5. Financial Responsibility Plan

Cost estimates for financial assurance associated with the proposed ADM CCS #5-7 wells are generated based on prices incurred for similar work and reflect the current pricing environment. The cost summary presented in Section 5.6 applies both inflation and cost discounting assumptions based on the expected project timeline. See Appendix A for Financial Responsibility documentation.

5.1 Area of Review and Corrective Action Cost Estimate

As outlined in Appendix B of the permit application, the area of review (AoR) refers to the maximum area extent of the effected injection reservoir in which Mt. Simon pressure will exceed a critical pressure and have the potential to hypothetically drive fluids upwards into the lowermost USDW (St. Peter formation) if a vertical pathway is present. The AoR is based on results from current numerical modeling including all proposed wells at the site (including CCS #1-7) and is subject to change if operational measurements deviate significantly from modeled predictions. However, no known deep penetrating wells were found to exist within the AoR. Based on this review, no cost has been assigned for corrective action since no pathways for hypothetical leakage were found to exist.

5.2 Injection Well Plugging and Site Reclamation Estimate

Plugging costs for the three injection wells (CCS#5, CCS#6, and CCS#7) will be incurred at the end of their respective operational periods. A series of cement plugs will be placed to seal the entire wellbore, and each well will be capped and covered below ground level. Table 5.2-1 presents an approximate breakdown of total estimated cost based on the procedures provided in Section 10.

TABLE 5.2-1. Cost Summary for Injection Well Plugging/Site Reclamation

Activity	No. Wells	Cost/Well	Subtotal
Sensitive, Confidential, or Privileged Information [redacted]			
Total Estimated Cost for P&A / Site Reclamation:			**$2,325,000**

5.3 Post-Injection Site Care Cost Estimate

Post-injection monitoring extends the use of the verification wells (VWs) and geophysical monitoring wells (MWs) by means of the operational testing and monitoring plan described in Section 9 of the permit application. Monitoring activities, locations and frequencies are summarized in Table 5.3-1. Monitoring costs assume that VW #4 and VW#5 will be installed as a single wellbore with multi-zone sampling capacity.

TABLE 5.3-1. Cost Summary for Post-Injection Monitoring

Activity	Tested Wells	Frequency	Cost/Test	Total No. of Tests	Subtotal (10-yr)
Sensitive, Confidential, or Privileged Information [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
		Total Estimated Cost for Post-Injection Monitoring:			**$2,250,000**

5.4 Site Closure Cost Estimate

The site closure costs summarized in Table 5.4-1 include plugging and reclamation activities for all VWs and MWs (the procedure is identical to that described in Section 5.2 for injection wells). The VWs extend to the approximate depth of injection wells but have a smaller diameter, which significantly reduces the volume of cement and time required for plugging. The GWs are installed to the base of the St. Peter formation, which is approximately half the depth of injection and verification wells. Site closure estimates assume VW #4 and #5 exist as single wellbores; multiple, smaller-diameter wellbores would likely incur the same total plugging cost.

TABLE 5.4-1. Cost Summary for Site Closure

Activity	No. Wells	Cost/Well	Subtotal
Sensitive, Confidential, or Privileged Information [redacted]	[redacted]	[redacted]	[redacted]
Total Estimated Cost for Site Closure:			**$2,335,000**

5.5 Emergency and Remedial Response Cost Estimate

The primary sources of risk evaluated in the current plan are similar to the risk categories utilized in the previously approved CCS#1 and #2 permits, and CCS#3 and CCS#4 permit applications. For the current evaluation, additional consideration was given to surface equipment and to the slight changes to some FEP probabilities impacted by the presence of the additional wells and the increased volume and pressure associated with the incremental injection operations in the fourth site injector. In this site-wide financial risk assessment, Monte-Carlo analysis was used to calculate an expected present value (PV) of financial liability based on the probability and expected cost of risk events occurring over the 15-year operational and 10-year post operational periods. Probabilities for each event were assigned primarily based on a 2007 risk assessment report submitted as part of the FutureGen Environmental Impact Statement (FutureGen, Contract No. DE-AT26-06NT42921). Table 5.5-1 summarizes the range of probabilities estimated in the FutureGen report for each respective risk event and used as part of the input values for this evaluation.

