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Energy & Environmental Research Center (EERC)

Implementing Financial Assurance for Class VI Emergency Remedial Response Actions

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OVERVIEW

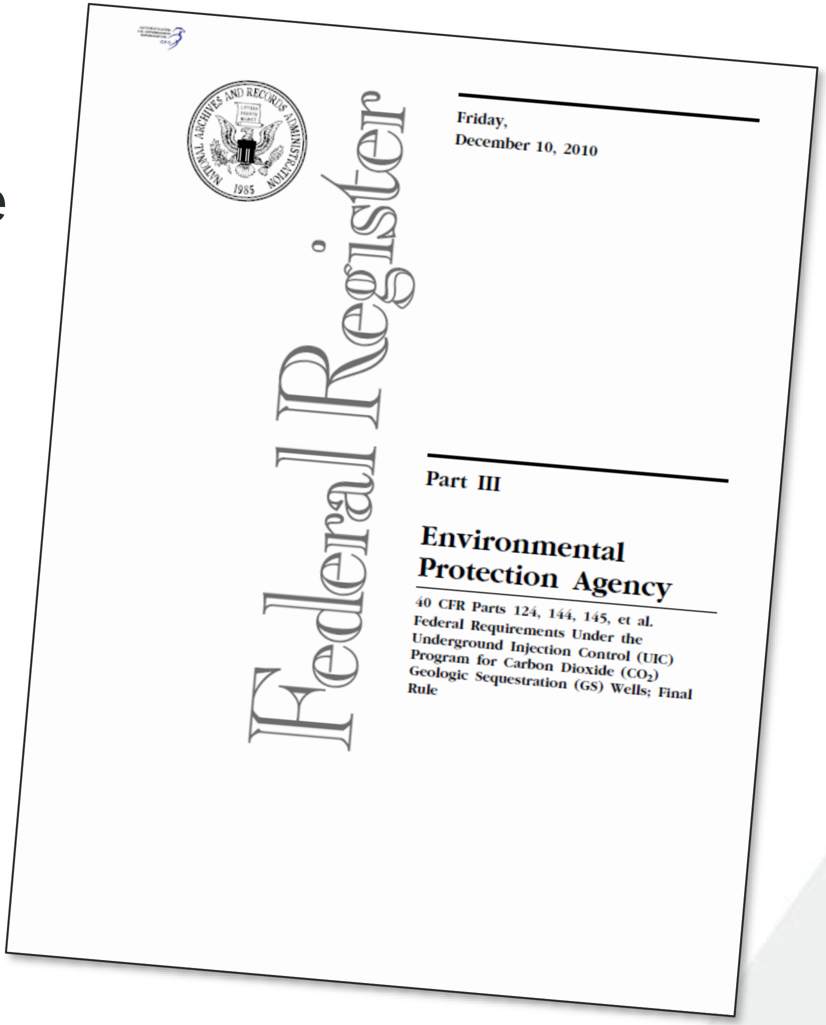
- Summarize the financial assurance demonstration plan (FADP) requirements and how they relate to the emergency and remedial response plan (ERRP).
- Review our technical approach for:
  - Identifying potential emergency events,
  - Their corresponding trigger events, and
  - The response actions.
- Discuss cost estimates and the challenges inherent in estimating these costs.

REQUIRED FADP COMPONENTS

The FADP must meet the regulatory requirements prescribed by the federal regulations for the underground injection control (UIC) program found in Title 40 of the Code of Federal Regulations (CFR) (Parts 124, 144, 145, 146, and 147).

- Corrective action on wells in the area of review (AOR)
- Postinjection site care (PISC)
- Facility closure
- **ERRP (the focus of this presentation)**
- Endangerment of underground sources of drinking water (USDWs)

Known to a reasonable degree of accuracy (corrective action on wells in the AOR, PISC, facility closure)



Federal Register

Friday,
December 10, 2010

Part III

Environmental Protection Agency

40 CFR Parts 124, 144, 145, et al.
Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells; Final Rule

RECOMMENDED FINANCIAL TOOLS

Table 4: Recommended financial responsibility instruments for GS activities (relative ranking)[10]

