Committee on Resources

Statement

Environmental Effects of Mining in the Anthracite Region:

Problems and Possible Solutions

Presented to the US House of Representatives Committee on Resources

Kenneth M. Klemow, Ph.D. Certified Senior Ecologist and Botanist

Wilkes University, Wilkes-Barre, PA 18766

Phone: 570-408-4758. FAX: 570-408-7862, e-mail: kklemow@wilkes.edu

19 January 1999

Summary

The extraction and processing of anthracite coal caused an enormous environmental impact to thousands of acres of terrestrial and aquatic habitat throughout northeastern and east-central Pennsylvania. Original terrestrial forests were destroyed by strip mining and the deposition of culm material. Due to those activities, thousands of acres are marred by steep slopes and coarse substrates characterized by low fertility, toxic levels of certain elements, extreme drought, and high summertime temperatures. Natural revegetation has proceeded slowly on mine-impacted sites, resulting in sparse communities of low-value scrubby species. Ecological productivity, biological diversity, and recreation values are substantially lower on mined sites than on forested unmined areas. Animal life is also impaired due to insufficient food and water, and to extreme physical conditions.

Anthracite mining has also damaged aquatic communities like streams and wetlands. Mining caused physical loss to stream channel habitat and created acid mine drainage (AMD). Mining often isolates headwater streams from lower reaches in the watershed, leading to losses of biological diversity and productivity. The loss of wetlands by mining exacerbates downstream flooding, degrades the capacity for natural water filtration, and reduces biological diversity among wetland-dependent species. Millions of gallons of AMD enters waterways throughout the region, causing concentrations of dissolved iron, aluminum, and sulfate to exceed the tolerances of aquatic species. That AMD flows into major rivers like the Susquehanna and Lackawanna, contributing thousands of pounds of iron per day that coats the bed and migrates toward the Chesapeake Bay.

Corrective measures can be taken to address the ecological damage of mining. The methodologies employed are improving thanks to new research findings. Terrestrial reclamation typically involves regrading and fertilizing the site, and adding a mix of plant seeds, usually of grasses and legumes. The result is a meadow-like community that prevents erosion and can be used as pasture. However, that approach may prevent the

formation of natural forests and may not be sustainable in the long run. A new reclamation paradigm may be needed to tailor restoration to the ultimate use of the site, and to encourage native woody species on those sites targeted for greenspace.

Mining-related damage to aquatic communities can also be corrected. Stream channels should be restored following newly developed ecological approaches that keep water on the surface, maximize biological diversity, and provide a continuous corridor connecting headwaters to major rivers. AMD can be ameliorated by use of passive approaches (wetlands, anoxic limestone drains) and by preventing its formation through stream channel restoration, reclamation of culm banks, and possibly injecting materials like fly ash into underground mine voids.

Solving the environmental problems of mining will require the collaboration of federal and state agency officials, scientists, and the private sector. Sufficient funding will be needed to pay for the expertise, labor, and materials needed to develop and execute a successful plan. The American Heritage River initiative should play a central role in coordinating the effort and securing funding.

Introduction

Over the past 150 years, large parts of northeastern and east-central Pennsylvania have been affected by mining for anthracite coal. Mining practices have profoundly influenced the economy, social structure, politics, physical landscape, and natural ecology of the affected regions. My testimony given in this essay will largely focus on the environmental impacts, including the effect on the landscape and ecological relationships. Economic and social impacts will be mentioned only briefly. Comments about restoration strategies and needs will be provided at the end.

Understanding the impacts of coal mining requires a general knowledge of the geologic history of eastern Pennsylvania. Virtually all of the bedrock of northeastern and east-central Pennsylvania originated 300-360 million years ago, when the state was covered by a huge sea. Fine rock particles settled and formed sedimentary deposits of sandstone and shale. However, certain areas were dominated by swamp forests. Individual plants did not decompose when they died, but instead they underwent a chemical change, forming vast coal deposits. Those deposits became buried by additional sedimentation, often forming alternating layers of coal and non-coal sedimentary rock. The coal forming process was most prevalent in certain parts of eastern Pennsylvania, forming four major coal fields separated by areas that lack anthracite.