TABLE 5.5-1. Annual Probabilities of Relevant CCS Risk Events

Risk Event	Event Description	Annual Frequency of Failure (Single Item)	
		Low Estimate	**High Estimate**
1	Pipeline Rupture	Sensitive, Confidential, or Privileged Information [redacted]	[redacted]
2	Pipeline Puncture	[redacted]	[redacted]
3	Wellhead Equipment Rupture	[redacted]	[redacted]
4	Upward rapid leakage through CO_2 injection well	[redacted]	[redacted]
5	Upward slow leakage through CO_2 injection well	[redacted]	[redacted]
6	Upward rapid leakage through deep oil & gas wells	[redacted]	[redacted]
7	Upward slow leakage through deep oil & gas wells	[redacted]	[redacted]
8	Upward rapid leakage through caprock	[redacted]	[redacted]
9	Upward slow leakage through caprock	[redacted]	[redacted]
10	Release through existing faults	[redacted]	[redacted]
11	Release through induced faults	[redacted]	[redacted]
12	Leaks due to undocumented deep wells, high rate	[redacted]	[redacted]
13	Leaks due to undocumented deep wells, low rate	[redacted]	[redacted]

Each Monte-Carlo simulation observation assigns random event probabilities using uniform distributions based on the respective low and high estimates shown in Table 5.5-1. The resulting probabilities are then multiplied by the number of relevant items: events 1-5 apply to three CO_2 injection wells, events 6-7 are applied to approximately 100 oil and gas wells within the project's area-of review (AoR), and the remaining events are interpreted as project-wide risks with a multiplier of 1.

If an event occurs in a particular Monte-Carlo realization based on the probability distribution and the multiplier for the potential number of events from the process described above, it is then assigned a cost based on a triangular distribution. Most-likely costs assigned for events 4-13 are volume-based remediation estimates based on the magnitude of potential leakage (Appendix 8 provides additional information on the methodology of cost assignments). Table 5.5-2 summarizes the distribution parameters used for each risk event (low, most-likely, and high estimates).

TABLE 5.5-2. Remediation Cost Parameters for Risk Events

Event	Event Description	Event Cost (Triangular Distribution)		
		Low	Most Likely	High
1	Pipeline Rupture	Sensitive, Confidential, or Privileged Information		
2	Pipeline Puncture			
3	Wellhead Equipment Rupture			
4	Upward rapid leakage through CO_2 injection well			
5	Upward slow leakage through CO_2 injection well			
6	Upward rapid leakage through deep oil & gas wells			
7	Upward slow leakage through deep oil & gas wells			
8	Upward rapid leakage through caprock			
9	Upward slow leakage through caprock			
10	Release through existing faults			
11	Release through induced faults			
12	Leaks due to undocumented deep wells, high rate			
13	Leaks due to undocumented deep wells, low rate			

Using the defined probability and cost distributions, the Monte-Carlo simulation creates thousands of viable scenarios that project annual liability costs over a 25-year timeframe (15 years operational and 10 post-operational). Future payments are discounted at a rate of 2.0% and incorporate an annual inflation rate of 2.75%. Figure 5.5-1 illustrates the final distribution of total project liability based on the aggregate results of 100,000 simulations. The Monte Carlo analysis was used to generate an expected value of $4.47 million based on the results from all modeled outcomes.

Sensitive, Confidential, or Privileged Information

Figure 5.5-1. Distribution of Emergency and Remedial Response Net Present Value

5.6 Cost Summary

Cost estimates detailed in Sections 5.1 through 5.5 were adjusted to present values using the same method described in the emergency and remedial response section (future costs were inflated assuming an annual inflation rate of 2.75% and discounted at a rate of 2.0%). Table 5.6-1 summarizes the pre-adjusted and adjusted cost totals for the five cost categories.

TABLE 5.6-1. Financial Assurance Cost Summary, CCS #5, CCS #6 and CCS #7

Category	Pre-adjusted	Adjusted NPV
Sensitive, Confidential, or Privileged Information [redacted]		
Total Financial Assurance Required:		**$13,220,000**

APPENDIX A: Financial Responsibility Documents

8.0 APPENDIX

To assess the financial assurance requirements[1] associated with the ADM Decatur CCS development, Petrotek combined UIC subject matter expertise with Monte Carlo modeling. The utility of a Monte Carlo approach is that it eliminates reliance on a deterministic value for future events as well as the implied certainty of those events occurring, no matter their likelihood. As has been established from prior evaluations used to assess risks associated with Class I Hazardous Injection wells, occurrence of failures is extremely rare[2,3]. Accounting for both random occurrence and stringent well construction criteria mandated by the US Environmental Protection Agency (EPA), along with using available data regarding occurrences of failure and their mechanisms, the ability to produce a single estimate of the probability of an event occurring is impractical and is likely to be erroneous[2]. Therefore, a statistical method rather than a deterministic method has been used in this evaluation to assign probabilities of outcomes that could result in costs that require financial assurance.

Monte Carlo evaluation involves stochastic modeling to define the probable liability; rather than determining a value from a single future event, Monte Carlo models thousands of discrete scenarios, each regarding a possible circumstance at any point in the future.

Monte Carlo modeling has been used for decades with wide applicability, including the evaluation environmental risk[4], with extension to CCS[5]. Monte Carlo methods have also been used extensively to provide risk estimates for the EPA[2]. The Monte Carlo method being used for the Decatur project in particular follows methodologies similar to those that have been used in the past[6,7], and also adheres to EPA guidance[8].

