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DEVELOPMENT DOCUMENT FOR FINAL EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS FOR THE WESTERN ALKALINE COAL MINING SUBCATEGORY

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Office of Water
Office of Science and Technology
Engineering and Analysis Division
U.S. Environmental Protection Agency
Washington, DC 20460

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The primary contact regarding questions or comments on this document is:

William A. Telliard
Engineering and Analysis Division (4303)
U.S. Environmental Protection Agency
Ariel Rios Building, 1200 Pennsylvania Avenue
Washington, DC 20460
Phone: 202/260-7134
Fax: 202/260-7185
email: telliard.william@epamail.epa.gov

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Acronyms

acre-ft: acre-feet

ASCM: Alternative Sediment Control Measure

BAT: Best Available Technology

BMP: Best Management Practice

BPT: Best Practicable Control Technology Currently Available

BTCA: Best Technology Currently Available

Btu: British thermal unit

cfs: cubic feet per second

CHIA: Cumulative Hydrologic Impact Assessment

CWA: Federal Water Pollution Control Act of 1972; the Clean Water Act

DEQ: Department of Environmental Quality

EASI: Erosion and Sediment Impacts Model

EPA: U.S. Environmental Protection Agency

FEIS: Final Environmental Impact Statement

LQD: Land Quality Division

mg/L: milligrams per liter

ml/L: milliliters per liter

MMD: New Mexico Mining and Minerals Division

MUSLE: Modified Universal Soil Loss Equation

NMA: National Mining Association

NOV: Notice of Violation

NPDES: National Pollution Discharge Elimination System

NRCS: Natural Resource Conservation Service

NSPS: New Source Performance Standard

OSMRE: Office of Surface Mining and Reclamation Enforcement

PHC: Probable Hydrologic Consequence

RUSLE: Revised Universal Soil Loss Equation

SCS: Soil Conservation Service

SEDCAD: Sediment, Erosion, Discharge by Computer Aided Design

SEDIMOT II: Sedimentology by Distributed Model Treatment

SMCRA: Surface Mining Control and Reclamation Act

SS: Settleable Solids

TSS: Total Suspended Solids

DOT: Department of Transportation

USDA: United States Department of Agriculture

USLE: Universal Soil Loss Equation

WIEB: Western Interstate Energy Board

Glossary

Alkaline Mine Drainage: Mine drainage which, before any treatment, has a pH equal to or greater than 6.0 and a total iron concentration of less than 10 mg/L.

Approximate Original Contour: Surface configuration achieved by backfilling and grading of mined areas so that the reclaimed land surface closely resembles the general surface configuration of the land prior to mining and blends into and complements the drainage pattern of the surrounding terrain.

Arid and semiarid area: An area of the interior western United States, west of the 100^{th} meridian west longitude, experiencing water deficits, where water use by native vegetation equals or exceeds that supplied by precipitation. All coalfields located in North Dakota west of the 100^{th} meridian west longitude, all coal fields in Montana, Wyoming, Utah, Colorado, New Mexico, Idaho, Nevada, and Arizona, The Eagle Pass field in Texas, and the Stone Canyon and the Ione fields in California are in arid and semiarid areas (30 CFR Ch. VII § 701.5).

Armoring: Lining drainage channels with rock to limit re-transport of the channel bottom.

Arroyo: A term applied in the arid and semiarid regions of southwest United States to the small deep flat-floored channel or gully of an ephemeral stream or an intermittent stream, usually with vertical or steeply cut banks of unconsolidated material at least 60 cm high. It is usually dry, but may be transformed into a temporary water-course or short lived torrent after heavy rainfall (Bates and Jackson, 1980).

Bank Carving: A form of erosion in which the foundation of the banks of a stream or river are undermined due to an increase in flow rate causing the bank to fail.

Bank Slumping: See bank carving.

Berming: An engineering technique which creates a long mound of earth to control the flow of water.

Best Management Practice: Schedules of activities, prohibitions or practices, maintenance procedures, and other management or operational practices to prevent or reduce the pollution of waters of the United States.

British Thermal Unit: The amount of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit, approximately equal to 252 calories. The Btu is a convenient measure by which to compare the energy content of various fuels.

Channel Head: The upper reaches of a stream where the kinetic energy of water is highest.

Channel Head-Cutting: Loss of sediment from the upper reaches of a stream.

Channel Bed: The sediment at the deepest portion of a stream.

Coal Surface Mine: A coal-producing mine that extracts coal that is usually within a few hundred feet of the surface. Earth and rock above the coal (overburden) is removed to expose the coal seam which is then excavated with draglines, bulldozers, front-end loaders, augering and/or other heavy equipment. It may also be known as an area, contour, open-pit, strip, or auger mine.

Concentration of Contaminant: The amount of pollutant parameter proportional to the total volume.

Contour Furrowing: A soil-loss prevention technique adapted to control sediment runoff. The sediment is plowed along the contour lines which helps impede water flow.

Disturbed Area: An area which has been altered in generally an unacceptable manner by human or natural actions.

Diverting Runoff: An engineering technique to force water away from natural watercourses, allowing for reduction in water velocity and volume.

Dry wash: A wash (stream or gully) that carries water only at infrequent intervals and for brief periods, as after a heavy rainfall.

Ephemeral Stream: A stream which flows only in direct response to precipitation in the immediate watershed or in response to snow melt, and which has a channel bottom that is always above the prevailing water table.

Erosion: A natural process by the action of water, wind, and ice in which soil and rock material is loosened and removed. The major factors affecting soil erosion are soil characteristics, climate, rainfall intensity and duration, vegetation or other surface cover, and topography.

Evapotranspiration: That portion of precipitation returned to the air through direct evaporation or by transpiration of vegetation.

Ferruginous: Of coals, minerals and rocks containing iron. Water running off such materials is usually rust colored, and will tend to be acidic.

Flash Flooding: A large surge of water runoff from a storm event. Flash floods are worsened by lack of vegetation or natural flow-retarding elements such as soils, lakes or impoundments.

Flow Naturally: The course of water unimpeded or altered by man-made activity or structures.

Fluvial: Relating to, or occurring in a river.

Fluvial Processes: The physical actions of water on sediments, changing and being changed by the results of those actions.

Fluvial Morphology: Landforms and structures created by the activity of water both in motion and at rest.

Forb: A broad-leaved herbaceous plant, as distinguished from grasses, shrubs and trees.

Geotextiles: Porous fabrics composed of woven synthetic materials. Geotextiles also are known as filter fabrics, road rugs, synthetic fabrics, constructions, or geosynthetic fabrics.

Grading: Cutting and/or filling land surfaces with heavy equipment to create a desired configuration, slope or elevation.

Grass Filter Strips: Sections of land with planted grass to help retain eroding sediment.

Harvested Precipitation: The rainfall that is channeled by gutters or ditches to a storage area or for an immediate specific use.

Head-cut Erosion: The sudden change in elevation or knickpoint at the leading edge of a gully. Head-cuts can range from less than an inch to several feet in height, depending on several factors. The formation and movement of a gully head-cut are often the dominant form of damage observed in an earth spillway.

High-Yield Storm: A rain storm with a large amount of impact.

Hydrophytic Vegetation: Water-loving vegetation requiring considerable water to survive.

Hydrologic Balance: The relationship between the quality and quantity of water inflow to, outflow from, and storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake or reservoir. A water budget that encompasses the dynamic relationships among precipitation, surface runoff, evaporation, and changes in surface water and ground water storage.

Infiltration: Surface water sinking into the sediment column as the first step towards becoming ground water.

Irrigation: Application of water to agricultural or recreational land for promoting plant growth.

Kinetic Energy: Energy contained by mass in motion. In particular, rapidly moving water will have relatively high kinetic energy, allowing for the movement of large amounts of sediment (see turbulent flow).

Mass wasting: The movement of regolith downslope by gravity without the aid of a transporting medium. Mass wasting depends on the interaction of soils, rock particles and moisture content.

Morphology: The form and structure of the landscape, i.e., slope, errosional features, hills, etc.

Mulch: A temporary soil stabilization or erosion control practice where materials such as grass, hay, woodchips, wood fibers, or straw are placed on the soil surface. A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Non-consumptive retention: The impoundment of water without its extraction for other uses.

Non-process Area: The surface area of a coal mine that has been returned to required contour and on which revegetation (specifically seeding or planting) work has commenced.

Perennial Rivers: Rivers which flow during particular seasons in a predictable manner.

Periodic Releases: An infrequent discharge of water either by design or by naturally intermittent precipitation.

Precipitation: The discharge of water, in liquid or solid state, from the atmosphere, generally onto a land or water surface. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated. Forms of precipitation include drizzle, rainfall, glaze, sleet, snow, and hail.

Receiving Stream: A down-gradient stream that catches runoff from a mining area.

Reclaimed Area: A disturbed area that is restored by remediation activities to an acceptable condition.

Regolith: The layer or loose unconsolidated rock material, including soil, resting on bedrock, constituting the surface of most land.

Rill Erosion: Rill erosion is the removal of soil by concentrated water running through little streamlets, or head-cuts.

Riparian Habitat: Areas adjacent to rivers and streams that have a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

Runoff: That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface waterbody.

Runoff Event: In arid and semiarid areas, the majority of the annual precipitation occurs during infrequent rainfalls causing surface water runoff events that result in most of the erosion.

Scouring: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt from the stream bed and outside bank of a curved channel.

Sediment: Soil and rock particles washed from land into waterbodies, usually after significant rain. For the purpose of this document, sediment is all material transported by surface water drainage, including total settleable solids, suspended solids, and bedload.

Sediment Control Measures: Engineering and biological techniques and practices to control the quantity and location of sedimentation.

Sediment Imbalance: An abnormally high increase or decrease in sedimentation rates caused by some activity.

Sediment Yield: the sum of the soil losses minus deposition in macro-topographic depressions, at the toe of the hillslope, along field boundaries, or in terraces and channels sculpted into the hillslope.

Sedimentation: The process of depositing soil particles, clays, sand, or other sediments transported by flowing water.

Sedimentation Pond: A sediment control structure designed, constructed, and maintained to slow down or impound precipitation runoff that allows the water to drop its sediment load and reduce sediment concentrations at the point source discharge.

Seep: A point where water oozes or flows from the earth.

Semiarid: Landscape characterized by scanty rainfall. Pertaining to a subdivision of climate in which the associated ecological conditions are distinguished by short grass and scrubby vegetation.

Sheet Erosion: The detachment of land surface material by raindrop impact and thawing of frozen grounds and its subsequent removal by overland flow.

Sodic: Pertaining to or containing sodium: sodic soil.

Soil Erodibility Factor: The inability of a soil to resist erosive energy of rains A measure of the erosion potential for a specific soil type based on inherent physical properties such as particle size, organic matter, aggregate stability, and permeability.

Soil Loss: that material actually removed from the particular hillslope or hillslope segment. The soil loss may be less than erosion due to on-site deposition in microtopographic depressions on the hillslope.

Steepness Factor: Combination factor of for slope length and gradient.

Terrace Levels: Sediment platforms within stream channels, where different volumes of water periodically flow.

Turbulent Flow: Chaotic water movement with high kinetic energy which allows for fast sediment erosion and sediment high carrying capacity.

Underfit: A small water flow eroding a sub-channel within a large currently dry stream channel.

Vegetation Encroachment: Abnormal vegetative growth which impedes the natural flow of a water course.

Volume of Flow: A measure of the quantitu of water moving per unit of time.

Water-monitoring Program: A sampling of water at designated locations and times to characterize how its qualitites and quantities change over space and time.

Watershed: An area contained within a drainage divide above a specified point on a stream.

Executive Summary

Purpose

This document supports the United States Environmental Protection Agency's (EPA's) promulgation of a new Western Alkaline Coal Mining Subcategory under existing regulations at 40 CFR part 434 for the Coal Mining industry. The document was developed primarily using information supplied by a Western Coal Mining Work Group consisting of representatives from federal and state regulatory agencies and industry. The purpose of this document is to provide a summary of the information collected and used by EPA to support promulgation of this subcategory and to develop the requirements under the final rule.

Western Alkaline Coal Mining Subcategory

The Western Alkaline Coal Mining Subcategory addresses sedimentation and erosion control issues that are characteristic to the arid and semiarid coal producing regions of the western United States. EPA finds that the use of additional or alternative sediment control best management practices (BMP) in non-process areas within these regions can be less harmful to the environment than the impacts resulting the use of sedimentation ponds only to comply with numeric limits. EPA believes that controlling sediment generation at the source with the implementation of BMPs will reduce erosion and sedimentation. EPA also believes that the implementation of appropriate BMPs in these regions can prevent the formation of unnatural geomorphic land and stream forms, and will improve water management, vegetation, and land uses.

This rulemaking effort adds a Western Alkaline Coal Mining subcategory to 40 CFR part 434 for coal mining operations conducted in arid and semiarid regions in the western United States. The Western Alkaline Coal Mining Subcategory is applicable to alkaline mine drainage from non-process areas, brushing and grubbing areas, topsoil stockpiling areas, and regraded areas at western coal mining operations. "Western coal mining operation" is defined as a surface or underground coal mining operation located in the interior western United States, west of the 100^{th} meridian west longitude, in an arid or semiarid environment with an average annual precipitation of 26.0 inches or less. "Alkaline mine drainage is defined in the existing regulations as "mine drainage which, before any treatment, has a pH equal to or greater than 6.0 and total iron concentration of less than 10 mg/L." The regulation applies to the following areas:

- "Non-process area" is the surface area of a coal mine which has been returned to required contour and on which revegetation (specifically, seeding or planting) work has commenced.
- "Brushing and grubbing area" is the area where woody plant materials that would interfere with soil salvage operations have been removed or incorporated into the soil resource that is being salvaged.
- "Topsoil stockpiling area" is the area outside the mined-out area where soil is temporarily stored for use in reclamation, including containment berms.
- "Regraded area" is the surface area of a coal mine which has been returned to required contour.

Presumptive Rulemaking

The Western Alkaline Coal Mining Subcategory was developed using a presumptive rulemaking effort, implementing recommendations of EPA's Effluent Guidelines Task Force for streamlining the regulations development process and expediting promulgation of effluent limitations guidelines (May 28, 1998, 63 FR 29203). Under these recommendations, this rulemaking effort relies on stakeholder support for various stages of information gathering; utilizes existing information; focuses on an industry segment for which controls have been identified that would result in environmental improvements; and is based on early presumptions regarding effective control technologies and key pollutant parameters. Development of this subcategory relies on existing technical and economic information compiled from demonstrated successful state approaches, federal regulatory requirements, and regulated community partnerships.

Section 1.0 Background

1.1 Legal Authority

EPA is promulgating the Western Alkaline Coal Mining Subcategory under the authority of Sections 301, 304, 306, 307, 308, and 501 of the Federal Water Pollution Control Act (Clean Water Act; CWA). EPA is promulgating this subcategory also under Section 304(m) of the Clean Water Act which requires EPA to publish a biennial Effluent Guidelines Plan, set a schedule for review and revision of existing regulations and identify categories of dischargers to be covered by new regulations.

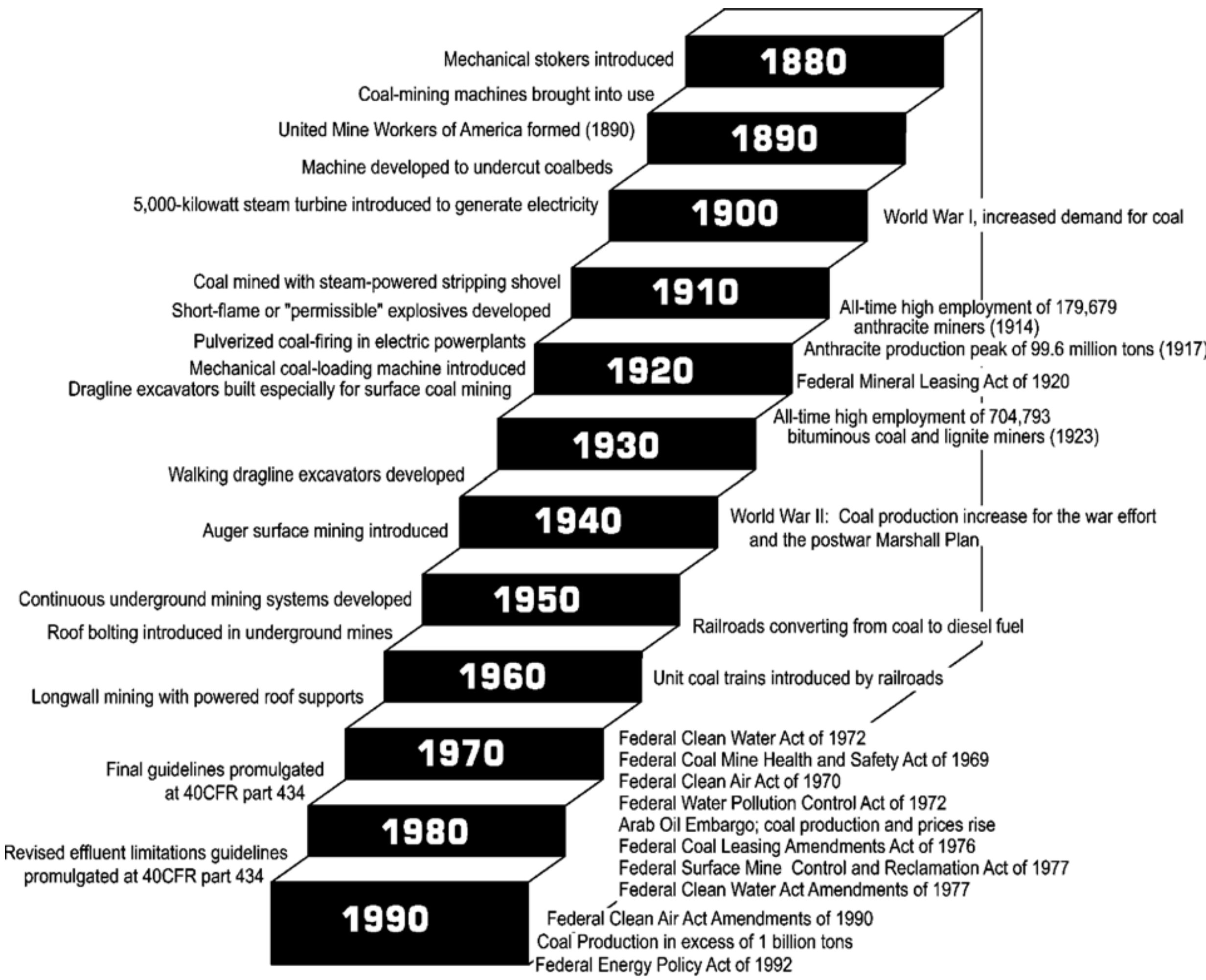
EPA's legal authority to promulgate BMP regulations is found in Section 304(e), Section 307(b) and (c), Section 308(a), Section 402(a)(1)(B), Section 402(a)(2) and Section 501(a) of the Clean Water Act, 33 U.S.C. § 1251, et. seq. EPA's legal authority also relies on 40 CFR part 122.44(k). This BMP regulation is consistent with the Pollution Prevention Act of 1990, 42 U.S.C. § 13101, et. seq.

This subcategory is being promulgated in response to the consent decree in NRDC et. al. v. Browner (D.D.C. Civ. No. 89-2980, January 31, 1992, as modified) which commits EPA to schedules for proposing and taking final action on effluent limitations guidelines. The consent decree publication date for final revised effluent limitations guidelines for the coal mining industry was published on August 31, 2000 at 65 FR 3008.

1.2 Regulatory History

The coal mining industry in the United States has a history covering over two centurie. During the last thirty years, the proliferation of federal environmental laws has altered the coal mining industry considerably (Figure 1a), and environmental impact considerations are now commonly woven into most regulatory and industry decision-making. Laws such as the Surface Mining Control and Reclamation Act (SMCRA) and the Clean Water Act (CWA) reflect a strong consideration for preservation of resources and protection of fragile and life-supporting ecosystems.

Figure 1a: Time line of Selected Events Affecting the Coal Mining Industry (modified from EIA, 1995)



This section presents a summary of SMCRA and CWA regulations affecting the coal mining industry and, in particular, sedimentation requirements in the arid and semiarid western coal mining region. This section also describes selected state programs that deal successfully with sedimentation issues of coal mines in arid and semiarid regions.

1.2.1 Clean Water Act

The Clean Water Act of 1972 and the Clean Water Act Amendments of 1977 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." To implement the program, EPA was charged with issuing effluent limitation guidelines standards, pretreatment standards, and new source performance standards (NSPS) for industrial discharges. These regulations were to be based principally on the degree of effluent reduction attainable through the application of control technologies.

On October 17, 1975 (40 FR 48830), EPA proposed regulations adding part 434 to Title 40 of the Code of Federal Regulations. These regulations, with subsequent amendments, established effluent limitations guidelines for coal mine operations based on the use of the "best practicable control technology currently available" (BPT) for existing sources in the coal mining point source category. These regulations were followed on April 26, 1977 (42 FR 21380) by final BPT effluent limitations guidelines for the coal mining point source category. BPT guidelines were established for total suspended solids, pH, total iron, and/or total manganese for three subcategories: Acid Mine Drainage, Alkaline Mine Drainage, and Coal Preparation Plants and Associated Areas. At that time the guidelines did not apply to discharges from non-process areas, nor did TSS limitations apply to any discharges from coal mines located in Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.

On October 9, 1985 (50 FR 41296), EPA promulgated the revised effluent limitations guidelines and standards that are in effect to date under 40 CFR part 434. Currently, there are four subcategories: Coal Preparation Plants and Coal Preparation Plant Associated Areas, Acid or Ferruginous Mine Drainage, Alkaline Mine Drainage, and Post-Mining Areas, along with a subpart for Miscellaneous Provisions with BPT, BAT, and NSPS limitations for TSS, pH, total iron, total manganese, and settleable solids (SS). Specifically, effluent limitations for discharges from non-process areas include SS and pH at 0.5 ml/L and 6 to 9 standard units, respectively.

On October 18, 1997, Vice President Gore called for a renewed effort to restore and protect water quality. EPA and other federal agencies were directed to develop a Clean Water Action Plan that addressed three major goals: (1) enhanced protection from public health threats caused by water pollution; (2) more effective control of polluted runoff; and (3) promotion of water quality protection on a watershed basis. The Clean Water Action Plan was to be based on three principles:

- Develop cooperative approaches that promote coordination and reduce duplication among federal, state, and local agencies and tribal governments wherever possible;

- Maximize the participation of community groups and the public, placing particular emphasis on ensuring community and public access to information about water quality issues; and

- Emphasize innovative approaches to pollution control, including incentives, market-based mechanisms, and cooperative partnerships with landowners and other private parties.

Based on the efforts of interagency work groups and comments from the public, EPA and other federal agencies developed the final Clean Water Action Plan that was submitted on February 14, 1998. One of several Key Actions specifically identified to implement the goals of the Clean Water Action Plan was EPA's project to re-examine 40 CFR part 434 to better address coal mining in arid western areas.

On May 28, 1998 (63 FR 29203), EPA announced plans for developing new and revised effluent limitations guidelines for selected industrial categories, and described revisions to its regulations development process. Included in this program was the re-examination of 40 CFR part 434. The program and schedule announced in May 1998 were established in response to a consent decree resulting from legal action taken by the Natural Resources Defense Council (D.D.C. No. 89-2980, January 31, 1992).

1.2.2 Surface Mining Control and Reclamation Act (SMCRA)

1.2.2.1 SMCRA History

In 1977, Congress enacted the Surface Mining Control and Reclamation Act, 30 U.S.C. 1201 *et seq*, to address the environmental problems associated with coal mining. The previous lack of uniformity among state surface mining programs and the increase in unreclaimed land and associated pollution of water and other resources forced the federal regulation of surface coal mining activities. SMCRA established a coordinated effort between the states and the federal government to prevent the abuses that had characterized surface and underground coal mining in the past, and created two major programs:

- An environmental protection program to establish standards and procedures for approving permits and inspecting active coal mining and reclamation operations both surface and underground; and

- A reclamation program for abandoned mine lands, funded by fees on coal production, to reclaim land and water resources adversely affected by pre-1977 coal mining.

SMCRA created the Office of Surface Mining Reclamation and Enforcement within the Department of Interior, and charged it with the responsibility of preparing regulations and providing financial and technical assistance to the states to carry out regulatory activities. Title

V of the statute gives OSMRE broad authority to regulate specific management practices before, during, and after mining operations. OSMRE has promulgated comprehensive regulations to control both surface coal mining and the surface effects of underground coal mining (30 CFR part 700 *et seq*). Implementation of these requirements has led to significant improvements in mining practices and serves to control the pollution of water and other resources.

1.2.2.2 SMCRA Requirements

SMCRA requirements set general performance standards for environmental protection for any permit to conduct surface coal mining and reclamation operations. The performance standards that are particularly applicable to the final Western Alkaline Coal Mining Subcategory are summarized as follows:

- Restore the land affected to a condition capable of supporting the uses which it was capable of supporting prior to mining, or higher or better uses;

- Stabilize and protect all surface areas affected by the mining and reclamation operation to effectively control erosion;

- Create, if authorized in the approved mining and reclamation plan and permit, permanent impoundments of water on mining sites as part of reclamation activities only when it is adequately demonstrated that: such water impoundments will not result in the diminution of the quality or quantity of water utilized by adjacent or surrounding landowners for agricultural, industrial recreational, or domestic uses;

- Minimize disturbance to the hydrologic balance at the mine-site and in associated offsite areas and to the quality and quantity of water in surface and ground water systems both during and after surface coal mining operations and during reclamation;

- Establish an effective, permanent vegetative cover at least equal in extent of cover to natural vegetation or as necessary to achieve the approved postmining land use;

- In those areas or regions where the annual average precipitation is twenty-six inches or less, assume the responsibility for successful revegetation for a period of ten full years;

- Protect offsite areas from slides or damage occurring during the surface coal mining and reclamation operations;

- Meet other criteria as necessary to achieve reclamation in accordance with SMCRA, taking into consideration the physical, climatological, and other characteristics of the site; and

- To the extent possible using the best technology currently available, minimize disturbances and adverse impacts of the operation on fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable.

Each SMCRA permit includes detailed pre-mining baseline conditions, a prediction of the probable hydrologic consequences of mining on the hydrologic balance, a hydrologic reclamation plan designed to minimize predicted consequences, and a detailed monitoring plan to verify and characterize hydrologic consequences. However, meeting numeric effluent limitations under the CWA has taken precedence over SMCRA's requirement to minimize, to the extent possible, impacts to the hydrologic balance. This precedent has, at times, resulted in adverse environmental effects and impacts to the hydrologic balance.

Under SMCRA, coal mine operators are required to collect a minimum of one year of pre-mining or baseline surface and ground water monitoring data before submitting a coal mining and reclamation permit application. The baseline information is used to prepare site-specific erosion and sedimentation plans capable of minimizing adverse impacts within the permit area and adjacent lands. It is also used to perform a Probable Hydrologic Consequences (PHC) evaluation to identify regional hydrologic impacts associated with the coal mining and reclamation operation. When potential adverse impacts are identified, appropriate protection, mitigation, and rehabilitation plans are developed and included in mining and reclamation permit requirements. The PHC and the accompanying plans are reviewed and approved by regulatory authorities before mining and reclamation activities are initiated.

Coal mine operators are required to submit bonds covering the costs of reclaiming and restoring disturbed areas to acceptable environmental conditions in the event of default and failure to discharge this obligation. Mid-term mining and reclamation permit reviews and renewals assess the adequacy of the site's erosion and sedimentation control, treatment, mitigation, and rehabilitation.

Coal mine operators are required to conduct and submit the results of surface and ground water monitoring under SMCRA and CWA NPDES permits on a periodic basis. Monitoring results are used to assess the adequacy of erosion and sedimentation control measures. At the conclusion of mining and reclamation activities, surface water monitoring information is used to summarize the effectiveness of erosion and sedimentation control in restoring the hydrologic system. This evaluation is part of a Cumulative Hydrologic Impact Assessment (CHIA) required when the coal mining company applies for final reclamation liability and bond release.

1.2.2.3 Flannery Decision

SMCRA requirements include performance standards for surface mining operations to be conducted in a manner that minimizes disturbance to the prevailing hydrologic balance. SMCRA specifies sediment control performance standards for

> "conducting surface coal mining operations so as to prevent, to the extent possible using best technology currently available (BTCA), additional contributions of suspended solids to stream flow, or to runoff outside the permit area. In no event shall contributions be in excess of requirements set by applicable state or federal law (30 U.S.C. § 1265(b)(10)(B)(i))."

OSMRE implemented the statutory hydrologic balance protection performance standard by requiring, with some exceptions, that all surface drainage from disturbed areas pass through sedimentation ponds before leaving the permit area (30 CFR part 816.42(a)(1) and 817.42(a)(1)).

In 1981 (46 FR 34784), OSMRE proposed revisions to the siltation structure regulations that incorporated the flexibility to allow the use of alternative sediment control measures in lieu of sedimentation ponds. OSMRE received extensive comments on the question of whether sedimentation ponds and similar siltation structures constitute BTCA in all circumstances. The final rule promulgated in 1983 deleted the provision that allowed alternative sediment control measures, and retained the prior requirement that all drainage from disturbed areas (except for small areas) pass through a siltation structure before leaving the permit area.

The coal industry challenged the blanket requirement in OSMRE's rules that all surface drainage from disturbed areas pass through a siltation structure before leaving the permit area, and in 1985 the United States District Court for the District of Columbia remanded the rules as arbitrary and capricious. Judge Thomas Flannery found that OSMRE failed to adequately explain why siltation ponds were considered BTCA (In Re Permanent Surface Mining Regulation Litigation, 620 F. Supp. 1519, 1565-68 D.D.D. 1985). The decision was supported by record evidence that siltation structures are not always BTCA and OSMRE's recognition that these structures may pose negative impacts. In 1986 (51 FR 419252), OSMRE suspended the rule and explained that the regulatory authority will determine on a case-by-case basis what constitutes BTCA.

In 1990 (55 FR 47430), OSMRE proposed revisions to the federal rules to allow the use of alternative sediment control measures in lieu of sedimentation ponds in the arid and semi-arid west. OSMRE never took further action on the proposal. Currently, it is the responsibility of the regulatory authority to determine, on a case-by-case basis, what constitutes BTCA for preventing, to the extent possible, additional contributions of suspended solids to stream flow or runoff outside the permit area.

1.2.3 State Regulatory Guidelines for Sediment Control

The states of Wyoming and New Mexico, under federally approved SMCRA primacy programs, have developed regulations to allow the use of sediment control BMPs to prevent environmental problems associated with preferential use of sedimentation ponds in the arid and semiarid west. The regulations or guidelines have been reviewed and approved by OSMRE. Utah is developing alternate sediment control guidelines that have not been published to date. Although the requirements for these programs vary somewhat between states, the intent is to provide greater protection to the hydrologically sensitive watersheds in this region.

1.2.3.1 Wyoming Coal Rules and Regulations, Chapter IV

Under Wyoming's Coal Rules and Regulations, implemented by the Land Quality Division (LQD) of Wyoming's Department of Environmental Quality (WY DEQ), exemptions to the use of sedimentation ponds may be granted where, by the use of alternative sediment control measures, the drainage will meet effluent limitation standards or will not degrade receiving waters (Chapter IV, Section 2(f)(i)). Chapter IV of these regulations also sets environmental protection performance standards that require coal mine operators to implement best management practices including contemporaneous backfilling and grading, reclamation to approximate original contour, and erosion reduction measurements. Under Chapter IV, Section 2(e)(i), discharges should be controlled as necessary to reduce erosion, to prevent deepening or enlargement of stream channels, and to minimize disturbance of the hydrologic balance.

Chapter IV of these regulations also states that appropriate sediment control measures (e.g., stabilizing, diverting, treating or otherwise controlling runoff) shall be designed, constructed, and maintained using BTCA to prevent additional contributions of sediment to streams or to runoff outside the affected area. Chapter IV requires that a surface water-monitoring program be used to demonstrate that the quality and quantity of runoff from affected lands will minimize disturbance to the hydrologic balance. Wyoming's Coal Rules and Regulations, Chapter IV are provided as Appendix A to this document.

1.2.3.2 Wyoming Coal Rules and Regulations, Guideline No. 15

Wyoming's LQD developed Guideline No. 15 for Alternative Sediment Control Measures (ASCMs) or best management practices that may be used in addition to or in place of sedimentation ponds. The guideline supports requirements of the Wyoming DEQ/LQD Coal Rules and Regulations, Chapter IV and provides guidance for determining best technology currently available for designing, constructing, implementing, and maintaining ASCM, and for determining the contents of an ASCM proposal.

Guideline No. 15 identifies specific sediment control measures that may be used in addition to or in place of sedimentation ponds and supports the use of alternative sediment control measures as an option under Wyoming's Coal Rules and Regulations. Guideline No. 15 recommends: determination of BTCA on a case-by-case basis, prevention of soil detachment and erosion, retention of sediment as close as possible to its point of origin, and implementation of sediment traps only as a second line of defense. Wyoming's Guideline No. 15 are provided in Appendix B of this document. A summary of the guideline is presented below.

<u>Determination of Best Technology Currently Available</u>

Guideline No. 15 recognizes that design methods, construction techniques, maintenance practices, and monitoring all contribute to a system that can be considered BTCA. Additionally, the guideline recognizes that BTCA must be determined on a case-by-case basis. Factors considered in BTCA determinations include the size and type of disturbance and the length of time the ASCM will be in place. Determination also should be based on how effective the ASCM is at preventing soil detachment and erosion, and how effective the ASCM is on retaining sediment as close as possible to its point of origin.

Design of ASCM (for areas 30 acres and larger)

For sites larger than 30 acres, the mine operator is required to submit a general description of the area to be controlled by ASCM and the types and duration of expected disturbance, including the distance to and type of nearest receiving stream. A description of the sediment control plan, including justification for ASCM design parameter values and date of construction or implementation, is to be included. The use of site-specific data is encouraged. Topographic maps detailing the use of ASCM in relation to the mining and reclamation sequence is required. Annual reports detailing ASCM modifications are required if adjustments are made to the approved permit system. The guideline recommends that the ASCM design be based on predicted sediment loads or yields from the area disturbed compared to predicted or measured native sediment yields. State-of-the-art computer watershed models are recommended for use as a design tool.

Design of ASCM (for areas less than 30 acres)

Sediment control design requirements for small disturbed areas are concerned primarily with establishing use and safety criteria commensurate with the intended use and life of the structures. For these areas, the operator is required to submit the sedimentation control plan and justification, a plan view location, and a general description of the type of ASCM structures. The sediment control plan should implement sediment trapping structures to pass or detain runoff from storm events such as toe ditches and rock check dams. ASCM proposals for small areas also should present the inspection and maintenance programs the operator will use to regularly evaluate the stability and effectiveness of each ASCM. The program recognizes that the effectiveness and capabilities of many ASCM have been documented and need not be reiterated for small area application.

Implementation Priorities (for post-mining surfaces)

Guideline No. 15 highly recommends ASCM design approaches that stabilize land forms to minimize sediment yield. Short-term slope erosion control methods are recommended, such as regrading, mulching, and rapid establishment of vegetation. The guideline also recommends in-channel sediment retention and removal of trapped sediment. Sedimentation ponds should be implemented when maintenance of ASCMs is a chronic problem.

ASCM Performance Monitoring

Monitoring of small ephemeral receiving streams should include visual inspection following each runoff event, and repeat photographs taken at least annually and after major runoff events. Monitoring of large ephemeral receiving streams should include visual inspection, repeat photographs, repeat surveys, and upstream and downstream sediment yield monitoring stations. Guideline No. 15 recognizes that each type of ASCM has construction and maintenance guidelines that are specified in most handbooks on sediment control. The operator is required to:

> "report, repair and log any significant damage to an ASCM as soon as possible after the damage occurs. The operator should inspect the ASCM at the beginning and at the end of each runoff season, and after each runoff event. An inspection and maintenance log should be kept to document the condition of each ASCM at the time of each inspection. The log should describe any damage, required maintenance, and the date repairs were made."

1.2.3.3 New Mexico's ASC Windows Program

New Mexico's Mining and Minerals Division (MMD) enforces the state's federally approved SMCRA primacy program. BMP regulations for mining and reclamation operations in

New Mexico may be found under 19 NMAC 8.2 Subpart 20 Section 2009 which addresses requirements for minimizing changes to the prevailing hydrologic balance in both the permit and adjacent areas. Section 2009 of Subpart 20 is included as Appendix C of this document.

Under New Mexico's program at Section 2009.E (commonly referred to as the "ASC Windows Program"), requirements to pass all disturbed area runoff through a sedimentation pond or series of sedimentation ponds can be waived. If the operator chooses not to operate under the provisions set forth at 2009.E, then all runoff must be passed through sedimentation ponds before leaving the permit area. To waive sedimentation pond requirements, the operator must demonstrate that erosion is sufficiently controlled and that the quality of area runoff is as good as or better than that of water entering the permit area. The regulations recognize that certain methods are capable of containing or treating all surface flow from the disturbed areas and shall be used in preference to the use of sedimentation ponds or water treatment facilities. These practices to control sediment and minimize water pollution include, but are not limited to:

- Stabilizing disturbed areas through land shaping, berming, contour furrowing, or regrading to final contour;
- Planting temporary vegetation that germinates and grows quickly;
- Regulating channel velocity of water and diverting runoff;
- Lining drainage channels with rock or revegetation; and
- Mulching disturbed areas.

The operator's plan for alternative sediment control must demonstrate that there will be no increase in the sediment load to receiving streams. The plan also must demonstrate that there will be no resulting environmental harm or degredation, threat to public health or safety, or resulting pollution or other diminishment of existing streams and drainages that could cause imminent environmental harm to fish and wildlife habitats. The operator is responsible for taking baseline and ongoing surface and ground water monitoring samples. The MMD may require additional tests and analyses as deemed necessary by baseline and ongoing monitoring results. Surface water monitoring continues until final bond release.

Several mine operations in New Mexico have applied for and received reclamation liability bond releases for lands where sediment control BMP plans were implemented (e.g., Carbon II mine and De-Na-Zin mine). These sites demonstrated that there was no contribution of additional suspended solids to the hydrologic regime of the area and that runoff from regraded areas was as good as or better than runoff from undisturbed areas (WCMWG, 1999a).

Section 2.0 Industry Characterization

This section describes the coal mining industry in the arid and semiarid areas west of the 100th meridian and details the environmental factors that make mining and reclamation activities in these areas different than coal mining in the rest of the United States.

2.1 Location and Production

The United States is divided into three major coal producing regions: Appalachian, Interior, and Western (Figure 2a). Mines affected by the proposed Western Alkaline Coal Mining Subcategory are within the Western Coal Region and are defined as mines that:

- Are west of the 100th meridian west longitude,
- Are located in arid or semiarid areas with an average annual precipitation of 26 inches or less, and
- Produce alkaline mine drainage.

The Western Coal Region contains extensive deposits of low-sulfur coal (Figure 2a). Most of the coal mined in the Western Region is sub-bituminous, i.e., has a lower Btu content (8,3000 - 13,000) than eastern bituminous coal (>13,000). Western coal seams lie at various depths below the surface and vary in thickness from a few inches to over 70 feet (Energy Information Administration, 1995). The economic ability to mine the coal seams varies throughout the region and is dependent on coal quality, seam thickness, depth of overburden, geologic characteristics, and market factors. In areas such as the Southern Powder River Basin of Wyoming, thick coal seams and shallow overburden enable the extraction of large volumes of coal at relatively low cost. The low-sulfur content, in demand since the passage of the Clean Air Act, and the potentially low cost of extraction mean that coal resources in the Western Coal Region represent a highly competitive fuel in the power generation market. As the fuel market has changed, coal production within the Western Region has increased, now being nearly equal to the formerly dominant Appalachian Region. The United States produced 1.1 billion short tons of coal in 1997, with the Appalachian Region producing 469 million short tons, the Interior Region producing 172 million short tons, and the Western Region producing 451 million short tons (Table 2a).

Figure 2a: Coal Producing Areas (modified from USGS, 1996)

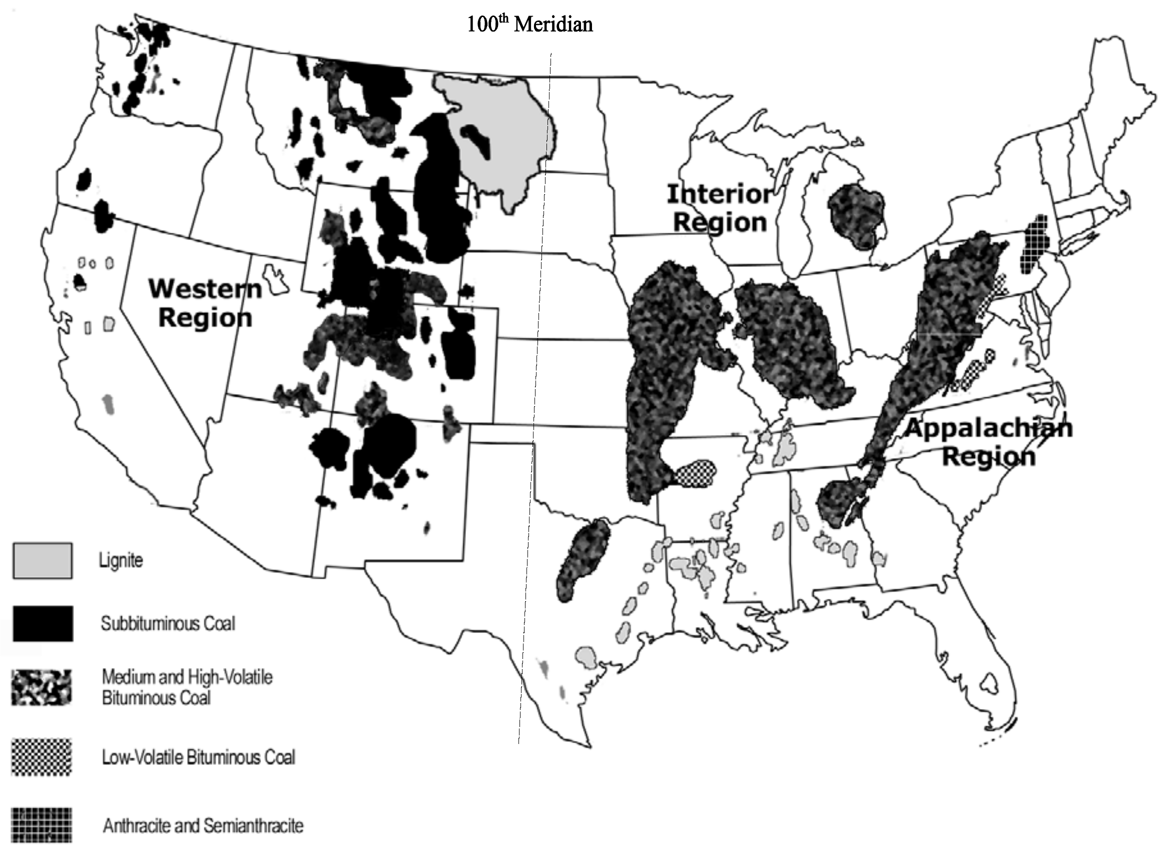


Table 2a: United States Coal Production by Region (short tons; Energy Information Administration, 1997)

	1970	**1997[1]**
Appalachian Region	427,600,000	468,778,000
Interior Region	149,900,000	171,863,000
Western Region	35,100,000	451,291,000
Total	**612,600,000**	**1,089,932,000**

[1]The total does not equal the sum of components due to independent rounding.

While domestic coal production has increased since 1970, fewer operating mines exist today, representing higher mine production. In 1997, the number of mines producing coal was less than half the number producing coal in 1988 (e.g., 3,860 mines in 1988 compared to 1,828 mines in 1997), and in the Western Region the number of mines fell from 114 to 77 in the same time period (Energy Information Administration, 1997). According to the Energy Information Administration, in 1988, the Western Region produced approximately 308 million short tons of coal, 68 percent of the 451 million short tons of coal the Western Region produced in 1997 (Energy Information Administration, 1997).

Of the 77 mines operating in the Western Region, EPA has identified 47 surface mines that potentially will be affected by the Western Alkaline Coal Mining Subcategory. One of these mines, however, currently is in the final reclamation phase and most likely will be unaffected. The 47 mines produce approximately 497 million tons of coal annually, affect 192,411 acres of land, and are located in Arizona (2 mine sites), Colorado (5 mine sites), Montana (6 mine sites), New Mexico (6 mine sites), and Wyoming (28 mine sites). These sites are listed along with operation and production statistics in Table 2b.

Table 2b: Operation and Production Statistic of Potentially Affected Coal Mines in the Arid and Semiarid Coal Producing Region (modified from Western Coal Mining Work Group, 1999b).

