoring strategy. This description, at a minimum, should provide the predicted values over time at each well and describe how the generated monitoring data will be compared to these results.	
		Integrated deformation monitoring			2 year min.	Continuous	Continuous	Continuous		
		Time-lapse gravity			Once	Semi-annually	Semi-annually	Semi-annually		
		Microseismic monitoring			1 year min.	Continuous	Continuous	Continuous		

PLUME MONITORING - Post-Injection Phase

Instructions: **Please complete** the yellow highlighted cells in the table below and **answer** the questions listed in the column "Questions for Permit Applicant".

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - PISC	Questions for Permit Applicant	Responses to Questions
Plume Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Fluid sampling	Single-level montoring wells Locations of wells?	2 point locations Depth of sampling intervals?	Every 5 years	• If any anomalies are observed, more frequent fluid sampling may be necessary. FutureGen should specify triggers for identifying any evidence that the plume is not behaving as expected.	
			Multi-level monitoring well Location of well?	1 point location with multiple sampling intervals Depth of sampling intervals?			
Plume Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Pulsed neutron capture logging or determination of reservoir CO2 saturation			None	• Please provide a description of the strategy that will be employed to track the plume using the data generated from each of these monitoring activities and how each activity will contribute to an overall monitoring strategy. This description, at a minimum, should provide the predicted values over time at each well and describe how the generated monitoring data will be compared to these results.	
		Integrated deformation monitoring			Continuous		
		Time-lapse gravity			Every 5 years		
		Microseismic monitoring			Continuous		

PRESSURE-FRONT MONITORING - Injection Phase

40 CFR 146.90(g):
Testing and monitoring associated with geologic sequestration projects must, at a minimum, include testing and monitoring to track the extent of the carbon dioxide plume and the presence or absence of elevated pressure (e.g., pressure front) by using:
(1) Direct methods in the injection zone; and
(2) Indirect methods (e.g., seismic, electrical, gravity, or electromagnetic surveys and/or down-hole carbon dioxide detection tools), unless the Director determines, based on site-specific geology, that such methods are not

Instructions: **Please complete** the yellow highlighted cells in the table below and **answer** the questions listed in the column "Questions for Permit Applicant".

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - Baseline	Frequency - DOE Active Injection Startup (Years 1-3)	Frequency - DOE Active Injection (Years 4-5)	Frequency - Commercial Injection (Years 6-20)	Questions for Permit Applicant	Responses to Questions
Pressure-Front Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Pressure and temperature monitoring	Single-level montoring wells Locations of wells?	2 point locations Depth of sampling intervals?					• More specific monitoring strategy information is needed for this method (i.e., predicted pressure values at each well over time and how pressure monitoring results will be compared to these predicted values).	
			Multi-level monitoring well Location of well?	1 point location with multiple sampling intervals Depth of sampling intervals?					• More specific monitoring strategy information is needed for this method (i.e., predicted pressure values at each well over time and how pressure monitoring results will be compared to these predicted values).	
Pressure-Front Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon								• The Class VI Rule at 40 CFR 146.90(g)(2) requires indirect monitoring of the pressure front, unless the UIC Program Director determines that such methods are not appropriate for the site. What indirect monitoring methods will be used to track the pressure front and how will they contribute to the overall monitoring strategy?	

PRESSURE-FRONT MONITORING - Post-Injection Phase

Instructions: **Please complete** the yellow highlighted cells in the table below and **answer** the questions listed in the column "Questions for Permit Applicant".

Monitoring Category and Class VI Rule Citation	Target Formation	Monitoring Activity	Data Collection Location(s)	Spatial Coverage	Frequency - PISC	Questions for Permit Applicant	Responses to Questions
Pressure-Front Monitoring [40 CFR 146.90(g)] **DIRECT MONITORING**	Mt. Simon	Pressure and temperature monitoring	Single-level montoring wells Locations of wells?	2 point locations Depth of sampling intervals?		• The permit application states that "at least two wells in the injection zone will be retained for this purpose" during PISC (page 5.24). At which wells will monitoring take place? • More specific monitoring strategy information is needed for this method (i.e., predicted pressure values at each well over time and how pressure monitoring results will be compared to these predicted values).	
			Multi-level monitoring well Location of well?	1 point location with multiple sampling intervals Depth of sampling intervals?			
Pressure-Front Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Not yet determined	Not yet determined	Not yet determined		• The Class VI Rule at 40 CFR 146.90(g)(2) requires indirect monitoring of the pressure front, unless the UIC Program Director determines that such methods are not appropriate for the site. What indirect monitoring methods will be used to track the pressure front and how will they contribute to the overall monitoring strategy?	