For the purposes of this assessment, the Monte Carlo analysis was conducted in a step-wise manner. A list of risk event groups was generated, along with their individual probability of occurrence, distribution of costs if the event occurred, and a specified time frame. For each discrete scenario, the Monte Carlo model assigns a random probability for each risk event, within each event's provided range, for each year. The cost of each risk event for each year would then be determined from its cost distribution. Total cost would then be determined by summing the costs of each individual risk event for every year, then adjusting subsequent years to a present value. The process would be repeated 100,000 times to simulate a large set of outcomes. From the 100,000 different scenarios, a distribution of possible costs is generated, from which an expected value of the liability cost can be ascertained.

8.1 Risk Scenario Identification

Multiple frameworks exist to identify the potential risks and hazards from the operation of a CCS project[9], most with a global perspective. The potential risks collated for the Decatur CCS project were identified using multiple, specific sources[10,11,12,13,14,15]. However, for relevancy each risk is required to be discrete and independent unto itself, as well as relevant to ADM's project and the area in and around Decatur. For example, Quintessa Ltd., a UK based consultancy with sponsorship from the EU, generated a thorough list of over 140 different possible features, events, and processes (FEP) to assess the specific risk and performance of CCS projects[10]. This list was consulted to determine the potential relevancy and applicability of a FEP to the ADM CCS operation.

Cross-referencing was then completed with the dataset of risks provided in the environmental impact statement (EIS) created for the FutureGen CCS project[11]. FutureGen was a consortium of entities with the bulk of funding from the Department of Energy (DOE). The list of risks provided by the FutureGen EIS were generated through research of historical oil, gas, and pipeline operations throughout the United States with relevancy to handling CO2. This list of applicable risk factors was then compared with risk factors previously used to quantify the financial assurance for the ADM CCS-2 well in previously approved submittals. The final list of risks, based on this review, was then utilized for the Decatur Monte Carlo analysis:

1. **Pipeline Rupture**. Encompasses the total rupture of a pipeline due to accidental causes or intentional sabotage, during which CO2 will be released in the area local to the project as well as the surrounding vicinity.

2. **Pipeline Puncture**. Encompasses a range of scenarios to describe a hole in the pipeline, most of which are a low level of risk and cost and are easy to repair but which would cause the release of CO2 at surface. Includes a wide range of the rate of leakage, the causes of which could be due to accident or intentional sabotage.

3. **Wellhead Equipment Failure (either slow or catastrophic)**. Encompasses the accidental or intentional sabotage of a wellhead used for the injection or monitoring purposes of the project but which would allow the release of CO2 at surface. Causes are found at the extremes, through either slow corrosion or the catastrophic failure of an accidental nature or from impact, such as from a vehicle or airplane.

4. **Leakage (rapid and slow) through installed wells (injection, monitor)**. Encompasses the leakage of CO2 through loss of integrity of installed wells. Causes are wide, but inclusive of improper initial installation or through continuous physical or chemical processes. The assumption with this risk is that eventually CO2 or other fluids would escape the injection zone by means of these wells.

5. **Leakage (rapid and slow) through currently existing wells that transect through the injection of confining zone, either active or plugged**. Encompasses artificial penetrations within the areal extent of the CO2 plume. Includes historical oil and gas wells with a wide range of installation or plugging practices, some of which may be unable to withstand the elevated pressure within the plume or contact with the injected CO2 and would subsequently allow CO2 or other fluids to escape the injection zone.

6. **Leakage (rapid and slow) through undocumented wells which may transect through the injection or confining zone**. Similar to the risk event associated with

existing wells that transect the injection or confining zone, this risk event assumes that there may be wells that transect either zone, but which are unaccounted for and will be in contact with the elevated pressure of the plume or injected CO2 at some point in the future and would allow the leakage of CO2 or other fluids into adjacent strata.

7. **Leakage (rapid and slow) through the seal(s) adjacent to the injection zone through means other than existing or created wells, faults, or fractures**. Encompasses those risks which would cause injected CO2 or other fluids to leak through the caprock and into adjacent strata. The range is large, but includes a combination of elevated pressures beyond the mechanical strength of the rock coupled with thermal changes, physical changes and chemical changes which would allow the CO2 to escape. Also includes those risks associated with a seismic event not associated with the injection of CO2.

8. **Leakage through existing and assessed faults**. The risk scenario in which injected CO2 or other fluids would escape the injection zone through existing faults, whether they are open or sealed.

9. **Leakage through induced faults**. The risk scenario in which CO2 or other fluids escape the injection zone through pressure induced faulting or seismic events associated with the injection of the CO2.

The list provided in the financial assurance discussion includes the same nine risks, albeit in discrete form, such that rapid and slow leaking scenarios are differentiated for each risk, so that there are 13 total risk factors indicated[13] and used as model input.

