Appendix C

Cost Estimate to Demonstrate Financial Responsibility for Class VI UIC Permit

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Confidential/Business Sensitive

I. Introduction

The U.S. Environmental Protection Agency (EPA) has published federal regulations for Underground Injection Control (UIC) Class VI wells that inject carbon dioxide (CO_2) for the purpose of geologic sequestration. The regulations require that owners or operators of Class VI wells must demonstrate and maintain financial responsibility for taking corrective action on wells in the Area of Review (AoR), plugging the injection wells once injection ceases, undertaking post-injection site care (PISC) and site closure, and conducting any necessary emergency and remedial response actions to ensure that owners or operators have the resources to allow a third party to carry out any activities that may be needed to protect Underground Sources of Drinking Water (USDW) as required by the regulation. The FutureGen Industrial Alliance, Inc. (Alliance) is submitting applications for Class VI permits for the proposed construction and operation of CO_2 injection wells at a site in Morgan County, IL. This third-party cost estimate was prepared in support of those applications.

II. Company qualifications

Patrick Engineering Inc. is a nationwide engineering, design, and project management firm with a long history of success on a variety of complex infrastructure projects. Their client list includes key government agencies, private and public utilities, and FORTUNE 500 companies in a broad range of industries. They provide pre-construction services, procurement, and construction management of heavy civil infrastructure projects. Patrick has technical experts in the fields of civil, structural, hydraulic, environmental, geotechnical, and electrical engineering, geology, surveying, construction management, process control, and geographic information systems. Engineering News Record (ENR) has included Patrick in its ENR Top 500 for 17 consecutive years and the company has been ranked as one of the Midwest's Top 10 Design Firms for the past five years.

III. Project description

FutureGen 2.0 is a first-of-its-kind, near-zero emissions coal-fueled power plant with carbon capture and storage. In cooperation with the U.S. Department of Energy (DOE), the FutureGen 2.0 project partners would upgrade a power plant in Meredosia, Illinois with oxy-combustion technology to capture approximately 1.1 million metric tons of CO_2 each year—more than 90 percent of the plant's carbon emissions. Other emissions would be reduced to near-zero levels. The captured CO_2 would be compressed to a super-critical fluid and, using safe and proven pipeline technology, the CO_2 would be transported approximately 30 miles and stored underground at a site in northeastern Morgan County, Illinois.

Four horizontal injection wells would penetrate approximately 4,030 feet vertically and 2,000 feet horizontally into the Mt. Simon formation – a porous, saline-saturated sandstone – where the CO_2 would be sequestered. Surface facilities at the injection site would consist of a site control building and a well maintenance and monitoring system building. The Alliance is evaluating locating the site control and pumping functions at the power plant facility in Meredosia. If that proves to be functionally and economically preferable, the injection wells site would only have a well maintenance and monitoring system building.

In addition to the injection wells, the Alliance would use its existing stratigraphic well that was drilled into the Mt. Simon formation as a monitoring well and would drill two additional monitoring wells into the Mt. Simon formation. The Alliance would also install up to three monitoring wells above the Eau Claire caprock formation at approximately 3,400 feet, and one monitoring well into the St. Peter formation (considered the lowest USDW [LUSDW]) at 1,900 feet.

IV. Description of activities considered to demonstrate financial responsibility

In estimating the costs to demonstrate financial responsibility for the geologic sequestration of carbon dioxide by the FutureGen Alliance at the Morgan County site, Patrick Engineering has considered the costs associated with: 1) corrective action on wells, 2) plugging of the four injection wells and the three monitoring wells, 3) post-injection site care, 4) site closure, and 5) emergency and remedial response, as detailed below:

1. Corrective action on wells in the AoR
    a. Review existing plume model
    b. Remodel plume
    c. Review of state databases of known wells and abandoned mines
    d. Well integrity testing
    e. Plug deficient wells
    f. Perform remedial cementing of defective wells
2. Injection wells and monitoring wells plugging and site reclamation
    a. Injection wells plugging
        i. Casing evaluation
        ii. Repair problems & cleanup of any impacted groundwater
        iii. Cement materials used to plug the well
        iv. Labor, engineering, rig time, equipment
        v. Decontamination of equipment
        vi. Disposal of any equipment
    b. Land reclamation
        i. Phase I demolition of surface site buildings at injection well site
        ii. Removal of gravel well pads and land restoration at injection well site
    c. Well remediation
        i. Sample analysis (Fluid or Soil)
        ii. Site assessment/hydrogeologic study
        iii. System removal
        iv. Disposal system modification
        v. Installation of monitoring well
3. Post-injection site care
    a. Monitoring wells for geochemical and geophysical analyses
        i. LUSDW monitoring well
        ii. Injection zone monitoring well
        iii. Above confining zone monitoring well
    b. Operation and maintenance of monitoring wells
        i. LUSDW monitoring well
        ii. Injection zone monitoring well
        iii. Above confining zone monitoring well
    c. Site management and EPA reporting
4. Site closure
    a. Non-endangerment demonstration
    b. LUSDW monitoring well plugging and site reclamation

   i. Casing evaluation
   ii. Evaluation of any problems discovered by the casing evaluation
   iii. Cost for repairing problems & cleanup of any groundwater or soil contamination
   iv. Cost for cementing or other materials used to plug the wells
   v. Cost for labor, engineering, rig time, equipment and consultants
   vi. Cost for decontamination of equipment
   vii. Cost for disposal of any equipment
   viii. Gravel pad removal
- c. Injection zone monitoring well plugging and site reclamation
   i. Casing evaluation
   ii. Evaluation of any problems discovered by the casing evaluation
   iii. Cost for repairing problems & cleanup of any groundwater or soil contamination
   iv. Cost for cementing or other materials used to plug the well
   v. Cost for labor, engineering, rig time, equipment and consultants
   vi. Cost for decontamination of equipment
   vii. Cost for disposal of any equipment
   viii. Gravel pad removal
- d. Above confining zone monitoring well plugging and site reclamation
   i. Casing evaluation
   ii. Evaluation of any problems discovered by the casing evaluation
   iii. Cost for repairing problems & cleanup of any groundwater or soil contamination
   iv. Cost for cementing or other materials used to plug the well
   v. Cost for labor, engineering, rig time, equipment and consultants
   vi. Cost for decontamination of equipment
   vii. Cost for disposal of any equipment
   viii. Gravel pad removal
- e. Land reclamation
   i. Phase II demolition
   ii. Remove access roads
- f. Document plugging and closure process

5. Emergency and remedial response
   - a. Post-injection USDW contamination
      i. Acidification due to migration of CO_2
      ii. Toxic metal dissolution and mobilization
      iii. Displacement of groundwater with brine due to CO_2 injection
   - b. Post-Injection Failure Scenarios (acute)
      i. Upward leakage through CO_2 injection well
      ii. Upward leakage through deep oil and gas wells
      iii. Upward leakage through undocumented, abandoned, or substandard wells
   - c. Post-injection failure scenarios (chronic)
      i. Upward leakage through caprock through gradual failure
      ii. Release through existing faults due to effects of increased pressure
      iii. Release through induced faults due to effects of increased pressure
      iv. Upward leakage through CO_2 injection well
      v. Upward leakage through deep oil and gas wells
      vi. Upward leakage through undocumented, abandoned, or substandard deep wells
   - d. Other

i. Catastrophic failure of caprock
ii. Failure of caprock/seals or well integrity due to seismic event

V. Basis used to develop cost estimates

The FutureGen Alliance contracted with Patrick Engineering to provide a third-party cost estimate to meet the required financial responsibility activities: corrective action on wells in the AoR; injection well plugging; post-injection site care and site closure; and emergency and remedial response. Patrick used the EPA's UIC Program Class VI Financial Responsibility Guidance[1] as the basis to define the activities required to be included in the cost estimate. The costs of the required activities were then estimated from 1) historic price data from other projects the company has managed, 2) cost quotes from third-party companies, 3) EPA's Geologic CO_2 Sequestration Technology and Cost Analysis document[2], and 4) professional judgment on the level of effort required to complete an activity. The estimated costs are in current (2012) dollars and reflect the costs of a third party to complete the work. The unit costs are fully loaded with general and administrative costs; overhead and profit are also included.

