

**DEVELOPMENT OF CHINA'S COALBED METHANE
TECHNOLOGY/CO₂ SEQUESTRATION PROJECT**

**FINAL PROJECT REPORT
Project No. A-030841**

Submitted to

Canadian International Development Agency

By

Alberta Research Council

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ACRONYMS

APEC	Asia Pacific Economic Cooperation
ARC	Alberta Research Council
CBM	Coalbed Methane
CCCDF	Canadian Climate Change Development Fund
CDM	Clean Development Mechanism
CDN	Canadian
CEA	Canadian Executing Agency
CEAA	Canadian Environmental Assessment Act
ChEA	Chinese Executing Agency
CIDA	Canadian International Development Agency
CMG	Computer Modelling Group
CMM	Coal Mine Methane
CSLF	Carbon Sequestration Leadership Forum
CUCBM	China United Coalbed Methane Co.
DAF	Dry-ash-free
ECBM	Enhanced Coalbed Methane Recovery
EIA	Environmental Impact Assessment
GC	Gas Chromatograph
GE	Gender Equality
GFP	Gender Focal Points
GHG	Greenhouse Gases
IW	Injector Well
JPETC	Joint Project Executive Technical Committee
JPSC	Joint Project Steering Committee
LCO	Local Community
LFA	Logical Framework Analysis
MOFCOM	Ministry of Commerce
MOFTEC	Ministry of Trade and Economic Cooperation
MOU	Memorandum of Understanding
PEL	Porteous Engineering Limited
PIP	Project Implementation Plan
PPS	Primary Porosity System
PSC	Production Sharing Contract
PW	Producer Well
RBM	Results Based Management
SLI	SNC Lavalin Inc.
SPS	Secondary Porosity System
WBS	Work Breakdown Structure

EXECUTIVE SUMMARY

BACKGROUND

This project was one of the projects selected under the Canadian Climate Change Development Fund (CCCDF). The goal of CCCDF is to contribute to Canada's international objectives on climate change by promoting activities in developing countries that seek to address the causes and effects of climate change, while at the same time contribute to sustainable development and poverty reduction.

Canada and China agreed to participate in the Development of China's Coalbed Methane Technology/CO₂ Sequestration Project (the Project). The Project goals are to promote environmentally sustainable development in China by enhancing its capacity to manage its environment and to promote economic linkages and partnerships between Canada and China. The purposes of the Project are: a) to transfer to China the technology to effectively exploit coalbed methane (CBM), a cleaner source of energy while storing CO₂, a greenhouse gas (GHG), in unmineable deep coal beds, if possible in poorer western China and b) to try and establish sustainable economic linkages between Chinese and Canadian CBM related industries.

A Memorandum of Understanding (MOU) between the Government of Canada and the Government of the People's Republic of China concerning this Project was signed on March 15, 2002. The expected completion date of the Project was March 31, 2006. The MOU was later amended to extend the Project completion date to December 31, 2006. A Project Implementation Plan (PIP) was formulated and was attached as an Appendix in the MOU.

Canada designated the Canadian International Development Agency (CIDA) to assume its responsibilities under this MOU. CIDA contracted the Canadian Consortium of Enhanced Coalbed Methane Recovery led by the Alberta Research Council (ARC), Sproule International Ltd. and the Computer Modelling Group (CMG) to be the Canadian Executing Agency (CEA). The contribution of Canada would consist of the provision of professional, technical, training and project management services and related training aids, as well as monitoring and evaluating the Project. The total value of Canada's contribution would not exceed five million dollars (CDN \$5,000,000).

China designated the Ministry of Foreign Trade and Economic Cooperation (MOFTEC), now the Ministry of Commerce (MOFCOM) to assume the responsibilities related to the implementation of the Project under the MOU. MOFTEC designated the China United Coalbed Methane Co. (CUCBM) as the Chinese Executing Agency (ChEA). The value of China's contribution would not exceed twenty five million Renminbi (25,000,000 RMB).

Project Title: Development of China's Coalbed Methane Technology/Carbon Dioxide Sequestration Project

CIDA Project number: A-030841

Chinese Executing Agency:

China United Coalbed Methane Co.

Canadian Executing Agency:

Alberta Research Council

Sproule International

Computer Modelling Group

The Project would provide assistance to China in seven major areas, each involving the joint cooperation of CUCBM (the ChEA) and the Canadian Consortium (the CEA):

1. General inventory of existing and potential CBM sites.
2. Detailed site selection, including environmental impact assessment (EIA)/Canadian Environmental Assessment Act (CEAA) screening report, and ranking to identify the three best sites for the micro-pilot field tests and identify CO₂ sources for the tests in China's interior.
3. Design of micro-pilot test procedures for the three highest ranked sites to evaluate CBM reservoir properties.
4. Carry out a single micro-pilot field test at the best suitable site. Drill one well/use existing well in the selected coalbed methane reservoir; complete the well and add surface facilities to allow injection and production tests and document results. If the results of the first micro-pilot test are not favorable, a second micro-pilot test will be carried out at a second suitable site. If this fails, a third final micro-pilot test may be required to obtain satisfactory results to go forward.
5. Engineering evaluation of micro-pilot test results and numerical model calibration for full-scale pilot test and commercial performance prediction.
6. Full-scale field pilot design for one selected site and model prediction of its potential commercial performance.
7. Training programs for technology transfer for up to 200 managers, engineers and technicians in China (including a gender equality strategy to maximize the involvement of women through, if required, affirmative action measures), at least 24 of whom will also be trained in Canada.

If the Project's micro-pilot tests are successful after the first or second well, the budget set aside for the second and/or third micro-pilot test would be used, with CIDA's approval, to provide more in-depth technical assistance/training for the full-scale pilot test if China decides to proceed with it.

The Project would provide China with enough knowledge and information to make an educated decision on whether or not to proceed with the full-scale pilot test, which if successful, would lead to commercial demonstration and operation.

PROJECT OVERVIEW

CIDA's Results Based Management (RBM) approach was employed in the management and implementation of the Project. The project design was therefore based on a set of clearly defined results, set in a Logical Framework Analysis (LFA) that was agreed upon by both the ChEA and the CEA and summarized below.

The **goal** of the Project is to promote environmentally sustainable development in China by enhancing its capacity to manage its environment.

The **purposes** of the Project are:

- To transfer to China the Canadian CO₂ enhanced CBM recovery/CO₂ sequestration technology (*Canadian CBM/CO₂ technology*) to effectively exploit coalbed methane, a cleaner source of energy, while storing CO₂, a GHG, in unmineable deep coal beds, if possible, in poorer areas of China's interior.
- To try and establish sustainable economic linkages between China and Canada CBM related industries

Expected results include:

- At the **goal** level (the developmental impacts)
 - Mitigating climate change through increased use of coalbed methane (CBM) and reduced CO₂ emissions.
- At the **purpose** level (the developmental outcomes):
 - Canadian CBM/CO₂ technology applied for full-scale pilot test (hopefully leading to CBM commercial production) and/or for replication of micro-pilot tests at other locations in China.
 - Commercial cooperation between Canadian and Chinese Firms on Canadian CBM/CO₂ technology.

To achieve these goals, the Project was divided into work breakdown structures (WBSs) through which activities were implemented. The WBSs are briefly described below:

WBS	Name	Sub-WBS	Description
WBS 100	Potential pilot sites	WBS 100	WBS 100 – Identification of 3-6 potential pilot sites
WBS 200	Geological/ engineering/ environmental characterization and ranking of top 3 pilot sites	WBS 201, 202, 203, 204	WBS 201: Site geological characterization WBS 202: Site engineering characterization WBS 203: Environmental screening WBS 204: Site selection and ranking
WBS 300	Micro-pilot field test design	WBS 301, 302, 303	WBS 301 Micro-pilot design and test procedures for Site #1 WBS 302 – Design and procedures for site #2, if necessary WBS303 – Design and procedures for site #3, if necessary
WBS 400	Micro-pilot field tests (up to 3)	WBS 401, 402, 403, 404	401 – Engineering and field supervision for site #1 WBS 402 – Engineering and field supervision for site #2, if required. WBS 403 – Engineering and field supervision for site #3, if required. WBS 404 – Pro-forma Environmental Impact Statement, monitoring of mitigation measures (if necessary).
WBS 500	Micro-pilot test evaluation and model calibration	WBS 501, 502, 503	WBS 501 Engineering evaluation of up to three micro-pilot test results WBS 502 Numerical model modifications and calibration WBS 503 History matching of micro pilot field test data
WBS 600	Preliminary design for full scale pilot test and conceptual design for one	WBS 601, 602, 603a, 603b, 604a,	WBS 601 – Field operation design WBS 602 – Drilling and completion design

	commercial scale surface facility	604b, 605	<p>WBS 603a – Full scale pilot surface facility preliminary engineering design</p> <p>WBS 603b – Commercial surface facility conceptual engineering design</p> <p>WBS 604a – reservoir performance prediction for full scale pilot</p> <p>WBS 604b – Reservoir performance prediction for conceptual commercial operation</p> <p>WBS 605- CO₂ source and gas market development</p>
WBS 700	Enhanced CBM/ CO ₂ technology skills applied at project test site and other coal beds in China	WBS 701, 702, 703a, 703b, 703c	<p>WBS 701- Needs analysis and gender equality strategy</p> <p>WBS 702 - Training and technology transfer plan</p> <p>WBS 703a – Training/technology transfer to CUCBM technical and managerial staff in China and in Canada</p> <p>WBS 703b - Training/technology transfer to CUCBM trainers</p> <p>WBS 703c – Study tours to Canada by Senior Managers from Chinese CBM industry</p> <p>WBS 704 – Monitoring of gender equality results</p>
WBS 800	Project management	WBS 801, 802, 803	<p>WBS 801 - Inception Mission</p> <p>WBS 802 – Project management by results</p> <p>WBS 803 - Dissemination of project results in China and in Canada</p>

At the Project **output** level, the key outputs are:

- Output 1.1 - 1 micro-pilot test meets requirements for full-scale pilot test (WBS 100 to 500)
- Output 1.2 - Preliminary design for full scale pilot test: field operation design, drilling and completion design; surface facility preliminary engineering design; reservoir performance prediction (WBS 601, 602, 603a, 604a)
- Output 1.3 - Conceptual design for one commercial scale surface facility, including conceptual engineering design; reservoir performance prediction for conceptual commercial operation; CO₂ source and gas market developments (WBS 603b, 604b, 605)

The output includes EIA/CEAA screening, if required (WBS 404).

- Output 1.4 - Enhanced CBM/CO₂ technology skills applied at project sites and other coal beds in China: needs analysis and gender equality strategy; training/technology transfer plan, transfer to CUCBM technical/managerial staff in China (up to 200 persons) and in Canada, (at least 24 persons) and transfer to CUCBM trainers; monitoring of gender equality results (WBS 701, 702, 703a, 703b, 704)
- Output 2.1 - Contacts established between Canadian and Chinese Senior Managers in CBM related industries (WBS 703c, 803)

SUMMARY OF IMPACTS, OUTCOMES AND OUTPUTS

The following tables summarize in more detail and from a RBM perspective, the results achieved over the life of the Project. The summary is in accordance with the expected results described in the LFA.

<i>NARRATIVE SUMMARY</i>	<i>Expected Impacts</i>	<i>Impacts Achieved/ In Progress</i>
<p>Project Goal:</p> <p>To promote environmentally sustainable development in China by enhancing its capacity to manage its environment</p>	<p>Project Impacts:</p> <p>- Mitigating climate change through increased use of CBM and reduced CO₂ emissions</p>	<p>Not measurable during life of Project</p>

<i>NARRATIVE SUMMARY</i>	<i>Expected Outcomes</i>	<i>Outcomes Achieved/ In Progress</i>
<p>Project Purposes:</p> <p>- To transfer to China the Canadian CO₂ enhanced CBM recovery/CO₂ sequestration technology (<i>Canadian CBM/CO₂ technology</i>) to effectively exploit coalbed methane, a cleaner source of energy, while storing CO₂, a GHG, in unmineable deep coal beds, if possible, in poorer areas of China's interior.</p> <p>- To try and establish sustainable economic linkages between China and Canada CBM related industries</p>	<p>Project Outcomes:</p> <p>Canadian CBM/CO₂ technology applied for full scale pilot test (hopefully leading to CBM commercial production) and/or for replication of micro pilot tests at other locations in China.</p> <p>Commercial cooperation between Canadian and Chinese Firms on Canadian CBM/CO₂ technology.</p>	<p>The Project confirmed that the Canadian CBM/CO₂ technology can be applied in China's coalbeds and recommended proceeding to multi-well pilot test at the south Qinshui site. However, it will be China's responsibility to decide whether to go ahead. CUCBM engineers now have a good understanding of the Canadian technology and will be able to apply it at other coal beds.</p> <p>The prospect is very promising: The ARC, on behalf of the Canadian Consortium, signed letters of understanding with three Canadian Companies and with the Heilongjiang Coal Field Bureau to evaluate the feasibility of applying the Canadian CBM/CO₂ technology in China. Two of these companies signed commercial Production Sharing Contract with CUCBM. Two other companies have expressed interest in CBM in China.</p>

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<i>NARRATIVE SUMMARY</i>	<i>Expected Outputs</i>	<i>Outputs Achieved/ In Progress</i>
	Project Outputs:	
To have a successful micro-pilot test (meeting all technical objectives) at a selected site (out of the top three sites)	Output 1.1 - 1 micro-pilot test meets requirements for full scale pilot test	<p>Micro-pilot test at TL-003 well, south Qinshui met all technical objectives</p> <ul style="list-style-type: none"> - 6 coal basins/coal fields were evaluated - The top 3 sites are: south Qinshui, Hedong coalfield and Hancheng coalfield - Micro-pilot design completed for south Qinshui - Project would not require CEEA screening report - First micro-pilot test successfully implemented at TL-003 well in south Qinshui; monitoring equipment installed; 192 tonnes of CO₂ were injected into seam #3 and the coal reservoir was successfully characterized. - The field test data were successfully history matched with a tuned reservoir model. - A good data set was collected.
Design and cost the full scale multi-well pilot at the selected site	Output 1.2 - Preliminary design for full scale pilot test: field operation design; drilling and completion design; surface facility preliminary engineering design; reservoir performance prediction.	<p>Preliminary design of a multi-well pilot test at south Qinshui completed</p> <ul style="list-style-type: none"> - The design is a 20-acre 5-spot pilot which will consist of four existing wells and one new injector well to be drilled approximately at the center of the pattern. The procedure is to inject 40 tonnes of CO₂ per day

		<p>for 6 months.</p> <ul style="list-style-type: none"> - 3-10 time enhancement of the CBM production rates and significant CO₂ storage in the coal seam will be observed. - The full scale pilot will cost about US \$ 9.5 million.
<p>Determine the initial economic feasibility of a commercial scale operation (including capital and operating costs, potential CO₂ sources, predicted performance and scale of operation) at the selected site</p>	<p>Output 1.3 - Conceptual design for one commercial scale surface facility: conceptual engineering design; reservoir performance prediction form conceptual commercial operation; CO₂ source and gas market development prediction.</p>	<p>Conceptual commercial operation with 100 wells, based on 160 acre 5-spot pattern is designed, performance predicted and cost estimated</p> <p>The conclusions for the commercial prospect of Canadian CBM/CO₂ technology at Qinshui basin are</p> <ul style="list-style-type: none"> - project is technically feasible; - project is possibly economic using zero or reasonable CO₂ credit value; - opportunities exist to reduce costs; - downhole water disposal is important;
<p>Canadian CBM/CO₂ technology transferred to China</p>	<p>Output 1.4 - Enhanced CBM/CO₂ technology skills applied at project sites and other coal beds in China: needs analysis and gender equality strategy; training/technology transfer plan, transfer to CUCBM technical/managerial staff in China (up to 200 persons) and in Canada (at least 24 persons) and transfer to CUCBM trainers; monitoring of gender equality results.</p>	<p>All training courses as per Final Training Plan completed</p> <ul style="list-style-type: none"> - since first micro-pilot test is a success, additional training courses, high level study tour and a recommended practices manual are added - 16 training courses in CBM and ECBM technologies, attended by 279 CUCBM staff (44 female or 16%) in China and 37 (11 female or 30%) in Canada. - Gender equality (GE)

		strategy developed; local coal bureau and gender focal points recruited; GE baseline profile developed and 2 GE workshops held.
Publicize the Project results and establish high level contacts between the Chinese and Canadian CBM industries	Output 2.1 - Contacts established between Canadian and Chinese Senior Managers in CBM related industries	<p>High level contacts established between Canadian and Chinese CBM Industry</p> <ul style="list-style-type: none"> - 2 high level study tours were held for 16 senior executives (5 female or 31%). - The Project was nominated and selected as a Carbon Sequestration Leadership Forum (CSLF) project. - Papers and presentations were made at international and Chinese technical conferences.

The Project has achieved all the Outputs as per the PIP. A copy of the Final Joint Project Steering Committee (JPSC) meeting minutes is included in Appendix 2.

MAJOR PROJECT CONCLUSIONS

The major conclusions from the Project are:

- Enhancement of coalbed methane recovery and storage of CO₂ is feasible in the anthracitic coals of Shanxi Province.
- The recommendation is to proceed to full scale pilot test at south Qinshui.
- Prospect is good in other coal basins in China

PROJECT PROCUREMENT

Project procurement by the CEA totalled about CDN \$ 221,000. The purchases include:

- PC's CDN \$70,000 (in lieu of the CO₂ purchased as per the PIP);
- Field monitoring equipment (GC and sample delivery system, pressure monitoring system and CO₂ pump) CDN \$152,000

The equipment is in good working order and is acknowledged by the JPSC in the Final meeting minutes.

KEY LESSONS LEARNED

As the Project involves field testing, assuring data integrity is of critical importance to the success of the Project. During the critical operating phases, the CEA supplied experts to the field to supervise the operation (for example, Ms. Bernice Kadatz for the field instrumentation and Mr. John Robinson for the CO₂ pumping). CUCBM also sent one expert (Mr. Wang Guoqiang) who spent three months in the field. It was still a challenge to have expert in the field all the time. For some periods, there won't be any coverage. There was a close call when electric power at the site was unknowingly tripped off. At the end, a good data set was collected. The data integrity was not compromised. If we were to do the micro-pilot test again in China, the long term development would be to have remote data access and control. In this manner, it would be less stringent to have personnel in the field all the time in order to make timely corrective actions.

Another consideration is to have a full time Canadian supervisor in China. In one occasion (casing head leaks), it was difficult to diagnose the problem and recommend the corrective measures from long distance. Obviously the full time field staff would increase the operating budget of the CEA. However, the advantage is that we could have quick corrective measures taken in the field when operating problems arise.

The other lesson that the CEA has learned was the time required for equipment shipping and clearing customs in China. It was not realistic to expect that customs could be cleared in a couple of days, even though all the paper work may have been completed. A minimum of 10 days should be allowed for custom clearing.

Similarly, the ChEA should allow plenty of time to clear visa for Chinese trainees to Canada. CIDA has streamlined the visa application process and made the time line very predictable. However, often the trainees did not have passports in their possession. This would take extra days to have the passports issued. The ChEA should screen the trainees for passports and allow minimum extra 3 weeks so that the CEA can have realistic schedule for planning training missions to Canada.

1.0 INTRODUCTION AND TECHNICAL BACKGROUND

Coal forms by the compaction of plant material. Gases, principally methane, are generated during this process and are either adsorbed onto the coal surface or dispersed into the pore spaces around the coal seam. The amount of gas formed depends on the rank of the coal. In addition, the maturation process releases large amounts of water so that the coal beds formed are often water saturated. The surface area of the coal, on which the methane is adsorbed, is very large (20-200 m²/g) and if saturated, coal bed methane reservoirs can have five times the amount of gas that are contained in a conventional, sandstone gas reservoir of comparable size.

The majority of the coalbed methane (CBM) is present in the sorbed state, attached to the coal surface in the coal matrix (the micropore system). However, some of the methane can also be stored either as free gas or dissolved in water in the cleat space in the natural coal fracture (macropore system). Normally there is little free flow of gas after the well is drilled, as the water pressure is greater than the gas pressure at the virgin coalbed methane reservoir. One way to induce gas flow is to remove water from the coal reservoir. As the water is removed from the cleat system, the pressure in the coal is reduced until the water pressure equals the gas pressure (termed desorption pressure); then methane gas is desorbed from the coal matrix (i.e. the micropore system) to the adjacent cleats (the macropore system). Therefore, large quantities of water usually have to be extracted from the coal bed before desorption pressure is reached. Often, CBM production is hampered by low flow rates, as permeability in coal beds is generally low (<10 md).

While the pressure depletion method described earlier is a simple and effective way to produce coalbed methane, it is not efficient. Reduction in reservoir pressure deprives the fluids of the energy necessary to flow to the wellbore. Furthermore, when the reservoir is water saturated, there are disadvantages associated with the long delay in methane gas production and the large quantities of water produced. This may be overcome by injection of a gas into the coal seams. Due to the presence of a gas phase, methane gas recovery can be enhanced either by reducing the partial pressure of methane through the introduction of a lower-adsorbing gas such as nitrogen (N₂) or displacement by the introduction of a higher-adsorbing gas such as CO₂. This technology is called enhanced coalbed methane recovery (ECBM).

Injected CO₂ is preferentially adsorbed at the expense of CBM, which is simultaneously desorbed and thus can be recovered as free gas. The CO₂ remains sequestered within the coal seam and with world interest in reducing CO₂ emissions, this process is capable of providing storage for CO₂ as well as enhancing the production of the methane gas. If the deep coal bed is never mined, it is likely the CO₂ would be sequestered for geological time scale.

The challenge is to refine the technology to exploit and utilize China's abundant CBM resources – not only to increase China's clean gas energy but to also improve China's energy structure and reduce energy waste which will have significant impact to the

growth of China's economy. The Canadian CBM/CO₂ technology is expected to increase the exploitation and utilization of CBM while at the same time, reduce emissions of CO₂.