It should be noted that each of the assumed risks will incorporate different time frames. Risks associated with surface equipment will be no longer be a relevant factor once the injection period is complete. Additionally, after injection has stopped and associated wells are plugged to regulatory standards, by definition they will no longer be a factor contributing to ongoing risk. Within the injection zone, the induced pressure caused by the injection of the CO2 into the Mt. Simon will dissipate over time; it will be the highest at the point that injection is ceased and will be the highest proximal to the injection wellbores. Over time, as the pressure dissipates, the risk of a pressure-induced leak or failure decreases as well.

The rapid and slow leakage qualifiers denote the rate at which CO2 would hypothetically have the potential to leak from the injection zone into adjacent strata, with the possibility of continuing into overlying aquifers or underground sources of drinking water (USDW). A slow leak includes scenarios wherein transfer of a given volume of CO2 may take a longer period of time to occur, whereas a rapid leak indicates the loss of a given volume extremely quickly if not catastrophically.

8.2 Risk Scenario Probability of Occurrence

Each identified risk was individually assigned a distribution of annual probability of occurrence. Since the outcome of the analysis is highly dependent on the probability of each risk scenario occurring, a deterministic probability would introduce bias into the analysis, whereas using a distribution for the probability alleviated this bias. Likewise, although the EPA stipulates criteria for the proper construction of injection wells which are intended to reduce the probability of a risk event occurring[3], such standards and practices do not completely eliminate all risk and low probabilities still exist of an event occurring. Additionally, each risk can have any form of causation, and a distribution of probability of occurrence can take this into account. For modeling purposes, risk causation scenarios are innumerable, so professional judgement must be utilized to provide a range of probabilities for each scenario[16].

As previously indicated, research has been done to investigate potential failure mechanisms (observed to date) for some of the limited number of Class I Hazardous Injection Wells and carbon sequestration projects located in the US and throughout the world. This work provides useful and relevant information regarding the probability distributions for different risk scenarios below ground (regarding injection and monitor well failures, leakage, and faulting)[2,3,11,12,17]. Above ground, pipeline and treatment equipment data sets exist for probability estimation within the United States and elsewhere[18,19,20,21,22,23].

For the risk scenarios previously collated and identified as relevant to the Decatur facility, the assumed probabilities of occurrence for each are noted in Table 1.

Table 1. Risk Event Probabilities of Occurrence.

Risk Event	Event Description	Annual Frequency of Failure (Single Item)	
		Low Estimate	High Estimate
1	Pipeline Rupture	0.00470%	0.590%
2	Pipeline Puncture	0.00940%	1.20%
3	Wellhead Equipment Failure	0.0010%	0.0030%
4	Upward rapid leakage through Installed well	0.00010%	0.0010%
5	Upward slow leakage through Installed well	0.00010%	0.0010%
6	Upward rapid leakage through deep transecting wells	0.00010%	0.1000%
7	Upward slow leakage through deep transecting wells	0.00010%	0.1000%
8	Leaks due to undocumented deep wells, high rate	0.0010%	0.1000%
9	Leaks due to undocumented deep wells, low rate	0.0010%	0.1000%
10	Upward rapid leakage through caprock	0.000000010%	0.000000030%
11	Upward slow leakage through caprock	0.0030%	0.0050%
12	Release through existing faults	0.0000010%	0.0000030%
13	Release through induced faults	0.0000010%	0.0000030%

These probabilities mirror those found in the FutureGen EIS, but also incorporate a distribution instead of a deterministic forecast of probability.

For some of the risk scenarios, the probability of occurrence is only inclusive of installed equipment, such as the pipeline or an injection well; for the remainder, the risk is relevant to the whole project and is impacted by the volume of CO2 injected, any stray constituents, the increase in pressure caused by injection, and the reservoir area over which the pressure will be increased compared to in-situ conditions. For the latter case, risks are modeled for the volume of CO2 injected, the leakage mechanism, and the volume of leakage as well as impacted strata or leakage effects on the surface, human, wildlife, or environment. For those which encompass individual components such as injection or monitor wells, the risks must be multiplied by the number of wells, installed or previously existing[24,25]. Table 2 outlines the number of items for each risk category relevant to the Decatur site and project.

Table 2. Number of Items per Risk Scenario.

