

Methodologies and Experience with CMM Resource Assessment

Global Methane Initiative

**Promoting Coal Mine Methane (CMM) for Energy, Safety and the
Environment: Legislation and Project Development in
Kazakhstan**

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Introduction

- Gas resource assessments play an important role in the evaluation of new exploration prospects, and accurate production modeling is critical to achieving optimal development decisions and reliable production forecasts.
- Unlike oil and gas (and coalbed methane), there is no classification scheme nor resource estimation methodology designed specifically for categorizing coal mine methane (CMM).
- However, the basic principles established by the major classification schemes (e.g., SPE/PRMS, JORC, etc.) to quantify in-place resources and estimate recoverable quantities can be applied to CMM.
- When developing a CMM project or designing a mine degasification plan it is important to understand the size of the gas resource and the drainage (i.e., production) potential.
- This presentation summarizes the general methodology used to calculate in-place resources and provides specific examples for estimating recoverable quantities of methane using in-mine, vertical pre-mine, and gob boreholes.

Gas-In-Place Calculation for CBM/CMM

- Gas-in-place (GIP) is the volume of gas stored within a specific bulk reservoir rock volume (e.g., coal).
- A GIP analysis is generally performed for a specific purpose such as gas resource assessment, reservoir production modeling, or geologic hazard evaluation.
- GIP analysis is also used in the mining industry to determine if methane emissions will be a hazard during tunnel construction or during the mining of coal, oil shale, trona, and potash.
- GIP analysis is a very complex process that involves numerous data collection and analysis challenges. The complexity is due, in part, to the fact that most reservoir parameters used for calculating the GIP cannot be measured directly but must instead be indirectly estimated using data obtained by analysis of various rock properties.
- Four reservoir parameters are generally needed to calculate the GIP for coal gas reservoirs: area, thickness, coal density, and in-situ gas content.
 - The coal area and the coal thickness are usually determined through analysis of geophysical well logs, seismic data, and structure maps.
 - The coal density and gas content are usually determined using data obtained from well logs or laboratory analysis of drill cuttings and core samples.

Volumetric GIP Calculation

The equation relating the four components to gas in place is:

$$\mathbf{GIP = GC \times h \times A \times P}$$

Where:

GIP = Gas-In-Place (cubic feet)

GC = Gas Content (cubic feet per ton)

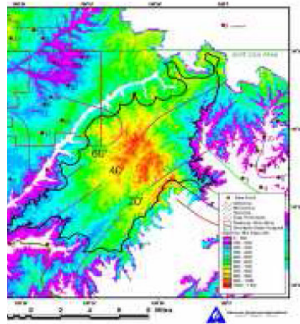
h = Coal thickness (feet)

A = Drillable area (acres)

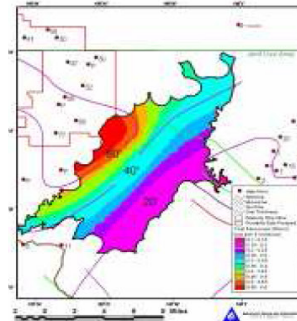
P = Coal density (tons/acre-foot)

