CHAPTER 26

SURFACE STABILIZATION PROGRAM

CHAPTER 26

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CHAPTER 26

SURFACE STABILIZATION

Introduction

Chapter 26 presents the detailed program for establishing a reclaimed landscape that will be effective in providing long term erosion control. The program is presented in three major segments: background on the environmental and geomorphological setting and evaluation of current reclamation practices relating to surface stability; the proposed surface stabilization program; and procedures, design criteria, and other documentation in support of the proposed program. The program establishes the basis for PWCC's operational decisions for reclamation; it takes into account site parameters, material properties, reclamation procedures, and Best Technology Currently Available (BTCA) practices that are unique or most applicable; it provides detailed criteria for design and implementation of the various stabilization measures; and it provides measures which will insure that the implemented stabilization program remains functional and effective over the long run. The surface stabilization program, accompanying documentation and supporting information, and appropriate sections of the PAP, when reviewed in total, clearly demonstrate that reclamation can be successfully accomplished.

Regional Environmental and Geomorphologic Setting

A brief review of the more important processes that influence regional land surface stability are provided in this section. Such a review is necessary because the inherent nature of the region, which includes the Black Mesa leasehold, has a high erosion potential. Past and present reclamation practices related to surface stabilization have, to a large degree, been dictated by the processes inherent to the region where the leasehold is situated. The proposed surface stabilization program contained in this chapter evolved through monitoring the response of the reclaimed lands to the processes that effect surface stability, gaining a better understanding of the processes themselves, and applying this knowledge to select the appropriate techniques needed to insure sustained surface stability.

Chapter 15 (Hydrologic Description) contains detailed information on the regional and local hydrology of Black Mesa. It includes descriptions of the geologic and hydrologic features and processes that determine basin responses to the semi-arid climate. The interrelationships among the various independent and dependent variables which characterize drainage basin geomorphology on Black Mesa are complex and typical of arid and semi-arid conditions. Native drainage basin morphologies are characterized by high drainage densities, moderate to steep upland hillslopes that feature shallow, highly erosive soils, and prominently entrenched channels in the higher order streams. These drainage basin characteristics are indicative of the typical Black Mesa watershed responses to the high energy rainfall events over time. The climate of Black Mesa is arid to semi-arid, and typically produces from 8 to 12 inches of precipitation annually (Chapter 11). Most rainfall occurs as intense summer thunderstorms that produce high kinetic energies. Thunderstorms result in large amounts of soil detachment and subsequent entrainment of soil particles by overland runoff. Both overland and channelized runoff produced by the thunderstorms rapidly develop supercritical flow regimes, which increases the erosive potential of the runoff due to high tractive forces.

Soil resources of the Black Mesa leasehold are quantified and described in Chapter 8 and Appendix A in Chapter 8. The majority of these soils possess physical characteristics, which make them moderately to highly susceptible to sheet erosion ("K" factors). Their potential for producing surface water runoff (hydrologic group) is variable, ranging from low to high. In the native landscape, these soils are generally shallow and the existing degree of erosion is moderate to severe depending in part on slope position. These constraints must be considered to achieve the proposed postmining land uses, and to comply with regulatory requirements intended to conserve the available soil resource by utilizing it in the reclamation process.

The degree of erosion that has been documented in the native landscapes on the Black Mesa leasehold is further influenced by the amount (cover) and kind (structure) of vegetation that occurs on these soils (see Chapter 9 for a complete description of the premining vegetation). In their present condition, the vegetation communities existing on the leasehold are less effective for protecting the soil against erosion than they might be under more pristine conditions. Land use practices, particularly moderate to severe overgrazing by domestic livestock, have resulted in a retrogressive vegetal complex and concomittant loss of hydrologic cover. Chapter 14 contains a complete description of the premining land uses and documents the current condition and trend of the rangeland resources on the leasehold. These constraints must also be considered in the reclamation planning process in order to minimize their potential occurrence on postmining landscapes.

Surface Stabilization Program

Introduction. The surface stabilization program described in the following sections has been formulated to provide the greatest level of assurance possible that all permanent program reclaimed lands are effectively stabilized and protected to minimize or control erosion and meet water quality standards for receiving streams. Furthermore, the program provides the means for sustaining landform stability, productivity, and postmining land uses over time, keeping in mind the environmental and geomorphic processes which act upon the Black Mesa area. Baseline data collection and ongoing monitoring programs have resulted in, or been designed to, achieve a greater understanding of these natural processes. This has allowed PWCC to take a more realistic approach in selecting or defining input parameters for engineering designs; selecting or developing appropriate reclamation practices; and developing documentation, through demonstrations such as that contained in Attachment A "Terrace Spacing Justification", which lend support to the selected designs or practices.

The previous section described the general environmental and geomorphological setting for Black Mesa in order to provide an understanding of the type of conditions under which operations are conducted and how these relate to reclamation activities and their successful accomplishment. The current reclamation practices have served to return stable landforms, minimize erosion on reclaimed lands, and to establish permanent and effective vegetative cover. Small watershed studies show that water quality is not being degraded and that sediment yield (which is also related to soil loss) is equal to or better than background levels. Revegetation monitoring data show that ground cover in the reclaimed areas is approaching or has met the success standard for cover. Thus, it can be demonstrated that reclamation is feasible, and when compared to performance standards related to water quality and revegetation, has been successful. The results of these studies also support the current reclamation plan approach as a basis for the surface stabilization program presented in the following sections. The program has been developed to improve on or expand current reclamation and surface stabilization practices in order to achieve the objectives stated at the beginning of this chapter.

The surface stabilization program has been developed to provide long term and effective erosion control and sustain productivity and the postmining land uses over time. This will be possible through development of a stable postmining landform and the establishment of an effective and permanent vegetative cover. In order to achieve this, a number of procedures and practices, relating both to planning and application will be applied in a logical progression. Figure 1, "Surface Stabilization Plan Summary", summarizes the major reclamation and surface stabilization plan or program components and illustrates the progression in which the plan components or practices will be implemented. Furthermore, Figure 1 illustrates the interrelationships of the plan components and how these facilitate an approach for successful accomplishment of the surface stabilization and reclamation objectives.

In order to clearly present the Surface Stabilization Program, the discussion has been structured to follow the logical progression of events presented in Figure 1. Discussion of the major components is presented in terms of Best Technology Currently Available (BTCA) practices related to their inclusion as plan components, reference to appropriate sections of the PAP that provide the detailed implementation procedures for a particular plan component or practice, and adequate detail of a component not presented in other areas of the PAP (e.g., topographic manipulation).

In accordance with the requirements of 30 CFR, Sections 780.18, 780.21(h), 816.41, 816.43, 816.45, 816.95, 816.102, 816.111, and other appropriate sections of the regulations, PWCC proposes to use BTCA to: 1) minimize sheet erosion as a result of overland flow; 2) reduce uncontrolled rill and gully development by properly designing and constructing conveyance structures; 3) maintain a stable landform; and 4) insure that productivity and postmining land uses are sustained. The following three publications discuss BTCA methods currently being proposed or used by the coal industry and PWCC:

1. "Handbook of Alternative Sediment Control Methodologies for Mined Lands", by Mining and Reclamation Council of America and Hess & Fisher Engineers, Inc., March, 1985;
2. "Design of Sediment Control Measures for Small Areas in Surface Coal Mining", by Simons, Li & Associates, Inc., May, 1983.
3. "Surface Mining Water Diversion Design Manual", by Simons, Li & Associates, Inc., OSM/TR-82/2, September, 1982.

FIGURE 1

SURFACE STABILIZATION PLAN SUMMARY

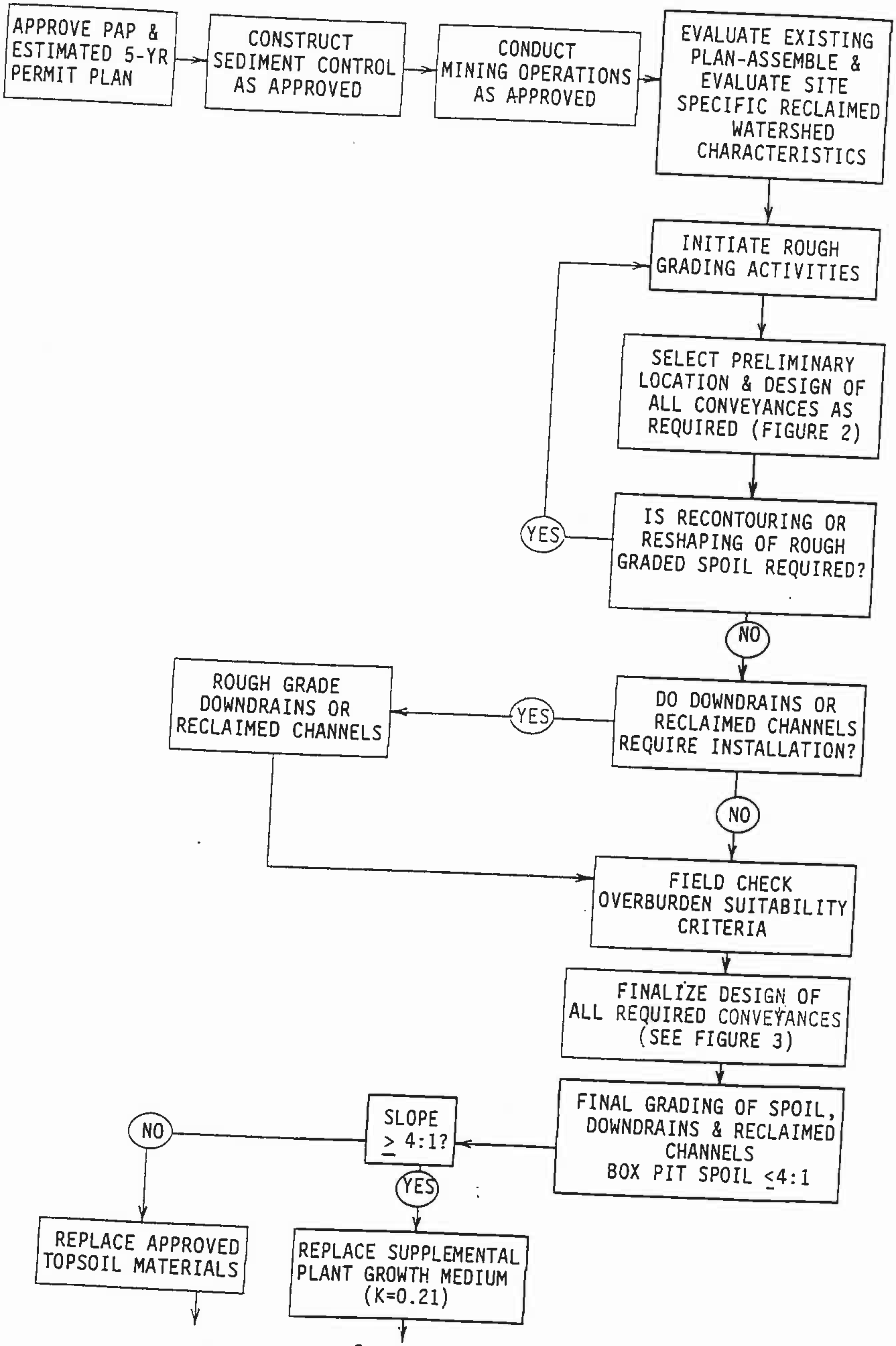


FIGURE 1 (Cont.)

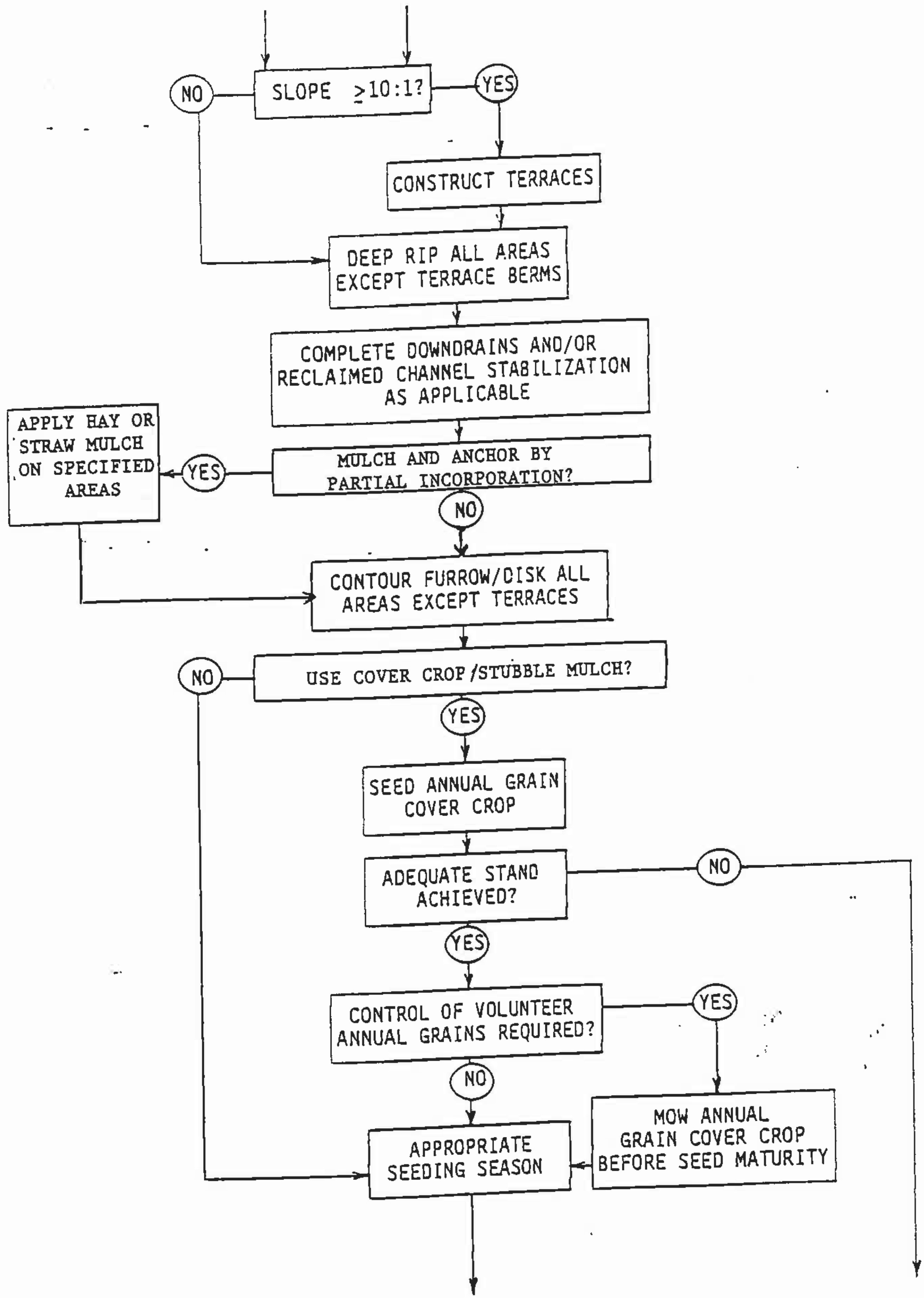
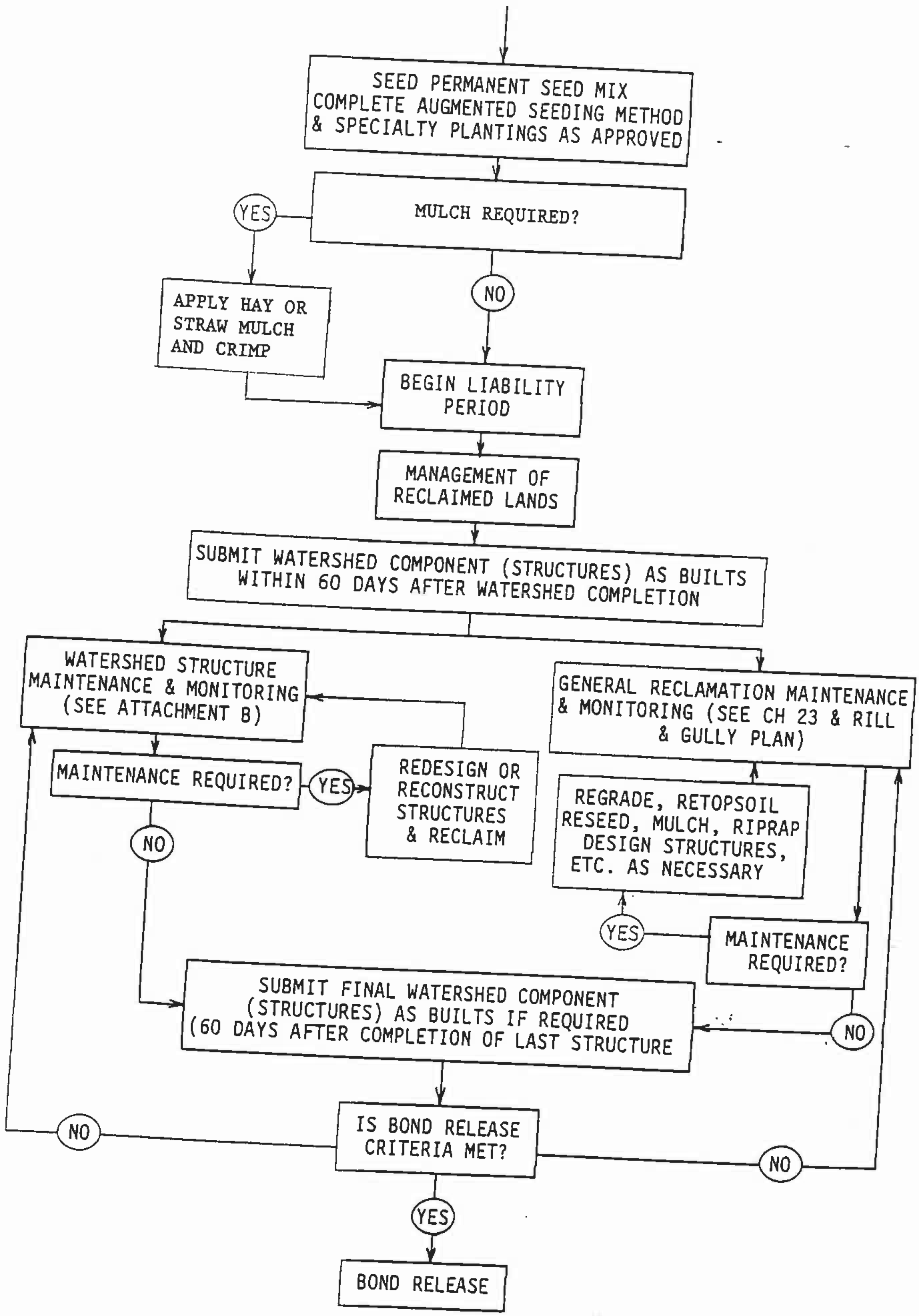


FIGURE 1 (Cont.)



These publications are referenced frequently throughout this section. In addition, PWCC's engineers and reclamation personnel frequently utilize design procedures, construction techniques, and reclamation practices developed by other organizations such as the U.S. Natural Resource Conservation Service (NRCS), the U.S. Bureau of Reclamation, the U.S. Department of Transportation, the U.S. Army Corps of Engineers, related state agencies, research organizations and universities, and other coal mining and reclamation related organizations.

The methods and support measures necessary to implement the surface stabilization plan are summarized below with reference to their location in the PAP where appropriate. Attachment B to this chapter, Reclamation Surface Stabilization Design Handbook, provides the guidelines for designing and constructing conveyance structures and establishing the reclaimed drainage system. Attachment C provides additional supporting information.

Primary components of the measures to be used for reclaimed surface stabilization are the engineered design and construction of gradient terraces on slopes greater than ten percent, downdrains, and reclamation channels (see Topographic Manipulation Discussion). The spacing between the terraces are dependent on slope gradient (see Attachment A to this chapter). These terraces will direct flow to a network of downdrains or primary reclamation channels, also properly designed and constructed (see Attachment B to this chapter). The terraces will break up the slope length on reclaimed hillslopes into shorter segments, and the downdrains and channels will aid in safely directing flows off of the reclaimed hillslopes and out of the reclaimed areas. Surface mechanical manipulations, mulching, and establishment of permanent cover on the inter-terrace slopes, as well as the slopes less than ten percent, will further aid in the stabilization of reclaimed lands. Attachment A, "Terrace Spacing Justification", details the beneficial effects of these and other measures in achieving a stable reclaimed landscape.

The following is a summary of the plan components and their location in the PAP.

1. Backfilling and grading as described in Chapter 21.
2. Implementation of the spoil sampling plan and mitigation as necessary to achieve suitable plant growth medium depths (Chapter 22).
3. Identification of primary drainage locations (Chapter 26).
4. Replacement of topsoil or supplemental surface plant growth medium except in certain downdrains and primary drainages (Chapter 22 and Chapter 26).

5. Construction of terraces on slopes greater than ten percent and creation of initial alignments for downdrains and location of drainages (Chapter 26).
6. Deep ripping of all areas except constructed terrace berms (Chapters 22 and 23).
7. Contour furrowing/disking on all areas except terrace berms and downdrains. Incorporate and anchor straw mulch if applied (Chapters 22 and 23).
8. If cover crop/stubble mulch used, seed cover crop. All reclaimed acres either straw mulched or cover cropped (Chapter 23).
9. Seed, plant, or transplant approved seed mixes or planting lists at appropriate periods (Chapter 23).
10. Monitoring, maintenance, reclaimed land management prior to bond release, and rill and gully plan implementation as necessary (Chapters 22, 23, and 26).
11. Postmining land use and management following bond release (Chapter 14).

The program discussion presented below should be considered along with Figure 1 "Surface Stabilization Plan Summary", the above referenced chapters in the PAP, the specific sections of the PAP as identified in the individual component and BTCA practice discussions, and Attachments A and B to this chapter.

Implementation of the Surface Stabilization Program. Upon approval of the PAP and estimated five-year permit plan, sediment control has been implemented by construction of required facilities or use of other appropriate measures. The following sections discuss the procedures utilized to implement the Surface Stabilization Program.

Sedimentation Ponds and Other Sediment Control Measures. In accordance with 30 CFR 816.45, PWCC will design, construct, and maintain appropriate sediment ponds and other sediment control measures to prevent, to the extent possible, additional contributions of sediment to streamflow or to runoff outside the permit area due to mining activity and to minimize erosion to the extent possible. Initially, before mining disturbance begins and during mining and reclamation operations, sedimentation ponds will be the primary method used to control runoff and additional contributions of sediment from the permit area except for those permitted areas exempted by the requirements of the regulations. With the start of reclamation operations after coal removal, and up to ten years after the last year of augmented seeding or revegetative efforts during the bonding period, PWCC will utilize siltation structures and other sediment control methods individually or in combination to assist in the surface stabilization of the reclaimed areas and the development of a postmining drainage system which is compatible with the postmining land use.

A discussion of the purpose and design of the siltation structures can be found in Chapter 6, "Sedimentation Ponds and Impoundments". The location of all the existing and proposed siltation structures can be found on Drawing 85405 "Sediment and Water Control Structures Map". As required by the regulations, all areas disturbed by surface mining will be treated by a siltation structure downstream of the area before the runoff leaves the permit area. All siltation structures will be constructed and maintained until PWCC has regulatory authorization to remove the structure, or until the applicable regulatory authority approves the structure as a permanent impoundment.

Alternate sediment control measures may be used in conjunction with the siltation structures or, in the case of the permitted areas which are exempt (e.g., roads), may be utilized individually or in combination to minimize erosion and additional contributions of sediment to streamflow or to runoff outside the permitted area. Sediment control measures include practices utilized within and adjacent to the mining disturbance areas. Sediment control measures will consist of the utilization of proper mining and reclamation methods and various sediment control practices, singly or in combination. Sediment control practices may include, but are not limited to the following:

1. Disturbing the smallest practicable area at any one time during the mining and construction operation;
2. Stabilizing graded material to promote a reduction in the rate and volume of runoff;
3. Retaining sediment within disturbed areas;
4. Diverting runoff away from disturbance areas including stockpiles, backslopes, and material storage;
5. Diverting runoff through disturbed areas using stabilized earth channels, culverts, or pipes so as to prevent, to the extent possible, additional contributions of sediment to streamflow or to runoff outside the permit area;
6. Using straw dikes, silt fences, small V-ditches, riprap, mulches, check dams, ripping, contour furrowing, vegetative sediment filters, small depressions, sediment traps, and other measures that will reduce overland flow velocity, reduce runoff volume, or trap sediment;
7. Treating traffic areas with water or dust suppressant to reduce the potential for wind and water erosion.

Upon implementation of the sediment control plan and installation of sediment control measures and facilities for an operational area, mining operations within that area are conducted as approved in the Mine Plan. Preliminary watershed design, components of which have been previously initiated, is undertaken at this time.

Preliminary Watershed Design. The preliminary watershed design process actually begins prior to mining operations. The first steps involve assembly of basic design data including topographic data, hydrologic data, and hydraulic data. After mining operations are completed, but before rough grading of spoil is started, the next phase of the preliminary watershed design process is undertaken based on site-specific characteristics of the watershed to be rough graded. Attachment B to this chapter provides a detailed discussion of the preliminary watershed design process.

