

**REPORT AND RECOMMENDATIONS OF  
THE CARBON SEQUESTRATION WORKING GROUP  
TO  
THE JOINT MINERALS, BUSINESS AND  
ECONOMIC DEVELOPMENT COMMITTEE  
AND  
THE JOINT JUDICIAL COMMITTEE OF THE  
WYOMING STATE LEGISLATURE**

September 2009

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## EXECUTIVE SUMMARY

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### *Background*

The United States is in the midst of a transition to a low carbon intensive economy. Our historical reliance upon fossil fuels for affordable and reliable power has expanded to include additional demands for lower carbon resources and a desired increased reliance on domestic fuel sources. Given our nation's traditional energy infrastructure, the size and scope of the transition, our national and global dependence on fossil fuels today and projected into the future, geologic carbon sequestration is likely to play an important role in our future energy economy.

This transition to a lower carbon based energy mix has significant implications for Wyoming's economy. Geologic carbon sequestration of carbon dioxide provides a mechanism for a continued role for Wyoming's abundant carbon based resources in a low carbon intensive economy.

### *The Carbon Sequestration Working Group (CSWG) Task*

Two years ago, Wyoming's leadership recognized that without a financial assurance foundation to address liability issues, geologic carbon sequestration would likely fail to advance as part of the solution in a low carbon energy economy. The legislature identified the need to develop a financial assurance regime which offers assurances to both the public and private sector and which appropriately manages the risks inherent to geologic carbon sequestration activities in Wyoming.

The CSWG sought to develop an integrated framework which provided a menu of financial instruments to project developers that ensure funds are adequate (if and when needed) and readily available to pay for site closure, post-closure and corrective activities, both now and in the future in the event of default by the permit holder or failure of the containment zone after the end of the permit term.

### *The Phases of Geologic Sequestration*

The CSWG identified four phases in the geologic sequestration process for which FA needs to be considered. They are:

- Site characterization and permitting;
- Operations including injection, monitoring and closure tasks;
- Post-closure including monitoring until plume stabilization is confirmed; and
- Long-term stewardship after bond release and permit termination, where the sequestration site still requires periodic monitoring to confirm it remains stable over an indefinite period of time.

## *The Risks of Geologic Sequestration*

While the Environmental Protection Agency has to this point only considered risks to drinking water in their discussion of geologic sequestration, the CSWG identified a much wider range of risks. Key risks were categorized by phase and linked directly to activities, events and features associated with geologic sequestration. The following were identified as the major categories of risk associated with geologic sequestration.

- Contamination of underground sources of water, which may include potable water,
- Trespass (mineral rights infringement),
- Atmospheric releases of carbon dioxide, and
- Property damage (including changes to surface topography and structures).

These key risks were further expanded upon and explored to estimate potential financial assurance limits. Special consideration was given to the potential effects of fluid displacement in Wyoming's saline aquifers and the potential need for brine removal pressure relief along the hydraulic front.

## *Financial Assurance Levels*

This report sets average levels for financial assurance based on the initial cost estimates for reclamation and mitigation activities for key risk categories. Cost estimates will vary greatly based on specific site attributes and need to be further refined with risk management modeling to develop accurate risk management plans and financial assurance requirements. Good site selection and risk assessment during the permitting phase is of critical importance in reducing and estimating risk and will influence FA requirements.

Based on a sample Wyoming project injecting 2-4 million tons/year of CO<sub>2</sub> over a period of 30 years the total financial assurance requirement is \$77 million. A portion of financial assurance is applicable to bonding, and a portion is applicable to insurance. Recommended ranges for a mid-size operation through post-closure were estimated at \$40-50 million and \$25-45 million, for bonding and insurance respectively. Numbers will vary based on site specific, project specific attributes and a comprehensive risk assessment needs to be completed for each project. Financial assurance levels should also be reviewed periodically and revised accordingly based on project performance and risk assessments. The project modeled intends to provide an order of magnitude on the FA costs for a sample project, major categories of cost and the likely distribution between bonding and insurance levels.

## *Financial Assurance Recommendations*

The CSWG explored the following forms of financial assurance to address risk events: third-party instruments (surety bonds, collateral bonds, insurance), self-insurance (financial test, corporate guarantee) and public and public/private frameworks (MMV accounts and trust/compensation funds). From this, the group established definitions and identified those forms most appropriate for each project phase considering each risk mitigation activity. Trespass and non-causally-connected events were not considered for financial assurance. Specific recommendations follow:

- DEQ should be afforded flexibility to promulgate rules allowing different financial assurance methods and adjustment mechanisms to account for site specific risk, the phase of the project and the specific risk mitigation activity addressed.

- Traditional performance bonds, self bonds and deposits are generally preferred. They work well especially for obligations that are readily capable of cost estimating such as replacement of well components, well control procedures, reservoir pressure reduction techniques, site restoration and reclamation, well closure and abandonment, and post-closure monitoring activities. Self-bonds are not recommended during the Post-closure Phase. The procedures to establish, revise, release and/or forfeit performance bonds can be largely taken from those applicable to surface coal mining operations.
- Because bonds and deposits may not be available or appropriate for larger risks, particularly unanticipated one-time events, non-traditional environmental impairment or special risk insurance was considered by the CSWG as an option for financial assurance against larger site-specific risks during active geologic carbon sequestration. The procedures would be similar to those for performance bonds except that an annual review is advised and language would be needed to reflect a claims procedure (as opposed to bond forfeiture). The State should be a named insured, and statutory language would clarify that insurance would not constitute a waiver of the State's immunity under the Governmental Claims Act.
- Traditional public liability insurance is recommended as protection against third-party claims, similar to that required for surface coal mining operations.
- A Wyoming Special Revenue Account is recommended to cover DEQ's costs in measurement, monitoring and verification during the Long-term Stewardship Phase. This Account would be funded by project operators during the life of the project and administered by DEQ.
- Insurance may not be well suited to manage risks that are present when the geologic sequestration facility is well past its active life and either the permit has terminated, financial assurance is unavailable, or all financial assurance instruments have been exhausted. Given this, a privately funded-publicly managed Wyoming Trust Fund is considered on the condition that a Federal Trust Fund is also created to assume liability in the Long-term Stewardship period. A Wyoming Trust Fund would be privately-funded through a fee paid by geologic sequestration operators during the life of the project, with a tiered funding mechanism and administration by DEQ. This Fund is not recommended in the Draft Statute but is explored as a Concept Paper as an Appendix to the report.
- Given the complexity of the various financial instruments and the financial industry, combined with the relatively early state of geologic carbon sequestration industry development and the extremely long-term nature of a sequestration project, the legislature should authorize and fund a minimum of three new positions: (1) Financial Analyst, (2) Geophysical Engineer or Geological Engineer, and (3) Reservoir Engineer.

### *The Duration of the Post-Closure Period*

EPA currently defines the post-closure care period to include the Long-term Stewardship phase. Several States have indicated a post-closure care period ranging from 10 to 100 years. The CSWG recommends the following requirements for the Post-closure care period:

- That period of time necessary for the operator to show plume stabilization is achieved without the use of control equipment, based on a minimum of three consecutive years of data showing no change in plume dynamics.
- At a minimum, the post-closure care period should be no less than 10 years from the time of last CO<sub>2</sub> injection, appropriate plugging and abandonment of all wells (excluding monitoring wells), cessation of all subsurface operations and activities, and appropriate removal and abandonment of all surface equipment and improvements.
- DEQ should be authorized to develop rules setting the standards and criteria for determining and verifying CO<sub>2</sub> plume stabilization.
- DEQ should issue certificates of closure certifying that the plume has stabilized and the operator has completed all injection operations, well closure, reclamation, and all required monitoring and remediation activities.

### *Additional Market and Federal Government Impacts*

A few additional factors warrant comment as well. First, permanent geologic sequestration of carbon dioxide is in its infancy. Projects currently in development will add much to the body of knowledge about this process and most certainly reduce the uncertainty regarding potential long term impacts on geologic sequestration. Development of multiple geologic carbon sequestration pilot and commercial scale demonstration projects will likely significantly enhance the accuracy and availability of financial assurance resources which satisfy the State and are reasonable for the private sector. Due to the nascent nature of the industry and the extremely long time horizon for a project, any financial assurance system should also provide sufficient flexibility to adjust for actual operating history, calculable loss events and completion of project phases, as these projects develop and perform in years to come.

Second, liability assumption by the Federal government in the Long-Term Stewardship phase is a critical component to any system. Federal legislation has been proposed in both the House and Senate to address the Long-term Stewardship liability requirements. Any federal legislation will affect state programs and related FA mechanisms and should be closely monitored.

## SCOPE AND AUTHORITIES

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HB 90 Section 1 amended the Environmental Quality Act (EQA) to provide for the regulation of geologic carbon sequestration by the Department of Environmental Quality and the Oil and Gas Conservation Commission. The report which follows derives from the purpose and requested recommendation specified in section 35-11-313(g) of the Wyoming Statute which:

“Authorizes the state geologist, oil and gas supervisor and the director to convene a working group for the purpose of developing an appropriate bonding procedure and other financial assurance methods to assure adequate financial resources are provided to pay for mitigation or reclamation costs that the state may incur as a result of default by the permit holder, which bond or other financial assurance requirement shall be required during the operating life and throughout the post-closure care period. The working group shall recommend the duration of the post-closure care period.”

A copy of HB90 is attached as Appendix A.

## **WORKING GROUP PARTICIPANTS**

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### **WORKING GROUP CONVENERS**

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## Acknowledgments

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This report is the product of a dedicated group of professionals who put in numerous hours of work participating in meetings and conference calls, contributing their professional experience, research and analyses, and taking valuable time to travel to working group meetings.

In addition to the members of the working group, a number of other experts and industry professionals contributed to the body of knowledge that informed the development of this product. The working group would like to especially thank Daniela Golden of the EPA; Bob Van Voorhees of Bryan Cave LLP; John Villar, a private energy consultant; Fred Eames of Hunton & Williams on behalf of the Carbon Capture and Sequestration Alliance; Malcolm Anderson of Southern California Edison; Lindene Patton of Zurich Financial Services; Rick Hawkinberry of the Willis Environmental Practice; Dwight Peters of Schlumberger Carbon Services; Rick Adcock of the Camco International Group; Brian McPherson of the Southwest Regional Partnership on Carbon Sequestration, Brian Jeffries of the Wyoming Pipeline Authority and Frank Alix of Powerspan Corporation for their contributions to this effort.

Special thanks also go to Chiara Trabucchi of Industrial Economics, Inc. and Sarah Wade of AJW, Inc. who shared their professional experience and published research with the group, responded thoughtfully to specific working group questions and reviewed draft reports.

## Summary of Public Comment

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The work of the Working Group was set up to be an open process with all meetings open to the public and opportunities always given for public input. All meetings were advertised in at least the local paper where the meeting was held and posted on the web site. In some cases, individual e-mails were sent to parties who had expressed an interest in attending. The web site was also used to post information about what information was presented at the meetings and all presentations to the group were posted there for subsequent reference.

Throughout the course of the seven meetings there were a number of visitors representing a wide variety of constituencies. Included among them were: members of affected industry groups, other State agencies, environmental groups, private citizens and the media. Most of the industry members present were interested in how their business or organization might be affected by this process, but did not offer any suggestions to the group. One business group expressed an interest in developing contacts for eventual purchase and trading of carbon credits and an environmental group stated support for keeping the working group process open to the public.

## BACKGROUND

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Wyoming's coal industry is deeply rooted in the State's history, its economy and its future. Today, Wyoming's fossil-based industries meet more than 10% of our nation's energy demands predominantly through the extraction and export of coal, natural gas and oil. Revenues from mineral extraction and energy development provide roughly 70% of the State's income. Wyoming's exceptional natural resources extend to its geologic capacity for permanent sequestration of carbon dioxide. Formations in southwestern and central Wyoming have been identified by the State Geologist and the DOE National Energy Technology Laboratory (NETL) as some of the best potential sites for long-term geologic sequestration of carbon dioxide in the United States.

The United States is in the midst of a transition to a low carbon intensive economy. Our historical reliance upon fossil fuels for affordable and reliable power has been expanded to include additional demands for lower carbon resources and a desired increased reliance on domestic fuel sources. Given our traditional energy infrastructure, the size and scope of this transition, our national and global dependence on fossil fuels today and projected into the future, geologic carbon sequestration is likely to play a vital role in a successful transition to a low carbon intensive economy.

