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**CO₂-ECBM and CO₂
Sequestration Technology
in Coal Seams of Qinshui
Basin, China**

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China United Coalbed Methane Co., Ltd.

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- ◆ 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)**

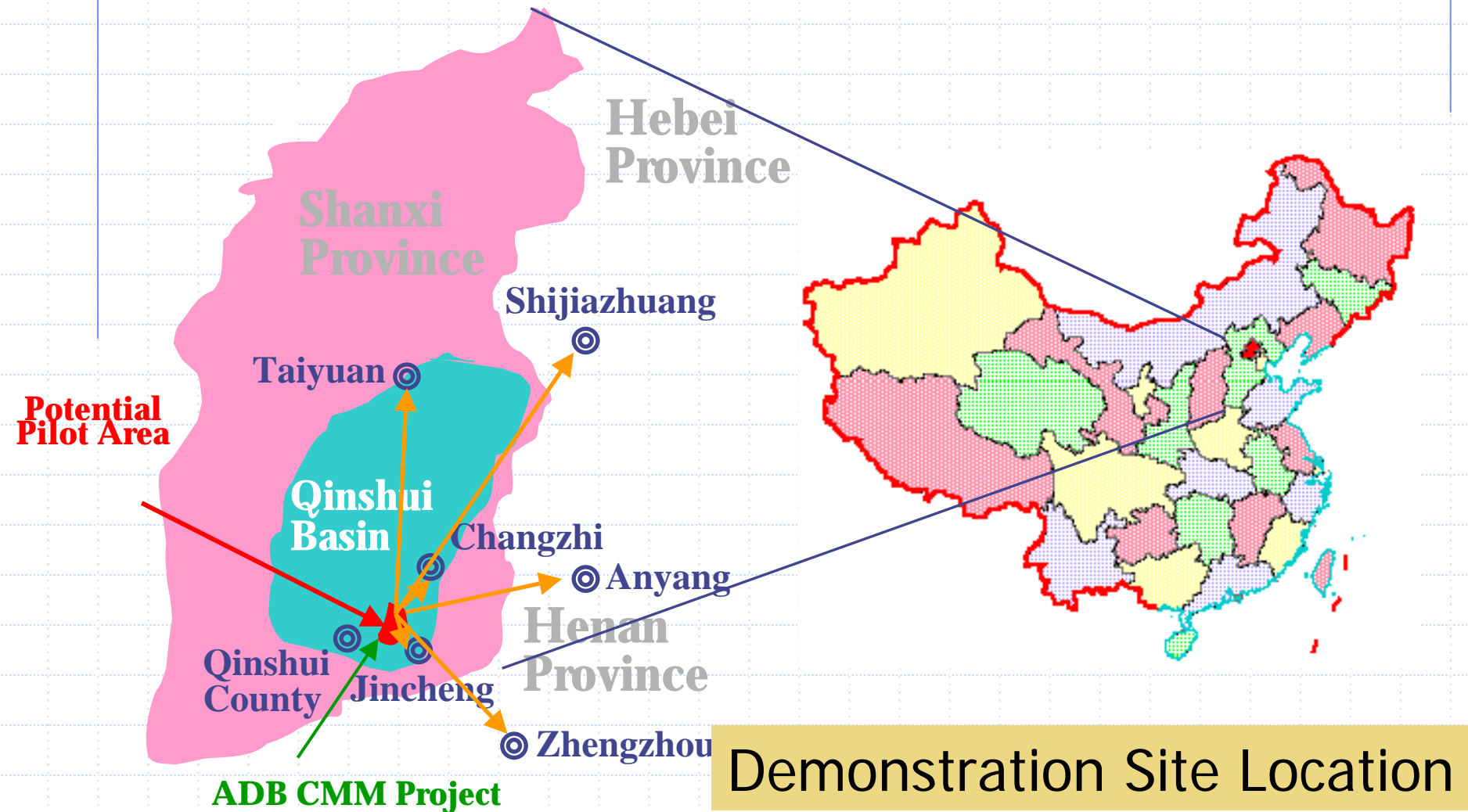
**Ministry of Commerce
(MOFCOM)**

**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



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 CO₂ 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 CO₂-ECBM recovery process indicated that more than 4 times the average CH₄ production rate compared to primary recovery can be achieved**
- ◆ **CO₂ storage into high-rank anthracite coal seam in Qinshui Basin is feasible**
- ◆ **Design of multi-well pilot on site**