In developing the estimate, Patrick assumed the costs would be incurred if the FutureGen Alliance was no longer involved in the project and a third party was asked to conclude the project in a manner to protect USDWs. Thus, the costs included in this estimate would cover the efforts required to ensure the protection of USDWs at no cost to the public. The cost estimate includes the assumption that the third party would not take over and complete the full vision of FutureGen's research project and thus that CO_2 injection would cease immediately.

VI. Area of Review and Corrective Action Cost Estimate

The estimated costs in this section cover the periodic reevaluation of the AoR and the identification and remediation of newly identified deficient wells. For the purposes of this cost estimate, the initial study area was defined as an area of approximately 5,000 acres surrounding the injection well pad for the four injection wells. This area was based on a computational model that assumed injection of 1.1 million metric tons of CO_2 annually for 20 years (total of 22 million metric tons). Based on the model, the area covered by CO_2 plume after plume movement ceased would be contained within the 5,000-acre area. All deficient wells found in the initial AoR would be remediated before injection begins. Therefore, no cost is included to remediate deficient wells within the initial AoR.

As noted above, this cost estimate assumes CO_2 injection would cease at, or would have ceased by, the time a third party was needed to take over responsibility for the injection well and storage site. For purposes of the cost estimate, a reevaluation of the AoR would occur at the time a third party took responsibility and then would occur once every five years during the 50-year post-injection period – the default frequency required by the Class VI regulations. Should the injection reservoir tracking data obtained over the five-year period deviate significantly from the predictions of the original (or updated) computational model, the model would be updated to reflect the actual measured shape and extent of the CO_2 plume and improve the accuracy of the

[1] *Underground Injection Control (UIC) Class VI Program. Financial Responsibility Guidance.* USEPA

[2] *Geologic CO2 Sequestration Technology and Cost Analysis.* USEPA Office of Water (4606-M). EPA 816-D-10-008, November 2010.

predicted AoR. It is assumed this would only be necessary once during the post-injection period as the model would have been regularly verified and updated during the injection period.

Any newly identified wells are assumed to be either deficient wells within the initial AoR which were not discovered before injection, or deficient wells added because of adjustments to the AoR due to ongoing monitoring of the plume during injection. Based on current investigations by Patrick and the Alliance, the closest well in any direction that penetrates the confining zone (the Eau Claire Formation) is approximately 16 miles away from the proposed injection site. For this reason, Patrick believes that the likelihood of encountering additional wells within an adjusted AoR is small and, for purposes of the cost estimate, has assumed that there would be one newly identified well.

Remediation costs were estimated based on Patrick's experience and costs incurred or estimated for other projects.

Table 1: Corrective Action on Wells in Area of Review

Activity	Unit			Unit Cost ($)			Total Costs ($)
a. Review existing plume model (every five years)	1,600	hrs	@	153	per hour	=	245,000
b. Remodel plume (once)	1,500	hrs	@	153	per hour	=	230,000
c. Review of state databases of known wells and abandoned mines (every five years)	200	hrs	@	153	per hour	=	31,000
d. Well integrity testing	1	well	@	26,000	per well	=	26,000
e. Plug deficient wells	1	well	@	15,000	per well	=	15,000
f. Perform remedial cementing of defective wells	1	well	@	15,000	per well	=	15,000
g. Project management and oversight (every five years)	400	hrs	@	153	per hour	=	61,000
Total Corrective Action on Wells in AoR over 50-year Post-injection Period							**623,000**

VII. Injection Wells Plugging and Site Reclamation Cost Estimate

The estimated costs in this section cover the plugging of the four injection wells after injection had ceased. Site reclamation for the plugged sites is included in the cost as well.

