INCREASING THE EFFICIENCY OF HORIZONTAL IN-SEAM DRAINAGE

Global Methane Forum, March 28-30, 2016

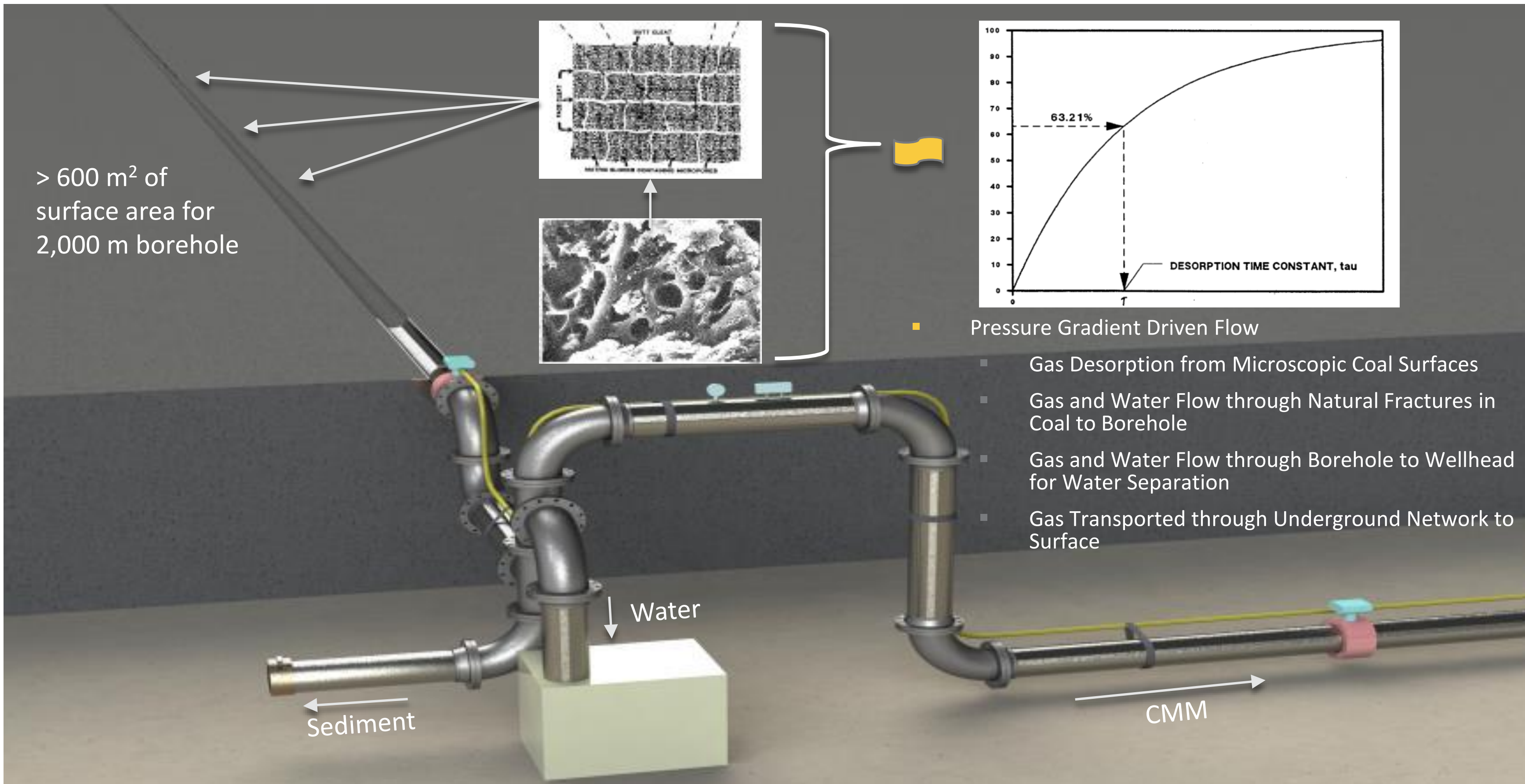
Increasing Efficiency of In-Seam Drainage

dpi DRILLING PRODUCTS

REI | DRILLING DIRECTIONAL UNDERGROUND

- Effectiveness
  - Significantly Reduce In-Situ Gas Contents in Advance of Mining
  - Improve Mine Safety and CMM Production (Quantity and Quality)
- Implementation
  - Drilling Technology
  - In Advance of Mining From Underground and Surface
- Increasing Efficiency
  - Engineering Design Considerations
  - Gas Management Considerations
  - Mine Appropriate Approach
- Summary

Effectiveness of In-Seam Drainage



- Pressure Gradient Driven Flow
  - Gas Desorption from Microscopic Coal Surfaces
  - Gas and Water Flow through Natural Fractures in Coal to Borehole
  - Gas and Water Flow through Borehole to Wellhead for Water Separation
  - Gas Transported through Underground Network to Surface

Implementation of Horizontal In-Seam Drainage

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Drilling Technology

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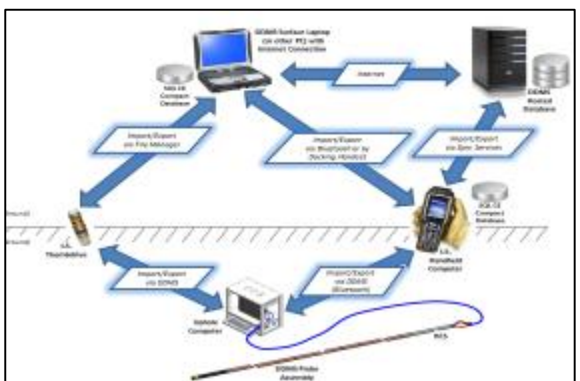
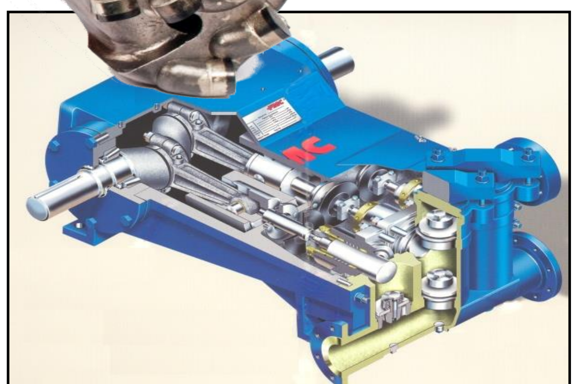
DIRECTIONAL UNDERGROUND





Implementation of Horizontal In-Seam Drainage

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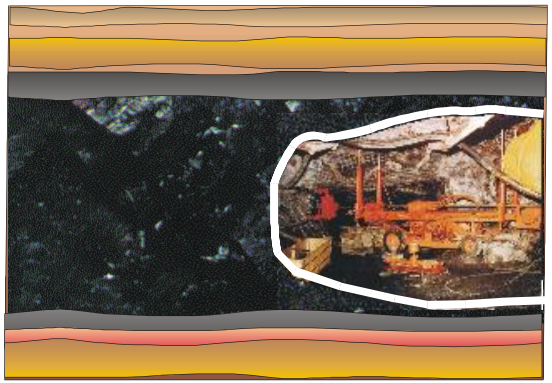
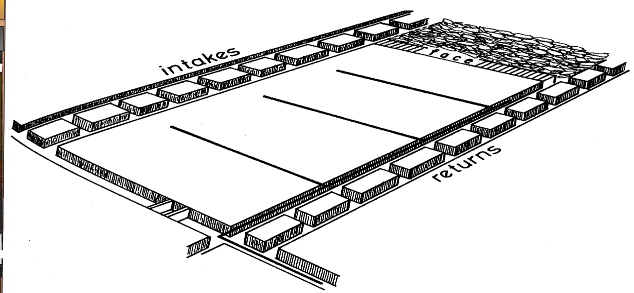
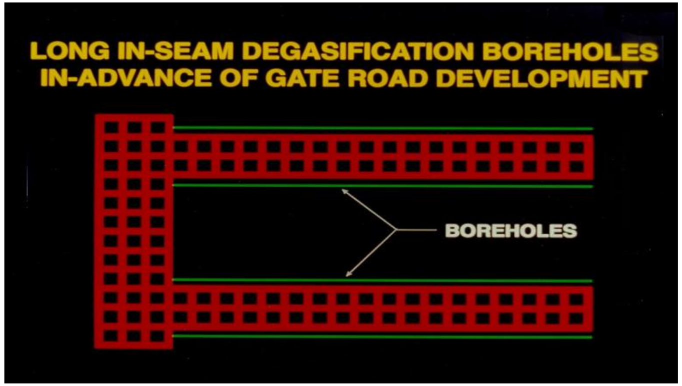
- Underground