In order to exploit and commercialize the Canadian CBM/CO₂ technology internationally, a Canadian Consortium on enhanced coalbed methane recovery was formed. The first target was China. The Canadian Consortium is made up of seven Canadian companies, which collectively possess all the necessary skills to undertake major projects internationally on coalbed methane development. The Alberta Research Council was nominated as the leader of the Canadian Consortium. These seven companies and their expertise are:

- (1) Alberta Research Council Inc (ARC), the largest provincial research organization in Canada, based in Edmonton, Alberta
 - Proponent of the Canadian enhanced coalbed methane recovery technology
 - Technology development and commercialization
 - Project management, reservoir simulation, and economic/environmental assessment
- (2) Cal Frac Well Services Ltd., a Calgary, Alberta based private sector oilfield service company
 - Coil tubing, well stimulation and completion
- (3) Computalog Ltd., a private sector oilfield service company based in Calgary, Alberta
 - Wireline logging, directional and horizontal drilling
- (4) Computer Modelling Group Ltd. (CMG), a Calgary, Alberta private sector energy software company
 - Reservoir modelling and simulation
- (5) Porteous Engineering Limited (PEL), a Calgary, Alberta engineering and management services company
 - Training assessment and coordination
- (6) SNC Lavalin Inc. (SLI) – a national private sector full range engineering and procurement construction company in Canada
 - Surface facility design, environmental assessment and economics
- (7) Sproule International Ltd., a private sector engineering consultant based in Calgary, Alberta
 - Reservoir engineering, well testing, hydrogeology, geological and economic assessments, and reserve estimate

The first contact with China United Coalbed Methane Co. (CUCBM) was initiated by the ARC and CMG in September 1998. The major business of CUCBM involves the exploration, development and production of China's CBM resources, building of pipeline

system, transportation, utilization and sale of CBM. CUCBM is granted by the State Council the exclusive right to undertake the exploration, development and production of CBM in cooperation with foreign enterprises. The Canadian Consortium is a collection of Canadian companies with the necessary strengths and expertise to seek out significant opportunities internationally for the development and application of coalbed methane technology. This is a case for transferring Canadian technology to China. It is a nice fit for both organizations.

The Canadian Consortium, jointly with CUCBM made an unsolicited project proposal to the Canadian International Development Agency (CIDA) in 2001.

This project was one of the projects selected under the Canadian Climate Change Development Fund (CCCDF). The goal of CCCDF is to contribute to Canada's international objectives on climate change by promoting activities in developing countries that seek to address the causes and effects of climate change, while at the same time contribute to sustainable development and poverty reduction.

The purposes of the project were twofold: a) to transfer to China the Canadian coalbed methane/CO₂ technology to effectively exploit CBM, a cleaner source of energy, while storing CO₂, a greenhouse gas, in unminable deep coal beds, if possible, in poorer western China and, b) to try to establish sustainable economic linkages between Chinese and Canadian CBM related industries.

This project would provide assistance to China in seven major areas, each involving the joint cooperation of all participants of CUCBM (the Chinese Executing Agency) and the Canadian Consortium (the Canadian Executing Agency):

1. General inventory of existing and potential CBM sites.
2. Detailed site selection, including environmental impact assessment (EIA)/Canadian Environmental Assessment Act (CEAA) screening report, and ranking to identify the three best sites for the micro-pilot field tests and identify CO₂ sources for the tests in China's interior.
3. Design of micro-pilot test procedures for the three highest ranked sites to evaluate CBM reservoir properties.
4. Carry out a single micro-pilot field test at the best suitable site. Drill one well/use existing well in the selected coalbed methane reservoir; complete the well and add surface facilities to allow injection and production tests and document results. If the results of the first micro-pilot test are not favorable, a second micro-pilot test will be carried out at a second suitable site. If this fails, a third final micro-pilot test may be required to obtain satisfactory results to go forward.
5. Engineering evaluation of micro-pilot test results and numerical model calibration for full-scale pilot test and commercial performance prediction.
6. Full-scale field pilot design for one selected site and model prediction of its potential commercial performance.
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If the project's micro-pilot tests are successful after the first or second well, the budget set aside for the second and/or third micro-pilot test will be used, with CIDA's approval, to provide more in-depth technical assistance/training for the full-scale pilot test if China decides to proceed with it.

The project will provide China with enough knowledge and information to make an educated decision on whether or not to proceed with the full-scale pilot test, which if successful, will lead to commercial demonstration and operation.

A Memorandum of Understanding between the Government of Canada and the Government of the People's Republic of China concerning this Project was signed on March 15, 2002. The expected completion date of the Project was March 31, 2006. The MOU was later amended to extend the Project completion date to December 31, 2006. A Project Implementation Plan (PIP) was formulated and was attached as an Appendix in the MOU.

This document is prepared by the Alberta Research Council representing the CEA and submitted to CIDA as the project completion report for the Development of China's Coalbed Methane Technology/Carbon Dioxide Sequestration Project (the Project).

This Final Project Report provides a "semi-technical" overview of the Project. For more in-depth technical detail, please refer to the technical reports issued.

2.0 PROJECT IMPLEMENTATION

2.1 EXECUTING AGENCIES OF THE PROJECT AND MANAGEMENT STRUCTURE

The CEA for the Project is the Canadian Consortium on enhanced coalbed methane recovery led by the ARC, Sproule International Ltd. and CMG. The CEA is responsible and accountable to CIDA for managing and administering direct Canadian inputs to the Project both in Canada and China, providing Canadian technical assistance and training (from in-house resources and on a sub-contract basis), procuring Training aids if required, achieving Project outputs and contributing to Project outcomes and developmental impacts. The CEA executes the Project as planned in the PIP approved by CIDA and MOFTEC/CUCBM.

The ChEA is CUCBM. CUCBM is responsible for the overall coordination of Chinese inputs to the Project including local logistics for trainees, and for liaison and coordination with CIDA. The CUCBM contributions include salaries and other benefits of the Chinese technical, managerial, administrative staff involved in the Project; their project related travel expenses in China; geological, hydro-geological and geophysical data; all permits; micro-pilot test well drilling and completion equipment and services; purchase and transportation of CO₂ for one micro-pilot test; laboratory tests conducted in China; training/workshops related local expenses such as training rooms, project related ground

transportation within the selected province(s) for Canadian experts; Chinese project office expenses.

The Project organization chart is shown in Figure 1. The key committees are the Joint Project Steering Committee (JPSC) and the Joint Project Executive Technical Committee (JPETC).

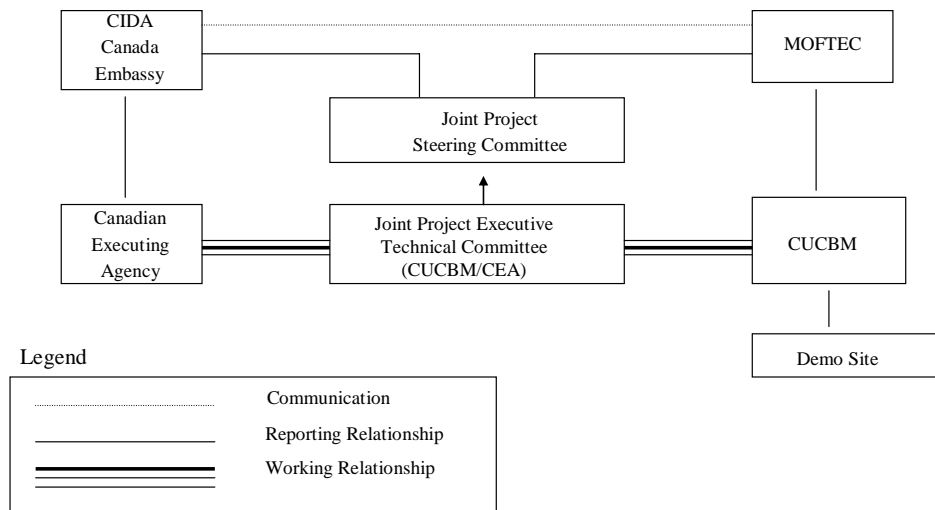


Figure 1: Organization Chart

The role of the JPSC is to determine Project policies and priorities, provide guidance and overall strategic direction, consider future Project orientation, and review project programming and performance, assessing results achieved in relation to objectives and expected results, and modifying inputs as necessary to achieve expected results. It is not concerned with day-to-day operations, but plays a substantive management and review role. It is expected to meet at least annually and more often as required, and review and comment on the PIP and annual work plans.

The JPSC is comprised of five members: one from MOFCOM, two from CUCBM and two from CIDA. The JPSC is co-chaired by MOFCOM and CIDA; the CEA is the secretariat. Decision of the JPSC is by consensus.

The role of the JPETC is to discuss technical issues in the Project and make recommendations for decision to the JPSC. The JPETC develops and executes

implementation plans that have been approved by the JPSC. The JPSC consists of three members each from CUCBM and the CEA. The members are:

- Dr. Bill Gunter (ARC), Project Manager, Chief Representative for the Canadian Consortium
- Mr. Sun Maoyuan (CUCBM), Project Leader, Chief Representative for CUCBM
- Mr. Rudy Cech (Sproule), Vice Project Manager
- Mr. Du Ming (CUCBM), Vice Project Leader
- Mr. Peter Ho (CMG), Chief Liaison Officer representing Canadian Consortium
- Mr. Fan Zhiqiang (CUCBM), Chief Liaison Officer representing CUCBM

When Mr. Sun Maoyuan was promoted to President of CUCBM, his membership at the JPETC was replaced by Mr. Feng Sanli, Vice President of CUCBM.

The CEA also maintained a Project office in Beijing to coordinate the logistics of Canadian experts traveling to the field for supervisory services and training in China. The office was staffed by CMG Beijing personnel and was closed when all field operations were completed.

2.2 GOALS AND PURPOSES OF THE PROJECT

CIDA's Results Based Management (RBM) approach was employed in the management and implementation of the Project. The project design was therefore based on a set of clearly defined results, set in a Logical Framework Analysis (LFA) that was agreed upon by both the ChEA and the CEA. The Project LFA is attached as Annex A in the PIP. The complete PIP is included in Appendix 1 of this report for easy reference.

The **goal** of the Project is to promote environmentally sustainable development in China by enhancing its capacity to manage its environment.

The **purposes** of the Project are:

- To transfer to China the Canadian CO₂ enhanced CBM recovery/CO₂ sequestration technology (*Canadian CBM/CO₂ technology*) to effectively exploit coalbed methane, a cleaner source of energy, while storing CO₂, a GHG, in unmineable deep coal beds, if possible, in poorer western China.
- To try and establish sustainable economic linkages between China and Canada CBM related industries

Expected results include:

- At the **goal** level (the developmental impacts)
 - Mitigating climate change through increased use of coalbed methane (CBM) and reduced CO₂ emissions.
- At the **purpose** level (the developmental outcomes):
 - Canadian CBM/CO₂ technology applied for full scale pilot test (hopefully leading to CBM commercial production) and/or for replication of micro-pilot tests at other locations in China.
 - Commercial cooperation between Canadian and Chinese Firms on Canadian CBM/CO₂ technology.

2.3 EXPECTED OUPUTS AND RESULTS

The Project expected outputs and activities are depicted in blocks in Figure 2.

Development of Coalbed Methane Technology/CO₂ Sequestration

Results-Based WBS

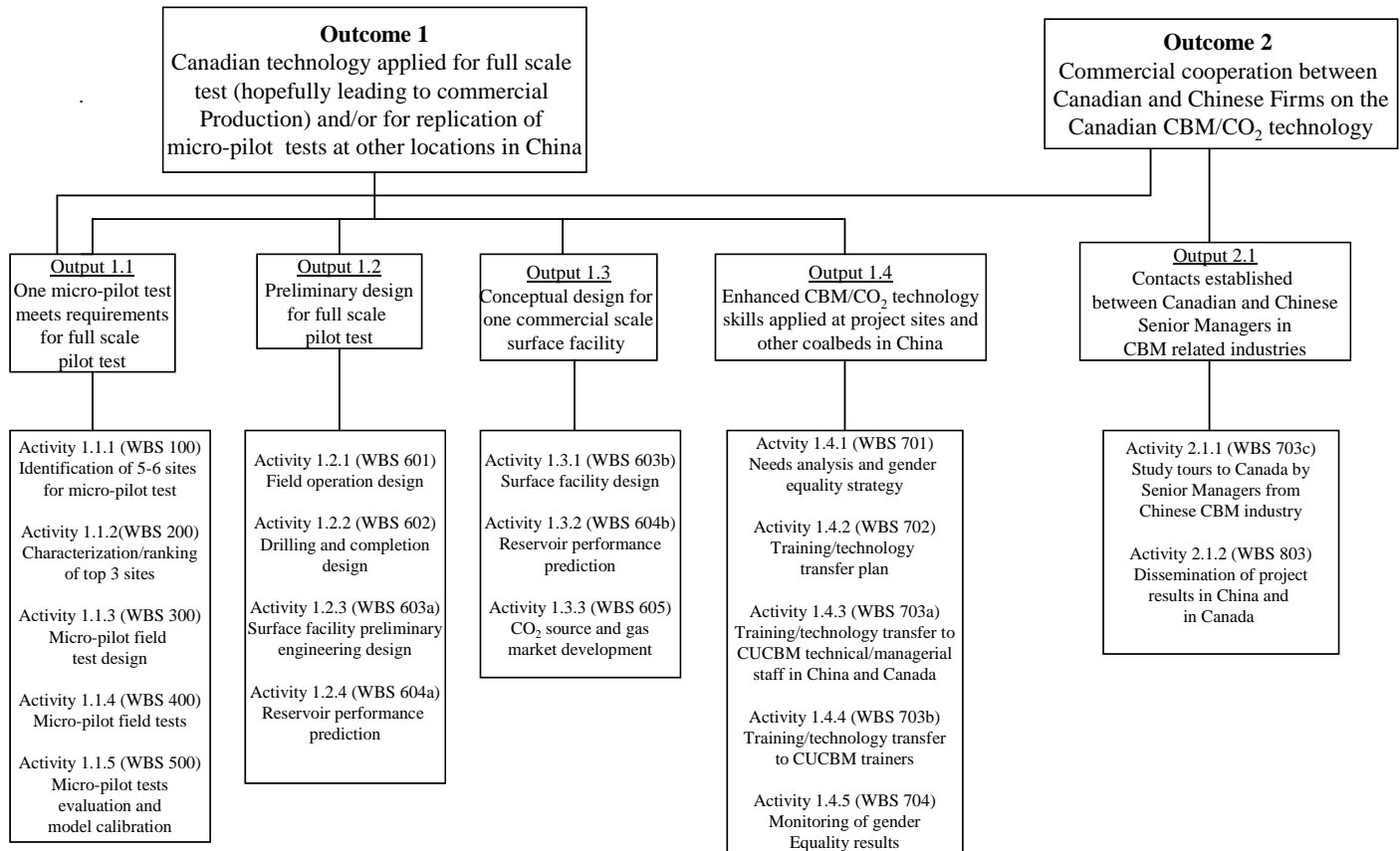


Figure 2: Expected Outputs and Activities of the Project

3.0 RESULTS ACHIEVED

3.1 OUTPUT 1.1 ONE MICRO-PILOT TEST MEETS REQUIREMENTS FOR FULL-SCALE TEST

3.1.1 WBS 100: Identification of 5-6 Sites for micro-pilot test

The objectives of WBS 100 are twofold: (a) identify five to six potential sites for micro-pilot tests and (b) select the top three sites for further characterization. A general inventory of existing and potential CBM sites was presented to the CEA by CUCBM. Six potential basins/coalfields were selected for evaluation. These included:

- South Qinshui Basin (Shanxi Province)
- Hedong Coalfield (Shanxi Province)
- Enhong Coalfield (Yunnan Province)
- Hegang Coalfield (Heilongjiang Province)
- Hancheng Coalfield (Shaanxi Province)
- Huaibei Basin (Anhui Province)

In order to assess the enhanced coalbed methane recovery potential of any area, a number of geological and specific coal parameters needed to be evaluated, along with available test and production data, infrastructure, sources and availability of CO₂. The geological and coal parameters that control the generation, storage, retention and producibility of gas from coal are:

- Reservoir depth – the minimum 300 meters and maximum 2,000 meters coal depth is considered from methane adsorption, storage, reservoir pressure and permeability considerations;
- Seam thickness – the minimum single seam thickness of 1 meter and sequence of coal seams to be considered for multiple seam completions or storage;
- Coal composition/rank – the percentage of ash, moisture, coal quality and maturity (indicated by vitrinite reflectance, $R_0 > 0.6\%$);
- Permeability – this parameter is essential to allow the methane to desorb from the matrix and flow through the fracture system to the borehole, and to allow flow of the injected gases into the coal seam ($k > 1$ md);
- Saturation – the retained gas volume within the coal structure and pressure regime will influence the production and storage profile;
- Water utilization – it is an economic consideration directly influencing reservoir production and water disposal.

Data and information were collected from public and non-confidential sources. In the case of the South Qinshui Basin site, the CUCBM's data were used. The Sproule team visited the three sites (South Qinshui Basin, Hancheng and Hedong Coalfields) in August 2002 in order to assess and confirm some selection criteria, namely the accessibility, terrain and infrastructure in the area.

The six sites were evaluated based on a set of five factors: (1) CBM Resource/CO₂ Storage Potential; (2) Production Potential; (3) CO₂ Supply Potential; (4) Data Availability; and (5) Market Potential.

Based on this set of ranking criteria, the top three sites selected for further characterization in WBS 200 are:

- South Qinshui Basin;
- Hedong Coalfield; and
- Hancheng Coalfield.

The main reasons for the other three potential basin/coalfields being eliminated from further process are the lack of CBM data (Enhong and Hegang Coalfields) and/or the poor results of the pilot project (Huaibei Coalfield).

The final report for WBS 100 was released on February 14, 2003.

3.1.2 WBS 200: Characterization/ranking of top 3 sites

The objective of WBS 200 is to establish a ranked list of the most promising sites from which the micro-pilot test design can be based. The list is of importance in setting the priority on which site should be selected for the orderly development of the Canadian CBM /CO₂ technology in China.

The Sproule team followed with a second site visit in November 2002. The WBS 200 addressed the following sub-tasks: WBS 201 – Geological Characterization; WBS 202 – Engineering Characterization; WBS 203 – Environmental Screening; and WBS 204 – Site Selection and Ranking.

Since two of the selected sites from WBS 100 have presently limited available data (Hancheng Coalfield) or physical site constraint (Hedong Coalfield) the site selection and ranking was limited to the South Qinshui Basin.

The investigation of potential micro-pilot sites in South Qinshui Basin focused on the Fanzhuang Exploration Block, where CUCBM has drilled 18 CBM wells and have 9 wells on continuing production since 2000. Remaining wells are standing to be and awaiting completion. Available reports, tests, data and information were reviewed and analyzed.

The Fanzhuang area is some 80 km from the city of Jincheng and 70 km from the city of Gaoping. Transportation and infrastructure is relatively good. Terrain is not complicated which will allow easy access for fieldwork. The Yangcheng Power Plant that was under construction at the time is a short distance southeast of the subject block and could be among the CO₂ suppliers.

The test area was selected as potential micro-pilot site with favorable geological and reservoir parameters. The recommendation is to conduct the micro-pilot test on coal seam #3, which is laterally consistent, thick, with sparse faulting, deposited in a simple monoclinical structure and has good seal. The reservoir parameters include good gas content, acceptable permeability and sustained production history. The under-saturated and under-pressured reservoir conditions are judged unfavorable from the CBM production aspect; however, the effect on CO₂ sequestration process is not considered adverse.

Based on the review of general field properties and individual well histories, FZ-002, FZ-008 and TL-003 were recommended as the three micro-pilot candidate wells.

The FZ-002 well, located in the interior of the field, is the most productive of the nine wells. The gas-water ratio of this well at the conclusion of the production test was indicative of a coal with substantial free gas. For these reasons, this well is the preferred micro-pilot candidate well. High gas recovery from the FZ-008 well and a structurally high position makes this well the second candidate for the micro-pilot test. The TL-003 well is favored due to its structurally high position, the steady gas-water ratio and to the undisturbed location between indicated faults. The seismic lines interpretation was discussed with CUCBM technical staff in order to assure that the selected well site is not at risk to be in the vicinity of the fault.

The Hedong Coalfield is considered a second choice due to favorable reservoir parameters indicated by information obtained from published data. The CUCBM Joint Venture with previous (British Petroleum) and current partner (Texaco) prevents the access to the data and information. The sites of two pilot projects are reclaimed and suspended. The wells were abandoned and in order to proceed with the micro-pilot project, new wells would have to be drilled. Until the Texaco's decision is made on continuation of the program, the site is not available. However, the Hedong Coalfield site is still considered the second most favorable micro-pilot test site.

At the Hancheng Coalfield, Shaanxi Province Coalfield Geological Bureau drilled three CBM wells. One well was on production for a year. The coal has good gas content and is a little under-pressured. The indicated permeability data are the highest seen so far. The data needed to evaluate the site in detail, are the properties of the Geological Bureau and would not be available for us to review. It is our understanding that the data could be available for purchase. The site is currently ranked in third place.

On WBS 203, after reviewing CIDA's contribution to the Project, the CIDA CEAA Specialist advised the CEA that this Project would not trigger the CEAA. Therefore, there is no need for a CEAA screening report before the field tests start.

The WBS 200 final report was released to CUCBM in March 2003.

3.1.3 WBS 300: Micro-pilot field test design

WBS 301 is to design a plan and the procedures for performing a single well micro-pilot testing at site #1, based on information and data obtained from WBS 100 & 200. Both the CEA and CUCBM agree that TL-003 is the top rank for site #1. Hence, the design provides a guideline for operating a micro-pilot test at the existing TL-003 well.

The micro-pilot approach to coalbed reservoir evaluation has three primary goals. The first goal is to accurately measure data while injecting into and producing from a single well. The second goal is to evaluate the measured data to obtain estimates of reservoir properties and sorption behavior. The third goal is to use calibrated simulation models to predict the behavior of a larger scale pilot project or full field development.