Corrective Action	Injection Well Plugging	Post-injection Site Care and Site Closure	Emergency and Remedial Response
1. Trust Fund	1. Trust Fund	1. Trust Fund	1. Insurance
2. Letter of Credit	2. Letter of Credit	2. Insurance	2. Letter of Credit**
3. Surety Bond	3. Surety Bond	3. Financial Test and Corporate Guarantee*	3. Surety Bond**
4. Escrow Account	4. Insurance	4. Surety Bond	4. Financial Test and Corporate Guarantee*
5. Financial Test and Corporate Guarantee*	5. Financial Test and Corporate Guarantee*	5. Escrow Account	5. Trust Fund
6. Insurance	6. Escrow Account	6. Letter of Credit	6. Escrow Account

*Financial tests and corporate guarantees present the lowest direct costs to owners or operators, but the highest risk to the public.
**Letters of credit and surety bonds are likely most appropriate for emergency and remedial response during operation phases.

- Source: EPA's Geologic Sequestration of Carbon Dioxide: Underground Injection Control (UIC) Program Class VI Financial Responsibility Guide https://www.epa.gov/sites/default/files/2015-06/documents/uicfinancialresponsibilityguidancefinal072011v.pdf

FINANCIAL RESPONSIBILITY

Phased Release from Financial Instrument
(define phases and associate with specific instrument)