Subsequently, a series of geologic events involving mountain formation, erosion, and glaciation produced the current ridge-and-valley topography of the region. Following the recession of the most recent glacier 12,000 years ago, eastern Pennsylvania became vegetated by a lush forest composed of evergreens like white pine and hemlock, and by hardwoods like oaks, chestnut, birch, maple, and ash. Beginning 250 years ago, the original forest was cleared for timber and agriculture by white settlers. Thousands of acres remain in agriculture or have become urbanized. However, large areas have reverted back to natural forest. Such lands are ecologically sound, supporting diverse, productive terrestrial and aquatic ecosystems. Our forests are valuable for recreation, timber management, and watershed uses.

The Mining Procedure and Its General Ecological Impacts

Vast areas of eastern Pennsylvania underlain by anthracite deposits were greatly influenced by the extraction and processing of coal during the past 150 years. The US Department of Agriculture lists approximately 51,000 acres (ca. 80 square miles) of soils as being mine-impacted in Luzerne and Lackawanna counties alone.

The successful removal of coal required that it be extracted from intervening layers of sandstone and shale. Historically, two methods were used to extract coal: underground mining and strip (surface) mining. Underground mining typically followed seams of coal downward, producing vertical shafts and horizontally arranged tunnels that often extended for miles. In contrast, strip mining involved the use of large shovels and draglines to physically remove the overburden, thus exposing the coal seams. Once removed, the raw coal was separated from energy-poor "culm" material having high concentrations of silica, iron, and sulfur.

Regardless of the extraction method, anthracite mining has had huge environmental effects that can be classified in several ways. First, one can distinguish between aboveground and belowground effects. Second, mining caused physical damage to the landscape, as well as impacts to the original flora and fauna. Finally, the environmental effects can also be classified by effects on terrestrial vs aquatic ecosystems, though in many instances the former contributes to the latter.

Because most of the activity was well below the surface, the actual removal of coal by underground mining did not have much environmental effect. As will be noted later, however, it did produce secondary effects, especially to water quality. In contrast, strip mining has had a profound impact on the local terrain because of the creation of huge depressions (stripping pits), nearly vertical highwalls, and high mounds of accumulated overburden material.

Whether removed by underground or strip mining, purifying the anthracite created additional impacts on the landscape. One type of impact involved the creation of mounds of coal waste in the form of culm banks (also called gob or bony). Such banks typically contain rock fragments often 0.5-2' in diameter that are rich in carbon, iron, and sulfur. Some of the larger banks are 200' high and occupy hundreds of acres.

Preparation of coal for market also involved washing, breaking, and sorting coal pieces of various sizes. That process resulted in the creation of small coal fragments, often less than 0.5" in diameter, having low commercial value. Those fine coal fragments were separated from the larger, more valuable pieces of coal by settling, creating deposits of "mine wash" that were allowed to develop in sedimentation basins. Mine wash was often removed from the basins and spread over adjoining areas. In other instances, mine wash particles were carried downstream as wash water was released from impoundments.

Thus, the mining process left a significant percentage of northeastern Pennsylvania covered by gaping pits, huge mounds of coarse material, and sterile deposits of mine wash. The mining process created profound disruptions to the natural ecosystems in which they occurred. As noted, the ecological effects have both terrestrial and aquatic components.

Effects of Mining on Terrestrial Ecosystems

Anthracite mining has devastated tens of thousands of acres of terrestrial ecosystems in eastern Pennsylvania. Strip mining especially caused the removal of the original vegetation and all soils on the site. The result was a barren landscape covered by a coarse substrate, often with steep slopes. In some cases, those culm banks caught fire, producing even more hazardous and stressful conditions. Unlike unmined sites that can recover relatively quickly after clearing, revegetation on strip mined sites occurs slowly. It is not uncommon to see 50-80 year old culm banks that are essentially barren.

A combination of physical and biological factors interact to restrict the rate of natural revegetation on abandoned anthracite mines. Severe substrate conditions are perhaps the greatest problem, on both burned and unburned areas. Studies conducted over the past several decades have documented that sites underlain by culm, ash, and mine-wash have low concentrations of important nutrients like nitrate, phosphate, calcium, and potassium. Moreover, they often have toxic levels of iron and aluminum. The coarse substrate on culm banks does not retain water, resulting in drought-prone conditions that often rival the most severe deserts on the planet. The black substrate also absorbs solar energy and converts it to heat, resulting in summertime surface temperatures that exceed 150°F.

