Abandoned Coal Mined-Land Research Program
Project Review Seminar

Twelfth Project Review Seminar

CAMPLEX, Gillette, WY

November 28, 2000

The seminar series is sponsored jointly by the University of Wyoming, Office of Research and the Abandoned Mine Lands Program of the Wyoming Department of Environmental Quality.

Twelfth Project Review Seminar
ABANDONED COAL MINE LANDS RESEARCH PROGRAM
Tuesday, November 28, 2000 Gillette, Wyoming

You are cordially invited to attend the Twelfth Project Review Seminar for the Abandoned Coal Mine Lands Research Program (ACMLRP), hosted by the University of Wyoming. The Seminar will be held on Tuesday, November 28, 2000 at the CAMPLEX Heritage Center, Gillette, Wyoming beginning at 1:15 p.m. in the Gallery.

Speakers will present interim or final reviews on research projects currently funded by the ACMLRP:

All presentations will be open to the public and there is no charge for participation in the Seminar. The agenda will include a brief review and discussion of the progress that has been made to date on each of these projects with time for questions and answers.

The ACMLRP is designed to support projects, which can aid in the development of practical solutions to some of the concerns that face the State and the Nation with respect to reclamation of coalmines. The projects were selected in open competition.

The seminar series is sponsored jointly by the University of Wyoming Office of Research and the Land Quality Division of the Wyoming Department of Environmental Quality. If you would like to have further information about this seminar series or if you would like to be placed on the mailing list to receive information about the ACMLRP, please call the Office of Research at 307/766-5353 or 766-5320.

Evaluation of Wildlife Data Collected by Five Coal Mines in the Southern Powder River Basin, Wyoming

2000 FINAL REPORT

Prepared by

Trent L. McDonald,
M. Dale Strickland,
and
Paula S. Becker,
Western EcoSystems Technology, Inc
2003 Central Ave
Cheyenne, WY 82001

Phone: 307-634-1756
Fax: 307-637-6981
E-mail: tmcdonald@west-inc.com

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Summary of Conclusions

This study inspected and analyzed all available wildlife data collected from five mines located at the southern end of the Powder River Basin, Wyoming. Our objectives were to answer the following questions:

1. Do pre and/or post Appendix B monitoring data provide useful information for determining the response of wildlife populations to mines?
2. Are the data collected under Appendix B meeting objectives for the monitoring program established by the Wyoming Department of Environmental Quality and Wyoming Game and Fish Department?
3. Are critical data not being collected under Appendix B?
4. Can data under Appendix B be collected more economically and provide equivalent information about wildlife resources?
5. Can reporting formats be modified to improve the utility of wildlife monitoring data?

Besides answering the above questions, additional objectives of this study were: (1) To evaluate the quality and quantity of all wildlife data collected from five selected Wyoming coal mines and make analysis recommendations, (2) analyze wildlife data using the most appropriate methods, (3) make recommendations for future monitoring and/or amendment of Appendix B.

Our conclusions were the following:

6. Based on our inspection of wildlife data from Jacob's Ranch, North Antelope, Rochelle, North Rochelle, and Black Thunder mines we found that the *quantity* of data collected during permitting and subsequent annual reporting was large, but that the *quality* of data was seriously compromised by lack of a standardized reporting procedure.
7. For collected data, the best available statistical analyses were long-term trend analyses that make use of extraneous environmental variables such as weather, surrounding herd counts, prey densities, etc.
8. Our analysis of data from five mines indicated:
   Pronghorn, mule deer, and elk densities increased on some mines and decreased on others during the period of data collection.
   The average number of golden eagle, Swainson's hawk, and Ferruginous hawk hatchlings and fledglings on mine sites decreased between 1980 and 1996. After 1990 (the only time period in which lagomorph densities were collected), Swainson's and Ferruginous hawk nest success was correlated with prey density. Considering this correlation, there remained a decrease in the number of Swainson's and Ferruginous hawk hatchlings and fledglings that was unexplained by decreases in lagomorph density; however, that decrease was not statistically significant.
   The number of sage grouse attending seven leks on three mines decreased after initiation of data collection.

Regarding Appendix B we concluded the following:

9. Data collected under Appendix B are currently not meeting objectives for the monitoring program because,
   Data are not currently housed in a readily accessible standard format.

Regular analysis reports are not currently being issued.

10. Provided our recommendations regarding standardized data entry are followed, we find Appendix B mandates collection of data that will eventually be useful for assessing mining impacts on wildlife populations.
11. Critical data are currently being collected under Appendix B; however, we recommend establishment of control areas because they would yield stronger and more interpretable data (i.e., data that could be used in a BACI analysis). We realize the difficulty involved in establishing these areas and, while recommended, control areas are not absolutely necessary for overall success of the monitoring program provided adequate environmental covariates are also collected.
12. Appendix B should allow and encourage cooperative collection of data to economize survey methods. Under cooperative surveys, each mine should report data for their mine area separately.
13. Guidance regarding data collection and reporting procedures in Appendix B is wholly inadequate. We strongly recommend standardized raw data forms and electronic database files be submitted with or in lieu of annual reports.

To ensure the long-term utility of the wildlife-monitoring program, we recommend, in order of importance, the following:

14. Standardized reporting formats be implemented.
15. Regularly scheduled analysis reports be issued.
16. Standardized reporting of environmental and mining related variables (such as weather, herd count, total miles of road, number of employees, tons of coal mined, etc.)
17. Establishment of control areas
18. Replication of surveys within years (e.g., bi-annual or tri-annual surveys)
19. Coordination of survey effort.

Methods

The five mines chosen for study were: 1) Jacobs Ranch, 2) Black Thunder, 3) North Rochelle, 4) Rochelle, and 5) North Antelope. All relevant sections of each mine's permit application and annual reports were photocopied and bound in labeled three-ring binders. A Microsoft Access™ (Version 7) database was constructed to hold the data. Data entry was performed by one individual trained to interpret the reports and locate data by type. Approximately 450 hours over 2.8 months were required for data acquisition and entry.

Trend analyses were conducted using Poisson regression. The Poisson regression analysis fit equations of the form,

$$\log(\mu_i / a_i) = \beta_0 + \beta_1(Date_i) + \beta_2(Snow_i) + \beta_3(Temp_i) + \beta_4(Precip_i) + \beta_5(Herd\ count_i) + \beta_6(Statewide\ count_i) + \beta_7 x_{i2} + \ldots + \beta_p x_{ip}$$

where μ_i was the (estimated) average count during the i^{th} survey, a_i was total square miles searched during the i^{th} aerial survey or length of the i^{th} ground survey, β_0 through β_p were unknown parameters to be estimated, $Date_i$ was the date on which the i^{th} survey was conducted, $Snow_i$ was the average snowfall in the winter preceding the date on which the i^{th} survey was conducted, $Temp_i$ was the average temperature during the winter preceding the date on which the i^{th} survey was conducted, $Precip_i$ was the average precipitation in the spring of the year of the i^{th} survey, Herd $Count_i$ was the estimated size of the local ungulate herd, Statewide $Count_i$ was the estimated number of ungulates of the same species in the whole state, and x_{ij} was the value of the j^{th} mine indicator variable during the i^{th} survey. The Poisson regression equation for raptor nest success analyses was the same except that either number of hatchlings or number of fledglings were modeled instead of density, ungulate counts were not considered, and lagomorph numbers were included for raptor nest surveys after 1990. The Poisson regression equation for sage grouse lek counts modeled count as a function of date, snowfall, temperature, precipitation, and mine.

Backward elimination was used to discard unimportant variables from the Poisson regression model. Significance of terms in the model was assessed using approximate F tests. Estimated annual increases or decreases were reported after accounting for the important environmental covariates.

