Amendment to

Project Annex I – Weyburn CO_2 Sequestration Project
Under the
Implementing Agreement Between The Department of Energy of the United States of America
and
The Department of Natural Resources Canada for Cooperation in the Area of Fossil Fuels

Background

Geologic storage of carbon dioxide (CO_2) has been proposed as a viable option to be used for reducing anthropogenic CO_2 emissions. The potential for geological storage is very large. There is significant and active worldwide interest in geological storage projects from a wide range of stakeholders – industry, regulators, reservoir owners, environmental organizations, public interest groups, and the general public. Important issues concerning geological storage include:

- Demonstration of the safety and long-term security of geological CO_2 storage;
- The general effect of economic factors, including incentives and taxes;
- What factors should be considered for permitting, operation and abandonment of storage sites;
- Determining long-term monitoring capabilities and requirements to manage long-term liability for industry and the public sector.

The Weyburn CO_2 Sequestration Project, Phase 1, was a field demonstration project launched by the Petroleum Technology Research Centre (PTRC) in July, 2000, in close collaboration with EnCana Resources of Calgary, Alberta (formerly PanCanadian Petroleum Limited). EnCana Resources of Calgary, Alberta, currently operates the Weyburn Unit 1 Oilfield. The project addressed CO_2 storage in conjunction with economic CO_2 enhanced oil recovery (EOR) operations. The overall mission of Phase 1 of the Weyburn CO_2 Sequestration Project was to assess the technical and economic feasibility of geological CO_2 storage in oil reservoirs, and to develop implementation guidelines for such projects. Implicit in the assessment was the identification of the risks associated with this method of CO_2 storage, especially long-term risk of CO_2 leakage. This required establishing comprehensive knowledge of the geological nature of the reservoir and the region where the CO_2 was to be stored, the movement and ultimate geochemical fate of the CO_2 within the reservoir, reservoir storage capacity, and the economic viability of CO_2 storage in the reservoir. It also required developing an overall risk assessment of the probability and consequences of CO_2 leakage.

Areas identified during Phase 1 as requiring additional research included the following:

- The Phase 1 risk assessment did not achieve a complete solution. The project has successfully tested a risk assessment 'base case' that should, with further development, lead to a tool that can be used at Weyburn and can form the basis for risk assessment applications elsewhere.

- Wellbore integrity was clearly identified as a major risk element that was not completely addressed. Additional research projects focusing on cement and casing material integrity are critical to the risk assessment.

- The geochemical models provided only limited, usable operational information. These geochemical models should be integrated with the seismic data/interpretations, reservoir simulation models, and compared to natural analogs.

- Additional interpretation of the seismic data is needed to yield more precise information on the movement, location, and concentration of the CO_2.

- The seismic data and processing costs were high, and would not be cost effective for future projects. The seismic data costs need to be reduced significantly using the most cost effective techniques possible.

- Long-term monitoring techniques must be improved to make them more affordable, more fieldwork "friendly," and less invasive.

- The successful technologies and processes from Phase 1 must be more effectively integrated into a methodology and document that addresses all the issues in geological storage of CO_2.

The work conducted in Phase 1 has provided guidance for the Phase 2 project scope. Several new questions and extensions of the earlier questions have been raised, leading to the Phase 2 scope of the Weyburn CO_2 Sequestration Project.

Pursuant to Section 7 of "Project Annex I – Weyburn CO_2 Sequestration Project Under the Implementing Arrangement between Department of Energy of the United States of America and the Department of Natural Resources Canada for Cooperation in the Area of Fossil Fuels" (hereinafter "Project Annex I"), the Department of Energy of the United States of America and the Department of Natural Resources Canada amend Project Annex I as follows, to identify the tasks to be performed during Phase 2:

Program Scope and Task Allocation

The Phase 2 project will build on the successes of Phase 1 to address research and demonstration opportunities that have been identified in Phase 1. Phase 2 results will provide vital information relating to subsurface properties and processes involving CO_2 rich fluids, as well as those involved in assessing the reliability of and requirements for establishing CO_2 storage projects.

The specific objectives for Phase 2 of the Weyburn CO_2 Sequestration Project include:

- Build upon the dataset that exists from Phase 1 to provide a comprehensive dataset that can serve as the international standard of comparison of CO_2 storage/injection projects.

- Enhance the Phase 1 risk assessment model and process so that these risk assessment tools can be the international standard for CO_2 projects.

- Complete all research necessary to generate a detailed "Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects."

These objectives will provide useful information for all sponsors including EOR operators, government policy makers, industrial sponsors, and other stakeholders. Enhanced analyses and interpretation of these data collected from Phase 1 will provide significant additional knowledge.