The costs are broken into three areas: 1) plugging and abandoning the four injection wells, 2) land reclamation including removal of injection site buildings and appurtenances, and 3) remediation cost in the unlikely event that the plugging activity causes the need to remediate local shallow wells. The costs are one-time costs that would be paid at the end of the anticipated 30-year injection period or when injection ceased, whichever came first.

The plugging of all wells would include mechanical integrity testing, plugging the hole with cement for the entire depth of the well, and cutting the well off below the ground. All structures and appurtenances at the sites of the first and second injection wells would be removed except for those directly necessary to the continued monitoring of the plume. The surface facilities remaining for post-injection monitoring would be removed during site closure.

Well plugging and site remediation costs were estimated based on Patrick's experience and costs incurred or estimated for other projects. Four previous UIC applications for CO_2 sequestration wells were reviewed and average costs for mobilization and plugging costs per inch-foot of bore were developed.

Table 2: Injection Wells & Monitoring Wells Plugging & Site Reclamation Summary

Activity	Total Cost ($)
a. Injection wells plugging	1,633,000
b. Land reclamation	1,037,000
c. Well remediation	53,000
Total Injection Wells & Monitoring Wells Plugging & Site Reclamation	**2,723,000**

Table 2a: Injection Wells Plugging & Site Reclamation Detail

Activity	Unit			Unit Cost ($)		Total Costs ($)	
a. Injection wells plugging							
i. Casing evaluation	4	wells	@	62,000	per well	=	248,000
ii. Repair problem & groundwater cleanup	4	wells	@	31,000	per well	=	124,000
iii. Cement materials used to plug the well	4	wells	@	140,000	per well	=	560,000
iv. Labor, engineering, rig time, equipment	4	wells	@	114,000	per well	=	456,000
v. Decontamination of equipment	4	wells	@	4,000	per well	=	16,000
vi. Disposal of any equipment	4	wells	@	3,000	per well	=	12,000
Miscellaneous and minor contingencies (10%)	4	wells	@	36,000	per well	=	144,000
Project Management and Oversight (480 hours @ $153/hour)							73,000
						Total injection wells plugging	**1,633,000**

b. Land reclamation							
i. Phase I demolition of site control building at injection well site	1	site	@	836,000	per site	=	836,000
ii. Removal of gravel well pads and land restoration at injection well site	1	pad	@	186,000	per pad	=	186,000
Project Management and Oversight (100 hours @ $153/hour)							15,000
						Total land reclamation	**1,037,000**

c. Well remediation						
i. Sample analysis (fluid or soil)	1	@	1,000	each	=	1,000
ii. Site assessment/ hydrogeological study	1	@	15,300	each	=	15,300
iii. System removal	1	@	7,600	each	=	7,600
iv. Disposal system modification	1	@	1,500	each	=	1,500
v. Installation of monitoring well	1	@	15,300	each	=	15,300
Project management and oversight (80 hours @ $153/hour)						12,000
				Total remediation		**53,000**

VIII. Post-Injection Site Care Cost Estimate

The estimated costs in this section cover the tracking and modeling of the plume during the 50-year post-injection period.

The PISC activities would include collecting geochemical and geophysical monitoring data from three injection zone monitoring wells, up to three above-caprock monitoring wells, and one LUSDW (St. Peter formation) monitoring well. The data collected would include continuous formation temperature and pressure readings and annual well samples. The geochemical and geophysical data from the deep well would be used to verify and, if necessary, recalibrate the computational model. PISC costs would also include record keeping and reporting the information to the proper governmental agency.

The PISC costs were estimated based on Patrick's experience, costs incurred or estimated for other projects, and EPA guidance[3].