A variety on biological factors also limit revegetation on mined sites, and these act in subtle ways that are still being discovered by ongoing research. Certainly, fresh culm and mine-wash lack seeds or rootstocks that would serve as a source of new plants. Instead, vegetation development must depend on the fortuitous immigration of seeds from plants growing off-site. In the case of large culm banks, the nearest source of seeds might be a quarter of a mile away. Moreover, those seeds must successfully germinate and produce established seedlings, which is difficult in the highly unfavorable thermal, chemical, and moisture environments of culm and mine wash.

Research conducted in the past several decades has shown that mine-derived soils lack a healthy population of soil microbes, including fungi, bacteria, and invertebrates. Plants on strip mines cannot form associations with certain soil fungi that normally serve as a feeder system for critical nutrients and water. Moreover, the lack of fungi and many types of bacteria and invertebrates prevent normal recycling of nutrients within the soil, further impairing fertility.

The vegetation that does develop on mined sites in eastern Pennsylvania is very different from that on unmined sites. Culm banks especially bear a mix of scrubby growth having much lower stature than more favorable off-mine sites. Mineland vegetation rarely exceeds thirty feet in height, in sharp contrast to maturing forests that often exceed 100'. Species composition is also rather distinctive in that the dominant woody species on mined sites include invasive species that have low commercial value like gray birch, black locust, and trembling aspen. More valuable oaks, maples, hickories, ashes, and hemlocks are rare on mined sites. The understory of mined sites is also rather poorly developed, being composed of prickly shrubs like tall blackberry and multiflora rose, as well as weedy, alien herbs like spotted knapweed, switchgrass, and white sweet clover.

Functionally, the vegetation that develops on mined sites has several characteristics that are indicative of an unhealthy system. First, the level of species diversity is lower than that of unmined sites, making mineland vegetation relatively unstable. Second, the vegetation has low level of productivity, measured by the relative inability to capture energy and pass it to higher trophic levels. Third, the vegetation is composed of species that cannot generally reproduce in its own shade, and thus may not be sustainable. Fourth, the stressful physical conditions on mined sites make the component species more susceptible to disease. For example, trembling aspen trees on stressful sites are often damaged by hypoxylon canker while those on unstressed sites resist that fungal disease. Finally, mineland woods do not provide much soil stabilization, oxygen production, or water purification, which are important functions normally associated with natural forested ecosystems.

Animal populations, including both game and non-game species, are also severely restricted on mined sites. The scrubby vegetation characterized by high densities of prickly shrubs, confers poor habitat for species normally accustomed to shaded or grassland conditions in Pennsylvania. Also, the lack of moisture and extreme thermal conditions excludes most species except for a few snakes, spiders, and tolerant insect species. Mine-land vegetation is often unpalatable and has relatively low nutritive value for grazing animals.

Effects of Mining on Aquatic Ecosystems

Mining has had a profound impact on aquatic ecosystems like wetlands, creeks, and lakes of northeastern Pennsylvania. Such ecosystems are extremely valuable from both ecological and recreational perspectives. Communities that develop in aquatic ecosystems are typically composed of microscopic species, larger invertebrates like caddisflies and stoneflies, and vertebrates like fish and amphibians. Those organisms interact in complex ways, and play crucial roles in nutrient turnover and energy processing. An important property of aquatic ecosystems is that they are interconnected by the flow of water downstream. Thus, energy and nutrients received by small creeks and wetlands high in the watershed are often used by populations of commercially important finfish and shellfish in downstream rivers and estuaries.