An estimated postmining topography has been developed that is similar to the original landform (see Drawings 85350 and 85352). As a result of creating this landform, the postmining drainage network will also develop characteristics similar to the premining drainage system (see Chapters 15 through 19). The premining drainage networks on Black Mesa are characterized by deeply incised channels which develop supercritical flows during large precipitation events. Generally, within interior spoil reclaimed areas, the postmining drainages are graded and revegetated to allow natural meandering channels to develop within broad revegetated swales during low to moderate runoff events. During larger runoff events, the revegetated swales will be large enough to contain the peak runoff without affecting adjacent reclamation areas. Grade control structures may be required in reclaimed outslope areas, reclaimed areas where steeper slopes occur, and areas where reclamation is blended into the adjacent natural or previously reclaimed topography, to control peak velocities and reduce runoff and erosion. The type and size of these structures will be based on site-specific conditions including watershed size, land use, curve number, peak discharge, topography, soil conditions, etc. The general methodology used to size these structures will be discussed in this section; however, the physical geometry and location of each structure is too site-specific to be precisely determined prior to grading. The location and size of structures will be determined in conjunction with the rough grading of the spoil (see Chapter 26, Attachment B).

On January 29, 1982, OSM issued interim program Permit AZ-0001 for the Black Mesa and Kayenta Mining areas; on December 21, 1984, OSM issued permanent program Permit AZ-0002A for the J-21 mining area; and on July 6, 1990, OSM issued permanent program Permit AZ-0001C (renewed as Permit AZ-0001D on July 6, 1995) for the remainder of the Kayenta Mine permanent program lands. All mining and related reclamation after July 6, 1990 will be implemented in accordance with the approved Permanent Program Permit and applicable regulations.

This PAP contains specific requirements for surface stabilization measures, such as designed terraces and downdrains, which are not required in the pre-law, in the preinterim permit, in the AZ-0001 permit, and in a portion of the AZ-0002A PAP areas. (Lands in the AZ-0002A PAP area that do have specific requirements for terraces, downdrains, etc., are those included in the revision approvals dated February 9, 1989 (J-21 Disturbance Line Revision) and June 26, 1989 (J-21 Incidental Boundary Revision)). The Jurisdictional Permit Map, Drawing 85360, shows where these and other jurisdictional boundaries are located.

In some locations, subwatersheds will contain multi-jurisdictional lands. The design engineer and reclamation manager will determine the best method to safely convey the runoff onto or from the AZ-0001D and portions of the AZ-0002A permanent program lands across other jurisdictional lands. New conveyance structures will be designed in accordance with accepted engineering practices and design requirements in the surface stabilization plan provided herein. Upon completion of the preliminary watershed design process and rough grading plan, rough grading operations and topographic manipulation activities will be undertaken.

Topographic Manipulation. Topographic manipulation includes recontouring or reshaping of the spoil after coal removal in a manner that minimizes the potential for soil erosion and facilitates the establishment of a stable landform. Utilizing the methods described in Chapter 21 "Backfilling and Grading", an estimated postmining topography has been developed that is similar to the original landform (see Drawing Nos. 85350 and 85352). Drawing No. 85350 shows the estimated life-of-mine postmining topography; whereas, Drawing No. 85352 shows the estimated postmining topography through approximately 1993. Since implementation of the Surface Stabilization Program in 1990, Drawing No. 85352 has been replaced and PWCC utilizes the guidelines outlined for backfilling and grading in Chapter 21, the procedures outlined in Figure 1, and the approved Surface Stabilization Program to develop the postmining landform. As a result of creating this landform, the postmining drainage network will also develop characteristics similar to the premining drainage system (see Chapters 15 through 19). The premining drainage network on Black Mesa typically produces many deeply-incised channels which develop supercritical flows during large precipitation events. In order to minimize these deeply-incised channels within the postmining drainage network, generally PWCC will utilize grass-lined swales in flatter graded interior spoil reclaimed areas, gradient terraces, reclaimed downdrains, and reclaimed ephemeral and intermittent channels in steeper outslope, ramps, and final pit reclaimed areas to intercept surface runoff and convey runoff away from the reclaimed areas and to develop an adequate postmining drainage system.

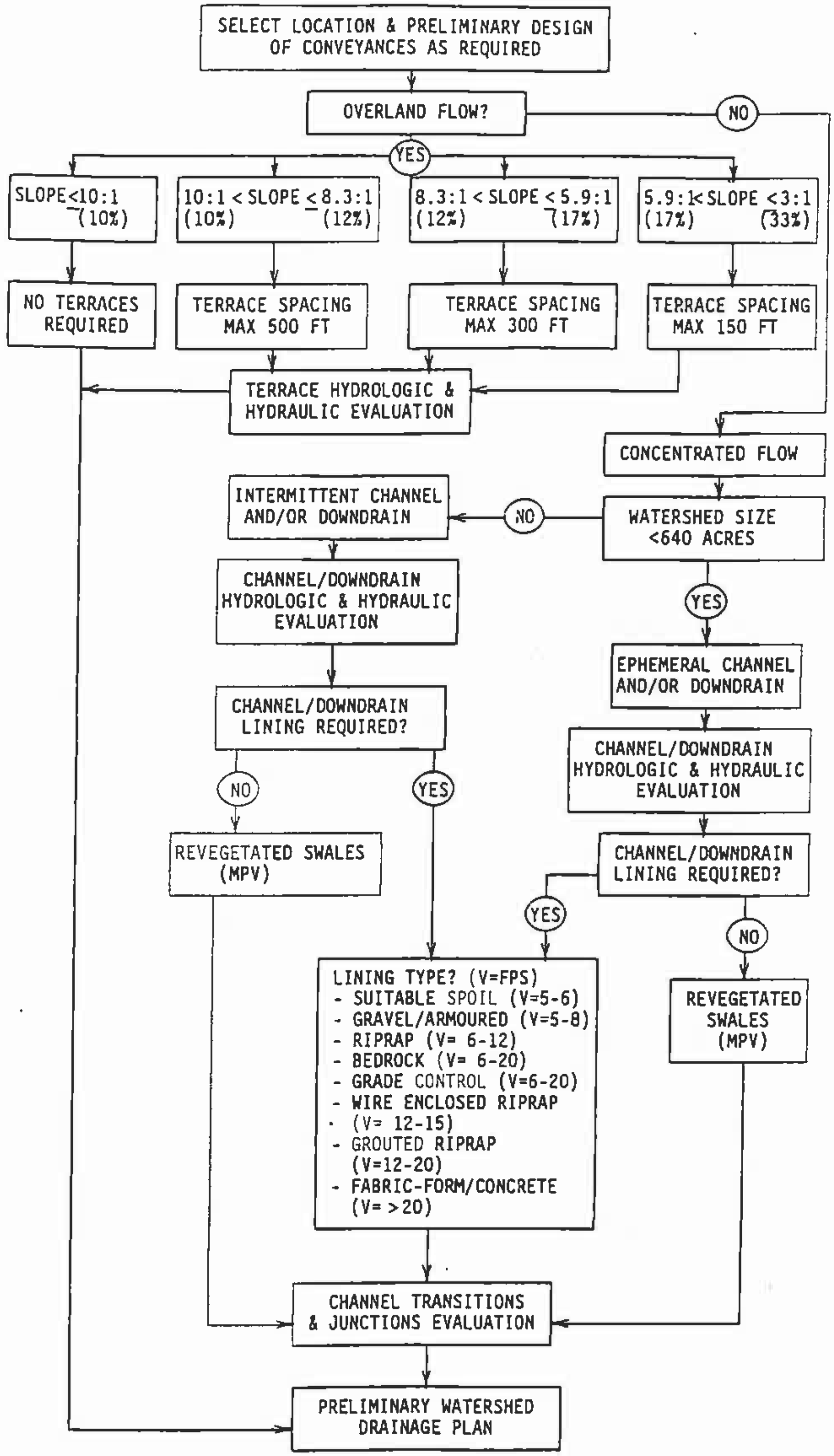
The topographic manipulation process begins as the overburden is placed in the spoil piles and the coal has been removed (see Figure 1). The type of mining operation, the direction of overburden removal and the final spoil pile configuration will begin to dictate grading operations and the development of drainage patterns in the reclaimed watershed. Once the spoil is placed in its final resting place, but before rough grading of the spoil peaks, the engineer will begin the preliminary design of conveyances as outlined in Figure 2. This preliminary design will provide the preliminary watershed drainage plan which will be used by the field reclamation crew for guidance in rough grading the spoil around and in the conveyance structures locations (i.e., reclamation channels and downdrains). This watershed drainage plan will be based on the engineer's estimate of the reclaimed watershed size, time of concentration, conveyance geometry, and other appropriate site-specific watershed characteristics. The preliminary watershed drainage plan will conform to the backfilling and grading requirements discussed in Chapter 21. This plan will guide the field reclamation crew during the rough grading operation, including general direction of dirt movement.

Once the rough grading has been initiated, the engineer will develop the final design of all conveyances including main reclaimed channels and main downdrains based on the preliminary drainage conveyance plan and the basic design data collected from the site. Before the topsoil is spread on the graded spoil, and after the graded spoil has been field checked for suitability criteria, the engineer will determine the watershed size and final location of all conveyances including terraces and downdrains. Conveyance structures' size, slope, and lining type will be designed based on updated topography data (see Figures 1 and 3).

The majority of the area within each reclaimed resource area consists of graded interior spoil. These areas are relatively flat compared to other areas in the reclamation. Observations of surface mechanical manipulation and revegetation measures implemented to date appear adequate to control rill and gully formation in these areas. Revegetated swales are utilized in conjunction with the surface mechanical manipulation measures to control runoff and velocities. In other areas where slopes are steeper or where ephemeral drainages are designed to occur, including reclaimed outslopes, reclaimed highwalls, major reclamation channels, reclaimed ramps, and facilities areas, PWCC will use a combination of gradient terraces, reclaimed downdrains, or reclaimed ephemeral and intermittent channels to minimize erosion while still approximating the original landform.

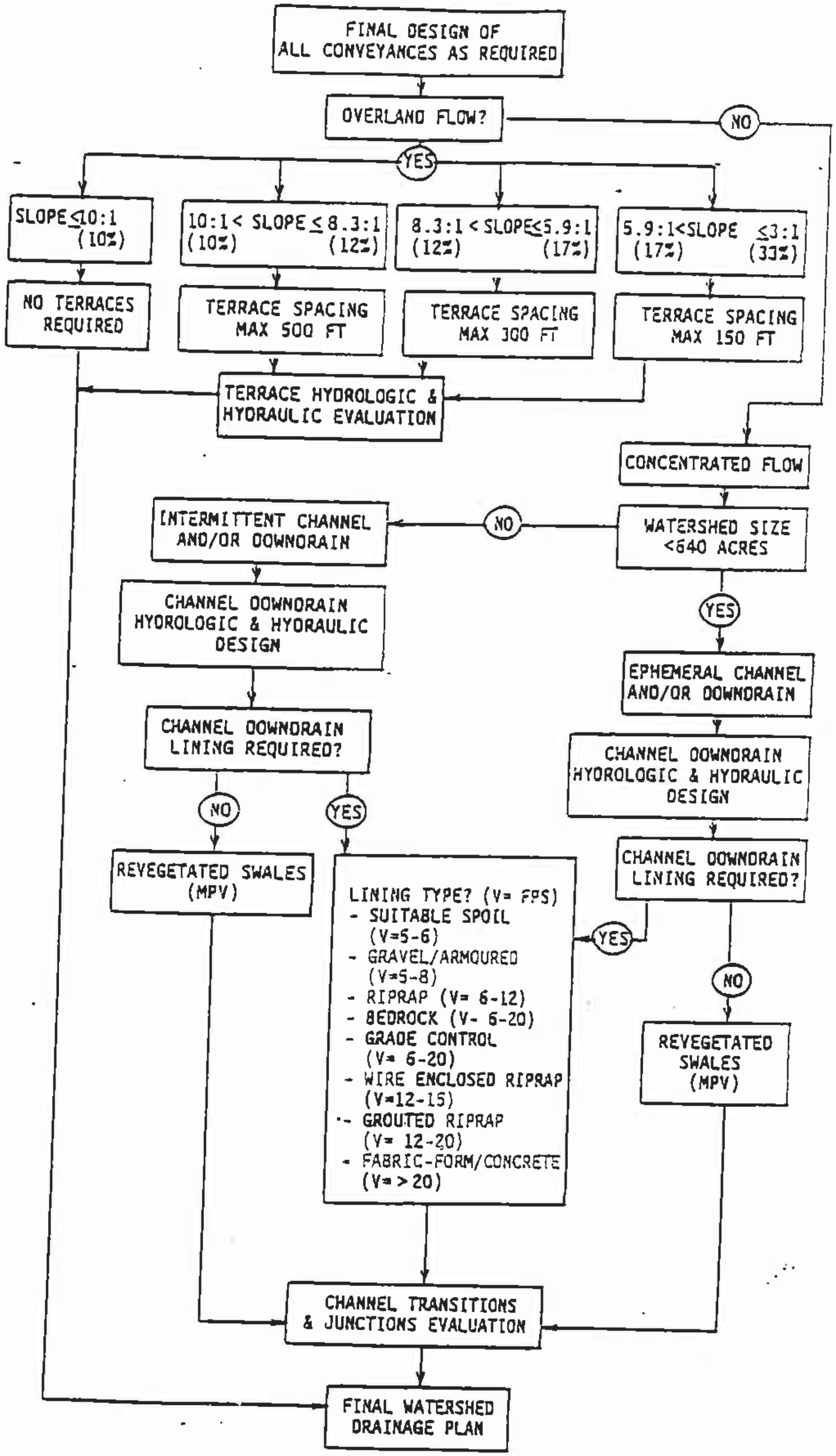
The reclaimed downdrains and the reclamation channels will be designed during reclamation

FIGURE 2



SELECT LOCATION & PRELIMINARY DESIGN OF CONVEYANCES AS REQUIRED
OVERLAND FLOW?
YES
NO
SLOPE<10:1 (10%)
10:1 < SLOPE ≤ 8.3:1 (10%) (12%)
8.3:1 < SLOPE < 5.9:1 (12%) (17%)
5.9:1< SLOPE <3:1 (17%) (33%)
NO TERRACES REQUIRED
TERRACE SPACING MAX 500 FT
TERRACE SPACING MAX 300 FT
TERRACE SPACING MAX 150 FT
TERRACE HYDROLOGIC & HYDRAULIC EVALUATION
CONCENTRATED FLOW
WATERSHED SIZE <640 ACRES
NO
INTERMITTENT CHANNEL AND/OR DOWNDRAIN
CHANNEL/DOWNDRAIN HYDROLOGIC & HYDRAULIC EVALUATION
CHANNEL/DOWNDRAIN LINING REQUIRED?
NO
YES
REVEGETATED SWALES (MPV)
YES
EPHEMERAL CHANNEL AND/OR DOWNDRAIN
CHANNEL/DOWNDRAIN HYDROLOGIC & HYDRAULIC EVALUATION
CHANNEL/DOWNDRAIN LINING REQUIRED?
YES
NO
REVEGETATED SWALES (MPV)
LINING TYPE? (V=FPS)
- SUITABLE SPOIL (V=5-6)
- GRAVEL/ARMOURED (V=5-8)
- RIPRAP (V= 6-12)
- BEDROCK (V= 6-20)
- GRADE CONTROL (V=6-20)
- WIRE ENCLOSED RIPRAP (V= 12-15)
- GROUTED RIPRAP (V=12-20)
- FABRIC-FORM/CONCRETE (V= >20)
CHANNEL TRANSITIONS & JUNCTIONS EVALUATION
PRELIMINARY WATERSHED DRAINAGE PLAN

FIGURE 3



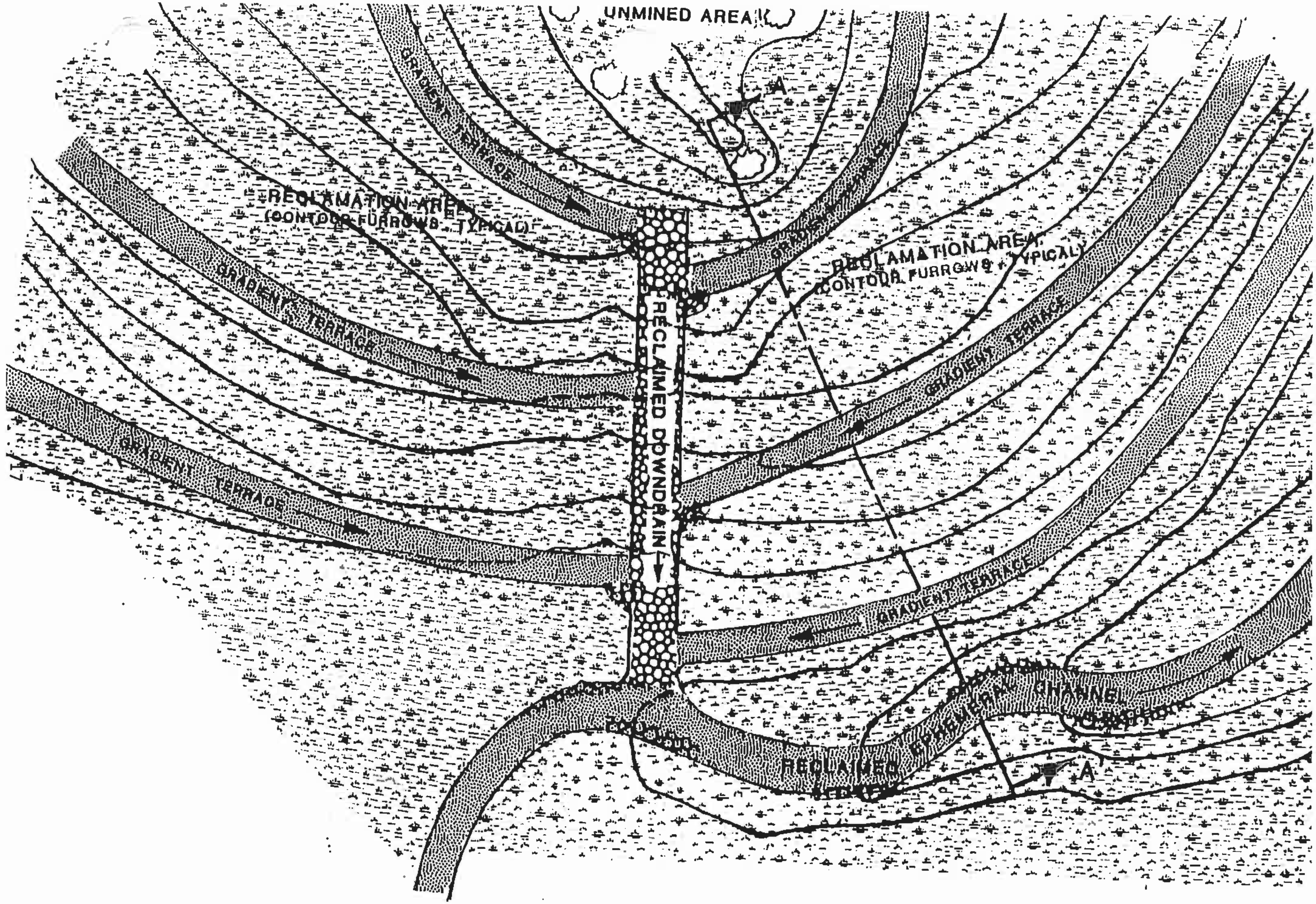
FINAL DESIGN OF ALL CONVEYANCES AS REQUIRED
OVERLAND FLOW?
YES
NO
SLOPE≤10:1 (10%)
10:1< SLOPE ≤ 8.3:1 (10%) (12%)
8.3:1 < SLOPE≤5.9:1 (12%) (17%)
5.9:1<SLOPE ≤3:1 (17%) (33%)
NO TERRACES REQUIRED
TERRACE SPACING MAX 500 FT
TERRACE SPACING MAX 300 FT
TERRACE SPACING MAX 150 FT
TERRACE HYDROLOGIC & HYDRAULIC EVALUATION
CONCENTRATED FLOW
WATERSHED SIZE <640 ACRES
NO
INTERMITTENT CHANNEL AND/OR DOWNDRAIN
YES
EPHEMERAL CHANNEL AND/OR DOWNDRAIN
CHANNEL DOWNDRAIN HYDROLOGIC & HYDRAULIC DESIGN
CHANNEL DOWNDRAIN HYDROLOGIC & HYDRAULIC DESIGN
CHANNEL DOWNDRAIN LINING REQUIRED?
CHANNEL DOWNDRAIN LINING REQUIRED?
NO
YES
YES
NO
REVEGETATED SWALES (MPV)
LINING TYPE? (V= FPS)
- SUITABLE SPOIL (V=5-6)
- GRAVEL/ARMOURED (V=5-8)
- RIPRAP (V= 6-12)
- BEDROCK (V- 6-20)
- GRADE CONTROL (V= 6-20)
- WIRE ENCLOSED RIPRAP (V=12-15)
- GROUTED RIPRAP (V= 12-20)
- FABRIC-FORM/CONCRETE (V= > 20)
REVEGETATED SWALES (MPV)
CHANNEL TRANSITIONS & JUNCTIONS EVALUATION
FINAL WATERSHED DRAINAGE PLAN

grading operations under the supervision of a Registered Professional Engineer. All of these structures will be permanent. Ephemeral channels will be designed for the 10-year, 6-hour precipitation event, and the 100-year, 6-hour precipitation event will be utilized for intermittent and geology, topography, and land slope for the premining topography, the estimated postmining topography, and the actual postmining topography, PWCC will provide general guidelines for these structures (see Chapter 26, Attachment B). Figure 3 outlines the decision process for the type of conveyance, size of conveyance structure, and the type of channel lining material to be used where required. As part of the final watershed drainage plan, all conveyance structures in the rough graded area will be constructed as design.

A design file for each conveyance structure will be maintained at the mine site that contains calculations utilizing the procedures, design criteria and format described in this section and Chapter 26, Attachments A and B. Each conveyance structure design will be a part of a master file for each of the 68 primary reclamation watersheds, which are described in this chapter. Other designed structures, which might be used in the associated reclaimed watersheds, will also be included in the appropriate file. The as-built certification for each reclamation watershed will be submitted to OSMRE within 60 days after reclamation of the watershed is completed. In addition, an annual report will be submitted to OSMRE summarizing monitoring and maintenance activities for each constructed watershed.

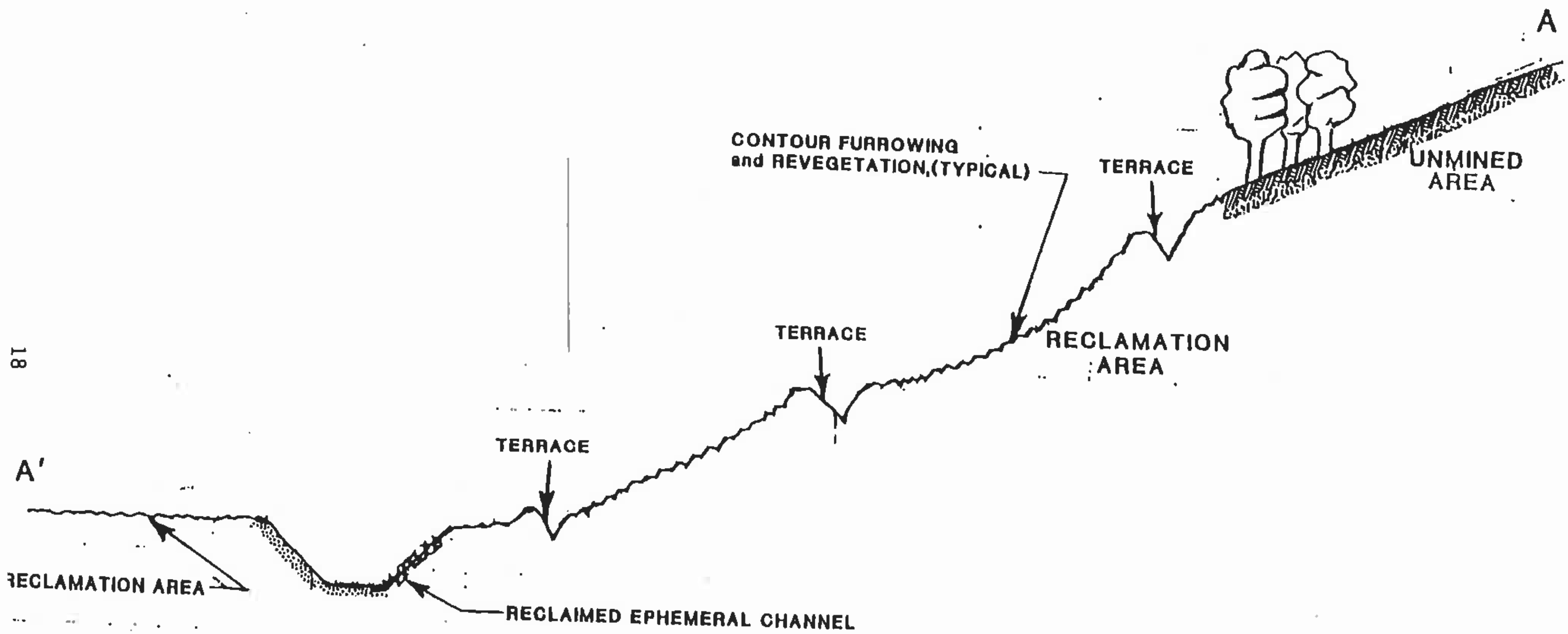
After finish spoil grading is completed and the spoil materials meet the suitability criteria, the topsoil or supplemental plant growth medium will be replaced. Terraces will be constructed as necessary. The area will receive surface manipulation measures, surface protection measures, and revegetation as described in the sections following Topographic Manipulation. Using these guidelines and the site-specific conditions found in the field after spoil grading, and before topsoil spreading, will provide the design flexibility required by the Registered Professional Engineer to develop a realistic postmining drainage control plan for each reclaimed area.

