10

Greenhagen, Andrew

om:	Gilmore, Tyler J <Tyler.Gilmore@pnnl.gov>
ent:	Wednesday, January 29, 2014 1:16 PM
To:	McDonald, Jeffrey
Cc:	Greenhagen, Andrew; Bayer, MaryRose
Subject:	Re: FG T&M table
Attachments:	IR6_01-21-14_FutureGen TM Strategy Tables.xlsx

Jeff,
Attached is the T&M table with the missing holes filled in. Please call if you have questions.

Also, the AoR shapefile that you requested last week has been uploaded to the input advisor.
Thanks
Tyler

From: <McDonald>, Jeff McDonald <mcdonald.jeffrey@epa.gov>
Date: Tuesday, January 21, 2014 10:40 AM
To: Tyler Gilmore <tyler.gilmore@pnnl.gov>
Cc: "Greenhagen, Andrew" <Greenhagen.Andrew@epa.gov>
Subject: FW: FG T&M table

ler,
As noted, we think that this might help you and the FGA people fill in some holes in testing and monitoring requirements. The folks here in the region went over it and agree with Molly's assessment. Let me know if you have any questions.
Jeff

Jeffrey R. McDonald, Geologist
Underground Injection Control Branch
U.S. EPA - Region 5
(312) 353-6288 [office]
(312) 408-2240 [direct fax]
mcdonald.jeffrey@epa.gov

From: Bayer, MaryRose
Sent: Friday, January 17, 2014 3:45 PM
To: McDonald, Jeffrey
Cc: Greenhagen, Andrew
Subject: FG T&M table

Jeff,
Attached is the T&M table I had Cadmus pull together. This should be VERY helpful in getting them to narrow in on what they are planning. I would encourage you to take a quick look and send it on to Tyler ASAP!
hanks,
olly

Mary Rose Bayer
Geologist, UIC GS Team Leader

U.S. Environmental Protection Agency
Office of Ground Water & Drinking Water: Prevention Branch
Phone: (202) 564-1981

INTRODUCTION

This file is intended to summarize FutureGen's testing and monitoring strategy to comply with the Class VI requirements under:

- 40 CFR 146.90(d) for geochemical monitoring above the confining zone; and
- 40 CFR 146.90(g) for plume and pressure front monitoring.

The information presented in the following tabs for these monitoring strategies is compiled from the permit application revision dated May 2013 and subsequent communications in November and December 2013. Copies of submitted information are also presented in the "Submissions" tab for reference purposes.

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 additional zones, including USDWs,

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

Alliance's responses are in blue

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? --> See **surficial aquifer detail** provided on Alliance Submission worksheet	Approx. 10 point locations Depth of sampling intervals? --> See **surficial aquifer detail** provided on Alliance Submission worksheet	3 events (minimum)	NA	NA	NA	1. The permit application lists this monitoring method as "under consideration." Will shallow aquifer sampling be carried out during the injection phase? 2. 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. 3. What arrangements have been made to ensure access to these wells for the lifetime of the project? 4. 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.	1. The St. Peter Formation (1,740bgs) has been designated as the lowermost USDW based on the regulatory guidelines of being the deepest permeable formation having a salinity of less than 10,000 ppm TDS. Because near-surface environmental impacts are not expected, surficial aquifer (<100ft bgs) monitoring will only be conducted for a sufficient duration to establish baseline conditions (minimum of 3 sampling events); surficial aquifer monitoring is not planned during the injection phase, however, the need for additional surficial aquifer monitoring will be continually evaluated throughout the operational phases of the project, and may be reinstituted if conditions warrant. Given our current conceptual understanding of the subsurface environment, early and appreciable impacts on near-surface environments are not expected, so extensive networks of surficial aquifer monitoring wells are not warranted. 2. See surficial aquifer detail in Alliance submissions worksheet for well locations. The project installed surficial aquifer monitoring well (FG-1) in 2012 so the location is finalized. 3. Access to the surficial aquifer wells will not be required over the lifetime of the project. Access to wells for baseline sampling has been on a voluntary basis by the well owner. Ten local landowners originally agreed to have their surficial aquifer wells sampled, one opted out during a recent sampling event. 4. Target parameters include pressure, temperature, and hydrogeochemical indicators of CO2 and brine composition. A comprehensive suite of geochemical and isotopic analyses will be performed on collected fluid samples during the baseline monitoring period. Selection of this initial analyte list was based on relevance for detecting the presence of fugitive brine and CO2. Results for this comprehensive set of analytes will then be evaluated and a determination made regarding which analytes to carry forward through the operational phases of the project. This selection process will consider the uniqueness and signature strength of each potential analyte and whether their characteristics provide for a high value leak detection capability. Trigger values for the surficial aquifer have not been defined. If a leakage response is observed in the ACZ early-detection monitoring wells (Ironton) then the decision not to institute surficial aquifer triggers will be reevaluated based on the magnitude of the observed leakage response and predictive simulations of CO2 transport between the Ironton and the surficial aquifer.
			Project-installed well Location of well? --> See surficial aquifer detail provided on AllianceSubmission worksheet	1 point location Depth of sampling interval? --> See surficial aquifer detail provided on Alliance Submission worksheet. FG-1 is the one project installed well.						
	St. Peter	Fluid sampling	Lowermost USDW monitoring well Location of well? --> See monitoring well location detail provided on the Alliance Submissions worksheet.	1 point location Depth of sampling interval? --> See monitoring well location detail. Note that depths are approximate; actual depth will be determined based on site specific conditions encountered during drilling.	3 events (minimum)	Quarterly	Semi-Annually	Annually	1. 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. 2. What arrangements have been made to ensure access to this well for the lifetime of the project? 3.• 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.	1. The location of this well has been finalized, pending final signing of landowner agreements. 2. Land access will be secured through either a purchase or long-term lease agreement. 3. Target parameters include pressure, temperature, and hydrogeochemical indicators of CO2 and brine composition. A comprehensive suite of geochemical and isotopic analyses will be performed on collected fluid samples during the baseline monitoring period. Selection of this initial analyte list was based on relevance for detecting the presence of fugitive brine and CO2. Results for this comprehensive set of analytes will then be evaluated and a determination made regarding which analytes to carry forward through the operational phases of the project. This selection process will consider the uniqueness and signature strength of each potential analyte and whether their characteristics provide for a high value leak detection capability. Trigger values for this lowermost USDW monitoring well have not been defined. If a leakage response is observed in the ACZ early-detection monitoring wells (Ironton) then the decision not to institute USDW aquifer triggers will be reevaluated based on the magnitude of the observed leakage response and predictive simulations of CO2 transport between the Ironton and the St. Peter aquifers.