Effects of mining on aquatic resources are both physical and chemical in nature. Most of earthmoving activities of mining occurred well before the enactment of laws designed to protect aquatic resources - particularly the 1977 Federal Water Pollution Control Act. Strip mining and the deposition of culm material occurred without any regard to wetlands, watercourses, and other waterbodies. Thus, miles of stream channel habitat and many hundreds of acres of wetland in the anthracite areas have been destroyed by indiscriminate digging and filling. One prime example of such destruction can be seen in the Nanticoke Creek corridor in central Luzerne County. There, the normal course of water that drains the unmined upper slopes of Wilkes-Barre Mountain is blocked by a huge culm bank complex near Warrior Run. As a result, the headwaters of Nanticoke Creek are completely isolated from the lower reaches of that creek, and ultimately the Susquehanna River. Results from preliminary studies indicate that biological diversity and food chain support are lower than expected in the Nanticoke Creek headwaters, compared to similar creeks that are directly connected to lower reaches of their watershed.

In many places where streams flow through mine impacted areas, the fractured bedrock allows surface streamflow to seep underground. That loss of water is directly opposite to the typical gain in flow as one proceeds to lower positions in watersheds not impacted by mining. As will be noted shortly, that "lost" water is only temporarily hidden from view. Instead, the water resurfaces further down the watershed, often in a highly contaminated form.

Even if not completely obliterated, stream channels are often altered and degraded on mined sites. Studies of stream channel morphology on mined sites show that creeks there have unusually steep banks composed of unstable material. That morphology is highly unfavorable during floods because it causes unacceptably high levels of erosion, and because it often exacerbates downstream flooding. Siltation of creeks lower in the watershed is especially problematic because many valuable stream invertebrate species cannot tolerate sediment deposition.

The loss of wetlands in mined areas is another source of concern. Wetlands have many environmental benefits and enjoy the protection of federal and state laws. Wetland soils are typically porous and absorb water during periods of heavy precipitation, therefore reducing the severity of downstream flooding. Wetlands also act as excellent natural water purifiers because they trap suspended sediments and remove dissolved pollutants like nitrates, phosphates, and heavy metals. Wetlands also provide habitat to plants and animals. In that context, wetlands serve as spawning and rearing sites for fish and amphibians, breeding locations for many birds, and locations for food chain support for dozens of mammal species. The loss of wetlands due to mining activities has led to dirtier water downstream, exacerbated flooding in some cases, and a regional loss of biological diversity and ecological productivity.

Concurrent with the loss of healthy aquatic habitat, mining has created two types of unproductive open-water conditions: stripping-pit pools and sedimentation lagoons. The former are bodies of open water that develop in strip mine operations, where the excavated pit intercepts the prevailing water table. These inadvertent, artificial lakes are characterized by steep walls and depths that exceed 30'. Aside from the inherent danger that they pose, stripping-pit pools have low ecological productivity because they are typically isolated from other aquatic habitats, and because their water often contains pollutants that cannot support life. Sedimentation lagoons are natural or artificial bodies of water that are found near old mining operations. They functioned as settling basins to clarify water used to wash coal. As a result, the substrate of such lagoons is composed of deposits of fine-grained mine-wash. Such deposits are infertile and often contain high concentrations of toxic elements. Therefore, sedimentation lagoons are typically lifeless, save a few very hardy species of low ecological value.

Perhaps the best known effect of mining on aquatic ecosystems comes in the form of acid mine drainage (AMD). AMD is characterized by the presence of inorganic elements like iron, manganese, aluminum, and sulfates that are carried by water discharging from culm banks or mine voids. The chemistry of AMD has been well studied, especially in the bituminous coal fields of western Pennsylvania and southern Appalachia. The AMD problem in the anthracite fields has received some attention between 1940 and 1985, but work done in the 1990s has both increased our understanding of the pattern of AMD effects and trends in water quality over the last 40 years.

AMD forms when water intercepts underground pyrite or aluminum-bearing deposits, and leaches harmful substances from those deposits. In some cases, AMD is generated when rainwater or snowmelt enters into culm banks, and dissolves the iron-rich coal waste material. In other cases, AMD forms when the water table contacts residual pyrite in underground mine workings, and then flows to the surface. AMD normally enters creeks in two ways. The first is in the form of seeps that often discharge from the bases of culm banks. Such seeps are rarely exceed 50 gallons per minute, but often contain high concentrations of dissolved metals and sulfates. The second is in the form of deep mine outfalls that often spew thousands of gallons of mine water per minute into receiving waterbodies. Such outfalls exist at the points of old mine shafts or ventilation holes, but some are actually boreholes that were intentionally excavated to relieve underground flooding. Some of the worst mine outfalls in the anthracite region include the Jeddo mine tunnel northwest of Hazleton, the old Newport Dump west of Nanticoke, the Solomon's Creek boreholes south of Wilkes-Barre, the Butler mine tunnel in Pittston, and the Old Forge discharge south of Scranton.

