A METHOD FOR DETECTING DEWATERING EFFECTS OF UNDERGROUND MINING ACTIVITIES ON SURFACE WETLANDS [1]

by

Larry D. Hayden-Wing, John R. Baldwin, Kenneth Webber, and Jeffrey B. Winstead [1]

Abstract: In 1996 U.S. Energy/Kennecott Uranium Company initiated a large-scale, long-term monitoring program to document whether or not proposed uranium mining activities under Green Mountain in Central Wyoming would cause a groundwater draw-down resulting in changes in the existing riparian/wetland habitats. The monitoring program consisted of establishing 12 study drainages on Green Mountain and six control drainages on an adjacent but hydrologically isolated mountain not scheduled for mining. Baseline data were collected in 1996 and 1997 prior to the commencement of mining. For each drainage, breeding bird densities (birds/km) and richness (species/km), winter wild ungulate fecal pellet group densities (groups/km), small mammal densities (captures/trap night), and density and species composition of aquatic macroinvertebrates were measured along permanent, marked transects within each riparian zone. In order to characterize the baseline vegetation and isolate the effects of livestock grazing, species composition, percent cover, production, and type boundary delineation of riparian vegetation were quantified within adjacent fenced and unfenced half-acre sample sites within each drainage. Baseline photographs were taken at permanent marked points from fixed angles at each of the sample sites. Piezometer holes were drilled at each monitoring site for measuring potential changes in ground water levels over time. If, during mining, water levels are found to drop significantly from baseline, a new study of wildlife and vegetative parameters would be conducted to determine whether or not significant decreases in wetland function or changes from baseline characteristics have occurred.

Additional Key Words: wetlands dewatering, monitoring methodology, underground uranium mine, Wyoming

Introduction

Underground mining can affect or modify ground water and surface water hydrology in the vicinity of the mine (Hill and Price 1983, Hobba 1993, Kendorski 1993, McCulloch and Nairn 1996, Williams et al. 1986), and many studies have been directed at monitoring ground water, stream flows, and general effects on biological resources. However, few studies have focused on studying changes in the biotic characteristics of wetlands and riparian communities that might be produced by mine-induced modifications of hydrologic regimes.

The Bureau of Surface Mine Reclamation, in cooperation with the Bureau of Water Quality Management and the U.S. Geologic Survey, initiated a baseline study in 1977 of the chemical, physical, and biological characteristics of streams in an unmined watershed in Fayette County, Pennsylvania (Sheaffer 1979). The goal was to proved baseline, pre-mining data that could be compared to mining and post-mining measurements of the same parameters and thereby facilitate the identification of mining impacts. The goal in conducting our study was similar to the Pennsylvania study, but our focus was on the biota of wetlands and riparian habitats rather than purely aquatic parameters.

McCulloch and Nairn (1996) stated that: "Probably the most important information that is collected as part of the probable hydrologic consequences (PHC) is the baseline data. These data indicate the water quantity and quality prior to mining in an area and provide valuable information in determining post-mining impacts." This same rationale, in our opinion, is equally applicable to the biological baseline data that we collected.

---

[1]Paper presented at the 16th Annual National Conference of the American Society for Surface Mining and Reclamation in Scottsdale, Arizona, August 13-19, 1999.

[2]Larry D. Hayden-Wing, Principle Scientist, John R. Baldwin, Sr. Wildlife Biologist, and Jeffrey B. Winstead, Sr. Wildlife Biologist, Hayden-Wing Associates, Laramie, WY 82070. Kenneth Webber, Manager Environmental Affairs, U.S. Energy Corp., Riverton, WY 82501

Proceedings America Society of Mining and Reclamation, 1999 pp 641-650
DOI: 10.21000/JASMR99010641

https://doi.org/10.21000/JASMR99010641

Site Specific Circumstances and Need for Study

The Green Mountain Mining Venture (GMMV) was formed in June of 1990 between U.S. Energy Corp./Crested Corp (U.S. Energy) and Kennecott Uranium Company. In 1996, when GMMV proposed an underground mine to extract 40 million pounds of uranium oxide (U_3O_8) from the Jackpot Mine located on 56 square miles of holdings in South Central Wyoming, the question of dewatering effects on surface wetlands became a major issue.

The site of GMMV's Jackpot Mine is on Green Mountain in Fremont County, approximately 129 km northwest of Rawlins and 113 km southeast of Riverton (Figure 1). Two parallel declines enter the south side of Green Mountain and provide access for personnel and equipment, fresh air and exhaust ventilation, pipe systems for pumped water, and a conveyor gallery for mined ore. The declines enter the mountain at an elevation of 2,406 m, extend downward along a grade of 16.8 percent for approximately 3,749 m, and terminate at an elevation of approximately 1,745 m. The extent of the underground area to be mined is approximately 300 acres. The mine plan calls for the extraction of approximately 3,000 tons of ore per day over a 15-year period. However, project activities may extend over a 25-year period when other factors such as standby periods, construction of mine facilities, exploration, and stabilization activities are included.

