International Workshop , May 24, 2007 ,Beijing, China

CO_2-ECBM and CO_2 Sequestration Technology in Coal Seams of Qinshui Basin, China

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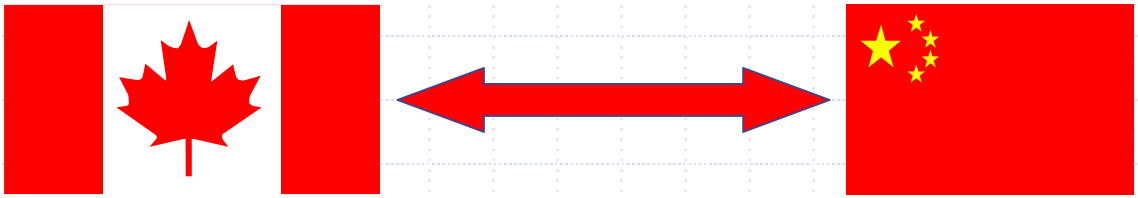
China United Coalbed Methane Co., Ltd.

China United Coalbed Methane Co.,Ltd (CUCBM)

- **State-owned company under the direct auspices of the State Council, including the State Plan, Finance, Science and Technology**
- **Exclusive rights for exploration, development and production of CBM in cooperation with foreign companies**
- **Professional company responsible for exploration, development, production and sale of CBM in China**

China ECBM Project



Canadian International Development Agency (CIDA)

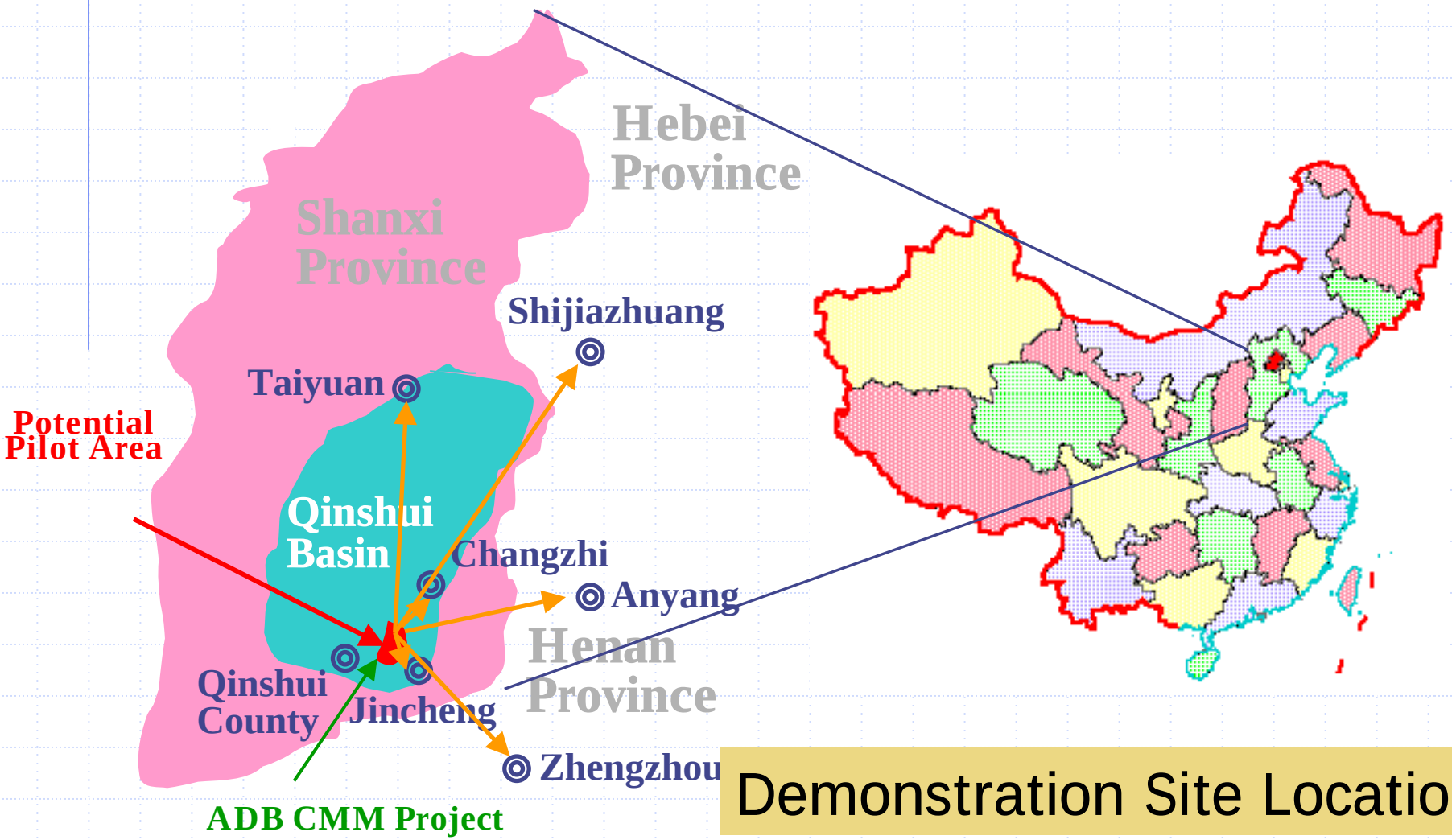
Ministry of Commerce (MOFCOM)

Canadian Climate Change Development Fund (CCCDF) (CA $ 5 million)

China United Coalbed Methane Corporation Ltd. (CUCBM) (CA $ 5 million)

3.5 - year CA $ 10 million Project (Started March 2002)

Enhanced CBM Micro-pilot Test in the Anthracitic Coals of the Qinshui Basin, Shanxi Province, China



Demonstration Site Location

Activities in South Qinshui Basin

- **830 wells and more than 660 2-D seismic lines have been completed by CUCBM. (Up to May, 2007)**

- **3 CBM pilots have been set up.**
- **1 National test field for CBM development has been confirmed.**
- **1 Z-pinnate System has been tested.**
- **1 CO_2 micro-pilot**

First Micro-Pilot Test

Qinshui Basin

- **The first micro-pilot test was successful**
- **CMG's GEM CBM Model has been validated based on successful history match of the micro-pilot field data**
- **Prediction of the performance of CO_2-ECBM recovery process indicated that more than 4 times the average CH_4 production rate compared to primary recovery can be achieved**
- **CO_2 storage into high-rank anthracite coal seam in Qinshui Basin is feasible**
- **Design of multi-well pilot on site**