STATE	MINING SINCE[1]	ANNUAL PRODUCTION (1,000s of tons)[2]	AVG. $/TON (STATE)[3]	YEARLY VALUE (1,000s)[4]	INDIAN LANDS	AFFECTED ACRES[5]	MINE LIFE (YEARS)	PROJECTED DISTURBANCE (ACRES)
AZ	Jan-70	4,634	$ 25.17	$ 116,638	Navajo & Hopi	6,255	6	7,236
AZ	May-74	7,090	$ 25.17	$ 178,455	Navajo & Hopi	13,604	12	16,351
CO	Feb-77	5,544	$ 18.46	$ 102,342	No	2,782	16	3,810
CO	Pending	0	$ 25.00	-	No	0	15	1,161
CO	-	-	$ 18.46	-	No	-	-	-
CO	Jan-64	1,350	$ 18.46	$ 24,921	No	-	-	-
CO	Jan-77	2,002	$ 18.46	$ 36,957	No	5,116	16	6,300
MT	Jul-94	7,051	$ 9.84	$ 69,382	No	-	-	-
MT	Jan-69	4,335	$ 9.84	$ 42,656	No	3,437	6	500
MT	Feb-71	117,000	$ 9.84	1,151,280	No	6,093	28	8,579
MT	Jan-68	9,146	$ 9.84	$ 89,997	No	-	-	-
MT	Oct-58	330	$10.10	$ 3,333	No	430	20	875
MT	Dec-80	9,015	$ 9.84	$ 88,708	No	2,251	17	4,485
NM	Aug-86	2,375	$ 21.83	$ 51,846	No	1,799	18	2,085
NM	Jan-84	4,900	$ 21.83	$ 106,967	No	3,800	30	11,300
NM	Jan-64	6,607	$ 21.83	$ 144,231	Navajo	13,000	12	4,546
NM	Jan-63	8,200	$ 26.00	$ 213,200	Navajo	7,188	18	11,000
NM	Jan-73	4,072	$ 21.83	$ 88,892	No	4,969	18	6,216
NM	Feb-89	1,259		$ 27,484	No	-	-	-
WY	Jan-83	13,559	$ 6.00	$ 81,354	No	3,059	18	5,172
WY	-	0	n.a.	-	No	249	-	-
WY	Nov-72	22,800	$ 6.00	$ 136,800	No	11,621	-	-
WY	-	80	$ 6.00	$ 480	No	1,969	-	-
WY	-	1,857	$ 6.00	$ 11,142	No	14,860	-	-
WY	Aug-76	50,000	$ 6.00	$ 300,000	No	13,017	24	12,172
WY	Jan-81	18,000	$ 4.00	$ 72,000	No	3,789	-	-

STATE	MINING SINCE[1]	ANNUAL PRODUCTION (1,000s of tons)[2]	AVG. $/TON (STATE)[3]	YEARLY VALUE (1,000s)[4]	INDIAN LANDS	AFFECTED ACRES[5]	MINE LIFE (YEARS)	PROJECTED DISTURBANCE (ACRES)
WY	Jan-78	19,946	$ 6.00	$ 119,676	No	9,686	-	-
WY	Nov-82	14,681	$ 6.00	$ 88,086	No	2,374	14	6,631
WY	-	5,805	$ 6.00	$ 34,830	No	8,310	-	-
WY	Dec-76	13,324	$ 6.00	$ 79,944	No	4,576	14	7,275
WY	Oct-58	4,200	$ 9.00	$ 37,800	No	4,590	9	2,000
WY	-	2,986	$ 6.00	$ 17,916	No	3,124	-	-
WY	Jan-78	17,921	$ 6.00	$ 107,526	No	5,706	-	-
WY	Mar-97[6]	1,005	$ 6.00	$ 6,030	No	145	28	1,886
WY	Aug-76	27,113	$ 6.00	$ 162,678	No	5,624	15	8,207
WY	May-73	6,231	$ 6.00	$ 37,386	No	7,792	25	10,429
WY	Jan-50	4,402	$ 6.00	$ 26,412	No	10,622	26	4,960
WY	Jan-74	600	$ 6.00	$ 3,600	No	5,551	12	5,765
WY	Jan-83	34,965	$ 6.00	$ 209,790	No	2,687	-	-
WY	Sep-89	5,000	$ 6.00	$ 30,000	No	4,016	-	-
WY	Nov-77	10,706	$ 6.00	$ 64,236	No	8,316	-	-
WY	Nov-85	26,640	$ 6.00	$ 159,840	No	7,041	-	-
WY	-	-	$ 6.00	-	No	-	-	-
WY	Jan-73	500	$ 6.00	$ 3,000	No	3,523	12	3,576
WY	Oct-76	769	$ 6.00	$ 4,614	No	1,011	-	-
WY	-	-	$ 6.00	-	No	-	-	-
WY	Jan-22	3,242	$ 6.00	$ 19,452	No	959	32	2,129
Total	-	496,608	$ -	$ 4,235,243	-	192,411	-	141,521

[1]Month and year from DOE database.
[2]1997 or 1996 reported total annual production obtained from either the Keystone Manual (cite) or the Department of Energy Web site (cite).
[3]The average value of a ton of coal sold by all reporting mines in the state in which the mine is located. Where state values are unavailable, the Western Region average value was used.
[4]The Annual Production figure multiplied by the average price/ton.
[5]The total number of all acres disturbed to date by the mining operation. Acres disturbed for the extraction of coal are contemporaneously reclaimed (i.e., within four spoil ridges or 180 days whichever comes first), unless a variance is approved by the regulatory authority.
[6]The date of last permit transfer. Mining commenced prior to this date.

2.2 Environmental Conditions

Coal mining operations potentially affected by the Western Alkaline Coal Mining Subcategory operate under environmental conditions that are noticeably different from those in other regions of the United States. Background surface conditions are defined in this environment by the direct response of the geologic and soil-forming environment to the arid climate. Climatic, geologic, soil-forming, and topographic factors directly influence distribution and composition of vegetation in the arid and semiarid west. Western arid and semiarid areas may contain naturally unstable areas with highly eroded landscapes that are created by flash flooding which transports large volumes of sediment. Water resources are severely limited and highly valued. Common conditions occurring throughout the arid and semiarid western coal-bearing region are summarized categorically below.

2.2.1 Temperature

Temperatures in the arid and semiarid western United States fluctuate over wide daily and seasonal ranges. A daily range of 30°F to 50°F (-1°C to 10°C) is common, while the seasonal temperature ranges from -40°F to 115°F (-40°C to 46°C). Large diurnal fluctuations contribute to the physical weathering of surface materials, which increases the amount of small sediment particles available for transport by runoff generated during significant storm events. Intense wind storms generated by frontal weather systems and regional weather patterns in this region also can transport substantial amounts of sediment.

2.2.2 Precipitation

Arid and semiarid locations average 26 inches or less of annual precipitation, with roughly equal parts occurring as snowfall and rainfall. Average annual precipitation received in western states containing arid and semiarid areas is presented in Table 2c.

Table 2c: Average Annual Precipitation (inches) in Arid and Semiarid Coal States
(from National Oceanic and Atmospheric Administration, 1998)

State	**Long-Term Average Annual Precipitation (inches) 1899 - 1998**
Arizona	12.77
Colorado	15.90
Montana	15.36
New Mexico	13.45
Wyoming	13.16

Much of the rainfall in the arid and semiarid western United States is received during localized, high-intensity, short-duration thunderstorms, and research has indicated that relatively few storms may produce the greatest amount of erosion (Peterson, 1995). Western precipitation storms producing runoff are typically:

- Cellular in nature - localized intensity and relatively limited in areal extent;
- Of short duration; and
- Characterized by large raindrops with high kinetic energy.

Studies of precipitation typically received in arid areas indicate that the dominant precipitation events that produce runoff generally have between 1-hour and 3-hour duration peaks. For arid lands, up to 80 percent of the total 24-hour rainfall occurs within 3-hours (Hromadka, 1996). These storm events result in short-duration, sediment-rich flash flood runoff. Hjemfelt (1986) reported that only three to four percent of storm events accounted for 50 percent of long term sediment yields.

Evapotranspiration normally exceeds precipitation since solar energy is high in western arid and semiarid areas and humidity is characteristically very low. Water infiltration and retention in the soil is frequently limited, creating a net negative water balance. The negative water balance results in severe soil moisture deficits, extremely limited surface water resources, and poor plant growth and cover.

2.2.3 Erosion Prone Soils

Certain soils in arid and semiarid areas may be prone to erosion and weathering. On steep slopes, soil-forming materials frequently erode faster than they are formed. Where erosion rates are lower and soil is capable of forming, the soil typically is poorly developed with low organic matter and plant nutrient content. Soil moisture contents are characteristically low because of limited precipitation, low soil infiltration rates, and nominal amounts of organic matter.

A source of erosion is the energy created by "raindrop splash." Raindrops contain enough energy to mobilize sediment and transport it down slope. In a sediment rich environment, overland flow reaches its suspended solids carrying capacity after a short distance or period of time. When overland flow reaches dynamic sediment loading equilibrium, entrained particles are dropped and new ones are picked up until the kinetic energy of the flow is changed. When overland flows decrease in velocity, such as at the base of a concave slope, kinetic energy decreases, and entrained sediments are released and deposited. Ephemeral gullies on these lands carry flow only at times of severe storm or spring snowmelt (Heede, 1975).

2.2.4 Hydrology and Sedimentation

The western region of the United States is geomorphically young and active with a weathered topography. The landscape in the arid and semiarid regions is a mixture of mountains, mesas, plains, buttes, valleys, and canyons, and the effects of active erosion, flash flooding, and other dynamic geologic processes are pervasive. Flow channels frequently contain multiple terrace levels. Instability within drainage systems is readily observed with channel head-cutting, aggradation, bank slumping and actively changing watercourses commonly occurring.

Perennial rivers are predominant in this region and most commonly originate in mountainous areas with significant snow (in areas with average annual precipitation greater than 26 inches per year) or in very large watersheds. Ephemeral drainage systems predominate in small to medium-sized headwater areas. These ephemeral drainage systems are composed primarily of dry washes and arroyos, the lower ends of such features sometimes being depicted on USGS topographic maps as intermittent streams. More often than not, drainage features thus depicted:

- Conduct ephemeral surface water flow;
- Are mainly composed of sand bed channels;
- Have channel banks of unconsolidated alluvial deposits;
- Possess a nearly unlimited source of sediment that may be transported by flash flooding; and
- Commonly contain sediment at concentrations as high as 1×10^6 mg/L during flash flood runoff events.

For an average of 11 to 11 ½ months a year the washes and arroyos are dry, normally flowing only in direct response to precipitation runoff. When rainfall does generate runoff, it is frequently characterized by high-volume, high-velocity, sediment-laden, and turbulent flows with tremendous kinetic energy that ceases soon after the precipitation event stops. For many very short-duration precipitation events, the runoff water never reaches the main-stem channels downstream. This turbulent flow pattern establishes a fluvial dynamic equilibrium in arroyos and washes that is characterized by episodic aggradation and degradation of channel morphologic characteristics. The sediment is continually transported down-stream, normally at the maximum level of concentration possible for the kinetic energy available within a given flow.

Floodplains that develop on arid landscapes are wide and unstable, as the morphology and position of the main stem channels change with every major precipitation event. The migration of the channels across the landscape redistributes the sediment, with the primary source of sediment the mass wasting of the vertical sides of the arroyo channels. In comparison to the total amount of sediment involved in erosion, transport, and deposition during runoff from a given storm event, a relatively small amount of sediment actually leaves the watershed.

2.2.5 Vegetation

The response of vegetation to the low amount of precipitation in the arid and semiarid coal regions is evident. The major vegetation zones in this western environment are desert, grass and brush lands, and open forests types (e.g., pinyon-juniper and ponderosa pine) characterized by discontinuous and sparsely distributed grasses, forbs, shrubs, and trees. Species composition varies from north to south and at various elevations. Slope, aspect, moisture retention, and solar insulation play a significant role in the distribution of plants within a given area. Most plants within the arid and semiarid precipitation zones have adapted their ability to germinate, establish, and grow to the dry conditions and cycles prevalent throughout the region. With moisture availability being the primary limiting resource to plant growth, floral adaptations and growth habits center around a variety of moisture harvesting, conservation, and retention strategies. Living ground cover is frequently sparse, although cumulative ground cover may be significant since decomposition tends to be retarded by limited moisture availability.

2.2.6 Watershed Runoff Characteristics

Ephemeral and intermittent flows in the arid and semiarid western United States are unique in their flow and duration characteristics. Runoff generated by a single storm event may last from a few minutes to hours depending upon the size and characteristics of the affected watershed. Typically, flows last a few hours and, except for a high-water debris line, any evidence of their passage is gone within 48 hours or less. Frequently, flows run above ground for short to moderate distances, and gradually dissipate into the beds of the dry washes and arroyos they have followed or created.

While storms in this region typically drop less precipitation than their eastern counterparts, the intensity is often greater, and the amount of runoff generated is normally equal to or greater than that created by an eastern precipitation event of equivalent size. The increased runoff occurs because the poorly developed soil and sparse vegetation of western areas have a greatly reduced capacity to capture and harvest precipitation. The water that collects and drains from western precipitation events is nominally impeded and runoff characteristically takes the form of turbulent, high-velocity, flash floods. Rising stages often start initially as a trickle of water, followed by a wall of water roaring through the channel a few minutes later. Multiple crests may occur as subwatershed runoff is delivered to a main channel. As the flow recedes, velocity and volume fall off rapidly and trickle to an end over a period of a few hours.

Sediment concentration in these turbulent flows normally has a direct relationship to their kinetic energy. Sediment is in abundance within the channels where flow occurs and occurs at concentration levels near or at flow carrying capacity. Sediment concentration frequently varies over a wide range of concentration levels during a given flow event. Sediment content from a few thousand to 500,000 mg/L may be expected with values in the 25,000 to 150,000 mg/L range being common. The variation occurs primarily with changes in flow volume and velocity, although rising and falling stages may exhibit differing sediment concentrations at similar stage heights.

2.2.7 Cumulative Effect

The cumulative effect of the geologic, hydrologic, and climatic conditions unique to this arid and semiarid region can be summarized as follows:

- Western arid and semiarid areas are naturally geomorphically unstable;
- Landforms frequently exhibit dynamic geomorphologic and erosion processes;
- There is virtually an unlimited supply of sediment available within the arroyos and washes;
- Large volumes of sediment are normally transported by short duration, flooding, and turbulent flows;
- Particle erosion from a rough steep topography contributes dramatically to the natural generation of sediment;
- The runoff pattern predominating in ephemeral watersheds is flash flooding; and
- The sediment yield in tons per acre per year from these lands is significantly

higher than from similarly undisturbed vegetation covered lands of the mid-western and eastern United States.

Although water is sparse, the amount of water that physically runs off is significant due to the nature of the soils and the lack of effective surface cover. It is this runoff that has created the landscape and variable topography that is prevalent throughout this region. Environmental conditions limit surface and shallow subsurface water resources and the distribution and development of aquatic and riparian biologic resources. Direct use of surface-water runoff by man and wildlife also is limited due to its sporadic availability and poor physical quality. The limited surface-water resources that do occur within the region have high habitat and use values. Infiltration of surface runoff to local water tables provides limited, but valuable, useable ground-water resources.

Section 3.0 Best Management Practices

This section the use of sedimentation ponds in arid and semiarid regions, presents the theory behind BMP implementation, presents modeling techniques that aid in BMP design and prediction of BMP effectiveness, and describes the site-specific sediment control measures and techniques that may be employed.

3.1 Sediment

In arid and semiarid watersheds, sediment can be defined as all material transported by surface water drainage, including dissolved, total suspended, and settleable solids and bedload. In this environment, climate, topography, soil, vegetation and hydrologic components all combine to form a hydrologic balance that is naturally sediment rich. The dynamic fluvial systems in these watersheds depend upon a continuous source and flow of sediment to maintain the existing natural sediment balance. Consideration of the importance of sediment balance in this region is as critical as the availability of water.

3.2 Sedimentation Pond Use and Impacts in Arid and Semiarid Regions

The numeric effluent limitations established at 40 CFR part 434 for discharges in mining and non-process areas were based upon the treatment capabilities of sedimentation ponds, with nominal consideration of the impacts on the environment in the Western Region. Implementation of sedimentation ponds to meet these numeric effluent limitations has taken precedence over SMCRA's requirement to minimize possible impacts to the hydrologic balance.

Reliance on sedimentation ponds as the primary technology to control sediment and to achieve effluent limitations has resulted in the construction and operation of a significant number of ponds at coal mining and reclamation operations in the arid and semiarid west (Western Coal Mining Work Group, 1999a). While sedimentation ponds may be capable of achieving the sediment concentration reductions necessary to meet EPA discharge limitations, the net effect of achieving those reductions can represent a disruption of the hydrologic balance (Doehring, 1985). In summary, sedimentation pond use in arid and semiarid western regions can:

- Require significant additional surface disturbance;
- Result in environmental harm through the disruption of hydrologic balance;
- Adversely affect valuable riparian or aquatic communities; and
- Create contention during the administration of basin water rights.

3.2.1 Surface Disturbance

Due to topographic constraints, lease boundary constraints, and a high occurrence of ephemeral and intermittent drainage within western surface coal mine permit areas, sedimentation ponds are often constructed within natural drainage ways that convey surface runoff from both disturbed and undisturbed areas (Simons. Li & Associates, 1982). The larger volumes of runoff and sediment from these combined areas must be detained long enough to achieve CWA effluent limitations, requiring the construction of larger ponds and the disturbance of larger surface areas. With the establishment of the SS limits at 40 CFR part 434, sedimentation ponds were upgraded through expansion and new ponds were designed to increase detention times by providing larger volume capacity.

As an example of the significant impact of sedimentation ponds in arid and semiarid environments, the Western Coal Mining Work Group provided the following information from four coal mining sites. A breakdown of the number of sedimentation ponds being used, area disturbance and acres of watershed drainage at each mine site is presented in Table 3a. The Pittsburg & Midway Coal Mining Company's McKinley Mine in New Mexico uses 79 ponds, BHP Coal Company's Navajo Mine in New Mexico uses 30 sedimentation ponds, and Pacificorp's Dave Johnston Mine in Wyoming operates 14 sedimentation ponds. There are currently 149 sedimentation ponds with the potential to impound 4,500 acre-feet of water at the Peabody Western Coal Company’s Black Mesa Mine in Arizona. The total area of disturbance from the implementation of these sedimentation ponds is approximately 887 acres, resulting in an average of 3.3 surface acres disturbed per sedimentation pond.

Table 3a: Area Disturbance and Watershed Drainage of Sedimentation Ponds at Four Western Mine Operations (Western Coal Mining Work Group, 1999a)

Mine Site	Number Of Sedimentation Ponds	Acres Disturbed	Watershed Acres Draining Into Ponds
Black Mesa Mine	149	540	45,720
McKinley Mine	79	211	7,050
Navajo Mine	30	100	4,331
Dave Johnston Mine	14	36	4,567
Total	**272**	**887**	**61,668**

In contrast, Bridger Coal Company's operation in southern Wyoming (Section 5, Case Study 2) has successfully applied alternative sediment control measures for over 5,260 acres with only 3.9 acres of additional disturbance. If sedimentation ponds had been implemented at this site, the extensive surface area affected by mining and the drainage density would require operation of roughly 200 sedimentation ponds disturbing roughly 660 acres to control all runoff during the life of the mine.

3.2.2 Water Impoundment

Sediment control historically has focused on the capture of surface water runoff in sedimentation ponds located on the bottom periphery of disturbance areas (Western Coal Mining Work Group, 1999a). Surface water runoff contained in a sedimentation pond may evaporate, and therefore, may not be available for downstream or consumptive uses.

Sedimentation ponds typically are sized to treat or contain the combined sediment and runoff volume resulting from a 10-year, 24-hour storm event (Appendix C: 19 NMAC 8.2.20.2014, 1997). A result of the implementation of this design in arid and semiarid regions is that, for the majority of storm events, downstream channel flow is either eliminated or significantly attenuated. Loss of runoff water, through the storage of runoff in sedimentation ponds, evapotranspiration, and localized infiltration, can significantly affect the local hydrologic balance, downstream resources, ground water hydrology, and the spatial pattern of alluvial recharge (Doehring, 1985).

Sedimentation ponds have the potential in some cases to disrupt hydrologic balances and impact associated environmental resources. Downstream surface runoff volumes may be drastically reduced or completely eliminated if non-discharging structures are used for sediment treatment, and typically are reduced 80 to 90 percent below pre-mining flow rates when discharging ponds are used for water treatment (Western Coal Mining Work Group, 1999a). Disruption of flow volume at this magnitude is a concern in arid and semiarid regions. Avoiding or minimizing disruption to stream flow is also a "key program objective and activity to be undertaken in the next decade" by the Water Quality Criteria And Standards Plan-Priorities for the Future (U.S. EPA, 1998).

The National Mining Association employed computer modeling techniques to predict BMP and sedimentation pond performance and resulting sediment yield at non-process areas for three representative model mines in the arid and semiarid west (Western Coal Mining Work Group, 1999c). Details of these prediction studies are presented in Section 5, Case Studies 1, 2, and 3, and in Appendix D of this document. In a model of the Desert Southwest Coal Region, the maximum storage capacity of sedimentation ponds used for the model was 60 acre-feet. This means that out of 73 acre-feet of runoff (predicted from a 10-year, 24-hour precipitation event for the reclaimed and adjacent undisturbed areas), only about 13 acre-feet would pass through the sedimentation pond. The model assumed an additional 30 acre-feet of water would be released from the pond system to the downstream watershed by automatic dewatering over an 8-day period. Thus, the runoff volume from the storm event that would pass through the pond and be available to the down-drainage hydrologic system would be only 41 percent of the total runoff volume produced by the storm. In addition, the peak flow was predicted to be 45 cfs when sedimentation ponds are implemented and 602 cfs when alternative sediment control BMPs are implemented. This peak flow compares to 679 cfs predicted to occur naturally under undisturbed conditions. Similar model results for the Intermountain and Northern Plains coal regions resulted in a 96-97% reduction in naturally occurring peak flow when sedimentation ponds are used to meet numeric limits, compared to a 33-38% reduction in naturally occurring peak flow when using alternate sediment controls. The result of these models demonstrate that the use of alternate sediment control systems increases the amount of precipitation runoff that is available to the drainage area.

BMP systems minimize disruption to the hydrologic balance through the use of alternate sediment controls (Western Coal Mining Work Group, 1999c). Case Study 1 predicted that, with BMP system application in the Desert Southwest, approximately 73 acre-feet of water would be available as a result of the receipt of a 10-year, 24-hour precipitation event. By depriving downstream channels of small but relatively frequent flows, channel geometry is not maintained (Doehring, 1985). Unused channels are modified by the processes of mass wasting; caving banks and slope processes that destroy the channels and eliminate their ability to convey flows of sediment and water. In cases where some flow is maintained, a small, "underfit", inner channel is produced. While sedimentation ponds may be capable of achieving the sediment concentration reductions necessary to meet EPA discharge limitations, the net effect of achieving those reductions is often the triggering of large bursts of sediment produced by channel adjustments. When substantial flows return, either due to a high yield storm or due to removal of the sedimentation pond, accelerated erosion and flooding can be expected.

Many western states have long recognized the social and economic importance of their limited surface water and ground water resources and have instituted water rights procedures to prioritize and allocate beneficial usage. However, in order to achieve existing CWA effluent criteria for coal mining operations, regulations and guidelines emphasizing the construction of sedimentation ponds may discourage beneficial usage of water. Regardless of the magnitude of drainage area controlled, the construction and operation of sedimentation ponds reduces the amount of surface runoff available for downstream users. The loss of surface water runoff and ground water recharge due to sedimentation ponds continues to be an issue in water rights negotiations (Western Coal Mining Work Group, 1999a).

3.2.3 Sediment Retention

In arid and semiarid western coal mine regions, large amounts of sediment are readily and naturally transported. Sediment is an important and integral part of these hydrologic systems. In fact, these systems depend upon a continual source and flow of sediment to maintain the existing natural sediment balance.

In order to predict the amount of sediment that will be transported out of a representative model mine in an arid western watershed, the Western Coal Mining Work Group implemented SEDCAD 4.0 (Western Coal Mining Work Group, 1999c). With the implementation of sedimentation ponds to comply with numeric effluent guidelines, SEDCAD 4.0 estimated that 0.0 acre-feet of sediment per year would be transported out of the watershed. With implementation of appropriate alternative sediment control BMPs, SEDCAD 4.0 estimated that an average annual sediment yield of 6.7 acre-feet would be transported out of the watershed, which closely approximates the 8.3 acre-feet per year estimated sediment yield for an undisturbed watershed (see Section 5.1, Case Study 1). The essential containment realized by the sedimentation ponds represents a gross disruption of sediment movement through the fluvial system.

3.2.4 Scouring and Seeps

SMCRA requires operators of coal mines to prevent, to the extent possible, additional contributions of sediment to receiving waters, and to protect the balance of the hydrologic system. Since sediment is an integral part of the arid and semiarid geomorphic and hydrologic system, maintenance of background levels of sediment in mine discharges is crucial to maintaining the hydrologic balance (Water Engineering and Technology, 1986). At times of normal runoff in this region, sedimentation ponds can intercept and detain virtually all flow and waterborne sediment, including both the natural and the mining-generated components (Doehring, 1985). Additionally, clean water that is released from the ponds can accelerate erosion in channel beds in the reach immediately downstream (Williams and Wolman, 1984).

The combination of localized scour (increased erosion caused by sediment-free water) coupled with attenuated flows can cause the incised channel width to decrease within this reach. Riparian and other hydrophytic vegetation are limited in arid and semiarid regions, and fluctuations in water tables fed by surface water runoff can cause these valuable biologic communities to shrink considerably or even disappear.

Another potential impact from the implementation of sedimentation ponds, as the only means to control sediment, is the occurrence of intermittent seeps that have been observed and monitored at several sites since the early 1980s (Western Coal Mining Work Group, 1999a). Intermittent seeps reported at Peabody Western Coal Company's Black Mesa Mine have developed as a result of impounded water interacting with local geologic materials in the vicinity of the sedimentation pond embankments. These seeps are expected to persist intermittently at several pond locations until the ponds are removed and reclaimed. Concerns expressed by local residents resulted in an EPA requirement to study the seeps, report the findings of the study, and develop a plan to mitigate the seeps as part of the Black Mesa NPDES permit. The formation of springs and seeps in the immediate downstream vicinity of sedimentation ponds also can result in a localized proliferation of vegetation that can encroach on channels (Williams and Wolman, 1984).

3.3 Sediment Control BMPs

Erosion and sediment controls are used to reduce the amount of soil particles that are carried off of a land area and deposited in receiving water. Soil erosion and sediment control is not a new technology. Many sediment control BMPs already are an integral part of mining and reclamation operations and do not require additional engineering designs or construction. For this reason, implementation can require minimal additional labor and the use of conventional equipment and materials that already are on site and operational. Most BMPs are adaptable to all regions of the country, with the exception of extremely arid regions of the West (Montana DEQ, 1996). In these regions, conventional BMP designs may need to be refined to account for high evaporation rates, and new or modified BMP options should be explored. The USDA Soil

Conservation Service and a number of state and local agencies have been developing and promoting the use of sediment control technologies for years (EPA, 1992).

Design and application of erosion and sedimentation control technology has improved since the passage of SMCRA and since EPA's promulgation of technology-based numerical effluent limits. Extensive monitoring and case studies have been performed on arid and semiarid lands to characterize the nature and extent of erosion occurring within these areas. Computer sedimentation modeling of arid and semiarid fluvial systems has advanced significantly, evolving into site-specific models that are sensitive to the highly variable environmental factors found within the region. Designers and manufacturers of erosion and sedimentation control products have also contributed significantly to the improvement of BMPs. Manufacturers are providing improved and innovative products capable of addressing generic and specific sediment and erosion control problems. Advanced computer prediction models, comprehensive environmental erosion and sediment management practices, and new erosion control materials and equipment form the core of the BMPs that may more appropriately address sedimentation in arid and semiarid coal mining regions.

Using BMP systems designed to address site-specific erosion and sedimentation concerns using current modeling techniques, it is now possible to effectively control erosion and sediment transport, while concurrently minimizing disruption of the fluvial balance. Allowing runoff to "flow naturally" from disturbed and reclaimed areas is environmentally and socially preferable to non-consumptive retention in sedimentation ponds that is accompanied by episodic releases of runoff resulting in sediment imbalances that are potentially disruptive to watershed fluvial morphology.

In summary, BMPs may be either short-term or long-term in their effectiveness. Methods and practices that are capable of harvesting and conserving moisture, limiting soil detachment and erosion, or accomplishing both simultaneously with reasonable economic expenditures find ready acceptance and wide use throughout the mining industry (Western Coal Mining Work Group, 1999a). Many types of erosion and sediment control BMPs and methods are currently used by the coal mining industry within reclaimed areas, serving to reduce the total sediment impoundment volume required to treat runoff to numerical effluent standards. Increased focus on the implemention of site-specific sediment control BMPs serves to address sediment at the source, enhance vegetation growth and stabilize reclaimed lands.

BMPs can be categorized into two descriptive types, either Managerial or Structural. These may vary over the life of the disturbance or reclamation period, depending upon changing site conditions. The characteristics and components of each type of BMP are presented in greater detail in Sections 3.3.1 and 3.3.2.

3.3.1 Managerial BMPs

Managerial sediment control BMPs include project design and planning methods used to protect water quality and minimize erosion and sedimentation. Managerial BMPs are employed prior to, during, and following reclamation of a site. Managerial methods that may be employed at a site are listed in Table 3b.

Table 3b: Examples of Managerial Sediment and Erosion Control Practices (Western Coal Mining Work Group, 1999a)

Managerial Sediment	Implementation Technique
Minimizing the Area of Disturbance	Surface disturbances are minimized to that specific area necessary to conduct the mining and reclamation.
Appropriate Application	BMPs are judiciously used based on erosion and sedimentation control capabilities, site-specific environmental conditions, and sedimentation predictions.
Timely Placement	Structures are placed at the most appropriate time to function properly and effectively during their anticipated use period.
Control Sediment at Source	BMPs are implemented at the source of sediment. Terraces, check dams, straw bales, riprap, mulch, silt fences, etc. are implemented to control overland flow, trap sediment in runoff or protect the disturbed land surface from erosion.
Contemporaneous Reclamation	After mineral extraction is complete, disturbed areas are reclaimed as rapidly as is practicable and rehabilitated for the designated post-mining land use.
Periodic Inspection, Maintenance and Replacement	BMPs are periodically inspected during construction and use. Based on these inspections, maintenance is scheduled and adequately performed. When structures can no longer be reasonably maintained, they are replaced if necessary. When BMP structures are no longer needed, they are removed, if necessary, and the disturbed area reclaimed. Most BMPs are installed as integral components of the surface drainage system and their removal is not needed.

3.3.2 Structural BMPs

Structural BMPs are the physical structures, methods, practices, and products implemented and used to achieve erosion and sedimentation control. These BMPs are combined with managerial practices and monitoring plans to form complete BMP systems for a given site. Structural sediment control BMPs primarily include regrading, revegetation, sediment trapping, and control of surface runoff. Examples of common structural sediment control BMPs are listed in Table 3c. EPA recognizes that Table 3c is not inclusive of all sediment control BMPs that are appropriate for use in arid and semiarid regions. Numerous additional BMPs and BMP combinations currently exist and are being used effectively.

Table 3c: Examples of Structural Best Management Practices (Western Coal Mining Work Group, 1999a, Carlson, 1995, Bonine, 1995, Toy and Foster, 1998, U.S. Mining and Reclamation Council of America, 1985)

BMP	Sediment Control Characteristics And Design Techniques
Straw Bales	Inhibit surface runoff and stop the movement of sediment. Bales are used across medium slopes or at the toes of steep slopes.
Terraces or Benches	Reduce slope lengths and water velocities and increase infiltration. Constructed as wide (10'-20') horizontal, level or slightly reverse sloping steps in intervals down the slope on or near contours.
Deep Ripping	Breaks compacted layers, heavy clays, and soil-minesoil interfaces. Increases infiltration and reduces flow velocities. Ripping loosens and mixes subsoil and allows root penetration and subsurface water storage.
Contour Berms	Control or divert surface runoff flow. Care must be taken to assure a level top surface with no low spots where breaching could occur. Berm height varies from one to three feet. Berms that will be in existence for longer than one year are vegetated to reduce erosion.
Diversion Channels	Convey runoff from points of concentration across, through, along, and around areas to be protected. Designed for peak flows based upon a 10-year, 24-hour storm event. Typically two feet deep with a run-to-rise ration of 3:1. Those in existence for longer than one year are vegetated to reduce erosion.
Check Dams	Stabilize channel grades and control channel head cutting. Reduce or prevent excessive erosion by reducing velocities in diversions, conveyances and sedimentation pond inlets or by providing partial channel sections or structures that can withstand high flow velocities. Dam height is dictated by flow amount, channel slope, and available cross sectional area. Sized to pass 10-year, 24-hour runoff event.
Interceptor Ditch - Slope Drain (Contour Ditch)	Ditches are placed horizontally at vertical intervals on long slopes to reduce the effective slope length, slow runoff, reduce erosion and enhance sediment deposition. They are generally 1.5 feet deep with a run-to-rise ration of 2:1. Ditches are spaced approximately 50 feet apart horizontally.
Mulch	Temporary soil stabilization. Used to increase infiltration, retain water, add surface roughness, decrease runoff, protect soil surface from erosive action of raindrops, and to enhance seedbed for vegetative growth. When used together with seeding or planting, mulching can aid in plant growth by holding the seeds, fertilizers, and topsoil in place. Helps to retain moisture and insulate against extreme temperatures. In general, higher mulch application rates (lbs/acre) are needed for western regions.
Mulch Crimping	Increases the effectiveness of mulch against surface erosion by water and wind. It is accomplished by tacking mulch materials into the soil surface using blunt or notched disks that are forced into the soil.
Geotextiles	Geotextiles, when used alone, can be used as matting to stabilize runoff flow. Geotextile matting also can be used on recently planted slopes to protect seedlings until they become established or as a separator between riprap and soil.

BMP	Sediment Control Characteristics And Design Techniques
Roughened Surface - Control Discing	Increases infiltration. Surface roughening is commonly accomplished through the use of agricultural techniques including discing, plowing, contour furrowing, and land imprinting.
Pitting	A mechanical treatment measure which creates small, basin like depressions that increase surface water revegetation potential of a site. Pitting as a water conservation and erosion control measure is used on mined lands before seeding and planting. The method has been used mainly in arid or semiarid regions where the water conservancy methods are most critical.
Sediment Traps	Provide small storage or detention areas without special inlet or outlet controls. Constructed by excavation, or by creating an impoundment with logs, silt fence or brush barrier/filter cloth as a low head dam.
Contour Plowing	Prevents rill formation. Furrows formed by contour plowing also add roughness and enhance infiltration.
Complex Slope	Slopes graded with three segments: upper convex, middle straight, lower concave. Straight slopes are minimized and concave slope is maximized to reduce erosion and promote deposition on the lower slope segment.
Drainage to Pit	Runoff from disturbed areas drains either directly to or is diverted to the pit. This water evaporates or is pumped to holding ponds. Holding pond water is discharged in accordance with NPDES requirements.
Cover Crop	Broadcast or drill seeded. Establishes quick live cover & root system. Stubble acts as surface roughness during winter.
Regrading	Regrading to approximate original contour or other acceptable slope gradients and configurations can substantially reduce soil loss rates. Although the construction of complex or concave hill slope profiles offer grading challenges, these shapes can substantially reduce soil loss rates.
Livestock Grazing	Controlled livestock grazing can have positive sediment control impacts on reclaimed areas, such as increasing vegetation cover and production, creating surface roughening, promoting soil formation, and increasing soil microbial populations, all of which serve to control erosion and sedimentation. It is important to have established vegetative cover prior to allowing grazing on reclaimed land.
Irrigation	If there is not enough rainfall on the area for establishing vegetation, the area can be irrigated.
Landscape Configuration	Establishes reclaimed topography that is stable with surrounding terrain and climate. Configuration measures include shorter slopes, complex slopes, and proper drainage profiles.
Revegetation	Adds soil stability and surface roughness, reduces rainfall erosion, and physically secures soil making it less erosive.
Toe Drain Ditches	Store or divert slope runoff. These channels are open, of any cross sectional shape and are constructed at the toe of exposed slope surfaces.

3.3.3 BMP Implementation

Selection of sediment control BMPs for mining or reclamation activities should be based on site-specific conditions. The BMP plan should be designed to: minimize the amount of disturbed soil, control runoff flowing across a site, remove excess sediment from onsite runoff before it leaves the site, and meet or exceed local or state requirements for sediment and erosion control plans. In most situations, a combination of BMPs is necessary to adequately control sediment and erosion. Moreover, these BMPs must be properly designed, implemented and maintained in order to be effective. Implementation of managerial practices and structural sediment control BMPs, either in addition or as an alternative to sedimentation ponds, should be expected to:

- Maintain adequate "natural sediment loading" to avoid disruption of the fluvial system, while preventing impacts to environmental and biologic resources in watersheds affected by mining;
- Minimize reductions in downstream runoff;
- Reduce unnecessary additional disturbance of surface acreage; and
- Restore or improve riparian and natural vegetative species.

Appropriate alternative sediment control BMPs can be designed and implemented using site-specific design evaluations of the various disturbance activities anticipated over the life of the mining or reclamation operation. BMPs may be used singly or in combination to effectively control and minimize erosion and sedimentation from disturbed areas.

BMP plans should consider the background environmental conditions (i.e., size of site, soil types, drainage pattern, rainfall data, receiving channels, and land use) to establish reasonable and acceptable implementation and monitoring design criteria. The design should include modeling of disturbance phases to determine the control and treatment practices and methods to be used to ensure compliance with the site-specific performance-based standards during the various disturbance and reclamation phases. BMP designs should demonstrate that erosion will be controlled, deepening or enlargement of stream channels will be prevented, disturbance of the hydrologic balance will be minimal, and additional contributions of sediment of stream flow and runoff outside the permit area will be prevented to the greatest extent possible. BMP design, construction, implementation, and monitoring represent the complete BMP system for a given location.

The key to the effective planning and implementation of a BMP system is deployment flexibility. For a given situation, there may be several BMP combinations that will adequately control erosion and sedimentation. The type of BMP that is most effective may also change through time. For example, during the early stages of establishing vegetation on non-process areas, livestock grazing represents a potentially disruptive land use activity. However, once the vegetation is firmly established, livestock grazing can act as an effective BMP. The operational preferences of mining companies can result in the design and use of a variety of different combinations of sediment control practices for essentially similar areas. The critical goal that must be realized is the adequate control of surface erosion and retention of sediment in order to meet the site's water quality requirements. The primary purpose of sediment control BMPs is to control sediment at the source and to minimize erosion caused by wind and water. A sediment control plan should demonstrate that all exposed or disturbed areas are stabilized to the greatest extent possible.

Sediment control BMPs can be categorized according to function as follows: Topographic, Slope Erosion, Flow Structures, Soil Conservation, and Vegetation. BMPs that fall within these categories may be universal or limited in their application. For example, reconstructed drainage channels usually are limited to use within low-lying reclaimed areas, while permanent vegetation typically is established throughout a reclaimed landscape. Appropriate sediment control BMPs are designed and implemented using site-specific evaluations of the various activities anticipated during mining or reclamation operations.

3.3.3.1 Topographic BMPs

In order to prevent unnatural sedimentation, mined land surface areas should be reclaimed to a grade necessary to control surface water runoff and promote appropriate drainage and stability. Terrace and bench-type grading can prevent slides and sedimentation while promoting slope stability. Topographic BMPs include:

- Planning post-mining topography using modeling to mimic approximate original contour or pre-mining natural, background erosion and sedimentation yields;
- Designing and implementing a BMP plan that will approximate natural drainage as closely as possible;
- Choosing sediment control structures according to review of existing topography, flow direction and volume, outlet location, and feasibility of construction;
- Backfilling and grading to approximate original topography or other acceptable slope gradients and configurations. Blending disturbed areas into the surrounding terrain; and
- Eliminating unstable areas to the greatest extent possible.

3.3.3.2 Slope Erosion

BMPs that control slope erosion are implemented to stabilize and protect slopes against surface erosion. Slope surfaces should be mulched, vegetated or otherwise stabilized to minimize sediment movement, and, on a site-specific basis, to address particular erosion problem spots according to need. Construction of terraces, benches, and other grading or drainage control measures can be utilized to prevent erosion and ensure slope stability. These structures should be designed to be non-erodible and to carry short-term, periodic flows at non-erosive velocities. These BMPs often help stabilize steeply sloped areas until vegetation can be established. BMPs that serve to control erosion and sedimentation from slopes include:

- Limiting slope length according to modeling prediction of surface runoff sediment yield;

- Creating slope shapes which promote stability through protective surface configurations (concave vs. convex, simple vs. complex);
- Providing non-erosive mulches or surface cover materials (e.g., durable rock fills that limit erosion through adequate surface protection); and
- Segmentation of slopes through construction of terraces or benches to limit slope length and provide protected drainage.

3.3.3.3 Flow Structures

Hydrologic flow structures are implemented to ensure that additional contributions of sediment to stream flow and to runoff outside the permit area are prevented to the greatest extent possible. These BMPs are implemented to direct runoff away from exposed or unstable surface areas, to control runoff volume and velocity, and to provide water for establishment of vegetative cover. These structures should be inspected regularly, compacted according to applicable standards, and maintained properly to ensure maximum effectiveness. BMPs that utilize flow structures include:

- Implementing diversions, reclaimed channels, drains, terrace drains, down-drains, and ditches capable of conveying surface water runoff from designated worst-case storm events and worst-case watershed disturbance conditions around, through or from the disturbed/reclaimed area;
- Implementing flow structures in a manner that reduces runoff flow velocity and thus reduces loosening or removal of soil particles; and
- Designing flow structures with adequate sizing, configuration and protective linings to provide stable watercourses for anticipated flow volumes and velocities.

3.3.3.4 Soil Conservation

BMPs that are implemented to conserve soil tend to protect exposed surfaces against the erosive effects of wind and water by manipulating the soil surface or providing surface cover amendments. A sediment control BMP plan should demonstrate that all exposed or disturbed areas are stabilized to the greatest extent possible, as quickly as possible following disturbance. Surface erosion protection practices and materials include:

- Mulching with organic or inorganic materials or applying geotextile fabrics;
- Preserving existing vegetation;
- Establishing quick-growing cover crops with annual or perennial plant species; and
- Roughening exposed surfaces. Surface roughening is commonly accomplished through the use of agricultural techniques including discing, plowing, and contour furrowing.

3.3.3.5 Vegetation

Land in arid and semiarid climates tends to have relatively low vegetation cover and productivity, particularly where annual rainfall is less than 9 inches per year. Total vegetation cover values frequently fall within the range of 5 to 20 percent. Yearly vegetation production tends to be low, with most reclaimed areas producing between 500 to 1,000 pounds per acre annually (Western Coal Mining Work Group, 1999a).

Preserving existing vegetation or vegetating disturbed soil as soon as possible after surface disturbance is the most effective way to control erosion (U.S. EPA, 1992). A vegetative cover reduces erosion potential by: (1) shielding the surface from the direct erosive impact of raindrops, (2) reducing sediment runoff to downstream areas, (3) filtering sediment, (4) improving the soil's water storage capacity, (5) slowing runoff and allowing sediment to drop out or deposit, and (6) physically holding the soil in place.

Establishment of vegetation can be a short-term (temporary) or long-term (permanent) method for controlling erosion and sedimentation. Plant species are selected based upon land use, growth conditions, and environmental requirements. Temporary seeding should take place as soon as practicable after the most recent land disturbing activity. In arid and semiarid regions where the climate prevents fast growth, temporary seeding may not be effective (U.S.EPA, 1992). In these regions, mulching may be more appropriate for short-term stabilization.

Common goals for permanent vegetation include the establishment of adequate cover, production, and diversity to support designated post-mining land use(s), and to protect the soil from excessive surface erosion. Proper seedbed preparation, the use of high-quality seeds, and the application of mulch may be necessary for effective erosion control. In arid and semiarid regions, irrigation and the addition of topsoil or other soil amendments may be required to make conditions more suitable for plant growth. Although the use of native species is recommended, both non-native and native plant species may be used for routine and specialized seeding and transplanting programs. Bioengineering or specialized plantings may be used singly or in combination with hard structures to achieve erosion control and protect and enhance the effective life of critical erosion and sedimentation control structures or features.

Seed mixtures are an integral component of a BMP reclamation plan and are an important component in vegetative success. A diverse seed mixture, coupled with appropriate water management, accelerates early plant community development and diversity. Mixtures and application rates dramatically influence vegetation germination, establishment and development.

Land use can have a dramatic effect on a reclaimed area's vegetation characteristics. Reclamation land use in the arid and semiarid western United States is primarily rangeland with livestock grazing normally a part of the post-mining land use. Controlled grazing can be used effectively to promote vegetation growth and development, soil stability and surface water hydrology. Livestock grazing has been successfully used as part of BMP systems to increase vegetation density on most western coal mine non-process areas.

3.3.3.6 Geochemistry

The geochemistry of the western arid and semiarid coal regions, which is generally alkaline, differs from that of the eastern coal regions. Western alkaline coal regions, unlike eastern regions, contain large quantities of sandstone and limestone that contain high levels of calcium and carbonate minerals (e.g., calcite, dolomite). These minerals inhibit H^+ formation from pyrite via the following equation (Hornberger, 1981; Williams, 1982; Perry and Brady, 1995):

$$FeS_2 + 4\ CaCO_3 + 3.75\ O_2 + 3.5\ H_2O \rightarrow Fe(OH)_3 + 2\ SO_4^{2-} + 4\ Ca^{2+} + 4\ HCO_3^-$$

Dissolved carbonate minerals also promote precipitation of dissolved iron and other metals ions to further neutralize acidity. Studies have shown that a 3% (or greater) concentration of carbonate minerals will produce alkaline mine drainage (*Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania*, 1999). The net alkalinity of drainage from these coal regions indicates high concentrations of carbonate that will counter potential acidity. As a result, the production of acid mine drainage is much less typical due to the inherent buffering capacity.

In natural undisturbed conditions, surface water samples in the arid/semiarid western United States can register values for total iron as high as 40,000 mg/L (or 4%), due to the sediment that is collected as part of the water sample. The primary mineral responsible for the high total iron readings is often magnetite, which is often visible on the floor of arroyos.

In addition, in the western coal regions there is a low occurrence of pyrite which, along with dissolved iron, is the common culprit of acid mine drainage generation. Instead, iron often occurs in the form of magnetite (Fe_3O_4), a solid, inert iron oxide that has no acid-forming potential. The following data from a USGS website support the commenter's assertion that there is comparatively less iron (average of almost 1:3) and pyritic sulfur (average of over 1:5) in western coal versus eastern coal (Table 3d):

Table 3d: Summary of Coal Quality Data in Western and Eastern Coal Regions

	Western Coal Region[1]			Eastern Coal Region[2]		
	N	**Range**	**Average**	**N**	**Range**	**Average**
Total Iron (mg/L)	1258	110 - 52,000	5652	4511	72 - 120,000	15,082
Sulfate (%)	1045	0 - 0.69	0.03	3623	0 - 25.54	0.07
Pyritic Sulfur (%)	1045	0 - 4.5	0.25	3905	0 - 12.1	1.32
Total Sulfur (mg/L)	1191	15 - 31,000	3722	4401	4 - 20,000	1072

Data from http://energy.er.usgs.gov/coalqual.htm : National Coal Resources Data System, U.S. Coal Quality Database.

[1]Data from the following States were considered under the Western Coal Region: AZ, CO, NM, WY

[2]Data from the following States were considered under the Eastern Coal Region: AL, KY, MD, OH, PA, TN, VA, WV

Of the forms of iron that can exist in coal mine discharges, only pyrite and dissolved iron have acid-forming potential at pH $\geq$6. Dissolved iron contained in coal mine drainage can come from multiple sources, one of which is pyrite. The series of reactions below characterize pyrite oxidation and the resulting acid formation. As can be seen, dissolved iron (Fe^{2+}, Fe^{3+}) is an intermediate product of acid formation from pyrite.

1) FeS_2 (pyrite)(s) + 3.75 O_2 + 3.5 H_20 = Fe^{2+} + 2 SO_4^{2-} + 2 H^+

2) Fe^{2+} + 0.25 O_2 + H^+ = Fe^{3+} + 5 H_2O

3) FeS_2 (pyrite)(s) + 14 Fe^{3+} + 8 H_2O = 15 Fe^{2+} + 2 SO_4^{2-} + 16 H^+

4) Fe^{3+} + 3 H_2O = $Fe(OH)_3$(s) + 3 H^+

Studies have shown that, in most coal mine drainage, an abundance of dissolved iron indicates H^+ formation from pyrite oxidation (Rose and Cravotta, 1999). Therefore, even if pyrite is present (which is unlikely in the western coal regions), the effect of its presence will not escape detection so long as dissolved iron is measured. Other forms of iron, such as iron hydroxide ($Fe(OH)_3$(s)) and magnetite (Fe_3O_4(s)), are insoluble and unreactive at pH $\geq$ 6. In fact, encouraging magnetite precipitation is being investigated for use in treatment of acid mine drainage (Morgan, 2001).