Gradient Terraces. The reclaimed landscape will contain some areas of potentially steep and long rolling slopes. These areas include outslopes (i.e., areas of reclaimed box cut spoils, final pit and highwall reclamation, areas adjacent to ramps and haul roads, and areas which blend into adjacent, non-permanent program reclaimed lands or natural topography). Gradient terraces, on a positive grade, to prevent overtopping, and approximately 0.5 to 1.0 percent slope with subcritical flow velocity unless the appropriate channel liner is provided, will be used to break up slope length, collect runoff, and convey the collected runoff safely off the reclaimed slopes and into the downdrains or reclaimed drainage channels, (see Figures 4 and 5) The gradient terraces were



TYPICAL RECLAMATION OUTSLOPE AREA

Date:12/04/87
NOT TO SCALE
FIGURE 4



PEABODY COAL COMPANY
BLACK MESA-KAYENTA MINE
P.O. BOX 626
KAYENTA,ARIZONA 86033

TYPICAL RECLAMATION OUTSLOPE AREA
SECTION A-A'

FIG. NO.	APP'D BY.	DRAWN BY.	DATE:	SCALE:
5	J.S.	M.B.	/87	N/A

conservatively designed using the 100-year, 6-hour precipitation event even though the channels will typically be ephemeral channels. The design concept and utility of the gradient terraces are based on a review of Natural Resource Conservation Service (NRCS) technical literature and personal communications with NRCS technical personnel. Design guidelines for terraces are contained in Attachment B to this chapter.

A gradient terrace is a small earthen embankment, channel, or a combination of ridge and channel constructed to intercept surface runoff. The terrace will be constructed with a gentle grade (i.e., approximately 0.5 to 1.0 percent) to an outlet in a natural ephemeral channel, a primary reclamation channel, or a reclaimed downdrain.

Terraces are used to break up the slope length at predetermined intervals and are approximately perpendicular to the overland flow direction. The terraces intercept the runoff, decrease the flow velocity, and allow a percentage of the settleable sediment sizes to deposit while the remaining suspended sediment is carried off the slope.

The effectiveness of terraces constructed as agricultural soil erosion control was evaluated by R.E. Highfill (1983). According to the author, the terraces reduce sheet and rill erosion by shortening the slope length. The sediment is redistributed over the terrace channel and ridge and a small part of the terrace interval uphill from the channel. Terraces effectively collect runoff before it becomes erosive and carry it, along with the sediment load, at non-erosive velocities to safe outlets. A terrace with a vegetated outlet traps 60 to 80 percent of the sediment moving into the terrace channel.

A two-year study in Breathitt County, Kentucky, indicated that terraces can effectively control runoff and erosion on surface mine benches (Curtis, 1971). Two pairs of experimental plots were constructed on areas with shale and sandstone as the predominating lithology. Terracing significantly reduced total runoff from the shale area by an average of 42 percent. In comparison, the average total runoff reduction from the terraced sandstone area was six percent. In all cases, the sediment yield on the unterraced plots was greater than that of terraced plots. The averages were 16,000 and 7,600 ppm, respectively, on the shale spoil and 1,350 and 400 ppm on the sandstone spoil. Sediment yield on the shale spoil exceeded that on the sandstone spoil for all storms.

Typical terrace geometry is shown in Figure 6. The gradient terrace designs are based on the more conservative V-ditch configuration. The flat bottom terrace will have a larger cross sectional area; therefore, the flat-bottom terraces would have additional capacity or freeboard. In order to accommodate standard construction equipment, either the V-ditch or flat bottom terrace will be constructed. Scrapers can more easily operate on the flatter slopes; therefore, flat bottom terraces are more likely to be constructed on these flatter slopes. The V-ditch terraces are constructed with dozers or road graders, which can operate more effectively on the steeper slopes. The V-ditch terraces will be more prevalent on the steeper slopes.

The following gradient terrace spacing criteria was developed based on the utilization of the revised Universal Soil Loss Equation (REVUSLE) (see Chapter 26, Attachment A).

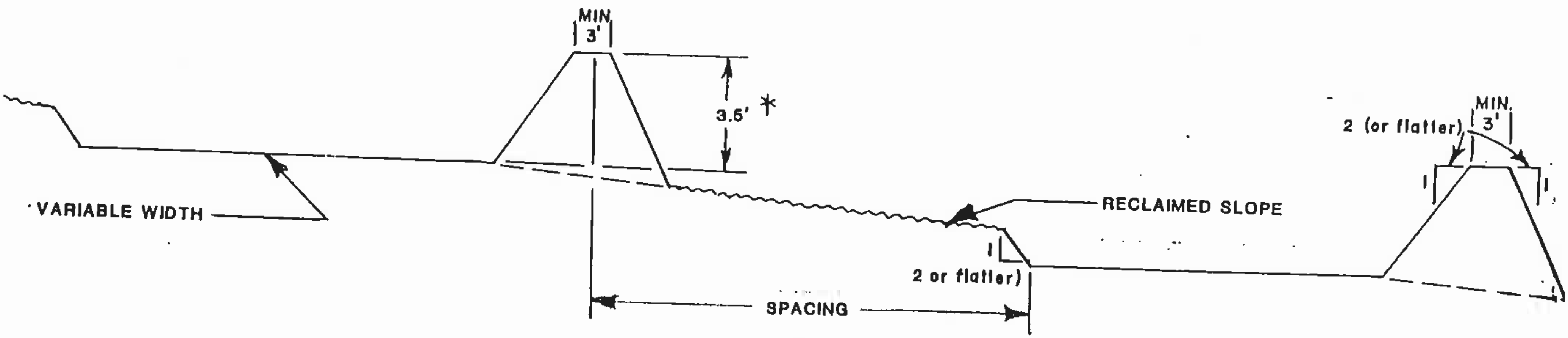
Slope Category (%)	Horizontal Spacing (ft)
> 10 to < 12	500
> 12 to < 17	300
> 17 to < 33	150

Terraces will be constructed on slopes equal to or greater than ten percent.

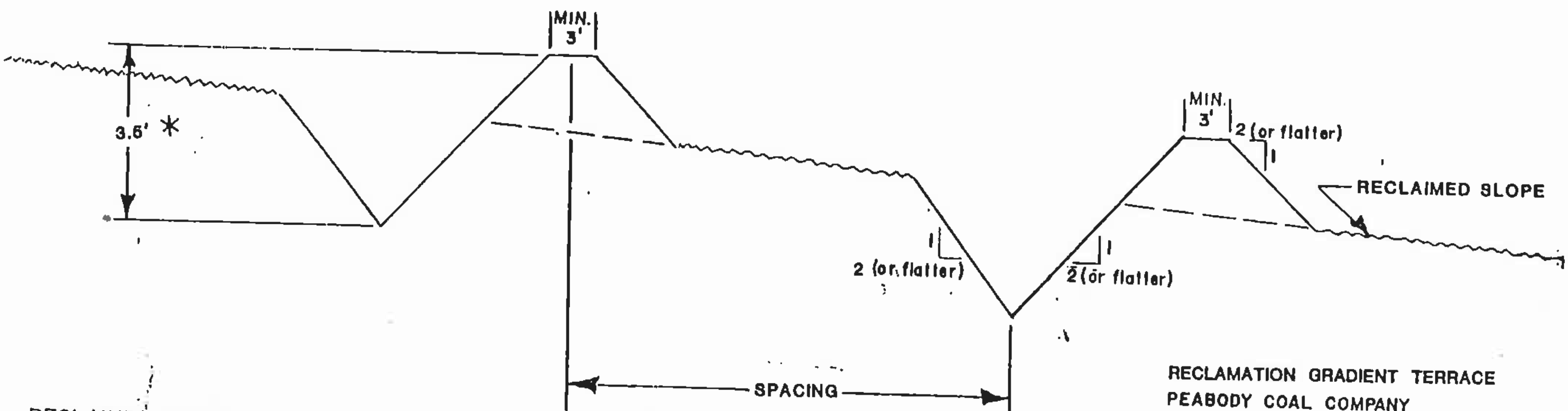
Standardized terrace depths of 3.5 feet for terrace lengths less than 3,500 feet long, to 4.5 feet for terrace lengths greater than 3,500 feet long, on reclaimed slopes of 10 to 33 percent will safely handle the flow from the 100-year, 6-hour precipitation event and be capable of storing approximately 1.5 feet of sediment while still allowing a minimum of 1.0 to 2.0 feet of freeboard. Spacing for the gradient terraces may be decreased to facilitate alignment or location, reclamation equipment, or to reach a satisfactory outlet. The gradient terraces will be constructed as near parallel as practicable on an approximate 0.5 to 1.0 percent slope.

The gradient terraces have been designed and will be constructed by using scrapers and dozers to construct the terrace berm, or the cut and fill method based on NRCS-type procedures. All slopes will be stabilized and revegetated in accordance with the reclamation plan. After the first growing season, the contour furrowed slopes between the gradient terraces will have established vegetation that will increasingly assist in reducing the overland flows and preventing rills and gullies. Attachment B contains the necessary guidelines and criteria for construction of the terraces.

FLAT BOTTOM GRADIENT TERRACE (TYPICAL)



V-DITCH GRADIENT TERRACE (TYPICAL)



RECLAIMED SLOPE	LENGTH (ft.)	SPACING (ft)	TERRACE DEPTH (ft.) *
10-12%	0-3500	500	3.5
12-17%	0-3500	300	3.5
17-33%	0-3500	150	3.5

RECLAMATION GRADIENT TERRACE
PEABODY COAL COMPANY
BLACK MESA/KAYENTA MINE
FIGURE NO. 6
DATE: 01/20/89
(NOT TO SCALE)

* DEPTH WILL VARY WITH LENGTH AND AREA. TYPICALLY, FREEBOARD WILL BE 1'(0-3500) & 2'(>3500'). ALSO SEE CHAPTER 26, ATTACHMENT B

In summary, the purposes of the gradient terraces include the following:

a. Reduce slope length;

b. Control runoff velocities;

c. Convey overland runoff to the downdrains and drainage channels.

d. Reduce sediment content in runoff water;

e. Reduce soil loss;

f. Minimize rill and gully development;

g. Improve water quality;

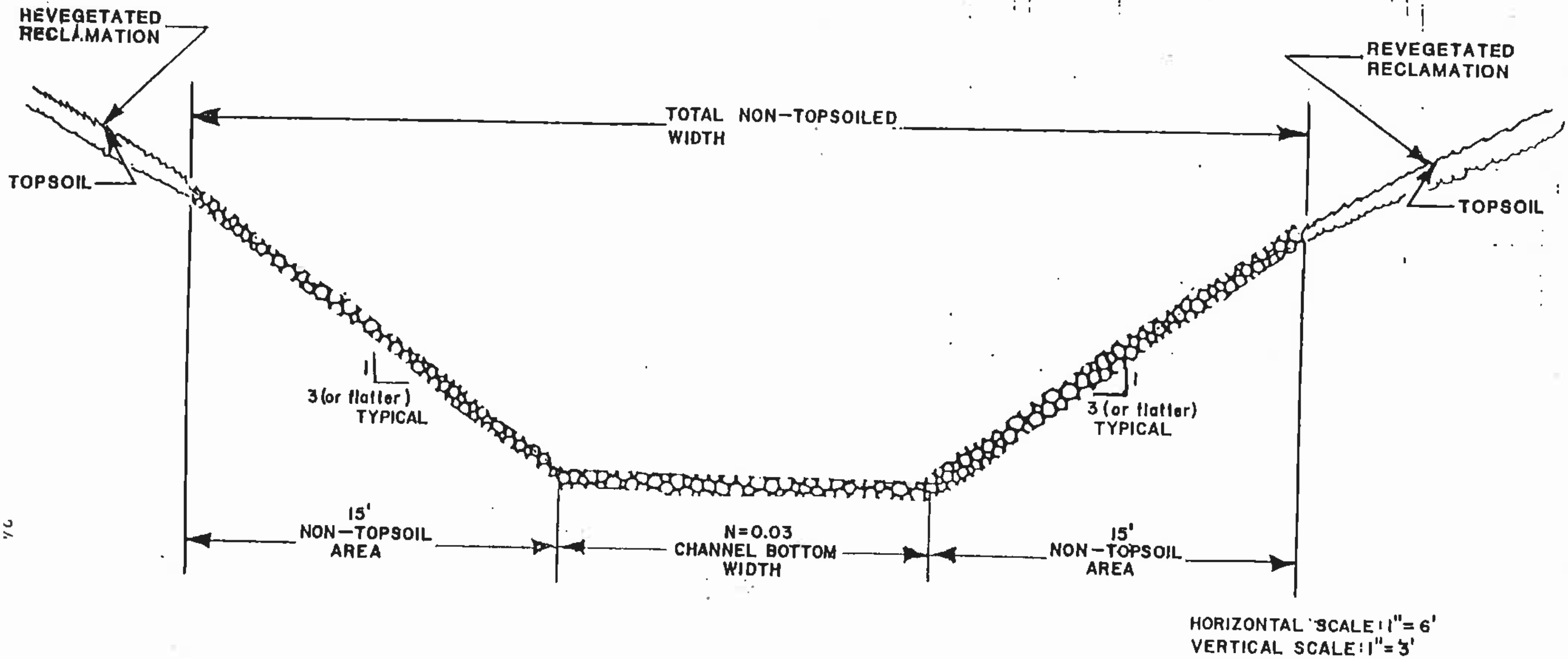
Reclamation Downdrains. The Black Mesa topography is very rolling and steep in certain areas. When these areas are mined and the reclamation grading is completed, it is necessary to blend the permanent program reclamation areas into the adjacent non-permanent program reclaimed lands or natural topography; therefore, downdrains may be required if the reclaimed watershed size is large and steep enough to cause significant concentrated runoff. Reclamation downdrains will be erosion-resistant grade control structures which will perform as ephemeral or intermittent channels in steep reclaimed areas. Figures 4 and 5 show a typical, generic outslope area which might be on an exterior reclaimed slope, adjacent to a reclaimed ramp, in the final highwall area, or in an isolated reclaimed area, etc. where the topography would not allow the gradient terraces to be graded directly into a primary channel. The gradient terraces would intercept the overland runoff and drain into the downdrains which in turn drain into a primary ephemeral channel. The increased travel time of the runoff will significantly reduce the peak runoff in the primary ephemeral channel and thus reduce the peak velocities and reduce erosion. Typically, a downdrain will be located in a reclaimed ramp area, or where significant concentrated flow is entering the reclaimed area and a conveyance structure is required to drain the area into a primary channel.

Due to the estimated nature of the postmining topography and the potential for variations in the actual postmining graded surface, a projection of the best location for the reclaimed downdrains at this time would be premature. However, the downdrains will be field located based on site-specific conditions and the volume of anticipated peak runoff from the adjacent areas. The process for design and as-built certifications submitted for downdrains will be similar to that presented for reclamation channels. When the design peak velocity exceeds critical velocity, the appropriate surface protection measure will be provided (see Chapter 26, Attachment B).

If the location of the downdrain is known prior to topsoil redistribution activities, topsoil will not be placed in the downdrain. Should the location of a downdrain be defined after topsoil replacement, the topsoil will be removed in the immediate vicinity of the downdrain. The minimum width along the downdrain alignment which will not be topsoiled is approximately 45 feet. This is based on a minimum estimated bottom width of 15 feet with an additional 15 feet of width each side of the downdrain channel as shown on Figure 7. Topsoil material loss will be minimized. If adequate erosion-resistant material does not exist in the channel bottom and meanders are anticipated to develop that exceed the 45-feet minimum width of the non-topsoiled channel, riprap or grade control structures will be used to prevent the channel from eroding into the adjacent topsoiled areas.

In summary, downdrains will be designed under the direct supervision of a Registered Professional Engineer using procedures discussed in Chapter 26, Attachment B.

Reclamation Channels. The postmining topography maps were reviewed to determine the magnitude of the reclaimed drainage networks, evaluate the estimated drainage watersheds, and identify potential conditions within the watersheds to determine what drainage controls and methodologies are necessary. This evaluation provided a preliminary indication of the number and general characteristics of watersheds and their drainage channels that could be found in the reclaimed areas. Approximately 68 primary postmining watersheds have been delineated in the postmining areas and are shown on Drawing No. 85350. The primary watersheds, which contain more than 30 acres, were chosen on the basis of containing at least one main, well-defined, reclamation drainage channel which could collect runoff from within the watershed and transport the flow into adjacent non-permanent program reclaimed lands or natural channels. Where the reclaimed slopes are steep and peak overland flows may cause too much erosion, PWCC may use gradient terraces, constructed on a slight positive grade, to convey the runoff into the main reclamation channels. In steep areas where revegetated swales are not feasible for blending the toe of the spoil into adjacent non-permanent program reclaimed lands, natural topography, or ephemeral channels; erosion-resistant downdrains may be required in the reclamation. The downdrains will also be constructed in smaller more remote areas to prevent erosion and severe headcutting from encroaching into the permanent program reclaimed areas.



PEABODY COAL COMPANY BLACK MESA-KAYENTA MINE P.O. BOX 605 KAYENTA, ARIZONA 86033				
RECLAMATION DOWNDRAIN CHANNEL CROSS-SECTION				
FIG. NO. 7	APP'D BY. J.S.	DRAWN BY. M.B.	DATE: 12/04/87	SCALE: AS SHOWN

In order to determine the drainage characteristics of the postmining topography, each of the 68 primary postmining watersheds were evaluated using the Hydrologic Computer Model SEDIMOT II to predict runoff from each watershed. Table 1 lists both the input parameters and output results of the analysis for each watershed. The estimated maximum size of the reclaimed ephemeral or intermittent channels that could potentially develop was then determined. The peak runoff from a 10-year, 6-hour precipitation event was calculated at the outlet of the reclaimed postmining watershed for the ephemeral channels and the peak runoff from a 100-year, 6-hour precipitation event was calculated for intermittent channels.

TABLE 1

Black Mesa/Kayenta Mines

Postmining Drainage Channel Summary

Watershed	Area (Ac)	Curve Number	Time of Concentration (Hrs)	Peak Flow (cfs)
J7-1w	76.6	81	0.182	32.35
J7-2w	148.7	81	0.458	40.13
J7-3w	110.0	81	0.238	41.56
J7-4w	107.3	81	0.186	44.90
J7-5w	123.3	81	0.268	44.10
J7-6w	231.5	81	0.357	71.91
J7-7w	40.80	81	0.148	17.84
J7-8w	152.1	81	0.015	63.30
J7-9w	120.2	81	0.273	42.63
J7-10w	281.4	81	0.220	95.13
J7-11w	39.2	81	0.168	17.09
J16-1w	170.1	81	0.360	52.60
J16-2w	111.5	81	0.202	44.97
J16-3w	209.1	81	0.404	60.73
J16-4w	182.7	81	0.407	52.85
J16-5w	122.3	81	0.250	45.18
J16-6w	203.4	81	0.269	72.62
J16-7w	254.9	81	0.327	82.87
J19-1w	1036.1	81	0.790	554.28*
J19-1.1w	220.9	81	0.349	69.46
J19-1.2w	289.5	81	0.422	82.03
J19-2w	1235.4	81	0.859	585.86*
J19-3w	164.2	81	0.317	54.21
J19-4w	211.0	81	0.262	76.23
J19-5w	926.7	81	0.704	498.97*
J19-6w	94.7	81	0.189	39.35
J19-7w	107.1	81	0.184	45.03
J19-8w	58.6	81	0.141	25.63

TABLE 1 (Cont.)

Black Mesa/Kayenta Mines

Postmining Drainage Channel Summary

Watershed	Area (Ac)	Curve Number	Time of Concentration (Hrs)	Peak Flow (cfs)
J19-9w	42.7	81	0.084	27.81
J19-10w	137.9	81	0.204	55.40
J19-11w	339.1	81	0.388	100.69
J19-12w	106.2	81	0.243	39.75
J19-13w	37.90	81	0.135	16.58
J21-1w	413.4	81	0.436	114.93
J21-2w	94.9	81	0.199	38.52
J21-3w	562.1	81	0.680	119.88
J21-4w	137.4	81	0.248	50.95
J21-5w	702.7	81	0.523	452.16*
J21-6w	152.5	81	0.317	50.35
J21-7w	185.8	81	0.213	73.42
J21-8w	225.9	81	0.251	83.30
J21-9w	238.0	81	0.284	82.83
J21-10w	506.6	81	0.380	152.09
J21-11w	203.9	81	0.261	73.79
J21-12w	217.4	81	0.321	71.33
J21-13w	471.4	81	0.541	115.10
N6-1w	507.2	81	0.377	152.90
N6-2w	1649.1	81	0.732	866.66*
N6-3w	147.5	81	0.404	42.84
N6-4w	704.5	81	0.761	361.23*
N6-5w	509.2	81	0.480	133.74
N6-6w	87.5	81	0.259	31.79
N10-1w	467.7	81	0.449	157.44
N10-2w	604.4	81	0.519	151.65
N11-1.1w	466.9	81	0.344	128.70
N11-1.2w	151.2	81	0.311	50.37

Revised 07/14/99

TABLE 1 (Cont.)

Black Mesa/Kayenta Mines

Postmining Drainage Channel Summary

Watershed	Area (Ac)	Curve Number	Time of Concentration (Hrs)	Peak Flow (cfs)
N11-1.3w	134.6	81	0.283	46.92
N11-2w	75.5	81	0.127	33.02
N11-3w	72.6	81	0.158	31.75
N11-4.1w	964.6	81	0.131	718.05*
N11-4.2w	181.3	81	0.337	58.05
N11-4.3w	142.9	81	0.311	47.63
N11-4.4w	555.3	81	0.397	162.85
N14-1w	514.8	81	0.526	127.87
N14-2w	411.4	81	0.498	105.70
N14-3w	226.6	81	0.349	71.25
N14-4w	1440.0	81	0.851	687.10*
N14-5w	1507.2	81	1.005	645.99*

Note: See Drawing No. 85350 for location

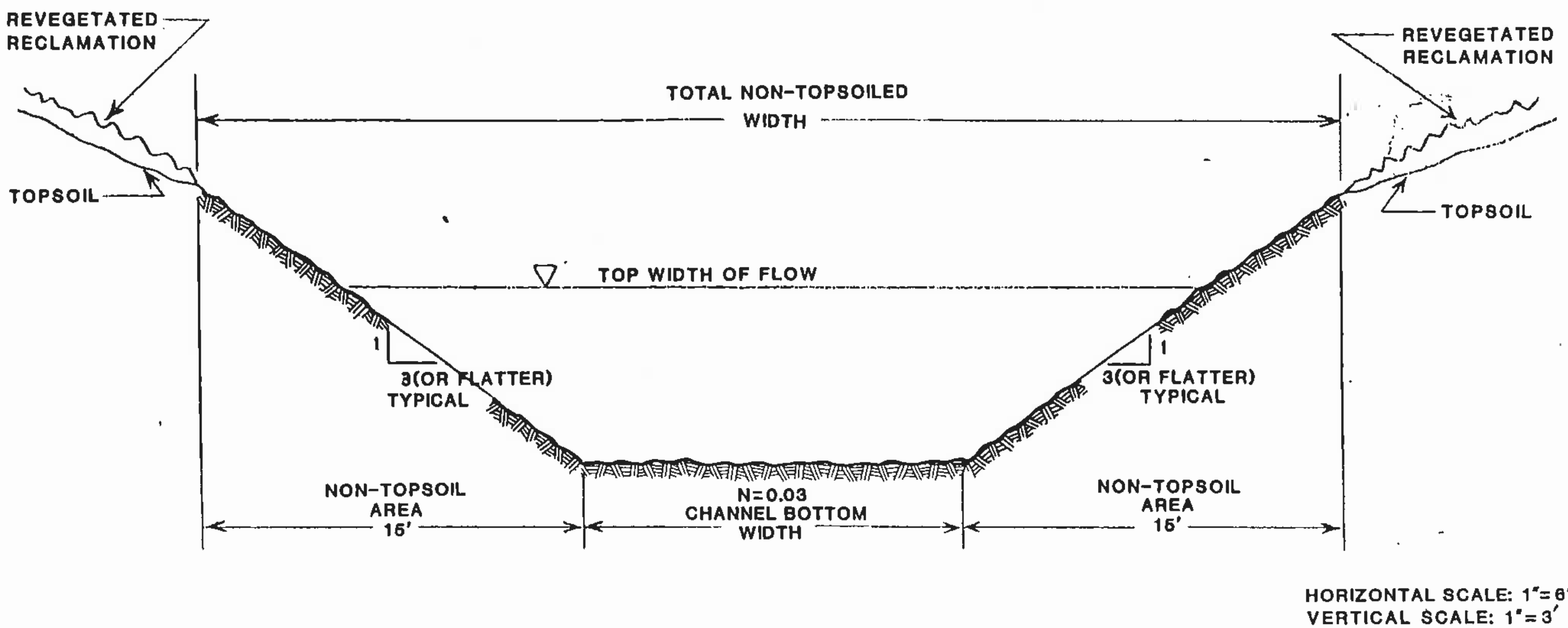
*100-year, 6-Hour Storm Event

In order to prevent loss of topsoil resources, the reclaimed channels will not be topsoiled. Rather, four feet of suitable plant growth spoil material will be left in the drainage channel. This material, due to its moderate coarse fragment or rock content, will form an armored surface, increasing the potential for channel stabilization. Also, an additional 15 feet on each side of the designed reclaimed channel bottom will not be topsoiled to allow for containment of the high flows and to confine any low meandering flow within the channel area and away from the topsoiled and revegetated areas (see Figure 8). Revegetation of this additional 30-foot width will be carried out only as a means of providing opportunities for vegetation establishment within the channel as it develops its characteristics.