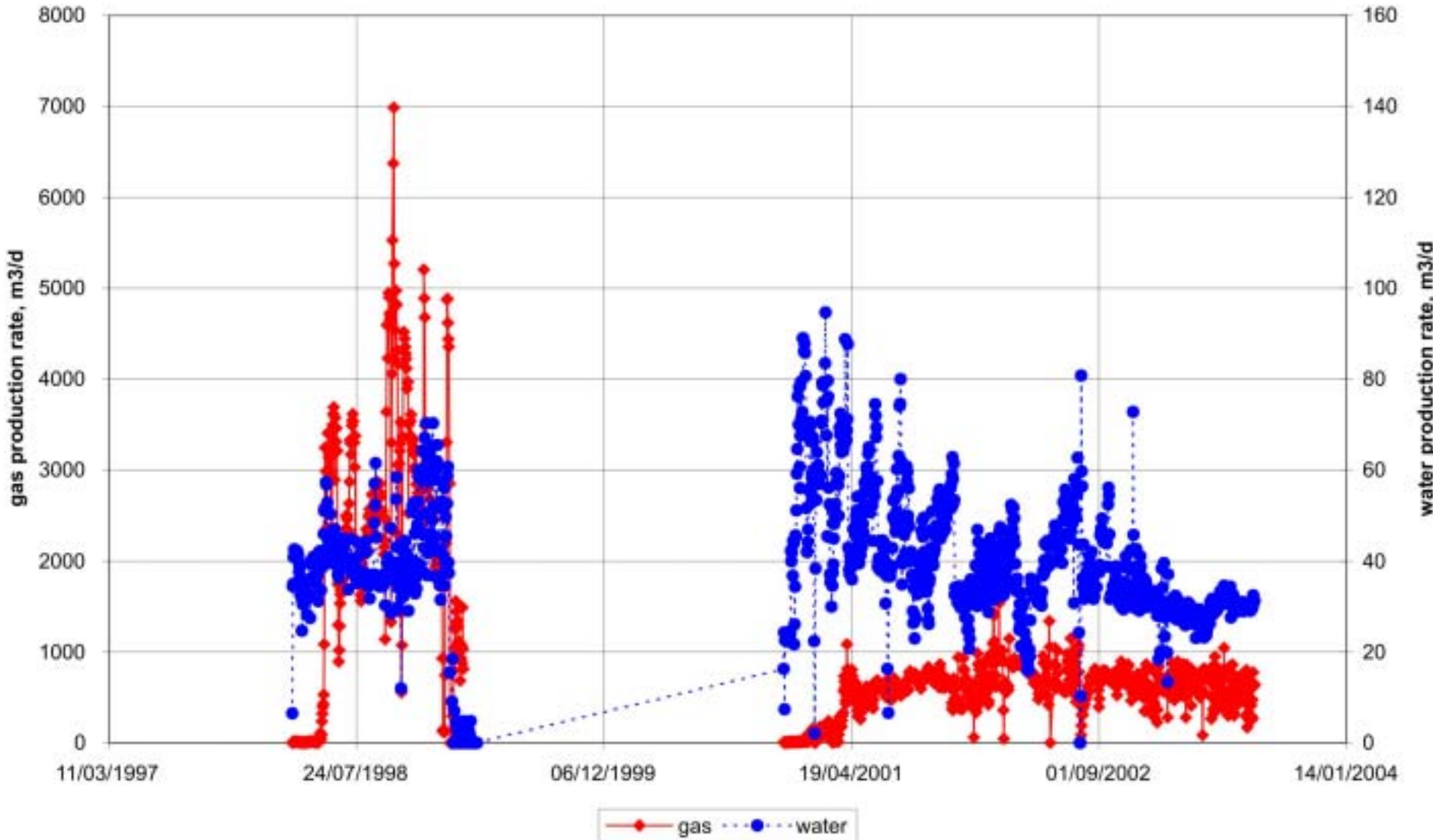
Micro-pilot Test Goals

- To accurately measure data while injecting into and producing from a single well
- To evaluate the measured data to obtain estimates of reservoir properties and sorption behavior
- To use calibrated simulation model to predict the behavior of a larger scale pilot or full field development