Risk Event	Event Description	Number of Items
1	Pipeline Rupture	3
2	Pipeline Puncture	3
3	Wellhead Equipment Failure	9
4	Upward rapid leakage through Installed well	9
5	Upward slow leakage through Installed well	9
6	Upward rapid leakage through deep transecting wells	100
7	Upward slow leakage through deep transecting wells	100
8	Leaks due to undocumented deep wells, high rate	1
9	Leaks due to undocumented deep wells, low rate	1
10	Upward rapid leakage through caprock	1
11	Upward slow leakage through caprock	1
12	Release through existing faults	1
13	Release through induced faults	1

8.3 Risk Scenario Cost Distribution

Each risk scenario identified as relevant was assigned a triangular distribution of representative costs in the event that the risk scenario occurred. Because each risk event has a range of probability of occurrence, the severity of the effects when the risk event occurs is also modeled with a distribution. As such, for each risk scenario, a minimum cost, maximum cost, and most likely cost was stipulated to generate the triangular distribution of the severity.

From the stipulated triangular distribution for a risk event, the probability density and cumulative density functions can be generated. In the event that the risk scenario occurs, the probability of occurrence would then directly translate to the associated cost of that occurrence. Likewise, the lower the probability of the risk scenario, the lower the resulting damages in the event the scenario occurs. Triangular distributions also follow guidance from the EPA in cases for which data is infrequent and professional judgement must be used[26], such as the case with CCS within the US.

Table 3 demonstrates the distributions for each of the risk scenarios identified.

Table 3. Triangle Distributions for Each Risk Scenario.

Risk Event	Event Description	Cost Estimates (Triangular Distribution)		
		Low	Most Likely	High
1	Pipeline Rupture	$1,000	$515,000	$3,950,000
2	Pipeline Puncture	$0	$4,500	$302,000
3	Wellhead Equipment Failure	$2,000	$25,000	$725,000
4	Upward rapid leakage through Installed well	$150,000	$1,253,000	$11,750,000
5	Upward slow leakage through Installed well	$150,000	$260,000	$1,828,000
6	Upward rapid leakage through transecting wells	$150,000	$1,220,000	$12,200,000
7	Upward slow leakage through transecting wells	$150,000	$228,000	$2,280,000
8	Leaks from undocumented deep wells, high rate	$865,000	$2,120,000	$14,700,000
9	Leaks from undocumented deep wells, low rate	$766,000	$1,130,000	$4,780,000
10	Upward rapid leakage through caprock	$3,310,000	$7,940,000	$49,600,000
11	Upward slow leakage through caprock	$333,000	$799,000	$4,990,000
12	Release through existing faults	$331,000	$3,310,000	$33,100,000
13	Release through induced faults	$331,000	$3,310,000	$33,100,000

For each of the risk scenarios presented in Table 3, the cost distributions estimate the likely range of severity and the associated costs. In the event of a risk scenario occurring, the costs include the consequences of:

- Impacts to human and wildlife health and life within the modeled region of the Decatur project;
- Impacts to plant life and environment within proximity of the Decatur site;
- Impacts to bodies of water within proximity of the Decatur site;
- Impacts to air quality;
- Impacts to soils and sediments within the modeled region of the Decatur project;
- Impacts to groundwater or other aquifers whether actively used or under consideration.

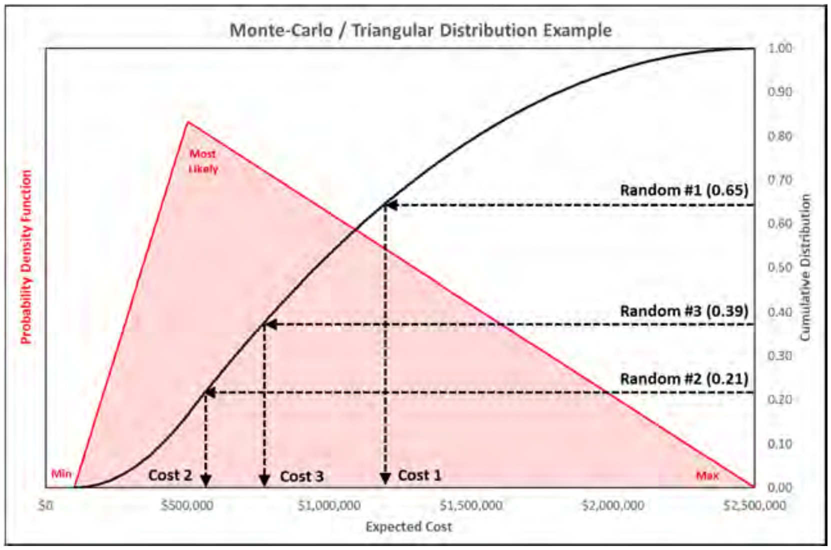
The severity of impacts in the event of a risk scenario occurring are largely estimated from the FutureGen EIS[11] while adjusting the costs for specificity to the Decatur project site. The categories also incorporated the demographics in and around the Decatur area[27].

Costs associated with repair of equipment on surface (risk scenarios 1 - 3) are estimated from the Office of Pipeline Safety[18,19,20,21] and professional judgment. Cost estimates for remediation of leakage (risk scenarios 4 – 13) are estimated from similar studies[11,28] and professional judgment. Due to the lack of particular CCS risk events occurring, and associated cost data, confidence in the costs is assumed by using a 100x multiplier when necessary between the low cost estimate and the high cost estimate. The multiplier, when used, is applied uniformly.