Table 3: Post-injection Site Care Summary

Activity	Total Cost ($)
a. Monitoring wells for geochemical and geophysical analyses	10,870,000
b. Monitoring well mechanical integrity testing	3,650,000
c. Site management and EPA reporting	3,800,000
Total post-injection site care	**$18,320,000**

[3] *Ibid.*

Table 3a: Post-injection Site Care Detail

a. Monitoring wells for geochemical and geophysical analyses

Activity	Number of Wells	Base Cost ($)	Unit Cost ($)	Annual Cost ($)
LUSDW well (geochemical analyses)	1	7,000	4,000	11,000
Injection zone monitoring well (pressure, temperature, electrical resistivity tomography (ERT)	3	80,000	16,000	128,000
Above confining zone monitoring well (pressure, temperature, ERT)	3	27,000	12,000	63,000
Project management and oversight (100 hours @ $153/hour)				15,300
Annual well monitoring cost				217,300
Total well monitoring cost for 50 years post-injection				**10,870,000**

b. Monitoring well mechanical integrity testing

Activity	Number of Wells	Base Cost ($)	Unit Cost ($/ft)	Well Depth (ft)	Annualized Cost ($)
LUSDW well, monitoring sensors O&M (every five years - annualized)	1	2,000	4.25	1,900	2,000
Injection zone monitoring well (annually)	3	2,000	4.25	4,300	56,800
Above confining zone well monitoring sensors O&M (every five years - annualized)	3	2,000	4.25	3,400	9,100
Project management and oversight (160 hours @ $153/hour every five years)					5,000
Annualized monitoring well operation and maintenance					72,900
Total monitoring well operation and maintenance for 50 years post-injection					**3,650,000**

c. Site management and EPA reporting

Activity	Annual hours		Unit Cost ($)		Total Costs ($)
Record keeping and reporting	250	@	153	per hour	38,000
Project management and oversight	250	@	153	per hour	38,000
Annual site management and EPA reporting					76,000
Total site management and EPA reporting over 50 years					**3,800,000**

IX. Site Closure Cost Estimate

The estimated costs in this section cover the final closure of the site. After the default 50-year, post-injection and site care period, and when it could be demonstrated that the project would no longer pose a risk of endangerment to any USDWs, the site would be permanently closed.

The costs are broken into four functional areas; 1) preparing the non-endangerment report, 2) plugging and abandoning all monitoring wells, 3) reclaiming land including removal of remaining surface site buildings and appurtenances, and 4) documenting the site closure process. The costs would be one-time costs that would be paid at the final project termination.

The plugging of the monitoring wells would include mechanical integrity testing, plugging the hole with cement the entire depth of the well, and cutting the well off below the ground. All structures and appurtenances at the sites of the monitoring wells would be completely removed and the sites would be restored to pre-project condition.

Well plugging and site remediation costs were estimated based on Patrick's experience and costs incurred or estimated for other projects. Four previous UIC applications for CO_2 sequestration wells were reviewed and average costs for mobilization and plugging costs per inch-foot of bore were developed.

Table 4: Site Closure Summary

Activity	Total Cost ($)
a. Non-endangerment demonstration	26,000
b. LUSDW monitoring well plugging	319,000
c. Injection-zone monitoring well plugging	1,609,800
d. Above-confining zone monitoring well plugging	1,288,500
e. Remove surface features and reclaim land	140,000
f. Document plugging and closure process	17,000
Total site closure	**3,402,000**

Table 4a: Site Closure Detail

a. Non-endangerment demonstration			
Activity	**Cost per Well ($)**	**Number of Wells**	**Total Cost ($)**
Prepare non-endangerment demonstration report			26,000
Total cost non-endangerment demonstration			**26,000**

b. LUSDW monitoring well plugging (1900 feet deep)			
Activity	**Cost per Well ($)**	**Number of Wells**	**Total Cost ($)**
Casing evaluation	21,000	1	21,000
Evaluation of any problems discovered by the casing evaluation	7,000	1	7,000
Cost for repairing problems & cleanup of any groundwater or soil contamination	14,000	1	14,000
Cost for cementing or other materials used to plug the well	62,000	1	62,000
Cost for labor, engineering, rig time, equipment and consultants	52,000	1	52,000
Cost for decontamination of equipment	4,000	1	4,000
Cost for disposal of any equipment	2,000	1	2,000
Gravel pad removal (175' x 175')	143,000	1	143,000
Project management and oversight (90 hours @ $153/hour)			14,000
Total cost plug LUSDW monitoring well			**319,000**