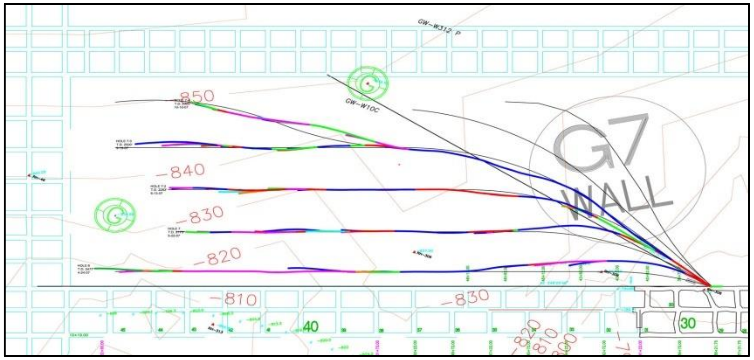




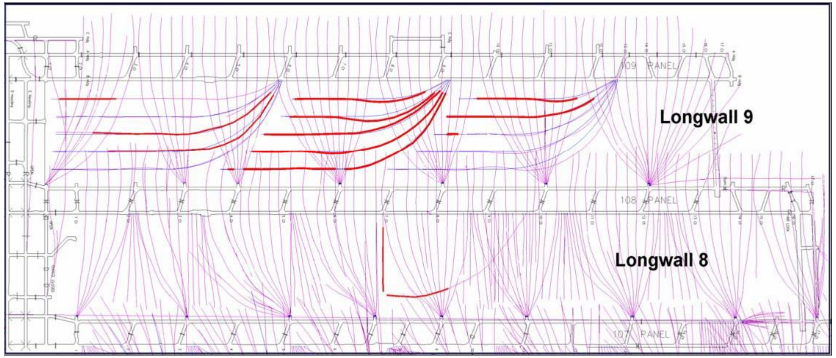
- Cross-Panel Boreholes



- Shield Gateroad Developments



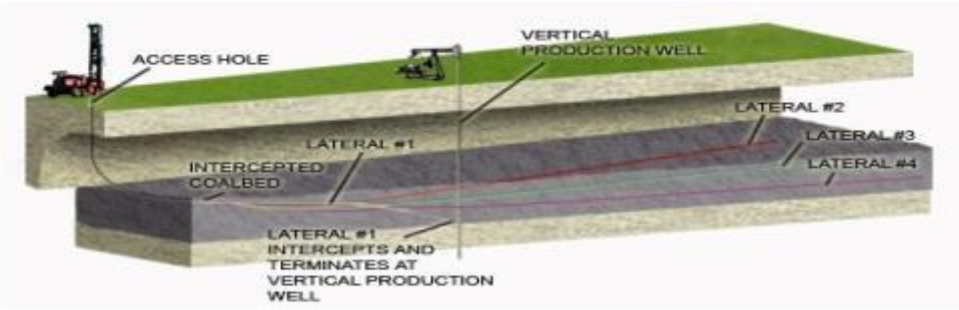
- Reducing GC in Longwall Panels

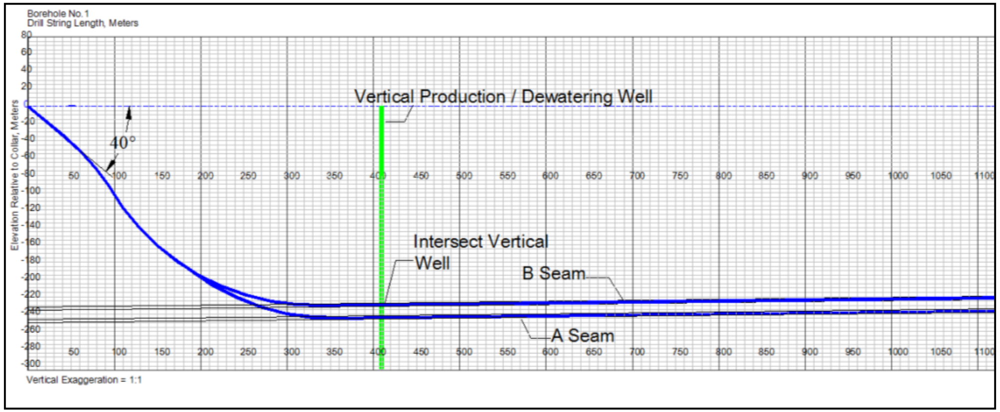


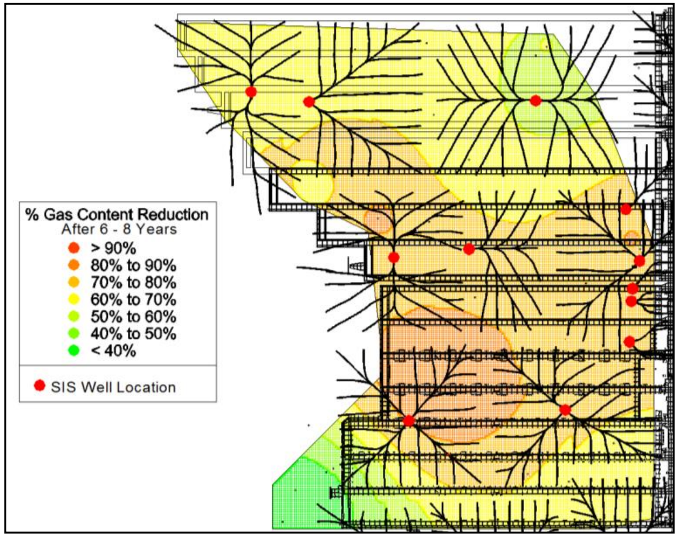
- Reducing GC with Outburst Protection

Implementation of Horizontal In-Seam Drainage

- Surface



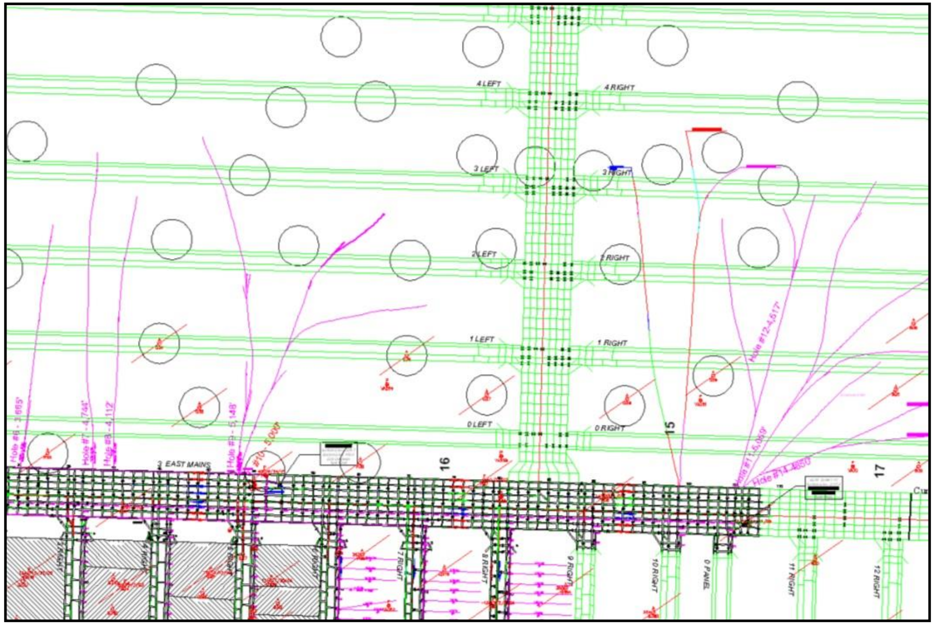




- **Medium Radius SIS Approach**
- **Short Radius Approach**

Implementation of Horizontal In-Seam Drainage

- Complementary Approach



- Directionally Drilled Boreholes to Complement Vertical Frac Wells

- From Mine Infrastructure

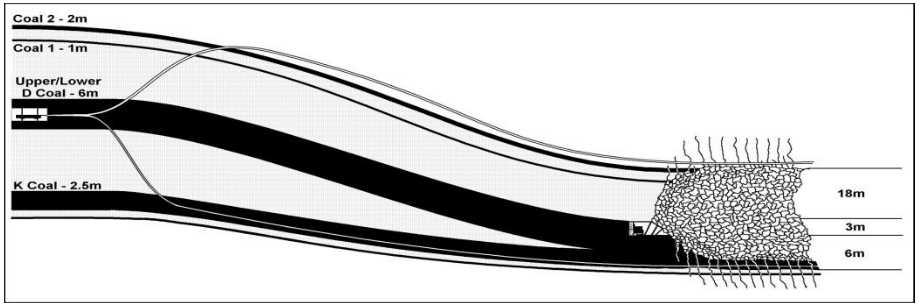
- From Bottom of Shaft Developed in Advance of Mining

What Makes Horizontal In-Seam Drainage Systems Efficient?

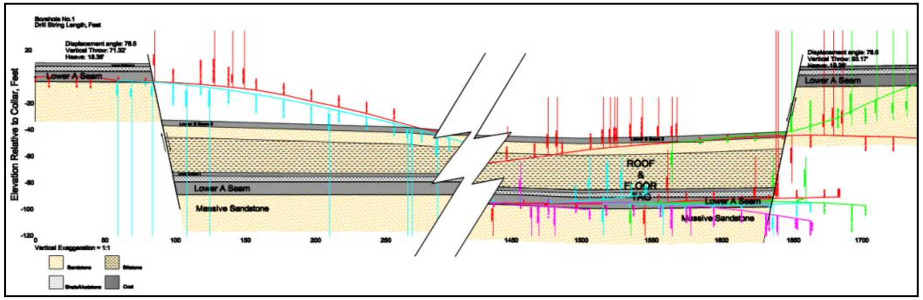
- **<u>Engineered</u>** and strategically placed and spaced long horizontal in-seam boreholes developed significantly in advance of mining that consider geologic conditions, reservoir conditions, and mining plans.