A series of hydraulically separated perched aquifers occurs in Green Mountain due to the presence of siltstone and mudstone lithological units that create barriers to the seepage of groundwater. As a result of the lensoid character of these sediments and the essential lack of lateral hydraulic continuity of the higher permeability materials, a continuous water table aquifer in the mountain does not occur. The water that feeds the springs and seeps on the mountain flanks is provided by the perched aquifer systems, which generally occur above 2,316 m. These perched aquifers are not expected to be affected by the proposed mining because they are hydraulically separate from the water-bearing strata adjacent to, and above, the ore zones to be mined (U.S. Energy Corp 1994).

The hydrological environment of Green Mountain could potentially be affected by mining activities by groundwater inflows to the declines, inflow to the excavations within the ore body zones, and the subsequent disposal of the mine drainage. Based on existing records, hydrological data, and other data collected and analyzed, GMMV's hydrologists do not feel that underground mining activities would cause the dewatering of surface wetlands. However, differences in opinion exist between agency regulators and mining officials as to the probability that mining operations would, over time, result in a draw-down or dewatering effect on the mountain and subsequent effects to the existing riparian habitats. The development of a method for detecting dewatering effects of underground mining activities on surface wetlands and the establishment of a long-term program to monitor such potential effects is one of the goals of the GMMV proactive program. A description of the rationale and methodology that was developed to fulfill this goal is the focus of this paper and is presented below.

Study Area

The study area consists of Green Mountain (experiment area) and the adjacent ridge and mountain known as Whiskey Peak (control area). Whiskey Peak was selected as a control area because of its close proximity to, and hydrologic isolation from Green Mountain (Figure 1). Green Mountain and Whisky Peak extend in a generally east-west direction for approximately 16 and 8 km, respectively (Figure 1). These adjacent mountains rise approximately 762 m above the surrounding plains, to over 2,743 m in elevation and are located between the Granite Mountains to the north and the Great Divide Basin to the south. Green mountain covers approximately 181 square km and is flat-topped with a steep escarpment on the south edge that grades into long rolling toeslopes with deeply incised drainages that descend into the sagebrush plains. The north slope of the mountain is steeper and more abrupt, and grades into the sagebrush flats that lead into the Granite Mountains. Whisky Peak, to the east, is smaller (approximately 104 square km) and slightly higher than Green Mountain, and has steep slopes that drop away on all sides to form a rather angular ridge line and mountain top. The land surface over most of the study area is owned by the Bureau of Land Management (BLM) with a few small inholdings of private land. The primary land uses are livestock grazing (cattle), recreational camping and hunting, mining, and small-scale timber cutting.

The gross physiognomy and species composition of the vegetative cover on Green Mountain and Whiskey Peak vary considerably with elevation and aspect. The lower toe and foothill slopes are dominated by dense stands of sagebrush (*Artemisia* spp.) mixed with areas of both stabilized and blowing dune sand and a scattering of juniper (*Juniperus communis*). The drainages characteristically support strips of several species of willows (*Salix* spp.), and a scattering of other shrub species. The intermediate slopes are characterized by stands of dense sagebrush interspersed with stands of mixed lodgepole pine (*Pinus contorta*) and limber pine (*Pinus flexilis*).