Gas-In-Place Analysis

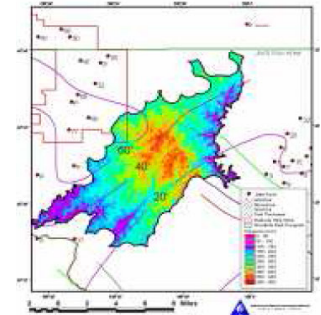
**1) DEPTH, THICKNESS
SCREEN**



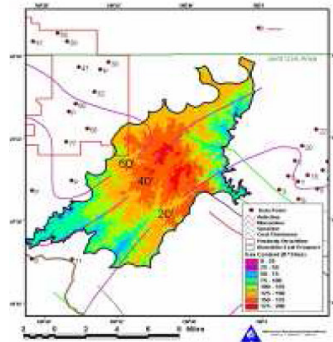
2) COAL RESOURCES



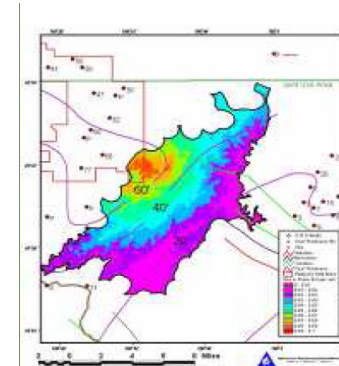
**3) DEPTH / RESERVOIR
PRESSURE**



4) GAS CONTENT



5) GAS-IN-PLACE

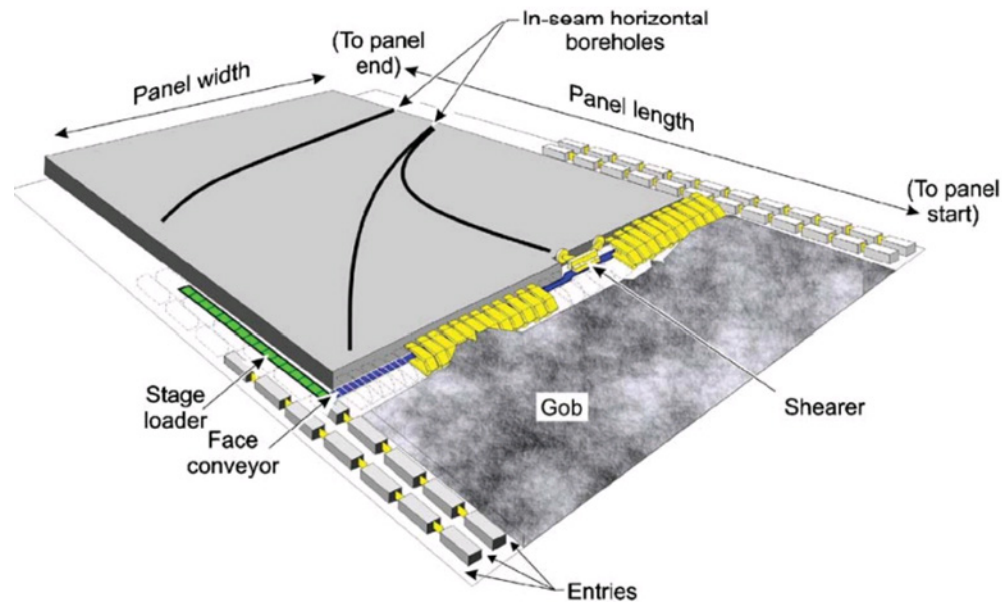


Estimating Recoverable Methane Quantities

- Methods for the assessment of CBM/CMM resource/reserves have been adapted largely from techniques developed for conventional reservoirs. Four general methods are applied:
 - Volumetric
 - Material balance
 - Production data analysis (PDA)
 - Reservoir simulation
- The appropriate application of these methods depends on the phase of development of the CBM/CMM reservoir.
- Although both volumetric and simulation methods can be applied at all stages of development, their accuracy will improve with increased data availability.
- Material balance, decline curve, and PDA methods can only be applied after a significant amount of production, flowing pressure, and shut-in pressure data become available.
- The following slides present project examples using reservoir simulation and other modeling techniques to estimate the volume of recoverable methane (i.e., drainage potential) associated with selected CMM degasification methods.

Selected Degasification Methods: In-Mine Boreholes

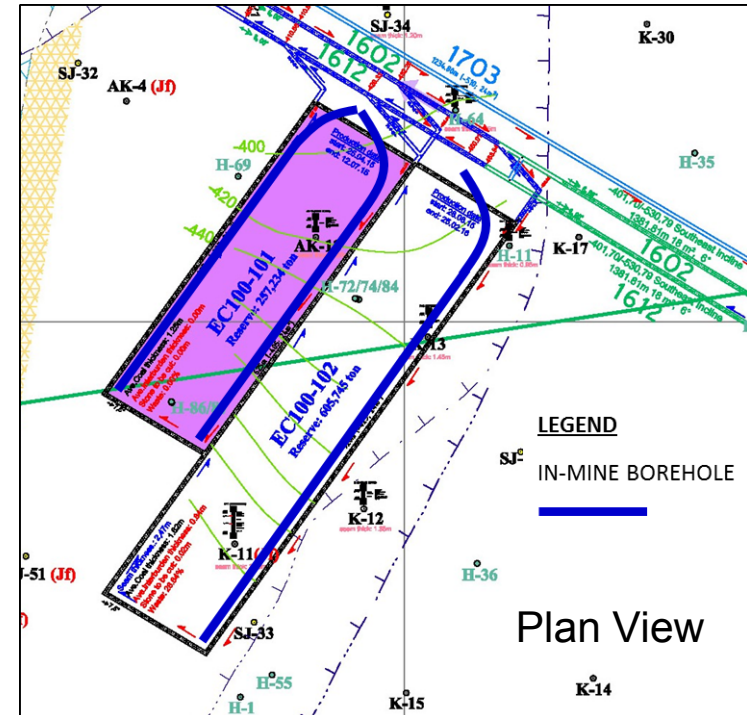
- Drilled horizontally parallel to the face (short hole), longitudinally through the panel or across many panels (long holes), or superjacent.
- Drain 50% to 80% of GIP depending on geology (permeability important).
- Concentration generally around 90%.



Selected Project Experience: Estimating Gas Drainage from In-Mine Boreholes

Gas Drainage Approach

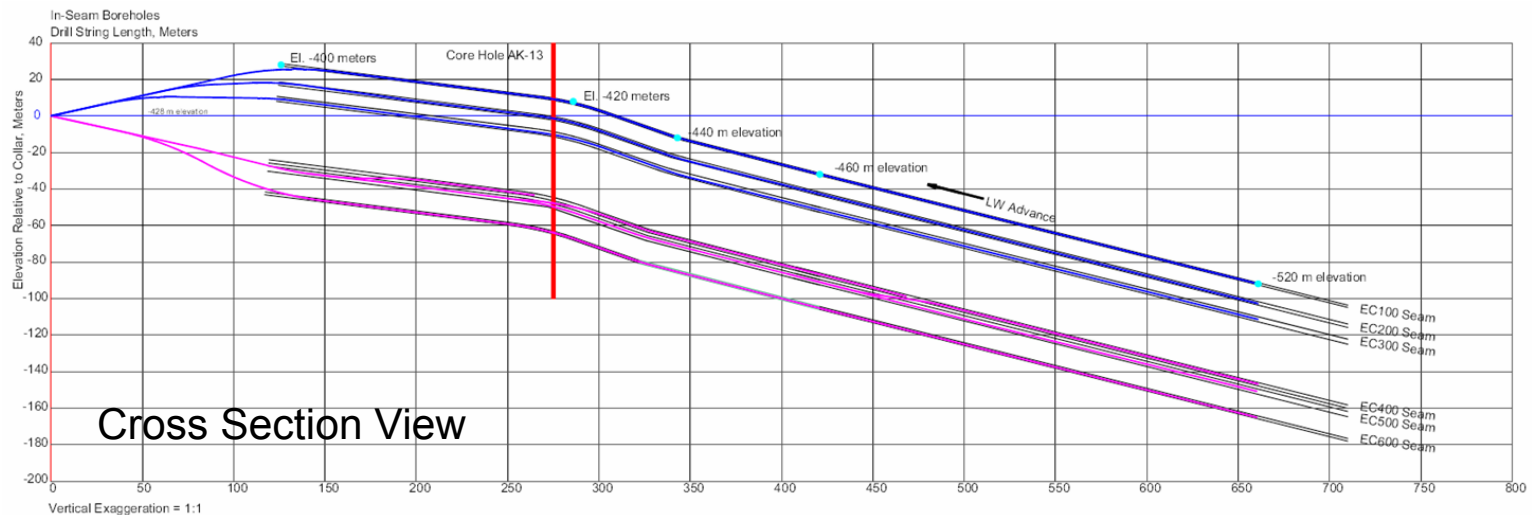
- Drilling approach utilizing in-seam drilling in advance of developments.
- Flanking in-seam boreholes to shield and drain gas ahead of development galleries.
- Coordination of drilling operations with mining sequence.
- Down-dip boreholes.
- Long directionally drilled boreholes cover entire length of each panel from a single setup location.
- Ability to drain multiple mining levels for each panel from a single setup location.



