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Environmental Research Series
Land Reclamation Research

U.S. Department of Energy
Assistant Secretary for Environment

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Water harvesting

Arid mine land reclamation

Plant breeding

Water quality

Oil shale land reclamation

Water quality

Revegetation

Prime farmland reclamation

As the United States moves toward its goal of energy independence, the need to use more of the country's vast coal resources becomes clearer. Coal, the most abundant fossil fuel, can be burned as it comes from the ground or converted into liquids and gases called synthetic fuels. The mining of coal, especially from near the surface, can produce unwanted environmental consequences.

The United States Department of Energy (DOE) has assigned its Office of Environment (EV) the task of developing methods that will prevent or reduce damages caused by surface mining. Before that task can be accomplished, more must be learned about the functioning of organisms and their surroundings—the ecosystems threatened by disruptions from surface mining. While new federal and state laws require the full reclamation of mine sites, there is no assurance now that reclaimed areas can be self-sustaining, especially in the arid and semiarid West.

To these ends, the Ecological Research Division within the Office of Health and Environmental Research of the Department's Office of Environment has begun a number of related programs. They are aimed at understanding more clearly soils, plants, animals, and other components of the ecosystem so that ways may be found to improve environmental quality or to prevent damage from mining. Another aim is to produce efficient and cost-effective techniques for returning to productive use land that has been scarred by mining.

Two national laboratories and six universities carry out these research programs. The work extends from broadly based studies, such as the effects of mining on the hydrologic balance, to very specific studies, such as evaluation of the reproductive cycle of a native grass. The research supports DOE/EV Reclamation Research Plan which is committed to maintaining environmental quality while meeting energy production goals.

The following pages describe each project and its goals. Although short-term research may identify major problems, it must be remembered that longer-term investigations must be initiated to obtain solutions.

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Maintaining a quality environment while meeting the nation's energy demands is the major goal of DOE reclamation research.

Argonne National Laboratory's Land Reclamation Program is designed to solve the wide range of problems associated with the surface mining of coal. Basic and applied studies seek efficient and cost-effective methods for reclaiming land and ways for passing on that information to government and industry as well as to the environmental community.

Each project is conducted by a team that includes engineers, geologists, ecologists, hydrologists, soil scientists, agronomists, and land-use specialists. These scientists are based at Argonne, near Chicago. Additional Program research is carried out by scientists at 10 universities throughout the country.

The Land Reclamation Program has set up research projects at one abandoned and four active coal mines. Research costs are shared by coal companies at the active mines in Alabama, Illinois, New Mexico, and Wyoming. The State of Illinois and DOE have jointly sponsored research at the abandoned coal mine in southern Illinois.

These project sites were chosen carefully so that the most serious environmental issues related to surface mining were attacked first. These issues include:

Reestablishment of stable ecosystems on arid western lands.

Preservation of water quality and conservation of water in the West.

Restoration of prime farmland to pre-mining productivity levels.

Disposal of mining wastes in an environmentally acceptable way.

Discovery of the best techniques for complying with state and federal regulations for reclamation.

Improved coordination between the coal mining industry and land-use planners.

The program is the principal connection between DOE's Ecological Research Division and the coal industry, academic institutions, regulatory agencies, and the public. As such, it works to ensure that the needs of these groups are incorporated into DOE's research plan.

Snowfences capture snow, which would otherwise be blown away, to provide added moisture for reclamation plants.

Cooperative research carried out by Brigham Young University personnel is developing hybrid plants suitable for reclamation in arid climates.

Argonne scientists are studying surface and groundwater quality in mines in the eastern and western coal regions.

Developing techniques to restore prime farmland to pre-mining productivity is imperative because of the large deposits of coal lying beneath agricultural land.

This acidic, eroded gob pile was regraded and reclaimed during a successful demonstration project at an abandoned mine in southern Illinois.

Supporting activities utilizing sophisticated laboratory and data management techniques complement Argonne's field studies.

This color infra-red photograph of a Missouri surface mine is typical of the photos used to determine the extent of vegetation on reclaimed land.

An example of a photo after computer digitizing. The mine site is categorized into three classes: blue indicates water, red indicates bare soil, and yellow indicates vegetation.

University of Missouri research is aimed at measuring revegetation success by using color infrared aerial photographs

Successful reestablishment of desirable plants on surface mined lands is one of the most important goals in reclamation. However, there are no generally accepted ways of measuring that success objectively and inexpensively.

University of Missouri researchers are developing a way to quantify plant growth using remote sensing. This approach involves digitized, color infrared, aerial photographs. A computer assisted method of interpreting the photographs compares them to measurements obtained by researchers gathering field data on the ground.