c. Injection zone monitoring wells plugging (Assumes 3 wells 4300 feet deep)			
Activity	**Cost per Well ($)**	**Number of Wells**	**Total Cost ($)**
Casing evaluation	51,000	3	153,000
Evaluation of any problems discovered by the casing evaluation	20,000	3	60,000
Cost for repairing problems & cleanup of any groundwater or soil contamination	31,000	3	93,000
Cost for cementing or other materials used to plug the well	140,000	3	420,000
Cost for labor, engineering, rig time, equipment and consultants	114,000	3	342,000
Cost for decontamination of equipment	4,000	3	12,000
Cost for disposal of any equipment	3,000	3	9,000
Gravel pad removal (175' x 175')	143,000	3	429,000
Project management and oversight (600 hours @ $153/hour)			91,800
Total injection zone monitoring wells plugging			**1,609,800**

d. Above confining zone monitoring well plugging (3,400 feet deep)			
Activity	**Cost per Well ($)**	**Number of Wells**	**Total Cost ($)**
Casing evaluation	34,000	3	102,000
Evaluation of any problems discovered by the casing evaluation	11,000	3	33,000
Cost for repairing problems & cleanup of any groundwater or soil contamination	23,000	3	69,000
Cost for cementing or other materials used to plug the well	102,000	3	306,000
Cost for labor, engineering, rig time, equipment and consultants	86,000	3	258,000
Cost for decontamination of equipment	4,000	3	12,000
Cost for disposal of any equipment	2,000	3	6,000
Gravel pad removal (175' x 175')	143,000	3	429,000
Project management and oversight (480 hours @ $153/hour)			73,500
Total cost plug above confining zone monitoring wells			**1,288,500**

e. Land reclamation			
Activity	**Unit Cost ($)**	**Number**	**Total Cost ($)**
Phase II demolition (@ 50 years following cessation of injection) - injection well site 1 well maintenance and monitoring building, and appurtenances	112,000	1	112,000
Remove access roads (miles)	11,000	2.5	28,000
Total remove surface features and reclaim land			**140,000**

f. Documentation			
Activity	**Hours**	**Rate ($/hr)**	**Total Cost ($)**
Document plugging and closure process (well plugging, post-injection plans, notification of intent to close, and post-closure report).	110	153	17,000
Total documentation			**17,000**

X. Emergency and Remedial Response Cost Estimate

It was assumed the response to discovered CO_2 leaks, both acute/high volume and chronic/low volume, would be to plug leaks where possible, assess any impact to USDWs, and remediate any contamination of USDWs. Potential consequences and response actions were taken from Esposito 2010[4]. The cost estimate assumes a maximum affected area of about 4 square miles. The costs include installation and sampling of 10 monitoring wells, installation and operation of 4 extraction wells, extraction, treatment of 10 to 20 gallons per minute of groundwater for 2 years using absorption, and removal of system. The extent and costs of treatment were adapted from Federal Remediation Technologies Roundtable website[5]. The cost of study and well installation were derived from previous experience. Costs for municipal water hook-up are not included as this scenario is deemed to be extremely unlikely, although the cost of remediation may make municipal water hook-up preferable. Also note that treatment costs can vary significantly depending on specific metal and concentration.

The costs of responding to catastrophic events assumed wide areas with groundwater impacted from CO_2 seeps which would require groundwater remediation and providing alternative water supplies to affected residents.