Micro-pilot Test Goals

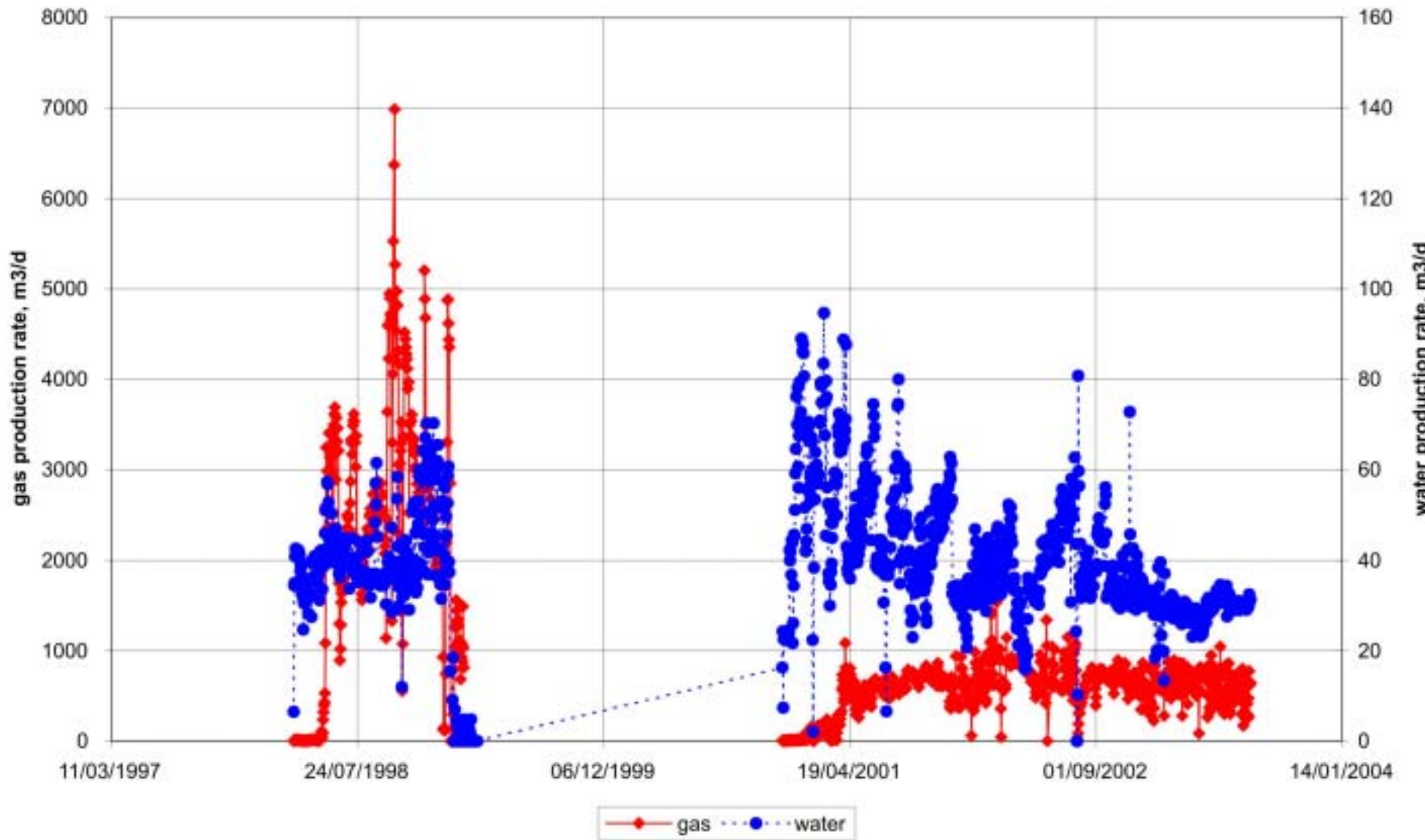
- ◆ To accurately measure data while injecting into and producing from a single well
- ◆ To evaluate the measured data to obtain estimates of reservoir properties and sorption behavior
- ◆ To use calibrated simulation model to predict the behavior of a larger scale pilot or full field development

Primary CBM Recovery Operation



CBM Production Well

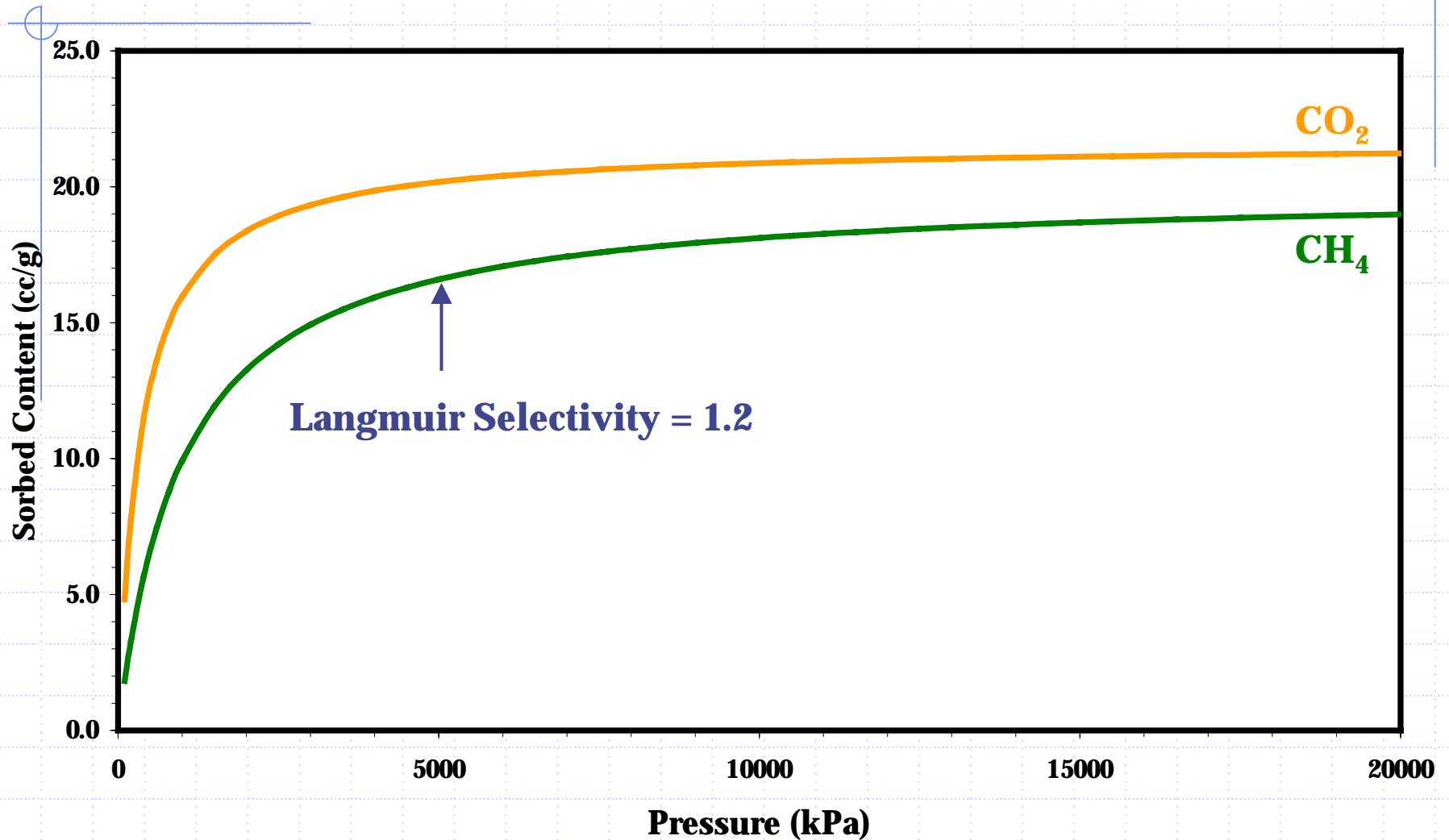
Gas / Water Separator



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 CO₂ and followed by a 30 days shut-in period
- ◆ Stage 5. Production testing after the CO₂ injection period
- ◆ Stage 6. The final shut-in test