8.4 Monte Carlo Modeling

To demonstrate how the Monte Carlo model generates a scenario, Figure 1 represents the triangular distribution of a hypothetical risk scenario which has minimum estimate of \$100,000, a most-likely estimate of \$500,000 and a maximum estimate of \$2,500,000. The resulting cumulative distribution function (CDF) curve is shown as the solid black line. For each scenario generated in a Monte Carlo simulation, a value between 0 and 1 would be randomly assigned (as seen on the y-axis of the CDF). Using the random value, the representative cost is then determined (as reflected on the x-axis of the CDF). Figure 1 illustrates the results from three random successive cases where this particular event was assumed to take place (65%, 39%, and 21%) and the random probability represented by the CDF curve was then used by the model to assign a cost value for that case.

Figure 1. Monte-Carlo Method Using Random Probabilities



This process is conducted for each risk scenario for the stipulated number of trials. The more trials that are conducted, the smoother the resulting probability distribution function (PDF) becomes. As can be seen in Figure 2, as the number of trials is increased for a hypothetical triangular distribution, the PDF curve of the distribution becomes more defined. However, although the number of trials increases the definition of the distribution, the change in the CDF becomes smaller and smaller, so the efficiency of the Monte Carlo begins to drop, as shown in Table 4. As such, the number of trials best utilized for the Monte Carlo analysis resides in the window of good distribution definition and at the point of minimal decrease in efficiency.

Figure 2. Triangular Distribution Definition vs Number of Trials Conducted

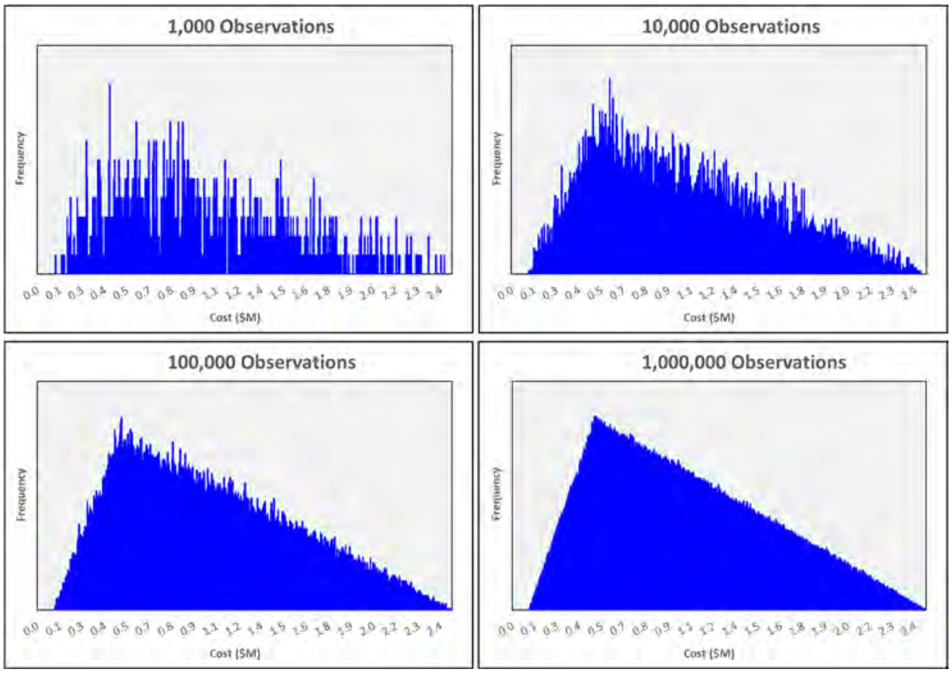


Table 4. Generated Mean from Increasing Trial Counts

Trial Count	Mean
1,000	$0.959 Million
10,000	$0.947 Million
100,000	$0.951 Million
1,000,000	$0.950 Million

For the Decatur project, 100,000 trials were utilized for the Monte Carlo analysis. For each risk scenario, random probabilities were assigned for each year of injection as well as the 10 years of post-injection monitoring and site care. Costs for each year were adjusted upward assuming that future inflation is projected based on an average historical rate of inflation (based on the Consumer Price Index)[29]. The costs for each risk scenario in each year were then totaled to create the total liability cost for that given year; afterward, the cost for that year was adjusted to present value using a long-term bond rate, such as the 10-year or 20-year treasury bond, that best matches the duration of the cashflows from the project[30]. The present values from all 100,000 trials of the Decatur project are shown in Figure 3, and the cumulative distribution of the trials is shown in Figure 4.