EPA has established the applicability of the Western Alkaline Coal Mining Subcategory as follows: “This subpart applies to drainage at western coal mining operations from non-process areas, brushing and grubbing areas, topsoil stockpiling areas, and regraded areas where the discharge, before any treatment, meets all the following requirements: pH is equal to or greater than 6, dissolved iron concentration is less than 10 mg/L, and net alkalinity is greater than zero.” This applicability is consistent with the definitions of both acid and alkaline mine drainage, and with EPA recognition that net alkalinity or acidity is a the defining characteristic of acid mine drainage in terms of the potential to form more acidity.

3.4 Prediction Models for BMP Design and Implementation

The major factors affecting soil erosion are soil characteristics, climate, rainfall intensity and duration, vegetation or other surface cover, and topography. Understanding the factors that affect erosion makes it possible to predict the extent and consequences of onsite erosion (U.S. EPA, 1992). Although an estimate of sediment erosion and deposition can be derived over time using water samples or sediment accumulation markers, this method of erosion prediction can be time consuming and labor intensive. Prior to implementation of sediment control BMPs, it is important to determine both the quantity of sedimentation and the sedimentation patterns that can be expected. Sites must be assessed to determine pre-mining drainage patterns and topography, to quantify effects of storm runoff and the yield of coarse- and fine-grained sediment, and to determine morphologic evolution of streams, washes, and arroyos.

Although an estimate of sediment erosion and deposition can be derived over time using water samples or sediment accumulation markers, these methods of erosion prediction are time consuming and often labor intensive. The collection of sufficient soil-loss data from natural rainfall events on erosion plots to permit confidence in the results of statistical analyses has proven to be a long-term, expensive, and inefficient undertaking (Toy, 1998). Sediment transport can be predicted with reasonable accuracy using computer models developed for this purpose during the last 20 years.

Computer models have been developed to assess and predict erosion, soil loss, and sediment yields from undisturbed lands experiencing overland flow, from lands undergoing disturbances, and from newly established or reclaimed lands. Computer models are commonly used to evaluate watershed response and assess impacts of land use and are capable of determining the effectiveness of BMPs on erosion control and sediment production prior to field use. These models are particularly valuable in arid and semiarid areas because the infrequency of precipitation discourages compilation of data from instrumented watersheds. When calibrated, the models provide a means for comparing sediment loss under undisturbed (premine) and reclaimed mine land conditions (Peterson, 1995). Examples of soil loss prediction models include:

- SEDCAD 4.0
- RUSLE
- EASI
- SEDIMOT II
- MULTSED

The efficiency and accuracy of these models has improved dramatically as extensive environmental databases and product specifications have been developed. A great deal of study has been performed regarding mined land and new erosion and sedimentation control and treatment products, to develop and verify these modeling programs. Most importantly, the models provide a constant base from which to evaluate pre-mining and post-mining sediment delivery (Peterson, 1995). Computer simulations allow mine operators to determine which combination of managerial and/or structural BMPs will be most effective at controlling sediment and erosion at a specific mining or reclamation site.

3.4.1 Revised Universal Soil Loss Equation (RUSLE)

The Universal Soil Loss Equation (USLE) developed in 1961, was designed to predict average annual soil loss caused by sheet and rill erosion. The USLE can estimate long-term annual soil loss and guide conservationists on proper cropping, management, and conservation practices, but it can not be applied to a specific year or a specific storm event. USLE was modified as the Modified Universal Soil Loss Equation (MUSLE) to replace USLE's rainfall factor with a runoff factor. The MUSLE model assumes that sediment yield is related to peak discharge and runoff volume.

The Revised Universal Soil Loss Equation (RUSLE), based extensively on the USLE model and its data, was developed to estimate average annual soil loss in larger, steeply sloped areas and can accommodate undisturbed soil, spoil, and soil-substitute material, percent cover, random surface roughness, mulches, vegetation types, mechanical equipment effects on soil roughness, hill-slope shape, and surface manipulation. RUSLE is applicable to sheet and rill detachment only, and does not estimate gully or stream-channel erosion or compute deposition.

RUSLE is based on a set of equations that estimate annual soil loss (soil removed from the hillslope or hillslope segment). It was derived from the theory of erosion processes, more than 10,000 plot-years of data from natural rainfall plots, and numerous rainfall-simulation plots. RUSLE retains the structure of USLE (Pennsylvania Department of Environmental Protection, 1999, Renard, 1997) and takes the form of the following equation (Toy, 1998).

$$\mathbf{A = RKLSCP}$$

Where:

A = Computed Soil Loss (Annual Soil Loss as tons/acre/year)

R = Climatic Erosivity or Rainfall erosion index - a measure of the erosive force and intensity of a specific rainfall or the normal yearly rainfall for specific climatic regions

K = Soil Erodibility Factor - Ability of soils to resist erosive energy of rain. A measure of the erosion potential for a specific soil type based on inherent physical properties (particle size, organic matter, aggregate stability, permeability). Soils with a K value of 0.17 or less are considered slightly erodible, and those with a K value of 0.45 or higher are highly erodible. Soils in disturbed areas can be more easily eroded regardless of the listed K value for the soil type because the structure has been changed.

LS = Steepness Factor - Combination factor for slope length and gradient

C = Cover and Management Factor - Type of vegetation and cover. The ratio of soil loss from a field with specific cropping relative to that from the fallow condition on which the factor K is evaluated.

P = Support Practice - Erosion control practice factor, the ratio of soil loss under specified management practices.

3.4.2 SEDCAD

SEDCAD is a comprehensive model that enables the user to evaluate the performance of erosion and sediment controls. SEDCAD calculates the amount of runoff and sediment generated in response to a given precipitation event for specific soil and vegetative cover conditions, analyzes the effectiveness of sediment/erosion control structures in meeting effluent standards, and allows the design of cost effective sediment erosion control structures. SEDCAD is widely used throughout the mining industry and is the program used by the OSMRE to review mine permits, and to design and evaluate structure performance in OSMRE's Abandoned Mine Land Program.

SEDCAD is a hydrology and sedimentology routing model used to simulate peak flows, drainage volumes, and sediment yields from undisturbed and disturbed/reclaimed watersheds. Hydrograph development and peak flow determination are based on user inputs of a design storm (e.g., rainfall amount and duration and selection of a rainfall distribution). Hydrographs are developed on a subwatershed basis with the input area, time of concentration, Natural Resources Conservation Service (NRCS) curve number, and selection of one of three dimensionless double triangle unit hydrographs. Routing of hydrographs is accomplished by Muskingum's method (Warner and Schwab, 1998).

The sediment yield and concentrations of TSS and SS are also determined on a subwatershed basis. SEDCAD uses a subroutine that implements a method similar to RUSLE to determine average annual sediment yield. SEDCAD sedimentology input values may be taken directly from RUSLE results, allowing the two models to work in tandem. Sediment routing is determined in conjunction with runoff hydrograph routing, and considers the eroded particle size distributions of the soils exposed to rainfall and runoff. An example of combining RUSLE and SEDCAD computer models to determine background sediment yield and predict the effects of sediment controls is presented in Section 5, Case Study 1.

3.4.3 SEDIMOT II

SEDIMOT II considers a number of field parameters (sediment type and concentration, vegetation type, slope and length of filters) that affect sediment transport and deposition through filtering materials or vegetation. SEDIMOT II is capable of evaluating the hydraulic and sediment response of a watershed as well as the effectiveness of detention ponds, grass filters, and check dams (Wilson, 1984). Flow is described by the continuity equation and by steady-state infiltration (i.e., flow decreases linearly from upstream to downstream in the filter). SEDIMOT II is based on the hydraulics of flow and the transport and deposition profiles of sediment in laboratory conditions. The model does not handle time dependent infiltration or changes in flow resulting from sediment deposition during a storm event.

The user of the model divides the drainage basin into subwatersheds of relatively uniform land use. A hydrograph, sediment graph, and particle size distribution are determined for each subwatershed, routed downstream, and then combined to form a composite hydrograph, sediment graph, and particle size distribution. In the hydrologic component of SEDIMOT II, the Soil Conservation Service (SCS) curve number method is used to determine rainfall excess, the unit hydrograph theory is used to calculate a runoff hydrograph, and the Muskingum procedure is used for channel routing. An example of combining SEDIMOT II and SEDCAD computer models to determine background sediment yield and design sediment control plans is presented in Section 5, Case Study 2.

3.4.4 HEC-6

The HEC-6, Scour and Deposition in Rivers and Reservoirs model was developed by the United States Army Corp of Engineers (U.S. Army Corp of Engineers, 1999). It is a one-dimensional, movable boundary, open channel flow, numerical model. HEC-6 was designed to simulate and predict changes in river profiles resulting from scour and/or deposition over moderate time periods (typically years, although applications to single flood events are possible). HEC-6 calculates water surface and sediment bed surface profiles by computing the interaction between sediment material in the stream bed and the flowing water-sediment mixture.

HEC-6 simulates the capability of a stream to transport sediment, given the yield from upstream sources. Prediction of sediment behavior requires that the interactions between the flow hydraulics, sediment transport, channel roughness, and related changes in boundary geometry be considered. HEC-6 is designed to incorporate these interactions into the simulation. Channel bed elevation changes resulting from net scour or net aggradation are reported after a series of uniform discharges of finite duration have been simulated. In this way, a continuous hydrograph is simulated by a histogram. HEC-6 can be used to predict the impact of land manipulation or construction on the river hydraulics, sediment transport rates, and channel geometry.

3.4.5 MULTSED

The Watershed and Sediment Runoff Simulation Model for Multiple Watersheds (MULTSED) simulates the sedimentation processes of detachment, transport, and deposition. MULTSED was developed at Colorado State University with support from EPA and the USDA-Forest Service. In a 1990 comparison of MULTSED, ANSWERS, KINEROS, PRMS, and SEDIMOT II, MULTSED was found to be the best overall model for semiarid lands (WET, 1990).

One of MULTSED's strengths is its simulation of channel processes, which often have a greater impact than hillside processes in a semiarid environment. MULTSED represents the watershed as a cascade of planes and channels and simulates channel infiltration, erosion and deposition in addition to calculating sediment transport by size fraction. Rainfall is input independently for each plane, and runoff is simulated as a kinematic wave with laminar characteristics. Channel runoff is simulated as a kinematic wave with finite difference.

Section 4.0 Benefits of Sediment Control BMPs

The use of sediment control BMPs as an alternative or in addition to sedimentation ponds for controlling sediment and erosion in arid and semiarid watersheds, has numerous environmental and enforcement benefits that are not realized when sediment control is designed around the implementation of sedimentation ponds alone. This section presents the distinct advantages provided by implementation of a fully integrated, site-specific, and appropriate sediment control BMP system.

4.1 Environmental Benefits

The capabilities of sediment control BMP systems that are designed to address site-specific conditions can expedite improved protection and rehabilitation of local natural and environmental resources that are potentially impacted by mining and reclamation activities. The fact that BMP Systems are specifically designed to minimize disruption of fluvial stability, minimize mine related disturbances, foster sustainable sediment equilibrium, and minimize potential for catastrophic release events, makes them appropriate for erosion and sedimentation control at arid and semiarid mine sites.

4.1.1 Source Control

Minimizing erosion and sedimentation problems and treating surface runoff at the source are distinct advantages that BMP systems have over sedimentation pond treatment technology. Sediment and erosion control BMP Systems are capable of controlling sediment at its source, preventing erosion across disturbed areas, and preventing impacts to adjacent undisturbed areas. Treating erosion and sedimentation at or near the source allows surface water runoff to seek sediment-content equilibrium throughout the entire watershed. This equilibrium results in the creation of an acceptable, system-wide dynamic balance between flow volumes and sediment transport. Source control is needed to achieve and maintain this balance between sediment loading from surface water runoff and long-term erosion control after mining and reclamation activities have been completed. To this end, avoiding the construction and subsequent removal of sedimentation ponds for sediment treatment purposes and establishing a viable BMP system is paramount to hydrologic system maintenance and rehabilitation.

4.1.2 Minimizes Disturbance to the Hydrologic Balance

Congressionally mandated regulatory goals require protection of the waters of the United States and the avoidance or minimization of disruption to the hydrologic balance where surface coal mining and reclamation activities are conducted. With the implementation of alternative or additional BMPs, erosion and sediment control is focused on the source which allows surface water that does not infiltrate to discharge from mining or non-process areas in a controlled fashion. Sediment levels in the runoff are allowed to fluctuate with the erosion potential conditions in the watershed, and are not artificially reduced by large in-channel structures (i.e., sedimentation ponds). This approach to the control and release of surface drainage adjusts the hydrologic system gradually, allowing it to adjust slowly over time. This slow adjustment provides system stability and enables the components of the watershed to effectively interact and maintain the hydrologic balance. By allowing natural sediment flow through the system, the fluvial balance in the watershed benefits through the establishment of natural erosion processes that will prevail after mining and reclamation activities have ceased.

Exposing the down-drainage system to sudden flushes of drainage following removal of flow restricting or constricting structures is avoided. Sudden flood events can be very disruptive to channel morphology. Seasoning channels with a range of flows over a period of time, and avoiding flash flood events or extended periods of water unavailability, facilitates reclamation. Problem areas associated with various flow volumes can be identified and corrected. Channel and hydrologic rehabilitation is nurtured for a period of several years under realistic and natural post-mining flow conditions. The net result can be improved and reclaimed areas with increased hydrologic stability and nominal disruption to undisturbed lands adjacent to or downstream from the affected areas.

4.1.3 Maintains Natural Sediment Yield

Surface water drainage with sediment concentrations approximating background levels avoids the accelerated erosion that is associated with and frequently occurs immediately downstream from points where low sediment content waters are discharged (Western Coal Mining Work Group, 1999a). Accelerated erosion is disruptive to the existing down-drainage hydrologic balance. In its more dramatic visible forms, accelerated erosion manifests itself in head-cutting, increased scouring (channel degradation), mass caving, and bank failures in receiving channels. In severe cases, this type of erosion may affect tributaries throughout a portion of or an entire watershed. Establishing sediment yields that approximate natural levels for the prevailing environmental and hydrologic conditions increases the rehabilitation of watershed characteristics and provides for increased channel stability.

Water released from sedimentation ponds contains low concentrations of sediment and usually occurs in flow volumes significantly less than flow volumes that occurred prior to mining. When discharges from a sedimentation pond occur, the essentially sediment-free water begins to immediately entrain sediment from the fluvial system below the pond. The small discharge volumes typically do not have the capacity to transport large amounts of sediment immediately below the pond, but the discharge can have the potential to accelerate erosion and degrade the stream channel immediately downstream from the sedimentation pond (Western Coal Mining Work Group, 1999a). Due to the cumulative nature of this erosion, it can become visibly apparent during the Phase II reclamation liability and bonding period (i.e., 10+ years).

An additional receiving channel impact may occur due to the alteration of sediment concentration. A lowering or a raising of sediment concentration in drainage from the non-process area watershed can trigger degradation or aggradation of the receiving channel, respectively. Degradation is possible when sediment concentration is lowered and additional sediment is entrained by the flow event. Conversely, if drainage from the undisturbed watersheds below the sedimentation pond is higher in sediment concentration, the reduction in lower sediment concentration flow from the non-process area watershed may trigger aggradation of the receiving channel. This decrease in entrainment capacity and flow can result in increased sediment.

Implementation of sediment control BMPs in addition, or as an alternative, to sedimentation ponds, provides an advantage in allowing drainage to entrain and carry a sediment load that approaches its energy capacity to do so and that is not artificially adjusted by an in-stream structure (sedimentation pond) before being released. The result is the prevention of severe erosion and instability problems directly downstream.

4.1.4 Minimizes Surface Disturbance

The appropriate application of alternative sediment and erosion control BMPs can avoid a significant amount of unnecessary surface disturbance on western mine lands. The amount of land that must be disturbed for construction of sedimentation ponds varies based on site specific environmental conditions. For example, the number of acres of surface land disturbance resulting from the use of sedimentation ponds at four coal mine sites in the arid western coal region are presented in Table 3a, Section 3.2.1. The four mine operations vary significantly in their use of ponds, from 14 to 149 total ponds that disturb from 36 to 540 acres. The use of BMP systems would avoid the disturbance of these additional acres.

Under Wyoming's Guideline No. 15, the Jim Bridger Mine uses alternative sediment control BMPs (e.g., berms, diversion ditches, and small catchments) to manage drainage from reclaimed areas and has only disturbed 3.9 acres (Western Coal Mining Work Group, 1999b). The Jim Bridger mine estimates that an additional 200 acres would be disturbed if sedimentation ponds were used to manage drainage at this site (Western Coal Mining Work Group, 1999a). The reduction in surface disturbance that may be expected by implementation of sediment control BMPs as an alternative to sedimentation ponds is significant.

4.1.5 Encourages Vegetation

A BMP system approach to erosion and sediment control maximizes the land's ability to harvest or use precipitation which is key to the success of vegetation in the arid and semiarid western United States. Sediment control has historically focused primarily on the capture of surface water runoff in sedimentation ponds located on the bottom periphery of the disturbed area. Surface water runoff captured by sedimentation ponds in the arid and semiarid regions is typically allowed to evaporate, and is not made available for vegetative growth or soil conditioning. Sediment control BMP plans encourage the infiltration and retention of precipitation in the soil where it benefits microbial activity and plant growth. These BMP plans are designed to maximize the availability of limited precipitation for improving soil and enhancing vegetation and are critical to the growth and establishment of vegetation and the development of plant communities. Even small increases in plant cover and associated root mass can have significant impacts on the stability of reclamation surfaces by reducing flow velocity, increasing soil cohesiveness, and promoting biological diversity.

4.1.6 Improves Soil and Promotes Soil Conservation

The characteristics of soil are key to successful reclamation. Water management and soil improvement practices that are inherent to sediment control BMPs can effectively improve soil moisture availability. Soil characteristics that are critical to the growth and establishment of vegetation can be readily influenced by these BMPs both temporarily and permanently. BMP systems promote water infiltration and availability, which increase incorporation of organic materials capable of improving soil structure, nutrient retention and availability, water infiltration and harvesting, and long-term plant production and diversity.

Western topsoils are generally poorly developed and tend to be characteristically poor in nutrients (Western Coal Mining Work Group, 1999a). Ensuring that this valuable resource is conserved and even improved during reclamation is an important concern. Implementation of appropriate sediment control BMPs can be expected to conserve and protect this resource by controlling overland flow and its associated erosion force, limiting slope lengths, increasing surface roughness, harvesting precipitation, increasing moisture content, promoting vegetation diversity, increasing organic matter, improving soil texture, and fostering soil formation processes. These factors combine to result in improvements to soil characteristics that promote and encourage stability, soil biota content, cohesiveness, and plant growth. Increases in soil biota and above ground vegetation in turn promote soil formation and stability.

4.1.7 Addresses Site-Specific Environmental Conditions

The design of sedimentation control plans incorporating appropriate BMPs allows for sediment control on a site-specific basis, according to a site's environmental conditions and requirements. Implementation of BMPs that are designed to address specific sedimentation and erosion concerns, background sediment levels, and hydrologic conditions of a particular site, allows more appropriate, performance-based sediment criteria to be developed prior to issuance of permits. Implementation of site-specific, comprehensive sediment and erosion control BMP plans also allows for consideration of the long-term effects of mining and reclamation operations and avoids the shock that can be experienced by these watersheds from the implementation and subsequent removal of water impounding structures (i.e., sedimentation ponds).

4.1.8 Stabilizes Landforms

Topography plays a key role in the long-term surface stability of arid and semiarid non-process areas. The primary goal in designing, constructing, and implementing sediment control BMPs that will determine post-mining topography is to achieve a stable landform. An appropriate and natural topography created by implementation of BMP plans that consider site-specific drainage patterns is essential to minimizing erosion rates and encouraging the growth of vegetation.

BMPs that are implemented to provide appropriate topography increase channel stability, improve soil moisture availability, foster the creation of shallow perched water tables, encourage increased infiltration of precipitation and drainage into ground water resources and decrease soil erosion. All of these functions allow the establishment of vegetation within the reconstructed channels where little or no vegetation existed prior to mining and reclamation operations.

4.1.9 Minimizes Disruptions to Flow Regime and Evapotranspiration Losses

Sedimentation ponds have significant potential for removing runoff from the hydrologic system, and precluding potential down-drainage uses. With the implementation of alternative sediment control BMPs, drainage is allowed to flow relatively unimpeded. As a result of the appropriate implementation of these systems, impacts to downstream water users and to intermittent or perennial water resources, are minimized or avoided. In addition, the long-term flow pattern is established early in the reclamation process and sudden impacts to stream morphology and flow regime experienced after the removal of a sedimentation pond at Phase II bond release can be prevented. Disruption of the prevailing hydrologic balance in arid and semiarid regions can be expected to be much greater when the use of sedimentation ponds is predominant, than when BMPs are used to simulate pre-mining, undisturbed conditions.

BMP systems also avoid the unnecessary impounding of water and associated evaporation losses. Losses from ponds can be significant in the arid and semiarid west where evaporation rates are characteristically much higher than the annual precipitation (Western Coal Mining Work Group, 1999a). Implementation of sediment control BMP plans also serves to increase the availability of surface and ground water, because water loss is avoided and runoff is allowed to flow naturally and recharge local downstream resources.

4.2 Implementation and Enforcement Benefits

4.2.1 Implements Existing Requirements

The Surface Mining Control and Reclamation Act already institutes specific requirements for surface coal mining and reclamation operations to achieve acceptable reclamation standards. These performance standards include successful revegetation, approved post-mining land use, stabilizing and protecting all surface areas to effectively control erosion, and minimizing disturbance to the prevailing hydrologic balance while taking into consideration the physical, climatological, and other characteristics of the site. SMCRA's performance standards require establishment of an effective, permanent vegetative cover that is at least equal in extent to the natural vegetation or to that necessary to achieve the approved post-mining land use.

Implementation of a sediment and erosion control BMP plan designed to address site-specific sedimentation issues incorporates and complies with all requirements under SMCRA, without precluding consideration for local hydrologic balance.

4.2.2 Improves Monitoring and Inspection Capability

Under the existing effluent guidelines, a mine is required to monitor point source discharges to demonstrate that Settleable Solids (SS) are equal to or less than 0.5 mL/L when released from reclaimed areas. To meet Phase II bond release requirements, the inflow into sedimentation ponds must be equal to or better than background and meet all applicable federal, state, local and tribal laws and regulatory requirements. When these requirements are met, the operator is eligible to apply for a Phase II bond release for the reclaimed area and terminate the existing guideline monitoring obligation. With the implementation of alternative or additional sediment control BMPs, inspection and enforcement compliance monitoring would be improved dramatically. It would no longer be necessary to wait for a precipitation event to obtain samples to determine compliance. Alternative sediment control BMPs would allow Phase II bond release inspection and compliance evaluations to proceed independently of the season of the year or storm events and on a more frequent basis. The BMP approach uses the inspection of BMP design, construction, maintenance and operation to demonstrate compliance.

4.2.3 Provides Control and Treatment Flexibility

Sediment control BMP plans have been and are being successfully implemented. These BMP plans are highly adaptable to nearly all erosion and sedimentation control situations. This means that each site's unique and diverse environmental conditions may be considered and addressed through the implementation of site-specific BMP plans that can be designed and adjusted to achieve a variety of prioritized goals best suited to the needs of a particular location.

Section 5.0 Case Studies

The Western Coal Mining Work Group (WCMWG) submitted data and information for five case studies demonstrating that computer models can be used to 1) predict mine site hydrology and sedimentology and 2) design and select alternative sediment controls to control hydrology and sedimentology at coal mine sites in the arid/semiarid western coal mining region. The data and information submitted by WCMWG are summarized in the following five case studies.

- Case Study 1 - Compares the performance, cost, and benefits of a model mine located in the *Desert Southwest* region using sedimentation pond systems versus alternate sediment control measures;

- Case Study 2 - Is a follow-up study to Case Study 1 comparing the performance, cost, and benefits of model mines located in the *Intermountain* and *Northern Plains* regions using sedimentation pond systems versus alternate sediment control measures;

- Case Study 3 - Contains surface water runoff modeling and performance-cost-benefit information supporting the addition of lands affected by certain pre-mining activities.

- Case Study 4 - Demonstrates that since 1984, the Jim Bridger Mine, located in southwestern Wyoming, has successfully used alternate sediment control measures, in addition to several sedimentation ponds, to treat disturbed area runoff to prevent degradation of local stream water quality.

- Case Study 5 - The study evaluated available computer models for prediction of watershed runoff and sediment yield for selection of a model that best represents these processes at mine sites in semiarid regions.

5.1 Case Study 1 (Western Coal Mining Work Group, 1999c)

The National Mining Association (NMA), as part of the WCMWG, conducted studies comparing the performance, costs, and benefits of model mines located in the *Desert Southwest* (Case Study 1), *Intermountain* (Case Study 2), and *Northern Plains* (Case Study 2) coal regions. The studies compared results under conditions designed to meet numeric limits with conditions designed for use of alternative sediment control to maintain background sediment yield (WCMWG, 1999c). This section discusses the results of NMA's *Desert Southwest* model mine study.

A representative model mine located in the arid/semiarid southwestern United States was developed for the comparison, including contour maps and corresponding hydrologic and soil databases typical of desert southwest mines. Original and approximate topography were used to model surface drainage, sediment yield, and soil loss rates from the affected watersheds. Results from RUSLE and SEDCAD modeling were generated for the following three scenarios:

1) Pre-mining Undisturbed Watershed - Modeling of the area prior to any surface preparation, surface disturbance, or mining activities was conducted to characterize background water quality, soil loss rates, and sediment yield. Data were used to establish background standards for BMP system control;

2) Post-mining Reclaimed: Numeric Limitations - A sedimentation pond-focused treatment system was modeled that meets 0.5 ml/L settleable solids (SS) at the perimeter outfalls.

3) Post-mining Reclaimed: Sediment Control BMPs - A BMP system focusing on the use of alternate sediment controls was modeled to provide erosion and sediment control for reclaimed lands seeking to approximate undisturbed

background surface drainage volumes and peaks, total settleable solids (TSS) and SS concentrations, soil loss rates, and sediment yields.

Characteristics of the representative model mine area and information used to perform performance and cost evaluations are presented in Table 5a.

Table 5a: Representative Mine Characteristics and Model Input Information

Parameter	Input information
Total Acres	1,188
Actual Disturbed Acres	381.8
Affected Acres	616.7
Unaffected Acres	571.3
Storm Event	10 year – 24 hour
Rainfall	1.8 inches
Soil Type	Sandy clay loam, Loamy sand
Sediment Control BMPs	Manipulation of topography, gradient bench terraces, terrace drains, contour furrows, reclaimed channels, diversion ditches, establishment of permanent vegetation, mulching and detention basins.
Number of Sedimentation Ponds	3, in series
Types of Surface Conditions	Undisturbed; Spoil, backfilled and graded, topdressed, straw mulched and seeded; Revegetated, 1-3 years Revegetated, 4-8 years
Computer Model Input Information (RUSLE)	Rainfall amount, intensity, frequency and duration; soil moisture conditions, soil types, susceptibility to erosion, eroded particle size distributions, infiltration rates, and soil permeability; vegetative ground cover and evapotranspiration rates

The non-process area within the representative model mine contained the following surface conditions: areas containing spoil outslopes and rough and final backfilling and grading; areas where soil resources are being replaced (including topdressing, contour furrowing, mulching, and seeding); and areas with 1-3 years of vegetative growth, or with 4-8 years of more permanent growth.

Non-process area surface conditions also included a final pit undergoing reclamation with the potential for non-process mine drainage to run off the site. This configuration normally represents peak sediment yield potential for a reclaimed area during the mining and reclamation processes. The non-process area was positioned within a portion of the watershed, so that drainage from both the non-process area and the adjacent undisturbed lands were considered in choosing and developing sediment control strategies.

The alternate sediment control BMPs used during reclamation were:

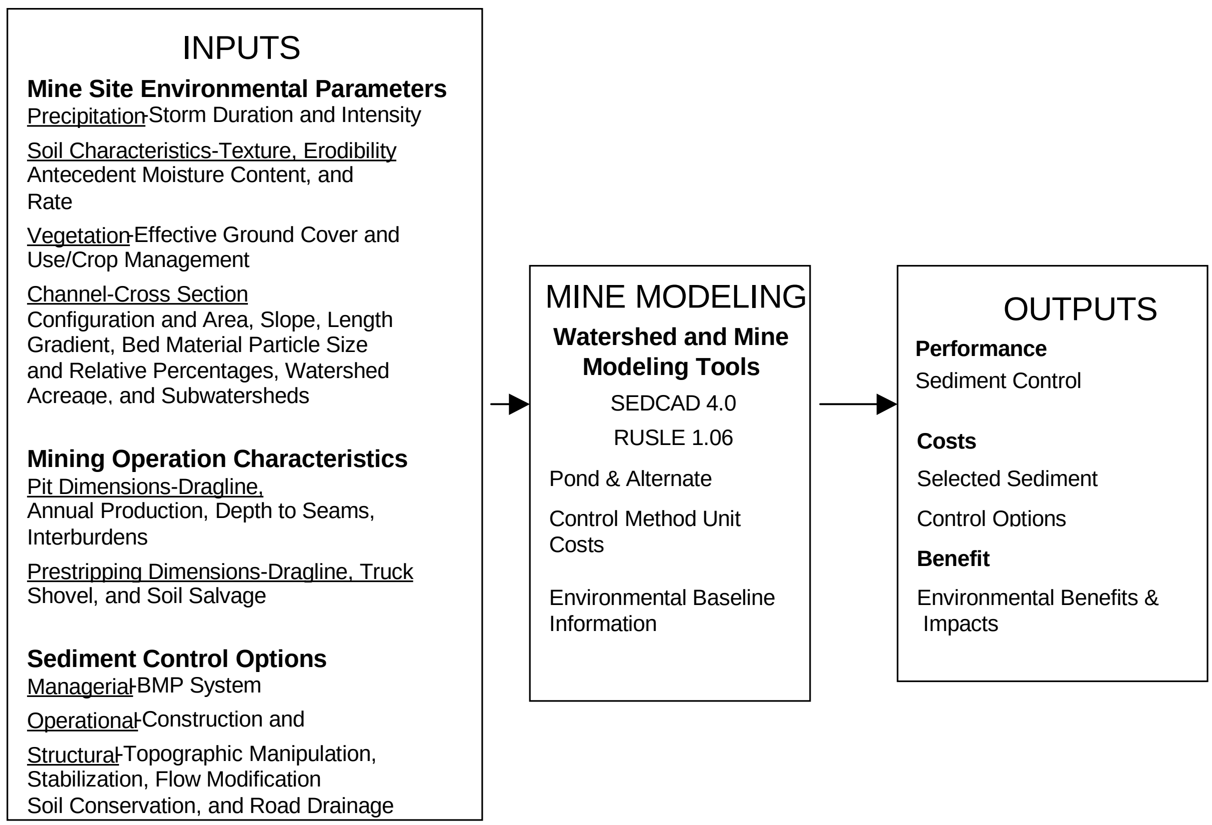
- Manipulation of topography to develop more stable slopes
- Earthen terraces and berms
- Terrace drains
- Contour furrows
- Diversion ditches
- Surface roughening/land imprinting
- Sediment detention basins
- Revegetation

Reclaimed area topography and the extent of area disturbance were held constant in modeling both reclamation sediment control scenarios. Holding these inputs constant enabled and facilitated the analysis and comparison of model results for soil loss, surface drainage rates, surface drainage volumes, and BMP performance.

5.1.1 Modeling Results

The modeling approach used for this study is shown in Figure 5a. The RUSLE 1.06 and SEDCAD 4.0 models were used to estimate values that characterize site hydrology and sedimentology.

Figure 5a: Mine Model Approach: A Method for Evaluating Erosion and Sediment



Control Options (WCMWG, 1999c)

5.1.1.1 RUSLE 1.06

Annual average soil loss was predicted for two scenarios with the help of RUSLE version 1.06. The two scenarios were for pre-mining (undisturbed) conditions and for post-mining (reclaimed with BMPs). The type of input information for the modeling effort is listed in Table

5b. Information input values were based on vegetation, soils, and surface configurations obtained from case study mines and mine permits. Representative data were entered into the RUSLE program to generate sediment loss values. RUSLE input and output data are presented in Appendix D, Tables D-1 through D-5.

For pre-mining, undisturbed conditions, the predicted, weighted average annual soil loss was 4.7 tons/acre/yr. According to the WCMWG, this is a reasonable value for the arid and semiarid coal regions (WCMWG, 1999c). The weighted average annual soil loss of the reclaimed mine lands was 3.0 tons/acre/yr. Data supporting the weighted average soil loss estimates are presented in Appendix D, Table D-6. The soil loss is slightly lower after reclamation because the BMPs allow for improved infiltration and retention of storm water, and for the growth and establishment of vegetation. Also, implementation of BMPs results in landforms that have been reconstructed to facilitate lower erosion rates and enhanced deposition at down-gradient slope boundaries.

5.1.1.2 SEDCAD 4.0

All sediment and hydrology model results from the mine prior to mining and from the mine after reclamation using BMPs to control sediment are similar, whereas the model results for the area reclaimed to meet numeric effluent limitations (0.5 ml/L SS) are considerably lower than the pre-mining conditions. The decrease in sediment yield and runoff resulting from compliance with this limit is expected due to the implementation of sedimentation ponds that impound runoff. To avoid potential adverse impacts on the hydrologic and sediment balance, and to maintain the stability of the fluvial system, drainage from the non-process areas should be as similar to pre-mining drainage as possible. Based on this standard, implementation of BMPs would be a preferred option. Sediment loss, soil loss, and surface runoff model results for undisturbed conditions, non-process areas with sedimentation ponds, and non-process areas with alternative sediment control BMPs are presented in Table 5b. SEDCAD output for each of the three scenarios is presented in Appendix D.

5.1.2 Cost

The WCMWG completed an extensive analysis of costs associated with meeting effluent limitations using sedimentation ponds and implementing BMPs under a Western Alkaline Coal Mining subcategory. Cost estimating criteria for sedimentation ponds and BMPs implemented at the model mine were collected from approved mine permit applications, developed from mine records, and estimated using technical resources and industry experience. These unit cost data are presented in detail in NMA's Mine Modeling Report (WCMWG, 1999c).

The model cost assessment was based on capital costs (design, construction, and removal) and operating costs (inspection, maintenance, and operation) associated with BMPs used over the anticipated bonding periods. The bond release period for meeting numeric effluent standards in the arid and semiarid western coal region can be expected to be ten years or longer (WCMWG, 1999a; Peterson, 1995). With the implementation of alternative sediment control BMPs, reclaimed areas may be eligible for Phase II bond release about five years after they have been successfully revegetated (WCMWG, 1999a).

Capital and operating reclamation costs, as estimated by the WCMWG, for both the effluent numeric limitation and the proposed non-numeric option are presented in Table 5c. The present value of the reclamation costs over the ten year period (discounting at seven percent) is $1,700,000 for the existing guideline and $1,028,000 for the proposed subcategory, or a present value total savings of $672,000 over ten years. This represents a 39 percent overall reduction in costs or $1,764 in savings per disturbed acre. The annualized savings is $95,000 (annualized at seven percent) or $251 annualized savings per acre for the 381 reclaimed acres.

Table 5b: Comparison of Hydrology and Sedimentology Results (modified from WCMWG, 1999c)

	Pre-Mining Undisturbed Conditions	Reclaimed to Meet Numeric Limitations[1,2]		Reclaimed Under Alternate Sediment Control Measures[3]	
	Result	Result	% Change from Pre-mining	Result	% Change from Pre-mining
RUSLE (V 1.06) Modeling Results					
Soil Loss (tons/acre/year) (Weighted Average)	4.7	NM[4]	N/A	3.0	-36
SEDCAD (V 4.0) Modeling Results					
Peak Discharge (cfs) (10 year, 24-hour storm event)	679.09	44.79	-93	601.89	-11
Total Runoff Volume (acre-feet) (10 year, 24-hour storm event)	80.01	48.83	-39	72.93	-9
Sediment (tons) (10 year, 24-hour storm event)	7,004.2	666.1	-90	5,611.1	-20
Sediment (tons/acre) (10 year, 24-hour storm event)	5.9	0.6	-90	4.7	-20
Peak Sediment (mg/L) (10 year, 24-hour storm event)	155,091	28,235	-82	114,800	-26
Peak Settleable Solids (ml/L) (10 year, 24-hour storm)	38.22	0.00	-100	25.86	-32
Settleable Solids (ml/L) (24-hr Volume Weighted) (10 year, 24-hour storm)	17.89	0.00	-100	13.96	-22
Sediment Yield (acre-feet/year) (Average Annual)	8.3	0[5]	-100	6.7	-19

[1] Sediment was controlled with sedimentation ponds.
[2] Assumes ponds are filled to design storage capacity with 3 years of sediment runoff.
[3] Sediment was controlled by alternative sediment control BMPs.
[4] Not measured.
[5] Assumes no sediment is stored in the ponds, and 3 years of annual sediment runoff volume is available. SEDCAD 4.0 uses a subroutine that implements a method similar to RUSLE to determine average annual sediment yield. SEDCAD sedimentology input values were taken directly from the RUSLE version 1.06 analysis.

Table 5c: Cost of Compliance with Numeric Limitations vs. Cost to Implement Alternative Sediment Control BMPs (adapted and revised from WCMWG, 1999c)

Year	Numeric Effluent Limits				Alternate Sediment Control BMPs			
	Capital	Operating	Total	Present Value[1]	Capital	Operating	Total	Present Value[1]
1	$975,435	$15,384	$990,819	$990,819	$760,816	$3,300	$764,116	$764,116
2	2,720	142,804	145,524	136,004	43,577	103,368	146,944	137,332
3	0	190,181	190,181	166,112	0	59,876	59,876	52,298
4	0	88,956	88,956	72,615	0	77,895	77,895	63,586
5	0	26,231	26,231	20,011	0	14,147	14,147	10,793
6	0	161,999	161,999	115,503	-	-	-	-
7	0	15,269	15,269	10,175	-	-	-	-
8	0	15,269	15,269	9,509	-	-	-	-
9	0	133,377	133,377	77,626	-	-	-	-
10	171,607	15,269	186,876	101,648	-	-	-	-
Total (not discounted)	$1,149,761	$804,739	$1,954,501	$1,700,021	$804,393	$258,586	$1,062,979	$1,028,124
Annualized @ 7% over 10 years				$242,045				$146,382

Annualized Savings	$95,663	Present Value Total Savings	$671,897
Annualized Savings per Reclamation Acre[2]	$251	Present Value Total Savings per Acre[2]	$1,764

Costs expressed in 1998 Dollars
[1] *Discount Rate: 0.07*
[2] *Based on 381 disturbed acres*

5.2 Case Study 2 (Western Coal Mining Work Group, 2000a)

To complement the results of the model mine study presented in Section 5.1 (Case Study 1), NMA also conducted this follow-up study comparing the performance, cost, and benefits of model mines located in both the *Intermountain* and *Northern Plains* coal regions to meet numeric effluent limitations versus the use of alternative sediment control BMPs (WCMWG, 2000a).

Two models were developed using representative non-process areas within the *Intermountain* and *Northern Plains* regions in the western United States. These models were based on site-specific hydrology and soil databases for the *Intermountain* and *Northern Plains* coal regions. Site-specific input variables include

- Rainfall amount
- Rainfall intensity
- Rainfall frequency
- Rainfall duration
- Antecedent soil conditions
- Soil types
- Susceptibility to erosion
- Eroded particle size distribution
- Infiltration rates
- Soil permeability
- Vegetative ground cover

Other variables such as topography, disturbance area (disturbance footprint), and non-process areas (e.g., backfilling and grading area, surface roughening area, revegetation area, etc.) were standardized and held constant to aid in the comparison of the case studies from the different regions.

For both the *Intermountain* and *Northern Plains* examples, modeling was performed for three scenarios:

1) Pre-mining background - A characterization prior to surface disturbance by mining and reclamation activities that is used to establish site-specific sediment control standards for the proposed BMP treatment system;

2) Numeric Limitation Requirements - Modeling and design of a sediment control system that meets numeric limitations for runoff from non-process areas; and

3) Sediment Control BMPs - Modeling and design of a BMP alternate sediment control system that meets background levels for runoff from non-process areas.

Modeling prior to surface disturbance by mining was conducted to characterize pre-mining background water quality, soil loss rates, and sediment yield. The modeled values serve as a benchmark, establishing standards for the sediment control measures.

Non-process areas also were modeled to meet numeric limitations using typical surface water runoff control and treatment methods for the model's standardized disturbance footprint for both *Intermountain* and *Northern Plains* environmental conditions. Typical surface water runoff treatment systems (sedimentation ponds) were designed to meet the discharge requirements for numeric limitations for surface water runoff (0.5 ml/L settleable solids).

A third modeling scenario using the standardized disturbance footprint was used to meet background sediment yields. This scenario emphasized implementation of an alternate erosion and sediment control system to meet pre-mining watershed runoff conditions and prevent the contribution of additional sediment to the receiving stream.

5.2.1 Modeling Results

Average annual erosion quantities were predicted based on the RUSLE model version 1.06. Input parameter values for the modeling effort were based on vegetation, soils, and surface configurations obtained from existing case study mines and mine permits. RUSLE variables were input to SEDCAD 4.0 to model watershed sedimentology. Since the analysis of a 10-year, 24-hour design storm is typically required, all three scenarios were assessed using the design storm in the SEDCAD 4.0 model. Modeling erosion and sediment controls for non-process areas under numeric and non-numeric (sediment control BMPs) requirements produced the hydrology and sedimentology data for the *Intermountain* and *Northern Plains* non-process areas as shown in Tables 5d and 5e, respectively.

For the *Intermountain* reclaimed area, the sediment control BMPs reduced peak discharge by approximately 38% below background levels, while the treatment designed to meet numeric limitations reduced the peak discharge by 96% below background levels. For the *Northern Plains* reclaimed area, the BMP system reduced peak discharge by approximately 33% below background levels, while the treatment to meet numeric limitations reduced the peak discharge 97% below background levels. For both areas modeled, the sediment control system mimics the background peak discharge levels more closely.

Table 5d: Comparison of Hydrology and Sedimentology Results for the Intermountain Reclamation Model (Western Coal Mining Work Group, 2000a)

	Pre-mining Undisturbed Conditions	Reclaimed to Meet Numeric Limitations		Reclaimed Under Alternate Sediment Control Procedures	
	Result	Result	% Change from Pre-mining	Result	% Change from Pre-mining
Intermountain Non-process Area					
Sediment Production (tons)	1,030	0[1]	-100	660	-36
Peak Discharge (cfs) (10 year, 24-hr storm event)	160	6[2]	-96	100	-38
Total Runoff Volume (acre-ft) (10 year, 24-hr storm event)	27	22[3]	-19	21	-22
Settleable Solids (ml/L) (24-hr Volume Weighted) (10 year, 24-hr storm event)	18	0	-100	15	-17
Peak Settleable Solids (ml/L)	58	0[4]	-100	48	-17
Peak Sediment (mg/L) (10 year, 24-hr storm event)	100,800	0[5]	-100	82,400	-18

[1]Most sediment is trapped in the sediment pond. Minimum amount of sediment released during discharge.
[2]Assumes 100% of runoff volume is discharged from pond over a 2-day period.
[3]Assumes 100% of runoff volume is treated and discharged. This is conservative as some water will be lost to infiltration, minimum pool ponding, and evaporation.
[4]Containment in pond with slow discharge rate will remove all settleable solids.
[5]Containment in pond with slow discharge rate will remove most suspended sediment.

For the *Intermountain* reclaimed area, the proposed sediment control system achieved peak sediment concentrations that were approximately 18% lower than pre-mining background levels, while the treatment designed to meet numeric limitations had peak sediment concentrations that were near zero. This is a direct result of capturing almost 100% of the sediment in sedimentation ponds. The BMP treatment system also achieved superior results in the *Northern Plains* example, with peak sediment concentrations that were approximately 14% lower than pre-mining background levels, while the current subcategory treatment system again had peak sediment concentrations that were near zero.

Table 5e: Comparison of Hydrology and Sedimentology Results for the Northern Plains Reclamation Model (Western Coal Mining Work Group, 2000a)

	Pre-mining Undisturbed Conditions	Reclaimed to Meet Numeric Limitations		Reclaimed Under Alternate Sediment Control Procedures	
	Result	Result	% Change from Pre-mining	Result	% Change from Pre-mining
Intermountain Non-process Area					
Sediment Production (tons)	850	0[1]	-100	520	-39
Peak Discharge (cfs) (10 year, 24-hr storm event)	250	8[2]	-97	167	-33
Total Runoff Volume (acre-ft) (10 year, 24-hr storm event)	42	31[3]	-26	30	-29
Settleable Solids (ml/L) (24-hr Volume Weighted) (10 year, 24-hr storm event)	10	0	-100	8	-13
Peak Settleable Solids (ml/L)	30	0[4]	-100	26	-13
Peak Sediment (mg/L) (10 year, 24-hr storm event)	52,500	0[5]	-100	45,100	-14

[1]Most sediment is trapped in the sediment pond. Minimum amount of sediment released during discharge.
[2]Assumes 100% of runoff volume is discharged from pond over a 2-day period.
[3]Assumes 100% of runoff volume into pond is treated and discharged. This is conservative as some water will be lost to infiltration, minimum pool ponding, and evaporation.
[4]Containment in pond with slow discharge rate will remove all settleable solids.
[5]Containment in pond with slow discharge rate will remove most suspended sediment.

In the *Intermountain* example, sediment yield resulting from the BMP treatment system more closely approximated background at 660 tons (a reduction of 370 tons from background) versus the treatment to meet numeric limits which resulted in a sediment yield of 0 tons (a reduction of 1,030 tons from background). In the *Northern Plains* example, sediment delivery resulting from the BMP system more closely approximated background at 520 tons (a reduction of 330 tons from background) versus treatment to numeric limits that resulted in a yield of 0 tons (a reduction of 850 tons). Settleable solids were released from the *Intermountain* BMP system at a concentration of 48 ml/L (17% below background levels), while treatment to numeric limits reduced SS by almost 100%. For the *Northern Plains* example, SS were released from the BMP treatment system at a concentration of 26 ml/L (13% below background levels), while treatment to numeric limits reduced SS by almost 100%. These results demonstrate that BMP treatment systems are capable of and better suited to release runoff that more closely approximates pre-mining watershed conditions. Using BMP sediment control systems to treat runoff from non-process areas can be expected to significantly improve protection of hydrologic and fluvial balances in watersheds affected by mining in western arid and semiarid alkaline environments.

5.2.2 Costs

Detailed capital and operating costs associated with the sediment control options specified for both the *Intermountain* and *Northern Plains* model mines were developed for 1) meeting numeric limitations, and 2) implementing sediment control measures to mimic background conditions. As was done for the *Desert Southwest* model in Case Study 1, capital costs include design, construction, and removal activities. Operating costs include inspection, maintenance, and operating activities. The costs were developed for anticipated bonding periods of five years and ten years. Design criteria used as the basis of costs for both the *Intermountain* and *Northern Plains* models are summarized in Table 5f.

