U.S. EPA Coalbed Methane OUTREACH PROGRAM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Pre-feasibility Study for Coal Mine Methane Recovery and Utilization at Mopanshan Mine, Guizhou Province, China

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Sponsored by:
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Prepared by:
Raven Ridge Resources, Incorporated

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Executive Summary

With funding from the United States Environmental Protection Agency (USEPA), under the auspices of the Global Methane Initiative (GMI), this pre-feasibility study evaluates the utilization of coal mine methane (CMM) produced from a proposed degasification system comprising pre-mine drainage and gob wells, for use as fuel to generate electricity for the Mopanshan Coal Mine in Guizhou Province, China.

Presently, there are no mining activities occurring at Mopanshan Coal Mine (Mopanshan), but mine planning and development are underway. In October of 2005, the Guizhou Qianxi Energy Development Co. Ltd. (GQEDC) obtained the exploration rights to conduct the coal resource assessment at Mopanshan. The "Coal Exploration and Geological Report" conducted by the Shandong Coal Geological Engineering Investigation Institute (SCGEII) provided the basis for the geologic review presented herein, as well as the coal exploration and resource data. An additional study, "Mopanshan Mine Feasibility Report," completed in November of 2013 by the Nanjing Design Institute of Coal Science and Industrial Group (NDICSIG), assessed the feasibility to site a coal mine in the Mopanshan coalfield and laid out a preliminary mine plan. With the completion of NDISCSIG's feasibility report, initial mine development planned to commence in the near future, but is dependent on China's coal markets which have been depressed during the last two years.

Mopanshan will be an underground coal mine aiming to produce 900 thousand tonnes of coal per year when full design capacity is reached. Owned and operated by GQEDC, the mine has targeted two primary coal seams, the 5 and 9 seam. The calculated economically recoverable coal reserves within the mining area are estimated to be 60.75 million tonnes, providing an expected mine service life of over 66 years.

Gas content test data provided by mine management along with results of a methane adsorption isotherm test, were used to provide a frame of reference within which the potential gas volume of each coal seam could be estimated. Gas resources were estimated for each of the coal seams by multiplying the volume of coal resources within the designated mining area to a probability distribution representing the range of gas content values. The p50 total methane resource for the mineable coal seams at the Mopanshan mine is estimated to be 2,921.6 million cubic meters.

Production modeling performed for this study included the potential gas produced from a proposed series of 22 pre-mine drainage wells positioned vertically throughout the mining area and three gob drainage wells drilled annually over a ten year period. The total estimated p50 CMM production over the project life is 165.9 million cubic meters of methane, available for use by the mine.

The Permian age stratigraphic sequence that contains the mineable coal seams is directly overlain by thick Triassic and Permian limestone beds. In the Mopanshan region, the relentless dissolution of calcium carbonate from the limestone beds gives rise to a specific type of geologic terrain known as karst topography characterized by sinkholes, caves and underground drainage systems. The water contained in these aquifers can pose safety concerns for miners and require that design of pre-mine and gob wells accommodate the need to hold back the water while drilling, and preserve the integrity of the well as it passes through karstic cavities.

The energy market in the Guizhou region was assessed to determine end-uses for the Mopanshan mine's CMM. China's electricity consumption grew at a robust average rate of 11.1 percent from 2005 - 2011. Electricity consumption within Guizhou is also on the rise, reporting a growth of 7.3 percent in 2013, and it is reasonable to assume that Guizhou's economy and its electricity consumption will grow within the projected eight to ten percent range for the country as a whole in the medium term. Neverthe-less, virtually all power generated by Guizhou CMM plants is being distributed through the mining companies' grids for their own consumption, and some mining companies with the capability to generate excess power have been forced to idle capacity due to their inability to reach interconnection and sales agreements.

End-use options for the CMM drained from the Mopanshan mine are limited as there is no existing infrastructure in the region that would enable the mine to transport produced gas to market. This feasibility study proposes the mine consider on-site power generation using CMM fueled internal combustion engines. The proposed power generation project operating 8,000 hours annually would generate 13.5 MW of electricity once the project reaches peak gas production. The capital costs are estimated to be $27.47 million USD yielding an IRR of 45 percent and a payback period of 3.8 years. The proposed power generation project is estimated to reduce CMM emissions by 397.4 thousand tonnes of CO_2e over the project's 10 year life.

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Acronyms and Abbreviations

CBM	coalbed methane
CMM	coal mine methane
CAPEX	Capital expenditures
CNY	Chinese yuan (currency)
CO_2e	carbon dioxide equivalent
CSPGC	China Southern Power Grid Company
GMI	Global Methane Initiative
GQEDC	Guizhou Qianxi Energy Development Company Limited
GZICCEP	Guizhou International Cooperation Center for Environmental Protection
IRR	internal rate of return
km	kilometers
kV	kilovolt
kWh	kilowatt hour
m	meters
m^3	cubic meters
mD	millidarcies
mm	millimeter
MW	megawatt
MWh	megawatt hour
NDICSIG	Nanjing Design Institute of Coal Science and Industrial Group
NPV	net present value
OGIP	original gas-in-place
OPEX	operating expenditures
p10	Indicates a 10% chance that forecast will be ≥ to the p10 amount
p50	Indicates a 50% chance that forecast will be ≥ to the p50 amount
p90	Indicates a 90% chance that forecast will be ≥ to the p90 amount
PSC	production sharing contract
RRR	Raven Ridge Resources, Incorporated
SCGEII	Shandong Coal Geological Engineering Investigation Institute
US	United States
USD	United States dollar
USEPA	United States Environmental Protection Agency

Acknowledgments

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1. Background

This pre-feasibility study was sponsored by the United States Environmental Protection Agency (USEPA) under the auspices of the Global Methane Initiative (GMI), of which both the United States (US) and China are members. The study was conducted by Raven Ridge Resources, Incorporated (RRR), with support from the Guizhou International Cooperation Center for Environmental Protection (GZICCEP) and Cenergy Corporation.

The Mopanshan Coal Mine (Mopanshan) is a new property being developed by Guizhou Qianxi Energy Development Co., Ltd. (GQEDC) in Qianxi County, Guizhou Province with design capacity of 900 thousand tonnes of anthracite coal per year. Coal from Mopanshan will be used to meet the demands of the nearby Qianxi Power Plant, as well as other power plants in the area such as the Dafang Power Plant. The site is located near the Qinglong Mine, also operated by GQEDC. Mopanshan has economically recoverable coal resources estimated at 60.75 million tonnes from the Permian Longtan Formation seams 5, 9, 12, 14 and 15, and an anticipated mining life of over 66 years. A gas content sampling program was conducted at Mopanshan during which 33 coal samples were measured for gas content. Gas content results ranged from 5.24 – 23.74 cubic meters/tonne, indicating that the mine will be classified as a high-gas coal mine. Initial geologic investigations show the mineable coal seams are overlain by several water-bearing limestone aquifers. Consideration of these aquifers needs to be taken into account during the mine's development stage and the pre-mine and post-mine drilling activities proposed in this report. GQEDC recognizes the importance of implementing a methane drainage program in order to manage emissions and have been progressive partners in a previous USEPA-funded pre-feasibility study at Qinglong Mine with GZICCEP. Understanding the benefits of assessing coal mine methane (CMM) resources and determining an appropriate approach to recovery and utilization, Mopanshan and its owners were identified as the host mine to perform this pre-feasibility study.

Demand for natural gas in Guizhou is currently triple the supply, so extraction of gas for self-supply of electricity is attractive to the mine. Applicability of other end-use options for the CMM drained from the Mopanshan mine is limited as there is no existing infrastructure in the region that would enable the mine to transport produced gas to market. At least until the gas resource is proven to be economically producible, the option with the lowest technical and economic risk available is on-site use of the gas to fuel electricity generation for the mine's consumption.

Currently Mopanshan is 100 percent owned by GQEDC. The mine will be an underground mine using a single longwall system to extract coal. The mine managers believe the construction and operation of the Mopanshan coal mine will help to promote local economic development and social stability of the area. As stated by the Nanjing Design Institute of Coal Science and Industrial Group (NDICSIG) in a study commission by GQEDC, "Mine construction and production will raise the local tax base, increase employment and promote the development of related industries, so that local people [will rise] out of poverty" (NDI, 2013).

2. Introduction

The objective of this pre-feasibility study is to examine the potential for employing pre-mine and post-mine drainage wells, to reduce global methane emissions, to increase mine safety and to capture methane gas for use as fuel to generate power at the Mopanshan coal mine.

This report is the result of investigations that entail:

- Field visits to the mine;
- Translation and review of technical documents;
- Estimates of the in situ methane resources and forecasts of production based on statistical analysis of the gas that may be contained by the coal resources and the potential for pre-mine methane drainage via surface drilled wells; and,
- Analysis of the economic performance of a proposed gas-to-electricity pilot project based on current energy markets and quotes from vendors.

Results of this pre-feasibility study are intended to provide a foundation for a full-scale feasibility study. The approach taken is designed to develop a program that attracts the attention of investors or other stakeholders such that a full-scale feasibility study and eventually a drainage and utilization project are funded and executed.

2.1. History

Presently, there are no mining activities occurring at Mopanshan, but mine planning and development is underway. In October of 2005, the GQEDC obtained the exploration rights to conduct the coal resource assessment at Mopanshan. The "Coal Exploration and Geological Report" conducted by the Shandong Coal Geological Engineering Investigation Institute (SCGEII) provided the basis for the geologic review presented, as well as the coal exploration and resource data. An additional study, "Mopanshan Mine Feasibility Report" completed in November of 2013 by the NDICSIG assessed the feasibility to site a coal mine in the Mopanshan coalfield as well as laid out a preliminary mine plan. With the completion of the NDICSIG report, initial mine development is planned to commence in the near future, but is dependent on China's coal markets which have been depressed during the last two years. These reports are the basis for the geologic assessment discussed in this document.

3. Geologic Setting

3.1. Location

The Mopanshan coalfield, located in the north east portion of Qianxi County and within Guizhou Province, covers an area just over 30 square kilometers. The coalfield property is centered at 106° 21' 34" E longitude and 27° 06' 34" N latitude, and is approximately 68.5 kilometers northwest of Guiyang. **Figure 1** shows the location of the Mopanshan coalfield within Guizhou Province.

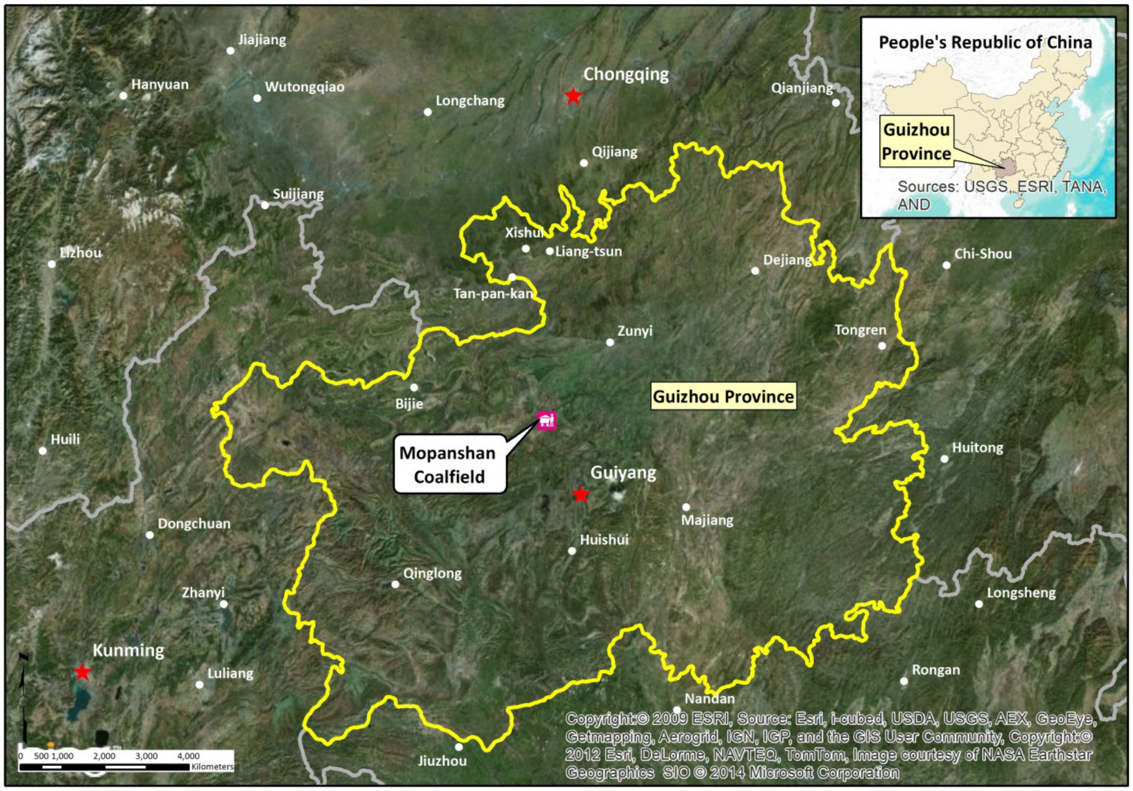

Figure 1: Overview Area Map

The Mopanshan mining area lies atop the Yangzi Plateau, and is situated on a plateau of undulating karstic terrain which is bounded on the east by a dammed portion of the Wu River known as Yachi Lake, and on the north by an unnamed tributary to the Wu. The property elevation ranges from the low point near the river, at 703 meters, to the region's highest point, referred to as the Eagle's Nest, at 1,409 meters above sea level. The average elevation over the mining property is between 1,100 and 1,200 meters.

3.2. Regional Geology

As a part of the Yangzi Plateau, the tectonic structure of the Mopanshan coalfield consists of northeast-southwest trending gently dipping asymmetrical anticlines and synclines, bisected by a number of normal and reverse faults and bounded on the east by a series of folded and faulted horst and graben blocks. **Figure 2** shows the anticline and syncline axes in green, with the fault traces shown in red. Generally, the folding precedes the faulting, suggesting the initial elastic deformation occurred during a period of northwest to southeast compressional stresses, or squeezing, which later evolved into tensional stresses. Under the tensional stress regime, normal faulting and slip along those faults allowed for the creation of the horst and graben structures to the east and south.

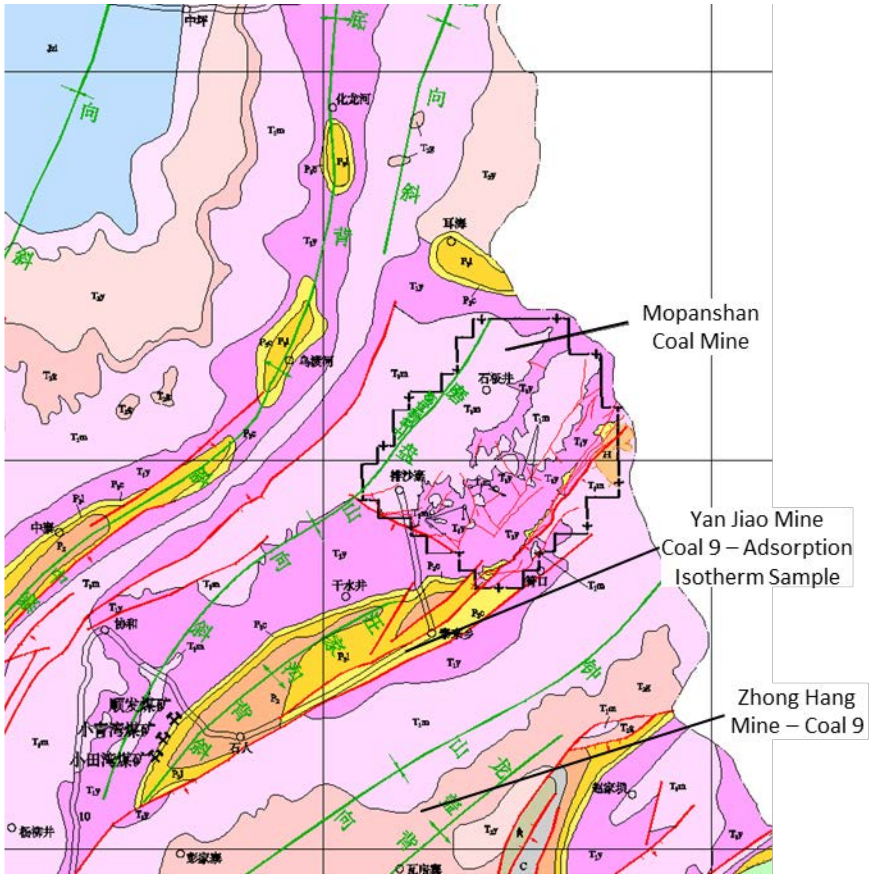

Figure 2: Mopanshan Regional Geologic Map

3.3. Mining Geology

3.3.1. Stratigraphy and Hydrogeology

The following discussion regarding the stratigraphy of the Mopanshan area is focused on those characteristics that directly impact mining, and the drilling of pre-mine gas drainage and gob vent boreholes proposed in **Section 7.1**, of this report. The Permian age stratigraphic sequence that contains mineable coal seams is directly overlain by thick Triassic and Permian limestone beds that were deposited in a shallow marine environment. Subsequent to deposition these limestone strata have undergone significant chemical and structural alteration, principally as a result of groundwater moving through the strata and dissolving calcium carbonate, the main constituent of the limestone. In the Mopanshan region, the relentless dissolution of calcium carbonate from the limestone beds gives rise to a specific type of geologic terrain known as karst topography characterized by sinkholes, caves and underground drainage systems. In strata where mechanical and chemical removal of limestone has taken place, pore spaces are enlarged and permeability develops, forming reservoirs and conduits through which huge volumes of water may flow. The water contained in these aquifers can pose safety concerns for miners and require that the design of pre-mine and gob vent wells protect the wellbore while drilling through karstic cavities.

Plate 2 is a graphic representation of the stratigraphic sequence that will be penetrated by boreholes drilled at Mopanshan. With the exception of the uppermost Quaternary formation, each of the geologic formations present at the site, contain aquifers whose effects must be taken into account when the final layout of the mine is being developed or a degasification drilling program is undertaken.

Maocaopu Limestone

Five boreholes drilled during the coal exploration program discovered a fractured karstic aquifer in the Maocaopu Formation. The largest karstic feature encountered during drilling was a cave measuring 11 meters in diameter. Pump tests, which are used to determine water flow and permeability, were unsuccessful because the formation is highly fractured. Consequently, these important parameters could be measured in subsequent drilling programs by simply producing water from the formation and monitoring rate and volume. While this aquifer is unlikely to interfere with mining as the zone lies far above the mineable seams and is separated by impermeable mudstone strata, it could pose issues with drilling pre-mine and gob vent wells.

Yelang Limestone

Eight coal exploratory boreholes identified fractured karst aquifers in the Yelang Limestone. The largest cave structure encountered by these boreholes was 5.4 meters in diameter. However, void spaces were frequently encountered and all were water-filled. Mining operations would be separated by impermeable mudstone and siltstone barriers; therefore the water within this aquifer does not pose imminent danger to mining in the underlying strata. Again, however, if these aquifers are not given proper consideration, they could become a significant challenge during drilling of the proposed degasification program.

Changxing and Dalong Formations

These two formations comprise a conformable stratigraphic sequence of limestone and silicic limestone directly overlying the coal bearing Longtan formation. **Figure 3** provides a more detailed view of the stratigraphy of the rocks directly overlying the Changxing Formation. These formations contain a fractured karst aquifer that was identified in 25 of the 34 exploratory boreholes drilled in the Mopanshan area. Values of greater than 73 percent porosity were measured in some boreholes. This aquifer, which lies only about 40 meters above coal seam 5, poses the most immediate threat to mining in the Longtan formation. This distance is well within the zone of strata relaxation and fracturing that will take place as longwall mining extracts coal from seam 5 and the underlying coal seam 9. Pre-mine drainage boreholes will have to be designed in such a way as to accommodate potential unwanted water flows.

Longtan Formation

Four limestone beds occurring in the upper part of the Longtan Formation are water bearing; these beds numbered sequentially from uppermost to lowermost are the: L1 – 10.3 meters thick; L2 – 0.8 meters thick; L4 – 1.4 meters thick; and, L5 – 1.8 meters thick. However, there is no recognizable impermeable layer separating the L1 and L2 aquifers, suggesting that the two beds will act as one aquifer. Porosity was measured for the L1 and L2 limestone beds, resulting in measured values of 58.8 percent and 32.4 percent porosity, respectively. The average distance between the base of the L1 and coal seam 5 is 28.9 meters, which is well within the collapse and strata relaxation zone that will develop as coal is extracted from coal seams 5 and 9, potentially posing a mining hazard.

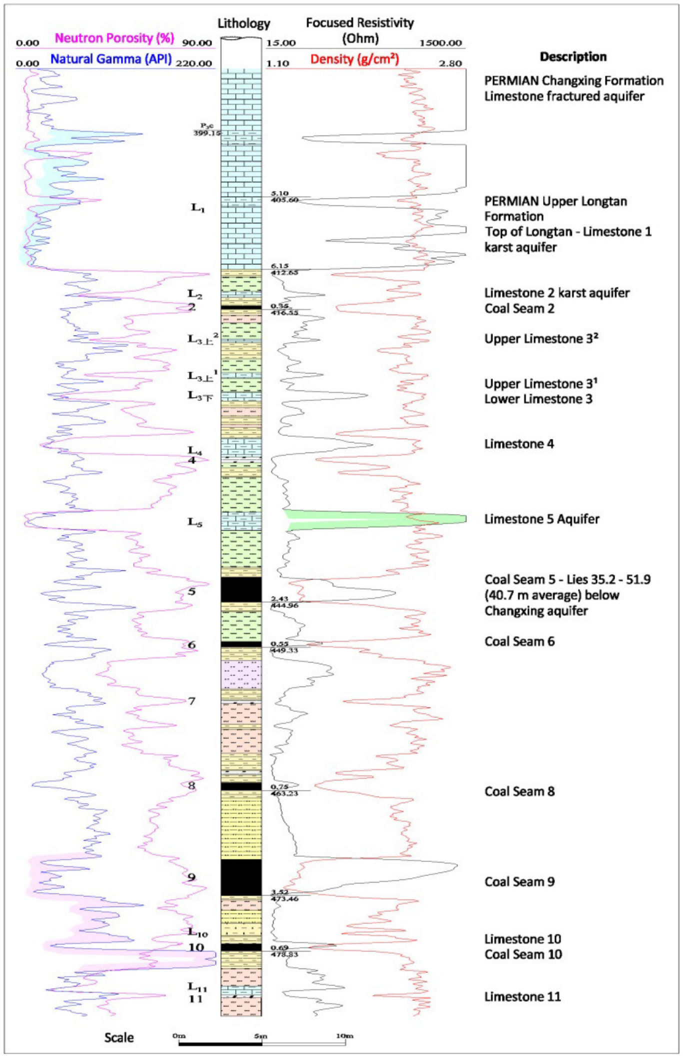

Figure 3: Stratigraphic Section of Coal and Water Bearing Strata

3.3.2. Structural Geology

Digital image files of the cross-sections developed during the coal exploration process were used to construct a simple three-dimensional model of the mining area. This model was used as a basis for understanding the geologic and structural history within the mining area. Within the immediate mining area, shown by the Mopanshan Coal Mine outline in **Figure 2**, the degree of structural complexity is moderate. The moderately undulating structure contains small localized folds, with little change in dip within the initial mining and development area, ranging between 6 and 10 degrees and dipping to the northwest. Over the entire mining area, however, the dip ranges between 4 – 22 degrees. Steeply pitched normal and reverse faulting was discovered in the eastern and southern portions of the mining area, with vertical displacement ranging up to as much as 24 meters. **Figure 4** shows two example cross-sections, one looking toward the northeast and one looking toward the northwest. The extensive faulting shown on Cross-section 6 is located along the eastern boundary of mining, while the area of extensive faulting is shown along the southern boundary of mining in Cross-section L2.

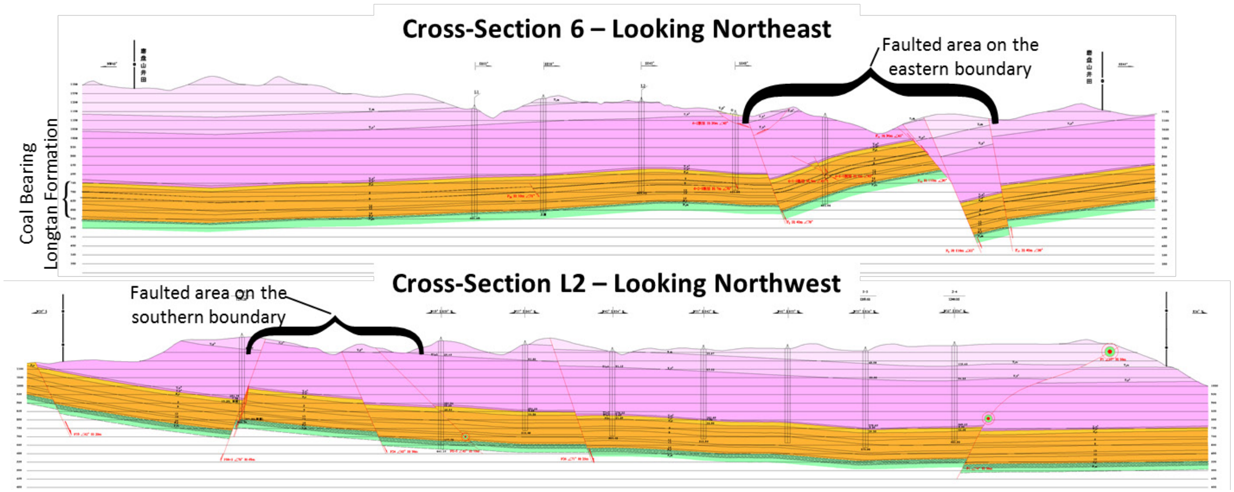

Figure 4: Example Cross-sections within the Mining Area

3.3.3. Coal Bearing Strata

The Permian Longtan Formation contains 18 coal seams, of which coal seam 5 and coal seam 9 are considered by GQEDC as the two primary mineable coal seams within the Mopanshan Coal Mine lease block. The range in thickness of the Longtan Formation is between 142.3 and 177.7 meters, with an average thickness of 160.6 meters. Coal seams 1 through 11 lie within the Upper Longtan, while seams 12 through 15 and a few unnamed coal seams lie within the Lower Longtan.

The Longtan Formation comprises interfingered marine and continental sediments. Coal seams are found within the continental clastic sediments deposited during nine depositional cycles, which occurred as sea level changed over time. Clastic sediments including grey mudstones, siltstones, fine-grained sandstones, limestones and carbonaceous shales are interbedded with the coal throughout. The marine environment formed along the continental margin in which 18 limestone beds were deposited, principally in the upper portions of the Longtan. A number of these beds are recognizable throughout the area and serve as marker beds to provide control for coal resource exploration activities. The Longtan Formation is also rich in animal and plant fossils. **Figure 3** depicts a stratigraphic section of the Upper Longtan Formation, showing the focused resistivity, density, natural gamma and neutron geophysical log curves and the identified coal and limestone layers. A description of the strata occurring within the local stratigraphic sequence is included in **Plate 2: Mopanshan Coal Mine Stratigraphic Column**.

Coal seam 5 lies between 35.2 – 51.9 meters below the bottom of the Permian Changxing Limestone, where limestone and siltstones are the primary interbedded layers separating the two. The adjacent overlying and underlying strata of coal seam 5 are predominantly mudstones. Coal seam 9 lies between 18.5 – 27.4 meters below coal seam 5, and the primary interbedded layers are siltstones, coals, fine-grained sandstones and sandy mudstones. The adjacent strata overlying seam 9 is a sandy mudstone whereas the underlying strata is predominantly mudstone.

3.3.4. Thickness and Physical Properties

Coal seam 5 ranges in thickness from 0.65 to 3.28 meters, with an average thickness of 1.82 meters and a mineable seam thickness ranging between 0.8 to 3.28 meters. In some locations, the seam contains a carbonaceous mudstone parting, and according to the initial mine design, the mine is expecting to recover 82 percent of the coal. Coal seam 9 ranges in thickness from 1.42 to 3.80 meters, with an average thickness of 3.01 meters. This seam is continuous, and the mine expects to achieve 100 percent recovery (NDI, 2013).

Both coal seams 5 and 9 are anthracite and exhibit a semi-bright luster. **Table 1** shows the key coal properties that were collected in the coal exploration campaign conducted in 2005 by SCGEII.

Table 1: Coal Seam 5 and Coal Seam 9 Physical Properties

Physical Properties (float coal)	Moisture M_{ad} (%)	Ash A_d (%)	Volatiles V_{daf} (%)	Total Sulfur $St,_d$ (%)	Phosphorus P_d (%)	Heat Qgr,d (MJ/kg)
Seam 5 Range	0.56 – 2.54	6.87 – 12.75	6.60 – 8.06	0.39 – 1.63	0.002 – 0.010	30.97 – 33.88
Average (# of samples)	1.53 (31)	9.17 (30)	7.25 (31)	1.06 (31)	0.006 (12)	32.46 (21)
Seam 9 Range	0.34 – 2.85	5.24 – 11.25	6.38 – 7.75	0.38 – 1.06	0.002 – 0.012	31.63 – 33.90
Average (# of samples)	1.65 (29)	9.11 (29)	7.00 (29)	0.58 (29)	0.007 (13)	32.64 (20)

4. Coal Resources

According to the findings of the 2013 NDICSIG report, the best estimates of coal resources at Mopanshan were collected during the exploration program carried out by SCGEII. The exploration activities, conducted in 2005, consisted of:

- Identification of the stratigraphic sequence and its age;
- Detailed analysis of the coal and coal-bearing strata;
- Identification of the major structural features within the mine area;
- Map of the basal structural contours of the mineable coal seams;
- Detailed identification of the mineable coal thickness variation and continuity of the coal layers;
- Basic hydrogeological conditions and potential water flow within the mine;
- Coal and coal dust spontaneous combustion and explosion hazards;
- Roof and floor characteristics that affect ground temperature changes and other mining conditions; and,
- Coal reserves estimates based on reasonable and reliable parameters.

According to SCGEII, the mine area contains a total of 215.8 million tonnes of coal resources from the targeted 5 and 9 coal seams (**Table 2**). If the mine operates at its design capacity of 900,000 tonnes/year, the service life of the mine will be approximately 66 years. Below, **Figure 5** shows the coal resources presented by coal seam and coal resource classification. Based on the China Solid Mineral Resource/Reserve Classification document (2009), GQEDC's exploratory drilling campaign on portions of the mine property delineated four categories of reserves: 331, 332, 333 and 334. According to this classification system, reserves designated in the 331 class are measured reserves; 332 are indicated reserves; 333 are inferred reserves; and the 334 class are hypothetical reserves. Table 2 shows the reserves estimated by SCGEII.

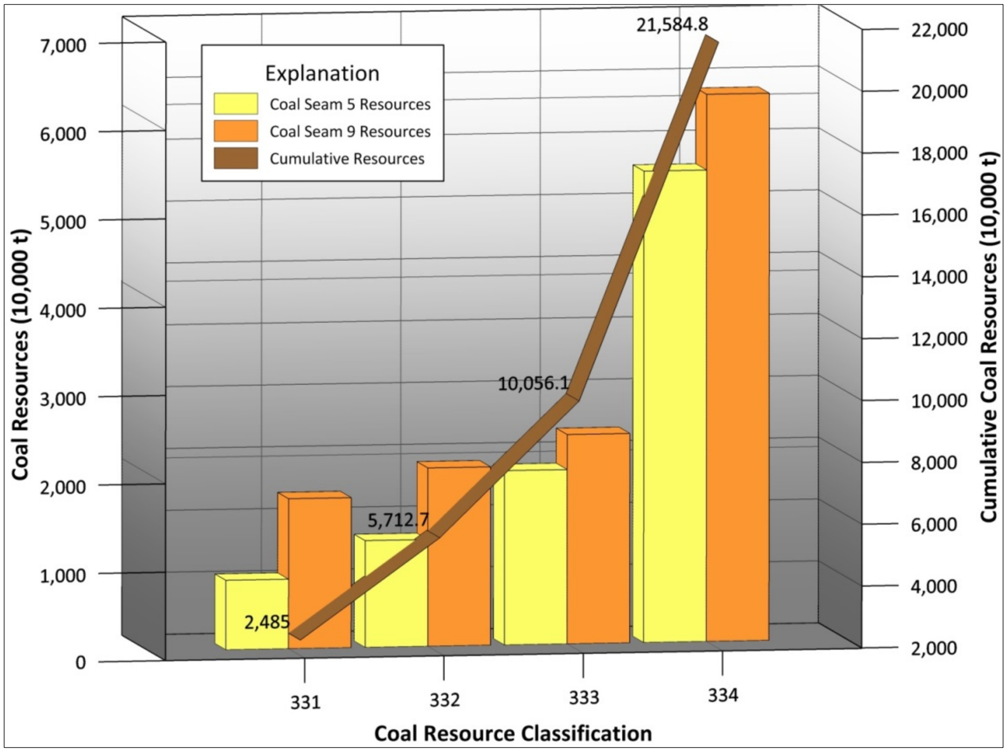

Figure 5: Seam 5 and Seam 9 Coal Resources

Table 2: Coal Resources within the Mining Property

Coal Reserves Classification	Coal 5 Mass (10,000 tonnes)	Coal 9 Mass (10,000 tonnes)	Total Coal Resources (10,000 tonnes)
331	787.2	1,697.8	2,485.0
332	1,208.7	2,019.0	3,227.7
333	1,973.4	2,370.0	4,343.4
334	5,335.6	6,193.1	11,528.7
TOTAL	**9,304.9**	**12,279.9**	**21,584.8**

5. Coal Mining

5.1. Projected Coal Production and Mining Plan

Mine maps provided by GQEDC's managers were used to assess the potential design layout of the mine and as a basis for gas resource and drainage analysis. At the time of this study, a detailed mine plan was not yet completed; however, a map showing the location of the first panel with an initial skeletal plan was available. Using the initial mine layout and for the purposes of this investigation, **Figure 6** depicts the plan used to estimate gas resources and propose the pre-mine drainage and gob well drainage layouts proposed in **Section 7.1**. **Table 3** shows the assumed initial coal production and timing to ramp up to the mine's goal design capacity.

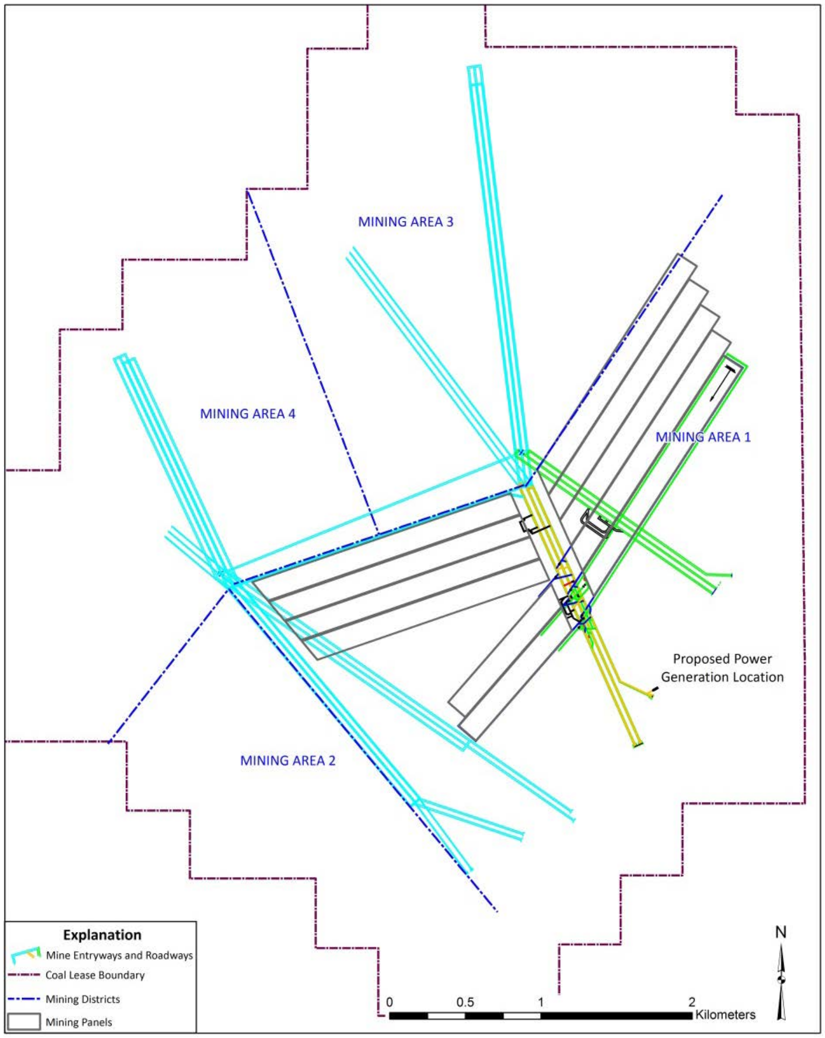

Figure 6: Mopanshan Mining Panels Map

Table 3: Projected Coal Production

Production Assumptions	YEAR									
	1	2	3	4	5	6	7	8	9	10
Annual Coal (thousand tonnes)	300	600	900	900	900	900	900	900	900	900

6. Gas Resources

The coal resource values obtained from the mine's resource and planning reports served as the basis for calculating the overall original gas-in-place (OGIP) at the Mopanshan mine. A widely accepted method of coarsely estimating the gas resource associated with the coal resource is to multiply mass of the coal by the gas content of the coal. The mine furnished gas content data collected during their exploration phase for coal seams 5, 8, 9, 12, 13, 14 and 15. In order to avoid calculating an estimate that was based on a single point value, gas content values were used to generate a Mopanshan coalfield isotherm model, which mathematically describes the variations of gas content values across the coal seams within the immediate mining area. A seam 9 coal sample was obtained from the Yan Jiao Mine, 5 kilometers to the south, which was submitted for adsorption isotherm testing. Results from this testing were used as a reference for the gas storage capacity that may be present in coal seam 9. Results, presented on a dry-ash free basis, for the calculated Mopanshan coalfield isotherm model curve, the Mopanshan gas content points, and the seam 9 adsorption isotherm test are shown in **Figure 7**.

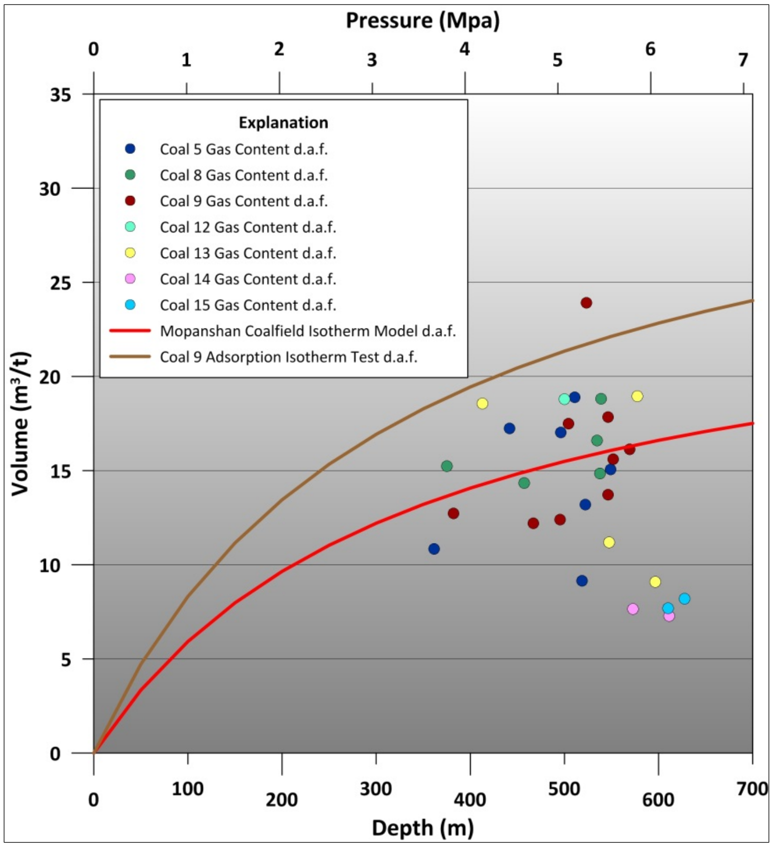

Figure 7: Adsorption Isotherm Curves and Gas Content Points

Methane adsorption isotherm testing was conducted to provide a broader frame of reference that was used to estimate the total gas saturation in the coals and the potential OGIP associated with Mopanshan's coal resources. An adsorption isotherm mathematically describes the relationship between pressure and gas capacity under equilibrium conditions at a stable temperature, usually chosen to represent the reservoir conditions of the coal seam occurring at the depth from which the sample was taken. This adsorption isotherm indicates the gas capacity of one sample taken from coal near the mine and may not depict the situation for all coal seams; however, the mine's gas content data values resulting from gas desorption testing, provide a near in-situ representation of the potential gas present in the mineable coal seams. The estimated gas resources at Mopanshan represent the amount of gas that may be released during mining if not recovered before coal extraction begins.

The calculated isotherm constants (Langmuir pressure and Langmuir volume) derived from the Mopanshan coalfield isotherm model curve were utilized to perform statistical analysis of the potential gas resources. The Langmuir equation below was used to calculate the gas content of coal at a given depth.

$$V = V_L * P / (P_L + P); \text{ where:}$$

V = gas content (cubic meters/tonne)

V_L = Langmuir volume constant (cubic meters/tonne)

P = reservoir pressure (MPa)

P_L = Langmuir pressure constant (MPa)

Pressure was converted into depth of burial by assuming a normal hydrostatic gradient[1]. The curves shown on **Figure 7** relate gas content of the coal sample to the expected content at a given mining depth. The brown and red curves have been adjusted to reflect the gas capacity for the coal on a dry, ash free basis, allowing the results of this test to be compared to any isotherm conducted on a coal sample from anywhere in the world. The red curve is considered to best represent the Mopanshan coal seams even though it predicts lower gas content values as it mathematically models actual gas content values acquired throughout the mining area.

In order to estimate OGIP, the previously described coal resources were multiplied by a probability distribution representing the range of gas content values. The probabilistic approach to estimating the OGIP takes into account the uncertainty of the coal density, thickness, and the gas content values of the mineable coal. Gas resource forecasts were calculated for each of three probability thresholds, p10, p50 and p90. The gas resource forecasted at each threshold has the probability of being the actual value that will be measured equal to or greater than the stated probability. The total OGIP resource forecast over the entire mining property of coal seam 5 (**Figure 8**) ranges from 619.4 up to 1,772.6 million cubic meters (p90 through p10). The total estimated p50 OGIP resource for seam 5 within the mine lease area is 1,057.8 million cubic meters. The total OGIP gas resource forecast over the entire mining property of coal seam 9 (**Figure 9**) ranges from 1,204.1 up to 2,883.5 million cubic meters (p90 through p10). The total estimated p50 GIP resource for seam 9 within the mine lease area is 1,863.8 million cubic meters. Therefore, there is a 50 percent probability that the recoverable gas resources for both coal seam 5 and 9 will be equal to or greater than 2,921.6 million cubic meters.

[1] The hydrostatic gradient is the change in hydrostatic pressure per unit of depth. It is assumed that this area is under normal hydrostatic gradient, which is 9.8 kPa/m of water column.

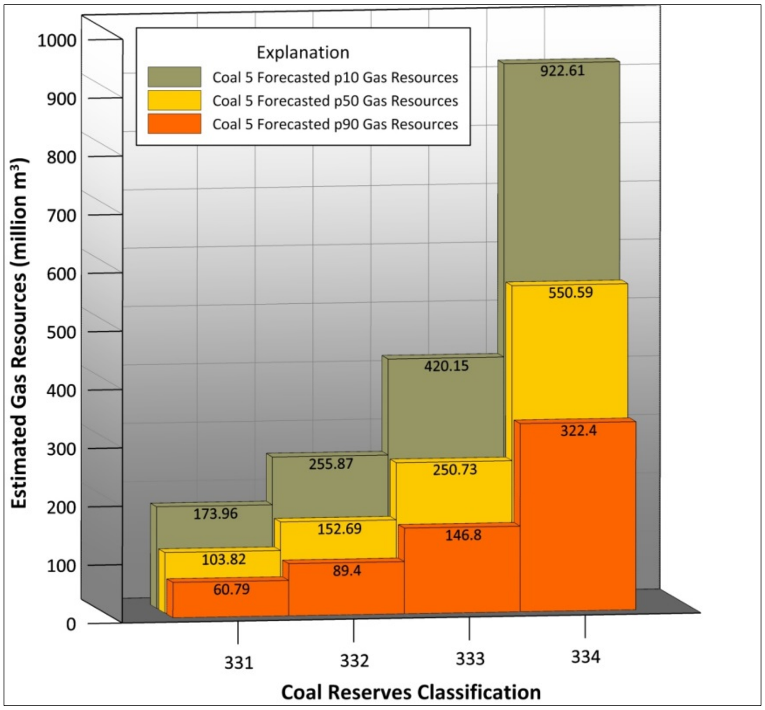

Figure 8: Coal Seam 5 Forecasted Gas Resources

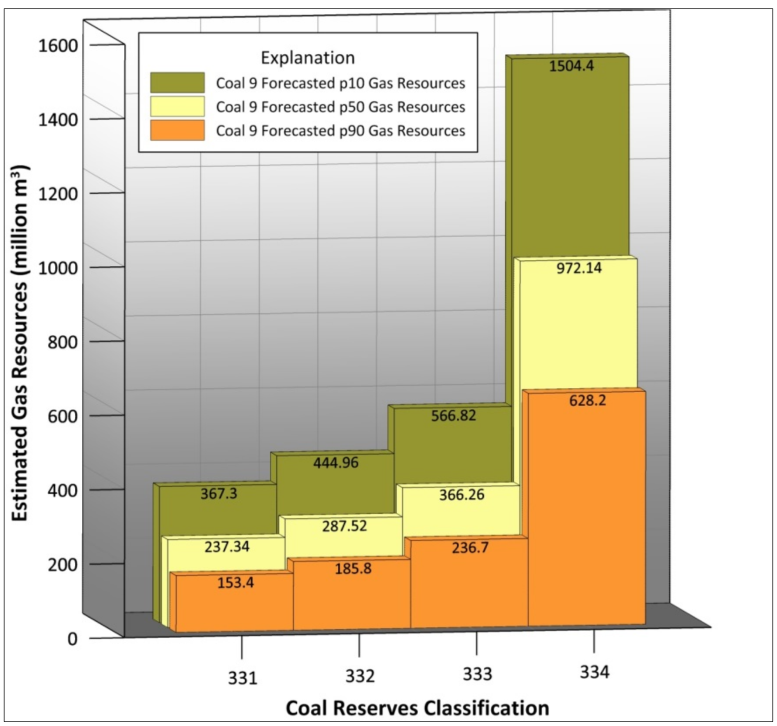

Figure 9: Coal Seam 9 Forecasted Gas Resources

This study proposes drilling 22 vertical wells in order to recover CMM prior to coal extraction (described in detail in **Section 7.1**). The OGIP was also calculated for the coal resource that may be present within the area drained by each proposed pre-mine well as well as a typical coal mining panel. The appropriate gas content was chosen using the average depth of the bottom of coal seam 5 and coal seam 9 recorded for the intercept of the exploratory boreholes. Depth was converted to hydrostatic pressure and the gas content was calculated using the red curve shown in **Figure 7**. As shown in **Figure 10**, the total estimated p50 OGIP of the drainage area for a single proposed pre-mine drainage well is 15.7 million cubic meters, of which coal seam 5 is 5.77 million cubic meters and coal seam 9 is 9.96 million cubic meters (**Table 4**). Also shown in **Figure 10**, the total estimated p50 OGIP of a typical mining panel is 20.1 million cubic meters, where coal seam 5 comprises 7.36 million cubic meters of the total gas, and coal seam 9 comprises 12.76 million cubic meters (**Table 5**).

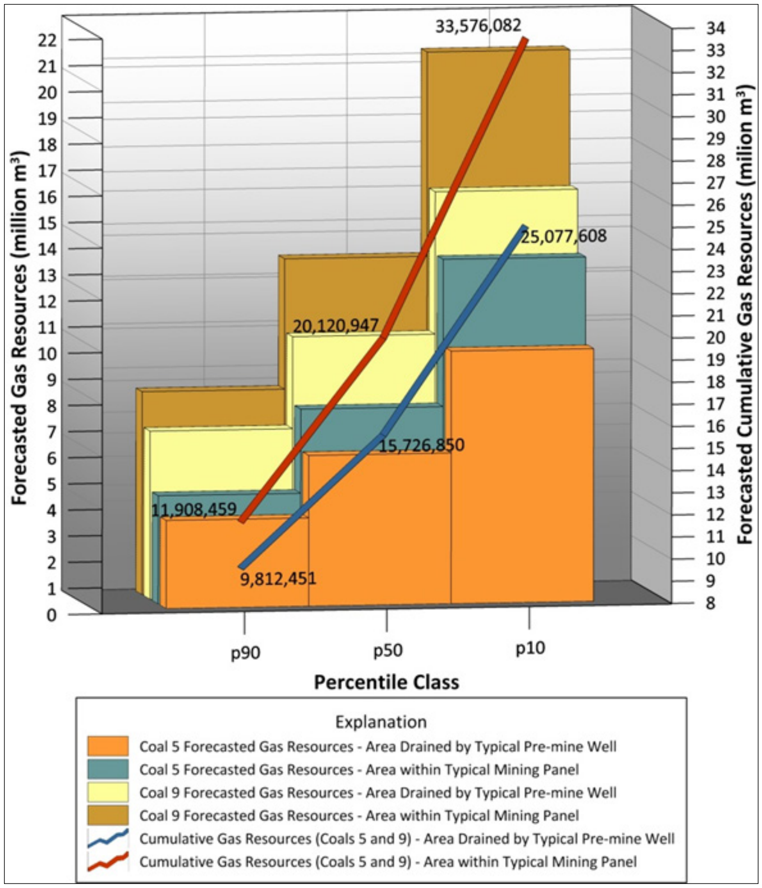

Figure 10: Forecasted Gas Resources - Typical Mining Panel and Area Drained by Pre-mine Well

Table 4 and Table 5 present the gas resource forecasts of the p10, p50 and p90 percentile classes, estimated for a typical pre-mine drainage well by coal seam and a typical mining panel.

Table 4: Probabilistic Gas Resource Forecasts of Coal Seams 5 and 9 within the area Drained by a Typical Pre-Mine Drainage Well

Percentile Class	Coal Seam 5 Forecasted Gas Resource (cubic meters)	Coal Seam 9 Forecasted Gas Resource (cubic meters)	Total Forecasted Gas Resource (cubic meters)
p10	9,668,302	15,409,306	25,077,608
p50	5,769,752	9,957,098	15,726,850
p90	3,378,312	6,434,139	9,812,451

Table 5: Probabilistic Gas Resource Forecasts of Coal Seams 5 and 9 within a Typical Mining Panel

Percentile Class	Coal Seam 5 Forecasted Gas Resource (cubic meters)	Coal Seam 9 Forecasted Gas Resource (cubic meters)	Total Forecasted Gas Resource (cubic meters)
p10	13,000,972	20,575,111	33,576,082
p50	7,363,399	12,757,549	20,120,947
p90	4,142,216	7,766,243	11,908,459

7. Potential Gas Production

The potential gas resources at Mopanshan mine are estimated range from 619.4 to 2,883.5 million cubic meters, which includes gas contained in coal seams 5 and 9 that lie within the Mopanshan mining area (**Figure 8 and Figure 9**). It is possible to capture CMM before and after mining, using pre- and post-mining drainage techniques. The following proposed drilling plan utilizes both techniques, and provides suggested resources for selecting the most safe and effective solutions.

7.1. Drilling Design and Basis for Production Forecasts

Pre-mine drainage of gas from mineable coal seams is a best practice option for capturing and using gas that would otherwise be released during mining, and is the only means of reducing methane flow directly from the targeted mining seams (UNECE, 2010). Moreover, gas produced from pre-mine drainage boreholes, if handled properly, can contain greater than 90 percent methane by volume, thus giving the mine operator the greatest range in potential options for gas utilization. A pre-mine drainage program may comprise one or a combination of several options for draining the coal prior to mining, using boreholes that are drilled from either the surface or from underground sites located in a mine's workings. Cost-effective means of pre-mine drainage, aimed at lowering the emission of methane into the mine workings and ultimately the atmosphere, must account for operational considerations such as access to drilling sites that may be dictated by topography, surface water drainages, surface rights ownership and other social and environmental issues. It is assumed that surface conditions and land ownership are issues which can be addressed and satisfactorily resolved. If the technical and economic effectiveness of surface drilled boreholes can be proven, there are many advantages to utilizing this method, including less competition for space in the underground portion of the mine.

The efficiency of draining gas from coal seams at Mopanshan will be impacted by geologic conditions such as gas content, permeability, and the occurrence of water bearing zones overlying the targeted coal seams. These conditions should be understood and addressed appropriately prior to mining. The gas content of the target coal seams is understood well enough to conclude that there is sufficient gas present to warrant concern for mine safety and indicate that there is an opportunity to develop this resource in parallel with the coal resource.

Permeability, in simple terms, is a measure of the connectivity of open pathways, through which gas can move from the seam to the well bore or mining face. Utilizing permeability as a basis of determining the most suitable pre-mine drainage option, and assuming the mineable coal seams at Mopanshan have permeability values ranging between 3 and 20 mD, the most effective pre-mine drainage wells should be drilled vertically and stimulated using hydraulic fracturing techniques to open and prop fractures within the coalbeds (Palmer, 2010). Issues relative to the occurrence of water-bearing strata overlying the target coal seams are addressed later in this section.

A conceptual design of a drilling program to drain gas from coal seams 5 and 9 using 22 vertical wells is presented below. The proposed wells are laid out in an array on 640 meter spaced centers creating a drainage area of approximately 32.4 hectares per well. In order to capture CMM prior to its release by future mining activities, wells are located on the up-dip side of Mining Areas 1, 2 and 4. Proposed locations for these wells are shown on **Figure 11**. **Figure 12** is an example cross section showing the proposed placement of borehole BH 4; the location of section, A-A', is delineated on **Figure 11**.

A simplified well construction design was used to examine the technical and economic feasibility of draining gas from coal seams prior to mining. The design used in this document is based on one that is commonly employed in North America, but it should be noted that drilling these wells should not be undertaken without using the services of a qualified drilling engineer that has experience drilling and completing wells in similar geologic conditions. As a basis for examining the technical and economic feasibility, a design for a surface-drilled pre-mine drainage well is provided. Each well is forecast to produce CMM for 10 years, with individual well gas production peaking in year two as the reservoir is de-watered. The pre-mine drainage wells could be constructed as follows:

- A 200 millimeter diameter borehole drilled to a total depth reaching 2 meters below the basal target, coal seam 9 (approximately 530 meters depth).
- 140 millimeter diameter production casing is then set and to total depth of the borehole and cemented to the surface, covering both the 5 and 9 seams. Subsequently the casing is perforated at the depth of the coal seams and hydraulically fractured.
- For water production purposes, 73 millimeter diameter tubing is run in the cased hole from the surface to the bottom of the hole, and a surface pump jack will be used to remove water from the coal seam and lower the water level in the wellbore.

Produced gas will flow through perforations in the casing into the well bore and up the annulus space between the casing and the tubing. Formation water will be pumped up the tubing and would be available for onsite use or could be discharged at a local disposal site. **Figure 13** is an example representing the proposed well design.

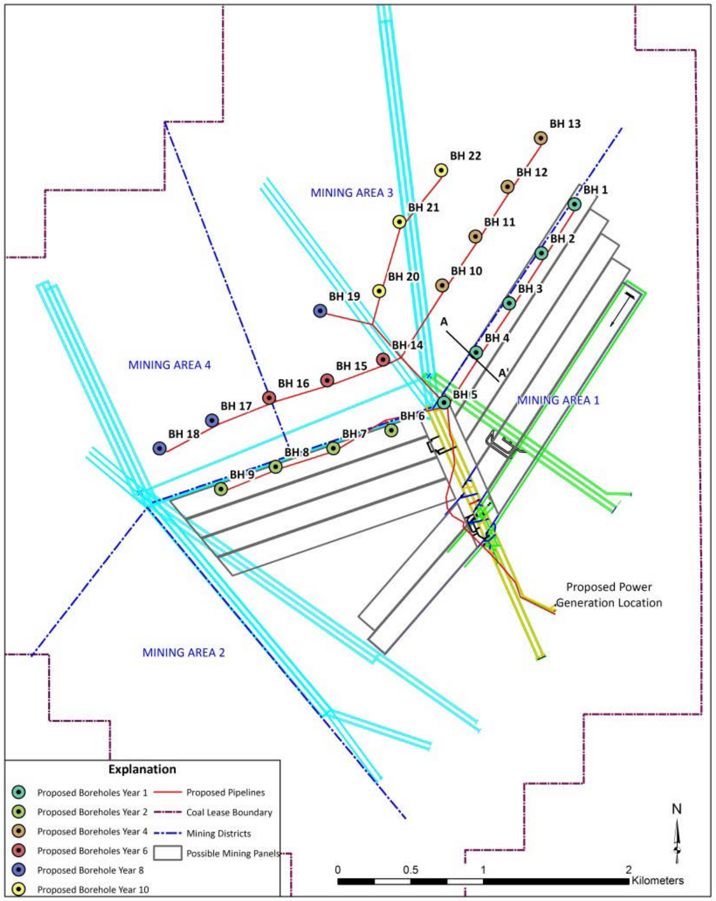

Figure 11: Layout of Proposed Pre-Mine Wells

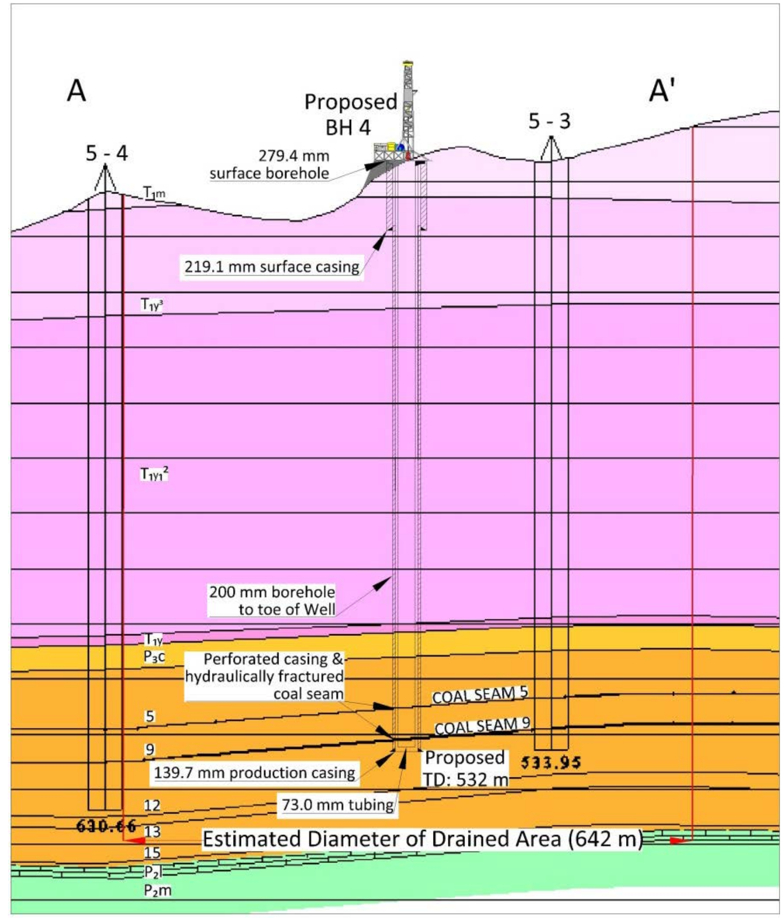

Figure 12: Example Proposed Pre-mine Well

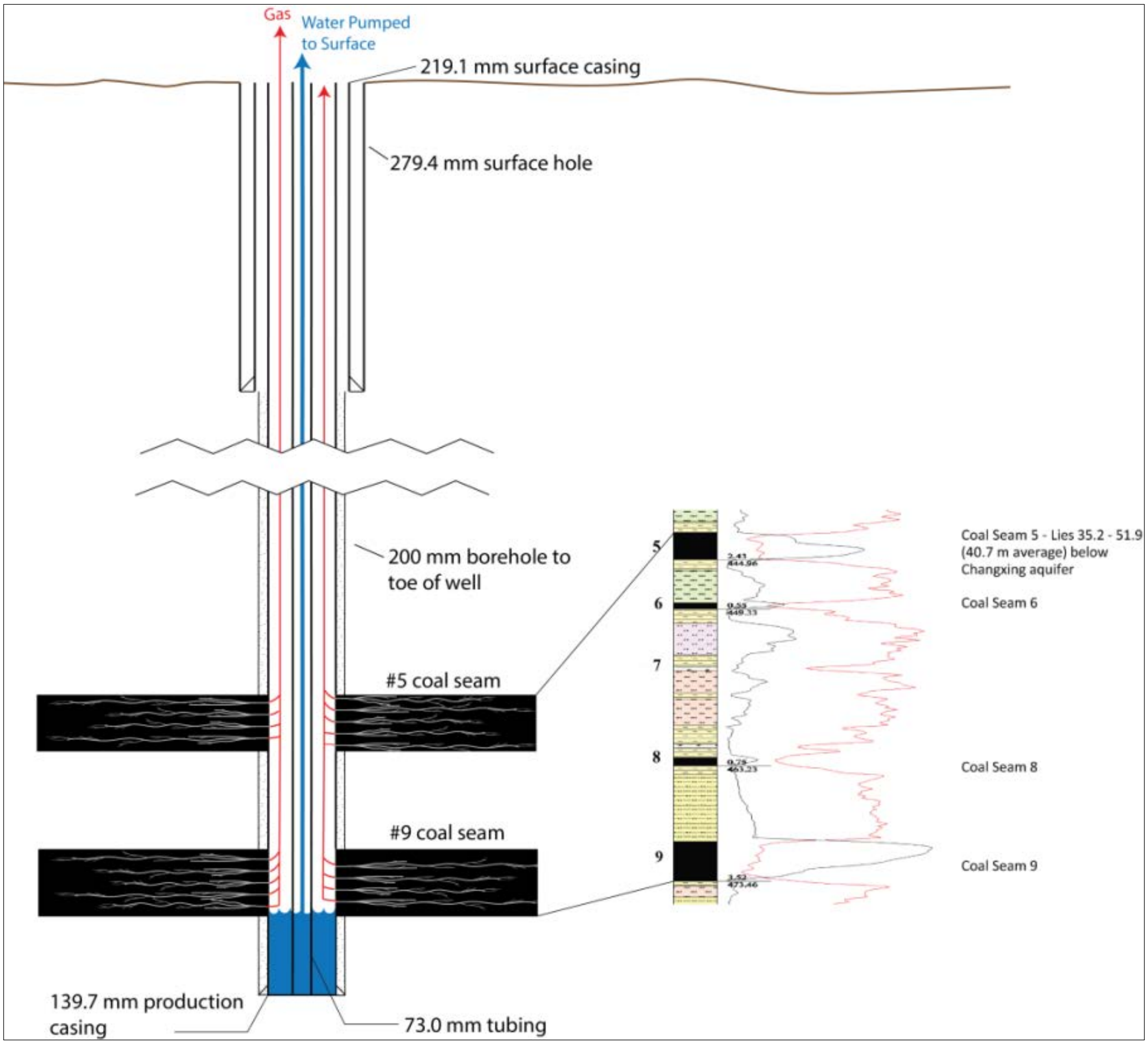

Figure 13: Pre-mine Well Diagram

A proposed layout schematic for annual gob well drilling is shown in **Figure 14.** This analysis assumes that three gob wells would be placed prior to mining, approximately 500 meters apart along the long axis of each longwall panel and slightly off the center line toward the return airway. Construction of a gob well could be constructed as follows:

- A 444.5 millimeter borehole drilled to 25 meters depth and 339.73 millimeter surface casing is run in the hole and cemented to surface.
- A 311.2 millimeter diameter borehole is drilled out from surface casing and down to a depth 2 meters below the L2 aquifer into what will become the relaxed zone above seam 5.
- In order to protect the borehole from water incursion, 244.48 millimeter production casing will be run in the hole to total depth and cemented back to surface. (**Figure 15**).

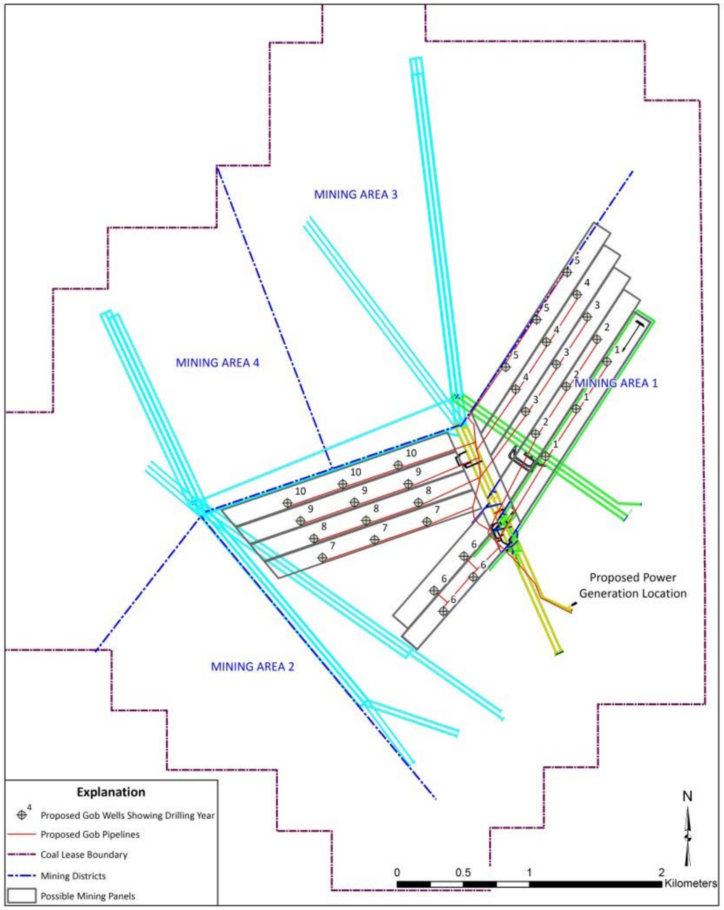

Figure 14: Layout of Proposed Gob Drainage Wells

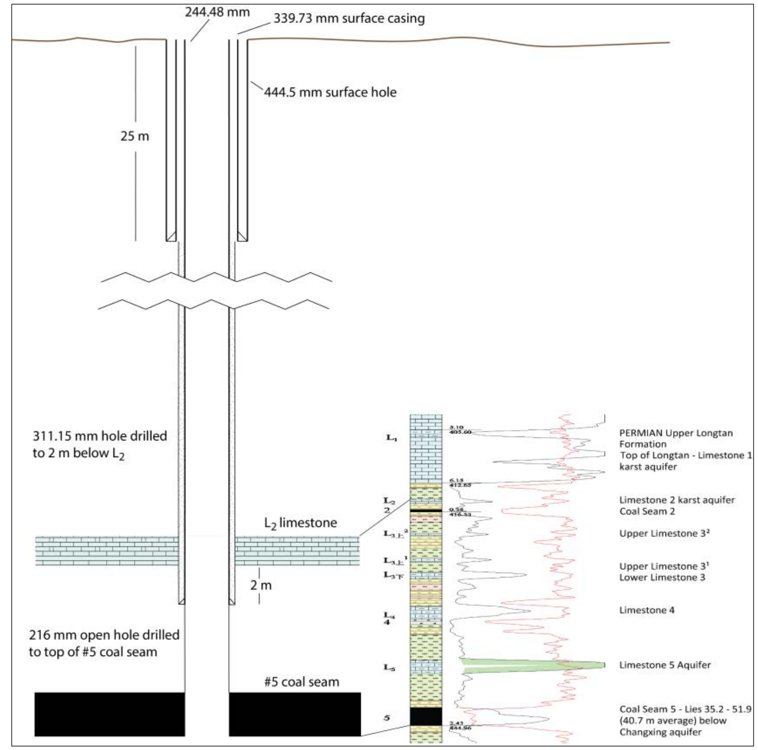

Figure 15: Example Proposed Gob Well

7.2. Gas and Water Production Forecast

7.2.1. Approach to Forecasting Pre-mine Drainage Gas and Water Production

Future gas production can be predicted using several approaches, the most common of which are: basing future production on actual past production of wells in the field being studied; reservoir simulation modeling using early production and/or geologic and engineering data acquired through field testing; and using production profiles from wells that were drilled in areas exhibiting similar geologic and reservoir conditions. A similar coalfield to the Mopanshan mine property with developed coalbed methane (CBM) production was identified and used for production profile modeling. The nearest actively producing CBM field in China is the Shouyang CBM Field, located in Qinshui Basin in Shanxi Province. **Figure 16** shows that the Shouyang CBM field lies just over 1,300 kilometers to the northeast of Mopanshan. The Taiyuan coals of the Upper Carboniferous Taiyuan Formation along the eastern edge of the Qinshui Basin are similar in rank and gas content, and have comparable burial depths and total coal thickness to the coals found at Mopanshan.

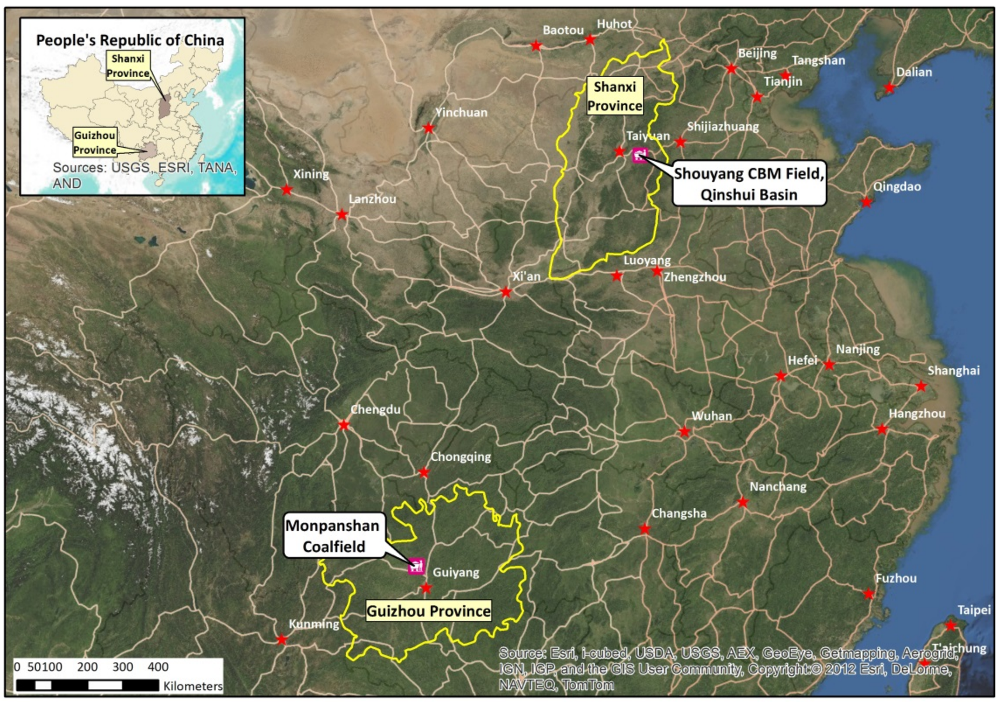

Figure 16: Gas Production Forecast Analogy Location Map

Table 6 shows a comparison between some of the geologic properties of the two coal fields (Operations-Shouyang Block, n.d.). While both were deposited during the Upper Paleozoic Era, Mopanshan coals were deposited during Permian time and Shouyang coals were deposited during Carboniferous time. The variation in depth of burial between the two coal fields has been accounted for with the Mopanshan field adsorption isotherm, discussed above in **Section 6**, which predicts the gas content at varying depths of burial. Permeability data at Mopanshan is unavailable, therefore further field testing should be conducted to refine and more accurately forecast the potential gas and water production. However, gas production data at Shouyang is the basis for the gas and water production forecasts presented for Mopanshan.

Table 6: Comparison Table of Mopanshan and Shouyang Geologic Properties

	Mopanshan	Shouyang
Coal Age/Formation	Permian Longtan Formation	Permian Shanxi Formation and Carboniferous Taiyuan Formation
Rank	Anthracite	Anthracite
Average Coal Gas Content (cubic meters/tonne)	Coal 5 – 14.5 Coal 9 – 15.8	15.5
Methane Saturation of Coal (%)	71	75
Coal Thickness (meters)	Coal 5 – 1.8 Coal 9 – 3.0	3.5 – 5
Coal Depth (meters)	500	900
Permeability (mD)	N/A	80 - 120
Recovery Efficiency (%)	~ 47	~ 60

The CBM production history of the Shouyang Block, controlled and operated by Far East Energy Corp., provided sufficient historical gas production data to perform a reservoir simulation analysis (Reeves, 2008). The simulation included reservoir conditions and well production history data of coal seam 15 of the Taiyuan Formation, and the probability-based forecasted results for the p10, p50 and p90 gas production from a vertical well, spaced at 642 meter centers (Reeves, 2008). These forecasts were used as the basis for forecasting gas production at Mopanshan. In order to scale these forecasts to simulate potential production of pre-mine drainage wells at the mine, it was necessary to adjust the forecasts for the differences in reservoir conditions between the two locations. A comparison of the estimated OGIP at each location showed that Mopanshan contains approximately 43.2 percent of the total gas resource at Shouyang. Therefore, it is reasonable to expect the potential gas production is also 43.2 percent of the total forecast from Shouyang. The lower portion of the graph shown in **Figure 17** illustrates the p50 gas decline curves from Shouyang and the scaled p50 decline curve that represents the potential gas production at Mopanshan.

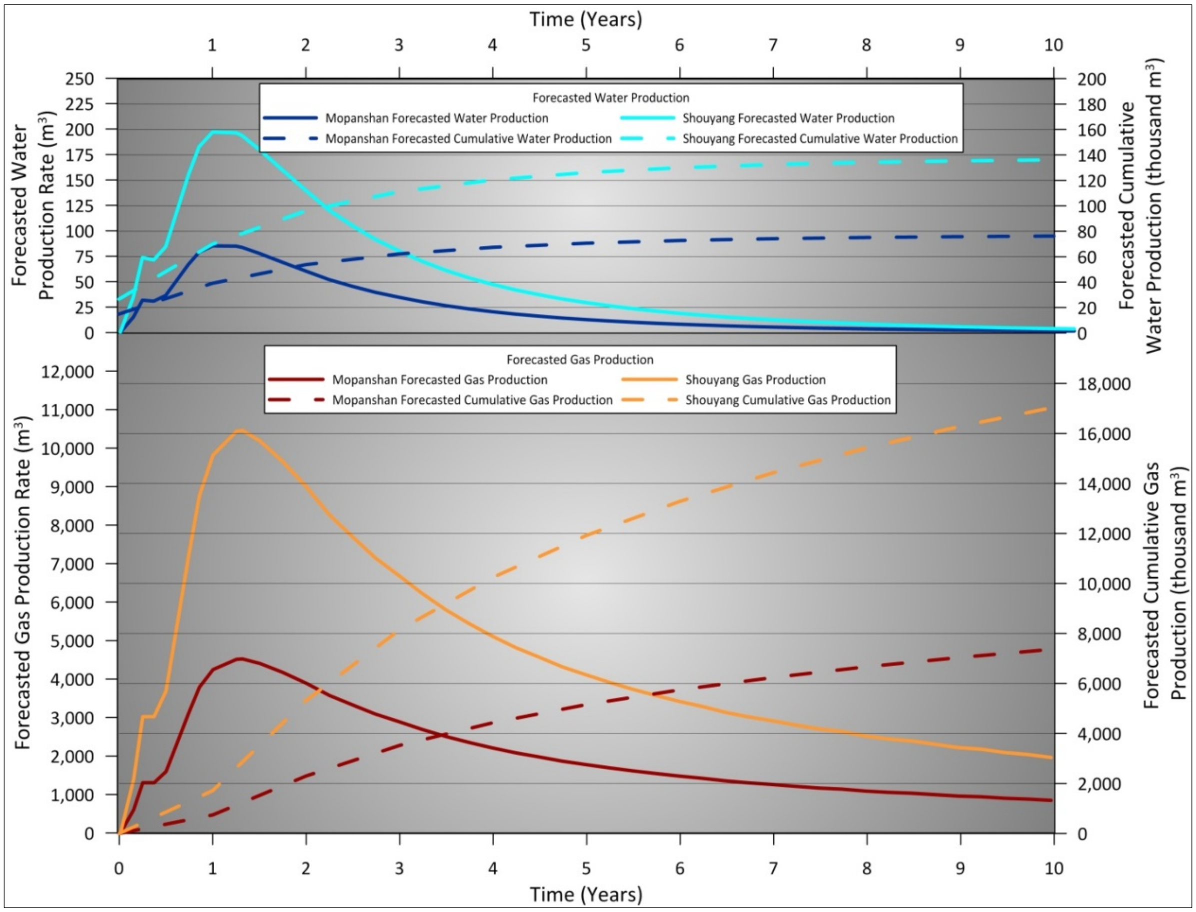

Figure 17: Forecasted Gas and Water Production - Comparing Mopanshan to Producing CBM Field

According to the p50 production forecast, 118.3 million cubic meters of methane could be drained by the proposed pre-mine drainage wells. In order to determine the volumes of water that would be produced in association with the forecasted gas production, a water/gas ratio plot was first generated based on Shouyang Field historical production (**Figure 18**). An exponential decline curve was fit to the data, and the resultant formula defining the curve was used to calculate the ratio at which the water production should decline relative to gas production. This declining ratio was then applied to the modeled gas production to determine the volume of annual water production associated with the forecasted annual gas production at Mopanshan. The associated water production estimates are considered high; however, actual associated water production should be considerably less as the coal permeability at Mopanshan is likely to be less than that of the Shouyang Field. The upper portion of the graph shown in **Figure 17** illustrates both forecasted water production curves.

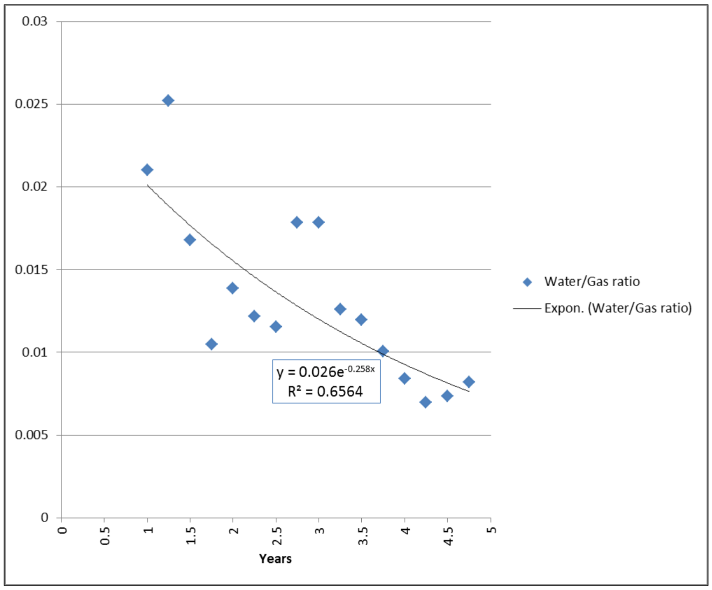

Figure 18: Water/Gas Ratio of Shouyang Production (cubic meters/cubic meters)

Figure 19 depicts the relationship of the gas and water production forecasts. As water reaches peak production, estimated in the first year of production, the gas production ramps up to peak around year two. This is typical of gas production from coal seams; as water in the coal is produced, the relative permeability to gas increases, allowing for an increase of gas production.

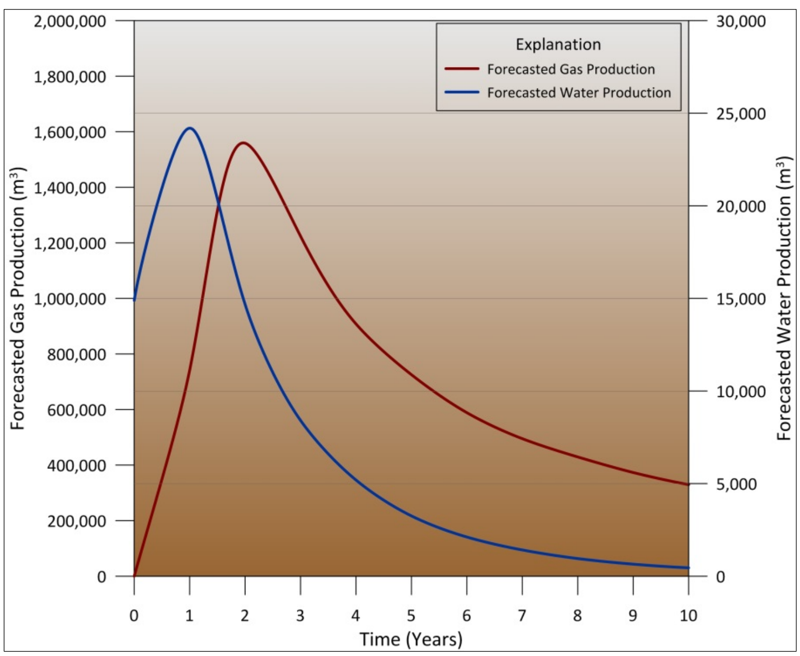

Figure 19: Forecasted Gas and Water Production

7.2.2. Pre-mine Drainage Gas and Water Production Forecast Results

Relying on the comparisons between the Mopanshan coalfield to the Shouyang CBM field, gas and water production forecasts were generated. These production forecasts are different than the OGIP calculations, because the OGIP estimates represent the total amount of gas present within the mineable coal seams, whereas the gas and water production forecasts represent only that percentage of the OGIP and associated water that may be drained by the proposed pre-mine wells. Based on the proposed boreholes and their drilling schedule, **Table 7** shows the forecasted annual gas and water production.

Table 7: Pre-mine Drainage Gas and Water Production Forecast Results

Production Forecasts	YEAR										
	1	2	3	4	5	6	7	8	9	10	TOTAL
Annual Gas (million cubic meters)	3.71	10.76	12.36	12.40	13.50	12.97	13.14	12.92	13.34	12.19	118.28
Annual Water (thousand cubic meters)	120.97	170.16	100.77	156.39	95.75	129.83	80.34	121.26	75.12	118.11	1,168.68
Number of Pre-mine Drainage Wells Operating	5	9	9	13	13	16	16	19	19	22	22

The total forecasted p50 gas production for the proposed 22 pre-mine well gas capture system is 118.3 million cubic meters of methane. Forecasted p50 water production totals 1,168.8 thousand cubic meters. Given the estimated p50 OGIP and the p50 forecasted gas production, the recovery efficiency of the pre-mine drainage wells over the 10 year project life is 47 percent, which is acceptable by industry standards.

The forecasted average volume of potential water production of the proposed pre-mine drainage wells is approximately 116.9 thousand cubic meters annually. In China, water disposal practices currently employed are mainly surface impounds and evaporation. To date, the environmental effects of produced water discharge have been overlooked and there are currently no relevant regulations or environmental impact assessment guidelines in place (Meng et al, 2014). Evaluation of technologies to handle produced water from pre-mine drainage wells at Mopanshan should employ best practices to account for local water use needs.

7.2.3. Approach to Forecasting Gob Gas Drainage Production

The gob gas drainage production forecast assumes that each well would be placed into service only after the longwall passes underneath and the strata overlying seam 5 begins to relax; and for each year, a gas drainage efficiency of 50 percent of the total amount of gas liberated is achieved collectively from all operating gob wells. Total gas liberated is calculated by multiplying the average specific emissions value for the 5 seam of 12 cubic meters per tonne (NDI, 2013) by the annual coal production, ramping up to the mine's design capacity of 900,000 tonnes per year in year three. The 50 percent drainage system efficiency factor is then applied, resulting in total annual gob gas drained. Production from gob drainage boreholes is also included into the total gas production forecast based on the assumption that this volume would then be combined with gas produced from pre-mine drainage wells to provide fuel for the gensets. All costs associated with both the gas and water production are incorporated into the economic analysis; however, water disposal costs are not included.

7.2.4. Gob Gas Drainage Production Forecast Results

Based on the proposed boreholes and their drilling schedule, **Table 8** shows the forecasted p50 annual gas production. The total p50 forecasted gas production for the proposed gob well gas capture system is 47.63 million cubic meters of methane.

Table 8: Gob Gas Production p50 Forecast Results

Production Forecasts	YEAR										
	1	2	3	4	5	6	7	8	9	10	TOTAL
Annual Gob Gas (million cubic meters)	1.09	2.91	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	47.63

7.3. Total Gas Production Forecast Results

Table 9 summarizes the total gas production forecasted from pre-mine and gob drainage wells. This volume represents the gas available for utilization by the mine.

Table 9: Total Gas Production p50 Forecast Results

Production Forecasts	YEAR										
	1	2	3	4	5	6	7	8	9	10	TOTAL
Annual Pre-mine Drainage Gas (million cubic meters)	3.71	10.76	12.36	12.40	13.50	12.97	13.14	12.92	13.34	12.19	118.28
Annual Gob Gas (million cubic meters)	1.09	2.91	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	47.63
TOTAL	4.80	13.67	17.81	17.86	18.95	18.42	18.59	18.38	18.79	18.65	165.91

The total forecasted p50 gas production for the proposed pre-mine drainage and gob well gas capture system is 165.91 million cubic meters of methane over the course of the ten year project.

8. Energy Markets

8.1. Coal Market

8.1.1. China's Coal Market

Coal dominates China's energy market with a 69 percent contribution to energy needs in 2011. The Chinese government plans to cap coal use to below 65 percent of total primary energy production by 2017 to reduce air pollution. Coal's share of the total energy mix is expected to fall to 63 percent by 2020 due to anticipated increased efficiencies and China's goal to reduce its carbon intensity; however, absolute coal consumption is expected to double over this period, reflecting the large growth in total energy consumption. China plans to reduce carbon emissions per unit of GDP by at least 40 percent from 2005 levels by 2020. China has also announced plans to reduce its energy intensity levels (energy consumed per unit of GDP) by 16 percent between 2010 and 2015 and increase non-fossil fuel energy consumption to 15 percent of the energy mix in the same time period (EIA, 2014a). **Figure 20** shows estimates of various components' contributions to China's energy mix.

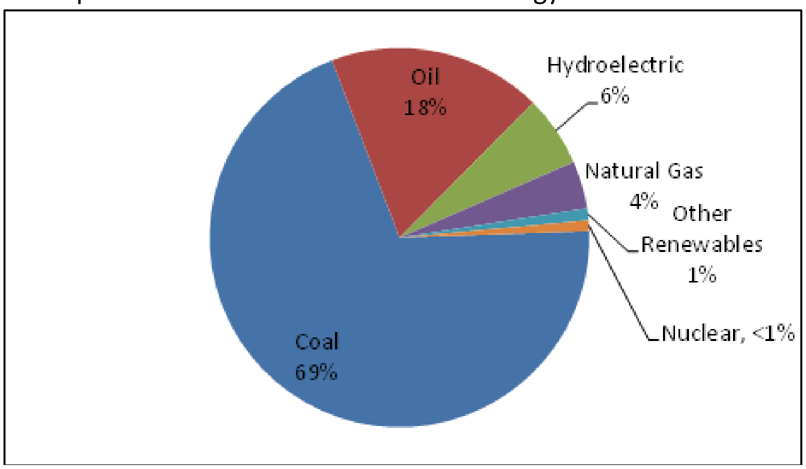

Figure 20: China's Energy Mix 2011. Source: EIA (2014a)

Historically, a net coal exporter, China became a net coal importer in 2009 for the first time in over two decades and has since become the world's largest importer, with net imports reaching 168 million tonnes, or 4.8 percent of total consumption on a physical quantity basis, and over 5 percent on a heat value basis in 2011 (EIA, 2014a). Imports are consumed primarily in the southern and eastern coastal cities, the primary victims of coal transportation bottlenecks, and in steel mills. Thermal power generation has been the most important driver for coal industry expansion, accounting for approximately half of total consumption in recent years, followed by steel and cement, which have accounted for about 25 percent of the total. **Figure 21** shows China's coal production, exports, and imports between 2000 and 2012.

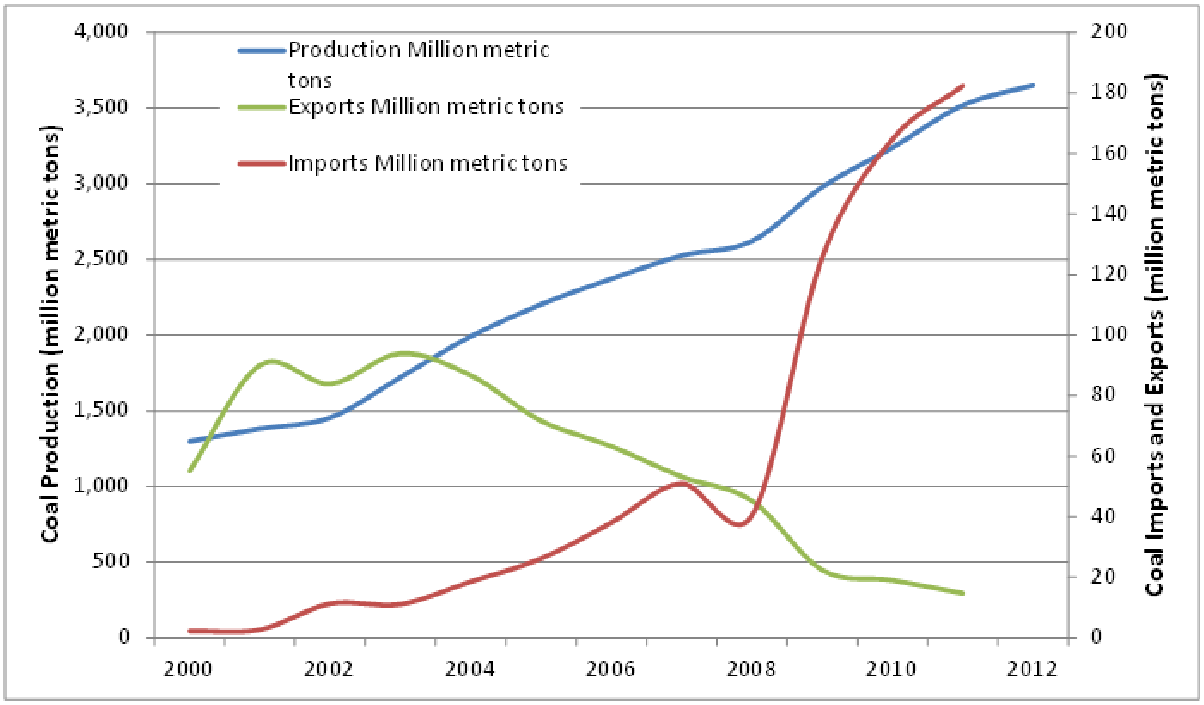

Figure 21: China's Raw Coal Supply. Source: EIA (2014b)

8.1.2. Guizhou's Coal Market

Guizhou has traditionally been a coal exporting province, shipping 25 – 30 million tonnes to outside customers in recent years. The Guizhou Coal Bureau has projected in-province demand growth at 11.5 percent per year from 2010-2015 to approximately 170 million tonnes, driven largely by electric power plant construction. Guizhou's coal quality also makes it relatively attractive to neighboring provinces and Guizhou is virtually the only source of coking coal in south and southwest China.

8.2. Electricity and/or Gas Market

8.2.1. China Electricity Market

China's electricity consumption grew at a robust average rate of 11.1 percent from 2005-2011. With the exception of 2008-2009, growth in electricity consumption surpassed overall economic growth by an average margin of 19 percent. In an investment-centered economy, industry was the primary driver of electricity, accounting for close to 70 percent of total consumption. Metals, building materials, and chemicals alone accounted for 37 percent, with residential and commercial consumption accounting for only 19 percent (USEPA, 2012).

As China is a zero importer/exporter of electricity, its growth has come entirely from domestic generation, with output and generating capacity increasing by an average of 11.1 and 12.5 percent annually from 2005-2011 to 4,700 Terawatt Hours, and 1,060 Gigawatts, respectively. Thermal power, overwhelmingly coal-fired, dominates the generation mix.

8.2.2. Regional Electricity Market

The Guizhou power grid is one of five interconnected provincial grids which are controlled by the state-owned China Southern Power Grid Company (CSPGC). Although Guizhou is one of China's smallest, poorest, and least urbanized provinces, its interconnections with the rest of the country have grown stronger in recent years, and as is the case for most inland provinces, Guizhou's economy has continued to grow at double digit rates throughout the second decade of the 21st century even as national economic growth has moderated. In a sharp break with past patterns, however, electricity consumption growth has trailed economic growth by increasing margins over the period, falling to 7.2 percent in 2013. Manufacturing remains the most important driver for economic growth in Guizhou, increasing at well over 10 percent per year and accounting for approximately 75 percent of total electricity consumption in the province. Guizhou's disproportionate economic dependence on energy-intensive extraction and manufacture of commodities such as coal and aluminum, however, creates the potential for some volatility in local electricity demand. In continuation of an electric power investment boom initiated at the beginning of the 21st century in connection with a program to supply electricity to Guangdong, Guizhou's power generation capacity increased by about 17,000 megawatts, or 63 percent to almost 45,000 MW between 2009 and 2013. Guizhou has become an important electricity supplier to nearby Guangdong and it is expected that Guangdong will continue to depend on significant volumes of electricity purchase from Guizhou and other CSPGC provinces for the foreseeable future.

The expansion included major hydroelectric plants as well as a number of large thermal power plants burning Guizhou's plentiful coal resources. As of the beginning of 2014, coal plants accounted for 54 percent of total capacity and hydro for 42.6 percent.

Power generation in Guizhou increased by an average of 5.4 percent annually between 2009 and 2012. While power consumption growth has exceeded the growth rate of power generation, some installed capacity has not been commissioned and this has led to restrictions on power usage in Guizhou. If demand within Guizhou and Guangdong continues as projected, supply and demand for electricity within the larger region could be more closely balanced than in the past. There will continue to be considerable variability on a year-to-year basis due to the unpredictability of water conditions; in bad water years, the Guizhou grid will likely dispatch every unit that it can, whereas in good water years, it may not fully dispatch the available coal-fired capacity. Given their lower wholesale prices, the hydroelectric plants will always enjoy priority for dispatch. It would thus appear that the public grid could potentially require all that distributed power producers such as CMM power plants could produce in some years, but not all. Especially if they are unable to meet or beat the cost of coal-fired power to the grid of approximately 0.38-0.39 yuan per kWh, distributed generators will need to rely on enforcement of policy mandating favorable dispatch of their output. Guizhou regulatory authorities have not yet taken concrete measures to enforce NDRC requirements[2]. Virtually all power generated by Guizhou CMM plants, therefore, is being distributed through the mining companies' grids for their own consumption. Some mining companies with the capability to generate excess power have been forced to idle capacity due to their inability to reach interconnection and sales agreements.

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[2] NDRC April 2007 *Opinions Regarding Use of Coalbed Methane and Coalmine* Methane: public grid companies purchase all power generated in excess of mining companies' own needs by CMM generation plants, pay the purchase price in a "timely manner," and pay the CMM power generators the same prices as for power from biomass generation plants, equivalent to the regulated wholesale purchase prices for power from new coal-fired plants, plus a 0.25 CNY per kwh surcharge.

9. Proposed End-use Option and Economic Performance

End-use options for the CMM drained from the Mopanshan mine are very limited as there is no existing infrastructure in the region that would enable the mine to transport produced gas to market. Moreover, the CMM resources have not yet been proven at Mopanshan, so work to plan and build the necessary infrastructure to move CMM is premature. Therefore, the best option available is on-site use.

9.1. Power Generation

The most viable option for utilization of CMM produced in advance of mining and post mining is as fuel for an internal combustion power generation facility located in close proximity to the mine's surface facilities. The mine is still in the pre-development stage as of late-2014, and timing of mine construction is dependent on China's coal markets which have been depressed during the last two years. Therefore the mine's electricity consumption is not available. However, the magnitude of coal production of the initial mine plan indicates that electricity generated by the proposed project could be consumed on-site, and supplant electricity that would be purchased from other sources.

The following sections discuss basic background information of the project as well as all inputs and assumptions used in the production analysis and the economic analysis, followed by a discussion on the economic performance of the project.

9.1.1. Technology and Deployment

Power generating equipment from two western suppliers was evaluated based on price and performance. The averaged costs and fuel requirements from the two systems (USD/kWh installed) were used in the analysis. This equipment has a fuel consumption factor of 0.2475 cubic meters per kWh installed. Operating 8,000 hours each year, once the project reaches peak production (year five), 108,000 MWh of electricity could be generated annually. This equates to an installed capacity of approximately 13.5 MW of combined electrical and thermal generating capacity.

The unit costs for this equipment were derived from correspondence with a representative of a western company with offices in Asia. Below, **Table 10** shows the annual capital investments along with the operating costs of the project's design. Included in the capital cost (CAPEX) estimates are equipment purchase, installation and testing, gas gathering, as well as all drilling and completion costs. For this study, operating costs are assumed to be 25 percent of capital expenditures, which is a common industry practice when estimating project costs. Installation of the internal combustion power generation facilities is scheduled in the first, second, third and fifth years. Operating costs for power generation increase as additional capacity is added. Operating costs for gas production, however, increase annually as new wells are drilled and brought online.

Table 10: Annual Project Costs

Annual Project Costs (USD x1,000)										
YEAR	1	2	3	4	5	6	7	8	9	10
Capital Expenditures (CAPEX)										
Power Generation	2,199	3,665	1,924	0	458	0	0	0	0	0
Drilling	2,568	2,088	768	2,088	768	1,758	1,758	1,758	1,758	1,758
Total CAPEX	4,767	5,753	2,692	2,088	1,226	1,758	1,758	1,758	1,758	1,758
Operating Costs (OPEX)										
Power Generation	550	1,466	1,947	1,947	2,062	2,062	2,062	2,062	2,062	2,062
Gas Production	105	153	153	201	201	237	273	309	345	381
Total OPEX	655	1,619	2,100	2,148	2,263	2,299	2,335	2,371	2,407	2,443

9.1.2. Risk Factors and Mitigants

As with any project, there are risks associated with developing a successful project. **Table 11** lists the risks that have been identified, an assessment of the level of risk, and possible mitigants to each identified risk. Overall, the risks associated with technology and implementation are low to moderate, but other than using the electricity generated on-site, the risks associated with market and policy issues are high. Access to the electricity marked in the region is a large hurdle for the mine. In order to overcome this hurdle, on-site use of any electricity generated by the drained CMM would serve to eliminate the need for the mine to purchase power from the grid, and alleviate the necessary steps to tie into the electricity grid and negotiate a power purchase agreement. The risk associated with obtaining the rights to extract and utilize CMM relative to national and regional policy is also high; however, taking the step to conduct careful planning with the right agencies in order to obtain the hydrocarbon rights in conjunction with the coal rights can mitigate this risk.

Table 11: Risk Factors and Mitigants: Power Generation and Use Options

Risk	Assessment	Mitigants
Market:		
Access to and the ability to dispatch all available generated power to the grid	High	Use power on-site and avoid sale to national grid.
Access to national electricity market	High	Use power on-site and avoid sale to national grid.
Ability to get rational prices for power sold to grid	High	Use power on-site and avoid sale to national grid.
Policy:		
Rights to CMM extraction and use	High	Careful planning, meetings with cognizant agencies; obtain the hydrocarbon rights along with rights to the coal.
Technology:		
Reliability and dependability of equipment	Low	Very dependable equipment; train local technicians to monitor, maintain, and repair engines and associated systems.
Fluctuations in gas concentrations	Low	The concentrations of gas drained in advance of mining should not fluctuate significantly.
Implementation:		
Fluctuation in pricing of equipment and services	Moderate	Current trend for prices is downward; Procure contracts that lock in favorable prices.
Procurement of permits and rights-of-way	Low	Develop timeline that incorporates time necessary to secure all necessary permits and right-of-ways, allow for delays.
Delays in deliverability of equipment	Low	Detailed planning; incorporate necessary lead time into orders.
Delays in installation	Low	Detailed planning.

9.2. Economic Analysis

The project was modeled to determine the economic performance of on-site power generation and use. The subsections below list the assumptions and inputs used for the modeling, followed by a subsection reporting the resulting estimates of economic performance.

9.2.1. Inputs and Assumptions

Inputs and assumptions used to model this option are listed in **Table 12**. When available, actual costs and pricing are used in the model; otherwise, reasonable estimates based on industry standards were used. The drilling costs used in the economic model were actual costs taken from a report on the Shouyang CBM project (Barker, 2013), adjusted for depth and inflation.

The project evaluation period is for 10 years, where the drilling of pre-mine drainage wells is carried out throughout the life of the project so as to optimize supply of fuel to the gensets. This production is supplemented by drained gas from gob wells, whereas three wells are placed into service each year and achieve a gas drainage efficiency of 30 percent of the total amount of gas liberated as a result of mining operations. Power generation equipment is scheduled for installation in years one, two, three and five.

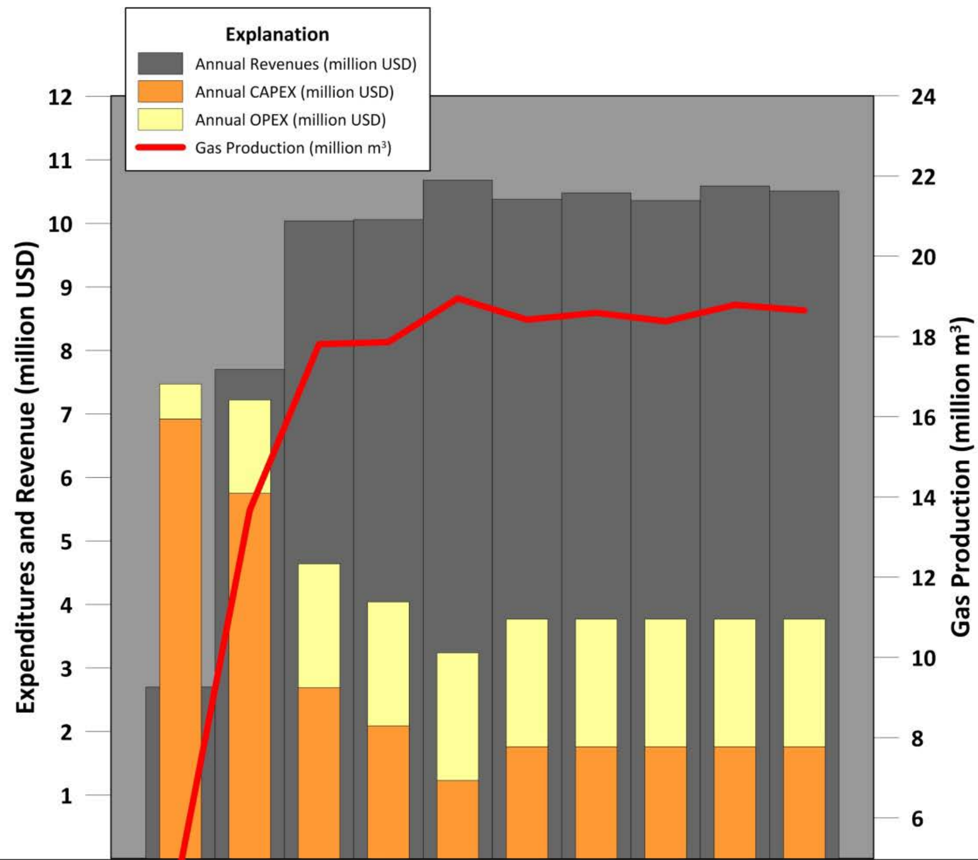
According to the p50 production forecast, 165.9 million cubic meters of methane could be drained and used to generate electricity. All electricity generated will be used by the mine, so the sales price of electricity used in this analysis is 0.60 CNY/kWh (0.096 USD), which is the price that the mine would otherwise have to pay to the grid. Annual project operating costs are assumed to be 25 percent of the capital costs.

Table 12: Inputs and Assumptions Used in Economic Model

Project duration	10 years	
Gas production available to the project	Based on analogous p50 production forecast from the Shouyang Field in the Qinshui Basin in Shanxi Province, adjusted for depth and differences in original gas in place estimates.	
Drilling & completion costs – Pre-mine drainage wells	300,000 USD / well	Actual costs taken from third-party assessment report of Shouyang Field, adjusted for depth.
Drilling & completion costs – GOB wells	226,000 USD / well	
Gathering & hook-up costs	30,000 USD / well for all wells	
Production well operating costs	1,000 USD / well / month	
Drilling rig mob / demob	150,000 USD	
Main gas transmission line	200,000 USD / km	Industry standard "rule of thumb" costs
Water production handling costs	0.67 USD per cubic meter produced and transported	Industry average costs
Plant construction	Site construction and installation is conducted in the first year, additional generator sets are installed in years two, three and five.	
Capital Investment for p50 scenario	Power Stations & auxiliary facilities includes drilling and completing 22 production wells: 5.41 million USD	Power station investment based on unit costs 916.23 USD/kW
Annual power sales	Electricity generated available to mine: 108,000 MWh	
Annual operating hours	8,000 per year	
Gas consumption efficiency	0.2475 cubic meters per kWh generated Utilizes 5.0 percent of gas stream as fuel for compressors.	Based on manufacturer's representatives.
Power sales price, avoided cost	0.60 CNY per kWh (0.096 USD)	Avoided cost that mine would have paid to grid.
Annual project operating and maintenance costs	25 percent of capital costs for gensets annually. 1,000 USD per well per month for all producing wells (pre-mine drainage and gob wells).	Based on information provided by manufacturer's representative and drilling contractor.
Federal tax rate	25 percent	

9.2.2. Probabilistic Economic Forecast Results

Using the p50 CMM production forecast, 165.9 million cubic meters of CMM could be available for use. **Figure 22** shows a chart of the forecasted annual gas production along with the annual modeled expenditures and revenues. The number of active pre-mine drainage and gob wells, gas and water production for the period is shown for each year of operation in the table below the graph.



YEAR	1	2	3	4	5	6	7	8	9	10
Number of Gob Drainage Wells	3	3	3	3	3	3	3	3	3	3
Number of Pre-mine Drainage Wells	5	9	9	13	13	16	16	19	19	22
Gob Drainage Production (million m^3)	1.09	2.91	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45
Pre-mine Drainage Production (million m^3)	3.71	10.76	12.36	12.40	13.50	12.97	13.14	12.92	13.34	12.19
Annual Water (thousand m^3)	120.97	170.16	100.77	156.39	95.75	129.83	80.34	121.26	75.12	118.11

Figure 22: Gas Production, Expenditures and Revenues of the Proposed Methane Mitigation Plan

The initial two years of the project are considered investment years, as the project costs are expected to exceed project revenues. During this same period, coal reservoir dewatering takes place and gas production increases. As shown in **Figure 22**, gas production should begin to stabilize and project revenues should exceed all project capital and operating costs around years three and four. With the forecasted gas production, a series of internal combustion engines could be installed at the mine, totaling 13.5 MW, fueled by all available CMM. The CAPEX for the project is forecasted to be 27.5 million USD, and the OPEX for the proposed project are forecasted to be 20.6 million USD, for a total of 48.1 million USD for the ten year life of the project. **Table 13** below summarizes the results of the modeling performed to determine the economic performance of a power generation option. At the p50 production rate, the project returns a positive value for the NPV at 13.3 million USD, and an IRR of 45.0 percent with a payback period of 3.84 years.

Table 13: Power Generation Option Base Case Forecast Results

Power Generation Scenario	
Evaluation Scenario	Base Case
Annual Operating Hours	8,000
Gas Forecast-Project (million cubic meters)	165.9
Total CAPEX (million USD)	27.5
Tonnes of CO_2e (x thou.)	397.4
Carbon Sales Price (USD)	0.00
Plant Size (MW)	13.5
CAPEX/tonnes CO_2e	0.07
Electricity Sales Price (¥/kWhr)	0.600
NPV/tonnes CO_2e	33.48
NPV (Million USD)	13.3
IRR (%)	45.0
Return on Investment (%)	48.4
Payback Period (years)	3.84

9.2.3. Sensitivity Analysis of Power Generation

A sensitivity analysis was performed on the power generation option, utilizing the p10 and p90 10 year well production forecasts to determine the impact of varying methane production on project economics (**Table 14**). For the p10 scenario, while the total 10-year gas production summary is greater than that of the p50 scenario, the NPV of 15.6 million USD, and IRR of 43.9 percent do not vary significantly due to the additional costs associated with increased water production. The p90 scenario also shows favorable results, indicating that the risk of economic failure is low for a gas recovery project based on the current assumptions and inputs described in this report.

Table 14: Comparison Table of Economic Indicators with Varying Gas Production Forecast

Evaluation Scenario - Gas Forecast	p90	Base Case - p50	p10
Gas Forecast-Project (million cubic meters)	153.6	165.9	181.8
Water Production Forecast (thousand cubic meters)	1,056	1,169	1,369
Total CAPEX (million USD)	27.4	27.5	28.9
Tonnes of CO_2e (x thousand)	367.9	397.4	435.6
Plant Size (MW)	13.0	13.5	15.8
CAPEX/tonnes CO_2e	0.07	0.07	0.07

Evaluation Scenario - Gas Forecast	p90	Base Case - p50	p10
NPV/tonnes CO_2e	31.43	33.48	35.77
NPV (Million USD)	11.6	13.3	15.6
IRR (%)	43.4	45.0	53.9
Return on Investment	42.2	48.4	54.0
Payback Period (years)	3.92	3.84	3.37

10. Conclusions and Recommended Next Steps

The Mopanshan coal mine, located in northeast Qianxi County, Guizhou Province, has a design capacity of 900,000 tonnes per annum, and resources of 215.8 million tonnes of anthracite coal from coal seams 5 and 9.

Data and reports provided by the mine's technical staff were evaluated in order to better understand the factors that controlled the distribution and size of CMM resources contained within the mine lease boundary. After constructing a relatively simplistic three dimensional geologic model, it is estimated that the gas resource contained within the coal measures has the potential to produce between 153.6 and 181.8 million cubic meters of gas from the proposed 22 pre-mine drainage wells and 30 gob drainage wells over the examined life of the project. It is estimated that the proposed project could produce enough gas to fuel a 13.5 MW power generation facility to be used by the mine. It is also estimated that the project could produce 1,169 thousand cubic meters of water, available for the mine's use. The capital costs are estimated to be $27.5 million USD with an IRR of 45.0 percent and a payback period of 3.84 years. Carbon emissions would be reduced by 397.4 thousand tonnes of CO_2e over the project's ten year life.

In order to minimize the geologic uncertainty which might affect the success of the coal mine methane drilling and recovery campaign, such as the proposed drilling program, a comprehensive data collection program should be carried out first. The different types of testing and sampling in this program should include:

- Gas desorption testing: currently, there are some gas content data points available; however, the lateral extent of the distribution of gas content data over the entire license block is lacking. An extensive campaign should be designed and carried out to collect gas content data for all coal seams over the entire license block.
- The desorbed gas from select desorption samples should be tested for gas composition.
- Injection fall-off testing should be carried out in one or more test boreholes to better understand the gas flow capacity (gas producibility) of the coal, average reservoir pressures, and the impacts that drilling and completion-related stresses will have on the reservoir permeability.
- All exploration boreholes planned should be rotary drilled, rather than cored, and a full suite of geophysical logs should be run over the entire openhole section for each borehole.
- A three dimensional seismic acquisition program should be designed and carried out over the entire mine lease to identify and determine the extent and impact of faulting, fracturing, and overlying aquifers on the coal-bearing strata.

Methane production from the proposed drilling program supplies sufficient gas to fuel a 13.5 MW plant, a program which requires drilling new boreholes throughout the life of the project. Once this initial data is collected and integrated into the existing geologic model and interpreted, the number and placement of these scheduled boreholes can be optimized to ensure sustained gas delivery to the power generation station over the project life. The removal of methane gas from the targeted coal seams in advance of mining will not only provide benefits in the form of electricity generated from the gas, but it will also increase the safety of mining operations and reduce greenhouse gas emissions.

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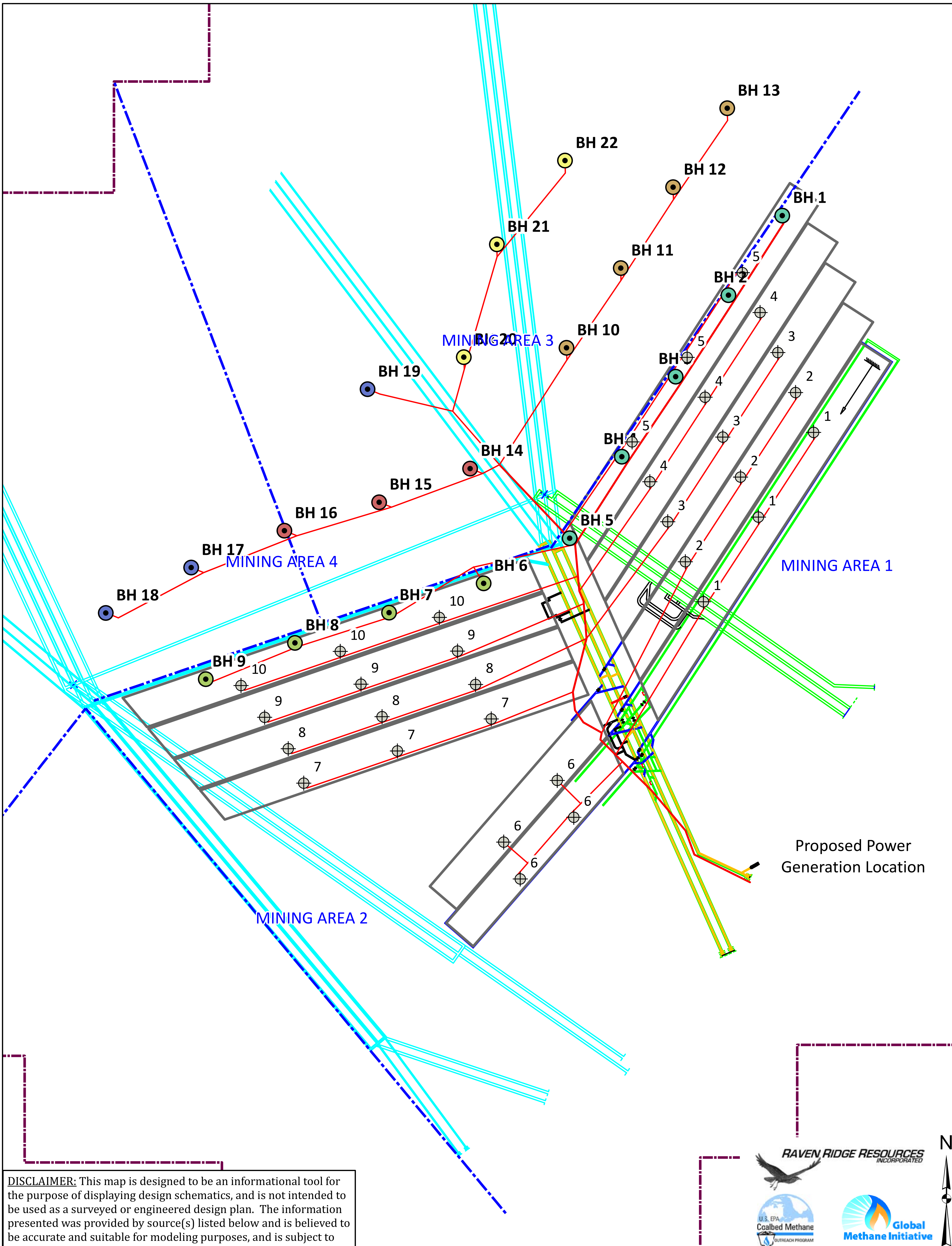

DISCLAIMER: This map is designed to be an informational tool for the purpose of displaying design schematics, and is not intended to be used as a surveyed or engineered design plan. The information presented was provided by source(s) listed below and is believed to be accurate and suitable for modeling purposes, and is subject to the limitations stated above.

- Proposed Pre-Mine Wells Drilled Year 1
- Proposed Pre-Mine Wells Drilled Year 2
- Proposed Pre-Mine Wells Drilled Year 4
- Proposed Pre-Mine Wells Drilled Year 6
- Proposed Pre-Mine Wells Drilled Year 8
- Proposed Pre-Mine Wells Drilled Year 10
- Proposed Gob Wells Showing Year of Operation
- Mine Entryways and Roadways / Proposed Gob Pipeline
- Proposed Gas Gathering Lines
- Proposed Gas Transport Lines
- Coal Lease Boundary
- Mining District Boundaries
- Potential Mining Longwall Panels

PLATE 1: Mopanshan Coal Mine Proposed Drilling Map

1 cm = 150 meters

0 0.5 1 Kilometers

Xian 1980 3 Degree GK Zone 35;
False Easting 35500000.0, Latitude of Origin 0.0

Lithology, physical and hydrological characterization

Quaternary (Q)

LOESS: Deposited mainly near the river, along part of the hillsides, at the base of the mountains, and within other relatively low-lying valleys. The deposit comprises mainly colluvium, alluvial material and residual material, from the bedrock of the $T1y^{3}+^{2}$, P_3c, and contains flint limestone or limestone of yellow-gray, gray, gray and yellow, gray and purple and other colors of gravel; boulders; sandy soil; powder soil and clay. Drilling revealed thickness ranges between 0- 7.60m. The deposit lies uncomformably (angular) atop the underlying strata.

Physical characteristics: The strata structure is relatively loose, showing lower density than the underlying strata; low resistivity curve amplitude; higher neutron porosity curve anomaly amplitude and low amplitude natural gamma curve.

Maocaopu (T_1m)

LIMESTONE: The formation is widely distributed in the mining area, but occurs mainly in the western portion. It ranges in thickness between 4.55 - 119.45m, and averages 49.33m. Within the region, the Maocaopu is partially exposed. The deposit comprises thick gray mud, layered with crystal structure of the light gray Fenxie thin-bedded limestone at the bottom of 1.70m ± thickness. Yellow-gray weathered strata appear before bedded micritic argillaceous limestone structure. The formation lies conformably atop the underlying strata.

Physical characteristics: The limestone based formation, shows the apparent resistivity curve has a higher amplitude density than the underlying strata; the magnitude of the natural gamma curve is lower; and the neutron porosity curve amplitude is low. When the development of the apparent resistivity curve values are lower and the density curve value increase, it suggests rock fissures and caverns are present. In the upper, weathered section of formation, resistivity values and density values are lower.

Upper Yelang (T_1y_3)

SANDY MUDSTONE - CALCAREOUS MUDSTONE: Gray and yellow, gray and purple, fuchsia thin-bedded silty mudstone, muddy siltstone, mudstone, with Klinefelter clams, scallops and other animal fossils sandwiched in 4 to 6 layers of light gray argillaceous limestone. Drilling has exposed the formation thickness to range between 4.65 - 108.30m, with an average of 85.14m.

Physical characteristics: There are five areas of developed marl, with higher amplitude resistivity curves; spontaneous potential curve showing negative anomalies reflect crenellations; the natural gamma curve clip showed low amplitude with high amplitude reflection, characterized by obvious physical signs are good layers. The bottom boundary of the formation where the apparent resistivity curves and underburden show significant difference in the magnitude of the natural gamma curve and where the neutron curve amplitude is higher than the underlying strata, there are obvious and easily distinguishable steps.

Middle Yelang (T_1y_2)

LIMESTONE - MARL: Exposure revealed through drilling showed a range of thickness between 63.00 - 316.85m, with an average of 275.51m. Gray mud with thick crystal structure to powder-like or layered with thin and thick-bedded limestone; gray to light gray massive oolitic limestone; upper part is light gray, gray, yellow-gray and weathered appears before the thick-bedded limestone; marl sandwiched with thin-bedded gray and yellow, gray-green thinly-bedded argillaceous siltstone and silty mudstone 1 to 2 layers 0.9 - 1.24m thick. The central light gray, thick bedded gray limestone is argillaceous locally, with biological clastic rocks containing raw limestone breccia and worms; the lower part is gray, dark gray thinly-bedded, medium to thick-bedded mud limestone with thin mudstone.

Physical Characteristics: The formation comprises mainly limestone and marl, where the apparent resistivity curve showed a high impedance in the limestone section; and the marl resistivity curve showed lower resistance, reflected by changes in amplitude. Depending on the density, the natural gamma and neutron porosity variation is small in the upper section, whereas the magnitude of those curves within the marl section exhibits a significant step change. According to physical characteristics, it can further be divided into distinct segments of the upper and lower sub-sections:

Sub-segments:
(T_1y_{2-2}) within the upper sub-section of purer quality limestone, the focused resistivity curve showed high amplitude changes where the density curve also showed large variations in amplitude; the low amplitude of the gamma and neutron porosity curves suggesting a calmer depositional setting.

(T_1y_{2-1}) the limestone and shale content increased gradually from top to bottom, the apparent resistivity curve shows less variation of the fine sharp jagged shape and the amplitude decreases; the natural gamma curve shows more variation then the upper sub-section and increases in the lower portion of the section, the neutron porosity curves reflect abnormal spikes where the lithology changes to less dense material. The curve amplitude gradually increases and is higher than the overlying strata where the unit is closer to marl than limestone.

Lower Yelang (T_1y_1)

MUDSTONE: Pale yellow, yellow and gray, gray-green thinly-bedded silty mudstone; muddy siltstone; light gray thinly-bedded argillaceous limestone; calcareous shales with bivalve fossils and yellow-green mudstone containing flakes montmorillonite. This section ranges in thickness between 6.60 - 12.70m, with an average of 9.50m.

Physical characteristics: Within the mudstone segment, the apparent resistivity curve is flat showing low resistivity; the natural gamma and neutron porosity curve amplitudes are higher than the upper and lower strata, with the obvious physical characteristics showing stable thickness of this unit.

Changxing (P_3c) + Dalong (P_3d)

LIMESTONE: The formation thickness ranges between 18.65 ~ 35.30m, with an average of 24.55m. It is composed mainly of ash-gray micritic thick-bedded limestone \ with a layer of thickly-bedded limestone flint, containing local bands of thin organic carbonaceous mudstone, rich in fossils and fossil debris. The Dalong (P_3d) bed ranges in thickness of only 0.82 - 1.40m, with an average of 1.11m. It comprises dark gray thinly-bedded and thick bedded siliceous limestone. Reflected only in the logs, visual identification is difficult to distinguish from the Changxing limestone, therefore they are represented together. The formation lies conformably with the lower formation.

Animal fossils:

Palaeo fusulina sp.;
Reichelina sp.;
Colaniella sp.;
Spinomarginifera sp.;
Oldhamina squamosa;
Wilkingia komiensis;
Pernopecten sichuanensis.

Physical characteristics: The focused resistivity curve showed a high resistance, the natural gamma and neutron porosity curves are lower than the amplitude of the hump-shaped upper and lower strata. The formation shows stability throughout the unit.

Longtan (P_3l)

MUDSTONE, SILTSTONE, LIMESTONE and COAL: The group ranges in thickness between 142.25 and 177.70 m, with an average of 160.58m. The formation outcrops within a small portion of the eastern and southern mining area. The Longtan formation is the coal-bearing strata of the area. The group is interbedded and composed of coal-bearing strata deposited through nine depositional cycles. The lithology comprises gray-dark gray, dark gray mudstone, silty mudstone, muddy siltstone, gray-brown gray fine-grained sandstone, gray-gray limestone, bioclastic limestone, gray and black carbonaceous shale and coal seams. There are a total of 18 coal layers (on the first 1,2,3,4,5,6,7,8,9,10,11,12,13,13, the seams 14, 15), where the first 5 , 9,12,13,15 seams are more stable, the group contains limestone (marl) 18 layers (L1, L2, L3 on 2, L3 on 1, L3 down, L4, L5, L10 , the L11, limestone, L12, L12, the upper L14, the L14, the L15, L15 of, L15 next, L16), wherein, L1, L2, L3 combination, L4, L5 composition, L12 combination, L14 combination, L15 combination of the region's horizon shows obvious characteristics and can be used as a marker layer. Coal from seams 5 and 9 is the main exploration purpose; the 12, 13 coals are used for proper control. The Longtan lies atop the underlying strata along a parallel unconformity. The group is rich in fossils in the mudstone, siltstone and limestone (marl) layers.

Animal fossils:

Oldhamina grandis;

Derbyia disalata;

Dielasma acutangula var.minor;

Pernopecten guizhouensis;

Oldhamina anshunensis;

Leptodus sp.;

Lingula sp.;

Crinoids;

Plant fossils:

Gigantopteris sp.;

Sphenophyllum cf.;

Compsopteris cf.;

Cladophlebis sp. ;

Pecopteris sp.;

Lepidodendron sp.;

Annularia sp.; and

Gigantonoclea sp.

Physical characteristics: According to lithology, lithofacies, coal characteristics and physical properties of coal-bearing strata of the group, the formation can be divided into two sections.

(1) P3l2:
This section comprises nine limestones (L1, L2, L3 on 2, L3 on 1, L3 down, L4, L5, L10 and L11) and eleven coal seams (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11). These interbedded layers mark the stable development of the sedimentary sequence showing a good sign of markers which depict phase transition, allowing stratigraphic correlation and the ability to identify of five important coal intervals. Limestone and marl layers are reflected by the increased magnitude of the resistivity and decreased magnitude of the neutron porosity curves. Coal seams 5,6,8,9 are stable, while seams 1,2,3,4,7,10,11 are unstable; their thickness and structural changes are larger and where multi-phase variations become carbonaceous mudstone. Coal 5 contains a layer of coal partings, the 9 seam has a single structure, as most of the coal layer or region. Coal seams 6 and 8 are single layers with stable structure. Each seam in this section, has a marker be with sufficient thickness showing stable spacing making for easily distinguishable coal stratigraphy. Top 10 coal seams, bottom of mudstone, shale contains more radioactive elements, and therefore have a higher amplitude anomalies in the natural gamma curve, showing a thickness of about 2.50m, due to its stable deposition. L10 and L11 lithology shows larger changes, with multiple phases of calcareous mudstone, but the layer is stable. The group of properties under this section show a clear distinction based primarily on the segment division. Coal has a high resistivity, low gamma ray, and high density and small physical changes of the neutron porosity which make it easy to distinguish from other lithologies, the seam curves reflect the significant parameters, reliable qualitative and thickness due to the development of a more stable marker layer to determine the coal layers bits and reliable.

(2) P3l1:
This section is mainly developed on the upper L12, the lower L12, the upper L14, the lower L14, the L15, L15 middle, L15 lower, L16 limestone, where the L14, L14 lower, L15, middle L15, and lower L15 the limestone layers thickness and stability, is to determine the next 13, lower 13, 14, 15 coal seam important symbol layer. This section is mainly developed under 12,13,13, 14,15 coal, which is more stable seams 12, 13, in which the top three layers of coal, rock and bottom seams contain high internal radioactivity, So has the physical characteristics of a high amplitude anomalies in the natural gamma curve; 13 under unstable coal seams, coal seam 14 into multiphase carbonaceous mudstone, due to its high content of radioactive elements in the natural gamma curves high amplitude anomalies, and 14 on the upper coal seam development L14, L14 under limestone "peak forest landform" curve characteristic properties.15 roof and floor mudstone and aluminum mudstone, shale and mudstone containing more aluminum radioactive elements, and therefore have a higher amplitude anomalies in the natural gamma curve, limestone, coal and shale low amplitude, aluminum Physical characteristics of the combination of high amplitude mudstone, which features a combination of physical characteristics obviously, is an important indicator to determine the interval 15 coal seams and the bottom boundary of Longtan Formation and top of the Maokou formation.

Coal has a high resistivity, low natural gamma, density and physical characteristics of small high neutron porosity and other lithologic easy to distinguish.

Maokou (P_2m)

LIMESTONE: This formation is not exposed at the surface in the mining area, but the thickness of the zone is > 100m. 61.30 m of thickness was drilled and recorded in borehole 10-1. The formation comprises a thick layer of grayish-white, massive limestone, containing small quantities of dolomite, dolomitic limestone, and chert containing a large mass in the upper zone.

Physical characteristics: The focused resistivity curves are jagged with variation in amplitude and reflected impedance, the variation of the density, natural gamma, neutron porosity is small, showing low amplitude curves. The group has a weathered zone near the top 3 - 5 m, fissures and caverns are developed in the sections showing lower curve amplitude on the resistivity curve, and high natural gamma and neutron porosity curve amplitude.

Modified from Mopanshan Coal Exploration and Geological Report, Prepared for Guizhou Qianxi Energy Development Co., Ltd.

EXPLANATION

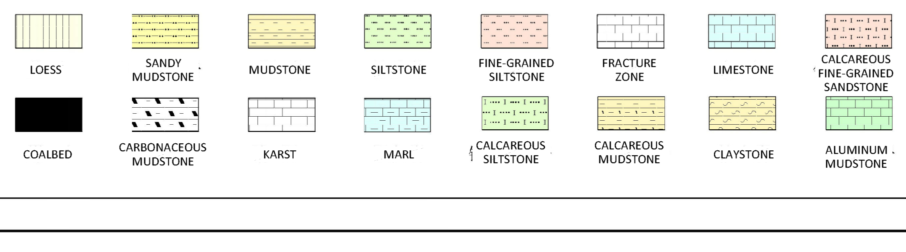

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PLATE 2: Mopanshan Coal Mine Stratigraphic Column