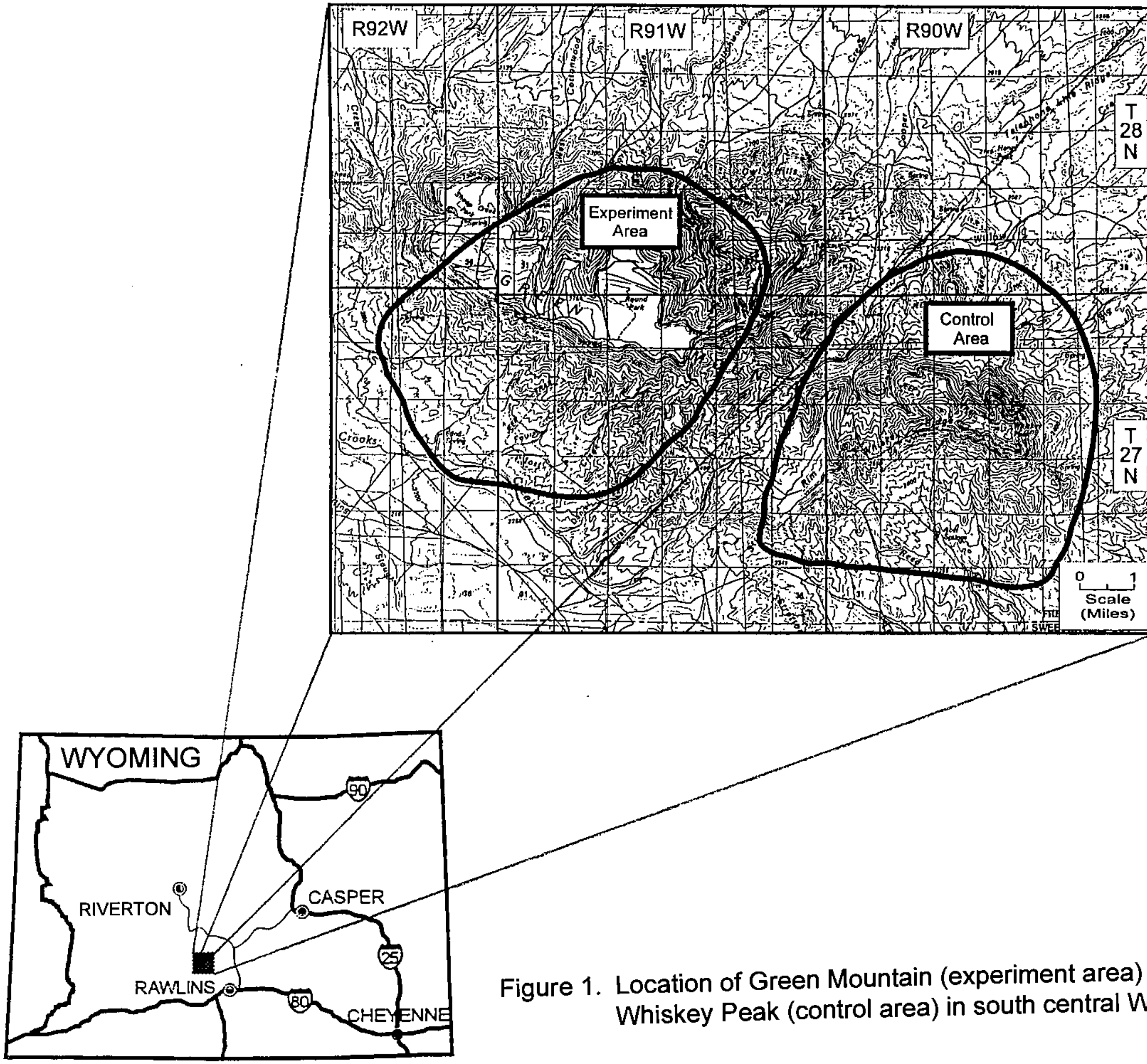

Figure 1. Location of Green Mountain (experiment area) and Whiskey Peak (control area) in south central Wyoming.

Drainages contain scattered stands of willows and aspen (*Populus tremuloides*). Mountain and ridge tops and the upper north-facing slopes support a mixed vegetation consisting of dense stands of pure lodgepole pine interspersed with subalpine meadows and sparse sagebrush openings. Vegetation along, and in, drainages exhibits a greater diversity of species than lower elevation sites and is characterized by a mix of overstory species that include: lodgepole pine, subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and aspen.

During 1992, GMMV performed a wetlands survey on Green Mountain that resulted in the description of approximately 400 acres of wetland types on the 18,043-acre study area (HWA/EEC 1992). These wetland types cover approximately 2.2 percent of the mountain study area and consist of: (1) wet meadow - 42%, (2) riparian forest/scrub - 33%, (3) montane wetlands - 22%, open water - 2%, and unconsolidated bed - 1%. In addition, approximately 56 miles of active stream channel occur on the study area. This study did not include Whiskey Peak, but general observations, along with the results of subsequent vegetation sampling during 1997 and 1998, indicate that these same wetland types occur there but in somewhat different proportions.

Wet meadows occur throughout the mountain along streams, around seeps and springs, behind beaver dams, and wherever else the subsurface water table provides perennially wet or saturated soil or subsoil conditions where hydrophytic plant species predominate. This wetland type is common on very poorly drained areas on top of Green Mountain. Typical species include redtop (*Agrostis stononifera*), largeleaf-avens (*Geum macrophyllum*), Nebraska sedge (Carex nebraskensis,) tufted hairgrass (*Deschampsia caespitosa*), sedges (*Carex* spp.), Baltic rush (*Juncus balticus*), and sword-leaf rush (*Juncus ensifolius*). Ground cover ranges from 70 to 100 percent and vegetation height ranges from 3 to 24 inches. In larger areas of wet meadow, there is often a scattered, sparse to moderate overstory of willow shrubs. This wetland type may occur independently or in the understory of the riparian forest/scrub cover type along drainages.

The montane wetland type occurs on the top of Green Mountain, as well as along drainages on the north face of the mountain. Montane wetlands have an overstory of lodgepole pine, subalpine fir, Engelmann spruce, and aspen. On the top of the mountain, the montane wetlands are relatively dry and the understory is predominantly small-wing sedge (*Carex microptera*) and tufted hairgrass. Montane wetlands along drainages typically contain a greater diversity of species. Understory species in these areas are typical of the riparian scrub and/or wet meadow types. Understory vegetal cover ranges from moderately sparse to abundant (30 to 100 percent), and tree canopy cover is typically moderate (60 percent).