Stuffing Box

Polish Rod
BOPS

V1

V2

Wireline Packoff
Assembly

Tubing head
Flange

Leak

V3

BHP Wireline
Connection

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Target Coal Seam Well for Field Test

◆ No. 3 seam – Shanxi Formation

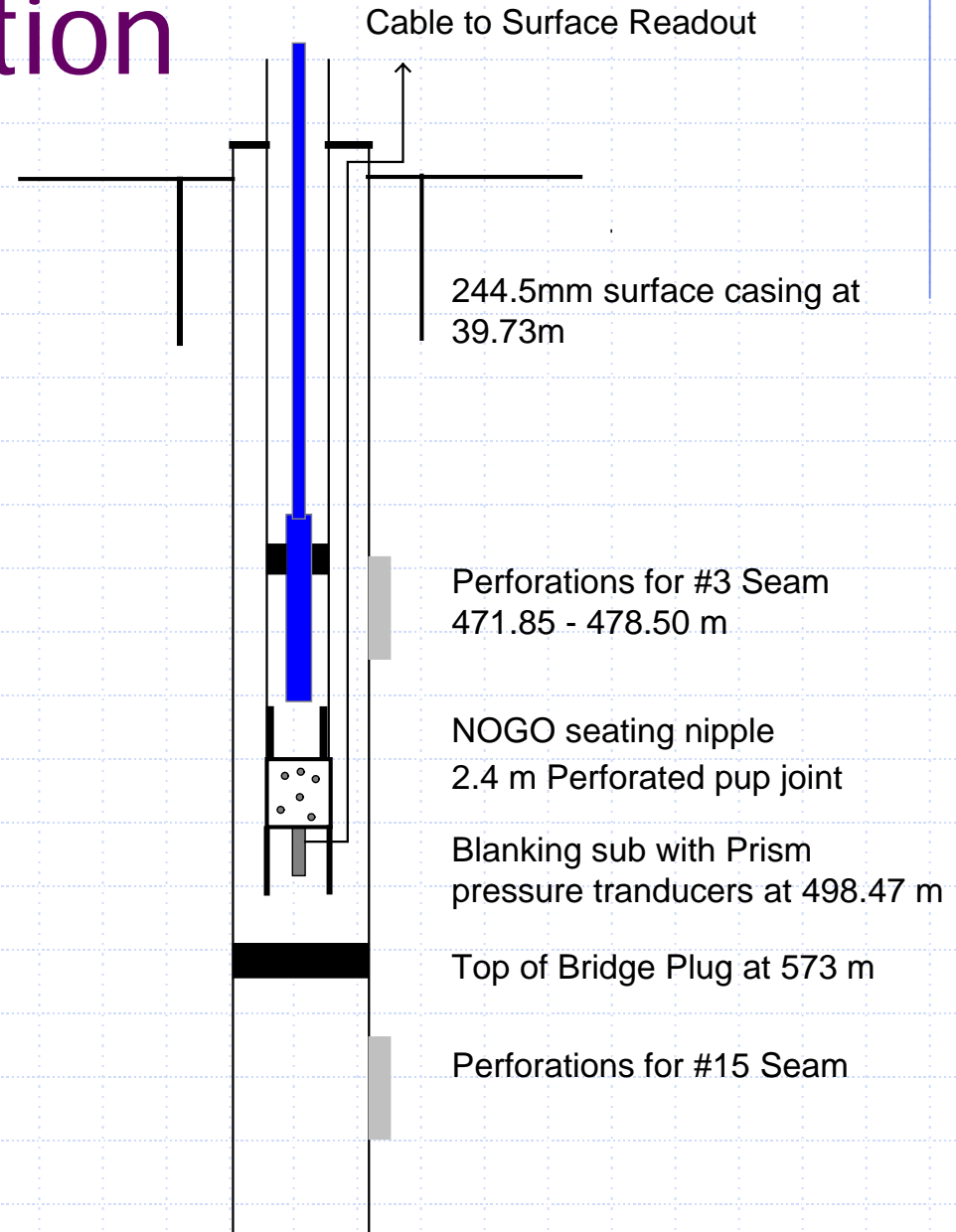
- Age: Carboniferous Permian coal
- Depth: 478 meters
- Average thickness: 6 meters
- Reservoir temperature & pressure

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 CO₂ 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 450m³/day and water 0.9 m³/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 CO₂ pump to inject CO₂, Feb 2004
- ◆ CO₂ source secured– Zhongyuan Oilfield located in Henan province, Jan 2004

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CO₂ Injection Strategy

- ◆ Goal is to inject 200 tonnes into reservoir over a 12 day period. Each truck can transport 18 tonnes of CO₂
- ◆ Injection rate to be maintained below reservoir fracture pressure (1100 psi)
- ◆ Estimate average injection rate of 30L/min over 8-10 hr period