Task 1 – Geosphere and Biosphere Studies and Development of Universal Screening Protocols for the Selection of CO_2 Storage Sites

In this task, small scale geosphere and biosphere projects will be completed that will further the knowledge acquired from the Phase 1 study, as well as fill in data gaps from the Phase 1 study. In addition, protocols for the selection of CO_2 storage sites will be developed and incorporated into a section of the "Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects" that is being developed in Phase 2. Information for these protocols will be generated from: 1) the construction of an earth model for Weyburn developed from Phase 1 data and, 2) the determination of the requirements for selection of a CO_2 storage site using performance assessment tools.

Sub-task 1.1 – In this sub-task, small scale geosphere and biosphere projects will be completed from target subjects that have been identified by the work in Phase 1. These are likely to include studies to refine the characterization of near surface sediments and transport properties, as well as studies to better assess the continuity and integrity of units that serve as seals throughout the geologic column. Other studies will likely focus on features that may serve as vertical pathways for fluid migration such as faults and geophysical anomalies; these will be studied in conjunction with regional hydrogeological data. A Workplan will be developed for all geosphere and biosphere projects planned in this task, and submitted to the U.S. Department of Energy (DOE) for review and input. DOE will provide a suggested outline for the Workplan and, as new projects are planned, they can be added to the initial Workplan developed.

Sub-task 1.2 – In this sub-task, protocols for the selection of CO_2 storage sites will be developed and incorporated into a section of the "Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects" that is being developed in Phase 2. The work completed in Phase 1 provides an excellent data set that was used to construct an earth model for Weyburn and the surrounding area. This earth model was used in the Phase 1 risk assessment model and will be used for Phase 2 risk assessment. A key deliverable from the work in Phase 2 will be to use the performance assessment tools and scientific principles to determine data requirements for

selection of CO_2 storage sites. These 'universal screening protocols' will form a significant section of the "Best Practices Manual for Development and Operation of $CO2_2$ Geological Storage Projects." In addition to this work, this task will also include the development of an outline for the 'universal screening protocols for selection of CO_2 storage sites' section for the "Best Practices Manual for Development and Operation of $CO2_2$ Geological Storage Projects;" the outline will be submitted to DOE for review and input.

Task 2 – Prediction, Modeling and Verification of CO_2 Plume Movements and Development of A Long-term Monitoring Program for CO_2 Reservoirs

In this task, technical methods that were successful for predicting, monitoring, and verifying CO_2 movement in Phase 1 will be further developed. Long-term monitoring of the CO_2 reservoir will require the integration of the successful prediction, verification, and monitoring techniques identified during Phase 1. When integrated into a monitoring program, they will provide a protocol that can be adapted to a range of geologic sites and industrial applications and operations throughout the globe. The monitoring techniques must be modified to be more cost-effective and easier to use in the field. If geological storage is to become an economically viable and environmentally acceptable solution to greenhouse gas emissions, a monitoring program that is effective, reliable, cost-efficient, and environmentally acceptable must be developed. Results from the Weyburn CO_2 Monitoring and Storage Phase 2 Project will permit industry operators to move forward with storage projects with greater confidence to effectively monitor and maintain the storage sites long into the future.

In this task, activities to be conducted include: 1) further development of seismic techniques utilized in Phase 1; 2) research to improve the cost-effectiveness of seismic data acquisition and processing; 3) continuation of the surface geochemical monitoring and water production sampling programs; 4) geochemical natural analog and modeling studies; and 5) integration of selected, successful technologies into a long-term monitoring program approach. Long-term monitoring of the CO_2 reservoir will require the integration of the successful prediction, verification, and monitoring techniques identified during Phase 1. The field and equipment designs developed, the field data acquired, and the results from the modeling and simulations conducted will be provided to DOE. In addition, a report containing the long-term monitoring program that was developed for the CO_2 reservoir by integrating monitoring and simulation technologies will be provided to DOE for review and input.

The ability to predict and model CO_2 movement, then verify the three-dimensional location of the CO_2 plume, is a critical component in establishing operational conformance and validation of geological storage. Furthermore, it can provide the ability to verify stored CO_2 volumes for greenhouse gas credits. For example, considerable value can be obtained from the current 4D seismic data sets acquired in Phase 1. The integration of 4D seismic data with reservoir simulation results and production provided improved verification techniques to assess CO_2 movement and EOR processes. Additional work in this area includes determination of saturation, comparison of matrix and fracture pore volumes from seismic and reservoir modeling, and integration of borehole and surface seismic data sets. The 4D seismic data set may also aid in evaluating pore volume and fracture connectivity from determining the presence of CO_2. Predictions made from conventional 3D seismic can be tested and, if successful, extended to the

rest of the Weyburn field and to similar areas.