	Ironton	Fluid sampling	ACZ early-detection monitoring well Location of well? --> See monitoring well location detail provided on the Alliance Submissions worksheet.	2 points location Depth of sampling interval? --> See monitoring well location detail. Note that depths are approximate; actual depth will be determined based on site specific conditions encountered during drilling	3 events (minimum)	Quarterly	Semi-annually	Annually	1 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. 2 What arrangements have been made to ensure access to this well for the lifetime of the project? 3 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.	1. The location of these wells has been finalized, pending final signing of landowner agreements. 2. The land will either be purchased or leased for the life of the project, so access will be secured. 3. Target parameters include pressure, temperature, and hydrogeochemical indicators of CO2 and brine composition. A comprehensive suite of geochemical and isotopic analyses will be performed on collected fluid samples and analytical results will be used to characterize baseline geochemistry and provide a metric for comparison during operational phases. Selection of this initial analyte list was based on relevance for detecting the presence of fugitive brine and CO2. Results for this comprehensive set of analytes will be evaluated and a determination made regarding which analytes to carry forward through the operational phases of the project. This selection process will consider the uniqueness and signature strength of each potential analyte and whether their characteristics provide for a high value leak detection capability. Once baseline conditions have been established, observed differences in the geochemical and isotopic signature between the reservoir and overlying monitoring intervals, along with predictions of leakage-related pressure response, will be used to specify triggers values that would prompt further action, including a detailed evaluation of the observed response and possible modification to the monitoring approach and/or storage site operations. This evaluation will be supported by numerical modeling of theoretical leakage scenarios that will be used to evaluate leak detection capability and interpret any observed pressure and/or geochemical/isotopic change in the ACZ wells.

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".

Alliance's responses are in blue

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.	* See response for injection phase ACZ monitoring (including well location/depth information). This same approach would be carried through the post-injection phase.
			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.	* See response for injection phase ACZ monitoring (including well location/depth information). This same approach would be carried through the post-injection phase.
	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.	* See response for injection phase ACZ monitoring (including well location/depth information). This same approach would be carried through the post-injection phase.

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".

Alliance's responses are in blue

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? --> See monitoring well location detail provided on the Alliance Submissions worksheet.	2 point locations Depth of sampling intervals? --> See monitoring well location detail. Note that depths are approximate; actual depth will be determined based on site specific conditions encountered during drilling.	3 events	Quarterly	Semi-annually	Annual	1 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. 2 What arrangements have been made to ensure access to these wells for the lifetime of the project? 3 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.	1. The location of these wells has been finalized, pending final signing of landowner agreements. 2. The land will either be purchased or leased for the life of the project, so access will be secured. 3.Target parameters include pressure, temperature, and hydrogeochemical indicators of CO2 and brine composition. A comprehensive suite of geochemical and isotopic analyses will be performed on collected fluid samples and analytical results will be used to characterize baseline geochemistry and provide a metric for comparison during operational phases. Selection of this initial analyte list was based on relevance for detecting the presence of CO2 within the reservoir and fugitive brine and CO2 above the primary confining zone. Results for this comprehensive set of analytes will be evaluated and a determination made regarding which analytes to carry forward through the operational phases of the project. This selection process will consider the uniqueness and signature strength of each potential analyte and whether their characteristics provide for a high value leak detection capability. Once baseline hydrogeochemical/isotopic conditions have been established and the reservoir model has been refined, predictive simulations of pressure and CO2 arrival response will be generated for each single-level reservoir monitoring well. These predicted responses will be compared to monitoring results throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.
			~~Multi-level monitoring well~~ Location of well? --> NA	~~1 point location with multiple sampling intervals~~ Depth of sampling intervals? --> NA	~~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.	A multi-level reservoir monitoring well will not be installed. The Alliance has modified the monitoring network design since the UIC permit application was submitted by eliminating this "multi-level monitoring well". The previously planned multi-level completion has been replaced by two fully cased reservoir access tubes (RATs) that will be installed within the boundaries of the simulated 5-year CO2 plume. The RATs will extend to the base of the reservoir and into the Precambrian bedrock. The RATs will be non-perforated, cemented casings used to monitor CO2 arrival and quantify saturation levels via downhole pulsed-neutron capture (PNC) geophysical logging across the reservoir and confining zone.
Plume Monitoring [40 CFR 146.90(g)] INDIRECT MONITORING	Mt. Simon	VSP survey	-> See monitoring well location detail provided on the Alliance Submissions worksheet; VSP for characterization will be performed in ACZ and/or RAT wells.	--> See monitoring well location detail. Note that depths are approximate; actual depth will be determined based on site specific conditions encountered during drilling.	Once	None	None	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.	VSP will not be used for monitoring plume evolution
		Pulsed neutron capture logging or determination of reservoir CO2 saturation	-> See monitoring well location detail provided on the Alliance Submissions worksheet; RAT locations	PNC logging across reservoir and caprock	3 events	Quarterly	Quarterly	Annually		Once the reservoir model has been refined based on site specific information from the injection site, predictive simulations of CO2 arrival response will be generated for each RAT installation These predicted responses will be compared to monitoring results throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.
		Integrated deformation monitoring	-> See Collocated Microseismic and Integrated Surface Deformation Monitoring Station detail provided on the Alliance Submissions worksheet.	Surface measurements	1 year min.	Continuous	Continuous	Continuous		Integrated deformation monitoring integrates ground data from permanent GPS stations, tiltmeters, supplemented with annual DGPS surveys, and larger-scale Differential Interferometric Synthetic Aperture Radar (DInSAR) surveys to detect and map temporal ground-surface deformation. These data reflect the dynamic geomechanical behavior of the subsurface in response to CO2 injection. These measurements will provide useful information on the evolution and symetry of the pressure front. These results will be compared with model predictions throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.
		Time-lapse gravity	-> See Time-Lapse Gravity detail provided on the Alliance Submissions worksheet;	Surface measurements	3 events	Annual	Annual	Annual		The gravity data are supplemental data for comparison with other monitoring methodologies. No trigger levels will be defined.