Phase	Prep	Operational	Closure	Postclosure

Initial FR Demo Required for Permitting

Injection/Operation/Monitoring
Area of Review (AOR) Reevaluation and

Corrective Action and Phased Corrective Action

$0

Injection Well Plugging

$1 M

Postinjection Site Care and Facility Closure

~ $6 M

Emergency and Remedial Response and Endangerment of USDWs

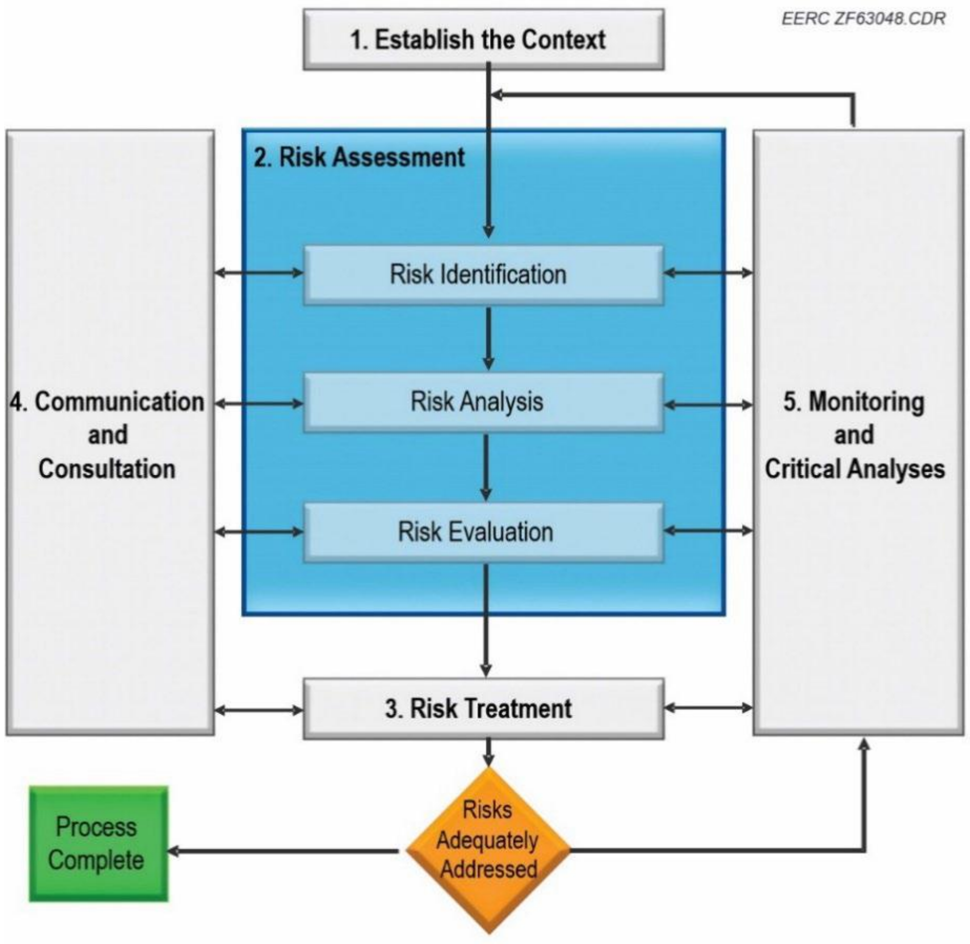
~ $13 M + ~ $3 M

INTERPLAY BETWEEN THE ERRP AND FADP

- **ERRP:** Describes what actions would be necessary in the unlikely event of an emergency at the storage project site or within the AOR to address the movement of the injection fluid or formation fluid in a manner that may endanger a USDW during the construction, operation, or PISC periods.
- **FADP:** Describes actions the storage project operator has taken and shall take to ensure state and federal regulators that sufficient financial support is in place to:
  - Cover the cost of any corrective action required at the storage facility during any operation phases, e.g., well plugging, PISC, and facility closure.
  - ***This includes implementing emergency and remedial response actions***.

RISK ASSESSMENT TO IDENTIFY EMERGENCY EVENTS

- Risk assessment is a process of:
  - Risk identification.
  - Risk analysis (likelihood and severity).
  - Risk evaluation.
- Through facilitated work group meetings with subject matter experts (SMEs), we identified a set of potential ***emergency events***.
  - *Events that pose an immediate or acute risk to human health, resources, or infrastructure and require a rapid, immediate response.*



EXAMPLE EMERGENCY EVENTS

Emergency Events

- **E1:** Failure of the CO_2 flow line
- **E2:** Integrity failure: injection well
- **E3:** Injector monitoring equipment failure
- **E4:** Integrity failure: monitoring well
- **E5:** Vertical migration of stored CO_2 and/or formation fluids (brine) from the storage reservoir to the USDW via pathways other than injection or monitoring wells
- **E6:** Natural disasters (seismicity and other)

Environmental Impacts

- **E7:** CO_2 or brine impacts to a USDW, surface water, and/or the land surface.
  – Each emergency event has the potential to result in environmental impacts.
  – These impacts are treated separately from the mitigations of the emergency events E1–E6.

Decomposing Events into Response Actions and Cost Ranges

Integrity Failure: Injection Well

ERRP-02: Integrity Failure: Injection Well			
Cost Element ERRP-02	Response Action	Cost Estimate, $ Low	High
1.0	Shutdown injection well	$ -	$ -
2.0	Diagnose injection well	$ 57,000	$ 100,000
2.1	Review injection history (e.g., pressure spike/drop or other anomalies) (<1 day)	$ 1,000	$ 5,000
2.2	Internal and external well pressure test (< 1 day). Assumes casing tubing annulus and inside tubing.	$ 1,000	$ 10,000
2.3	Download and interpret well fiber optic data (1 to 7 days)	$ 5,000	$ 10,000
2.4	Pulsed-neutron well logs (PNLs) (1 to 7 days)	$ 50,000	$ 75,000
3.0	Workover rig (5 to 30 days)	$ 50,000	$ 300,000
4.0	Other downhole measurements and/or tests - ultrasonic tool (UST) logging	$ 25,000	$ 50,000
5.0	Scenario severities		
5.1	Minor case (e.g., replace seals in the packer, replace tubing joints, etc.)	$ 25,000	$ 100,000
5.2	Moderate case (e.g., casing integrity failure, cement squeeze job, casing patch, etc.)	$ 100,000	$ 1,500,000
5.3	Major case (unable to repair, must plug and abandon [P&A] the well, and drill a new injection well)	$ 10,200,000	$ 15,500,000
5.3.1	P&A the injection well	$ 200,000	$ 500,000
5.3.2	Drill and complete a new injection well	$ 10,000,000	$ 15,000,000
5.4	Worst case addition of environmental impacts at the surface	$ 12,700,000	$ 23,500,000
5.4.1	P&A the injection well	$ 200,000	$ 500,000
5.4.2	Drill and complete a new injection well	$ 10,000,000	$ 15,000,000
5.4.3	Additional environmental impacts (see ERRP-07)	$ 2,500,000	$ 8,000,000
6.0	Diagnose additional injection well on the well pad (if needed reference back 2.1-2.4)	$ 57,000	$ 95,000
6.1	Review injection history (e.g., pressure spike/drop or other anomalies) (<1 day)	$ 1,000	$ 5,000
6.2	Internal and external well pressure test (< 1 day)	$ 1,000	$ 5,000
6.3	Download and interpret well fiber optic data (1 to 7 days)	$ 5,000	$ 10,000
6.4	Pulsed-neutron well logs (PNLs) (1 to 7 days)	$ 50,000	$ 75,000
	GRAND TOTAL (MINOR CASE)	**$ 157,000**	**$ 550,000**
	GRAND TOTAL (MODERATE CASE)	**$ 232,000**	**$ 1,950,000**
	GRAND TOTAL (MAJOR CASE)	**$ 10,332,000**	**$ 15,950,000**
	GRAND TOTAL (WORST CASE)	**$ 12,832,000**	**$ 23,950,000**