The riparian forest/scrub type consists mostly of various species of willow, water birch (*Betula occidentalis*), thinleaf alder (*Alnus tenuifolia*), and red-osier dogwood (*Cornus stononifera*). This type primarily occurs at mid to lower elevations along intermittent and perennial stream channels that occur on both the north and south sides of the mountain. At lower elevations on the north side, scattered cottonwoods and/or aspen trees create a sparse to moderate arboreal overstory to the riparian scrub species. In such areas, the intermediate layer of shrubs, primarily willows, reaches heights of up to 3.7 m. Understory vegetation includes those species found in the wet meadow cover type, and total vegetal cover ranges from 70 to 100 percent.

The 762-m change in elevation between the tops of Green Mountain and Whiskey Peak and the adjacent plains, along with the incised topography of the slopes, provides many types of vegetative cover and habitats for wildlife species. Dern (1989) conducted surveys and analyses in 1987 and estimated that the Green Mountain area had the potential to support 243 species of resident and migratory wildlife. This included 180 species of birds, 54 mammals, 2 fish, and 7 amphibians.

Overview of Procedures

In 1994 Hayden-Wing Associates (HWA) prepared a long-term riparian habitat enhancement and monitoring plan (HWA 1994) for GMMV's Jackpot Mine. This plan was based on the premise that any changes in water availability on Green Mountain would be reflected in the characteristics of the resident biota of the wetland and riparian communities. It is generally accepted that plants are integrators of their total environment and that a complex of interacting physical factors such as nutrient availability, soil moisture, temperature, and light primarily determines their distribution (Daubenmire 1967,1968, Oosting 1956). When the availability of one of these basic requirements is changed over a long enough period of time, it is reflected by corresponding changes in plant species composition and production. Animals, in turn, are dependent upon vegetative communities and adjust their utilization patterns and behavior to maximize their use of preferred plant species and assemblages.

Any long-term major changes in the water regime that may be produced by mining activities should result in measurable changes in the biotic characteristics of the wetland and riparian habitats. A quantification of the biotic parameters allows for a more meaningful assessment of the significance of dewatering effects by translating them into ecological and land management terms. e.g. Reductions in vegetative production will reduce carrying capacity for livestock and big game, and changes in plant species composition and diversity may reduce the suitability of these habitats to small mammals and birds.

The initial plan was amended and improved by input from a Wetlands Evaluation Committee (WEC) that was formed by GMMV in an attempt to incorporate the best thinking of all resource management agencies that had interests in the Green Mountain area. The committee was made up of representatives from the Wyoming Department of Environmental Quality (WDEQ), Wyoming Game and Fish Department (WGFD), the Army Corps of Engineers (ACOE), BLM, GMMV and HWA. The plan presented in this paper represents the base plan prepared by HWA as modified by the WEC.

The long-term monitoring program is intended to demonstrate whether or not changes to existing riparian communities (wetlands) occur during the mining operation, and to quantify and describe the nature of such changes if they occur. Under this program, measurements of existing wildlife and vegetation characteristics were made within selected riparian areas in drainages on both the north and south sides of Green Mountain. In addition, control sites were selected within comparable riparian areas in drainages of Whiskey Peak. The remeasurement of the same biological parameters on the same sample sites in future years during the course of mining, and following the completion of mining, will allow comparisons to pre-mining baseline conditions and the detection of changes.

Because of their hydrological isolation from Green Mountain, the control sites will be used to separate the effects of natural climatological variations on ground water hydrology from the possible draw-down effects on the Green Mountain water table that could result from the operation of the Jackpot Mine. Separating these effects will be essential to the analysis of causes for changes in characteristics of wetland vegetation and wildlife over time.

Surveys of big game utilization, breeding bird densities and richness, and small mammal species composition and density were conducted in 1996 as the first step in describing baseline biological conditions on Green Mountain and Whiskey Peak. The species composition and density of aquatic macroinvertebrates was surveyed in 1997, while vegetation work was initiated in 1997 and completed during 1998. Vegetation work consisted of measuring species composition, percent cover, frequency of occurrence, production, and community type boundaries, both inside and outside of fenced exclosures. The purpose of these initial measurements is to establish an environmental baseline from which to measure future changes in wetland characteristics and function. Any documented changes could provide a basis for assessing the effects of watertable draw-down, if one should occur, and give insights into what remedial actions might be appropriate.

Ten drainages were selected on Green Mountain for the collection of baseline and subsequent monitoring data, and six sites were selected on Whiskey Peak to serve as control sites. Of the ten drainages selected for placement of study sites, four were located on the south toe slopes of Green Mountain and six on the north slopes. The extensive wetlands survey and inventory completed in 1992 was used as the basis for the initial selection of drainages to be monitored (HWA/EEC 1992). Each drainage was reviewed again in 1996 and specific locations selected for the placement of vegetation study sites. Because no previous wetland survey had been conducted on Whisky Peak, a helicopter survey of each drainage was conducted in 1996 to search for suitable sample sites. Selection criteria included: similarities in slope, elevation, aspect, and community type to previously selected sites on Green Mountain. Three of these sites were located on the north slopes and three on the south slopes.