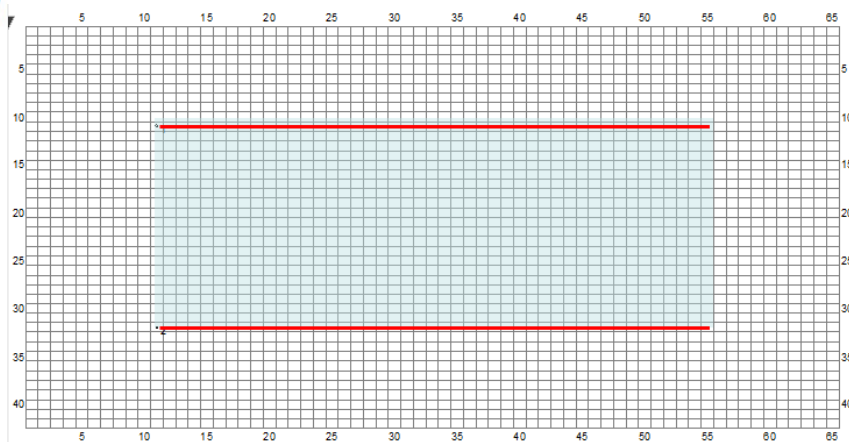
Selected Project Experience: Estimating Gas Drainage from In-Mine Boreholes

Gas Drainage Approach (continued)

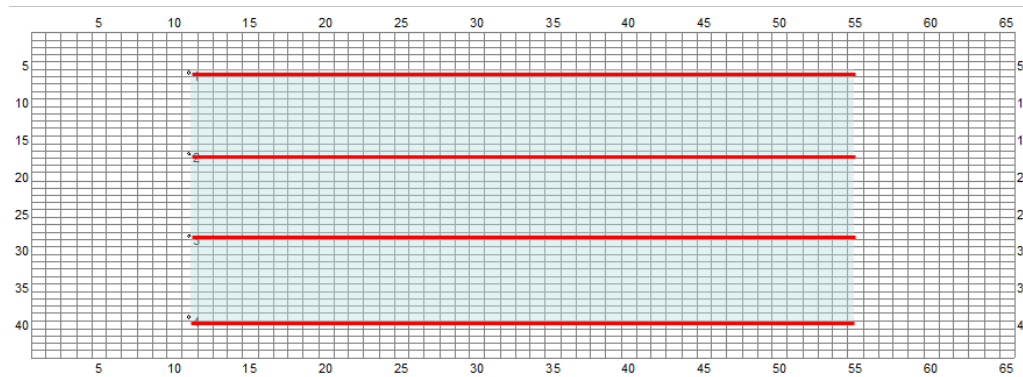
- Drilled in advance of gateroad gallery advancement.
- Boreholes are drilled in parallel to advance and flank the gateroad developments.
- Coordination of drilling operations with mine plans is key to the success of an in-seam drainage program.
- Depending on drilling conditions and hole deviations, boreholes can be drilled up to 1500+ meters.



Estimating Methane Recovery Using Reservoir Simulation: Model Layout



— Wells
■ LW Panel



2 Wells Per Panel Case

Model length = 3,317 ft (1,011 m)
Model width = 1,641 ft (500 m)
Total model area = 125 ac (51 ha)

Number of wells: 2
Lateral length: 2,297 ft (700 m)
Spacing between wells: 820 ft (250 m)

4 Wells Per Panel Case

Model length = 3,317 ft (1,011 m)
Model width = 1,094 ft (333 m)
Total model area = 83 ac (34 ha)

Number of wells: 4
Lateral length: 2,297 ft (700 m)
Spacing between wells: 273 ft (83 m)

Estimating Methane Recovery Using Reservoir Simulation

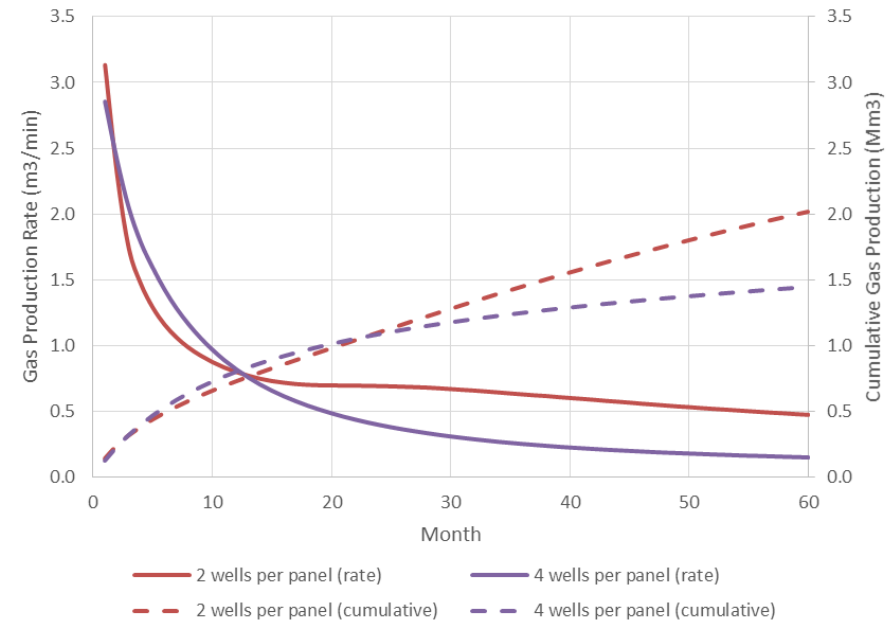
Project Details

- Mine Name: Amasra Hard Coal Mine
- Mine Location: Amasra, Turkey
- Mine Operator: HEMA Energi