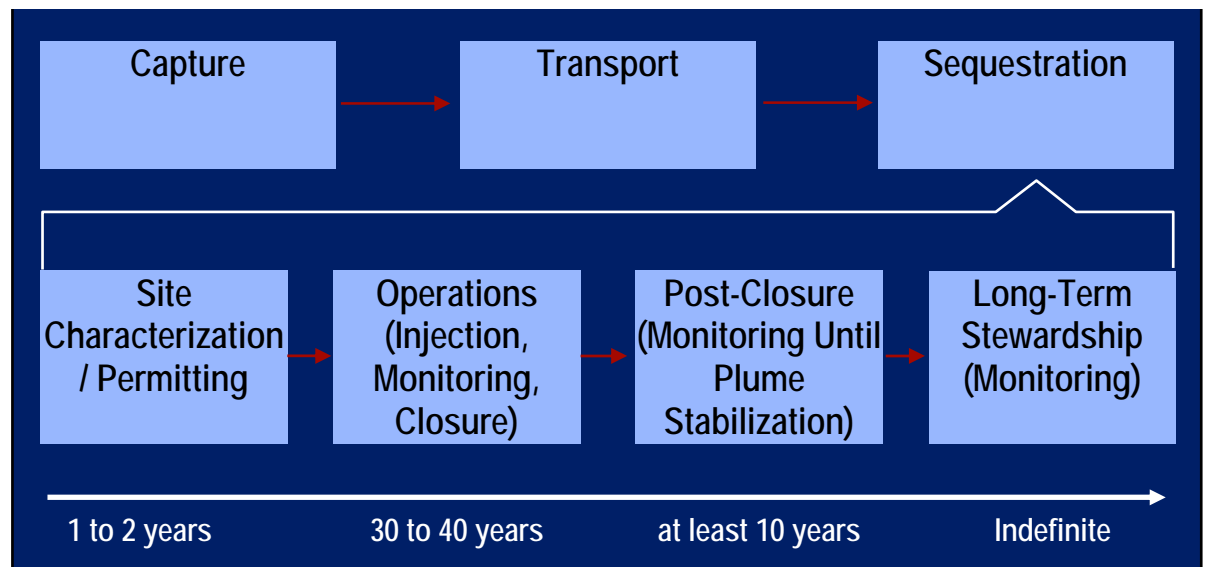
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## WHAT IS GEOLOGIC CARBON SEQUESTRATION OF CARBON DIOXIDE?

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Geologic carbon sequestration is the injection of carbon dioxide and associated constituents into subsurface geologic formations in order to permanently prevent their release into the atmosphere. Once injected, carbon dioxide becomes further entrained in the rock formation by becoming trapped within the pore space, dissolved in formation fluids, or mineralized. Figure 1 highlights the entire carbon capture and geologic sequestration process as well as the components within the sequestration phase and potential timeframes associated with each phase. Phase durations will vary on a project by project basis.

**Figure 1: Phases of Geologic Sequestration**



For the purposes of developing a financial assurance framework, the sequestration process can be divided into four phases;

- Site characterization and permitting (estimated at 1-2 years);

- Operations including injection, monitoring and closure tasks (estimated at 30-40 years);
- Post-closure including monitoring until plume stabilization is confirmed (estimated to be at least 10 years and duration is tied to plume stabilization characteristics); and
- Long-term Stewardship including intermittent monitoring to confirm site remains stable over time (indefinite period of time) and, potentially, future corrective actions, if warranted.

A more detailed description of the various phases of geologic carbon sequestration can be found in Appendix B.

## WHAT IS FINANCIAL ASSURANCE?

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Wyoming requires permittees/operators to provide for safe and environmentally sound operations associated with permitted activities as well as adequate reclamation for impacts associated with the activities at the conclusion of operation. “*Financial Assurance*” is the requirement that permittee/operators demonstrate either adequate financial ability or adequate available financial resources to complete their permit or enforcement obligations in the event of default by the permit holder or other related third parties. The types of financial assurance mechanisms explored here are third-party instruments (surety bonds, collateral bonds, insurance), self-insurance (financial test, corporate guarantee) and public and public/private frameworks (trust/compensation funds).

This report begins with a definition of each type of financial assurance and citation of key risks to the regulator and permittee/operator as well as the applicability of the instrument for geologic carbon sequestration. Procedural recommendations to the regulator are also provided. These recommendations are intended to reduce risks of a particular financial assurance method for use in a geologic carbon sequestration project.

The report also identifies the type of financial assurance most applicable during each project phase and by each risk mitigation activity. The regulatory authority should be afforded the flexibility to allow for different financial assurance methods and adjustment mechanisms which account for site specific risk, the phase of the project and the specific risk mitigation activity addressed.

## WHY IS A FINANCIAL ASSURANCE FRAMEWORK FOR GEOLOGIC CARBON SEQUESTRATION IMPORTANT?

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Two years ago the Wyoming Legislature and Governor began to develop the legal and regulatory foundation for geologic carbon sequestration activities in Wyoming. Wyoming's leadership recognized that without a financial assurance foundation, to address liability issues, geologic carbon sequestration would likely fail to advance as part of the solution in a low carbon energy economy. Further, the legislature identified the need to develop a financial assurance regime which offers assurances to both the public and private sector and which appropriately manages the risks inherent to geologic carbon sequestration activities in Wyoming.

One financial risk management expert succinctly summarized the need for a financial assurance framework stating:

*"The design of a geologic carbon sequestration liability regime is essential to offer assurances both to the public and private sector that the risk of leakage/migration and other potential risks associated with geologic carbon sequestration are appropriately managed. An integrated framework is needed to provide a menu of financial instruments to project developers that ensure funds are adequate (if and when needed) and readily available to pay for site closure, post-closure and remedial activities, both now and in the future in the event of default by the permit holder or failure of the containment zone after the end of the permit term. A carbon sequestration liability regime will provide interested stakeholders with the assurance that the non-zero probability of carbon dioxide leakage has been considered and an appropriate public policy response exists."*

*Chiara Trabucchi, Principal, Industrial Economics, Inc.*

Geologic carbon sequestration is relatively unproven with many technological, economic, regulatory and political challenges yet to be resolved. Currently there are no U.S. commercial scale projects in existence with storage in saline aquifers. The DOE commitment for geologic carbon sequestration through the American Recovery and Reinvestment Act as well as proposed 2010 budget allocations for up to 10 demonstration projects will allow for critical investments which will help to prove the safety and effectiveness of geologic carbon sequestration and the financial assurance framework needed to protect the public.

The financial, technical, policy and market forces which impact the viability and timing of commercial scale geologic carbon sequestration system fall outside the scope of this report. Nevertheless, a brief summary of the status of these issues is important. The early stage of project and industry development appears to affect the availability of third party financial instruments for purposes of demonstrating financial assurance, particularly in later stages of a project.

At present, third party insurance brokers are willing to extend limited coverage during the post-closure phase, but currently are not willing to extend coverage during the Long-term Stewardship phase. According to prospective project developers, pilot and commercial projects have been postponed or canceled, in part, due to the lack of availability of financial assurance for all phases of a project.

The nascent nature of the industry affected the Working Group's best efforts at estimating risk. Estimates of how much financial assurance is needed to support each phase of the carbon sequestration process vary widely and require further analysis by financial and risk management professionals equipped with statistical and economic modeling tools and based on real projects in the coming years. Financial assurance

requirements should be amended as appropriate based on actual results and/or improved modeling estimates.

Given the early state of industry development and the extremely long-term nature of the projects (50 years or more), any financial assurance framework needs to be flexible and easily amended as our nation tests the science and builds a track record in successful large scale demonstration projects. The financial assurance framework needs to allow for new developments while simultaneously ensuring that funds are adequate and available to pay for activities in each phase of the project.

It is important to understand that financial assurance not only encourages compliance and provides funds to the State in the event of operator default, but these instruments, particularly insurance instruments, may be available for third-party liability claims.

Third-party liability claims could be based on:

- 1) contract (e.g., permit);
- 2) negligence and negligence per se;
- 3) trespass;
- 4) nuisance; and
- 5) strict liability theories.

See Appendix C *Summary of Legal Liability Theories*. The legislature could consider creating one or more statutory causes of action (see, e.g., Wyo. Stat. §35-11-416(b)), with an eye to reconciling the various liability theories. This might help manage risk and make insurance products more available and affordable.

It is important to envision how this industry might develop and impact Wyoming for many years to come. Wyoming is well suited to become a regional hub for the development of geologic carbon sequestration. This economic development likely brings a host of issues related to education and training, labor availability, technological development, infrastructure development and local community impacts.

Further, if Wyoming's saline aquifers become a significant carbon dioxide sink, Wyoming will need to address both intrastate and interstate transfers of carbon dioxide and the related Federal interstate commerce laws as well as consider the implications for its indigenous power consumption. Water laws may also be affected as a result of the significant fluid displacement that is expected from injecting massive quantities of carbon dioxide. These issues fall outside the bounds of this group's scope of work, but merit mentioning to underscore the vast array of opportunities and challenges geologic carbon sequestration presents for Wyoming's future.

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## Recommendation Development Process

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Shortly after HB 090 was enacted in July, 2008, the State Geologist, the Director of the Department of Environmental Quality, and the Supervisor of the Oil and Gas Conservation Commission appointed an 11 person working group. Group members were selected from a variety of backgrounds and expertise, many of whom will likely be involved in or affected by geologic carbon sequestration activities in Wyoming.

Once the working group was formed, a charter was developed to guide the work of the group. This charter is included as Appendix D. The group sought to develop a risk management framework that protected the State and provided a realistic and reasonable structure which would support the development of geologic carbon sequestration projects. A series of information gathering meetings were held throughout 2008 to lay the groundwork for development of the recommendations called for in the Statute.

During this phase of the group's work, 20 presentations were made on a number of topics including but not limited to:

- Technologies of carbon capture, transport, injection and related geology;
- Existing financial assurance mechanisms;
- Projected financial assurance mechanisms for geologic carbon sequestration;
- Risk assessment approaches for geologic carbon sequestration; and
- Third party insurance underwriter and broker assessment of financial assurance for geologic carbon sequestration.

A summary of the presentation materials as well as additional reference materials is listed in Appendix E. These presentation materials are available on disk and by hard copy upon request. Presentation materials are also available on-line at:

<http://deq.state.wy.us/carbonsequestration.htm> and <http://wogcc.state.wy.us/>.

In early 2009, the working group divided into three sub-groups with specific focus areas in risk attributes, cost, and regulatory issues. The sub-groups utilized publications and presentations, material from the United States Department of Energy Carbon Sequestration Regional Partnerships and input from other industry experts to conduct independent analysis, debate key issues and develop specific recommendations. Several of the tools which the group developed and which formed the basis for the quantitative recommendations included in this report are included as appendices and on the disk of reference materials. Draft statutory language accompanies this report and is included in Appendix F for consideration by the legislature.

In order to prepare this recommendation, the group identified key risks inherent to geologic carbon sequestration and developed cost estimates for mitigation and reclamation for specific risks that may occur during each phase of the sequestration process. Cost estimates were based on other similar oil and gas activities and on the presumption of good site selection and a rigorous permitting process. The group reviewed the attributes and availability of financial assurance mechanisms for these types of risk at both the State and Federal level. From this work, the group identified a suite of financial assurance vehicles that are appropriate for different project phases and dollar amounts. The group also developed a recommendation for the duration of the post-closure care period.

The group believes it has responded to the request outlined in the Statute and that this information provides a good foundation for a financial assurance system. However, additional work remains to be done to provide comfort to financial assurance providers and companies interested in geologic carbon sequestration. Development of accurate and reliable remediation and mitigation cost estimates requires actuarial and financial modeling and actual project experience.

Resolution of a Federal versus State versus private indemnity model for the Long-term Stewardship phase remains an open and critical issue. The group believes that a Federal indemnity model to address the Long-Term Stewardship phase risk is necessary and appropriate because CO2 emissions are not bound by state lines and the storage of CO2 is a public interest. However, another potential Long-Term Stewardship and Care Trust Fund model which provides for a shared Federal and State managed indemnity model is contemplated in Appendix G. The group has not reached consensus on this model but it is provided to highlight one potential Trust Fund model.

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## REPORT FORMAT

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Having outlined the approach to the work and the need to develop a geologic carbon sequestration financial assurance framework, the balance of the report is organized to respond separately and substantively to the request outlined in the Statute. A recommendation is provided for an appropriate bonding procedure and other financial assurance methods which ensure adequate financial resources are available to pay for the mitigation or reclamation costs the State may incur as a result of default by the permit holder at any stage of the project. A recommendation for the duration of the post-closure period is also provided. To address each component of this request, the balance of the report is broken down into the following sections:

- A review of financial assurance, specific types of financial assurance, risks and applicability of each form of financial assurance for geologic carbon sequestration;
- A summary of the key risks and potential impacts of geologic carbon sequestration broken down by each phase of a geologic carbon sequestration project;
- A review of projected costs for mitigation and reclamation for selected risks;
- Recommendation of financial assurance levels and appropriate split between third party financial assurance methods;
- Recommendation of the duration of the post-closure care period;
- Recommendation of a draft statute, and
- Summary of findings and recommendations.