Figure 3. Probability Distribution of the Present Values from the Monte Carlo Analysis

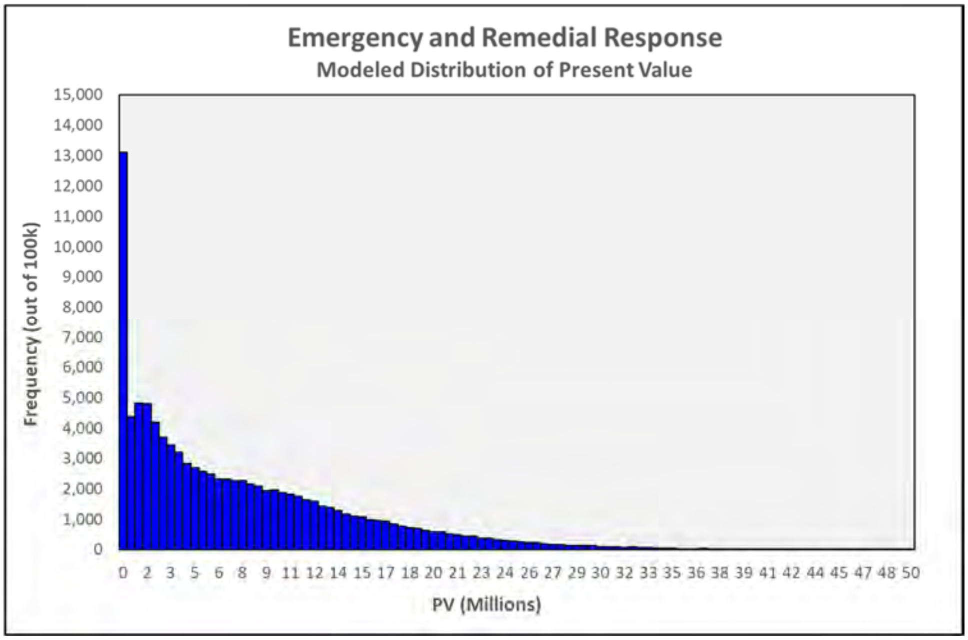
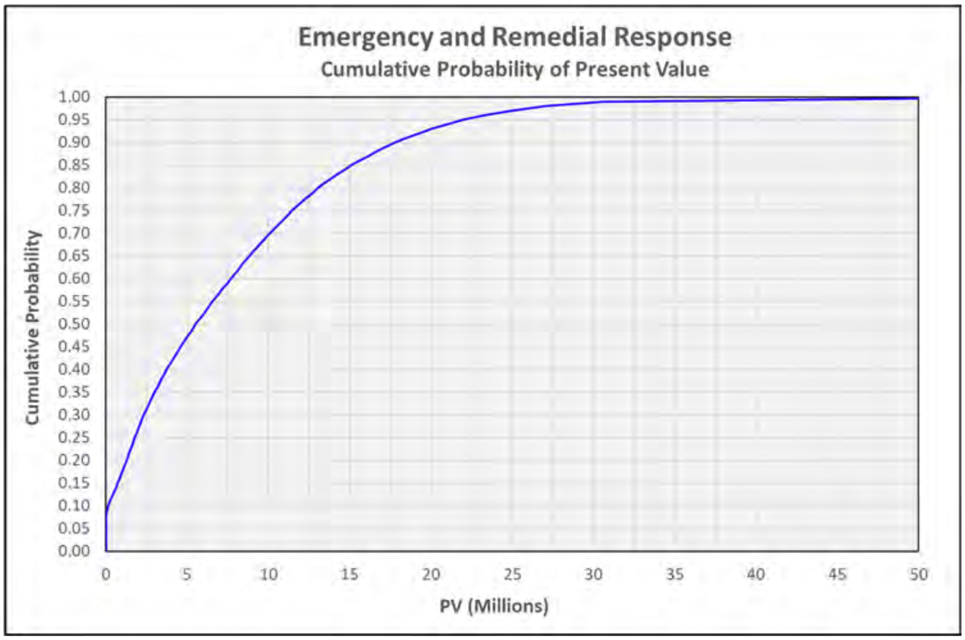


Figure 4. Cumulative Distribution of the Monte Carlo Analysis



To obtain the probable liability cost from the calculated distribution shown in Figure 4, the expected value needs to be determined. The expected value is the weighted average of the liability costs using the probability of occurrence of each cost for weighting[31]. The expected value also corresponds to the mean value of a distribution. The expected value of the Monte Carlo analysis generated for the Decatur project is approximately $5,530,000.