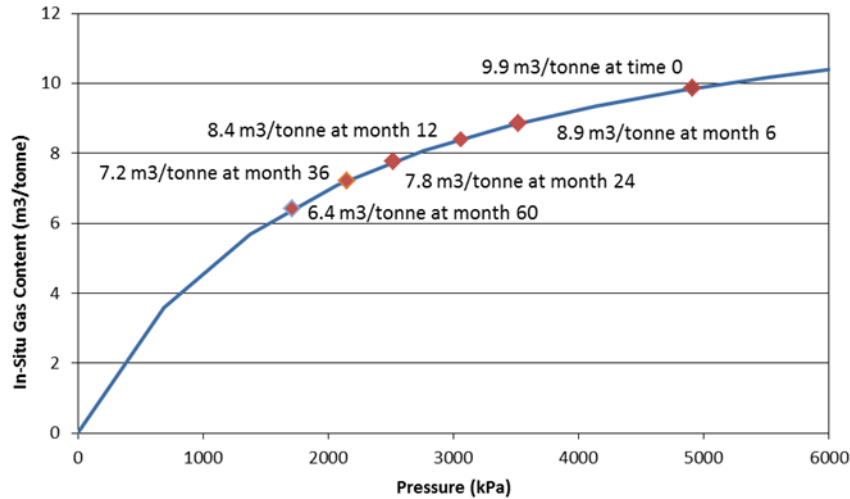
Relevant Reservoir Parameters

- Coal Depth: 500 m (avg.)
- Coal Thickness: 2 m
- Coal Density: 1.68 g/cc
- Water Saturation: 100%
- Gas Content: 9.85 m³/t
- Sorption Time: 17 days
- Permeability: 0.5 md
- Porosity: 2%

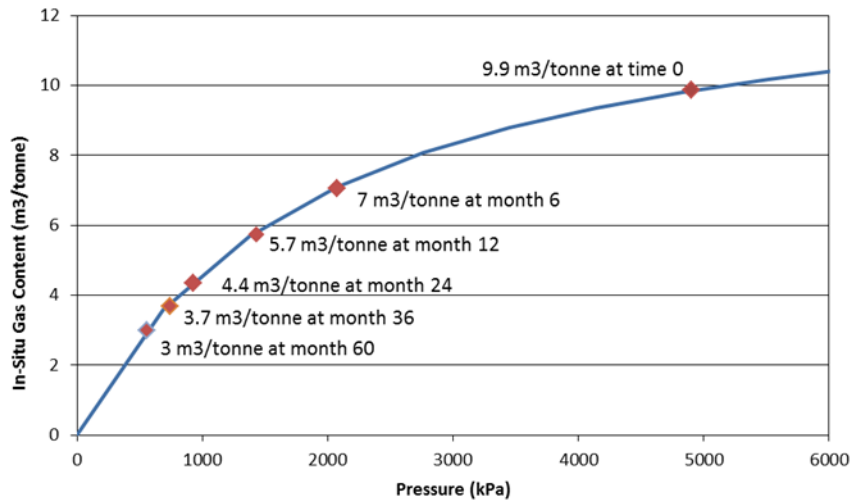
Simulation Results: Single Well Production Profiles



Reduction of Coal Seam Gas Content Over Time



Reduction Using 2
Wells Per Panel



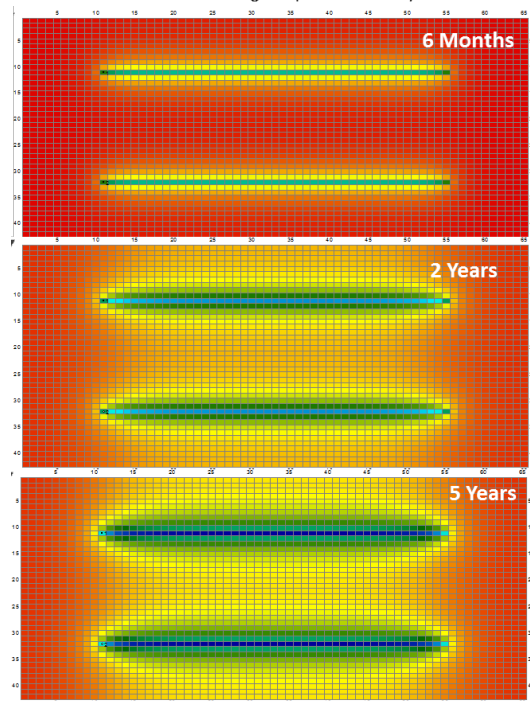
Reduction Using 4
Wells Per Panel

Reduction of Coal Seam Gas Content Over Time

2 Wells Per Panel

Production Duration	Cumulative Gas Production (Mm3)	Reduction in Gas Content* (% Reduction)
After 6 Months	0.97	10%
After 1 Year	1.45	15%
After 2 Years	2.20	21%
After 3 Years	2.26	27%
After 5 Years	2.32	35%