Background materials supporting the quantitative and qualitative work completed to design the risk management framework can be found in the Appendices.

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## Financial Assurance Key Considerations and Definitions

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### *Surety Bond*

A “*surety bond*” is an indemnity agreement in a sum certain payable to the State, executed by a principal (the permittee/operator), which is supported by the performance guarantee of a corporation licensed to do business as a surety in the State where the operation is located. The surety ensures that the principal’s obligations will be performed if the principal fails to uphold its promises to the State up to the maximum amount that the surety is required to pay in the event of the principal’s default. This “sum certain” allows the surety to assess the risk involved in giving the bond, and the premium charged is determined accordingly. If the principal defaults and the surety turns out to be insolvent, the bond fails. Thus, the surety on a bond is usually an insurance company whose solvency is verified by private audit, governmental regulation, or both. State insurance commissioners are responsible for regulating corporate surety activities within their jurisdictions. The commissioners also license and regulate brokers or agents who sell the bonds. The risks associated with surety bonds are low and are identified as follows:

Risks to regulator and permittee/operator: (1) irregularities in surety bond review by staff which may cause the surety bond to be unavailable as the performance guarantee; (2) cost computation uncertainties and/or irregularities which may result in costs to the State above the surety bond amount; (3) possible inability to renew a surety bond; (4) termination of authorization for surety to do business by the State’s insurance commissioner; (5) cancellation by company of doing business in the State; (6) the expense or burden may result in their unavailability; and (7) surety insolvency.

### *Collateral Bond*

A “*collateral bond*” is an indemnity agreement in a sum certain executed by a principal (the permittee/operator) which is supported by depositing with the State: (1) a cash account (or cash) payable only to the State upon demand; (2) negotiable bonds endorsed to the order of and placed in the possession of the State; (3) negotiable certificates of deposit made payable or assigned to the State and held by a federally insured bank; (4) an irrevocable letter of credit payable only to the State upon presentation; (5) a perfected, first-lien security interest in real property in favor of the State; or (6) other investment-grade rated securities having a rating of AAA, AA, or A or equivalent, endorsed to the order of, and placed in the possession of the State. The risks associated with collateral bonds are low and are identified as follows:

Risks to regulator and permittee/operator: (1) irregularities in the review or administration of the indemnity agreement or of the collateral by staff which may cause the collateral bond to not be available as the performance guarantee; (2) cost computation uncertainties and/or irregularities which may result in costs to the State above the collateral bond amount; (3) added legal costs and delay associated with a foreclosure; (4) depreciating values resulting in costs to the State above the value of the collateral; (5) their expense or burden may result in their unavailability; (6) financial institution insolvency combined with collateral bonds in excess of FDIC limits; and (7) liquidity and costs associated with liquidating collateral.

### *Self Bond*

A “*self bond*” is an indemnity agreement in a sum certain executed by the principal or by the principal and a corporate guarantor and made payable to the State with or without separate surety. The risks associated with self bonds are medium to high.

Risks to regulator and permittee/operator: (1) no money readily available as a performance guarantee; (2) irregularities in self bond review by staff which may cause the indemnity by the corporate guarantor to be unavailable as a performance guarantee; (3) cost computation uncertainties and/or irregularities which may result in costs to the State above the self bond amount; (4) permittee/operator insolvency; and (5) corporate guarantor insolvency.

A self-bond may not be well-suited for geologic carbon sequestration risks other than possibly managing those measurable and finite risks that are present when the geologic carbon sequestration facility is being sited/permitted, operational, or undergoing site closure activities including well capping, facilities removal and site reclamation.

#### *Public Liability Insurance*

“*Public liability insurance*” is a type of insurance contract purchased up to a maximum amount, to cover personal injury and property damage (possibly including ongoing disability payment) caused by processes and activities by the policyholder that have the potential to affect third parties (members of the public, visitors, trespassers, sub-contractors). Such insurance is usually maintained, through renewal, in full force and effect for a specified period or activity (e.g., the length of reclamation operations). When the policy is compulsory, a rider may be requested requiring the insurance company notify the State regulatory agency whenever substantive changes are made in the policy including any termination or failure to renew. Underwriting requirements vary by site and the policies come with an assortment of conditions, exclusions, and warranties which can be a burden. These policies frequently include a “pollution exclusion.” In some cases underwriters refuse to insure the liability of certain industries or choose to apply a large deductible in order to minimize the potential compensations. Claims are usually dealt with in lawsuits applying common law or statutory/regulatory principles. These policies tend to be commercial risk management tools for risks from ordinary practices where the frequency and magnitude of the risk can be evaluated with reasonable

probability. The risk to the regulator is considered to be medium to high if this policy is considered for environmental damage. The risks are identified as follows:

Risks to regulator and permittee/operator: (1) irregularities in policy review by staff given the potential for exclusions to result in the policy being unavailable as a full performance guarantee; (2) cost computation uncertainties and/or irregularities which may result in costs to the State above the policy amount; (3) cancellation/non-renewal risk; (4) potential for competing claims for payment under the policy which may pose the risk of double payment jeopardy (payment demanded by insured and by regulators to third parties); (5) termination of authorization for company to do business by the State's insurance commissioner; (6) cancellation by insurance company of doing business in the State; (7) potential cost to the regulator of claims collection and enforcement; (8) short-term nature of policy term and risk of non-renewal; and (9) insurance company insolvency.

This product may not be well suited to manage risks that are present when the geologic carbon sequestration facility is well past its active life and either the permittee/operator no longer exists or it cannot leverage funds to finance the insurance products. This product is not currently available for risk management during the Long-term Stewardship phase and may only be available for limited purposes during the post-closure phase.

### *Pollution Insurance*

*“Pollution insurance”* or *“environmental impairment insurance”* is a type of insurance contract that covers costs and damages related to pollution. Insurance serves to allocate risk through classifying and pricing it, the use of exclusions and deductibles, and the creation of risk management activities which leads to better management. Such insurance can cover the costs of brownfield restoration and cleanup, liability for injuries and deaths caused by pollution, and closure and post-closure insurance. One of the purposes for such insurance policies is that in the event companies that cause

environmental disasters go bankrupt, the victims can still be compensated. The insurance may also protect against cost overruns or regulatory changes that increase the cost of cleanup (cost-cap protection). With some exceptions, most policies are written on a “claims-made and reported” basis. Unlike occurrence forms, claims-made forms require that the environmental claim must be received by the policyholder and reported to the company within the policy period or within an extended reporting period. To be continuously covered, the policyholder must continue to renew the coverage at the end of each term. There are no standard forms, and there is no standard coverage. Underwriting requirements will vary greatly by site, and exclusions should be expected to be extensive and idiosyncratic, requiring much attention to the fine print. However, with the help of insurers and risk analysts, corporate risk managers can try to select available, cost-effective products and processes, which minimize the sum of insurance premiums, expected payments to victims in excess of insurance coverage, and risk-reduction expenditures. It is unlikely that all environmental impairment risks will be insurable (e.g., climate risk with a large release to the atmosphere).

The risk to the regulator is considered to be medium. The risks are the same as identified under the public liability insurance option.

### *Special Risk Insurance*

“*Special risk insurance*” is a type of insurance contract that covers a non-standard risk, such as insurance for property damage, bodily injury, environmental damages and economic losses caused by pollution, transportation, out-of-control wells, geo-mechanical events, business interruption, increased/accelerated closure, and in some cases cost overruns during operation, closure and post-closure of a geologic carbon sequestration facility. The risk to the regulator is considered to be medium to high if this policy is considered for environmental damage. The risks are the same as identified under the public liability insurance option. There could also be few risk partners which may increase the risk of insurer insolvency.

### *Long-term Care Special Revenue Account*

“*Long-term Care Special Revenue Account*”, if created by the Wyoming legislature, would be a privately-funded, publicly-controlled account within Wyoming’s Special Revenue Fund under Wyoming Statute section 9-4-204(t)(i)(B), which would be used to receive proceeds paid by all permittees of geologic sequestration sites based on a per-ton injection fee and/or a closure fee. The account would be used by the director of the Department of Environmental Quality to pay for measurement, monitoring and verification of geologic sequestration sites following site closure certification, release of all financial assurance instruments, and termination of the permit.

Risks to regulator and permittee/operator: (1) the account would be subject to the biennial appropriation process so there may be insufficient money available depending on the appropriation, (2) cost computations uncertainties and/or irregularities which may result in insufficiency of funds for the work that would be needed for measurement, monitoring and verification activities or for corrective action, (3) inability to access funds for significant corrective action that may be required if the site fails after termination of the permit and release of the operator-supplied financial assurance instruments.

### *Long-term Care, Stewardship and Compensation Trust Fund (Trust Fund)*

“*Long-term Care, Stewardship and Compensation Trust Fund (Trust Fund)*”, would be a privately-funded, publicly-controlled trust fund set up for the purpose of addressing long-term costs and liabilities post-closure. Collection of funds would be anticipated during the permitting and operating phases of the project. Such fund would address long-term costs and risks associated with long-term sequestration or storage of carbon dioxide and associated constituents after the post-closure phase of a project or projects for which traditional financial assurance instruments or mechanisms may not be either available or appropriate.

No such Trust Fund structure exists today in the context of geologic carbon sequestration. However, there are Trust Fund analogs which have been successfully used for other industries and environmental issues. The use of long-term liability and Federal indemnity models is fairly common. Federal Trust Fund models include the Hazardous Substances Superfund, the Oil Spill Liability Trust Fund, the Harbor Maintenance Trust Fund and the Presidio Trust. Congress has recently introduced a bill (S – 1502, The Carbon Storage Stewardship Trust Act – 2009) which contemplates a Federal Trust Fund for the long-term liability associated with carbon sequestration. The Price-Anderson Act also provides a Federal indemnity model based on risk pooling among nuclear sites and liability coverage from the pooled interests with a set cap on liabilities.

There is less precedent for privately-funded, publicly-controlled trust funds within the State of Wyoming. If a Wyoming Trust Fund were created by the Wyoming legislature, it would be a fiduciary Private-Purpose Trust Fund under Wyoming Statute section 9-4-204(t)(iii)(A).

The Trust Fund liability would provide for corrective actions and delimited compensatory damages resulting after release or insolvency of the permittee/operator/corporate guarantor, and after the bond or insurance products are released, exhausted or terminated. Some trusts are established as a “revolving fund” with a minimum and maximum balance, which can be replenished as required after an event which causes expenditures from the fund. Flexibility in the fee structure is encouraged based on experience and site specific risk information. Multiple funds or accounts are also possible to provide separate and distinct funding sources for different activities such as ongoing measurement, monitoring and verification costs or unpredictable and infrequent events which require corrective action.

Risks to regulator and permittee/operator: (1) the account would be subject to the biennial appropriation process so there may be insufficient money available depending on the appropriation, (2) cost computations uncertainties and/or irregularities which may result in insufficiency of funds for the work that would be needed, (3) inability to access funds depending upon trustee and governance structure, (4) potential for competing claims for payment which may reduce sufficiency of fund assets available as financial assurance.

## Financial Assurance Procedural Recommendations

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With an understanding of financial assurance methods and the risks inherent to them, as well as the different phases of geologic carbon sequestration activities, specific procedural recommendations related to different assurance methods follow. These recommendations highlight the complexity and unique attributes of different forms of financial assurance. They also demonstrate the need for the Wyoming DEQ to develop technical and risk management skills sufficient to best assess each permit and financial assurance requirement at each phase in the project. The Wyoming DEQ today lacks a sufficient expertise and resource depth to adequately assess geologic carbon sequestration permit applications and structure an appropriate and feasible risk management framework.

It is recommended that the legislature authorize funds for a minimum of three new positions within the DEQ. The first would be a Financial Analyst with the skills and capabilities to review, manage, and update financial assurance documents, compare levels of assurance with levels of risk for adequacy, track the financial health of permittees who are self-bonded, work closely with other State agencies (i.e. the State insurance commissioner, State treasurer or others) to maintain current status and understanding of financial markets and the surety industry, provide the necessary accounting and evaluation of adequacy of special revenue accounts and potential trust accounts, and advise the director on financial assurance decisions. The second position is a geophysical engineer or geological engineer with experience in geophysical techniques and structural geology. The third position is a reservoir engineer with experience in oil and gas well liquid and gaseous activity in deep reservoir rocks. These positions will assist the administrator in the evaluation and approval of modeling and monitoring techniques that are unique to geologic carbon sequestration.