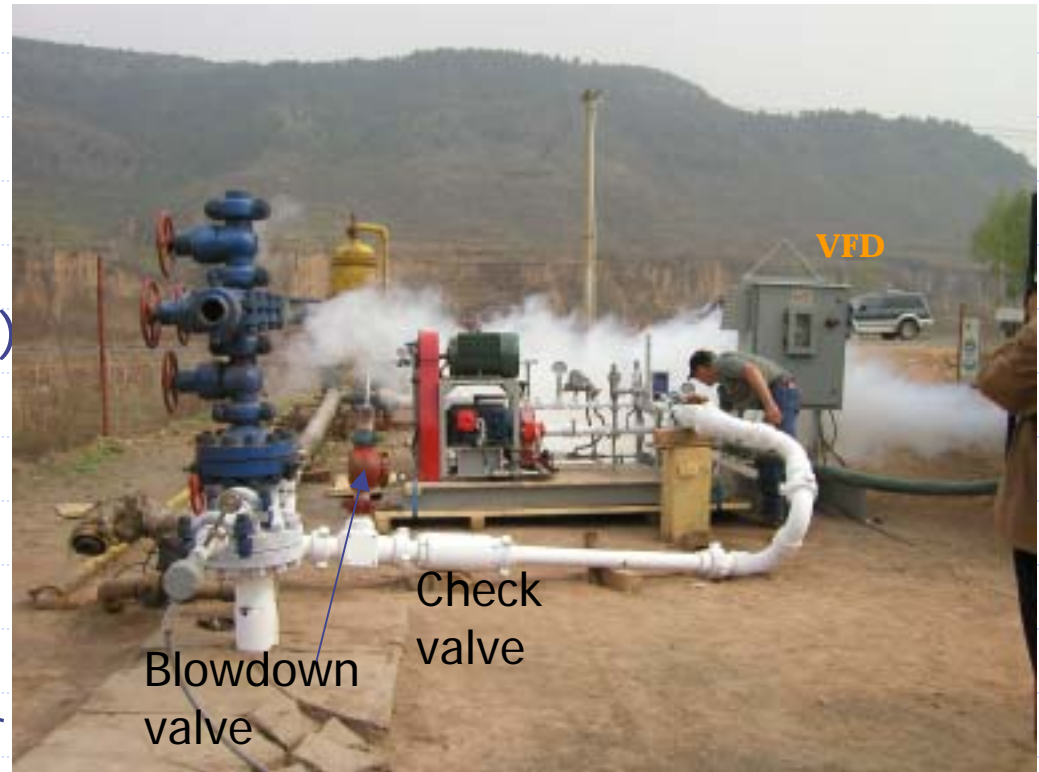


Zhongyuan Oilfield CO₂ Truck Fleet

CO₂ Pumping Equipment

◆ CO₂ 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

- ◆ CO₂ pumping equipment shipped to China
- ◆ Pressure tested well before CO₂ injection
- ◆ Injected over 192 tonnes of CO₂
- ◆ CO₂ 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