Primary CBM Recovery Operation

CBM Production Well

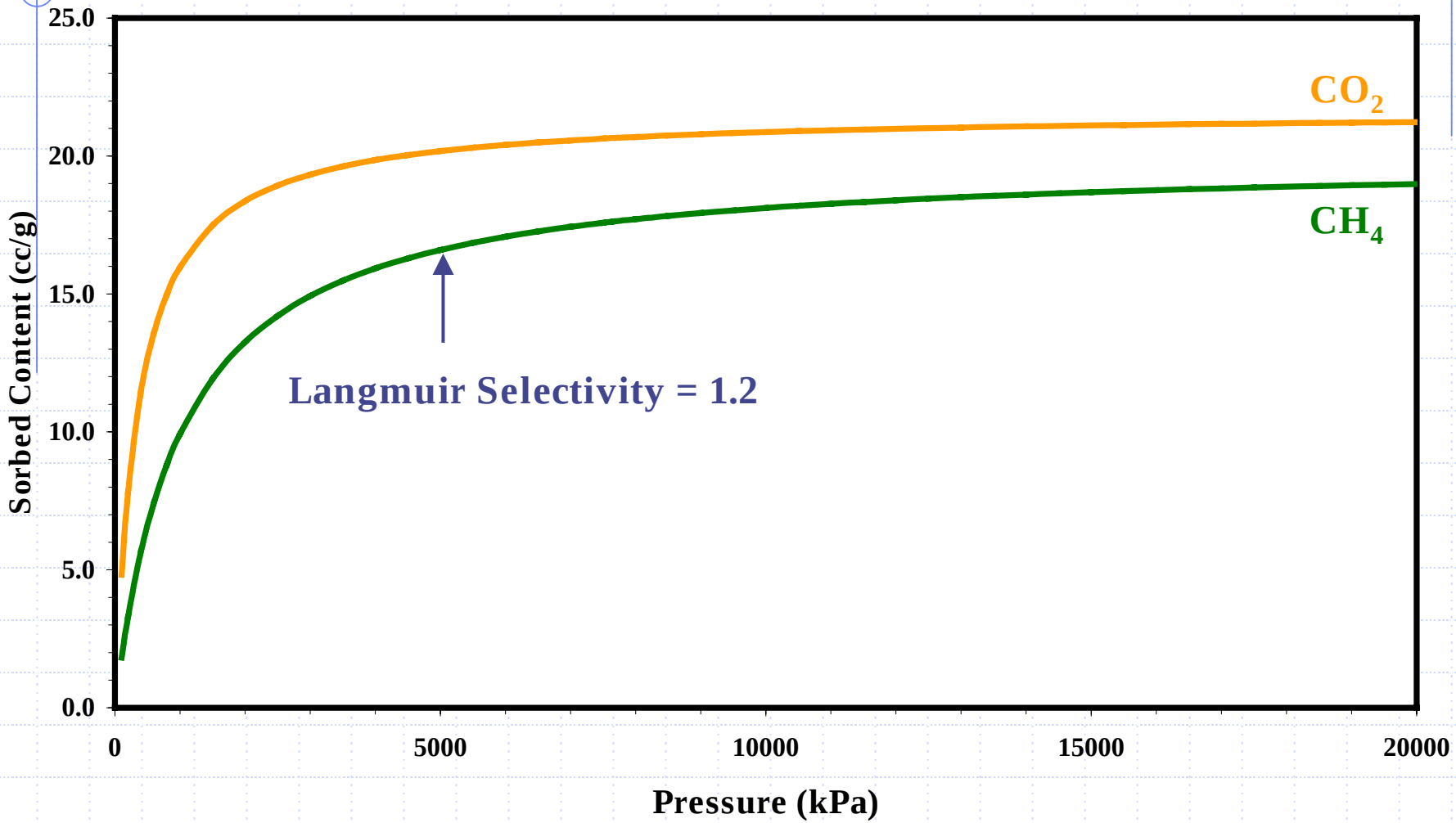
Gas / Water Separator



Well TL-003 Primary Production History

Adsorption Isotherms

Qinshui Basin



Micro-pilot Test Design

- Stage 1. Inspection of wellhead equipment
- Stage 2. Isolation of # 3 seam from # 15 seam and install additional downhole and surface equipment
- Stage 3. Initial production testing to determine baseline reservoir properties
- Stage 4. Intermittent injection of 200 t CO_2 and followed by a 30 days shut-in period
- Stage 5. Production testing after the CO_2 injection period
- Stage 6. The final shut-in test

Stuffing Box
Polish Rod
BOPS
V1
V2
Wireline Packoff
Assembly
Tubing head
Flange
V3
Leak
BHP Wireline
Connection

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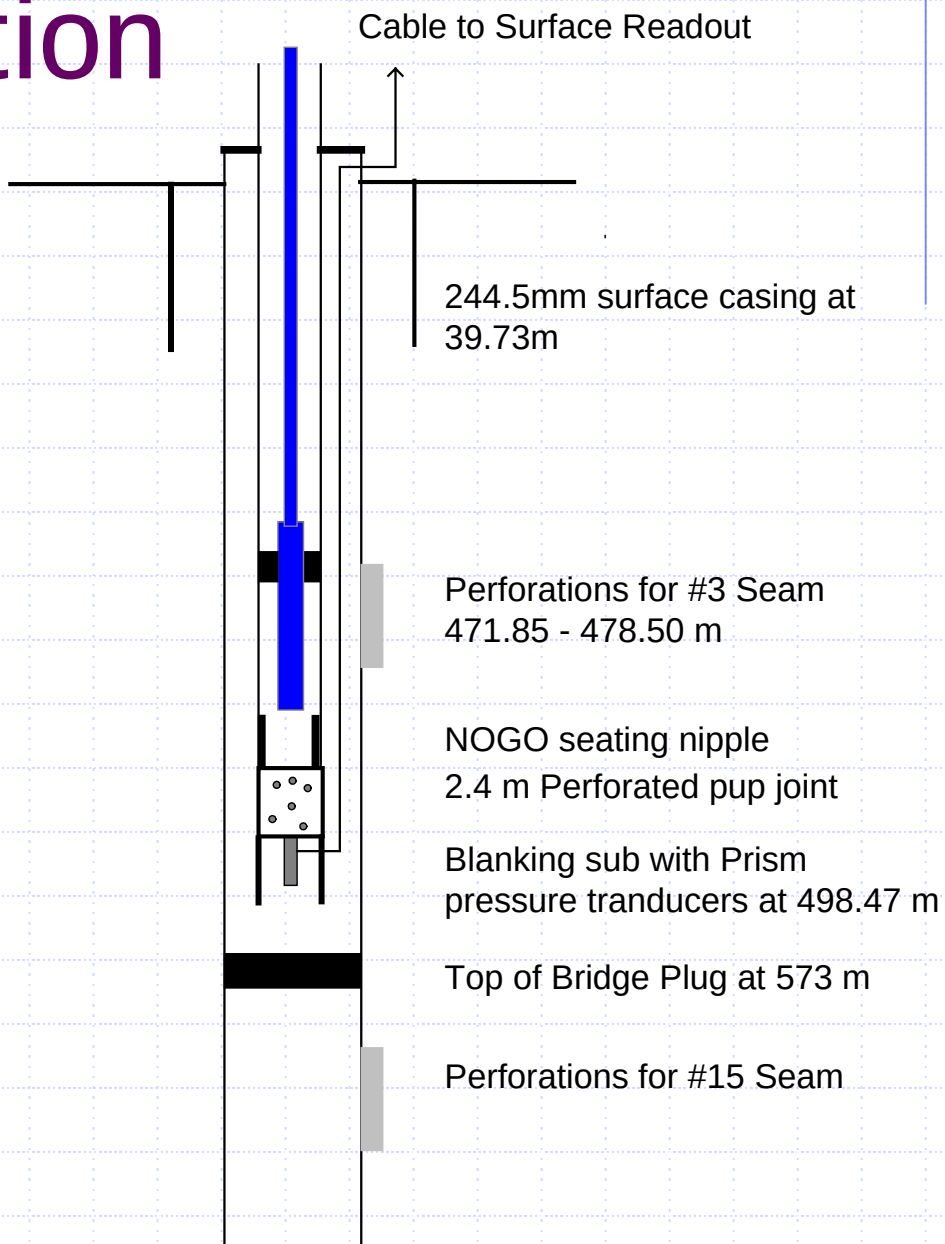
Target Coal Seam Well for Field Test

- No. 3 seam – Shanxi Formation
  - Age: Carboniferous Permian coal
  - Depth: 478 meters
  - Average thickness: 6 meters
  - Reservoir temperature & pressure

    25C & 500 psi
- To isolate seam from lower No. 15 seam, a bridge plug set in TL003 well at 573 meters

Well Configuration

- Downhole gauges
- Perforated pup
- Nogo seating nipple
- pump
- wellhead



Downhole Gauge Installation

- Installed 2 sensors
  - 0 – 1500 psi range
  - 0.025% full scale accuracy
  - 0.0003% resolution
  - 120 C temperature
- Signals transmitted via multi-conductor electro-mechanical wireline cable
- Surface Readout
  - Live data readouts
  - 1M data points storage capacity

Gauge Carrier

Surface Readouts

On-line Gas Chromatograph

- Capable of measuring produced gas composition "on-line"
- Separates and quantitates:
  - CO_2, CH_4, O_2, N_2, C_2-C_4, H_2S
- Analysis every 5 minutes initially & decreased to 1/hr as pilot continues
- Baseline Composition: CH_4-96.3%, CO_2 – 0.5%, N_2 – 3.67%, C_2 – 0.01%

TL-003 Wellsite & Wellhead

Instrument Trailer

Well head with Downhole gauge packoff

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Project Steps

- Well TL003 identified for CO_2 micro-pilot test, July 2003
- Downhole gauges installed to measure reservoir pressure & temperature during micro-pilot, Oct. 2003
- Well put on primary production to establish baseline information - Gas production 450m^3/day and water 0.9 m^3/day, Oct, 2003- Feb. 2004
- Shut-in/Buildup test for permeability (12 md)
- Installation of gas chromatographic equipment for on-line gas compositional analysis, Nov 2003
- Procurement of CO_2 pump to inject CO_2, Feb 2004
- CO_2 source secured– Zhongyuan Oilfield located in Henan province, Jan 2004