		Microseismic monitoring	-> See Collocated Microseismic and Integrated Surface Deformation Monitoring Station detail provided on the Alliance Submissions worksheet.	Surface measurements plus downhole sensor arrays at the two ACZ wells.	1 year min.	Continuous	Continuous	Continuous		The objective of the microseismic monitoring network is to accurately determine the locations, magnitudes, and focal mechanisms of injection-induced seismic events with the primary goals of 1) addressing public and stakeholder concerns related to induced seismicity, 2) estimating the spatial extent of the pressure front from the distribution of seismic events, and 3) identifying features that may indicate areas of caprock failure and possible containment loss. Once a seismic event has been identified, a decision must be made regarding the level of impact a given event could have on storage site operations, whether a response is required, and if yes, what the response will be. This decision and response framework will consist of an automated event location and magnitude determination, followed by an alert for a technical review in order to reduce the likelihood of false positives. Identification of events with sufficient magnitude or that are located in a sensitive area (caprock) will be used as input for decisions that guide the adaptive strategy. Seismic events that affect the operations of CO_2 injection can be divided into two groups/tiers: 1) events that create felt seismicity at the surface and may lead to public concern or structural damage, and 2) events not included in group one, but that might indicate failure or impending failure of the caprock. The operational protocol for responding to events in group one (Tier I) will follow a "traffic light" approach (modified after Zoback 2012; National Research Council 2012) that uses three operational states: 1. Green: Continue normal operations unless injection-related seismicity is observed with magnitudes greater than M=2. 2. Yellow: Injection-related seismic events are observed with magnitude $2 < M < 4$. The injection rate will be slowed and the relationship between rate and seismicity will be studied to guide mitigation procedures, including reduced operational flow rates. 3. Red: Magnitude 4 or greater seismic events are observed that are related to CO_2 injection. Injection operations will stop and an evaluation will be performed to determine the source and cause of the ground motion. Tier II operational responses to an event or collection of events that indicate possible failure of the primary confining zone may include initiation of supplemental adaptive monitoring activities, injection rate reduction in one or more injection laterals, or pressure reduction using brine extraction wells.

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".

Alliance's responses are in blue

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.	* See response for injection phase plume monitoring (including well location/depth information). This same approach would be carried through the post-injection phase.
			~~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.	* See response for injection phase plume monioring (including location/depth information). This same approach would be carried through the post-injection phase.
		Integrated deformation monitoring			Continuous		
		Time-lapse gravity			None		
		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

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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? --> See monitoring well location detail provided on the Alliance Submissions worksheet	2 point locations Depth of sampling intervals? --> See monitoring well location detail. Note that depths are approximate; actual depth will be determined based on site specific conditions encountered during drilling.	Continuous	Continuous	Continuous	Continuous	• 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).	Once the reservoir model has been updated with detailed site specific information from the injection site, predictive simulations of pressure response will be generated for each single-level reservoir monitoring well. These predicted responses will be compared to monitoring results throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.
			~~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).	A multi-level reservoir monitoring well will not be installed. The Alliance has modified the monitoring network design since the UIC permit application was submitted by eliminating this "multi-level monitoring well". The previously planned multi-level completion has been replaced by two fully cased reservoir access tubes (RATs) that will be installed within the boundaries of the simulated 5-year CO_2 plume. The RATs will extend to the base of the reservoir and into the Precambrian bedrock. The RATs will be non-perforated, cemented casings used to monitor CO_2 arrival and quantify saturation levels via downhole pulsed-neutron capture (PNC) geophysical logging across the reservoir and confining zone.
Pressure-Front Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Integrated deformation monitoring	-> See Collocated Microseismic and Integrated Surface Deformation Monitoring Station detail provided on the Alliance Submissions worksheet.	Surface measurements	1 year min.	Continuous	Continuous	Continuous	• 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?	Integrated deformation monitoring integrates ground data from permanent GPS stations, tiltmeters, supplemented with annual DGPS surveys, and larger-scale Differential Interferometric Synthetic Aperture Radar (DInSAR) surveys to detect and map temporal ground-surface deformation. These data reflect the dynamic geomechanical behavior of the subsurface in response to CO_2 injection. These measurements will provide useful information on the evolution and symetry of the pressure front. These results will be compared with model predictions throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.