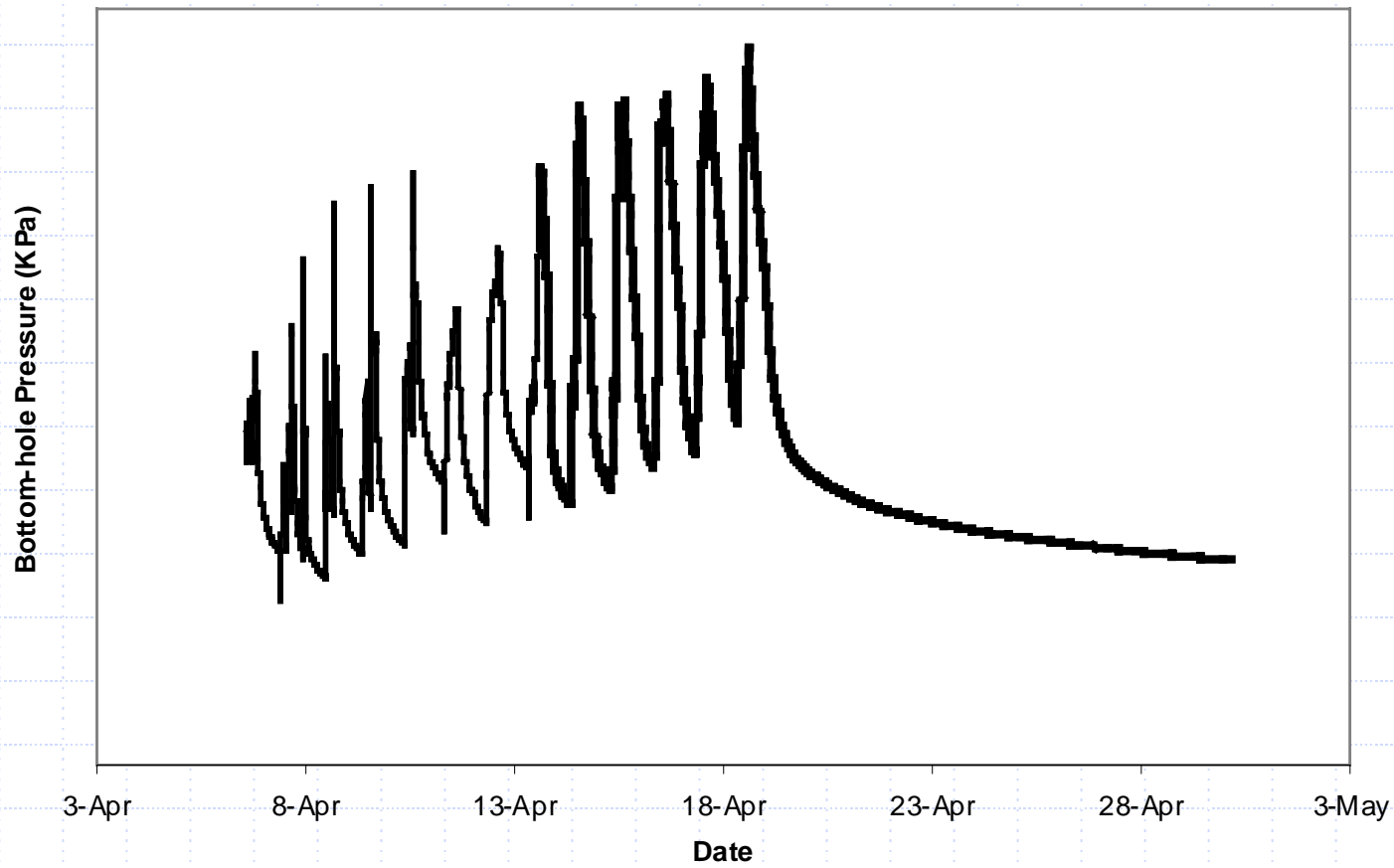
Cooling Down the System



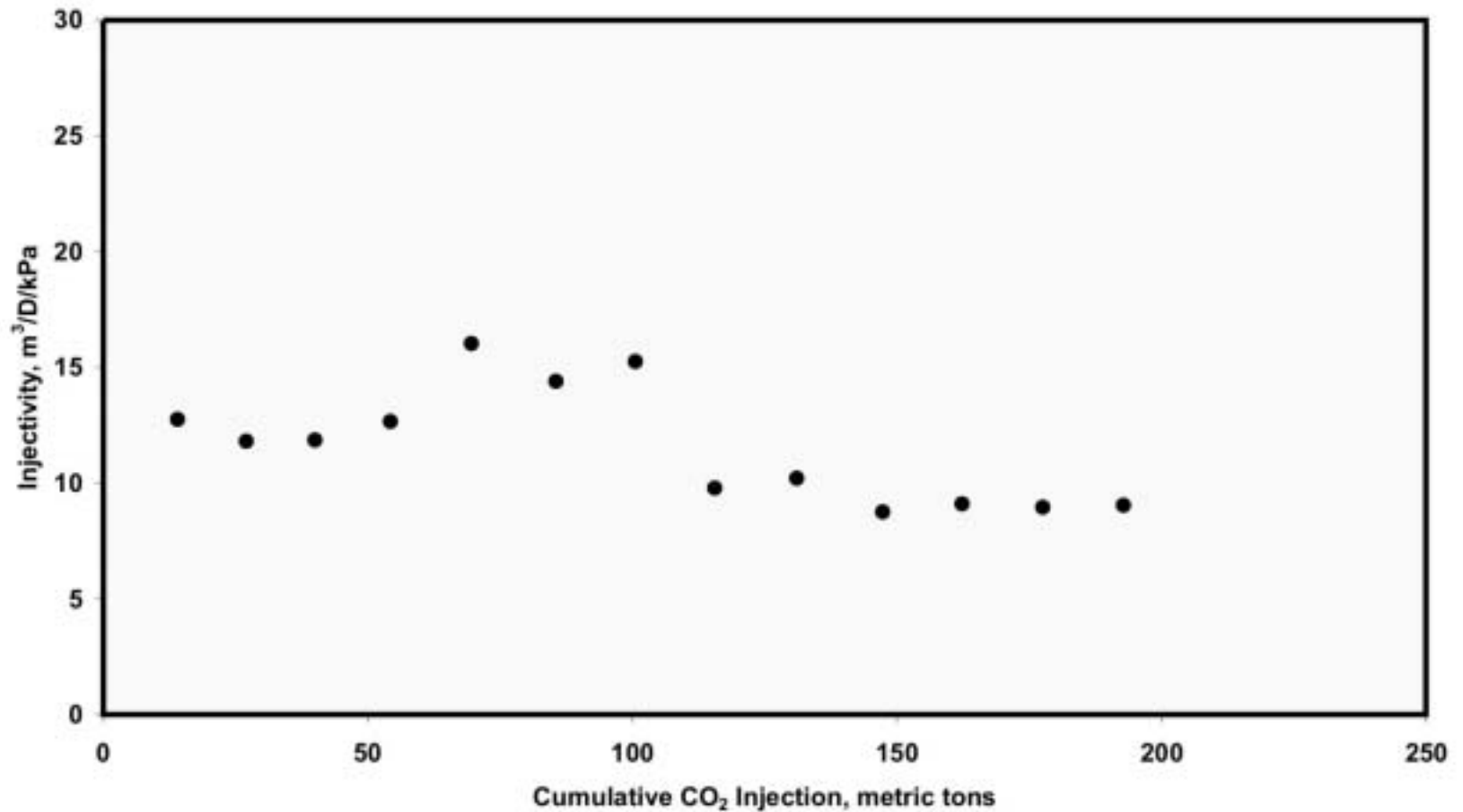
Injecting Liquid CO₂