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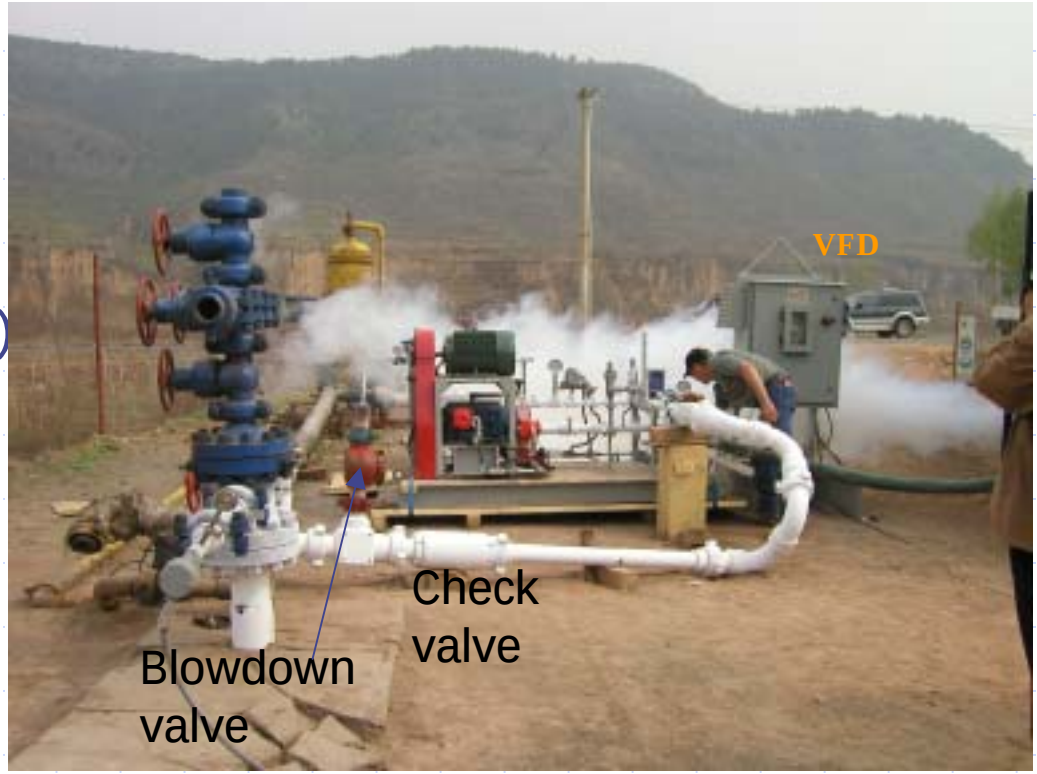
CO_2 Injection Strategy

- Goal is to inject 200 tonnes into reservoir over a 12 day period. Each truck can transport 18 tonnes of CO_2
- Injection rate to be maintained below reservoir fracture pressure (1100 psi)
- Estimate average injection rate of 30L/min over 8-10 hr period

Zhongyuan Oilfield CO_2 Truck Fleet

CO2 Pumping Equipment

- CO_2 Pumping Equipment:
  - National Oilwell N30 triplex pump
  - Toshiba Variable Frequency Drive (VFD)
  - Low & high pressure shut-down switches
  - High pressure relief valves
  - Flow stabilizers
  - Flow meter & totalizer



Pump Skid testing at TL-003 well in Qinshui basin

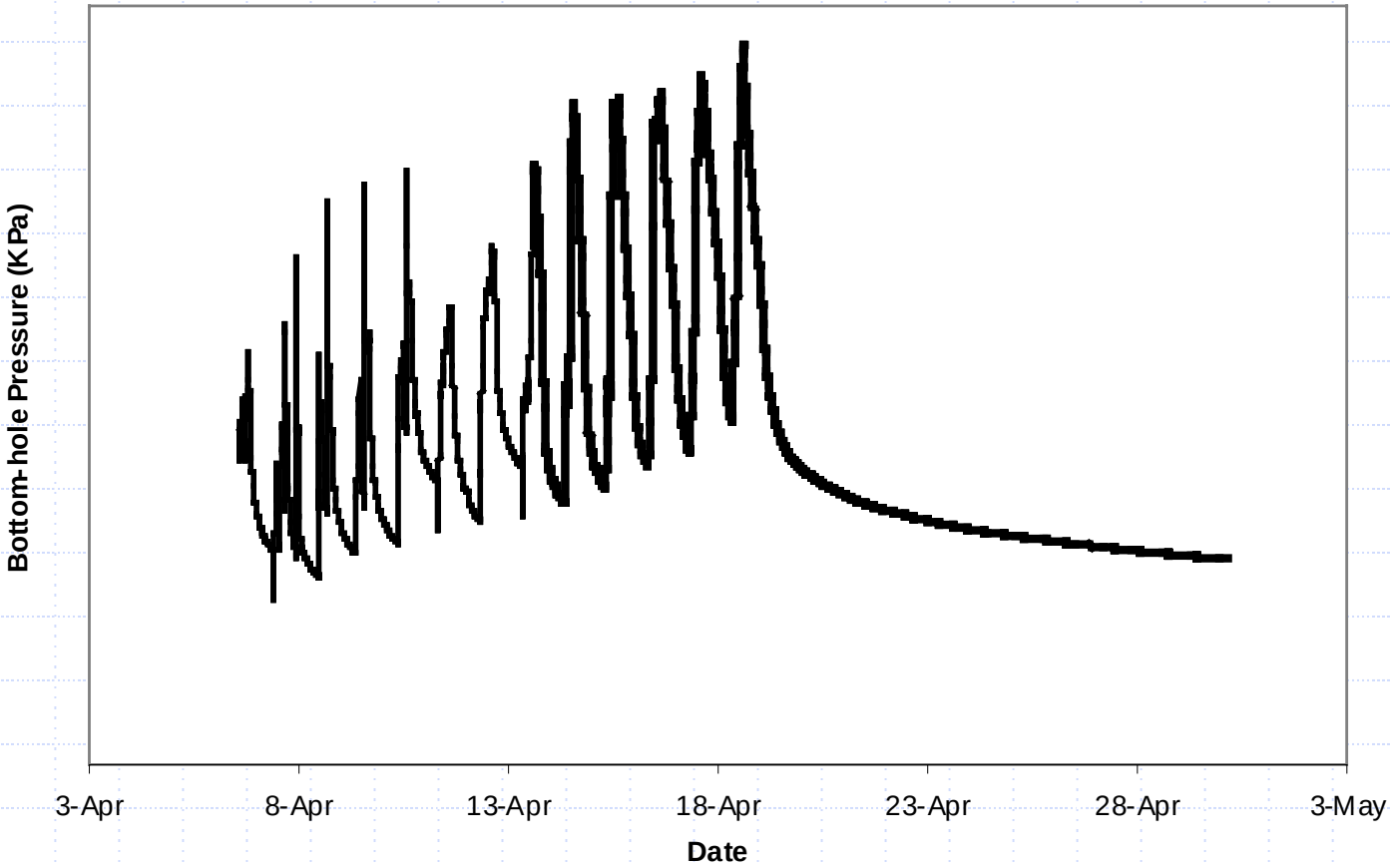
Completion of Field Micro-Pilot

- CO_2 pumping equipment shipped to China
- Pressure tested well before CO_2 injection
- Injected over 192 tonnes of CO_2
- CO_2 soak for 30 days
- Production for 60 days measuring gas composition, pressures and flow rates
- Well shut-in/pressure build-up for final permeability estimate
- Micro-pilot test engineering evaluation and numerical model historymatch and prediction