THE EFFECTS OF VARYING TOPSOIL REPLACEMENT DEPTH ON VARIOUS PLANT PARAMETERS WITHIN RECLAIMED AREAS

Submitted by:

Brenda K. Schladweiler

BKS Environmental Associates, Inc.
P.O. Box 3467
Gillette, WY 82717

Dr. Larry C. Munn

Department of Renewable Resources (Soil Science)
University of Wyoming
Box 3354
Laramie, WY 82071

Rose Harolan, Scott Belden

Powder River Coal Company, NA/RC Complex
Caller Box 3035
Gillette, WY 82717

November 28, 2000

SUMMARY OF 2000 ACTIVITY

This project has been divided into five major tasks: 1) review existing vegetation/soil information from the WDEQ-LQD and obtain permission from the WDEQ-LQD to conduct the proposed variable topsoil study on Rochelle Mine; 11) establish and construct the study site at the Rochelle Coal Mine; 111) obtain quantitative field data of three treatments on reclaimed areas and the corresponding reference areas; IV) summarize findings from the field sampling in No. "III" and provide annual/final recommendations; and V)disseminate that information to interested parties.

The project was awarded in May 1998. **Task 1** was primarily conducted in 1998 but is somewhat ongoing. **Task II** was completed during Fall 1998 to Fall 1999. **Task III** was initiated in 2000 and will extend through 2002. Refer to the 1999 summary for a complete description of project construction.

2000 Reference Area Establishment

Initial reference areas were established in 1998, one each in the Breaks Grassland and Upland Grassland overall reference areas for the North Antelope/Rochelle Mine Complex. Three contiguous blocks within each reference area "replicate" that ran perpendicular to the slope, i.e., top, middle and bottom, were established. The "top" represented the "top of the slope" and the 6 inch reclaimed area treatment. The "middle" represented the "middle of the slope" and the 12 inch reclaimed area treatment. The "bottom" represented the "bottom of the slope" and the 22 inch reclaimed area treatment. At the time, it was difficult to locate three replicates for each reference area that exhibited the same slope, aspect and undisturbed topsoil depth that mirrored the reclaimed area treatments. Final selection of reference areas was deferred to the 2000 sampling year.

Based on discussion with David Legg, University of Wyoming, Department of Renewable Resources Statistician, it was determined that, based on the limitations discussed above, three new reference area replicates were selected prior to the 2000 vegetation sampling. Final selection of these reference areas indicated the inherent difficulty of comparing a native, undisturbed location with the reclaimed area environment. Undisturbed areas have varying topsoil depth on any given slope and contain somewhat varying taxonomic development and parent material. These reference area replicates did not undergo the initial "baseline" laboratory analyses that the 1998 selected reference areas had undergone but were analyzed for pH, EC and/or SAR during 2000.

2000 Vegetation Sampling Methodology

Reclaimed Area Treatments

Random 30 meter cover intercept transects were sampled within each treatment

replicate. A total of 5 transects were sampled in each treatment replicate for an overall total of 15 per treatment, i.e., 15 each in the 6, 12, and 22 inch treatments.

Quantitative sampling was conducted during late July and early August 2000. Methodology followed WDEQ, LQD, Rules and Regulations, Appendix A (Revised May, 1998), wherever applicable, or WDEQ Guideline 14.

All sample locations within the various reclaimed area treatments were randomly determined by placing a grid over the 1" = 500' photographic base map. Grid interval of the reclaimed areas at the scale utilized was approximately 50' on the ground. Sampling location coordinates were randomly generated by an HP20S hand calculator. Sample points were located in the field by pacing from known localities. Latitude and longitude of the vegetation sample points were recorded; when possible, those points will be surveyed by PRCC, NA/RC personnel.

Cover sampling was conducted with a 30 meter line intercept transect. Within line transects, sample hits were read at 1 meter intervals along the entire length of the 30 meter transect. First hit (50) readings constituted the absolute cover values for individual species, total vegetation and total cover. In addition, litter/rock and bare ground percentages were recorded. Transects that exceeded designated vegetation boundaries were randomly reoriented to be within the sampled reclaimed area.

Note that scientific plant names may often be listed under previous genera and not what is currently taxonomically correct, e.g., *Agropyron smithii* instead of *Elymus smithii*. This was done since previous names are often used in seed mixture designations

Reference Area

Systematic 30 meter cover intercept transects were sampled within each reference area "treatment" replicate, i.e., top, middle and bottom. A total of 3 transects were sampled in each reference area "treatment" replicate for an overall total of 9 per "treatment" replicate, i.e., 9 each in the top, middle and bottom. Systematic samples were chosen within the reference area due to size limitations.

All other sampling and summarization was similar as described for the reclaimed area treatments above.

In order to compare the numbers derived from systematic sampling of the reference areas with random sampling within those same areas, one replicate was randomly chosen each within the Breaks Grassland and Upland Grassland. Numbers for those randomly selected transects were summarized and compared with those derived from the systematic transects. No statistical tests of significance were conducted for purposes of this summary write-up.

2000 Soil Sampling Methodology

Reclaimed Area Treatments

Soil samples were collected at the beginning of each cover transect which was a previously selected random point. Samples were collected at maximum six inch increments to the interface between topsoil and backfill. At that point, an additional six inches of backfill were collected. All soils were analyzed by the University of Wyoming Soil Test Laboratory for pH and EC. Approximately twenty-five percent of these samples were then randomly selected for reanalysis of SAR on the same extract. If possible, at least one complete soil profile was completed for all three parameters within each treatment. Since soil sample locations correspond to the beginning of the vegetation transect, latitudes and longitudes were also recorded; when possible, those points will be surveyed by PRCC, NA/RC personnel as described above under vegetation.

Reference Area

In order to characterize the soils within the "treatment" replicates, one soil sample location was randomly located on the 30 meter cover transect to avoid soil sample locations that were only on the outside edge of the "treatment" replicate. At that location, samples were described by horizon in the field but bagged and analyzed by six inch increments to mirror the methodology employed in the reclaimed area treatments. For example, within the "top" "treatment" replicate, samples were collected 0-6" and 6-12". Within the "middle" "treatment" replicate, samples were collected 0-6", 6-12" and 12-18". Within the "bottom" "treatment" replicate, samples were collected 0-6", 6-12", 12-18", 18-24" and 24-30". Latitudes and longitudes were not recorded for these sample points; however, sample locations were staked and, when possible, will be surveyed by PRCC, NA/RC personnel.

Results

Initial results are shown in the attached tables. No statistical summarization or comparison was completed for purposes of this summary. Tables 1a and 1b indicate the average number of species/sample, percent total vegetation cover, and percent total cover by treatment. In addition, those tables show the initial results of the random transects within the one replicate for that vegetation type. Tables 2a, 2b and 2c indicate the average EC and SAR by replicate and overall treatment for the 6 inch, 12 inch, and 22 inch treatments. Table 3 displays plant species encountered during sampling or observed within each reclaimed area treatment or reference area "treatment".

Further statistical analysis will be necessary this winter on all the numbers derived from the 2000 vegetation and soil sampling. Laboratory analyses of the reference area soil sampling was not completed by the 2000 summary date. Once that analysis is available, that information will be incorporated for statistical analysis, as well.

2001 Tasks

Additional vegetation and soil sampling will be conducted, similar to 2000 methodology. Additional measured parameters may be considered such as root mass or bulk density.

Grass Competition and Sagebrush Seeding Rates: Influence on Sagebrush Seedling Establishment

Interim Progress Report

M. I. Fortier

Department of Renewable Resources
University of Wyoming
Laramie, WY 82071

G. E. Schuman

High Plains Grasslands Research Station
USDA, ARS
Cheyenne, WY 82009

A. L. Hild

Department of Renewable Resources
University of Wyoming
Laramie, WY 82071

L. E. Vicklund

RAG, Coal West, Inc.
Belle Ayr Coal Mine
Gillette, WY 82717

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Introduction

Coal mine reclamation in Wyoming strives to provide a diverse vegetative community with adequate shrub and grass cover to support post-mining land uses. Successful reclamation techniques are implemented to direct and accelerate plant succession toward desired land uses such as wildlife habitat and livestock grazing. An important component of the post-mining plant community is Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Nutt. Beetle and Young). Studies on this dominant shrub (i.e. Schuman et al. 1998; Stahl et al. 1998) have improved our understanding of the roles of seedbed preparation, direct seeding, and arbuscular mycorrhizae (AM) that aid in its establishment on coal mined lands.