AMD impairs the ecological productivity in receiving waterbodies in several ways. First, the dissolved iron undergoes a series of chemical reactions that lead to the formation of insoluble iron hydroxide, which is really liquid rust. Iron hydroxide particles coagulate in the water, staining the water bright orange. Over time, those particles settle onto the creekbed forming deposits known as "yellow boy." The cloudy water and accumulated deposits create conditions harmful to all forms of aquatic life. Indeed, studies recently done in the southern Wyoming Valley indicate that AMD-impacted streams are completely devoid of invertebrates and fish life. In the middle and southern anthracite fields, dissolved aluminum and low pH conditions typify the AMD problems. Dissolved aluminum presents a problem to aquatic animals because it collects on gills, thus rendering them incapable of gas exchange. Low pH levels, indicative of high acidity loads, also impair the functioning of all forms of life because they disrupt normal cellular metabolism.

Because it enters into creeks and streams, AMD is normally carried downstream to receiving rivers, thus impairing their function. In the northern anthracite field of the Wyoming and Lackawanna Valleys, AMD is ultimately received by the Susquehanna and Lackawanna Rivers. The effect of AMD on the Susquehanna-Lackawanna complex is really unknown and deserves intensive study. Spot analyses indicate that water quality in those rivers is at least impaired at points of entry and for some distance downstream. Indications of that impairment are obvious at the discharge of the Old Forge borehole into the Lackawanna River, the confluence of the Lackawanna and Susquehanna Rivers, and where Solomon's Creek, Nanticoke Creek, and Newport Creek all enter the Susquehanna. At those places, the riverbed is heavily stained by deposits of iron hydroxide. The nature of accumulation of those iron deposits, and their transport downriver are unknown and need further investigation. Moreover, the effects of mine drainage on invertebrates and fish in the river are also unknown. While numerous species of both types of aquatic life are found, biodiversity and productivity are probably both impaired to some degree by discharges of contaminated mine water from outfalls and creeks that receive AMD.

Remedying the Ecological Effects of Mining

As with most problems, the environmental degradation caused by mining can be rectified. One can classify such remedies by whether they fix terrestrial vs aquatic ecosystems. Many approaches to fixing mining-related problems are based on straightforward methods that are decades old. However, novel approaches have been developed within the past twenty years, largely drawing from the new discipline of Restoration Ecology. Those new approaches have been used to a limited degree in remedying environmental problems within the anthracite region. Much more can be done to implement that new knowledge and to discover even better approaches in the future.

In terms of terrestrial ecosystems, successful restoration depends upon improving the physical environment and introducing plant stock to enhance the rate at which vegetation can develop. Improving the physical environment for plant growth typically involves regrading the disturbed landscape to eliminate highly erodable steep slopes, and improving the soil by the adding fertilizers and organic mulch. Plant stock is usually added by seeding the area with species tolerant of reclaimed mine sites, and able to form a dense vegetative cover quickly.

When they are implemented, mine reclamation practices generally follow the guidelines given in the 1977 Surface Mining Control and Reclamation Act (SMCRA). In essence, that legislation mandates that mine reclamation is accomplished when the mined site is regraded to a topographic contour that approximates the original conditions, and a dense cover of vegetation is established. Reclamation specialists satisfy the requirements of SMCRA by first bulldozing the disturbed area to a smooth contour having uniform grades. A fertilizer containing nitrogen, phosphorous, potassium and lime is then added. Finally, the area is seeded, typically by a grass-legume mix. Those practices usually create a meadow-like stand of vegetation that protects against erosion and can even by used as pastureland.

Because the environmental damage caused by mining in the anthracite region occurred long before the implementation of SMCRA, reclamation is mostly conducted by governmental agencies. The most active agency involved in mine reclamation is the Bureau of Abandoned Mine Reclamation (BAMR), of the Pennsylvania Department of Environmental Protection (PADEP). In the northern anthracite field, the Earth Conservancy (EC) is also engaged in reclamation efforts on its land holdings.