Figure 2: DEQ-Carbon Sequestration Phases and Oversight Components

Activity	Site selection, data collection, modeling, permit application prepared. Possible pilot project	Permit review by agency and bond/financial assurance requirements are defined	Operating, reporting, maintaining, plugging wells, reclamation work begins, closing and monitoring	Post injection site care and monitoring	Long term care-Limited monitoring
WYDEQ Phase	I		II	III	IV
WDEQ Phase Name	Site Selection and Characterization		Operation (Injection)	Post-Closure	Long Term Stewardship
Potential Duration (Years)	1-2		30 - 40	> 10	Indefinite
Decision or Event	← Decision by applicant to proceed	← Permit submitted	← Injection starts	← Injection is complete	← Plume is stable (Site certified and Responsible Party is released)
Financial Assurance Required?	Maybe if a pilot is conducted or if test wells are drilled	Maybe if pilot continues	Financial assurance required	Financial assurance required. Amount could be less than prior phase.	Special Revenue Account/ Trust Fund

Figure 2 summarizes key activities in each phase, Wyoming DEQ’s description and key decision events associated. It also addresses, very broadly, when financial assurance is required with each phase. This chart references the review of adequacy and issues associated with different financial assurance for different risk phases which follows.

*Traditional Performance Bond:* Surety, collateral, and self bonds are well established and widely used. These products should form the basis for financial assurance to enforce geologic carbon sequestration regulatory provisions through the operation and post-closure phases, particularly those that are readily capable of cost estimating such as replacement of well components, well control procedures, reservoir pressure reduction techniques, site restoration and reclamation, well closure and abandonment, and post-

closure monitoring activities. The procedure to establish, revise, release and/or forfeit bonds can be largely taken from those applicable to surface coal mining operations which include:

- The permittee/operator is responsible for calculating the bond initially, subject to State oversight and approval, and then the permittee/operator undertakes an annual adjustment and approval process through the annual report mechanism, with all bonding estimates done consistent with guidelines developed by DEQ.
- Bonds may be released, in phases or in full, upon the request of the permittee/operator and the approval of the regulatory oversight agency.
- Inspections are mandatory for the area sought for release.
- The final bond release requires public notification with an opportunity for public comment and a public hearing.

However, some additional performance bond requirements applicable to geologic carbon sequestration should be considered; these include:

- The post-closure bond liability period must be separately established for geologic carbon sequestration projects. Reclamation liability may be separated from other post-closure liabilities. A State Special Revenue Account should be considered and funded by the permittee/operator which is available for use to provide for predictable long-term monitoring, maintenance and verification costs after the permit is terminated and the financial assurance instruments are released.

*Traditional Public Liability Insurance:* The surface coal mining regulatory program requires the mine permittee/operator to show proof of a public liability insurance policy in effect, which provides for personal injury and property damage protection to adequately compensate persons damaged as a result of regulated activities. This model can be the framework for geologic carbon sequestration third party liability claims with the following additional recommendations:

- Proof of insurance should be provided annually.
- Consideration should be given to increasing the policy amounts compared to those applicable to surface coal mining operations.

*Non-traditional Environmental Impairment Liability Insurance:* The use of pollution liability insurance to manage environmental risk is also well developed. However, site-specific environmental impairment liability insurance to manage operational and large scale, infrequent risks is not as traditional. It has the potential to be a viable, flexible and appropriate mechanism for geologic carbon sequestration financial assurance. In addition to those procedures applicable to third party insurance (identified above), the following are additional procedural recommendations:

- Flexibility should be afforded to the Director to require a suitable policy with adequate coverage tailored to insure against site specific environmental impairment risks, both operational and unanticipated one-time events. The policy should remain in force and effect through the duration of all geologic carbon sequestration, and it should be reviewed annually or periodically as determined by the Director.
- At the time of review, the permittee/operator should be required to integrate monitoring data into performance models to evaluate and/or verify the models, the site management, and the risk assessments.
- State of Wyoming should be named as additional insured though policy inclusion does not constitute a waiver of the State's rights under the Governmental Claims Act.

Managing legal risk could be a key part of making these policies available and affordable particularly during the early periods for geologic carbon sequestration.

*Special Revenue Account:*

A private-sector funded, State of Wyoming managed Special Revenue Account is contemplated for measurement, monitoring and verification costs during the Long-Term Stewardship Phase.

*Long-term Care, Stewardship and Compensation Trust Fund (Trust Fund):*

Some form of a Long-Term Care, Stewardship and Compensation Trust Fund may be advantageous to address potential liabilities which may arise during the Long-term Stewardship phase after the permit is terminated and traditional financial assurance instruments are released.

These risks and costs which occur during the Long-term Stewardship Phase are anticipated to be the responsibility of the Federal government since the development of a geologic carbon sequestration industry is for the benefit of the public, our national industrial economy and the environment as a whole. The Federal government is currently contemplating the creation of a Trust Fund for just this purpose.

A privately-funded, publicly managed Trust Fund should seek to ensure that funds are sufficient and accessible and the funding and governance mechanisms should support these goals.

While a Federal Trust Fund program for liability coverage in the Long-term Stewardship Phase is envisioned and is the simplest solution, it is outside of the bounds of the Wyoming legislature to create. Appendix G summarizes an alternative concept for a Trust Fund which could provide limited coverage in addition to or while a Federal trust fund model develops.

The Fund model profiled in Appendix G still requires Federal liability coverage, it also provides for a Wyoming-based private sector funding model to address some level of costs incurred for corrective action required in the Long-term Stewardship Phase.

This Trust Fund has three distinct funding components:

- 1) pre-funding by project operators on a project basis to cover required mitigation for specific Wyoming projects;
- 2) pre-funding by project operators into a State managed pool to provide additional mitigation coverage after the first pool has been exhausted. This pool could have minimum and maximum coverage levels; and
- 3) Federal indemnity above the pool 2 threshold for all additional mitigation. This model would only be implemented with the creation of a Federal backstop for all costs above the coverage levels identified in the third pool of funding.

A Wyoming Trust Fund is not contemplated in the Draft Statute. However, if a Wyoming Trust Fund is desired by the Wyoming legislature, some additional requirements should be considered. These requirements are listed below.

- In addition to long-term monitoring, maintenance and verification costs and corrective action costs, such fund also may address other risks during other phases of the project or operation for which traditional financial assurance instruments and mechanisms are either not available or not appropriate (for example, acts of God or acts of war). However, a permittee/operator may not use such fund to address risks and liabilities subject to the permittee/operator's control for which other financial assurance mechanisms are available through the post-closure phase, or to provide financial assurance for a site or entity identified by the director or some other entity as a high-risk site, operation, or facility. The Trust funds are to be used to protect the State of Wyoming from liability and responsibility for geologic carbon sequestration sites and facilities, and to provide a pool of funds for costs, expenses, insurance, or other needs and requirements for covered geologic carbon sequestration sites after the post-closure phase.

- Financing for such a Trust Fund would be supported through fees paid by permittee/operators, which may include:
  - a per-ton injection fee which may be adjusted based on a site specific risk assessment; and
  - a closure fee, which may address inadequate funding of the Long-term Care, Stewardship and Compensation Trust Fund relevant to the site or facility through the post-closure phase. It should be noted that a closure fee may be difficult to determine and even more difficult to collect.
  
- Management and oversight of a Special Revenue Fund and/or a Trust Fund does not constitute a waiver of the State of Wyoming from its immunity from suit, nor does it constitute an assumption of any liability for geologic carbon sequestration sites or the carbon dioxide and associated constituents injected into such sites.

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## What Are The Potential Carbon Dioxide Sequestration Risks/Impacts?

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The following is an overview of the risks and potential impacts related to geologic sequestration of carbon dioxide. A discussion of risk is a complex topic and this discussion should be considered to be only a high level review of the topic. More than 100 potential risk events ranging from well failure to cost overruns to negligence were reviewed to determine the most critical issues for which financial assurance would be required in event of a default by a permittee/operator or failure of the containment zone before or after the end of the permit term. At a summary level, the following are the major categories of risk that are associated with geologic carbon dioxide sequestration:

- Contamination of underground sources of water, which may include drinking water supplies,
- Trespass (mineral rights infringement),
- Atmospheric release of carbon dioxide that impacts human health and safety and/or causes ecological damage, and
- Property damage (which includes changes to surface topography and structures).

The consequences of each of these outcomes, or risks, can range from minor to significant. For each possible outcome, there are many factors, events or processes that could be the primary contributor to each outcome. Many of the contributing factors can potentially result in one or more of the above-listed outcomes. In some cases multiple compounding events or factors would need to occur in order for the outcome to occur.

One of the major activities during the site characterization and permitting phase is to perform a thorough risk assessment. The risk assessment would include: 1) an examination of the events and processes that could result in an unfavorable outcome, 2) preparation of an estimate of the probability of those events occurring, 3) quantifying the impact of those outcomes and costs for mitigation, and 4) preparation of a risk management plan. Permittees/operators will be required to develop a risk management

plan is to define the processes, practices, and engineering solutions that will be put in place to address those potential pathways to an undesirable outcome and identify opportunities to improve the risk profile. During the operation phase, permittee/operators will periodically review the risk management plan and adjust it according to any new conditions.

One of the key elements of the risk assessment is the need to quantify the risks associated with the sequestration process. Typically risk is viewed as “the chances of an event occurring.” In this case, however, risk is considered to be the quantification of an undesirable outcome. Risk, used in this context, is the probability of an event (the chance the event may occur) multiplied by the consequence of the event (the financial/economic/other impact of the event, including the cost to mitigate the outcome should the event occur). Quantifying risk is not an easy task. It requires many different disciplines, and is expected to be a resource intensive enterprise, especially while geologic carbon sequestration is in its infancy and the scientific, operating and regulatory requirements of geologic carbon sequestration are still in development.

Most of the process equipment and activities that will be applied in geologic carbon sequestration are essentially similar to those used in oil and gas well-field and enhanced oil recovery operations. As with oil and gas field operations, financial assurance will be required to cover these types of specific known activities that will be required to close the sequestration wells and the sequestration site itself. These are known operating requirements for which financial assurance will be required in accordance with standard operating activities. These types of known activities include well plugging, capping and removal, purging and plugging of pipe left in situ, removal of above ground facilities, and site reclamation. These normal compliance activities would be covered by financial assurance instruments. They are standard activities and do not need additional discussion in this section.

For the purposes of developing recommendations for financial assurance, it should be noted that financial assurance should not be considered as a vehicle that can, or will,

cover any and all risks associated with geologic carbon sequestration. To elaborate, recommendations for financial assurance should be expected to address primary consequences or requirements, but may not necessarily address secondary consequences or externalities.

The following is a more detailed discussion of the potential range of consequences that may occur and the extent to which financial assurance requirements will be needed to cover some or all of those consequences. As an example of how financial assurance may cover different risks, consider the case of a carbon dioxide injection well failure during the operation phase. The cause of the well failure may be due to a number of factors, but for this example, the underlying cause is not the issue. The well failure may result in injected carbon dioxide entering an underground aquifer that is a potential drinking water supply.

A prudent and responsible permittee/operator, recognizing the well failure event, would discontinue injecting carbon dioxide into that particular well. It may even be necessary to discontinue all injection into the field. The well failure contributed to a primary consequence that affects the public good, i.e. potential contamination of a drinking water source. Curtailing or shutting off operation would likely result in a significant loss of income to the permittee/operator and possibly may have implications on the upstream carbon dioxide source. Assuming the permittee/operator failed to meet his responsibility to address the cause for the leaking well, financial assurance, in this circumstance, would provide the funds needed to address the primary consequence, to prevent contamination of the water supply and to mitigate contamination. Assuming default by the permittee/operator, the financial funds would be used to plug the well to ensure the leakage pathway was sealed.