Generally, the gradient terraces and grass-lined swales will be graded to drain into the primary reclaimed channels on a non-erodible slope (see Figure 9). Depending on the nature of the material at the exits of the gradient terraces and swales into the reclamation channels, erodible material will be stabilized with appropriate surface protection measures which may include rock riprap, straw mulch or bales, geotextile fabrics, and/or organic fiber matting. Appropriate surface protection measures will be provided along outside curves or at points along the reclamation channel where excessive erosion might cause the channel to encroach into adjacent topsoiled and revegetated areas.

In summary, primary reclamation channels will be designed under the direct supervision of a Registered Professional Engineer using procedures discussed in Chapter 26, Attach. B.

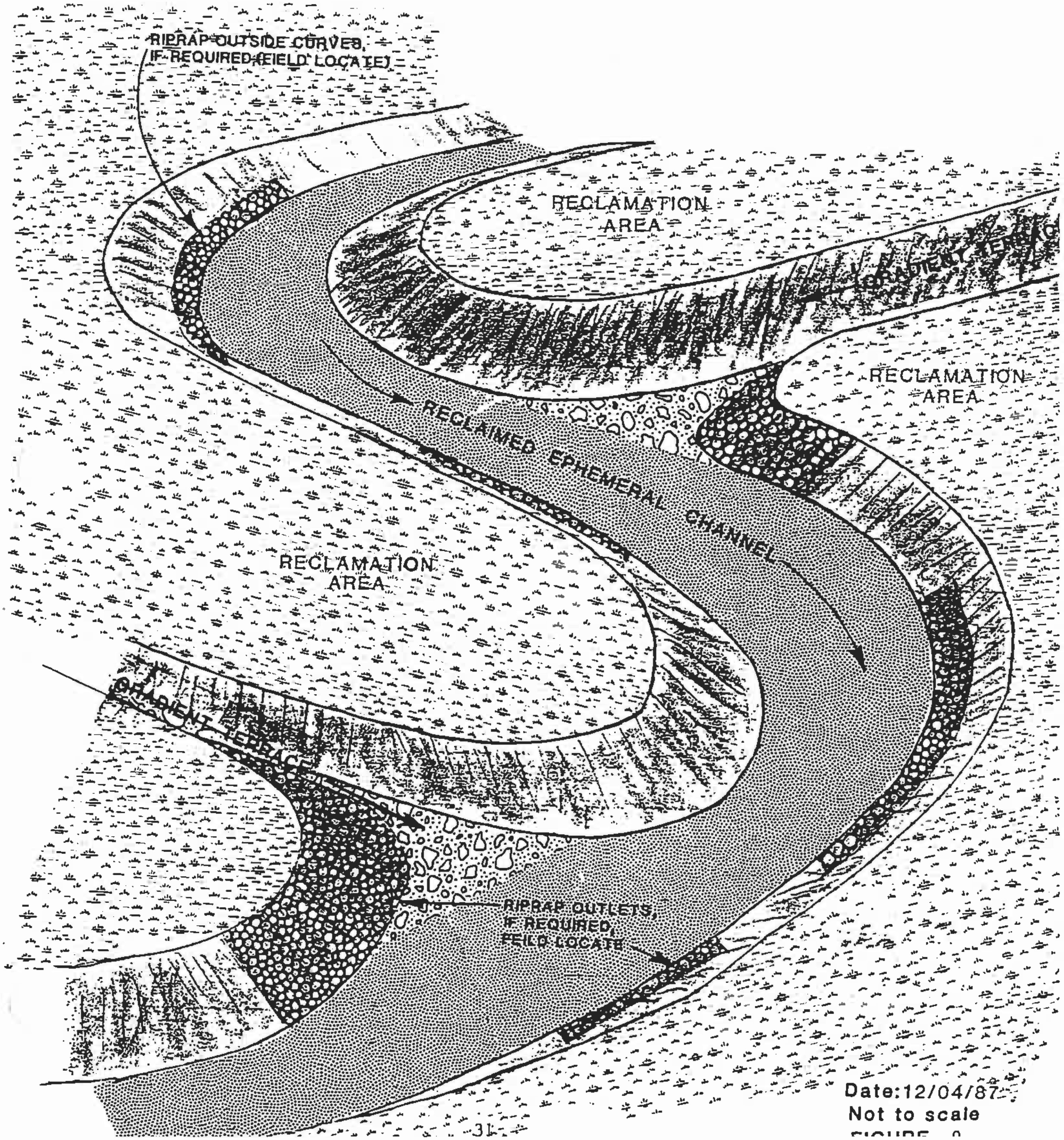
Generic Watershed Design Example. A request was made by OSMRE to apply the design principles for terraces, downdrains, reclamation channels, grade control structures, and riprap to a "generic watershed" typical of those experienced during mining/reclamation operations at the Black Mesa Mine site. The design example resulted in a preliminary design plan, but that plan is representative of the application of the design handbook contained in Attachment B. PWCC chose, with OSMRE's staff concurrence, a generic watershed. This was accomplished after a meeting with OSMRE's staff on November 10, 1988. Watershed No. N14-4W was chosen because this watershed is one of the larger watersheds among the 68 reclaimed watersheds, the N-14 mine area was to have coal removal



EXAMPLE: (J7-3W) WATERSHED NO. IDENTIFICATION (SEE DRAWING 85350)

PEABODY COAL COMPANY BLACK MESA-KAYENTA MINE P.O. BOX 625 KAYENTA,ARIZONA 86033				
TYPICAL RECLAMATION CHANNEL CROSS-SECTION				
FIG. NO.	APP'D BY.	DRAWN BY.	DATE:	SCALE:
8	J.G.S.	J.H.	01/23/89	N/A

TYPICAL RECLAMATION CHANNEL



Date:12/04/87
Not to scale

operations completed by 1995, this watershed could possibly contain many of the conveyance structures discussed in this handbook, and the watershed contains significant areas that have been reclaimed and areas that will remain undisturbed. In addition, the generic watershed design example shows how permanent program reclaimed lands and conveyance structures could be blended into the adjacent non-permanent program or undisturbed lands. The principles in Attachment B were applied to this watershed, and this example application of the design process may be found in Attachment B.

The watershed design example in Attachment B is similar to a preliminary watershed plan developed from a rough grading plan (Figure 2). Once the area approaches finish grading, then updated topographic data will be obtained and a final drainage plan will be developed (Figure 3). The locations and alignment of all drainage structures will be staked and construction will occur during the finish grading process.

Within 60 days after completion of the reclamation in the entire watershed, the certified as-built maps will be submitted to OSMRE. A watershed file will be maintained at the mine site for inspection by OSMRE. OSMRE will receive a report regarding rill and gully activities and the maintenance status report for drainage structures by June 1 of each year.

Measures Used in Support of Topographic Manipulation and Conveyance Structures. Measures used in conjunction with diversions and overland conveyances include check dams, drop structures, erosion-resistant liners, sediment traps, water level spreaders, etc. These structures are designed and constructed for grade stabilization and diversion outlet control, or solely constructed for the purpose of trapping sediment. This application is discussed in detail in the Procedures for Design of Reclamation Drainage Structures in Attachment B.

Check Dams, Drop Structures, and Erosion-Resistant Liners. A check dam is a low-head structure constructed across a channel to stabilize the grade or to control head cutting in natural or constructed channels. Check dams are used to reduce or prevent excessive erosion by reducing velocities in diversions, conveyances, and sedimentation pond inlets or by providing partially-lined channel sections or structures that can withstand high flow velocities. Check dams are used where the capability of earth and/or vegetative measures is exceeded in the safe handling of water at permissible velocities, or sections with excessive grade.

A drop structure is a riprap-lined structure, or a structure constructed over an erosion-resistant ledge rock which outcrops in the channel. The ledge rock acts as a grade control structure and a rock-lined stilling basin is provided at the outlet. An erosion-resistant liner is a surface protection measure provided in critical portions of the channel to control excessive erosion.

Sediment Traps. A sediment trap is a small storage or detention area without special inlet and outlet controls or specific side slopes. Sediment traps are typically constructed by excavation, or by creating an impoundment with logs, silt fence, or brush barrier/filter fabric as a low head dam. This measure is not considered by PWCC as a long term feature of the postmining landscape, but a temporary measure for specialized applications such as control of sediment in roadway ditches or immediate remedial control of areas contributing temporary excessive sediment yield.

Level Spreaders. A level spreader is an outlet constructed at zero percent grade across the slope. The purpose of the structure is to convert a concentrated flow of sediment-free runoff into sheet flow and to discharge it at non-erosive velocities onto undisturbed areas stabilized by existing vegetation.

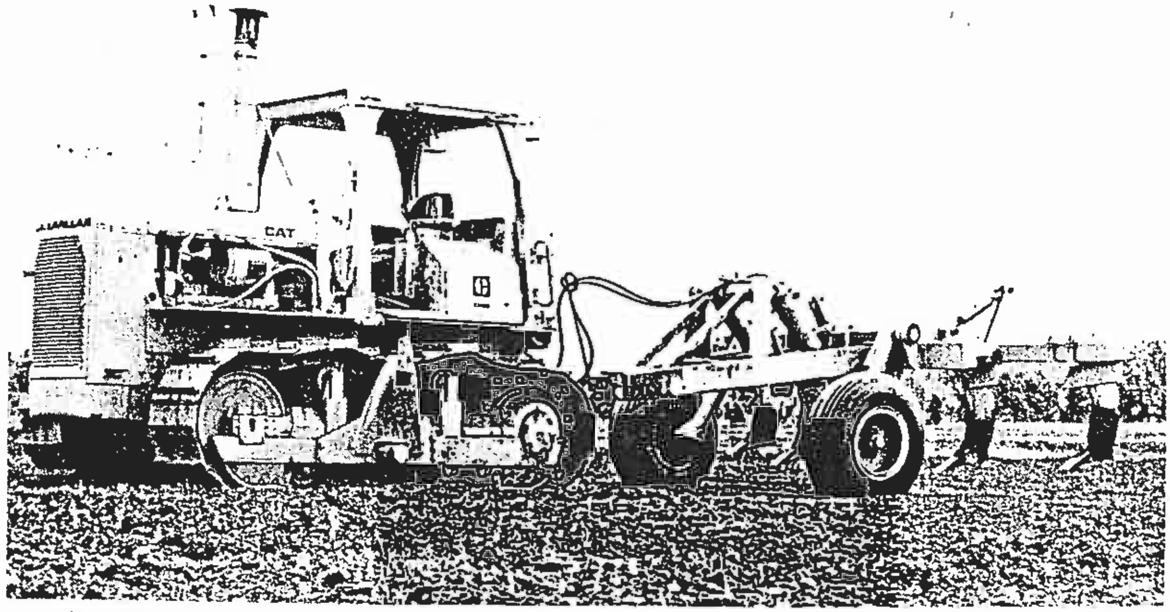
In conclusion, the development of the drainage channels and the networking of downdrains and/or gradient terraces into the drainage channels will provide a more controlled development of postmining drainages. During this process, rough grading and finish grading activities will be conducted. After all channels or other conveyances have been located or constructed and an area is finish graded, surface mechanical manipulations and/or minesoil reconstruction activities will begin.

Surface Mechanical Manipulations. Surface mechanical manipulations are conducted both prior to and after minesoil reconstruction activities and are critical to insuring that erosion is minimized and plant establishment maximized. This stabilization component is presented at this point in the surface stabilization program sequence because ripping operations may be conducted prior to minesoil reconstruction. Various surface mechanical manipulations will be carried out on reclaimed areas at Black Mesa to enhance surface stability and revegetation efforts. The primary surface mechanical manipulations or operations to be used are deep ripping, contour furrowing/disking, and drill seeding on the contour. Other types of mechanical manipulation that have proven useful in surface stability and revegetation efforts, and which may be used as optional or additional methods from time to time, include chisel plowing, slope or dozer tracking, contour ditching, land imprinting, and pitting.

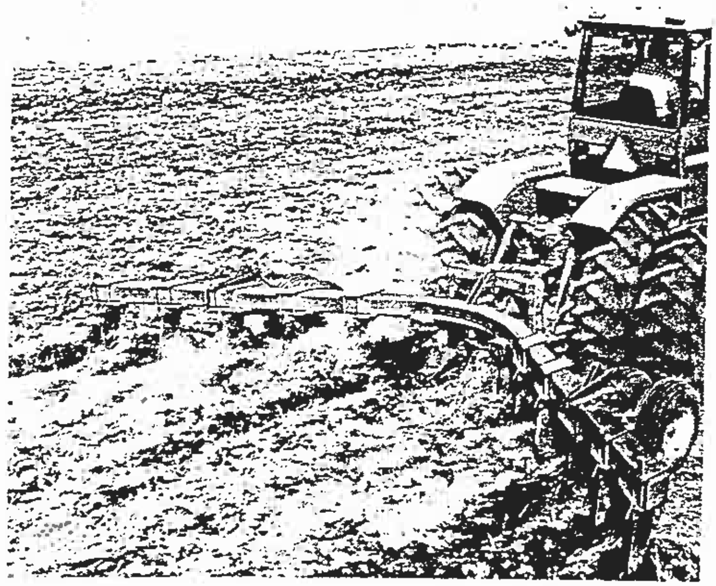
Examples of the types of ripping equipment to be used on Black Mesa are shown in Figure 10. A chisel plow, which may be used periodically in these operations, is also illustrated in Figure 10. The large modified offset disk used in contour furrowing/disking operations on Black Mesa is shown in Figure 11, as is the land surface configuration resulting from the operation. Examples of land imprinting and range pitting equipment are shown on Figures 12 and 13, respectively. Minesoil reconstruction activities, if not completed, will be conducted at this time.

The surface mechanical manipulations will enhance surface stability by creating a roughened surface and more open soil/subsoil profile that will also have reduced levels of compaction. The interface contact between the graded spoil and topsoil will also be benefited, reducing opportunities for slippage. The roughened surface will slow runoff and allow for increased infiltration, further reducing the opportunities for erosion. Since these operations are to be restricted to the contour, the above benefits will be maximized. The enhanced surface stability, reduced runoff, and increased infiltration will greatly benefit the establishment of a permanent and effective vegetative cover. Increased available soil moisture, improved rooting zone characteristics, increased rooting depths, and protection from erosive forces during establishment and development of the reclaimed plant communities are benefits that result from surface mechanical manipulations. These positive affects will better insure that the reclaimed plant communities will provide long term surface stability.

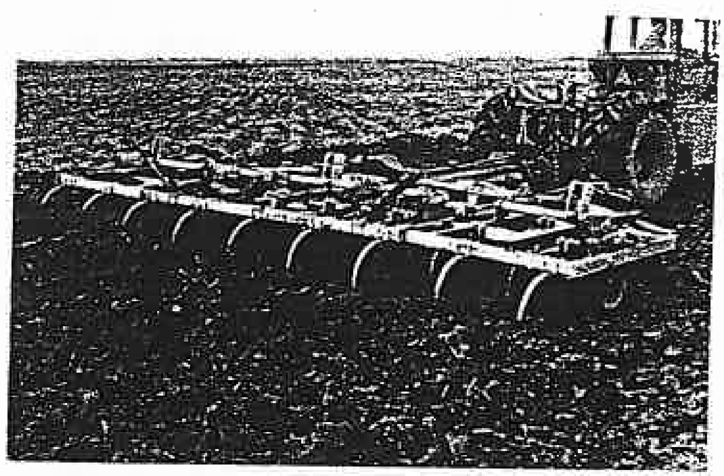
A detailed discussion of surface mechanical manipulations to be used at Black Mesa is presented in Chapter 22, Minesoil Reconstruction. Attachment A "Terrace Spacing Justification", presented later in this chapter, provides additional supporting information on the beneficial effects to surface stability provided by the primary surface mechanical operations to be employed at Black Mesa.



Heavy duty rippers mounted on a tool carrier for use with dozers or rubber tired tractors (Source: Rome Industries)

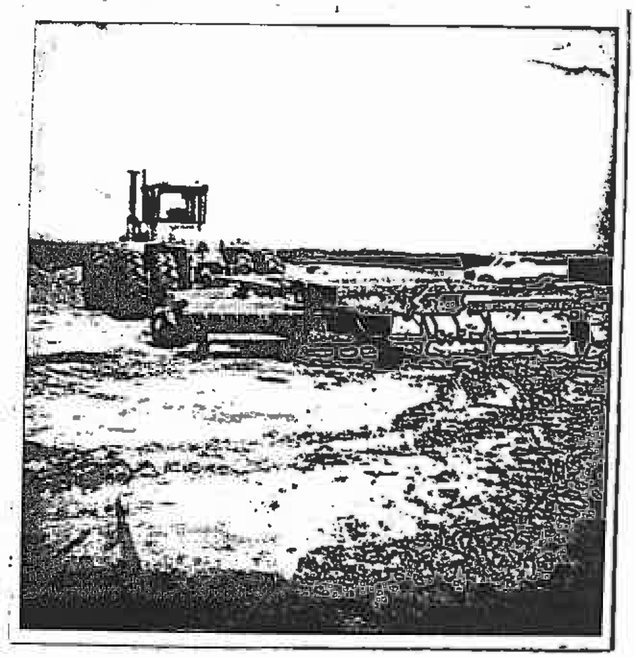


V-plow subsoilers used to shatter hardpans (Source: Larson 1980)



Heavy duty chisel plow with spring-loaded chisel shanks (Source: Larson 1980)

Figure 10 Examples of heavy duty ripping, subsoiling, and chisel plowing equipment



Modified offset disk used for contour furrowing at the Black Mesa and Kayenta Mines

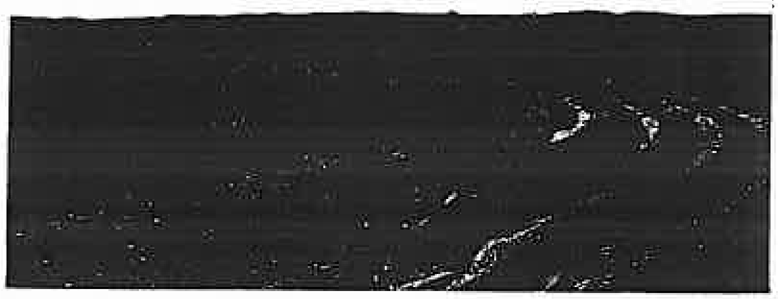
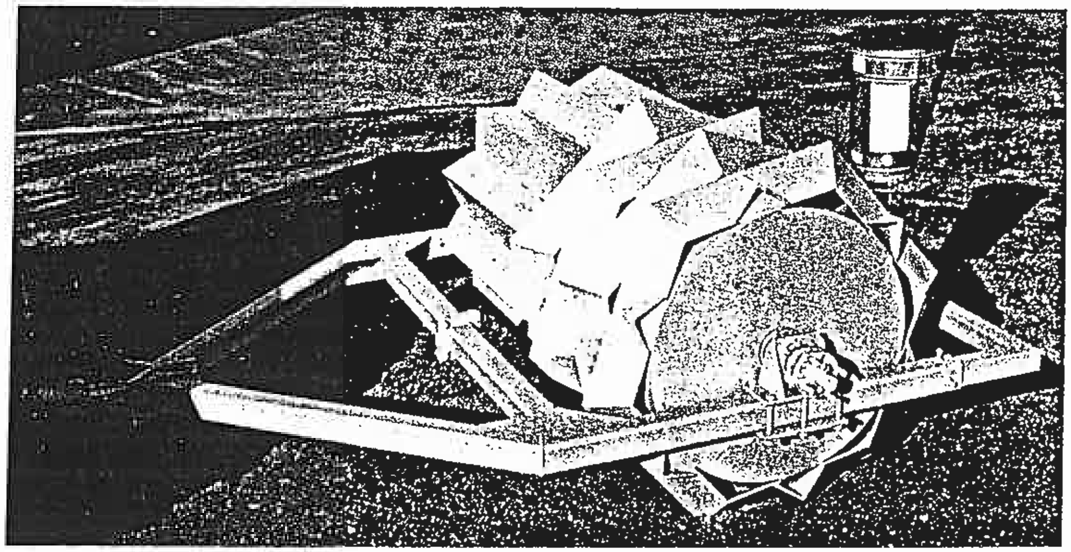
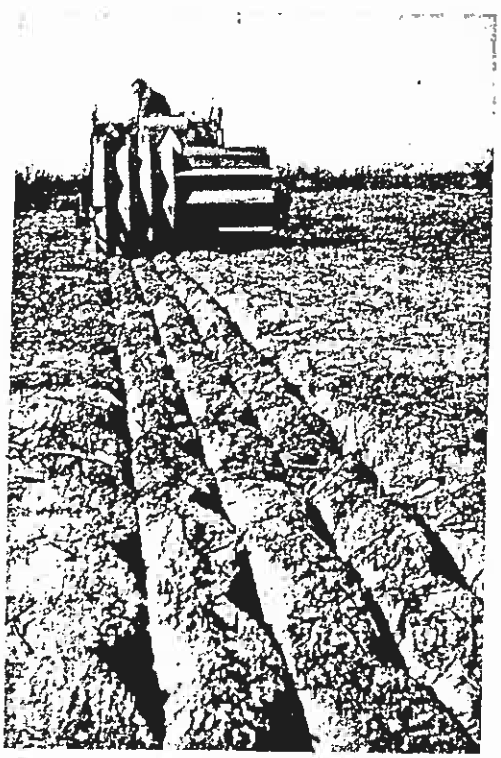


Figure 11 Contour furrowing implement and land surface configuration



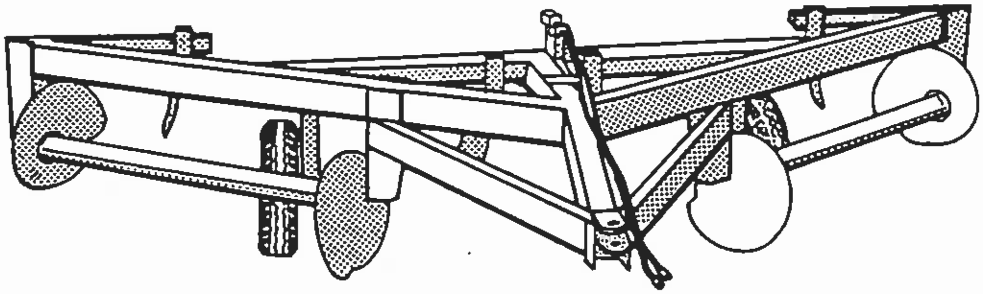
The Dixon Land Imprinter, a standard surface imprinting tool (Source: Laird Mfg.)



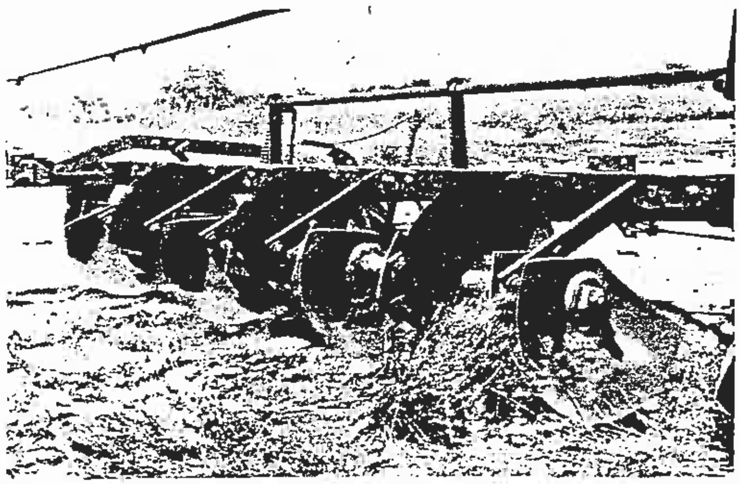
Land imprinter surface configuration

Established vegetation in land imprinter surface depressions

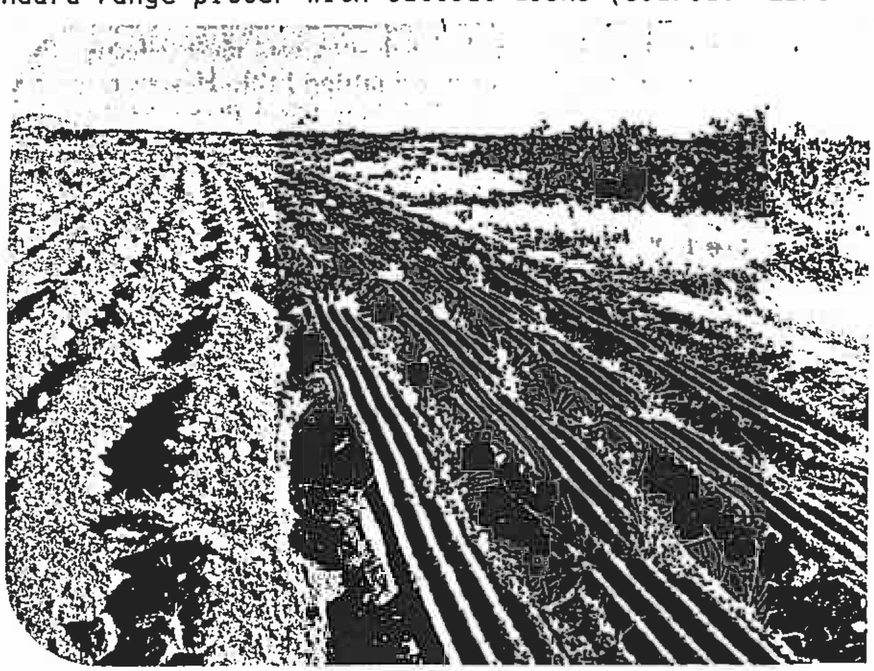
Figure 12 Standard land imprinting tool and surface configuration (Source: Laird Welding and Mfg. Works)



Standard range pitter with eccentric disks (Source: Larson 1980)



Standard range pitter with cuttout disks (Source: Larson 1980)



Surface configuration following range pitting (Source: Valentine 1971)

Figure 13 Standard range pitting equipment and surface configuration

Minesoil Reconstruction. PWCC's minesoil reconstruction plan (Chapter 22) is designed to insure that a suitable plant growth medium is reconstructed on graded spoils prior to revegetation. Specifications in the plan insure that suitable plant growth materials are identified and properly handled, and that physically and/or chemically unsuitable graded spoils are buried to a minimum depth of four feet. Implementation of the plan will enhance the rapid establishment of an effective vegetation cover and will provide the optimum potential for vegetal development (cover, productivity, and diversity). These vegetal attributes in turn promote surface stability in the postmining landscape. Specifications in the plan also insure that the most erosionally resistant suitable plant growth materials that are available are placed on areas where the erosion potential is the greatest (i.e., supplemental surface plant growth materials or residual soils with low "K" factors are placed on the steepest reclaimed slopes). See Attachment A to Chapter 26 for a detailed supporting discussion relating to this subject. Upon completion of minesoil reconstruction activities, appropriate surface protection measures are implemented.