While the efforts to reclaim mine lands according the SMCRA guidelines do improve their ecological productivity, some concern has been expressed over the long-term effects of current reclamation practices. Specifically, the grass-legume mixture introduced as a vegetative cover is viewed as being artificial because it uses alien species not really belonging to the native flora of Pennsylvania. Also, the meadow-like vegetation may actually hamper the development of a forest community that is normal for eastern Pennsylvania. In short, reclaimed sites may remain in an arrested state of ecological development, and might not be sustainable over the course of decades. As an alternative, some restoration ecologists are calling for an alternate "smart" reclamation strategy that involves rough-grading the site, and introducing native species that will ultimately be consistent with the development of forest conditions. The feasibility of using that "smart" approach to reclaim abandoned mined sites in the anthracite region deserves to be explored.

Efforts to reclaim impaired aquatic habitats have also been conducted in the anthracite area, but the practices employed are evolving as new knowledge becomes available. Restoration of aquatic habitats is aimed at promoting healthy streams, lakes, and wetlands with high ecological productivity and biological diversity. To accomplish that goal, attention must be devoted to restoring the both the physical conditions and chemical makeup of local waterways.

Historically, addressing chemical contamination in the form of acid mine drainage often meant adding additional chemicals, such as lime or caustic soda. The aim was to neutralize the acidity and quickly precipitate the heavy metals. While generally effective, adding neutralizing chemicals to AMD can be costly and dangerous.

During the past fifteen years, passive approaches to addressing AMD have been developed. Such approaches involve technologies such as the use of constructed wetlands, anoxic limestone drains, and sequential alkalinity producing systems (SAPS). Often, those technologies are combined in a given project. The goal is to raise the level of alkalinity of the water and promote the oxidation and removal of heavy metals, particularly iron, manganese, and aluminum, in a controlled location.

One of the first AMD-treatment wetlands in the anthracite region was constructed by the Earth Conservancy in Hanover Township, Luzerne County. Completed in 1996, it treats a large seep that enters into Espy Run, a tributary of Nanticoke Creek. Based upon the success of that wetland, the EC constructed a 2.2 acre wetland to treat mine water discharging from the Dundee Outfall, 0.7 miles from the original wetland. That second wetland utilizes a novel water aeration system to promote iron oxidation, and began working in May 1999. Analyses of that system's performance indicate that it removes over 95% of the iron in the water, exceeding 300 lbs per day.

Further implementation of constructed wetland technology is possible. However, it should not be viewed as the total solution to the AMD problem, largely because not enough land is available for wetland construction. Instead, fixing the AMD problem will probably require the elimination of root causes of mine drainage. In one sense, the removal of culm banks and the implementation of sound reclamation techniques in terrestrial mine-impacted sites should reduce the infiltration of rainwater and snowmelt into pyrite-bearing rock strata. Second, mine voids can be filled with various materials like fly ash, as done in West Virginia. Filling mine voids reduces the flow of mine water from normal discharge points, but should be used with care, especially if done in populated or industrial areas.

A third, highly promising approach to eliminating the formation of AMD is to restore normal creekbed conditions in abandoned minelands. Because many creeks in minelands often lose water to underground mine pools making them impermeable to water loss is an attractive option. The idea of lining creekbeds with impermeable material is not entirely new. Indeed, coal companies often enclosed watercourses in flumes to prevent seepage into inactive mines. However, such structures often deteriorated and failed over time. The confinement of watercourses in smooth-walled flumes also prevents a productive aquatic community from forming.

Within the past ten years, new techniques have been developed to restore stream channels following ecologically sound principles. First, channels are constructed to mimic the horizontal morphology of natural watercourses, specifically by using a "channel within a channel" design. That morphology allows the channel to accommodate wide ranges of flow conditions from low volume baseflows to periodic floods. Second, the new designs provide for the development of pools and riffles that create the diversity of habitats needed by the array of invertebrates and vertebrates found in healthy aquatic ecosystems. Third, the materials used to form the bed and banks of newly restored stream channels are selected to mimic natural conditions and promote high levels of biological diversity. For example, new approaches abandon the use of conventional rip-rap and concrete in favor of "bioengineering" materials like layered shrubs and carefully oriented tree trunks. Finally, wooded buffer zones are placed along the sides of creeks because they provide both organic matter to feed aquatic invertebrates, as well as shade in reducing extreme summertime temperatures.