- Properly designed **<u>Gas Management Systems</u>** that maintain pipelines accessible, safe from damage or leaks, free of entrained water, requiring minimal maintenance, and equipped with gas monitoring and control systems to maximize methane drainage efficiency and recover high quality CMM.
- Cost effective implementation that is **<u>Mine Appropriate</u>** – considers mine operator plans and flexibility, CMM developer objectives and risks, product and market changes, and CMM end-use plans.

Engineering Design

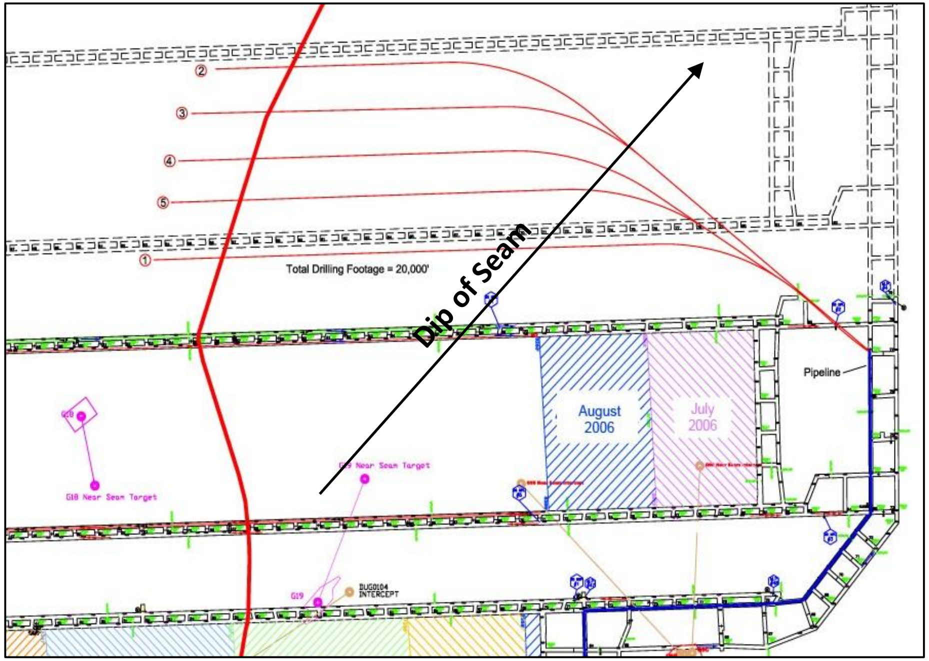
- Geologic Considerations
  - Coal thickness, stratigraphy, rank, geologic structure, ash



- Borehole Placement in Adjacent Strata



- Borehole Placement to Consider Geologic Structure

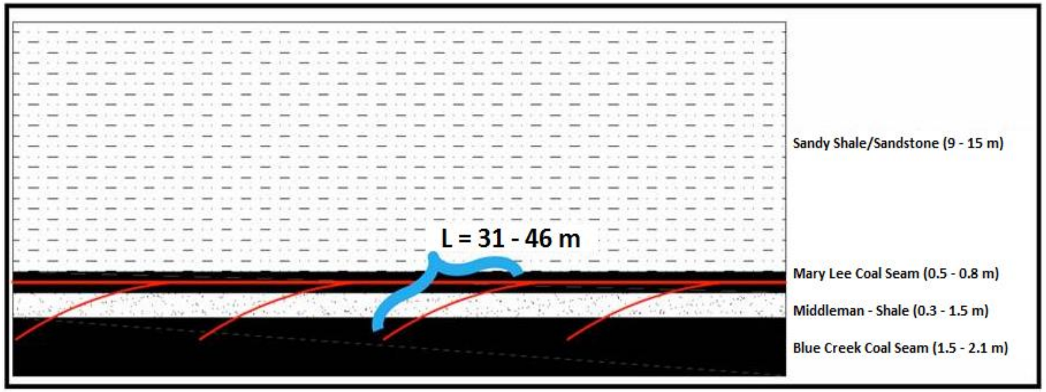


- Boreholes Placed Up-Dip to Efficiently Manage Water Accumulation

Engineering Design

- Geologic Considerations
  - Coal Seam Friability

- Hardgrove Grindability Index > 100



- Borehole Placement from Adjacent Drillable Horizons

Engineering Design

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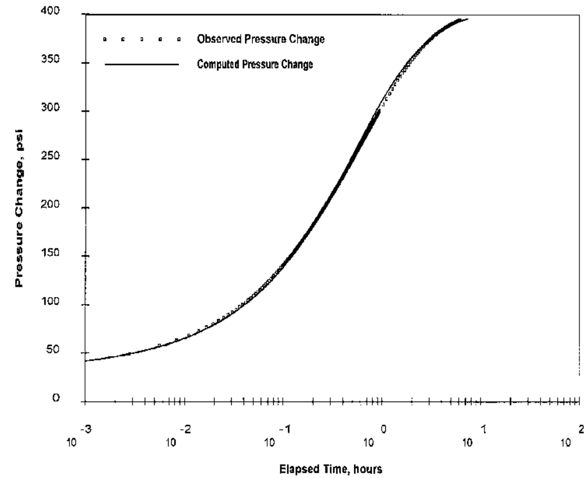
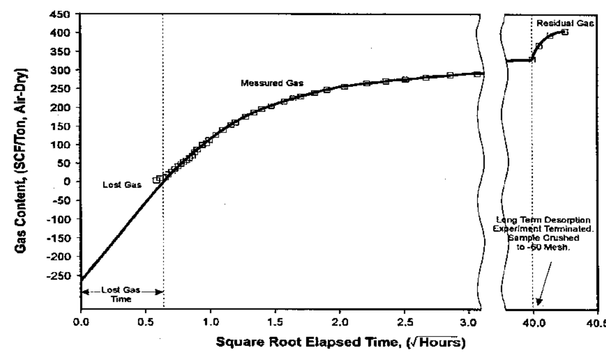
- Reservoir Considerations
  - Gas Content
  - Diffusion Time Constant
  - Adsorption/Gas Saturation
  - Permeability
  - Reservoir Pressure, Water Saturation