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".

Alliance's responses are in blue

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? ~~Multi-level monitoring well~~ Location of well?	2 point locations Depth of sampling intervals? ~~1 point location with multiple sampling intervals~~ Depth of sampling intervals?	Continuous	1. 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? 2. 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).	1. Monitoring will continue in the two single-level monitoring wells 2. Once the reservoir model has been updated with detailed site specific information from the injection site, predictive simulations of pressure response will be generated for each single-level reservoir monitoring well. These predicted responses will be compared to monitoring results throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.
Pressure-Front Monitoring [40 CFR 146.90(g)] **INDIRECT MONITORING**	Mt. Simon	Integrated deformation monitoring	-> See Collocated Microseismic and Integrated Surface Deformation Monitoring Station detail provided on the Alliance Submissions worksheet.	Surface measurements	Continuous	• 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?	Integrated deformation monitoring integrates ground data from permanent GPS stations, tiltmeters, supplemented with annual DGPS surveys, and larger-scale Differential Interferometric Synthetic Aperture Radar (DInSAR) surveys to detect and map temporal ground-surface deformation. These data reflect the dynamic geomechanical behavior of the subsurface in response to CO_2 injection. These measurements will provide useful information on the evolution and symetry of the pressure front. These results will be compared with model predictions throughout the operational phase of the project and significant deviation in observed response would result in further action, including a detailed evaluation of the observed response, calibration/refinement of the numerical model, and possible modification to the monitoring approach and/or storage site operations.

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

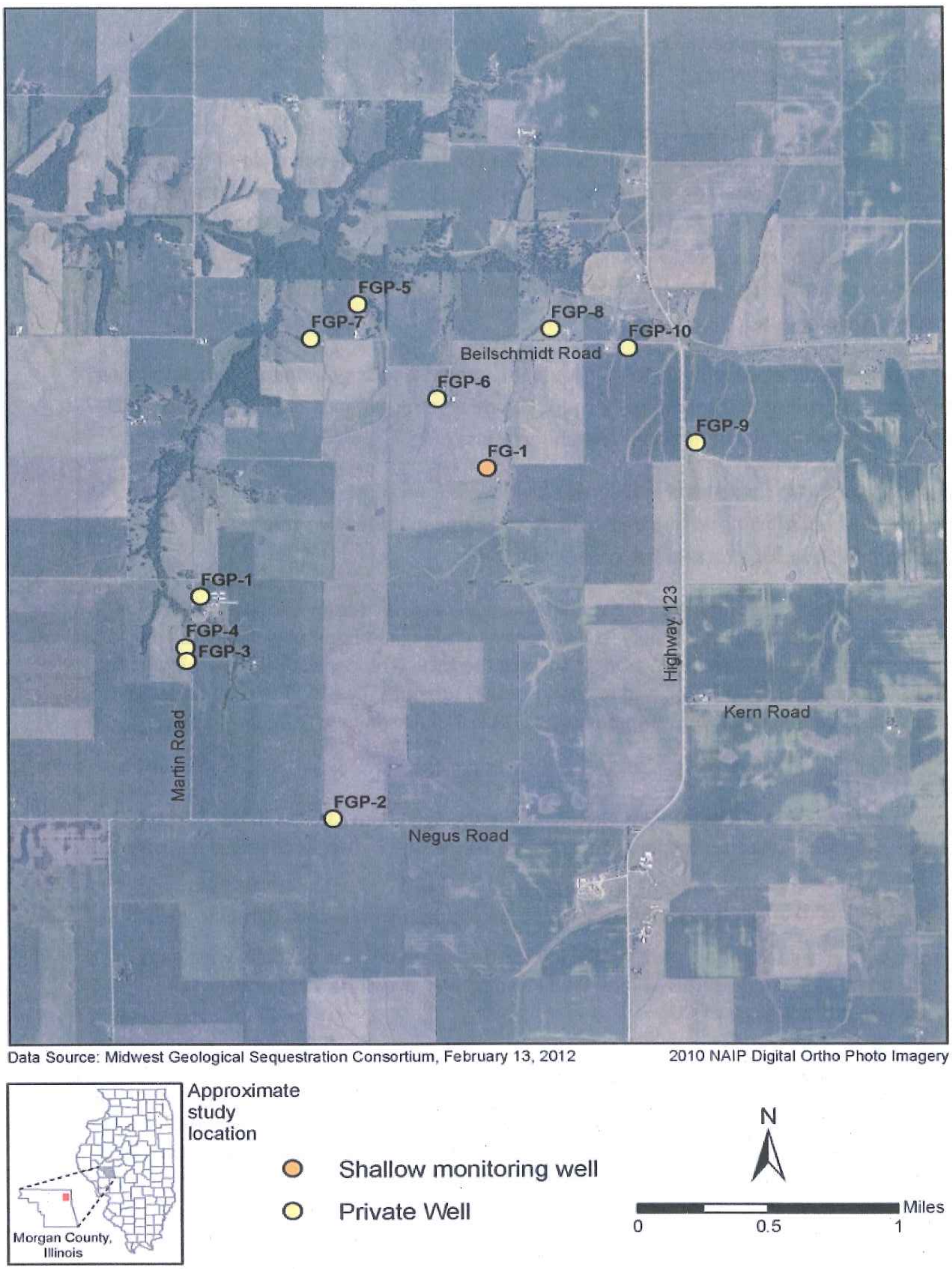
The screening of the indirect monitoring approaches was conducted as part of the Front End Engineering Design process. The selected indirect technologies will include the following:

- 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.