This method has proven to be fast, cost-competitive, and more than 90% accurate compared with manual methods. Quick and accurate measurements of ground covered by vegetation will help mine operators and government regulators determine the success of reclamation efforts.

University of Missouri researchers gather direct field measurements at all of Missouri's operating surface coal mines. These data are used in conjunction with the aerial photographs.

University of Tennessee researchers are studying water quality impacts from both mining and reclamation. To predict the environmental consequences of surface mines, as much information as possible should be gathered about an area before mining begins. A sample area can be selected as representative of a large number of potential mining sites. University of Tennessee researchers adopted that approach in detailed studies of six small watersheds in eastern Tennessee's New River Basin, an area of extensive strip mining. Only two of the watersheds had been disturbed by mining when the study began in 1975. Later, mines were opened in three more.

Environmental data gathered in the early portion of the study have made it possible to identify the impacts of new mining operations. Of particular importance are changes in the quantity and quality of surface water and the ensuing effects on aquatic insects and other animal and plant life. Recent findings indicate that the streams are returning to pre-strip mined conditions much faster than the scientists believed they would. The fish and aquatic insect populations have returned to near normal levels some 20 years after mining activities ceased. These sites were not subject to reclamation requirements, and some problems have been found with adhering to new reclamation regulations.

Slope stability on restored strip-mined slopes is causing problems because of their tendency to erode. Recommendations for alternative reclamation procedures regarding back-to-contour regulations are being made.

The impact of acidic runoff and sediment on aquatic life is part of ongoing research in Tennessee's New River Basin.

University of Tennessee research has found that back-to-contour reclamation often produces unstable slopes. Even a successful stand of grass could not prevent this restored slope from eroding.

Rubber sheeting covers mine spoil banks (background) and allows rainfall to run off the slopes and into cultivated areas between the banks. This technique provides enough water to grow wheat and other crops.

Battelle is seeking alternative reclamation methods for arid regions through water harvesting.

Researchers at Battelle Pacific Northwest Laboratory, near Richland, Washington, are working on a portion of DOE's plan which is directed towards the development of alternative reclamation methods.

Strip-mined land normally is reclaimed by grading spoil banks to approximately the same contours that existed before mining, followed by seeding and fertilizing. Battelle's alternative method involves grading troughs between the spoil banks and treating or covering the slopes so that they repel water. Rainfall runs off the slopes and collects in topsoil that has been applied in the troughs. Topsoil stores the moisture and provides the nutrients for crops. In that way, three-quarters of the land collects moisture to supply the other quarter. In effect, one inch of rainfall becomes four inches of moisture in the cultivated strips.

The effectiveness of the system depends on the waterproofing material applied to the slopes. Butyl rubber sheeting, rubberized asphalt, and paraffin are among the materials being tested. Results indicate that paraffin is the best choice.

Alternative reclamation procedures that allow water conservation in the West are a high research priority for DOE, and to further test this system, a demonstration site has been established at an operating coal mine in Arizona.

Battelle's innovative approach to water harvesting is proving to be an effective method of reclamation in arid climates.

University of Montana scientists are determining the best native plants for reclamation.

Selection of the most suitable plant species for revegetation is crucial to reclaiming land in arid and semiarid regions after coal has been mined. It would seem that plants native to the mined area would be the logical choices. This is not necessarily so. Many native species have difficulty adapting to post-mining conditions. In 1975, scientists from the University of Montana began studies in the southeastern part of the state, where surface mining is expanding rapidly. These studies are evaluating the potential of native plants for revegetation.

So far, more than 100 native species have been examined for the viability of their seeds, their vigor, and their production—all traits that indicate the plants' ability to be self-sustaining. Detailed analyses have been made on the plants' need for sunlight, moisture, and heat. Seed germination has had special attention. Significant differences in temperature requirements for germination have been found between species.

Plantings at the Western Energy Mine at Colstrip have shown 15 native species to be well suited for reclamation, while another 24 native plants appear to be of only marginal use. Studies are continuing on these plants, since they are considered essential to the reestablishment of the native ecosystem on reclaimed land.

University of Montana research is determining how well native plants such as winterfat (*ceratoides lanata*) can be established on mine spoils.

DOE research covers the full spectrum of reclamation problems in arid and semi-arid regions. Revegetating mine spoils such as these at Decker, Montana (below), to re-create stable western prairie ecosystems (above) is one research area.

Researchers at Montana State University have been documenting the development and stability of plant communities.

Fourteen areas near Colstrip, Montana, were fenced off for plant studies, including several with 50-year-old mine spoils that had naturally revegetated, and others that had been seeded in the last 8 to 10 years. Researchers analyzed how well plants had established themselves and how plants succeeded other species within the special test areas.