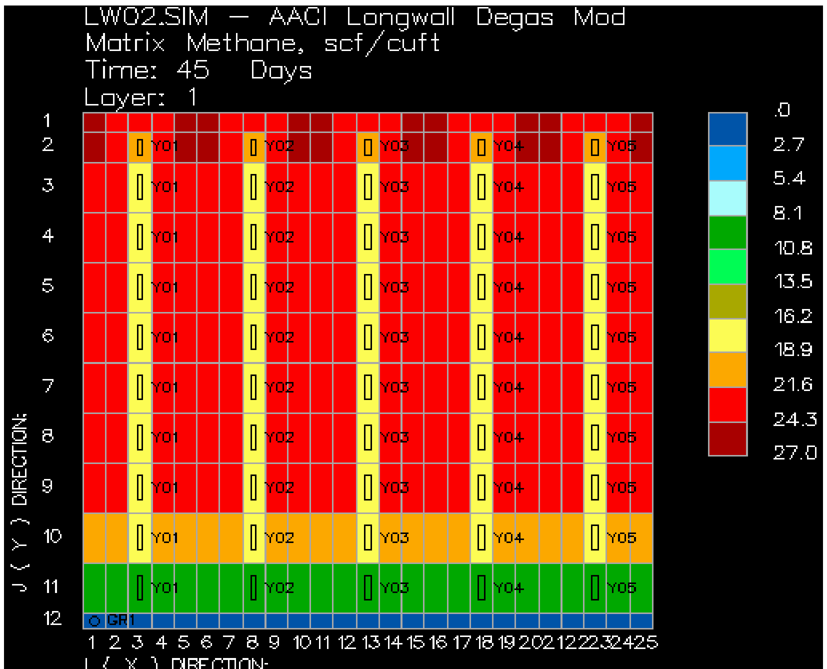




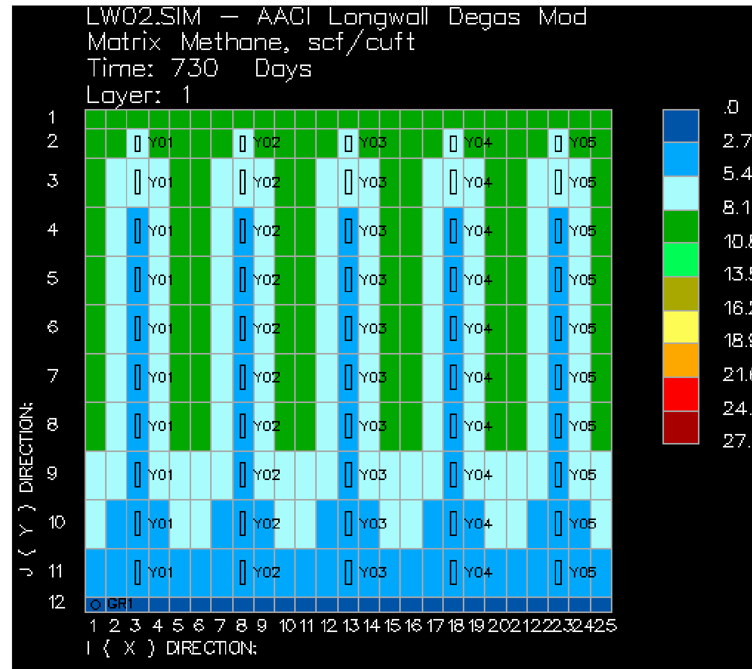
- Gas Content Measurement by Direct Method
- Injection/Fall-Off

Engineering Design

Using Reservoir Modeling



GC$_I$ = 15 m^3/t, Spacing 20 m

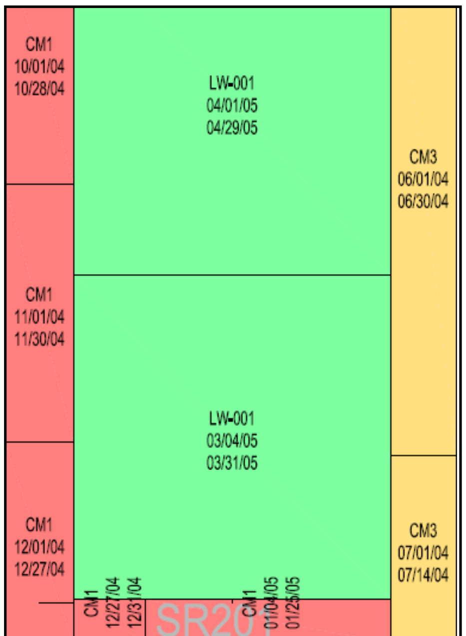


GC$_R$ = 6 m^3/t , 2 Years

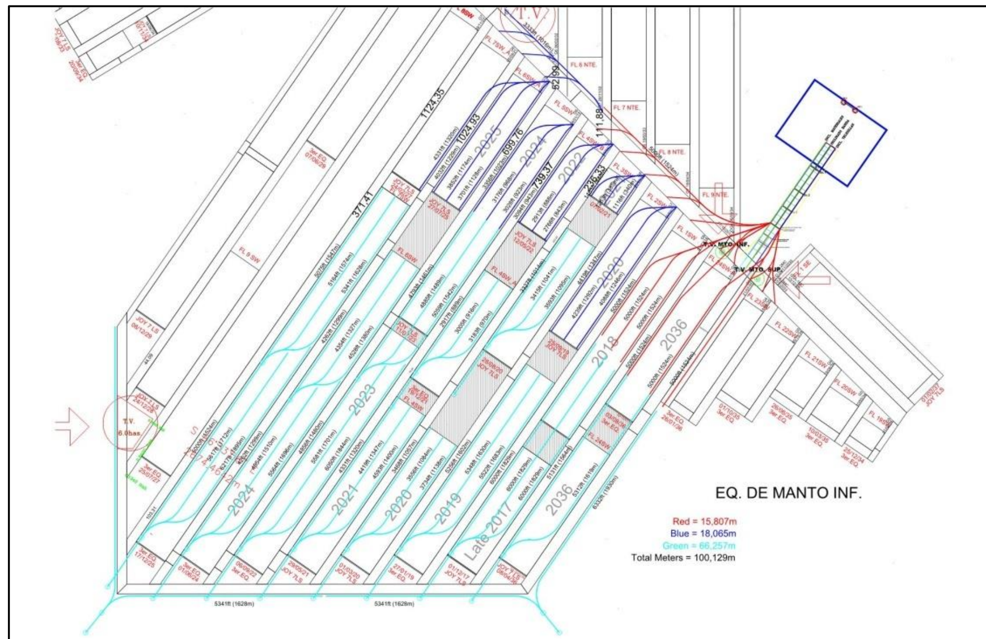
- **Borehole Spacing as a Function of Drainage Time**

Engineering Design

- Mining Plan Considerations
  - Gateroad Development Timing, Start of Longwall (Just in Time)
  - Available Drainage times, Multiple seams, Surface/Underground Approach