Table 5f- Model Mine Design Criteria

Sediment Control Technology	Northern Plains Model Mine				InterMountain Model Mine				Comments
	Numeric Limits		Alternate Sediment Control		Numeric Limits		Alternate Sediment Control		
	Quantity	Unit	Quantity	Unit	Quantity	Unit	Quantity	Unit	
Sedimentation Pond (n=1)	31	ac-ft	-	-	22	ac-ft	-	-	
Spillway for Sedimentation	200	linear feet	-	-	175	linear feet	-	-	2:1 side slopes with 50-ft bottom width; Allowed 1.5 ft for rip rap depth, 1 ft freeboard, depth Intermountain=1.35, Northern Plains=1.53
Small Depressions (n=3)	-	-	<1	ac-ft	-	-	<1	ac-ft	
Gradient Bench Terraces	27,637	linear feet	27,637	linear feet	27,637	linear feet	27,637	linear feet	Intermountain=1.8, Northern Plains=2-ft depth with 3:1 and 10:1 cut and fill slopes, 25% of land requires terracing @ 150 ft intervals.
Terrace Drains	8,298	linear feet	8,298	linear feet	8,298	linear feet	8,298	linear feet	Cross-section is V-shaped 2.5' depth; side slopes 3h:1v; 1.5 ft excavation depth for riprap liner, 8-ft bottom width
Channel Stabilization Rip Rap	400	linear feet	-	-	400	linear feet	-	-	Used to stabilize reconstructed drainage channel when sediment pond is removed Yr 10, 8 structures 50-ft in length will be placed at intervals for channel gradient and X-section control, 3:1 side slopes, channel depth = 4.5 ft.
Diversion Channel #1	3,600	linear feet	3,600	linear feet	3,600	linear feet	3,600	linear feet	Trapezoidal X-Section, 8 ft bottom, 3:1 side slope, Northern Plains 2.4ft deep, Intermountain= 2.0 ft deep
Diversion Channel #2	3,650	linear feet	3,650	linear feet	3,650	linear feet	3,650	linear feet	Trapezoidal X-Section, 8 ft bottom, 3:1 side slope, Northern Plains 2.4ft deep, Intermountain= 2.0 ft deep
Diversion Channel #3	880	linear feet	880	linear feet	880	linear feet	880	linear feet	Trapezoidal X-Section, 8 ft bottom, 3:1 side slope, Northern Plains 2.4ft deep, Intermountain= 2.0 ft deep
Revegetation	393.0	Acres	381.2	Acres	392.4	Acres	381.2	Acres	Includes seedbed preparations, seeding, mulching and fertilizing
Surface Roughening	393.0	Acres	381.2	Acres	392.4	Acres	381.2	Acres	Including ripping, contour furrows and land imprinting

The sediment control structures and BMPs used for the *Intermountain* and *Northern Plains* models are as follows:

- Models designed to meet numeric limitations use a single sedimentation pond. Runoff from undisturbed conditions entering the main drainage in the vicinity of the sedimentation pond is conveyed around each side of the pond using grass lined diversions. Some mulching and limited surface roughening has been applied. The reclaimed land surface has been recontoured with terraces to reduce slope lengths and steepness. The reclaimed area for both *Intermountain* and *Northern Plains* scenarios is approximately 381.2 acres, with additional acres of disturbance for the sedimentation pond and diversions of 11.2 acres in the *Intermountain* scenario and 11.8 acres in the *Northern Plains* scenario.

- Models designed to approximate or improve background conditions use a BMP system instead of a sedimentation pond to treat surface runoff. The BMP system includes the same surface topography manipulation as applied to meet numeric limitations, including terraces and recontouring to reduce slope lengths and steepness. No diversions or sedimentation ponds were used. More extensive mulching and surface roughening were applied, including deeper contour furrows, land imprinting and the use of surface depressions. Since these practices typically result in better water harvesting and a subsequent increase in vegetation density, credit was taken for the vegetation density increase on older reclaimed areas.

Capital and operating reclamation costs for meeting numeric limitations and for implementing alternative sediment control measures for the *Intermountain* model mine are presented in Table 5g (WCMWG, 2001). The present values of the total reclamation costs over the ten year period (discounting at seven percent) are $844,132 to meet numeric limitations and $645,266 to implement alternative sediment control measures. This represents a present value total savings of $198,866 over ten years, a 24 percent overall reduction in costs or $522 in savings per disturbed acre when alternate sediment control measures are used. The annualized savings is $28,315 (annualized at seven percent) or $74 annualized savings per acre for the 381 reclaimed acres.

Capital and operating reclamation costs for meeting numeric limits and for implementing alternative sediment control measures for the *Northern Plains* mine model are presented in Table 5h. The present values of the total reclamation costs over the ten year period (discounting at seven percent) are $889,011 to meet numeric limitations and $653,636 to implement alternative sediment control measures. This represents a present value total savings of $235,375 over ten years, a 26 percent overall reduction in costs or $618 in savings per disturbed acre when alternate sediment control measures are used. The annualized savings is $33,512 (annualized at seven percent) or $88 annualized savings per acre for the 381 reclaimed acres.

Table 5g: Cost of Meeting Numeric Limits vs. Cost to Implement Alternative Sediment Control BMPs for the Intermountain Model Mine (adapted and revised from WCMWG, 2001)

Year	Numeric Limitations				Alternate Sediment Controls Measures			
	Capital	Operating	Total	Present Value[1]	Capital	Operating	Total	Present Value[1]
1	$479,458	$10,777	$490,235	$490,235	$428,315	$3,677	$431,992	$431,992
2	43,577	65,142	108,718	101,606	43,577	58,065	101,642	94,993
3	0	36,230	36,230	31,645	0	29,142	29,142	25,454
4	0	67,818	67,818	55,360	0	60,808	60,808	49,638
5	0	45,677	45,677	34,847	53,049	3,563	56,612	43,189
6	0	41,310	41,310	29,453	-	-	-	-
7	0	10,663	10,663	7,106	-	-	-	-
8	0	10,663	10,663	6,641	-	-	-	-
9	0	11,698	11,698	6,808	-	-	-	-
10	134,550	13,319	147,869	80,431	-	-	-	-
Total (not discounted)	$657,585	$ 313,296	$970,881	$844,132	$524,940	$155,255	$680,195	$645,266
Annualized @ 7% over 10 years				$120,186				$91,871

Annualized Savings	$28,315	Present Value Total Savings	$198,866
Annualized Savings per Reclamation Acre[2]	$74	Present Value Total Savings per Acre[2]	$522

Costs expressed in 1998 Dollars

[1] *Discount Rate: 0.07*

[2] *Based on 381 disturbed acres*

Table 5h: Cost of Meeting Numeric Limits vs. Cost to Implement Alternative Sediment Control BMPs for the Northern Plains Model Mine (adapted and revised from WCMWG, 2001)

Year	Numeric Limitations				Alternate Sediment Control Measures			
	Capital	Operating	Total	Present Value[1]	Capital	Operating	Total	Present Value[1]
1	$513,552	$11,682	$525,234	$525,234	$432,631	$3,677	$436,309	$436,309
2	43,577	66,628	110,204	102,995	43,577	58,646	102,223	95,536
3	0	37,426	37,426	32,689	0	29,433	29,433	25,708
4	0	68,723	68,723	56,099	0	60,808	60,808	49,638
5	0	46,582	46,582	35,537	57,317	3,563	60,880	46,445
6	0	42,408	42,408	30,236	-	-	-	-
7	0	11,568	11,568	7,709	-	-	-	-
8	0	11,568	11,568	7,204	-	-	-	-
9	0	12,699	12,699	7,391	-	-	-	-
10	140,054	14,224	154,278	83,917	-	-	-	-
Total (not discounted)	$697,183	$323,508	$1,020,691	$889,011	$533,525	$156,127	$689,651	$653,636
Annualized @ 7% over 10 years				$126,575				$93,063

Annualized Savings	$33,512	Present Value Total Savings	$235,375
Annualized Savings per Reclamation Acre[2]	$88	Present Value Total Savings per Acre[2]	$618

Costs expressed in 1998 Dollars

[1] Discount Rate: 0.07

[2] Based on 381 disturbed acres

5.3 Case Study 3 (Western Coal Mining Work Group, 2000b)

This case study contains surface water runoff modeling and performance-cost-benefit information regarding alternative sediment control technologies for non-process areas in the Western Alkaline Coal Mining Subcategory (WCMWG, 2000b). The areas include:

- **Brushing and grubbing** - removal or incorporation of woody plant material that would interfere with soil salvage operations
- **Soil salvage** - soil reconstruction materials (soil, subsoil, and neutral dressing), and
- **Soil stockpiling activities** - activities where soil resources are stockpiled for future use in soil reconstruction or reclamation

Land affected by these activities are considered to be appropriate for the implementation of alternate sediment control technologies when sediment is the only constituent of concern in non-process surface water runoff. This case study contains an analysis comparing the predicted performance-costs-benefits associated with sedimentation pond systems to the use of alternate BMP sediment controls to minimize impacts to the hydrological and fluvial balance of western coal mine watersheds.

Modeling was conducted for a representative mine in the arid/semiarid western United States using the following three scenarios:

1) Pre-mining background - A characterization prior to surface disturbance by mining and reclamation activities;

2) Numeric Limitations - Modeling and design of a sediment control system that meets numeric limitations for runoff from areas where pre-mining activities supporting reclamation are being conducted; and

3) Alternate Sediment Control Measures - Modeling and design of a BMP-based alternate sediment control system that meets background sediment yield standards for runoff from areas where pre-mining activities supporting reclamation are conducted.

Modeling of conditions prior to surface disturbance by mining was conducted to characterize pre-mining background water quality, soil loss rates, and sediment yield. The modeled values serve as a benchmark, establishing standards for the alternate sediment control system.

Non-process areas were modeled using 1) alternate sediment control measures, and 2) a treatment system designed to meet a maximum daily TSS concentration of 70 mg/L and a 30-day average TSS concentration of 35 mg/L.

NMA developed a third scenario using alternative erosion and sediment control techniques. The alternate sediment control BMPs used in the modeling effort were:

- Silt fences
- Infiltration berms
- Porous rock check dams
- Rock diversions
- Rotoclearing or chipping

The same contour mapping and corresponding hydrographic and soils databases that were developed for Case Study 1 were used to support modeling of the hydrology and sedimentology of a typical watershed in the arid/semiarid western United States.

5.3.1 Modeling Results

Average annual erosion quantities were predicted based on the RUSLE model version 1.06. Input parameter values for the modeling effort were based on vegetation, soils, and surface configurations obtained from existing case study mines and mine permits. RUSLE variables were input to SEDCAD 4.0 to model watershed sedimentology. Since hydrologic conditions were also modeled (analysis of a 10-year, 24-hour design storm), all three scenarios were assessed with SEDCAD 4.0.

40 CFR Part 434, Subcategory H requires establishment of pre-mining background watershed conditions, against which the adequacy of the sediment control system is measured. Use of alternate BMP sediment control systems during mining and reclamation facilitates deployment of controls designed to mimic site-specific, pre-mining background watershed conditions. Mine modeling of pre-mining activities supporting reclamation was performed in order to characterize potential benefits of these systems.

Modeling erosion and sediment controls for pre-mining activities produced the results shown in Table 5i.

Table 5i: Comparison of Hydrology and Sedimentology Results (Western Coal Mining Work Group, 2000b)

	Pre-mining Background	Reclaimed to Meet Numeric Limits[1]		Reclaimed Under Alternate Sediment Control Measures	
	Result	Result	% Change from Pre-mining	Result	% Change from Pre-mining
Total Contributing Area (acre)	291	266	-9	291	0
Peak Discharge (cfs) (10 year, 24-hr storm event)	103	7	-93	93[2]	-10
Total Runoff Volume (acre-ft) (10 year, 24-hr storm event)	12	16[3]	+33	18	+50
Sediment (tons) (10 year, 24-hr storm event)	1,067	0	-100	586	-45
Sediment Loss (tons/acre)	3.7	0	-100	2.0	-46
Peak Sediment (mg/L) (10 year, 24-hr storm event)	129,300	40	-100	119,200	-8
Peak Settleable Solids (ml/L) (10 year, 24-hr storm event)	58	0	-100	24	-65
Settleable Solids (ml/L) (24-hr Volume Weighted) (10 year, 24-hr storm event)	30	0	-100	5	-83

[1]Assumes pond is filled to design storage capacity with 1 year of transported sediment.
[2] Four porous rock check dams were used as BMPs. SEDCAD 4.0 does not give credit for reduction or attenuation in peak flow when using the check dam structure analysis option. The two upstream check dams (Stru#1 and Stru#2) were very small and on steep gradients and were modeled as check dams. The two larger dams (Stru#8 and Stru#12) were on flatter gradients and were modeled as ponds to take peak flow attenuation into account.
[3]Sediment pond outflow devices include a fixed siphon (which was modeled) and a gate pipe with a floating inlet designed to remove water from the pond by decanting water from near the pond surface.

The most important modeling results are for peak discharge and peak sediment concentration. The BMP treatment system reduced peak discharge by only 10% below background levels, while the system for treatment to numeric limitations reduced the peak discharge by 93% below background levels.

Prolonged changes in peak sediment concentrations are capable of disrupting fluvial balances and introducing degradation or aggradation in the receiving channel. The proposed BMP treatment system achieved peak sediment concentrations approximately 8% less than pre-mining background levels, while the current subcategory treatment system had peak sediment concentrations that were near zero to comply with the effluent standard of 35/70 mg/L TSS. This is a direct result of capturing almost 100% of the sediment in the sediment pond.

Sediment delivery from the BMP treatment sediment control system more closely approximated background at 2.0 tons (a reduction of 1.7 tons) vs. the treatment system's delivery of 0 tons (a reduction of 3.7 tons). Settleable solids levels released from the BMP treatment system were a little more than half the background conditions, while the treatment system reduction was almost 100%.

5.3.2 Costs

An analysis of costs was conducted under both the sediment control system and the system designed to treat to numeric limitations. Cost assessment was based on capital costs (design, construction, and removal) and operating costs (inspection, maintenance, and operation) associated with the sedimentation pond system and the BMP-based system used over the two-year development period. These costs were developed for the two-year period of pre-mining activities supporting reclamation. A summary of the costs associated with both the current subcategory and proposed subcategory options are presented in Table 5j.

The present value of the reclamation costs over the two-year premining period (discounting at seven percent) is $463,582 for the existing guideline and $202,190 for the proposed subcategory, or a present value total savings of $261,392 over two years. This represents a 56 percent overall reduction in costs, or $2,489 is saving per disturbed acres. The annualized savings are $135,115 (annualized at seven percent), or $1,287 annualized savings per acre for the 105 disturbed acres.

Table 5j: Cost of Sedimentation Pond System vs. Cost to Implement Alternative Sediment Controls (adapted and revised from WCMWG, 2000b)

Year	Sedimentation Pond System				Alternate Sediment Control Technologies			
	Capital	Operating	Total	Present Value[1]	Capital	Operating	Total	Present Value[1]
1	$420,512	$24,845	$445,357	$445,357	$174,050	$9,177	$ 83,227	$183,227
2	-	19,501	19,501	18,225	9,718	10,572	20,290	18,963
Total (not discounted)	$420,512	$44,346	$464,858	$463,582	$183,768	$19,749	$203,517	$202,190
Annualized @ 7% over 2 years				$239,629				$104,514

Annualized Savings	$135,115	Present Value Total Savings	$61,392
Annualized Savings per Reclamation Acre[2]	$1,287	Present Value Total Savings per Acre[2]	$2,489

Costs expressed in 1998 Dollars

[1] Discount Rate: 0.07

[2] Based on 105 disturbed acres.

5.4 Case Study 4 (Bridger Coal Company, Jim Bridger Mine)

Wyoming Department of Environmental Quality, Land Quality Division Rules and Regulations, Chapter IV, Section 3g(1) states that exemptions to the use of sedimentation ponds may be granted where, by the use of alternative sediment control (ASC) measures, mine drainage will not degrade receiving waters. The Jim Bridger Mine located in southwestern Wyoming, has successfully used ASC measures, in addition to several sediment ponds, to treat disturbed area runoff and prevent degradation of local stream water quality since 1984.

Case Study 4 presents a summary of a Jim Bridger Mine study provided by the Western Coal Mining Work Group (Bridger Coal Company, 1987). Bridger Coal Company began coal production in 1974. The Bridger mine is located in a desert located 28 miles northeast of Rock Springs in southwest Wyoming. Mean annual precipitation is 6-8 inches, and the mean frost free period is 100 days. High winds are frequent and evapotranspiration is high. Some soils and spoils are saline or sodic. The local receiving water consists of ephemeral streams.

An experimental practice for a portion of the mine was initiated in 1983 to test the effectiveness of alternate sediment control techniques compared to sediment ponds for preventing additional contributions of sediment to receiving streams. The alternate sediment control practices became standard in 1987, and are still in use today. The effectiveness of alternate sediment control techniques continues to be monitored.

5.4.1 Justification of Alternate Sediment Controls

Initial water quality data available for receiving streams are presented in Figure 5b. The data indicate that undisturbed mine area runoff is high in suspended solids. Data from single stage sediment samples show total suspended solids (TSS) concentrations of 110 to 820,000 mg/L for discharges from 1 to 500 cubic feet per second (cfs). The highest values measured by single stage sediment samples were enriched in coarse sediment by continued circulation during the runoff event. However, values of 800,000 mg/L indicate that sediment transport is high.

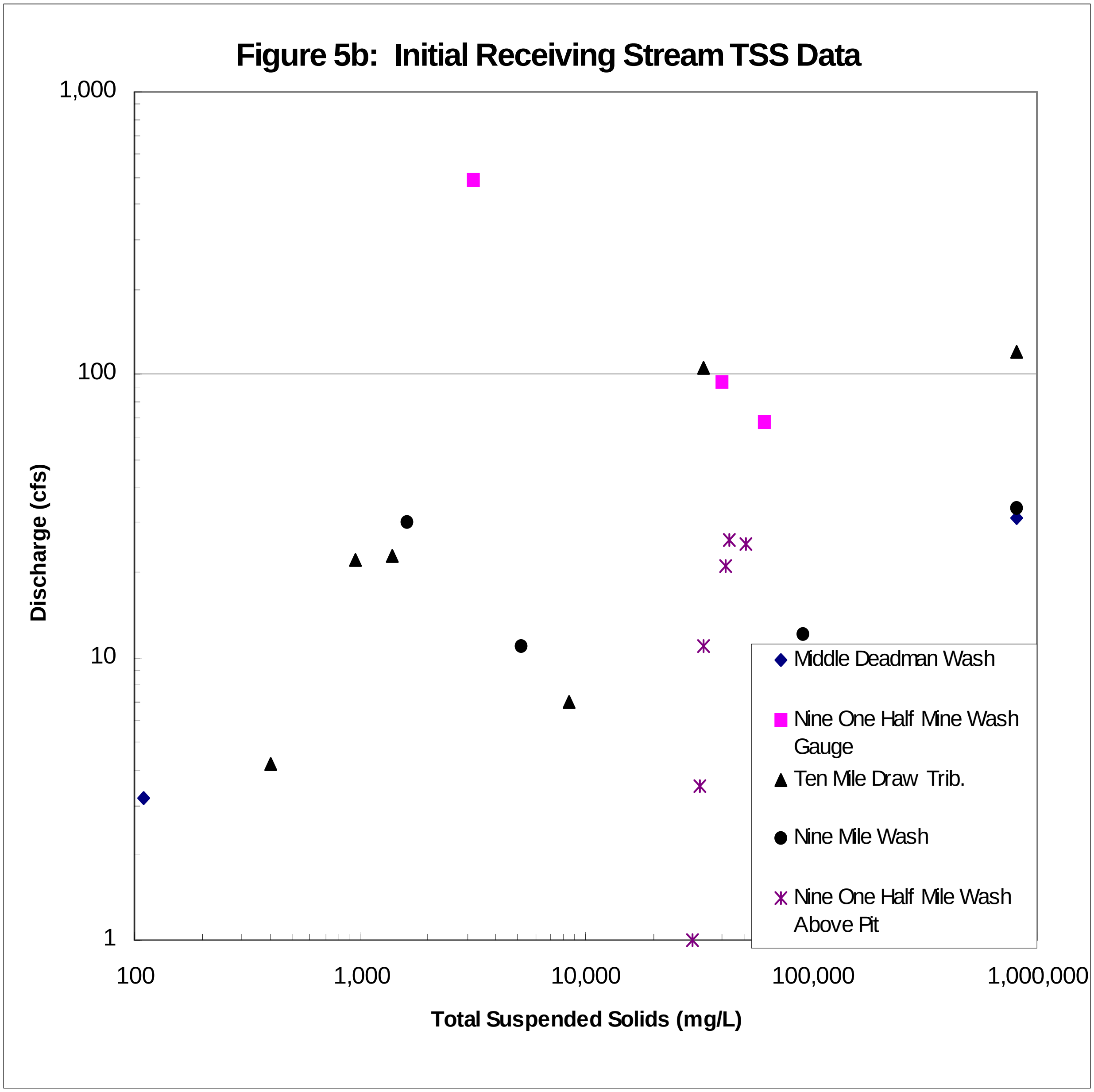


Figure 5b: Initial Receiving Stream TSS Data
1,000
100
10
1
Discharge (cfs)
100
1,000
10,000
100,000
1,000,000
Total Suspended Solids (mg/L)
Middle Deadman Wash
Nine One Half Mine Wash Gauge
Ten Mile Draw Trib.
Nine Mile Wash
Nine One Half Mile Wash Above Pit

Logistical concerns regarding sediment ponds were important in the decision to implement alternate sediment control techniques. The extensive mining area and the drainage density would necessitate approximately 200 ponds to control all mining disturbed runoff over the life of the mine. This would entail disturbing over 400 additional acres. Such land disturbance is essentially eliminated by use of alternate sediment control techniques.

The benefits of the use of alternate sediment controls instead of sediment ponds are:

- Channel degradation below dams, produced by the discharge of unnaturally clear and erosive water, is precluded;
- Additional disturbance due to dam and pond construction is avoided; and
- With the elimination of impoundment storage time, seepage, and evaporation, there is less disruption of natural stream flows.

5.4.2 Description of Alternate Sediment Control Techniques

Several techniques are used by the Bridger Coal Company to limit sediment discharge from mined land to background levels (Hargis, 1995). Most of these techniques are appropriate for small drainage areas. Drainage from larger areas can be diverted to the pit floor where it can be stored and used for road watering. The first group of techniques involves preventing the runoff from leaving the disturbed areas. These techniques include:

- Berms
- Diversion ditches
- Toe ditches
- Small catchments
- Drainage to pit floor via haul roads and ramps

The second group of techniques involves the use of rock check dams or hay bales for the purpose of filtering and temporarily detaining runoff water until some of its sediment load settles. Check dam size is determined by using the SEDIMOT II computer program. These materials are used a short distance downstream from the disturbed land. They are installed before soil removal and maintained while the disturbed drainage area is unstable.

A third group of techniques involves appropriate mine land reclamation practices and includes:

- Prudent geomorphic design
- Reconstruction of complex slopes
- Restoration of drainage density
- Roughening of soil surface
- Mulching
- Contour farming
- Timely establishment of permanent vegetative cover

Bridger Coal Company continuously evaluates the effectiveness of sediment control technologies that are in place at this site as well as the predicted effectiveness of additional techniques, and modifies the alternate sediment control plan appropriately when necessary.

5.4.3 Alternate Sediment Control Design

In order to determine the most appropriate ASC techniques for each mining area, Bridger Coal Company used the computer models SEDIMOT II and SEDCAD. These models allow evaluation of disturbed area runoff prior to the disturbance and simulate the various alternate sediment control s. These models also allow the determination of alternate sediment control size and location necessary to reduce the sediment discharge to levels below the receiving stream water quality. Once an alternate sediment control plan has been designed and implemented, a monitoring program is then used to determine the effectiveness of the control techniques and record water quality degradation, should any occur.

Prior to the original permit application at this site, surface water quality data showed that TSS was the only parameter that was consistently high, and was, therefore, of concern to in stream water quality. These data are presented in Table 5k. For this reason, and because of the importance of sediment transport in fluvial systems, TSS is the primary water quality parameter considered in design of alternate sediment control techniques.

Table 5k: Pre-mining Surface Water Quality Data

Site	Type	Date	Iron (mg/L)	Manganese (mg/L)	Field pH	TSS (mg/L)	Discharge (cfs)
BCTR	PD	04/14/80	1.47	0.044	7.20	411.0	-
BCTR	PD	05/15/80	1.32	0.048	9.00	303.0	-
L10MD	SC	01/17/80	1.42	0.190	-	182.0	-
L10MD	SC	04/14/80	0.52	0.033	-	1240.0	-
MDW	SC	06/17/80	475.00	7.600	-	21750.0	-
MDW	SC	05/14/80	1.08	0.449	-	66152.0	-
MDW	SS	06/17/80	475.00	7.600	-	21750.0	-
UDW	SS	03/17/80	1.15	0.430	7.80	1672.0	-
U10MD	SC	04/26/79	0.55	0.180	-	24.0	-
U10MD	SC	05/31/79	0.47	0.050	8.40	40.0	-
U10MD	SC	08/22/79	4.76	0.120	7.30	79.0	-
U10MD	SC	10/24/79	0.06	-	8.00	52.0	-
U10MD	SC	03/11/80	0.16	0.064	7.70	68.0	-
U10MD	SC	04/14/80	0.21	0.029	8.30	916.0	-
U10MD	SS	03/19/81	1.24	0.190	-	56.0	-
10MDT	SC	04/16/80	2.78	0.090	-	8728.0	-
10MDT	SC	06/17/80	165.00	3.200	-	8141.0	18.0
10MDT	SS	03/13/80	164.00	2.100	-	1532.0	28.0
10MDT	SS	04/16/80	180.65	2.715	-	8728.0	1.0
10MR3	PD	04/26/79	2.40	0.050	7.80	68.0	-
10MR3	PD	08/22/79	23.60	0.260	8.20	275.0	-
10MR3	PD	09/25/79	32.00	0.440	6.00	816.0	-
10MR3	PD	04/16/80	0.56	0.210	8.80	71.0	-
10MR3	PD	05/15/80	0.50	0.200	7.30	418.0	-

Site	Type	Date	Iron (mg/L)	Manganese (mg/L)	Field pH	TSS (mg/L)	Discharge (cfs)
10MR3	PD	06/18/80	4.12	0.075	7.90	37.0	-
10MR3	PD	07/10/80	1.27	0.130	7.50	65.0	-
10MR3	PD	08/04/80	3.04	0.385	7.20	180.0	-
10MR3	PD	09/05/80	4.20	0.410	7.40	368.0	-
10MR3	PD	10/02/80	1.42	0.020	8.30	438.0	-
10MR3	PD	11/06/80	3.15	0.332	8.75	-	-
10MR4	PD	04/26/79	31.00	0.370	-	620.0	-
10MR4	PD	08/22/79	16.00	0.190	7.80	348.0	-
10MR4	PD	09/25/79	1.67	0.270	6.20	30.0	-
10MR4	PD	10/24/79	1.59	0.000	7.40	36.0	-
10MR4	PD	04/14/80	0.47	0.120	7.40	19.5	-
10MR4	SC	05/15/80	0.46	0.210	7.50	715.0	-
10MR4	SS	06/18/80	55.50	1.570	6.80	1700.0	-
9.5MD	SS	04/15/80	0.34	0.450	-	4516.0	-
9.5MD	SS	08/22/79	1470.00	22.100	-	3211.0	-
9.5MW	SC	07/29/81	936.00	-	-	61600.0	72.0
9.5MW	SS	09/15/81	930.00	-	-	38700.0	104.0
9MW	SS	06/17/80	140.00	3.500	-	11660.0	-
9MW	SS	08/21/79	520.00	12.100	-	5373.0	-
9MW	SS	03/08/80	42.20	0.920	-	1768.0	19.7
9MW	SS	07/15/81	1050.00	-	-	93600.0	-

PD = Pond; SC = Stream Channels; and SS = Sediment Sampling Stations.

In the SEDIMOT II and SEDCAD models, the SCS curve number is used for flow runoff calculations; the Modified Universal Soil Loss Equation (MUSLE) is used for soil loss calculations; the Muskingum method is used to route water flow; Williams Model I is used to route sediment in channels; and Yang's unit stream power equation is used to route sediment overland. Application of these models allows increased temporal and spatial variability to be incorporated into the analysis, and allows for channel segments and subwatershed areas to be specified to simulate individual contributions to the total basin output.

For this site, a database containing TSS concentrations in a small ephemeral stream during pre-mining, undisturbed conditions existed prior to the initial alternate sediment control application submittal. Data from this database are presented in Table 5l. From this database, a design TSS input value for the SEDIMOT II/SEDCAD simulations was calculated. The arithmetic average of these data (30,000 mg/L) was used as a design criterion to determine the location and size of the alternate sediment control structures. Preferably, disturbed area runoff should be near or below the mean TSS concentration of the observed data (30,000 mg/L). The actual impact of the mine runoff on the receiving stream water quality was determined from the data collected from the alternate sediment control monitoring program.

The actual alternate sediment controls selected differ for each reclaimed area and are determined by site-specific analysis. As part of this analysis, the company uses SEDIMOT II/SEDCAD to model the effects of seven alternate sediment control techniques, simulated in sequence as presented in Table 5m. The sequence is determined by experience with alternate sediment control effectiveness in reducing sediment discharges.

Table 5l: Existing Database, Undisturbed TSS Concentration Data

Location	Date	TSS (mg/L)	Peak Monthly Flow (cfs)	10-Yr.-24-hr. Peak Discharge (cfs)
Nine Mile Wash	08/21/79	5,373.0	13.0	1,646.0
	03/08/80	1,768.0	35.4	
	10/05/80	37,700.0	50.4	
	10/05/80	22,640.0	50.4	
	07/15/81	93,600.0	12.0	
	08/09/82	34,050.0	55.0	
9.5 Mile Wash @ Crest Gage	08/22/79	3,211.0	375.0	625.0
	07/29/81	61,600.0	72.0	
	09/15/81	38,700.0	104.0	
	08/05/82	95,700.0	120.0	
Middle Deadman Wash	5/14/80	66,152.0	5.0	887.0
	06/17/80	21,750.0	8.0	
9.5 Mile Wash @ Temp. Recording Sta.	09/14/82	53,540.0	27.0	
		44,500.0	28.0	
		42,920.0	22.0	
		34,660.0	11.0	
		32,780.0	4.0	
		29,420.0	1.0	
	9/24/82	3,155.0	NA[1]	
		17,000.0	NA[1]	
		20,300.0	NA[1]	
		15,540.0	NA[1]	
		24,840.0	NA[1]	
		20,490.0	NA[1]	
		17,150.0	NA[1]	
		19,900.0	NA[1]	
		16,120.0	NA[1]	
		20,020.0	NA[1]	
		14,670.0	NA[1]	
		13,340.0	NA[1]	
		36,860.0	NA[1]	
		8,160.0	NA[1]	
		14,800.0	NA[1]	
		Average = 29,770	**(Round to 30,000)**	

[1] Not available, hydrograph not recorded.

Table 5m: Order of Simulation of Sediment Control Best Management Practices

Order of Implementation in Design	Sediment Control Technique
1	Rock Check Dams
2	Interceptor Ditch (Contour Ditch)
3	Contour Berms
4	Vegetative Buffer Strip
5	Toe Drain Ditch
6	Temporary Barrier
7	Benches

5.4.4 Monitoring Program

Monitoring is conducted during runoff events between May 1 and September 30 (when temperatures are above freezing). Each monitoring station is serviced generally after each storm, and at least once per month, from May through September. In addition, checks are performed every two weeks from May through September.

Through the first three mining periods, eight paired watersheds (four pairs) and one control station were equipped with automatic pump samplers and manometers. Each watershed pair consisted of one disturbed watershed treated with alternate sediment controls and an undisturbed watershed. The nine sampling stations were:

SWPS-2 Station SWPS-2 was a control watershed location on a tributary of Deadman Wash. This station was impacted by mining in 1990 and decommissioned in 1991. However, no data were collected because very little runoff was generated by the small storms that occurred in the watershed since the station was installed.

SWPS-3 Station SWPS-3 is the upstream receiving stream station located near the upper mining limit. SWPS-3 is located on Deadman Wash and provides pre-mining, undisturbed data.

SWPS-4 Station SWPS-4 was located on Deadman Wash, downstream from SWPS-3. SWPS-4 was the disturbed watershed paired with SWPS-3 during the experimental period (1984-1987). The site was decommissioned in 1987 and mined through in 1988.

SWPS-7 Station SWPS-7 was located on Deadman Wash, just above the outlet of the SWPS-8 watershed. SWPS-7 was the undisturbed watershed paired with SWPS-8 during the experimental period (1984-1987). The site was decommissioned in 1987.

SWPS-8 Station SWPS-8 monitors a disturbed watershed on a tributary of Deadman Wash. SWPS-8 is located approximately 1,000 feet upstream from Deadman Wash.

SWPS-9 Station SWPS-9 is a Deadman Wash downstream receiving station that is located approximately 100 feet upstream from the confluence of Deadman Wash and Nine Mile Draw.

SWPS-10 Station SWPS-10 is a disturbed watershed location on Nine Mile Draw. This location is located approximately 300 feet upstream from the confluence of Nine Mile Draw and Deadman Wash.

SWPS-13 Station SWPS-13 is upstream from the pit and represents the receiving stream.

SWPS-14 Station SWPS-14 is downstream of all mining disturbance in the Ten Mile Draw drainage basin.

5.4.5 Data Reduction

During the first permit term, the discharge monitoring data were reduced using standard U.S. Geological Survey (USGS) procedures for continuous sediment and water stage data. The reduced data were then analyzed using either a covariance test or a modified Student's t-test in order to determine whether degradation occurred in the receiving stream as a result of the disturbed area runoff.

During the second and all subsequent permit terms, the data reduction procedure followed Porterfield (1972). This procedure is summarized as follows:

1. The stage recorder chart is adjusted for applicable pen, data, or time corrections.
2. Discrete sediment sample data are used to construct a continuous temporal sediment concentration graph on the same scale as the flow record.

3. Water stage and sediment graphs are subdivided by mid-intervals into discrete water discharge, sediment concentration, and sediment discharge values. In order to avoid biasing the data in subsequent analyses, equal time intervals are used for the disturbed stream and receiving stream subdivisions.
4. The subdivided water discharge and sediment discharge data are used to calculate storm sediment yields in tons per acre and storm water yields in acre-feet per square mile.
5. A log-log data plot of all monitoring stations is prepared with storm sediment yield plotted against storm water yield.

5.4.6 Data Analysis

Once data have been reduced they are analyzed to determine if degradation has occurred (i.e., sediment yield has increased over background conditions). During the first permit term (1984-1987), the discharge monitoring data were reduced using standard USGS procedures for continuous sediment and water stage data. The allowable TSS change criteria initially were based on a statistical comparison of storm sediment concentrations in the receiving stream before and after addition of the disturbed area runoff. Sediment data were analyzed with either a covariance test (for multiple pairs), or a modified Student’s t-test (for a single pair of TSS data points) in order to determine whether the receiving stream (Deadman Wash) was degraded by runoff from the disturbed area. Since no degradation had been detected in over 65 storms, alternate sediment control techniques were determined to be successful.

A simpler method for assessing differences in TSS concentrations between paired watersheds was approved for the second and subsequent terms of the permit. First, instantaneous TSS concentrations and flow rates are collected at adequate intervals to accurately calculate storm water and sediment yield. An example of reduced storm yield data is presented in Table 5n.

Table 5n: Example Water and Sediment Yield Data (1984 - 1998)

Station	Date	Stream Type	Water Yield (acre-ft/mi^2)	Sediment Yield (tons/acre)
SWPS-3	7/31/84	Receiving	1.477484022	0.050618459
SWPS-3	6/25/85	Receiving	0.005176922	0.0000418
SWPS-3	7/18/85	Receiving	0.031431064	0.00089235
SWPS-3	7/23/85	Receiving	0.11673182	0.005699971
SWPS-3	7/30/85	Receiving	0.080180455	0.001962336
SWPS-3	4/24/86	Receiving	0.002708907	0.0000293
SWPS-3	5/8/86	Receiving	0.009636635	0.0000606
SWPS-3	7/4/86	Receiving	0.010107986	0.0007701
SWPS-3	8/29/86	Receiving	0.003897468	0.00012434
SWPS-3	9/24/86	Receiving	0.001839712	0.0000272
SWPS-3	9/26/86	Receiving	0.002459572	0.0000167
SWPS-3	9/27/86	Receiving	0.001592364	0.000009
SWPS-3	5/29/87	Receiving	0.02346527	0.00057052
SWPS-3	5/30/87	Receiving	0.002834567	0.0000439
SWPS-3	6/9/87	Receiving	0.025076508	0.0005538
SWPS-3	9/3/87	Receiving	0.007832187	0.00028004
SWPS-3	9/4/87	Receiving	0.021765622	0.00035631
SWPS-3	7/12/89	Receiving	0.00843516	0.00030093
SWPS-3	9/19/89	Receiving	0.010161131	0.00017763
SWPS-3	8/21/90	Receiving	0.001368857	0.000008
SWPS-3	5/22/91	Receiving	0.011213602	0.00036676
SWPS-3	6/1/91	Receiving	0.519122156	0.012856543
SWPS-3	6/13/91	Receiving	0.03358617	0.00099266
SWPS-3	7/25/91	Receiving	0.12759526	0.00192681
SWPS-3	9/9/91	Receiving	0.034409669	0.001002066
SWPS-3	9/29/91	Receiving	0.13113313	0.004085589
SWPS-3	7/11/92	Receiving	0.333143	0.004893302
SWPS-3	7/21/92	Receiving	0.063889	0.001587215
SWPS-3	6/3/93	Receiving	0.094653	0.00055171
SWPS-3	6/17/93	Receiving	0.16531	0.00061545
SWPS-3	6/26/93	Receiving	0.14757	0.004199484
SWPS-3	9/12/94	Receiving	0.005984	0.00011808
SWPS-3	5/25/96	Receiving	0.014834	0.0000742
SWPS-3	9/8/95	Receiving	0.090383	0.002519272
SWPS-4	7/31/84	Disturbed	1.281434215	0.059088767
SWPS-4	7/18/85	Disturbed	0.038092331	0.00066273
SWPS-4	7/23/85	Disturbed	0.089620306	0.006017068
SWPS-4	7/30/85	Disturbed	1.315367177	0.037101028
SWPS-4	7/4/86	Disturbed	0.017723258	0.00096693

Station	Date	Stream Type	Water Yield (acre-ft/mi^2)	Sediment Yield (tons/acre)
SWPS-4	9/3/87	Disturbed	0.036651076	0.002640955
SWPS-4	9/4/87	Disturbed	0.051385958	0.001527354
SWPS-7	7/31/84	Receiving	0.883773652	0.03245597
SWPS-7	8/6/84	Receiving	0.018663956	0.00091022
SWPS-7	8/18/84	Receiving	0.008212654	0.00029353
SWPS-7	9/6/84	Receiving	0.078186652	0.002446697
SWPS-7	7/18/85	Receiving	0.026335062	0.00052174
SWPS-7	7/20/85	Receiving	0.037043061	0.001852661
SWPS-7	7/23/85	Receiving	0.080330902	0.004302842
SWPS-7	7/30/85	Receiving	1.64197228	0.036970469
SWPS-7	7/4/86	Receiving	0.031810992	0.001072226
SWPS-7	5/29/87	Receiving	0.049678773	0.002706261
SWPS-7	6/9/87	Receiving	0.010749402	0.00050693
SWPS-7	9/3/87	Receiving	0.017177596	0.0008806
SWPS-7	9/4/87	Receiving	0.06342408	0.001558256
SWPS-8	7/9/84	Disturbed	0.864063707	0.039664882
SWPS-8	7/31/84	Disturbed	2.989430677	0.346925851
SWPS-8	8/6/84	Disturbed	1.377395402	0.128622236
SWPS-8	8/18/84	Disturbed	0.65060337	0.029959021
SWPS-8	9/6/84	Disturbed	2.053912776	0.0679606
SWPS-8	7/30/85	Disturbed	7.646761495	0.747331783
SWPS-8	5/29/87	Disturbed	0.942419621	0.034361881
SWPS-8	7/23/89	Disturbed	16.7603059	0.85378317
SWPS-8	9/18/89	Disturbed	1.953010004	0.05122973
SWPS-8	7/20/90	Disturbed	0.756138294	0.017944103
SWPS-8	9/4/90	Disturbed	24.80262338	0.729661636
SWPS-8	7/12/92	Disturbed	3.338507	0.040114953
SWPS-8	7/21/92	Disturbed	0.386208	0.03935179
SWPS-8	6/7/93	Disturbed	1.28865	0.008883994
SWPS-8	7/26/93	Disturbed	2.903206	0.129072306
SWPS-8	9/7/95	Disturbed	3.5058	0.220394066
SWPS-8	9/21/97	Disturbed	1.292154	0.048861472
SWPS-9	7/31/84	Receiving	0.968139808	0.066406744
SWPS-9	8/6/84	Receiving	0.030162507	0.001983688
SWPS-9	9/6/84	Receiving	0.340016234	0.023758994
SWPS-9	7/18/85	Receiving	0.037446771	0.00087062
SWPS-9	7/20/85	Receiving	0.393764689	0.024798275
SWPS-9	7/23/85	Receiving	0.145318019	0.005443206
SWPS-9	7/30/85	Receiving	2.115498217	0.129639835
SWPS-9	6/9/87	Receiving	0.046868004	0.003246825
SWPS-9	9/19/89	Receiving	0.60228965	0.013080951
SWPS-9	8/4/90	Receiving	0.377490999	0.009658689

Station	Date	Stream Type	Water Yield (acre-ft/mi^2)	Sediment Yield (tons/acre)
SWPS-9	5/15/91	Receiving	0.524044071	0.00476637
SWPS-9	8/4/91	Receiving	0.137681387	0.003731229
SWPS-9	9/7/95	Receiving	1.280506	0.037841673
SWPS-9	9/21/97	Receiving	0.808959	0.036334021
SWPS-9	7/24/98	Receiving	0.233039	0.006275786
SWPS-9	7/25/98	Receiving	0.114991	0.003876858
SWPS-9	8/3/98	Receiving	0.070143	0.003449813
SWPS-10	7/21/84	Disturbed	0.027840712	0.00060744
SWPS-10	7/31/84	Disturbed	1.273303295	0.063190439
SWPS-10	8/1/84	Disturbed	0.059938324	0.001226025
SWPS-10	8/4/84	Disturbed	0.024953331	0.00072447
SWPS-10	8/23/84	Disturbed	0.187992353	0.004881808
SWPS-10	9/6/84	Disturbed	1.220188727	0.024843723
SWPS-10	9/13/84	Disturbed	0.29014207	0.01063298
SWPS-10	9/21/84	Disturbed	0.086033362	0.00068546
SWPS-10	6/25/85	Disturbed	0.225655459	0.004346816
SWPS-10	7/18/85	Disturbed	0.088624058	0.003332559
SWPS-10	7/20/85	Disturbed	1.274837051	0.057595307
SWPS-10	7/23/85	Disturbed	0.490645525	0.016545764
SWPS-10	7/30/85	Disturbed	1.892771051	0.07519991
SWPS-10	9/2/85	Disturbed	0.301326036	0.014233035
SWPS-10	9/11/85	Disturbed	0.224095213	0.004608739
SWPS-10	9/19/85	Disturbed	0.285482526	0.00433567
SWPS-10	7/4/86	Disturbed	0.065318389	0.003137509
SWPS-10	7/9/86	Disturbed	0.03566578	0.00096967
SWPS-10	9/8/86	Disturbed	0.040836576	0.001148005
SWPS-10	7/11/87	Disturbed	0.045726581	0.00097525
SWPS-10	9/4/87	Disturbed	1.077011708	0.01375377
SWPS-10	7/26/88	Disturbed	0.345285	0.023645
SWPS-10	8/3/88	Disturbed	0.881732	0.034852
SWPS-10	7/12/89	Disturbed	10.2879986	0.4594194
SWPS-10	7/23/89	Disturbed	9.266459047	0.493653359
SWPS-10	9/18/89	Disturbed	0.204264997	0.007283703
SWPS-10	9/19/89	Disturbed	1.70304627	0.026197923
SWPS-10	9/20/89	Disturbed	0.350679062	0.004809361
SWPS-10	7/20/90	Disturbed	0.005629069	0.00015047
SWPS-10	7/24/90	Disturbed	6.277730829	0.26287646
SWPS-10	8/4/90	Disturbed	0.207790781	0.010900476
SWPS-10	8/30/90	Disturbed	1.216872212	0.064923592
SWPS-10	6/1/91	Disturbed	1.261933901	0.079357249
SWPS-10	6/13/91	Disturbed	0.289479827	0.013982257
SWPS-10	8/27/91	Disturbed	0.068529	0.00109785

Station	Date	Stream Type	Water Yield (acre-ft/mi^2)	Sediment Yield (tons/acre)
SWPS-10	9/9/91	Disturbed	0.040127	0.00635304
SWPS-10	9/29/91	Disturbed	0.019763991	0.00064645
SWPS-10	6/3/93	Disturbed	0.38052	0.006587097
SWPS-10	6/17/93	Disturbed	0.820869	0.007857705
SWPS-10	7/26/93	Disturbed	0.576255	0.019192863
SWPS-10	8/11/93	Disturbed	0.077249	0.002496633
SWPS-10	9/17/93	Disturbed	0.030802	0.00046812
SWPS-10	9/18/93	Disturbed	1.749732	0.02525054
SWPS-10	9/8/95	Disturbed	0.155225	0.004313379
SWPS-10	9/21/97	Disturbed	2.60624	0.107340165
SWPS-13	9/21/97	Receiving	9.156198	0.139136745
SWPS-14	9/21/97	Disturbed	0.039105	0.001971105
SWPS-14	7/29/98	Disturbed	0.009494	0.00032269

Next, the 95% prediction bands confining the regression equation $y = 0.0339(x)^{1.0925}$ are calculated using Equation 5a developed for predicting any value of "y" for a given "x" (Kleinbaum, 1978). Unit water and sediment yield are plotted with the 95% prediction intervals in Figure 5c, and a graphical comparison is made of the individual storm sediment yield relative to the general trend. Any points (storms) which fall inside the 95% prediction interval show that no significant variation from background sediment yield has occurred. If the disturbed monitoring station points (storms) plot above the predicted interval, degradation has technically occurred and mitigation measures are immediately taken. No unit sediment yields, of storms less than a 10-year, 24-hour event, plotted outside of the confidence bands between 1984 and 1998.