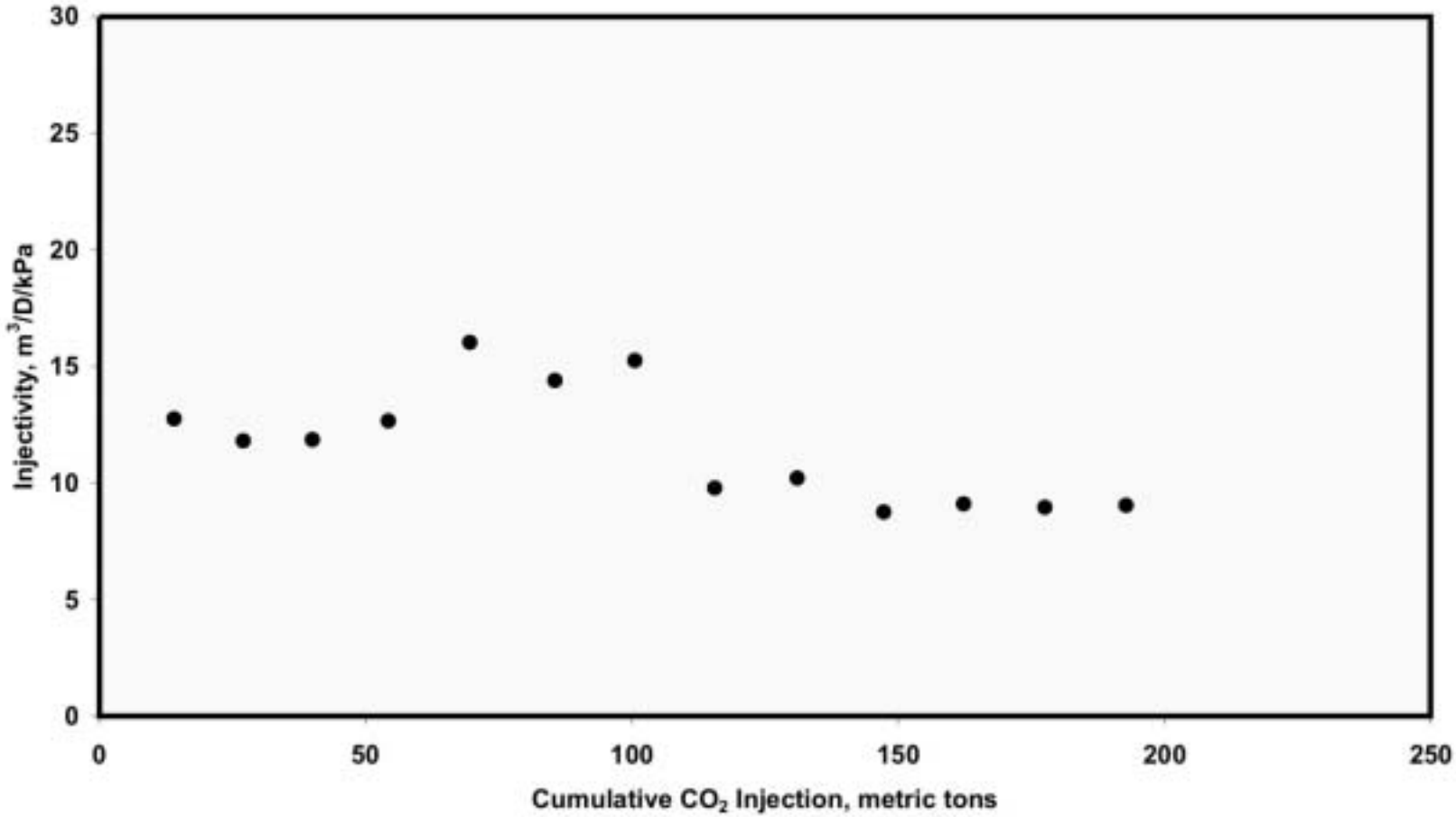
Cooling Down the System

Injecting Liquid CO_2

Bottom-hole Pressure Response During CO_2 Injection



Injectivity versus Cumulative CO_2