Funds through the financial assurance mechanism would also be applied to address any necessary water treatment associated with the carbon dioxide contamination. However, financial assurance would not cover the secondary consequence, i.e., the loss of income to the permittee/operator during the period when operation of the site was curtailed or

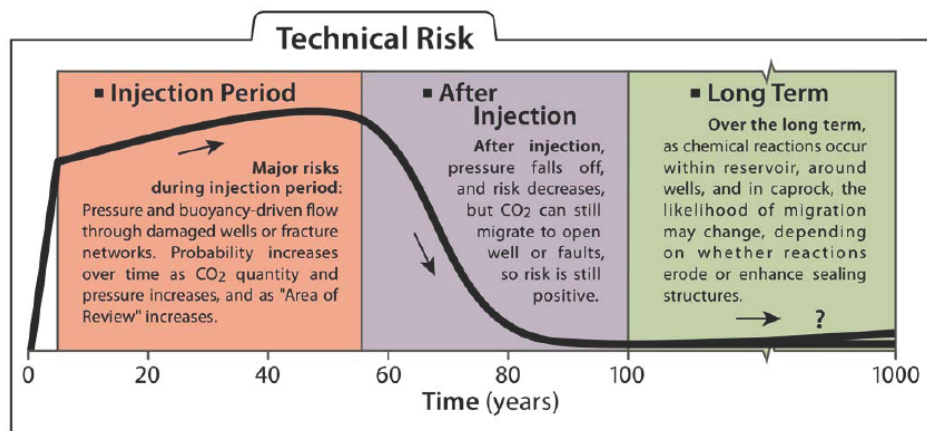
discontinued; the permittee/operator would need to address this through some form of insurance product, or some other means. Financial assurance to address business interruption is not a risk addressed in our financial assurance framework recommendation.

The purpose of the proposed financial assurance model is to address primary consequences that could result in potential harm to human health or immediate harm to the environment. As in the previous example, securing the leak and mitigating the impact on the water supply is a critical issue. In the event of a carbon dioxide leak to the atmosphere, and to the extent there was default by the permittee/operator, the financial assurance mechanism would be used to stop the source of the leak; however the financial assurance mechanism would likely not provide for the potential consequences of any long-term environmental effect due to escaped carbon dioxide.

As described earlier, the overall sequestration process has been separated into four phases. There are different risks that could occur during each phase. Furthermore, the severity of a particular risk is expected to change with time. Figure 3 illustrates how overall risk is expected to change between the major phases and within each phase. The risk value on the vertical axis is shown for illustration purposes only. The underlying significance is that risk will be minimal during the site characterization and permitting phase, and is expected to increase during the operation phase (depicted below as the injection period). Risk is expected to decline as injection ceases and as the carbon dioxide stabilizes and becomes less mobile. The period after injection corresponds to the post-closure phase.

The area identified as “long-term” in the Figure 3 includes both the post-closure and Long-term Stewardship phases described earlier. Please note that the Y-axis intends to portray risk levels. No specific measure is provided as the chart is intended to be anecdotal only.

**Figure 3: Phases of Technical Risk<sup>1</sup>**



The time horizon for a geologic carbon sequestration project will vary based on the site and injection levels. However, most geologic carbon sequestration activities are assumed to last more than 50 years before the Long-term Stewardship phase begins. Project duration is an important characteristic when designing the financial assurance system.

With this understanding of the major categories of risk, the group developed a more extensive list of geologic carbon sequestration risks. Potential risks include surface or subsurface trespass which results in mineral rights or storage rights infringement, water quality contamination, a single large volume release to the surface which could cause bodily injury, property and/or ecological damage, low level releases which cause ecological damage, induced seismicity or subsidence or uplift events, entrained contaminant (non-CO<sub>2</sub>) releases and accidents. Incomplete or inaccurate modeling during the site characterization and permitting phase may also result in failure of the containment zone.

<sup>1</sup> Figure 3 has been provided by and used with the permission of the Southwest Regional Partnership on Carbon Sequestration.

The primary features, events or processes that potentially could result from geologic sequestration include:

- Mineral Rights Infringement
- Water Quality Contamination
- Single Large Volume Release of Carbon Dioxide
- Low Level Carbon Dioxide Leakage to Surface
- Storage Rights Infringement
- Modified Surface Topography
- Entrained Contaminant (Non Carbon Dioxide) Releases
- Unplanned (Insurable) Events

Furthermore, the following issue deserves special consideration as it has the potential to trigger other risks if not appropriately addressed or managed in the permitting and operating phases or in the event of unanticipated activity.

- Excessive Unmitigated Formation Fluid and Brine Releases

The following chart profiles the relationship between the major categories of risk and the potential features/events/processes.

**Figure 4: Features/Events/Processes Overlay to Categories of Risk**

Categories of Risk	Potential features/events/processes
Contamination of underground water supply	<ul style="list-style-type: none"> <li>• Water Quality Contamination</li> <li>• Entrained Contaminant (Non-CO2) Releases</li> <li>• Unplanned events</li> <li>• Excessive unmitigated formation fluid and brine releases</li> </ul>
Trespass	<ul style="list-style-type: none"> <li>• Mineral rights infringement</li> <li>• Storage rights infringement</li> <li>• Entrained Contaminant (Non-CO2) releases</li> <li>• Excessive unmitigated formation fluid and brine releases</li> <li>• Unplanned events</li> </ul>
Atmospheric Release of CO2 that impacts human health and safety and/or causes ecological damage	<ul style="list-style-type: none"> <li>• Single Large Volume Release of CO2</li> <li>• Low Level CO2 leakage to Surface</li> <li>• Unplanned Events</li> </ul>
Property damage (including land and structures)	<ul style="list-style-type: none"> <li>• Modified Surface Topography</li> <li>• Single Large Volume Release of CO2</li> <li>• Low Level CO2 leakage to surface</li> <li>• Entrained Contaminant (Non-CO2) Releases</li> <li>• Excessive unmitigated formation fluid and brine releases</li> <li>• Storage rights infringement</li> <li>• Unplanned Events</li> </ul>

A much more detailed matrix organized by each of these categories is attached as Appendix H. The matrix assesses within each risk category, the major feature, event, or process (cause) that could result in the risk (or outcome). More detail on each of the potential events contributing to these risks and economic consequences follow in the cost section of the report.

Appendix H also identifies in which phase or phases a particular risk may occur. A value of the potential severity of each risk-causal factor has also been estimated. This risk severity value is not quantitative; it is intended to indicate that the type and intensity of activities being performed during a particular phase may have a lesser, or greater impact of that risk and provide comparative values among different potential risks at different phases of the project. They are provided here for illustrative purposes only.

For example, during the site characterization and permitting phase, the likelihood of mineral rights infringement due to over-pressurization is expected to be negligible since little if any carbon dioxide would be injected during this phase, affected zones would be very small, and the potential of mineral rights trespass would have been addressed in the review of mineral rights owners and contracting for pore space. However, during the operation phase, when large amounts of carbon dioxide have been injected at high injection rates, the probability of trespass increases. If the injection zone was over-pressurized resulting in a seal failure that created a large migration path, the impact of mineral rights infringement could be significant.

As mentioned earlier, many of the events or processes are common; for instance, over-pressurization could result in mineral rights infringement, water quality contamination or a number of the other risks identified. A thorough evaluation of risks, and the causal events or processes will need to be performed as part of the risk assessment process during the site characterization and permitting phase. It should be noted that the list of contributing causes to a risk is not exhaustive.

Appendix H summarizes the need for financial assurance and the types of financial assurance that may be required. An excerpt from Appendix H is profiled below in Figure 5 and highlights the risks identified, the phase of risk and severity during the phase, the potential impact and the type of financial assurance required at each phase.

**Figure 5: Modified Surface Topography Risk Profile**

Major Risk (Impact) - Triggering Activity (FEP = Feature, Event, or Process)	Phase				Impact	Cover by FA?	Performance Bonds	Optional Self-Bonding	Cover by 3rd Party Insurance ?	Cover by Trust Fund?	Mitigation
	Permitting	Operation	Post Closure	Long Term							
<b>Modified Surface Topography (subsidence or uplift) resulting in Property/Infrastructure Damage</b>											
Induced Seismicity - Pressure or geochemistry induced reactivation of historic fault	0	2	1	1	Loss of revenue: 1) temporary closure of sequestration site until remediated, 2) permanent closure if no remediation possible, 3) remediation costs, 4) fines, 5) loss of use due to damages. Upstream impact of closure of remediation site.	Yes; but amount based on clear risk assessment (vertical distance to surface; any geotechnical considerations, etc)	Phases I thru III (and Phase IV if available)	Phases I & II only	Phases I thru III (and Phase IV if available)	Applicable to Phase IV (?? Possibly to Phases I thru III depending on the scope and structure of the Trust Fund??)	

Phases I-IV ranked the severity of risk on a 0-3 scale with 0: no risk up to 3: high risk. Impact is defined as the consequences that would be experienced. Risk is defined as the probability of event multiplied by the cost of the consequence of event.

The importance of a comprehensive, rigorous permitting process cannot be overstated. Permitting review should include site characterization and geologic modeling demonstrating the stability of the cap rock, natural risk of seismicity, proximity to private property and surface structures and other natural resources including minerals and the drinking water sources.

The risk assessment conducted during the permitting process will be used by regulators to assist in determining specific financial assurance requirements. It will also be needed to inform potential customers of the sequestration site, investors, and insurers. The risk assessment provides quantification of outcomes, thereby providing information needed to

establish financial assurance requirements. Appendix I profiles a project risk calculation which can be used to adjust for financial assurance levels assessed during the permitting process. This calculation would take into account the credit risk of the operator, the site specific risk and the event risk to calculate an overall project risk. A range of project risks could then correspond to premiums or discounts to the base level of financial assurance required. The next section of the report goes into greater detail quantifying risk for a typical project along each risk attribute and at each stage of a project. Appendix I is provided only as an example of how regulators might assess risk for credit, site specific and event risk on an overall project basis. The specific methodology and approach will be at the discretion of the regulator to deploy.

## **WHAT ARE THE MITIGATION OR RECLAMATION COSTS OF CARBON DIOXIDE SEQUESTRATION AND ACCEPTABLE LEVELS OF FINANCIAL ASSURANCE?**

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A high level summary of acceptable financial assurance methods and recommended financial assurance levels was completed and is outlined in this section. Cost estimates are provided to identify an order of magnitude for risk events, coupled with a relative comparison of costs among risks. It should be pointed out that these are very high level estimates and that detailed assessments will be required to provide accurate estimates. Recommendations are based on numerous assumptions and cost estimates for other similar activities. Assumptions are summarized below and available in greater detail in Appendix J.

The focus in this section is on the development of a range of estimates on the mitigation and reclamation costs; the statistical probability of occurrence is not included. Simulation modeling will be necessary on a site specific basis by experts in order to develop a robust and accurate risk assessment. Actual project experience will provide the best data for risk calculations.

Some events are outside of the scope of this financial assurance recommendation, particularly where a risk event is completely unpredictable and difficult to assess to the project (e.g. Act(s) of God).

Following the identified risks and features, events or processes outlined in Appendix J and based on the assumptions outlined below, estimated remediation costs for each risk are provided for the Operation Phase of a proxy project. Discussions of closure and reclamation costs, post-closure inspection and maintenance costs, monitoring costs, financial assurance contingency provisions and recommended financial assurance levels follow. This report concludes with a summary of the total recommended levels of a financial assurance system.

## Key Assumptions

Several key assumptions which impact the financial assurance methods and recommended levels follow:

**Costs.** All estimates are based on 2009 dollars.

**Permitting.** The site characterization and permitting phase follows the risk assessment profile stated above. Good site selection and thorough review of site characteristics in the permitting process are expected to have significant bearing on the potential mitigation or reclamation costs of a carbon dioxide sequestration project. See attached Appendix I for an example of how site specific risk coupled with operator risk might be used by DEQ to calculate an overall initial project risk factor. These site specific factors could then be used to adjust project specific financial assurance cost requirements for any given project. All necessary permits shall be obtained prior to commencement of any regulated activities. In some cases preliminary investigation wells may be needed, in which case, well permits will be required prior to drilling exploration wells.

**Chemical and geological characteristics which impact mitigation and monitoring cost estimates.** Cost estimates assume that risk and mitigation aspects are based on fluid phases<sup>2</sup> of the injected materials, and that injection and reinjection of materials, or injecting to alternate approved strata, are viable options while addressing any excursion impacts. Cost estimates also assume that some impacts can be addressed by replacement of well components where feasible. These risks, especially the cost to remediate water quality damage from plume migration, are expected to be highest during the Operation Phase.

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<sup>2</sup> In traditional oil and gas activities, mitigation costs can vary based on the density and form of the fluids. For purposes of this analysis, cost estimates were based on fluid rather than gaseous phases of the injected material.

**Scale.** The likely range of geologic carbon sequestration operations will be from one million tons per year (tpy) to four million tons per year at a single project injected over a period of 30 years, resulting in a range of 30 million to 120 million tons of total CO<sub>2</sub> injected.

**Contingency provisions.** Contingency provisions will be applied to the financial assurance considerations that are subject to bonding. The following factors are based on Guideline 12 of the Wyoming Department of Environmental Quality, Land Quality Division:

- Contractor Profit, overhead, mobilization and demobilization costs
  - From 8 to 15 percent of the total financial assurance level
- Field management<sup>3</sup>, on a sliding scale, anticipated to be approximately \$1M for the mid-range example
  - Unknowns; for geologic carbon sequestration projects assumed to be in the range of 10%

*Risks Determined To Be Addressed By Other Mechanisms*

It is important to restate that for the purposes of developing recommendations for financial assurance, financial assurance should not be considered as a vehicle that can, or will, cover any and all risks associated with sequestration. To elaborate, recommendations for financial assurance should be expected to address primary consequences or requirements, but may not necessarily address secondary consequences or externalities.