Equation 5a

$$y_0 = \overline{Y} + B_1(X_0 - \overline{X}) \pm t_{(n-2,\ 1-\alpha/2)} * S_{y/x} * \sqrt{\left(1 + \frac{1}{n} + \frac{(X_0 - \overline{X})^2}{(n - 1) * S_X^2}\right)}$$

Where:

$\overline{Y}$ = Mean of Y values

$\overline{X}$ = Mean of X values

B_1 = Coefficient of Regression Equation
X_0 = Value in Question
y_0 = Value in Question
$t_{(n-2, 1-\alpha/2)}$ = t statistic
n = Number of values
S_x^2 = Variance of x values

$$S_{y/x} = \sqrt{\left(\frac{n - 1}{n - 2}\right) * (S_y^2 - (B_1^2 * S_X^2))}$$

Where:

S_y^2 = Variance of Y values
n = Number of values
S_x^2 = Variance of X values
B_1 = Coefficient of Regression Equation

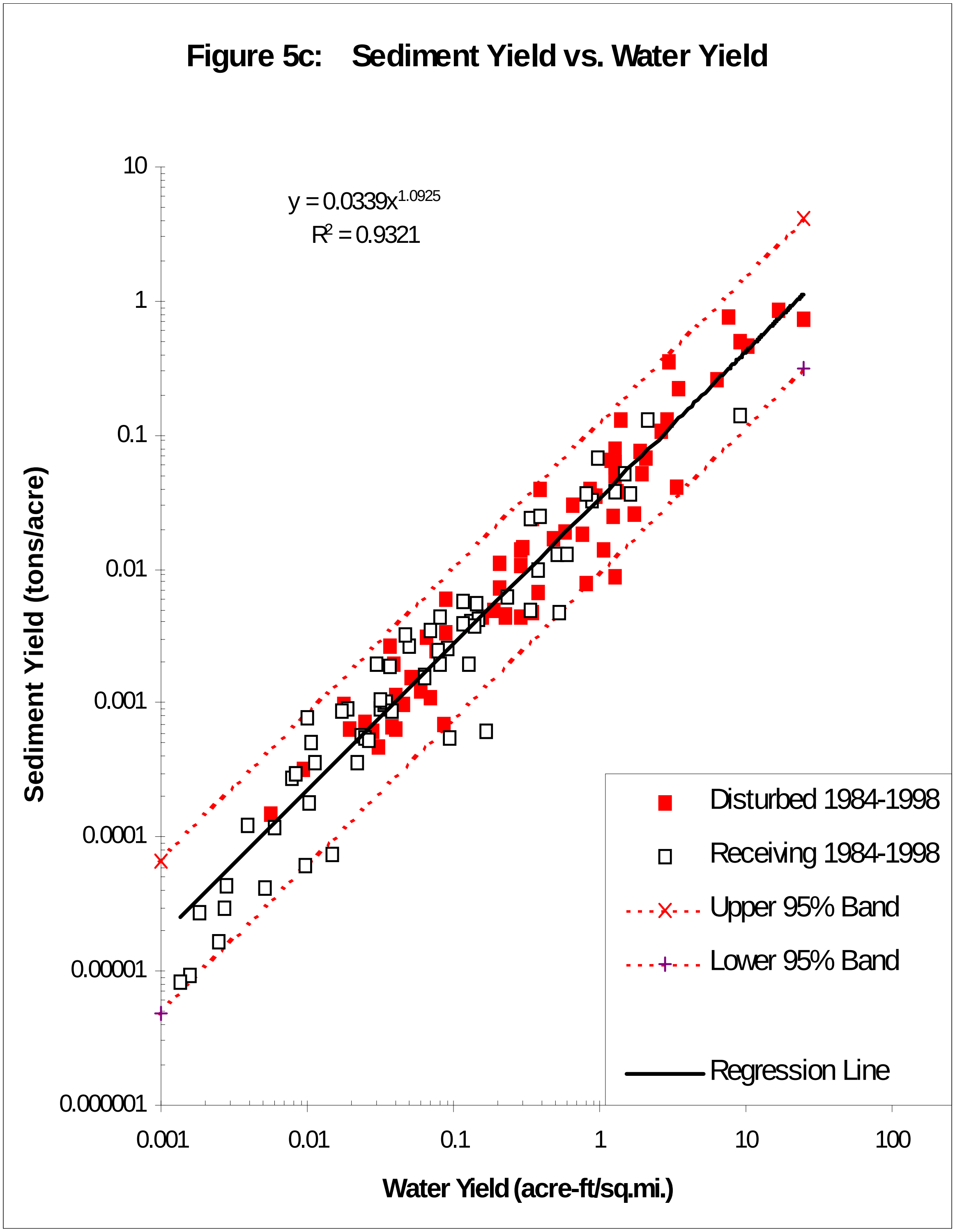


Figure 5c: Sediment Yield vs. Water Yield
y = 0.0339x^1.0925
R² = 0.9321
Sediment Yield (tons/acre)
10
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.001
0.01
0.1
1
10
100
Water Yield (acre-ft/sq.mi.)
Disturbed 1984-1998
Receiving 1984-1998
Upper 95% Band
Lower 95% Band
Regression Line

To confirm that the use of alternate sediment controls is effective, Bridger also conducts annual surveys of the receiving streams. For example, Bridger Coal Company has conducted an annual survey of Nine and One-Half Mile Draw since 1987. The surveys include up to nine cross sections used to model Nine and One-Half Mile Draw. Two cross sections are located upstream from the final highwall, three are located in the reclaimed reach, and four are located downstream from the boxcut disturbance limit. Areas of head cutting, aggradation, or degradation are noted and reported each year. Based on data available (up to 1992), no aggradation or degradation has been detected downstream of the disturbance in Nine and One-Half Mile Draw.

5.4.7 Summary

Alternate sediment control technology is the primary means of sediment control at the Jim Bridger Mine. Ongoing surface water monitoring is used to detect the impact of mine disturbance treated with ASC techniques on receiving stream water quality. Analysis of monitoring results to date (1984-1998, Table 5m) has shown that, for storm events less than 10-year, 24-hour, background sediment levels have not been exceeded in disturbed watersheds. Analysis also has shown that sediment in disturbed watersheds correspond to sediment in receiving watersheds relative to sediment storage and release. These alternate sediment control design and monitoring methods have proven successful over a lengthy period of experimentation, evaluation, and application.

5.5 Case Study 5 (Water Engineering & Technology, Inc., 1990)

Case Study 5 summarizes a study performed for the Office of Surface Mining Reclamation and Enforcement during 1987-1989. This extensive project was jointly commissioned by the National Coal Association, the Office of Surface Mining Reclamation and Enforcement, BHP-Utah International Inc., Peabody Coal Company, and the Pittsburgh and Midway Coal Mining Company and was prepared by Water Engineering & Technology, Inc. (WET, Inc.). Details of the project are provided in the "Determination of Background Sediment Yield and Development of a Methodology for Assessing Alternative Sediment Control Technology at Surface Mines in the Semiarid West" (WET, Inc., 1990).

The study had four major objectives:

- Assess average annual background sediment yield at three mine sites based on surveying and computation of sediment accumulation in ponds;
- Evaluate available computer models for prediction of watershed runoff and sediment yield and select the model that best represents these processes at semiarid mine sites;
- Evaluate runoff and erosion response to rainfall using rainfall simulation testing on test plots (12 feet wide by 35 feet long). Use resulting data and information to calibrate and validate the computer model selected; and
- Apply the model to evaluate alternative sediment control practices and the ability of such practices to maintain erosion from reclaimed lands at or below comparable background erosion levels.

The study targeted sedimentation and erosion conditions in semiarid coal regions using data and information collected at the at Navajo Mine near Farmington, New Mexico (BHP-Utah International, Inc.), McKinley Mine near Gallup, New Mexico (Pittsburgh & Midway Coal Company), and the Black Mesa Mine near Kayenta, Arizona (Peabody Coal Company). All three mines are located in a semiarid environment where sediment yield is large and variable. Erosion generally results from the occurrence of short duration, high intensity rainfalls.

5.5.1 Background Sediment Yield

Surveys were conducted in ponds located near the McKinley and Navajo Mines to determine average sediment yields from undisturbed, semiarid watershed basins. No suitable ponds were identified at the Black Mesa Mine.

Eight ponds were surveyed near the McKinley Mine. Measured sediment yields (sedimentation rate, tons/acre/year) ranged from 0.11 to 3.2 tons/acre/year. The average sediment yield was 1.16 tons/acre/year with a standard deviation of 1.13 tons/acre/year. The lowest value of sediment yield was measured in a pond corresponding to basins with low relief and low hillslope gradients (MCM-3). The highest values of sediment yield were measured in ponds corresponding to basins with incised channels (MCM-1, 2, and 8). Ten ponds were surveyed near the Navajo Mine. Measured sediment yields for the Navajo Mine ponds ranged from 1.56 to 16.00 tons/acre/year. The average sediment yield was 4.82 tons/acre/year with a standard deviation of 4.54 tons/acre/year.

Sediment volume, sediment density, and sedimentation rate results from basins located near the McKinley and Navajo Mines are presented in Table 5o. The high variability in sediment yields is thought to be attributed in part to the age of the ponds (from 8 to 38 years), size of the basin drainage areas (averages are 0.17 and 0.64 square miles for Navajo and McKinley Mines, respectively), and types of soil (clay, sandy loam, loam, sandy clay loam, and clay loam).

Table 5o: Measured Sediment Yields at Navajo and McKinley Coal Mines

Pond	Sediment Volume (ft^3)	Drainage Area (acres)	Age (years)	Sediment Density (lbs/ft^3)	Sedimentation Rate (tons/acre/yr)
NM-2	152,440	109	8	107	9.36
NM-3	115,060	183	8	100	3.93
NM-4	39,110	42.2	8	77.8	4.50
NM-5	25,140	57.6	8	82.6	2.25
NM-6	5,180	19.2	8	92.7	1.56
NM-7	55,440	71.6	8	60.6	2.93
NM-8	21,860	5.1	8	60.6	16.00
NM-9	25,390	64.0	8	87.1	2.16
NM-10	221,780	320	8	89.1	3.86
NM-11	113,710	192	15	82.3	1.62
MCM-1	175,690	89.6	33	68.9	2.05
MCM-2	220,100	110.2	34	72.7	2.13
MCM-3	71,000	570	33	58.5	0.11
MCM-4	137,830	211	33	68.5	0.68
MCM-6	120,310	580.4	38	81.0	0.23
MCM-7	105,770	173	37	71.5	0.59
MCM-8	642,370	224	36	79.4	3.16
MCM-9	154,350	509	31	69.4	0.34

NM = Navajo Mine
MCM = McKinley Mine

In general, sediment yields measured from the Navajo Mine basins were greater than those from the McKinley Mine basins. This observation has been attributed to the following factors:

- Average drainage area for the Navajo Mine basins (0.17 square miles) is less than the average drainage area for basins at the McKinley Mine (0.64 square miles);
- Drainage density is greater at the Navajo Mine basins (15.2 miles/square miles) than at the McKinley Mine basins (4.2 miles/square miles);
- The vegetation density is greater near the McKinley Mine basins (41 percent) than for basins near the Navajo Mine (15 percent); and
- The Navajo Mine basins have badland soil associations and none of the McKinley mine basins have badland soil associations.

The usefulness of this information for evaluation of background sediment yield is limited by several factors. First, the age of the the ponds was often uncertain and some may not have been in existence long enough to have received runoff and sediment resulting from large storm events that control watershed response in a semiarid environment. Second, reliable measurements of sediment yield can only be obtained if the ponds have not been breached or overtopped, and this information was not known. Third, ponds should be located in basins having geologic properties and morphometric (drainage area and density) properties similar to those of the mine watersheds. Some of the ponds near the McKinley mine did not meet this latter condition and exhibited low rates of sediment yield possibly due to the presence of geologic controls in channels and watersheds (i.e., exposed bedrock). Finally, sediment yield in the semiarid west is largely governed by the occurrence of localized, relatively large storm events. Without accurate data describing the rainfall conditions in the watershed, it is difficult to compute a meaningful average annual sediment yield. It is difficult to determine if the sediment yield is the result of a single, rare storm event (i.e., 50-year storm) or the result of a sequence of smaller events. Lacking accurate rainfall data, pond sediment volumes could not be used to directly calibrate a computer model.

5.5.2 Evaluation of Watershed Computer Models

The second objective of the study was to assess available watershed hydrologic and sediment transport models to determine the model most appropriate for use in evaluation of alternative sediment control practices. Detailed evaluations were made of five models (Water Engineering & Technology, 1990):

- ANSWERS - Areal Nonpoint Source Watershed Environmental Response Simulation
- KINEROS - Kinematic Erosion Model
- MULTSED - Watershed and Sediment Runoff Simulation Model for Multiple Watersheds
- PRMS - Precipitation-Runoff Modeling System
- SEDIMOT II/SEDCAD version - Hydrology and Sedimentology Watershed Model II

Each model was evaluated with respect to:

- Watershed representation;
- Rainfall components;
- Infiltration, interception and surface detention components;
- Runoff components;
- Sedimentation components;
- Ease of file generation;
- Performance with test data; and
- Sensitivity analysis of the various inputs and parameters.

Rather than developing an artificial data set to test the models, a data set obtained from the USDA-ARS Sedimentation Laboratory, Oxford Mississippi for a 4.7 acre, severely eroding soybean field in northwest Mississippi was used. These data include nine events that occurred during the 1985-1986 growing season and represent a wide range of vegetation cover. Two of the nine events were relatively extreme (both of approximate 10-year return periods, one having a duration of two hours and the other having a duration of four hours). Accurate measurements of rainfall, runoff and sediment yield were available for each event at this site, and the topography of the field was surveyed in great detail. Although this data set does not represent coal mines in a semiarid environment, the processes of infiltration, runoff generation, soil detachment, sediment transport and deposition can be considered universal.

Results of computer model tests are presented in Table 5p. Five models were ranked from one (most accurate) to five (least accurate) for seventeen categories. Twelve categories deal with physical processes. The other categories are (1) watershed representation, (2) generalization of watershed reproduction, (3) ease in subdividing watersheds and generating watershed data, (4) ease in generating other data files, and (5) performance of the model with test data.

Table 5p: Ranking of Five Computer Models

Category	ANSWERS	KINEROS	MULTSED	PRMS	SEDIMOT II
Rainfall	P 2	P 2	P 2	P 4	S 5
Interception	P 3	P 3	P 1	P 3	S 5
Infiltration					
Hillslope	E 4	P 2	P 2	P 2	S 5
Channel	N 4	P 2	P 1	N 4	N 4
Runoff					
Hillslope	P 2	P 1	P 4	P 3	S 5
Channel	P 2.5	P 2.5	P 2.5	P 2.5	P-S 5
Detachment					
Hillslope	P? 2.5	P? 2.5	P? 2.5	P? 2.5	S 5
Channel	N 3	P? 2	P? 1	N 4.5	N 4.5
Transport					
Hillslope	P? 1.5	P? 3	P? 1.5	P? 4	S 5
Channel	P? 1.5	P? 3	P? 1.5	P? 4.5	E 4.5
Deposition					
Hillslope	P? 1	P? 2	N 4	N 4	N 4
Channel	P? 1.5	P? 3	P? 1.5	N 5	E 5
Watershed Representation					
Generality	1.5	1.5	4	4	4
Generation	5	3	3	3	1
Performance with Test Data	3	1.5	1.5	(1 to 5)	4
Data File Generation	4	2	3	5	1
Areas of Concern	2	3	1	5	4
Sum of Ranks	**44**	**39**	**37**	**(60 to 65)**	**70**
Number of First Ranks	**8**	**7**	**12**	**3**	**2**

E = Empirical Relationship; N = Not Simulated; P = Process Based; P? = Process Assumption
1 = Highest Rank; 5 = Lowest Rank

As a result of these analyses, the MULTSED model achieved the most number of first place scores. Therefore, MULTSED was selected for use in subsequent phases of this project.

5.5.3 Rainfall Simulation Data Collection

Rainfall simulation testing was conducted at the Navajo Mine during 1987 and 1988 and at the McKinley Mine during 1988 to measure and collect data regarding the following parameters:

- Rainfall
- Runoff
- Sediment yield
- Soil properties
- Vegetation and cover densities

By testing paired plots (one plot to be used for model calibration and one to be used for model verification) and collecting data from two simulated rainstorms, four sets of data were obtained from each test site. Test sites encompassed a range of slopes, ages of reclamation and reclamation practices and included five test sites in undisturbed areas at each mine. The rainfall simulation testing program provided 76 data sets describing the rainfall-runoff-erosion process at the Navajo Mine (19 sites x 2 plots x 2 test runs) and 80 data sets at the McKinley Mine (20 sites x 2 plots x 2 test runs).

In addition, data were available for the Black Mesa Mine from 24 test plots (10-feet wide by 35-feet long) representing a range of slopes, surface treatments and watershed size (from 3 to 41 acres). Runoff and sediment yield generated by natural rainfall for Navajo Mine and McKinley Mine test plots and Black Mesa Mine watersheds were available for the period of 1983 to 1987. Tables 5q, 5r, and 5s contain a summary of the runoff and sediment yield information obtained from the Navajo, McKinley, and Black Mesa Mines, respectively.

Table 5q: Rainfall, Runoff and Sediment Yield Data for Navajo Mine

Plot	Storm Event Run	SubPlot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
1	1	Right	2.5	1.42	27.0	8,690
	1	Left	2.2	0.72	6.7	4,240
	2	Right	2.6	2.02	36.8	8,320
	2	Left	2.6	2.08	33.0	7,260
2	1	Right	2.0	0.91	16.3	8,180
	1	Left	2.0	1.23	18.0	6,690
	2	Right	2.7	1.66	41.2	11,400
	2	Left	2.6	1.76	34.9	9,070
3	1	Right	2.0	0.75	10.1	6,210
	1	Left	2.7	0.85	13.0	6,970
	2	Right	2.1	1.31	32.4	11,300
	2	Left	2.4	1.31	30.0	10,500
4	1	Right	2.3	1.97	38.2	8,890
	1	Left	1.8	1.72	28.3	7,530
	2	Right	2.2	1.36	17.6	5,920
	2	Left	1.0	0.87	9.0	4,720
	3	Right	2.1	1.88	23.6	5,740
	3	Left	1.4	1.06	10.6	4,600
5	1	Right	2.0	0.28	0.8	1,310
	1	Left	2.3	0.71	1.4	922
	2	Right	2.7	0.90	6.1	3,110
	2	Left	2.2	0.98	5.4	2,530
6	1	Right	2.9	0.40	0.0	35
	1	Left	2.7	0.33	0.6	849
	2	Right	2.8	1.10	1.8	727
	2	Left	2.6	1.18	5.0	1,920
	3	Right	NDC	NDC	-	-
	3	Left	2.4	1.32	2.2	759
	4	Right	NDC	NDC	-	-
	4	Left	1.4	1.05	1.5	636

Plot	Storm Event Run	SubPlot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
7	1	Right	2.3	0.50	0.3	283
	1	Left	2.2	0.81	0.4	238
	2	Right	2.6	0.68	0.6	281
	2	Left	2.3	1.14	0.6	224
8	1	Right	3.1	0.27	0.3	501
	1	Left	2.0	0.32	0.2	359
	2	Right	2.7	0.14	0.1	434
	2	Left	2.7	0.14	0.1	416
	3	Right	2.2	0.42	0.4	471
	3	Left	1.8	0.42	0.4	404
9	1	Right	2.3	1.32	209.0	72,500
	1	Left	2.7	0.53	244.8	73,200
	2	Right	2.4	2.26	341.1	68,900
	2	Left	2.2	1.89	240.8	58,300
10	1	Right	2.6	1.24	4.8	1,790
	1	Left	2.7	1.20	4.0	1,550
	2	Right	2.1	1.62	7.5	2,130
	2	Left	2.3	1.50	7.6	2,320
11	1	Right	2.3	1.12	6.9	2,800
	1	Left	2.2	1.02	11.5	5,160
	2	Right	2.4	1.68	22.5	6,150
	2	Left	2.0	1.29	19.2	6,800
12	1	Right	2.2	1.32	209.2	72,200
	1	Left	2.2	1.26	176.2	64,100
	2	Right	2.5	2.07	314.7	69,600
	2	Left	2.3	1.94	306.1	72,200
13	1	Right	2.4	0.00	0.0	0
	1	Left	2.2	0.00	0.0	0
	2	Right	2.7	0.41	0.8	866
	2	Left	2.4	0.44	1.0	1,050
14	1	Right	2.3	0.36	1.2	1,490
	1	Left	2.4	0.17	0.4	996
	2	Right	2.2	1.66	11.8	3,240

Plot	Storm Event Run	SubPlot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
14	2	Left	2.6	1.58	9.6	2,790
15	1	Right	2.6	0.00	0.0	0
	1	Left	2.6	0.20	0.4	809
	2	Right	2.5	0.70	1.4	945
	2	Left	2.6	1.50	7.2	2,200
16	1	Right	2.5	0.55	1.6	1,380
	1	Left	2.6	0.47	2.2	2,100
	2	Right	2.9	2.51	5.5	1,010
	2	Left	2.9	2.56	6.1	1,080
17	1	Right	2.4	2.03	107.6	24,200
	1	Left	2.4	1.97	98.9	23,000
	2	Right	2.8	2.50	106.3	19,400
	2	Left	2.8	2.69	136.4	23,200
18	1	Right	2.3	0.63	0.8	569
	1	Left	2.0	0.28	0.2	396
	2	Right	2.5	1.24	2.3	849
	2	Left	2.5	1.30	1.4	496
19	1	Right	2.6	2.33	38.3	7,530
	1	Left	2.3	1.98	35.3	8,150
	2	Right	3.1	2.92	46.5	7,280
	2	Left	2.5	1.90	36.0	209.0

Table 5r: Rainfall, Runoff and Sediment Yield Data for McKinley Mine

Plot	Run	SubPlot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
1	1	Right	1.9	0.09	0.6	3,150
	1	Left	2.8	0.98	6.2	2,880
	2	Right	3.0	0.81	6.3	3,550
	2	Left	2.4	1.05	6.0	2,630
2	1	Right	1.9	0.09	0.1	689
	1	Left	1.8	0.06	0.1	735
	2	Right	2.7	0.62	2.4	1,400
	2	Left	2.6	0.41	3.7	3,350
3	1	Right	2.8	0.74	4.1	2,520
	1	Left	2.1	0.61	18.8	14,000
	2	Right	3.0	1.43	8.2	2,610
	2	Left	1.8	0.77	4.6	2,750
4	1	Right	2.5	1.02	6.2	2,800
	1	Left	3.4	1.32	7.3	2,530
	2	Right	2.6	1.63	6.7	1,880
	2	Left	3.0	1.68	5.9	1,590
5	1	Right	3.6	1.40	15.1	4,940
	1	Left	3.2	0.87	13.8	7,240
	2	Right	3.1	1.74	14.6	3,830
	2	Left	2.9	1.09	12.2	5,100
6	1	Right	2.5	0.82	4.8	2,680
	1	Left	3.0	1.46	8.6	2,690
	2	Right	3.1	1.45	7.0	2,210
	2	Left	3.0	1.71	10.5	2,820
7	1	Right	3.1	0.53	0.5	322
	1	Left	2.9	0.012	0.04	1,530
	2	Right	2.4	0.98	0.5	184
	2	Left	3.3	1.28	2.8	923
8	1	Right	2.7	1.02	3.8	1,710
	1	Left	2.8	0.94	2.8	1,340

Plot	Run	SubPlot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
8	2	Right	3.1	1.81	7.3	1,840
	2	Left	2.9	1.86	7.8	1,910
9	1	Right	2.3	0.46	1.9	1,910
	1	Left	3.1	0.81	8.2	4,640
	2	Right	2.8	1.13	8.4	3,420
	2	Left	2.9	1.02	12.6	5,650
10	1	Right	3.2	0.42	5.6	6,180
	1	Left	2.9	0.17	0.6	1,650
	2	Right	2.6	1.04	9.3	4,100
	2	Left	2.2	0.45	3.3	3.340
11	1	Right	3.1	0.89	19.5	10,010
	1	Left	3.4	1.44	39.1	12,470
	2	Right	3.2	2.05	44.2	9,850
	2	Left	2.5	1.66	31.2	8.580
12	1	Right	2.9	1.67	21.5	5,900
	1	Left	3.0	1.88	17.1	4,170
	2	Right	1.9	1.28	10.9	3,920
	2	Left	2.4	2.21	14.1	2,920
13	1	Right	2.3	0.74	12.0	7,430
	1	Left	3.1	0.98	32.3	15,050
	2	Right	2.5	1.27	19.4	6,980
	2	Left	2.6	1.41	31.5	10,230
14	1	Right	2.6	1.48	7.0	2,150
	1	Left	2.3	1.22	5.4	2,000
	2	Right	2.5	1.47	6.5	2,040
	2	Left	2.7	1.75	8.6	2,260
15	1	Right	2.4	1.65	7.1	1,960
	1	Left	2.5	1.46	8.3	2,610
	2	Right	2.3	2.00	9.3	2,120
	2	Left	3.1	2.19	10.9	2,280
16	1	Right	2.6	2.38	153.7	29,500
	1	Left	2.4	1.98	115.7	26,780

Plot	Run	SubPlot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
16	2	Right	2.4	1.89	100.5	24,290
	2	Left	2.2	1.83	81.3	20,350
17	1	Right	3.0	0.35	4.8	6,330
	1	Left	2.8	0.55	9.6	7,960
	2	Right	3.0	0.90	6.0	3,070
	2	Left	3.4	1.09	13.3	5,550
18	1	Right	2.3	0.80	11.7	6,730
	1	Left	3.1	1.10	40.5	16,890
	2	Right	3.1	1.78	53.6	13,760
	2	Left	2.5	1.42	42.1	13,550
19	1	Right	2.7	0.99	3.0	1,320
	1	Left	2.7	0.57	2.0	1,420
	2	Right	2.7	1.90	4.9	1,130
	2	Left	3.3	1.90	4.8	1,050
20	1	Right	2.4	1.54	86.5	25,710
	1	Left	2.6	1.62	95.8	27,070
	2	Right	2.7	2.19	93.4	19,510
	2	Left	2.8	2.27	100.0	20,160

Table 5s: Rainfall, Runoff and Sediment Yield Data for Black Mesa and Kayenta Mines

Watershed	Run Date	Plot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
N2 Small	7-21-86	221	0.9	0.012	0.190	8,710
	8-31-86		0.5	0.162	4.391	14,900
	9-23-86		0.9	0.057	0.208	1,990
	7-30-87		0.6	0.195	1.709	4,810
	8-31-86	222	0.5	0.256	8.077	17,300
	9-23-86		0.9	0.103	1.172	6,260
	7-30-87		0.6	0.147	4.049	15,100
	7-21-86	223	0.9	0.005	0.012	1,360
	8-31-86		0.5	0.116	1.849	8,720
	7-30-87		0.6	0.067	0.282	2,330
	7-21-86	224	0.9	0.005	0.010	1,120
	8-31-86		0.5	0.094	0.796	4,630
	9-23-86		0.9	0.024	0.042	960
	7-30-87		0.6	0.068	0.275	2,230
N2 Large	8-31-86	225	0.5	0.161	3.049	10,400
	9-23-86		0.9	0.138	0.250	991
	8-31-86	226	0.5	0.184	4.538	13,500
	9-23-86		0.9	0.149	0.377	1,390
	7-30-87		0.6	0.219	1.418	3,560
J27	8-31-85	271	0.5	0.004	0.004	500
	9-11-85		0.3	0.010	0.002	107
	7-20-86		0.5	0.006	0.003	288
	9-23-86		1	0.010	0.003	156
	8-31-85	272	0.5	0.006	0.015	1,440
	9-11-85		0.3	0.010	0.008	442
	7-20-86		0.4	0.007	0.011	893
	9-23-86		1	0.010	0.067	3,720
	8-31-85	273	0.5	0.027	0.098	1,970
	9-11-85		0.3	0.007	0.010	876
	7-20-86		0.5	0.005	0.009	886

Watershed	Run Date	Plot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
J27 (cont.)	9-23-86		1	0.078	0.167	1,180
	8-31-85	274	0.5	0.008	0.013	984
	9-11-85		0.3	0.005	0.002	242
	9-23-86		1	0.049	0.089	997
	8-31-85	275	0.5	0.037	0.087	1,310
	8-31-85	276	0.5	0.017	0.026	848
	9-11-85		0.3	0.003	0.000	0
	9-23-86		1	0.047	0.095	1,110
J3	7-29-85	303	1	0.307	7.802	13,900
	9-11-85		0.6	0.100	0.455	2,490
	9-18-85		0.5	0.026	0.132	2,770
	8-29-86		0.2	0.015	0.155	5,850
	9-08-86		0.3	0.017	0.198	6,270
	8-08-87		0.9	0.030	0.390	7,130
	7-29-85	304	1	0.436	10.538	13,300
	9-11-85		0.6	0.118	0.512	2,390
	9-18-85		0.5	0.085	0.143	927
	8-29-86		0.2	0.015	0.153	5,650
	9-08-86		0.3	0.033	0.315	5,270
	8-08-87		0.9	0.102	1.160	6,230
	7-29-85	305	1	0.436	16.936	21,300
	9-11-85		0.6	0.176	1.529	4,760
	9-18-85		0.5	0.133	0.400	1,650
	8-29-86		0.2	0.048	0.847	9,730
	9-08-86		0.3	0.089	1.508	9,280
	8-08-87		0.9	0.176	4.009	12,500
	7-29-85	306	1	0.257	3.354	7,170
	9-11-85		0.6	0.024	0.098	2,270
	9-18-85		0.5	0.023	0.067	1,620
	8-29-86		0.2	0.026	0.318	6,700
	9-08-86		0.3	0.028	0.144	2,810
	8-08-87		0.9	0.101	0.861	4,690
	7-29-85	307	1	0.163	3.755	12,700

Watershed	Run Date	Plot ID	Total Rainfall (in)	Total Runoff (in)	Total Sediment Yield (lbs)	Average Sediment Concentration (ppm)
J3 (cont.)	9-11-85		0.6	0.084	0.397	2,600
	9-18-85		0.5	0.024	0.067	1,530
	8-29-86		0.2	0.006	0.019	1,900
	7-29-85	308	1	0.180	4.953	15,100
	9-11-85		0.6	0.080	0.879	6,020
	9-18-85		0.5	0.024	0.163	3,760
	8-08-87		0.9	0.028	1.097	21,300
N6	9-18-85	261	0.4	0.023	0.407	9,510
	9-23-86		0.8	0.074	0.445	3,290
	9-18-85	262	0.4	0.018	0.060	1,820
	9-23-86		0.8	0.072	0.330	2,540
	9-18-85	263	0.4	0.003	0.006	1,190
	7-21-86		0.6	0.012	0.037	1,670
	9-08-86		0.9	0.191	1.200	3,450
	9-23-86		0.8	0.090	0.144	884
	9-18-85	264	0.4	0.017	0.034	1,090
	7-21-86		0.6	0.017	0.060	1,900
	9-08-86		0.9	0.106	1.219	6,310
	9-23-86		0.8	0.115	0.750	3,570
	9-18-85	265	0.4	0.006	0.012	1,130
	7-20-86		0.5	0.005	0.032	3,880
	7-21-86		0.6	0.028	0.218	4,200
	9-23-86		0.8	0.045	0.132	1,610
	9-18-85	266	0.4	0.010	0.018	993
	7-20-86		0.5	0.005	0.019	1,980
	7-21-86		0.6	0.018	0.135	4,110
	9-23-86		2.5	0.039	0.103	1,440

5.5.4 Calibration and Validation of the MULTSED Model

The first step in the application of MULTSED for prediction of runoff and sediment yield involved calibration and validation of the model using the data collected from the Navajo, McKinley, and Black Mesa/Kayenta mines. One-half of the simulated rainfall test plot data were used for calibration and determination of appropriate infiltration and soil detachment coefficients. Following calibration, the MULTSED model was run using the calibrated infiltration and detachment coefficients to predict sediment yield and mean sediment concentration. Finally, total runoff, sediment yield, and mean sediment concentration predicted by MULTSED were compared to the remaining half of the simulated rainfall test plot data and to the available Black Mesa/Kayenta Mine data. Model verification determined that runoff amounts were predicted with the greatest accuracy, followed by mean concentration, and sediment yields.

Model results also showed a tendency for the model to over predict sediment. Runoff rates for low flow conditions should not be of major concern, because long-term erosion rates generally are dominated by extreme conditions when large magnitude runoff volumes occur. However, when predicting the runoff and sediment responses of various erosion control alternatives, the model should not be used for small storms that produce small amounts of runoff (< 0.5 inches).

5.5.5 Evaluation of Alternative Sediment Control Techniques

Successful calibration and validation of the MULTSED model provided a means to evaluate the effectiveness of alternative sediment control techniques relative to background conditions. To make these comparisons, a procedure was developed that uses rainfall depth-duration information available from National Oceanic and Atmospheric Administration (NOAA) Atlases at each mine site. Rainfall data describing storm events with recurrence intervals of 2, 5, 10, 25, 50, and 100 years were used to develop hypothetical storm distributions. MULTSED was then used to determine the runoff and sediment generated from a hill slope for this range of storm events.

Comparisons were made between background sediment yield and predicted sediment yields associated with alternative sediment control techniques. Average annual sediment yield was computed using a probability weighting procedure that uses an incremental probability of occurrence of the aforementioned sequence of storms. Since the average value computed using this procedure is based on a broad range of storm events, it is expected to represent a reasonable long-term average. It should be noted that, depending on the sequence of storm events that actually occur, sediment yield within any given year could significantly deviate from this average value. For purposes of comparison, however, this calculation procedure provides a reasonable value for sediment yield.

Modeling was performed to evaluate sediment yield response to variations in slope length, slope gradient, cover density, and the presence or absence of furrows (depression storage) on the reclaimed surface. The results agreed with expectations: sediment yield increases with increasing plot slope gradient and slope length, decreases with increasing vegetative cover, and decreases with increased depression storage. Model prediction results for the sediment yield response to ASCs at the Navajo Mine, McKinley Mine, and Black Mesa/Kayenta Mine are presented in Figures 5d through 5q.

Figure 5d: Navajo Mine Sediment Yield vs. Plot Slope

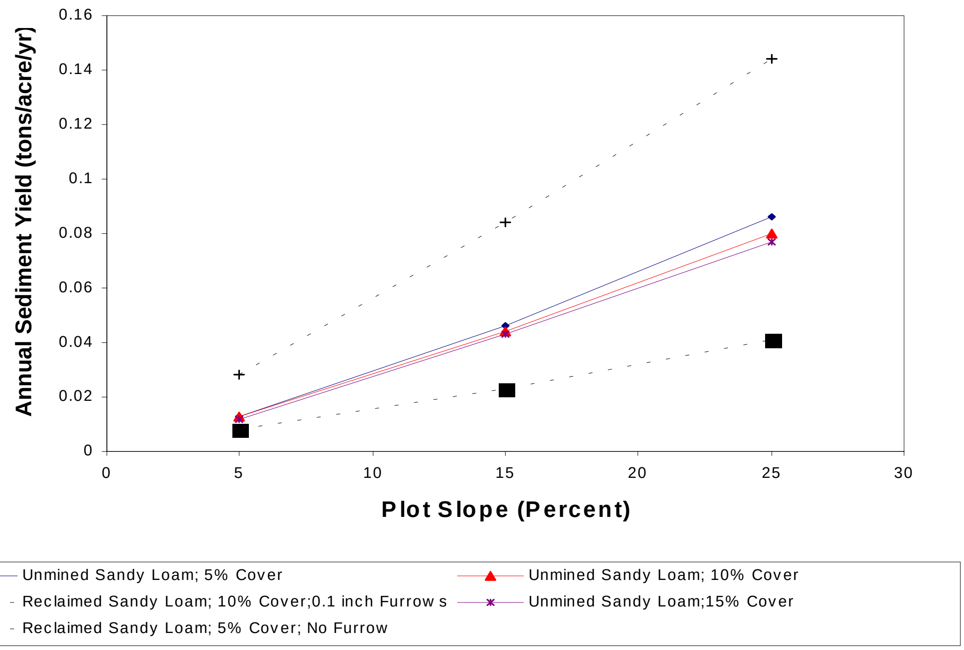
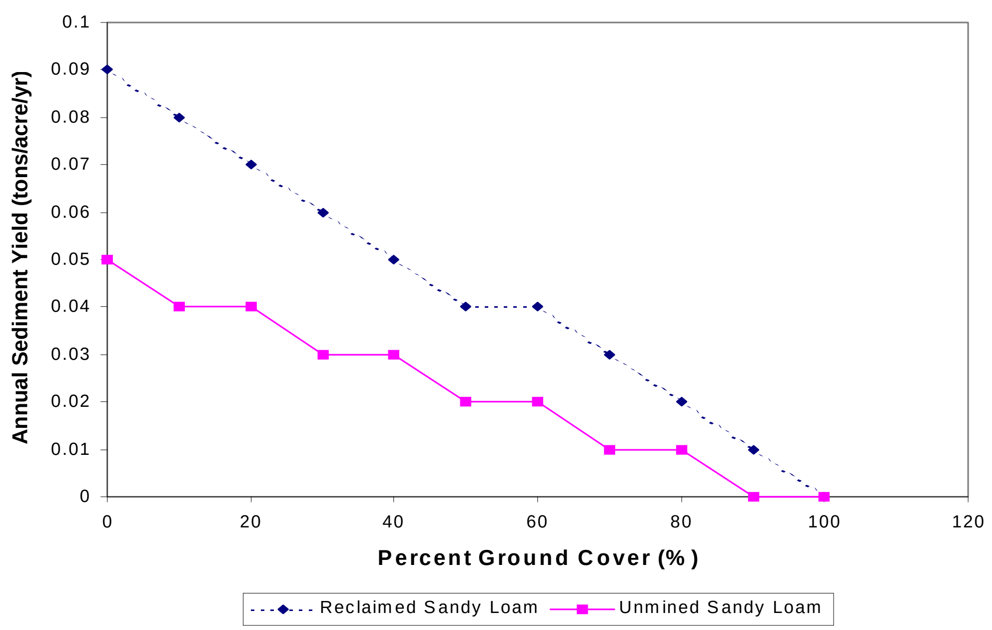


Figure 5e: Navajo Mine Sediment Yield vs. Percent Ground Cover



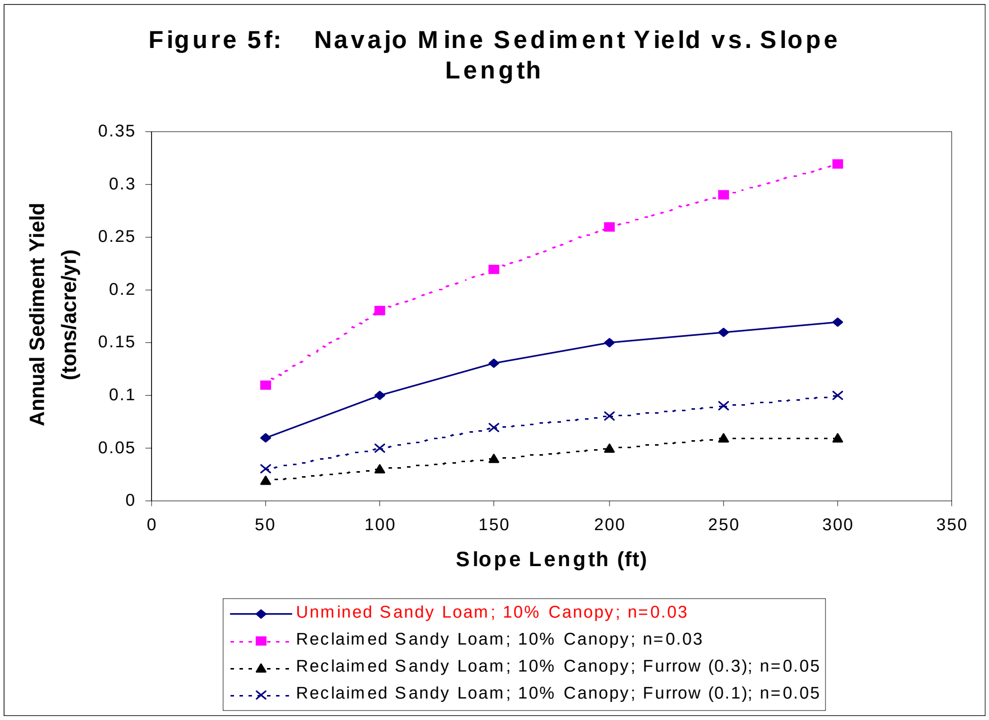


Figure 5f: Navajo Mine Sediment Yield vs. Slope Length
Annual Sediment Yield (tons/acre/yr)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350
Slope Length (ft)
Unmined Sandy Loam; 10% Canopy; n=0.03
Reclaimed Sandy Loam; 10% Canopy; n=0.03
Reclaimed Sandy Loam; 10% Canopy; Furrow (0.3); n=0.05
Reclaimed Sandy Loam; 10% Canopy; Furrow (0.1); n=0.05

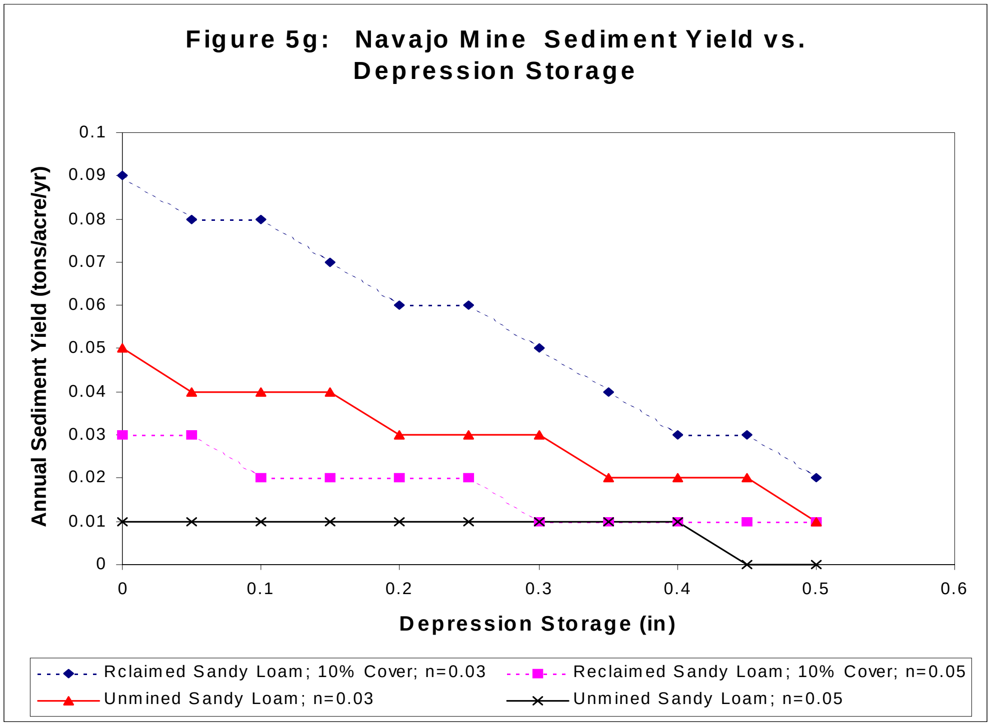


Figure 5g: Navajo Mine Sediment Yield vs. Depression Storage
Annual Sediment Yield (tons/acre/yr)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Depression Storage (in)
Rclaimed Sandy Loam; 10% Cover; n=0.03
Reclaimed Sandy Loam; 10% Cover; n=0.05
Unmined Sandy Loam; n=0.03
Unmined Sandy Loam; n=0.05

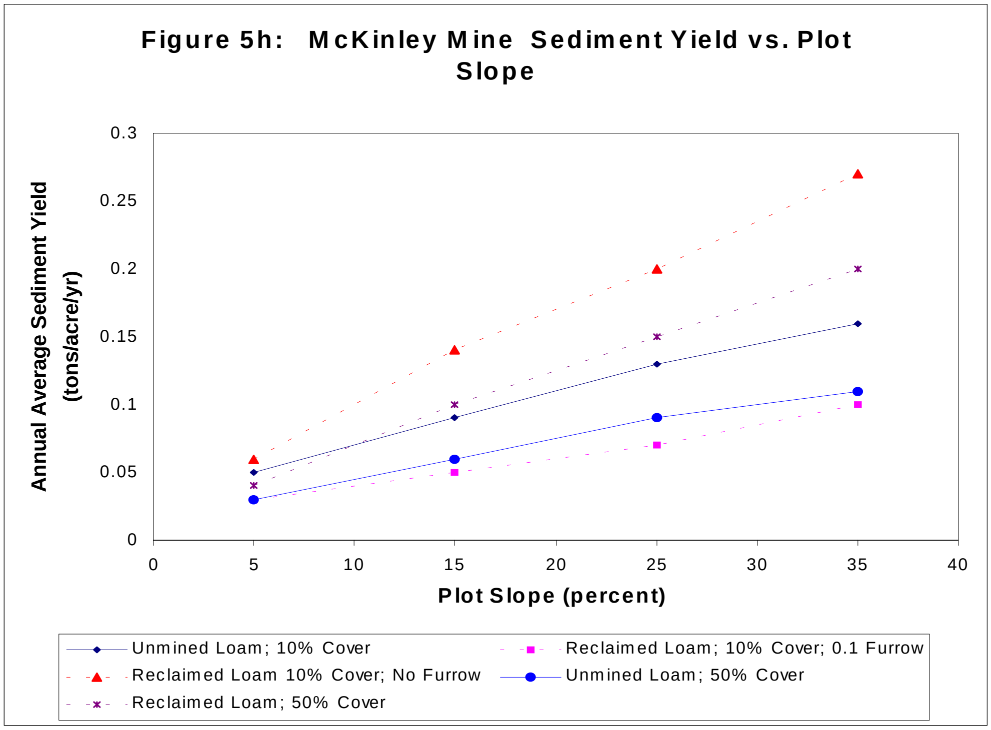


Figure 5h: McKinley Mine Sediment Yield vs. Plot Slope
Annual Average Sediment Yield (tons/acre/yr)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
5
10
15
20
25
30
35
40
Plot Slope (percent)
Unmined Loam; 10% Cover
Reclaimed Loam; 10% Cover; 0.1 Furrow
Reclaimed Loam 10% Cover; No Furrow
Unmined Loam; 50% Cover
Reclaimed Loam; 50% Cover