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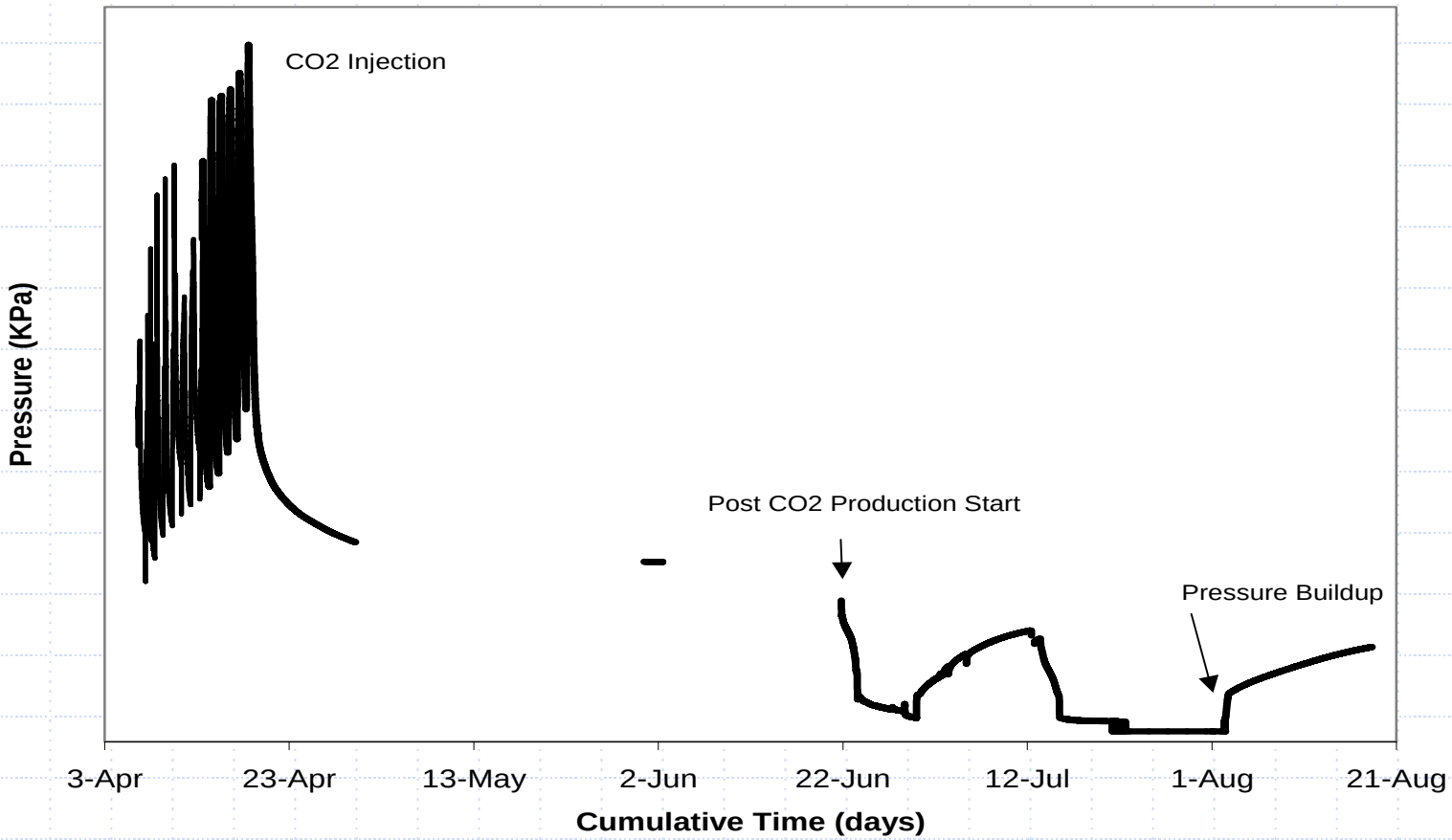
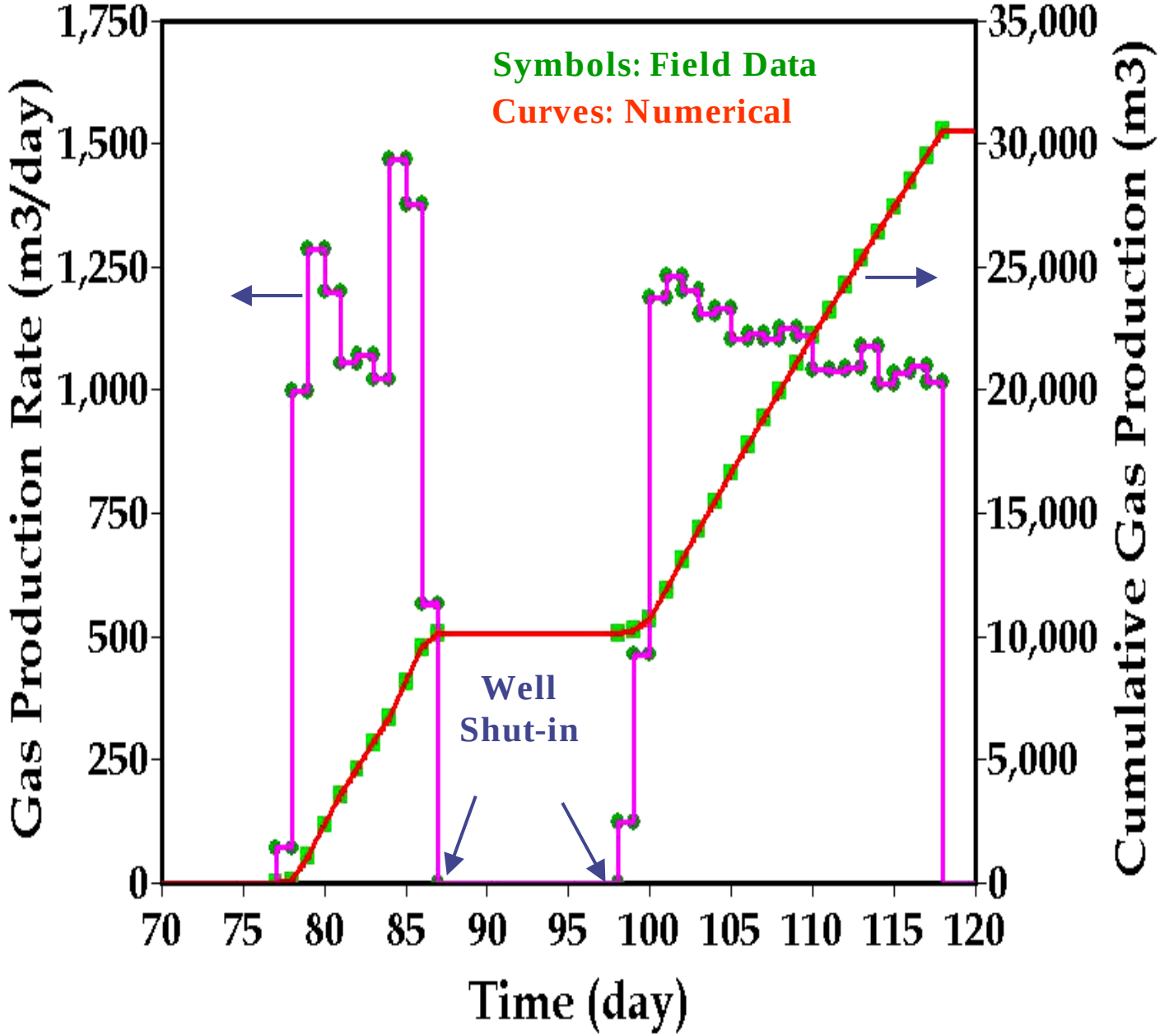
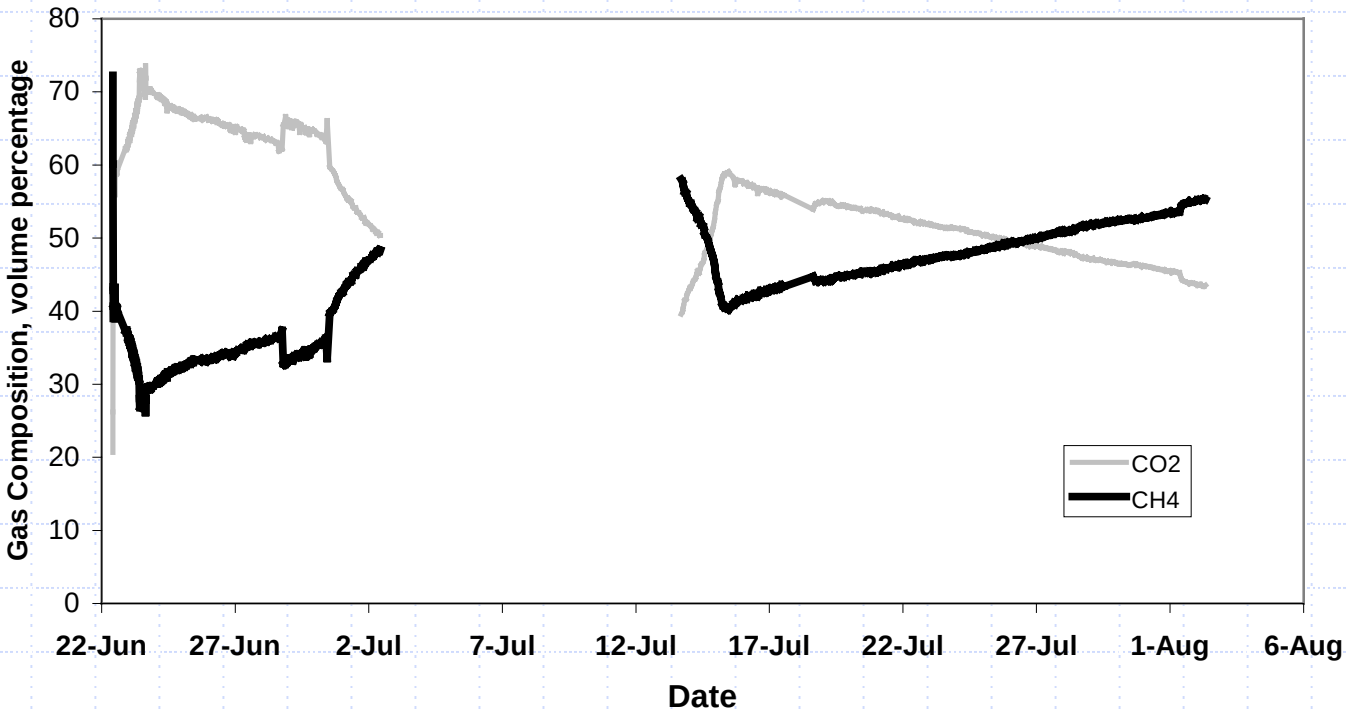
Bottom-hole Pressure During Final Production Test