Measured data include the injection rates, surface and bottom-hole pressure and temperature while injecting CO₂, the surface and bottom-hole pressure and temperature during shut-in periods, and the bottom-hole pressure and temperature, gas and water production rates, and gas composition during producing periods. The micro-pilot test was designed in six stages as follows:

- Stage 1. Inspection of wellhead equipment.
- Stage 2. Isolation of the #3 coal seam from the #15 coal seam and installing additional downhole and surface equipment.
- Stage 3. Initial production testing to determine baseline reservoir properties.
- Stage 4. Intermittent injection of CO₂ for up to 30 days followed by a 30-day shut-in period.
- Stage 5. Production testing after the CO₂ injection period.
- Stage 6. The final shut-in test.

The micro-pilot test design for Site #1 was completed and the WBS 301 Final Report was issued in July 2003.

3.1.4 WBS 401: Micro-pilot field test #1

Well history

The TL-003 well is the structurally highest well of all nine wells in the field and is the original well drilled and production tested before any of the other wells were drilled. Based upon the field production data, this well has commingled production of 289,000 m³ of gas and 23,900 m³ of water from two coal seams (#3 and #15 of the Carboniferous Permian Shanxi Formation) starting in March, 1998. However, the well was shut-in for a substantial amount of time from March 1999 to January 2001. The gas to water ratio has steadily decreased after the well was put back on production. However,

the well was still producing 30 to 40 m³ of water per day. It was determined that most of the water is coming from a water wet sand just above the lower coal seam. The lower water sand was isolated prior to initiating the micro-pilot by setting a bridge plug just below the #3 coal seam. The completed # 3 coal seam has a net thickness of 6 meters.

Stage 1 – Inspection of wellhead equipment

The wellhead and associated surface equipment was inspected and deemed satisfactory for the Project. The TL-003 well was equipped with a 250 mm Chinese made wellhead rated to 25 MPa (3,600 psig), and a 12 mm choke. However, the wellhead did not have a master valve. The production casing is 139.7 mm (5.5-inch) J-55 25 kg/m. Figure 3 shows the wellhead equipment at the time of the Stage 1 inspection.



Figure 3: Wellhead Equipment

Stage 2 - Isolation of the #3 coal seam from the #15 coal seam and installing additional downhole and surface equipment

The initial workover of the TL-003 was performed to isolate the lower water sand from the #3 coal seam and install down-hole pressure recording equipment. A bridge plug was set at 573 meters, isolating the #3 coal seam from the #15 coal seam. Downhole pressure gauges were installed on the 2-7/8” EUE 2.4 m pup joint and located at the bottom of the tubing string. The downhole gauge assembly is located approximately 25 meters below the perforations for the #3 coal seam. A schematic of the well configuration after the workover is illustrated in Figure 4.

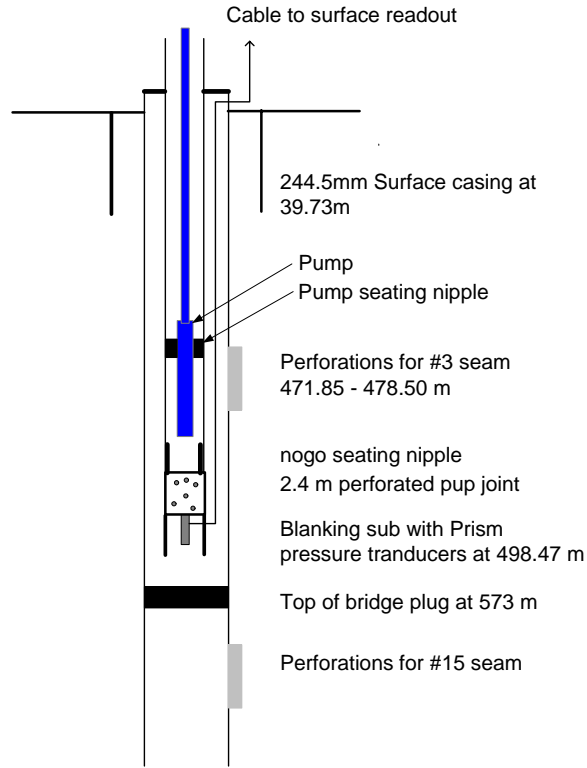


Figure 4: Schematic of Wellhead Configuration

One of the key elements for a successful micro-pilot is the acquisition of quality gas composition data; during primary production, to obtain a baseline, and post production after the CO₂ injection. To successfully monitor the gas composition, a system to obtain on-line gas analysis is required. Traditional bench gas chromatographs (GC) have exceptional detection limits with the ability to choose from an assortment of detectors. However, bench GCs are not very portable or robust, require lengthy stabilization times and are very bulky. Micro GCs meet all of our requirements and offered the best choice of instrumentation. Gas from a connection downstream of the gas separator connects to the sample delivery system. Moisture from the sample gas is removed by passing through a series of filters, first a coalescing filter and then through a membrane separator. A slipstream of the dry sample gas is then injected onto the micro GC and analyzed. Standard gases of known concentration are used to calibrate the micro GC.

A detailed evaluation of the downhole pressure measuring systems for the micro-pilot at South Qinshui was conducted. Two basic systems were evaluated, self-contained bottom-hole gauges and downhole surface readout gauges. Self-contained bottom hole gauges are placed in the well and retrieved as required for data analysis. A wireline service company is required to retrieve and set the gauges. Downhole surface readout transducers are located near the bottom of the well and are normally attached to the tubing string using some type of gauge carrier or mandrel. The data from the pressure transducers are transmitted to the surface via some type of wireline assembly. Surface equipment

processes the data to provide digital information (normally pressure and temperature) and provides continuous monitoring of down-hole conditions at the surface. A workover of the well is required to install the surface readout gauges.

With the specific location of the test site and the limited accessibility to a wireline service rig, a downhole surface readout system was selected. The Prism Technologies system was selected based on its lowest bid. This was installed on location at the time of the workover. A gauge expert from Prism Technologies was on the well site to supervise the installation of the surface readout system. Figure 5 shows the installation of the surface readout gauges at the site.

During this workover ARC also installed and tested the portable gas chromatograph (GC) equipment on location. Training was also provided to field staff to use the on-line gas analysis equipment.



Figure 5: Pressure Gauge Installation

Stage 3 - Initial production testing to determine baseline reservoir properties

A production test was initiated on October 28, 2003 after the initial workover to obtain baseline information for the test well. Downhole pressure and temperature data, gas composition, and daily fluid production rates were monitored from the start of production. Gas composition during primary production was initially determined at daily intervals and then reduced to once every 3 days. Gas composition during the initial production test was predominately methane (97.52%) with a minor amount of nitrogen (2.42%) and traces of carbon dioxide (0.04%), ethane (0.01%) and other gases (0.01%).

Fifty-six days into production, the well was shut-in to obtain a reservoir pressure response and subsequently estimate the reservoir permeability. The well was shut-in on December 23, 2003. A leak was found where the production casing head is screwed into the 139.7 mm casing collar (Figure 3). Production continued until the leak at the casing head could be repaired. Tightening the casing collar repaired the leak. The well was then put back on production for 10 days to obtain stable production and was shut-in on March 9, 2004 for a pressure build-up test.

Downhole pressure and temperature data was monitored from the start of production. The surface readout and memory module for sensor #2 was faulty and primary production data was recorded from sensor #1, only. A replacement board for the faulty module was shipped but problem with getting the equipment through customs was experienced and the module was not received at the field site until February 2004.

Stage 4 – CO₂ Injection

Prior to the injection of the CO₂ the wellhead was replaced and pressure tested. Stage 4 included the intermittent injection of 192 metric tonne (mt) of liquid CO₂ over a 13-day period while monitoring surface and bottom-hole pressures and temperature.

Zhongyuan Oil Field supplied the liquid CO₂ product and transport. The same company also furnished personnel to perform the injection using a pump skid designed by and commissioned by the ARC. Figure 6 shows the testing of the pump at the CalFrac facility in Red Deer, Alberta. The liquid CO₂ was injected at an injection pressure less than the fracturing pressure of approximately 7 MPa (g) (1,000 psig).

All personnel arrived on location on April 6th, the first day of pumping. The internal pressure of the transport truck was 300 psig upon arrival. A safety meeting was held on location to describe the operations and define duties and safe areas in the event of an accident. The lines were pressure tested to 1,000 psig. The high-pressure shutdown switch was tested, as well.

Pumping of the liquid CO₂ downhole commenced at 09:44 on April 6th, 2004. On the second day of pumping, the internal pressure of the supply truck was bled down to 180 psig then pumping initiated at 35 l/m. The static wellhead pressure was zero psig. A total of 13 metric tonnes of product was pumped on April 7th, 2004.

On the third day of pumping, the internal pressure of the supply truck was bled down to 250 psig prior to pumping. The static wellhead pressure was 3,450 kPa (500 psig) but the bottom-hole pressure was 1,430 kPa (207 psig). This indicated a casing/tubing plug near the surface. Attempts to pump at a lower rate were unsuccessful. The surface lines were broken down and examined. Coal fines were found in the connections but the lines were not plugged. The lines were re-connected and pumping initiated. The plug cleared at 10:45 with an audible response, indicating that the plug was near the surface. The casing/tubing plugged one more time during the day at around 14:10. A total of 13 metric tonnes of product was pumped on April 8th, 2004.



Figure 6: Testing the CO₂ Pump at Calfrac Facility at Red Deer, Alberta

Injection of liquid CO₂ continued for the next 10 days. A total of 192.5 metric tonnes of liquid CO₂ were injected over the 13 days period. This is equivalent to 102,800 m³ (3,630 Mscf) of CO₂ gas.

By far the biggest concern during the injection of the CO₂ was plugging of the well. This well was flushed with water during the two workovers performed during the past six

months therefore the wellbore should have been relatively clean. Perhaps the liquid CO₂ shocked the casing wall and peeled off scale or coal dust deposits.

Figure 7 illustrates the bottom-hole pressure behavior measured during each injection and falloff period. The data were evaluated to determine the time dependent injectivity and reservoir properties. Temperature changes could not be determined because the transducers were placed 20 m below the perforations in the water filled sump.

Figure 8 illustrates the change in injectivity as a function of the volume of CO₂ injected. While there was a slight decrease in permeability over the injection period a dramatic decrease in injectivity was observed. The decrease in injectivity is due to a combination of factors, which include: the decrease in permeability, an increase in pressure (packing) of the near wellbore region, and possible plugging of the perforations.

CO₂ injection was completed on April 18. The well was shut-in for an extended soak period. It was later found that electric power was accidentally tripped off on about April 30 and hence there was no data from April 30 to June 1 about the time that production testing after CO₂ injection was to begin. Figure 9 shows the bottom-hole pressure during final production test.

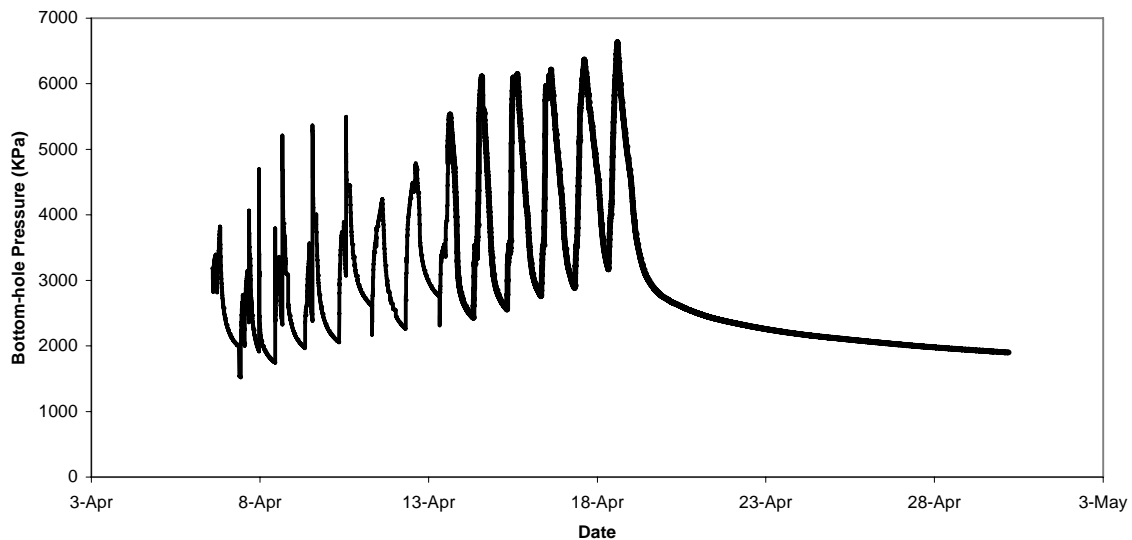


Figure 7: Bottom-hole Pressure Behavior during CO₂ Injection

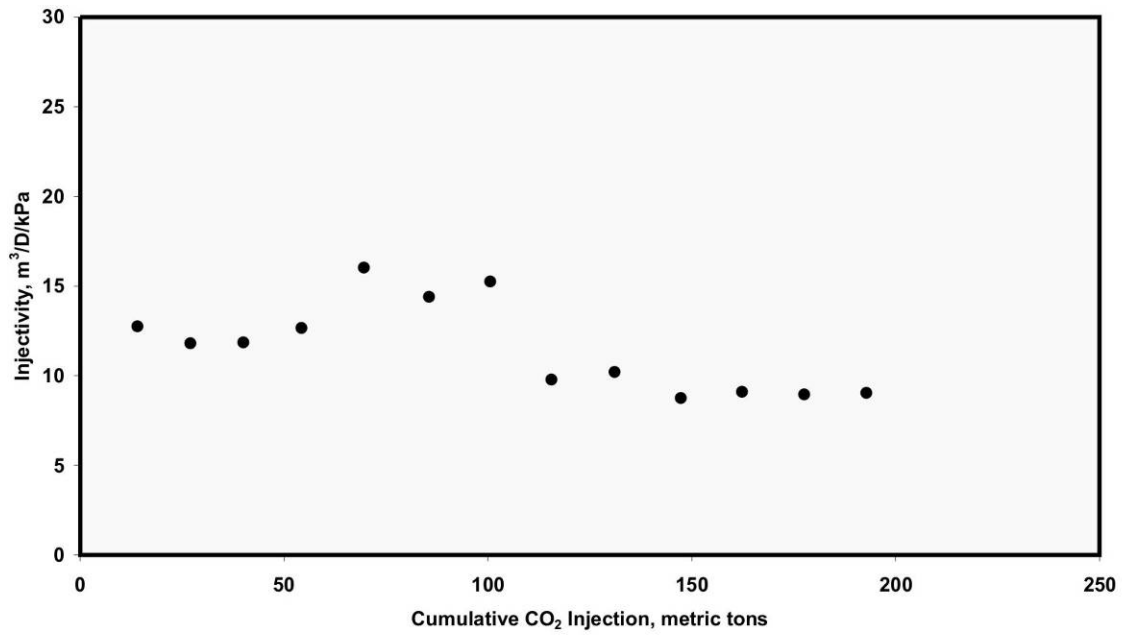


Figure 8: Injectivity Change

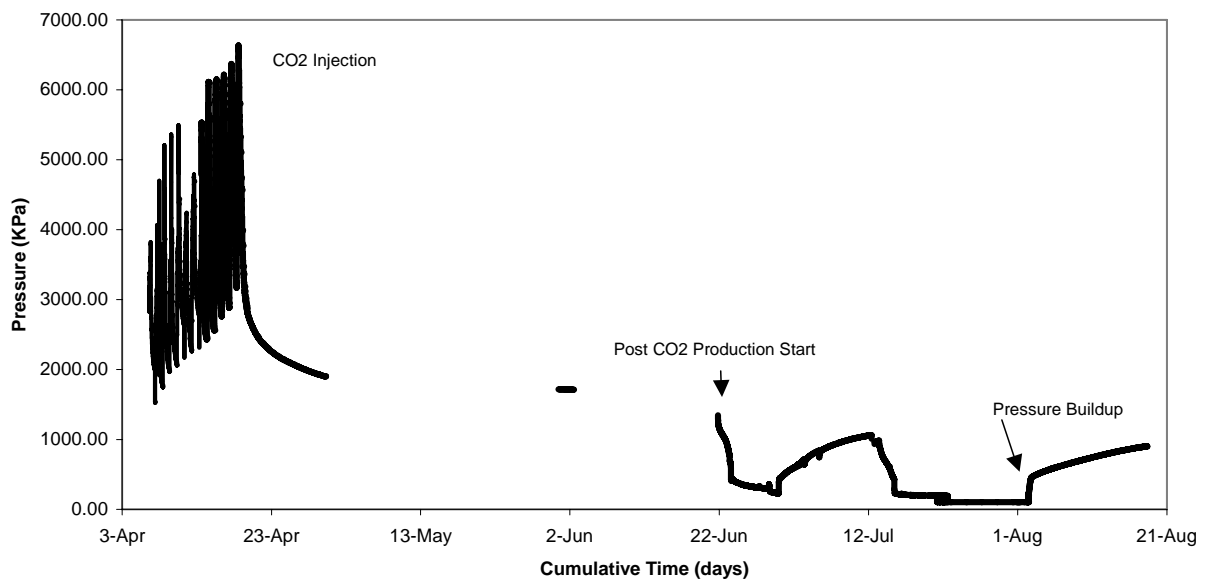


Figure 9: Bottom-hole Pressure during Final Production Test

Stage 5 – Production testing after the CO₂ injection period

For Stage 5, the well was placed on production from June to July 2004. This portion of the micro-pilot was the most important as the production rates and gas composition data were required to estimate the sorption behavior and to calibrate a reservoir simulator to estimate the behavior of full-scale pilots and full-field development.

Our approach to start off the production testing was to circulate the well first using river water and monitor the return water for particles. This circulation procedure should clean out any material that was present in the wellbore without having to pull the tubing. On June 2 the circulation test was conducted. Water samples were collected for visual inspection to observe the amount of returned solids. When very little solids were observed in the return line, it was presumed that the tubing string was adequately flushed and the rods were run into the hole. During the pump rod installation the workover crew realized that the tubing string was not holding water. The tubing was pulled up and found that three sections of tubing near the bottom of the well had burst during CO₂ injection. The pump was also completely plugged. On June 4, a new pump and the defective tubing sections were replaced. The pump was put back on production June 5. However, when the power was turned on, the pressure gauges did not give any readings and the well was shut down. Diagnostic tests were performed on the gauges, but the tools available at the site were very limited. It was suspected the most likely cause of the gauge problem was the wireline cable. New cable would have to be shipped from Canada or located in China. In addition the wireline gauges needed to be tested for faulty operation, which would require a lengthy shutdown. Eventually, a local supplier was found who could supply self-contained gauges. The self-contained gauges were installed on June 21 and the well was put back on production. The NOGO seating nipple, perforated pulp joint and the wireline gauge carrier were removed and replaced with the downhole gauge carrier and a section of tubing so as to keep the same relative spacing as before. The gauges were approximately 0.4 m higher and the pump would be 1.1 m higher than the previous installations.

On July 1, the gas and water production rates went down very rapidly and were also close to zero. Initially, it was suspected that the rod was broken and the well was shut down on July 2. A workover on July 12 revealed that the pump was plugged with coal fines. The pressure data from the self-contained gauges was downloaded, the batteries replaced and the gauges reset before being returned to the well during the workover. The well was returned to production and shut-in on August 2, 2004.

The self-contained pressure gauges were set to collect data at two different intervals. The first interval was set to 300 seconds during the production of the well. The rate of data collection was increased to a 5-second interval and was scheduled to change one day before the shut-in and subsequent pressure build-up test. The self-contained pressure gauges were retrieved on August 16, 2004.

Bottom-hole pressure and temperature behavior, fluid production rates, and produced gas composition were accurately monitored. Figure 10 illustrates the produced gas compositional data. The composition of the gas on initial flow back is 70% CO₂ and 30% methane. After one month on production, the CO₂ has dropped to 45% and the methane has risen to 55%.

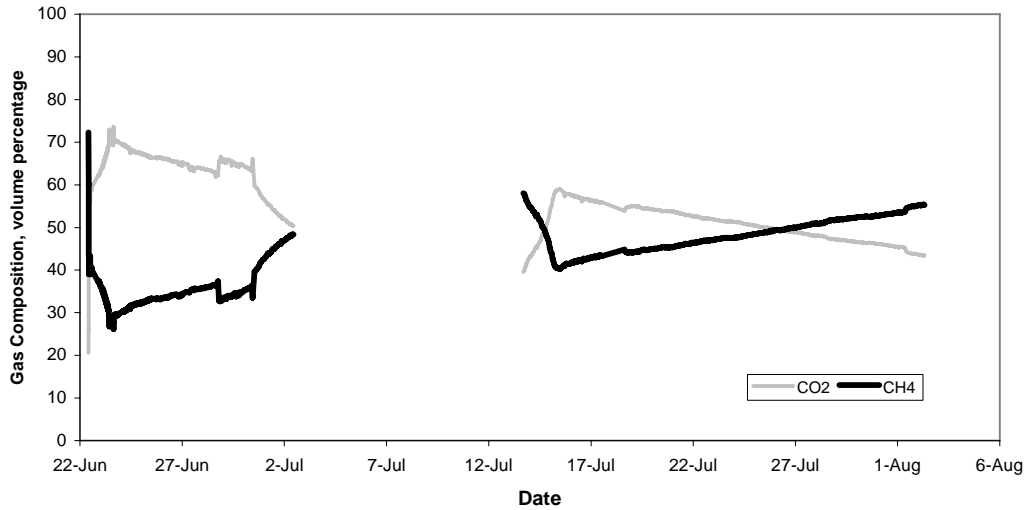


Figure 10: Produced Gas Composition

Stage 6: The final shut-in test

Stage 6 was a final shut-in test to obtain estimates of reservoir properties and near well conditions.

All the stages of the micro-pilot test have been successfully completed and a good data set has been collected. The WBS 401 Final report: Micro-pilot Implementation and Data Reporting was issued to CUCBM in October 2004.