Bottom-hole Pressure Response During CO₂ Injection



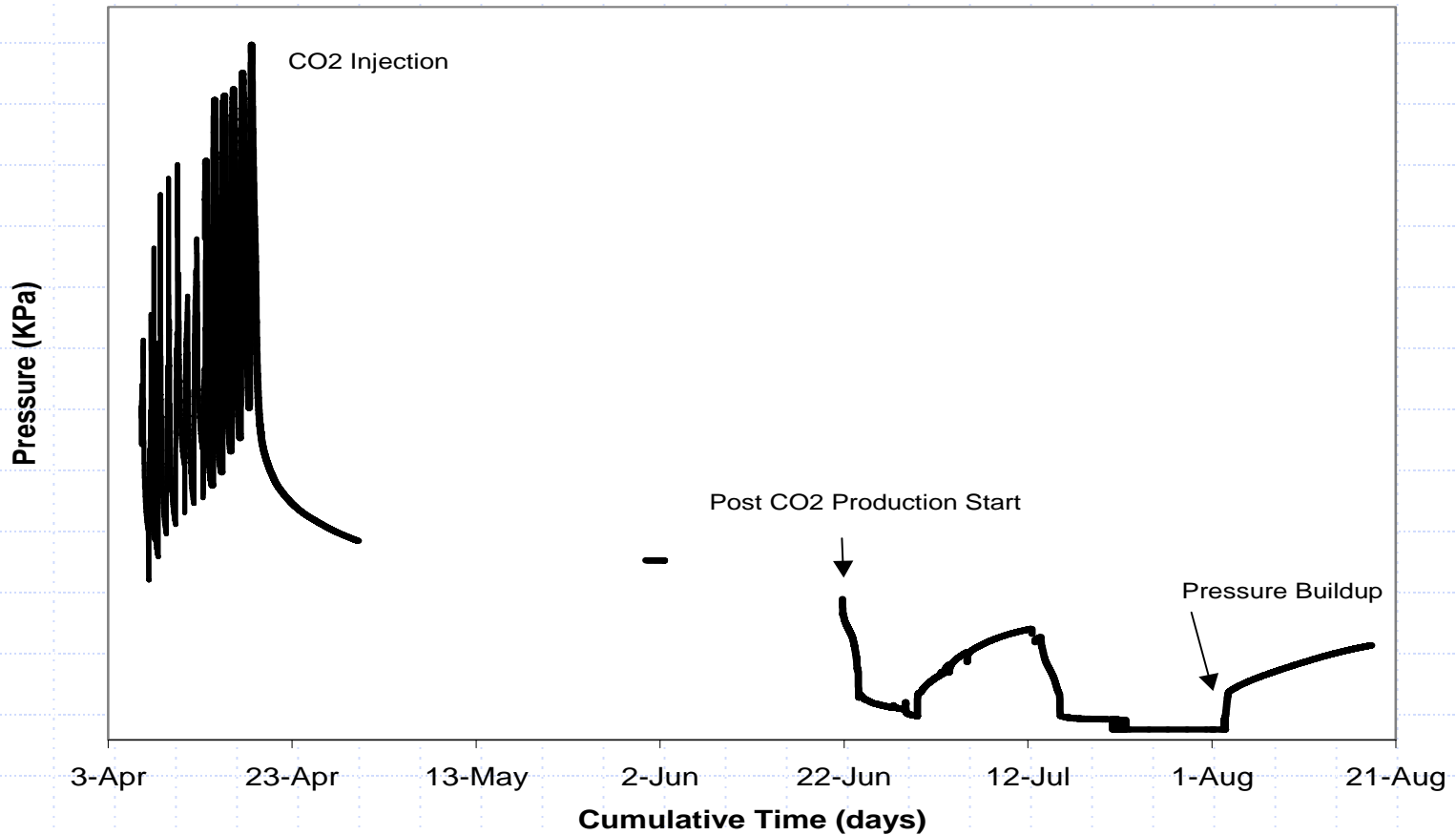
Injectivity versus Cumulative CO₂



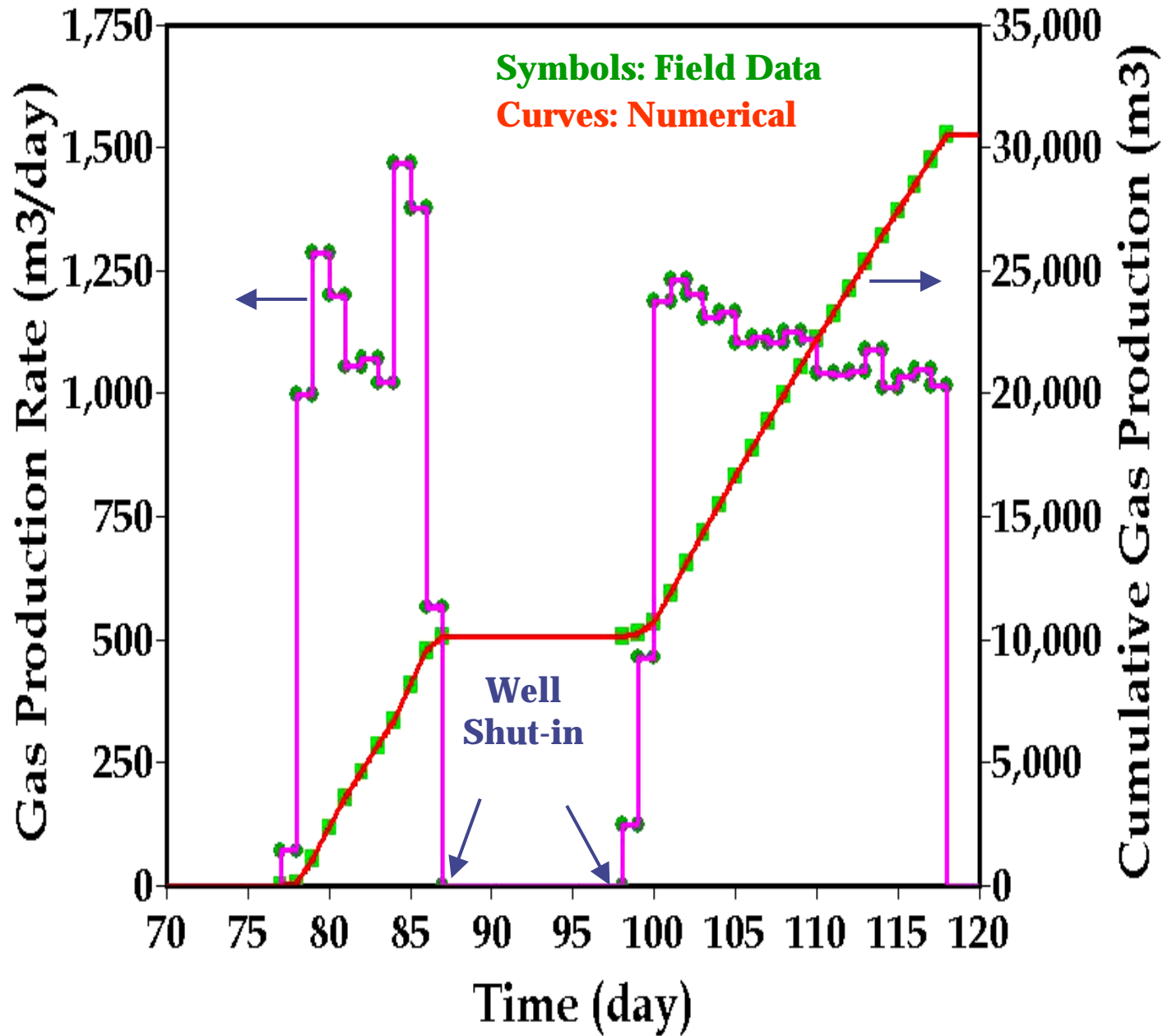