Time 0 = April 6, 2004



Gas Composition During Final Production Test



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Results

- All six stages of the micro-pilot test were successfully completed
- The average pressure of seam #3 is 1,241 kPa at a depth of 472 m
- Absolute permeability of the coal seam prior to CO_2 injection was 12.6 md, which was based on an effective permeability of gas of 2 md and a gas saturation of 40.8%
- 192 metric tonnes of CO_2 was injected
- The injectivity stayed relatively constant while the estimated permeability reduced substantially during injection (from 12.6 md to 1.4 md after injection)

Reservoir Simulation

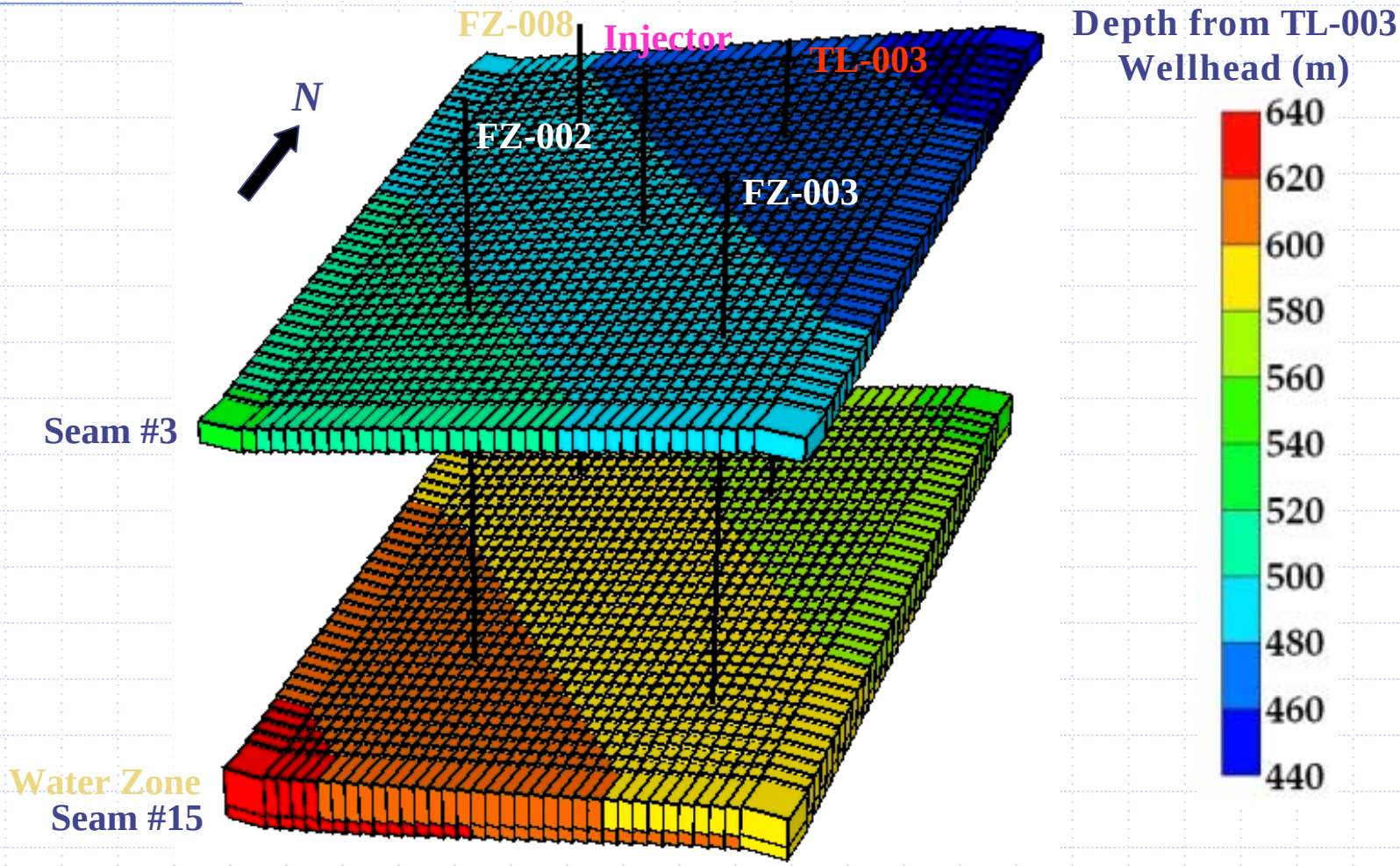
- Obtain a credible numerical model which can reflect the characteristics of the coal reservoir with the micro-pilot test
- Design the multi-well pilot test with the numerical model and further calibrate the numerical model
- Commercial development design with the established numerical model

The History Match of the Micro-Pilot Test

- Micro-pilot test data such as BHP and production gas composition have been successfully matched
- CMG's CBM Model has been validated and can be used to predict field-scale ECBM recovery performance
- Prediction from the successful history match numerical run could be used to study the micro-pilot test process mechanisms