Competition from herbaceous plants can have a substantial negative effect on big sagebrush seedling establishment (see Blaisdell 1949; Richardson et al. 1986; Schuman et al. 1998). However, details of the interactions between shrubs and grasses seeded together on mined lands of Wyoming are not well documented. This has prompted reclamationists to continue seeding shrubs and grasses concurrently despite Wyoming big sagebrush establishment failures. Research is needed to assess levels of herbaceous competition that will also favor sagebrush seedling establishment at the desired shrub density standard set by the Wyoming Department of Environmental Quality (WY DEQ 1996). Therefore, this study was conducted to investigate the relationship between Wyoming big sagebrush and a mixture of cool-season grasses seeded together on reclaimed land at the Belle Ayr Coal Mine near Gillette, Wyoming. We documented sagebrush seedling density over two growing seasons (1999 and 2000) under three sagebrush seeding rates and competition from seven grass seeding rates.

Materials and Methods

During December 1997 and January 1998, topsoil was spread on the study site to an average depth of 56 cm and seeded to barley (Hordeum vulgare var. 'Steptoe'). In late summer 1998 the barley was mowed to achieve a standing stubble mulch. Air temperature, precipitation, soil temperature, and soil moisture were monitored during the 1999 and 2000 growing seasons near the site. Gravimetric soil moisture was determined biweekly at 0-5 and 5-15 cm depths from 14 locations across the plot. To characterize basic chemical and physical properties of the topsoil, soil samples were taken at three depths (0-15, 15-30, and 30-45 cm) in seven random locations. Samples were analyzed for pH, electrical conductivity (EC), particle-size separation, organic carbon, Kjeldahl nitrogen, bicarbonate phosphorus, and soluble cations.

In December 1998, seven grass seeding rates (0, 2, 4, 6, 8, 10, and 14 kg pls ha^{-1}) comprised of a mixture of western, slender, and thickspike wheatgrasses were randomly drill seeded into 6.5 X 27 m main plots within each of four, 27 X 45.5 m blocks. Each grass main plot was separated into three, 6.5 X 9 m subplots, which were randomly broadcast seeded to one of three Wyoming big sagebrush seeding rates (1, 2, and 4 kg pls ha^{-1}) in March 1999. Prior to seedling emergence six, 1-m^2 permanent quadrats were established in each sagebrush by grass seeding rate subplot to assess sagebrush seedling density.

Aboveground plant biomass was clipped in June 1999 and July 2000. Clippings were separated into planted grasses, other grasses, and forbs. Grass culm density was counted in June 2000 within six, 0.18-m^2 quadrats for each sagebrush by grass seeding rate subplot. Density of sagebrush seedlings (shrubs per m^2) was determined within each 1-m^2 permanent quadrat on six sampling dates (June 30, August 3, August 31, and October 25, 1999; June 5 and September 18, 2000).

Analysis of variance (ANOVA) was performed in SAS (SAS Institute 1999) to analyze soil moisture, aboveground biomass, grass density and sagebrush densities for their relationship to sagebrush and grass seeding rate treatments. Repeated observations of sagebrush density on six sampling dates were used to indicate differences over time as related to sagebrush and grass seeding rates. Where F-test probabilities were significant ($\alpha = 0.05$), least significant difference (LSD) mean separations were used to indicate differences among treatment means.

Results and Discussion

Air and soil temperature varied slightly between 1999 and 2000. Texture of the topsoil is clay loam to sandy clay loam with an average pH of 7.6. Spring and summer precipitation was above normal in 1999 with April, June, and July amounts being 81, 64, and 39% above the 67-year average for Belle Ayr Mine. In 2000, precipitation amounts were below normal except in April and July.

Soil moisture during both growing seasons differed among sampling dates. In 1999 soil moisture generally declined over the season and was highest on June 17 and August 13. High soil moisture in August is likely due to precipitation events during late July and early August. Soil moisture varied considerably at the 0-5 cm depth whereas moisture at 5-15 cm depth was more consistent over the 2000 growing season; however, both depths decreased during August. As expected from precipitation records, soil moisture during 2000 was generally lower than in 1999.

Total aboveground biomass was not different among the grass seeding rate treatments during either growing season. The relative amount of each plant type (planted grass, other grass, and forb) was different among grass rates in 2000 (Figure 1). Planted grass biomass was greatest in the high grass seeding rates, whereas other grass and forb biomass were greatest in the low grass seeding rates. In comparison, sagebrush density in September 2000 was 50% lower in the high grass seeding rate (14 kg pls ha^{-1}), but was not significantly associated with greater biomass of planted grass. Even so, this does provide insight into the relationship between sagebrush seedling density and grass production within higher grass seeding rates. Herbaceous production, species diversity, and sagebrush seedling density (5.3 shrubs m^{-2} on average) were greatest with the 2 to 6 kg pls ha^{-1} grass seeding rates. Above 6 kg pls ha^{-1} grass seeding rate volunteer biomass was reduced, however effects on sagebrush seedling density were not consistent.

Planted grass biomass and number of grass culms were greatest in the higher grass seeding rates (Figure 2). The 14 kg pls ha^{-1} grass seeding rate produced the highest grass density of all rates, but grass density did not differ significantly among the 6, 8, and 10 kg pls ha^{-1} grass rates. Comparable grass production was achieved with seeding 4 to 14 kg pls ha^{-1}. Since grass production and density for the 6-10 kg pls ha^{-1} grass seeding rate show little difference and if the cover is sufficient to prevent soil erosion, it would be

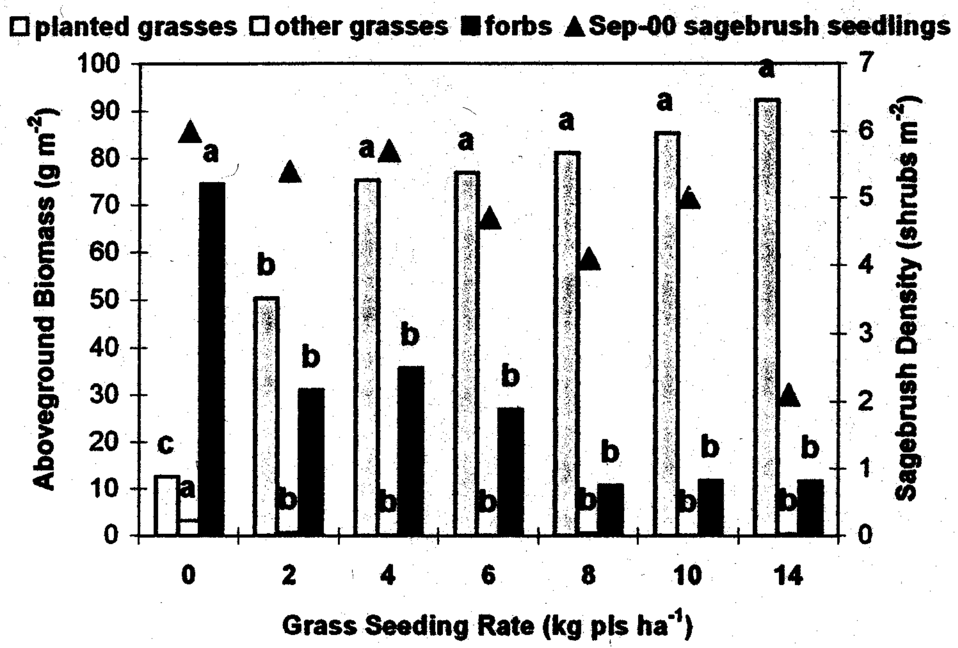

Figure 1. Biomass production (columns) and sagebrush seedling density in September 2000 (triangles across seven grass seeding rates. Within a plant type (planted grass, other grass, or forb) grass rate means with different lowercase letters are significantly different at P<0.05, LSD