Total cost is sensitive to the severity of the failure and its associated environmental impacts.

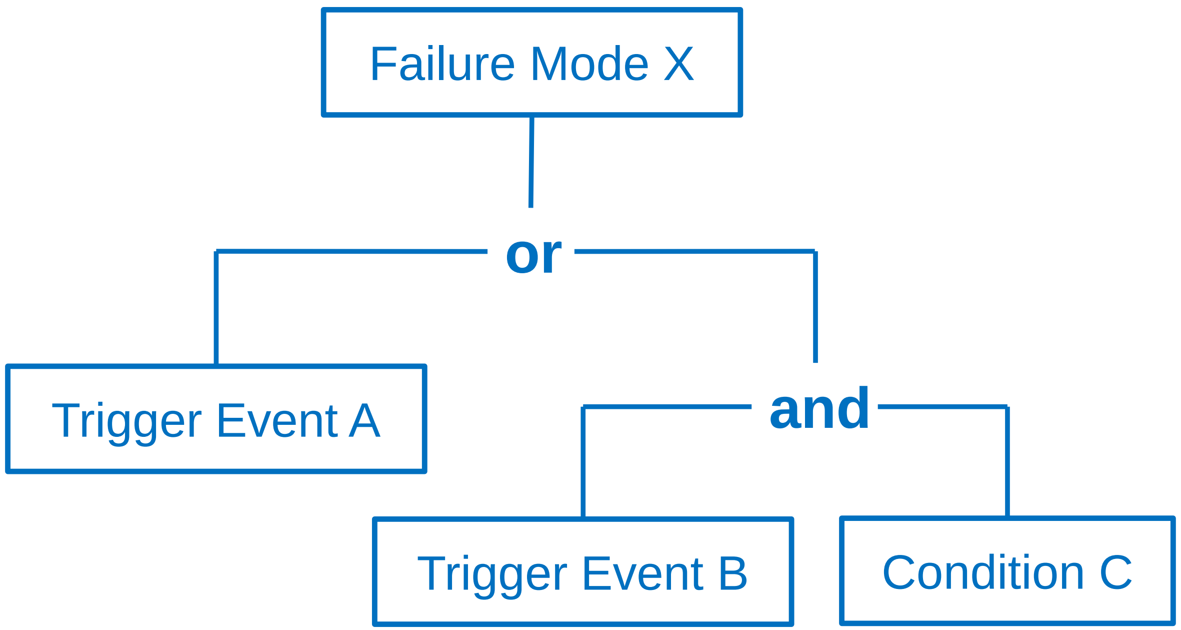
ERRP-07: CO_2 or brine impacts to a USDW, surface water, and/or the land surface			
Cost Element ERRP-02	Response Action	Cost Estimate, $ Low	High
1.0	Site investigation to determine the nature and extent of environmental impacts.	$ 1,000,000	$ 2,000,000
2.0	Replace the USDW water supply for agricultural, livestock, and/or human consumption.	$ 500,000	$ 1,000,000
3.0	Long-term monitoring of environmental media as part of the MNR remedial action.	$ 1,000,000	$ 5,000,000
	GRAND TOTAL	**$ 2,500,000**	**$ 8,000,000**

Note: Costs are generic and not project-specific.