Surface Protection Measures. Surface protection measures include surface stabilizers such as hay or straw mulch (either anchored or tackified), cover crop/stubble mulch, surface netting, organic fiber matting, geotextile fabrics, rock riprap, etc. These are primarily short term measures until the long term surface protection measure of a permanent and effective vegetative cover has established.

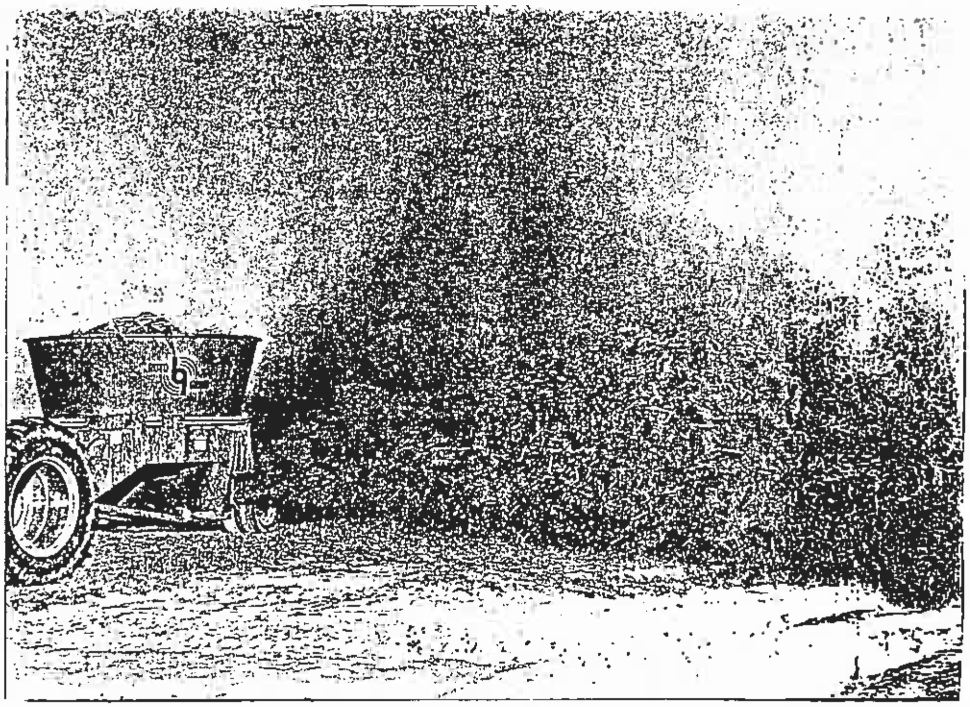
Surface protection measures control erosion by protecting the soil surface from raindrop impact and by reducing the velocity of overland flow. These measures also enhance the establishment and development of seedlings by providing an enhanced micro-environment with more uniform temperature and moisture regimes that benefit seed germination and seedling vigor. The increased soil water from reduced runoff and increased infiltration will continue to provide plant benefits during and after permanent vegetation establishment. These measures provide temporary protection from erosion during seed germination and seedling establishment on steeper slopes. Temporary and long term protection can also be provided by these measures in areas of concentrated flow or drainage control.

Surface protection measures can be applied to a wide range of soil surface conditions. Temporary protection can be provided for exposed soil surfaces in which permanent reclamation may be delayed. These areas include topsoil stockpiles, denuded areas, cut and fill slopes for roads and temporary diversions. These can be mulched and a temporary vegetative cover established by seeding with appropriate rapid growing annual plants. Permanent stabilization for these areas will be accomplished during final reclamation.

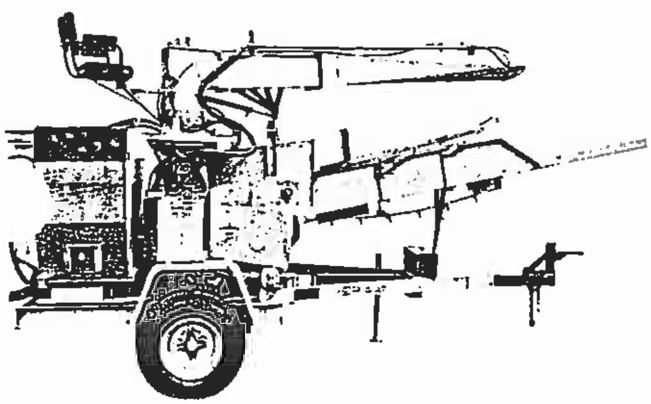
Mulching, either as an applied hay or straw mulch or as an established cover crop/stubble mulch, will be the primary means of temporary surface stabilization and protection while the permanent vegetative cover establishes. Mulching is to be used on all reclaimed acres. Figure 14 shows typical straw mulching equipment.

Attachment A "Terrace Spacing Justification", was developed as supporting documentation for the mulching practices (BTCA practices) used in conjunction with the terracing program - major components of the surface stabilization program. The USLE soil loss equation (Wischmeier and Smith, 1978), updated in a USDA-ARS revised program titled REVUSL (Simanton, 1987), was used in Attachment A exercise to estimate soil loss when terraces and other BTCA practices, including cover cropping and mulching, were applied to reclaimed lands. The soil loss estimates derived from the REVUSL program supported the validity of the proposed mulching and BTCA practices and documented their benefits. The values for factor C (cover and management factor) used in the soil loss estimates were developed through the use of the REVUSL program based on the expected level of cover and management affects resulting from cover cropping and mulching. The determined C factor values, which reflected a good level of effectiveness, were determined through inputs which represent actual reclamation procedures and site-specific conditions at Black Mesa.

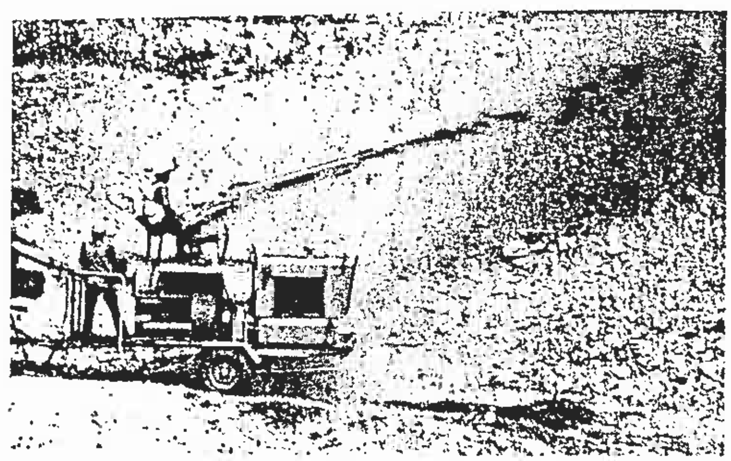
The primary mulching methods (straw or hay mulch or cover crop/stubble mulch) used on a reclaimed unit will be dependent on the timing of topsoil replacement, a requirement for a more immediate stabilizing cover, and the type of revegetation activities to be conducted. The detailed mulching plan (Mulching and Other Soil Stabilization Practices) and a discussion of the variables determining form and level of implementation is presented in Chapter 23, Revegetation Plan. In addition, Figure 1 in Chapter 23 and the accompanying discussion on Reclamation Sequencing and Seeding Methods should be reviewed simultaneously with the mulching plan.



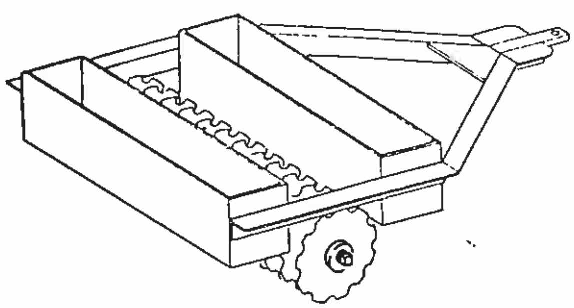
Large tub grinder type mulcher (Source: Burrows Enterprises, Inc.)



Standard power mulcher (Source: Larson 1980)



Mulch application using a power mulcher
(Source: Larson 1980)



Typical straw crimper for anchoring straw mulch
(Source: Finn Equipment Company)

Figure 14   Typical straw mulching and crimping equipment

Rock riprap will be used for a variety of general and specialty applications, including downdrain construction and the armoring of drainage and reclaimed stream channels where erosion potential may be high. It will also be used in the repair of rill and gully areas where it has been determined to be the most effective long-term mitigation measure. Important criteria for the proper application of this practice include selection of competent materials, proper sizing of the rock materials to be used in a particular application, and proper site preparation and placement of the rock. Additional information on the use of rock riprap and necessary design criteria may be found in Attachment B to this chapter under "General Riprap Considerations".

Surface netting, organic fiber netting, and geotextile fabrics include a variety of products available on the market at this time. Surface netting includes materials constructed from various synthetic materials or jute. Organic fiber matting includes shredded wood fiber, straw, coconut husks, or other organic materials that are held in place by netting. Geotextile fabrics, a relatively new area of erosion control materials, include synthetic woven fabrics used under rock riprap to prevent soil loss from scouring and surface erosion control mats developed from plastic strands that are woven into a complex web or mesh. While the effectiveness of the above materials is good, the cost per unit area is high due to material expense and the labor inputs required for installation. These materials will be used in concentrated flow areas or situations where intensive erosion control measures are required and will not be used outside of the manufacturer's design limitations or constraints for such materials.

With the exception of rock riprap, which is discussed in Attachment B, these measures are temporary surface protection measures and are not features of the postmining landform.

Following application of the appropriate surface protection measures, activities relating to establishment of effective cover and permanent vegetation will begin. An exception to this is when erosion control netting or matting is used. These areas are seeded before placement of the netting or matting.

Establishment of Effective Cover and Permanent Vegetation. The use of temporary stabilizing covers and establishment of permanent vegetation will insure that the reclaimed landscape is protected from erosion and will attain a stable surface configuration. This is achieved on permanently reclaimed areas by the establishment of an effective diverse and permanent vegetative cover, while the seeding of cover crops and temporary seed mixes will provide similar protection to temporarily reclaimed areas. The implementation of the previously discussed BTCA practices, which are conducted prior to final revegetation activities, provides the basis for the effective establishment and development of the vegetative cover. The permanent vegetative cover is one of the key components to the long term surface stability of the reclaimed landscape (see Attachment A to this chapter). Additionally, surface stability, important during the establishment and development phases of revegetation, will be enhanced during this period by the previously discussed supporting BTCA practices.

Chapter 23, Revegetation Plan, provides a detailed plan and discussion on the types of revegetation activities to be undertaken, when these activities will occur, and how these activities will be implemented to insure that the development of a permanent and effective vegetative cover is maximized. Planning and implementation factors relating to the "what, when, and how" of revegetation are critical to successful achievement of revegetation objectives.

To this end, the Revegetation Plan in Chapter 23 has been developed to address these factors in a detailed and realistic fashion. In Chapter 23, Figure 1 "Reclamation Sequencing and Summary of Revegetation Activities", and the accompanying discussion "Reclamation Sequencing and Seeding Methods", detail when and how the revegetation activities will be conducted on the reclaimed areas. The discussions concentrate on site and environmental conditions specific to Black Mesa and the adoption and application of revegetation BTCA practices best suited to the Black Mesa site and the type of operations conducted there. The types of plant materials selected and their combination into specific seed mixes and planting lists represents an additional effort to fine tune BTCA practices to the site-specific characteristics and environmental conditions at Black Mesa. This effort satisfies the "what" factor in revegetation planning and application.

The seed mixes contain a high percentage of grasses (approximately 65 percent of the composition) and the structural diversity provided by the overall mix will aid in effective dissipation of moderate flow energies related to overland flow, removal or filtering of sediment, and protection of the reclaimed surface from potential erosional impacts relating to the regional semi-arid climate. The potential diverse structure provided by the seed mix includes short grasses (e.g., galleta and blue grama), and a variety of mid-to-tall grasses (e.g., wheatgrasses, Russian wildrye, Indian ricegrass, alkali sacaton, sideoats grama, etc.). The forbs and shrubs included in the mix provide benefits in the mid to tall vegetation category and the woody plants provide added resistance to overland flows, especially in drainages. A number of species are sodformers or have a prostrate growth form. These include western wheatgrass, thickspike wheatgrass, pubescent wheatgrass, galleta, prostrate alfalfa, and blue grama.

In reclaimed drainages, there is a potential for increased vegetation growth, vigor, and stand diversity due to the availability of supplemental moisture. There are a number of areas that will be planted to shrubland or woodland habitat areas to enhance overall wildlife habitat and return areas to woodland dominated vegetation. The methods and plant materials used to establish these areas have been developed with consideration for surface stability and erosion protection as well as revegetation objectives.

Temporary stabilization will be achieved through the use of annual cover crops or the temporary stabilization mix as presented in Chapter 23, Appendix B. The temporary stabilization mix is to be used on selected areas that have not been permanently reclaimed but require a permanent vegetative cover. The use of pubescent, thickspike and western wheatgrasses plus Russian wildrye and yellow blossom sweetclover will provide an effective hydrologic cover. For areas requiring a protective cover for less than two years, a cover crop of annual grain will be seeded. When the temporary stabilizing cover has been established above areas that have been permanently reclaimed, it can also function as a vegetative filter strip.

Many of the revegetation methods and plant materials presented in Chapter 23 have been used in past reclamation efforts at Black Mesa. The current plan builds and improves on these past efforts. A review of Attachment A "Terrace Spacing Justification" found later in this chapter, shows the effectiveness of the permanent vegetation in maintaining long term surface stability. Proper management of the reclaimed lands following implementation of the postmining land uses will maintain an effective vegetative cover while enhancing the longevity of supporting BTCA practices.

Following completion of revegetation activities and addition of any necessary soil amendments (fertilizer), construction of any necessary linear detention or filtering structures is undertaken. Following this activity, or in areas where the revegetation activities have been completed, the reclaimed areas will enter into a maintenance and monitoring phase during the reclamation liability period. Following release of liability, the postmining land uses will be implemented. The following section discusses linear detention and filtering structures and is followed by the discussion on maintenance, management, and postmining land use.

<u>Linear Detention and Filtering Structures</u>. Linear detention and filtering structures will be used to help temporarily stabilize certain reclaimed areas during vegetation establishment, provide sediment control for small or localized disturbance areas, and as aids in rill and gully repair and maintenance activities. These structures may be used to satisfy a short term requirement (e.g., alternate flows during permanent vegetation establishment) or they may serve a longer term function (e.g., localized sediment control). However, these structures are not considered permanent and are oriented towards complimenting other practices. These structures generally lend themselves best to treatment of smaller or more localized sites.

Linear detention and filtering structures include filter fence, straw bale barrier, brush barrier, etc. These structures are temporary sediment barriers consisting of synthetic filter fabric, brush or straw bales placed along the contour of a slope. A filter fence is a linear filter barrier constructed of synthetic filter fabric, posts, and, depending on the strength of the fabric used, wire fence. Brush barriers are linear filter barriers which makes use of residue materials available from clearing and grubbing operations. Trenching and anchoring of the brush may be required for effectiveness. A straw bale barrier consists of a row of entrenched and anchored straw bales.

The structures are constructed on the contour perpendicular to the surface water flow. These measures slow sediment-laden water and cause it to pond, thus reducing its ability to transport sediment. Under these conditions, sediment will settle out of the water and deposit. The efficiency of a detention and filtering structure will depend on the amount of time the flow remains in the detention area. Larger size particles settle quickly while small size particles require a longer time to settle. Detention and filtering structures discussed within this section are designed to temporarily pond only two to three feet of water. In addition to detaining sediment laden water, various filter barriers are available for removing sediment from moving water. Filtering is accomplished by allowing the sediment laden water to flow slowly through the small pores of a filter material. Because of the small pore size, the majority of the soil particles are restricted and water is allowed to pass through the fabric or other filtering substrate.

Synthetic fabrics have become the dominant material used in the design of filtering structures. The fabrics, both woven and nonwoven, are permeable and have numerous small pores which trap sediment. These fabrics have a low permeability enabling the water to pool behind the filter structure. Because of this low permeability filter, structures will not be suitable for use where high concentrations of water occur such as in channels or gullies. Filter fabrics will trap all sand-size particles and 60 to 80 percent of silt and clay-size particles. Large particle sizes will tend to settle out before they are filtered, but the distinction is not necessary since all of these sizes will be removed in either case.

Filter structures can be easily combined with other sediment control practices to form a complete sediment control system or they may provide sediment control for a localized area. These structures are very effective in reducing the amount of suspended sediment generated from an area. Filter fabrics have a low permeability and are limited to situations where unconcentrated, overland flows are expected. In addition, these structures are especially appropriate in areas where the vegetation has not yet been established or in areas where disturbance needs to be minimized such as revegetated areas.

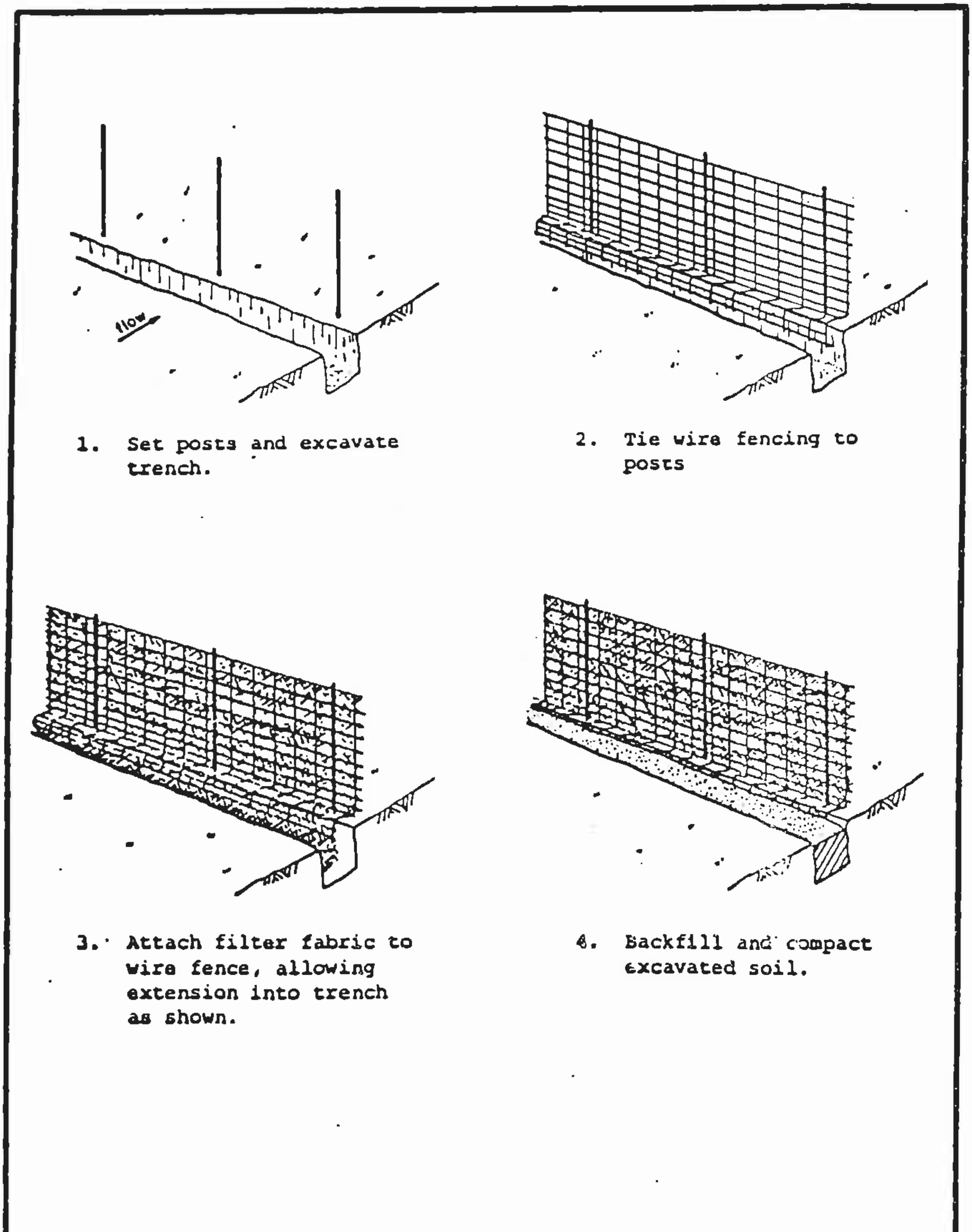
Filter Fence. A filter fence is a linear filter barrier constructed of filter fabric, posts, and depending on the strength of the fabric used, wire fence. The filter fabric structures are used where there is a need for temporary control of suspended solids in areas with low to moderate flows. It is the vertical barrier that intercepts surface runoff and sediment particles. Filter fence is constructed of a fabric supported in an upright position by posts and support mesh. The bottom end of the structure is buried in the ground to prevent runoff flowing beneath the fabric. The posts and wire mesh are the support elements while the fabric provides retention. Installation procedure as outlined by Simons et al., 1983, are given below. Figure 15 illustrates the building of a filter fence (Virginia Soil and Water Conservation Commission, 1980).

The following procedures are recommended to construct a filter fence:

1. Set wood or steel posts securely at intervals no greater than ten feet apart. Wood posts should be at least two inches in diameter; with steel, only the T-shaped posts should be used.
2. Fasten fence wire securely to the upstream side of the posts. Wire should extend into the soil a minimum of 2 inches, and be a minimum of 36 inches in height.
3. Excavate a trench six inches deep along the upstream base of the fence.
4. Staple or wire the filter to the fence, allowing the fabric to extend into the trench as shown in Figure 15. The fabric should not extend over 36 inches above original ground on the wire fence.
5. Backfill and compact the soil over the fabric extending into the trench.
6. If the filter fence is to be constructed across a ditch line or drainageway of low flow, the barrier should be of sufficient length to contain the design storm volume from the upland area.
7. The fence should be constructed parallel to the contours of the slope. The ends of the fence should bend upslope a sufficient distance to eliminate end flow.

It has been established that silt fences, when constructed and maintained properly, are effective in controlling levels of suspended solids in overland flow.

The "retention" efficiency of a silt fence was tested by Wyant (1980). The fabric retention efficiency of 75 percent measured during tests indicates that a large proportion of the sediment should be intercepted by the fence. The degree of the trapping potential of the fabric fence depends on the particle size groups in the overland flow.



Typical Filter Fence. (Virginia Soil and Water Conservation Commision, 1980).

FIGURE 15

In the situations where the required trapping efficiency of one fence is not achieved, the filter fence may be placed in series such that the cumulative retention efficiency will secure the needed water quality.

The selection of the filter fabric depends on the strength of the fabric sufficient to resist installation stresses and burst pressures when retaining sediment and water.

Straw Bale Barrier. A straw bale barrier used as a temporary sediment filter consist of a row of entrenched and anchored straw bales. Straw bale barriers are used as temporary sediment filters placed in areas of low overland flows, usually parallel to the contour. The bales are placed to reduce flow velocities resulting in sediment deposition. They may also be used as a barrier to divert or direct flow to a slope drain, sediment trap, or other control measure.

The installation procedure for a straw bale barrier as outlined by Simons et al. (1983) is given below.