In addition to the expected value, the generated distribution also provides quantitative insight into the statistical "tails" of the distribution. In this case, roughly 10% of the distribution incurs $0 cost, whereas beyond three standard deviations from the mean, the distribution is fairly flat; this long "tail" is associated with those costs which are significant, but that are extremely unlikely to occur. This agrees with the probabilities presented in section 8.2, such that some of the probabilities of an event occurring are so unlikely that the practical cost is $0 almost 100% of the time. For example, risk scenario 10 (rapid leakage through caprock) has a probable occurrence of only 3 in 100,000,000. This also mirrors a similar analysis of Class I Hazardous Injection Wells which found low probabilities for occurrences of such events that ranged from 1 in 1,000,000 and 1 in 10 quadrillion[2].

For these reasons, the expected value of the distribution works well for a practical cost of liability. Beyond that, costs may become larger, but they also have a larger chance of not occurring than actually occurring. The expected value thus strikes a balance of matching the appropriate cost with the actual probable risk of occurrence.

References:

1. US EPA. Preamble: Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells; Final Rule.
2. Rish, William R. A probabilistic Risk Assessment of Class I Hazardous Waste Injection Wells.
3. US EPA. Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells.
4. Poulter, Susan; et al. Monte Carlo Simulation In Environmental Risk Assessment--Science, Policy And Legal Issues.
5. Trabucchi, Chiara; et al. Application of a Risk-Based Probabilistic Model (CCSvt Model) to Value Potential Risks Arising from Carbon Capture and Storage.
6. Trabucchi, Chiara; et al. A multi-disciplinary framework to monetize financial consequences arising from CCS projects and motivate effective financial responsibility.
7. Trabucchi, Chiara; et al. Valuation of Potential Risks Arising from a Model, Commercial-Scale CCS Project Site.
8. US EPA. Guiding Principles For Monte Carlo Analysis document.
9. Pawar, R; et al. Recent Advances In Risk Assessment And Risk Management Of Geologic CO2 Storage.
10. Quintessa Limited. Features, Events, and Processes Database. https://www.quintessa.org/co2fepdb/v2.0.0/
11. FutureGen EIS.
12. Shi, Ji-Quan; et al. A Methodology For CO2 Storage System Risk And Uncertainty Assessment.
13. Price, P.N. Carbon Sequestration Risks and Risk Management.
14. US EPA. Vulnerability Evaluation Framework For Geologic Sequestration Of Carbon Dioxide.
15. US EPA. Cost Analysis for the Federal Requirements Under the Underground Injection Control Program for Carbon Dioxide Geologic Sequestration Wells (Final GS Rule).
16. Hoffman, F.O.; et al. An Introductory Guide To Uncertainty Analysis In Environmental And Health Risk Assessment.
17. Jewell, Stephen. CO2 Storage Liabilities In The North Sea An Assessment Of Risks And Financial Consequences.
18. Pipeline and Hazardous Materials Safety Administration. Distribution, Transmission & Gathering, LNG, and Liquid Accident and Incident Data. Hazardous Liquid Accident Data – Pre 1986 Data Set. https://www.phmsa.dot.gov/data-and-

statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-accident-and-incident-data

19. Pipeline and Hazardous Materials Safety Administration. Distribution, Transmission & Gathering, LNG, and Liquid Accident and Incident Data. Hazardous Liquid Accident Data – 1986 to January 2002 Data Set. https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-accident-and-incident-data
20. Pipeline and Hazardous Materials Safety Administration. Distribution, Transmission & Gathering, LNG, and Liquid Accident and Incident Data. Hazardous Liquid Accident Data – January 2002 to December 2009 Data Set. https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-accident-and-incident-data
21. Pipeline and Hazardous Materials Safety Administration. Distribution, Transmission & Gathering, LNG, and Liquid Accident and Incident Data. Hazardous Liquid Accident Data – January 2010 to Present Data Set. https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-accident-and-incident-data
22. Nussey, Clive. Failure frequencies for major failures of high pressure storage vessels at COMAH sites: A comparison of data used by HSE and the Netherlands.
23. Harper, Peter; et al. Assessment of the major hazard potential of carbon dioxide (CO2).
24. Illinois Oil and Gas Resources Interactive Map. https://isgs.illinois.edu/illinois-oil-and-gas-resources-interactive-map
25. Illinois Water Well Interactive Map. https://isgs.illinois.edu/ilwater
26. US EPA. Use of Monte Carlo Simulation in Risk Assessments. https://www.epa.gov/risk/use-monte-carlo-simulation-risk-assessments
27. Decatur Illinois 2019 Census. https://datacommons.org/place/geoId/1718823
28. Lee, Yong-Gyo; et al. Ultimate Costs of the Disaster: Seven Years after the Deepwater Horizon Oil Spill.
29. Bureau of Labor Statistics CPI Database. https://www.bls.gov/cpi/
30. United States Treasury. https://home.treasury.gov/resource-center/data-chart-center/interest-rates/TextView?type=daily_treasury_yield_curve&field_tdr_date_value=2022
31. Anderson, David R.; et al. Modern Business Statistics. Cengage Learning. 2008.