Surficial Aquifer Detail



Monitoring Well Location Detail

Location of Monitoring Wells

The monitoring well network (Figure 1) has been updated in accordance with discussion in the UIC application supporting documentation.

> Chapter 5 of the UIC Supporting Documentation, Section 5.1, p. 5.2: The monitoring network design was developed based on the current conceptual understanding of the Morgan County CO_2 storage site and was used to guide development of the testing and monitoring approaches described in Section 5.2. The technical approaches described in Section 5.2 should be considered working versions that over time will be updated and modified as required in response to changes in the site conceptual model and/or operational parameters.

The objective of the monitoring program is to select and implement a suite of monitoring technologies that are both technically robust and cost-effective and provide an effective means of 1) evaluating CO_2 mass balance and 2) detecting any unforeseen containment loss.

The application proposed two single-level in-reservoir (SLR) wells, one above confining zone (ACZ) well, one underground source of drinking water (USDW) well, and a one multi-level in-reservoir (MLR) well within the injection reservoir for a total of five monitoring wells.

As part of the project's design optimization, the monitoring well network design has been revised (Figure 2) to increase its effectiveness, simplify its engineering design, and hopefully eliminate any permitting challenges that might have been associated with the MLR. The revisions include eliminating the MLR well in favor of adding two fully cased reservoir access tube (RAT) wells. The revised design includes a total of seven monitoring wells summarized in Table 1 and as follows:

- **Two ACZ wells**

  These wells will be used to monitor immediately above the Eau Claire caprock in the Ironton Sandstone. **Monitored Parameters: pressure, temperature, and hydrogeochemical indicators of CO_2.**

- **Two SLR wells** (one of which is a reconfiguration of the previously drilled stratigraphic well)

  These wells will be used to monitor within the injection zone beyond the east and west ends of the horizontal CO_2-injection laterals. **Monitored Parameters: pressure, temperature, and hydrogeochemical indicators of CO_2.**

- **Two RAT wells**

  These are fully cased wells, which allow access for monitoring instrumentation in the reservoir via pulsed-neutron logging equipment. The wells will not be perforated so as to avoid two-phase flow near the borehole, which can distort the CO_2 saturation measurements. **Monitored Parameters: quantification of CO_2 saturation across the reservoir and caprock.**

- **One USDW well**

  This well will be used to monitor the lowermost USDW (St. Peter Sandstone). **Monitored**

Note that the specific geographic coordinates of each well remain "proposed" because the project is in the process of finalizing legal agreements with surface landowners. Also, we believe this proposed network should substantially exceed the intent of the regulations. Thus, we respectfully ask that only those wells required to meet the minimum permit requirements be included in the permit as prerequisite permit conditions.

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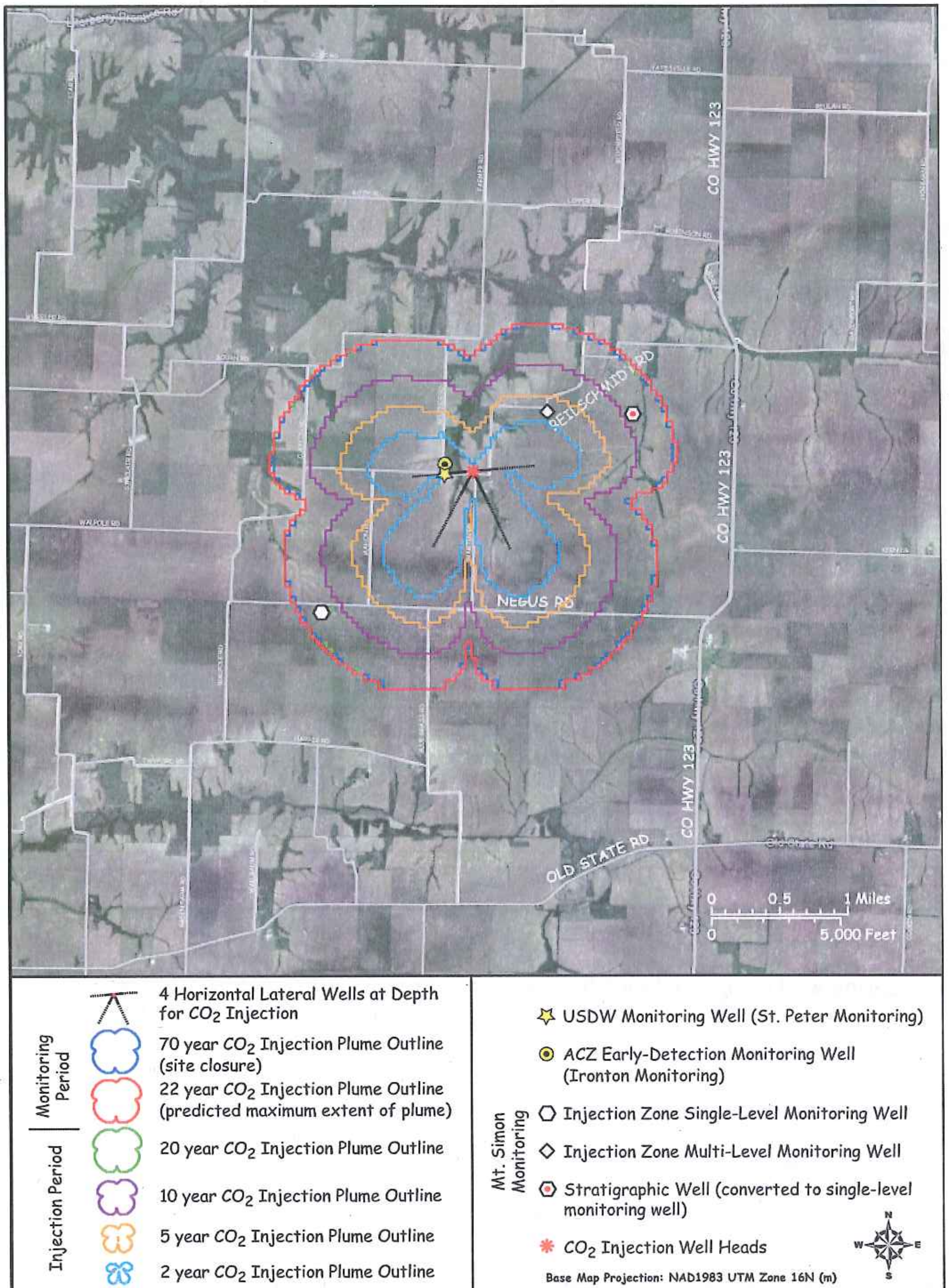