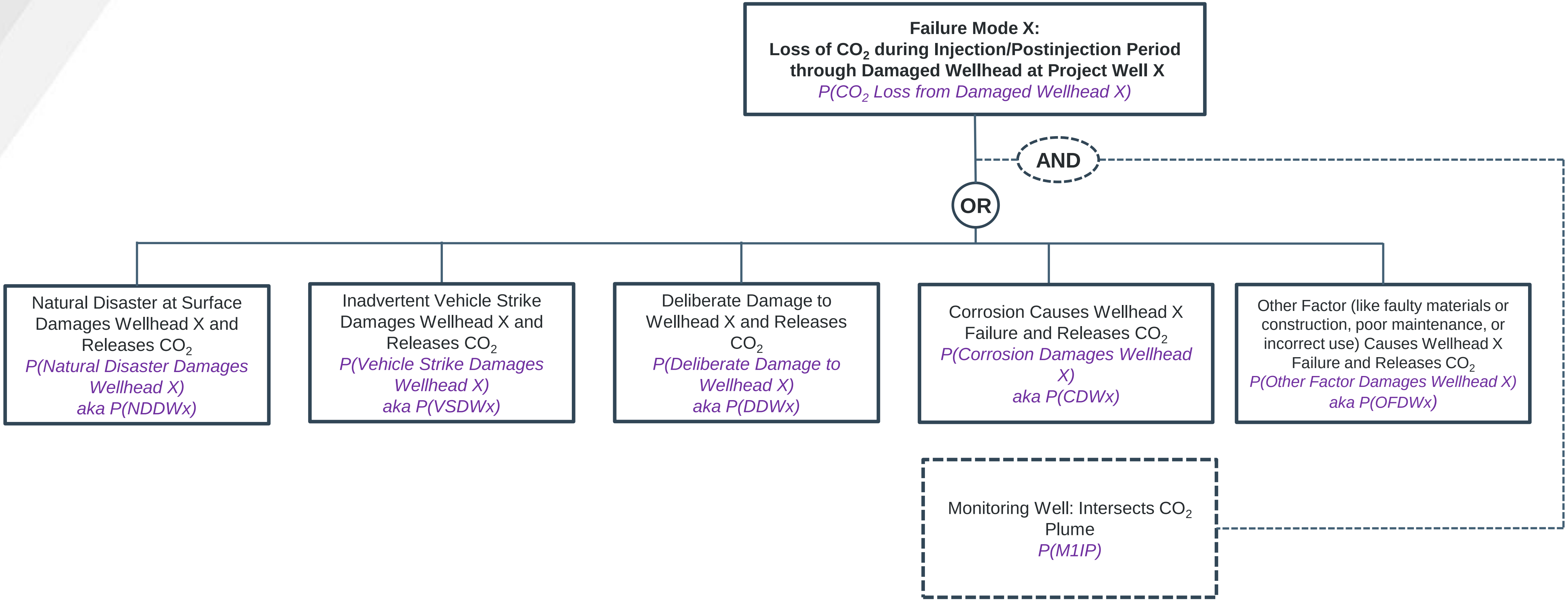
QUANTITATIVE RISK ANALYSIS TO ASSESS PROBABILITIES

Fault Trees

- Well-established analytical approach (e.g., DOE, DOD)
- Builds up the probability of failure from combinations of “trigger events”
- Assesses trigger probabilities via expert judgment informed by modeling and available site data



HYPOTHETICAL FAULT TREE EXAMPLE



P(CO_2 Loss From Damaged Injection Wellhead X) = P(NDDWx U VSDWx U DDWx U CDWx U OFDWx)

= 1 – [1-P(NDDWx)][1-P(VSDWx)][1-P(DDWx)][1-P(CDWx)][1-P(OFDWx)]