Twenty one shallow wells were drilled between 1990 and 1998 for the purpose of measuring changes in piezometric levels of ground water on Green Mountain and Whiskey Peak over time. The 15 wells located on Green Mountain vary in depth from 30 to 60 feet. The six wells located on Whisky Peak are all 20 feet in depth. One well was placed at each of the 16 wetland study sites so that changes in water levels over time can be compared to any changes in biotic parameters. Ground water measurements at some of these wells and other wells located in the area of the declines have been underway since 1990 in order to establish baseline ground water conditions. Measurements are taken monthly during the entire year. Based on current monitoring schedules, when or if three successive monthly measurements show a deviation of five feet or more from the mean water levels recorded during the base line monitoring, specific investigative activities will be initiated to identify the cause, and the WDEQ will be notified (BLM 1995). Depending on the nature and extent of the ground water reduction at a given site or sites, WDEQ could initiate the resampling of biotic parameters to determine whether or not significant changes from baseline conditions have occurred.

Specific Procedures

Breeding Bird Surveys

Breeding bird surveys were conducted in June, 1996 along transects that were placed parallel to and within the riparian zones of the 16 sample drainages on Green Mountain and Whiskey Peak. Biologists slowly traversed the medial line of transects and stopped for several minutes every 100 meters to record the numbers and species of birds seen or heard within the riparian zone. Surveys were conducted from sunrise until approximately 10:00 a.m., depending upon weather conditions and singing intensity of breeding birds. Locations along the transects where birds were seen or heard were recorded on enlarged USGS 1:24000 topographic maps. Transect width was usually equal to the width of the riparian zone being surveyed, but was never more than 100 m wide. Transect widths were never less than 20 m, and extended to the 100-m maximum in only three places along portions of riparian areas that consisted of large wet meadows.

In order to make bird density estimates as accurate and representative as possible, line transects were extended to cover contiguous wetlands within the entirety of sample drainages. Because the length of contiguous wetland habitats within the individual drainages varied considerably, lengths of transects varied correspondingly (925 to 2,469 m). Most transects (14) were longer than the 1,000 m recommended by Emlen (1971), but riparian zones along two of the Whiskey Peak drainages were shorter than average (925 and 965 m respectively). With the exception of not limiting transect length to 1 km, survey methodology was in accordance with Emlen (1971).

Numbers of birds and densities for each species were calculated and listed as the number of birds per transect and as the number of birds per kilometer of transect. Species richness is expressed as the number of species per transect and per kilometer of transect.

Wild Ungulate Dropping Surveys

Wild ungulate pellet group/dropping surveys were performed from June 10th to the 25th, 1996 along the same drainage segments in which breeding bird surveys were conducted. Transects were 1.8 m in width and placed parallel to the drainage. Within the riparian zone of each drainage a biologist slowly walked a transect that bisected the zone. Because the width of the zone varied, the distance of the transect from either the bottom of the drainage (if dry) or the water's edge, varied from 1.8-4.6 m. Winter pellet groups (groups deposited during the previous fall, winter, and early spring) were recorded for deer, elk, moose, and pronghorn. Winter fecal deposits or piles of wild horses were also documented. Pellet group/pile densities for each species were calculated and are expressed as the total number of groups/piles per transect and as densities (the number of groups/piles per kilometer for each transect).

Small Mammal Trapping

Small mammal trapping was conducted in July and August, 1996 along the same drainages on Green Mountain and Whiskey Peak in which breeding bird and big game surveys were conducted. From 25 to 27 trap stations were established within the riparian zone of each of the 16 drainages. At each trap station one Sherman live trap, one snap-type rat trap, and two snap-type mouse traps were set. Trap stations were spaced at least 15 m apart and each trap was placed where the potential for capture was greatest and damage from livestock minimal. In addition, five pitfall traps (1.10 kg-coffee cans filled with 7.6 cm of water) were placed at locations along the transect where capture was thought to be likely (i.e.; within runs, vegetation tunnels, and natural micro-topographic funnels). Finally, several mouse traps were placed on each transect and baited with bacon to increase the chances for a good representation of carnivorous small mammals in the catch.

Sherman live traps were baited with a mixture of pinched oats, barley, wheat, and corn that was coated with melted pig fat. Mouse and rat traps were baited with peanut butter. Traps were checked and reset twice a day, in the morning and evening, for four consecutive days. Animals captured in live traps were killed to avoid recapture. Animals that could not be positively identified in the field were bagged, frozen, and later identified in the laboratory (all voles and shrews, except for water shrews, were identified in the laboratory). The number of trap nights per transect varied from 404 to 456. Numbers of mammals caught and densities for each species were calculated and listed as the number of mammals per transect and as the number of mammals per 100 trap nights. Trapping methodology was in accordance with the WDEQ (1990).

Aquatic Macroinvertebrates

Aquatic macroinvertebrates were sampled twice during 1997 (early June and early September) in the streams and ponds of 13 of the 16 drainages selected for study. Sampling was performed during two different periods because of the seasonality of some aquatic macroinvertebrates (Hawkins and Sedell 1981). Aquatic macroinvertebrates were not sampled on three of the drainages because not enough open water was present.