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<sup>3</sup> Field management is defined as changes in design, operations and activities made in the field by professional engineers and management.

*Risks typically covered through litigation which were generally viewed to be outside the scope of the report.*

The group reviewed and evaluated a broad spectrum of the potential risks associated with geologic carbon sequestration, and the potential mitigation/remediation options for each. For some of the risks, these evaluations determined that if the risk event occurred, the nature of the event did not fall within the scope of financial assurance considerations the regulatory authority should address. Such risks have characteristics of being not causally connected to permittee/operator performance and may include the following:

- Caprock/reservoir fractures, unrelated to induced over-pressurization or induced seismicity, resulting in a single large-volume release to the surface (inclusion in this list is provisional on adequately conservative modeling in the permitting phase).
- Caprock/reservoir fractures, unrelated to induced over-pressurization or induced seismicity, resulting in chronic low-level releases to the surface (inclusion in this list is provisional on adequately conservative modeling in the permitting phase).
- Sabotage or a terrorist attack resulting in a single large-volume release to the surface.
- Mineral rights impacted by:
  - Plume leakage migrating into or hydraulically impacting a recoverable mineral zone
  - Post injection discovery of recoverable minerals that are or may be impacted
- Storage rights infringement by injected CO<sub>2</sub> or other entrained contaminant gases by:
  - New technology development that makes storage of gas in adjacent pore space(s) desirable to the injection permittee/operator
- Externalities related to project operations such as:
  - Unanticipated site closure makes it too expensive or environmentally unfeasible for utility plant CO<sub>2</sub> source emitter to operate

- Preemption of storage rights by out of state CO2 emitters limits Wyoming based CO2 point sources ability to procure economically feasible storage option, resulting in closure of Wyoming based industrial operations and potentially need for higher cost power supplies.

Insurance may be available for some or all of these risks, but the regulator should not seek financial assurance for these risks through its permitting process.

**Outside the group’s consensus for this report.** Regulatory remedies notwithstanding, some of the risk evaluations could not be addressed in a consensus manner and were tabled. Those risks include the following:

- Mineral rights specifically impacted by:
  - New technology (or economic conditions) enabling recovery of previously unrecoverable minerals
  - Act(s) of God affecting access to mineral rights
  
- Act(s) of God where causality is clear, resulting in:
  - Water quality contamination on/adjacent the permit area
  - A single large-volume release to the surface
  - Chronic low-level releases to the surface
  - Storage rights infringement

With an understanding of these assumptions, and events covered through other mechanisms, an assessment of the mitigation and reclamation costs for key risk factors and activities associated with each event follows.

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*Operation Phase.* The Operation Phase of a carbon dioxide storage project includes site preparation, surface disturbance, operating and monitoring well drilling and construction, possibly auxiliary carbon dioxide compression, and injection of carbon dioxide and monitoring and closure activities. During this phase, the permittee/operators shall be required to provide financial assurance in the form of performance bonds, self-bonds or third party insurance for these risks at estimated remediation and reclamation cost levels. Appendix J provides additional details and background for each.

**Water quality contamination during the fluid phase and resulting from:**

- **Plume migration outside of the permitted area.** Costs and mitigation of injectate excursions beyond permit boundaries; category costs range from \$35K to \$5M or more per event. In extreme cases, establishing capture, conveyance, re-injection or alternative disposal options for captured fluid/gas could be required. This potential represents the upper bound (\$5M) of the cost range. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.
- **Unpermitted leakage of CO<sub>2</sub> contaminants into aquifer.** Costs and mitigation as listed above for plume migration but also include establishing a temporary-semi-permanent-permanent replacement source of drinking water. Category costs range up to \$15M or more per event if the contaminated source is heavily utilized for drinking water or by sensitive receptors. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.
- **Unpermitted leakage of drilling fluid contaminants into aquifer.** Similar to leakage of CO<sub>2</sub> contaminants case discussed above, but with a generally lower

scale of cost ranges and mitigation requirements. Maximum mitigation costs estimated at \$2M per event. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.

- **Unpermitted rock/acidified water interaction contaminates aquifer by carryover of dissolved contaminants.** Similar to leakage of CO<sub>2</sub> contaminants, with costs and mitigation dependent upon the products of the interaction. If the dissolved contaminants are deleterious then recovery wells and replacement drinking water sources, with significant mitigation costs up to \$15M per event could apply. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.

Permittee/operators shall be required to provide financial assurance in the form of performance bonds, self-bonds or third party insurance for these risks at estimated remediation and reclamation cost levels. Please see the summary discussions of *Recommended Financial Assurance Level* at the end of this section.

Please also see Appendix J for additional details and discussions of mitigation considerations for the risk of water quality contamination during the fluid phase.

**Single large volume release to the surface which causes asphyxiation, health or ecological damage resulting from:**

- **Over-pressurization with either wellbore seal failure or caprock/reservoir fracture.** Mitigation actions and costs will be highly dependent on the source and location of the release. If the source of the release is due to over-pressurization fracturing the caprock/reservoir then establishment of relief wells and/or flowback systems may be required, with costs ranging up to \$15M per event. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.

- **Well seal failure.** Mitigation actions and costs will be highly dependent on the location and extent of the seal failure; e.g., shallow failures will generally entail lower costs and remediation/mitigation efforts. If significant containment and clean-up efforts are required, mitigation costs could range up to \$3M per event. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.
- **Well blowout at surface or bore failure below ground for both operating and monitoring wells.** Mitigation actions and costs will be highly dependent on the location and extent of the failure. If significant surface clean-up or subsurface containment and mitigation efforts are required, costs could range up to \$10M per event. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.
- **Major mechanical failure of distribution system or storage facilities above or below ground.** Typical valve and control systems of the operations should facilitate isolating the failure. Impacts should be generally minimal, with below-ground contamination limited in extent. Deep contamination<sup>4</sup> mitigation could range up to \$5M per event. Risks have been estimated as low during both Post-closure and virtually non-existent during the Long-term Stewardship phases.

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<sup>4</sup> Deep contamination is considered to be pollution impacts occurring at significant depths below surface. For this review, that is considered to be deeper than a few hundred feet below the surface. Typically any contamination from mechanical failures of distribution or storage systems would be expected to occur at shallow depths. However, this is the potential that contaminants could reach significant depths by flowing along well annuli or other means. The likelihood of those occurrences is low but the upper end of the cost estimate is provided to address it.

**Chronic low-level releases to the surface which cause health or ecological damage resulting from:**

- **Mechanical failure of piping or tankage above or below ground.** Typical valve and controls systems of the operations should facilitate isolating the failure. Impacts should be generally low, with below ground contamination limited in extent. Deep contamination<sup>5</sup> mitigation could range up to \$5M per event. Risks have been estimated as low during both Post-closure and Long-term Stewardship phases.
- **Orphan wells not discovered prior to injection.** The extent of this risk will depend heavily on the baseline knowledge of the injection permit area. If orphan wells exist in the area of extent and allow injectate contamination of a drinking water source, mitigation costs could range up to \$10M per event. Risks have been estimated as virtually non-existent during both Post-closure and Long-term Stewardship phases.
- **Induced over-pressurization.** Surface releases due to induced over-pressurization indicate strata fractures have occurred from the pressure. Identifying the causes leading to the low-level releases will be critical to the mitigation and cost options available. Mitigation could require relief wells and/or flowback systems with costs ranging up to \$15M per event. Risks have been estimated as low during the Post-closure phase and virtually non-existent during the Long-term Stewardship phase.
- **Incomplete geological seal resulting from inaccurate characterization of subsurface geology.** The extent and location of the seal failure(s) leading to the low-level releases will be critical to the mitigation and cost options available. At a minimum, temporary cessation of injection operations will be required during

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<sup>5</sup> Ibid.

mitigation, with possible requirements for relief wells and/or flowback systems with costs ranging up to \$15M per event. Risks have been estimated as low during the Post-closure phase and Long-term Stewardship phase.

- **Induced seismicity.** Surface releases due to induced seismicity indicate strata fractures or opening of pre-existing cemented faults have occurred from one or more of the seismic events. Identifying the causes leading to the low-level releases will be critical to the mitigation and cost options available. Mitigation could require relief wells and/or flowback systems with costs ranging up to \$15M per event. Risks have been estimated as low during the Post-closure phase and Long-term Stewardship phase.

**Modified surface topography resulting from induced seismicity, subsidence/uplift events which cause property or infrastructure damage**

Significant fluid and pressure changes from injection of fluids has the potential to change the state of stress of receiving rock, with the potential to cause failure along pre-existing fractures and faults. Additionally, injecting CO<sub>2</sub> in a fluid state can potentially initiate subsidence by dissolution of minerals in the receiving strata leading to collapse of upper material. In the extreme, if structural or infrastructure damage occurs as a result, or if the movement allows extensive deep contamination by injectate, mitigation costs could involve replacement/clean-up that could range up to \$5M per event. Risks have been estimated as low during the Post-closure phase and Long-term Stewardship phases.

### **Entrained contaminant (non-CO2) releases**

Depending upon the nature of the contaminants and the receiving media for the releases, costs and mitigation could be very similar to the discussions for plume migration above. If the contaminants are released into a drinking water source, mitigation could include establishing a temporary-semi-permanent-permanent replacement drinking source; category costs would range up to \$10M or more per event if the contaminated source is heavily utilized for drinking water or by sensitive receptors. Risks have been estimated as low during the Post-closure phase and Long-term Stewardship phases.

### **Accidents or unplanned events which are typically insurable and which result in surface infrastructure damage or saline water releases from surface storage impoundment.**

This category could apply to actions involving pipelines or transport of the injectate, other handling processes, management of any brine pumping and surface storage that may be required or other similar processes. Applying the considerations of the unknown cost category from Guideline 12 of the WDEQ-Land Quality Division to accidents and unplanned events, the range of Financial Assurance would be 2 to 5 percent of the total level of Financial Assurance required. It is suggested that a level of 4 percent be applied. Risks have been estimated as virtually non-existent to low during the Post-closure phase and virtually non-existent during the Long-term Stewardship phase.

### **Formation fluid and brine removal contingency considerations**

The need to treat formation fluid and remove brine is not in and of itself a risk event, as the need to remove the fluid may be required to eliminate the impacts of the hydraulic front as it relates to the risks previously identified. The displacement of formation fluid and potential need to relieve pressure along the hydraulic front will need to be evaluated in the initial DEQ permitting process and addressed during the subsequent operational

phase. However, there is the potential that excessive amounts of formation fluid and brine during the Long-term Stewardship phases may need to be addressed in order to relieve the impacts of the hydraulic front. The mitigation costs associated with brine removal or fluid relocation to address the hydraulic front are potentially large and deserve special consideration

Treatment methods for other operations with large saline water effects and treatment requirements range from the use of evaporation ponds, to fluid reinjection, to pumping and processing the fluids to drinking water standards or to some level that allows for discharge. The available and acceptable fluid treatment process will depend upon the geologic formation, quantity and characteristics of the fluid, cost and other environmental considerations. These considerations will likely be addressed through submittal of a permittee/operator plan and review and approval of the regulatory agency.

It is expected that an operational process will be approved which significantly reduces risks of leakage or modified surface topography from hydraulic front movement. However, a conservative cost estimate follows which assumes that additional brine removal and treatment may be required during the Post-closure and Long-term Stewardship phases.

Assumptions regarding the size of the hydraulic front, the time period of remediation, the amount of brine that must be relocated, and the duration of operating a brine removal system all have a significant bearing on cost. It is important to note that there is little information available to calculate the formation fluid and brine removal costs associated with a geologic carbon sequestration projects.

There is not consensus even among the group about the assumptions used to estimate the formation fluid and brine removal costs. Therefore, these estimates should be taken as that—estimates based upon a variety of modeling assumptions. Actual operating history of large projects may significantly change these assumptions and underscore the need for commercial demonstration projects where the amount of formation fluid, brine removal

or relocation methods determined acceptable and the amount of brine that must be removed can be monitored and tracked over time. Best estimates project a central estimate of 25% of the hydraulic front volume needing to be addressed during the combined Post-closure and Long-term Stewardship phases, with a significant level of uncertainty in that estimate resulting in an error band equivalent to +/- 25% of the hydraulic front volume.

Using Rock Springs Uplift modeling as an example, injection of 750M tons of CO<sub>2</sub> can be expected to displace 800,000 acre-feet of brine.

