Abandoned Coal Mined-Land Research Program Project Review Seminar

Eleventh Project Review Seminar

Holiday Inn, Gillette, WY

November 17, 1999

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.

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

1999 PROGRESS REPORT

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Eleventh Project Review Seminar

ABANDONED COAL MINE LANDS RESEARCH PROGRAM

Wednesday, November 17, 1999 Gillette, Wyoming

You are cordially invited to attend the Eleventh Project Review Seminar for the Abandoned Coal Mine Lands Research Program (ACMLRP), hosted by the University of Wyoming. The Seminar will be held on Wednesday, November 17, 1999 at the Holiday Inn, 2009 S. Douglas Highway, Gillette, Wyoming beginning at 1:15 p.m. in the Mesa/Butte Room.

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

Influence of Post-Harvest and Preplanting Seed Treatment on Sagebrush Seeding Vigor Booth	**Interim**
Evaluation of Previously Collected Coal Mine Related Wildlife Data McDonald, Strickland, Johnson, Derby	**Interim**
Climatic Control of Sagebrush Survival for Mined Land Reclamation Perryman, Olson, Hild	**Final**
The Effects of Varying Topsoil Replacement Depth on Various Plant Parameters within Reclaimed Areas Schladweiler, Wolken, Munn, Haroian	**Interim**
Grass Competition and Sagebrush Seeding Rates: Influence Sagebrush Seedling Establishment Schuman, Hild	**Interim**
Research and Development of a GIS-Based Data Management and Model Integration Tool for Coal Mine Permitting and Reclamation in Wyoming Kohley, Hamerlinck, Jones, Warner, Schwab, Vicklund, Warner	**Interim**
Ambient Fine Particle Measurement in the Powder River Basin Chartier, Weitz	**Interim**

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.

1. Introduction

This study was funded by the Abandoned Coal Mine Lands Research Program (AML) to answer several key questions about the wildlife data collected by coal mines. These key questions are: 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 established by DEQ and the Wyoming Game and Fish Department (WGFD) for the monitoring program; 3) are critical data not being collected under Appendix B; 4) can data under Appendix B be collected more economically and at the same time provide equivalent information about wildlife resources; and 5) can reporting formats be modified to improve the utility of wildlife monitoring data?

Phase 1 of our project was designed to take a detailed look at all available wildlife data collected from five mines located at the southern end of the Powder River Basin, Wyoming, in an effort to answer the key questions posed above. We found five major types of wildlife data in the permit applications and subsequent annual reports of the mines housed at the Cheyenne office of the DEQ. Based on our findings from a trend anlaysis of the wildlife data, the AML steering committee agreed to implement Phase 2 of the study, a re-analysis of the wildlife data with the incorporation of environmental variables as covariates.

2. Methods

The five mines chosen for study during Phase 1 of the project 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.

The five major types of data we located were: 1) aerial surveys for large ungulates (primarily pronghorn (*Antilocapra americana*), mule deer (*Odocoilius hemionus*), and elk (*Cervus elaphus*)), 2) ground and aerial surveys for raptor nests, 3) ground surveys for large ungulates, 4) sage grouse (*Centrocercus urophasianus)* lek attendance surveys, and 5) ground surveys for lagomorphs (rabbits and hares (*Lagomorpha spp.*)).

Trend analyses were the primary analytical approach to data analysis in this study. We would have liked to conduct Before-After-Control-Impact (BACI) analyses, but data for this purpose were insufficient because pre-mining information on control areas was missing. Phase 1 of our study involved estimating the trends in the wildlife counts independent of environmental changes that could have influenced the counts. In Phase 2 we attempted to locate relevant environmental variables that could be used to explain trends in ungulate counts, raptor productivity, and sage grouse lek counts. Incorporation of additional environmental data (hereafter referred to as covariates) into the trend models enabled us to determine if observed

trends in wildlife counts and productivity were influenced by mining activity, changing environmental conditions, or both.

Trend analyses were conducted using Poisson regression. Poisson regression is parallel to regular (Normal theory) regression except that the response (i.e., Y) is assumed to be a Poisson random variable. Poisson random variables are non-negative integers and are likely better approximations for counts than Normal random variables. When modeling density, the Poisson regression fit the equation,

$$\log(\mu_i / a_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip}$$

where μ_i was the (estimated) average count during the ith survey, a_i was total square miles searched during the ith aerial survey or length of the ith ground survey, β_0 through β_p were unknown parameters to be estimated, and x_{ij} was the value of the jth covariate during the ith survey. In all analyses, x_{i1} was the date of the ith survey and the values of x_{i2} through x_{ip} depended on the number of mines and other covariates in the model. Covariates such as mine were either 0 or 1 depending on some event and are called >indicator variables=. For example, x_{i2} was 1 if the ith survey was conducted at the Jacob=s Ranch mine and 0 otherwise, x_{i3} was 1 if the ith survey was conducted at the North Antelope mine and 0 otherwise. The Poisson regression equation for raptor nest success analyses was the same as above except that either number of hatchlings or number of fledglings were modeled instead of density.

3. Results

Results of the Poisson regression analysis of pronghorn counts by aerial survey showed a significant difference in trend across mines ($p<0.0001$, Poisson likelihood F test) while accounting for annual estimates of pronghorn in the state (Figure 1). For mines with more than five years of data, the estimated annual change in density index ranged from a 19.1% decrease at North Antelope to a 27.8% increase at North Rochelle. Models of the number of pronghorn seen per mile driven during ground surveys indicate no significant difference in trends between mines. The estimate of the yearly trend for both areas combined was a significant decrease of !13.6% annually from the year 1989 through 1996 ($p=0.0001$, Poisson likelihood F test), again accounting for annual estimates of pronghorn in the state (Figure 2).

The number of mule deer seen per mile driven during aerial surveys showed a significant difference in trend across mines ($p=0.0001$, Poisson likelihood F test) while accounting for annual estimates of the Thunder Basin mule deer herd. Among mines with more than five years of data, the estimated annual change ranges from a 19.0% decrease to a 31.3% increase (Figure 3).

Trend in the mean number of Golden eagle chicks hatched per nest was an estimated decrease by 4.3% per year ($p=0.0032$), after accounting for the amount of winter snow. The average number of Golden eagle fledglings per nest on all six study areas decreased significantly between 1980 and 1996 ($p=0.0345$) annually by 3.3%, after accounting for winter

temperatures. Figure 4 contains a graph of the Golden eagle fledgling numbers and estimated trend.

We estimate that the multi-mine average number of Swainson=s hawk hatchlings per nest declined at an annual rate of 5.6% between 1981 and 1996 (p=0.0013) after accounting for winter temperature. We estimate that the average number of Swainson=s hawk fledglings per nest declined at an annual rate of 6.1% from 1981 to 1996 (p=0.0015). Figure 5 contains a graph of the Swainson=s hawk fledgling numbers and estimated trend.

Since lagomorph data was only recorded after 1990, raptor models were estimated with and without the use of rabbits as a covariate. When yearly trends in hatching and fledgling numbers are estimated for Golden Eagles and Swainson=s hawks without regard to lagomorph numbers, trends were significantly decreasing. These yearly trends were not significantly different from zero when estimated for the period of 1990 to 1996 and incorporating rabbits as a covariate (Swainson=s hawk). Trends in hatching and fledging for Ferruginous hawks were significantly different among mines before the use of rabbits as a covariate in modeling and using data from 1982 to 1996. For the reduced data set incorporating rabbits, both hatching and fledging trends were estimated across all mines to be decreasing by 12.9% and 19.7% per year respectively.

The estimated trend in bird counts at sage grouse leks differed in magnitude by lek ($p<0.0001$). Fit separately, the estimated trend was negative at all leks and ranged from an annual decline of 58.1% to an annual decline of 9.9% after accounting for winter snow and spring precipitation (Figure 6).

4. Discussion

Based on our inspection of five mines out of approximately thirty in Wyoming, we suspect that the *quantity* of wildlife data state wide is adequate to meet most monitoring objectives and it is likely worthwhile pursuing analysis of this data. We are slightly apprehensive about the *quality* of wildlife data state wide. We feel that enough quality information existed in the five mines we studied to warrant entry and analysis, but if certain difficulties in the data from these five mines are ubiquitous throughout the state, analysis of the state wide data will be problematic. These difficulties relate to reporting of survey effort, survey area size, differences in reporting formats, and standardization of methods. We feel that the existing Appendix B will eventually yield data which are adequate to detect long term trends in wildlife populations via regression analysis. If Before-After-Control-Impact (BACI) analyses are desired, Appendix B will need to be modified to require collection of data on control areas.