A "D" net sampler with a 500-micron mesh screen was used for sampling within each drainage. A modified "ten-kick" sample (Plafkin et al. 1989, Klemm et al. 1990) was taken along each drainage near and within the fenced-exclosure location. At ten different locations along the stream or pond (beginning downstream and progressing upstream) the "D" net was used to sweep through either the stream or, in several cases, the aquatic vegetation, for about two to three feet. The net was also placed downstream from rocks that were washed by hand in the stream, two to three feet in front of the net, allowing the current to take invertebrates into the net. The contents of the entire ten-kick sample were then rinsed into a two-gallon white tray using clean tap-water. Small portions of the sample were then poured into another white tray and the invertebrates were picked out by hand. This process was repeated until all of the macroinvertebrates from the entire sample had been removed. Macroinvertebrates were then placed into jars of 70% alcohol for preservation and subsequent identification.

In order to capture the maximum number of invertebrate taxa within the sample, the "kicks" of the "ten-kick" sample were not spaced at regular intervals, but were distributed within the stream so as to represent the variety of stream habitats present (i.e. pools, runs, riffles, rocks, submerged vegetation, overhanging banks, etc.

Vegetation

A site within each of the 16 drainages designated for study was selected for vegetation sampling. Each site was typical of the riparian/wetland vegetation of the drainage and was large enough to allow the placement of a 0.2 ha livestock exclosure. The rationale for fencing the monitoring sites was to exclude them from livestock grazing and thereby separate the effects of potential water table draw-down from those of livestock grazing. Fencing of the monitoring sites commenced in 1996 and was completed in 1997.

Livestock Exclosures. The exclosures were constructed of log bucks that were 15.2 cm in diameter and rails that were 10.2 cm in diameter and no more than 4.9 m long. In order to facilitate access by deer, elk and moose, the height of the top rail was only 106.7 cm above the ground. Clearance between the ground and bottom rail was 45.7 cm to allow passage of pronghorn. The corners and other likely stress areas were reinforced. Exclosure shape varied somewhat, depending on the ruggedness of the terrain and the width of the riparian zone.

Characteristics of the wetland vegetation, both inside and outside of the fenced exclosures, were sampled and described and included: (1) boundary locations between wetland vegetation zones, (2) ground cover and species composition, and (3) biomass production. Outside of the exclosures, 0.2-ha riparian sites that most closely duplicated or resembled the vegetation inside the exclosures were selected for comparative sampling. Sometimes the outside area selected for sampling was upstream from the exclosure fence and sometimes downstream. In either case, sampling procedures applied outside of the exclosure were identical to those used inside.

Delineation of Wetland Vegetation Type Boundaries. Wetlands vegetation on the study area generally shows a distinct stratification or zonation that is directly related to the degree and duration of soil moisture present. Such zonation is typical of wetlands in general, and mountain wetlands in particular. As illustrated in Figure 2, and described by Hayden-Wing (1979) and Wing (1969) for mountain meadows in Idaho, this zonation includes an inner, low-lying central hydric core that maintains water-saturated soils through all or most of the growing season. The hydric core is dominated by sedges, rushes, and horsetails, with a variety of hydrophillic species of forbs, grasses, and shrubs. A second wetland zone occurs adjacent to and slightly higher in elevation than the central hydric core and exhibits moist soils that are better drained and not as water saturated as the core zone. This area is referred to as the mesic zone in our study and is characterized by nearly equal dominance of mesic forbs and grasses with a variety of sedges, rushes, and horsetails present. The third zone described by Hayden-Wing (1979) and Wing (1969) is the dry zone and does not support wetland/riparian vegetation (Figure 2). The upslope boundary between the mesic zone and the adjacent well-drained upland sage or conifer vegetation type is usually abrupt or discrete, but is sometimes indistinct and grades gradually into the next type (Figure 2). In our study, the hydric zone typically occurs at the water's edge while the mesic zone generally occurs above the hydric area and below the adjacent, dry upland zone. In our study, the riparian vegetation usually included a representation of both the hydric and mesic zones, which were the only vegetative zones surveyed.

The aerial extent and boundaries of wetland vegetation zones were measured along permanent line transects that were perpendicular to, and extending entirely across, the riparian area. Ten transects were placed both inside and outside the exclosure fence. Steel stakes were driven into the earth at the ends of each transect to discourage removal by occasional visitors. A steel tape was stretched between the end stakes of each transect and the width and position of each vegetation zone along the tape was documented to the nearest 0.03048 m.

Exclosures were large enough to accommodate ten transects within the fenced area. The ten transects outside the fenced exclosures were placed in areas of comparable riparian vegetation located as close as possible to the exclosure. Transects were randomly selected from predetermined strata that intersected the creek or drainage at right angles.

