Surface Mine Methane Emissions: Current Practices, Challenges, and Opportunities

Workshop on
Coal Mine Methane and Abandoned Mine Methane in the context of Sustainable Energy
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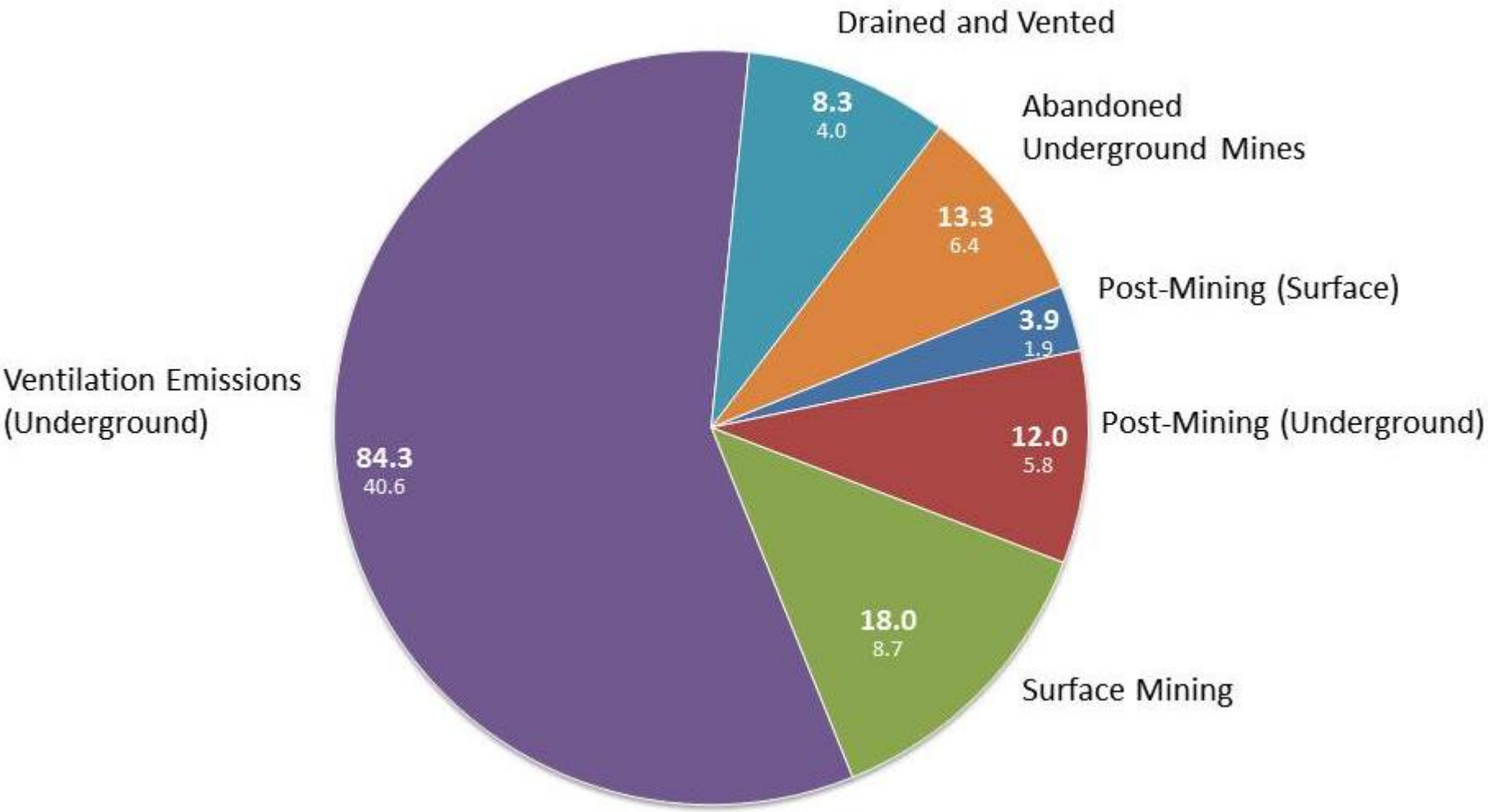
The Future of Surface Mining

Surface Mining in the 21st Century

- During the 20th century, underground mining was the dominating technique
- Today, coal production is undergoing a significant shift to open pit mining
- Technological developments have made it possible to mine reserves of declining grades and more complex geology without increasing costs
  - reduce energy consumption and cultivate their renewable energy sources
  - investing in renewable energy installations, deploying innovative energy technologies and driving towards more automated mine processes to optimize energy consumption

2015 U.S. CMM Emissions

Billion Cubic Feet (bcf), $MMTCO_2e$



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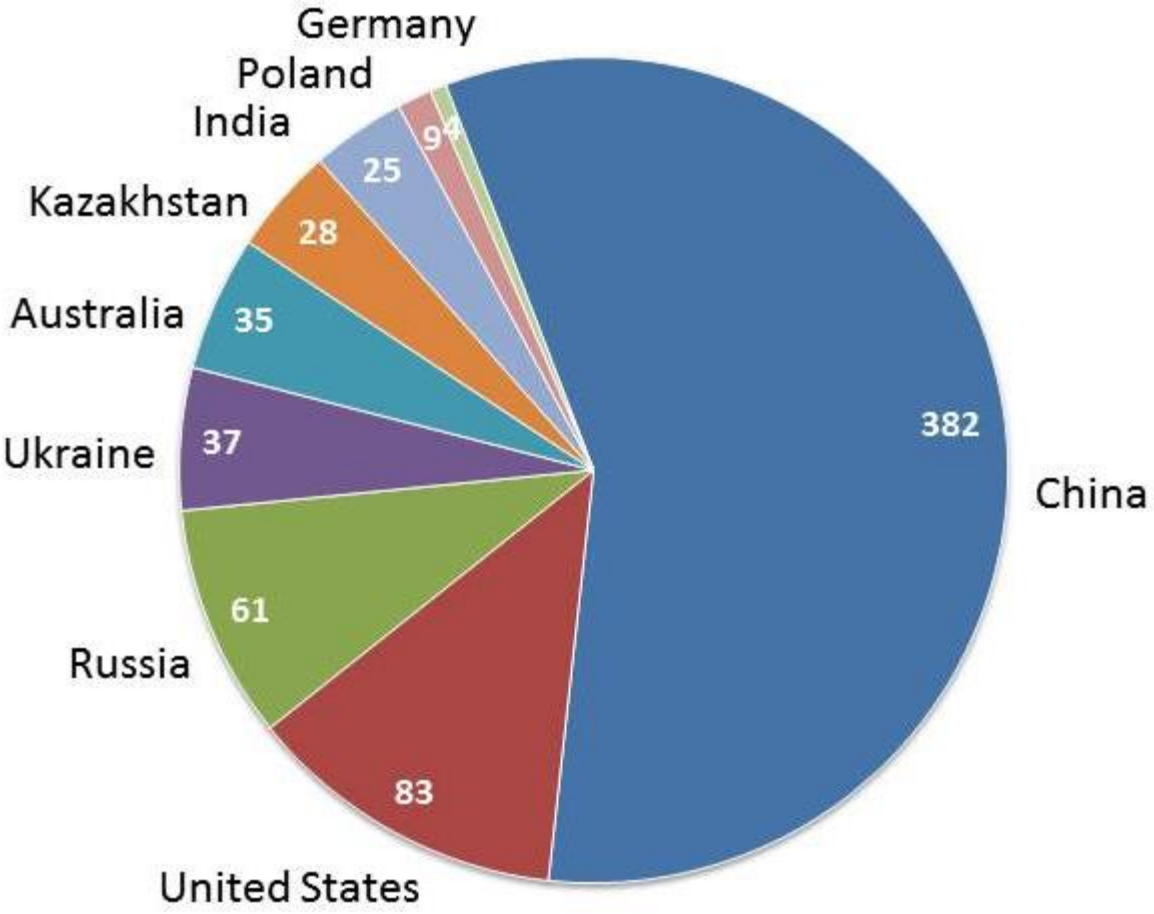
Estimated 2015 Global CMM Emissions