We have listed the recommended changes and/or enhancements to Appendix B which we feel should be considered the next time Appendix B is modified. The recommended changes are listed in the order of importance.

I. *Standardize reporting of wildlife data*: We recommend that Appendix B give more guidance regarding standardized reporting formats. We recommend mines submit standardized data forms for raw data, and also submit electronic copies (dBase or text format) of all wildlife data.

II. *Standardize reporting of existing environmental and mining related variables*: We recommend key environmental and mining variables be reported with the wildlife data (in standard format).

III. *Regularly scheduled reports*: We recommend that either DEQ, WGFD, the mines, or an independent third party conduct standard analyses of the wildlife data at regular intervals.

IV. *Establish control areas*: We recommend establishing regional control areas which are monitored using the same methods as mine areas. Perhaps mines could cooperatively establish, fund, and conduct surveys on the regional control areas.

V. *Replication*: If information is required on single mines, we recommend replication of certain surveys within year.

VI. *Coordination:* We recommend that that Appendix B provide more guidance on coordination by explicitly stating which surveys might be advantageously coordinated.

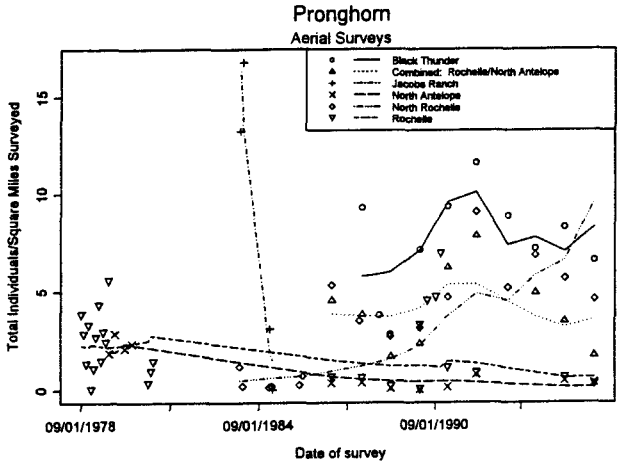

Figure 1. Pronghorn per square mile during aerial surveys. Significantly different trends in density index exist among mines ($p<0.0001$). $R^2=0.74$.

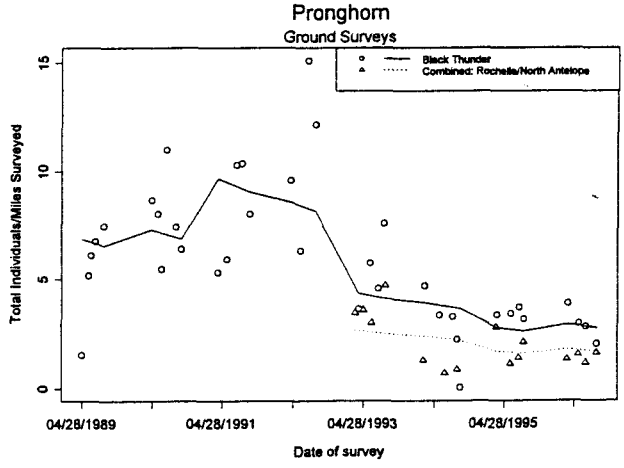

Figure 2. Pronghorn per square mile during ground surveys. Estimated annual change = -13.6% per year ($p=0.0001$). $R^2=0.60$.

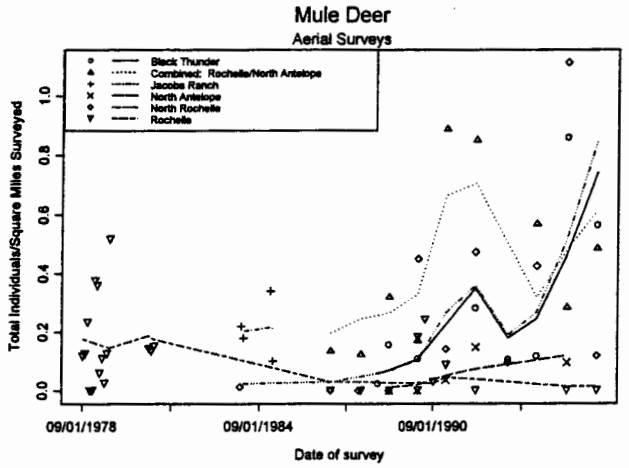

Figure 1. Mule deer per square mile during aerial surveys. Significantly different trends in density index exist among mines (p=0.0001). R^2=0.60.

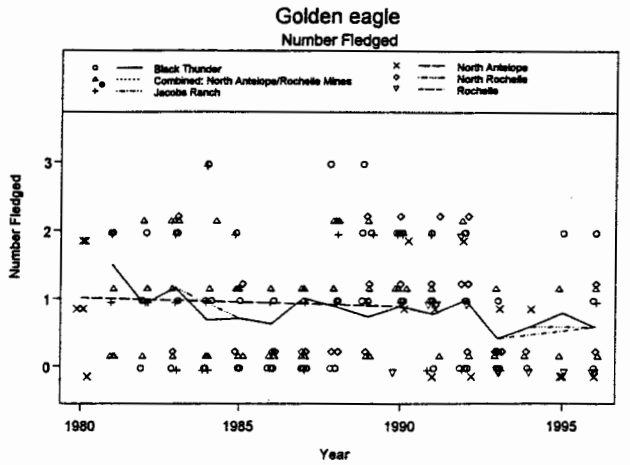

Figure 4. Number of Golden Eagle chicks fledged per year showing a significant annual decline of 3.3% per year (p=0.0345). Counts offset slightly.

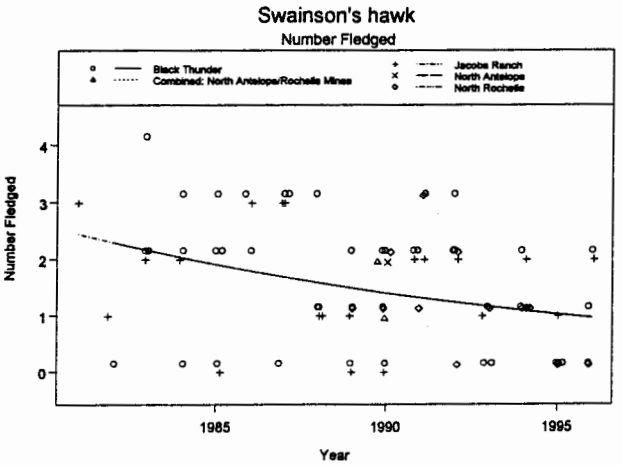

Figure 5. Number of Swainson's hawk chicks fledged per year showing a significant annual decline of 6.1% per year (p=0.0015). Counts offset slightly.

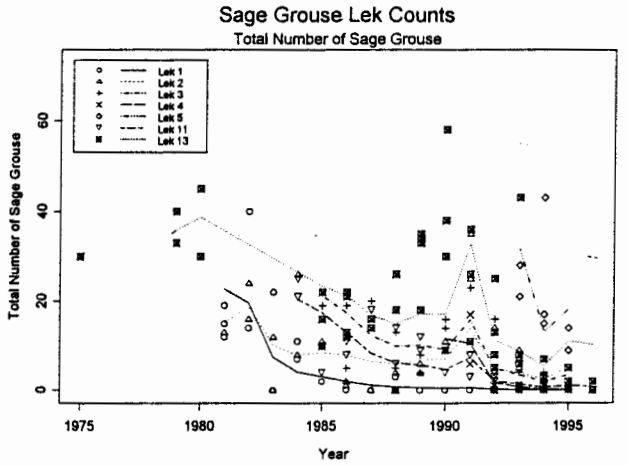

Figure 6. Total sage grouse counts on leks 1, 2, 3, 4, and 5 from Jacob's Ranch, lek 11 from Black Thunder, and lek 13 from Rochelle. Significant negative trends occurred at all leks.

SUMMARY REPORT

University of Wyoming
Abandoned Coal Mined-Land Research Program
Project Review Seminar
November 17, 1999, Gillette, WY

Climatic Control of Sagebrush Survival for Mined-Land Reclamation
Final Report

B.L. Perryman, R.A. Olson, Ann L. Hild, and A.M. Maier

Introduction

Xerophytic shrubs such as big sagebrush (*Artemisia tridentata*) are a major component of rangelands throughout the western United States. Wyoming rangelands are no exception. In most cases, the dominant shrub species present in baseline plant communities is big sagebrush. For this reason, big sagebrush is often the primary shrub involved in reclamation efforts.