- Just in Time Development



- Underground Directional Drilling Complemented by SIS Approach

Engineering Design

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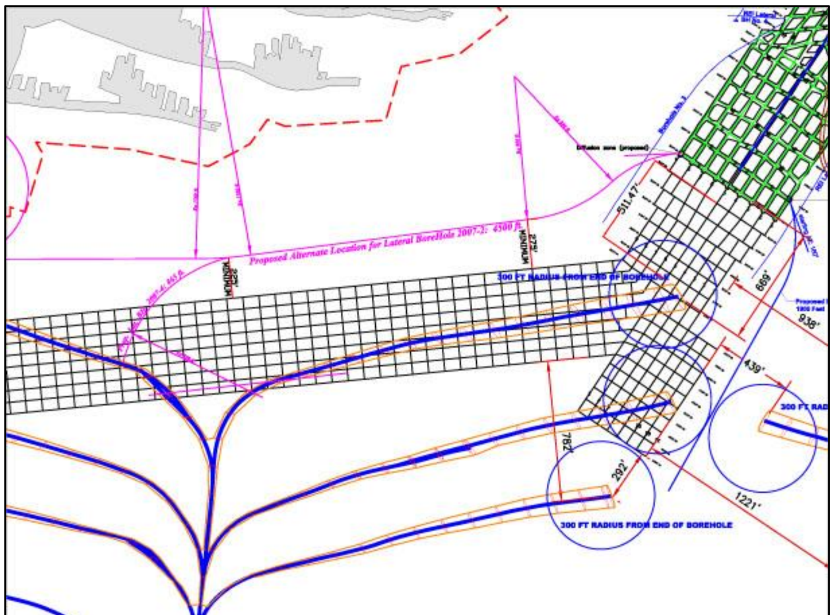
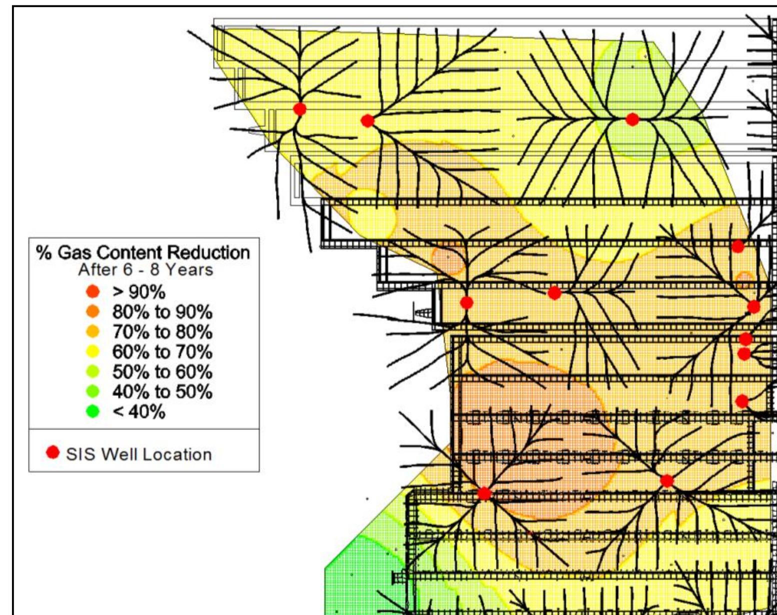
- Mining Considerations
  - Conflict in Objectives Between Mine Operator and Gas Producer

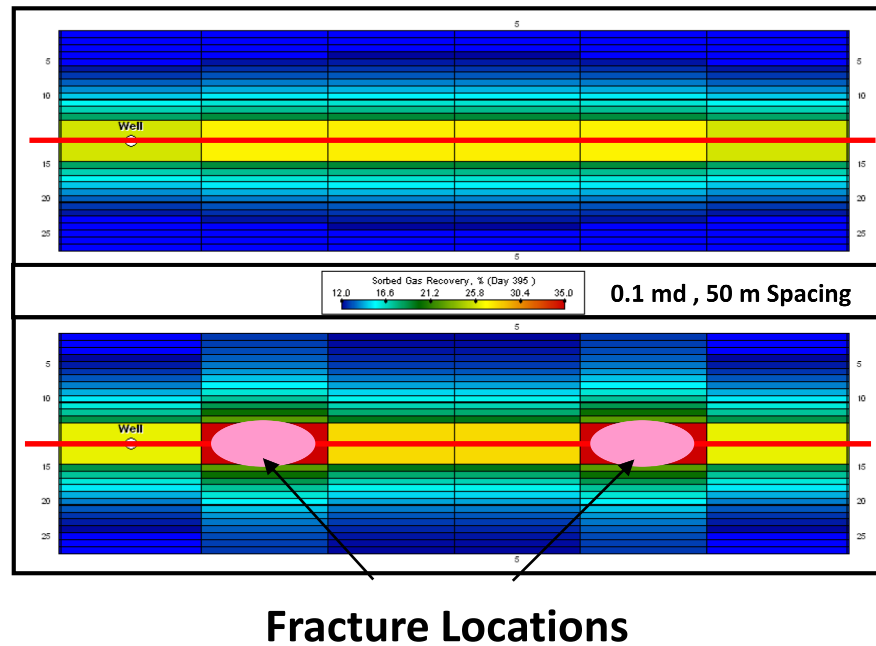




- **Mining to Intercept SIS Gas Production Prior to Plan**
- **Gas Producer Aligned with Mine Operator**

Engineering Design

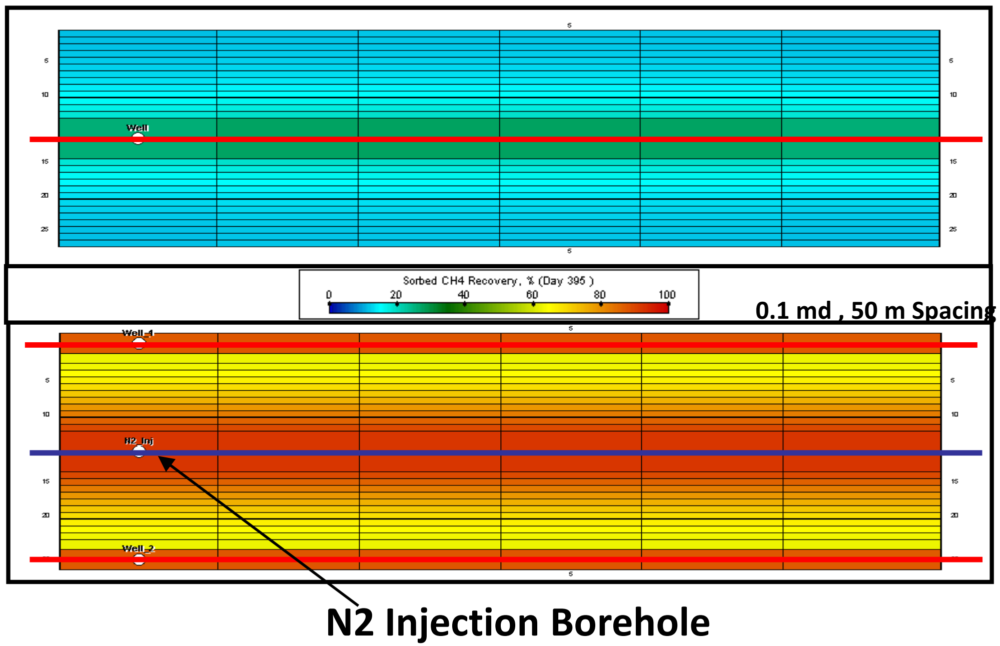
- Enhanced CMM Recovery Considerations
  - When Drainage Times Need Accelerated