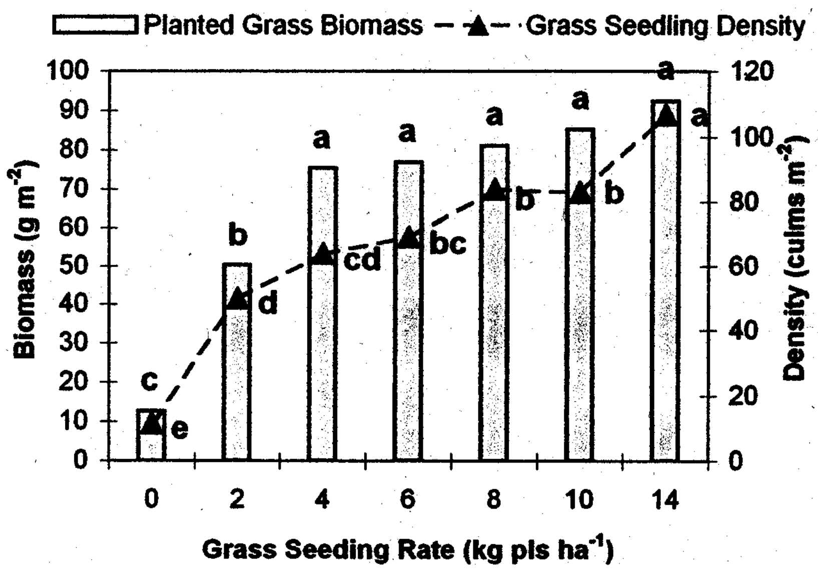

Figure 2. Aboveground planted grass biomass (line) and grass seedling density (columns) in seven grass seeding rates (kg pls ha^{-1}) in 2000. Grass seedling density means with different lowercase letters are significantly different at P<0.05, LSD. Grass biomass means with different lowercase letters are significantly different at P<0.05, LSD.

reasonable to use a grass seeding rate of 8 kg pls ha^{-1} to reduce herbaceous competition for sagebrush since sagebrush seedling density was reduced when grass was seeded above 10 kg pls ha^{-1} (Figure 1).

Sagebrush seedling density was greater in the 4 kg pls ha^{-1} sagebrush seeding rate than the 2 and 1 kg pls ha^{-1} rates on all sampling dates (Figure 3). No significant change in sagebrush density occurred within the three sagebrush rates from August 31 to October 25, 1999. Low precipitation occurred during this period and since the grass and forb community had matured by this time, competition for moisture was limited. Available moisture during the second growing season may have prevented significant mortality in sagebrush seedlings from June to September in 2000. An increase in sagebrush density occurred in the 2 and 4 kg pls ha^{-1} rates from October 25, 1999 to June 5, 2000. Increases in Wyoming big sagebrush years after initial seeding have been reported in other studies in this region (i.e. Schuman et al. 1998; Schuman and Booth 1998) and could be due to prolonged seed viability and favorable spring conditions in 2000. Seeding at moderate to high sagebrush seeding rates (2-4 kg pls ha^{-1}) with other herbaceous species may increase the probability of sagebrush establishment in subsequent years when conditions become favorable for germination.

Lower sagebrush seedling density (2.1 shrubs m^{-2}) within the 14 kg pls ha^{-1} grass seeding rate suggests that it may be preferable to reduce grass seeding rates since grass may have an impact on sagebrush density at high rates. Over time, sagebrush densities within the higher grass seeding rates may decline as grass plants mature and competition for soil moisture becomes acute, especially during less favorable years. Although grass and forb cover is needed to prevent erosion, our study shows that grass seeding rates can be reduced while maintaining good grass production and favoring sagebrush seedling establishment.

September sagebrush seedling density within four sagebrush and grass seeding rate combinations have been compared to survival rates for Wyoming big sagebrush in other studies (Table 1). Nine years after initial seeding of big sagebrush at a neighboring mine in the Powder River Basin, Wyoming big sagebrush showed a 52% survival rate (G. E. Schuman, personal communication). Kriger et al. (1987) reported that one third of the sagebrush seedlings survived 11 years after the initial seeding. If at least one third of our shrubs survive during the 10-year bond period and persist during the last three years of this period then shrub density standards for Wyoming big sagebrush will be met (Table 1).

With use of moderate grass seeding rates (6-8 kg pls ha^{-1}) in reclamation seed mixes, the vegetative community should be adequately diverse and productive to support post-mining land uses and may allow for natural recruitment of other native species. Using reduced grass seeding rates with moderate to high sagebrush seeding rates (2-4 kg pls ha^{-1}) when reclaiming mined lands could help achieve Wyoming big sagebrush standards and reduce costs of the seed for reclamation.

Conclusion

Favorable growing conditions for Wyoming big sagebrush establishment occurred during this study. Results from the first and second growing season show limited effects

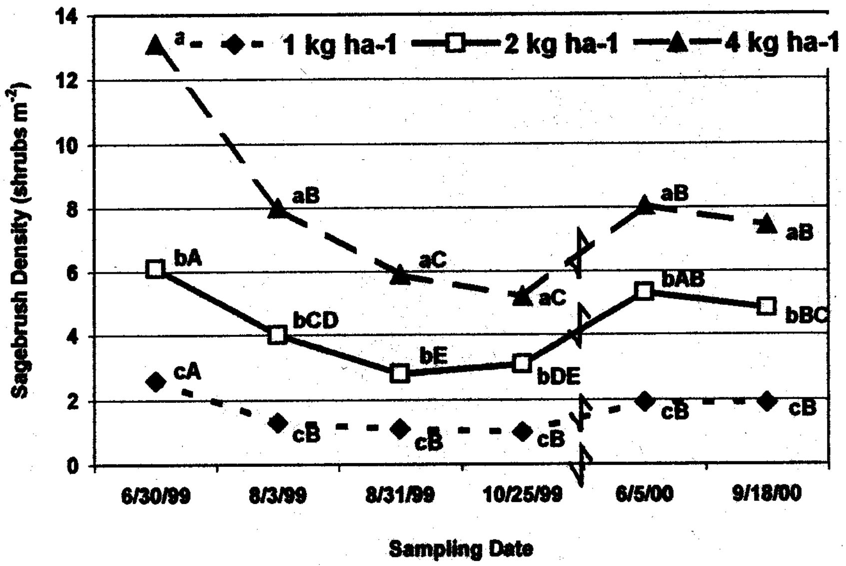

Figure 3. Sagebrush seedling density in three sagebrush seeding rates across six sampling dates in 1999 and 2000. Within a date, density means with different lowercase letters are significantly different at P<0.05, LSD. Within a sagebrush rate, density means with different uppercase letters are not significantly different at P<0.05, LSD.

Table 1. Wyoming big sagebrush seedling survival within four sagebrush and grass seeding rate combinations.

Sagebrush seeding rate kg pls ha^{-1}	Grass seeding rate kg pls ha^{-1}	Sagebrush density[a] September 2000	Sagebrush density[b] 33% survival	Sagebrush density[c] 52% survival
4	6	8.1	2.7	4.2
4	8	7.5	2.5	3.9
2	6	4.2	1.4	2.2
2	8	4.0	1.3	2.1

[a]Sagebrush densities reported in shrubs m^{-2}.
[b]Survival rate 11 years after initial seeding in Intermountain West (Kriger et al. 1987).
[c]Survival rate nine years after initial seeding in Powder River Basin (G. E. Schuman, personal communication 2000).

of grass competition on Wyoming big sagebrush seedling establishment, which may be attributed to climatic conditions. Long-term monitoring of Wyoming big sagebrush density, survival, and cover at the site may unveil critical information about sagebrush and grass seeding rate interactions as sagebrush and grass seedlings develop and mature.