Although big sagebrush is well adapted to the region when mature, establishment from seed has proven difficult. This is ironic considering that mature stands of big sagebrush occur on millions of hectares of surrounding undisturbed rangelands. Several studies have investigated cultural practices in an attempt to improve establishment. However, none of these were based on a target set of micro climatic conditions assumed to be optimum. Several researchers have indicated that the age-class structure of big sagebrush stands is characterized by the existence of cohorts, and that there may be many years in between recruitment years. That is to say that recruitment occurs in pulses. If recruitment is episodic, there must be a control mechanism(s) responsible for success. A literature search suggested that climate (amount and timing of precipitation) was the controlling factor.

Implications

First, if a specific set of climatic conditions controlling recruitment can be elucidated, reclamation efforts such as cultural practices and the design of microsites can be concentrated in areas that offer a greater chance for success. Acreage scheduled for shrub stands can be identified and targeted to mimic the required climatic conditions, optimizing the use of resources by allowing reclamation specialists to focus establishment efforts in a specific direction.

Second, the project will demonstrate the frequency with which these precise climatic conditions occur. If threshold conditions are infrequent, planting big sagebrush each year on large acreages may not be an efficient use of resources. Results are presented in two sections, *Climatic Controls* and *Demography.*

Results and Discussion

Climatic Controls

Logistic regression was used to relate monthly precipitation amounts and mean

monthly temperatures to the 5 most successful recruitment years since 1949 in each stand for the year prior to establishment, year of establishment, and the year after establishment. Two variables, above-average December and January precipitation following the first growing season, were consistently identified as climatic controls for Wyoming big sagebrush. Coefficients of determination for the three regional stand combinations ranged from 0.12 to 0.54 for December and 0.01 to 0.12 for January. In the statewide model values were 0.10 for December and 0.04 for January. All other variables had extremely low or negative coefficients of determination. The relatively low r^2 values are an artifact of the regression analysis. Logistic models included 1,080 climatic variables in each regional stand combination, and 3,240 variables in the statewide assessment. The large geographic scale increased climatic variation in the models, and the large number of variables spread the variance. In other words, 100% of the variance was spread across 1,080 or 3,240 climatic variables.

Results indicate that years with the most successful recruitment statewide, have winters (following the first growing season) with above-average December and January precipitation. In northeast Wyoming, above-average winter precipitation translates to winter snowpack. Wyoming big sagebrush seedling survival may be enhanced by persistent snow cover and subsequent protection from winter desiccation. Greater than average winter snowpack also provides more soil moisture for seedlings during the second growing season.

Higher than average statewide recruitment for basin big sagebrush occurs in years with above- average June precipitation during the first growing season. Regional stand combination r^2 values ranged from 0.01 to 0.21. Above-average March, May, and June precipitation the following year also showed high correlations (r^2 values were: March, 0.06 - 0.20; May, 0.09 - 0.11; June, 0.09 -0.20). The statewide model r^2 values were 0.10-June (year of establishment) and 0.06-June, 0.09-March, and 0.18-May (year after establishment). These precipitation variables correspond well with expected periods of high seedling demand for moisture.

Statewide recruitment of mountain big sagebrush is enhanced by below-average February, April, and June precipitation the year of establishment. Coefficient of determination values for regional stand combinations ranged from 0.01-0.03 February, 0.04-0.14 April, and 0.08-0.14 June. Statewide models had r^2 values of 0.03, 0.04, and 0.04, respectively. The literature suggests that sagebrush seedling germination is reduced with cooler temperatures. Spring moisture is coincident to cooler temperatures at high elevation mountain sagebrush sites, creating conditions that should reduce recruitment.

Demography

Demographic analyses of all three subspecies indicated the presence of episodic recruitment. The combined recruitment interval for all Wyoming sagebrush stands was 2.3 years; mountain sagebrush 2.2 years; and basin sagebrush 1.6 years. The percent of years with recruitment was 37% for *wyomingensis*, 39% for *vaseyana*, and 59% for *tridentata*. In fact our data indicates that in the case of the Wyoming subspecies, statewide recruitment occurred in only 33 of the past 75 years.

Individual plants and stands were generally younger than those found in previous big sagebrush dendrochronologic studies in southwestern states. Analysis of

variance indicated that mean stand ages of the the three subspecies were different (P=0.002), and post hoc testing revealed that Wyoming and mountain sagebrush stand ages (32, ± 9 and 26, ± 9 years respectively) were older than basin sagebrush (17, ± 3 years) stand age (LSD, α=0.05).

Age-class frequency distributions of each stand and regional stand combination were assessed for dispersion across each associated period of record. Chi-square goodness-of-fit tests were performed for both the Poisson and negative binomial distributions. No stands or regional stand combinations fit the Poisson distribution, and all variances were greater than the mean, indicating that recruitment is not random, but clustered, aggregated, or contagious across a period of record. All stands (with the exception of one mountain sagebrush stand) and all three regional stand combinations fit the negative binomial distribution. Cohort or age-class negative binomial distribution patterns were characterized by a relatively large number of years with no recruitment, a moderate number of years with minimal recruitment, and a few years with relatively high recruitment.

Conclusions and Recommendations

These results suggest big sagebrush plants that dominate much of the current vertical structure of plant communities in Wyoming are relatively young. However mean stand ages of Wyoming sagebrush in northeast and central Wyoming are approximately 3 to 4 times older than the mean fire-free interval (8 years) for the area. Irregular pulses of recruitment are characteristic of big sagebrush stands in Wyoming. Recruitment intervals, percent of years with recruitment, and negative binomial distributions are all validations. Logistic regressions identify the climatic controls responsible for these episodic recruitment events.

Application of these results fall into two categories. First, sagebrush recruitment in native stands is episodic. Reclamation specialists may be doing everything possible with respect to current cultural practices aimed at enhancing sagebrush establishment, and still endure complete failures. In fact, recruitment failure is more common than success on undisturbed sites. Success potentials can be improved over that of native stands by employing known cultural practices, however, criticism of the industry for seeded shrub establishment failures is unfounded at this point in time.

Second, current cultural practices should continue in combination with cultural practices that will reduce potentials for winter desiccation of Wyoming sagebrush seedlings. This study as well as a growing body of anecdotal evidence from reclamation personnel, indicates that winter seedling desiccation may be the major contributing factor in recruitment failures in northeast Wyoming. We have identified a climatic control of Wyoming big sagebrush recruitment that is consistent across a large geographic area.

Additionally, consideration must be given to transplantation of big sagebrush plants. Knowing that recruitment failures are common and expected, continual seeding of sagebrush on large acreages may not always be an efficient use of resources. The cost of multiple failures must be compared with transplantation costs. Seeding big sagebrush in smaller, scattered areas that incorporate current cultural practices as well

as our newly proposed practices, used in combination with transplantation methods may be the better strategy.

Epilogue

In addition to climatic control identification and demography characteristic assessments, we also investigated age-stem diameter relationships. Regression models using maximum stem diameter as an indicator of plant age were constructed for each subspecies at stand, regional stand combination, and statewide geographic scales. Coefficient of determination values indicated a very good relationship with approximately one millimeter of diameter for each year of growth. The primary potential use of this relationship is related to the timing of sagebrush control measure implementation. If sagebrush stand age can be determined, it can then be compared to the characteristic fire interval of the area. Timing of control measures have historically been based on the amount of sagebrush cover in a stand, a morphologic characteristic of the plant. Comparison of stand age and fire intervals is a more ecological process based decision tool. Stand age can now be quickly assessed by measuring the maximum stem diameter of the largest plants in a stand, rather than time consuming annual growth-ring assessments. This relationship may also hold potential for use in 80/60 shrub density rule assessments, if enforcement is forthcoming.

ABSTRACTS

Maier, A.M., B.L. Perryman, R.A. Olson, and Ann L. Hild. 1998. Climatic influences of big sagebrush recruitment and survival. Abstracts 1998 Meeting, Society for Range Management. Omaha, NE.

Perryman, B.L., and R.A. Olson. 1998. Age-stem diameter relationships of the three subspecies of big sagebrush and their management implications. Abstracts 1998 Meeting, Society for Range Management. Omaha, NE.