Assuming an extreme situation exists where some or all of the hydraulic front brine must be pumped to the surface, impounded and treated, used, and/or discharged the following assumptions have been applied to develop cost estimates:

- The hydraulic front volume is proportional to the injection rate per year and the resulting total volume of CO<sub>2</sub> injected: e.g., a 2Mtpy injection rate over 30 years involves 60M tons CO<sub>2</sub>, 8% of the 750M ton figure and assumed to result in a hydraulic front of 64,000 acre-feet, representing 8% of the 800,000 acre-feet figure. Similarly, a 4Mtpy injection rate of 30 years would result in a hydraulic front of 128,000 acre-feet.
- Establishment of two relief wells with an average depth of 7000 feet, with associated pumps and conveyances, at an estimated establishment cost of \$3M each.
- Groundwater pumping costs correspond to those estimated in Newlin, et al, 2001, adjusted for Wyoming energy cost differentials and updated to 2009 dollars. That results in estimated pumping cost of \$0.07/acre-foot/foot of lift.
- Establishment of brine removal systems (ponds, pumps, disposal) at costs approximately equivalent to the pumping costs; both correlated to the volume of displaced fluids which is assumed to be proportional to the total amount of carbon dioxide injected. Example pumping cost estimates are provided in Figure 6 below.

- Re-injection into another formation is a possibility.
- Ion exchange treatment and discharge of withdrawn fluids might be another option. However at an estimated cost of \$0.30 per barrel for treatment, these costs would be greater than the cost of a brine removal and treatment system making this option not economically attractive. Sample costs are provided in Figure 6 below.
- Removal of 25% of the volume of the displaced fluids will be required for post-injection mitigation.
- For a mid-range 2Mtpy injection project with a 30-year life, this would set an upper mitigation bound for this risk category at \$6M for relief wells, \$8M for pumping, and \$8M for brine water treatment, totaling \$22M. Actual costs could be higher or lower.

The following two tables provide an overview of how changes in well depth, percentage of displaced fluid volume and acre-feet of water impacts the cost estimates for treatment of brine and formation fluids under two different scenarios which vary based on the amount of carbon dioxide injected and well depth. It should be noted that pumping brine to the surface may be the least desirable mitigation alternative in terms of economic cost.

**Figure 6: Pumping Costs at Multiple Injection Levels and Varying Depths/Hydraulic Front Percentages**

Operation injection rate and duration of operation	Hydraulic front (acre-feet)	Pumping Costs @ 7000' & 100% of hyd front volume	Pumping Costs @ 7000' & 25% of hyd front vol	Pumping Costs @ 5000' & 25% of Hyd front vol
2M tpy – 30 yrs	64,000	\$31M	\$8M	\$6M
4M tpy – 30 yrs	128,000	\$63M	\$16M	\$11M

**Figure 7: Ion Exchange Costs at Multiple Injection Levels**

Operation injection rate and duration of operation	Hydraulic front (acre-feet)	Barrels at 55 gal per barrel	Ion Exchange costs at \$0.30 per barrel and 25% of hydraulic front volume
2M tpy – 30 yrs	64,000	284M	\$29M
4M tpy – 30 yrs	128,000	569M	\$57M

## *Site Closure and Reclamation Costs*

These costs will relate to well capping, well abandonment, proper abandonment of underground piping, removal and disposal of above-ground facilities and reclamation of the site surface. With exception of well capping, these activities are most likely to take place during closure, and during the post-closure phases of a geologic carbon sequestration project.

### **Well capping**

- A cost of \$300,000 to \$400,000 per well is assumed for capping and abandonment of each injection well and associated operational monitor wells (assumed to be 3 monitor wells per injection well), including mobilization-demobilization.
  - Based on Table 8, Post-closure Well Plugging, Equipment Removal, and Site Care Unit Costs (EPA/ICF 2008 Geologic CO<sub>2</sub> Sequestration Technology and Cost Analysis, Technical Support Document):
    - Flushing, MIT, plugging, logging, removing surface materials and documenting for each 7000-foot injection well and documentation is estimated to be \$85,000.
    - Plugging, logging, removing surface materials and documenting for each of the 3 monitoring wells is estimated to be \$27,000
- For a field of 3 injection wells, the total estimated cost is in the range of \$.9M to \$1.2M with an average of \$1M

### **Removal of above-ground facilities**

- For facilities demolition and disposal, including pipelines, and reclamation of disturbed lands, it is recommended that the bonding provisions of WDEQ-LQD Guideline No. 12 be applied.
- The average estimated demolition and disposal cost for a typical coal mine in Wyoming, estimated from reference manuals, is approximately \$7M. Approximately half of those estimated costs are related to facilities that do not

have counterparts in geologic carbon sequestration operations. Adapting those estimates, the range of demolition and disposal costs for a geologic carbon sequestration operation is estimated to be \$0.5M to \$3.5M is estimated, with an average of \$2M.

### **Site reclamation**

- The upper bound for surface disturbance is estimated to be 10,000 acres total if significant disturbance is needed for brine treatment ponds, with a lower bound assumed to be 500 acres
  - For the 10,000 acre figure it is assumed that 2,000 acres consist of facilities, roads, etc, and that 8,000 acres are involved in water and brine treatment and evaporation ponds involved in treatment of 48,000<sup>6</sup> acre-feet of fluid from the hydraulic front)
- Typical surface reclamation costs average \$400 per acre. Surface disturbance reclamation is estimated to range from \$0.2M to \$4M.

### *Post-closure Inspection and Maintenance Costs*

Based on general ranges for post-closure inspection and stabilization costs discussed in WDEQ-LQD Guideline 12 it is assumed that the lower end of these ranges should be applicable to similar aspects of the post-closure phase of inspection and maintenance costs for geologic carbon sequestration operations. That results in application of a factor of approximately 1% of the total bond level.

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<sup>6</sup> An evap pond would also evaporate water with time minimizing the total volume of fluid handled. If water is treated to the point that it is either drinking water, or at least for use as process water, it would have value.

*Environmental Monitoring, Verification and Control Costs*

**Operations phase**

The background and assumptions utilized for these cost estimates are essentially the same as those discussed for post-closure monitoring in the subsection below, with the exception of the monitoring period. The operations phase is assumed to last 30-years, with a commensurate monitoring period and estimated costs.

It is assumed that monitoring requirements during the operations phase will include remote sensing (InSAR and GPS), monitoring of air, soil and tracers (ambient CO<sub>2</sub>, eddy covariance, soil CO<sub>2</sub>, tracers-isotopes), water quality and brine sampling, subsurface and wellhead pressure monitoring, and geophysical monitoring (3-dimensional seismic monitoring and tiltmeters)

Cost estimate ranges are provided for these key monitoring subcategories for a 30-year operation period and the estimated total monitoring cost for the range of project sizes from 30 M tons to 120 M tons of CO<sub>2</sub> geologically sequestered over the life of the operation:

Remote Sensing	-	\$ 0.5M to \$ 2.0M
Air, Soil Gas & Tracer Monitoring	-	\$ 4.0M to \$15.0M
Water and Brine Monitoring	-	\$ 0.2M to \$ 0.6M
Subsurface & Wellhead Pressure	-	\$ 0.4M to \$ 1.4M
Geophysical Monitoring	-	\$ 4.0M to \$17.0M
<b>Total</b>	-	<b>\$ 9M to \$ 36M</b>

*(If the larger plume factors noted from other modeling results were applicable, the total figure might be anticipated to range as high as \$110M)*

Please also see Appendix J for additional details and discussions of operations phase monitoring cost estimate.

## **Post-Closure Phase**

Estimates for these costs are based on several geologic carbon sequestration pilot project details and information available from WY State Geological Survey, NETL (2005) and Benson, et al (2004). While the post-closure phase may be as short as 10 years, to be conservative, the cost estimates are provided for a 15-year monitoring period which commences upon reaching the post-closure phase. Several assumptions are inherent in these cost estimates, these include: (1) monitoring costs will be proportional to the size of operation and the corresponding projected areal extent of the CO<sub>2</sub> plume and displaced fluids and (2) the operating phase monitoring network is assumed to be used in post-closure and a 5-10% equipment replacement cost factor has been provided for the 15-year post closure monitoring period.

The projected size of CO<sub>2</sub> plume resulting from a theoretical commercial injection project varies with local geology, injection design, the modeling tools utilized assumptions, etc. Plume area factors (in terms of square miles of plume per million tons of CO<sub>2</sub> injected) were derived from available information and ranged from approximately 0.133 (Wyoming State Geological Survey) to 0.29 - 0.47 (Lawrence Berkeley-Benson 2004; range dependent on residual gas saturation classification of the receiving strata). NETL (2005) also presented figures implying a factor of 0.75, but projected for a very small operation and is not considered applicable for larger Wyoming projects. The factor from the Wyoming State Geological Survey is derived from specific regional information on receiving strata and is considered the most applicable for geologic carbon sequestration projects within the State. A factor of 0.15 square miles per million tons CO<sub>2</sub> injection, based on the Wyoming State Geological Survey modeling information, has been applied to the related monitoring costs for projected CO<sub>2</sub> plumes and related hydraulic front areas.

Cost estimate ranges are provided for a range of operational scenarios from a lower bound of a commercial operation injecting 1 million tons/year of CO<sub>2</sub> and an upper bound involving 4M tons/year CO<sub>2</sub>. The range assumes the operation had a total 30-year period of injection by close.

Monitoring requirements will include remote sensing (InSAR and GPS), monitoring of air, soil and tracers (ambient CO<sub>2</sub>, eddy covariance, soil CO<sub>2</sub>, tracers-isotopes), water quality and brine sampling, subsurface and wellhead pressure monitoring, and geophysical monitoring (3-dimensional seismic monitoring and tiltmeters).

Cost estimate ranges are provided for these key monitoring subcategories for a 15-year period and the estimated total monitoring cost for the range of project sizes from 30 M tons to 120 M tons of CO<sub>2</sub> geologically sequestered over the life of the operation:

Remote Sensing	-	\$ 0.3M to \$ 1.3M
Air, Soil Gas & Tracer Monitoring	-	\$ 2M to \$ 9M
Water and Brine Monitoring	-	\$ 0.4M to \$ 1.6M
Subsurface & Wellhead Pressure	-	\$ 0.4M to \$ 1.5M
Geophysical Monitoring	-	\$ 1.4M to \$ 5.5M
<b>Total</b>	-	<b>\$ 4.5M to \$ 18.9M</b>

*(If the larger plume factors noted from other modeling results were applicable, the total figure might be anticipated to range considerably higher).*

Please also see Appendix J for additional details and discussions of post-closure monitoring cost estimates.

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## RECOMMENDED FINANCIAL ASSURANCE LEVELS

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The recommended financial assurance levels are provided below for a mid-range geologic carbon sequestration project (with an injection rate of approximately 2 million tons CO<sub>2</sub> per year for a 30-year operational period). The costs are estimated separately for operation risks and post-closure phase requirements. The risk mitigation levels are based on upper bound cost ranges for maximum mitigation requirements per event for the mid-range operation for the events assessed within each major risk category. The listings include references to the nature of the maximum mitigation considerations; additional details are provided in risk-specific discussions above and in Appendix J. Costs for post-closure phase requirements include contingencies for unknowns and default considerations.

**These financial assurance levels are ONLY ESTIMATES based on the assumptions outlined above. Site specific considerations, permittee/operator credit risk and actual operating experience will affect actual costs significantly. These financial assurance levels are provided only to offer an order of magnitude for financial assurance requirements and risk events for a geologic carbon sequestration project.**

### *Special consideration categories and mitigation costs for Bonding*

#### Formation Fluid and Brine Removal Contingency<sup>7</sup>

Extensive relief well and water treatment mitigation	\$ 22M
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<b>Sub-total for risks (applicable to Bonding)</b>	<b>\$ 22M</b>
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<sup>7</sup> Given the anticipation of some hydraulic front response to the CO<sub>2</sub> injection but the considerable uncertainties around the extent and mitigation of related impacts, consideration might be given to addressing this via a split between bonding and insurance.