3.1.5 WBS500: Micro-pilot test evaluation and model calibration

WBS 501 evaluates the field data using well test analysis. The purpose of this WBS is to evaluate the quality of the data set and estimate the reservoir properties.

Analysis of the March shut-in test at Stage 3

The shut-in pressure data was analyzed by examination of the log-log diagnostic graph. Figure 11 illustrates the log-log diagnostic graph with the match of the data. The initial estimate of effective permeability to gas based on the match was 2 md. The gas and water rates were used to estimate the relative permeability and a gas saturation of 41%. The absolute permeability was estimated to be 12 md based on relative permeability data from the San Juan Basin coals of southern Colorado.

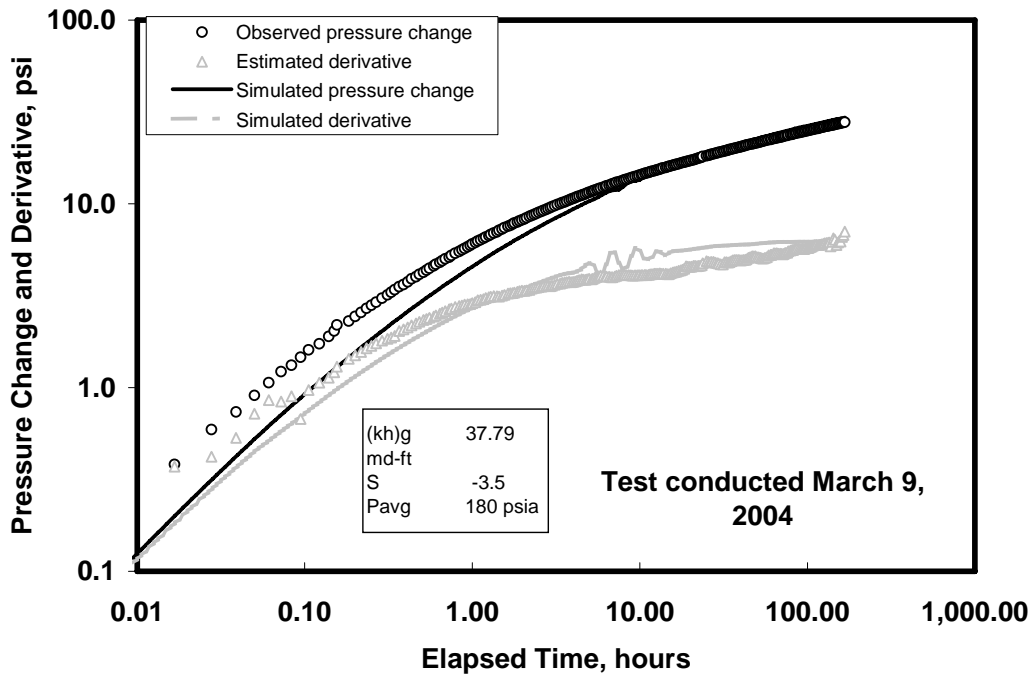


Figure 11: History Match of Build-up Data

The final shut-in test at Stage 6

The analysis of the test was based upon history matching the observed pressure changes and derivative behavior that were observed during the test. Figure 12 illustrates a diagnostic graph of the shut-in period pressure behavior. The entire shut-in period was dominated by wellbore storage and therefore would not be used to evaluate the final reservoir permeability.

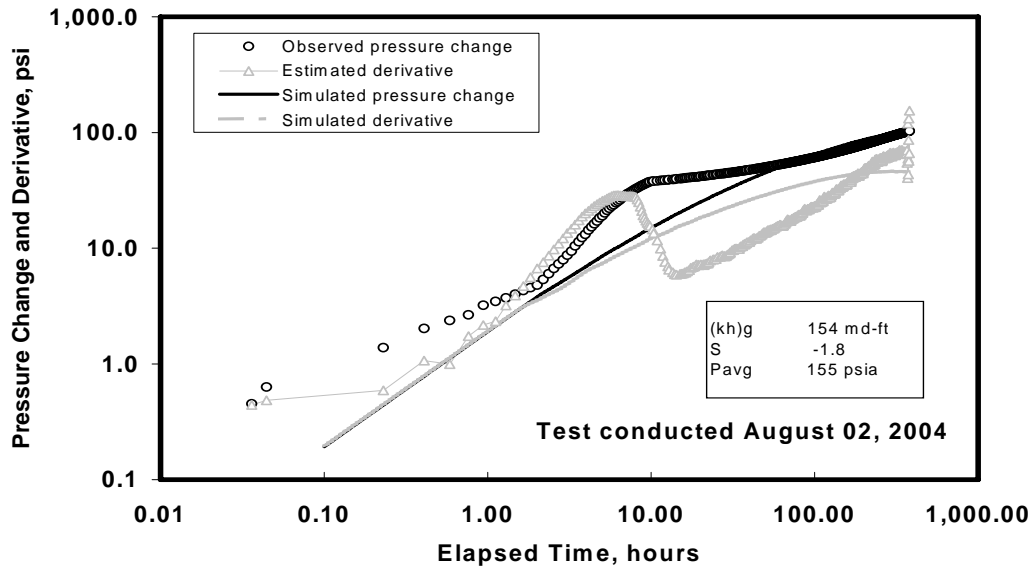


Figure 12: Diagnostic Graph of the Shut-in Period Pressure Behavior

A quality data set was collected, except for Stage 6. Stage 6 has too much well bore effect and is discarded for any reservoir parameter estimation. A good set of coal reservoir properties was estimated, even without Stage 6.

The average reservoir pressure of the #3 coal seam prior to CO₂ injection was 1,241 kPa (180 psia) at a depth of 472 meters. The absolute permeability of the coal seam prior to CO₂ injection was 12.6 milli-darcy (md), which was based on an effective permeability to gas of 1.8 md and a gas saturation of 40.8 percent. A total of 192 metric tonnes (103,611 Sm³) of CO₂ were injected into the formation. A preliminary analysis shows that the injectivity to CO₂ decreased initially but was stabilized during the injection of the 13 slugs of CO₂. The composition of the gas on initial flow back after CO₂ injection was 70% CO₂ and 30% methane (CH₄). After one month of production, the CO₂ has dropped to 45% and the methane has risen to 55%. This set of estimated reservoir parameters from the micro-pilot test will be used in the history matching to tune the reservoir model.

Coal reservoir characterization was completed. WBS 501 Final Report: Micro-pilot Results and Analyses, was issued in October 2004.

WBS 502 is to get the reservoir model (CMG's GEM model) ready for tuning with field collected data. A key element of WBS 502 is to test thoroughly the relevant features such as the multi-component coal swelling/ shrinkage sub-model to capture permeability change in response to CO₂ injection to allow the history match of the micro-pilot field data set.

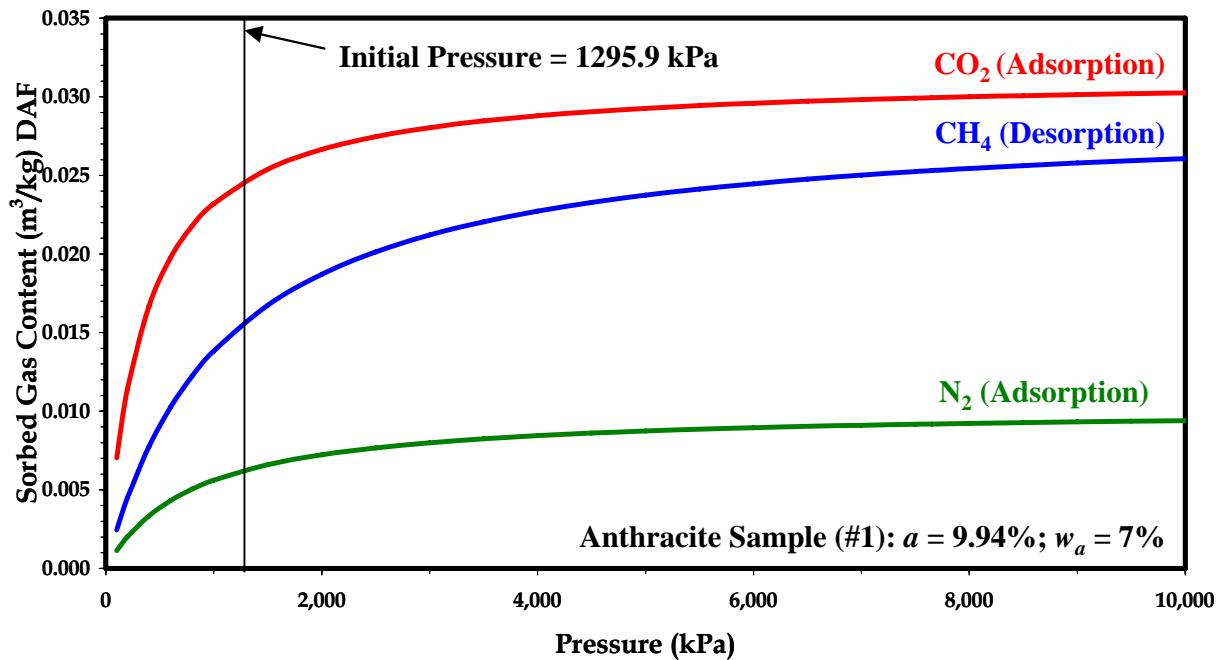
WBS 503 is history match of the micro-pilot test field data. A key technical goal of a micro-pilot test is the successful history matching of the field data using a tuned reservoir model which accounts for the changes in permeability due to swelling and pressure changes. A list of the coal properties used in the history match of the micro-pilot test results is summarized in Table 1.

Table 1: Estimates of #3 Coal Seam Properties

Property	Units	Value	Units	Value
Depth below ground at top of coal	m	471.85	ft	1,548
Depth below ground at bottom of coal	m	478.30	ft	1,569
Net coal thickness	m	6.05	ft	19.85
Total coal thickness	m	6.45	ft	21.16
In-situ coal density	kg/m ³	1,300	lb/ft ³	81.1
Wellbore radius	m	0.084	ft	0.276
Current coal seam pressure	kPa	1,295.9	psia	188
Current coal seam temperature	°C	25	°F	77
Methane concentration	%	97.54	%	97.54
Carbon dioxide concentration	%	0.04	%	0.04
Nitrogen concentration	%	2.42	%	2.42
Water density	kg/m ³	994.66	lb/ft ³	62.1
Water viscosity	Pa•s	8.96×10 ⁻⁴	cp	0.896
Water compressibility	kPa ⁻¹	5.8×10 ⁻⁷	psi ⁻¹	4.0×10 ⁻⁶

Coal seam pressure was estimated based on the average value of the bottom-hole pressure data collected prior to the initial production test. For simplicity, a gas composition of 97.54% CH₄, 2.42% N₂ and 0.04% CO₂ were used based on the average value of the data collected.

The sorption isotherms were provided by CUCBM and are shown in Figure 13. At the coalbed pressure of 1295.9 kPa (i.e., at the start of the micro-pilot test), the dry-ash-free (DAF) adsorbed gas content for CH₄ is 0.01304 m³/kg indicating a relatively high adsorbed gas content for a high-rank coal. At the same coalbed pressure of 1295.9 kPa, the CO₂/CH₄ adsorbed ratio is approximately 1.5 indicating a relatively low CO₂/CH₄ adsorbed ratio for a high-rank coal.



Ye, J.P. *et al* (2004)

Figure 13: Gas adsorption Isotherm used in History Match

The ARC developed a comprehensive permeability theory for multi-component gases that combined coal matrix shrinkage/swelling and net confining stress effects to predict porosity and permeability of the natural fracture system of the coal. A coal bed has dual porosities – a primary porosity system (PPS) in the coal matrix and a secondary porosity system (SPS) in the coal cleats. The change in porosity in the SPS is made up of two components: a pressure strain component and a sorption strain component. For the pressure strain, porosity is increased with increased SPS pressure and vice versa. For sorption strain, coal swells when the gas content increases and shrinks when gas content decreases. So these two strain components move in opposite directions. Permeability change is related to porosity change raised to a cubic power. The theory is an extension of the Palmer & Mansoori Theory, which is commonly used for primary CBM recovery process (single-gas component system), to multi-gas component system.

The micro-pilot test results have been successfully history matched using CMG's compositional numerical simulator, GEM[®] with special numerical features including the ARC Permeability Theory, and a gas diffusion model (to predict the diffusive flows of different gases between the coal matrix and natural fracture system). The methodology for history matching the test results for different stages of the field micro-pilot test is summarized in Table 2.

Table 2: History Match Methodology for Different Stages of the Field Micro-Pilot Test

Input Parameter	Matching Parameter	Methodology
Stage 3: Initial Production Testing		
<ul style="list-style-type: none"> • Gas production rate 	<ul style="list-style-type: none"> • Bottom-hole pressure • Cumulative water production • Fluid saturation 	<ul style="list-style-type: none"> • Check model productivity based on measured gas production rate • Estimate porosity for coal natural fracture system by matching cumulative water production • Verify coal fracture permeability
Stage 4: Injection of 200 Metric Tonnes of Liquid CO ₂		
<ul style="list-style-type: none"> • Gas injection rate 	<ul style="list-style-type: none"> • Bottom-hole pressure 	<ul style="list-style-type: none"> • Check model injectivity based on measured CO₂ injection rate • Apply ARC Permeability Theory to determine theory parameters for reasonable history match of bottom-hole pressure • Fine-tune near well permeability for best history match
Stages 5 & 6: Post Injection Production Testing & Final Shut-in Test		
<ul style="list-style-type: none"> • Gas production rate 	<ul style="list-style-type: none"> • Bottom-hole pressure • Production gas composition 	<ul style="list-style-type: none"> • Check model productivity based on measured gas production rate • Apply ARC Permeability Theory using parameters determined in Stage 4 • Fine-tune near well permeability for best history match • Estimate gas desorption time constants

Comparisons of CO₂ injection in Stage 4 and gas production in Stage 5 between numerical results and field measurements are shown in Figures 14 and 15, respectively. Successful history match of the well bottom-hole pressure in Stages 4 - 6 and production gas composition in Stage 5 are shown in Figures 16 and 17, respectively. The coal fracture permeability ratio used in the history match is shown in Figure 18. It shows the permeability reduction and enhancement relative to atmospheric versus pressure for the different gases.

It is concluded that the ARC Permeability Theory is capable in predicting large-scale ECBM/CO₂ storage performance. In an ECBM/CO₂ storage process in a five-spot pattern, CO₂ is usually continuously injected. Even with intermittent CO₂ injection, loss of CO₂ injectivity due to reduction of near well fracture permeability will rebound after each shut-in period after CO₂ injection resumes. On the other hand, the region near the producer will not swell until CO₂ breakthrough. In general, when CO₂ breakthrough occurs at the producer and swells the coal in the near well region, the CO₂ injection will be terminated.

Based on this analysis, CMG's GEM[®] numerical simulator has been validated based on the history match of the micro-pilot test results and can be used to predict multi-well test and commercial-scale field operation performance.

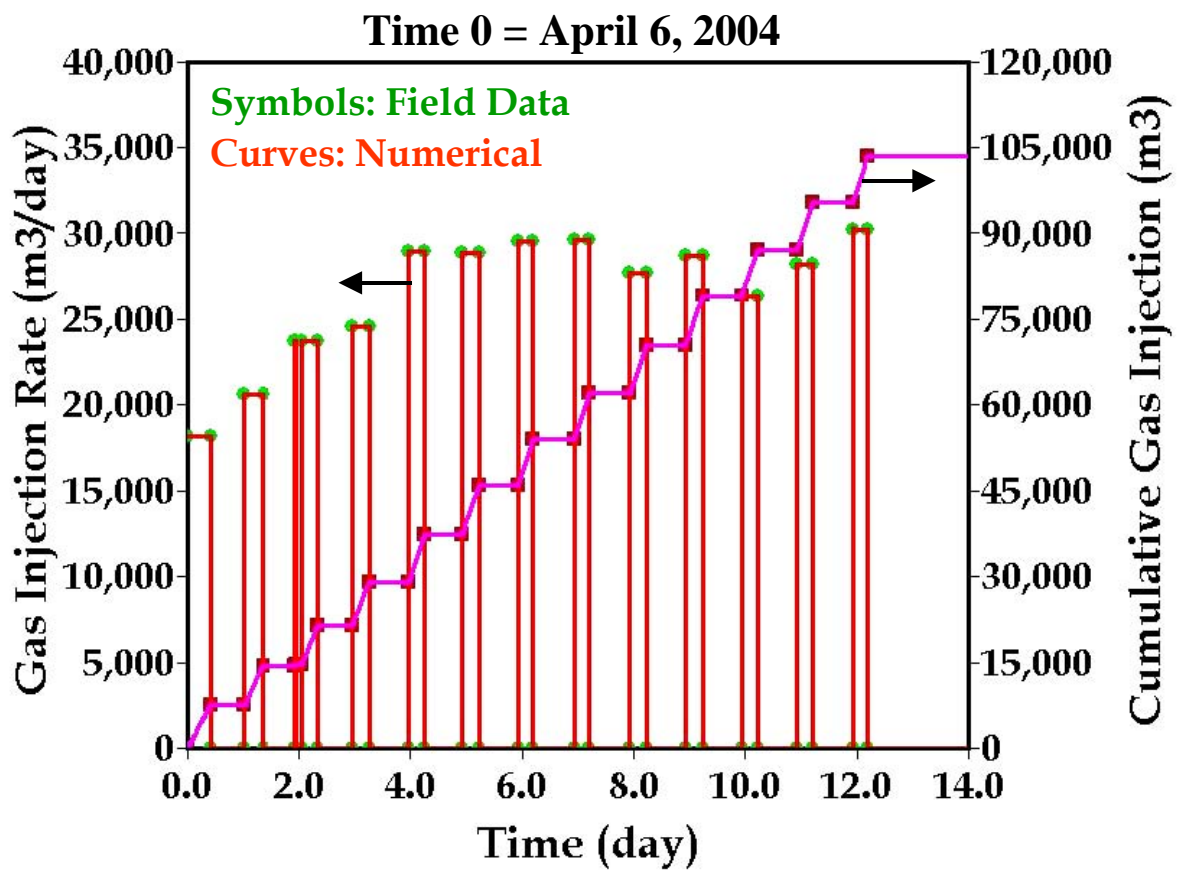


Figure 14: Stage 4: Injection of Liquid CO₂.

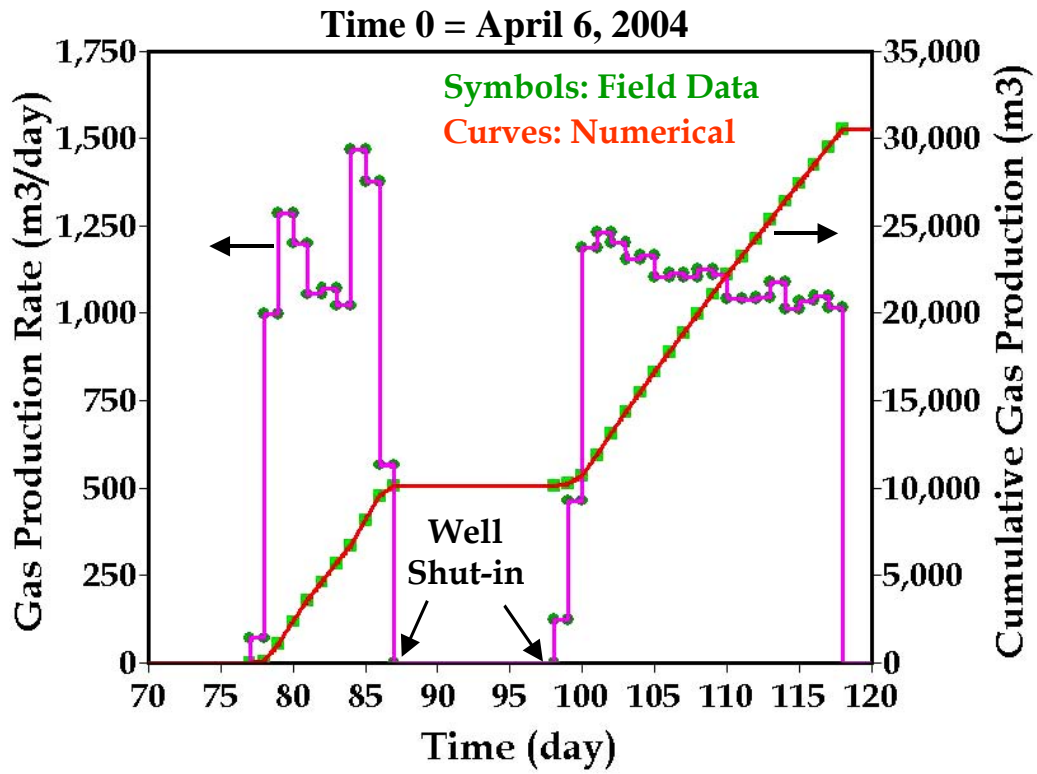


Figure 15: Stage 5: Post Injection Production Testing.