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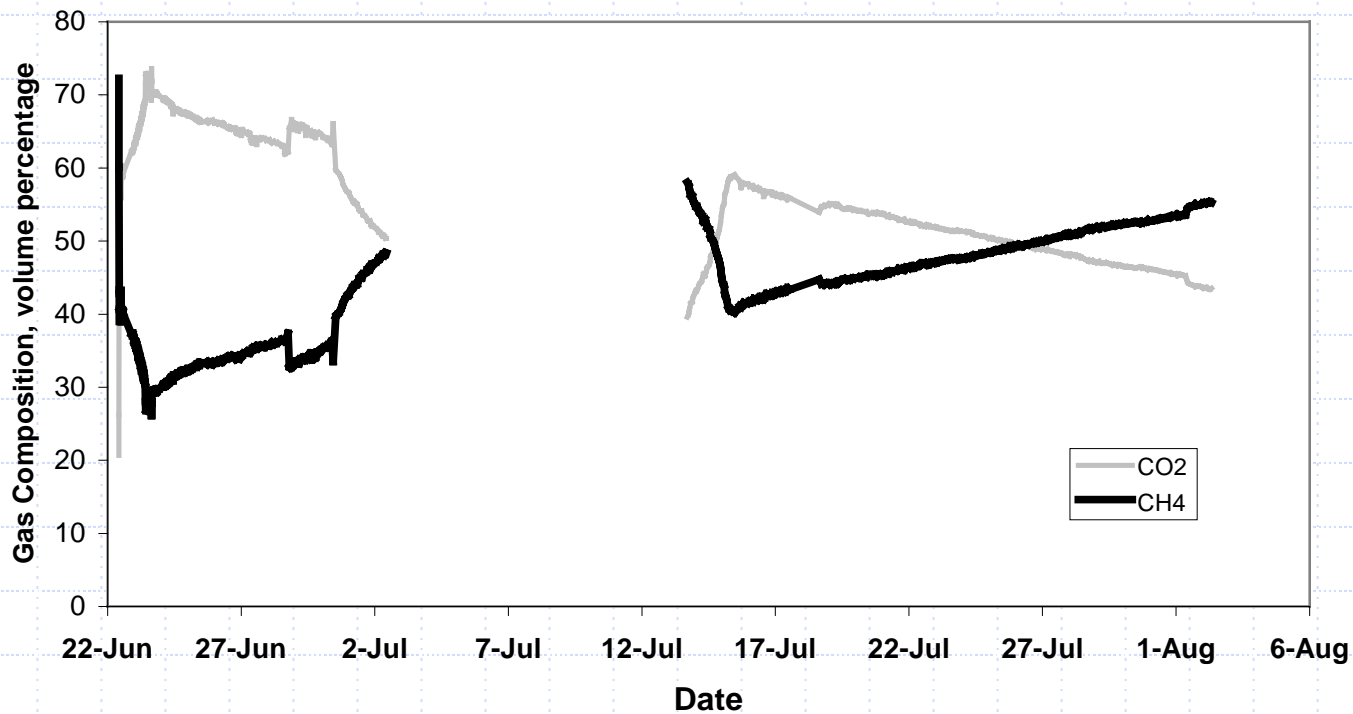
Bottom-hole Pressure During Final Production Test