PUBLICATIONS

Perryman, B.L. and R.A. Olson. 2000 (in press 5/00). Age-stem diameter relationships of big sagebrush and their management implications. *J. Range Manage.*

Perryman, B.L., A.M. Maier, Ann L. Hild, and R.A. Olson. (submitted 11/99). Demography characteristics of three subspecies of *Artemisia tridentata* Nutt. *J. Range Manage.*

Maier, A.M., B.L. Perryman, R.A. Olson, and Ann L. Hild. (submitted 11/99). Climatic influences on recruitment of *Artemisia tridentata* Nutt. *J. Range Manage.*

1999
Abandoned Coal Mine Land Research Program
Progress Report

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

submitted by:

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PROJECT ABSTRACT

Within native ecosystems, plant cover, production and diversity are often affected by the amount, type and quality (physical and chemical) of the topsoil present. Reclaimed areas at coal mines have federally mandated post-mining cover and production standards which are not difficult to meet; however, pre-mine levels of plant diversity have been difficult to attain.

According to current mining regulations, a uniform topsoil replacement depth must be utilized over a given mine permit area. For mine permit areas that have widely varying topsoil depths within large portions of their permit area, this poses significant complications from a mine planning standpoint. Approving variances for such conditions at existing coal mines often results in concerns from the Wyoming Department of Environmental Quality. Widely varying topsoil availability is inherent to abandoned mine situations where topsoil is often lacking or very limited.

In order to address concerns over utilizing varying topsoil replacement depth within a given permit area to enhance plant diversity, the proposed research will: 1) determine if shallower replacement depths of topsoil enhance plant species diversity; 2) determine if shallower replacement depths of topsoil affect vegetation cover and production; 3) evaluate the quality of replaced topsoil through time and between variable replacement depths; and based on these findings, 4) determine if variable soil replacement depths enhance the development and/or differentiation of post-mine vegetation communities.

Based on these objectives, the following specific null hypotheses will be tested: 1) variable topsoil replacement depths do not influence vegetation cover and production; 2) variable topsoil replacement depths do not influence plant diversity; and 3) quality, in terms of electrical conductivity and pH, of the replaced topsoil layer will not deteriorate with topsoil depth.

Information derived from this study will be used to quantitatively assess the issue of variable topsoil replacement depths and resulting plant diversity, as well as other vegetation parameters. This issue is currently a concern within the state's mining industry, as well as the regulatory authority. Information from this study will be used to assess the direction of future reclamation work regarding vegetation/topsoil issues.

Principal investigators for this project include various vegetation and soil specialists with appropriate backgrounds to complete the research. PI's include: Brenda K. Schladweiler, BKS Environmental Associates, Inc.; Dr. Larry Munn, University of Wyoming; and Rose Haroian, Powder River Coal Company, Rochelle Mine. Additional input is being provided by Scott Belden, Powder River Coal Company and David Legg, University of Wyoming.

SUMMARY OF 1999 ACTIVITY

This project has been divided into five major tasks: I) 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; II) establish and construct the study site at the Rochelle Coal Mine; III) 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.

Task I of the project was primarily conducted in 1998 but is somewhat ongoing. Such reviewed resources included the mine permit volumes (Appendix D-8, Vegetation, and D-7, Soil) and annual reports for various mines throughout the state on record at the WDEQ-LQD offices in Cheyenne, Sheridan (for Campbell County), and Cheyenne (for Converse County). In addition to information gathering during Task I, written approval by the WDEQ-LQD was obtained (September 1998); a stipulation of Powder River Coal Company/Rochelle Mine's involvement was written approval from WDEQ-LQD to conduct research on permanent reclamation with topsoil depths shallower than the designated mine plan replacement depth.

Task II of the project involved site preparation and plot construction on Rochelle Mine located approximately 10 miles southeast of Wright, Wyoming. Rochelle Mine provided the equipment and manpower necessary to construct the field site. Site selection was determined by specific mine limitations, i.e., spoil grading, spoil sampling, topsoil contractor schedule and seeding contractor schedule.

The study site location was rough graded in Spring 1998. Block construction activities were conducted from late August to October 1998 with the exception of the cover crop seeding which was conducted in early December 1998. A two year extension on this project enabled the cover crop aspect of typical reclamation at the Rochelle Mine to be maintained. The permanent reclamation seed mix was seeded in early November 1999 and was derived to represent the pre-mining Breaks Grassland vegetation type. Within the time frame of the study, the permanent reclamation will be evaluated for three growing seasons (2000, 2001, and 2002).

The area was mowed during the 1999 growing season (mid-July). Mowing of the cover crop is a normal practice at the Rochelle and North Antelope Mines to reduce competition from the barley stubble with the permanent seed mix.

The chosen design alternative was randomized complete block (RCB) and was chosen based on mine limitations with equipment and available area. Within the RCB, one contiguous rectangular area was selected within the reclaimed topography with three distinct replicate blocks. Treatment alternatives included: 1) 22 inch "designated permit" replacement depth; 2) 12 inch replacement depth; and 3) 6 inch replacement depth. The treatment blocks were constructed on: 1) a uniform site to control variables other than topsoil depth (e.g., similar slope, aspect, stockpiled topsoil source, and seed mix); and 2) a landscape position that would best represent a pre- and post-mine Breaks Grassland community. Slopes are generally 5:1 and are west-facing. The three designated depths were approximate over the treatment replicate and will have minor variation based on weather limitations present during 1998, topsoil source, and equipment utilized for topsoil replacement.

Treatment replication dimensions were 175 feet by 250 feet. A 25 foot buffer strip on all sides of

the treatment replication was considered to minimize edge effect between replications due to equipment limitations. Therefore, a sample area of 125' x 200' was created within each treatment replication. Corners of treatment replicates were staked with appropriate depth indicators for equipment operators. Both Rochelle and BKS personnel were present during the course of study area construction to visually ensure proper depth placement.

Normal backfill suitability sampling of the study site was conducted by Rochelle Mine on 500 foot centers prior to topsoil placement. Approximate three-year-old stockpiled material was utilized for this area and was previously removed from former Breaks Grassland topography. Soils within undisturbed Breaks Grassland type consist of shallow entisols on side slopes and hill tops with moderately deep to deep entisols on fans and narrow drainages.

Existing Breaks Grassland and Upland Grassland native reference areas will be used to distinguish plant community development and differentiation between treatments. The RCB design was utilized in these native areas as much as possible. Three distinct areas were chosen in each reference area to represent the general slope, aspect and soil depth found in the reclaimed portion of the study. Within these three areas, general replication of the 22, 12, and 6 inch blocks were chosen.

In order to establish baseline soil fertility status at the reclaimed area treatments and reference areas, a minimum of 2 sample locations were collected within each reclaimed treatment replication. For general comparison purposes only, two samples within each of two native areas by soil depth were also gathered. Samples, at six-inch increments, were collected at 2 random locations within each respective treatment block before cover crop seeding on reclaimed areas in 1998. In the reference areas, samples were collected by horizon up to paralithic contact. Analysis parameters followed Table I-3 in WDEQ-LQD, Guideline 1 (1994). Listed analysis parameters include: organic matter, pH, electrical conductivity (EC), nitrate-nitrogen, phosphorus, potassium, soluble cations: calcium (Ca), magnesium (Mg), and sodium (Na), sodium adsorption ratio, texture and particle size analysis. The University of Wyoming Soil Testing Laboratory conducted the analysis.

The study site, including treatments, will be marked after permanent reclamation seeding in November 1999. Original corners were surveyed by Rochelle personnel and can be easily remarked after equipment disturbance.

Task III will involve vegetation and soil quality field sampling and will be initiated in summer 2000. Field data collection will be conducted in 2000, 2001 and 2002. Cover, production, and plant diversity will be evaluated over all treatment levels.

Results of 1998 Backfill Sampling

All parameters were within WDEQ-LQD Guideline 1, Table I-4, criteria.

Results of 1998 Topsoil Sampling

Soil textures varied throughout the treatment blocks but were generally clay loams. Soils were more similar, in terms of texture, with the Upland Grassland reference area. SAR's and EC's

were generally somewhat higher within the reclaimed area than the Breaks reference area but were lower than the Upland Grassland reference area, especially at depth.

1999
Abandoned Coal Mine Land Research Program

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

Interim Progress Report

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Introduction

Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is common and widespread across the west, particularly throughout the Wyoming Basin, across the Continental Divide and east to the Black Hills (Beetle and Johnson 1982). Coal mining companies are required to re-establish sagebrush where it is the dominant shrub species prior to mining and where wildlife habitat is a key postmining land use (Wyoming DEQ 1996).