Table 5: Emergency and Remedial Response Events

Event	Consequences	Response Actions
<u>1. Post-injection USDW contamination</u>		
Acidification due to migration of CO_2	Decrease in pH by 1 to 2 units, mobilization of trace and alkali metals, other geochemical changes to groundwater that result in USDW exceeding applicable standards	Hydrogeological study to delineate 3-D extent and nature of impact to USDW. Groundwater extraction with treatment of groundwater or extraction coupled with injection of 'clean' water, if possible. Significant impact to USDW could require supplying municipal water to affected properties.
Toxic metal dissolution and mobilization	Concentrations of toxic metals in USDW greater than applicable standards	Hydrogeological study to delineate 3-D extent and nature of impact to USDW. Groundwater extraction with treatment of groundwater or extraction coupled with injection of 'clean' water, if possible. Significant impact to USDW could require supplying municipal water to affected properties.

[4] Exposito, Ariel M.M. *'Remediation of Possible Leakage from Geologic CO_2 Storage Reservoirs into Groundwater Aquifers.* Stanford University Department of Energy Resources Engineering. June 2010.

[5] Environmental Cost Estimating Tools. In *Federal Remediation Technologies Roundtable*. Retrieved June 9, 2011. From www.frtr.gov.

Table 5 (continued)

Event	Consequences	Response Actions
Displacement of groundwater with brine due to CO_2 injection	Concentrations of anions/cations in USDW greater than applicable drinking water standards.	Hydrogeological study to delineate 3-D extent and nature of impact to USDW. Groundwater extraction with treatment of groundwater or extraction coupled with injection of 'clean' water, if possible. Significant impact to USDW could require supplying municipal water to affected properties.
<u>2. Post-injection failure scenarios (acute)</u>		
Upward leakage through CO_2 injection well	Groundwater contamination	1) Pull and replace the tubing or the packer, 2) Repair the well by plugging it with cement, 3) Create a hydraulic barrier by increasing reservoir pressure upstream of the leak, 4) Install chemical sealant barrier to block leaks, and 5) Remediate groundwater (see 1. above).
Upward leakage through deep oil and gas wells	Groundwater contamination	1) Pull and replace the tubing or the packer, 2) Repair the well by plugging it with cement, 3) Create a hydraulic barrier by increasing reservoir pressure upstream of the leak, 4) Install chemical sealant barrier to block leaks, and 5) Remediate groundwater (see 1. above).
Upward leakage through undocumented, abandoned, or poorly constructed wells	Groundwater contamination	1) Pull and replace the tubing or the packer, 2) Repair the well by plugging it with cement, 3) Create a hydraulic barrier by increasing reservoir pressure upstream of the leak, 4) Install chemical sealant barrier to block leaks, and 5) Remediate groundwater (see 1. above).
<u>3. Post-injection failure scenarios (chronic)</u>		
Upward leakage through caprock through gradual failure	Groundwater contamination	Remediate groundwater (see 1. above)
Release through existing faults due to effects of increased pressure	Groundwater contamination	Remediate groundwater (see 1. above)
Release through induced faults due to effects of increased pressure	Groundwater contamination	Remediate groundwater (see 1. above)

Table 5 (continued)

Event	Consequences	Response Actions
Upward leakage through CO_2 injection well	Groundwater contamination	1) Repair the well by plugging it with cement, 2) Create a hydraulic barrier by increasing reservoir pressure upstream of the leak, 3) Install chemical sealant barrier to block leaks, and 4) Remediate groundwater (see 1. above)
Upward leakage through deep oil and gas wells	Groundwater contamination	1) Pull and replace the tubing or the packer, 2) Repair the well by plugging it with cement, 3) Create a hydraulic barrier by increasing reservoir pressure upstream of the leak, 4) Install chemical sealant barrier to block leaks, and 5) Remediate groundwater (see 1. above).
Upward leakage through undocumented, abandoned, or poorly constructed deep wells	Groundwater contamination	1) Pull and replace the tubing or the packer, 2) Repair the well by plugging it with cement, 3) Create a hydraulic barrier by increasing reservoir pressure upstream of the leak, 4) Install chemical sealant barrier to block leaks, and 5) Remediate groundwater (see 1. above).
4. Other		
Catastrophic failure of caprock	Groundwater contamination	Remediate groundwater (see 1. above)
Failure of caprock or well integrity due to seismic event	Groundwater contamination	Remediate groundwater (see 1. above)