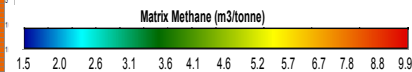
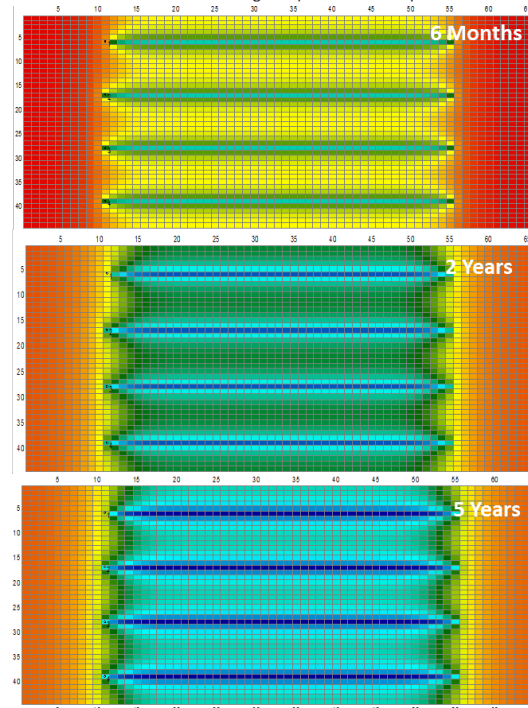
* Calculated from within longwall panel area only



4 Wells Per Panel

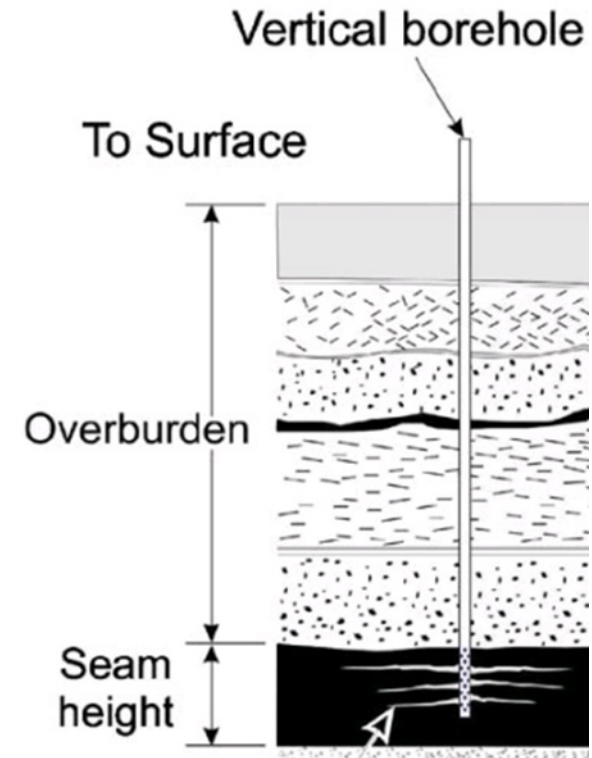
Production Duration	Cumulative Gas Production (Mm3)	Reduction in Gas Content* (% Reduction)
After 6 Months	2.12	29%
After 1 Year	3.21	42%
After 2 Years	4.36	56%
After 3 Years	4.42	63%
After 5 Years	4.49	70%

* Calculated from within longwall panel area only



Selected Degasification Methods: Vertical Pre-Mine Boreholes

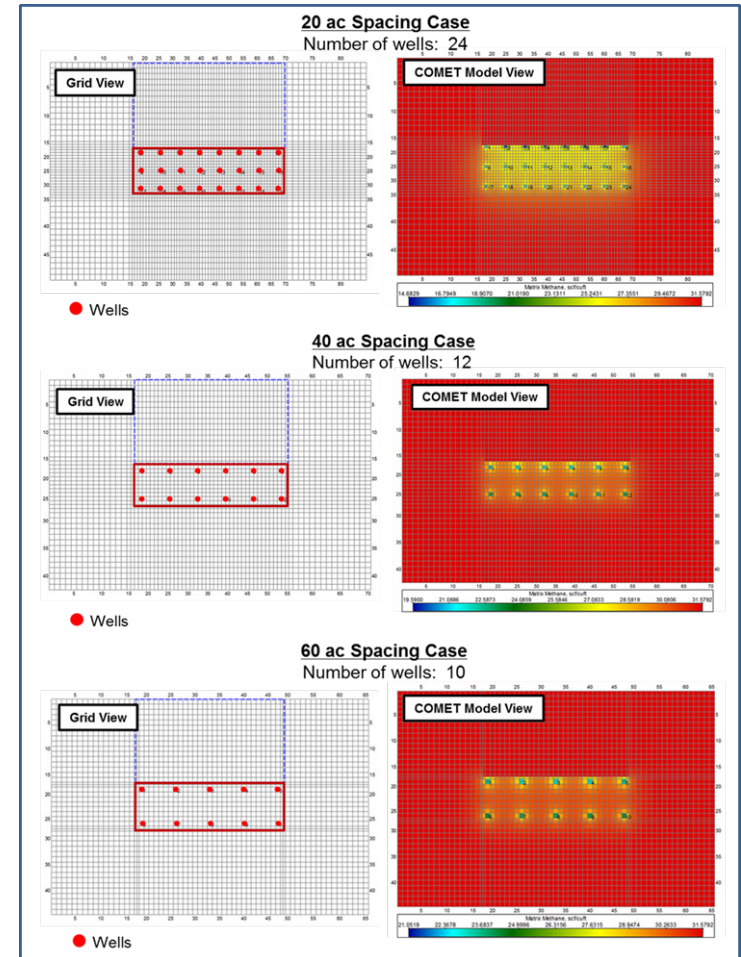
- Drilled from the surface (can be done years in advance).
- Drain around 80% of GIP depending on geology (permeability important).
- Concentration is generally around 90%.
- These type of wells are ideally suited for multiple, thin seam situations.



Selected Project Experience: Estimating Gas Drainage from Vertical Pre-Mine Boreholes

Gas Drainage Approach

- Drainage approach utilizing vertical pre-mine boreholes drilled from the surface.
- Vertical wells are projected to be drilled and completed to a depth of roughly 2800 ft (853 m) and completed in two stages corresponding to the L7 and L4 seams.
- Due to the low permeability present at the study area, three spacing cases of 60 ac, 40 ac, and 20 ac were investigated.
- The study area for the simulation includes two adjacent longwall panels and encompasses an area roughly 2100 m in length by 600 m in width.