Risk categories and mitigation costs for Insurance

Water quality contamination during the fluid phase

Drinking water replacement \$ 15M  
(Ranked as low risk in both post-closure and long-term stewardship phases)

A single large volume release to the surface

Relief well mitigation addressed above<sup>8</sup>  
(Ranked as low risk in both post-closure and long-term stewardship phases)

Chronic low-level releases to the surface

Relief well mitigation addressed above<sup>9</sup>  
(Ranked as low risk in both post-closure and long-term stewardship phases)

Entrained contaminant releases

Pumpback and treatment systems \$ 10M  
(Ranked as low risk in both post-closure and long-term stewardship phases)

Storage rights infringement

Relief well mitigation addressed above<sup>10</sup>  
(Ranked as a low to moderate risk in the post-closure phase and a low risk in the long-term stewardship phase)

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<sup>8</sup> For the listed risks, the maximum estimated remediation costs are entered and in some cases the maximum remediation method (relief well mitigation) is similar or the same for several risk/mitigation types. This is applicable to the entries of Formation Fluid and Brine Removal Contingency, A single large volume release to the surface, Chronic low-level releases to the surface, and Storage rights infringement. The likelihood of any of these occurring at a site is low, and the probability that all of these would occur at an injection site is extremely low. Therefore the bonding totals include one potential application of this maximum remediation method and the remainder of the entries with that same maximum remediation method as simply designated as “addressed above.”

<sup>9</sup> Ibid.  
<sup>10</sup> Ibid.

Modified surface topography		
Structural damages		\$ 5M
(Ranked as low risk in both post-closure and long-term stewardship phases)		
Accidents or unplanned events		
(Ranked as low risk in the post-closure phase and virtually a non-existent risk in the long-term stewardship phase)		
Surface clean-up		\$ 5M
<b>Sub-total for risks (applicable to Insurance/Trust)</b>		<b>\$35M</b>

Post-injection requirements and costs for Bonding

Well capping & abandonment (avg for 3 well field)	-	\$ 2M
Facilities/pipeline D&D/abandonment (est avg)	-	\$ 2M
<u>Surface disturbance reclamation (est avg)</u>	-	<u>\$ 2M</u>
<b>Sub-total for site closure &amp; reclamation</b>		<b>\$ 6M</b>
Post-injection monitoring (15-year block example) <sup>11, 12</sup>	-	\$ 9M
<u>Post- injection inspection and maintenance costs</u>	-	<u>\$ 1M</u>
<b>Sub-total monitoring, inspection &amp; maint.</b>		<b>\$ 10M</b>
Contractor contingencies for site closure & recl (15%)	-	\$ 2M
Field management	-	\$ 1M
<u>Unknowns for site closure &amp; reclamation (10%)</u>	-	<u>\$ 1M</u>
<b>Sub-total for contingencies in Bond</b>		<b>\$ 4M</b>

<sup>11</sup> The table above regarding post-injection requirements and costs for bonding considerations lists the monitoring entry as \$13M for the estimated costs of monitoring for a post-closure 15-year block example for the mid-range scenario of 60M tons CO2 sequestered (2Mtpy for 30 years).

<sup>12</sup> The estimated monitoring costs during the Operation Phase for the same mid-range scenario are projected to be approximately \$22M, a lesser amount; a similar relationship exists for the low range and high range scenarios as well.

**TOTAL FINANCIAL ASSURANCE** **\$ 77M**

Portion applicable to Bonding: **\$ 42M**

Portion applicable to Insurance: **\$ 35M**

**Recommended ranges for mid-size operation through post-closure:**

**Bonding** **\$ 40M to \$ 50M**

**Insurance** **\$ 25M to \$ 45M**

For bonding levels in both the operation and the post-closure phases it is recommended that the project-specific estimated post-injection monitoring amount should be applied to bonding during both the operating and the post-closure phases. That will address any potential of the State assuming the monitoring obligations in a forfeiture situation.

## MINIMUM DURATION OF THE POST-CLOSURE CARE PERIOD

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The Post-closure care period includes final reclamation and monitoring until plume stabilization has occurred. The Post-closure commences at the point when CO<sub>2</sub> injection ceases and all wells (excluding monitoring wells) have been appropriately plugged and abandoned. The Post-closure period concludes when the reservoir meets all of the standards specified below.

- All surface equipment and improvements have been appropriately abandoned or removed.
- Minimum Time Period of 10 years from the time of last CO<sub>2</sub> injection, appropriate plugging and abandonment of all wells (excluding monitoring wells), cessation of all subsurface operations and activities, and appropriate removal and abandonment of all surface equipment and improvements (beginning of the Post-closure care period). During this time, a monitoring protocol will continue at prescribed intervals. If the site is confirmed by DEQ to meet plume stabilization standards for the site, then the Long-term Stewardship phase can begin.
- Post-closure cannot conclude until all standards have been met and the stabilization criteria has been achieved for a minimum of three consecutive years. Standards for closure will be set at the time of permitting consistent with DEQ Rules and Regulations.
- Post-closure responsibilities for above ground site reclamation may be performed throughout the post-closure period. Financial assurance requirements for post-closure reclamation activities shall not be linked to the post-closure duration period described above. All surface mitigation obligations shall be met, however, prior to release of financial assurance related to these activities.

- The operator/permittee must petition the DEQ to release financial assurance after the plume stabilization has been demonstrated as determined by DEQ Rules and Regulations. DEQ (or appropriate agency) must certify the site and sign release document to end the period of post-closure care.
  
- DEQ will develop Rules and Regulations defining plume stabilization. At a minimum, monitoring during the post-closure period shall consist of, but will not be limited to:
  - Periodic reservoir pressure monitoring from sensors in monitoring well;
  - Periodic Water chemistry from reservoir zone in each monitoring well;
  - Periodic Water chemistry from useable aquifer zones in monitoring wells;
  - Periodic surface subsidence measurements;
  - Extent of migration of the plume through seismic or other acceptable means; and
  - Measurement of ambient CO<sub>2</sub> at the surface at each abandoned well and other sites determined during the initial permitting period.
  
- Anticipated minimum standards for closure (subject to standards and criteria that will be established when DEQ develops regulations to define what is meant by plume stabilization) are:
  - Attainment of acceptable reservoir pressure levels;
  - Stabilization of water chemistry in the reservoir zone;
  - Attainment of acceptable levels of pH, salinity, metals, (etc.);
  - No measurable surface subsidence;
  - Plume migration within acceptable limits set by pre- and during injection models; and
  - Attainment of acceptable levels of ambient CO<sub>2</sub> levels around abandoned wells.

## RECOMMENDATION OF DRAFT STATUTE

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Given that geologic carbon sequestration is relatively unproven with many technological, economic, regulatory, legal and political challenges yet to be resolved, the Working Group recommends the legislature afford DEQ broad rulemaking authority to establish the requirements for bonding and financial assurance. In addition, the statute should authorize rules that provide procedures and requirements for:

- Periodic reporting by the operator to allow the administrator to confirm or adjust the amount of financial assurance considering the site, facility, and operation-specific risks and conditions;
- Permit suspension or termination if financial assurance cannot be secured or replaced in the amounts required;
- Bond forfeiture and insurance claims;
- Bond release and insurance termination upon the issuance of a completion and release certificate, certifying that plume stabilization has been achieved, as defined by rules, without the use of control equipment based on a minimum of three consecutive years of monitoring data, and that the operator has completed site reclamation and any required monitoring and mitigation activities;
- Recordation of an affidavit in the county land records as public notice that a tract of land is underlain by a site used for geologic sequestration; and
- The adoption by regulations of a fee structure and amounts to be collected and credited to a newly created Geologic Sequestration Special Revenue Account as discussed below.

The Working Group also recommends an additional permit requirement that the operator show proof of public liability insurance in an amount and duration to be determined in rules, similar to the requirement for surface coal mining operations.

Further, because the Working Group anticipates that environmental impairment or special risk insurance may be allowed by DEQ as a financial assurance option (in lieu of allowing only performance bonds, self-bonds or deposits), statutory language is recommended that any such insurance shall name the State as an additional insured, and the presence of insurance shall not constitute a waiver of sovereign immunity.

Finally, the creation of a Special Revenue Account is proposed as a privately-funded, publicly-controlled account within Wyoming's Special Revenue Fund under Wyoming statute section 9-4-204(t)(i)(B), to cover all costs for measurement, monitoring and verification following site certification (i.e., during the Long-term Stewardship Phase). This Account would be funded by operators and administered by DEQ.

Proposed bill language is contained in Appendix F.

## CONCLUSION

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A geologic carbon sequestration financial assurance system is essential to offer assurances both to the public and private sector that the risk of failure of the containment zone is appropriately managed. The framework discussed in this report provides a menu of financial assurance options to project developers and regulators which ensure funds are adequate (if and when needed) and readily available to pay for site closure, post-closure and corrective activities, both now and in the future. Different financial assurance vehicles present different attributes and risks to regulators and operators.

This report sets average levels for financial assurance based on the initial cost estimates for reclamation and mitigation activities for key risk categories. Cost estimates will vary greatly based on specific site attributes and need to be further refined with risk management modeling to develop accurate risk management plans and financial assurance requirements. Good site selection and risk assessment during the permitting phase is of critical importance in reducing and estimating risk adequately.

The group recommends allowing a suite of financial assurance methods to meet potential reclamation and mitigation obligations during the first three phases of the project. Self-bonds shall be excluded in the post-closure phase when operator accountability declines and collection risk increases. Traditional performance bonds, insurance, a special revenue fund and potentially a separate trust fund (for a small portion of the covered amount) should be allowed through the post-closure phase.

DEQ has extensive experience setting and administering bonds for the many quantifiable and predictable activities associated with wells and drilling activity. Heavy reliance will be placed upon bonding instruments where possible and where the risk events are known and quantifiable such as drilling, well failure, injection, well closure, land reclamation, etc. Insurance is likely to be the preferred instrument in low probability, uncertain and typically insurable events during all phases of the project. But as noted above, insurance

may not be available for certain risks events or at certain project phases. DEQ will need to develop additional staffing resources with the necessary technical and risk management skills as bonding experience alone will not be sufficient to craft a financial assurance system for all the risk elements of a geologic carbon sequestration project.

It is recommended that the legislature authorize funds for a minimum of three new positions within the DEQ. The first would be a Financial Analyst with skill and capability to review, manage and update financial assurance documents, compare levels of assurance with levels of risk for adequacy, track the financial health of permittees who are self bonded, work closely with other State agencies (i.e. the State insurance commissioner, State treasurer others) to maintain current status and understanding of financial markets and the surety industry, provide the necessary accounting and evaluation of adequacy of special revenue accounts and potential trust accounts and advise the director on financial assurance decisions. The second position is a geophysical engineer or geological engineer with experience in geophysical techniques and structural geology. The third position is a reservoir engineer with experience in oil and gas well liquid and gaseous activity in deep reservoir rocks. This position will assist the administrator in the evaluation and approval of modeling and monitoring techniques that are unique to geologic carbon sequestration.

Creation of a State Special Revenue Account is also recommended to provide for measurement, monitoring and verification (MMV) costs after the post-closure period has concluded. Creation of a Trust Fund may be desirable to address the reclamation and mitigation costs of extremely low probability events which might occur after the post-closure period, likely many years after injection has ceased and a permittee/operator is no longer associated with the project. Appendix G includes a potential Wyoming Trust Fund model which would be privately funded up to an amount certain, with a Federal assumption of liability above and beyond a capped amount. Funds would be available primarily for low probability events in the Long-Term Stewardship Phase. The State of Wyoming would act as administrator of this fund. The Fund would only be created if and

when the Federal Government assumes liability for any risk event which occurs in the Long-term Stewardship phase exceeding the set cap.

Availability and affordability of financial assurance may dictate permittee/operators' options, but the State should be willing to accept multiple financial assurance mechanisms sufficient to pay for any mitigation or reclamation costs that the State may incur as a result of default by the permit holder.

The legislature requested a recommendation regarding the duration of the post-closure care period. It is important to note that EPA currently defines the post-closure care period to include the Long-term Stewardship phase. Several States have indicated a post-closure care period ranging from 10 to 100 years. The group concluded that the post-closure care period should be no less than 10 years and shall require favorable reporting of plume stabilization metrics to be outlined in DEQ rules and regulations and achieved over a period of not less than three consecutive years. DEQ (or appropriate agency) must certify the site and sign release document to end the period of post-closure monitoring and site care.

Development of multiple geologic carbon sequestration pilot and commercial scale demonstration projects will likely significantly enhance the accuracy and availability of financial assurance requirements and resources which satisfy the State and are reasonable for the private sector. Participation by the Federal government for the Long-Term Stewardship phase is a critical component to any system. Any financial assurance system should also provide sufficient flexibility to adjust for actual operating history, calculable loss events and completion of project phases, as these projects develop and perform in years to come.

## APPENDICES

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- A. HB 090
- B. Phases of Sequestration Project
- C. Summary of Legal Liability Theories
- D. Charter for the Working Group
- E. Summary of Presentation and Reference Materials on Disk
- F. Draft Statute
- G. Trust Model
- H. Risk Description and Matrix
- I. Bond Adjustment Matrix
- J. Additional Background for Cost Justification