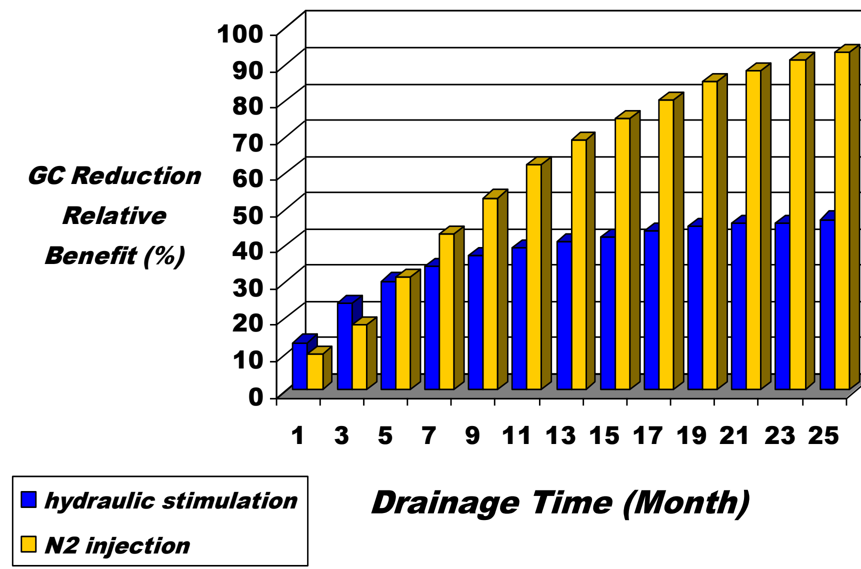


- In-Seam Straddle Packer for Fracing
- Impact of In-Seam Borehole Hydraulic Fracturing on GC Reduction

Engineering Design

- Enhanced CMM Recovery Considerations
  - When Drainage Times Need Accelerated

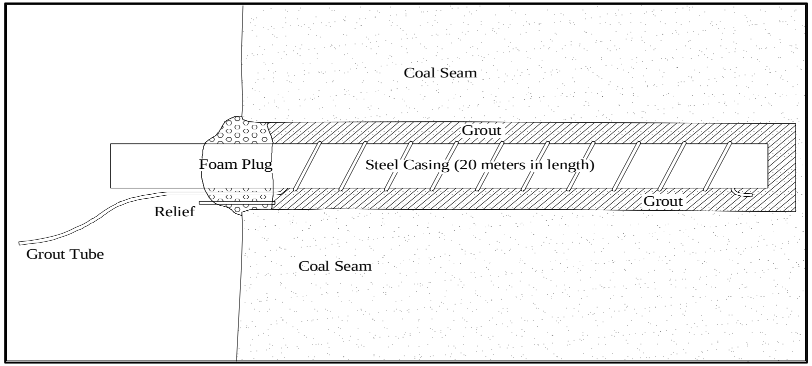


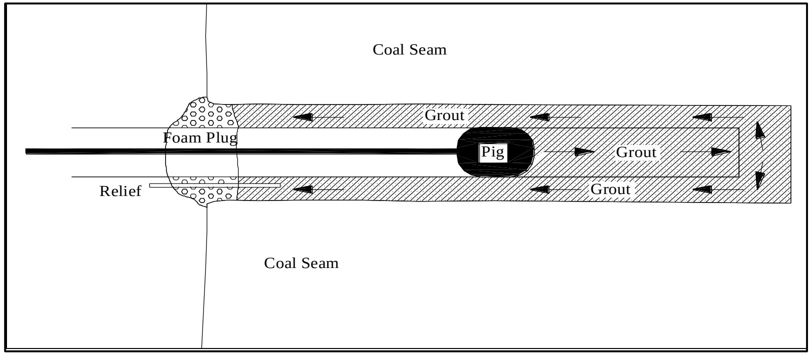


- Impact of Inert Gas Injection on Reduction of GC
- Relative GC Reduction Benefit of Fracing and Inert Gas Injection

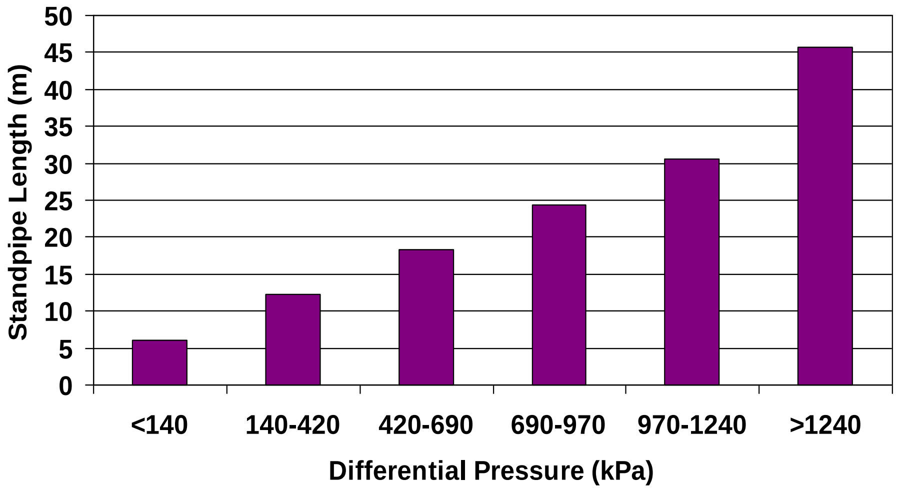
Gas Management

- Borehole Standpipes





- Initial and Secondary Grouting with Pressure Testing



- Minimizing Leakage Through Properly Designed Standpipes to Maximize CMM Recovery and Quality

Gas Management

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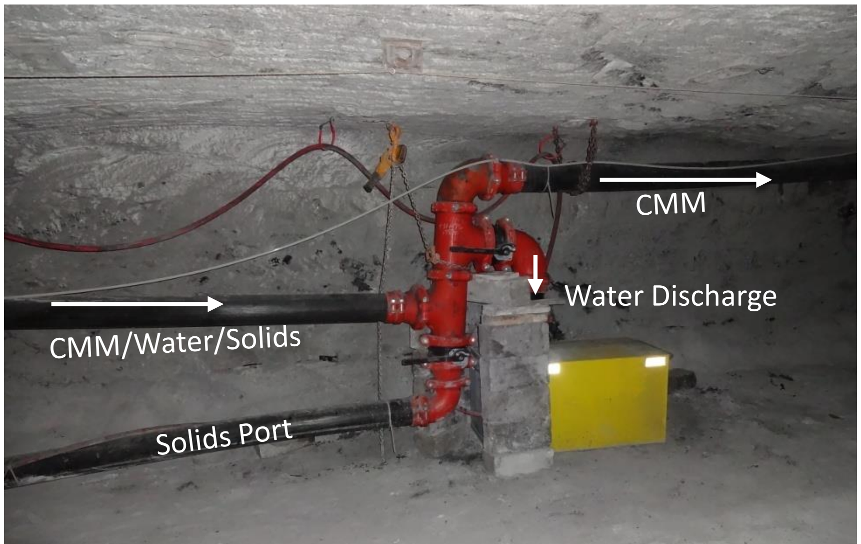
- Post-Drilling Wellhead