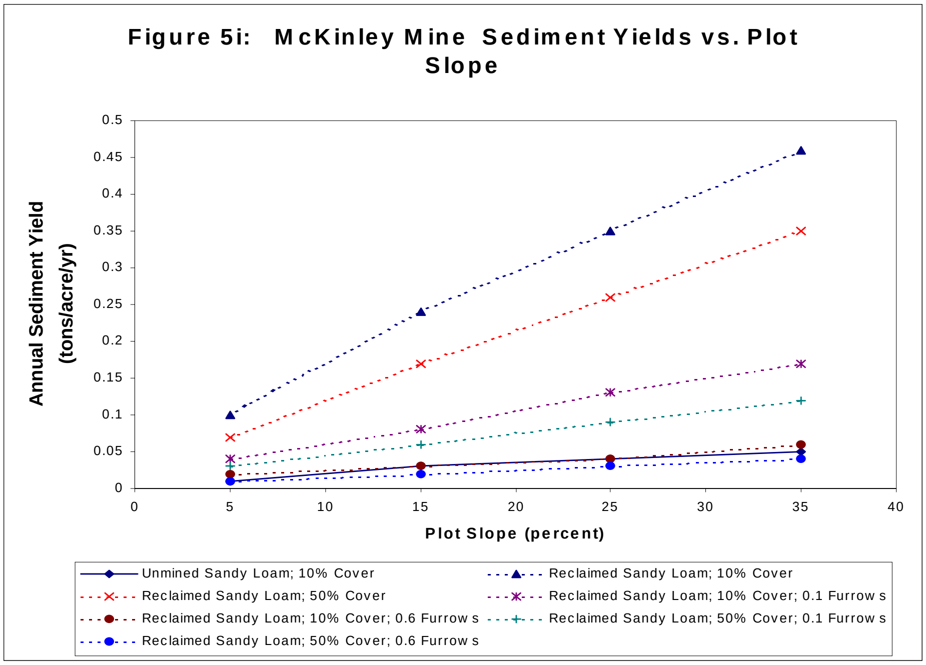


Figure 5i: McKinley Mine Sediment Yields vs. Plot Slope
Annual Sediment Yield (tons/acre/yr)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
5
10
15
20
25
30
35
40
Plot Slope (percent)
Unmined Sandy Loam; 10% Cover
Reclaimed Sandy Loam; 10% Cover
Reclaimed Sandy Loam; 50% Cover
Reclaimed Sandy Loam; 10% Cover; 0.1 Furrows
Reclaimed Sandy Loam; 10% Cover; 0.6 Furrows
Reclaimed Sandy Loam; 50% Cover; 0.1 Furrows
Reclaimed Sandy Loam; 50% Cover; 0.6 Furrows

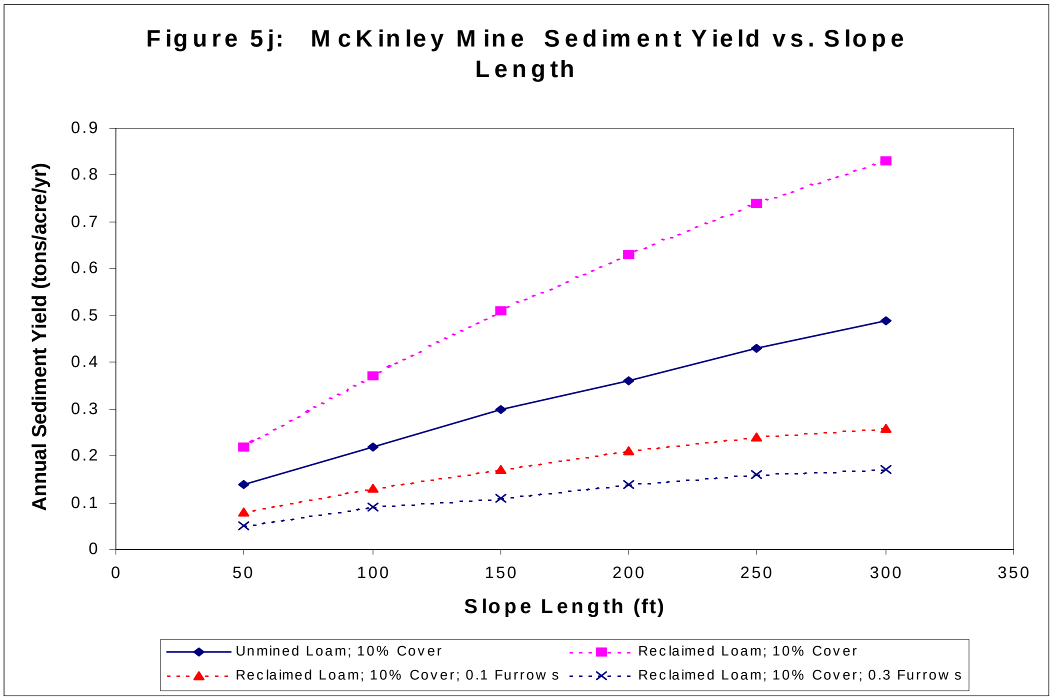


Figure 5j: McKinley Mine Sediment Yield vs. Slope Length
Annual Sediment Yield (tons/acre/yr)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
Slope Length (ft)
Unmined Loam; 10% Cover
Reclaimed Loam; 10% Cover
Reclaimed Loam; 10% Cover; 0.1 Furrows
Reclaimed Loam; 10% Cover; 0.3 Furrows

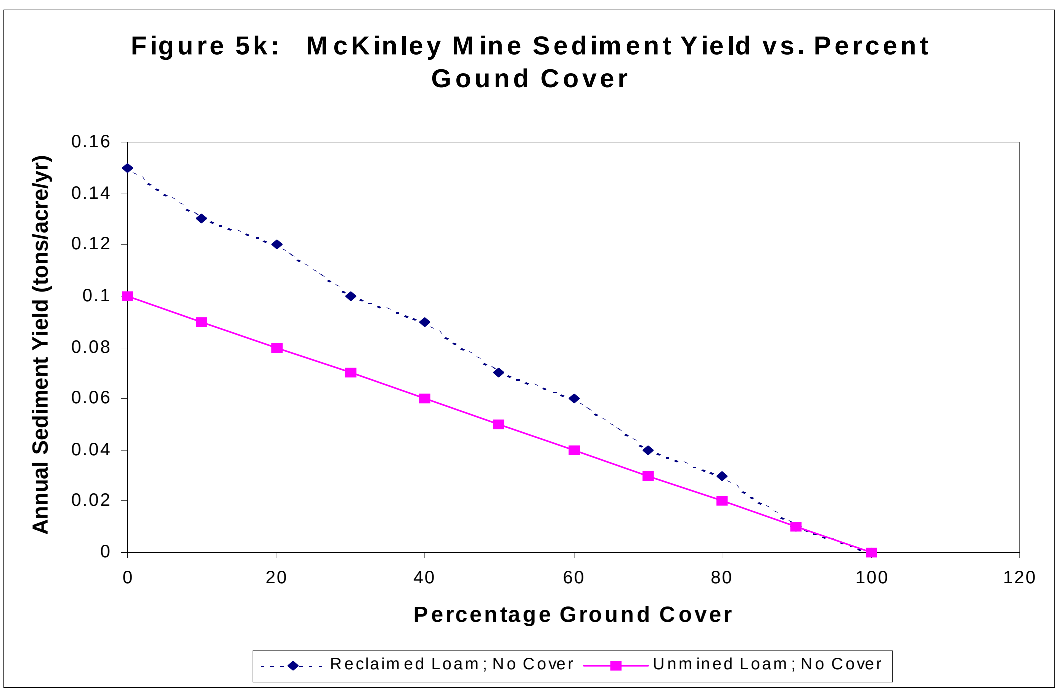


Figure 5k: McKinley Mine Sediment Yield vs. Percent Gound Cover
Annual Sediment Yield (tons/acre/yr)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
20
40
60
80
100
120
Percentage Ground Cover
Reclaimed Loam; No Cover
Unmined Loam; No Cover

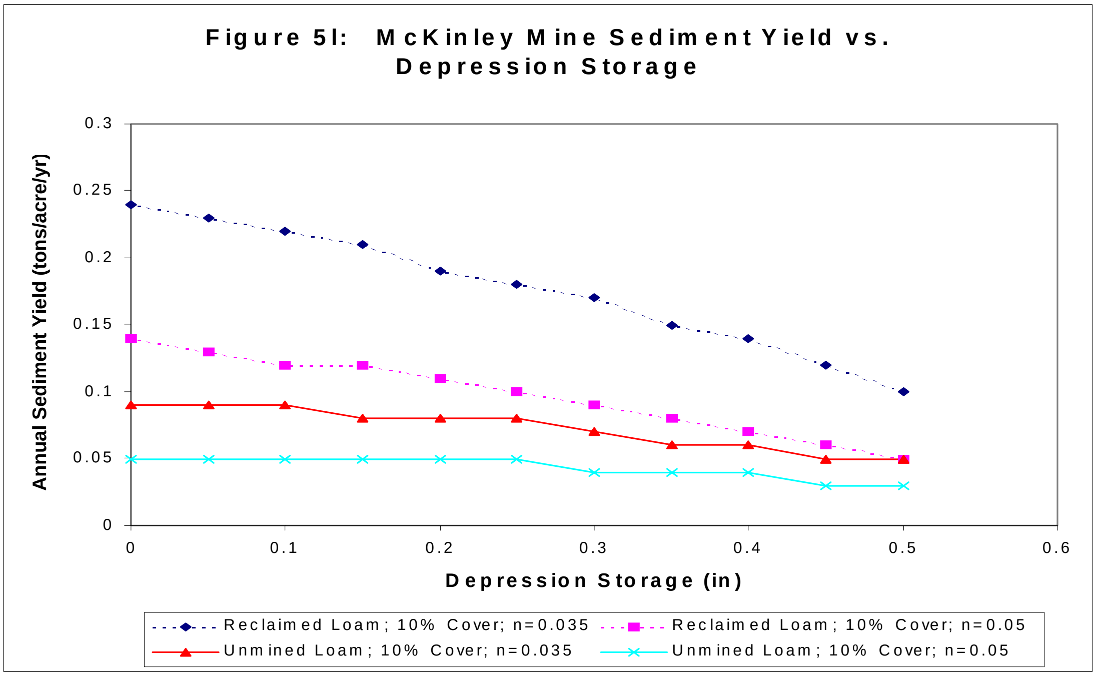


Figure 5l: McKinley Mine Sediment Yield vs. Depression Storage
Annual Sediment Yield (tons/acre/yr)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Depression Storage (in)
Reclaimed Loam; 10% Cover; n=0.035
Reclaimed Loam; 10% Cover; n=0.05
Unmined Loam; 10% Cover; n=0.035
Unmined Loam; 10% Cover; n=0.05

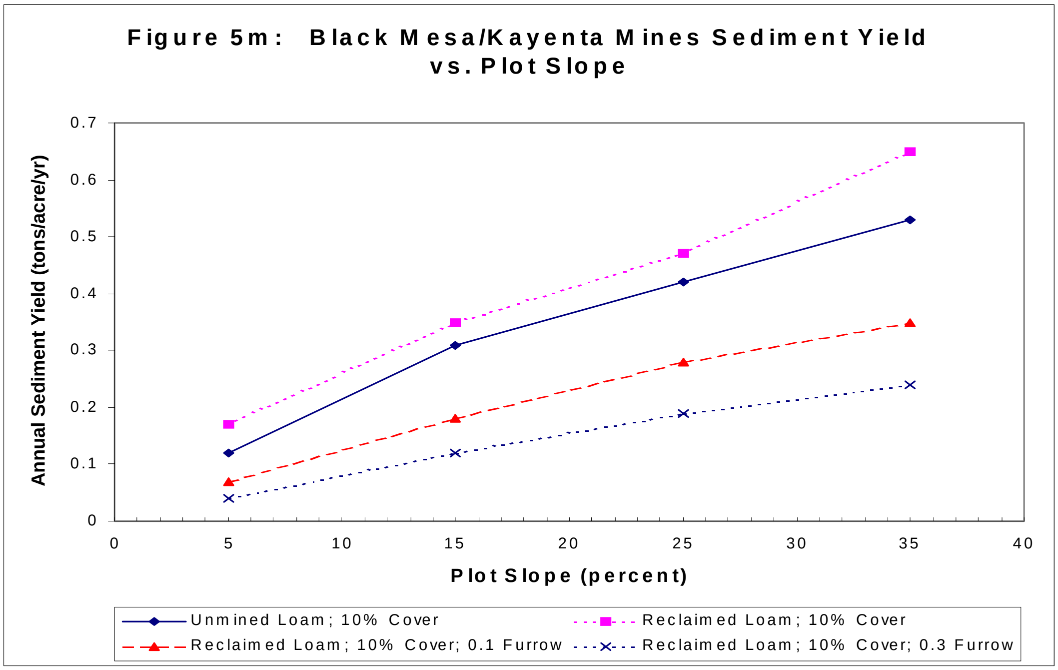


Figure 5m: Black Mesa/Kayenta Mines Sediment Yield vs. Plot Slope
Annual Sediment Yield (tons/acre/yr)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
35
40
Plot Slope (percent)
Unmined Loam; 10% Cover
Reclaimed Loam; 10% Cover
Reclaimed Loam; 10% Cover; 0.1 Furrow
Reclaimed Loam; 10% Cover; 0.3 Furrow

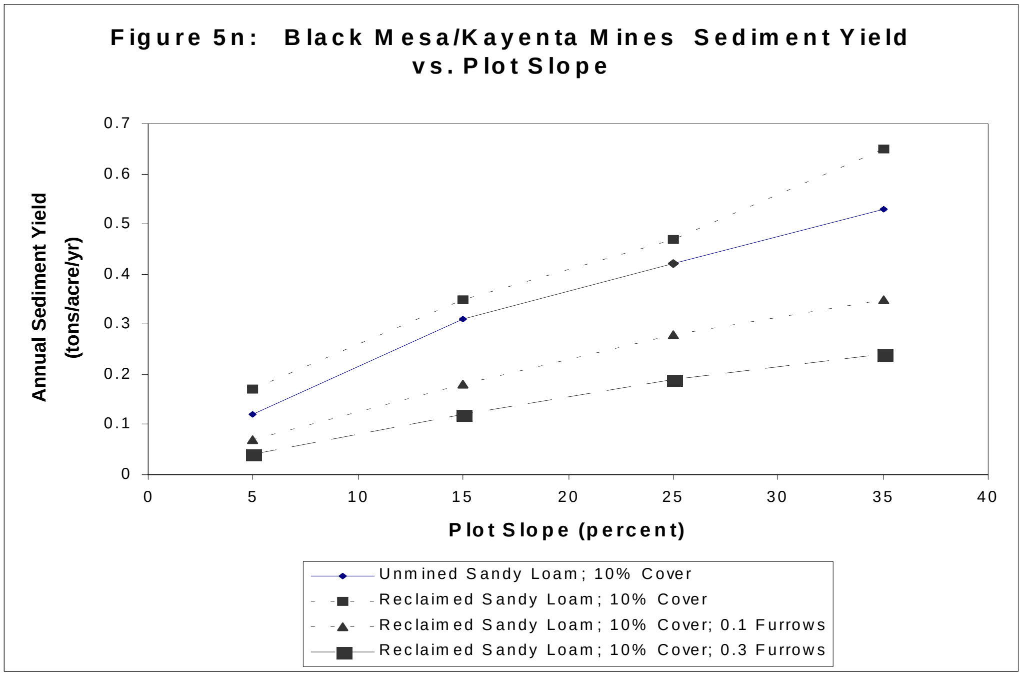


Figure 5n: Black Mesa/Kayenta Mines Sediment Yield vs. Plot Slope
Annual Sediment Yield (tons/acre/yr)
Plot Slope (percent)
Unmined Sandy Loam; 10% Cover
Reclaimed Sandy Loam; 10% Cover
Reclaimed Sandy Loam; 10% Cover; 0.1 Furrows
Reclaimed Sandy Loam; 10% Cover; 0.3 Furrows

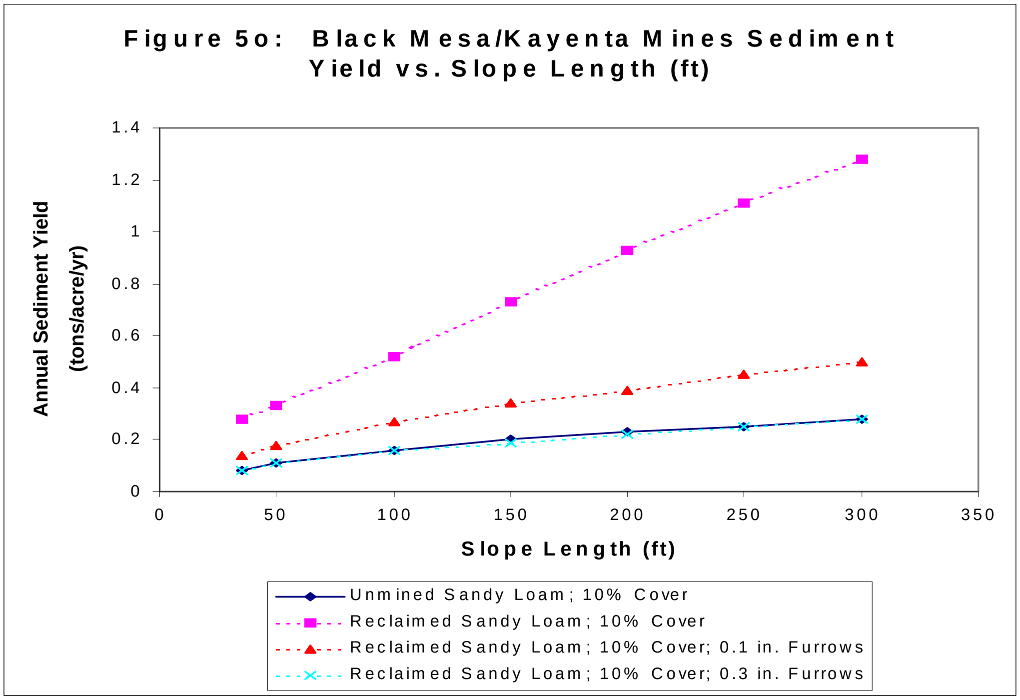


Figure 5o: Black Mesa/Kayenta Mines Sediment Yield vs. Slope Length (ft)
Annual Sediment Yield (tons/acre/yr)
Slope Length (ft)
Unmined Sandy Loam; 10% Cover
Reclaimed Sandy Loam; 10% Cover
Reclaimed Sandy Loam; 10% Cover; 0.1 in. Furrows
Reclaimed Sandy Loam; 10% Cover; 0.3 in. Furrows

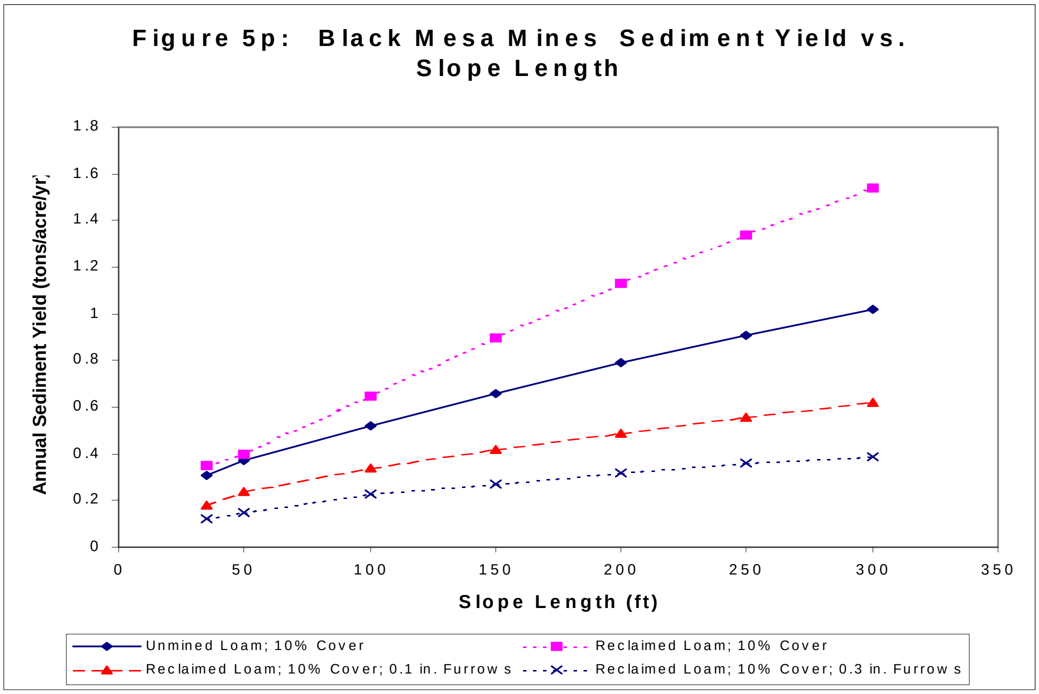


Figure 5p: Black Mesa Mines Sediment Yield vs. Slope Length
Annual Sediment Yield (tons/acre/yr)
Slope Length (ft)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
50
100
150
200
250
300
350
Unmined Loam; 10% Cover
Reclaimed Loam; 10% Cover
Reclaimed Loam; 10% Cover; 0.1 in. Furrows
Reclaimed Loam; 10% Cover; 0.3 in. Furrows

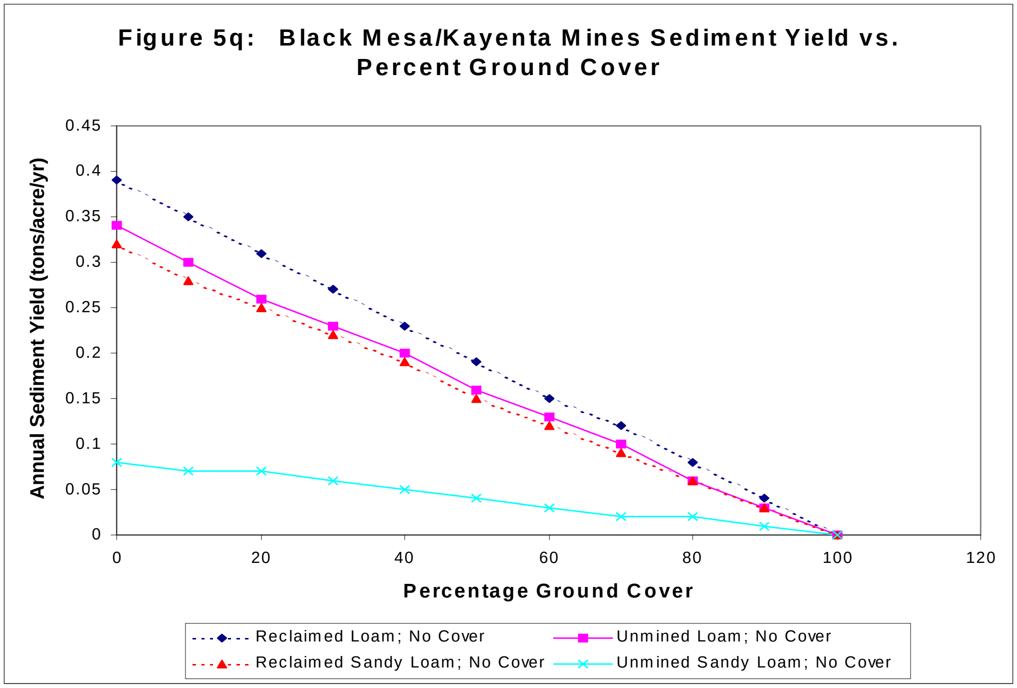


Figure 5q: Black Mesa/Kayenta Mines Sediment Yield vs. Percent Ground Cover
Annual Sediment Yield (tons/acre/yr)
Percentage Ground Cover
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0
20
40
60
80
100
120
Reclaimed Loam; No Cover
Unmined Loam; No Cover
Reclaimed Sandy Loam; No Cover
Unmined Sandy Loam; No Cover

5.5.5.1 Navajo Mine

Model prediction results indicate that alternate sediment controls can be used to produce sediment yields that are less than background or unmined conditions. For example, an unmined sandy loam of 15 percent slope and 10 percent vegetative cover density produces more sediment than a reclaimed sandy loam of 25 percent slope and a 5 percent vegetative cover density if furrows capable of retaining 0.1 inch of rainfall are present and slope lengths are equal (Figure 5d). It is important to note that these furrows are only a temporary measure and a more permanent reclamation technique should be implemented. An example of this would be using rock or mulch as a ground cover.

Figure 5d also provides a comparison of pre-and post-mined sandy loams. The figure indicates that reclaimed sandy loams (post-mining) with vegetation (5 percent cover) but without furrows results in higher sediment yields than unmined areas of similar soil/sand cover for any slope. Figure 5d also indicates that achievement of background sediment yields solely through manipulation of slope gradient requires that the reclaimed slope gradient be significantly reduced. For example, to maintain a reclaimed sediment yield comparable to that of an unmined sandy loam on a 10 percent slope, the reclaimed slope not exceed 5 percent.

The effects of varying ground cover on sediment yield for sandy loams are shown in Figure 5e. A reclaimed sandy loam site would require significantly more ground cover to produce the same sediment yield as an unmined sandy loam site. For example, a reclaimed sandy loam soil with at least 60 percent ground cover would yield approximately the same amount of sediment as unmined sandy soil with 20 percent ground cover.

Figure 5f provides a comparison of sediment yields from pre- and post-mining sandy loam sites based on slope lengths. Based solely on slope length, reclaimed slope lengths should be less than 50 feet to maintain background sediments yields for an unmined sandy loam site with an original slope length of 100 feet.

Figure 5g illustrates the effectiveness of furrows in reducing hillslope sediment yield. Surfaces with furrows tend to be rougher and therefore have higher Manning n values than surfaces without furrows. For computer modeling purposes, plots without furrows were given a Manning n of 0.03 and plots with furrows were given values of 0.05.

5.5.5.2 McKinley Mine

Similar to the Navajo Mine computer prediction results, Figure 5h shows that a significant reduction in reclaimed slope gradient is required to maintain sediment yield below background levels. Figure 5h also shows that reclaimed loam soil with 10 percent canopy cover and furrows capable of retaining 0.1 inch of rainfall produces less sediment than an unmined loam soil with 50 percent canopy cover. Figure 5i indicates that reduction of slope gradient by itself would not be sufficient to reduce sediment yield below background levels with a sandy loam soil at the McKinley Mine. A reclaimed sandy loam soil with a 50 percent canopy cover and furrows capable of retaining 0.6 inches of rainfall will produce less sediment than an unmined sandy loam with 10 percent canopy cover.

The average annual sediment yield for reclaimed loam soils also was compared to background conditions for different slope lengths, percentages of ground cover and amounts of depression storage as shown in Figures 5j, 5k, and 5l. Figure 5j shows that a 300-foot long reclaimed loam soil plot, with furrows capable of holding 0.1 inches of rainfall, produces less sediment than an unmined 150-feet long loam soil plot. Figure 5k illustrates that a reclaimed loam soil with at least 60 percent ground cover will yield approximately as much sediment as an unmined loam soil with 40 percent ground cover. Figure 5l shows the effect of depression storage and roughness on annual sediment yield. Reclaimed soils are much more sensitive to the amount of depression storage than unmined soils. Also as can be seen from 5l, a loam soil can be temporarily reclaimed to meet the background sediment yield of an unmined loam soil with 0.1 inch of depression storage (n = 0.035).

5.5.5.3 Black Mesa/Kayenta Mines

Figures 5m and 5n show the sediment yield response of a loam soil and sandy loam soil to changes in slope gradient for both pre- and post-mining conditions, respectively. Both figures show that a modest 3 to 5 percent reduction in slope gradient can maintain sediment yields at or below background levels. Also shown in both figures are the effects of contour furrows on sediment yield. Figure 5m shows that reclaiming loam soil with furrows that are capable of retaining at least 0.1 inch of rainfall will satisfy the requirement of producing less sediment than the amount produced by background conditions. Reclaimed sandy loam soil requires furrows capable of retaining 0.5 inches of rainfall to meet the background criteria as shown in Figure 5n.

Figures 5o and 5p show the same results as Figures 5m and 5n, except that they include slope length instead of plot slope. Figure 5o shows that for sandy loam soils, decreasing the slope length of the reclaimed area and reclaiming with furrows may be necessary to meet background sediment yields.

As shown in Figure 5q, for reclamation of loam and sandy loam soils that originally had 20 percent ground cover with rock mulch, a 30 percent ground cover and a 80 percent ground cover would be necessary for the loam and sandy loam soils respectively.

5.5.5.4 Conclusions

Comparisons were made between the erosion potential of reclaimed land versus undisturbed hillslope surfaces. In general, results of this evaluation tend to indicate that erosion potential of reclaimed surfaces exceeds that of unmined lands, when all other conditions are held constant. The addition of contour furrows to the land surface tends to significantly reduce erosion potential, however such features generally last only a few years. Contour furrows can also tend to hinder seeding and revegetation efforts.

More permanent forms of alternative sediment control practices include:

- Manipulation of the slope gradient,
- Manipulation of slope length,
- Modification of the density of surface cover (vegetation, mulch, etc.),
- Alteration of the hillslope surface to increase roughness or depression storage, and
- Enhancement of infiltrative capacity of the soil.

Evaluation of the first four sediment control alternatives listed above shows that these alternatives generally can be used to meet the background performance standard. Depending on the specific properties of any particular site, defined by such variables as hillslope gradient and length, cover density, soil particle size distribution and infiltration capacity, one or more of these measures may be required for alternative sediment control to be effective. According to this study, the recommended procedure for evaluation of alternative sediment control requires use of the MULTSED model to define the background conditions of runoff and sediment yield for a range of storm conditions. Modeling of the reclaimed conditions then indicates the relative differences in runoff/erosion response resulting from mining activities. If post-mining erosion exceeds the undisturbed erosion potential, MULTSED can be applied to evaluate the necessary modifications to the watershed system to meet the background performance standard.

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Appendix A: Wyoming Coal Rules and Regulations, Chapter IV

CHAPTER 4

ENVIRONMENTAL PROTECTION PERFORMANCE STANDARDS

FOR SURFACE COAL MINING OPERATIONS

Section 1. **General.**

This Chapter sets forth the environmental protection performance standards applicable to all coal mining operations. No mining operation shall be conducted except in compliance with the requirements hereof.

Section 2. **General Environmental Protection Performance Standards.**

(a) Land uses.

(i) Reclamation shall restore the land to a condition equal to or greater than the "highest previous use." The land, after reclamation, must be suitable for the previous use which was of the greatest economic or social value to the community area, or must have a use which is of more economic or social value than all of the other previous uses.

(ii) Operators are required to restore wildlife habitat, whenever the Administrator determines that this restoration is possible, on affected land in a manner commensurate with or superior to habitat conditions which existed before the land became affected, unless the land is private and the proposed use is for a residential or agricultural purpose which may preclude its use as wildlife habitat.

(iii) Water impoundments used for recreational purposes shall be constructed in accordance with the statutes and (g) of this Section. Recreational lands, other than water impoundments, represent changes in the land which may or may not be suitable for wildlife habitat.

(b) Backfilling, grading and contouring.

(i) Rough backfilling and grading shall follow coal removal as contemporaneously as possible based upon the mining conditions. The operator shall include within the application for a permit to mine a proposed schedule for backfilling and grading with supporting analysis.

(ii) Backfilled materials shall be replaced in a manner which minimizes water pollution on and off the site and supports the approved postmining land use.

Preparation of final graded surfaces shall be conducted in a manner that minimizes erosion and provides a surface for replacement of topsoil that will minimize slippage.

(iii) All affected lands shall be returned to their approximate original contour, except as authorized by a variance or exemption under Chapter 5, Sections 6 and 7, or Chapter 8, or Chapter 9.

(iv) All spoil shall be transported, backfilled, compacted (where necessary to insure stability or to prevent leaching) and graded to eliminate all highwalls, spoil piles, and depressions, except that:

(A) Soil conservation techniques may be employed if they are needed to retain moisture, minimize erosion, create and enhance wildlife habitat, and assist revegetation.

(B) Incomplete elimination of highwalls may be authorized in accordance with Chapter 5, Section 7.

(C) Spoil may be placed on an area outside the mined-out area to restore the approximate original contour by blending the spoil into the surrounding terrain if the spoil is backfilled and graded on the area in accordance with the requirements of this subsection.

(v) Postmining slopes shall not exceed a slope necessary to achieve a minimum long-term static safety factor of 1.3, to prevent slides and restore stable drainages and hillslopes.

(vi) Thin overburden. Where surface coal mining operations are proposed to be carried out continuously in the same limited pit area for more than one year from the day coal removal operations begin and where the volume of all available spoil and suitable waste materials over the life of the mine is demonstrated to be insufficient to achieve the approximate original contour considering bulking factor and coal removal, surface mining activities shall be conducted to use all available spoil and suitable waste materials to attain the lowest practicable stable grade, but not more than the angle of repose, and to meet the requirements of paragraphs (ii) and (iv) above.

(vii) Thick overburden. Where the volume of spoil over the life of the mine is demonstrated to be more than sufficient to achieve the approximate original contours considering bulking factor, coal removal and subsidence of backfilled material, excess spoil may be placed outside the pit area in accordance with the requirements of subsection (c).

(viii) Permanent impoundments: Where permanent impoundments are authorized in accordance with Chapter 2, Section 2(b)(xiv), spoil that may result from the impoundment will be handled in accordance with the requirements of this subsection.

(ix) Soft rock surface mining.

(A) If the reclamation plan does not provide for a permanent water impoundment, the final pit area shall be backfilled, graded, compacted and contoured to the extent necessary to return the land to the use specified in the approved plan. In preparation of slope specifications in the plan, the operator shall consider an average of the measured slopes in the immediate area of the proposed mine site. Slopes in the reclaimed area shall approximate the premining slopes. Individual slope measurements, locations of the measurements, and the average measurement shall be submitted with the reclamation plan. In determinations of the approximate premining slope, the Land Quality Division may make an independent slope survey. All backfilling, grading, and contouring will be done in such a manner so as to preserve the original drainage or provide for approved adequate substitutes. No depressions to accumulate water will be permitted unless approved in the reclamation plan as being consistent with the proposed future use of the land.

(B) Terraces or benches may be used only when it can be shown to the Administrator's satisfaction that other methods of contouring will not provide the required result. If terracing is proposed, detailed plans indicating the dimensions and design of the terraces, check dams, any erosion prevention techniques, and slopes of the terraces and their intervals will be required.

(C) If the reclamation plan provides for a permanent water impoundment and this use has been approved according to the requirements outlined in the Act and these regulations, the exposed pit areas must be sloped, graded, and contoured so as to blend in with the topography of the surrounding terrain and provide for access and revegetation. Riprapping where necessary to prevent erosion will be required. Sloping requirements will be as described above. Under certain conditions wherein it can be demonstrated to the Administrator's satisfaction that the pitwall can be stabilized by terracing or other techniques it may be permissible to leave not more than one-half of a proposed shoreline composed of the stabilized pitwall. The remaining portion of the shoreline must be graded and contoured so as to provide access and blend in with the topography of the surrounding terrain. In the event that a partial pitwall is proposed as final reclamation, the operator must submit a detailed explanation of the techniques to be used to establish the stability of the pitwalls in his reclamation plan. At the Administrator's discretion, a study of the proposed pitwall stabilization techniques may be required from an independent engineering company for purposes of verifying the effectiveness of the proposed stabilization techniques. The Land Quality Division will determine the acceptability of the proposed stabilization techniques based on this information and an on-site inspection.

(D) Highwall retention may be considered on a case-by-case basis for enhanced wildlife habitat. The Wyoming Game and Fish Department shall be consulted by the applicant for need and design of the land form. Any approval under this paragraph shall be based on a demonstration of safety, stability, environmental protection, and equal or better land use considerations.

(c) Topsoil, subsoil, overburden, and refuse.

(i) Topsoil.

(A) All topsoil or approved surface material shall be removed from all areas to be affected in the permit area prior to these areas being affected unless otherwise authorized by the Administrator. The topsoil may be mixed with the subsoil but shall be segregated so as not to become mixed with spoil or waste material, stockpiled in the most advantageous manner and saved for reclamation purposes. The Administrator may authorize topsoil to remain on areas where minor disturbance will occur associated with construction and installation activities including but not limited to light-use roads, signs, utility lines, fences, monitoring stations and drilling provided that the minor disturbance will not destroy the protective vegetative cover, increase erosion, nor adversely affect the soil resource.

(B) When topsoil is not promptly redistributed, the topsoil or approved surface material shall be stockpiled on stable areas within the permit area in such a manner so as to minimize wind and water erosion and unnecessary compaction. In order to accomplish this, the operator shall establish, through planting or other acceptable means, a quick growing cover of vegetation on the topsoil stockpiles. The topsoil shall also be protected from acid or toxic materials, and shall be preserved in a usable condition for sustaining vegetation when placed over affected land. Provided however, where long-term disturbance will occur, the Administrator may authorize the temporary distribution of topsoil to enhance stabilization of affected lands within the permit area. Where this is authorized, the Administrator shall find that the topsoil or subsoil capacity and productive capabilities are not diminished, that the topsoil is protected from erosion, and will be available for reclamation.

(C) Reclamation shall follow mining as soon as is feasible so as to minimize the amount of time topsoil must be stockpiled. Where topsoil has been stockpiled for more than one year, the operator may be required to conduct nutrient analyses to determine if soil amendments are necessary.

(D) Topsoil stockpiles shall be marked with a legible sign containing letters not less than six inches high on all approach roads to such stockpiles. Said signs shall contain the word "Topsoil" and shall be placed not more than 150 feet from any and all stockpiles of topsoil. Such signs must be in place at the time stockpiling is begun.

(E) If abundant topsoil is present, and it is not all needed to accomplish the reclamation required in the approved reclamation plan, the Administrator may approve of use of this topsoil by this or another operator in another area for reclamation purposes.

(F) Trees, large rocks and other waste material which may hinder redistribution of topsoil shall be separated from the topsoil before stockpiling.

(ii) Subsoil.

(A) Except as provided in (B), all subsoil determined by field methods or chemical analysis to be suitable as a plant-growth medium shall be removed from all areas to be affected and handled in accordance with the topsoil requirements of this Section.

(B) Upon an adequate demonstration by the operator that all or a portion of the subsoil material is not needed to meet the revegetation and land use requirements of these regulations, the Administrator may authorize all or a portion of the subsoil to not be used for reclamation. The unused subsoil may then be regarded as overburden material and handled in accordance with the requirements of this Section.

(iii) The topsoil (A and E horizons) shall be segregated from the subsoil (B and C horizons) where the Administrator determines that this practice is necessary to achieve the revegetation requirements of these regulations.

(iv) Before redistribution of topsoil or subsoil the regraded land shall be treated, if necessary, to reduce potential for slippage and encourage root penetration.

(v) Topsoil, subsoil, and/or an approved topsoil substitute shall be redistributed in a manner that:

(A) Achieves an approximate uniform, stable thickness consistent with the approved permit and the approved postmining land uses, contours and surface water drainage system;

(B) Prevents compaction which would inhibit water infiltration and plant growth;

(C) Protects the topsoil from wind and water erosion before and after it is seeded until vegetation has become adequately established; and

(D) Conserves soil moisture and promotes revegetation.

(vi) All rills and gullies which either preclude achievement of the approved postmining land use or the reestablishment of the vegetative cover, or cause or contribute to a violation of water quality standards for the receiving stream, shall be regraded or otherwise stabilized. Topsoil shall be replaced and the areas shall be reseeded or replanted.

(vii) Nutrients and soil amendments in the amounts determined necessary by soil test or field trials shall be applied to the replaced topsoil, subsoil or substitute material so that adequate nutrient levels are available to establish the vegetative cover. Fertilizer shall be applied at appropriate seasons and in amounts that will minimize pollution of surface waters or groundwaters.

(viii) The Administrator may not require topsoil or subsoil replacement on structures or within impoundments where replacement of this material is inconsistent with the intended use and the structures are otherwise stable.

(ix) If a sufficient volume of suitable topsoil or subsoil is not available for salvage or redistribution, then selected spoil material may be used as a topsoil or subsoil substitute or supplement. The operator shall demonstrate that the resulting plant growth medium is equal to, or more suitable for sustaining vegetation than the existing topsoil or subsoil and that it is the best available in the permit area to support revegetation. A demonstration of the suitability of the substitutes or supplements shall be based upon analysis of the texture, percent coarse fragments and pH. The Administrator may require other chemical and physical analyses, field site trials, or greenhouse tests if determined to be necessary or desirable to demonstrate the suitability of the topsoil or subsoil substitutes or supplements.

(x) Topsoil and subsoil substitutes.

(A) Topsoil substitute stockpiles shall be segregated from topsoil and overburden piles and shall be identified as substitute material. Identification signs shall be placed not more than 150 feet from all stockpiles of substitute material. Such signs shall be in place at the time stockpiling is begun.

(B) If overburden is to be used in reclamation as a substitute for topsoil, all large rocks and other waste material which may hinder redistribution shall be separated before stockpiling.

(xi) Overburden, spoil and refuse.

(A) All overburden, spoil material and refuse shall be segregated from the topsoil and subsoil and stockpiled in such a manner to facilitate the earliest reclamation consistent with the approved reclamation plan.

(B) Except where diversions are authorized by these regulations, all overburden, spoil material, and refuse piles must be located to avoid blocking intermittent or perennial drainages and flood plains in order to minimize loss and spread of material due to water erosion. Ephemeral drainages may be blocked if environmentally sound methods for dealing with runoff control and sedimentation are approved by the Administrator.

(I) For temporary stockpiles, material should be replaced in pits as soon as possible consistent with the approved reclamation plan to minimize the amount of time material is stockpiled.

(C) All topsoil shall be removed from areas to be used for piling spoil material prior to the beginning of piling this material.

(D) The operator may be required to have analyses made of spoil material in order to determine if it will be a source of water pollution through reaction with leaching by surface water. If it is determined that this condition may exist, the operator shall describe proposed procedures for eliminating this condition.

(E) All overburden and spoil material that is determined to be toxic, acid-forming or will prevent adequate reestablishment of vegetation on the reclaimed land surface, unless such materials occur naturally on the land surface, must be properly disposed of during the mining operation.

(F) All excess spoil shall be placed in approved excess spoil disposal sites located within the permit area. If permanent overburden, spoil, or refuse piles have been approved by the Administrator, they shall be:

(I) Located on moderately sloping and naturally stable areas where placement provides for stability and prevents mass movement.

(II) Located in areas which do not contain springs, seeps, natural or man-made drainages (excluding rills and gullies), croplands, or important wildlife habitat.

(III) Designed, graded and contoured so as to blend in with the topography of the surrounding terrain. Excess spoil pile sites shall not be located on an overall slope that exceeds 20 degrees unless keyway cuts (excavations to stable bedrock), rock toe buttresses or other special structural provisions are constructed to ensure fill stability. The operator must demonstrate to the satisfaction of the Administrator that this material will be stable and can be revegetated as required by this Section.

(IV) The slopes of all spoil areas must be designed so that they will be stabilized against wind and water erosion. After the grading and contouring of these stockpiles, topsoil or approved subsoil must be distributed over them in preparation for the revegetation procedure. Revegetation must be completed in accordance with requirements of this Chapter. A permanent drainage system must be established consistent with these regulations.

(G) Excess spoil may be returned to underground mine workings in accordance with the plan approved by the Administrator and by MSHA.

(H) Excess spoil piles shall be designed using current, prudent professional standards and certified by a qualified registered professional engineer. All piles shall be designed and constructed in accordance with the standards of this subsection. Special structural provisions shall be designed using prudent current engineering practices, in accordance with Chapter 2, Section 2(b)(xviii)(E).

(I) Excess spoil shall be placed in a controlled manner to:

(I) Prevent pollution from leachate and surface runoff from the fill on surface water or groundwater of the State.

(II) Ensure mass stability and prevent mass movement during and after construction and provide for stable drainages and hillslopes.

(III) Ensure that the land mass designated as the disposal site is suitable for reclamation and revegetation compatible with the natural surroundings and approved postmining land use.

(J) The spoil pile shall be transported and placed in horizontal lifts in a controlled manner, concurrently compacted as necessary to ensure mass stability and prevent mass movement, covered, and graded to allow surface and subsurface drainage to be compatible with the natural surroundings and ensure a minimum long-term static safety factor of 1.5. The Administrator may limit the horizontal lifts to four feet or less as necessary to ensure the stability of the fill or to meet other applicable requirements.

(K) No water impoundments or large depressions shall be constructed on the fill. Soil conservation techniques may be approved if they are needed to minimize erosion, enhance wildlife habitat or assist revegetation, as long as they are not incompatible with the stability of the fill.

(L) The foundation and abutments of the fill shall be stable under all conditions of construction. Sufficient foundation investigation and any necessary laboratory testing of foundation materials shall be performed in order to determine the design requirements for foundation stability. Analyses of foundation conditions shall include the effect of underground mine workings, if any, upon the stability of the structure.

(M) Slope protection shall be provided to minimize surface erosion at the site. Diversion of surface water runoff shall conform with the requirements of subsection (e) of this Section. All disturbed areas, including diversion ditches that are not riprapped, shall be vegetated upon completion of construction.

(N) Terraces may be constructed on the outslope of the fill if required for stability, control of erosion, to conserve soil moisture, or to facilitate the approved postmining land use. The grade of the outslope between terrace benches shall not be steeper than 2h:lv (50 percent).

(O) Excess spoil that is toxic, acid-forming or combustible shall be adequately covered with suitable material or treated to prevent pollution of surface and groundwater, to prevent sustained combustion, and to minimize adverse affects on plant growth and the approved postmining land use.

(P) The Administrator may specify additional design criteria on a case-by-case basis as necessary to meet the general requirements of this subsection.

(Q) The fill shall be inspected for stability by a qualified registered professional engineer or other qualified professional specialist under the direction of a professional engineer experienced in the construction of earth and rockfill embankments at least quarterly throughout construction and during the following critical construction periods: (1) foundation preparation, including the removal of all organic material and topsoil, (2) placement of diversion systems, (3) installation of final surface drainage systems, and (4) final grading and revegetation. Regular inspections by the engineer or specialist shall be conducted during placement and compaction of the fill materials. The registered professional engineer shall promptly provide certified reports to the Administrator which demonstrate that the fill has been maintained and constructed as specified in the design contained in the approved mining and reclamation plan. The report shall discuss appearances of instability, structural weakness, and other hazardous conditions. A copy of all inspection reports shall be retained at the mine site.

(xii) Coal mine waste.

(A) Coal mine waste shall be disposed only in existing or, if new, in an approved disposal site within a permit area. Coal mine wastes shall not be used in the construction of dams, embankments, or diversion structures. The disposal area shall be designed, constructed and maintained:

(I) In accordance with the excess spoil disposal requirements of (xi)(F)-(I), and (K)-(O) above; and

(II) To prevent combustion and not create a public health hazard.

(B) Disposal of coal mine waste in excess spoil piles may be approved if such waste is:

(I) Placed in accordance with the excess spoil requirements of (xi) above;

(II) Demonstrated to be nontoxic and nonacid-forming (or properly treated); and

(III) Demonstrated to be consistent with the design stability of the fill.

(C) In addition to (A) above, coal mine waste piles shall meet the following requirements:

(I) The disposal facility shall be designed to attain a minimum static safety factor of 1.5. The foundation and abutments must be stable under all conditions of construction.

(II) Following final grading of the waste pile, the site shall be covered with a minimum of four feet of the best available, nontoxic, nonacid-forming and noncombustible material, in a manner that directs runoff away from the waste pile. The site shall be revegetated in accordance with this Chapter. The Administrator may allow less than four feet of cover material based on physical and chemical analyses which show that the revegetation requirements will be met.

(III) Surface drainage from above the pile and from the crest and face of the pile shall be permanently diverted around the waste in accordance with subsection (e) of this Section.

(IV) All coal mine waste piles shall be inspected in accordance with the excess spoil requirements of (xi) above. More frequent inspections shall be conducted if a danger or harm exists to the public health and safety or the environment. Inspections shall continue until the waste pile has been finally graded and revegetated or until a later time as required by the Administrator. If any inspection discloses that a potential hazard exists, the Administrator shall be notified immediately, including notification of any emergency protection and remedial procedures which will be implemented. If adequate procedures cannot be formulated or implemented, the Administrator shall inform the appropriate emergency agencies of the hazard to protect the public from the area.