Table 5.3 from FutureGen's May 2013 Permit Application Revision:

Table 5.3. Monitoring Frequencies by Method and Project Phase for both Planned and Considered Monitoring Activities

Monitoring Category	Monitoring Method	Baseline 3 yr	DOE Active Injection (startup) ~3 yr	DOE Active Injection ~2 yr	Commercial Injection ~15 yr	Post Injection 50 yr
Monitoring Plan Update	NA	As required	As Required	As Required	As Required	NA
CO_2 Injection Stream Monitoring	Grab sampling and analysis	Up to 6 events during commissioning	Quarterly	Quarterly	Quarterly	NA
CO_2 Injection Process Monitoring	Continuous monitoring of injection process (injection rate, pressure, and temperature; annulus pressure and volume)	NA	Continuous	Continuous	Continuous	NA
Well Mechanical Integrity Testing	Oxygen activation, radioactive tracer, and/or temperature logging	Once after well completion	Annual	Annual	Annual	NA (wells plugged)
	Injection well pressure fall-off testing	NA	Every 5 yr	Every 5 yr	Every 5 yr	NA
Corrosion Monitoring of Well Materials	Corrosion coupon monitoring	NA	Quarterly	Quarterly	Quarterly	NA
	Wireline monitoring of casing and/or tubing corrosion and cement	Once after well completion	During well workovers	During well workovers	During well workovers	NA
Groundwater Quality and Geochemistry Monitoring	Early leak-detection monitoring in above confinement zone monitoring wells	3 events	Quarterly	Semi-Annual	Annual	Every 5 yr
	USDW aquifer monitoring (continuous parameter monitoring, aqueous sample collection as indicated)	1 yr continuous monitoring, 3 sampling events	Quarterly	Annual	Annual	Every 5 yr
Injection Zone Monitoring	Single-level monitoring wells	3 events	Annual	Annual	Every 2 yr	Every 5 yr
	Multi-level monitoring wells	3 events	Quarterly	Semi-Annual	Annual	Every 5 yr
Indirect Geophysical Monitoring Techniques (surface)	Integrated deformation monitoring	2 yr min	Continuous	Continuous	Continuous	Continuous
	3D multi-component surface seismic monitoring	Once	NA	Once	Every 5 yr	NA
	Magnetotelluric (MT) sounding	3 events	Once	Once	Every 5 yr	Every 5 yr
	Time-lapse gravity	Once	Semi-Annual	Semi-Annual	Semi-Annual	Every 5 yr

Table 5.3. (contd)

Monitoring Category	Monitoring Method	Baseline 3 yr	DOE Active Injection (startup) ~3 yr	DOE Active Injection ~2 yr	Commercial Injection ~15 yr	Post Injection 50 yr
Indirect Geophysical Monitoring Techniques (downhole)	Vertical seismic profile(ing) (VSP)	Once	Once	Once	Every 5 yr	Every 10 yr
	Cross-well seismic imaging	Once	Once	Once	Every 5 yr	Every 10 yr
	Passive seismic monitoring (microseismicity)	1 yr min	Continuous	Continuous	Continuous	Continuous
	ERT	1 yr min	Continuous	Continuous	Continuous	Continuous
	Real-time distributed temperature sensing (DTS)	1 yr min	Continuous	Continuous	Continuous	Continuous
Indirect Geophysical Monitoring Techniques (wireline logging)	Pulsed-neutron capture, sonic (acoustic) logging, and gamma-ray logging	Once after well completion	Annual	Annual	Annual	NA
Surficial Aquifer Monitoring	Continuous parameter monitoring in 1 project-installed well, aqueous sample collection as indicated	1 yr continuous monitoring, 3 sampling events	Quarterly	Annual	Annual	Every 5 yr
Soil-Gas Monitoring	Samples collected for CO_2, other noncondensable gases and tracers	4 events	Quarterly	Annual	Annual to every 5 yr	Every 5 yr
Atmospheric Monitoring	Continuous CO_2 monitoring, tracer sampling and analysis	1-yr baseline monitoring	Quarterly	Semi-Annual	Annual to every 5 yr	Every 5 yr
Ecological Monitoring	Eco survey for baseline, continuous surface-water monitoring, remote sensing of vegetation conditions as indicated	Eco survey once, 1 yr baseline monitoring,	Annual	Annual	Annual to every 5 yr	Every 5 yr

Update on indirect monitoring methods from November 2013 communication:

FutureGen Response
The screening of the indirect monitoring approaches was conducted as part of the Front End Engineering Design process. The selected indirect technologies will include the following: • pulsed neutron capture logging or determination of reservoir CO_2 saturation • integrated deformation monitoring • time-lapse gravity • microseismic monitoring. In addition, a baseline VSP survey in at least one of the "Above Caprock Zone" (ACZ) wells will be conducted after construction of the monitoring well network and if the EPA provides approval of the UIC permit application. The monitoring well locations have been identified; however land owner agreements still need to be finalized. We anticipate that we will have the final agreements before the end of January, 2014 and can map the locations at that time.