Our study supports the use of moderate sagebrush and grass seeding rates when seeding Wyoming big sagebrush and grass concurrently within a reclamation seed mix. Relationships among grass seeding rates, aboveground grass, forb, and shrub production, and Wyoming big sagebrush densities need to be considered when trying to achieve shrub density standards and herbaceous communities for post-mining land uses.

Acknowledgments

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Research and Development of a GIS-Based Data Management and Model Integration Tool for Coal Mine Permitting and Reclamation in Wyoming

July 1, 1999 – June 30, 2001

Principal Investigators:

Thomas W. Kohley
Beartooth Mapping, Inc

Richard C. Warner
Surface Mining Institute

Jeffrey D. Hamerlinck
University of Wyoming

Pamela J. Schwab
Civil Software Design

Greg E. Jones
Powder River Coal Company

Laurel E. Vicklund
RAG Coal West, Inc.

PROJECT OVERVIEW

This interim progress report provides a brief project background and summary of work undertaken in the year since the last ACMLRP review meeting in November 1999.

Problem Statement. A central focus of the Surface Mining Control and Reclamation Act of 1977 is the collection, analysis, interpretation and application of current, accurate and complete "baseline" data for mine plan, reclamation plan, and bond release monitoring components of the coal mine permit application process. To meet these challenges, a need exists for the development of computer application tools capable of: 1) managing large quantities of spatial and non-spatial digital mine and reclamation data; and 2) providing an efficient means for utilizing such information in an integrated data management, analysis, and modeling environment.

Objective. The primary objective of this research is to develop a geographic information system-based software application for the management, analysis and reporting of data associated with major components of the permit and bond release processes for coal mining in Wyoming. The study builds upon work recently completed by Hamerlinck et al (1999), which dealt with developing methods for the GIS-based integration of selected surface- and groundwater models supporting PHC/CHIA-based hydrologic impact assessments. The study will focus on enhancing the application of GIS technology in the hydrologic modeling arena, as well as an expansion of its use to address soils, revegetation, and wildlife management needs in coal mine permitting and reclamation.

STATEMENT OF WORK

The study will culminate in delivery of a Reclamation Management Tool (RMT) GIS software application containing components for management, analysis, and/or modeling of hydrology, soils, vegetation, and wildlife data. The completed application will integrate the four components into a comprehensive reclamation "tracking" application with data conversion, management, and report generation functionality. Nine primary tasks have been outlined. Tasks outlined in the original statement of work include the following:

Task 1: Consultation with RMT Advisory Group.
Task 2: Baseline Module Development.
Task 3: Hydrologic Module Development.
Task 4: Soils Module Development.
Task 5: Vegetation Module Development.
Task 6: Wildlife Module Development.
Task 7: Integrated Application Development
Task 8: Technology Transfer
Task 9: Report Generation.

Over the last year, some modifications have been made to the modular design of the application under development. Specifically, input from the project's advisory group members has resulted in a more targeted focus on bond release requirements, particularly as they apply to revegetation. As a result, development of the soils, vegetation, and wildlife modules is occurring in a more integrated fashion.

RECENT ACCOMPLISHMENTS

As outlined in the study's original Statement of Work, activities during the first year of the project were focused primarily on Tasks 1, 2, and 3. The initial 5-month progress in these areas was reported at the 1999 ACMLRP review meeting. From November 1999 through May 2000, work continued to focus on Task 3 – development of the Hydrologic Module. Beginning in June 2000, emphasis shifted to Tasks 4, 5, and 6. A brief description of progress in each of the task categories follows:

Consultation with RMT Advisory Group. To date, numerous discussions have been held with members of the RMT-Hydrologic Module advisory group. The focus of these discussions has been to ensure that the direction of the module's research and development will most effectively accommodate the module's future target users. The advisory group consists of individuals possessing strong backgrounds in areas of surface water hydrology, civil engineering, mining industry solutions, software design concepts, and third party surface mine consulting.

The most recent meeting of the RMT-Hydrologic advisory group was conducted during the Office of Surface Mining sponsored event, "SURFACE MINING RECLAMATION APPROACHES to BOND RELEASE: CUMULATIVE

HYDROLOGIC IMPACTS ASSESSMENT (CHIA) and HYDROLOGY TOPICS for the ARID, SEMI-ARID WEST", August 27-September 1, 2000. As a scheduled portion of this OSM event, the RMT Hydrologic Module component was demonstrated to more than 40 potential users. The demonstration consisted of a half-day workshop in which multiple hydrological scenarios were successfully tested utilizing the RMT module and limited spatial data from a Wyoming mine site. The module was well received with enthusiasm and interest. Follow-up discussions within the advisory group and several other workshop attendees proved extremely beneficial to refining the module to better fit the needs of prospective users.

Several other consultations have occurred with project investigator and SEDCAD software engineer, Pam Schwab. The topic of these discussions has been focused primarily on the means in which the RMT Hydrologic Module will transport and receive the necessary data to and from the SEDCAD program. The intent is to optimize the delivery of imports and exports between the two separate software applications.

For development of the soils and vegetation modules of the RMT, the project team has relied on input from the DEQ-WMA Bond Release Working Group. Consultations on this group's work include meetings with DEQ personnel from Cheyenne and Sheridan in June 2000 and ongoing communications with Co-PIs and working group industry members Laurel Vickland and Greg Jones. With regard to the wildlife module, the team is considering incorporation of data and information resulting from another ACMLRP-funded project being conducted by WEST, Inc.

Hydrologic Module Development. The RMT Hydrologic Module builds directly upon previous research conducted by the Spatial Data and Visualization Center at the University of Wyoming. During the initial months of RMT development, the previous research was critically reviewed and analyzed to determine more efficient and improved methods to satisfy the data requirements of SEDCAD 4.

Each of the RMT hydrologic module's components were assembled and designed to obtain the most efficient and effective means to interface ArcView 3.x with SEDCAD 4. Components include 1) a comprehensive ArcView pre-processor responsible for expediting the generation of the maximum number of SEDCAD parameter inputs, 2) a seamless delivery of all inputs directly into the SEDCAD environment for SEDCAD model analyses, and lastly, 3) the development of a post-processor capable of displaying SEDCAD outputs within the ArcView environment.

To date, pre-processing is nearly complete. The majority of all pre-processing operations are functioning properly. New utilities have been designed to detect regions possessing areas of internal drainage (i.e. playas) and factor those areas into predicting better subwatershed parameters. There is a new utility that allows a standardized method to automatically predict stream networks based on user-defined acres of upstream contribution. Other new utilities allow users to develop NRCS Curve Number layers and Precipitation Events within step-by-step *wizard* type interfaces. Additional functions allow users to click and draw various hydrologic structures including, multiple channels types, culverts, and sediment ponds. Using a mouse, the user locates these structures within the map window while slopes, lengths, routing, and other hydrologic parameters are automatically calculated. Subwatersheds may be drawn by hand or delineated automatically from a user specified point. Each delineated subwatershed uses area weighting to generate average soil properties, average precipitation, acre-area, and other time of concentration values for the specified subwatershed region.

Most recently, efforts have been focused on completing the online help system designed to provide dialog-specific help for each step throughout pre-processing. Also beginning last October, work has been conducted on exporting the hydrologic parameters from the RMT – Hydrologic Module into the proper SEDCAD input format (subtask 3.2). Currently, the *Precipitation*, *Networking*, and *Subwatershed Information* portions of the export operation are complete, leaving only *Structure Information* to finish.

Soils, Vegetation, and Wildlife Module Development. We have completed an initial database design for the soils, vegetation and wildlife modules, which we now refer to as the *reclamation history database* as it has been expanded to include data on precipitation, husbandry practices and reclamation contractors. The design of this database is based on: 1) a pre-existing database provided by one of our pilot mines, North Antelope-Rochelle complex, and 2) reporting guidelines defined by the draft bond release guidelines. The database is stored as multiple relational tables within Microsoft Access 2000.