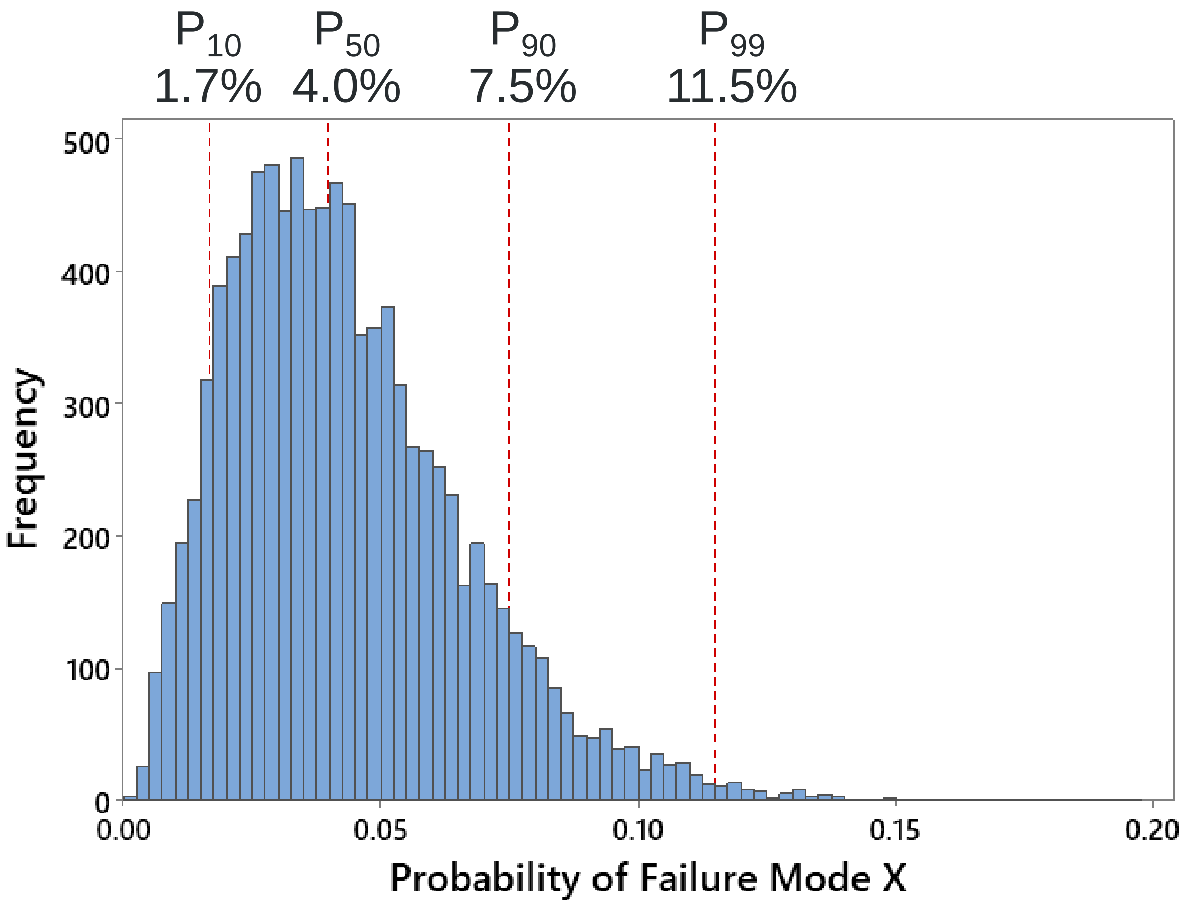
P(CO_2 Loss from Damaged Wellhead M1) = multiply corresponding expression above by P(M1IP)

PROBABILITY-WEIGHTED COST ESTIMATES

- Using the fault tree probabilities, we can estimate the expected likelihood (P_{50}) and uncertainty of emergency events.
- We can use these probabilities to generate probability-weighted total costs in the FADP.

$$(\text{Total Cost} \times \text{Probability})$$

- To date, most FADPs have assumed a 100% likelihood of emergency events (Probability = 1), resulting in the maximum amount.



SUMMARY AND CONCLUSIONS

- The FADP must meet the regulatory requirements for the UIC program, which includes implementing emergency and remedial response actions.
- Our process includes a risk-based methodology for identifying potential emergency events and deconstructing those events into sets of response actions.
- Cost ranges for response actions are derived from expert judgment and, where applicable, commercial quotes.
- Estimating the costs of the emergency response actions is challenging since no remediation measures dedicated to CO_2 storage impacts have been documented.
- Quantitative risk analysis methods like fault trees provide a technical approach for addressing uncertainties in the likelihood of emergency events, their severity, and their associated costs.

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