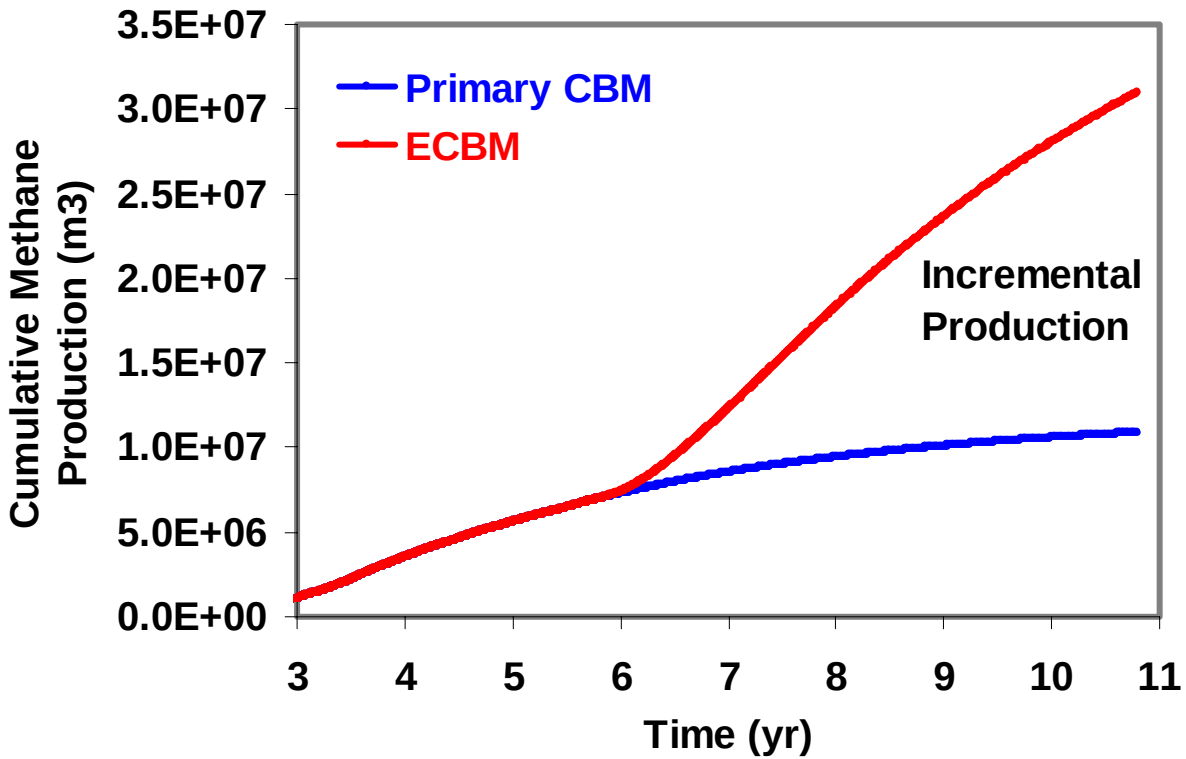
Multi-Well Pilot Test

Reservoir Simulation Model



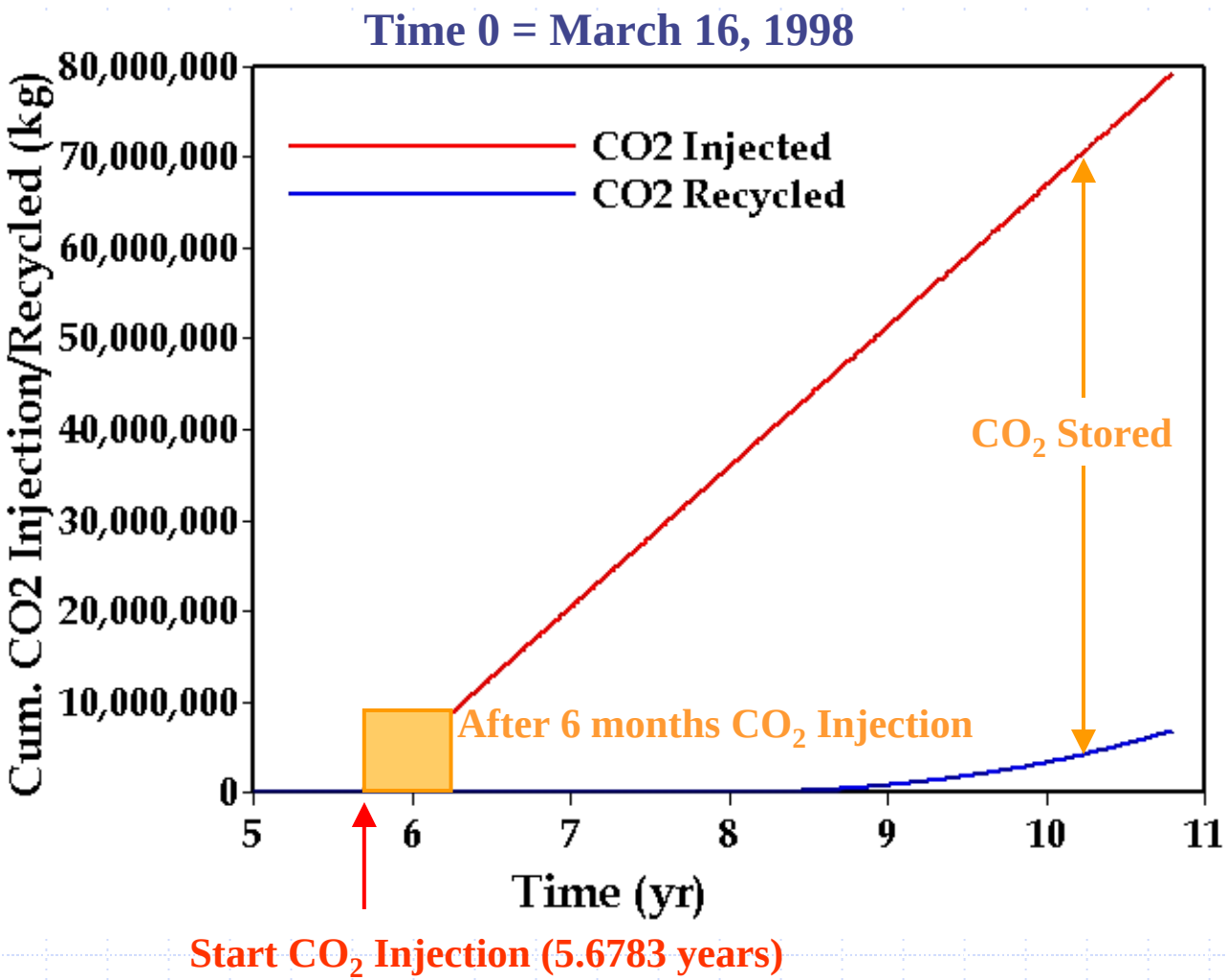
Multi-Well Pilot Test

Cumulative Methane Production



5-Spot Field Pilot Test Prediction

CO_2 Inventory



Summary

- **The single well micro-pilot test as conducted in the South Qinshui TL-003 well has been completed successfully and has met all the technical objectives of the micro-pilot test.**

- **Successful history matching of the dataset from the micro-pilot and use of the calibrated numerical simulator to predict the multi-well pilot performance will establish the level of production enhancement compared to primary production, and whether substantial CO_2 storage in the coal seam is feasible.**

Thank You