Seismic data acquisition costs are currently prohibitive, so another research objective of this task will be to determine how to reduce costs and extend benefits. This subtask will be completed before additional seismic data is acquired for Phase 2. Reducing the seismic costs may involve novel surface or borehole techniques, reducing sensor costs, and modifying acquisition methods. These newly developed techniques should also be applicable to EOR and storage projects.

The surface geochemical monitoring and water production sampling programs will also be continued in this task. These tools have the potential to provide rapid and inexpensive monitoring capability for long-term storage. Sampling of produced water may also serve as a means of monitoring the performance of the CO_2 EOR operations, as well as determining the effectiveness of CO_2 storage. These data will be especially valuable for areas in which 4D seismic control is unavailable.

In this task, other geochemical studies initiated from Phase 1 will be continued in Phase 2. Natural CO_2 analogues provide direct evidence for the impact of CO_2 on subsurface formations. Understanding the geochemical impact of CO_2 in natural analogues provides constraints on processes that impact reservoir and seal integrity, thereby either limiting or enhancing long-term sequestration of CO_2. In addition, geochemical modeling provides predictions of rock property changes with knowledge of rock and fluid properties and temperatures and pressures. A successful demonstration of this technology will permit more accurate future predictions. Improved accuracy of predictions of reservoir properties should facilitate CO_2 storage site approval. Furthermore, approval for injection of other fluids and injection operations should be more easily acquired.

Task 3 – CO_2 Storage Capacity, CO_2 Distribution Predictions, and Revised Economic Model

This task will include: 1) maintaining and updating the reservoir simulation and economic models (that will permit studying the relationship between produced and stored volumes, subsidies, and rates of return); 2) continuing studies to optimize the storage of CO_2 (that will permit economic and/or performance assessment impacts); and 3) studying a profile control as a means of providing an opportunity to improve economic production of oil during the CO_2 flood.

In this task, work will continue on optimizing storage of CO_2. Initial results show that significantly more CO_2 could be stored in the Weyburn field. Some options also result in additional oil production. Each option has tradeoffs in terms of economic and/or performance assessment impacts. Establishing the maximum storage potential will allow field operators/owners and regulators to determine the maximum storage potential and the value of EOR sites as storage sites. In addition, a generic economic model showing the relation between produced and stored volumes, subsidies, and rates of return has been generated, and it will be adapted in this task to all enhanced storage cases to be studied. A report describing this updated economic model will be submitted to DOE for review and input.

Another smaller impact study will be conducted in this task to study a profile control as a means

of providing an opportunity to improve economic production of oil during the CO_2 flood. This would also directly impact the capability to increase the volumes of CO_2 stored by removing the pore-filling oil, and provide a more uniform distribution of CO_2 in the reservoir.

Task 4 – Long-Term Performance and Risk Assessments of the Storage Site

In this task, activities focused on long-term performance of CO_2 storage will be performed. These include activities such as development of simulation models for the entire geosphere including the oil reservoir, and studying well bore integrity and other well bore issues over relatively long periods of time. In addition, the task will include completion of a risk assessment of the storage site to address the potential risks associated with CO_2 storage and sequestration operations.

Sub-task 4.1 – This sub-task will include development of tools and completion of studies that can be utilized to conduct a risk assessment of CO_2 storage areas. Activities in this task include developing simulation models for the entire geosphere including the oil reservoir, and characterizing all of the complex issues associated with well bore integrity over relatively long periods of time. Other research areas may include a project on well bore failure frequency analysis from the large database available in the Western Canadian Sedimentary Basin, an analysis of issues from the Gas Storage Industry, and additional analysis building on the Clean Coal Project (CCP)-SMV study of U.S. Permian Basin CO_2 -projects. A number of these activities will be crucial in conducting a risk assessment for the CO_2 storage and sequestration operations.

Sub-task 4.2 – This sub-task will develop a process for risk assessment of CO_2 storage areas. The process will identify the tools required to complete a. risk assessment of storage sites. Achieving an accurate and successful risk assessment study is absolutely critical to the Weyburn CO_2 Storage and Monitoring Project and other potential storage projects. This is the tool by which the long-term viability of a storage project can be demonstrated and compared. Developing simulation models for the entire geosphere, including the oil reservoir, and characterizing issues associated with well bore integrity over relatively long periods of time, are critical to successfully achieving an assessment process. Phase 1 achieved significant advances in understanding the problem, but did not achieve a solution. No other project has achieved a simulator-based solution, but the Weyburn project has successfully tested a 'base case' that should, with further development, lead to a tool that can be used at Weyburn and can be applied to other storage sites. The risk assessment process is not only useful for addressing the potential risks associated with the site, but Phase 2 studies will use it to determine the critical information needed to satisfy the design needs for a storage site.