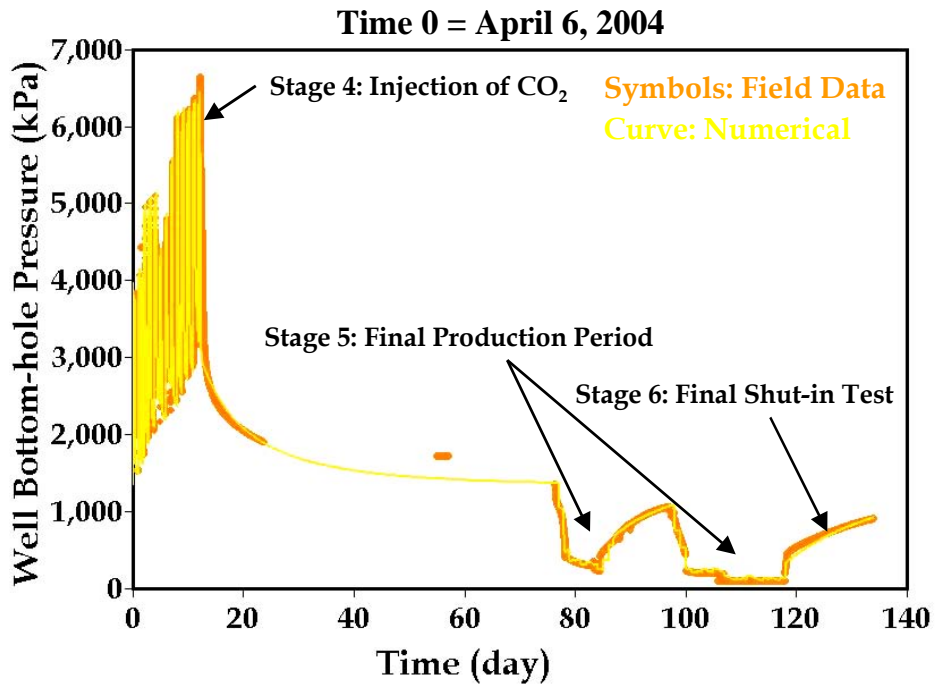


Figure 16: History Match of Bottom-hole Pressures in Stages 4-6 of Micro-Pilot Test

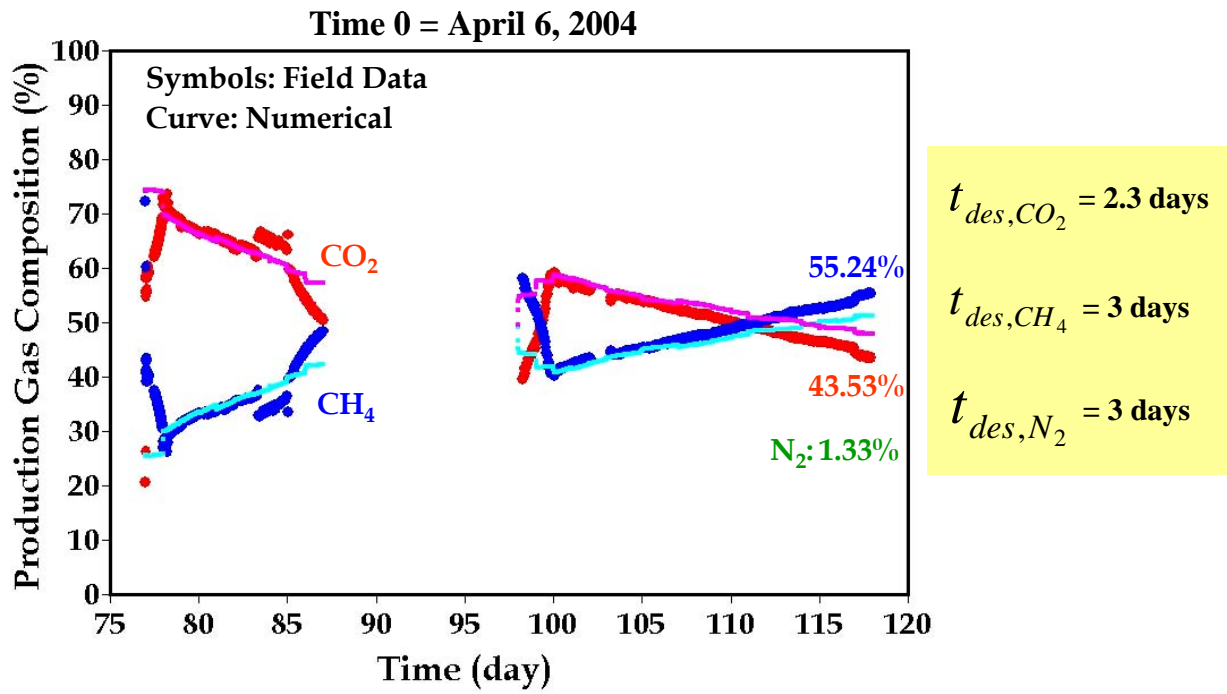
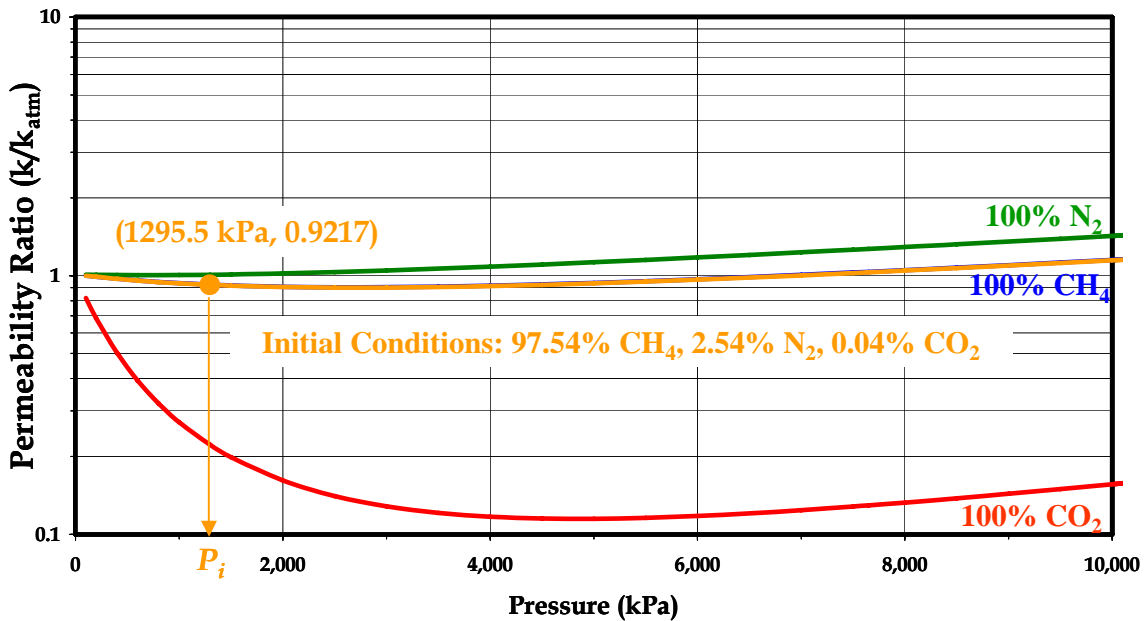


Figure 17: History Match of Gas Composition



$$k_{atm} = 13.67 \text{ md} \Rightarrow k_i = 12.6 \text{ md}$$

Figure 18: Coal Fracture Permeability Ratio Used in History Match

The results of the history match were discussed at the JPETC meeting on November 29, 2004. CUCBM agrees with the CEA that micro-pilot test #1 is a success, meeting all the technical objectives of the micro-pilot test and has economic potential (Output 1.1 achieved). The next step is to proceed to a full-scale pilot design. CUCBM further suggested that the multi-well full-scale pilot be carried out at the south Qinshui site and offered the TL-003 well as one of the wells for the multi-well pilot test. The JPETC decision is to proceed with PATH 1 (i.e. not going to a second micro-pilot test at another site).

WBS 503 Final Report: History Match of Micro-pilot Test was released on February 2005.

3.2 OUTPUT 1.2: PRELIMINARY DESIGN OF FULL SCALE PILOT TEST

Output 2.1 includes the following activities: WBS 601, 602, 603a and 604a.

Since CUCBM offers the TL-003 well to be part of the multi-well pilot scheme, WBS 604a becomes very specific, centered around the TL-003 well, rather than generic around the south Qinshui basin, as originally contemplated.

Closer examination of the existing wells around TL-003 identifies that three other wells are in close vicinity, FZ-008, FZ-002 and FZ-003. To design a multi-well pilot specifically at TL-003 would require detailed information of these four wells. A new injector well should also be optimally located so that early results can be observed. Dr. Ye Jianping, the CBM expert at CUCBM is very familiar with the coals and wells in the south Qinshui area. The CEA invited Dr. Ye to come to Canada and work with ARC on the multi-well pilot design and clarify all the data and technical/simulation issues with these four wells. Dr. Ye came to Canada on March 8, 2005 and successfully completed the mission on March 28, 2005 and returned to China.

The preliminary multi-well pilot design is an inverted 5-spot pattern, although a three well line drive has also been considered. The original test well used for the single-well micro-pilot test will be one of the corner producers (PW-1). Three existing wells in the vicinity of PW-1 will be the other corner producers (PW-2, PW-3 and PW-4). A new CO₂ injector well (IW), will be drilled approximately at the center of the pattern (Figure 19). All wells will be completed in the #3 coal seam only, similar to the single-well micro-pilot test.

In the design of the multi-well field pilot, a region of approximately 150 acres (780 m × 780 m) is considered which contains the five pilot wells. The reservoir model was first validated based on history match of the historic primary CBM production from the four existing producing wells. Then, numerical prediction of the multi-well field pilot performance was performed based on the following operating conditions:

- Continue CBM production at all four wells at their respective bottom-hole pressures
- Continue history matching of all four wells
- Start CO₂ injection at a constant rate of 22,653 m³/d (or 0.8 MMscf/d)
- Inject CO₂ to #3 coal seam only

It is found that significant enhancement in the CBM production was predicted after CO₂ injection at all four wells. Enhancement factors ranging from 2.8 to 15 were seen from the four wells (see Table 3). The enhancement factor is defined as the ratio of the average CBM production rate of the CO₂-ECBM case to the primary CBM case. CO₂ breakthrough (i.e., defined as 10% CO₂ by volume in the production gas stream) occurred first at PW-3 approximately 2.7 years after CO₂ injection (closest to the IW) and last (5.1 years) at PW-4 (farthest away from the IW). However, a methane production rate increase should be observed at all four wells after 6 months of CO₂ injection (see Figure 20).

Table 3: 5-Spot Field Pilot Test – Performance Prediction

Well		PW-3	PW-4	PW-2	PW-1
CO ₂ Breakthrough Time* (year after CO ₂ injection)		2.68	5.12	3.83	3.12
Average CH ₄ Production Rate Before CO ₂ Breakthrough (m ³ /day)	ECBM	5,275	3,600	4,657	1,394
	Primary	1,883	240	718	405
Peak CH ₄ Production Rate Before CO ₂ Breakthrough (m ³ /day)	ECBM	6,319	4,901	5,355	1,789
	Primary	2,036	627	1,305	520
Enhancement Factor**		2.80	15.00	6.49	3.44

* Time after CO₂ injection when 10% CO₂ occurred in production gas stream.

** Ratio of average CH₄ production rate: (CO₂-ECBM)/(Primary CBM).

Due to certain design uncertainties such as pressure and water saturation of the coal natural fracture system at the start of the multi-well field pilot test, a sensitive study of these initial conditions on the pilot test performance was conducted. The initial pore fracture pressure ranging from 1.29 – 3.15 MPa and water saturations ranging from 0.6 – 0.98 were investigated.

Based on the results from the sensitivity study, the following multi-well field pilot design was recommended:

- Conduct a five-well field pilot test with one new CO₂ injector and four existing CBM producers in an inverted 5-spot pattern configuration
- Block off water zone and the #15 coal seam (i.e., below the #3 coal seam) with perforation at the #3 coal seam only for all four existing producer wells
- Perforate new injector well at the #3 coal seam only
- Inject CO₂ at a constant rate of 22,653 m³/d (or 0.8 MMscf/d) for 6 months

- Injection pressure should be below the estimated coalbed fracture pressure of approximately 8.3 MPa
- CO₂ breakthrough should not occur at any of the producer wells in the 6 month period
- The first peak rate of CBM production would be observed at PW-3; however, this would not occur until about a year after CO₂ injection
- During the field pilot test, well bottom-hole pressures, gas injection/production quantities and gas injection/production composition should be monitored at all the pilot wells
- Numerical prediction should be refined from the pre-test prediction as more information such as initial conditions of the near-well regions are available
- After the post-test history match of the multi-well field pilot test data, the refined model will be used to design a commercial demonstration.

The multi-well pilot design was completed. The recommendation is to proceed to the next stage of multi-well pilot testing. Prediction of initial performance indicates that significant enhancement of CBM production while simultaneously storing the CO₂ is feasible with the high rank anthracite coal in Qinshui basin (see Figures 21 and 22).

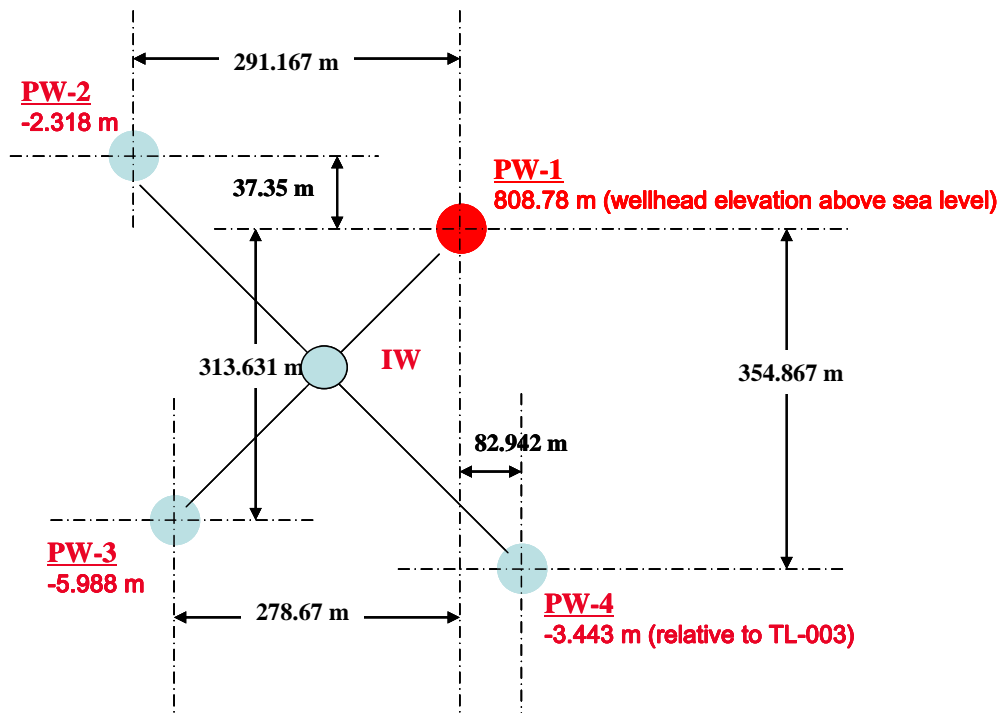


Figure 19: Pattern Configuration of the Multi-Well Pilot

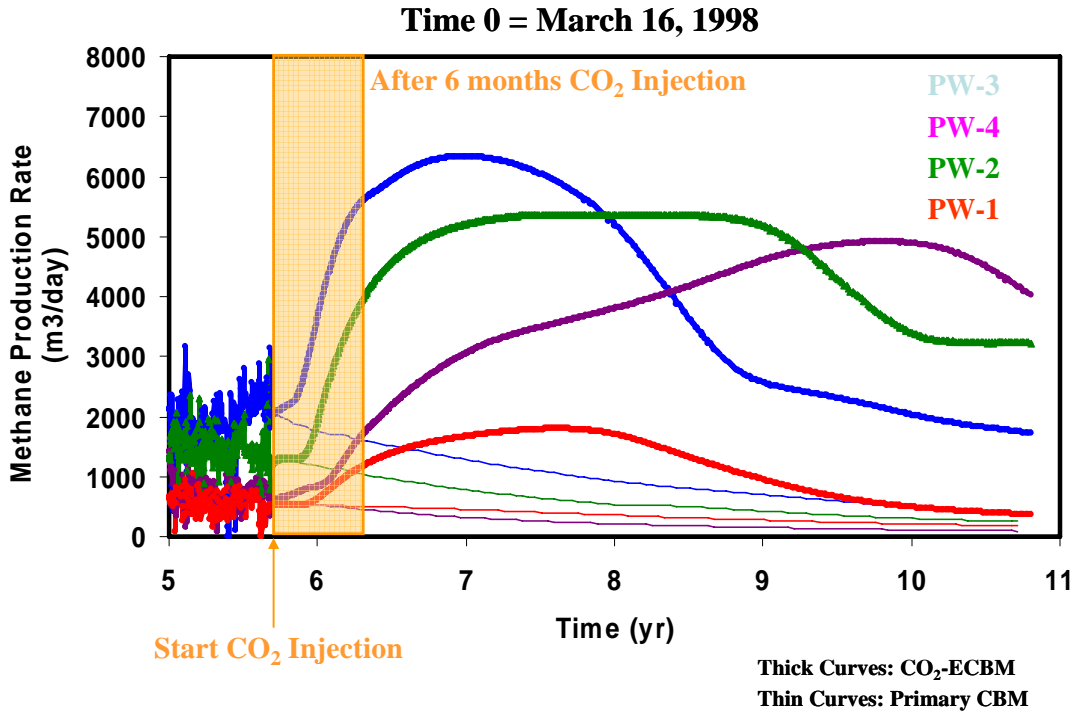


Figure 20: 5-Spot Pilot Test Prediction – Methane Production Rate

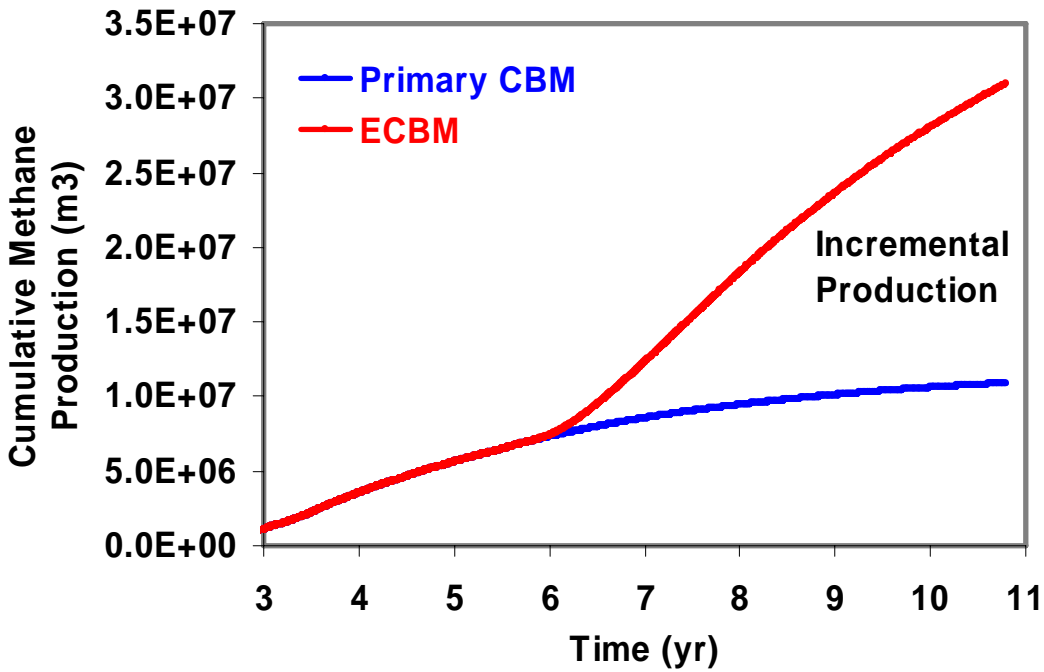


Figure 21: 5-Spot Field Pilot Test Prediction – Cumulative CBM Production

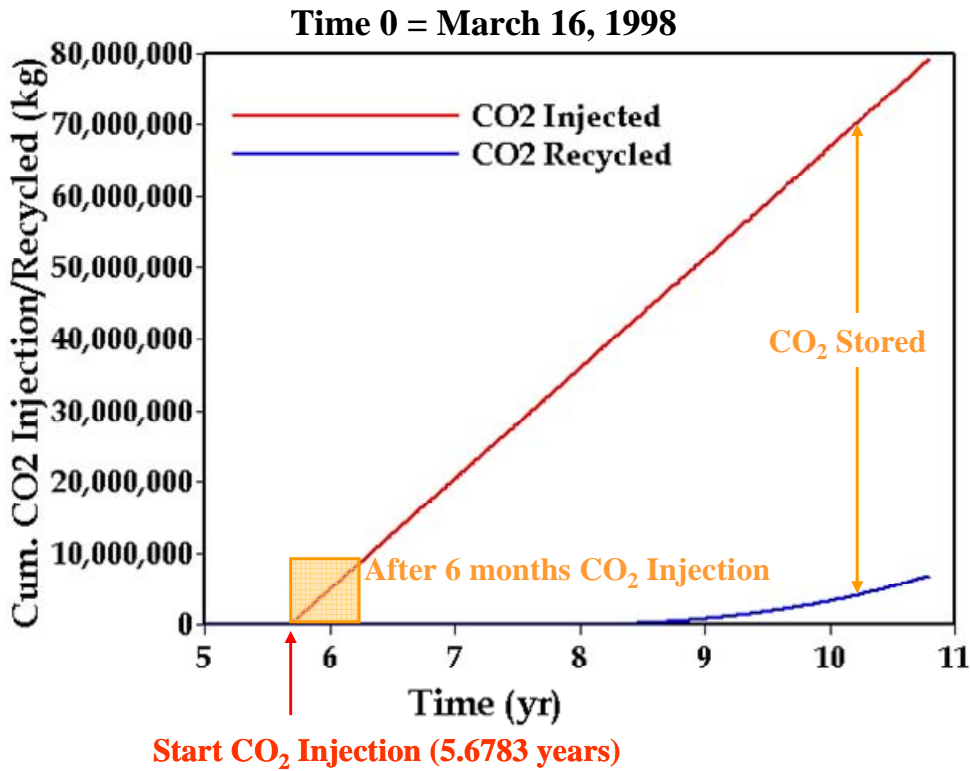


Figure 22: 5-Spot Field Pilot Test Prediction – CO₂ Inventory

SNC Lavalin then estimated the cost of the multi-well pilot at Qinshui to be about US \$9.5 million, in 2nd quarter 2006 dollars.