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 CO₂ 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 CO₂ 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)

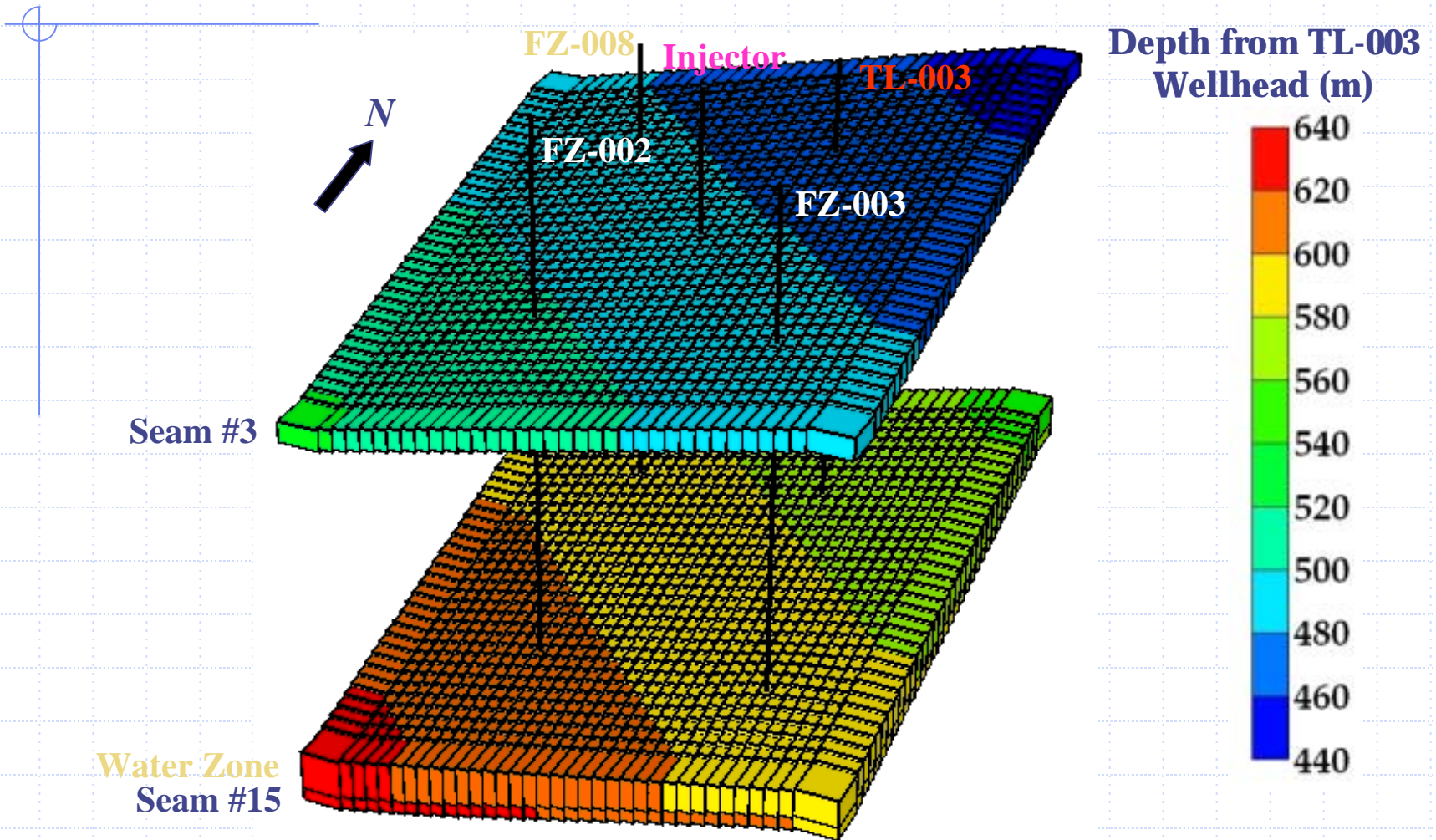
Reservoir Simulation

- 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

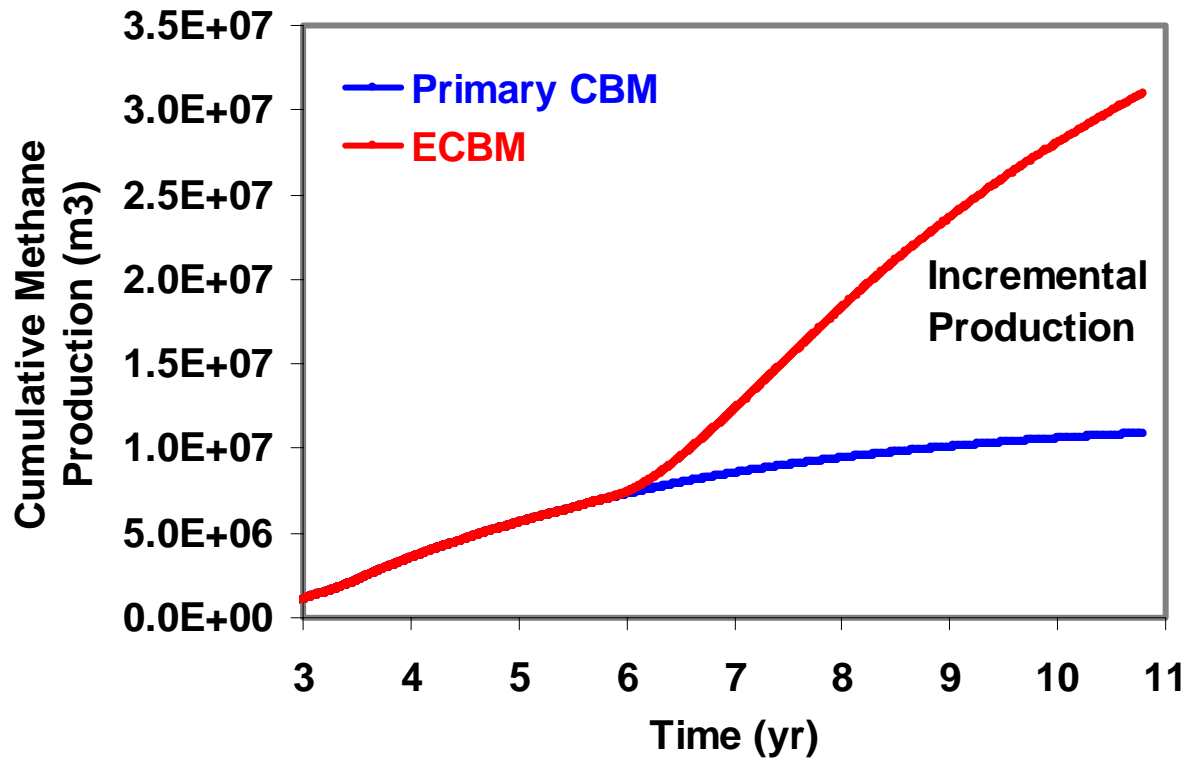
- ◆ Micro-pilot test data such as BHP and production gas composition have been successfully matched
- ◆ CMG's CBM Model has been validated and can be used to predict field-scale ECBM recovery performance
- ◆ Prediction from the successful history match numerical run could be used to study the micro-pilot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

Multi-Well Pilot Test Reservoir Simulation Model



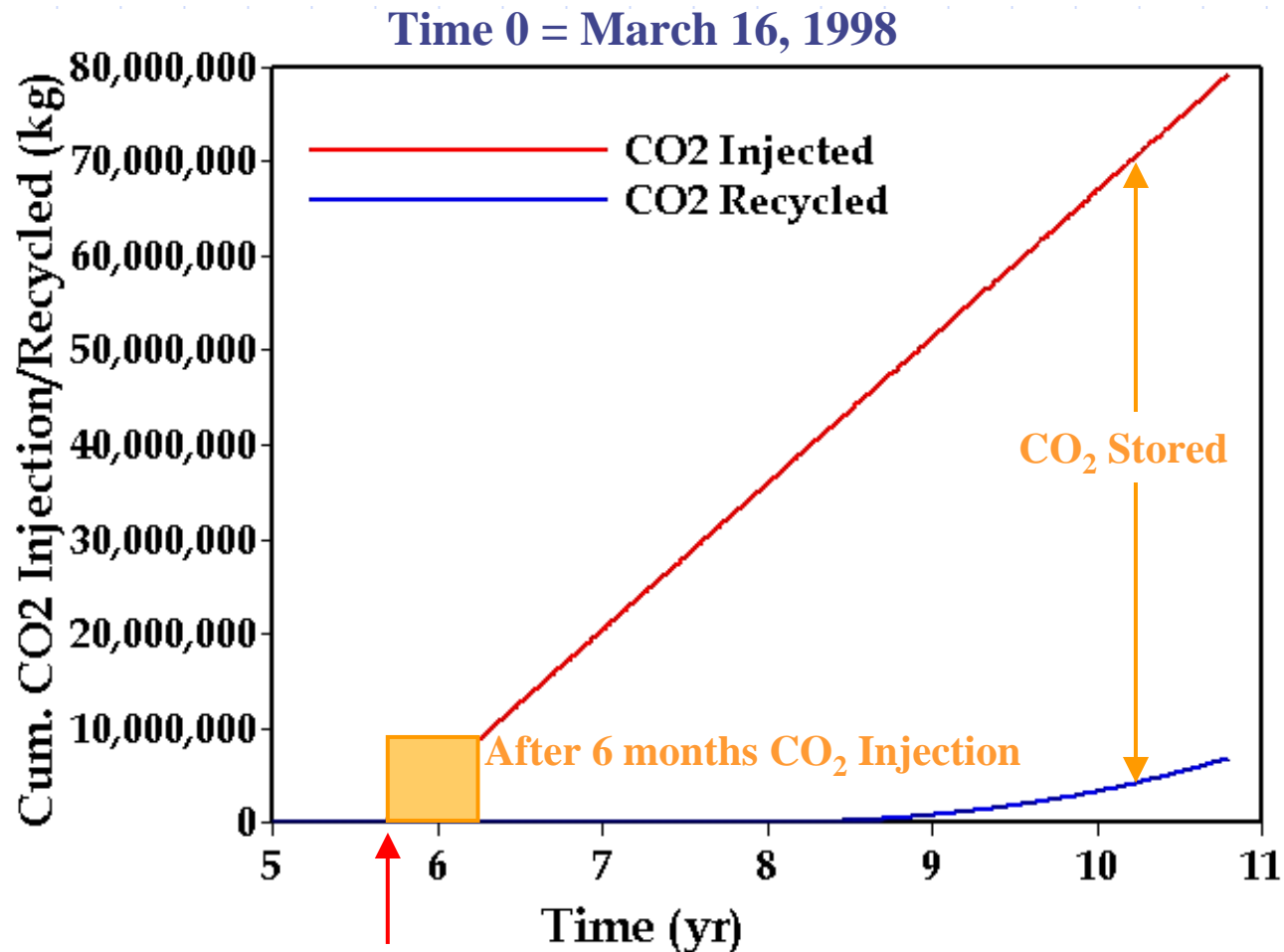
Multi-Well Pilot Test

Cumulative Methane Production



5-Spot Field Pilot Test Prediction

CO₂ Inventory



Start CO₂ Injection (5.6783 years)

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 CO₂ storage in the coal seam is feasible.**



Thank You