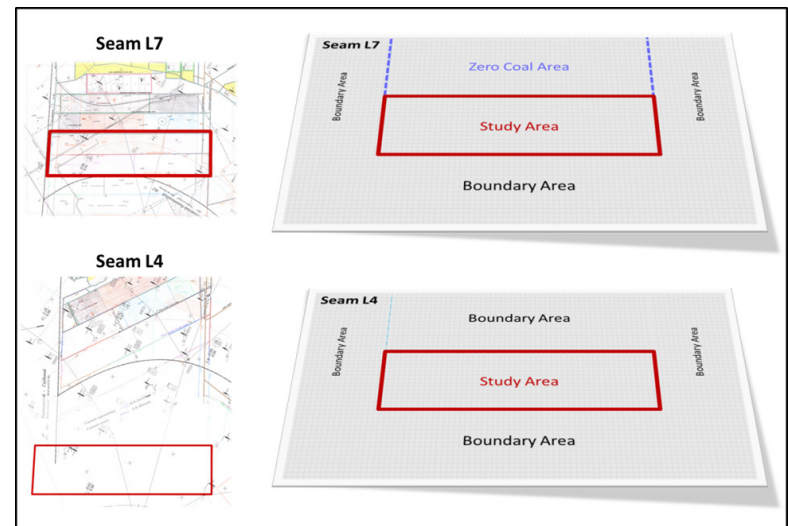
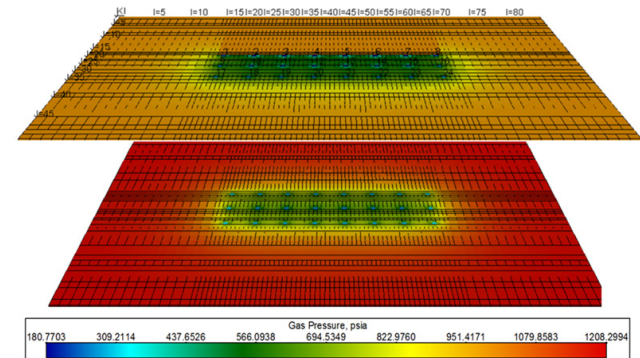
Estimating Methane Recovery Using Reservoir Simulation

Project Details

- Mine Name: Komsomolets Donbassa Mine
- Mine Location: Kirovskoye, Ukraine
- Mine Operator: DTEK

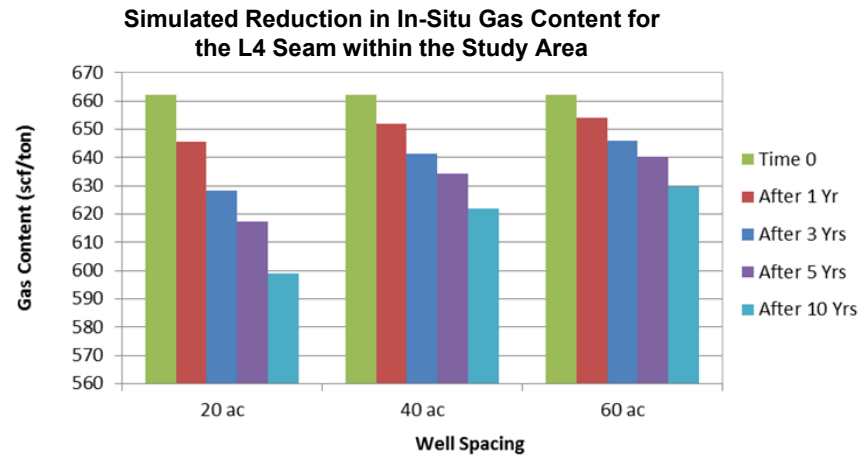
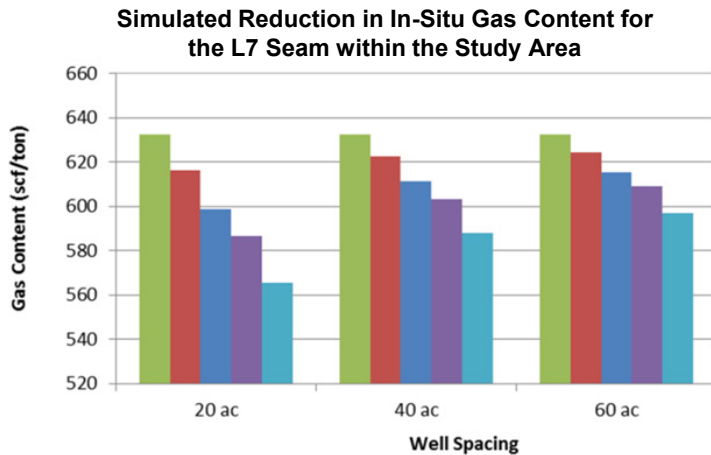
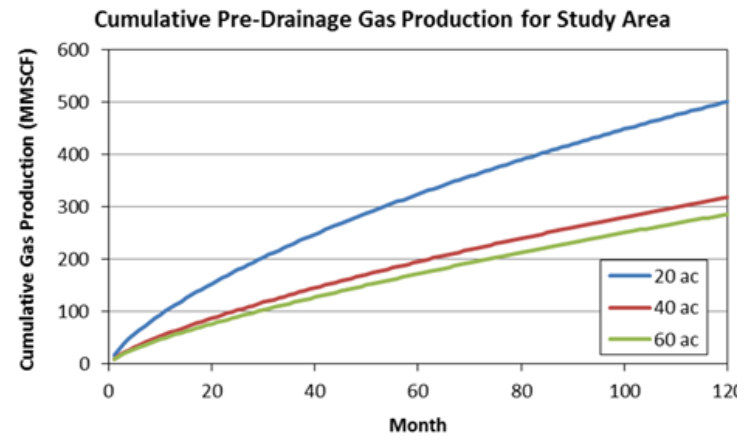
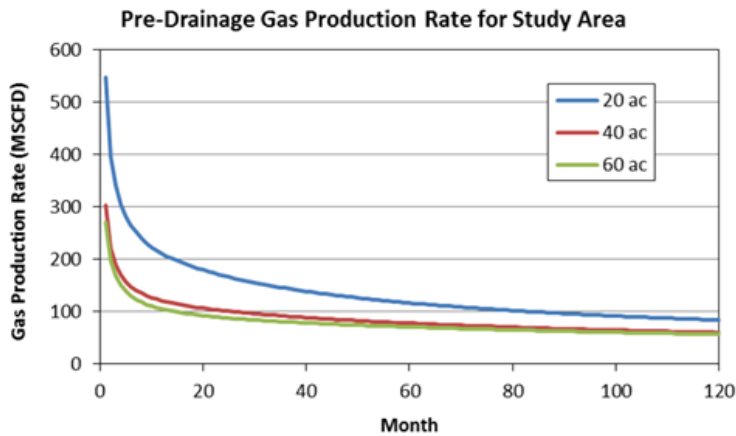
Relevant Reservoir Parameters