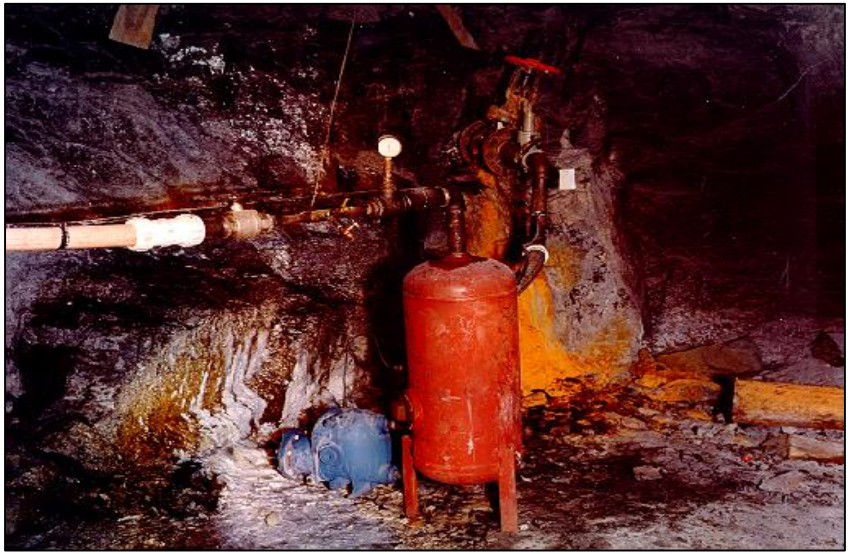


- **Maintenance Free Water Separation Under Vacuum**

- **Meter Run for CMM Flow, Pressure, and Quality Measurements**

Gas Management

- Pipeline Systems

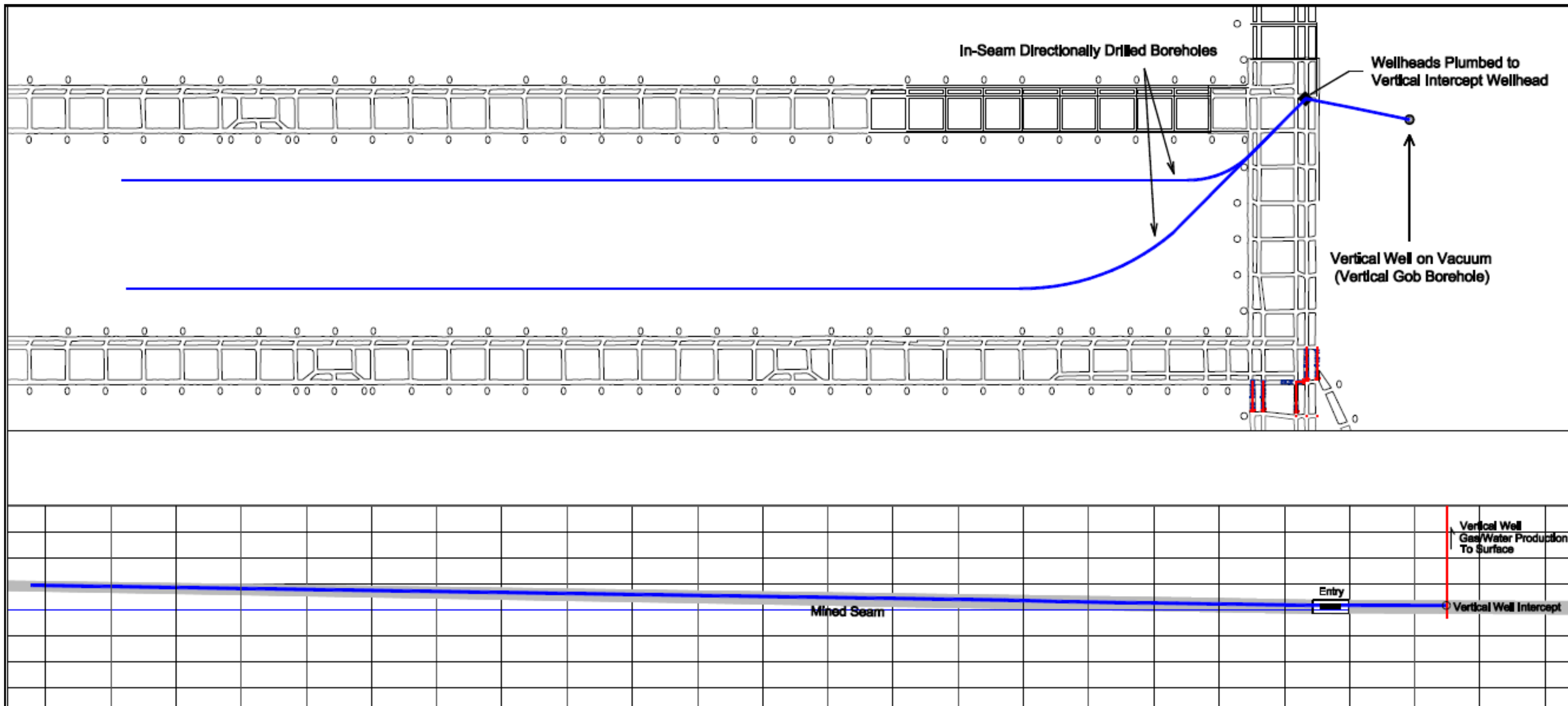


- Wellhead Isolation as Part of Sectionalization, Integrity Line

- HDPE, Grading, Sectionalization, and Integrity Line

Gas Management

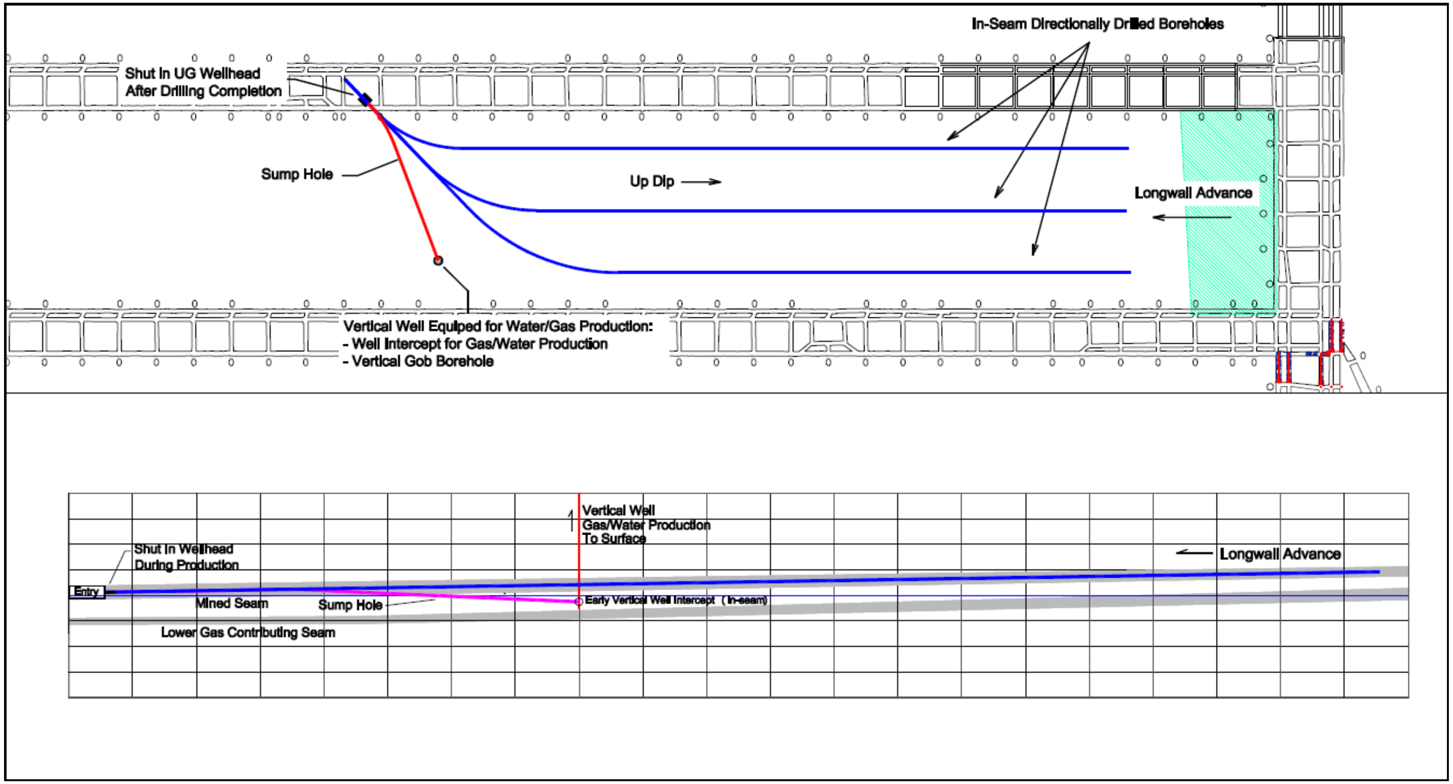
- Minimize the Use of Underground Pipelines