(V) All coal mine waste piles shall meet the requirements of 30 CFR §§ 77.214 and 77.215.

(D) Dams and embankments constructed to impound coal mine waste shall comply with the following:

(I) Each impounding structure shall be designed, constructed and maintained in accordance with the requirements applicable to temporary impoundments. Such structures may not be retained permanently as part of the approved postmining land use. Approval by the State Engineer's Office is not required.

(II) If the impounding structure meets the criteria of 30 CFR § 77.216 (a), the combination of principal and emergency spillways shall be able to safely pass the 100-year, 6-hour design precipitation event or a storm duration having a greater peak flow.

(III) Spillways and outlet structures shall be designed to provide adequate protection against erosion and corrosion. Inlets shall be protected against blockage.

(IV) Be designed so that 90 percent or more of the water stored during the design precipitation event can be removed within ten days.

(V) Runoff from areas above the disposal facility or runoff from the surface of the facility that may cause instability or erosion of the impounding structure shall be diverted into stabilized diversion channels designed to meet the requirements for diversions, and designed to safely pass the runoff from a 100-year, 6-hour design precipitation event or a storm duration having a greater peak flow.

(E) The Administrator may specify additional design criteria for waste piles or impounding structures on a case-by-case basis as necessary to meet the general performance standards of this subsection.

(F) Coal mine waste fires shall be extinguished by the operator in accordance with a plan approved by the Administrator and the Mine Safety and Health Administration. The plan shall contain, at a minimum, provisions to ensure that only those persons authorized by the operator, and who have an understanding of the procedures to be used, shall be involved in the extinguishing operations. No burning or burned coal mine waste may be removed from a permitted disposal area without a removal plan approved by the Administrator. Consideration shall be given to persons working or living in the vicinity of the structure.

(G) Coal preparation plants shall be included within a permit area. Refer to Chapter 3, Section 6 for requirements applicable to coal preparation plants.

(xiii) Acid-forming and toxic materials, and other waste.

(A) All exposed coal seams remaining after mining and any acid-forming, toxic, and combustible materials, or any waste materials that are exposed, used or produced during mining shall be adequately covered, within 30 days of its exposure with nontoxic, nonacid-forming and noncombustible material, or treated. Compaction followed by burial or treatment shall be provided to prevent pollution of surface and groundwater quality, prevent sustained combustion and to minimize adverse effects on plant growth and postmining land uses. Such materials may be stored in a controlled manner until final burial and/or treatment first becomes feasible as long as storage will not result in any risk of water pollution or other environmental or public health and safety damage. Storage, final burial and treatment shall be done in accordance with all local, State and Federal requirements.

(B) Acid-forming or toxic material, or any other waste material capable of polluting water, shall not be buried or stored in the proximity of a drainage channel or its flood plain so as to cause or pose a threat of water pollution.

(C) Final burial of noncoal mine waste materials (such as grease, lubricants, paints, flammable liquids, garbage, trash, abandoned mining machinery, lumber and other combustible materials) and any wastes classified as hazardous shall be in a designated disposal site authorized by the Solid Waste Management Section of the Department.

(D) Management and final burial on the permit area of solid wastes generated by a mine mouth power plant or mine mouth coal drier shall be in accordance with this Section and with provisions of the Solid Waste Management Rules and Regulations deemed appropriate by the Administrator.

(d) Revegetation.

(i) The operator shall establish on all affected lands a diverse, permanent vegetative cover of the same seasonal variety native to the area or a mixture of species that will support the approved postmining land use in a manner consistent with the approved reclamation plan. This cover shall be self-renewing and capable of stabilizing the soil.

(ii) Land which did not support vegetation prior to becoming affected land because of natural soil conditions need not be revegetated unless subsoil from such affected land will support vegetation. The operator shall demonstrate to the Administrator's satisfaction that revegetation or reforestation is not possible if he seeks to proceed under the provisions of the subsection.

(iii) After backfilling, grading, and contouring and the replacement of topsoil, and/or approved substitutes, revegetation shall be commenced in such a manner so as to most efficiently accommodate the retention of moisture and control erosion on all affected lands to be revegetated. In addition, any fertilizer requirements as determined on the basis of previous analysis must be fulfilled.

(iv) Mulch or other equivalent procedures which will control erosion and enhance soil moisture conditions shall be used on all retopsoiled areas.

(v) Seeding which is accomplished by mechanical drilling shall be on the topographic contour, unless for safety reasons it is not practicable, or perpendicular to the prevailing wind on flat areas. Seeding of affected lands shall be conducted during the first normal period for favorable planting conditions after final preparation unless an alternative plan is approved. Any rills or gullies that would preclude successful establishment of vegetation or achievement of postmining land use shall be removed or stabilized. The species of vegetation to be used in revegetation efforts shall be described in the reclamation plan indicating the composition of seed mixtures and the amount of seed to be distributed on the area on a per acre basis. Seed types will depend on the climatic and soil conditions prevailing in the permit area and the proposed use of the land after reclamation. Species to be planted as permanent cover shall be self-renewing. Seeding rates will depend on seed types, climatic and soil conditions and the techniques to be used in seeding.

(vi) Introduced species may be used only to achieve a quick, temporary, stabilizing cover to control erosion, or to achieve a postmining land use as approved by the Administrator. Naturalized or nonindigenous native plant species may be included in the approved seed mixture if they support the approved postmining land uses. The operator shall document, unless otherwise authorized by the Administrator, the suitability of these species using data from published literature, from experimental test plots, from on-site experience, or from other information sources.

(vii) When the approved postmining land use is for residential, industrial/commercial, or cropland, the reclaimed area shall be stabilized and revegetated to control erosion unless development or cropping shall immediately occur.

(viii) For areas previously disturbed by mining and not reclaimed to the requirements of these regulations, the areas shall, at a minimum, be revegetated to a ground cover and productivity level existing before redisturbance and shall be adequate to control erosion.

(ix) Bond release. The bond for revegetation shall be retained for not less than ten years after the operator has completed seeding, fertilizing, irrigation, or other work to ensure revegetation. The bonding period shall not be affected where normal and reasonably good husbandry practices are being followed. The success of revegetation shall be determined in accordance with Section 2(d)(x) of this Chapter and paragraphs (E)-(H) below. If the Administrator approves an alternative success standard, as allowed by Section 2(d)(x) of this Chapter, the standard shall be based on technical information obtained from a recognized authority (e.g. Soil Conservation Service, Agricultural Research Service, Universities, Wyoming Game and Fish Department, U.S. Fish and Wildlife Service, etc.), or be supported by scientifically valid research. Use of an alternative technical standard shall be supported by concurrence from State and Federal agencies having an interest in management of the affected lands.

(x) The Administrator shall not release the entire bond of any operator until such time as revegetation is completed, if revegetation is the method of reclamation as specified in the operator's approved reclamation plan. Revegetation shall be deemed to be complete when: (1) the vegetation cover of the affected land is shown to be capable of renewing itself under natural conditions prevailing at the site, and the vegetative cover and total ground cover are at least equal to the cover on the area before mining, (2) the productivity is at least equal to the productivity on the area before mining, (3) the species diversity and composition are suitable for the approved postmining land use and the revegetated area is capable of withstanding grazing pressure at least comparable to that which the land could have sustained prior to mining, unless Federal, State or local regulations prohibit grazing on such lands, and (4) the requirements in (1), (2) and (3) are met for the last two consecutive years of the bonding period. The Administrator shall specify quantitative methods and procedures for determining whether equal cover and productivity has been established including, where applicable, procedures for evaluating postmining species diversity and composition. The following options or an alternative success standard approved by the Administrator are available:

(A) The method utilizing control areas may be selected. If selected, the control areas shall be sampled for cover, productivity, species diversity and composition in the same season that the area to be affected is sampled for baseline data. Quantitative premining and postmining vegetation data from the control areas shall be used to mathematically adjust premining affected area data for climatic change. Premining affected area cover and productivity data will be directly compared by statistical procedures to data from the reclaimed vegetation type when evaluating revegetation success for final bond release. Species diversity and composition data will be qualitatively or quantitatively evaluated as determined by the Administrator.

(B) The method utilizing reference areas may be selected. If selected, the representativeness of the reference area is verified by a statistical comparison to the plant community that it typifies. Postmining cover and productivity data from the reference area are directly compared by standard statistical procedures to data from the reclaimed area when evaluating revegetation success for final bond release. Species diversity and composition data will be qualitatively or quantitatively evaluated as determined by the Administrator.

(C) Where the premining cover, productivity, species diversity and composition data cannot be collected, or where the area to be affected is small and incidental to the operation, comparison areas may be selected. For purposes of this method, postmining qualitative and quantitative data from the comparison area are directly compared by procedures acceptable to the Administrator to data from the reclaimed lands when evaluating success of revegetation for final bond release.

(D) Without regard to the type of method selected, control, reference or comparison areas should be at least two acres in size, located in areas where they will not be affected by future mining, while serving their designated use, managed in a fashion which will not cause significant changes in the vegetation parameters of cover, productivity, species diversity and composition and be representative of the postmining land use.

(E) The postmining density, composition, and distribution of shrubs shall be based upon site-specific evaluation of premining vegetation and wildlife use. Shrub reclamation procedures shall be conducted through the application of best technology currently available.

(I) Except where a lesser density is justified from premining conditions in accordance with Appendix A, at least 20 percent of the eligible lands shall be restored to shrub patches supporting an average density of one shrub per square meter. Patches shall be no less than .05 acres each and shall be arranged in a mosaic that will optimize habitat interspersion and edge effect. Criteria and procedures for establishing the standard are specified in Appendix A. This standard shall apply to all lands affected after August 6, 1996.

(II) Approved shrub species and seeding techniques shall be applied to all remaining grazingland. Trees shall be returned to a density equal to the premining conditions.

(III) For areas containing crucial habitat, designated as such prior to the submittal of a permit application or any subsequent amendment, or critical habitat the Wyoming Game and Fish Department shall be consulted about, and its approval shall be required for, minimum stocking and planting arrangements of shrubs, including species composition. For areas determined to be important habitat, the Wyoming Game and Fish Department shall be consulted for recommended minimum stocking and planting arrangements of shrubs, including species composition, that may exceed the programmatic standard discussed above.

(F) Where trees are part of the approved reclamation plan, at the time of bond release the trees to meet the required stocking rate shall be healthy, and at least 80 percent shall have been planted for at least eight years.

(G) Standards for the success of reforestation for commercial harvest shall be established in consultation with forest management agencies and prior to approval of any mining and reclamation plan that proposes reforestation. If reforestation for commercial harvest is the method of revegetation, reforestation shall be deemed to be complete when a reasonable population density as established in the reclamation plan has been achieved, the trees have shown themselves capable of continued growth for a minimum period of five years following planting, and the understory vegetation is adequate to control erosion and is appropriate for the land use goal. Quality and quantity, vegetation cover, productivity, and species diversity shall be determined in accordance with scientifically acceptable sampling procedures approved by the Administrator.

(H) If the Administrator approves a long-term, intensive agricultural postmining land use, the ten year period of liability shall commence at the date of initial planting for such long-term agricultural use.

(I) When the approved reclamation plan is to return to cropland, reclamation shall be deemed to be complete when productive capability is equivalent, for at least two consecutive crop years, to the premining conditions or approved reference areas. The premining production data for the reclaimed site shall be considered in judging completeness of reclamation whenever said data are available.

(xi) Monitoring of permanent revegetation on reclaimed areas before and after grazing shall be conducted at intervals throughout the period prior to bond release in accordance with the plan required by Chapter 2, Section 2(b)(vii). Monitoring results shall be presented in the annual report.

(xii) Any plans for irrigation must be explained.

(xiii) The operator must protect young vegetative growth from being destroyed by livestock by fencing or other approved techniques for a period of at least two years, or until the vegetation is capable of renewing itself with properly managed grazing and without supplemental irrigation or fertilization. The Administrator, permittee and the landowner or land managing agency shall determine when the revegetated area is ready for livestock grazing.

(xiv) In those areas where there were no or very few noxious weeds prior to being affected by mining, the operator must control and minimize the introduction of noxious weeds into the revegetated areas for a period of at least five years after the initial seeding.

(e) Diversion systems and drainage control.

(i) Diversion of streams.

(A) All diversions shall be designed to assure public safety, prevent material damage outside the permit area, and minimize adverse impacts to the hydrologic balance.

(B) All diversions and associated structures shall be designed, constructed, maintained and used to ensure stability, prevent, to the extent possible using best technology currently available, additional contribution of suspended solids to streamflow outside the permit area, and comply with all applicable local, State and Federal rules.

(C) Permanent diversions of intermittent and perennial streams shall be designed and constructed so as to be erosionally and geomorphically compatible with the natural drainage system.

(D) The design and construction of all diversions for perennial or intermittent streams shall be certified by a qualified registered professional engineer as meeting the diversion standards of these regulations and the approved permit.

(E) When permanent diversions are constructed or stream channels restored after temporary diversions, the operator shall:

(I) Restore, enhance where practicable, or maintain natural riparian vegetation on the banks and flood plain of the stream;

(II) Establish or restore the stream characteristics, including aquatic habitats to approximate premining stream channel characteristics; and

(III) Establish and restore erosionally stable stream channels and flood plains.

(F) The operator shall renovate all permanent diversions in accordance with the approved reclamation plan prior to abandonment of the permit area.

(G) When no longer needed to achieve the purpose for which they were authorized, all temporary diversions shall be removed and the affected land regraded and revegetated, in accordance with this Chapter. Before diversions are removed, downstream water treatment facilities previously protected by the diversion shall be modified or removed, as necessary, to prevent overtopping or failure of the facilities. This requirement shall not relieve the operator from maintaining water treatment facilities as otherwise required.

(ii) Control of discharge or drainage.

(A) Discharge from sedimentation ponds, permanent and temporary impoundments, coal-processing waste dams and embankments, and diversions shall be controlled, by energy dissipators, riprap channels, and other devices, where necessary, to reduce erosion, to prevent deepening or enlargement of stream channels, and to minimize disturbance of the hydrologic balance. Discharge structures shall be designed according to standard engineering design procedures.

(B) Drainage from acid-forming and toxic-forming material into ground and surface water shall be avoided by:

(I) Identifying, burying, and treating where necessary, material which, in the judgment of the Administrator may adversely affect water quality if not treated or buried;

(II) Preventing water from coming into contact with acid-forming and toxic-forming material and other measures as required by the Administrator; and

(III) Complying with the requirements of subsection (c)(xiii) of this Section and such other measures deemed necessary by the Administrator to protect surface water and groundwater.

(C) Surface water shall not be diverted or otherwise discharged into underground mine workings unless specifically authorized by the Administrator per the requirements of Chapter 19, Section 2(a) of these regulations.

(iii) In addition to meeting the standards of this Section, all diversions of groundwater discharge flows shall meet the standards of Section 2(e).

(iv) Diversion systems - Unchannelized surface water and ephemeral streams.

(A) Surface water shall be diverted around the operation for the following purposes:

(I) To control water pollution.

(II) To control unnecessary erosion.

(III) To protect the on-going operation.

(IV) To protect the water rights of downstream users.

(B) Temporary diversion of surface runoff or diversions used for erosion control shall meet the following standards:

(I) In soils or other unconsolidated material, the sides of diversion ditches shall be no steeper than 1½:1.

(II) In rock, the sides of diversion ditches shall not overhang.

(III) In soils or unconsolidated materials, the sides and, in ditches carrying intermittent discharges, the bottom shall be seeded with approved grasses so as to take advantage of the next growing season.

(IV) Rock riprap, concrete, soil cement or other methods shall be used where necessary to prevent unnecessary erosion.

(V) Culverts or bridges shall be installed where necessary to allow access by the surface owner for fire control and other purposes.

(VI) Diversion ditches shall in a nonerosive manner pass the peak runoff from a 2-year, 6-hour precipitation event, or a storm duration that produces the largest peak flow, as specified by the Administrator.

(C) In no case shall diversion ditches discharge upon topsoil storage areas, spoil or other unconsolidated material such as newly reclaimed areas.

(D) Permanent diversion structures shall be designed to be erosionally stable during the passage of the peak runoff from a 100-year, 6-hour precipitation event, or a storm duration that produces the largest peak flow, as specified by the Administrator.

(v) Diversion of intermittent and perennial streams.

(A) In no case shall spoil, topsoil, or other unconsolidated material be pushed into, or placed below the flood level of a perennial or intermittent stream except during the approved construction of the diversion of said stream.

(B) The Wyoming Game and Fish Department shall be consulted prior to the approval of a diversion of a perennial or intermittent stream.

(C) The banks of a diverted perennial or intermittent stream shall be protected by vegetation by planting approved species to take advantage of the next growing season.

(D) The banks and channel of a diverted perennial or intermittent stream shall be protected where necessary by rock, riprap or similar measures to minimize erosion and degradation of water quality. Permanent diversions shall be designed and constructed to be erosionally stable. The design of the permanent diversion shall also be consistent with the role of the fluvial system.

(E) Mining on the flood plain of a perennial or intermittent stream shall not be permitted if it would cause the uncontrolled diversion of the stream during periods of high water.

(F) Waters flowing through or by the mining operation shall meet the standards set by the U.S. Environmental Protection Agency and the Wyoming Water Quality Division in regard to the effect of the operation upon such waters.

(G) If temporary, the channel and flood plain shall be designed to pass, in a nonerosive manner, the 10-year, 6-hour precipitation event, or the capacity of the unmodified stream channel immediately above and below the diversion, whichever capacity is greater, or a duration having a greater peak flow, as specified by the Administrator. Cross-sections of the existing stream above, below and within the disturbed area may be used to determine the flow capacities, channel configuration and shape.

(H) If permanent, the channel and flood plain shall be designed to pass, in a nonerosive manner, the 100-year, 6-hour precipitation event, or a duration having a greater peak flow, as specified by the Administrator. Cross-sections of the existing stream above, below and within the disturbed area may be used to determine the flow capacities, channel configuration and shape.

(f) Sedimentation ponds.

(i) All surface drainage from affected lands excluding sedimentation ponds, diversion ditches, and road disturbances, shall pass through a sedimentation pond(s) before leaving the permit area. Sedimentation control devices shall be constructed prior to disturbance. The Administrator may grant exemptions to the use of sedimentation ponds where, by the use of alternative sediment control measures, the drainage will meet effluent limitation standards or will not degrade receiving waters.

(ii) Where the sedimentation pond(s) results in the mixing of drainage from affected lands with the drainage from undisturbed areas, the permittee shall comply with the applicable effluent limitation standards for all of the mixed drainage where it leaves the permit area.

(iii) Sedimentation ponds shall be designed and constructed to comply with the applicable requirements of subsection (g)(iv-vii) of this Chapter. They shall be located as near as possible to the affected lands and out of intermittent or perennial streams; unless approved by the Administrator.

(iv) Sedimentation ponds shall be operated and maintained to comply with the requirements of the Water Quality Division and the State Engineer's Office and satisfy the following requirements:

(A) Chemicals that will harm fish, wildlife, and related environmental values shall not be used for flocculation or other water treatments or if used these ponds will be protected.

(B) Sedimentation ponds shall be designed and maintained to contain adequate sediment storage as determined by acceptable empirical methods.

(C) Sluicing of collected sediments shall be prevented for the design precipitation event.

(D) All areas disturbed by the construction of the sedimentation pond shall be revegetated as soon as practicable to reduce erosion.

(v) The design, construction, and maintenance of a sedimentation pond or other sediment control measures in accordance with this subsection shall not relieve the operator from compliance with applicable effluent limitation standards of the Water Quality Division.

(vi) Sediment ponds shall be maintained until removal is authorized by the Division and the affected lands have been stabilized and initial vegetation established in accordance with the approved reclamation plan and the requirements of this Chapter. In no case shall sediment ponds treating reclaimed lands be removed sooner than two years after the last augmented seeding.

(vii) Sediment control measures for affected lands. Appropriate sediment control measures shall be designed, constructed, and maintained using the best technology currently available to prevent additional contributions of sediment to streamflow or to runoff outside the affected land. Such measures may consist of limiting the extent of disturbed land and stabilizing, diverting, treating or otherwise controlling runoff.

(g) Permanent and temporary water impoundments.

(i) Permanent water impoundments are prohibited unless authorized by the Administrator on the basis that:

(A) The impoundment and its water quality and quantity will support or constitute a postmining use equal to or greater than the highest previous use of the land.

(B) Discharge of water, if any, from the impoundment shall not degrade the quality of receiving waters.

(C) The surface landowner, if different from the mineral owner, has consented to the impoundment.

(ii) Permanent water impoundments. Permanent water impoundments shall be constructed in accordance with the following requirements:

(A) Dams must contain an overflow notch and spillway so as to prevent failure by overfilling and washing. Overflow notches and spillways must be riprapped with rock or concrete to prevent erosion.

(B) The slopes around all water impoundments must be gentle enough so as not to present a safety hazard to humans or livestock and so as to accommodate revegetation. Variations from this procedure may be approved by the Administrator based on the conditions present at the individual locality.

(C) Mineral seams and other sources of possible water contamination within the impoundment area must be covered with overburden or stabilized in such a manner to prevent contamination of the impounded water.

(D) Bentonite or other mire-producing material within the impoundment basin shall be removed or covered with materials which will prevent hazards to man or beast.

(iii) The phrase "major impoundment" shall mean any structure impounding water, sediment or slurry:

(A) To an elevation of 20 feet or more above the upstream toe to the crest of the emergency spillway; or

(B) To an elevation of five feet above the upstream toe of the structure and has a storage volume of 20 acre-feet or more; or

(C) Which will be retained as part of the postmining land use, and:

(I) Has an embankment height greater than 20 feet as measured from the downstream toe of the embankment to the top of the embankment; or

(II) Has an impounding capacity of 20 acre-feet or greater.

(iv) The design, construction and maintenance of permanent and temporary impoundments shall be approved by the State Engineer's Office. In addition, the following design and construction requirements shall be applicable:

(A) The design of impoundments shall be certified by a qualified registered professional engineer as designed to meet the requirements of this part and the applicable requirements of the State Engineer, using current, prudent engineering practices. For major impoundments, the certification also shall be filed with the State Engineer.

(B) The vertical portion of any remaining highwall shall be located far enough below the low water line along the full extent of highwall to provide adequate safety and access for the proposed water users.

(C) Faces of embankments and surrounding areas shall be vegetated, except that faces where water is impounded may be riprapped or otherwise stabilized in accordance with accepted design practices, or where appropriate, Water Quality Division rules and regulations.

(D) The embankment, foundation, and abutments for all impoundments shall be designed and constructed to be stable. For any major impoundment or any impoundment which may present a danger to life, property or the environment, the Administrator shall require sufficient foundation investigations and laboratory testing to demonstrate foundation stability, and shall require a minimum static safety factor of 1.5 for the normal pool with steady seepage saturation conditions, and a seismic safety factor of at least 1.2.

(E) All vegetative and organic materials shall be removed and foundations excavated and prepared to resist failure. Cutoff trenches shall be installed if necessary to ensure stability.

(F) All impoundments shall be inspected regularly during construction and immediately after construction by a qualified registered professional engineer or qualified professional specialist under the direction of a qualified professional engineer. These individuals shall be experienced in impoundment construction. Immediately following each inspection a report shall be prepared and certified by the engineer describing the construction work observed and its conformance with the approved designs. All inspection reports shall be retained at the mine site and submitted in the annual report to the Administrator.

(G) After completion of construction and until final bond release or removal, all impoundments shall be inspected annually by a qualified registered professional engineer, or by a qualified professional specialist under the direction of the qualified professional engineer. These individuals shall be experienced in impoundment construction. Immediately following each inspection a report shall be prepared and certified by the engineer describing:

(I) Existing and required monitoring procedures and instrumentation;

(II) Depth and elevation of any impounded water;

(III) Existing storage capacity;

(IV) Aspects of the dam that may affect its stability or present any other hazardous condition; and

(V) If the impoundment is being maintained in accordance with the approved design and this Chapter. All annual inspection reports shall be retained at the mine site and annually submitted to the Administrator.

(H) In addition to the post-construction annual inspection requirements contained in paragraph (G) immediately above, all impoundments must be inspected during each of the intervening calendar quarters by a qualified individual designated by the operator. These inspections shall look for appearances of structural weakness and other hazardous conditions.

(I) Those impoundments subject to 30 CFR § 77.216 shall also be inspected in accordance with 30 CFR § 77.216-3.

(J) If any examination of inspection discloses that a potential hazard exists, the operator shall promptly inform the Administrator of the finding and of the emergency procedures formulated for public protection and remedial action. If adequate procedures cannot be formulated or implemented the Administrator shall be notified immediately. The Administrator shall then notify the appropriate agencies that other emergency procedures are required to protect the public.

(K) Impoundments meeting the criteria of 30 CFR § 77.216(a) shall comply with the requirements of 30 CFR § 77.216. The plan required to be submitted to the District Manager of MSHA under 30 CFR § 77.216 shall also be submitted to the Administrator as part of the permit application.

(v) The design precipitation event for the spillways for temporary water impoundments shall be a 25-year, 6-hour precipitation event, or a storm duration having a greater peak flow, as may be required by the Administrator.

(vi) The design precipitation event for the spillways for a permanent impoundment shall be a 100-year, 6-hour precipitation event, or a storm duration having a larger peak flow, as may be required by the Administrator.

(vii) Before abandoning an area or seeking bond release, the operator shall ensure that all temporary structures are removed and reclaimed, and that all permanent structures are renovated, if necessary to meet the requirements of this subsection and to conform to the approved reclamation plan.

(viii) Tailings impoundments.

(A) Impoundments to contain mill tailings or slurry tailings shall be constructed in accordance with established engineering principles and shall be approved by the Wyoming State Engineer's Office. A copy of the State Engineer's approval shall be attached to the application.

(B) Reclamation of tailings impoundments shall be accomplished by removal and storage of all topsoil present within the tailings basin. After termination of operations, the topsoil shall be replaced and revegetated in accordance with these rules and regulations. If other methods of reclamation and stabilization against wind and water erosion are found to be necessary because of natural conditions, this must be stated and described subject to the Administrator's approval.

(h) Protection of Groundwater Recharge Capacity - The recharge capacity of the reclaimed lands shall be restored to a condition which:

(i) Supports the approved postmining land use;

(ii) Minimizes disturbances to the prevailing hydrologic balance in the permit area and in adjacent areas; and

(iii) Provides a rate of recharge that approximates the premining recharge rate.

(i) Surface water and groundwater quality and quantity shall be monitored until final bond release to determine the extent of the disturbance to the hydrologic balance. Monitoring shall be adequate to plan for modification of surface mining activities, if necessary, to minimize adverse affects on the water of the State. The operator is responsible for properly installing, operating, maintaining and removing all necessary monitoring equipment. In addition, the operator is responsible for conducting monitoring in accordance with the approved monitoring plan, and submitting all routine monitoring results to the Administrator at least annually. Routine monitoring results shall also be maintained on-site and available to the Director's designated authorized representative, and shall be reasonably current. Noncompliance results for NPDES discharges shall be promptly reported by the operator to the Water Quality Division Administrator. The operator shall promptly report all other noncompliance results to the Land Quality Division Administrator and shall, after consultation with the Administrator, implement appropriate and prompt mitigative measures for those noncompliance situations determined to be mining caused. The monitoring system shall be based on the results of the probable hydrologic consequences assessment and shall include:

(i) A groundwater monitoring program to determine:

(A) Infiltration rates, subsurface flows, and storage characteristics of the reclaimed land and adjacent areas;

(B) The effects of reclamation on the recharge capacity of the reclaimed lands; and

(C) Suitability of groundwater for current and approved postmining land uses.

(ii) A surface water monitoring program which includes monitoring of surface water flow and quality from affected lands including those that have been graded and stabilized. Results of the monitoring will be used to demonstrate that the quality and quantity of runoff from affected lands with or without treatment will minimize disturbance to the hydrologic balance. Water quality monitoring results for discharges other than those authorized by Water Quality Division shall be reported whenever results indicate noncompliance with effluent limitation standards or degradation of the quality of receiving water shall be reported immediately. Monitoring results shall be available for inspection at the mine site.

(j) Roads and other transportation facilities.

(i) General standards for all transportation facilities.

(A) Roads and railroads. Constructed or upgraded roads and railroad spurs shall be included within the permit area from that point that they provide exclusive service and shall be covered by a reclamation bond.

(B) Roads shall not be constructed up a stream channel or so close that the material shall spill into the channel, unless specifically approved by the Administrator.

(C) Streams shall be crossed at or near right angles unless contouring down to the streambed will result in less potential stream bank erosion. Structure of ford entrances and exits must be constructed to prevent water from flowing down the roadway.

(D) Drainage control structures shall be used as necessary to control runoff and to minimize erosion, sedimentation and flooding. Drainage facilities shall be installed as road construction progresses.

(E) Culverts shall be installed at prominent drainageways, or as required by the Administrator. Where necessary, culverts must be protected from erosion by adequate rock, concrete or riprap. Culverts and drainage pipes shall be constructed to avoid plugging, collapsing, or erosion at inlets and outlets.

(F) Trees and vegetation may be cleared only for the essential width necessary to maintain slope stability and to serve traffic needs.

(G) Access, haul roads and drainage structures shall be routinely maintained.

(H) Exemptions concerning roads.

(I) If approval is obtained from the surface landowner to leave a road unreclaimed, an operator may request in writing to the Land Quality Division that a road be permitted to remain unreclaimed. The operator must furnish proof of the surface landowner's approval. Final decision of road reclamation will be made by the Land Quality Division Administrator.

(II) In the event that the surface landowner, a city or town, another agency of the State of Wyoming or an agency of the United States government has requested that a road not be reclaimed, no bond shall be required of the applicant for the reclamation of the road and reclamation of the road shall not be required; provided, however, that the Administrator receives a copy of the written request from the surface owner, city or town, or agency of the State or Federal Government, for retention of the road.

(ii) General performance standards for haul roads, access roads or light-use roads:

(A) Roads shall be located on ridges or on the most stable available slopes to minimize erosion, sedimentation and flooding. All exposed surfaces shall be stabilized in accordance with current, prudent engineering practices.

(B) Acid or toxic-forming substances shall not be used in road surfacing.

(C) To the extent possible using the best technology currently available, roads shall not cause damage to fish, wildlife, and related environmental values and shall not cause additional contributions of suspended solids to streamflow or to runoff outside the affected land or permit area. Any such contribution shall not be in excess of limitations of State or Federal law or degrade the quality of receiving water.

(D) The normal flow of water in streambeds and drainage channels shall not be significantly altered. Damage to public or private property shall be prevented or controlled.

(E) All embankments shall have, at a minimum, a static safety factor of 1.3.

(F) The design and construction or reconstruction shall incorporate appropriate limits for grade, width, surface materials, surface drainage control, culvert placement, culvert size, and such other design criteria required by the Administrator to ensure environmental protection and safety appropriate for the planned duration and use.

(G) All roads shall be maintained and/or repaired, if damaged, to meet the performance standards of this subsection.

(H) All roads shall be closed to vehicular travel when no longer needed and reclaimed in accordance with this Chapter, unless the road is retained for use under an approved postmining land use.

(iii) Performance standards for haul roads and access roads.

(A) Design and construction: The design and construction or reconstruction of haul roads and access roads shall be certified by a registered professional engineer as meeting the requirements of this subsection; current, prudent engineering practices; and any design criteria required by the Administrator.

(B) Stream fords are prohibited unless they are specifically approved by the Administrator as temporary routes during periods of construction.

(C) Drainage.

(I) Haul and access roads shall be designed, constructed, or reconstructed and maintained with drainage control structures capable of safely passing the runoff from a 10-year, 6-hour precipitation event, or a storm duration having a greater peak flow, unless otherwise specifically approved by the Administrator. The drainage control system shall include, but not be limited to bridges, culverts, ditches, cross drains, and ditch-relief drains.

(II) All drainage pipes or culverts shall be constructed and maintained to avoid plugging, collapse and erosion at inlets and outlets.

(III) All culverts shall be designed, constructed, and maintained to sustain the vertical soil pressure, passive resistance of the foundation, and the weight of vehicles to be used.

(IV) Ephemeral (shown on a USGS 7.5 minute series quad), intermittent or perennial streams shall not be altered or relocated for road construction or reconstruction without approval from the Administrator, and then, only if the natural channel drainage is not blocked except during periods of low flow or when flow has been acceptably diverted around the site, there is no significant damage to hydrologic balance, and there is no adverse impact on adjoining landowners.

(V) Drainage ditches shall be designed to prevent uncontrolled drainage over the road surface and embankment. Trash racks and debris basins shall be installed in the drainage ditches where debris from the drainage area may impair the functions of drainage and sediment control structures.

(VI) Except as provided in (B) above, drainage structures which are used for stream channel crossings shall be made using bridges, culverts, or other structures designed, constructed, and maintained using current, prudent engineering practices.

(D) Surfacing: Roads shall be surfaced with rock, crushed gravel, asphalt, or other material sufficiently durable for the anticipated volume of traffic and weight and speed of vehicles to be used.

(E) Maintenance: Routine maintenance shall include repairs to the road surface, blading, filling potholes and adding replacement gravel or asphalt. It shall also include revegetation, brush removal, and minor reconstruction of road segments as necessary.

(iv) Railroad and other transportation and mine facilities.

(A) Railroad loops, spurs, sidings, surface conveyor systems, chutes, aerial tramways, or other transportation and mine facilities shall be designed, constructed, or reconstructed, and maintained and the area restored to:

(I) Prevent, to the extent possible using the best technology currently available, damage to fish, wildlife, and related environmental values, and additional contributions of suspended solids to streamflow or runoff outside the affected land and permit area. Any such contributions shall not be in excess of limitations of State or Federal law or degrade the quality of receiving water.

(II) Control and minimize diminution or degradation of water quality and quantity.

(III) Control and minimize erosion and siltation.

(IV) Control and minimize air pollution.

(V) Prevent damage to public or private property.

(B) Railroads and other transportation and mine facility areas shall be reclaimed when no longer needed for the operation in accordance with the requirements of this Chapter.

(k) Time schedule.

(i) Reclamation must begin as soon as possible after mining commences and must continue concurrently until such time that the mining operation is terminated and all of the affected land is reclaimed. If conditions are such that final reclamation procedures cannot begin until the mining operation is completed, this must be explained in the reclamation plan. A detailed time schedule for the mining and reclamation progression must be included in the reclamation plan. This time schedule shall:

(A) Apply to reclamation of all lands to be affected in the permit area;

(B) Designate times for backfilling, grading, contouring and reseeding;

(C) Be coordinated with a map indicating the areas of progressive mining and reclamation;

(D) Establish reclamation concurrently with mining operations, whenever possible. If not possible, the schedule shall provide for the earliest possible reclamation consistent with the orderly and economic development of the property; and

(E) If the Administrator approves a schedule where reclamation follows the completion of mining, describe the conditions which will constitute completion or termination of mineral production.

(l) Unanticipated conditions.

(i) An operator encountering unanticipated conditions shall notify the Administrator as soon as possible and in no event more than five days after making the discovery.

(ii) An unanticipated condition is any condition encountered in a mining operation and not mentioned by the operator in his mining or reclamation plan which may seriously affect the procedures, timing, or outcome of mining or reclamation. Such unanticipated conditions include but are not limited to the following:

(A) The uncovering during mining operations of any acid-forming, radioactive, inflammable, or toxic materials which must be burned, impounded, or otherwise disposed of in order to eliminate pollution or safety hazards.

(B) The discovery during mining operations of a significant flow of groundwater in any stratigraphic horizon.

(C) The occurrence of slides, faults, or unstable soil and overburden materials which may cause sliding or caving in a pit which could cause problems or delays with mining or reclamation.

(D) The occurrence of uncontrolled underground caving or subsidence which reaches the surface, causing problems with reclamation and safety hazards.

(E) A discovery of significant archaeological or paleontological importance.

(iii) In the case of the uncovering of hazardous materials, the operator shall take immediate steps to notify the Administrator and comply with any required measures to eliminate the pollution or safety hazard. Under all conditions the operator must take appropriate measures to correct, eliminate, or adapt to an unanticipated condition before mining resumes in the immediate vicinity of that condition.

(m) Disposal of buildings and structures.

(i) All buildings and structures constructed, used or improved by the operator must be removed or dismantled unless it can be demonstrated to the Administrator's satisfaction that the buildings or structures will be of beneficial use in accomplishing the proposed use of the land after reclamation or for environmental monitoring.

(ii) If the operator does not wish to remove certain buildings or facilities, he must obtain the written consent of the surface landowner to leave the buildings or facilities intact. The operator must make a request in writing, providing written proof of the above to the Land Quality Division, that the buildings or facilities be permitted to remain intact.

(n) All support buildings, including loading and storage facilities, plants, sheds, shops and other buildings shall be designed, constructed or reconstructed and located to prevent or control erosion, pollution, and damage to public or private property, fish, wildlife, and related environmental values. All operations shall be conducted so as to minimize disruption of any services provided by facilities located on, under or through the permit area, unless otherwise approved by the Administrator or owner of such facilities.

(o) Signs and markers. Uniform and durable signs and markers of an adequate size shall be posted by the operator at those points applicable to the areas or activities to which they pertain. Such signs and markers shall include mine and permit identification signs, perimeter markers, buffer zone markers, blasting signs and soil markers. The operator shall place and maintain all signs and markers prior to commencement and until the completion of the activities to which they pertain, which, for mine and permit identification signs, shall be at the time the bond is released.

(p) Drilled holes and other exposed underground openings: Plugging, sealing and capping of all drilled holes except those used solely for blasting or developmental drill holes which will be mined through within one year shall meet the requirements of Chapter 14. Developmental drilling shall meet the plugging and sealing requirements of W.S. § 35-11-404, where necessary. Temporary sealing and use of protective devices may be approved by the Administrator if the hole will be used for returning coal-processing waste or water to underground workings or monitoring groundwater conditions, and shall be used, at a minimum, for developmental drilling. Other exposed underground openings shall be properly managed as required by the Administrator to prevent access to mine workings and to keep acid or other toxic drainage from entering ground or surface water.

(i) With the prior approval of the Administrator and the State Engineer, wells may be transferred to another party for further use. The permittee shall remain responsible for the proper management of the well until final bond release.

(q) Air resources protection. All exposed surface areas shall be protected and stabilized to effectively control erosion and air pollution attendant to erosion.

(r) Fish and wildlife performance standards.

(i) An operator shall, to the extent possible using the best technology currently available and consistent with the approved postmining land use, minimize disturbance and adverse impacts on fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable, which activities shall include:

(A) Properly construct, locate and operate roads and power lines, including proper design of power lines to avoid electrocution of raptors.

(B) Prevent access to areas such as roadways or ponds with hazardous materials, to avoid damage to wildlife without limiting access to known important routes.

(C) Afford protection, restore and enhance where practicable important habitats to fish and wildlife. This shall include, but is not limited to, wetlands and riparian vegetation along rivers and streams and bordering ponds and lakes.

(D) Select plant species with shrubs well represented, which will enhance the nutritional and cover aspects of fish and wildlife habitat, where such habitat is identified as part of the postmining use, and distribute the reestablished habitat in a manner which includes a diversity and interspersion of habitats, optimizes edge effect, cover and other benefits for fish and wildlife, and is consistent with Section 2(d)(x)(E).

(E) Promptly report to the regulatory authority any species or critical habitat of such species listed as threatened or endangered, or any golden or bald eagle nest in or adjacent to the permit area, which was not reported or investigated in the permit application. Upon notification the Administrator shall consult with the Wyoming Game and Fish Department and the U.S. Fish and Wildlife Service and, after consultation, shall identify whether and under what conditions the operator may proceed.

(F) Where the postmining land use is for cropland, to the extent not inconsistent with this intended use, operators shall restore habitat types to break up large blocks of monocultures.

(ii) Stream buffer zone.

(A) No land within 100 feet of a perennial or intermittent stream shall be affected unless the Administrator specifically authorizes such activities closer to or through such a stream upon a finding that:

(I) Surface mining activities will not cause or contribute to the violation of applicable state or federal water quality standards, and will not adversely affect the water quantity and quality or other environmental resources of the stream; and

(II) If there will be a temporary or permanent stream-channel diversion, it will comply with all stream diversion requirements.

(B) The area not to be affected shall be designated a buffer zone, marked in the field and on the mine plan map.

(iii) No surface mining activity shall be conducted which is likely to jeopardize the continued existence of endangered or threatened species listed by the State or the Secretary of the Interior or which will result in the destruction or adverse modification of designated critical habitats of such species in violation of the Endangered Species Act (16 U.S.C. 1531 et seq.). No surface mining activity shall be conducted in a manner which would result in the unlawful taking of a bald or golden eagle, its nest, or any of its eggs. The Administrator shall consult with the State and Federal Fish and Wildlife Agencies to identify whether and under what conditions the operation may continue under this provision.

(iv) The operator shall perform periodic surveys, in the level of detail and for those areas as determined by the Administrator, in accordance with Appendix B of these rules and regulations.

(s) Slides and other damage. Where instability may exist in backfill materials, an undisturbed natural barrier shall be provided to prevent slides and erosion, beginning at the elevation of the lowest coal seam to be mined and extending from the outslope for such distance as may be determined by the Administrator.

(t) Only those operations designed to protect disturbed surface areas and which result in improved resource recovery, abatement of water pollution, or elimination of hazards to the public shall be conducted within 500 feet of an active or abandoned underground mine. Approval for such operation shall be obtained from MSHA for operations proposed to be conducted within 500 feet of an active underground mine. The Administrator shall specifically approve operations proposed to be conducted within 500 feet of an abandoned underground mine.

(u) Cessation of operations. When it is known that a temporary cessation of operations will extend beyond 30 days, the operator shall submit to the Administrator that information required in an annual report.

(v) The operator shall conduct operations so as to maximize the utilization and conservation of the solid fuel resource being recovered so that reaffecting the land in the future can be minimized.

(w) The operator shall conduct all operations in such a manner as to minimize disturbance of the hydrologic balance within the permit and adjacent areas, to prevent material damage to the hydrologic balance outside the permit area, to assure the protection or replacement of water rights, and to support approved postmining land uses in accordance with the terms and conditions of the approved permit and the performance standards of this Chapter. Mining and reclamation practices that minimize water pollution and changes in flow shall be used in preference to water treatment.

Appendix B: Wyoming Guideline No. 15

(HP/2-90, Riles Update/8-94)

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
LAND QUALITY DIVISION
GUIDELINE NO. 15

ALTERNATIVE SEDIMENT CONTROL MEASURES

This document is a guideline only. Its contents are not to be interpreted by applicants, operators, or LQD staff as mandatory. If an operator wishes to pursue other alternatives, he or she is encouraged to discuss these alternatives with the LQD staff.

I. INTRODUCTION

This guideline identifies specific sediment control measures that may be used in addition to or in place of sedimentation ponds. Operators should note that alternative sediment control design requirements are minimal for areas less than 30 acres. Monitoring requirements are also minimal for small ephemeral receiving streams (drainage areas less than 0.5 square miles). Land Quality Division (LQD) will rely on field inspections of small areas, focusing on construction and maintenance to ensure their effectiveness.

These recommendations do not constitute the only acceptable alternative sediment control techniques. LQD intends to maintain flexibility so that they can evaluate sediment control systems not envisioned in this guideline. The final sediment control system should conform to the standards described herein for design, construction, maintenance, and monitoring.

Even where sedimentation ponds are constructed, alternative sediment control changes can be used to minimize sediment delivery to ponds and thereby decrease the frequency of pond maintenance. Alternative techniques are especially applicable to large reclaimed watersheds, where erosion must be controlled before a downstream pond is eliminated.

II. Objective of Alternative Sediment Control Measures (ASCM's)

Alternative sediment control measures are presented as an option other than the use of sedimentation ponds in the WDEQ/LQD Coal Rules and Regulations when it can be demonstrated that they "will not degrade receiving waters" (Chapter IV, Section 2.(f)(I)). Receiving waters are defined by the LQD as:

1. Any unimpounded and undisturbed or permanently reclaimed stream outside of the permit area that is within three (3) channel miles downstream of an area controlled by an ASCM; or

2. Any unimpounded and undisturbed or permanently reclaimed stream within the permit area downstream of an ASCM.

As stated in Chapter IV, Section 2.(f)(vii), "Appropriate sediment control measures shall be designed, constructed, and maintained using the best technology currently available to prevent additional contributions of sediment to streamflow or to runoff outside the affected land". Also, a surface water monitoring program "...will be used to demonstrate that the quality and quantity of runoff from affected lands...will minimize disturbance to the hydrologic balance". (Chapter IV, Section 2.(I)(ii)).

These regulations suggest that there is a design/maintenance standard, **best technology currently available (BTCA),** a performance standard, **non-degradation of receiving waters,** and a verification standard, **demonstrable monitoring program.** ASCM's should be designed such that it can be demonstrated that sediment yields are not greater than background levels.

III. Best Technology Currently Available (BTCA)

A. Elements of BTCA.

The design methods, construction techniques, maintenance practices and monitoring system all contribute to a system that can be considered BTCA.

B. Determination of BTCA.

1. BTCA will be determined on a case by case basis. BTCA determinations will be based on the type of disturbance, the size of the disturbance and the length of time the ASCM will be in place. The LQD will not require the same ASCM sophistication on, for example, small temporary topsoil stockpiles or topsoil stripping areas as they will for a permanently reclaimed watershed. The determination of BTCA will be based on how effective the ASCM is at:

    a. Preventing soil detachment and erosion, using slope erosion control practices.

    b. Retaining sediment as close as possible to its point of origin, using on-slope and in-channel sediment trapping structures.

    It is preferable to use effective slope erosion control practices where possible. Sediment traps should constitute a second line of defense.

2. The LQD realizes that many technologies currently exist that can be considered the "best" technology. New technologies may be developed in the near future that may provide a higher degree of erosion protection than is "currently" available.

IV. Design of ASCM's

ASCM's can be considered for disturbed or reclaimed areas that are not within one-half mile (channel distance) of any class I, II, or III stream. (These classes are defined in the WDEQ/WQD Rules and Regulations, Chapter I, Section 4). Small areas (less than 30 acres) located within one half mile of a class I, II, or III stream, may be protected using ASCM's, subject to the discretion of the LQD administrator.

A. Designing ASCM's for Small Areas (less than 30 acres)

The only sediment control design requirements for small disturbed area (less than 30 acres) are:

1. Sediment trapping structures (e.g., toe ditches, rock check dams) should be designed to pass or detain runoff from storms of recurrence intervals determined by their expected lifetimes (see Appendix 1). A generic design may be acceptable where many similar small areas will be controlled by similar structures as long as they will withstand the design precipitation event.

2. Rocks used to construct check dams should be angular and have an appropriate size distribution so that the design peak flow cannot entrain them or else be enclosed in a staked wire mesh structure.

3. Toe ditches should be graded to a zero slope, where practical. Otherwise, toe ditches should be gently graded to a stabilized outlet that has a check dam of porous rock, staked hay bales, or a fabric sediment fence to retain sediment.