- Coal Depth: 2300 ft (L7)
2800 ft (L4)
- Coal Thickness: 3.28 ft (L7)
3.28 ft (L4)
- Coal Density: 1.6 g/cc
- Water Saturation: 50%
- Gas Content: 645 scf/ton (L7)
675 scf/ton (L4)
- Sorption Time: 24 days
- Permeability: 0.1 md
- Porosity: 1%



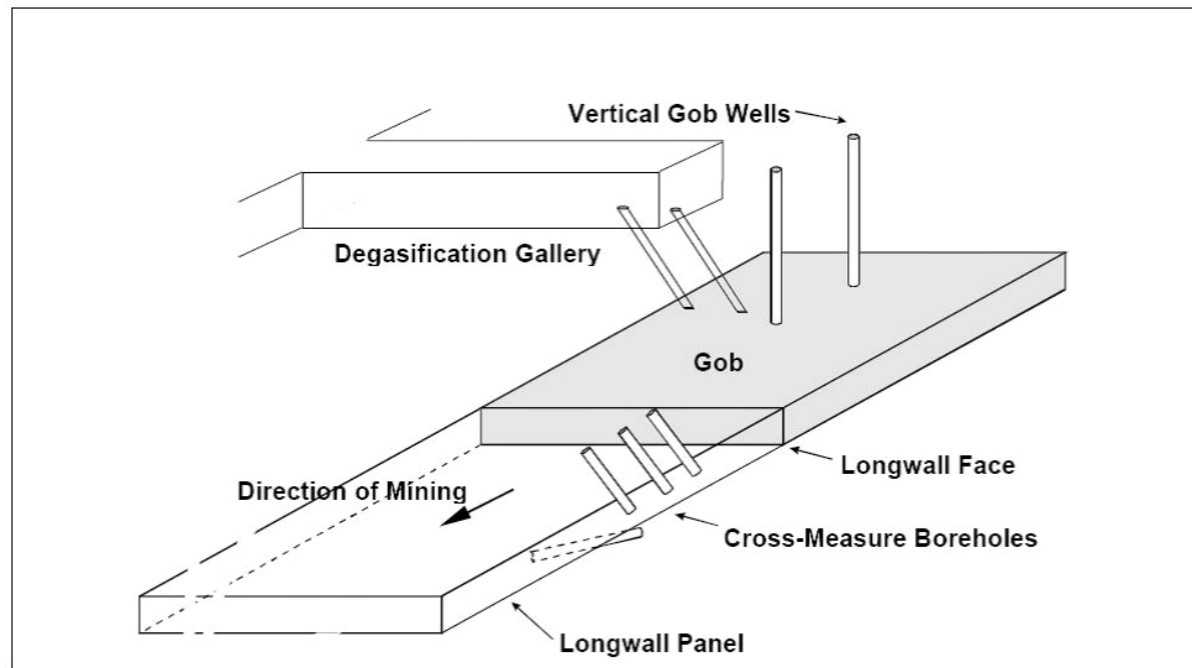
Vertical Pre-Mine Borehole Simulation Results

As expected, the 20 ac (8 ha) spacing case produces the most gas due to the greater number of wells drilled within the study area. However, due to the low permeability of the coal seams in the study area, only 17% of the methane-in-place is recovered from both seams after 10 years of production.



Selected Degasification Methods: Gob Boreholes

- Drilled vertically/deviated from the surface, from mine entries adjacent to the panel (cross-measure), or superjacent.
- Capture efficiencies of 30% to 70% depending on geological and reservoir settings.
- Concentration is generally 35% to 75%.