Ground Cover and Species Composition. Percent ground cover was estimated for each plant species, bare ground, and litter on rectangular 1/10 m^2 plot frames (Daubenmire 1959) along 6 of the ten transects inside each exclosure. One frame sample was taken in each vegetation zone (hydric and mesic), at the midpoint of the zone width, on each of the six transects within the exclosure. Sampling alternated back-and-forth from one side of the drainage to the other so that both sides were represented. Sampling procedures outside the fenced exclosures were identical.

Total vegetative ground cover was calculated for the hydric and mesic vegetation zones for each site by averaging the values of all of the plots on the site. Individual plot totals were calculated by summing the cover estimates for all plant species that occurred within the fame sample. The mean total vegetative cover was calculated for all monitoring sites, all control sites, and all sites combined.

Production. A measurement of vegetation biomass production was obtained by clipping square-meter plots within the hydric and mesic vegetation zones on each study site with one plot in each zone, both inside and outside the exclosure fence. Clipping was done during the late summer, following the cessation of most vegetative growth. Each plot was placed within an area typical of the vegetation zone that was large enough to accommodate the square-shaped frame. All plants within the frame were clipped at ground level and placed in brown paper bags for transporting. Clipped samples were dried to a constant weight in large drying kilns of the Department of Agriculture at the University of Wyoming and weights recorded to the nearest 0.10 gram. Data were summarized by site and two-sample T-Tests were performed for site comparisons to test for a significantly greater production of standing biomass within the exclosures as compared to the same vegetation zone outside the exclosure fences.

Permanent Photographic Record. Permanent photographic points were established at each exclosure site to provide a long-term photographic record of future physiognomic and compositional changes in vegetation. At each exclosure site, a series of photographs was taken from a variety of points (fence corners, transect stakes, and drainage bottoms) in order to cover the site adequately enough to produce a complete and accurate photographic record. All photographic methodology was

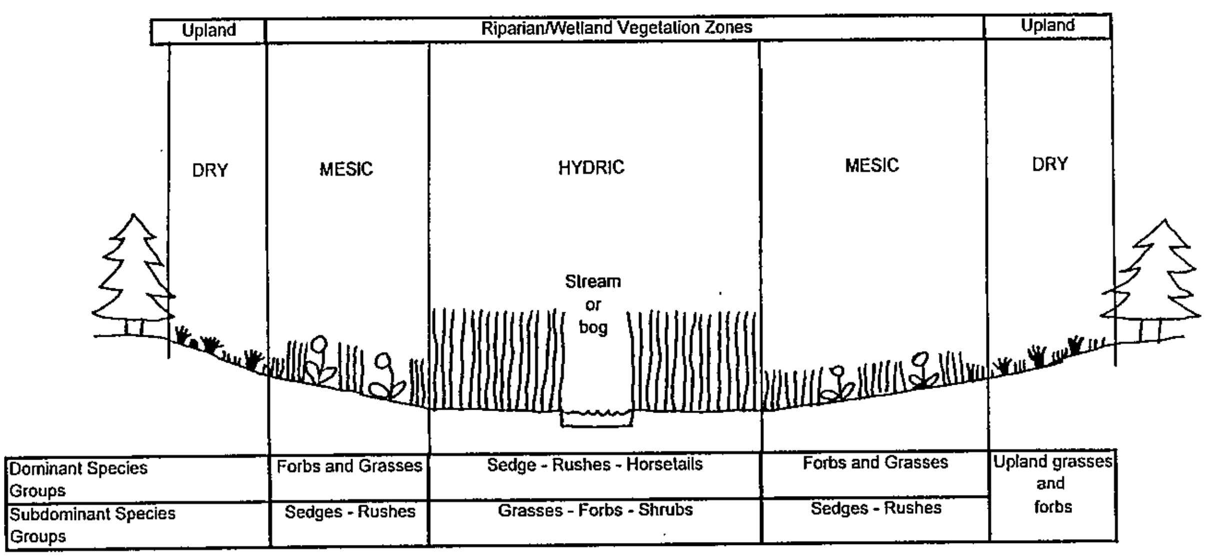

Figure 2. Typical cross-sectional profile of vegetation zones along the 16 drainages that were studied on Green Mountain and Whiskey Peak (modification of Wing 1969).

standardized and each point and angle was described and recorded so that comparison photographs can be made in the future.

Climatological Data

Regional measurements of precipitation, temperatures, humidity, wind speed, and barometric pressure from weather stations located on Green Mountain and at Muddy Gap, Jeffrey City, and Bairoil will be used to evaluate the effects of weather patterns on ground water levels. Because Green Mountain and Whiskey Peak are exposed to identical weather conditions, it will be possible to determine whether or not changes is ground water levels are due to changes in precipitation levels, or to mining effects. Changes due to weather would affect both Green Mountain and Whiskey Peak while changes due to mining would affect only Green Mountain.