Figure 1. Monitoring Well Network as Presented in Testing and Monitoring Plan (Chapter 5.0) of the UIC Permit Supporting Documentation as Submitted in May 2013

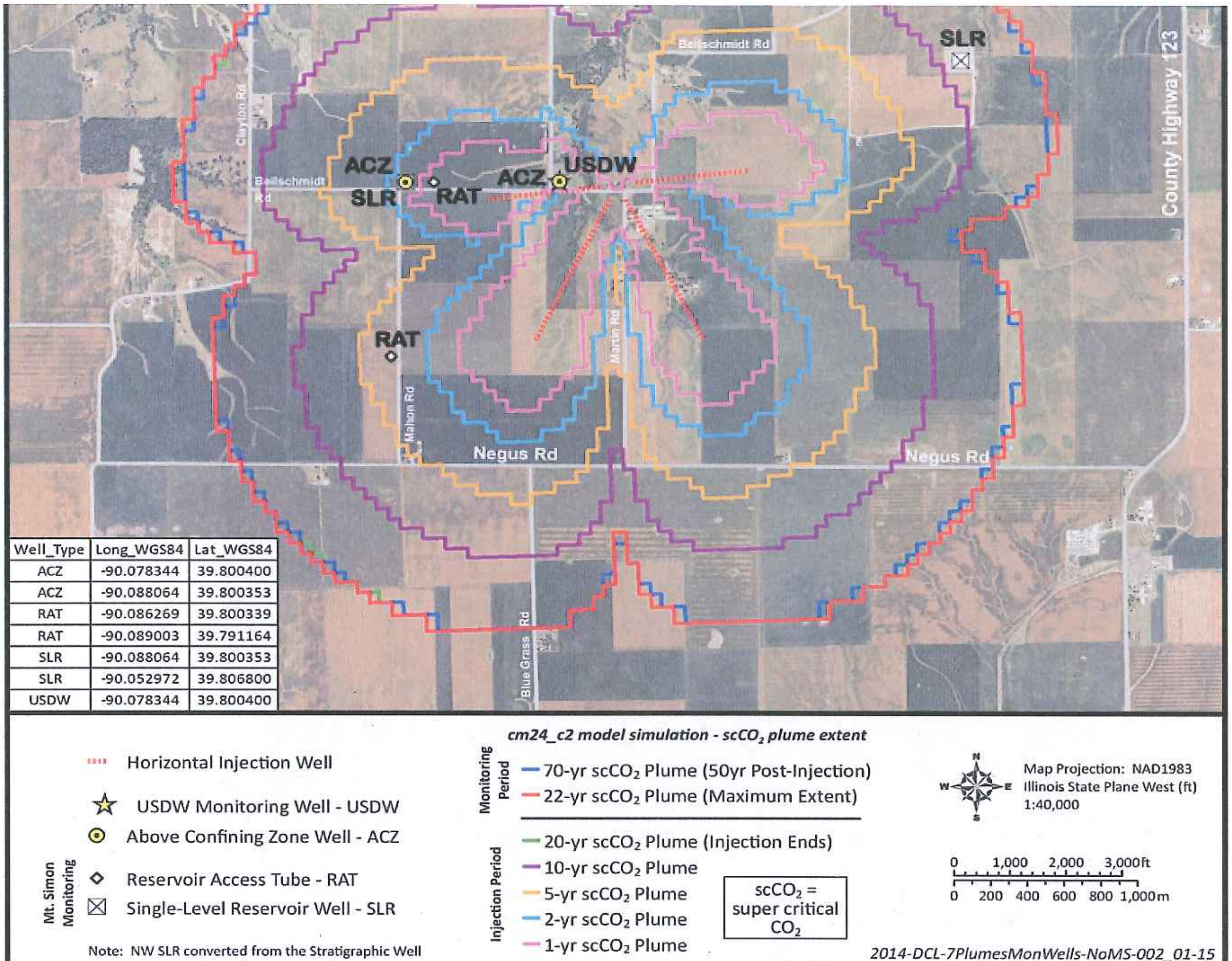

Figure 2. Updated and Revised Plan for Monitoring Wells

The most recent monitoring well design includes five deep monitoring wells and two RAT wells as listed in Table 1.