Transplantation of greenhouse grown seedling and direct seeding are two approaches used to achieve shrub density standards set by DEQ. Direct seeding is more desirable due to economic constraints; however, Wyoming big sagebrush is often difficult to establish from seed. Failure to establish seedlings is thought to be a result of poor seed quality, low seedling vigor, and its inability to compete with herbaceous species such as grasses (Frischknecht 1978 and Schuman et al. 1998). In addition, soil quality and seeding methods have been observed as factors relating to poor seedling establishment of big sagebrush (Monsen and Myers 1990 and Stahl et al. 1988). Schuman et al. (1998) through research funded by the ACMLRP, have found that big sagebrush seedling density standards can be achieved through proper cultural practices, although grass seeded concurrently with big sagebrush had a substantial negative effect on sagebrush seedling establishment. In addition, direct placement of topsoil increases seedling densities, arbuscular mycorrhizae (AM) infection, and subsequent drought tolerance (Schuman et al. 1998; Stahl et al. 1998).

Herbaceous competition is a crucial factor in the re-establishment of big sagebrush on mined lands, and as a result research is needed to assess levels of herbaceous competition that will also enable sagebrush seedling establishment at the desired and/or required density.

Research Objectives

Our research examines the relationship of several grass seeding rates to emergence/establishment and survival of sagebrush seedlings. The objective of this study is to document seedling density of sagebrush establishment from three sagebrush seeding rates in association with seven grass seeding rates.

Materials and Methods

During 1997 and 1998 the study area located at Belle Ayr Mine near Gillette Wyoming, was established using direct placed topsoil and subsequently seeded with barley. In late summer 1998 the barley was mowed to obtain a standing stubble mulch. Seven grass seeding rates (0, 2, 4, 6, 8, 10, and 14 kg PLS/ha) were drill seeded in early December 1998 in main plots (6.5 x 27 m). The grass seeding mix included equal weights of western wheatgrass, slender wheatgrass, and thickspike wheatgrass. Sagebrush seeding rates (1, 2, and 4 kg PLS/ha) were broadcast seeded in March of 1999 in 6.6 x 9 m subplots. Prior to sagebrush seeding we established six, 1-m^2 quadrats in

each grass seeding rate by sagebrush seeding rate subplot to assess sagebrush seedling density in 1999 and 2000.

Soil samples taken at three depths in seven locations within the plot will be used to determine pH, electrical conductivity, cation concentration (calcium, sodium, potassium, and magnesium), and organic carbon, nitrogen, and phosphorus concentrations at the USDA-ARS soil laboratory in Cheyenne, Wyoming. Precipitation, soil temperature and air temperature were monitored weekly at the site during the 1999 field season. In addition, soil moisture was determined biweekly in one replication of each grass seeding rate plot to examine possible relationships between grass seeding rate and soil moisture throughout the growing season. Samples were collected at 0-5cm and 5-15cm increments.

Experimental design of the study was set up as a randomized block design with four replicate blocks. Density of sagebrush seedlings was determined on four sampling dates (June 30, August 3, August 31, and October 25, 1999). Data summarization and analysis for the 1999 sagebrush density observations, annual plant biomass, and soil moisture has been initiated. Density of sagebrush seedlings as well as production of grasses and forbs will be determined in 2000. Grass seedling densities will also be evaluated in spring 2000.

Preliminary Results

Heavy spring and early summer precipitation resulted in a high abundance of volunteer species. As a result, the study site was mowed in late July to aid in the assessment of sagebrush density and to mimic adjacent reclaimed lands. Mowing was maintained at 10-15cm height to prevent damage to sagebrush seedlings.

Sagebrush seedling density exhibited a direct relationship to sagebrush seeding rates (Figure 1). Seedling density at 4 kg/ha sagebrush seeding rate was greater than the 2 and 1 kg/ha on all four sampling dates. Sagebrush seedling density declined for all sagebrush seeding rates in response to declining precipitation from late July through October.

Sagebrush seedling density was lowest at the higher grass seeding rates when averaged across sagebrush seeding rates (Figure 2). In general, fewer sagebrush seedlings were observed in high grass seeding rates; however this observation was not significant.

Soil moisture among the seven grass seeding rates collected at two depths in the 1999 growing season are presented in Figures 3 and 4. Soil moisture data have not been analyzed; however, the data exhibits reduced soil moisture from July to early August at both depths.

Discussion

Preliminary results suggest limited effects of grass competition on sagebrush establishment in the 1999 growing season. Since precipitation was above normal for the spring and early summer 1999 soil moisture did not exhibit the response generally observed with increasing grass seeding rates, hence, the lack of statistically significant difference in sagebrush establishment.

Higher sagebrush seedling densities can be achieved using 4 kg PLS/ha, although all three rates resulted in sagebrush seedling densities of $\geq 1/m^2$. Additionally, the highest sagebrush seeding rate (4 kg/ha) had the highest mortality of seedlings over the growing season.

We would anticipate that more normal or below normal precipitation and the development of the grass community will cause greater effects of grass seeding rates on sagebrush seedling survival in the next year's growing season. In addition, survival of sagebrush seedlings over the winter may also significantly affect future observed seedling density. We look forward to documenting these effects in the next year.

Projected Activities

Soil sample analyses will be conducted in the following months and completed by the end of this year. In June, August, and October of 2000 sagebrush seedling density will be monitored using the same methods as the previous year. We will also determine grass seedling density and peak standing grass and forb production on the site in 2000. Precipitation, soil and air temperature and soil moisture will be continuously monitored May through October 2000.

Final data summarization will begin in October 2000.

Acknowledgments

This study is possible through the cooperation and financial support from the ACMLRP, RAG Coal West, Inc at Belle Ayr Mine, USDA Agricultural Research Service, Cheyenne Wyoming, and Department of Renewable Resources, University of Wyoming. The research is accomplished in cooperation with Laurel Vicklund, Environmental Engineer, RAG Coal West, Inc. at the Belle Ayr Mine.