The result of a successful stream restoration effort has the dual benefit of keeping otherwise clean water on the surface, thus preventing the formation of AMD, and providing a biologically rich corridor that effectively links headwaters to lower reaches of the watershed. A well designed stream corridor also has recreational benefits for hiking, mountain biking, and horseback riding.

To date, a ecological stream restoration effort has been conducted near Hazleton by BAMR. A proposal to develop an even more comprehensive restoration effort along the Nanticoke Creek headwaters in central Luzerne County has been submitted by the US Army Corps of Engineers. Clearly, however, many miles of degraded streams and other aquatic habitats exist in the anthracite region, and deserve to be restored.

Conclusions and Recommendations

Two centuries of anthracite mining have severely degraded the ecological conditions in large portions of eastern Pennsylvania. Most of the impact has been to terrestrial ecosystems, in that the excavation of stripping pits and the deposition of culm banks have converted an otherwise healthy forest ecosystem into a barren landscape, vegetated by a sparse scrubland of low-value, often non-native, species. The region's aquatic resources in the form of streams, lakes, and wetlands, have also been greatly degraded by mining. Some of the destruction has been in the form of losses to original bodies of water. Other degradation is in the form of the discharge of millions of gallons of acid mine drainage each day into local creeks, and ultimately into major waterbodies like the Susquehanna and Lackawanna Rivers. As a result, the creeks are biologically dead, and the Susquehanna-Lackawanna complex shows impairment. The mining problems are interconnected in that AMD is caused by precipitation infiltrating through culm banks, by losses of streamflow in regions of degraded watercourses, and by the contact of groundwater with residual pyrite deposits in underground mine voids.

Aside from inherent losses to biological productivity and biodiversity, the damage inflicted by past mining has both sociopolitical and economic liabilities. Mined sites are viewed as being wastelands, and their drab dark-gray appearance contributes to a general feeling of despair and negativity felt by many residents. The presence of culm banks, huge stripping pits, and streams colored orange by mine drainage detracts from a sense of community pride and a land ethic. Indeed, as a building with a broken window invites further vandalism, mine lands often receive the brunt of illegal dumping by local residents.

In economic terms, abandoned mine lands have direct costs in that they are unproductive for agriculture and often unsuitable for residential or commercial development. Thus, they have inherently low property values, and usually generate far less tax revenue than unmined sites. Far more insidious is that fact that corporate officials looking to relocate companies in the anthracite region are often deterred by the residual environmental destruction. As a result, economic development within the region has seriously lagged behind that of other areas of the country.

Clearly, a large-scale initiative is needed to restore abandoned minelands. Since the problems took decades to create, they will not be solved overnight. Nor will the solutions be cheap, because the impact is dispersed over hundreds of square miles, and restoration will involve moving millions of tons of materials to regrade culm banks and fill stripping pits. Also, amending the soil to make it suitable for plant growth, adding appropriate plant stock, and restoring degraded stream channels will require enormous expenditures in terms of manpower, equipment, and materials.

Restoring the anthracite fields must be done in a way that maximizes the long term sustainability of the effort. In some cases, that will require abandoning current approaches, and adopting "smart" reclamation techniques that take the ultimate use of the site into account. For example, a site that is likely to be reclaimed for industrial development should not be treated the same way as a site intended for open space. Smart reclamation techniques will require thoughtful planning, ideally linking new Geographical Information System technologies with careful analysis of in-field conditions.

The American Heritage River initiative and associated Anthracite Task Force are ideal entities in which the current piecemeal approach can be organized into a well conceived, integrated strategy for successful, sustainable ecological reclamation. Clearly, no single organization or governmental agency can heal the environmental devastation caused by mining. Instead, an adequately funded, well conceived, integrated effort involving federal and state agencies, local scientists, the private sector, and existing and new non-profit organizations must be initiated to really fix the problem for the betterment of the region, the state, and the nation.

# # #