Multi-Well pilot cost

• Site facilities design & construct	\$3,500,000
• Injector drill & prep	\$ 750,000
• CO ₂ purchase & delivery	\$1,200,000
• Pilot operations	\$1,150,000
• Tech support & results analysis	\$ 700,000
• Contingency 30%	\$2,200,000
 Total	 \$9,500,000

Source: ARC Canadian Estimates for similar pilot

This cost estimate was based on the following:

- Purchase CO₂ FOB injection site (assuming Tian' Ji) as it is too expensive to construct unit to produce own CO₂
- Drill new injector well

- Inject 40 tonnes per day for 200 days
- Instrument and produce 4 wells for 300 days; shut in and measure pressure buildup
- Operations
- Technical support
- Analysis and Simulation

WBS 604 Report: Design of Multi-well Pilot Test & Conceptual Commercial Development Design was completed in December 2006. Output 1.2 is achieved.

3.3 OUTPUT 1.3: CONCEPTUAL DESIGN FOR ONE COMMERCIAL SCALE SURFACE FACILITY

The conceptual commercial development design was based on data obtained from coal seam #3, well TL-003 and the micro-pilot test in South Qinshui Basin. The design focused on well configurations (pattern), well spacing (pattern) and compositions of the injection gases. Mixed gas (combination of CO₂ and N₂) injection has also been considered and evaluated.

Based on reservoir simulation, the CO₂-ECBM process is favoured, for the following reasons:

- The recovery factors are about 95% in the CO₂-ECBM process in 80-acre pattern with 10-year production and in 160-acre pattern with 20-year production.
- The peak CBM production rate and the average CBM production rate are much higher than those in primary CBM process.
- The CO₂-ECBM process can sustain a long period of high CBM production rate before CO₂ breakthrough, for example, the CBM production rate averages more than 10,000m³/d for about 17 years in a 5-spot 160-acre pattern.
- CO₂ takes a long time to breakthrough at the production well due to the coal's preferential adsorption of CO₂ and the coal swelling in the CO₂ region.
- CBM produced at producer well is not affected by coal swelling due to CO₂ adsorption. The coal shrinkage effect due to CBM desorption around the production well actually further enhances the CBM production rate.
- Compared to the 9-spot pattern, the 5-spot pattern has less peak production rate, however, it has very similar average production rate and recovery factor.

Figures 23 and 24 show the CBM production rates and the recovery factors before CO₂ breakthrough, with different gas injection in a 5-spot 160-acre pattern, respectively. After evaluating the performances of the ECBM processes with different well configurations and pattern sizes, the 5-spot 160-acre pattern is chosen. This pattern has the following advantages compared to other well configuration and pattern size combinations:

- 1) Less capital investment on well drilling over the 9-spot patterns;
- 2) Comparable recovery factor with the 9-spot pattern;

- 3) Longer production period before breakthrough occurs than 80-acre pattern;
- 4) Longer production period also make better use of the capital investment over 80-acre pattern.

Thus, the 5-spot 160-acre pattern is recommended for the commercial development design in South Qinshui Basin.

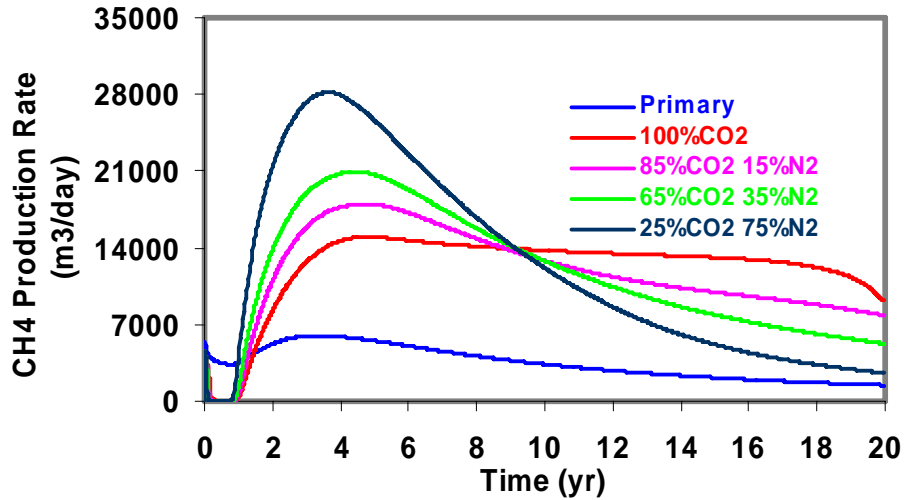


Figure 23: Example: CBM Production Rates with Different Gas Injection (5-spot 160-acre pattern)

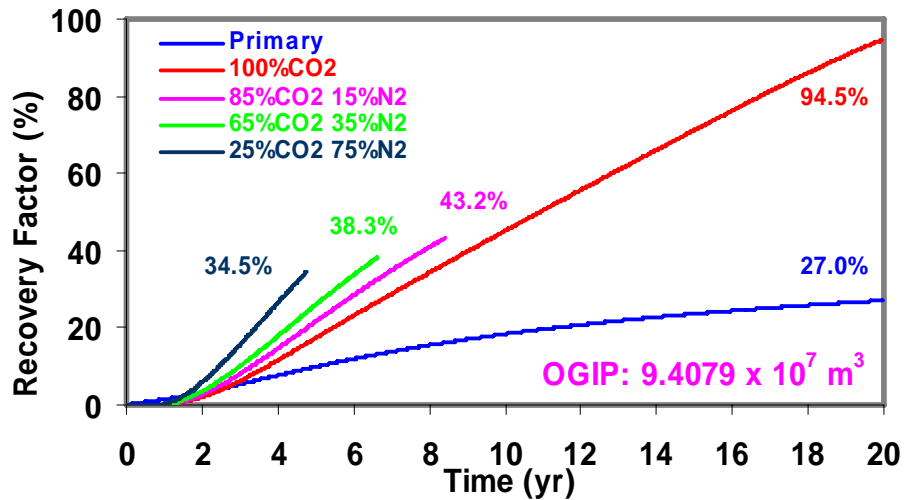


Figure 24: Example: Recovery Factor before Breakthrough with Different Gas Injection (5-spot 160-acre pattern)

SNC-Lavalin conducted a literature survey of potential CO₂ sources in the Shanxi region, estimated order-of-magnitude costs for delivered CO₂ from each source and ranked each source. The focus was on the commercial scale plant. The top four sites from the preliminary assessment were:

- Shanxi Tian'ji Coal Industry Group
- Shanxi Jincheng Chemical Fertilizer
- Shanxi Coking
- Luoyang Nitrogen Fertilizer Plant

The concept of using CO₂ from a high purity source such as a fertilizer plant should be pursued further, and adopted as the design basis for the conceptual design of the commercial scale plant, due to process simplicity to capture the CO₂ and favorable economics in CO₂ cost. With the assistance of CUCBM, Mr. Doug Macdonald of SNC Lavalin Inc. visited two of the four sites in May 2005. It is further concluded that:

- CO₂ production from a source at Tian'ji Chemical Fertilizers Plant, Lucheng is technically feasible.
- Obtaining CO₂ for the multi-well pilot from Tian'ji or other source not presently in the CO₂ business is likely too expensive to contemplate on its own, unless there are long term, high value markets for the small volumes of CO₂ produced.
- There appears to be about 360,000 tonnes per year surplus CO₂ available from Tian'ji; about 70% of what we are told is required for a full scale project.
- It is likely that other sources of CO₂ exist in the vicinity that could make up this difference.
- A project to capture CO₂ from Tian'ji, purify and pipeline it to the Qinshui basin is technically feasible and presents no unusual challenges.

The conceptual commercial operation at Qinshui basin is envisioned to comprise of 90 wells initially (45 injection wells and 45 producer wells). The CO₂ is delivered to site at a pressure of 8.3 MPa (1,204 psi). Maximum CO₂ required for the project is 30 MMSCFD total (1,575 t/day or 520,000 t/year). The CO₂ supply is assumed to come from Tian'ji Chemical Fertilizers Plant at Lucheng. It is expected that approximately 800 t/d CO₂ is theoretically available (~ 280,000 t/year with 95% recovery). Additional CO₂ sources have to be identified for the remaining 240,000 t/year. The conceptual study is based on 520,000 t/year of CO₂ being available at Tian'ji or near Lucheng.

The CO₂ is captured at source, dehydrated, compressed and delivered to site through a pipeline (at CO₂ supercritical conditions). Desulphurization facilities will be added, if required. At the field level, once the CO₂ is delivered to site, the CO₂ will be distributed to the wellheads for injection through a system of piping networks. The CO₂ will be directly injected without additional compression at the site. The commercial scale plant will also include produced water handling facilities and produced gas handling facilities.

Capital costs for the surface facilities are estimated based on second quarter 2006 US dollars, in a central China location, as follows:

CO ₂ plant capital cost	US \$27,260,000
Pipeline capital cost	US \$39,350,000 (based on US \$56,700/in-km)
Total capital costs	US \$66,610,000

The unit CO₂ cost is estimated at US \$6.70/t (without capital charge) and US \$17.40/t (with capital cost at 12% rate of return). The commercial project can provide an internal rate of return of 11.6%, or a simple payout of 9 years. If a CO₂ credit of US \$10/net tonne can be realized, the economics improve to an internal rate of return of 15.7% or a simple pay out of 7 years.

The conclusions from the conceptual commercial scale development at Qinshui basin are:

- Project is technically feasible
- Project is possibly economic using 0 or reasonable CO₂ credit values
- Opportunities exist to reduce costs
- Down hole water disposal important

According to Final Work Plan, three additional sites for potential ECBM projects are to be evaluated further. The three sites are:

1. Heilongjiang province in Northeast China, near the city of Hegang, northeast of Harbin, close to the Russian border;
2. Xinjiang province in Western China, close to the city of Urumqi;
3. Guizhou province in Southwest China, south of the city of Panxian, in the southwestern part of Guizhou province close to the border of Yunnan Province.

It is found that while no existing source as reported is able to deliver the full amount of 520,000 t/year of CO₂, the most attractive combination appears to be in Xinjiang, where one plant very close to the injection site can theoretically deliver about 70% of the required amount. Heilongjiang is ranked second, with Guizhou last owing to difficult terrain for pipelining and requirements for accessing three or four sources to deliver the requisite CO₂ volume. However, if the planned large Yuntianhua fertilizer plant nearby at Qujing in Yunnan is a reality, Guizhou would become the first choice location for an ECBM project, despite the challenging terrain.

Three Reports were issued by SNC Lavalin Inc.: (1) WBS 603, Cost Estimates for Surface Facilities Production, Transportation and Injection of CO₂ Multi-well Pilot and Conceptual Full Scale Operations, March 2007; (2) WBS 605 Preliminary Investigation into Sourcing of CO₂ for Multi-well Tests and Commercial Scale Plant, March 2007; and (3) Alternate Sites Evaluation: CO₂ Sourcing, March 2007.

3.4 OUTPUT 1.4: ENHANCED CBM/CO₂ TECHNOLOGY SKILLS APPLIED AT PROJECT SITES AND OTHER COAL BEDS IN CHINA

3.4.1 Gender Equality (WBS 701, WBS 704)

The Gender Equality (GE) study has five major activities: (1) Select and train gender focal points (GFP); (2) develop GE profiles of partner organization and the local community (LCO); (3) develop GE strategy; (4) raise awareness and promote appropriate GE policies and (5) carry out performance monitoring.

Ms. Li Mou was contracted as the GE specialist and was responsible for the delivery of the GE study. Shanxi Agricultural University was chosen as the local gender consultant to assist in collecting the baseline data and delivering the training workshops.

Qinshui Lanyan CBM Co. agreed to participate with us as the LCO to represent the CBM industry in south Qinshui at large. A total of ten GFPs, five from CUCBM and five from Qinshui Lanyan CBM Co. were selected. Two training sessions for GFPs were conducted – to CUCBM on February 11, 2004 and to Qinshui Lanyan CBM Co. on February 23, 2004.

To develop the GE strategy, two gender workshops were held, one with CUCBM and the other with Qinshui Lanyan CBM Co., representing the local community.

The workshop with CUCBM was held on June 11, 2004 in Beijing. The half-day workshop at CUCBM in Beijing included the following presentations: Xiaomei Li: Role of women in Canadian society; Aimei Hu: My Experience and Role of Chinese Women in Society; June Fan: Initial GE assessment and Bernice Kadatz: Gender Equity from a Western Canadian Perspective. A total of 19 people (including presenters) attended the workshop. Also in attendance were Mr. Sun Maoyuan and Mr. Feng Sanli, President and Vice President of CUCBM. Of the 15 CUCBM participants, 7 were females (47%) and 8 were males (53%).

The second workshop with Qinshui Lanyan CBM Co. was held on April 27, 2005 in Jincheng city, close to the planned multi-well pilot site. It was attended by 61 people including presenters (58 females and 3 males).

GE performance monitoring was carried out via questionnaire survey with 20 managers, regular employees and GFPs, including 14 females (70%) and 6 males (30%).

By and large, the GE study made advance towards the five major expected results at the output level:

- Gender awareness in partner organizations increased;
- Gender consideration incorporated into the human resource development and institutional development plans of partner organizations;

- GFP identified, trained and engaged;
- The capacity of the partner organizations strengthened in conducting gender analysis; and
- Implementation of Chinese GE policies and guidelines facilitated.

Three GE reports were produced: (1) Development and Implementation of a Gender Equality Strategy: the Baseline Assessment, January 2005; and (2) Gender Equality Performance Monitoring Report, February 2006; and (3) Gender Equality Project Completion Report, August 2006.

The project also promoted women participation in activities (see 3.4.2 below).

3.4.2 Training and Technology Transfer (WBS 702, 703a, 703b)

Technology transfer/training is a key element of the Project. In our training plan, most of the training in China would be done during field missions that would already be required for operational purposes. This method of scheduling would require less budget coverage for travel, and would simply extend some of the missions by a few days. However, the pitfall, as we have noticed, is that when the field activities were delayed due to operational issues, the training courses were pushed back. This made scheduling for training rather ad hoc during the field operation period. Nevertheless, all the training modules in China were completed according to the training plan.

In addition, a significant portion of the training was also done in Canada due to the availability of properly set-up computer training facilities using proprietary software, specialized equipment and visits to Canadian field operations and facilities. It offered the opportunity for the Chinese trainees to interface with a broad range of specialists who would normally not travel to China.

Training Course	Organizing Company	Timing and Training Days	Location	Total Trainees (female/male)
1. Numerical Simulation – Level 1	CMG	Oct. 2002 (16 days)	Canada	5 (1/4)
2. Lab Analysis & Characterization	ARC	Jan. 2003 (17 days)	Canada	5 (2/3)
3. CBM Geological Evaluation & Industrial Familiarization	Sproule	Feb. 2003 (11 days)	Canada	9 (3/6)
4. Numerical Simulation - Advanced	CMG	Feb. 2003 (17 days)	Canada	3 (0/3)
5. CBM Exploitation (well stimulation)	CalFrac	April 2004 (3 days)	China	25 (1/24)
6. Reservoir Simulation	CMG	May 2004 (1 day)	China	61 (6/55)

7. Reservoir Access – Drilling Technologies	Computalog	May 2004 (3 days)	China	61 (6/55)
8. Review of ECBM Technologies and Pilot Experience	ARC	May 2004 (2 days)	China	61 (6/55)
9. Review of History Matching Techniques	ARC	July 2004 (1 days)	China	19 (2/17)
10. History Match of Micro-Pilot Test and CBM Econ.	ARC	Nov. 2004 (2 days)	China	22 (11/11)
11. 1 st High Level Study Tour of CDN CBM Industry	Sroule, ARC, CMG	Sept. 2004 (11 days)	Canada	8 (2/6)
12. Multi-well Pilot Design	ARC	Mar. 2005 (15 days)	Canada	1 (0/1)
13. CBM Development and Production Management	Sroule, SLI,	Nov. 2005 (10 days)	Canada	6 (2/4)
14. CBM Software Update	CMG	Oct. 2005 (9 days)	China	5 (3/2)
15. History Match Multi-well Pilot	ARC	Nov. 2005 (11 days)	China	5 (3/2)
16a. ECBM Economics	ARC	April 2006 (2 days)	China	20 (6/14)
16b. CDM - CO ₂ Reduction	Delphi	April 2006 (1 day)	China	20 (6/14)
17. Well Stimulation and CBM Gathering (combined)	CalFrac, Sroule, SLI	Aug. 2006 (6 days)	Canada	8 (3/5)
18. 2 nd High Level Study Tour of CDN CBM Industry	Sroule, ARC, CMG	Dec. 2006 (6 days)	Canada	8 (5/3)
S/total Canada China TOTAL				53 (18 w-30%) 299 (50w-17%) 352 (68w-19%)

Because of the success of the first micro-pilot test, additional budget was allocated to training. This created two more courses in Canada as well as the second high level study tour. In total, the Project delivered 18 training courses (including the two high level study tours) in China and Canada, covering all aspect of CBM and ECBM technologies. 299 CUCBM and Chinese staff (50 females, or 17%) was trained in China and another 53 senior CUCBM managers (18 females, or 30%) were trained in Canada. It is noted that some CUCBM trainees were trained at more than one training course. Given the low percentage of women in the CBM sector in China (as in Canada) it can be considered that the project succeeded in promoting women in training activities. This exceeded the expected outputs of training up to 200 managers, engineers and technicians in China and at least 25 in Canada. Output 1.4 has been achieved.

3.5 OUTPUT 2.1 CONTACTS ESTABLISHED BETWEEN CANADIAN AND CHINESE SENIOR MANAGERS IN CBM RELATED INDUSTRIES

3.5.1 High Level Study Tours (WBS 703c)

The first high-level study tour took place from September 5 to 22, 2004 (WBS 703c). Mr. Jie Mingxun, Chairman of CUCBM, led the eight members' Chinese delegate. The purpose of this high-level study tour was "to establish contacts between Canadian and Chinese CBM industries and promote the transfer of Canadian ECBM technologies to China". The tour included presentations by Sproule, CMG, ARC, Computalog, SNC Lavalin Inc., CalFrac Well Services, Norwest Energy, EnCana, MGV Energy, BJ Services and Government departments in Calgary, Edmonton and Ottawa. EnCana hosted a site visit to their CBM site in southern Alberta. The delegates also visited the CIDA office in Ottawa and met with the Director General, Asia Branch to discuss progress of the Project. CUCBM appreciated the CEA's organization of the mission and acknowledged that the objectives of the mission were met. Norwest Energy, EnCana, MGV Energy and BJ Services showed interest of involving in CBM in China and the CEA had followed up on this prospect.

The second high level study tour took place from December 1 to 12, 2006. Mr. Sun Maoyuan, President of CUCBM led this 8 member delegates including senior officials from the National Development and Reform Commission, the Coal Association of China. The tour included presentations by Sproule, ARC, MGV Energy, Husky Energy, Petromin Resources, TerraWest Energy, Pacific Asia China Energy and the Alberta Government. High level contact has been established between these organizations.

There are a lot of interests shown in the Canadian CBM/CO₂-ECBM technology over the life of the Project. The CEA, on behalf of the Canadian Consortium, has signed letters of understanding with three Canadian based companies who want to investigate whether this technology can help their exploitation of CBM in China. They are:

- 1) Petromin Resources (based in Vancouver, British Columbia), who is evaluating CBM properties in Heilongjiang and Shanxi Provinces;
- 2) Pacific Asia China Energy (based in Kelowna, British Columbia), who has signed a Production Sharing Contract (PSC) with CUCBM in Guizhou Province; and
- 3) TerraWest Energy (baaed in Calgary, Alberta), who has signed a PSC with CUCBM in Xinjiang Province.

In addition, the CEA has signed a letter of understanding with Heilongjiang Coal Field Bureau to pursue this technology in their Province.

3.5.2 Dissemination of Project Results (WBS 803)

The Project produced 11 Technical Reports

1. WBS 100 Report: Potential Pilot Site Selection, February 2003
2. WBS 200 Report: Detailed Pilot Site Selection, March 2003
3. WBS 300 Report: Micro-pilot Test Design, July 2003.
4. WBS 401 Report: Micro-pilot Implementation and Data Reporting, October 2004
5. WBS 501 Report: Micro-pilot Results and Analysis, October 2004.
6. WBS 503 Report: History Match of Micro-pilot Test, February 2005.
7. WBS 604 Report: Design of Multi-well Pilot Test & Conceptual Commercial Development Design, December 2006.
8. WBS 603 Report: Cost Estimates for Surface Facilities Production, Transportation and Injection of CO₂ Multi-well Pilot and Conceptual Full Scale Operations, March 2007.
9. WBS 605 Report: Preliminary Investigation into Sourcing of CO₂ for Multi-well Tests and Commercial Scale Plant, March 2007.
10. Alternate Site Report: Alternative Sites Evaluation: CO₂ Sourcing, March 2007.
11. Gender Equality Project Completion Report, August 2006

In addition, CUCBM requested and CIDA/CEA agreed that the CEA writes a Recommended Practice Manual for Enhanced Coalbed Methane Pilot Test in China. This was completed in March 31, 2007.

The CEA also made the following Project presentations at national and international technical conferences and workshops:

1. Third China Coalbed Methane Forum, November 2002, Kunming, Yunnan, China.
2. Third International Forum on Geologic Sequestration of CO₂ in Deep, Unmineable Coal Seams, Coal-Seq III, March 2004, Baltimore, Maryland, USA.
3. Third International Workshop on Prospective Roles of CO₂ Sequestration in Coal Seams, October 2004, Sapporo, Japan.
4. Fourth International Symposium on CBM/CMM in China, December 2004, Beijing, China.
5. APEC CO₂ Capture and Storage Capacity Building Workshop, January 2005, Seoul, South Korea.
6. Coalbed Methane Workshop, Conference Board of Canada, March 2005, Calgary, Alberta, Canada.
7. Global Climate and Energy Project International Workshop on Clean Coal Technology Development, August 2005, Beijing, China.
8. Fourth International Forum on Geologic Sequestration of CO₂ in Deep, Unmineable Coal Seams, Coal-Seq. IV, November 2005, Denver, Colorado, USA
9. Eighth International Workshop in Greenhouse Gas Control Technologies, GHGT-8, June 2006, Trondheim, Norway.
10. APEC CO₂ Capture and Storage Capacity Building Workshop, October 2006, Beijing, China.