We have also completed beta programming of a Graphical User Interface (GUI) within ArcView GIS that interfaces with the MS Access tables. The GUI provides an easy-to-use "wizard-style" interface that can be used to rapidly query, display and report on various elements from the reclamation history database. The GUI currently offers "one-click" reporting for any reclamation unit in the database (see Attachment A).

ONGOING ACTIVITIES

Over the next six months, much of the work will be focused on completion of Tasks 3, 4, 5, and 6. The next scheduled task for the hydrology module development will be to complete all exports to SEDCAD and begin writing the routines designed to accommodate SEDCAD imports. Once the SEDCAD output information is imported, the RMT – Hydrologic Module post-processor will be fully functional. This post-processing component (subtask 3.3) will in turn be used to review and display all hydrologic and hydrographic information for each subwatershed or structure. After all components of pre-processing and post-processing are developed, there will be additional time spent administering tests and error checks to ensure all components are as stable as they are functional. Other quality measures will include extensive beta testing by the RMT-Hydrologic Module advisory group, followed by additional beta testing from selected target users.

We will continue to work with representatives of the bond release working group to further refine the reclamation history database to meet industry and regulatory agency reporting requirements. Over the next six months we will continue to refine the ArcView GUI and incorporate a mapping component that will provide "one-click maps" for inclusion in annual reports and bond release documents. Development of an on-line help system for the RMT will also be developed during this period.

Finally, with completion of the individual hydrology, soils, vegetation, and wildlife modules, work will shift to integrating access of the RMT components under one "start-up" graphical user interface customized to deliver user-selected RMT Modules to the ArcView desktop environment.

Attachment A

RECLAMATION HISTORY REPORT

November 22, 2000

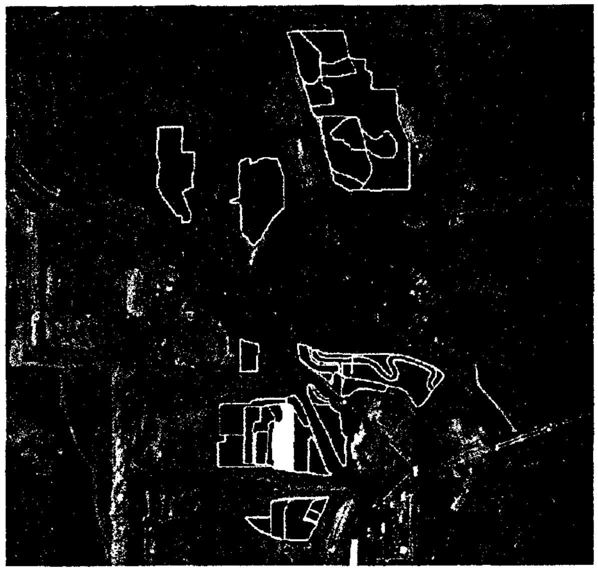
GENERAL INFORMATION

Mine: North Antelope
Reclamation Unit: N8801A
Legal Description:
Acres: 10.00

Pre-existing Vegetation: Grassland
Year(s) of Disturbance:
1983
1984
1985
1986

Bond Release Approval Dates:

60%:
75%:
Final :



TOPSOIL REPLACEMENT

Date: 1/1/1988 — **Spoil Surface Preperation** | **Year(s) Regraded** | **Pile Number(s)**

Haul Method: Direct — Scarified

Replacment Method: Truck/Scraper

Depth (in): 15

Volume (cy): 21,175

SPOIL SAMPLES

Sample ID	Sample Start Date	Sample End Date	Approval Date
88BF-1	Apr 1988	Jul 1988	Apr 1988
88BF-2	Apr 1988	Jul 1988	Apr 1988
88BF-3	Apr 1988	Jul 1988	Apr 1988
88BF-4	Apr 1988	Jul 1988	Apr 1988
88BF-5	Apr 1988	Jul 1988	Apr 1988
88BF-6	Apr 1988	Jul 1988	Apr 1988
88BF-21	Apr 1988	Jul 1988	Apr 1988
88BF-22	Apr 1988	Jul 1988	Apr 1988
88BF-23	Apr 1988	Jul 1988	Apr 1988
88BF-24	Apr 1988	Jul 1988	Apr 1988

RE-VEGETATION

SEED BED PREPARATION

Date	Method
Nov 1988	Disced

SEED MIX

Date Comments	Method	Seed Mix	Seed Vendor
Nov 1989	Drilled	NT2F89D1	Granite Seed Co.

MULCH

Date	Mulch	Method	Rate (lb.)
Nov 1988	Hay	Blown	
Nov 1989	Hay	Blown	

FERTILIZER

Date	Fertilizer	Rate (lb.)
Nov 1988	P205	50
Nov 1989	P205	50

TREE / SHRUB PLANTING

Shrub Acres: 0.00
Shrub Percent: 0

Supplemental

Date	Type Treatments	Method	Vendor	Rate	Additional Info

INTERIM MONITORING

Cover Study Year	1992
Shrub Study Year	1992
Production Study Year	1992

WILDLIFE HABITAT FEATURES

Habitat Feature	Number of Features
Rock Pile	1

HUSBANDRY / MOWING

Years Mowed	Years Grazed	Animal	Number	Start Date	End Date	Utility Est. AUM
1988			0			

CONTRACTOR INFORMATION

Contractor	Job
Rocky Mountain Reclamation	Not Specified

Ambient Fine Particle Measurement in the Powder River Basin
ACMLRP Annual Summary
November 20,2000
Chartier, Weitz
IML

Contents

1. Introduction:

Coalmines are regulated, in part, by the impacts that coal production, mine reclamation, and associated activities have on pollution levels in ambient air, through ambient air "standards". A new standard for "fine" particles was adopted in 1997 by the USEPA and has been implemented by State and Local air quality agencies, generally beginning in 1999.

The relationship between coal mining activities and the production of fine particles is not well understood. This research project addresses the need for the collection of a high quality data set which will be used to better understand the relationships of coal mining to the generation and transport of airborne fine particles.

This project established a regional network of fine particle measurement instrumentation in Wyoming's Powder River Basin coal mining area, beginning July, 1999. Several measurement techniques are employed to assess their effectiveness and practicality in a rural industrial application. The network is designed to provide data of high spatial and temporal resolution, allowing comparisons against upwind ambient air so that local impacts may be assessed. The establishment and operation of the network is a collaborative effort, with contribution and participation from a variety of organizations, thereby representing a unique approach to ambient air monitoring which serves as a model for regional air monitoring.

The study will provide essential information by which to tailor appropriate and effective industrial development and regulatory strategies to the unique conditions and needs of Wyoming. Also, the study will provide a solid basis for a variety of subsequent research related to fine particulate matter that include the influences of specific coal mining activities, coal transportation, meteorological influences, regional visibility, upwind and neighboring contributions, and for chemical and transport modeling of fine particles.

The project is in its data collection phase. Intensive data synthesis and analysis will occur during 2001.

2. Objectives

The objectives of this research are to:

- Determine the spatial and temporal distribution of fine particulate ($PM_{2.5}$) in ambient air in the Powder River Basin coal mining region of Wyoming.
- Evaluate continuous measurement techniques compared to EPA Reference Method manual sampling measurements.
- Evaluate the manual method currently employed by Wyoming Mining Association to collect baseline $PM_{2.5}$ data in the Powder River Basin in relationship to the EPA Reference Method.

3. Network Design:

This network spans monitoring over a north-south tract. Predominant winds in the Powder River Basin are such that this configuration provides upwind and impacted monitoring sites under most meteorological conditions. A variety of samplers are employed to provide both baseline PM2.5 concentrations, but also to allow comparison of monitoring methods. For a graphic depiction and description of all monitoring stations the reader is referred to either the Monitoring Network Plan or the Quality Assurance Project Plan which are on file with the Wyoming DEQ Air Quality Division, or can be found on IML's web site at *www.imlinc.com*.