The following procedures are utilized to construct a straw bale barrier:

1. Place bales tightly together. Drive sturdy wooden stakes or steel rods through each bale and into the ground to a depth sufficient to securely anchor the bales.
2. Wedge loose straw tightly between the bales.
3. Backfill and compact the excavated soil against the barrier, if necessary. Backfilled soil, if used, should conform to ground level on the downstream side and should be built up to four inches against the upstream side of the barrier.
4. The straw bale barrier should be constructed parallel to the contour of the slope. The ends of the barrier should bend upslope a sufficient distance to eliminate end flow.

Brush Barrier. A brush barrier is a linear filter barrier constructed of vegetative residue materials available from clearing and grubbing operations. The residue materials may be covered with synthetic filter fabric. Brush barriers are used as filtering structures in areas of overland flow to reduce levels of suspended solids in surface flows. The installation procedures for construction of brush filter barriers are similar to those given for the filter fence barriers.

Maintenance, Management, and Postmining Land Use. Management of reclaimed lands prior to bond release and implementation of the postmining land uses will be oriented towards remedial revegetation activities, maintenance of revegetated areas (where needed), activities related to stand development or specialized planting areas, and protection and management of reclaimed areas (fencing). Maintenance and management of reclaimed areas is discussed in detail in Chapter 23 "Revegetation Plan".

Upon release of reclamation liability, the postmining land uses will be implemented. The primary postmining land uses for the Black Mesa lease area are grazing of livestock and wildlife. The most intensive and extensive use for management considerations is livestock grazing. Under proper management of livestock grazing, both uses can be met and erosional stability will not be compromised. Thus, livestock grazing management will be synonymous with proper management for this discussion. A suggested grazing management plan is presented in Chapter 14, "Land Use". The plan details a recommended grazing management program for lands that have been released from reclamation liability and have been returned to the Tribes. If controlled grazing is to be carried out on any reclaimed lands that have not been released of bond and are under PWCC's control, a grazing management plan as presented in Chapter 14 will be developed and implemented.

The suggested grazing management plan stresses proper use and distribution of livestock in order to achieve sustained productivity of the resource and landform stability. Livestock distribution is enhanced by fencing and distribution of water. Any fencing installed for management of reclaimed lands, which is compatible with the grazing plan, will be retained. The distribution and number of watering sources on the postmine landscape will be enhanced from what existed prior to mining. The reader is directed to Chapter 6 and Chapter 14 for a detailed discussion of postmine water sources. A deferred rotation grazing system, as recommended, will insure proper use of forage plants and allow for periodic rest of pastures during the growing season. Thus, with basic plant physiological needs periodically met, the plant communities will be better able to sustain an effective vegetative cover while providing valuable forage resources for livestock and wildlife. This will in turn maintain long term stability of the reclaimed landscape.

Rill and Gully Plan

The following discussion will center on the identification of rills and gullies and measures used to address their formation so that the postmining land use and water quality are not adversely affected. The Watershed Structure Maintenance and Monitoring program presented in Attachment B to this chapter compliments the rill and gully plan presented here and should be reviewed simultaneously with this plan. Together they will insure that a complete effort will be undertaken to prevent, identify, and mitigate any rill and gully development.

Reclaimed areas will be monitored for rill and gully development during routine engineering and reclamation inspections and when revegetation sampling is conducted. Emphasis will be placed on periods following heavy snowmelt or rains. If rills or gullies are identified, the cause of their formation will be determined and documented. The cause will, in turn, provide the basis for (1) deciding whether or not remedial actions will be initiated, and (2) choosing the remedial activities. In this regard, it is important to note that the presence of rills and gullies is not necessarily an indication that active or significant erosion is occurring within a specific area. This fact was recognized by OSMRE in Directive No. REG-14 dated July 9, 1987, which was later rescinded by OSMRE.

Except in limited circumstances, the cause of rill and gully formation will be remedied and the rills and gullies will be repaired. In any event, rills and gullies which form in areas which have been regraded and topsoiled and which either (1) disrupt the approved postmining land use or the reestablishment of the vegetative cover, or (2) cause or contribute to a violation of water quality standards, will be filled, regraded, or otherwise stabilized; topsoil will be replaced; and the areas will be reseeded or replanted.

The locations of rill and gully areas, the causes of their formation, the type and extent of remedial action taken, and monitoring related to the remedial action will be documented in files maintained at the Black Mesa Complex. These files will be the same as the design files for the watershed in which the rills and gullies have formed. A rill and gully status report will be submitted to OSMRE by June 1 on an annual basis.

The cause of rill and gully erosion outside of designed drainageways, when such cause has been determined to be persistent and likely to contribute to continued erosion, will be remedied. Examples of rills or gullies where the cause may not be detrimental and, therefore, not need to be addressed include minor rills in newly planted areas caused by rainfall or snowmelt but not detrimental to the establishment of vegetation.

Rills and gullies for which the cause has been remedied may not be repaired by PWCC if (1) such repair would be detrimental to the overall reclamation effort in the areas where they have occurred, (2) they are no longer active after the cause has been remedied, (3) they will not interfere with the achievement of vegetation and water quality bond release standards, and (4) they are stable at bond release as judged by the following criteria:

(a) Rounding of channel sides;

(b) Discontinuance of channel expansion or extension;

(c) Extensive permanent establishment of vegetation on the sides and bottom of the channel;

(d) Lack of unanchored clumps of soil and vegetation that have fallen from channel sides;

(e) Discontinuance of down channel deposition of eroded materials;

(f) Establishment of a permanent vegetative cover on areas of erosional deposition;

(g) Accumulation of litter and organic matter in the channel.

The rill or gully may still be active if any of the above characteristics are present.

Surface Stabilization Program Summary

The foregoing presentation describes the methods and procedures that PWCC proposes to use to protect and stabilize all areas that have been regraded and covered with topsoil material or supplemental surface plant growth media. The elements of the program, including the application of advanced reclamation and engineering technology and follow-up monitoring and reporting commitments, insure the sustained, effective control of sheet and rill erosion caused by wind or water. Sustained and effective stabilization of the postmining land surface will, in turn, provide the basis for meeting the applicable reclamation performance standards and achieving the postmining land use goals. The program is also designed to provide the operator with the flexibility needed to effectively treat site-specific problematic areas, while providing the regulatory authority the necessary information to evaluate compliance and the success of the stabilization practices.

The surface stabilization program was developed on the basis of several important premises which validate the program components and design criteria, thus assuring that the program objectives are met. First, the underlying regional environmental and geomorphic processes that influence surface stability were acknowledged. The Black Mesa is situated in an area where these processes are complex and relatively extreme. Baseline and ongoing monitoring data collected to quantify these processes has allowed PWCC to take a realistic analytical approach to selecting the proper reclamation and engineering practices, and defining input parameters for engineering design. Second, the program was developed using experience gained from evaluating the response of landscapes reclaimed under past plans to processes previously mentioned. The data from the Small Watershed Studies and revegetation monitoring presented in this chapter strongly suggest that: 1) the hydrologic ground cover is progressing adequately; 2) reclaimed interior spoils are stable and yield less sediment from both overland and concentrated flows than similar undisturbed areas; and 3) limited areas (exterior spoil) which have higher relief ratios are stable with regard to sediment yield from overland flow, but sediment yield from uncontrolled channel flow can still exceed that of similar undisturbed areas. Finally, PWCC recognized the availability of additional advanced reclamation and engineering technology that can be applied to further insure that the applicable performance standards are met, soil loss is minimized, and the postmining land use goals are achieved. The intent here is to incorporate the appropriate technological components (Best Technology Currently Available) into the program, verify their design and application, and implement them in a logical manner to achieve a tolerable soil loss rate in order to sustain the positive characteristic of the reclaimed landscapes over time.

This chapter has outlined a program for minimizing overland flow and associated sheet erosion, and for establishing properly designed and implemented drainage systems to safely convey flow off reclaimed landscapes. The former objective is achieved by applying the appropriate technologies and BTCA practices outlined in the plan (e.g., deep ripping, mulching, contour furrowing, and timely revegetation) to promote infiltration, reduce raindrop impacts, reduce overland flow distances, and resist wind action. The latter objective is achieved by applying valid input parameters to design and install water conveyance systems that transport runoff from reclaimed lands in a safe and stable manner and which compliment the surrounding drainage patterns. The result is an integrated program that is consistent with the postmining land use objectives, provides for sustained conservation of the soil resource, and supports a determination of the feasibility of reclamation on the Black Mesa leasehold.

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ATTACHMENT A

TERRACE SPACING JUSTIFICATION

ATTACHMENT A

TERRACE SPACING JUSTIFICATION

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ATTACHMENT A

TERRACE SPACING JUSTIFICATION

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Introduction

The practice of constructing gradient terraces on farmland, rangeland, and reclaimed hillslopes has been and continues to be an effective practice to control runoff and erosion and provide landform stability. Terraces have been a component of Peabody Western Coal Company's (PWCC) Surface Stabilization Plan since permit approval in July 1990. The Surface Stabilization Plan is presented in Chapter 26. Terrace spacing justification originally included in Attachment A to that Chapter was based on conservative estimates and early versions of the Revised Universal Soil Loss Equation (RUSLE). In fact, RUSLE components were being formulated and evaluated by researchers as PWCC developed the initial terrace spacing justification and criteria. RUSLE has been refined and updated as Version 1.06 (Toy and Foster, 1998) for reclaimed lands. PWCC has also improved reclamation procedures and RUSLE input factors have been based on these procedures and actual field data or field conditions found in reclaimed areas.

The American Society of Agricultural Engineers (ASAE) promotes the use of slope length and gradient factors, as found in RUSLE, for calculating terrace spacing (ASAE, 1997). This method requires that horizontal terrace spacing not exceed the slope length determined for an allowable soil loss predicted by RUSLE. Another correlative requirement is that sufficient data is available to realistically apply RUSLE. The following sections present PWCC's current rationale for determining the horizontal spacing of gradient terraces on reclaimed hillslopes at the Black Mesa Complex.

Analysis Approach

The criteria for revised terrace spacing is similar to the approach presented in the original Attachment A to Chapter 26. This continued approach applies appropriate systems and Best Technology Currently Available (BTCA) practices that substantially reduce erosion from what would occur without the implementation and use of these systems. This approach shifts emphasis away from general values of "acceptable" or "tolerable" soil loss and concentrates on the effectiveness of conservation systems and BTCA practices in reducing erosion and providing landform stability.

There has been an increasing use of residual soils, red rock (scoria), or other similar suitable overburden materials on final graded box cuts and reduced highwalls at the Black Mesa Complex to enhance reclaimed slope stability and reduce the need for terraces. PWCC has reevaluated terrace spacing requirements based on field parameters, refined reclamation procedures, and Version 1.06 of RUSLE. The following sections discuss input factors, supporting information, and assumptions for revised terrace spacing and situations where terraces will not be required.

In order to apply this approach and determine acceptable horizontal spacing of gradient terraces, four reclamation scenarios were developed using RUSLE estimates for basis and comparison. These scenarios are presented following discussion of the RUSLE input factors. The first scenario reflects newly reclaimed areas with representative hillslope topography, typical plant growth medium or soiling materials including red rock (scoria) mediums, and seeding on the contour only. This reflects typical reclamation situations but with minimal BTCA practices. The second scenario includes similar soils and landform factors included in newly reclaimed area scenario one, but adds conservation system components and BTCA practices (terraces, ripping, contour furrowing, and mulching), and evaluates cover and roughness factors as a result of the BTCA practices. The third scenario includes similar reclamation situations found in scenarios one and two, but reflects established vegetation conditions anticipated at bond release (i.e., 10 or more years old), the weathering of contour furrows or other surface features, and the constructed terraces are in place and providing drainage and erosion control. Scenario 4 reflects year 10 if minimal initial BTCA practices were applied.

<u>Revised Universal Soil Loss Equation Factors</u>

The Revised Universal Soil Loss Equation is written as follows:

$$A = RKLSCP$$

where,

A = average annual soil loss in tons/acre/year

R = rainfall/runoff erosivity factor

K = soil erodibility factor

LS = hillslope length and steepness factor

C - cover-management factor

P = support practice factor

A general discussion of the various factors follows. Included in the discussion may be all or a portion of the basis used to develop factors for the RUSLE analysis. Further factor development or basis may be found in the four scenario discussions and their accompanying tables. A detailed discussion of RUSLE and the various factor inputs may be found in Guidelines for the Use of the Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands (Toy and Foster, 1998).

R-Factor. The R factor reflects the erosivity of rainfall and runoff for a given geographical area. The value of R increases as the amount and intensity of rainfall increases. Values for R have been computed for Arizona locations, and for the Black Mesa region, a value of 35 is representative. This value was used in all four scenarios and will be used in any future RUSLE calculations.

K-Factor. The K factor is an expression of the inherent erodibility of the soil or surface material at a particular site under standard experimental conditions. The value of K is a function of the particle size distribution, organic matter content, structure, and permeability of the soil or surface material.

K Factor for Topsoil. The K factors for topsoil salvage materials were determined as follows. Premine soil erodibility (K) values were determined for each projected mine pit disturbance area using Order 1/2 soil survey maps prepared by Intermountain Soils (IMS). These Order 1/2 maps (Volume 19, Drawing 85305A, Sheets 1-15) have a scale of 1"=400'. These maps were used to calculate the percentage of the different map units and soil series in each mine pit disturbance area as presented in Tables 15 and 16, respectively, as found in Appendix A of Volume 11A). This provides an estimate of the type and amount of soiling materials available for reclamation within the various pit areas.

Postmine K factor values are dependent upon premine soil types and projected topsoil salvage depths. IMS determined premine soil types and projected topsoil salvage depths as discussed in Appendix A (Volume 11A) and as shown on Drawings 85305A (Sheets 1-15, Volume 19) and 85305B (Sheets 1-15, Volumes 19 and 20). A K factor for each surface and subsurface horizon by soil series sample site was calculated using the RUSLE program and site specific analyses data contained in Attachments 2, 3, 4, and 5 of Appendix A (Volume 11A). The K Factor values were not adjusted for the volumetric rock fragment content as recommended by Toy and Foster (1998). Table 1 shows each sample site, soil horizon thickness, and the respective K factors. This information was used to determine weighted "K" values. These weighted values were summed for the entire topsoil salvage section to determine mean weighted postmine K values for each sample site and each soil series. The estimated disturbance areas for these soils types were multiplied by the respective "K" factor and topsoil salvage depth for the respective soil series to determine weighted postmine K values (Table 2). These weighted values were then summed to determine the mean weighted postmine K value of 0.38 for the entire projected Black Mesa leasehold disturbance area (Table 2). The mean postmine K value of 0.38 was utilized to determine the terrace spacing for a commonly anticipated reclaimed area soiling material as presented in the scenarios later in this attachment.

The upper limit K = 0.43 utilized in the scenarios represents the extreme postmine erodibility situation for soiling materials. The 0.43 K value was determined from information presented in Tables 1 and 2. Mean soil series K factor information presented in Table 2 shows 96 percent of the salvaged topsoil will have an erodibility value less than 0.43. Individual soil type and sample increment K factor values presented in Table 1 indicates 85 percent of the salvaged topsoil will have an erodibility value less than 0.43. The actual percentage of postmine K values less than 0.43 will range between 85 and 96 percent depending upon the degree of mixing which occurs during topsoil salvage, storage, and redistribution. K = 0.43 provides a conservative estimate.

K Factor for Supplemental Plant Growth Medium. Suitable overburden will be utilized as a surface plant growth medium (topsoil supplement) for reclamation of steep slope areas and to develop planting sites for cultural plants on the Black Mesa leasehold (see the Material Redistribution Plans section of Chapter 22). Suitable overburden is recommended primarily for its inherent stability, low erodibility potential, and as an appropriate

Table 1

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[1]

<u>Stop No. 27-108</u>: Begay

Depth (Inches)	0-3	3-13	13-33	33-50	50-71	71-86
Permeability[2]	2	2	3	2	2	2
Organic Matter(%)[3]	2.0	1.5	1.5	1.0	0.5	0.5
K Value	0.41	0.32	0.36	0.35	0.44	0.25

<u>Stop No. 12-12</u>: Begay

Depth (Inches)	0-3	3-9	9-21	21-35	35-59	59-83	83-112	112-137
Permeability	2	2	2	3	2	2	3	3
Organic Matter (%)	2.0	2.0	1.5	1.5	1.0	0.5	0.5	0.5
K Value	0.53	0.45	0.40	0.46	0.54	0.50	0.55	0.50

<u>Stop No. ISS-30079 - 12 Thru 16</u>:' Begay

Depth (Inches)	0-10	10-22	22-33	33-43	43-60
Permeability	2	2	2	2	2
Organic Matter (%)	2.0	1.5	1.0	1.0	0.5
Very Fine Sand (%)[4]	30	32	29	29	31
K Value	0.33	0.34	0.37	0.38	0.38

<u>Stop No. ISS-28979 - 1 thru 5</u>: Begay

Depth (Inches)	0-6	6-12	12-38	38-50	50-60
Permeability	2	2	2	2	3
Organic Mater (%)	2.0	1.5	1.5	1.0	0.5
Very Fine Sand (%)	23	24	24	25	31
K Value	0.29	0.30	0.31	0.30	0.39

<u>Stop No. ISS-28979 - 6 thru 9</u>: Begay

Depth (Inches)	0-2	2-26	26-52	52-65
Permeability	2	2	2	2
Organic Matter (%)	2.0	1.5	1.0	0.5
Very Fine Sand (%)	28	27	25	25
K Value	0.39	0.28	0.33	0.37

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[1/]

Stop No. ISS-28979 - 10 thru 14: Begay

Depth (Inches)	0-7	7-20	20-41	41-54	54-60
Permeability	2	2	2	2	2
Organic Matter (%)	2.0	1.5	1.0	0.5	0.5
Very Fine Sand (%)	23	24	26	26	28
K Value	0.34	0.32	0.35	0.35	0.31

Stop No. 19-5: Bond

Depth (Inches)	0-3	3-10	10-16
Permeability	2	3	3
Organic Matter (%)	2.0	1.5	1.0
K Value	0.49	0.45	0.42

Stop No. 12-48: Cahona

Depth (Inches)	0-2	2-10	10-25	25-39	39-71	71-88
Permeability	2	3	3	2	2	3
Organic Matter (%)	2.0	1.5	1.5	1.0	0.5	0.5
K Value	0.41	0.38	0.40	0.40	0.44	0.45

Stop No. 10-2: Cahona

Depth (Inches)	0-3	3-11	11-22	22-39	39-55
Permeability	2	2	3	3	3
Organic Matter (%)	2.0	1.5	1.5	1.0	0.5
K Value	0.61	0.47	0.47	0.40	0.28

Stop No. 121-224: Cahona

Depth (Inches)	0-2	2-4	4-12	12-20	20-38	38-54	54-77	77-102	102-119	119-141	141-171	171-186
Permeability	2	3	3	2	3	3	3	3	2	3	3	2
Organic Matter (%)	2.0	2.0	1.5	1.5	1.0	1.0	1.0	0.5	0.5	0.5	0.0	0.0
K Value	0.48	0.37	0.43	0.45	0.46	0.47	0.37	0.40	0.36	0.28	0.37	0.24

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[1]

<u>Stop No. 11-1</u>: Cahona

Depth (Inches)	0-3	3-15	15-23	23-48	48-83
Permeability	2	2	2	2	2
Organic Matter (%)	2.0	1.5	1.0	1.0	0.5
K Value	0.64	0.55	0.50	0.55	0.70

<u>Stop No. 19-61</u>: Cahona

Depth (Inches)	0-1	1-3	3-12	12-19	19-29	29-40	40-64
Permeability	2	2	2	2	2	2	2
Organic Matter (%)	2.0	2.0	1.5	1.5	1.0	1.0	0.5
K Value	0.42	0.34	0.27	0.34	0.27	0.25	0.13

<u>Stop No. 11-6</u>: Cahona

Depth (Inches)	0-3	3-9	9-18	18-42	42-61	61-73	73-83	83-97
Permeability	2	2	2	2	2	2	3	2
Organic Matter (%)	2.0	1.5	1.5	1.0	0.5	0.5	0.5	0.5
K Value	0.58	0.45	0.47	0.48	0.43	0.24	0.38	0.48

<u>Stop No. 11-67</u>: Cahona

Depth (Inches)	0-3	3-12	12-22	22-29	29-46	46-75	75-93
Permeability	2	2	2	2	2	2	2
Organic Matter (%)	2.0	1.5	1.5	1.0	1.0	0.5	0.5
K Value	0.53	0.47	0.39	0.41	0.43	0.48	0.32

<u>Stop No. ISS-29879 - 11 thru 14</u>: Cahona

Depth (Inches)	0-9	9-20	20-32	32-60
Permeability	3	2	2	5
Organic Matter (%)	1.5	1.5	1.0	0.5
Very Fine Sand (%)	30	34	28	18
K Value	0.38	0.35	0.28	0.33

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[1]

Stop No. ISS-29979 - 1 thru 4: Cahona

Depth (Inches)	0-7	7-24	24-45	45-60
Permeability	2	3	5	3
Organic Matter (%)	2.0	1.5	1.0	0.5
Very Fine Sand (%)	25	28	12	29
K Value	0.39	0.35	0.27	0.30

Stop No. ISS-2997 - 7 thru 10: Cahona

Depth (Inches)	0-10	10-22	22-35	35-46
Permeability	2	2	2	3
Organic Matter (%)	1.5	1.5	1.0	0.5
Very Fine Sand (%)	27	30	29	32
K Value	0.31	0.41	0.36	0.37

Stop No. ISS-29979 - 11 thru 14: Cahona

Depth (Inches)	0-10	10-17	17-30	30-40
Permeability	3	2	5	5
Organic Matter (%)	1.5	1.5	1.0	0.5
Very Fine Sand (%)	30	25	23	16
K Value	0.38	0.36	0.31	0.34

Stop No. ISS-2997 - 15 thru 18: Cahona

Depth (Inches)	0-10	10-26	26-39	39-60
Permeability	2	3	3	3
Organic Matter (%)	1.5	1.0	1.0	0.5
Very Fine Sand (%)	28	28	32	26
K Value	0.42	0.40	0.38	0.34

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[11]

Stop No. ISS-29879 - 18 thru 20: Dulce

Depth (Inches)	0-2	2-9	9-12
Permeability	2	3	2
Organic Matter (%)	2.0	1.5	1.5
Very Fine Sand (%)	22	31	23
Rocky Frag (% by vol)[5]	40	25	25
K Value	0.30	0.35	0.33

Stop No. ISS-300079 - 3 thru 5: Dulce

Depth (Inches)	0-1	1-7	7-12
Permeability	2	2	2
Organic Matter (%)	1.5	1.0	0.5
Very Fine Sand (%)	24	22	22
Rock Frag (% by vol)	40	25	25
K Value	0.35	0.34	0.35

Stop No. ISS-30079 - 6 thru 8: Dulce

Depth (Inches)	0-2	2-9	9-14
Permeability	2	2	2
Organic Matter (%)	2.0	1.5	1.0
Very Fine Sand (%)	22	28	28
Rock Frag (% by vol)	40	25	25
K Value	0.37	0.37	0.43

Stop No. 12-110: Dulce

Depth (Inches	0-1	1-6
Permeability	2	2
Organic Matter (%)	2.0	2.0
K Value	0.31	0.21

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[1]

Stop No. 12-263: Dulce

Depth (Inches)	0-2	2-7
Permeability	3	3
Organic Matter (%)	2.0	2.0
K Value	0.40	0.34

Stop No. 19-64: Las Lucas

Depth (Inches)	0-1	1-4	4-17	17-31
Permeability	2	5	5	3
Organic Matter (%)	2.0	2.0	1.5	1.5
K Value	0.36	0.34	0.32	0.33

Stop No. 14-13: Las Lucas

Depth (Inches)	0-5	5-20	20-38	38-59	59-96	96-110	110-132
Permeability	3	5	5	2	1	1	2
Organic Matter (%)	2.0	2.0	1.5	1.0	1.0	0.5	0.5
K Value	0.32	0.31	0.33	0.51	0.22	0.20	0.19

Stop No. 15-9: Las Lucas

Depth (Inches)	0-4	4-9	9-26	26-60	60-84	84-108	108-120
Permeability	2	2	3	4	3	2	3
Organic Matter (%)	2.0	2.0	1.5	1.0	0.5	0.5	0.5
K Value	0.33	0.33	0.38	0.39	0.34	0.22	0.29

Stop No. 15-9DSS: Las Lucas

Depth (Inches)	120-144	144-168	168-192	192-216	216-240	240-264
Permeability	3	3	2	2	3	2
Organic Matter (%)	0.5	0.0	0.0	0.0	0.0	0.0
K Value	0.35	0.32	0.25	0.27	0.36	0.35

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Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment [1]

Stop No. 12-111: Las Lucas

Depth (Inches)	120-144	144-168	168-192	192-216
Permeability	4	4	3	4
Organic Matter (%)	0.0	0.0	0.0	0.0
Very Fine Sand (%)	20	18	34	24
K Value	0.35	0.37	0.37	0.34

Stop No. 19-67: Las Lucas

Depth (Inches)	0-24	24-48	48-72	72-96
Permeability	3	2	3	3
Organic Matter (%)	1.5	1.0	1.0	0.5
Very Fine Sand (%)	27	25	27	26
K Value	0.38	0.30	0.34	0.39

Stop No. 19-69: Las Lucas

Depth (Inches)	0-24	24-48	48-72	72-96
Permeability	3	4	3	4
Organic Matter (%)	1.5	1.0	1.0	0.5
Very Fine Sand (%)	30	19	26	19
K Value	0.38	0.36	0.38	0.37