This Project was nominated and accepted as a demonstration project under the US led Carbon Capture and Sequestration Leadership Forum (CSLF), in which Canada and China are both partners. The objective of CSLF is to make these technologies broadly available internationally. Coal resources are abundant and widespread globally. China, India, Poland, to name a few, could use the ECBM technology.

China has an abundance of deep coal beds where geological storage of CO₂ is possible. In many of these areas, coal-burning power plants and coal-gasification plants are located. ECBM technology, together with new power plants equipped for CO₂ capture, offer the potential for a zero-emission sustainable energy supply. Under the China project, the technologies and processes first developed under the Alberta ECBM project are being tested in China, first with a micro-pilot test, to be followed by a full-scale multi-well pilot test. This is an excellent example of technology transfer related to CO₂ storage technologies.

3.6 OUTCOME 1: CANADIAN TECHNOLOGY APPLIED FOR FULL SCALE TEST AND/OR FOR REPLICATION OF MICRO-PILOT TESTS AT OTHER LOCATIONS IN CHINA

The micro-pilot test at south Qinshui meets all technical requirements and surface facility assessment indicates that commercial scale operation is possibly economic. The Project recommended proceeding to multi-well pilot test (full scale test) at the south Qinshui site. However, it will be China's responsibility to move the Project forward to full scale test and to conduct micro-pilot tests at other locations in China. If China decides to proceed with a full scale test or other micro pilot tests, CUCBM engineers who now have a good understanding of the Canadian technology and will be able to apply it at a full scale test and other coal beds.

3.7 OUTCOME 2: COMMERCIAL COOPERATION BETWEEN CANADIAN AND CHINESE FIRMS ON CANADIAN CBM/CO₂ TECHNOLOGY

The two high level study tours generated a lot of goodwill and high level contacts between Chinese and Canadian CBM industries. The ARC, on behalf of the Canadian Consortium, had signed letters of understanding with Petromin Resources, Pacific Asia China Energy, TerraWest Energy and with the Heilongjiang Coal Field Bureau to evaluate the feasibility of applying the Canadian CBM/CO₂ technology in China. The Pacific Asia China Energy and TerraWest Energy have actually signed commercial Production Sharing Agreement with CUCBM. Other than these companies, Husky Energy and MGV Energy have expressed interest in CBM in China. So the prospect is very promising, but it is too early to assess during life of the Project.

3.8 PROJECT IMPACT: MITIGATING CLIMATE CHANGE THROUGH INCREASED USE OF CBM AND REDUCED CO₂ EMISSIONS

The assumptions are: China remains committed to slowing down global climate change; and sufficient commitment and capacity in China to implement and maintain Canadian CBM/CO₂ technology. China is signatory to the Kyoto Protocol. However, as a developing country, China has no mandated target for GHG reductions. These require long term policy development. Therefore the impact is not measurable during the life of the Project.

4.0 FINANCIAL RESULTS

4.1 FEES

Canadian Personnel

	Estimated Budget	Project Actual March 02 – March 07
Alberta Research Council	703,293	1,053,973
Sproule International Ltd.	1,061,367	718,633
Computer Modelling Group	489,434	341,231

Canadian Outside Consultants

SNC Lavalin	349,545	196,843
Computalog	161,609	14,314
CalFrac	75,995	29,452
Porteous Engineering	98,151	141,123
Archon International	43,560	0
L. Mou (Gender Equality Specialist)		34,800
(Prism Technologies, CAD&T Consulting)		31,208
Misc. (TIPM, AGS, DELPHI GROUP)		26,170

Local Professionals

Locally Engaged Professional - CMG - Shanxi Agri. U.	113,020	54,594
Total Fees	3,095,974	2,642,341

4.2 REIMBURSEABLE EXPENSES

	Estimated Budget	Project Actual March 02 - March 07
Travel Expenses for Canadian Personnel and Canadian Outside Consultants	683,398	222,377
Expenses for Locally Engaged Professionals	37,116	3,185
Comm. Reproduction & China Office Rent, Translation & Misc. Supplies	66,110	25,574
CMG – Office Space & Computer Costs	25,260	16,521
CO₂ Pumping Equipment	153,619	68,106
Computer/Equipment	72,170	194,957¹
Training Expenses in China and Canada	186,353	244,818²
Total Expenses	1,224,026	775,538
Total Fees and Expenses	4,320,000	3,417,879

Note 1: Data measurement equipment was not in the initial budget

Note 2: Additional training and high level study tour in Canada

Total may not add due to rounding.

4.3 FINANCIAL BY WBS

A summary of financial by WBS is tabulated in the following Table:

	CIDA Contribution As per PIP	Project Actual March 02 – March 07	Remarks
WBS 100	75,000	63,958	
WBS 200	390,000	291,529	One site characterization
WBS 300	215,000	162,466	One micro-pilot design
WBS 400	935,000	530,032	One micro-pilot test
WBS 500	860,000	378,734	One micro-pilot test
WBS 600	370,000	595,974	Expanded work on additional sites and preparation of a micro-pilot test manual
WBS 700	660,000	660,702	
WBS 800	680,000	734,484	Project extended one additional year
Inflation	135,000		
Total	4,320,000	3,417,879	

5.0 KEY LESSONS LEARNED

Throughout the Project, there was very close co-operation between the ChEA and the CEA. There was no major issue. This was particularly credited to the hard working of the two project liaisons, Mr. Fan Zhiqiang of CUCBM and Mr. Peter Ho of CMG and the good relationship between CUCBM and the ARC.

As the Project involves field testing, assuring data integrity is of critical importance to the success of the Project. During the critical operating phases, the CEA supplied experts to the field to supervise the operation (for example, Ms. Bernice Kadatz for the field instrumentation and Mr. John Robinson for the CO₂ pumping). CUCBM also sent one expert (Mr. Wang Guoqiang) who spent three months in the field. It was still a challenge to have expert in the field all the time. For some periods, there won't be any coverage. There was a close call when electric power at the site was unknowingly tripped off. At the end, a good data set was collected. The data integrity was not compromised. If we were to do the micro-pilot test again in China, the long term development would be to have remote data access and control. In this manner, it would be less stringent to have personnel in the field all the time in order to make timely corrective actions.

Another consideration is to have a full time Canadian supervisor in China. In one occasion (casing head leaks), it was difficult to diagnose the problem and recommend the corrective measures from long distance. Obviously the full time field staff would increase the operating budget of the CEA. However, the advantage is that we could have quick corrective measures taken in the field when operating problems arise.

The other lesson that the CEA has learned was the time required for equipment shipping and clearing customs in China. It was not realistic to expect that customs could be cleared in a couple of days, even though all the paper work may have been completed. A minimum of 10 days should be allowed for custom clearing.

Similarly, the ChEA should allow plenty of time to clear visa for Chinese trainees to Canada. CIDA has streamlined the visa application process and made the time line very predictable. However, often the trainees did not have passports in their possession. This would take extra days to have the passports issued. The ChEA should screen the trainees for passports and allow minimum extra 3 weeks so that the CEA can have realistic schedule for planning training missions to Canada.

APPENDIX 1

ANNEX A

Logical Framework Analysis

Country/Region	China	Project No.	A-030841
Project Title	Coalbed Methane Technology Carbon Dioxide Sequestration Project	Project Budget:	10.75 million
CEA/Partner Organization	Alberta Research Council Inc/Computer Modelling Group Ltd./Sproule International Ltd. and Cal Frac Well Services Ltd; Computalog Ltd; Porteous Engineering Ltd; SNC Lavalin Inc.	Project Manager:	Charles Pellegrin
Related C/RPF Dated	China's CDPF (Nov. 1994)	Project Team Members:	Brian Weller (Environment) Josee Fluet (ClimateChange)
			Claire Martel (Contracts); Cecilla Leung (Embassy); Zhizhong Si (CEAA); Milos Rajicic (Energy: Oil & Gas)

Logical Framework Analysis

Project: China Coalbed Methane CO₂ Sequestration

Narrative Summary	Expected Results	Performance Measurement	Assumptions/Risk Indicators
Project Goal (Program Objective)	Impact	Performance Indicators	Assumptions - Risk Indicators
To promote environmentally sustainable development in China by enhancing its capacity to manage its environment.	- Mitigating climate change through increased use of Coalbed Methane (CBM) and reduced CO ₂ emissions.	- Number of operating commercial CBM production/CO ₂ storage sites.	ASSUMPTIONS: - China remains committed to slowing down global climate change - Sufficient commitment and capacity in China to implement and maintain Canadian CBM/CO ₂ technology (see purpose) RISK FACTOR: Medium RISK INDICATORS: - China's commitment to mitigating climate change not materializing - CBM exploited without utilizing Canadian CBM/CO ₂ technology.
Project Purpose	Outcomes	Performance Indicators	Assumptions - Risk Indicators
-To transfer to China the Canadian CO ₂ enhanced CBM recovery/CO ₂ sequestration technology (<i>Canadian CBM/CO₂ technology</i>) to effectively exploit coalbed methane, a cleaner source of energy, while storing CO ₂ , a greenhouse gas (GHG), in unmineable deep coal beds in poorer areas of China's interior. - To try and establish sustainable economic linkages between China and Canada CBM related industries	- Canadian CBM/CO ₂ technology applied for full scale pilot test (hopefully leading to CBM commercial production) and/or for replication of micro pilot tests at other locations in China. - Commercial cooperation between Canadian and Chinese Firms on Canadian CBM/CO ₂ technology.	- Full scale test reports - Number of CBM sites pilot tested beyond the project - Number of CBM related JV/commercial agreements (actual and under discussion) recorded by Embassy trade section.	ASSUMPTIONS - Selected coal beds accept the required amount of CO ₂ to economically produce sufficient methane for commercial viability. - China CBM Industry able to adapt/utilize advanced practices, including improved environmental management. RISK FACTOR: Medium RISK INDICATORS - CUCBM cannot absorb project technology transfer and/or unable to disseminate new knowledge - CUCBM not able to raise funds for full scale test and replication of micro pilot tests at other sites in China.

Resources	Outputs	Performance Indicators	Assumptions – Risk Indicators
<p><u>CIDA Contribution</u>: \$5 million for:</p> <ul style="list-style-type: none"> - Technology transfer - Technical assistance - Training - Engineering and management services - Monitoring equipment/operation (shared) - CO₂ pumping equipment purchase/rental - CO₂ supply and transportation for 2nd and 3rd well as required - Project related computer equipment - Travel and administration - CIDA Monitoring and evaluation <p><u>Canadian Consortium</u> - \$ 0.75 million for:</p> <ul style="list-style-type: none"> - Fee differential (commercial vs non-profit) - Free access/use of software during project <p><u>CUCBM – China</u> \$5 million for:</p> <ul style="list-style-type: none"> - Wells including drilling, completion and stimulation - CO₂ supply/transportation for 1st micro-pilot test - Logging, coring and laboratory adsorption tests - Monitoring equipment/operation (shared) - Coalbed data and information - Transportation - Personnel and Administration - Operating licenses and permits - Equipment and facilities 	<ul style="list-style-type: none"> - 1 micro-pilot test meets requirements for full scale pilot test <p>(WBS 100 to 500)</p> <ul style="list-style-type: none"> - Preliminary design for full scale pilot test: field operation design; drilling and completion design; surface facility preliminary engineering design; reservoir performance prediction (WBS 601-602-603a-604a) <ul style="list-style-type: none"> - Conceptual design for one commercial scale surface facility: conceptual engineering design; reservoir performance prediction for conceptual commercial operation; CO₂ source and gas market developments prediction (WBS 603B-604B-605) <p>(3 above outputs to include EIA/CEAA screening)</p> <ul style="list-style-type: none"> - Enhanced CBM/CO₂ technology skills applied at project sites and other coal beds in China: needs analysis and gender equality strategy; training/technology transfer plan, transfer to CUCBM technical/managerial staff in China (up to 200 persons) and in Canada, (at least 24 persons) and transfer to CUCBM trainers; monitoring of gender equality results (WBS 701-702-703a/b-704) <ul style="list-style-type: none"> - Contacts established between Canadian and Chinese Senior Managers in CBM related industries (WBS 703c-803) 	<ul style="list-style-type: none"> - CEA technical reports/Monitor's report - CUCBM publications (reports, newsletters, etc.) <ul style="list-style-type: none"> - CEA technical reports/Monitor's report - CUCBM publications (reports, newsletters, etc) <ul style="list-style-type: none"> CEA technical reports/Monitor's report - CUCBM publications (reports, newsletters, etc) <ul style="list-style-type: none"> - CEA technical reports/Monitor's report - CUCBM publications (reports, newsletters, etc.) 	<p>ASSUMPTIONS</p> <ul style="list-style-type: none"> - CUCBM and its associated partners in the CBM Industry provide sufficient personnel and information to select project activity sites and have sufficiently qualified work force to undergo technology training and transfer. - CUCBM' able to process the appropriate drilling and activity permits in a timely and cost efficient manner. - Canadian consortium members capable of supplying appropriate advisors and engineering services in a timely manner <p>RISK FACTOR: Medium</p> <p>RISK INDICATORS</p> <ul style="list-style-type: none"> - Canadian technology cannot be adapted to coal properties in China: inconclusive tests. - CUCBM unable to provide Chinese contribution in a timely manner (data to select micro-pilot test locations, permits, field tests, etc.) - Canadian Consortium unable to provide adequate and timely technical/management resources

APPENDIX 2

China – Canada Cooperation

Development of China's Coalbed Methane Technology /Carbon Dioxide Sequestration Project (A-030841)

Minutes of the Final Joint Project Steering Committee (JPSC) Meeting CUCBM Boardroom, Beijing, PRC 2:00 pm – 5:00 pm, December 14, 2006

The following minutes of the Final JPSC Meeting includes the major conclusions agreed by all parties related to the completion of the Development of China's Coalbed Methane Technology/Carbon Dioxide Sequestration Project in China. The meeting was co-chaired by MOFCOM and CIDA.

1. Introduction of Participants

CIDA

Mr. Charles Pellegrin
Ms. Marie-Christine Dube
Mr. Li Qingdong

MOFCOM

Mr. Liu Mingming

CEA

Mr. Bill Gunter/ARC
Mr. Sam Wong/ARC
Mr. Xiaohui Deng/ARC
Mr. Doug Macdonald/SNC Lavalin
Mr. Keith MacLeod/Sproule
Mr. Tony Wong/Sproule
Mr. Peter Ho/Petromin

CUCBM

Mr. Sun Maoyuan
Mr. Lin Jianhao
Ms. Hu Aimei
Mr. Ye Jianping
Mr. Fan Zhiqiang
Mr. Guo Benguang
Mr. Fan Hua
Mr. Sun Hansen

2. Opening Remarks (MOFCOM, CIDA, CUCBM, CEA)

- 2.1 Mr. Liu Mingming, Deputy Division Director from MOFCOM welcomed the participants and is pleased to co-chair the meeting with Mr. Charles Pellegrin from CIDA. In this final meeting, the focus is on project results. Congratulations are due for the good results of the project.
- 2.2 Mr. Charles Pellegrin, CIDA's Program Manager thanked Mr. Liu for the opening remarks. He hoped that Mr. Sun, Madame Hu and Mr. Fan had a productive high level trip to Canada. It was an ambitious work plan for the past year. He looked forward to hearing the project results. Also, he would like to hear CUCBM's view on final project results as regards to: Was the project worthwhile? How will the project influence CUCBM's future planning? What could have been done better? He looked forward to the discussion.

- 2.3 Mr. Sun Maoyuan, President of CUCBM said that he came back from the trip yesterday and enjoyed the mission to Canada. He is pleased with good field results of the Micro-Pilot Test. Production from TL-003 well is higher than expected. He thanked the Canadian and Chinese Government for their supports and particularly Mr. Pellegrin and Mr. Liu. This is a pioneer project in China for CO₂ Enhanced Coalbed Methane Recovery (ECBM) – a technology which enhances the coalbed methane production rates and the environmental reduction of greenhouse gases (GHG's).
- 2.4 Mr. Bill Gunter, the CEA Manager of the Project said that currently interest is high on the Project, as evidenced from the Coal Bureaus/Foreign companies (including 3 Canadian companies) engagement. Tomorrow, the CEA and CUCBM are holding a final technical project workshop in Beijing to be attended by 40+ people. Also, over the last year, he was flown to Beijing twice, to talk on the role of ECBM in CO₂ Capture and Storage (CCS) for China. Our ECBM project is recognized by the Carbon Sequestration Leadership Forum (CSLF) as an approved CCS project. This project is very timely for China in a time when it needs access to more energy resources while reducing GHG emissions.
- 2.5 Mr. Liu Mingming commented that the prospects for the future of the technology is good. He expressed his thanks to the commitments of CUCBM and the CEA (through participation of seven Canadian companies) for the success of the Project.

3. Review and Approval of the Agenda

The proposed agenda (see Appendix 1) was reviewed and one new item “ECBM and CO₂ Geological Storage Best Practices Manual” was added under Item 11: Other Business. The proposed Agenda was approved by the JPSC.

4. Summary of Results, including Gender Results, since the November 2005 JPSC (CEA-CUCBM)

A power-point presentation was made by Mr. Sam Wong of the CEA and is attached as Appendix 2 to these minutes. The micro-pilot test at TL-003 well in south Qinshui was successful. At the November 2005 JPSC Meeting, it was agreed that Output 1.1 (One micro-pilot test meets requirements of full-scale pilot test) has been achieved. The decision was to proceed to the preliminary design of the full-scale pilot test and develop the conceptual design for one commercial facility at south Qinshui. This was the major focus of last year's work. The presentation reported on project results of Outputs 1.2, 1.3, 1.4 and 2.1:

4.1 Output 1.2 Preliminary Design and Costing of the Full-scale Pilot

The preliminary design of the full scale pilot involves the following tasks: (1) Predict pilot performance using reservoir model simulation; (2) Identify sources of CO₂; and (3) Design CO₂ capture plant and field facilities and develop cost estimate.

- 1) The recommendation of the full-scale pilot is a 20-acre 5-spot field pilot which will consist of four existing wells (FZ-002, FZ-003, FZ-008 and TL-003), and a new injection well to be drilled approximately at the center of the pattern. The procedure is to inject 40 tonnes CO₂ per day for 6 months. Enhancement of coalbed methane production should be observed at all producer wells and no CO₂ breakthrough would be observed. Reservoir simulation shows significant coalbed methane enhancement and CO₂ storage.
- 2) For CO₂ capture facilities, the focus should be on the more pure CO₂ streams. A high purity CO₂ stream from Tian’Ji Chemical Fertilizers Plant at Lucheng, located at about 125 kilometer from the Qinshui micro-pilot test site, was identified.
- 3) The full-scale pilot would cost about US \$9,500,000.

4.2 Output 1.3 Conceptual Design of a Commercial Scale Facility

The tasks for Output 1.3 includes: reservoir simulation of a conceptual commercial operation; evaluation of potential CO₂ sources in Qinshui basin; economics of ECBM for Qinshui basin; and evaluation of other ECBM opportunities in other coal basins in China.

The reservoir simulation study has evaluated two different pattern sizes (320 acres and 160 acres), different pattern configurations (5-spot and 9-spot) and different injection gas compositions (CO₂, N₂ and mixed gas). The recommendation is 160 acre 5-spot patterns CO₂ injection for the conceptual commercial scale operation. The current Pattern for primary production at south Qinshui is 80 acre 9-spot. This can be converted to 5-spot 160 acre spacing by converting some producers to injectors. No new wells will be drilled. The commercial operation is based initially on 90 wells (45 injectors and 45 producers).

For the CO₂ supply, the commercial operation would require 1,500 tonnes per day of CO₂ or 520,000 tonnes per year. Tian’Ji Fertilizers Plant at Lucheng only has about half of this CO₂. Another CO₂ supply would need to be identified. In our investigation of CO₂ sources, there are plenty of good CO₂ sources in the Qinshui basin. CO₂ sourcing is not anticipated to be a major problem. The conceptual study is based on 520,000 tonnes per year of CO₂ near Lucheng. The unit cost of CO₂ from Tian’Ji is estimated at \$17.40/tonne.

The field facilities include CO₂ capture, dehydration and compression, CO₂ pipeline, and CO₂ distribution/ injection/ produced gas handling and produced water handling, at the field.

The conclusions for the commercial prospect of ECBM in Qinshui basin are:

- Project is technically feasible;
- Project is possibly economic using zero or reasonable CO₂ credit value;
- Opportunities exist to reduce costs;
- Downhole water disposal is important.

The economic results look good enough to move forward for further project definition and development at Qinshui basin. The remaining task to be completed is the evaluation of the prospects for ECBM at other coal basins.

4.3 Gender Equality (WBS 701)

Gender Equality Performance Monitoring and Final Report were completed.

4.4 Output 1.4 ECBM/CO₂ Technology Skills Applied at Project and Other Coal Beds in China

Two training sessions were held last year – one session on ECBM and Clean Development Mechanism in China; another session in a combined technical study tour in horizontal drilling and stimulation and completion in Canada.

All training as per the Final Work Plan was completed.

4.5 Output 2.1 Contacts Established between Canadian and Chinese Senior Managers

As mentioned by Mr. Sun in his opening remarks, the second high level study tour to Canada was very successful. The 8 delegates were led by Mr. Sun and included senior CUCBM executives, officials from MOFCOM, NDRC and the China Coal Association.

4.6 Results Dissemination

Project results dissemination was carried out through presentations at events sponsored by the IEA GHG R&D Programme (GHGT-8), EU/UK Workshop, APEC Workshop and Journal publication.

5. Summary of Overall Project Results versus Expected Results in the PIP's LFA (CEA-CUCBM)

<u>Project Results</u>	<u>versus</u>	<u>PIP</u>
a) Micro-pilot test meets requirements for full scale pilot test		Completed
b) Preliminary design for full scale pilot test (at 20 acre scale)		Completed
c) Conceptual commercial design (at 160 acre scale)		Completed
d) Technology transfer to CUCBM (total 16 training courses)		Completed
e) Gender Equality (awareness building; women participation)		Completed
f) Contacts established between Canadian & Chinese Senior Managers		Completed
g) Dissemination of project results		Completed

The Project has achieved all the Outputs as per the PIP.