Scientists have found that spoil texture is a major factor in successful reclamation. Better revegetation occurred on spoils high in silt and clay because of this type of soil's ability to hold water. This is important because state and federal reclamation laws require that newly planted vegetation continue to grow naturally—not an easy task in dry areas.

Problems still exist in establishing the permanent, self-sustaining plant communities required by law. However, evidence from the 50-year-old, naturally vegetated spoils indicates there is an excellent chance for future success. The science of reclamation ecology for the West is evolving steadily, and studies such as these by Montana State are providing information to make reclamation a reality.

Montana State University researchers are measuring the extent of plant cover, biomass production, and types of species in transects set up near Colstrip, Montana.

Naturally revegetated spoil piles, on land mined over 50 years ago, show that reclamation is possible.

University of Wyoming researchers are studying invading weeds to determine their effect on planted species in reclaimed areas.

University of Wyoming researchers are studying the effects of weeds that successfully invade reclamation sites.

While the invasion of weeds is considered undesirable, knowledge of how and why these plants adapt is useful in determining better ways of establishing desired reclamation species.

After three years of experiments at several coal mines in north eastern Wyoming, the scientists tentatively have concluded that weeds may not invade significantly if the planted species can be given a good start. Some weed species, such as Russian thistle (*Salsola kali*) and summer cypress (*Kochia scoparia*), often become dominant and may limit or prevent the desirable plants from growing. While these weeds have been found to dominate for up to two growing seasons, the desirable native species begin to replace the annuals that were introduced as part of the reclamation efforts. Because weeds adapt so successfully, they provide a higher total plant cover. This can create favorable microclimates for capture and germination of desirable seeds. Thus, seemingly negative conditions can eventually have positive effects.

Continued expansion of western strip mining will require more research into the roles played by native and introduced plants in reclamation.

Colorado State University scientists examine plants to determine the best revegetation techniques on soils disturbed by oil shale development.

Trucks are loaded with oil shale at Anvil Points, Colorado. The reclamation problems encountered with mining oil shale are similar to those of coal.

Colorado State University scientists are developing techniques to reclaim land mined for oil shale. Oil shale, like coal, can be converted to liquid fuel. Many of the environmental problems and potential solutions associated with oil shale are similar to those encountered in surface mining of coal.

In the Piceance Creek Basin of Colorado, one of the richest oil shale deposits in the West, CSU researchers are looking for effective ways to reclaim land from the waste material left after the oil like substance is removed from the shale. They are determining the most suitable revegetation plants and the best methods for seeding, watering, and fertilizing the plants. The role of soil microorganisms is being studied to improve the ability of plants to take up water and nutrients from soil disturbed by mining. Ways are sought to avoid or reduce damage to the microorganisms during the removal, storage, and replacement of topsoil.

These studies so far have shown that plants adapted for oil shale lands may be superior to native species, at least in the first few growing seasons, and that grasses dominate other vegetation in early stages before larger plant varieties can multiply. Gaining additional knowledge about reclamation of oil shale mine lands is imperative because of the increased need for synthetic fuels.

DOE/EV Reclamation Research Program

GOAL:

To maintain or improve environmental quality while achieving increased coal surface mining.

OBJECTIVES:

To develop energy efficient and cost-effective reclamation techniques that permit the orderly development of energy technology systems without impacting environmental quality.

To develop methods that ensure transfer of reclamation information and technology developments to the user groups concerned with energy and environmental quality issues.

ISSUES \ PROGRAMS	ANL/LRP	Battelle Pacific Northwest Laboratory	Colorado State University	University of Missouri	University of Montana	Montana State University	University of Tennessee	University of Wyoming
HYDROLOGIC BALANCE: Is maintenance of the hydrological balance always possible, necessary, and/or desirable?								
ECOLOGICAL SYSTEMS: At what level can ecological systems be restored?								
WATER QUALITY: Can coal production be increased while maintaining water quality?								
AIR QUALITY: Can an acceptable level of air quality be maintained during mining and reclamation?								
CONSERVATION: How can energy efficiency of mining and reclamation programs be optimized?								
LAND USE: Can existing or higher land use be achieved after mining?								
SOCIOECONOMIC: Can mining and reclamation be expanded without causing adverse socioeconomic impacts?								
LEGAL: Can the impact of regulations on mining be reduced while maintaining environmental quality?								
TECHNOLOGY TRANSFER: Can the information be efficiently and effectively transferred?								

DOE Land Reclamation Research Participants

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Argonne, Illinois

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Ft. Collins, Colorado

Montana State University
Bozeman, Montana

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Columbia
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University of Montana
Missoula, Montana

University of Tennessee
Knoxville, Tennessee

University of Wyoming
Laramie, Wyoming

Industry Cooperators

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