($MMTCO_2e$)



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Worldwide SMM Emissions

Country	Estimated Surface Mine Methane Emissions (Million cubic meters)	% of Total CMM Emissions	Year	Source
Russia	1,056	33%	2009	UNFCCC CRF
United States	903	18%	2009	USEPA (2011)
Indonesia	34	100%	2005	GMI (2010)
Mongolia	3.7	100%	2008	GMI (2010)
Philippines	0.22	92%	2008	GMI (2010), IPCC (2006)
India	43	2%	2008	GMI (2010), IPCC (2006)
Viet Nam	3.2	6%	1994	GMI (2010)

GMI (2010): Coal Mine Methane Country Profiles. Global Methane Initiative. December, 2010. http://globalmethane.org/tools-resources/coal_overview.aspx; IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy, Chapter 4: Fugitive Emissions. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf; UNFCCC Common Reporting Format, August 21, 2011; USEPA (2011): Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. USEPA #430-R-11-005. April, 2011. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Initiatives for Surface Mine Methane Drainage

Initiatives for Surface Mine Methane (SMM) Drainage

2003: U.S. Bureau of Land Management (U.S.BLM)

- Conflict Administration Zones (CAZs)

2005: EPA Surface Mine Methane Assessment (internal report)

2009: U.S. Verified Carbon Standard (VCS) methodology

2010: Clean Development Mechanism (CDM) methodology

- ACM0008 version 7 now includes opencast/surface mines

Recent Initiatives Impacting SMM Drainage

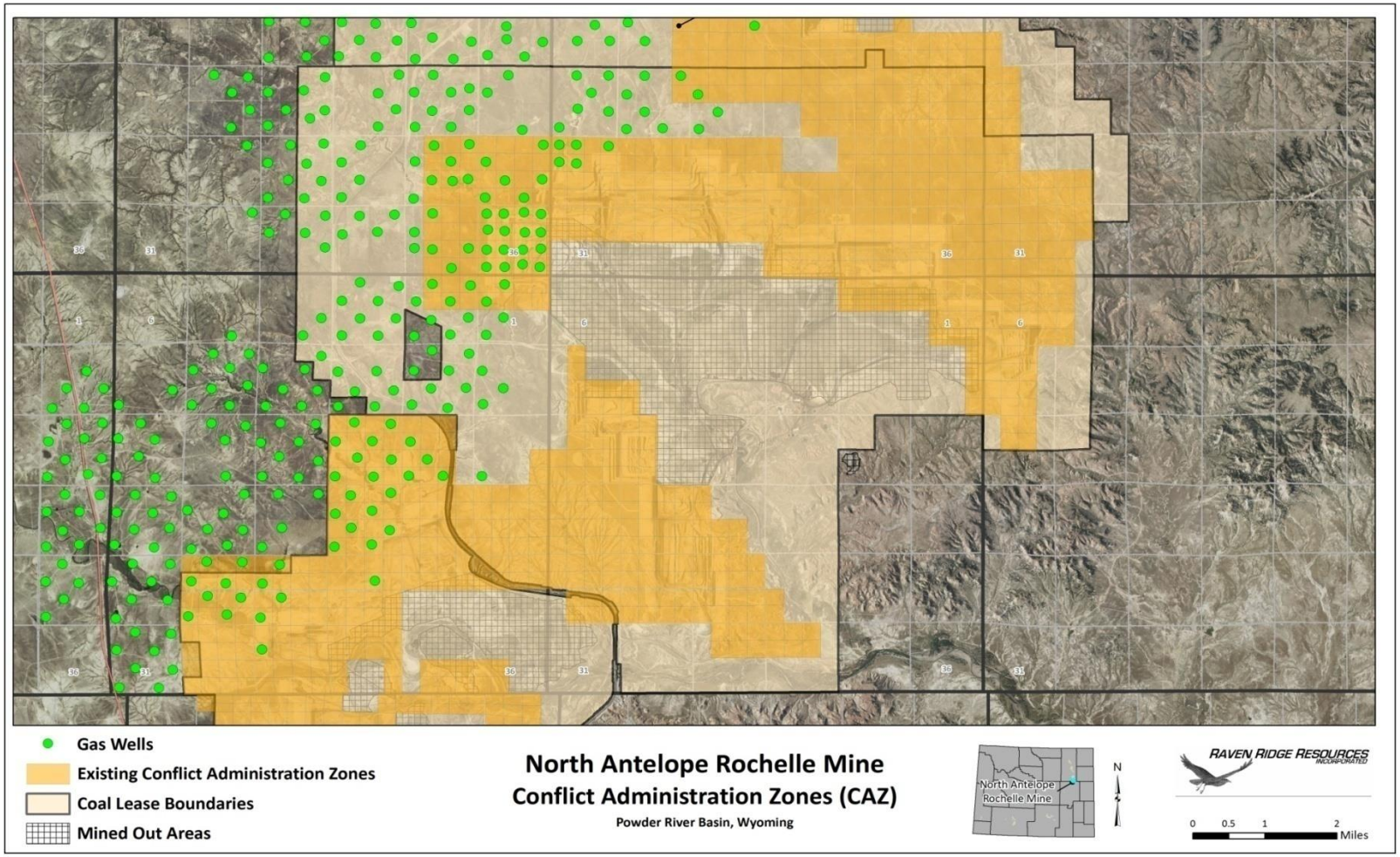
- 2012: Climate Action Reserve
  - Coal Mine Methane Project Protocol
    - Excludes surface mines
- 2013: Mexico's Voluntary Carbon Credit Exchange
  - Has projects registered through CDM, VCS< and CAR
- 2013: Québec Cap-and-Trade System for Greenhouse Gas Emissions Allowances
  - 5 protocols, 2 focus on coal mining
    - Active coal mines – Destruction of methane from a drainage system
  - Linked to California Registry in 2015
- 2014: California Air Resources Board
  - Mine Methane Capture Protocol
    - Active underground mine VAM
    - Active underground mine methane drainage Abandoned underground AMM
    - Active surface mine methane drainage

Mine Methane Capture Protocol

Methane drainage systems must consist of one, or a combination, of the following methane sources :

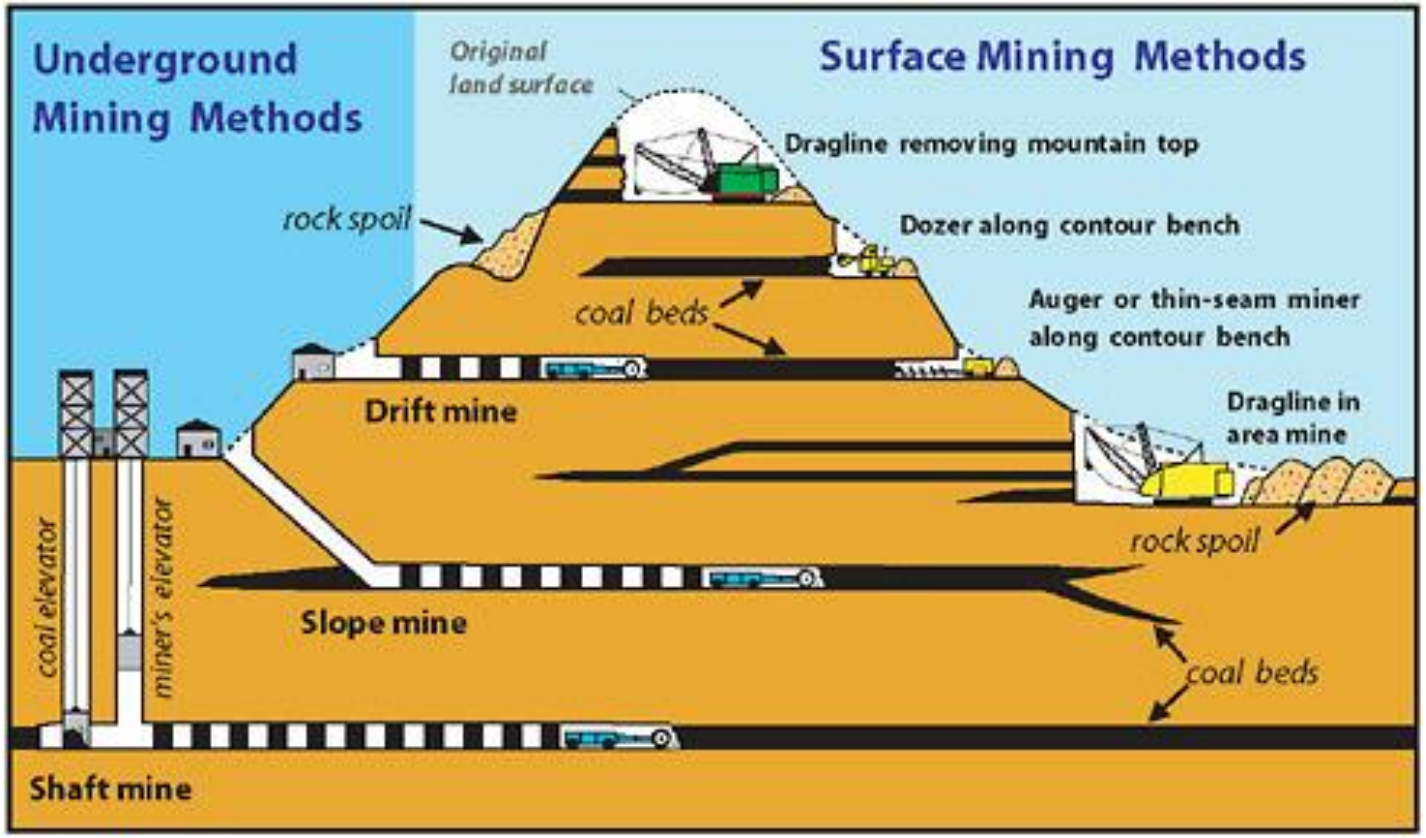
- (1) Pre-mining surface wells;
- (2) Pre-mining in-mine boreholes;
- (3) Existing CBM wells that would otherwise be shut-in and abandoned as a result of encroaching mining;
- (4) Abandoned wells that are reactivated; and
- (5) Converted dewatering wells

U.S. Surface Mine showing CAZ



Variability in Surface Mine Design – Challenges to Pre-Mine Drainage

Coal Mining Methods



Source: NRC-NAS (2007), Coal: Research and Development to Support National Energy Policy, p 61.

Variability in Surface Mine Design

Challenges to Pre-Mine Drainage

- Strip Mine
  - Mine develops along strike of the coal seam
  - Mine can be developed in tiers or contours parallel to strike
  - As each strip is mined, the waste rock is placed in the excavation produced by the previous strip.

Strip Mine

Bayan Resources, PIK Strip mine near Sekaret, East Kalimantan, Indonesia.

Variability in Surface Mine Design

Challenges to Pre-Mine Drainage

- Open-Pit Mine
  - Numerous levels or benches (stepped from surface to bottom of pit
  - Pit walls designed for slope stability and prevention of rock falls or wall failure
  - Haulage road located along side of pit to remove coal and waste rock
  - Waste rock is piled at surface near edge of pit

Open-Pit Mine

Panian Mine, Semirara Island, Philippines

Variability in Surface Mine Design

Challenges to Pre-Mine Drainage

- Mountain Top Mining
  - Mountaintop removal coal mining, often described as "strip mining on steroids," is an extremely destructive form of mining that is devastating Appalachia.
  - Huge draglines push overburden and interburden material into nearby streams and valleys, forever burying waterways.
    - In the past few decades, over 2,000 miles of streams and headwaters that provide drinking water for millions of Americans have been permanently buried and destroyed.

Mountain Top Mine

Approaches to Drainage

Vertical in Advance of Mining

- Boreholes are shut-in as mining approaches/evidence of air in produced gas
- Surface equipment and casing is removed prior to mine-through
- Timing – producing as far in advance of mining as possible
- Applicable to strip mines

Figure 1: Pre Mine Drainage

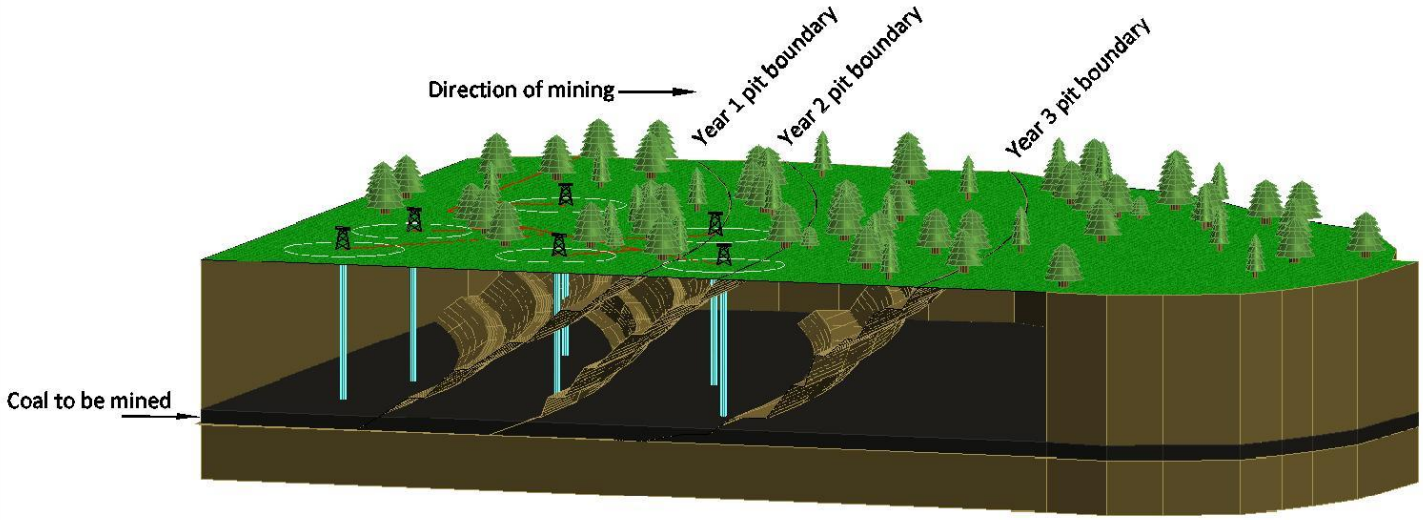
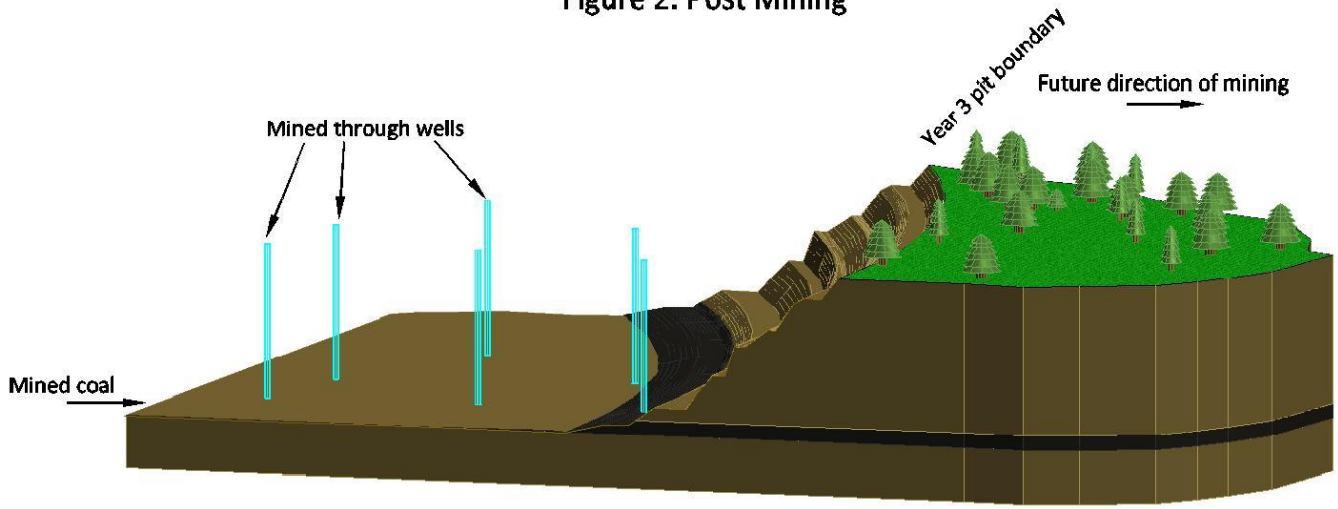


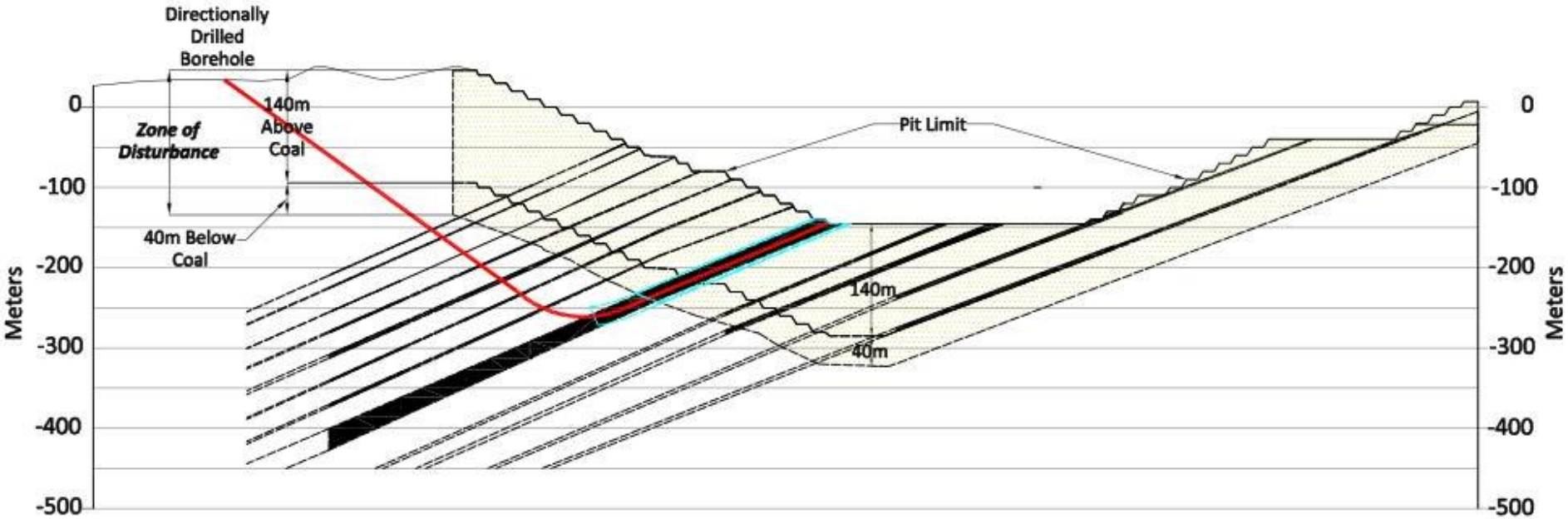
Figure 2: Post Mining



Lateral in Advance of Mining

- Depending on placement, boreholes may continue to produce during mining and post mining
- Applicable to some single seam strip mines and to open pit mines
- May access more coal if sidetracks are employed

Laterally-drilled Borehole

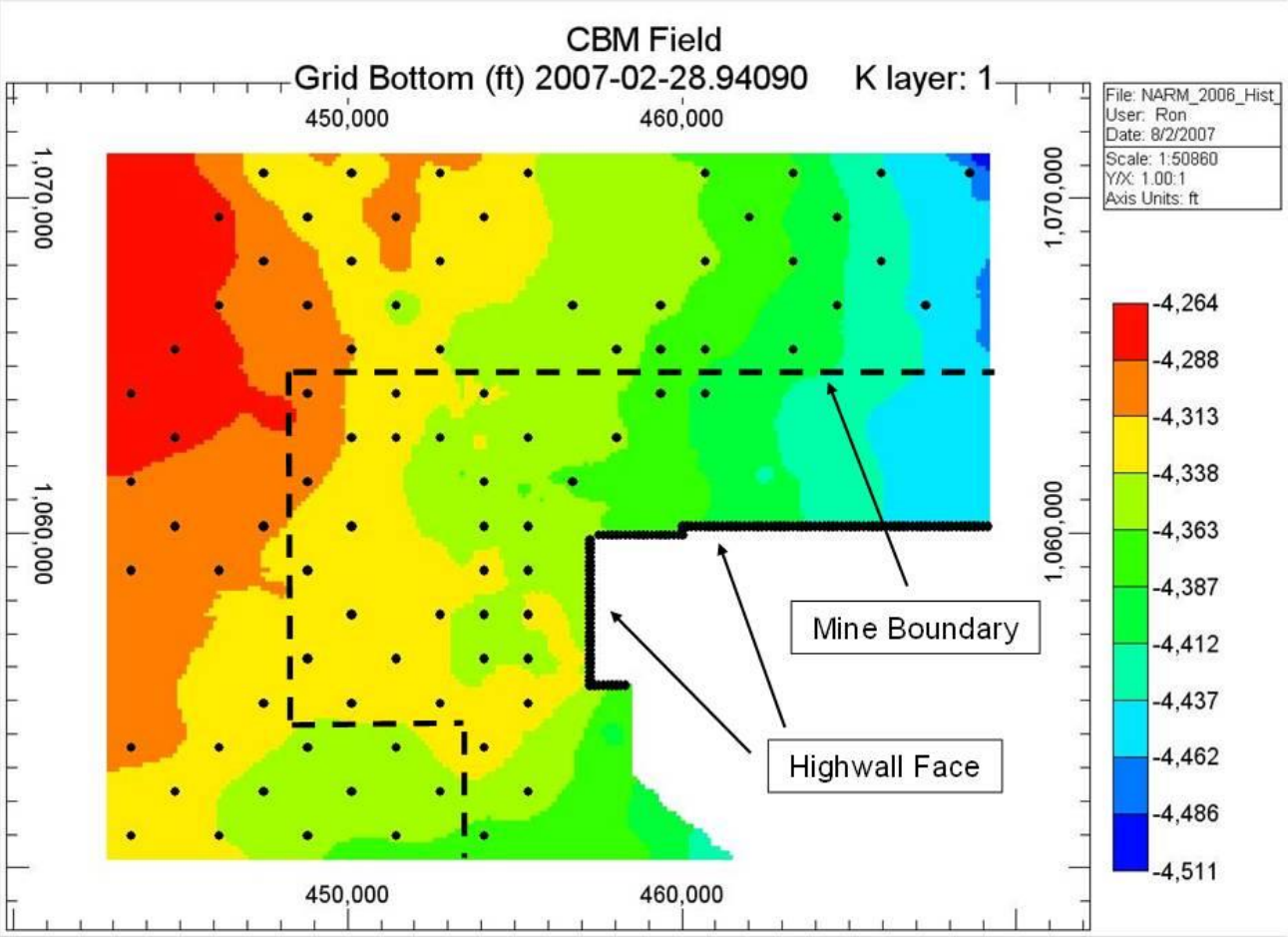


Surface Mine Drainage Considerations

- Coordination of gas drainage project development with mining operations is essential
- Surface logistics
  - Waste piles, storage, space issues
  - Gas transportation
    - Permanent vs. temporary gathering lines

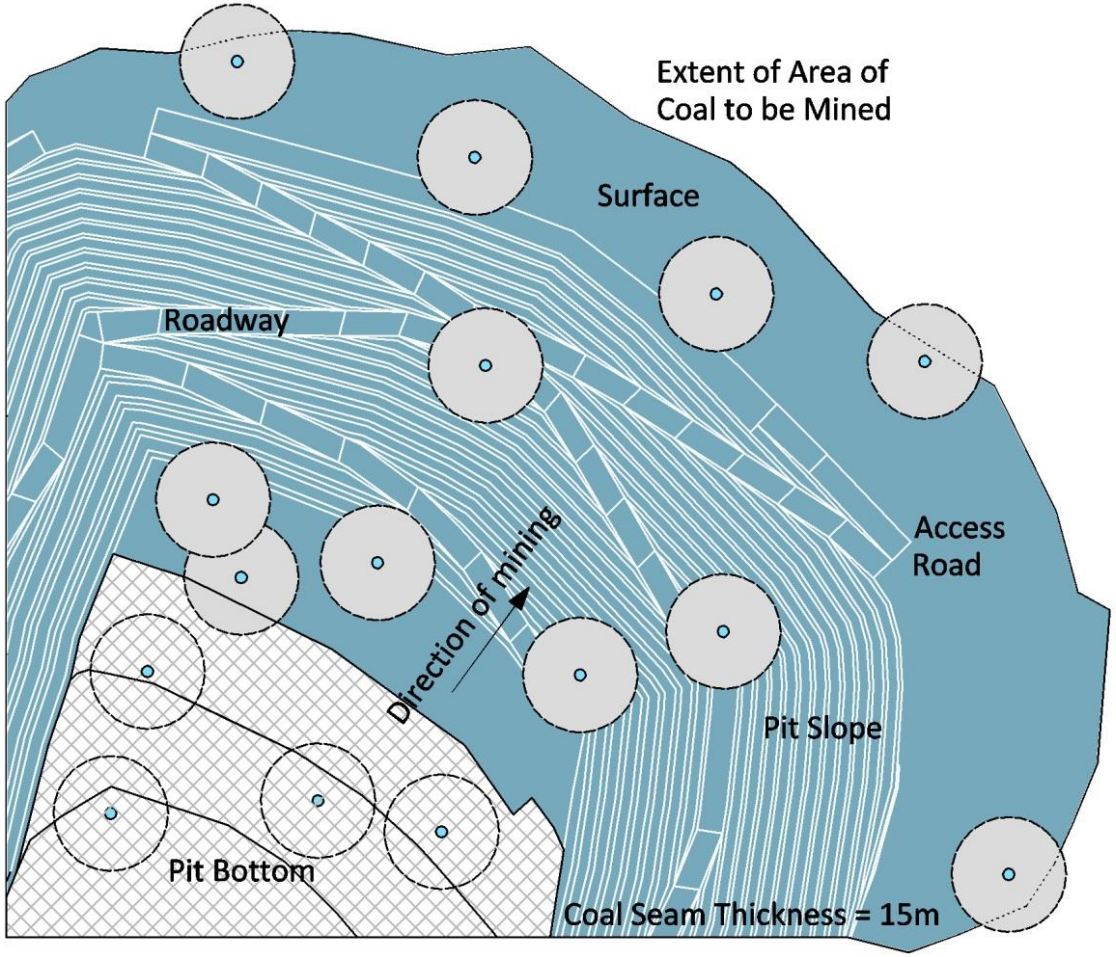
Qualifying Surface Mine Methane Production

Qualifying Production Under VCS



NARM PDD:
https://vcsprojectdatabase1.apx.com/mymodule/ProjectDoc/Project_ViewFile.asp?FileID=70&IDKEY=niquwesdfmnk0iei23nnm435oiojnc909dsflk9809adlkmlkf496530

Qualifying Production Under CDM



ACM0008: http://cdm.unfccc.int/methodologies/DB/OA37XAW7EI9WHJVZ97RGH2EZ5S9E93/view.html

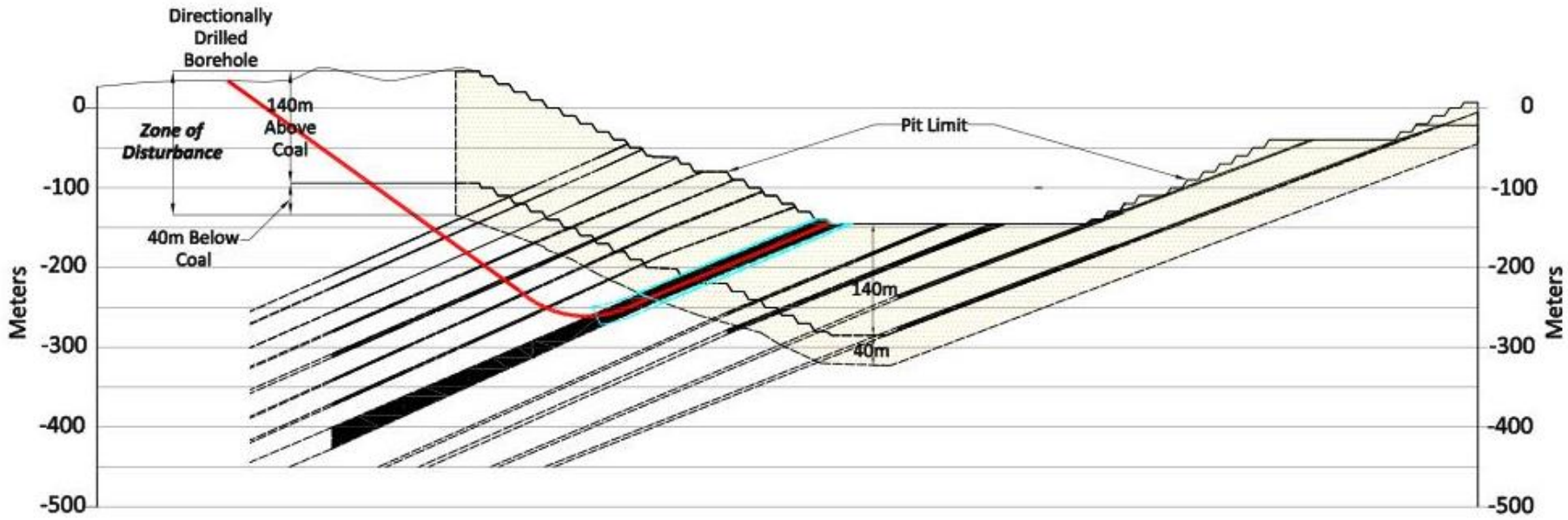
Qualifying SMM Production Under ARB

- Compliance Offset Mine Methane Capture Protocol
  - Performance based
  - The protocol provides eligibility rules, methods to quantify GHG reductions, offset project-monitoring instructions, and procedures for preparing Offset Project Data Reports. Additionally, all offset projects must submit to annual, independent verification by ARB-accredited verification bodies.
  - A methane destruction device for an active surface mine methane drainage activity must not have been operational at the mine prior to offset project commencement.
  - Project must be listed with an ARB approved offset project registry

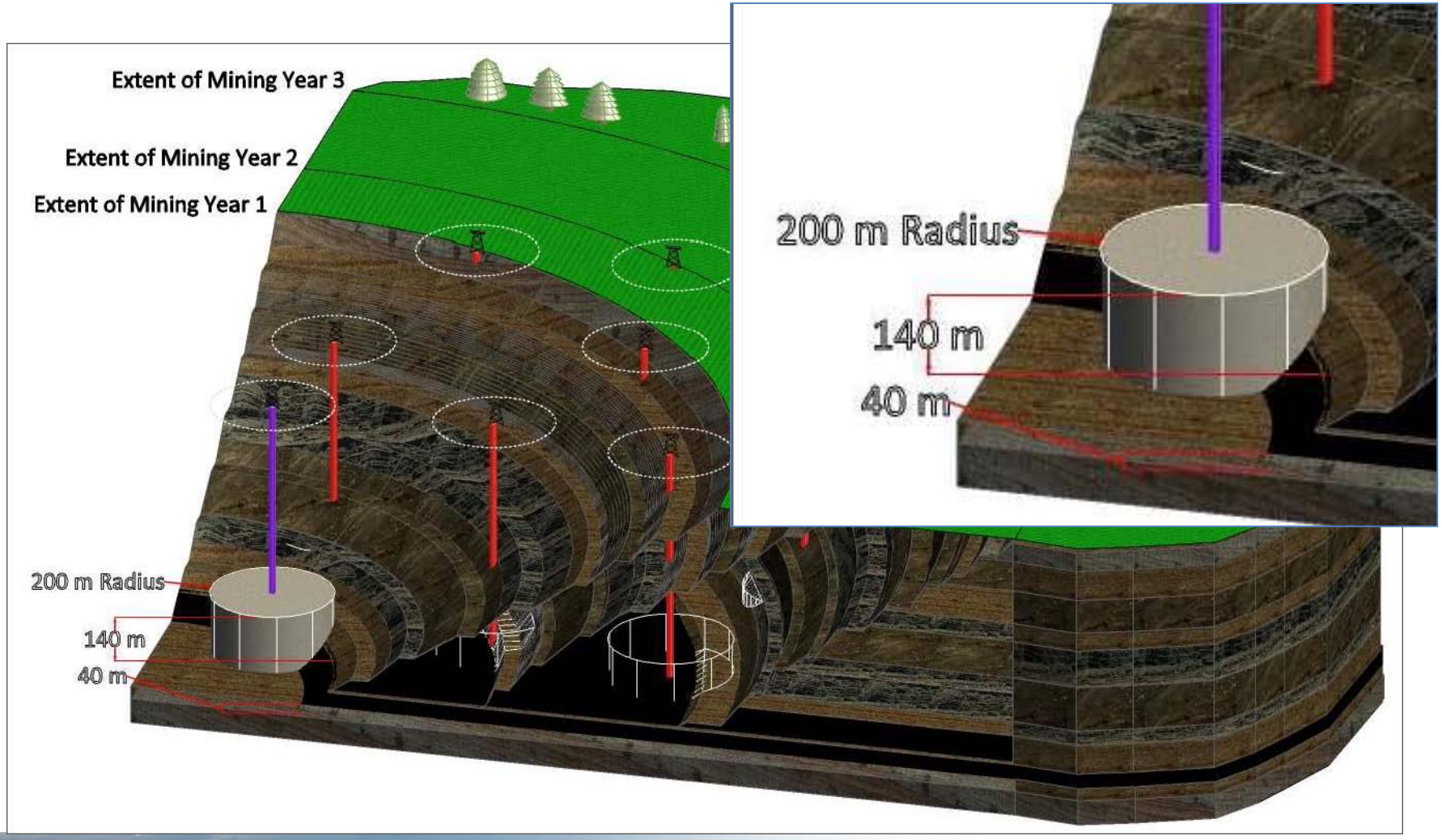
Understanding the Zone of Disturbance

The Zone of Disturbance

- Drilling into the Zone of Disturbance using a laterally drilled borehole
- According to ACM0008, the zone of disturbance is "typically 140 m above and 40 m below the targeted coal seam"



The Zone of Disturbance

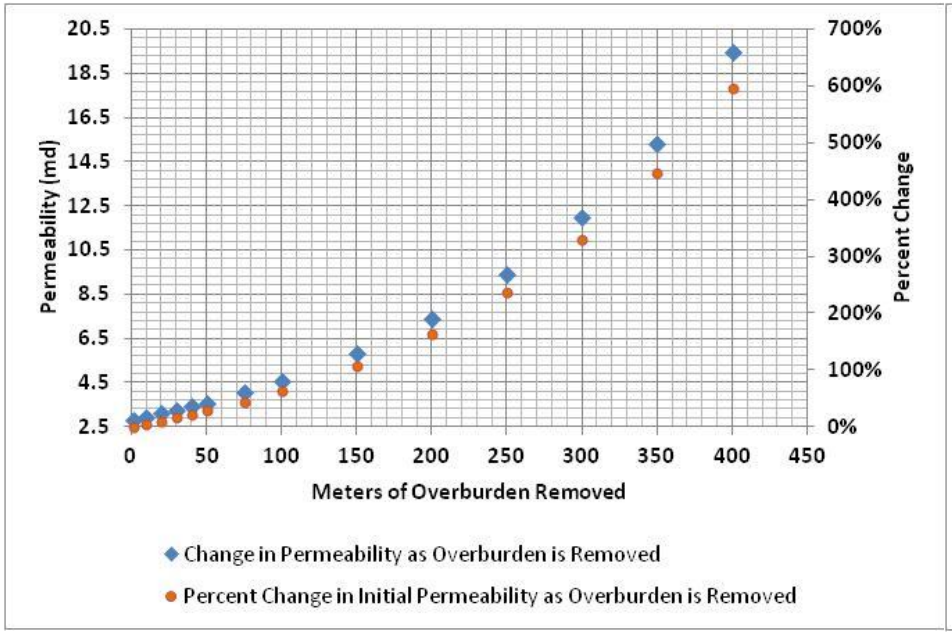


Overburden Removal Increases Permeability

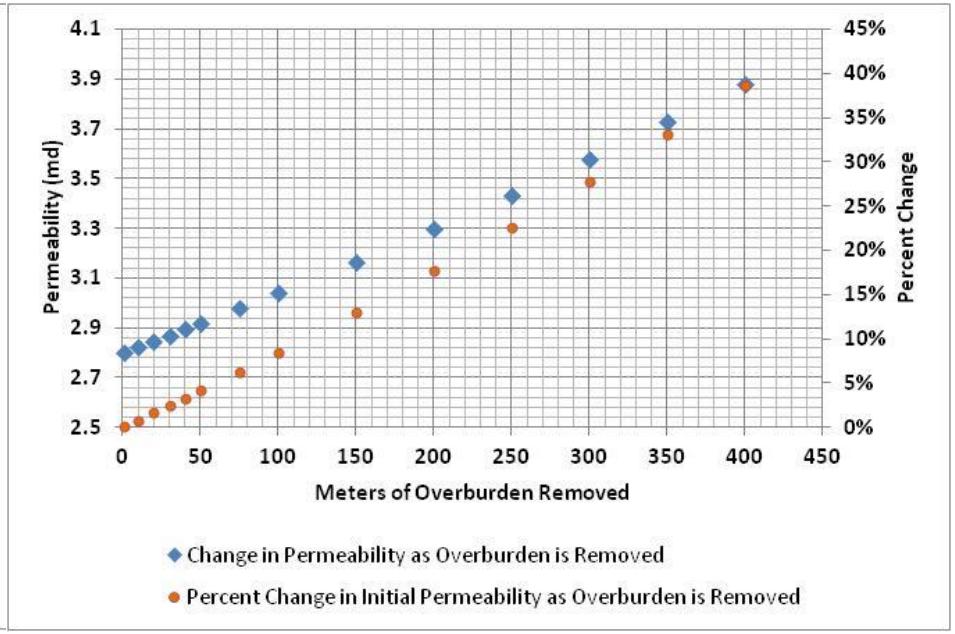
- Permeability increases exponentially with decreasing effective stress
- Effective stress is diminished as overburden is removed during mining
- Permeable pathways occurring in geologic structures such as breached folds or faults are enhanced as overburden is removed.
- Matrix and fracture permeability is enhanced as a function of the stiffness of the rock mass, density of fracturing and thickness of overburden removed.