Table 1. Planned Monitoring Wells within the FutureGen Site Network

	Single-Level In-Reservoir (SLR)	Above Confining Zone (ACZ)	USDW	Reservoir Access Tube (RAT)
# of Wells	2	2	1	2
Total Depth (ft)	4,150	3,470	2,000	4,465
Monitored Zone	Mount Simon SS	Ironton SS	St. Peter SS	Mount Simon SS
Monitoring Instrumentation	Fiber-optic P/T (tubing conveyed)[b]; P/T/SpC probe in monitored interval[(a)]	Fiber-optic (microseismic) cable cemented in annulus; P/T/SpC probe in monitored interval[(a)]	P/T/SpC probe in monitored interval[(a)]	Pulsed-neutron logging equipment

(a) The P/T/SpC (pressure, temperature, specific conductance) probe is an electronic downhole multi-parameter probe incorporating sensors for measuring fluid P/T/SpC within the monitored interval. The probe is installed inside tubing string, which is perforated (slotted) over the monitoring interval. Sensor signals are multiplexed to a surface data logger through a single conductor wireline cable.

(b) Fiber-optic cable attached to the outside of the tubing string, in the annular space between the tubing and casing.

SS = sandstone.

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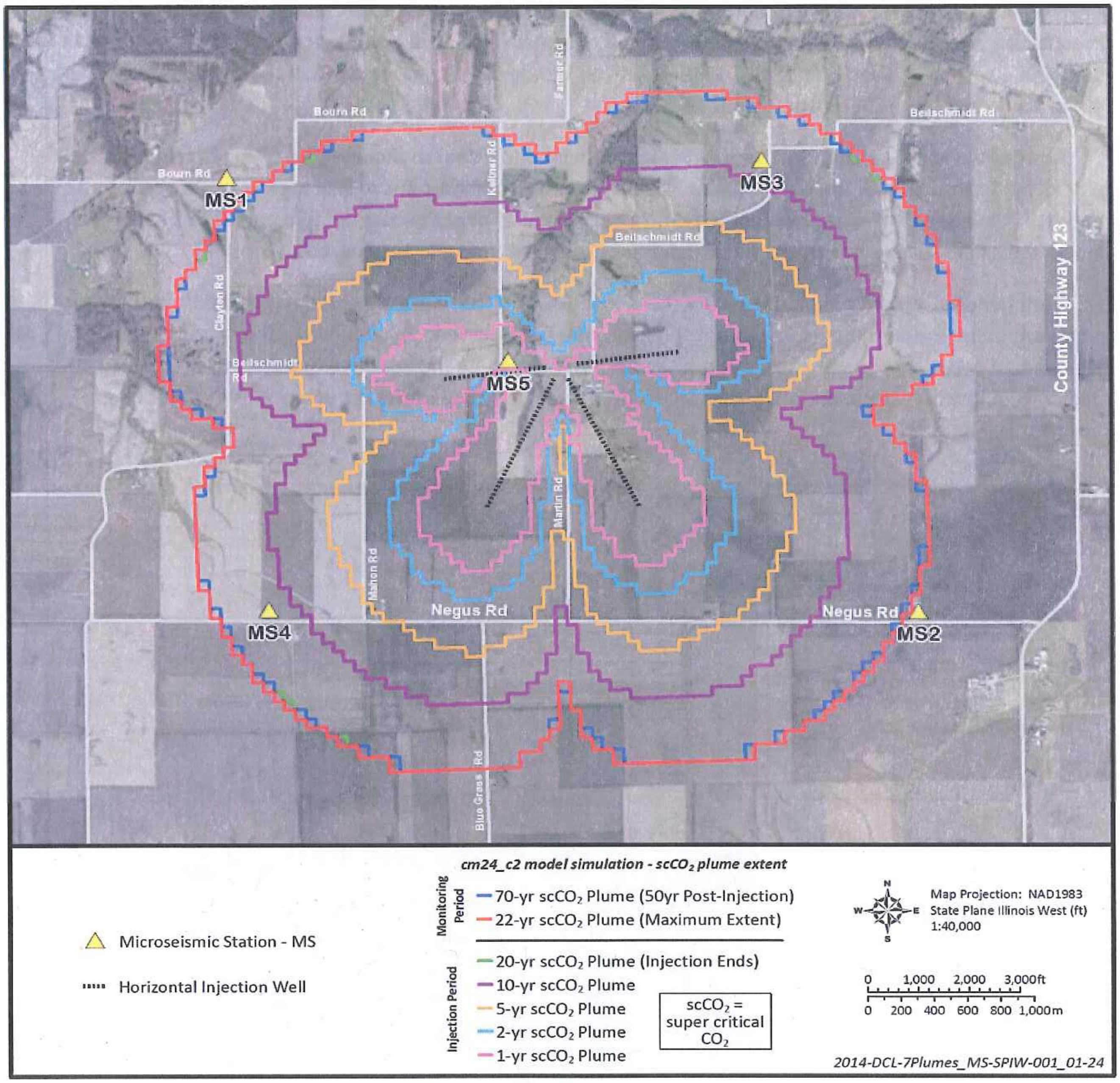
Collocated Microseismic and Integrated Surface Deformation Monitoring Stations



Time-Lapse Gravity

Objective. Observe changes in density distribution in the subsurface, caused by the migration of fluids; estimate the areal extent of the CO_2 plume.