4. Data Collection:
This project is in its intensive data collection phase. Data collection was stepped up from every-6-days to every-3-days beginning in April, 2000 and this accelerated schedule will continue for a year. Intensive data synthesis and analysis will commence this coming spring.

Data from the network is summarized as follows:

ACMLRP/Powder River Basin PM2.5 monitoring, July, 1999 – September, 2000

Monitoring sites, No. to South	Avg. Conc. (µg/m^3)	Max Conc. (µg/m^3)	Data Recovery (%)
PRB1 (FRM, Buckskin)	5.6	20.9	86.5
PRB2 (baseline, Belle Ayr)	6.4	21.9	94.7
PRB3 (FRM, Belle Ayr)	6.3	23.8	95.2
PRB4 (baseline Belle Ayr)	9.1	34.7	94.7
PRB5 FRM Black Thunder)	6.4	21.5	88.6
PRB7 (continuous, Black Thunder	7.8	28.0	95.5
PRB8 (FRM, Antelope)	3.5	14.5	84.3

5. Time line, schedule:
This project commenced July, 1999 and is due to finish with the monitoring and data collection April, 2001, unless the project is extended. The project is right on schedule and no delays have occurred. Data analysis and synthesis will occur following the cessation of monitoring.

6. Budget:
The budget through October, 2000 is summarized as follows:

Type	Budget	Charged	Remaining
Personnel	74,549.00	33,748.80	40,800.20
Travel	38,642.00	19,691.50	18,950.50
Support	9,014.00	1,750.00	7,264.00
Supplies	27,795.00	27,697.36	97.64
TOTAL COSTS	150,000.00	82,887.66	67,112.34

The budget is some 55% expended while the project is some 75% underway. Much of the project so far has involved collection and processing of raw data. Activities such as data analysis and synthesis, chemical speciation, and web-enabled data service are yet to be undertaken. These activities will commence as the monitoring concludes, Spring, 2001.

AML Progress Report

Relationship Between Soil Organic Matter Content and Sustainable Nutrient Cycling in Reclaimed Soils

Peter D. Stahl, Gerald E. Schuman and Lowell K. Spackman

Healthy soil is the foundation of stable, productive terrestrial ecosystems. Soil provides habitat for many terrestrial organisms, including plant roots, and is the site of a number of critically important ecosystem functions such as nutrient cycling and energy transfer (Coleman and Crossley, 1996; Killham, 1994). One of the most crucial challenges of mine land reclamation is to re-establish soils (plant growth media) to a level of health similar to those originally present before mining (Munshower, 1994). Rangeland forage production and wildlife habitat are dependent on the general productivity and quality of soils (Karlen, 1997; National Research Council, 1994).

The two basic objectives of this research are:

20) Examine the relationship between soil organic matter content and nutrient cycling in topsoil, subsoil and spoil (suitable plant growth material) using established methods of quantifying soil microbial biomass (i.e., chloroform fumigation and extraction technique) and nutrient cycling (i.e., nitrogen mineralization potential and carbon mineralization potential) in surface mine reclamation rooting zone materials varying in age, organic matter content, and reclamation success.
21) Evaluate the "CO_2 flush method" (Franzluebber et. al., 1996; Franzluebber et. al., 2000) as an indicator of the ability of mine land soil or spoil to sustain nutrient cycling by correlating the results of this method with results of standard techniques for quantifying soil microbial biomass and nutrient cycling as well as other measures of reclamation success (i.e. soil fertility analysis, plant community analysis and arbuscular mycorrhizae analysis).

In addition, we will address the following secondary objective:

22) Examine and compare nutrient cycling potential of long term stockpiled soil and direct hauled soil.

Funding for our project began on 15 May 2000. To date, we have completed all tasks designated in our research schedule with the exception of vegetation analyses at our research sites. We believe this will not be a problem, however, as we will be able to conduct these analyses in the 2001 growing season because we now have hired all personnel required to conduct the research as proposed.

Work completed as of mid-November 2000 includes establishment of field research sites, collection of soil samples from field research sites, and most proposed analyses of soils collected in year 2000. Our initial soil sampling trip to the Powder River Basin was made on 29-30 June during which a number of research sites were selected and sampled on the Buckskin Mine, the North Antelope Mine, and the Belle Ayr Mine.

At the Buckskin Mine, two locations were sampled. The first site was a direct-hauled topsoil site where topsoil was respread in the spring of 1997 and seeded in the fall of the same year. The second site sampled was where overburden had been respread as a plant growth medium (resulting from the excavation of a water holding pond) in late 1996 and seeded in 1997. Two locations were also sampled at the North Antelope Mine. One was a site reclaimed in 1985 and the other was reclaimed in 1997. At the Belle Ayr Mine we again sampled both older and newer reclamation sites. A second trip was made on 13 July 2000 to collect soils at the Jacobs Ranch Mine. At this mine we collected soils from a site reclaimed in 1999 with soil stockpiled for 10 years. The other site sampled was reclaimed in 1999 with direct hauled topsoil.

At all the above-mentioned research sites soils were collected along a 50 ft transect at 10 ft intervals. Samples were collected at 0-1, 1-6 and 6-12 inch depths. The 0-1 inch depth soils were removed from sampling locations to insure soil samples were not contaminated with coal dust or other materials blown in from haul roads. To date we have completed the following analyses of these soil samples: total nitrogen content, total carbon content, inorganic carbon content, organic carbon content, and microbial biomass content. Organic carbon to total nitrogen ratio has been calculated for all samples. Assays for determination of potentially mineralizable carbon and nitrogen will be completed this winter.

Table 1. Characteristics of Soils and Plant Growth Materials

Site	Total N (%)	Total C (%)	Inorganic C (%)	Organic C (%)	C/N ratio	Microbial Biomass C (mg g^{-1} soil)
Belle Ayr Mine, site BA55						
1-6"	0.065	1.13	0.30	0.83	12.9	0.13
6–12"	0.060	1.01	0.28	0.73	12.3	0.13
Belle Ayr Mine, site BA72						
1-6"	0.065	0.97	0.13	0.84	12.7	0.08
6-12"	0.040	0.75	0.18	0.57	14.4	0.06
Buckskin Mine, direct haul topsoil, 1997 reclaim						
1-6"	0.033	0.54	0.08	0.46	13.7	0.02
6-12"	0.018	0.33	0.33	0.30	19.4	0.03
Buckskin Mine, overburden material, 1997 reclaim						
1-6"	0.035	1.23	0.62	0.61	18.5	0.02
6-12"	0.025	1.08	0.52	0.56	20.7	0.02
Jacobs Ranch, stockpiled topsoil, 1999 reclaim						
1-6"	0.048	1.01	0.05	0.96	19.5	0.05
6-12"	0.053	0.86	0.07	0.79	15.3	0.04
Jacobs Ranch, direct haul topsoil, 1999 reclaim						
1-6"	0.030	0.37	0.01	0.36	14.4	0.07
6-12"	0.023	0.31	0.01	0.30	15.1	0.09
North Antelope, 1985 reclaim						
1-6"	0.043	0.98	0.18	0.80	20.8	0.16

6-12"	0.040	0.88	0.19	0.68	18.5	0.07
North Antelope, 1997 reclaim						
1-6"	0.058	1.02	0.08	0.94	16.8	0.18
6-12"	0.050	0.73	0.08	0.65	13.6	0.12

Sr isotopic characterization of coal and sandstone aquifers, Powder River basin, Wyoming

Carol D. Frost, Kathy M. Ogle, Robert M. Lyman and Edward L. Heffern

Interim Report, November 2000

Introductory Statement

This project was funded in the Spring 2000 competition. In addition to the principal investigators, the project involves a M.S. student and a senior undergraduate student at the Department of Geology and Geophysics, University of Wyoming, and provides partial support for a senior research scientist in the same department.