- **Gas Production Moved to Surface via Interception with Nearby Vertical Well or VGW with water separation in entry**

Gas Management

- Eliminate Underground Pipelines



- **Gas Production Moved to Surface via Interception with Vertical Well (Post Use Gob Well)**

Mine Appropriate Approach

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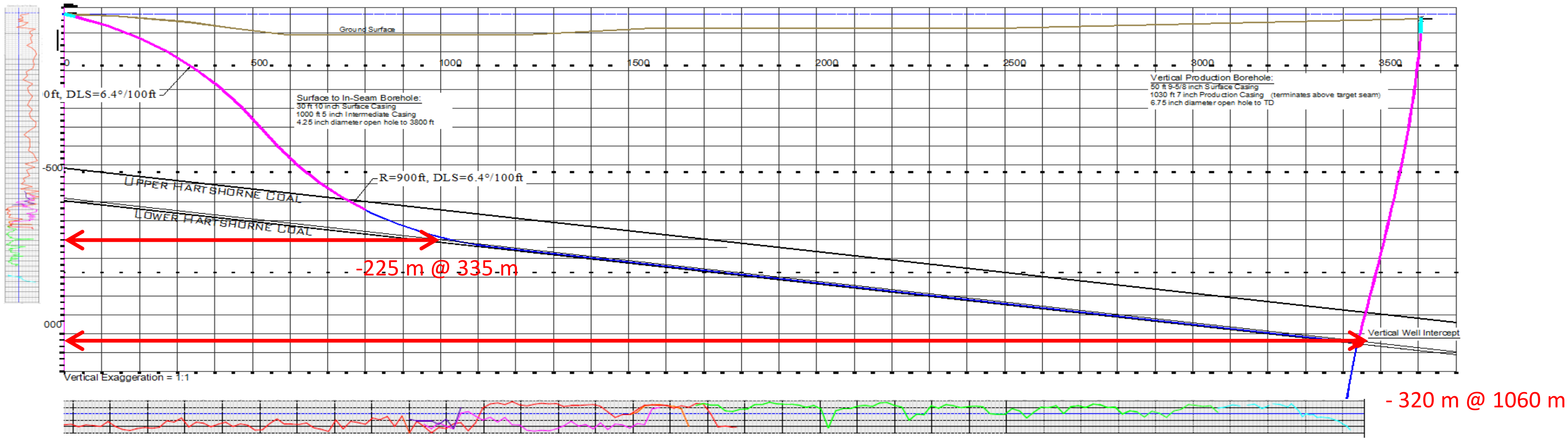
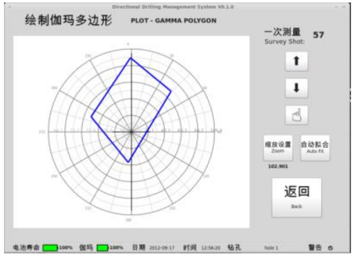
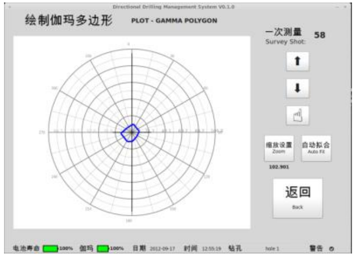
- Drilling Tools to Facilitate Implementation

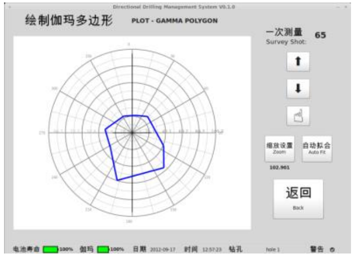




- Gamma Polygon – Near Roof



- Gamma Polygon - Coal



- Gamma Polygon – Near Floor

Mine Appropriate Approach

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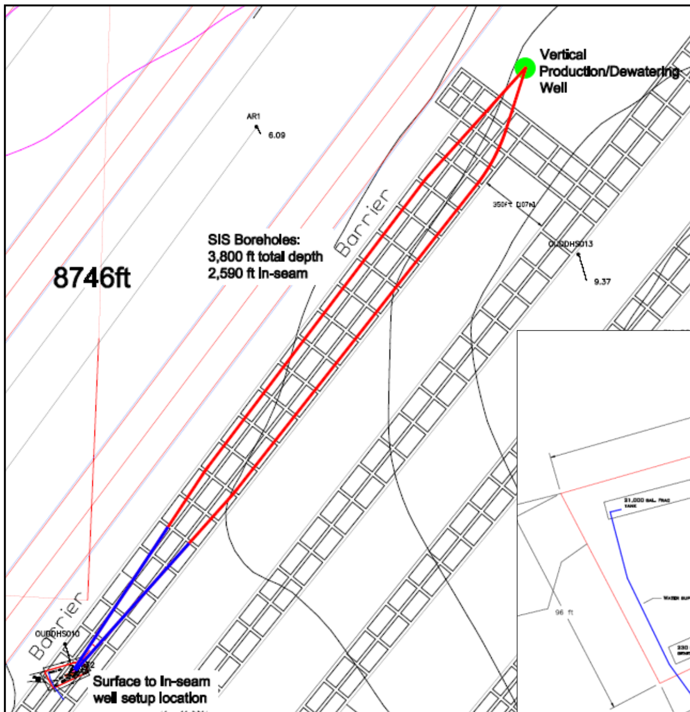
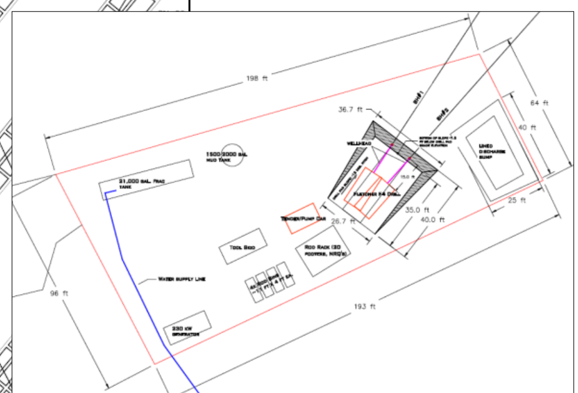
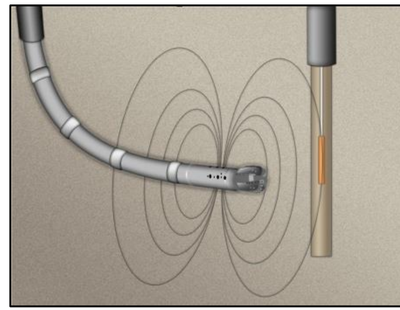
- Cost Effective Mine Appropriate Drilling Approach







- **1000 m SIS Gateroad Shield Boreholes Developed in Advance of Mining**
- **Medium Radius Drilling Equipment**

Mine Appropriate Approach

- Mine Appropriate CMM Use Objectives

- **CMM Quantity and Quality**
- **Reduce GHG Emissions**

Summary

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DIRECTIONAL UNDERGROUND

- State of the art in-seam directional drilling technology provides for longer length and more accurate placement of boreholes for improved methane drainage efficiency and longer drainage times.
- This technology provides the ability to maintain boreholes in-seam or in adjacent seams, or hit specific targets, and combine underground and surface systems.
- Extended reach technology to 2,000 m is available for underground applications.
- Geologic and reservoir properties, including mine plans, provide for Engineered solutions to improve the efficiency of horizontal in-seam methane drainage systems and increase CMM production and quality.
- In-Seam methane drainage solutions need to be implemented with a Mine Appropriate approach and consider mine plans, economics, and risks.

- **Extended Reach Drilling Equipment**