Selected Project Experience: Estimating Gas Drainage from Gob Boreholes

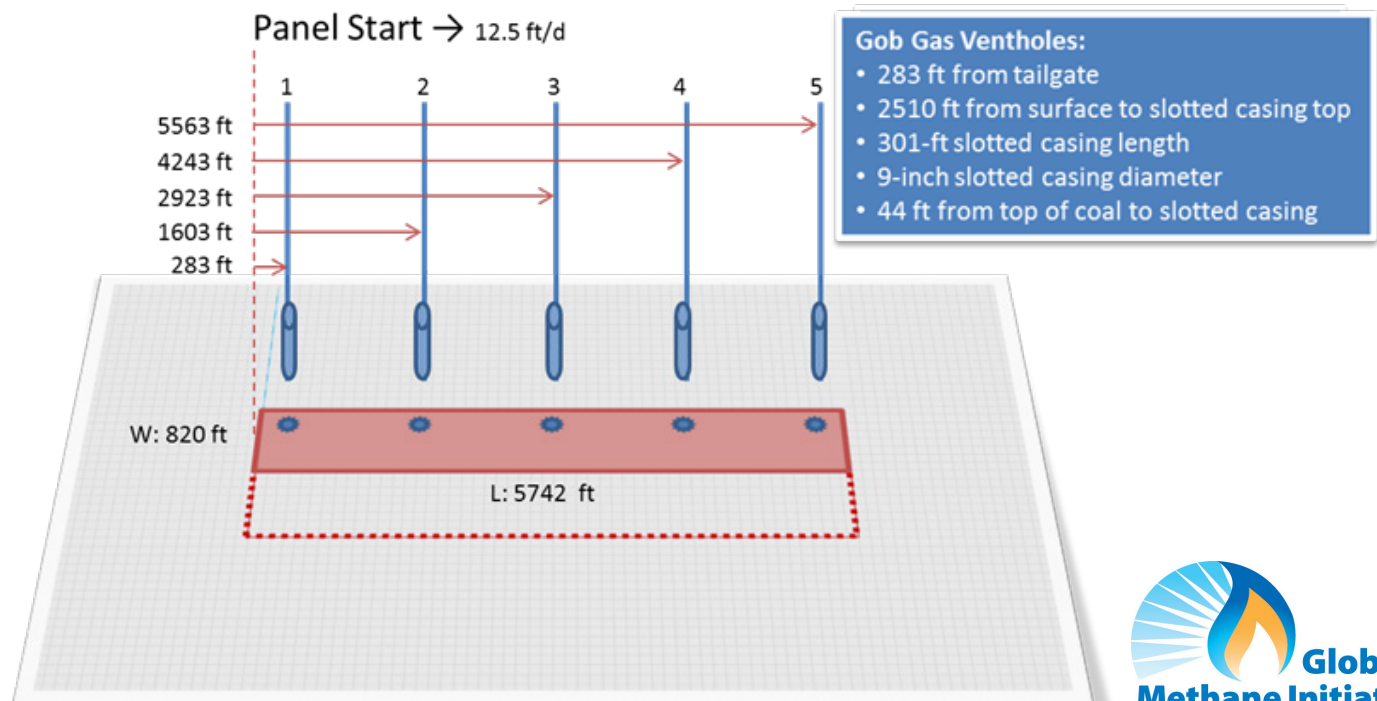
Gas Drainage Approach

- Drainage approach utilizing vertical gob boreholes drilled from the surface.

Project Details

- Mine Name: Komsomolets Donbassa Mine
- Mine Location: Kirovskoye, Ukraine
- Mine Operator: DTEK

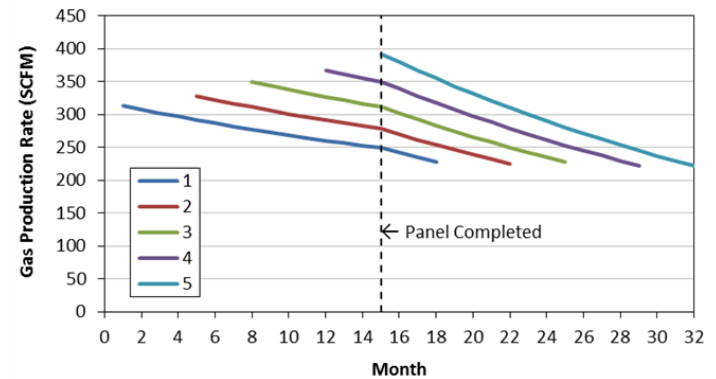
Schematic Diagram of Gob Model Layout



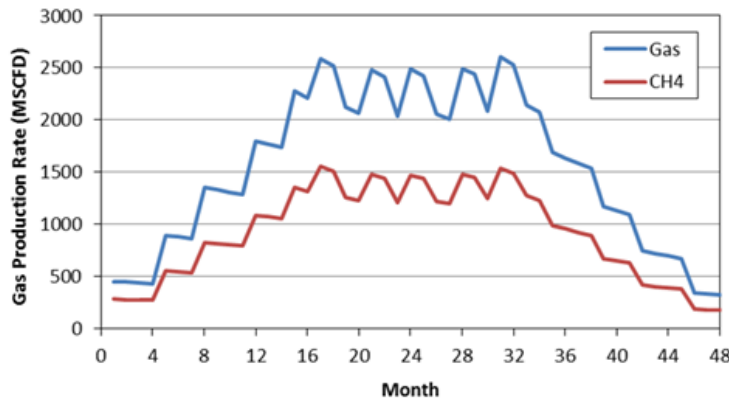
Gob Borehole Drainage Model Results

- To model surface gob gas production from longwall panels at the Komsomolets Donbassa mine, the Methane Control and Prediction (MCP) model was used.
- Specifically, the Gob Gas Venthole (GGV) Performance Prediction model for working depths exceeding 1,000 ft in active panels with advancing faces was used to model a longwall panel within the study area,

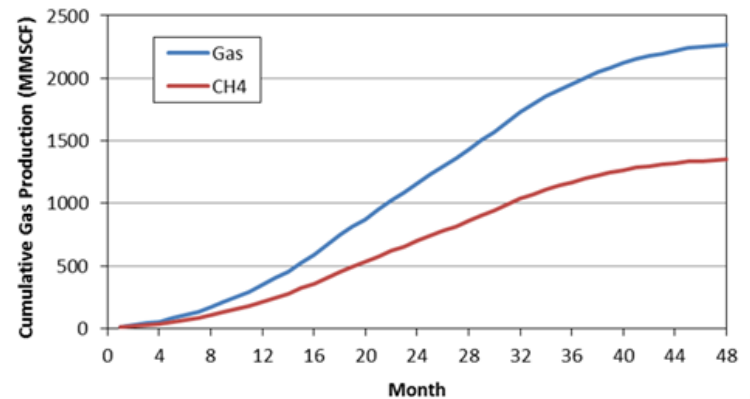
Gob Gas Production Rate by Well for Single Longwall Panel



Gob Gas Production Rate for Study Area



Cumulative Gob Gas Production for Study Area



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