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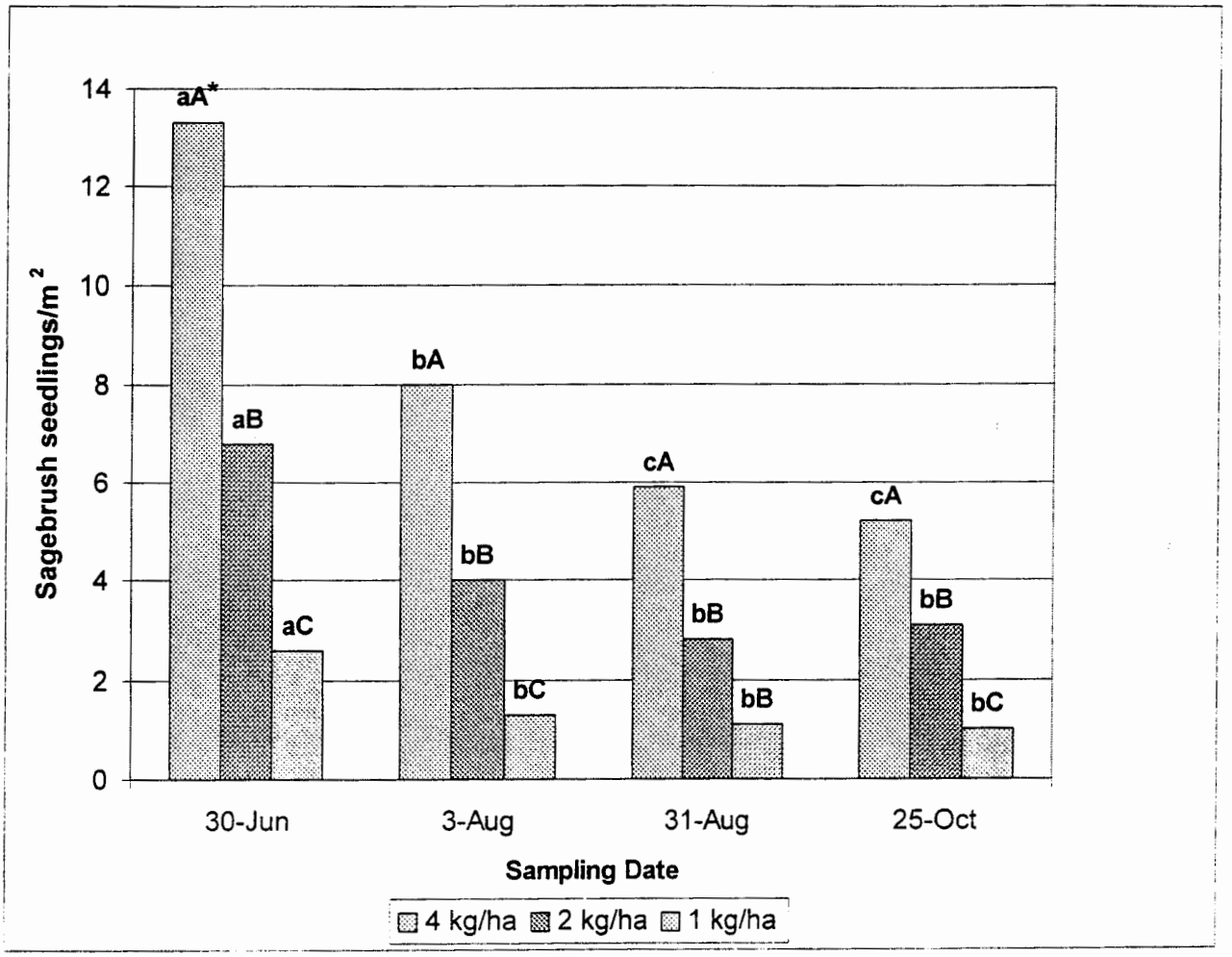
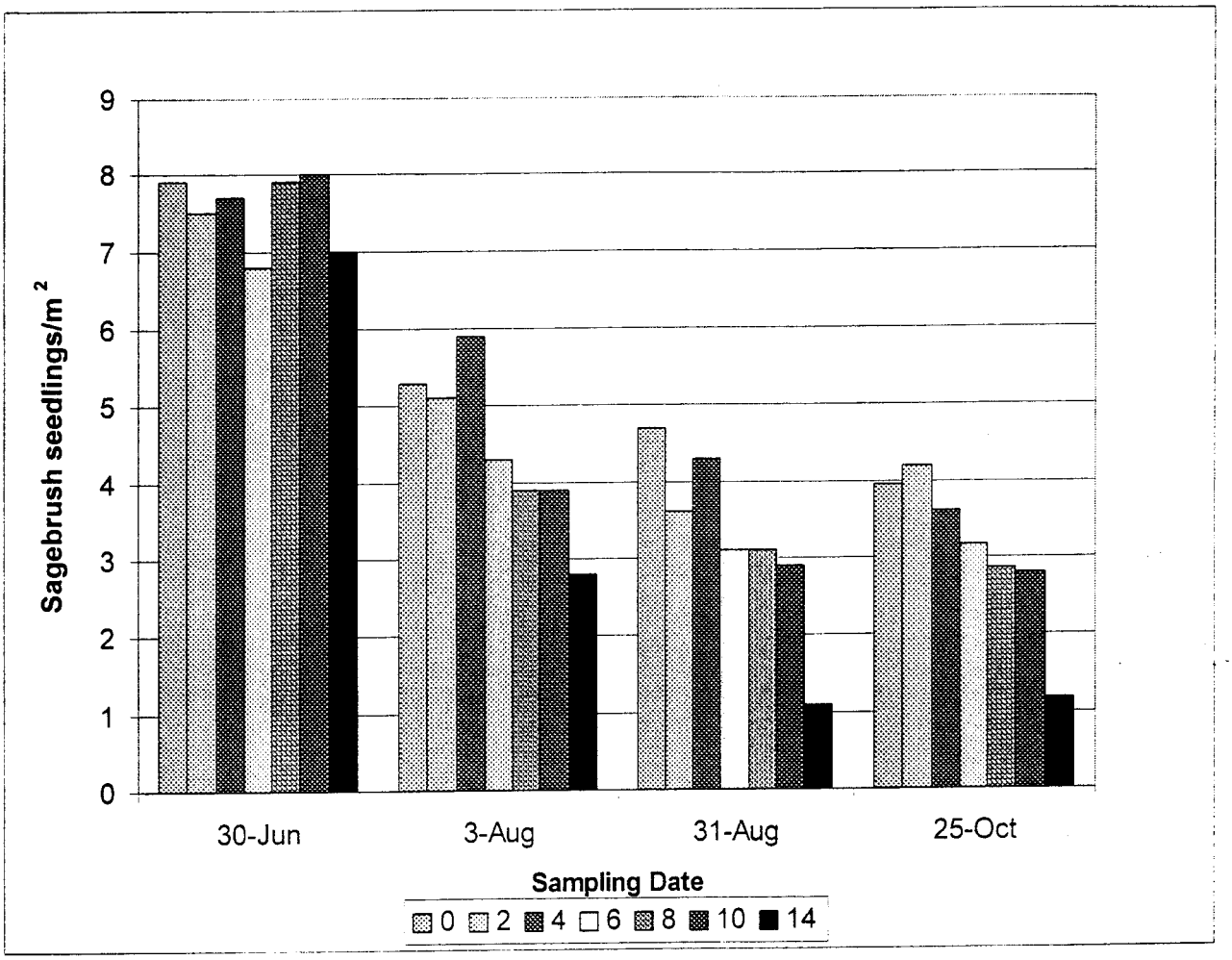
Figure 1 – Mean number of sagebrush seedlings in each sagebrush seeding rate on four sampling dates (June 30, August 3, August 31, and October 25) in 1999 at Belle Ayr Coal Mine, Gillette, WY.



*Uppercase letters indicate mean separation among rates within a date and lowercase letters indicate mean separation among dates within a specific rate. Means with the same letter are not significant.

Figure 2 – Mean number of sagebrush seedlings in each grass seeding rate (kg/ha) on four sampling dates (June 30, August 3, August 31, and October 25) in 1999 at Belle Ayr Coal Mine, Gillette, WY.



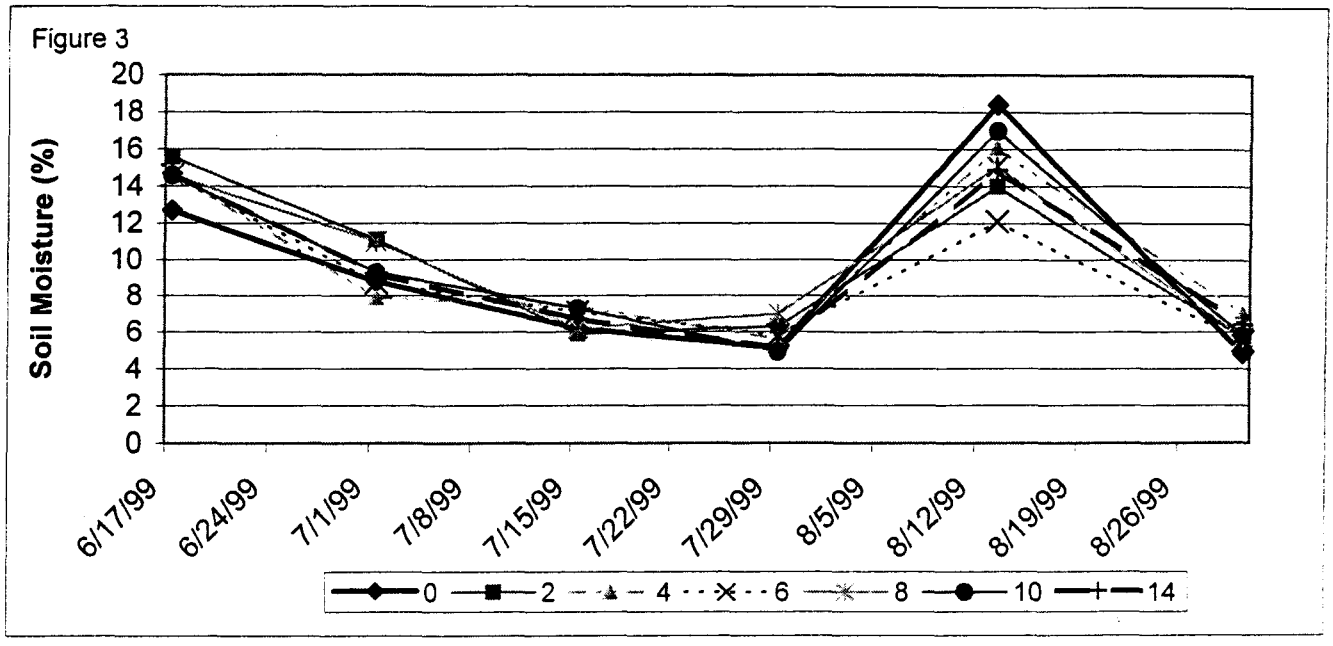


Figure 3 - Soil moisture at 0-5 cm in each grass seeding rate over time in 1999, Belle Ayr Mine, Gillette, WY.