4. Detention basins will be considered alternative sediment control only when their capacity is less than 0.5 acre-foot.

5. The operator need only report the ASCM design and its justification with a planview location and a general description of the type structure to the LQD. Proposals of this size should outline the inspection and maintenance programs the operator will use to regularly evaluate the stability and effectiveness of each ASCM.

B. Designing ASCM's for Large Areas (30 acres and larger)

1. The design of ASCM's for large areas should be based on predicted sediment loads or yields from the particular area of disturbance. The operator should compare predicted or measured native sediment yields to those predicted for the disturbed area.

2. A state-of-the-art computer watershed model should be used as an ASCM design tool. The LQD will work with the operator to determine which model(s) can be considered state-of-the-art for the particular application. Section VII of this guideline includes specific model information that should be submitted.

C. Implementation Priorities for Various ASCM's

The following lists prioritize the most desirable ASCM's for each particular disturbed area:

1. Topsoil Stripping Areas

    a. Divert undisturbed water around the stripped area into an approved diversion channel.
    b. Divert drainage from the stripped area into the pit.
    c. Divert drainage from the stripped area away from the pit through an ASCM:

1. Place native vegetation buffer strips or filter cloth between the disturbance and the channel.
2. Place sediment trapping structures in channel (porous rock check dams, staked straw bales).
3. Place sediment trapping structures below the channel grade.

2. Overburden/Topsoil Stockpiles

   a. Utilize a flat construction profile.
   b. Locate stockpiles away from drainageways.
   c. Use contour plowing, seeding and mulch on stockpiles.
   d. Establish a good vegetative cover.
   e. Grade contour ditch outlets to stabilized drainageways.
   f. Grade toe ditches to sediment trapping structure that retains minimum amount of water.
   g. Grade toe ditches to zero grade and less than 0.5 acre-foot capacity.

3. Postmining Surfaces

   a. Stable landform design

   Geomorphic approaches to stable landform design are highly recommended to minimize sediment yield. For example, drainage density and channel and hillslope profile shapes can be varied and lose lengths reduced to minimize sediment yield.

   b. Short-term slope erosion controls

      1. Regraded topsoil surfaces should be pitted with a large disc, chisel plow or ripper working along the contour to increase infiltration and detain runoff.

      2. Bare rounded surfaces should be mulched and vegetated rapidly. It is highly recommended that mulch be anchored in the topsoil and that vegetation be planted immediately after surface grading. Cover crops provide a standing mulch that can be mowed prior to subsequent plantings.

   c. In-channel sediment retention measures

   Vegetation is often sufficient to stabilize stream channels. A rock check dam should be placed in channel reaches that produce excessive sediment from their bed and banks. Accumulated sediment should be regularly removed from rock check dams. Check dams should be used as a final resort in permanently reclaimed stream channels.

D. Location of Sedimentation Ponds

Sedimentation ponds must be used to control runoff from facilities areas, coal stockpiles and pit drainage. Sediment ponds may also be necessary when maintenance of ASCM's is a chronic unresolved problem.

V. Construction and Maintenance of ASCM's

A. Construction of ASCM's

Each type of ASCM has construction and maintenance guidelines that are specified in most handbooks on sediment control (see list of references, Appendix 2). Some basic guidelines include:

1. Mulch must be anchored to prevent it from being washed or blown off the slope.

2. Rocks used in porous rock check dams should be the appropriate size, angularity, and density to prevent flows from transporting them or else they should be contained in anchored wire mesh.

3. Contour ditches should be constructed with a stabilized outlet and berms that are well compacted and vegetated.

4. Concentrating flow in a diversion ditch can result in severe erosion by gullying if the outlet is not adequately constructed and stabilized.

5. Baled hay check dams should be staked into the bed and banks of channels. Flow should pass over the low point of the channel. If hay bales are placed level across the channel, they should be staggered so that water will not pond behind them and be deflected into the banks.

B. Maintenance of ASCM's

The operator should report, repair and log any significant damage to an ASCM as soon as possible after the damage occurs. The operator should inspect the ASCM at the beginning and at the end of each runoff season, and after each runoff event. An inspection and maintenance log should be kept to document the condition of each ASCM at the time of each inspection. The log should describe any damage, the required maintenance, and the date repairs were made.

VI. Performance of ASCM's

A. Monitoring Ephemeral Tributary (Class IV) Streams

Where the receiving water is an ephemeral (Class IV) stream, the water quality standard set by WDEQ/WQD Rules and Regulations, Chapter 1, Section 15, is as follows:

"...substances...influenced by the activities of man that will settle to form sludge, bank or bottom deposits shall not be present in quantities which could result in significant aesthetic degradation, ... or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife, etc."

1. Small ephemeral receiving streams

   Small ephemeral receiving streams (drainage areas less than 0.5 square miles) that are receiving waters for ASCM's should be visually inspected after each runoff event.

   a. Channels and hillslopes should be inspected for signs of rill and gully erosion. The volume and location of any recently accumulated sediments should be recorded.

   b. Repeat photographs should be taken at least annually and after large runoff events at several permanent locations along the receiving stream to supplement the written record of observations.

2. Large ephemeral receiving streams

   In addition to the requirements for visually monitoring small ephemeral receiving streams, monitoring of large ephemeral receiving streams (drainage areas greater than 0.5 square mile) should include one, or both, of the following:

   a. Repeat surveys of representative permanently benchmarked stream channel cross sections located within the disturbed reach of the channel and continuing into the receiving stream channel.

   b. Upstream and downstream sediment yield monitoring stations that follow the plan set forth for Class I, II, and III streams below.

B. Monitoring Class I, II, and III streams

Any class I, II or III receiving stream should be monitored upstream and downstream of the disturbed area so that any potential increase in sediment load related to mining disturbance can be detected.

1. The methods of data collection and the analytical basis for determining whether or not degradation has occurred should be outlined in detail in the ASCM proposal.

2. Continuous flow recorders and automatic sediment samplers should be installed at permanent upstream and downstream station locations.

3. Automatic sediment samplers should begin sampling at the onset of each runoff event and continue at 5 to 10 minute intervals throughout each runoff event. Other sampling intervals or methods will be considered according to their ability to verify sediment yields.

4. The applicant should submit a monitoring station maintenance plan. Data from monitoring stations should be retrieved within 24 hours of each runoff event. Faulty equipment should be immediately repaired or replaced. Monitoring stations should be inspected by the operator after every runoff event, and a log of

monitoring and maintenance activities should be kept for LQD review. The LQD will be looking for a long-term record of maintenance as well as a company's efforts to correct problems in a timely fashion.

VII. Contents of an ASCM Proposal

The proposal for implementation of an ASCM for areas greater than 30 acres should include the following items:

A. A general description of the area to be controlled by ASCM's and the types and duration of expected disturbance include the distance to and type of nearest receiving stream and/or Class I, II, or III stream.

B. Description of the ASCM Design Procedure

1. List and justify values chosen for the watershed (or subwatershed) variables and model parameters (e.g., soils, sediment grain size distribution, slopes, etc.).

2. Where applicable, submit data used to calibrate model and the calibration results (e.g., design hydrographs, hyetographs, curve numbers, etc.).

3. Explain the choice of ASCM's.

4. Submit and justify the design storm recurrence interval and duration, runoff volume, and peak discharge.

5. Submit sample calculations and/or computer model output.

C. Provide a map of ASCM's on a mining sequence topographic map or overlay. Each ASCM should be referenced in the descriptive text and design information, and dates of construction or implementation of each ASCM should be given. This map should be updated in each Annual Report if modifications are made.

D. Provide specifications for each ASCM and a schematic diagram of each typical structure.

E. For reclaimed areas:

1. Refer to drainage basin and channel designs in reclamation plan:

a. Longitudinal profiles of reclaimed channels.

b. Typical reclaimed channel cross sections.

c. Reclaimed area contour map with 10' or less contour interval.

d. Justification of drainage basin design.

e. Reclaimed basin characteristics such as: relief ratio, drainage area, topsoil and spoil particle sizes, average channel slope. Include discussion of how reclaimed basins, slopes and channels are designed to minimize additional sediment yield to downstream areas.

2. Surface treatments (mulch, contour ripping).

3. Channel protection measures, if any.

F. Maintenance and inspection plan.

G. Monitoring plan and description of degradation analysis.

H. If any impounding structure is designed to retain more than 2.0 ac-ft of water, a WQD permit must be obtained.

I. ASCM's designed to control large disturbed watersheds (excluding isolated small areas) may need to be permitted through the State Engineer's Office (Form SW-1, Application to Appropriate Surface Water). The State Engineer's Office should be contacted directly to determine whether or not such a permit is required.

APPENDIX 1

Design Events for Temporary Structures

Exceedance of the design runoff is likely to result in destruction of in-channel ASCM's and in the remobilization of any stored sediment. Therefore, temporary structures should be designed for an event with some reasonably small probability of occurrence over the structure's lifetime.

Example:

The highest acceptable risk of structure failure during that structure's lifetime is 20%.

Table 1 shows event return periods for which the risk of failure (at least once) over a given number of years will be no greater than 20%. The return periods in Table 1 were calculated from the following equation:

$$P = 1 - (1-1/t)^{n}$$

where P is the probability that an event of return period t will be equaled or exceeded at least once during the course of n years (Linsley, Kohler and Paulhus, 1982).

Table 1 - Design Event Return Periods

Expected Lifetime of Structure (yrs)	2	5	7	10
Design Event Return Period (yrs)	10	25	33	50

Over any two-year period, a 10-year event has a 20% chance of being equaled or exceeded at least once. Therefore, based on the criterion of 20% acceptable risk of failure, the appropriate design storm for a structure intended to function for two years is the 10-year peak runoff, or predicted peak runoff from the 10-year rainfall. For structure lifetimes outside the range of those in Table 1, appropriate design storm return periods should be calculated in the same manner from the equation given above.

APPENDIX 2

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Appendix C: 19 NMAC 8.2, Subpart 20, Section 2009

Introduction

New Mexico's Mining and Minerals Division (MMD) enforces the state's federally approved SMCRA primacy program. BMP regulations for coal mining and reclamation operations in New Mexico may be found under 19 NMAC 8.2 Subpart 20 Section 2009 which addresses general requirements for minimizing changes to the prevailing hydrologic balance in both the permit and adjacent areas. Section 2009 of Subpart 20 is presented below:

19 NMAC 8.2.20.2009 HYDROLOGIC BALANCE: GENERAL REQUIREMENTS

2009.A Surface coal mining operations shall be planned and conducted to minimize changes to the prevailing hydrologic balance in both the permit and adjacent areas and prevent material damage outside of the permit area in order to prevent adverse changes in that balance that could result from those operations. [11-29-97]

2009.B Changes in water quality and quantity, in depth to ground water, and in the location of surface water drainage channels shall be minimized so that the approved postmining land use of the permit area is not adversely affected. [11-29-97]

2009.C In no case shall Federal and State water quality statutes, regulations, standards, or effluent limitations be violated. [11-29-97]

2009.D Operations shall be conducted to minimize water pollution and, where necessary, sediment ponds or other treatment facilities shall be used to control water pollution.

(1) Each person who conducts surface coal mining operations shall emphasize mining and reclamation practices that prevent or minimize water pollution. Methods listed in paragraph 2009.D(2) and (3) shall be capable of containing or treating all surface flow from the disturbed areas and shall be used in preference to the use of sediment ponds or water treatment facilities.

(2) Acceptable practices to control sediment and minimize water pollution include, but are not limited to:

(i) stabilizing disturbed areas through land shaping, berming, contour furrowing or regrading to final contour;

(ii) diverting runoff;

(iii) achieving quickly germinating and growing stands of temporary vegetation;

(iv) regulating channel velocity of water;

(v) lining drainage channels with rock or revegetation;

(vi) mulching;

(vii) selectively placing and sealing acid-forming and toxic-forming materials; and

(viii) selectively placing waste materials in backfill areas.

(3) In addition, unless demonstrated to the Director otherwise, all acceptable practices for controlling and minimizing water pollution at underground mines shall include, but not be limited to:

(i) designing mines to prevent gravity drainage of acid waters;

(ii) sealing all underground mine openings;

(iii) controlling subsidence; and

(iv) preventing acid mine drainage.

(4) If the practices listed in paragraph 2009.D(2) are not adequate to meet the requirements of paragraph 2009.D(1), the person who conducts surface coal mining operations shall comply with the requirements of Section 2010, unless the Director issues a waiver under paragraph 2009.E. [11-29-97]

2009.E The Director may waive the requirements of this Section for regraded areas if the operator can demonstrate to the Director that the runoff from the regraded area is as good as or better quality than the waters entering the permit area and erosion from the regraded area has been controlled to the satisfaction of the Director.

(1) To provide for baseline data for waters entering the permit area, the operator shall operate and maintain monitoring on all drainages leading into the permit area, in a manner approved by the Director, in order to obtain and evaluate occurrences and changes in water quality and quantity during the life of mining operations.

(2) In order to ensure that runoff from the regraded area is in no way a hazard to the environment of the adjacent areas, the waters draining off of the regraded area shall not:

(i) exceed the values of Total Suspended Solids, Iron, Manganese, pH and those parameters listed in paragraph 2009.E(3)(I) from the baseline analyses from the water entering the permit area;

(ii) create an increase in sediment load into the receiving streams;

(iii) create any environmental harm or threat to public health and safety; and

(iv) degrade, pollute or otherwise diminish the characteristics of existing streams and drainages so as to cause imminent environmental harm to fish and wildlife habitats.

(3) Baseline data shall be collected from waters in drainages entering the permit area and runoff from regraded areas shall be collected during any precipitation event that produces such runoff. The operator shall demonstrate to the Director that the runoff from the regraded area has as good as or better chemical quality than the baseline analyses from waters entering the permit area.

(i) In addition to paragraph 2009.E(2)(I), chemical analysis of the runoff from the regraded area and baseline data from waters entering the permit area shall include, but not limited to, the following parameters:

Arsenic (As)	Phosphorus (P)	Carbonate (CO3)
Boron (B)	Potassium (K)	Bicarbonate (HCO3)
Calcium (Ca)	Selenium (Se)	Nitrate (NO3)
Chloride	Sodium (Na)	Sulfate (SO4)
Cadmium (Cd)	Uranium (U)	Total Dissolved Solids (TDS)
Fluoride	Vanadium (V)	
Lead (Pb)	Radioactivity	Sodium Adsorption Ratio (SAR)
Magnesium (Mg)	Radium Ra226	
Radium Ra228		

(ii) The Director may require additional tests and analyses as he deems necessary.

(iii) If the operator can demonstrate that the analysis of any particular parameter are of little or not significance in the permit or adjacent areas, then such parameter(s) may be waived upon approval by the director.

APPENDIX D: Mine Modeling and Performance Analysis - Model Input and Output Data

Introduction

This Appendix contains model input and output data for the mine modeling performed for NMA using RUSLE version 1.06 and SEDCAD 4.0. This study was submitted to EPA as "DRAFT - Western Alkaline Mining Subcategory Mine Modeling and Performance-Cost-Benefit Analysis" in support of the Western Alkaline Mining Subcategory proposal (WCMWG, 1999c). These data and information support the sedimentology and hydrology modeling results presented in Section 6, Case Study 1 of this document. The supporting input and output data for the RUSLE modeling is presented first (Tables D-1 through D-6) followed by the SEDCAD output information (Exhibits D-1 through D-3)..

RUSLE Version 1.06 Modeling

Soil loss estimates from a representative model mine were developed using RUSLE version 1.06. The backup input and output data are summarized in table form here as:

- Table D-1: RUSLE Input Variables For Premining Subwatersheds
- Table D-2: Premining RUSLE Model Output
- Table D-3: RUSLE Input Variables For Reclaimed Subwatersheds
- Table D-4: Input And Output Variables For Reclaimed Areas
- Table D-5: Postmining Reclamation RUSLE Erosion Model Output
- Table D-6: Weighted Average Soil Loss Estimates For Disturbed and Reclaimed Subwatersheds (RUSLE)

SEDCAD Version 4.0 Modeling

Hydrology and sedimentology data were generated for the model mine under three scenarios: undisturbed (premining) conditions; reclamation under current 40 CFR Part 434 guidelines; and reclamation with alternative BMPs. The supporting reports as produced by SEDCAD for the three scenarios are presented in this Appendix:

- Exhibit D-1: Premining Undisturbed Conditions
- Exhibit D-2: Postmining Reclaimed Conditions, Existing Guidelines
- Exhibit D-3: Postmining Reclaimed Conditions, Proposed Subcategory

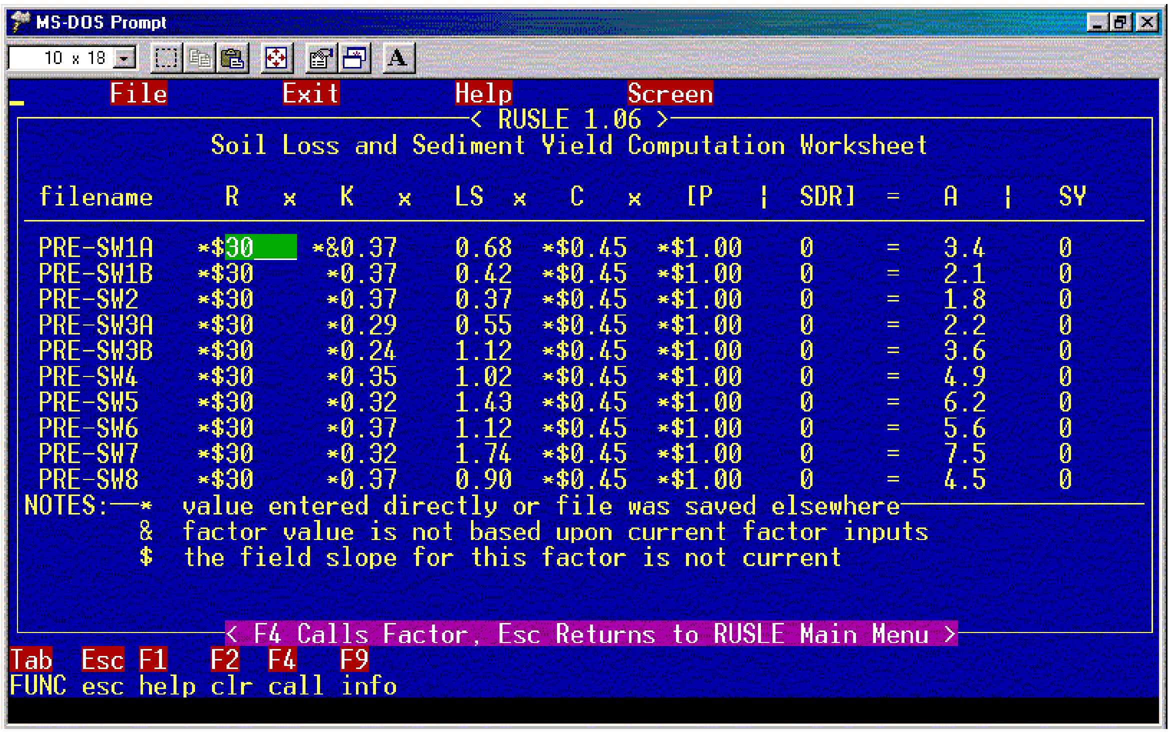
TABLE D-1: RUSLE Input Variables For Premining Subwatersheds

Reclaimed Watershed	Reclaimed Watershed Area (acres)	R	K	L	S	C	P	Composite Curve Number	Hydrologic Condition
SW3A	31.2	30	0.29	700	3.5	0.45	1.00	81	C
SW3B	15.5	30	0.24	435	5.0	0.45	1.00	79	B
SW7	25.9	30	0.32	500	10.0	0.45	0.47	88	D
SW9	290.0	30	0.24	425	7.0	0.45	1.00	77	B
SW10	14.0	30	0.32	500	6.7	0.45	1.00	90	D
SW11	15.0	30	0.35	275	7.1	0.45	1.00	91	D
SW13	105.3	30	0.27	390	6.7	0.45	1.00	81	C
SW14	9.3	30	0.32	300	5.4	0.45	1.00	88	D
SW15	30.520	30	0.32	160	12.5	0.45	1.00	88	D
SW17	78.5	30	0.36	375	7.6	0.45	1.00	92	D
Subtotal	**616.7**	**Acres for subwatershed that will contain 381.8 acres of mining disturbance.**							
SW1A	44.6	30	0.37	650	4.5	0.45	1.00	93	D
SW1B	140.1	30	0.37	800	3.0	0.45	1.00	93	D
SW2	104.1	30	0.37	850	2.5	0.45	1.00	93	D
SW4	75.3	30	0.35	350	7.0	0.45	1.00	92	D
SW5	5.5	30	0.32	190	10.0	0.45	1.00	88	D
SW6	26.1	30	0.37	250	8.0	0.45	1.00	93	D
SW8	23.8	30	0.37	315	6.3	0.45	1.00	93	D
SW12	72.6	30	0.37	360	8.3	0.45	1.00	93	D
SW16	55.9	30	0.33	440	8.2	0.45	1.00	92	D
SW18	23.3	30	0.32	375	7.0	0.45	1.00	88	D
Subtotal	**571.3**	**acres for subwatershed area that will not be disturbed by mining.**							
Total	**1188.0**	**acres**							

TABLE D-1: RUSLE Input Variables For Premining Subwatersheds (Continued)

Reclaimed Watershed	Soil Type	Surface Condition	Number of Years to Consolidate	General Land Use
SW3A	Loamy Sand	Undisturbed	7	6
SW3B	Loamy Sand	Undisturbed	7	6
SW7	Sandy Clay Loam	Undisturbed	7	6
SW9	Loamy Sand	Undisturbed	7	6
SW10	Sandy Clay Loam	Undisturbed	7	6
SW11	Sandy Clay Loam	Undisturbed	7	6
SW13	Loamy Sand	Undisturbed	7	6
SW14	Sandy Clay Loam	Undisturbed	7	6
SW15	Sandy Clay Loam	Undisturbed	7	6
SW17	Sandy Clay Loam	Undisturbed	7	6
SW1A	Sandy Clay Loam	Undisturbed	7	6
SW1B	Sandy Clay Loam	Undisturbed	7	6
SW2	Sandy Clay Loam	Undisturbed	7	6
SW4	Sandy Clay Loam	Undisturbed	7	6
SW5	Sandy Clay Loam	Undisturbed	7	6
SW6	Sandy Clay Loam	Undisturbed	7	6
SW8	Sandy Clay Loam	Undisturbed	7	6
SW12	Sandy Clay Loam	Undisturbed	7	6
SW16	Sandy Clay Loam	Undisturbed	7	6
SW18	Sandy Clay Loam	Undisturbed	7	6

TABLE D-2: Premining RUSLE Model Output



MS-DOS Prompt

File Exit Help Screen

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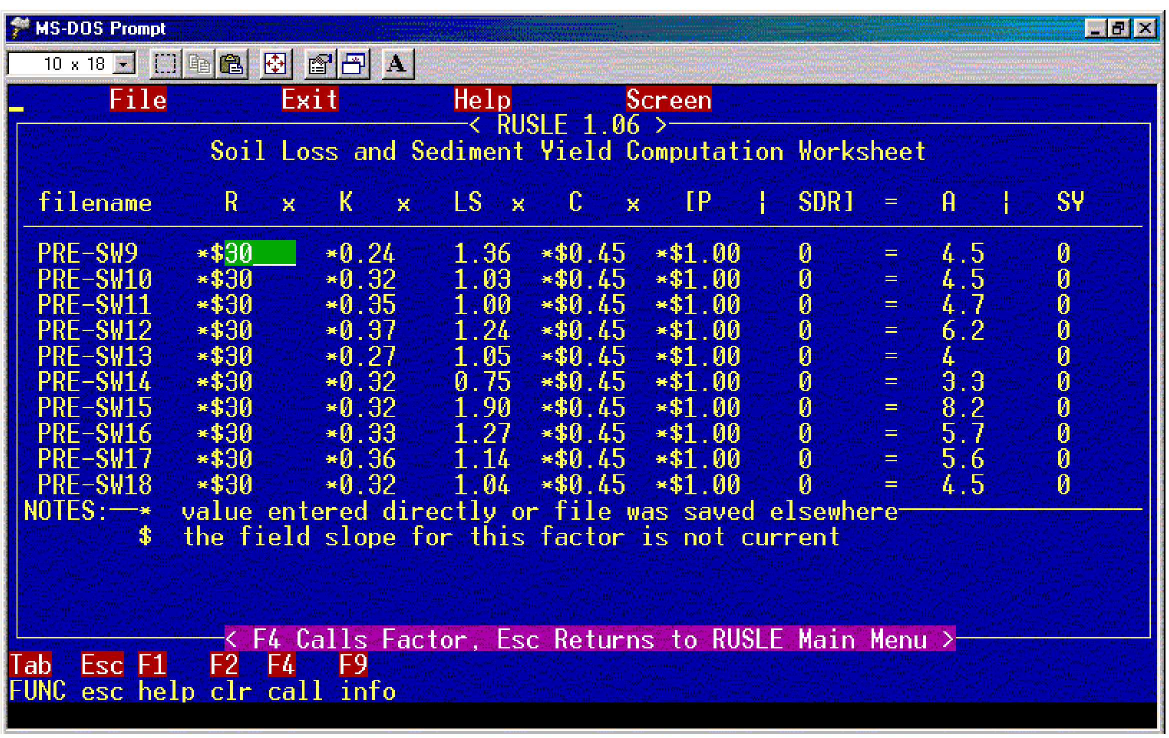
Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	¦	SDR]	=	A	¦	SY
PRE-SW1A	*$30		*&0.37		0.68		*$0.45		*$1.00		0	=	3.4		0
PRE-SW1B	*$30		*0.37		0.42		*$0.45		*$1.00		0	=	2.1		0
PRE-SW2	*$30		*0.37		0.37		*$0.45		*$1.00		0	=	1.8		0
PRE-SW3A	*$30		*0.29		0.55		*$0.45		*$1.00		0	=	2.2		0
PRE-SW3B	*$30		*0.24		1.12		*$0.45		*$1.00		0	=	3.6		0
PRE-SW4	*$30		*0.35		1.02		*$0.45		*$1.00		0	=	4.9		0
PRE-SW5	*$30		*0.32		1.43		*$0.45		*$1.00		0	=	6.2		0
PRE-SW6	*$30		*0.37		1.12		*$0.45		*$1.00		0	=	5.6		0
PRE-SW7	*$30		*0.32		1.74		*$0.45		*$1.00		0	=	7.5		0
PRE-SW8	*$30		*0.37		0.90		*$0.45		*$1.00		0	=	4.5		0

NOTES:—* value entered directly or file was saved elsewhere
& factor value is not based upon current factor inputs
$ the field slope for this factor is not current

< F4 Calls Factor, Esc Returns to RUSLE Main Menu >

Tab Esc F1 F2 F4 F9
FUNC esc help clr call info



MS-DOS Prompt

File Exit Help Screen

< RUSLE 1.06 >

Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	¦	SDR]	=	A	¦	SY
PRE-SW9	*$30		*0.24		1.36		*$0.45		*$1.00		0	=	4.5		0
PRE-SW10	*$30		*0.32		1.03		*$0.45		*$1.00		0	=	4.5		0
PRE-SW11	*$30		*0.35		1.00		*$0.45		*$1.00		0	=	4.7		0
PRE-SW12	*$30		*0.37		1.24		*$0.45		*$1.00		0	=	6.2		0
PRE-SW13	*$30		*0.27		1.05		*$0.45		*$1.00		0	=	4		0
PRE-SW14	*$30		*0.32		0.75		*$0.45		*$1.00		0	=	3.3		0
PRE-SW15	*$30		*0.32		1.90		*$0.45		*$1.00		0	=	8.2		0
PRE-SW16	*$30		*0.33		1.27		*$0.45		*$1.00		0	=	5.7		0
PRE-SW17	*$30		*0.36		1.14		*$0.45		*$1.00		0	=	5.6		0
PRE-SW18	*$30		*0.32		1.04		*$0.45		*$1.00		0	=	4.5		0

NOTES:—* value entered directly or file was saved elsewhere
$ the field slope for this factor is not current

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Tab Esc F1 F2 F4 F9
FUNC esc help clr call info

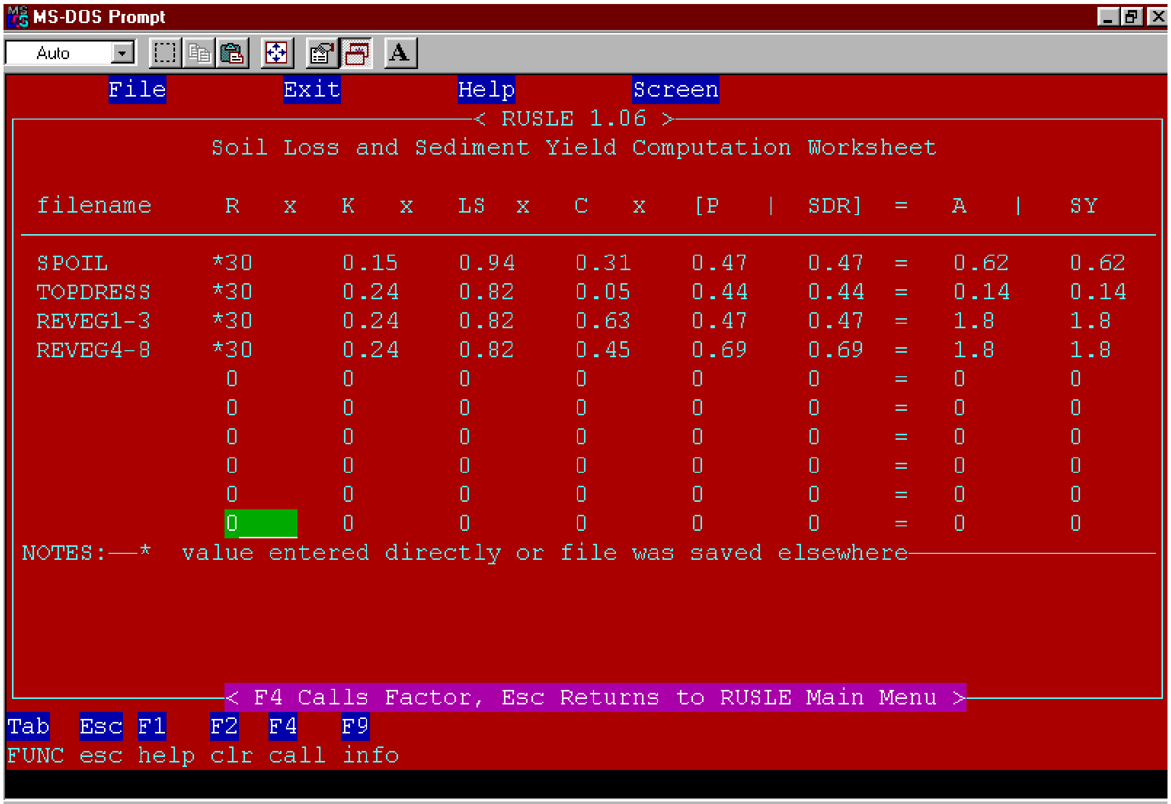
TABLE D-3: RUSLE Input Variables For Disturbed/Reclaimed Subwatersheds

Reclaimed Watershed	Reclaimed Watershed Area (acres)	R	K	L	S	C	P	Composite Curve Number	Hydrologic Condition
SW3A	20.295	30	0.29	650	7.0	0.45	1.00	80	B
SW3B	14.907	30	0.25	750	3.5	0.45	1.00	79	B
SW3C	8.414	30	0.24	250	11.0	0.45	1.00	79	B
SW3D	11.884	30	0.15	500	6.0	0.31	0.47	65	A
SW3E	5.500	30	0.29	450	6.0	0.05	0.44	74	B
SW3F	6.443	30	0.24	400	2.6	0.45	1.00	79	B
SW3G	14.513	30	0.24	475	5.0	0.63	0.45	74	B
SW3H	70.798	30	0.24	550	2.9	0.49	0.63	74	B
SW3I	8.314	30	0.24	250	8.2	0.45	1.00	79	B
SW7A	9.965	30	0.24	500	6.4	0.45	0.69	74	B
SW7B	11.735	30	0.32	125	8.0	0.45	1.00	88	D
SW9A	40.766	30	0.26	340	7.3	0.45	1.00	80	C
SW9B	7.113	30	6.3	250	6.0	0.31	0.47	65	A
SW9C	29.932	30	71.8	375	5.5	0.48	0.51	74	B
SW9D	9.575	30	36.4	400	6.4	0.45	0.69	74	B
SW9E	30.520	30	94.6	475	4.5	0.51	0.72	74	B
SW10	8.058	30	35.5	225	7.5	0.45	1.00	92	D
SW11A	15.142	30	59.1	500	6.0	0.45	0.69	74	B
SW11B	13.858	30	44.3	275	7.1	0.45	1.00	91	D
SW13A	22.100	30	57.5	500	5.0	0.45	1.00	79	B
SW13B	7.328	30	22.0	100	6.4	0.45	1.00	81	C
SW13C	13.158	30	12.8	450	5.0	0.31	0.47	65	A
SW13D	8.547	30	7.5	250	6.0	0.31	0.47	65	A
SW13E	13.831	30	13.4	250	5.0	0.30	0.45	74	B
SW13F	9.556	30	29.6	275	9.0	0.45	0.46	74	B
SW13G	16.221	30	50.3	375	6.6	0.55	0.47	74	B
SW13H	13.248	30	60.9	385	8.0	0.63	0.47	74	B
SW13I	12.053	30	35.0	375	5.3	0.49	0.63	74	B
SW13J	35.792	30	78.7	525	3.8	0.47	0.67	74	B
SW14A	5.974	30	16.1	300	5.4	0.45	0.69	74	B
SW14B	4.650	30	15.3	300	5.4	0.45	1.00	88	D
SW15A	15.352	30	64.5	375	7.2	0.45	0.69	74	B
SW15B	16.414	30	72.2	600	6.4	0.45	1.00	88	D
SW17A	3.038	30	11.5	100	6.5	0.45	1.00	93	D
SW17B	12.123	30	14.5	450	6.0	0.31	0.47	74	B
SW17C	8.741	30	8.3	450	6.0	0.18	0.45	74	B
SW17D	10.010	30	44.0	475	7.0	0.63	0.47	74	B
SW17E	50.821	30	264.3	375	7.0	0.45	1.00	92	D
Total	**616.7**								

TABLE D-3: RUSLE Input Variables For Disturbed/Reclaimed Subwatersheds (Continued)

Reclaimed Watershed	Soil Type	Surface Comdition	Number of Years to Consolidate	General Land Use
SW3A	Loamy Sand	Undisturbed	7	6
SW3B	Loamy Sand	Undisturbed	7	6
SW3C	Loamy Sand	Undisturbed	7	6
SW3D	Loamy Sand	Spoil, backfilled & graded	10	10
SW3E	Loamy Sand	Topdressed, straw mulched & seeded	10	8
SW3F	Loamy Sand	Undisturbed	7	6
SW3G	Loamy Sand	Reveg. 1-3 Years	10	8
SW3H	Loamy Sand	Reveg. 4-8 years/some reveg. 1-3 years	10	8
SW3I	Loamy Sand	Undisturbed	7	6
SW7A	Loamy Sand	Reveg. 4-8 years	10	8
SW7B	Sandy Clay Loam	Undisturbed	7	6
SW9A	Loamy Sand	Undisturbed	7	6
SW9B	Loamy Sand	Spoil, backfilled & graded	10	10
SW9C	Loamy Sand	Reveg. 1-3 Years/some topdressed area	10	8
SW9D	Loamy Sand	Reveg. 4-8 years	10	8
SW9E	Loamy Sand	Reveg. 4-8 years/some 1-3 years/some undisturbed	10	8
SW10	Sandy Clay Loam	Undisturbed	7	6
SW11A	Loamy Sand	Reveg. 4-8 years	10	8
SW11B	Sandy Clay Loam	Undisturbed	7	6
SW13A	Loamy Sand	Undisturbed	7	6
SW13B	Loamy Sand	Undisturbed	7	6
SW13C	Loamy Sand	Spoil, backfilled & graded	10	10
SW13D	Loamy Sand	Spoil, backfilled & graded	10	10
SW13E	Loamy Sand	Topdressed/some reveg. 1-3 years	10	8
SW13F	Loamy Sand	Reveg. 1-3 Years/some topdressed area	10	8
SW13G	Loamy Sand	Reveg. 1-3 Years/some topdressed area	10	8
SW13H	Loamy Sand	Reveg. 1-3 Years/some reveg. 4-8 years	10	8
SW13I	Loamy Sand	Reveg. 4-8 Years/some reveg. 1-3 years	10	8
SW13J	Loamy Sand	Reveg. 4-8 Years/some reveg. 1-3 years	10	8
SW14A	Loamy Sand	Reveg. 4-8 Years	10	8
SW14B	Sandy Clay Loam	Undisturbed	7	6
SW15A	Loamy Sand	Reveg. 4-8 Years/some reveg. 1-3 years	10	8
SW15B	Sandy Clay Loam	Undisturbed	7	6
SW17A	Sandy Clay Loam	Undisturbed	7	6
SW17B	Loamy Sand	Spoil, backfilled & graded	10	10
SW17C	Loamy Sand	Topdressed/some reveg. 1-3 years	10	8
SW17D	Loamy Sand	Reveg. 1-3 years/some topdressed/some spoil	10	8
SW17E	Sandy Clay Loam	Undisturbed/some reclaimed	7	6

TABLE D-4: RUSLE Model Input And Output Variables For Reclaimed Areas



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File Exit Help Screen

< RUSLE 1.06 >

Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	|	SDR]	=	A	|	SY
SPOIL	*30		0.15		0.94		0.31		0.47		0.47	=	0.62		0.62
TOPDRESS	*30		0.24		0.82		0.05		0.44		0.44	=	0.14		0.14
REVEG1-3	*30		0.24		0.82		0.63		0.47		0.47	=	1.8		1.8
REVEG4-8	*30		0.24		0.82		0.45		0.69		0.69	=	1.8		1.8
	0		0		0		0		0		0	=	0		0
	0		0		0		0		0		0	=	0		0
	0		0		0		0		0		0	=	0		0
	0		0		0		0		0		0	=	0		0
	0		0		0		0		0		0	=	0		0
	0		0		0		0		0		0	=	0		0

NOTES:—* value entered directly or file was saved elsewhere

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Area Filename	Description
SPOIL	Mine spoil backfilled and graded, consisting of loamy sand overburden; CN = 65; k = 0.15; hydrologic condition = A; 25% gravel, 10% cobble, 5% rock fragments; slow hydrologic response time.
TOPDRESS	Area topdressed, consisting of loamy sand topsoil; roughened with contour furrows; straw mulched (2 tons/acre); recently seeded with no growth started; CN = 74; k = 0.24; hydrologic condition = B; medium hydrologic response time.
REVEG1-3	Area originally prepared the same as previous topdressed area; 1-3 years of vegetative growth; surface roughening slightly decreased from erosion, sedimentation, and consolidation; CN = 74, k = 0.24; hydrologic condition = B; medium hydrologic response time.
REVEG1-4	Area originally prepared the same as previous topdressed area; 4-8 years of vegetative growth typically more dense than area with 1-3 years of vegetative growth; surface roughening continuing to decrease from erosion, sedimentation, and consolidation; CN = 74, k = 0.24; hydrologic condition = B; medium hydrologic response time.

TABLE D-5: Postmining Reclamation RUSLE Erosion Model Output

MS-DOS Prompt

File Exit Help Screen

< RUSLE 1.06 >

Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	|	SDR]	=	A	|	SY
PSTSW3A	*30		0.29		1.23		*0.45		1.00		1.00	=	4.8		4.8
PSTSW3B	*30		0.25		0.56		*0.45		1.00		1.00	=	1.9		1.9
PSTSW3C	*30		0.24		1.84		*0.45		1.00		1.00	=	5.9		5.9
PSTSW3D	*30		0.15		1.98		0.31		0.47		0.47	=	1.3		1.3
PSTSW3E	*30		0.24		1.64		*0.05		0.44		0.44	=	0.27		0.27
PSTSW3F	*30		0.24		0.37		*0.45		1.00		1.00	=	1.2		1.2
PSTSW3G	*30		0.24		1.33		0.63		*0.45		*0.45	=	2.7		2.7
PSTSW3H	*30		0.24		0.70		*0.49		*0.63		*0.63	=	1.5		1.5
PSTSW3I	*30		0.24		1.20		*0.45		1.00		1.00	=	3.9		3.9
	0		0		0		0		0		0	=	0		0

NOTES:—* value entered directly or file was saved elsewhere

< F4 Calls Factor, Esc Returns to RUSLE Main Menu >

Tab Esc F1 F2 F4 F9
FUNC esc help clr call info

MS-DOS Prompt

File Exit Help Screen

< RUSLE 1.06 >

Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	|	SDR]	=	A	|
PSTSW7A	*30		0.24		1.87		0.45		0.69		0.69	=	4.2	
PSTSW7B	*30		0.32		0.98		*0.45		1.00		1.00	=	4.3	
PSTSW9A	*30		0.26		1.13		*0.45		1.00		1.00	=	4	
PSTSW9B	*30		0.15		1.34		0.31		0.47		0.47	=	0.88	
PSTSW9C	*30		0.24		1.34		*0.48		*0.51		*0.51	=	2.4	
PSTSW9D	*30		0.24		1.68		0.45		*0.69		*0.69	=	3.8	
PSTSW9E	*30		0.24		1.16		*0.51		*0.72		*0.72	=	3.1	
PSTSW10	*30		0.32		1.02		*0.45		1.00		1.00	=	4.4	
PSTSW11A	*30		0.24		1.72		0.45		0.69		0.69	=	3.9	
PSTSW11B	*30		*0.24		1.00		*0.45		1.00		1.00	=	3.2	

NOTES:—* value entered directly or file was saved elsewhere

< F4 Calls Factor, Esc Returns to RUSLE Main Menu >

Tab Esc F1 F2 F4 F9
FUNC esc help clr call info

MS-DOS Prompt

File Exit Help Screen

< RUSLE 1.06 >

Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	|	SDR]	=	A	|	SY
PSTSW13A	*30		0.24		0.79		*0.45		1.00		1.00	=	2.6		2.6
PSTSW13B	*30		*0.29		0.77		*0.45		1.00		1.00	=	3		3
PSTSW13C	*30		0.15		1.48		0.31		0.47		0.47	=	0.97		0.97
PSTSW13D	*30		0.15		1.34		0.31		0.47		0.47	=	0.88		0.88
PSTSW13E	*30		0.24		0.99		*0.30		*0.45		*0.45	=	0.97		0.97
PSTSW13F	*30		0.24		2.10		*0.45		*0.46		*0.46	=	3.1		3.1
PSTSW13G	*30		0.24		1.69		*0.55		*0.47		*0.47	=	3.1		3.1
PSTSW13H	*30		0.24		2.17		0.63		0.47		0.47	=	4.6		4.6
PSTSW13I	*30		0.24		1.28		*0.49		*0.63		*0.63	=	2.9		2.9
PSTSW13J	*30		0.24		0.97		*0.47		*0.67		*0.67	=	2.2		2.2

NOTES:—* value entered directly or file was saved elsewhere

< F4 Calls Factor, Esc Returns to RUSLE Main Menu >

Tab Esc F1 F2 F4 F9

FUNC esc help clr call info

MS-DOS Prompt

File Exit Help Screen

< RUSLE 1.06 >

Soil Loss and Sediment Yield Computation Worksheet

filename	R	x	K	x	LS	x	C	x	[P	|	SDR]	=	A	|	SY
PSTSW14A	*30		0.24		1.18		0.45		0.69		0.69	=	2.7		2.7
PSTSW14B	*30		0.32		0.75		*0.45		1.00		1.00	=	3.3		3.3
PSTSW15A	*30		0.24		1.88		0.45		0.69		0.69	=	4.2		4.2
PSTSW15B	*30		0.32		1.01		*0.45		1.00		1.00	=	4.4		4.4
PSTSW17A	*30		*0.37		0.77		*0.45		1.00		1.00	=	3.8		3.8
PSTSW17B	*30		0.15		1.86		0.31		0.47		0.47	=	1.2		1.2
PSTSW17C	*30		0.24		1.64		*0.18		*0.45		*0.45	=	0.95		0.95
PSTSW17D	*30		0.24		2.05		0.63		0.47		0.47	=	4.4		4.4
PSTSW17E	*30		*0.37		1.04		*0.45		1.00		1.00	=	5.2		5.2
	0		0		0		0		0		0	=	0		0

NOTES:—* value entered directly or file was saved elsewhere

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TABLE D-6: Weighted Average Soil Loss Estimates For Undisturbed And Reclaimed Watersheds (RUSLE)

UNDISTURBED WATERSHED				RECLAIMED WATERSHED			
Undisturbed Watershed	Undisturbed Watershed Area (acres)	Average Annual Soil Loss (tons/acre)	Average Annual Soil Loss (tons)	Reclaimed Watershed	Reclaimed Watershed Area (acres)	Average Annual Soil Loss (tons/acre)	Average Annual Soil Loss (tons)
SW3A	31.2	2.2	68.7	SW3A	20.3	4.8	97.4
SW3B	15.5	3.6	55.8	SW3B	14.9	1.9	28.3
				SW3C	8.4	5.9	49.6
				SW3D	11.9	1.3	15.4
				SW3E	5.5	0.27	1.5
				SW3F	6.4	1.2	7.7
				SW3G	14.5	2.7	39.2
				SW3H	70.8	1.5	106.2
SW7	25.9	7.5	194.2	SW3I	8.3	3.9	32.4
				SW7A	10.0	4.2	41.9
				SW7B	11.7	4.3	50.5
SW9	290.0	4.5	1305.0	SW9A	40.8	4.0	163.1
				SW9B	7.1	0.88	6.3
				SW9C	29.9	2.4	71.8
				SW9D	9.6	3.8	36.4
				SW9E	30.5	3.1	94.6
SW10	14.0	4.5	63.1	SW10	8.1	4.4	35.5
SW11	15.0	4.7	70.6	SW11A	15.1	3.9	59.1
				SW11B	13.9	3.2	44.3
SW13	105.3	4.0	421.2	SW13A	22.1	2.6	57.5
				SW13B	7.3	3.0	22.0
				SW13C	13.2	0.97	12.8
				SW13D	8.5	0.88	7.5
				SW13E	13.8	0.97	13.4
				SW13F	9.6	3.1	29.6
				SW13G	16.2	3.1	50.3
				SW13H	13.2	4.6	60.9
				SW13I	12.1	2.9	35.0
				SW13J	35.8	2.2	78.7
SW14	9.3	3.3	30.7	SW14A	6.0	2.7	16.1
				SW14B	4.7	3.3	15.3
SW15	32.0	8.2	262.0	SW15A	15.4	4.2	64.5
				SW15B	16.4	4.4	72.2
SW17	78.5	5.6	439.6	SW17A	3.0	3.8	11.5
				SW17B	12.1	1.2	14.5
				SW17C	8.7	0.95	8.3
				SW17D	10.0	4.4	44.0
				SW17E	50.8	5.2	264.3
Totals	**616.7**		**2911.0**		**616.7**		**1859.8**
Weighted Average Soil Loss = 4.7 tons/acre/yr.				**Weighted Average Soil Loss = 3.0 tons/acre/yr.**			