Progress to Date

1. Geochemically and isotopically analyzed an initial sample set of groundwaters provided by the USGS-WRD (Cheyenne office), BLM and Wyoming State Engineer's Office, and presented results at two meetings: the Wyoming State Geological Survey/University of Wyoming/Wyoming Geological Association annual conference in Laramie, October 2000, and the annual meeting of the Geological Society of America in Reno, NV, November 2000.
2. Established collaboration with the USGS Geologic Division in Denver and obtained 50 additional groundwater samples from coal aquifers, which are in progress for Sr isotopic analysis.
3. Enlisted the support of Jacob's Ranch surface mine in developing a project for senior undergraduate student Jami Viergets, who is studying the acquisition of Sr into groundwaters near the recharge area. She has collected samples of waters from monitoring wells on the mine property, and will get a second collection later this month. We are in the process of obtaining rock samples of underburden, coal, overburden, spoil and clinker for rock leaching experiments.
4. Developed contacts for M.S. student Ben Pearson's regional study of coal and sandstone aquifers in the Powder River basin. Samples (or permission to sample) have been provided by Barrett Resources, Pennaco Energy, and J. M. Huber Corporation. In addition, the BLM is providing water samples from each new monitoring well that they establish.

Interim Results

1. The Wyodak-Anderson coal zone groundwaters have an Sr isotopic composition that is distinct from adjacent sandstone aquifer groundwaters, and different from a lower coal zone aquifer groundwaters.
2. The Sr isotopic ratio can distinguish aquifers that are indistinguishable in terms of major ion chemistry and stable isotopic compositions.
3. It appears that most of the water samples are derived from isolated aquifers, suggesting that coalbed methane production has not impacted adjacent sandstone aquifers. However, in several instances, intermediate Sr isotope ratios of groundwaters indicate aquifer interaction. In one case this is related to well construction, and in the other it appears that water from an overlying unconfined sandstone aquifer is entering a producing coal seam.

Publications

Frost, C.D., Ogle, Kathy M., and Lyman, R.M., 2000. Sr isotopic characterization of coal and sandstone aquifers, Powder River basin, Wyoming. Abstracts for Wyoming State Geological Survey/University of Wyoming/Wyoming Geological Association annual conference on Coalbed Methane in the Powder River basin, Laramie, October 12-13, 2000.

Frost, C.D., Ogle, Kathy M., and Lyman, R.M., 2000. Sr isotopic characterization of coal and sandstone aquifers, Powder River basin, Wyoming. Geological Society of America Abstracts with Programs v. 34, p. A547.

EVALUATION OF MODELING METHODOLOGIES
FOR PREDICTING VISIBILITY IMPACTS
OF COAL MINING OPERATIONS

George E. McVehil, Edward L. Addison
And Keith A. Baugues
McVehil-Monnett Associates, Inc.
Englewood, Colorado

The research carried out under the ACMLRP was conducted to provide a quantitative evaluation of air modeling methodologies specified by the Federal Land Managers' Air Quality Related Values Workgroup (FLAG) to assess visibility impacts of coal mining and other sources on National Parks. Specifically, the research focused on the impact of Powder River Basin (PRB) air pollution emissions at Badlands National Park (BNP), South Dakota.

The study utilized the required CALPUFF air modeling system to predict pollutant concentrations at BNP. Predicted concentrations and visibility impacts were compared to measurements at BNP over the time period 1989 – 1998. The area studied included eastern Wyoming, western South Dakota, and western Nebraska. Detailed inventories of air pollutant emissions were prepared from available data for the study region for the years 1990 and 1997. Surface coal mines in the Powder River Basin were included as a specific source group; emission changes over the 1990 – 1997 period were calculated on the basis of coal production changes and emissions data from recent permit applications. Also included in the inventory were coal train emissions, major point (stack) sources, and general area emissions from small emitters, mobile sources, and other activity in each county of the study area.

The latest approved version of the CALPUFF computer model was used. Detailed air flow/meteorological fields for the year 1990 as generated by a mesoscale meteorological model were applied as input to CALPUFF. The meteorological simulation (as used in prior CALPUFF studies) was augmented for this study by the addition of hourly surface wind measurements in the PRB and at BNP.

The CALPUFF model was run to predict pollutant concentrations on a daily and average annual basis in BNP for both 1990 and 1997 emission scenarios. Impacts on visibility were calculated from the predicted light extinction due to the modeled air pollutants.

Measurements from the IMPROVE monitoring station in BNP provide actual observed values of pollutant concentration, visibility and light extinction on a daily basis over the period of data collection beginning in 1989. These data were analyzed for comparison to model-predicted impacts, with particular emphasis on any documented trends over the 1990 – 1997 time period.

Predicted impacts at BNP were generally smaller than actual measured pollutant impacts for the 1990 base year. This result was expected since distant pollutant sources and those in other directions from BNP, as well as natural background concentrations, were not included in the model simulation. An exception was for nitrate (NO_3) concentrations, for which predicted concentrations were roughly equal to observed concentrations. In general, the comparison indicates that overall predicted concentrations from the inventoried sources are not inconsistent with observed concentrations and visibility impacts.

There has been no clear trend in pollutant concentrations or visibility at BNP over the period of record. The emission inventories for 1990 and 1997 indicate increases in regional emissions of approximately 20% for the gaseous pollutants SO_2 and NO_x, and larger increases for particulate matter. The particulate matter increases are not reflected in higher predicted impacts at BNP, owing in large part to the distance of the major increases from the Park and deposition of particles to the ground during transport. Increases in nitrate and sulfate (from NO_x and SO_2 emissions) are predicted by the model. These increases, if correct, are too small to be detected as a trend in the BNP IMPROVE data.

Model runs were made with CALPUFF to define the relative contributions of different types and groups of sources to predicted impacts at BNP. The county area sources contribute on average 70% of predicted impacts, and over 90% of the particulate matter (PM10) concentrations. Point sources (large power plants or other industrial sources) contribute a major fraction of the nitrate and sulfate impacts. Coal mines in the PRB, along with coal train emissions throughout the region, contribute on the order of

5% of predicted pollutant concentrations, ranging from less than one percent for PM10 to 13% for NO_3. Despite their relatively small fraction of total impacts, the incremental 1990 – 97 mine/coal train emissions generate impacts high enough to exceed the conservative FLAG criteria for "significant impact" on visibility at BNP.

The FLAG criteria for evaluating impacts on visibility require comparison of model-predicted changes in light extinction to reference conditions representative of a clean or unpolluted atmosphere. Calculations based on both hypothetical and modeled pollutant contributions indicate that if actual observed relative humidity conditions are taken into account, the frequency of visibility impacts will generally be lower than obtained by use of the FLAG reference humidity conditions. If model-predicted impacts are compared to actual existing visibility at BNP (rather than to unpolluted background) the occurrence of "significant" changes is near zero.

Model results showing the sensitivity of predictions to assumed background pollutant levels, particle size parameters, and various methods of source representation have also been obtained and will be presented in the Final Report.

In summary, the research indicates that the CALPUFF modeling methodology when applied with best available input information can provide generally reasonable predictions of pollutant concentrations on a long-term average basis. However, there are many uncertainties in input data and modeling assumptions that can have a significant influence on results. Coal mining activities in the PRB and related coal transportation have a relatively small contribution to total BNP pollutant levels. Nonetheless, the modeled contributions can exceed levels deemed by Federal Land Managers to cause a significant degradation in National Park visibility. It is important to recognize that these "potential" impacts do no necessarily imply the occurrence of a detectable change in actual visibility on most days.

This work was supported by the Abandoned Coal Mine Lands Research Program at the University of Wyoming. This support was administered by the Wyoming Department of Environmental Quality from funds returned to Wyoming from the Office of Surface Mining of the U.S. Department of the Interior.