Limitations and Difficulties. Sensitivity is lost with depth; there may be site-specific limitations. The solution is non-unique and is most useful when combined with other methods such as integrated surface deformation and seismic. Few implementation difficulties; requires placement of permanent station monuments and repeat accessibility.

Use at Other Sites. This technology has been successfully applied to a variety of subsurface injection studies, including carbon sequestration at Sleipner (Arts et al. 2008); aquifer recharge studies in Utah and elsewhere (Chapman et al. 2008; Davis and Batzle 2008); and to hydrocarbon waterflood surveillance in Alaska (Ferguson et al. 2007).

Analysis. Gravity changes at the surface are expected to be small but analysis of long-term trends may allow for tracking of the CO_2 plume. The cost of implementing this technology is the lowest of all methods considered and can be combined with Differential Global Positioning System (DGPS) surveys conducted as part of the integrated surface deformation monitoring to further reduce costs.

Conclusions. Gravity anomalies associated with CO_2 injection are expected to be quite small, but by averaging many measurements, meaningful signal may be observed. In addition, information obtained from annual time-lapse gravity surveys will be used to help guide the adaptive monitoring strategy. This method requires no permanent infrastructure to implement. A map of the proposed gravity stations is provided in Figure 1.

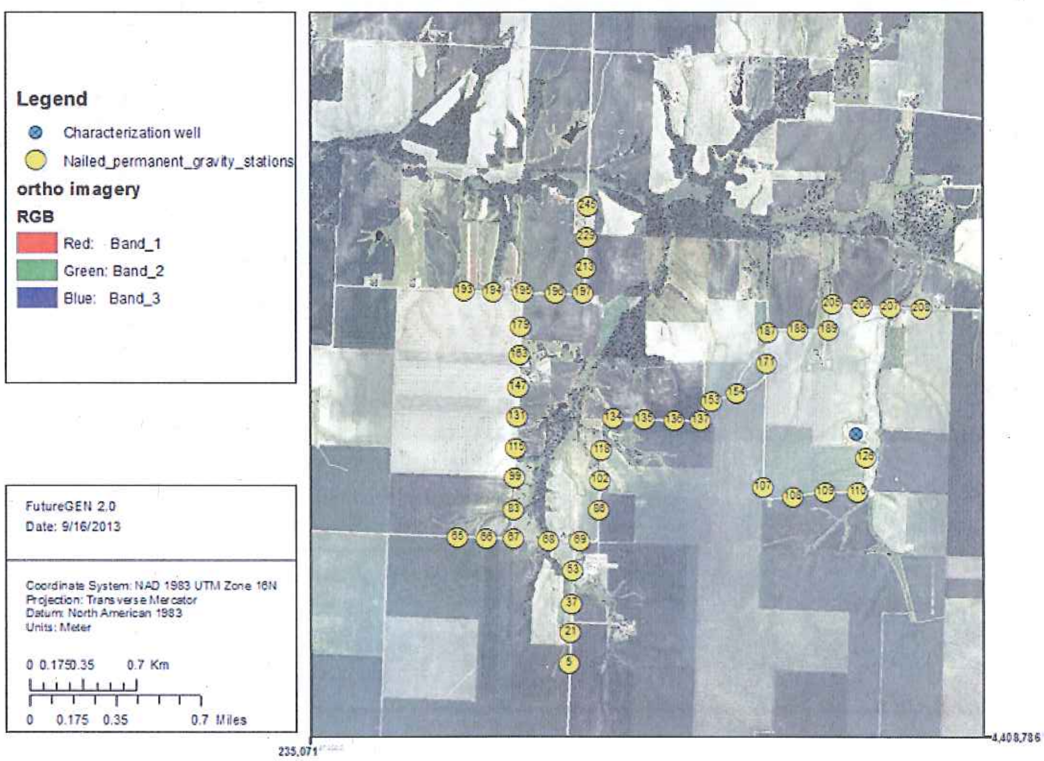


Figure.1. Location of Permanent Gravity and Supplemental DGPS Stations

Private water supply wells

Well ID	Status	Well Depth (ft)	Stick Up (ft)	Adjusted Depth (ft)	Land Surface Elevation (ft AMSL)	Depth to Water (ft)	Water Depth in well (ft)	Water Elevation (ft AMSL)	Diameter (ft)	Construction	Age (years)
FGP-1	domestic	30.9	1.00	29.90	630	19.02	18.02	612	5.0	brick lined	~100
FGP-2	domestic	--	--	--	641	--	--	--	Unknown	unknown	unknown
FGP-3	domestic	40.0	0.90	30.10	630	21.37	11.47	618	5.0	unknown	~100
FGP-4	inactive	28.5	0.50	28.00	627	9.40	8.90	618	3.0	brick lined	unknown
FGP-5	livestock	35.1	1.60	33.50	607	10.12	8.52	598	3.0	unknown	~60
FGP-6	inactive	34.5	0.30	34.20	620	13.04	12.74	607	3.0	cast concrete	unknown
FGP-7	inactive	49.0	2.20	46.80	614	13.39	11.19	603	0.7	steel	unknown
FGP-8	livestock	17.45	1.30	16.15	614	6.34	5.04	609	4.0	brick lined	unknown
FGP-9	inactive	22.3	1.60	20.70	630	16.34	14.74	615	5.0	brick lined	~100
FGP-10	inactive	37.1	0.40	36.70	614	15.80	15.40	599	4.0	cast concrete	unknown
FG-1	NA	23.0	2.05	20.95	635	10.16	8.11	627	0.17	PVC	new