Stop No. ISS-28979 - 15 thru 18: Las Lucas

Depth (Inches)	0-10	10-22	22-40	40-60
Permeability	2	2	3	2
Organic Matter (%)	1.5	1.5	1.0	0.5
Very Fine Sand (%)	27	27	27	40
K Value	0.31	0.27	0.24	0.34

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment [1]

Stop No. ISS-28979 - 19 thru 22: Las Lucas

Depth (Inches)	0-8	8-19	19-43	43-60
Permeability	2	2	2	3
Organic Matter (%)	1.5	1.5	1.0	0.5
Very Fine Sand (%)	26	24	20	34
K Value	0.47	0.51	0.33	0.39

Stop No. ISS-29879 - 1 thru 5: Las Lucas

Depth (Inches)	0-8	8-24	24-36	36-46	46-60
Permeability	2	3	2	2	2
Organic Matter (%)	2.0	1.5	1.0	1.0	0.5
Very Fine Sand (%)	30	26	30	32	32
K Value	0.39	0.33	0.31	0.32	0.32

Stop No. ISS-29879 - 6 thru 10: Las Lucas

Depth (Inches)	0-10	10-30	30-40	40-50	50-60
Permeability	2	3	2	2	2
Organic Matter (%)	1.5	1.5	1.0	0.5	0.5
Very Fine Sand (%)	24	31	22	25	23
K Value	0.30	0.39	0.35	0.38	0.39

Stop No. 190-55: Oelop

Depth (Inches)	0-4	4-10	10-20	20-40	40-60	60-84	84-108	108-132	132-156
Permeability	2	2	3	5	4	5	5	5	5
Organic Matter (%)	2.0	2.0	1.5	1.5	1.0	0.5	0.5	0.5	0.0
K Value	0.38	0.29	0.33	0.29	0.32	0.37	0.39	0.38	0.34

Stop No. 12-259: Oelop

Depth (Inches)	0-3	3-7	7-13	13-28	28-55	55-72	72-96	96-132	132-156	156-180	180-210
Permeability	3	4	4	3	4	2	3	3	2	3	3
Organic Matter (%)	2.0	2.0	1.5	1.5	1.0	0.5	0.5	0.5	0.5	0.0	0.0
K Value	0.39	0.40	0.36	0.37	0.38	0.35	0.41	0.44	0.51	0.45	0.48

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Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment [1]

Stop No. 12-231: Oelop

Depth (Inches)	0-24	24-48	48-72	72-96	96-120	120-144	144-168
Permeability	4	4	3	3	2	3	3
Organic Matter (%)	1.5	1.0	1.0	0.5	0.5	0.5	0.0
Very Fine Sand (%)	25	22	32	31	28	35	31
K Value	0.33	0.33	0.36	0.32	0.33	0.38	0.35

Stop No. 5-1: Pulpit

Depth (Inches)	0-3	3-12	12-23	23-30
Permeability	2	2	3	3
Organic Matter (%)	2.0	1.5	1.5	1.0
K Value	0.59	0.43	0.41	0.43

Stop No. 13-14: San Mateo

Depth (Inches)	0-4	4-9	9-24	24-47	47-73	73-97	97-111	111-144	144-168
Permeability	2	3	4	3	2	3	2	2	2
Organic Matter (%)	2.0	1.5	1.5	1.0	1.0	0.5	0.5	0.5	0.0
K Value	0.53	0.49	0.40	0.43	0.42	0.52	0.50	0.44	0.45

Stop No. 19-65: San Mateo

Depth (Inches)	0-6	6-13	13-30	30-48	48-72	72-96
Permeability	4	3	2	3	5	5
Organic Matter (%)	2.0	1.5	1.5	1.0	0.5	0.5
K Value	0.35	0.28	0.19	0.39	0.40	0.40

Stop No. 19-68: San Mateo

Depth (Inches)	0-24	24-48	48-72	72-96
Permeability	3	4	3	3
Organic Matter (%)	1.5	1.0	1.0	0.5
Very Fine Sand (%)	20	16	25	24
K Value	0.36	0.37	0.38	0.37

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment [1]

Stop No. 12-213: Sharps

Depth (Inches)	0-2	2-5	5-10	10-17	17-24	24-31
Permeability	2	2	2	3	3	5
Organic Matter (%)	2.0	2.0	1.5	1.0	1.0	0.5
K Value	0.33	0.34	0.31	0.36	0.32	0.32

Stop No. 19-48: Sharps

Depth (Inches)	0-2	2-6	6-15	15-21	21-27
Permeability	2	3	4	3	5
Organic Matter (%)	2.0	2.0	1.5	1.0	0.5
K Value	0.46	0.41	0.38	0.33	0.26

Stop No. 12-54: Sharps

Depth (Inches)	0-2	2-5	5-11	11-27	27-34
Permeability	2	3	3	3	4
Organic Matter (%)	2.0	2.0	1.5	1.0	0.5
K Value	0.42	0.32	0.34	0.38	0.33

Stop No. 6-2: Sharps

Depth (Inches)	0-2	2-10	10-30
Permeability	2	2	2
Organic Matter (%)	2.0	2.0	1.0
K Value	0.60	0.69	0.54

Stop No. 27-41: Travessilla

Depth (Inches)	0-2	2-7
Permeability	2	2
Organic Matter (%)	1.5	1.0
K Value	0.25	0.14

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increment[1/]

Stop No. 12-66: Zyme

Depth (Inches)	0-1	1-3	3-6
Permeability	3	5	5
Organic Matter (%)	1.0	1.0	0.5
K Value	0.37	0.28	0.32

Stop No. 12-261: Zyme

Depth (Inches)	0-3	3-6
Permeability	5	5
Organic Matter (%)	1.0	0.5
K Value	0.33	0.38

Stop No. ISS-29879 - 15 thru 17: Zyme

Depth (Inches)	0-6	6-11	11-15
Permeability	5	5	5
Organic Matter (%)	1.0	0.5	0.5
Very Fine Sand (%)	12	5	10
Rock Frag (% by vol)	40	15	15
K Value	0.34	0.32	0.35

Stop No. ISS-30079 - 1 thru 2: Zyme

Depth (Inches)	0-5	5-8
Permeability	4	5
Organic Matter (%)	1.0	0.5
Very Fine Sand (%)	24	14
Rock Frag (% by vol)	40	15
K Value	0.32	0.28

Table 1 (Cont.)

Postmine Soil Erodibility (K) Factor Determination by

Soil Type and Sample Increments[1]

Stop No. ISS-30079 - 9 thru 11: Zyme

Depth (Inches)	0-8	8-13	13-16
Permeability	4	3	5
Organic Matter (%)	1.0	0.5	0.5
Very Fine Sand (%)	12	13	7
Rock Frag (% by vol)	40	15	15
K Value	0.37	0.35	0.34

Stop No. ISS-30079 - 17 thru 20: Zyme

Depth (Inches)	0-3	3-9	9-19	19-23
Permeability	3	3	5	2
Organic Matter (%)	1.0	0.5	0.5	0.5
Very Fine Sand (%)	21	20	9	20
Rock Frag (% by vol)	40	15	15	20
K Value	0.37	0.34	0.33	0.51

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[1] Textural analysis data is contained in Volume 11A, Appendix A, Attachments 2,3,4, and 5. Very fine sand data is presented in Volume 11A, Appendix A, Attachments 2 and 4. Soil structure for the postmine soil surface was assumed to be blocky, platy, or massive.

[2] Soil permeability was determined from guideline information presented in Trenholme (1985) and Nyenhuis (1988) whereby 1 - rapid; 2 - moderately rapid; 3 - moderate; 4 - moderately slow; and 5 - slow.

[3] Organic matter percentages were estimated based upon normal depth/organic carbon distribution patterns (Schafer et al., 1979) and historical postmine topsoil organic matter content sampling at Black Mesa/Kayenta whereby the mean organic matter percentages for 207 samples was 1.1 percent with a standard deviation of 0.6 percent.

[4] Very fine sand values were estimated by texture class using very fine sand/sand ratio information presented in Volume 11A, Appendix A. Attachments 2 and 4 whereby silty clay loam - 73 percent; silty clay - 67 percent; silt loam - 61 percent; loam - 58 percent; sandy clay loam-57 percent; clay loam - 57 percent; sandy loam - 41 percent; and clay - 40 percent.

[5] Rock fragment content (percent by volume) was estimated from typical series description data presented in Volume 11, Appendix A, Attachments 2 and 6.

Table 2

Mean Postmine Soil Erodibility (K) Factor Values by Soil Series, Disturbance Area, and Topsoil Salvage Depth

Soil Type	Map Unit Designation	Area (Acres)[1]	Salvage Depth[2] (feet)	K Value[3]
Bond	2B	74.9	1.0	0.45
Dulce	1A,1,1B,1C,1D,3A,3BC,3C,3D,3E	4)	4)	0.33[4]
Pulpit	5	493.3	2.5	0.44
Sharps	6,6A,6B,6C	451.0	2.5	0.40
Travessilla	7B,7C,7D,7E	4)	4)	0.17[4]
Cahona	10,10A,10B,10C	4990.8	5.0	0.38
Cahona	11,11A,11B,11C	806.0	10.0	0.41
Cahona	X11,X11A,X11B,X11C	326.7	7.6	0.40
Begay	12,12A,12B,12C	251.9	9.7	0.39
San Mateo	13A	182.4	14.7	0.40
Oelop	14A,14B	68.3	9.7	0.38
Las Lucas	15A	859.9	11.6	0.33
Zyme	3A,3BC,3C,3D,3E,7B,7C,7D,7E	4)	4)	0.34[4]
TOTAL		4014.2	7.78	0.38

[1]This information is presented in Volume 11A, Appendix A, Table 15.

[2]This information is presented in Volume 19, Drawing 85305A, Sheets 1-15.

[3]Weighted means for the soil series were calculated from data presented in Table 1.

[4]The Dulce and Travessilla soils will be salvaged on as an needed direct haul basis for replacement within key habitat, cultural plantings, or steep-slope reclamation areas (see Chapter 22, Material Redistribution Plan). Zyme soils may also be replaced within these unique reclamation areas because the soil comprises a complex map unit with Dulce and Travessialla.

plant growth medium for pinyon pine and other culturally significant plants. Rock fragments on the surface and in the surface layer will protect the plant growth medium from wind and water erosion. Rock fragments protect the soil from erosion mainly by attenuating raindrop impact energy, causing flow energy to be dissipated on nonerodible fragments, and slowing the velocity of surface runoff (McCormack et al., 1984). Rock fragments in the supplemental plant growth medium profile have been disregarded for factor K in RUSLE as recommended by Toy and Foster (1998). Rock fragments on the surface are accounted for in C factor calculations.

K factor values for typical suitable overburden materials (red rock) and suitable regraded spoil are shown in Table 3. The suitable overburden material values are derived from samples collected in reclaimed areas with established red rock sites. These red rock sites are in the J19, J21, N11, and N14 pit areas. Rock or coarse fragment volumetric content for the suitable overburden materials ranged from 50 percent to 75 percent. K factors for these materials averaged 0.27 and varied from .32 for clay loam red rock materials to .23 for sandy loam red rock materials. Sandy loam red rock materials are highly representative of the types of red rock areas established. However, the more conservative average K value of 0.27 was used in the scenarios. The K factor value of .29 for suitable regraded spoil represents a value determined from the averaged parameter information contained in the extensive PWCC spoil sampling database for regraded areas at the Kayenta Mine. Rock or coarse fragment volumetric content for the suitable regraded spoil material averaged 45 percent. Regraded spoil data has been included in annual Minesoil Reconstruction and Revegetation Activities Reports submitted to OSMRE (PCC, 1988; PCC, 1992; PWCC, 1993-2001).

LS-Factor. Erosion as influenced by topography is accounted for by the LS factor in RUSLE. The effects of a hillslope length factor (L) are combined with a hillslope gradient factor (S) in the calculated LS factor. Soil loss tends to increase as the length or gradient of a hillslope increases. As the length of a hillslope increases, total soil loss and soil loss per unit area increase as a result of progressive accumulation of runoff downslope. With an increase in hillslope gradient, velocity and erosivity of runoff increases. Hillslope lengths and gradients for the four scenarios are representative of those conditions that currently exist or are anticipated for reclaimed areas.

Table 3

K Factor Values for Typical Suitable Overburden Materials (Red Rock) and Suitable Regraded Spoil[1]

Material	Sand (%)	Silt (%)	Clay (%)	Silt & Very Fine Sand (%)	Texture[2]	Coarse Fragment (%)	Organic Matter (%)	Strc[3]	Perm[4]	K Factor
Sandy Loam Red Rock	66	20	14	32	SL	65	1	M/L	MR	0.23
Sandy Clay Loam Red Rock	55	22	23	35	SCL	75	1	M/L	M	0.25
Clay Loam Red Rock	35	34	31	48	CL	50	1	M/L	MS	0.32
Averge K Factor for Red Rock Materials										0.27
Suitable Regraded Spoil	46	25	29	37	CL	45	0	M/L	MS	0.29

[1]Suitable overburden material (red rock) information is from samples taken in established reclaimed sites in J19, J21, N11, and N14. Suitable regraded spoil material information was derived from the PWCC spoil sampling database for regraded areas at the Kayenta Mine.

[2]Texture: SL-sandy loam, SCL-sandy clay loam, CL-clay loam

[3]Structure: M/L-massive/loose

[4]Permeability: MR-moderately rapid, M-moderate, MS-moderately slow

C-Factor. The C factor (cover-management) reflects the effect of plants, soil covers including rock cover, soil biomass (roots and incorporated residue), and soil disturbing activities on soil loss. A sub-factor method is used to compute soil-loss ratios (SLR), which are the ratios of soil loss at any given time in the cover-management sequence to soil loss from the standard condition. The C value is the average soil loss ratio weighted by the distribution of rainfall EI (energy x intensity) during the year.

Inputs for the sub-factors were mostly derived from actual field data or conditions, with the remainder selected from the most appropriate options in the RUSLE sub-routine. The time-invariant method option was used in all runs and for all scenarios. This method was used because all scenarios represented a point in time, or conservative evaluation for comparison purposes. The specific input parameters or assumptions to determine C factors are discussed in the scenarios and the footnotes of the accompanying tables.

P-Factor. The P factor accounts for practices designed to reduce erosion. The C and P factors are closely allied in their importance. The P factor accounts for practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil. Mechanical practices used at the Black Mesa Complex including contour deep ripping, disking, and contour seeding are accounted for in the P factor calculation. The type of soiling materials also have an affect on factor P; less erosive soils (lower K factor values) retain contouring features over a longer period of time. These same soils may have more pronounced contouring features when initially developed. Specific P factor assumptions are presented under the scenario and table discussions.

Soil Loss Predictions

Soil loss predictions calculated from RUSLE were evaluated to aid in determining acceptable horizontal spacing of gradient terraces. Three reclamation scenarios were used to provide RUSLE estimates for comparison and development of terrace spacing criteria.

Scenario 1. This scenario evaluates soil loss on typical reclaimed hillslopes with soil or scoria cover and no BTCA practices except contour drill seeding. Table 4

TABLE 4

RUSLE Soil Loss Estimates for
Newly Reclaimed Hillslopes With No Conservation
Or BTCA* Practices Except Contour Drill Seeding (Scenario 1)

Slope Length (Feet)[1]	Slope Gradient (%)[2]	RUSLE FACTORS[3] R	K	LS	C	P	Estimated Soil Loss T/AC/YR
350	33	35	0.27	13.40	0.07	0.56	5.0
300	33	35	0.38	12.00	0.77	0.86	106
300	33	35	0.43	12.00	0.77	0.90	125
750	25	35	0.27	16.00	0.07	0.56	5.9
400	25	35	0.38	10.63	0.77	0.86	94
400	25	35	0.43	10.63	0.77	0.90	111
500	20	35	0.38	9.23	0.77	0.86	81
500	20	35	0.43	9.23	0.77	0.90	96
600	15	35	0.38	6.86	0.77	0.86	61
600	15	35	0.43	6.86	0.77	0.90	72
800	10	35	0.38	4.17	0.77	0.86	37
800	10	35	0.43	4.17	0.77	0.90	42

*BTCA = Best Technology Currently Available

[1] Typical slope lengths corresponding to slope gradients found in reclaimed areas.

[2] Typical slope gradients found in newly reclaimed areas.

[3] Basis for RUSLE subfactors

R = Rainfall erosivity factor for the Black Mesa region

K = Soil erosivity factor

K = 0.27 = Average for scoria derived materials.

K = 0.38 = Typical soiling material

K = 0.43 = More erosive soiling material with higher silt and very fine sand

LS = Hillslope length and gradient factor

Variable based on the combination of gradient and slope length

C = Cover-management factors

C = 0.07 = Scoria material with average 49 percent rock cover, not ripped, seeded on contour, some surface roughness

C = 0.77 = Soiling material with minimal rock cover (1.5 percent), no BTCA except contour seeding

P = Support-practice factor

P = 0.56 = Minimal contouring and roughness effects for scoria materials

P = 0.86 = Minimal contouring effects on typical soils (K = 0.38)

P = 0.90 = Minimal contouring effects on more erosive soils (K = 0.43) illustrates the resulting estimated soil loss when evaluated under Scenario 1. As can be seen in Table 4, soil loss is high for all hillslope and gradient combinations except where scoria materials (K = 0.27) are used as a cover/plant growth medium. The more erosive soiling material (K = 0.43) has the highest soil loss estimates. The scoria material has a high rock content and a fairly rough surface configuration resulting in a low C factor of 0.07 and a P factor of 0.56. The more typical soiling materials have much higher C factors due to no cover other than a low rock cover of 1.3 percent and very little surface roughness. The P factors for the scoria soils are low due to some contouring but principally from roughness. Again, Scenario 1 demonstrates resulting soil loss with minimal BTCA practices applied.

Scenario 2. Scenario 2 addresses new reclamation of hillslopes where various conservation measures and BTCA practices have been applied (Table 5). Slope lengths reflect the placement of terraces. The exception to this is the 33 percent slope with scoria that is 350 feet long and the 25 percent slope with scoria that is 750 feet long. The scoria rock cover and the contoured surface roughness from ripping results in very low soil loss levels and thus terraces are not required. The more typical soils (K = 0.38 and K = 0.43) also have low soil loss estimates resulting from various conservation and BTCA practices. The conservation and BTCA practices reflect current procedures applied to reclaimed areas at the Black Mesa Complex. These include ripping and deep furrow disking on the contour, seeding of a permanent seed mix, application of an anchored hay mulch at two tons per acre on non-scoria soils (K = 0.38 and K = 0.43), and placement of terraces to reduce slope length.

The low C and P factors of 0.034 and 0.28, respectively, for scoria material reflect the high percentage of rock cover (field measured average of 49 percent) and the very rough field condition following contour ripping. The C factor of 0.05 for soils with K = 0.38 reflects a surface cover of 58.5 percent (57.2 percent mulch and 1.3 percent rock cover) based on field measurements from a 1999 reclaimed area in J19 that was hay mulched at two tons per acre. The K = 0.38 soils have a higher random roughness than K = 0.43 soils since surface features are more prevalent and not as impacted by equipment operations resulting in a slightly lower C factor for the K = 0.38 soils. The lower P factors for soils where K = 0.38 also reflect greater ridge height and contouring features than the K = 0.43 soils. Consequently, soils with K = 0.43 have greater C factor values and P

TABLE 5

RUSLE Soil Loss Estimates for
Newly Reclaimed Hillslopes With Installed Terraces
and Conservation and BTCA* Practices Applied (Scenario 2)

Slope Length (Feet)[1]	Slope Gradient (%)[2]	RUSLE FACTORS[3] R	K	LS	C	P	Estimated Soil Loss T/AC/YR
350	33	35	0.27	13.40	0.034	0.28	1.2
200	33	35	0.38	9.14	0.05	0.36	2.2
200	33	35	0.43	9.14	0.055	0.39	3.0
750	25	35	0.27	16.00	0.034	0.28	1.4
300	25	35	0.38	8.82	0.05	0.29	1.7
250	25	35	0.43	7.83	0.055	0.40	2.6
350	20	35	0.38	7.38	0.05	0.28	1.4
300	20	35	0.43	6.70	0.055	0.41	2.3
450	15	35	0.38	5.79	0.05	0.31	1.2
400	15	35	0.43	5.41	0.055	0.43	1.9
800	10	35	0.38	4.17	0.05	0.34	1.0
800	10	35	0.43	4.17	0.055	0.46	1.6

*BTCA = Best Technology Currently Available

[1] Typical slope lengths corresponding to slope gradients found in reclaimed areas.

[2] Typical slope gradients found in newly reclaimed areas.

[3] Basis for RUSLE subfactors

R = Rainfall erosivity factor for the Black Mesa region

K = Soil erosivity factor

K = 0.27 = Average for scoria derived materials.

K = 0.38 = Typical soiling material

K = 0.43 = More erosive soiling material with higher silt and very fine sand

LS = Hillslope length and gradient factor

Variable based on the combination of gradient and slope length

C = Cover-management factor

The C factor varies based on the amount of cover and the type and configuration of surface roughness.

P = Support-practice factor

The P factor varies based on the type or degree of tillage practice, contouring, or other surface configuration patterns and the results of the practices relative to the type of soiling materials used.

factor values because surface roughness, ridge heights, and contouring affects are reduced due to soil textural characteristics and equipment operations. The mulch cover is similar for soils with K = 0.38 or K = 0.43. Slope gradient also has an affect on the P factor.

Scenario 3. The soil loss estimates in the third scenario (Table 6) reflect permanently reclaimed hillslopes at year ten. They also reflect the previous application of a variety of conservation and BTCA practices. Soils or plant growth medium include scoria derived materials (K = 0.27) and more typical soiling materials (K = 0.38 and K = 0.43).

The C factor of 0.039 for the scoria areas reflects potential vegetation cover and residual rock cover based on sampling of several scoria areas reclaimed at the Kayenta Mine in the last several years. The C factor for scoria areas is based on 14 percent non-stratified vegetation cover and 39 percent rock and residue cover, but is also heavily influenced by the remaining good surface roughness. Ridges also influence the P factor of 0.8 and the contouring effects remaining as a result of this more resistant material. Where scoria materials are used, soil loss estimates are low even for very long slopes, and thus terraces are not required.

The C factors for soils with K = 0.38 and K = 0.43 were derived from spring 1998 vegetation sample data for the Black Mesa Complex. Precipitation prior to the sampling was near average. The data were averaged from eight large random sample units located in reclaimed areas from all active coal resource areas of the Complex. Many of the units contained vegetation more than ten years old, and a wide variety of soils and topography were present in the sample units. The resulting cover values included 30 percent non-stratified vegetation cover with 25 percent rock and residue cover. Annual production averaged 960 pounds per acre. The C factor for soils with K = 0.38 is 0.059 reflecting the above cover and production characteristics, but also considers residual surface roughness features. The C factor for soils with K = 0.43 is 0.077 considering the same cover and production values, but with less surface roughness due to more weathering effects for these types of soils. The P factor for both soiling materials equals 1, or no contouring affects remaining. This is a conservative estimate for P since many reclaimed areas retain some contouring and ridge features ten or more years after reclamation. Also, because seeding operations are conducted on the contour and contour

TABLE 6

RUSLE Soil Loss Estimates for
Permanently Reclaimed Hillslopes at Year 10, Conservation and BTCA* Practices Applied and Terraces Installed; No Terraces on K = 0.27 Material (Scenario 3)

Slope Length (Feet)[1]	Slope Gradient (%)[2]	RUSLE FACTORS[3]					Estimated Soil Loss T/AC/YR
		R	K	LS	C	P	
350	33	35	0.27	13.40	0.039	0.8	3.4
200	33	35	0.38	9.14	0.059	1	7.2
150	33	35	0.43	7.52	0.077	1	8.7
750	25	35	0.27	16.00	0.039	0.8	4.0
300	25	35	0.38	8.82	0.059	1	6.9
200	25	35	0.43	6.77	0.077	1	7.8
350	20	35	0.38	7.38	0.059	1	5.8
250	20	35	0.43	5.98	0.077	1	6.9
450	15	35	0.38	5.79	0.059	1	4.5
300	15	35	0.43	5.00	0.077	1	5.8
600	12	35	0.38	4.85	0.059	1	3.8
600	12	35	0.43	4.85	0.077	1	5.6
800	10	35	0.38	4.17	0.059	1	3.3
800	10	35	0.43	4.17	0.077	1	4.8

*BTCA = Best Technology Currently Available

[1] Typical slope lengths corresponding to slope gradients found in reclaimed areas.

[2] Typical slope gradients found in established and newly reclaimed areas.

[3] Basis for RUSLE subfactors

R = Rainfall erosivity factor for the Black Mesa region

K = Soil erosivity factor

K = 0.27 = Average for scoria derived materials.

K = 0.38 = Typical soiling material

K = 0.43 = More erosive soiling material with higher silt and very fine sand

LS = Hillslope length and gradient factor

Variable based on the combination of gradient and slope length

C = Cover-management factor

The C factor varies based on the amount of cover and the type and configuration of surface roughness.

P = Support-practice factor

The P factor varies based on the type or degree of tillage practice, contouring, or other surface configuration patterns and the results of the practices relative to the type of soiling materials used.

furrows provide areas of enhanced moisture during vegetation establishment, vegetation typically becomes oriented in contour strips.