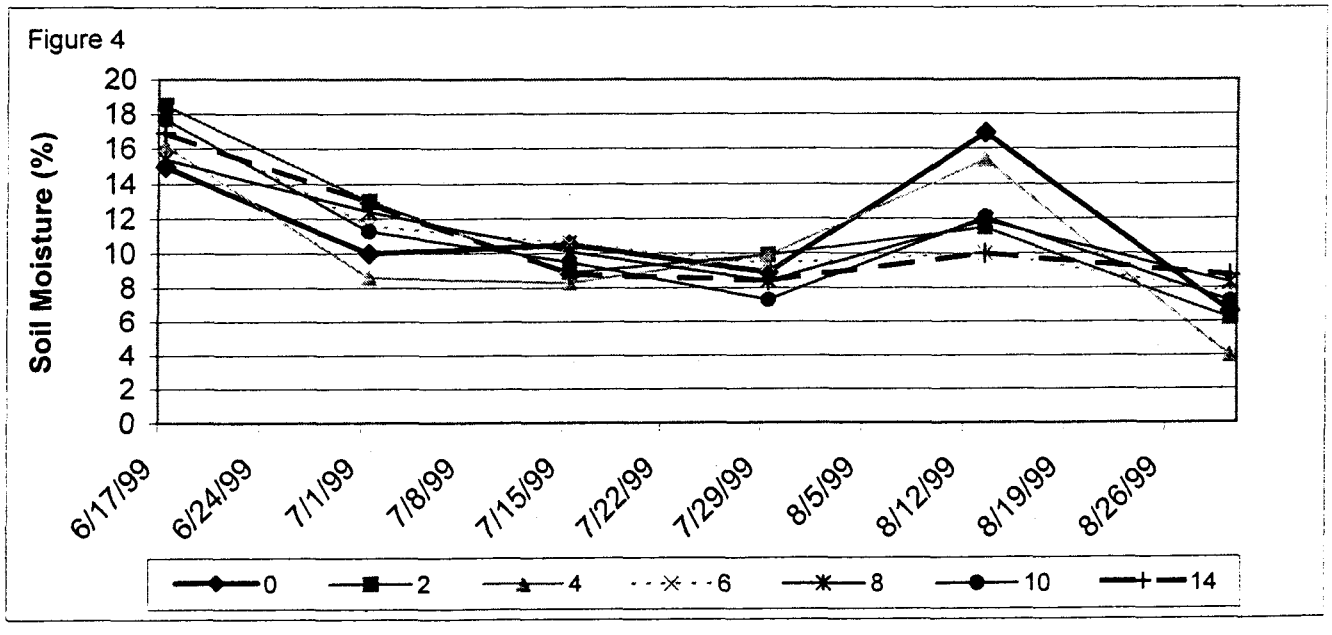


Figure 4 - Soil moisture at 5-15 cm in each grass seeding rate over time in 1999, Belle Ayr Mine, Gillette, WY.

Wyoming Abandoned Coal Mine Lands Research Program
Interim Project Review
November 1999

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

July 1, 1999 – July 1, 2001

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PROJECT OVERVIEW

This interim progress report provides a brief project background and summary of initial work undertaken in the five months between the project's beginning on June 1, 1999 and October 31, 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 bond release processes for coal mining in Wyoming. Th 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, re-vegetation, 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 include the following:

Task 1: Consultation with RMT Advisory Group.

An advisory group will be formed representing industry, regulatory, and research professionals to aid in the development of the baseline and modular components of the RMT. The advisory group will be involved in the formulation of goals and procedures for the application's data conversion, analysis, and reporting capabilities.

Task 2: Baseline Module Development.

The functionality of the RMT is dependent upon integration of existing spatial and non-spatial databases into the GIS-based tool. Conversion utilities for database integration from existing data sources and systems including CAD, spreadsheet databases, and relational databases.

Task 3: Hydrologic Module Development. A seamless integration between SEDCAD 4.0 and ArcView 3.x will be developed to assist and expedite hydrologic analyses. The three major subtasks are:

3.1 Development of an ArcView Graphical User Interface to facilitate the estimation of the input data and parameters required by SEDCAD (pre-processing).

3.2 Seamless Interface with SEDCAD 4

3.3 Provide visual GIS output capabilities of modeling results for calibration, validation and ultimately, decision making (post-processing).

Task 4: Soils Module Development. The RMT will contain a soil resource component that will focus on the automation and management of soil survey data collected prior to mining operation. The GIS-based tools will also facilitate modeling of soils data, and development of analysis and reporting tools for development of soil survey maps, annual reports, and volumetric soil salvage studies.

Task 5: Vegetation Module Development. The RMT Vegetation Component will integrate baseline resource inventory and monitoring studies with the analytical and presentation capabilities of a customized GIS. The spatial database tools will promote

efficient and consistent reporting and a comprehensive view of vegetation resources throughout the permitting, monitoring, and bond release phases of reclamation.

Task 6: Wildlife Module Development. The RMT will contain a Wildlife Module that will focus on the development of a new GIS-based approach to inventory and document wildlife in proposed mining areas. This approach will facilitate the inventory, analysis and reporting of wildlife resources necessary for annual reports.
Task 7: Integrated Application Development. The final ArcView RMT extension will be compiled from the four major modules into a complete package, including additional interaction between the sub-components.

Task 8: Technology Transfer. Technology transfer will involve three major activities: (a) development of a RMT User Guide and Tutorial; (b) sponsorship of an RMT Technology Transfer Workshop; and (c) Professional paper presentations and journal publications.

Task 9: Report Generation. This task will involve completion of two semi-annual reports, a Final Executive Summary Report, and a Final Technical Report, as defined by the ACMLRP reporting requirements.

RECENT ACCOMPLISHMENTS

As outlined in the study's original Statement of Work, activities during the first year of the project are focused primarily on Tasks 1, 2, and 3. Completed and ongoing activities for these tasks are describe below:

Task 1: Consultation with RMT Advisory Group. On June 15th, the project team met in Laramie, Wyoming to "kick-off" the project. Preliminary discussions focused on the four sub-tasks outlined for Task 1, including:

1.1 Identification of key resource management professionals for advisory group and formation of the advisory group.

1.2 Development of data requirements for the RMT and overall data integration design.

1.3 Development of analysis and reporting functionality requirements for the RMT.

1.4 Selection of pilot areas for RMT beta testing and database integration.

At that time a decision was made to delay formal establishment of an advisory group pending additional discussions on data requirements, and analysis and reporting

functionality. It was also decided that the development of the RMT should focus on bond release goals and should de-emphasize functionality to support mine permitting. To date, five additional meetings have been held with regard to industry needs for GIS technology utilization in the four RMT components: (1) August 17-19, 1999. P&M Coal in Gallup, New Mexico. Discussions were conducted with hydrologists, engineers, soil scientists, and reclamation specialists; (2) August 23-24: Powder River Coal Company and RAG Coal West, Inc. Discussions with Permit Supervisors and Environmental Managers; (3) September 20-23, 1999. Office of Surface Mining Interactive Forum *Approaching Bond Release: Re-vegetation.* Discussions concerned topics of re-vegetation and soils and the advantages of using GIS to facilitate SEDCAD 4 inputs; (4) October 5-8, 1999. Civil Software Design. Meetings with Pam Schwab concerning the development of a seamless interface between ArcView and SEDCAD 4 and perspectives of consulting, industry and regulatory personnel (continued dialog); and (5) October 18, 1999. Meeting with Office of Surface Mining Western Regional Coordination Center. Discussions with hydrologists and engineers regarding future advances of GIS for permit review.

Task 2: Baseline Module Development. On August 23-24, project team members visited the two pilot area mines to discuss the following sub-tasks with reclamation specialists:

2.1 Enhancement of GIS/CAD integration and customization of ArcView CAD Reader extension.

2.2 Development of DBMS integration protocol and enhancement of ArcView database integration technology.

2.3 Enhancement of report generation utilities and customization of ArcView Report Writer extension.

Based on the August meeting, a revised and more detailed description of the RMT was completed and distributed for review by the participating mines in October 1999. This document outlined some of the specific functionality of the RMT that was requested by the industry representatives. For example, it was requested that the RMT be able to merge two or more reclamation area polygons and all associated data in the relational database for easy tabulation and reporting on "logical" units. In addition, it was requested that the RMT be programmed with a suite of utilities to facilitate the creation of standardized reclamation summaries and maps for annual reports and bond release documents.