Analysis and Evaluation of Potential Mining Affects

Subsequent remeasurements of the parameters outlined in this paper would utilize the same procedures employed in the collection of baseline data. The two data sets would then be subjected to statistical analysis in order to determine whether or not significant differences occurred in vegetative cover and production, densities of small mammals, birds, aquatic macroinvertebrates, and big game winter droppings. Analysis and evaluation would be performed within-mountain; that is, baseline data on Green Mountain would be tested against subsequent data collected on Green Mountain for each of the sample drainages and for the overall mountain. Standard t-tests would be employed to test the significance of differences. The same comparisons would be performed on the Whiskey Peak data sets. For the Jackpot Mine, methodology is now in place to detect changes in the characteristics of wetland biota resulting from the operation of the mine and to assess the value or impact of such changes.

Literature Cited

Bureau of Land Management (BLM). 1995. Final Jackpot Mine Project Environmental Impact Statement. BLM/WY/PL-96/004+1990. 76 pp. + public comments.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Sci. 33:43-66.

Daubenmire, R. 1967. Plants and environment - a textbook of plant autecology. John Wiley & Sons. New York. 422 pp.

Daubenmire, R. 1968. Plant communities - a textbook of plant synecology. Harper & Row. New York. 300 pp.

Dern, G. 1989. Wildlife. Appendix D-9 of Green Mountain Mining Venture's mine permit application to the Wyoming Department of Environmental Quality for the Jackpot Mine. 16pp + 2 fig.

Emlen, J.T. 1971. Estimating breeding season bird densities from transect counts. Auk 94:455-468.

Hawkins, C. P. And J. R. Sedell. 1981. Longitudinal and seasonal changes in functional organization of macroinvertebate communities in Cascade Range streams of Oregon. Ecology 63:1840-1856.
https://doi.org/10.2307/1940125

Hayden-Wing, L.D. 1979. Elk use of mountain meadows in the Idaho Primitive Area. Pp. 40-46 *in* M.S. Boyce and L.D. Hayden-Wing (eds.), Proceeding of National Elk Symposium, University of Wyoming, Laramie.

Hayden-Wing Associates (HWA). 1994. Riparian habitat enhancement and monitoring plan and potential riparian (wetland) enhancement sites and possibilities for Green Mountain Mining Venture's Jackpot Mine. Unpublished report. Hayden-Wing Associates, Laramie, WY. 21pp + 7 fig.

Hayden-Wing Associates and Ecotone Environmental Consulting (HWA/ECC). 1992. Jurisdictional wetlands delineation and wildlife habitat wetland habitat analysis for the Green Mountain Area. Unpublished report. Hayden-Wing Associates, Laramie, WY. 222pp + 15 appendices and 4 maps.

Hill, J.G. and D.R. Price. 1983. The impacts of deep mining on an overlying aquifer in western Pennsylvania. Ground Water Monitoring Review, Vol. 3(1):138-143.
https://doi.org/10.1111/j.1745-6592.1983.tb00875.x

Hobba, W.A., Jr. 1993. Effects of underground mining and mine collapse on the hydrology of selected basins in West Virginia. U.S. Geological Survey Water-Supply Paper 2384. U.S. Govmt. Printing Office. 79 pp.

Kendorski, F.S. 1993. Effect of high-extraction coal mining on surface and ground waters. Pp. 412-425 *in* S.S. Peng (Ed), Proceeding, 12th Int.

Conference on Ground Control in Mining, West Virginia University, Morgantown, WV.

Klemm, D.J., P.A.Lewis, F. Fuldk, and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. EPA/600/4-90/030. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Cincinnati, OH.

McCulloch, C.M. and J.P. Nairn. 1996. Determining the impacts from mining on surface and ground water. Mining Engineering. Jan. 1996:57-60.

Oosting, H.J. 1956. The study of plant communities. W.H. Freeman. San Francisco. 440 pp.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish. EPA/440/4-89-001. U.S. Environmental Protection Agency, Assessment and Watershed Division, Washington, D.C.

Sheaffer, K.K. 1979. The impact of surface mining on the hydrologic environment of the Big Sandy Creek Watershed, Fayette County, Pennsylvania. Pp 91-98 *in* D.E. Samuel, J.R. Stauffer, C.H. Hocutt, and W.T. Mason, Jr. (Eds), Addendum to Proceedings of a Symposium on surface mining and fish/wildlife needs in the eastern United States, Morgantown, West Virginia. FWS/OBS-78/81 A.

U.S. Energy Corp. 1994. Mine plan. Vol. 1a of permit application to the Wyoming Department of Environmental Quality/Land Quality Division for the Jackpot Mine, Fremont County, Wyoming.

Williams, R.E., G.V. Winter, G.L. Bloomsburg, and D.R. Ralston. 1986. Mine hydrology: Society of Mining Engineers Inc., 169 pp.

Wing, L.D. 1969. Ecology and herbivore use of five mountain meadows in the Idaho Primitive Area. Ph.D. Thesis, University of Idaho, Moscow. 215pp.

Wyoming Department of Environmental Quality (WDEQ). 1990. Guideline Number 5 (Wildlife). Wyoming Department of Environmental Quality, Division of Land Quality, Cheyenne, Wyoming. 12pp.