Task 5 – Integration of Technologies and Communication Plan

This task consists of integrating the successful technologies from Phase 1 with the follow-on studies from Phase 2, to develop a 'Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects.' The manual can be used to guide the screening, construction, and implementation of CO_2 projects worldwide. Lessons learned from other sequestration projects will also be integrated into the document. The task will also include development and

implementation of a communication plan to distribute Phase 2 study results to interested stakeholders such as sponsors, researchers, technical audiences, governments, non-government organizations (NGOs) and the general public.

Sub-task 5.1 - This sub-task includes development of a 'Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects' that can be used to guide the screening, construction, and implementation of CO_2 projects worldwide. Phase 1 investigated a large number of technologies to understand the mechanisms of CO_2 distribution and containment within the reservoir, and the degree to which CO_2 can be permanently sequestered. In Phase 2, the opportunity to develop synergies with other external projects involving CO_2 storage will be carefully reviewed. Weyburn has the opportunity to integrate findings from Weyburn and other projects, and to complete analyses of these integrated findings. Collaboration with these projects will be required to ensure that the best results are being obtained in the most cost effective manner. Results will be documented in a 'Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects.' A draft of this manual will be submitted to DOE for review and input.

Subtask 5.2 - This sub-task shall include distribution of Phase 1 and Phase 2 results to as wide an audience as permitted under existing confidentiality agreements. In Phase 2, a communication plan will be developed and submitted to DOE for review and input. The communications strategy from Phase 1 will be built on in Phase 2 to integrate the needs of all stakeholders – sponsors, researchers, technical audiences, governments, NGOs, and the general public. The communication plan will then be implemented.

Deliverables

The specific deliverables for Phase 2 are:

1. A Workplan for geosphere and biosphere studies and results from these studies, as described in Task 1.

2. An outline of the process developed for "Universal Screening Protocols" for the selection of CO_2 storage sites, as described in Task 1.

3. A report containing the long-term monitoring program for the CO_2 reservoir that was developed by integrating monitoring and simulation technologies, as described in Task 2.

4. A report describing the updated Phase 2 economic model, as described in Task 3.

5. A risk assessment process/model for CO_2 geological storage sites as described in Task 4

6. A draft 'Best Practices Manual for Development and Operation of CO_2 Geological Storage Projects' and final manual as described in Task 5.

7. A communication plan to distribute the Phase 1 and follow-on Phase 2 results to stakeholders (sponsors, researchers, technical audiences, governments, NGOs, the general public, and others as described in Task 5.

8. A dataset from Phase 1 and the Phase 2 follow-on studies (permitted under existing confidentiality agreements) that will be a resource for existing and future CO_2 geological storage projects, as described in Tasks 1 through Task 5.

Duration of Project
To September 2009

Potential Project Supporters and Research Providers

Potential project sponsors and research providers for Phase 2 include:

Project Sponsors:

Government:
Alberta Energy Research Institute
The European Commission
The Department of Natural Resources of Canada
The United Kingdom Department of Trade and Industry
The United States Department of Energy
Saskatchewan Industry and Resources

Industry:
British Petroleum
Chevron Texaco
Dakota Gasification Company
Engineering Advancement Association of Japan
EnCana Corporation
Weyburn Unit 1 Owners (The Unit is owned by 28 oil and gas companies including EnCana)
Nexen Incorporated
SaskPower
TransAlta Utilities

Research Providers:

Canada:
Alberta Research Council
EnCana Corporation
GEDCO Inc.
J.D. Mollard and Associates Limited
Rakhit Petroleum Consulting Limited
Saskatchewan Industry and Resources
Saskatchewan Research Council
The Geological Survey of Canada
The Petroleum Technology Research Centre (PTRC)
University of Alberta
University of Calgary
University of Regina
University of Saskatchewan

European Community:
Bureau de Recherches Geologiques et Minieres

Istituto Nazionale di Geofisica e Vulcanologia
Quintessa Limited
The British Geological Survey
The Geological Surveys of Denmark and Greenland
The University of Rome

United States of America:
Colorado School of Mines
Lawrence Berkeley National Laboratory
Monitor Scientific Corporation International
North Dakota Geological Survey

FOR THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA:

Date: 4/28/05

Place:

FOR THE DEPARTMENT OF NATURAL RESOURCES CANADA:

Howard Brown
Assistant Deputy Minister
Energy Policy Sector

Date: APR 1 4 2005

Place: