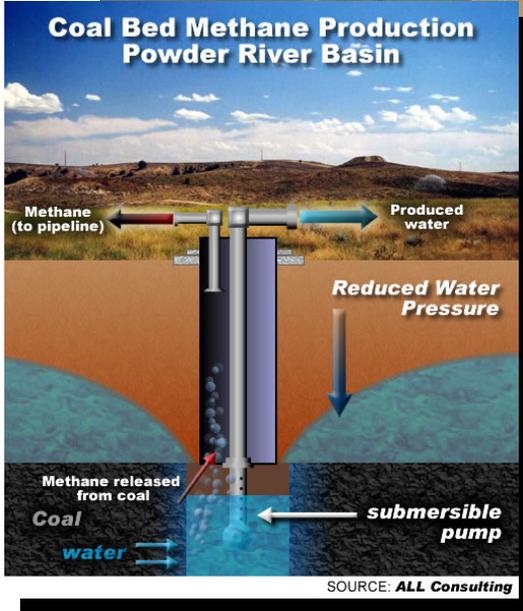


Development of Coal Bed Methane Utilizing GIS Technologies Final Report



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Principal Authors:

ALL Consulting
Tulsa, Oklahoma

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Submitting Organizations:

ALL Consulting
1305 East 15th Street, Suite 205
Tulsa, Oklahoma 74120

Montana Board of Oil & Gas Conservation
2535 St. Johns Avenue
Billings, Montana 59102

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Abstract

During the second half of the 1990's, Coal Bed Methane (CBM) production increased dramatically nationwide to represent a significant new source of income and natural gas for many independent and established producers. Matching these soaring production rates during this period were the advancements in Geographical Information Systems (GIS) technologies generating terra-bytes of new data for the oil and gas industry. Coupled to these accelerating initiatives are many environmental concerns relating to production wastes and water table depletion of fresh water resources. It is these concerns that prompted a vital need within the industry for the development of Best Management Practices (BMPs) and mitigation strategies utilizing GIS technologies for efficient environmental protection in conjunction with effective production of CBM. This was accomplished by developing a framework to take advantage of a combination of investigative field research joined with leading edge GIS technologies for the creation of environmentally characterized regions of study. Once evaluated these regions had BMP's developed to address their unique situations for Coal Bed Methane production and environmental protection. Results of the project will be used to support the MBOGC's Programmatic Environmental Impact Statement as required by the Montana Environmental Policy Act (MEPA) and by the BLM for NEPA related issues for acreage having federally owned minerals.

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Introduction

This project entailed the development of Best Management Practices (BMPs) and Mitigation Strategies utilizing GIS technologies for efficient environmental protection in conjunction with effective development of coal bed methane (CBM). This was accomplished by developing a framework to take advantage of a combination of investigative field research joined with leading edge GIS technologies for the creation of environmentally characterized regions of study. Once evaluated these regions had BMPs developed to address their unique situations for CBM production and environmental protection. Results of the project have been used to support state and federal Environmental Impact Statements in the Powder River Basin of Montana and Wyoming. The study area for the project was limited to the Montana portion of the Powder River Basin, although research was conducted nationally in an effort to determine the types of practices and mitigation being successfully and effectively to facilitate CBM development in a variety of environmentally sensitive areas that include a broad array of land and mineral ownership.

Experimental

This project's experimental methods were concentrated in using the latest technologies in original and innovative ways. The development of a Project Planning and Analysis Tool driven by a Geographic Information System (GIS) that was available over the Internet integrated several existing technologies in ways that had not yet been achieved. Combining this technology with the Best Management Practices and Mitigation Strategies also represented an experimental area that had not yet been researched and analyzed. The results of these experimental methods

created a powerful tool that has been broadly accepted and is gaining widespread use throughout both government and industry

Results And Discussion

The proposed project research operated in a manner that subdivided the project into the tasks listed below. Each of these tasks is a more manageable piece than the whole, with achievable goals at each level that allowed for a more productive environment that facilitated adjustment and reassessment of objectives when necessary. Each project research task is described below followed by a description of the accomplishments that have been achieved:

Task 1 - Field Analysis of Present Environmental Concerns: It is expected that the Powder River Basin may have previously undocumented environmental concerns directly linked to CBM production. The first task will involve the field inspection by experienced environmental assessment professional of many of the CBM wells to examine the possibility of apparent and palpable negative environmental effects. Some field sampling and laboratory analysis will be included to verify present condition.

- **Task 1 Accomplishments:** *Field analysis of present environmental concerns was performed and included field trips to the Arkoma basin of Arkansas, the San Juan Basin of New Mexico and Colorado, CBM producing areas in Utah, and too many areas throughout the Powder River Basin of Montana and Wyoming. Project researchers participated in public scoping meetings for an environmental impact statement and a resource management plan being done for CBM in Montana as well as other related CBM*

meetings. In addition, an extensive evaluation of environmental concerns was conducted, including researching a variety of technical and environmental documents. Data was collected from state and federal governmental agencies and field data and information was collected through coordinated efforts with several CBM producers.

In an effort to gain information toward CBM operations nationally, field reconnaissance was performed in April 2001 to the San Juan basin of New Mexico and Colorado and to producing fields in Utah. During this effort, project team members (including DOE) were able to interface with industry involved in CBM production, the southern Ute Indians, and the Bureau of Land Management. Overall success was proven through the successful transfer of technology/information in a bi-directional sense. In addition, in March 2001, researchers met with representatives of the Arkansas Oil & Gas Commission to discuss CBM development in the Arkoma basin of Arkansas and Oklahoma. Additional field trips were conducted by the research team to the Wyoming and Montana portions of the PRB to assess environmental protection issues and concerns specific to the PRB. This included several trips by MBOGC representatives of the research team to further analyze CBM operations in the Montana portion of the basin.

Further, research conducted from this project and especially this task has been used in other projects already. Data collected and compiled by the researchers was used in the Montana Statewide EIS/RMP Amendment; the Ground Water Protection Research Foundation's CBM Produced Water Management and Beneficial Uses Feasibility Study; NEPA planning efforts in Colorado, Wyoming, Utah, Alaska, New Mexico, and Kansas; and with regard

to several development efforts by industry and BLM. The potential synergies of this effort in research sharing has been staggering.

Task 2 - Delineation and Acquisition of Data for Analysis and GIS:

The Montana State Library Natural Resource Information System (NRIS) is a state supported data repository for Montana's wealth of geographically referenced natural resource data. The NRIS contains data on Montana's administrative/legal boundaries, land and water resources, environmental monitoring, mining, geology, mineral ownership, and other data that is available to the public free of charge. In conjunction with the acquisition of this data, the MBOGC also possesses and controls all of the oil and gas well records for the state of Montana, allowing the researchers maximum flexibility during the modeling process.

Preliminary investigations into data availability needed for this project have shown that much of the data already exists, but that some of the data will have to be created.

- **Task 2 Accomplishments:** *In order to delineate and acquire data for analysis and GIS applications, technical specialists on the research team visited with a variety of state and federal agencies to assess and obtain data for the project. Through this process, a substantial amount of spatial and environmental data was obtained. Information acquired in this effort includes, but is not limited to, data on area soil types, geology, hydrology, stream and river water quality, groundwater quality, surface land and mineral ownership, and well locations. Some of the agencies visited include the Bureau of Land Management, NRIS, Montana Department of Natural Resources and Conservation (various Bureaus), Montana Bureau of Mines and Geology, Montana Board of Oil & Gas Conservation, and others.*

The data acquisition process undertaken as part of this project was an extremely beneficial aspect of the project and was instrumental to the project's success. Significant time and effort were made by several state and federal agencies (as noted above). This compilation process provided a foundation of information that has been used elsewhere relative to CBM development and planning, including the recent EIS documents in the Powder River Basin.

Task 3 – GIS Analysis: The GIS analysis for this region will involve critically analyzing the present-day CBM production practices and the spatially related environmental data. The data will be utilized to spatially classify specific zonal regions of varying environmental characteristics. Characteristics anticipated for review include; water production, water quality, hydraulic fracturing, pipeline construction, storage facilities, water impoundment & disposal facilities, underground injection activities, compressor station operations, geological features, hydrogeological controls, present contamination, land ownership, sensitive ecosystems, and CBM production rates. Each of these site characteristics will be independently evaluated, however, only the significant factors relating to cause and effect will be included in the final model.

- **Task 3 Accomplishments:** *GIS analysis was performed and an Internet-based GIS application has been published to the MBOGC's web site (<http://www.bogc.dnrc.state.mt.us/mtgis>). The application, currently referred to as the WebMapper system, allows access using GIS tools to all conventional oil & gas wells and coal bed methane wells in the state of Montana. This system further allows users to perform spatial queries and access information on wells in the state*

(including coal bed methane wells). ALL compiled and combined coverages for use with the WebMapper system, including numerous spatial analysis coverages that focus on both state and federal lands in the Powder River Basin as well as Native American lands (including the Northern Cheyenne and Crow Reservations).

This has been a significant achievement considering the utility of spatial analysis to the oil & gas industry, the NEPA process, regulatory compliance, prospecting, and more. In publishing this system, a statewide land-grid system was prepared, well spot locations were converted to GIS compatible coordinates, and significant data quality analysis was performed by both ALL and MBOGC staff. Information derived from this research has been used in the statewide EIS and resource management plan amendment for coal bed methane in Montana and has greatly benefited that effort.

Task 4 – Mid-Term Report: The researchers will prepare a summary report covering the field investigation of the Powder River Basin, the delineation and gathering of existing GIS data and analysis of current CBM activities. Besides a narrative of the accomplishments, the report will present and interpret the current environmental conditions of the Powder River Basin, identify data gaps in the identified materials acquired, as well as discuss the GIS technologies employed during the analysis. Also to be included are recommendations for revisions to the framework for work before and during the BMP development task. This report will be issued within 60 days of the completing the GIS analysis.

- **Task 4 Accomplishments:** *A document was prepared that represents the Project Mid-Term Report. It included a summary of the many activities that had been conducted, data gathered, and accomplishments*

achieved to date. These accomplishments are summarized within that report according to the various project task elements.

Task 5 - Development of Best Management Practices and

Workshops: BMPs will be developed for the discrete zonal regions and will effectively describe how to administer practices to best protect the environmental conditions of the Powder River Basin. In the process of developing these BMPs, full consideration will be given to the economic ramifications of overly rigorous limitations, and efforts will be focused upon maintaining the viability of this industry while simultaneously minimizing long-term damage to the environment. The findings and recommendations by the MBOGC will be incorporated into the BMPs by region and address specific issues where applicable. The BMP and mitigation strategies will consist of those techniques endorsed by the MBOGC for use in various parts of the state during CBM exploration and production activities. The principal investigators will present several workshops to demonstrate BMPs to industry and the public. The workshops will be organized, scheduled, and advertised by the MBOGC.

- **Task 5 Accomplishments:** *ALL and MBOGC have completed a document entitled “Handbook on Best Management Practices and Mitigation Strategies for Coal Bed Methane in the Montana Portion of the Powder River Basin”. The research team believed that, before proceeding further with development of the GIS tools, a hard copy handbook that generally defines the types of Best Management Practices and Mitigation Strategies relative to coal bed methane was needed. The handbook was completed in January, 2002 and distributed to federal, state, and industry stakeholders for their review and comment. Incorporating these review comments into a final handbook and into the GIS tools early in the process*

significantly enhanced the overall usefulness of both of these products.

ALL staff have prepared and presented multiple papers/presentations on the issue of Coal Bed Methane in the Powder River Basin and the significance of Best Management Practices. Mr. Dan Arthur presented papers at the International Petroleum Environmental Conference in Houston and a Ground Water Protection Council conference in Reno, Nevada. Mr. Arthur and Dr. Bruce Langhus also prepared and conducted a 1-Day workshop on CBM operations and associated environmental issues and the use of Best Management Practices and Mitigation Strategies in addressing those issues at the Ground Water Protection Council Conference conducted during January of 2002 in Houston. MBOGC staff assisted in the preparation of the workshop materials. Mr. Arthur has also made additional presentations in Denver, Billings, and Houston. Mr. Arthur has presented project results at two IPEC meetings (Houston and Albuquerque). Additionally, Co-Researcher Tom Richmond of the Montana Board of Oil & Gas Conservation (MBOGC) has been extremely active with respect to the development of Coal Bed Methane throughout Montana. The MBOGC has openly discussed several Best Management Practices and Mitigation Strategies with industry and the public at public meetings, hearings, and business meetings of the MBOGC. Mr. Richmond also prepared and conducted a presentation to the Environmental Quality Council in March 2002, along with a presentation to the Montana Bar Association, Continuing Legal Education, in December 2002.

Task 6 - Development of Decision Analysis Processes: Long-term viability of the tools created by this project will require an immense infrastructure of data and programmatic decision-making. Once this infrastructure is in place, these tools will be able to provide a real-time analysis tool that will enable the MBOGC to quickly and efficiently examine environmental impacts of a proposed well. The general public will also have access to this information over the Internet, providing producers with the information they need to fully appraise a proposed well.

- **Task 6 Accomplishments:** *ALL staff evaluated the spatial data that was acquired and developed and outlined the various elements that made up the decision analysis process. This includes such elements as area geology, soil types, location of water use wells, watershed and drainage, proximity to urban areas, land and mineral ownership, and others. A Project Planning and Analysis Report was developed that allows the user to dynamically select environmental criteria to be included in the report, performs spatial calculations on this data, and provides the user with the detailed printable report of the applicable environmental, oil & gas, cultural resource, and civic data.*

Task 7 - Final Report: Within 90 days of completing the decisions analysis process a Final Report will be issued describing the GIS permitting model, development of the BMPs, regional delineation, significant site characterizations, and the infrastructure tools employed. The report will also analyze the changes in issuing a new permit and the requirements necessary to implement management practices recommended.

- **Task 7 Accomplishments:** *This document represents the Final Report. It details many of the processes that were performed, the data gathered and utilized throughout the project, and accomplishments achieved. Each accomplishment is summarized within this report according to the various project task elements. The following is a description of the infrastructure employed to develop this project, along with a description of the tools developed.*

Infrastructure

The software utilized for this site consists of an Internet map server, enterprise level GIS database gateway software, and an enterprise level database management system, all running on a Windows 2000 based web server.

ESRI's ArcIMS 4.0 was selected as the Internet map server for this application. ArcIMS provides many unique built-in functionalities and gives maximum flexibility for customization. The core of the web site is built using HTML frames embedded with Javascript to control code execution, dynamically generate requests to be sent to the server, send and receive requests between the client browser and the server, and dynamically generate output HTML in the client browser. Active Server Pages (ASP) are also used to dynamically generate the production data for each individual well. ArcIMS was chosen because of a rapid customization environment, rapid deployment tools, low overall cost, and ESRI's current position as an industry leader in GIS software.

ESRI's ArcSDE 8.2 was utilized as the enterprise-level GIS database gateway software. ArcSDE facilitates managing spatial data in a database management system such as IBM DB2, IBM Informix, Microsoft SQL Server, or Oracle. This application uses Microsoft SQL

Server as the database management system to leverage existing databases and facilitate customization. ArcSDE provides for greater flexibility and performance, database portability, schema portability, and better data integrity while providing an extensive application programming interface allowing for reduced database and application development costs.

Microsoft SQL Server 2000 was utilized as the enterprise-level database management system. SQL Server 2000 is Microsoft's premier database management system and has been an industry leader in that area for many years.

The Risk Based Data Management System (RBDMS) is also utilized in this application. Data stored in RBDMS on oil and gas wells is used to continually update the site with the latest information. The locations and production data stored in RBDMS are replicated to the MBOGC web server and are there used in this application.

Functionality

The functionality of this application is very diverse. The following is a discussion of many of the features of the application that make it both useful and unique.

Project Planning and Analysis Report

The Project Planning and Analysis Report is the most complex part of and is the core of the application. Generating a report provides the user with a list of the known environmental conditions of the selected study area. The report contains calculations of area features to produce total area of each individual feature type, length calculations for linear features, and a formatted list of all point

features contained in the study area. The report calculations and analysis were designed so that each individual layer is no more important than any other layer, thus the level of effort for future enhancements and transferring this technology to another state is reduced. The report is generated by following a few simple steps to define the study area and selecting the layers to be reported on. The following is a description of those steps.

- 1) **Define Study Area** – *Defining the study area is done simply by using the ‘Select Sections’ tool to select sections individually or as a group to be added to the study area. After pressing the ‘Select Sections’ tool, the user selects the sections to be included in the report by selecting (‘clicking’) on the section in the map. The sections that make up the study area are then shown in left frame for the user to review. All of the sections in the study area can be cleared to allow the user to start over or each individual section can be clicked on again in the map to de-select it.*
- 2) **Running the Report** – *Once the user has defined the sections to be included in the study area, the Project Planning and Analysis Report can be generated. The user has the capability to include data from any layer in the report. When the report is generated, it contains formatted sections of each layer grouping with each individual layer calculations. The calculations include total area of individual feature types, length calculations for linear feature types, and a formatted list of point feature types. Each individual layer name is also hyperlinked to the Legend to provide the user with information about the source and scale of the original data.*

Layer Management Tool

The layer management tool is a customized user interface for adding and removing layers from the map. The tool is opened by selecting the 'Add Layers' button. The layer management tool is designed to use a folder design, similar to Windows folders, that have each layer grouped inside folders with similar layers. The addition or removal of layers from the map is done by 'checking' the layer on or off and hitting the 'Update' button. Once a layer is selected to be drawn, it is shown in the Layers status area. The Layers status area shows all layers that available to be shown at the map at all scales. Each layer name is also linked to the layer's legend. The layers that are visible at the current scale are shown in white text, while the layers that are not visible due to scale constraints are shown in gray text. The active layer is also set in the Layers status area.

The groups that the layers are in are as follows: Base map Data, Land Designation, Oil & Gas, Water, and Powder River Basin specific data. The Base map Data group contains general base map layers, including roads, counties, cities, and soils. The Land Designation group features layers that signify special designation lands, including National Parks, Fish, Wildlife & Park lands, and Wilderness Areas. The Oil & Gas group contains layers specific to oil and gas and mineral production in the state, including wells, coal mines, and pipelines. The Water group features layers specifically dealing with water including streams and lakes. The Powder River Basin group features layers dealing specifically with the Powder River Basin in Montana.

Buffering

ArcIMS has extensive buffering capabilities. The buffering tool lets the user select a feature to buffer, specify the distance to buffer, and generates a list of all of the other geographic features that fall within that buffer distance. The buffer tool selects a feature to buffer based on the current active layer.

Legend

A highly customized map legend was built for this application. The legend lists all layers available in the system and shows the map style for each feature type in the legend. The legend also gives the user an abbreviated description of the original source data, along with a link to the original Federal Geographic Data Committee (FGDC) compliant metadata (when available). The legend also lists the source scale and most current reference (when available).

Identification of Features

Any feature available on the map can be identified and reported on. The user simply has to click the Identify button, then click the feature on the map to get information about that feature. The identify is based on the current active layer the user has selected in the Layers status area. When the user identifies an oil or gas well, a link also appears with each well that show the user all production records for the life of that well.

Zoom Scales

All layers in the application have zoom scales applied to them. A zoom scale is set up so that the layer only draws within certain maximum and minimum zoom levels. This prevents layers with

millions of features being drawn on a statewide level. Zoom scales also reduce server load thereby giving the user faster response times.

Map Printing Capabilities

The current view of the map can be printed at any time during the application. The user can also specify a title to be displayed on the map which opens in a new window.

Find/Query

The application can also search for any feature based on a text attribute of each feature in the active layer. The Find tool will search all attributes to find a matching string value, while the Query tool searches only one attribute at a time, giving the user the flexibility to search for numbers or strings.

Measure

The application also has a measuring tool. The measurement is displayed to the user in the current units of the map.

Overview Map

The application contains an overview map that continually gives the user the location of the current map relative to the statewide map. The Overview map can be toggled on or off as needed.

Zooming/Panning

The application contains full zooming and panning functions. The user can zoom in or out by drawing a box on the map or by just clicking on the map in the desired area of zooming. The user can also pan to any portion of the map by selecting the Pan tool, then 'grabbing' the map and dragging it to the desired panned location.

Zooming to the full extents (the statewide level) is also available at all times in the application.

Dynamically Selecting Units

The units the map is displayed in can be set at any time in the application. The user has the choice of feet, meters, miles, or kilometers. After selecting a specific unit, all measurements of distance are performed in those units including both measuring and buffering.

Extensive Help System

An extensive help system was designed for this application to give the user the instructions needed to perform all functions. There is a link to this system from the map and can be accessed at all times. The help system includes project details and scope, an introduction to Coal Bed Methane, CBM information and resources, links to the application, links to the legend, thumbnail images along with descriptions of all tools, and screen snapshots to serve as examples of certain functions.

Customization

Although ArcIMS has many built-in functions for simple GIS analysis, significant customization had to be performed to meet the requirements of this project. The customization performed for this project was in two categories: the HTML/JavaScript Browser interface; and the ArcSDE database.

HTML/JavaScript Browser Interface

The interface for this application had to be customized extensively from the original ArcIMS template interface. The Project Planning and

Analysis Report was new development specifically for this project. This involved the code needed for creating the study area, creating multi-stage HTML pages that present options to the user, the ArcIMS requests to the server for the data used in the report, and the analysis and formatting of the data returned from the server.

The Layer Management Tool used in this application was also new development specifically for this project. This involved purchasing CoolJSTree 1.1.8, customizing the tree menu to dynamically read the available layers from the ArcIMS viewer, and updating the ArcIMS viewer with the currently selected layers.

The Legend was also new development for this project. This involved capturing the symbols for each layer, providing a short description for each layer, providing the source scale and the most current reference for each layer, and hyper-linking to the original metadata for each layer. The HTML page was also 'bookmarked' on each layer name so that when the legend was accessed from the application, the browser would move directly to the layer of interest.

The Help System was also new development. The help system includes project details and scope, an introduction to Coal Bed Methane, CBM information and resources, links to the application, links to the legend, thumbnail images along with descriptions of all tools, and screen snapshots to serve as examples of certain functions.

The dynamic linking to the production data was done specifically for this project. This was done by editing the JavaScript code that dynamically writes out the identification data, and creating an Active Server Page that connects to the RBDMS database already residing

on the MBOGC web server, and reading the production data for that individual well.

ArcSDE Customizations

The main ArcSDE customization that was performed was the addition of stored procedures to dynamically update the Oil & Gas wells layer on a nightly basis with any updates that have been performed on the RBDMS database already residing on the MBOGC web server. This update is done automatically without administrator intervention.

Task 8 - Preparation of GIS Developed BMP Guidelines: An extensive manual detailing processes, lesson learned, and steps involved in the creation of the framework will be written and made available to the public. This discussion will include the applicability of this process for other CBM producing regions and will include the following: discussion of data needs and acquisition; discussion of analysis approach; discussion of processes used for BMP development; discussion of GIS application in CBM Environmental Assessment (EA) and BMP use in ongoing EIS.

- **Task 8 Accomplishments:** *ALL staff and members of the MBOGC prepared and presented the BMP Guidelines at multiple conferences and seminars during the project period. Presentations discussing lessons learned, data acquisition and processing, analysis, and BMP use during the ongoing EIS were given at multiple conferences of the Ground Water Protection Council, the International Petroleum Environmental Conferences, the Environmental Quality Council meetings, ALL/MBOGC sponsored workshops, and many other national and regional conferences. These presentations and the project web site include information relative to the guidelines.*

Task 9 - Demonstration Results Website: A full discussion the Powder River Basin project results will be generated and made available to the public. A website containing full disclosure of the details of the project will be created and maintained by ALL-LLC. The website will include related source information such as the GIS technologies utilized, data acquisition sources, applicability of decision process, ease of framework development, factors considered and areas for improvement. The site will be a Web-based self-study Microsoft PowerPoint97 product designed to be accessible from various search engines and designed to be completed in 30 to 45 minutes. The site will conclude with an incorporated feedback quiz that will track users names and the dates of review. This information will be used to identify possible training interests and track developments of CBM BMP in other states.

- **Task 9 Accomplishments:** *Multiple PowerPoint presentations were developed during the project that discussed the methodology, the Best Management Practices, and the multiple technical papers that were presented. The MBOGC website contains a wealth of information discussing the project including many of these PowerPoint presentations, the technologies utilized during the project, the BMPs developed during the project, an extensive help system for the WebMapper application, a discussion of beneficial uses for produced CBM water, animations of CBM wells, and a listing of all the current CBM wells permitted in the State.*

Conclusion

The researchers were committed to the successful completion of this project to facilitate the efficient development of CBM in an environmentally sound manner. The development of Best Management

Practices and Mitigation Strategies utilizing GIS technologies for efficient environmental protection in conjunction with effective development of CBM has recently become of national significance. The rapid increase of CBM production necessitated this research and the results of this research have been proven invaluable thus far as evidenced by its widespread use and national recognition. The framework developed during this project will continue to be utilized in both the short term and long term and is best supported by the fact that many other agencies throughout the nation are currently planning to use these tools in upcoming projects. The researchers believe a key factor in measuring the success of this project is that further tools are currently planned for development that utilize many of the technologies developed as part of this project.

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