Impact of Rock Stiffness on Increases in Permeability as Overburden is Removed

Medium-Volatile Bituminous Coal



Sub-bituminous Coal



Fracture compressibility for bituminous coal from *A New Coal-Permeability Model: Internal Swelling Stress and Fracture-Matrix Interaction* by Hui-Hai Liu and Jonny Rutqvist, Transp Porous Med (2020) 82: 157-171.

Fracture compressibility for sub-bitumious coal , high volatile bituminous and equation for relationship between overburden removal and permeability increase from *Improvements in Measuring Sorption-Induced Strain and Permeability in Coal* by E.P. Robertson, SPE 116259, 2008 SPE Eastern Regional/AAPG Eastern Section Joint Meeting held in Pittsburgh, Pennsylvania.

Opportunities for Emissions Reductions

Estimated Emission Reductions from Surface Mine Projects

Project	Average Annual Emission Reductions (tCO_2e)	Emission Reductions for Crediting Period (tCO_2e)
Wahana Baratama, South Kalimantan, Indonesia	207,111	1,449,778
Semirara, Philippines	385,478	2,698,346
North Antelope Rochelle, Wyoming, USA	90,463	904,628

Wahana Baratama Coalbed Methane Generation Project PDD: http://cdm.unfccc.int/Projects/Validation/DB/9Y4C1SLSOQIMHIZGRXF053RFNRQERO/view.html; Semirara Coalbed Methane Generation Project PDD: http://cdm.unfccc.int/Projects/Validation/DB/YCCWHT4J05P2A4OSN6LGDGK9RYEBXQ/view.html; NARM PDD: https://vcsprojectdatabase1.apx.com/mymodule/ProjectDoc/Project_ViewFile.asp?FileID=70&IDKEY=niquwesdfmnk0iei23nnm435oiojnc909dsflk9809adlkmlkf496530

End-Use Options

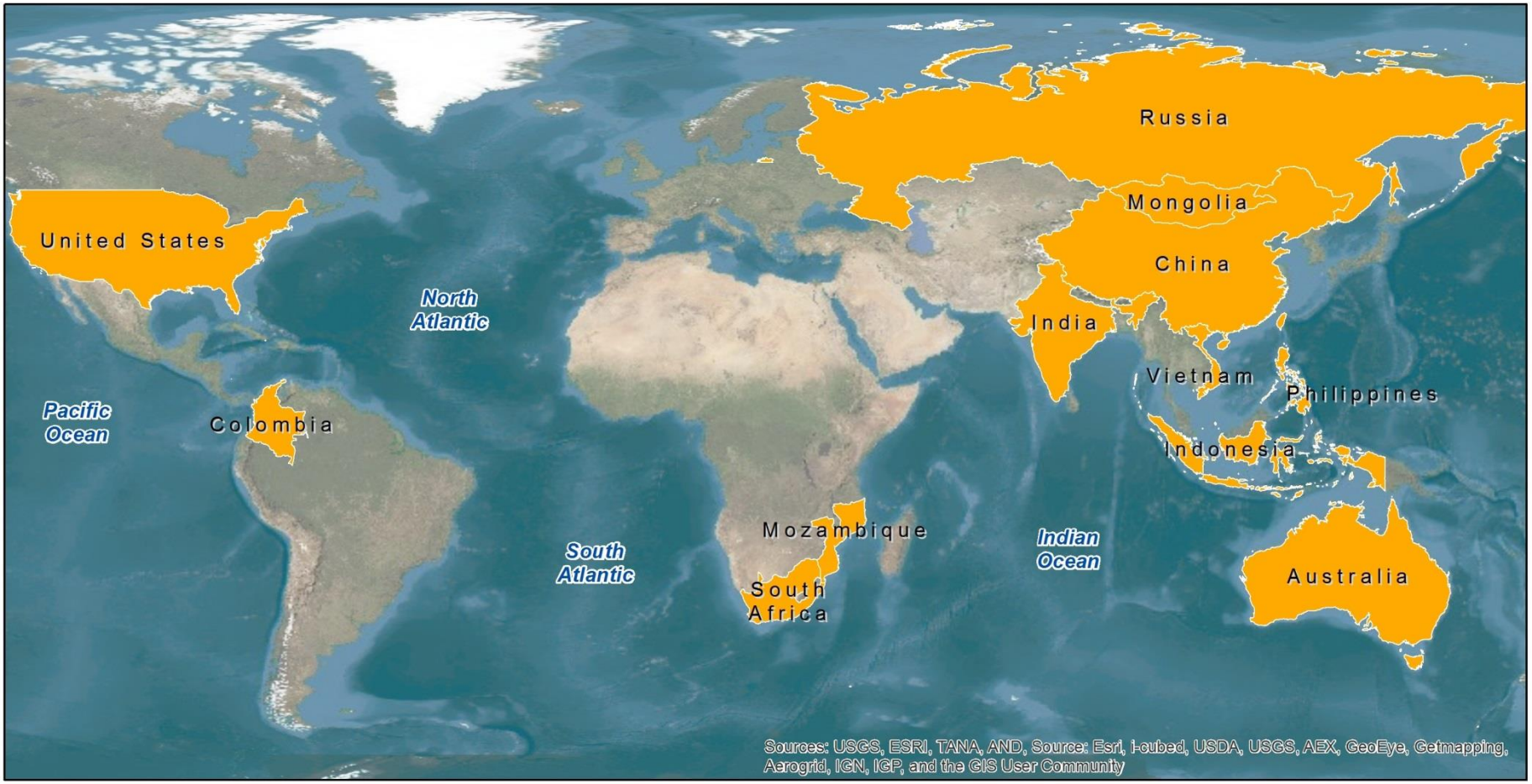
Pipeline Sales

Power Generation

Flaring

CNG/LNG

Prospective Opportunities



Conclusions

Conclusions

- Revision to ACM0008 and voluntary carbon market opportunities have put the spotlight on SMM
- Performance based protocols make validating projects much easier
  - No additionality
- Worldwide SMM market is untapped
  - The number of active surface mines is growing, and they are becoming bigger and bigger – emitting more and more methane.
  - Very large number of abandoned surface mines –opportunities where developer would not be in the way of the miner.
- SMM development considerations vary greatly
  - Mining method
  - Location
  - End use market
    - Pipeline quality gas allows access to all markets

Thank You

For more information…

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