Table 5a: Emergency and Remedial Response Estimated Costs

Event	Estimated Cost ($)
1. Post-injection USDW contamination	
Acidification due to migration of CO_2	305,000
Toxic metal dissolution and mobilization	5,865,000
Displacement of groundwater with brine due to CO_2 injection	270,000
2. Post-injection failure scenarios (acute)	
Upward leakage through CO_2 injection well	3,343,000
Upward leakage through deep oil and gas wells	2,111,000
Upward leakage through undocumented, abandoned, or poorly constructed wells	2,111,000
3. Post-injection failure scenarios (chronic)	
Upward leakage through caprock through gradual failure	5,865,000
Release through existing faults due to effects of increased pressure	5,865,000
Release through induced faults due to effects of increased pressure	6,100,000
Upward leakage through CO_2 injection well	821,000
Upward leakage through deep oil and gas wells	411,000
Upward leakage through undocumented, abandoned, or poorly constructed deep wells	411,000
4. Other	
Catastrophic failure of caprock	6,100,000
Failure of caprock/seals or well integrity due to seismic event	6,100,000

XI. Cost Summary

For the Morgan County CO_2 injection site, the total cost for a third party to take corrective actions on wells within the AoR, plug the injection wells, conduct post-injection site care and site closure actions necessary to protect USDWs if the Alliance were unable to do so is estimated to be $17,785,000 as shown in Table 6. Possible emergency and remedial response actions as necessary to protect USDWs could possibly amount to as much as $6,100,000 for a single event.

Table 6: Total Financial Responsibility Cost by Category

Activity	Total Cost ($)
Corrective action on wells in AoR	623,000
Injection wells & monitoring wells plugging & site reclamation	2,723,000
Post-injection site care	18,320,000
Site closure	3,402,000
Total Financial Responsibility	**25,068,000**

The costs, assuming a 20-year injection period, are shown by category projected over time in Table 7 on the following page

Table 7: Total Financial Responsibility Cost by Category and Year (in 2012 dollars)

Year After Injection Stops	Corrective action on wells in AoR Cost ($)	Injection wells & monitoring wells plugging & site reclamation Cost ($)	Post-injection Site Care Cost ($)	Site Closure Cost ($)
1	33,700	2,723,000	430,800	-
2	-	-	350,200	-
3	-	-	350,200	-
4	-	-	350,200	-
5	-	-	350,200	-
6	33,700	-	430,800	-
7	-	-	350,200	-
8	-	-	350,200	-
9	-	-	350,200	-
10	-	-	350,200	-
11	33700	-	430,800	-
12	-	-	350,200	-
13	-	-	350,200	-
14	-	-	350,200	-
15	-	-	350,200	-
16	263,700	-	430,800	-
17	-	-	350,200	-
18	-	-	350,200	-
19	-	-	350,200	-
20	-	-	350,200	-
21	33700	-	430,800	-
22	-	-	350,200	-
23	-	-	350,200	-
24	-	-	350,200	-
25	-	-	350,200	-
26	89,700	-	430,800	-
27	-	-	350,200	-
28	-	-	350,200	-
29	-	-	350,200	-
30	-	-	350,200	-
31	33,700	-	430,800	-
32	-	-	350,200	-
33	-	-	350,200	-
34	-	-	350,200	-
35	-	-	350,200	-

Table 7 (continued)

36	33,700	-	430,800	-
37	-	-	350,200	-
38	-	-	350,200	-
39	-	-	350,200	-
40	-	-	350,200	-
41	33,700	-	430,800	-
42	-	-	350,200	-
43	-	-	350,200	-
44	-	-	350,200	-
45	-	-	350,200	-
46	33,700	-	430,800	-
47	-	-	350,200	-
48	-	-	350,200	-
49	-	-	350,200	-
50	-	-	350,200	-
51	-	-	-	3,402,000
TOTAL	**623,000**	**2,723,000**	**18,320,000**	**3,402,000**