The revised RMT document also contained a preliminary list of proposed "core" reclamation data to be tracked within the RMT. This list will undergo review by the mines and the bond-release working group. Reclamation data has been initially

grouped into seven information categories including reclamation unit, re-graded surface, topsoil replacement, re-vegetation, wildlife habitat, precipitation, and management/husbandry.

Two pilot areas for RMT beta testing were identified in the August meeting: Powder River Coal Company's Antelope Mine and RAG West Coal, Inc's Belle Ayr Mine. Reclamation-related data for these pilot areas (primarily existing CAD and GIS layers) have been collected and are currently being reviewed for their content and data structure. Additional discussions for the baseline module development will take place at the ACMLRP Project Review Meeting in November 1999.

Task 3: Hydrologic Module Development. July and August, 1999 were spent planning and formulating the designs for the RMT 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 two 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 (3) the development of a post-processor capable of displaying SEDCAD outputs within the ArcView environment.

To date, pre-processing is progressing on-schedule. New utilities have been designed to convert digital topography lines into continuous raster surfaces necessary for most pre-processing operations. Additional enhancements from previous ACMLRP research include new functionality for delineating areas of internal drainage, such as playas, and accommodating these areas or "sinks" into the hydrologic model, SEDCAD. Other developments include a NRCS Curve Number utility that assists the user in creating a spatial layer to accurately represent runoff potential within the hydrologic model. The most recently completed module is the "Precipitation Developer" utility that provides multiple methods for distributing precipitation events spatially and temporally across a given study area.

ONGOING ACTIVITIES

Over the next six months, much of the work (and allocated resources) will be focused on completing Task 3 and (to a lesser extent) implementing Tasks 4, 5 and 6. Relative to development of the Hydrologic Module (Task 3), the next scheduled task for pre-processing is the development of an automated sub-watershed delineation utility. This utility will quickly delineate sub-watersheds and automate the collection and

organization of sub-watershed attributes including: contributing area, weighted curve number, weighted precipitation, time of concentration and other parameters required by the SEDCAD model. As part of the sub-watershed delineation process, the user will have tools provided to locate and identify various structures (i.e. culverts, channels, sediment ponds, etc.) and designate the sub-watersheds that contribute to each structure. Once all components of pre-processing are developed, the user will be able to export each component directly to the SEDCAD model that will conduct the hydrologic analyses. This post-processing component will in turn be used to review and display hydrograph information for each sub-watershed or structure outlet.

Relative to the development of the soils, re-vegetation and wildlife modules (Tasks 4,5&6), the next important step will be to work closely with the bond release working group to identify a core set of reporting requirements for bond release. With these reporting requirements in place, we expect to complete the final RMT database design by February of 2000 and standardize necessary data values for the RMT database by March of 2000. This will be followed by preliminary module design for re-vegetation, soils, and wildlife as a lead in to the focus of year 2 activities

Abandoned Coal Mine Land Research Program
Progress Report
November 10, 1999

Project: Ambient Fine Particle Measurement in the Powder River Basin
PI: Kevin Chartier, Mark Weitz

Introduction

The objectives of this project 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.

Good and timely progress has been made toward achieving these goals. A complete network of 8 instruments has been installed throughout the Basin and is operating on an ongoing basis. A Network Plan has been written and approved by the Wyoming DEQ, Air Quality Division. A Quality Assurance Project Plan has also been submitted for review to WY DEQ AQD. Due to the cooperation of all participants, the project is on schedule and high integrity data are being collected.

Preliminary Results

Sampling commenced in June, 1999. Through October, the overall PM2.5 data recovery rate for the network is 94%. A total of 166 24-hour concentrations have been measured. With less than ½ year's data, it is as yet premature to draw any conclusions concerning the objectives of the project. However, no 24-hour measurements have exceeded the 24-hour ambient standard (65 µg/m^3), and the average concentrations at all sites are below the annual ambient standard (15 µg/m^3).

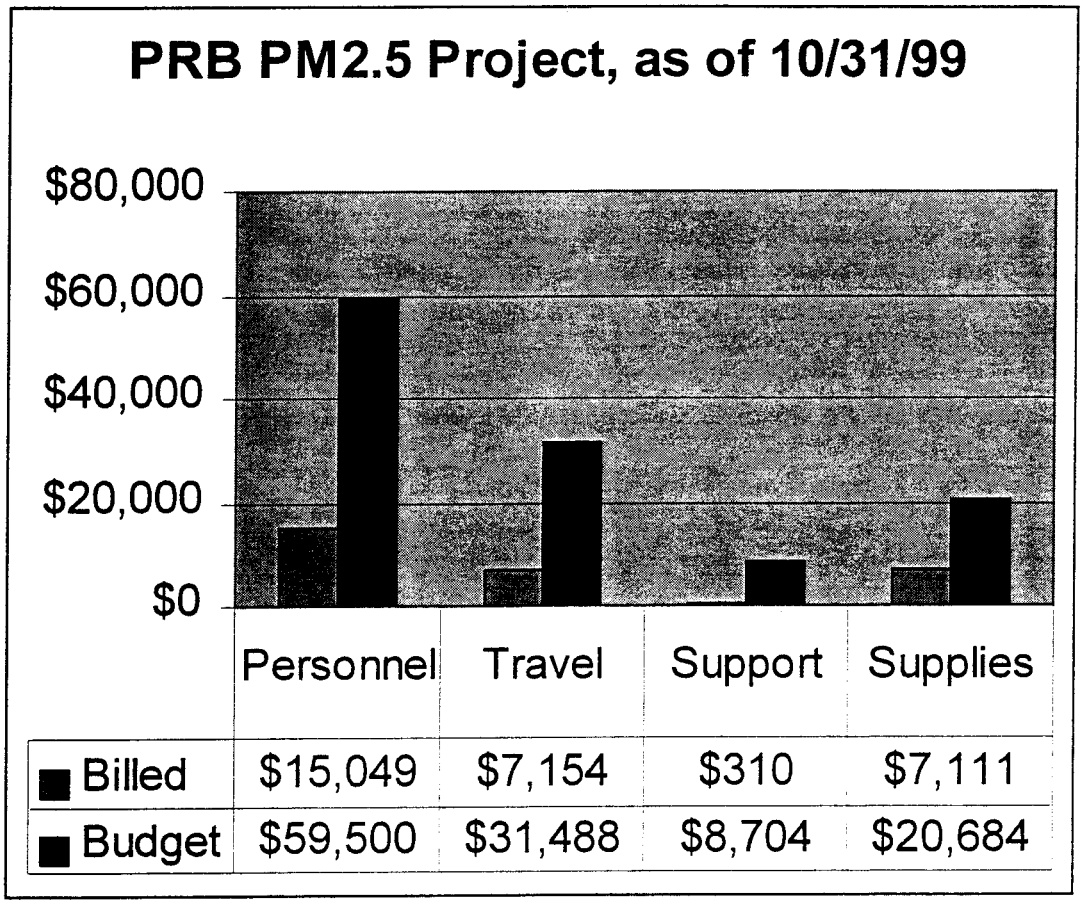
Project Status

The status of the major tasks associated with the project is summarized in the following table. All major scheduled goals have been met within in a few weeks of projection. Delays were experienced in the procurement of some of the equipment. However, only a few samples were lost due to these delays. Interpretation and reporting of the first quarter of data (July-September) has taken slightly longer than anticipated. A report of these data is nearly complete and will be submitted to the Wyoming DEQ, Air Quality Division in November.

Activity/Task	Schedule	Status
Network Plan	June 1999	A network plan was developed and presented to the WYDEQ Air Quality Division in May. AQD approval was obtained June 1999.
Equipment Procurement	June 1999	Equipment was received in June, July and August. A demonstration sampler was used in place of one unit that did not arrive until August.
Equipment Installation	June 1999	Installation of all new equipment was performed within one week of arrival from manufacturer.
Operator Training	June 1999	Operator training was completed in June.
Sample Collection	July 1, 1999	Samples collection began on July 12 at 2 sites, July 24 at 2 other sites.
Quarterly Report	October 1999	The first quarterly report is expected to be submitted to the AQD for review by November 16.
Quality Assurance Project Plan	Not projected	A draft QAPP has been submitted to the WY DEQ AQD for review.

Budget Status

The total ACMLRP award is $150,000 for 2 years. Billing toward the project through October 1999 is $29,624. Billing in all categories, personnel, travel, support, and supplies, is at, or below the budget projected in the application. To-date billing as compared to the total budget is summarized in the following chart.



	Personnel	Travel	Support	Supplies
Billed	$15,049	$7,154	$310	$7,111
Budget	$59,500	$31,488	$8,704	$20,684