Project Conclusions

- Enhancement of CBM and Storage of CO₂ is feasible in Shanxi
- Proceed to full scale pilot is justified in Shanxi
- Prospect is good in other coal basins

Project Procurement, Total 221K

- PCs \$70K (in lieu of CO₂ purchased as per the PIP)
- Field equipment (GC + sample delivery system, pressure monitoring system and CO₂ pump) \$152K

This equipment is in good working order and will be acknowledged by the JPSC (see #10 below).

6. Lessons Learned (CEA-CUCBM)

The Project implementation was very successful. However, there are some areas that can be improved if we were to do the Project again, for example:

- a. Need full time Canadian Supervisor in China
- b. Need experienced staff in field at all times (Mr. Sun's response to a) and b) in #9.1 below)
- c. 1) Equipment shipping clearing customs (minimum 10 days)
2) Need time to clear visa for Chinese visitors to Canada

7. Assessment of Potential for Applying the Canadian CBM/CO₂ Technology in China (CEA-CUCBM)

This refers to potential Outcome 1 (a) Canadian technology applied to full-scale test in the medium term. It is too early to measure at this time.

8. CUCBM Plans for Replication of Micro-Pilot Tests in Other Basins and for Full Scale Test/Commercial Operation (CUCBM)

This refers to potential Outcome 1 (b) Apply micro-pilot test to other basins and Outcome 2: Commercial cooperation between Canadian and Chinese firms on the Canadian CO₂-ECBM technology in the medium term. It is too early to measure at this time.

9. Discussion (All)

9.1 Mr. Sun Maoyuan led off the discussion with the following points:

- 1) CEA experts were supplied to the field (e.g. Bernice Kadatz); one expert from CUCBM spent 3 months in the field. A very good set of data was collected in the Project. The Project did not suffer.

- 2) Long-term development should focus on remote data access and control.
- 3) CUCBM has 27 Production Sharing Contracts (PSC) in 10 provinces – needs remote data control.
- 4) TL-003 showed CO₂ – ECBM used in high rank coal of Qinshui basin was successful.
- 5) Also, it is important for reduction of CO₂ emissions.
- 6) For scaling up micro-pilot to commercial, need support of 50 million dollars from government via MOFCOM and CIDA.
- 7) Should consider using flue gas from industry and not use only pure CO₂ for ECBM.
- 8) Target the deeper unminable coals for ECBM.
- 9) Microbes to convert CO₂ back to methane (an ARC Technology to complete the life-cycle in the long-term) should be tested in China.
- 10) The ECBM technology should be further developed in China and then exported to the world.
- 11) CUCBM wants CMG software for free/discounted so that CUCBM can do its job more efficiently.
- 12) Chinese Government emphasizes developing CBM Technology – like to see this Project be a focal point for future projects.

9.2 Mr. Charles Pellegrin commented that:

- 1) CIDA cannot expand project to include full-scale pilot. CIDA is only involved in micro-pilot testing. CIDA does not finance large infrastructure projects like the World Bank or the Asia Development Bank. CIDA's involvement ends with the successful micro-pilot test.
- 2) CMG software issue has been discussed before. The purchase of a License from CMG belongs to future commercial activities, possibly related to Production Sharing Contracts (PSC).

9.3 Mr. Bill Gunter added that integrated processes involving methanogenesis and use of flue gas are future targets. Present focus should be on establishment of a site in the Qinshui Basin for the full-scale field pilot and raising the money to run the pilot.

9.4 Mr. Charles Pellegrin asked if CUCBM could also apply the Canadian micro-pilot tests to other basins. Mr. Sun Maoyuan replied that CUCBM would need more investments for new micro-pilots in other basins.

9.5 Mr. Doug Macdonald commented that based on his experience of the projects he has been involved in around the world, the combination of pure CO₂ sources and CBM reservoirs in China represent a large chance of success compared to other countries for this new technology. CO₂ – ECBM is a “low hanging fruit” for China!

10. Equipment Handover

An Equipment Check List is included in these minutes (Appendix 3) as an acknowledgement by the JPSC of the equipment purchased by the Project and of its transfer to CUCBM.

11. Other Business

CUCBM would like to develop a best practices manual for the application of ECBM in China with examples. It was estimated that 50,000 RMB (or \$ 7,000 Canadian) would be the approximate cost for printing 1,000 copies of the manual. Mr. Ye Jianping clarified that the estimate was based on ½ million words (about 336 pages).

Mr. Bill Gunter commented that to produce the manual - the CEA would need to revise the reports into “Best Practices Manual” format; give draft to CUCBM for revision and agree on the final English copy; then translate into Chinese.

Mr. Charles Pellegrin suggested that perhaps one option is to put the manual on web site for down loading. He would need a proposal from the CEA for writing the manual plus 3 quotes on the costs of publication. CUCBM and CEA should meet to develop a proposal. The manual, including the printing, has to be completed by March 31, 2007.

12. Concluding Remarks (CEA,CIDA,CUCBM.MOFCOM)

CIDA Mr. Charles Pellgrin said that he sees a bright future for ECBM and CO₂ Storage in China. He thanks Mr. Sun & CUCBM for their participation and Mr. Bill Gunter & the CEA. The Project Liaisons, Mr. Fan and Peter Ho, were particularly important to the Project. The CEA is praised for sticking to the end even though their services are in great demand in Canada. He thanks CUCBM for dissemination of the technology in China and also to Mr. Liu Mingming for the MOFCOM support.

MOFCOM Mr. Liu Mingming said that he is happy to work together with experts from CUCBM, the CEA and CIDA. Publishing a manual for dissemination of project results is important. Although the Project is finished, he hopes both governments maintain linkages for projects such as this in the future. Friendship would be continued in future.

CUCBM Mr. Sun Maoyuan commented that this is a very fruitful meeting. He appreciates the support from both governments. Also the CEA did a very good job. He will do his best for achieving the final outcomes of the Project. Project is finished, but cooperation will continue forever.

CEA Mr. Bill Gunter added that the CEA is ready to move into full-scale pilot as soon as commercial investment is secured. This meeting is a successful conclusion to the Project.

13. Adjournment

The meeting was adjourned at 5:15 pm to attend a banquet hosted by CUCBM.

Mr. Liu Mingming, MOFCOM

Mr. Charles Pellegrin, CIDA

Date

Date

Mr. Sun Maoyuan, CUCBM

Mr. Bill Gunter, CEA

Date

Date

Attachments:

- Appendix 1. JPSC Meeting Agenda
- Appendix 2. Power-point Presentation
- Appendix 3. Equipment Check List

Appendix 1: JPSC Meeting Agenda

China-Canada Cooperation

Development of China's Coalbed Methane Technology /Carbon Dioxide Sequestration Project (A-030841)

FINAL JPSC MEETING (No. 3) (Co-Chaired by MOFCOM and CIDA)

Date: December 14, 2006

Time: 15h00

Location: Beijing (CUCBM)

PROPOSED AGENDA

1. Introduction of Participants
2. Opening Remarks (MOFCOM, CUCBM, CIDA, CEA)
3. Review and Approval of the Agenda
4. Summary of Results, including Gender Results, since the November 2005 JPSC (CEA - CUCBM)
5. Summary of Overall Project Results vs Expected Results in the PIP's LFA (CEA-CUCBM)
6. Lessons Learned (CEA - CUCBM)
7. Assessment of Potential for Applying the Canadian CBM/CO₂ Technology in China (CEA - CUCBM)
8. CUCBM Plans for Replication of Micro-Pilot tests in Other Basins and for Full Scale Test/Commercial Operation (CUCBM)
9. Discussion (All)
10. Equipment Handover
11. Other Business
12. Concluding Remarks (CEA, CIDA, CUCBM, MOFCOM)
13. Adjournment

Appendix 2. Presentation.

Slide 1

Summary of Results
Since November 2005 JPSC

Sam Wong, ARC
Final JPSC Meeting #3 at Beijing
December 14, 2006

Slide 2

Output 1.2 Design of Full-scale Pilot
WBS 601, 602, 603a, 604a

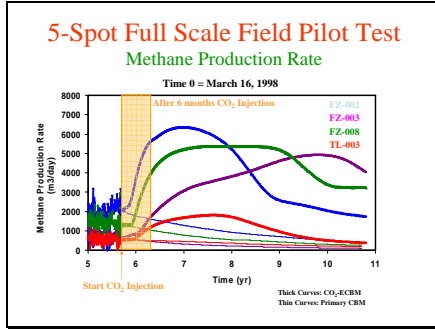
- Reservoir performance prediction
- CO₂ Capture, purification, compression, storage and shipping facilities at Lucheng
- CO₂ Receiving, storage and injection facilities at Qinshui
- Cost estimates for these facilities

Slide 3

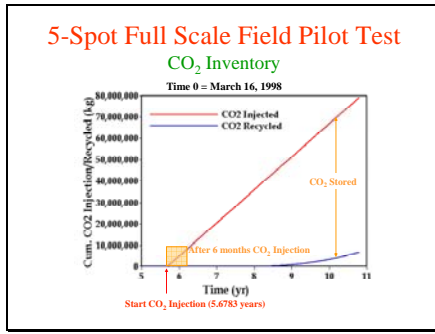
Output 1.2 Full-scale Pilot Design
Recommendation

- 20-acre 5-spot field pilot:
 - Four corner producers are existing CBM Wells FZ-002, FZ-003, FZ-008 and TL-003
 - Drill one new injector located approximately at the center of the pattern
- Inject CO₂ continuously at new injector at a constant rate of 22,653 m³/d (0.8 MMscf/d) for 6 months
 - Enhancement of CH₄ production should be observed at all producers even though no CO₂ breakthrough should be observed at all producers

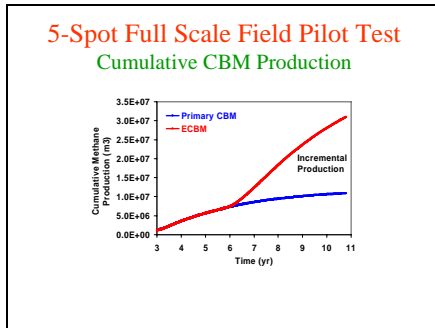
Slide 4



Slide 5



Slide 6



Slide 7

CO₂ Capture Facilities

- **CO₂ Source:** Tian'Ji Chemical Fertilizers Plant, Lucheng
- **Reasons**
 - Available at desired quantity (800 t/day total)
 - High concentration: 99% CO₂
 - Location close to the well site
 - Local experience in CO₂ recovery (existing CO₂ operation)
- **Feedstock**
 - 99% CO₂, 0.5% H₂S, 0.5% CH₄
 - 180 kPa, 11°C
- **Product Quality (food grade)**
 - 99.9% CO₂, 50 ppm CH₄, 0.1 ppm Sulphur

Slide 8

Full Scale Pilot Costs

- CO₂ capture capital cost estimate: Too expensive to construct unit to produce own CO₂
- Drill new injector
- Purchase CO₂ FOB injection well (Tian'ji?)
- Inject 40 tonnes per day for 200 days
- Instrument and produce 4 wells for 300 days; shut in and measure pressure buildup
- Operations
- Technical support
- Analysis and Simulation

Slide 9

Full Scale Pilot Costs

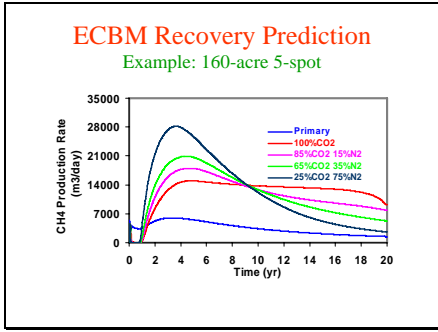
• Site facilities design & construct	\$3,500,000
• Injector drill & prep	\$ 750,000
• CO ₂ purchase & delivery	\$1,200,000
• Pilot operations	\$1,150,000
• Tech support & results analysis	\$ 700,000
• Contingency 30%	\$2,200,000
• Total	\$9,500,000
• Source: ARC Canadian Estimates for similar pilot	

Slide 10

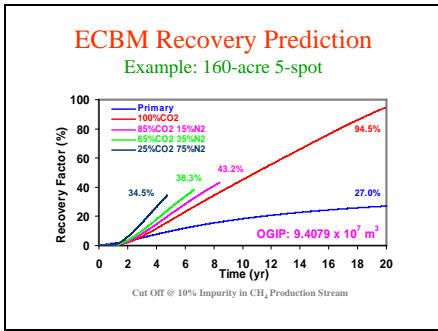
**Output 1.3: Conceptual Design for
Commercial Scale Facility
WBS 603b, 604b, 605**

- Reservoir simulation of south Qinshui basin
- Evaluation of potential CO₂ sources in Qinshui basin
- Economics of ECBM for Qinshui basin
- Evaluation of other ECBM opportunities in other China coal basins and commercial plan (to generate interest of other companies)

Slide 11



Slide 12



Slide 13

Qinshui Commercial Scale Design

- **90 WELLS, 160 acre 5-SPOT GRID:**
 - ~45 Injection Wells
 - ~45 Producer Wells
- **WELLHEAD CONDITIONS:**
 - Max. 30 MMSCFD Total (1,575 t/d, 520,000 t/y)
 - Delivery pressure 8.3 MPa (8,300 kPa, 1,204 psi)
- **CO₂ SOURCES:**
 - **Tian'ji Chemical Fertilizers Plant, Lucheng**
 - ~800 tonnes/day CO₂, theoretically available
 - ~280,000 t/y with 95% recovery
 - **Additional Sources to be identified for 240,000 t/y**
 - **Conceptual Study based on 520,000 kta available at Tian'ji or near Lucheng**

Slide 14

Commercial Scale Design (cont'd)

- **Configuration**
 - **At Source:** CO₂ Capture
 - Desulphurization (if required)
 - Dehydration
 - Compression
 - **Transport:** Pipeline at Supercritical Conditions
 - **In the Field:** CO₂ Distribution/Injection
 - Produced Gas Handling Facilities
 - Produced Water Handling Facilities

Slide 15

Commercial Scale Cost Estimate

2nd Qtr 2006 Central China Location

CO ₂ PLANT CAPITAL COST	US\$ 27,260,000
PIPELINE CAPITAL COST	US\$ 39,350,000
	US\$ 56,700 /in.km
TOTAL CAPITAL COST	US\$ 66,610,000
UNIT CO ₂ COST	\$ 6.70/t (without capital charge)
	\$17.40/t (with capital charge)

Slide 16

Qinshui Economic Results

- Unit Cost of CO₂ (no capital charge) \$11.98 / t
- Simple Payout 9 years
- Discount Rate for NPV Calculations 12.0%
- Internal rate of return 11.6%

Effect of CO ₂ Credits		
Value of credit, USD/net tonne	Simple Payout	Internal rate of return
0.00	9 years	11.6%
5.00	8 years	13.7%
10.00	7 years	15.7%
15.00	7 years	17.8%
20.00	6 years	19.8%

Slide 17

Qinshui Project: Conclusions

- Project is technically feasible
- Project is possibly economic using 0 or reasonable CO₂ credit values
- Opportunities exist to reduce costs
- Down hole water disposal important

Slide 18

Gender Equality (WBS 701)

- Female participation in professional training promoted:
 - 28% female participation (8 of 28) in last two training courses
- Gender Equity Performance Monitoring Report and Final Report completed

Slide 19

Output 1.4: ECBM/CO₂ technology Skills Applied at Project and Other Coal Beds in China – WBS 703a

- 20 CUCBM staff (6 female) trained in Enhanced Coalbed Methane recovery technology and Clean Development Mechanism April 3-4, 2006 Beijing
- 8 CUCBM staff (2 female) trained in the combined technical study tour in horizontal drilling and stimulation and completion August 13-23, 2006 in Canada

Slide 20

Output 2.1 Contacts Established between Canadian and Chinese Senior Managers – WBS 703c

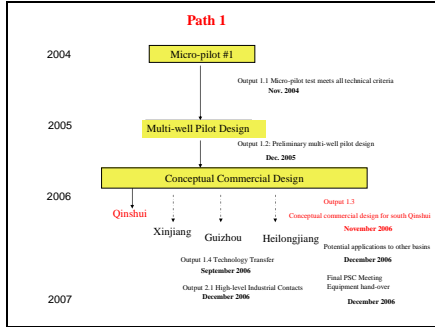
- 2nd High Level Study Tour delegates led by Mr. Sun Maoyuan, President of CUCBM visited Canada December 1-12, 2006
- 8 delegates (3 female) included senior CUCBM executives, officials from MOFCOM, NDRC and the China Coal Association

Slide 21

Project Results Dissemination

- Paper presented at the 8th International Conference on Greenhouse Gas Control Technologies (GHGT-8), Norway, June 2006
- Presentation at the EU/UK International Workshop on Near Zero Emission Coal Power Generation with CO₂ Capture and Storage, Beijing, July 2006
- Presentation at the APEC CO₂ Capture and Storage Capacity Building Workshop, Beijing, October 2006
- Extended GHGT-8 paper to be published in the International Journal of Greenhouse Gas Control Technologies

Slide 22



Slide 23

Summary of Overall Project Results versus Expected Results in the PIP

PIP

- Micro-pilot test at TL-003, south Qinshui met all technical objectives
- 20 acre 5-spot pilot designed at south Qinshui (4 existing wells and a new injector), costed and its performance predicted
- Micro-pilot test meets requirements for full scale pilot test (Output 1.1)
- Preliminary design for full scale pilot test (Output 1.2)

Slide 24

Summary of Overall Project Results versus Expected Results in the PIP

PIP

- Conceptual commercial operation with 100 wells, based on 160 acre 5-spot pattern is designed, performance predicted and cost estimated
- Conceptual design for one commercial scale surface facility (Output 1.3)

Slide 25

Summary of Overall Project Results versus Expected Results in the PIP

PIP

- 16 training courses in CBM and ECBM technologies, attended by 263 CUCBM staff (42 female) in China, and 34 (11 female) in Canada.
- Gender strategy developed; local coal bureau and gender focal points recruited; GE baseline profile developed and 2 workshops held;
- Technology transfer to CUCBM technical/ Management staff in China (up to 200 persons) and in Canada (at least 24 persons)
- Needs analysis and gender strategy (Output 1.4)

Slide 26

Summary of Overall Project Results versus Expected Results in the PIP

PIP

- 2 high level study tours held (16 senior executives, 5 female);
- project nominated and selected as Carbon Sequestration Leadership Forum demonstration project; papers and presentations at international and Chinese technical conferences
- Contacts established between Canadian and Chinese senior managers in CBM related industries;
- Dissemination of project results (Output 2.1)

Slide 27

Project Conclusion

- Enhancement of coalbed methane recovery and storage of CO₂ is feasible in the anthracitic coals of Shanxi Province
- Prospect is good in other coal basins in China

Slide 28

Project Procurement

- PCs (desk tops and lap tops and printer)
\$69,583 (in lieu of CO₂ up to \$ 70,000)
- Field equipment (GC, sample delivery system, pressure monitoring system, CO₂ pump)
\$151,622
- Total \$221,205

Slide 29

Lessons Learned

- **Involvement of Partner Technical Staff** – Integrating CUCBM staff in highly technical field operations required more effort than expected from the CEA (CEA had to provide operational instructions from Canada). To have a Canadian supervisor full time in China may be worthwhile.

Slide 30

Lessons Learned

- **Field Operations from distance** – It is extremely difficult to manage field operations from a distant location. This applied to both the CEA and CUCBM, based in Beijing, as local Chinese contractor staff performed the field operations. At non-critical stages, field staff was to left to attend the site themselves. Some problems did in fact develop (i.e power trip off). Experienced CUCBM or Canadian staff should be on site to protect the integrity of the data being generated.

Slide 31

Lessons Learned

- **Equipment Shipping** – CEAs always underestimate the time required to clear customs (delays at customs are normal, not the exception). Leave plenty of time to clear customs (minimum 10 days).

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Outcomes in the Medium Term

- **Outcome 1:** Canadian technology applied for full scale test (hopefully leading to commercial production) and/or replication of micro-pilot test at other locations in China
- **Outcome 2:** Commercial cooperation between Canadian and Chinese firms on the Canadian CBM/CO₂ technology

Appendix 3: Equipment Handover Checklist

LMFA #	Item Description	Quantity	Unit Cost	Total Cost	WBS	Procure. Mode	Origin	Supplier	Date of Purchase
1	Desktop PC P4 1 GB RAM	1	\$ 3,320	\$ 3,320	400	2	PRC	Dell China	Nov-02
1	Desktop PC P4 256 MB RAM	9	\$ 2,420	\$ 21, 780	400	2	PRC	Dell China	Nov-02
1	MS Office XP PRO	1	\$ 820	\$ 820	400	2	PRC	Dell China	Nov-02
1	MS WIN XP PRO	1	\$ 360	\$ 360	400	2	PRC	Dell China	Nov-02
2	CP-4900 Micro GC and accessories	1	\$ 56,906	\$ 56,906	400	3	CDN	Varian Canada	Dec-02
2	Sample delivery system	1	\$ 5,678	\$ 5,678	400	3	CDN	Various	Dec-02
3	Tubing conveyed pressure monitoring system	1	\$ 36,488	\$ 36,488	400	3	CDN	Prism Technologies	Sep-03
4	CO ₂ pump system	1	\$ 52,550	\$ 52,550	400	3	CDN	LOP International	Jan-04
1	PC Notebook	4	\$ 2,455	\$ 9,820	400	2	PRC	Dell China	Nov-04
1	Large printer	1	\$ 12,979	\$ 12,979	400	2	PRC	Epson	Nov-04
1	PC Laptop	4	\$ 2,044	\$ 8,176	400	2	PRC	Dell China	Mar-05
1	PC Desktop	8	\$ 1,541	\$ 12,328	400	2	PRC	Dell China	Mar-05
<u>TOTAL</u>			<u>\$221,205</u>						

Note: Procurement Mode:

2: Obtain minimum 2 quotes

3: ITT or RFP