Scenario 4. The soil loss estimates in the fourth scenario (Table 7) reflect permanently reclaimed hillslopes at year ten, but with no application of the variety of conservation and BTCA practices in Scenario 3. This scenario is presented to illustrate the amount of soil loss that would occur if no terraces, conservation, or BTCA practices except establishment of vegetation were present. In comparing the results of Table 6 and Table 7, it can be seen that a substantial reduction in soil loss will occur with installed terraces and applied conservation and BTCA practices.

Terrace Spacing

The spacing of terraces will be based on the slope length, slope gradient, RUSLE factors, and RUSLE soil loss estimates presented in Table 6. The spacing will be partially dependent on the type of soiling materials or plant growth medium. As can be seen, hillslopes covered with scoria-derived materials have low soil loss estimates regardless of hillslope gradients and lengths. Hence, terraces will not be used where scoria materials are placed. Scoria materials may be placed on portions of slopes to reduce the number of required terraces. For materials other than scoria, slope gradient will be a significant factor in the spacing, as will the type of soiling materials. The cover-management factor (C) presented in Table 6 has been determined from extensive data and should accurately reflect the potential long-term cover. Terrace spacing for soiling materials with K approximating 0.43 (more erosive soils with higher silt and very fine sand) will be reduced when compared to areas with slopes soiled with materials approximating K = 0.38. In some cases, slopes of 15 percent or less will not require terraces and terraces will not be required for any areas with slopes 10 percent or less.

Table 5 is based on initial reclamation and considers slope lengths based on installed terraces and applied BTCA and conservation practices. Comparing Tables 5 and 6 shows that terraces could be spaced farther apart and still achieve low soil losses. Applied BTCA practices greatly influence surface roughness and contouring features and have a resulting lowering effect on the C and P factors for initial reclamation. These effects

TABLE 7

RUSLE Soil Loss Estimates for Permanently Reclaimed Hillslopes at Year 10 With No Installed Terraces, Conservation, or BTCA* Practices Applied at Initial Reclamation Except Contour Seeding (Scenario 4)

Slope Length (Feet)[1]	Slope Gradient (%)[2]	RUSLE FACTORS[3]					Estimated Soil Loss T/AC/YR
		R	K	LS	C	P	
300	33	35	0.38	12.00	0.18	1	28.7
300	33	35	0.43	12.00	0.18	1	32.5
400	25	35	0.38	10.63	0.18	1	25.4
400	25	35	0.43	10.63	0.18	1	28.8
500	20	35	0.38	9.23	0.18	1	22.1
500	20	35	0.43	9.23	0.18	1	25.0
600	15	35	0.38	6.86	0.18	1	16.4
600	15	35	0.43	6.86	0.18	1	18.6
800	10	35	0.38	4.17	0.18	1	10.0
800	10	35	0.43	4.17	0.18	1	11.3

*BTCA = Best Technology Currently Available

[1] Typical slope lengths corresponding to slope gradients found in reclaimed areas.

[2] Typical slope gradients found in established and newly reclaimed areas.

[3] Basis for RUSLE subfactors

R = Rainfall erosivity factor for the Black Mesa region

K = Soil erosivity factor

K = 0.38 = Typical soiling material

K = 0.43 = More erosive soiling material with higher silt and very fine sand

LS = Hillslope length and gradient factor

Variable based on the combination of gradient and slope length

C = 0.18 = Cover management factor.

The C factor of 0.18 reflects reduced permanent cover and production because of limited initial BTCA and conservation practices applied.

P = 1 = Support-practice factor

The P factor of 1 reflects little or no remaining contouring or other surface features remaining.

are gradually reduced over time and P will approach 1. Therefore, determining terrace spacing on the basis of factors presented in Table 6 is a more realistic approach for long-term stability evaluations.

The application of conservation measures and BTCA practices such as terraces, contour furrowing, seeding, and hay mulching results in a significant reduction in soil loss both in newly reclaimed areas and reclaimed areas ten or more years old. For new reclamation with typical soiling materials, soil loss is often reduced over 95 percent on hillslopes where BTCA practices have been applied and terraces installed (Table 5) compared to hillslopes with no practices (Table 4). As noted previously, terrace spacing will be based on cover and surface configurations more typical of long term conditions. Thus, permanently reclaimed lands ten or more years old with applied BTCA practices and terraces installed (Table 6) are estimated to have greater than a 70 percent reduction in soil loss compared to permanently reclaimed lands with little or no BTCA practices and no terraces installed (Table 7). The cover-management factor (C) used in Table 7 evaluations is based on reduced cover and productivity as a result of increased soil loss and reduced landform stability.

Based on the above analyses and the concept of substantial reductions in soil loss, the following horizontal spacings of gradient terraces for corresponding slopes and soil types K = 0.38 and K = 0.43 are shown below. Horizontal spacing will be interpolated for intermediate gradients. Terraces are not required for scoria derived materials or other plant growth medium with K values of 0.27 or less. RUSLE allows input of field data or measurements to more accurately estimate soil loss or determine the affects of applied conservation or BTCA practices. PWCC may use RUSLE to adjust terrace spacing when specific data for K factors or other information to adjust input factors are available. The information will be documented and appropriately filed at the mine site. Unless based on specific field measurements to verify K factor or other values, the standard spacing assumptions will be based on the soil type K = 0.43 horizontal spacing shown below.

Soil Type K = 0.38 (comparison spacing)

Horizontal Spacing (ft)[1]	Slope Gradient[2]
200	33
300	25
350	20
450	15
800	10

Soil Type K = 0.43 (standard spacing)

Horizontal Spacing (ft)[1]	Slope Gradient[2]
150	33
200	25
250	20
300	15
800	10

[1] Maximum distance between terraces for a corresponding gradient.

[2] Horizontal spacing will be interpolated for intermediate gradients.

Summary

Revised terrace spacing for Black Mesa Complex reclaimed lands will be based on the approach for slope lengths, corresponding gradients, and soil type K = 0.43 soils as presented in Table 6. The evaluations are based on typical reclamation scenarios and practices for the Black Mesa Complex. Factors are supported by field measurements and data, observation, and operating experience. The terrace spacing associated with conservation and BTCA practices will significantly reduce soil loss and enhance landform stability compared to no installed terraces or applied practices. RUSLE may be used to further adjust terrace spacing based on documented field data or measurements. The widened terrace spacing, combined with the use of scoria material on slopes, will reduce the number of required terraces from that presented in the previous Attachment A to Chapter 26.

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ATTACHMENT B

RECLAMATION SURFACE STABILIZATION DESIGN HANDBOOK

ATTACHMENT B

RECLAMATION SURFACE STABILIZATION DESIGN HANDBOOK

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RECLAMATION SURFACE STABILIZATION DESIGN HANDBOOK

Introduction

The final postmining landform achieved in the field through backfilling and grading activities is a result of careful planning and implementation by the reclamation, engineering, and operations departments. This design handbook contains guidelines for establishing drainage systems to stabilize the reclaimed surfaces in the postmining landform. These guidelines will be used by Peabody's Engineering Department under the direct supervision of a qualified Registered Professional Engineer to design the postmining conveyance channels and grade control structures, by Peabody's Reclamation Department to implement and construct these structures, by the OSMRE's Technical Staff to review and approve Peabody's Mining Permit, and by OSMRE's Enforcement Staff for guidance during field inspections and to evaluate reclamation bond release applications after the appropriate bond liability period and performance standards have been satisfied.

This surface stabilization design handbook applies BTCA practices to the typical conditions anticipated to be encountered during the reclamation stage of the mining operations. In addition, this handbook identifies the typical conveyance and grade control structures, design and construction procedures and contains a commitment to apply these designs to control drainage in reclaimed areas. Also included is a typical example of an "engineered" reclaimed watershed and the associated worksheets and information which would be available at the mine site for review during an OSMRE inspection. This will ensure that the design methods approved in the Permit are being followed in the field.

Surface Stabilization BTCA Practices Summary

During mining and reclamation operations, sedimentation ponds will be the primary method used to control runoff and additional contributions of sediment from the permit area. With the start of reclamation operations and during the bond liability period, other sediment control methods will be utilized individually or in combination to assist in the stabilization of the reclaimed areas and the development of a postmining drainage system which is compatible with the postmining land use. Reclamation activities at the Black Mesa and Kayenta Mines will be oriented towards achieving a stable reclaimed landscape by implementing appropriate BTCA concepts, techniques, and methodologies.

Peabody will utilize appropriate surface stabilization, erosion, and sediment control measures patterned after the BTCA which may include, but not be limited to the following practices:

1. Topographic manipulations that involve recontouring or reshaping of graded spoil in a manner that minimizes the potential for soil erosion and designing and constructing stable revegetated swales, reclaimed ephemeral and intermittent channels, reclaimed downdrains, reclaimed gradient terraces, etc.
2. Measures used in conjunction with diversions and overland conveyances including check dams, drop structures, sediment traps, erosion-resistant liners, water level spreaders, etc.;
3. Spoil or soil surface mechanical manipulation measures that include contour furrowing, contour ditching, slope tracking, land imprinting, pitting, chisel plowing, ripping, etc.;
4. Surface protection measures that include surface stabilizers such as straw mulch, used with or without mulch binder, surface nettings, organic fiber netting, geotextile fabrics, rock riprap, etc.
5. Linear detention and filtering structures that include filter fences, straw bale barriers, brush barriers, filter berms, etc.;
6. Vegetative filters, temporary cover crops, reestablished permanent vegetation covers, proper management of the postmine landscape, etc.

The surface stabilization program is summarized below.

Surface Stabilization Program Summary

The surface stabilization program described in Chapter 26 has been formulated to provide the greatest level of assurance possible that all reclaimed lands are effectively stabilized and protected to minimize or control erosion and meet water quality standards for receiving streams. Furthermore, the program provides the means for sustaining landform stability, productivity, and postmining land uses over time, keeping in mind the environmental and geomorphic processes which act upon the Black Mesa areas. Baseline data collection and ongoing monitoring programs have resulted in, or been designed to, achieve a greater understanding of these natural processes. This has allowed Peabody to take a more realistic approach in selecting or defining input parameters for engineering designs; selecting or developing appropriate reclamation practices; and developing documentation, through demonstrations such as that contained in Attachment A "Terrace Spacing Justification", which lend support to the selected designs or practices.

The program will provide long term and effective erosion control and sustain productivity and the postmining land uses over time. This will be possible through development of a stable postmining landform and the establishment of an effective and permanent vegetative cover. In order to achieve this, a number of procedures and practices, relating both to planning and application will be applied in a logical progression. Figure 1, "Surface Stabilization Plan Summary", summarizes the major reclamation and surface stabilization plan components and illustrates the progression in which the plan components or practices will be implemented. Furthermore, Figure 1 illustrates the interrelationships of the plan components and how these facilitate the successful accomplishment of surface stabilization and reclamation objectives.

A primary component of the surface stabilization program is the engineered design and construction of gradient terraces on slopes greater than ten percent, downdrains, and reclamation channels. The spacings between the terraces are dependent on slope gradient (see Attachment A). These terraces will direct flow to a network of downdrains or primary reclamation channels, also properly designed and constructed. The terraces will break up the slope length on reclaimed hillslopes into shorter segments, and the downdrains and channels will aid in safely directing flows off of the reclaimed hillslopes and out of the reclaimed areas. Surface mechanical manipulations, mulching, and establishment of permanent cover on the inter-terrace slopes, as well as the slopes less than ten percent, will further aid in the stabilization of reclaimed lands. Attachment A, "Terrace Spacing Justification", details the beneficial effects of these and other measures in achieving a stable reclaimed landscape.

The following is a summary of all the plan components and their location in the PAP.

1. Backfilling and grading as described in Chapter 21.
2. Implementation of the spoil sampling plan and mitigation as necessary to achieve suitable plant growth medium depths (Chapter 22).
3. Identification of primary drainage locations (Chapter 26).
4. Replacement of topsoil or supplemental surface plant growth medium except in certain downdrains and primary drainages (Chapter 22 and Chapter 26).
5. Construction of terraces on slopes greater than ten percent and creation of initial alignments for downdrains and location of drainages (Chapter 26).

FIGURE 1

SURFACE STABILIZATION PLAN SUMMARY

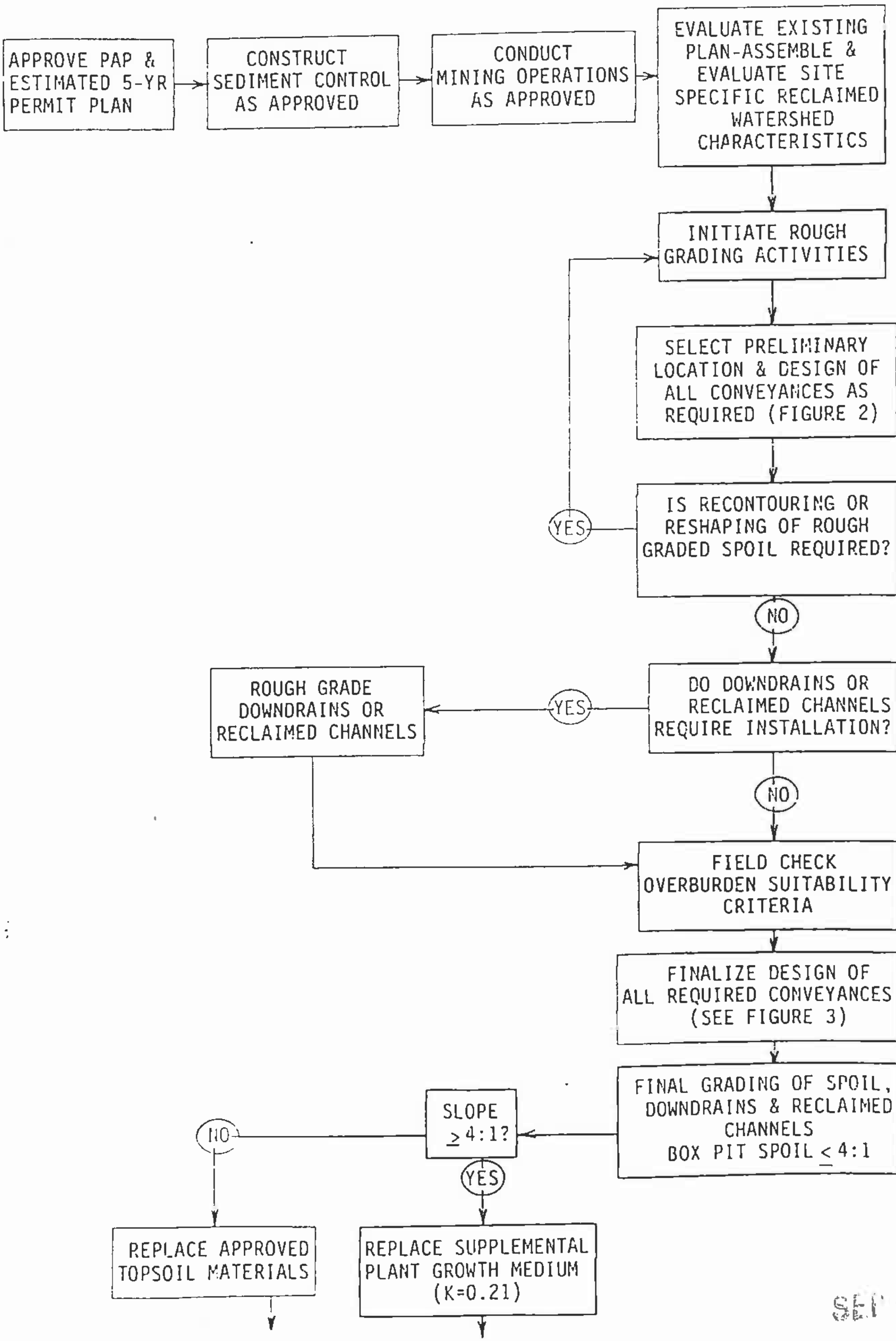

FIGURE 1 (Cont.)

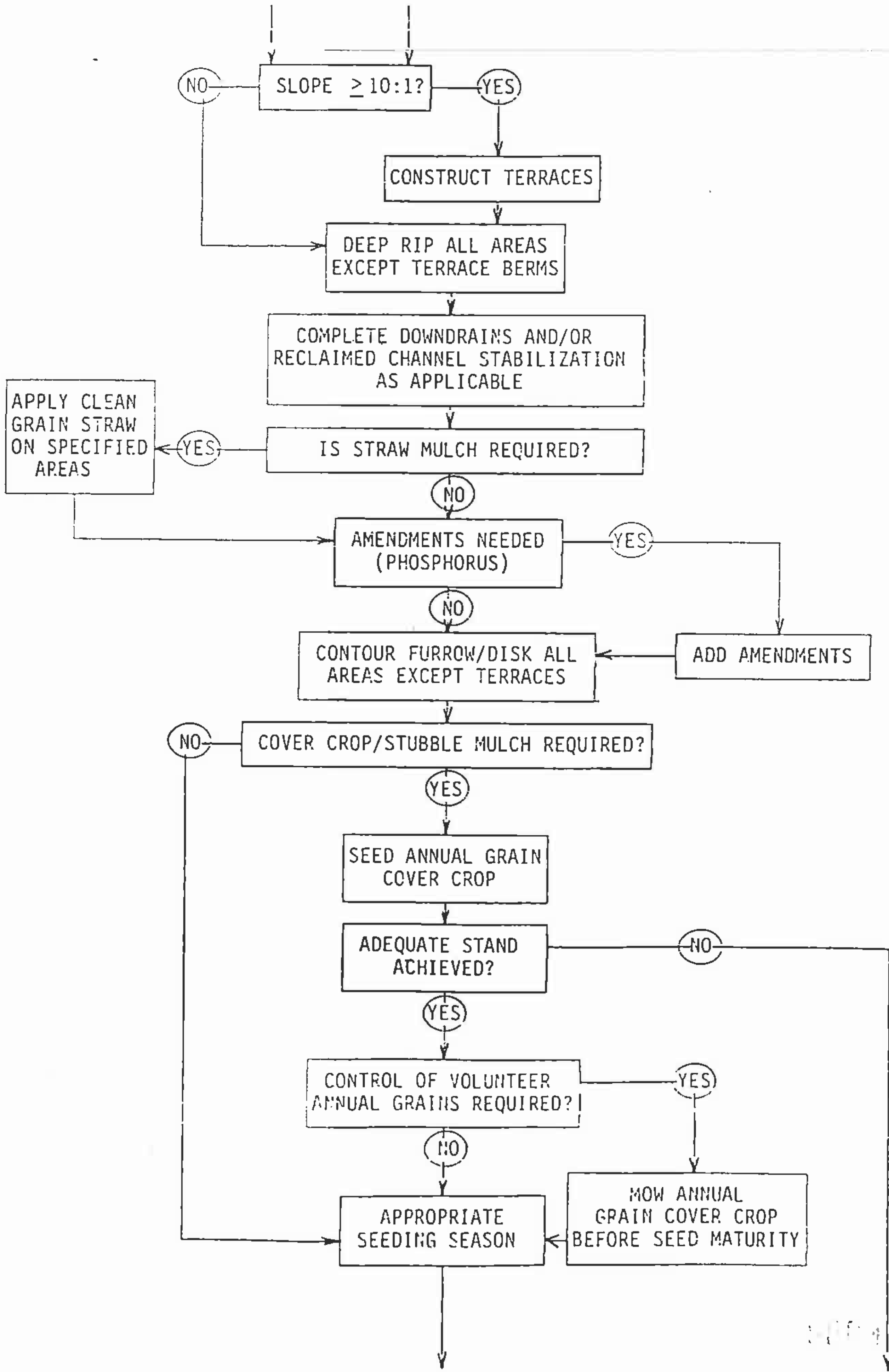

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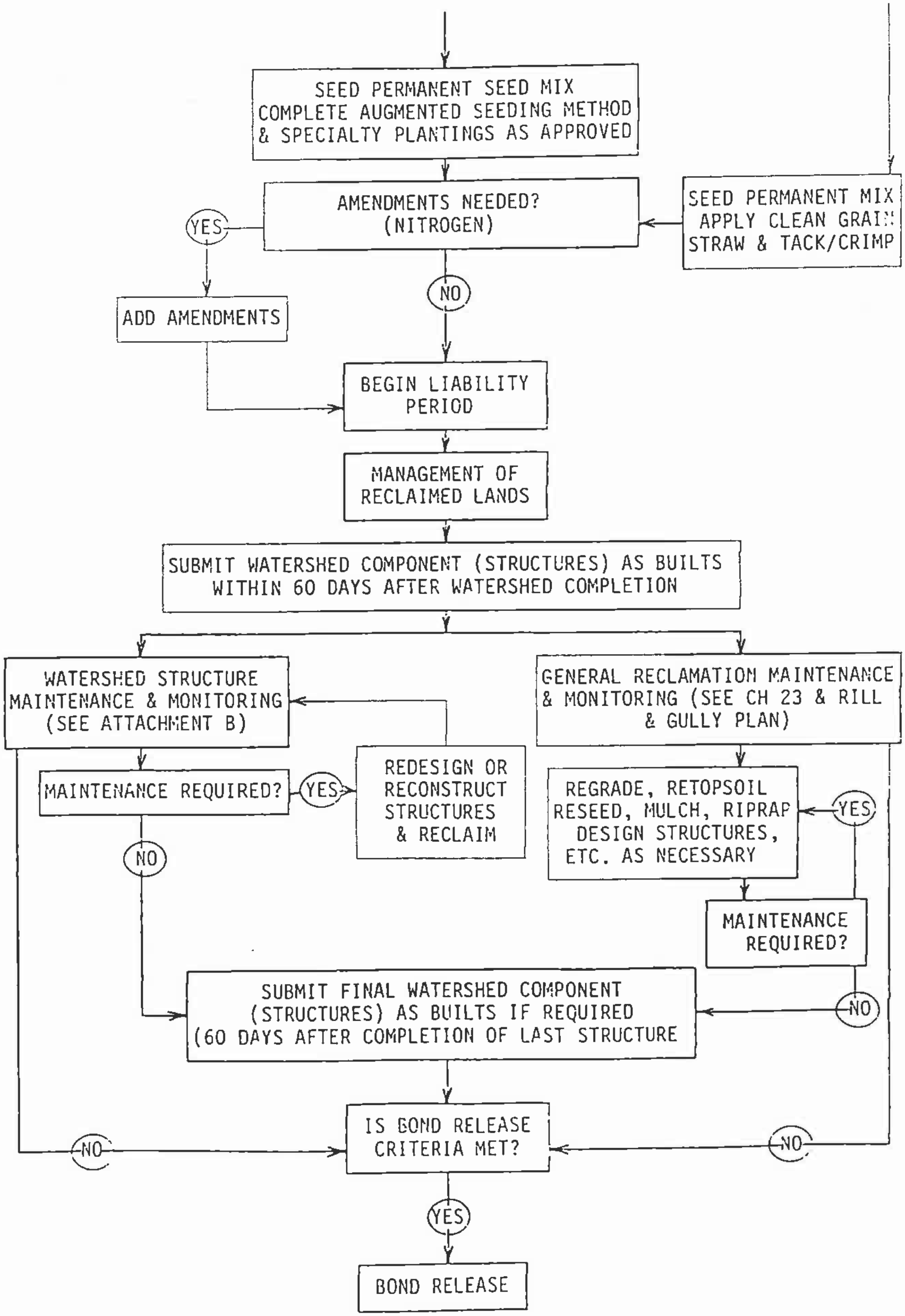
FIGURE 1 (Cont.)



6. Deep ripping of all areas except constructed terrace berms (Chapters 22 and 23).
7. Contour furrowing/disking on all areas except terrace berms and downdrains. Incorporate and anchor straw mulch if applied (Chapters 22 and 23).
8. If cover crop/stubble mulch used, seed cover crop. All reclaimed acres either straw mulched or cover cropped (Chapter 23).
9. Seed, plant, or transplant approved seed mixes or planting lists at appropriate periods (Chapter 23).
10. Monitoring, maintenance, relcaimed land management prior to bond release, and rill and gully plan implementation as necessary (Chapters 22, 23, and 26).
11. Postmining land use and management following bond release (Chapter 14).

The design methods and support measures necessary to implement the primary components of the plan are provided in the following discussion.

Engineering Design Requirements

Successful reclamation surface stabilization practices requires a "systems" approach in the design and implementation of a Surface Stabilization Plan. In addition, a close working relationship is required between the design engineer and the field reclamation crew. All of the drainage components in the reclaimed watershed should be evaluated before applying the appropriate BTCA practice and developing a drainage conveyance system.

Figure 1 illustrates the program components and decision points which will occur after the mining permit is approved through maintenance and monitoring, and reclamation bond release. Peabody's team of professional engineers, environmental scientists and reclamation personnel will evaluate, design, and implement the appropriate BTCA reclamation practice(s) which will result in a landform that approximates the premining landform, is stable, and functionally serves the postmining land use of livestock grazing and wildlife management. The program provides the operator the flexibility to address site-specific problematic areas, and provides the regulatory authority the information to evaluate the success of the reclamation efforts. Figures 2 and 3 illustrate the two phases of the engineering design process for the primary components.

Basic Design Data. Prior to initiating rough grading activities, the reclaimed watershed evaluation process will begin with the engineer assembling basic design data needed to conduct the preliminary topographic, hydrologic, and hydraulic analyses. Once the spoil

PRELIMINARY WATERSHED DRAINAGE PLAN
Figure 2

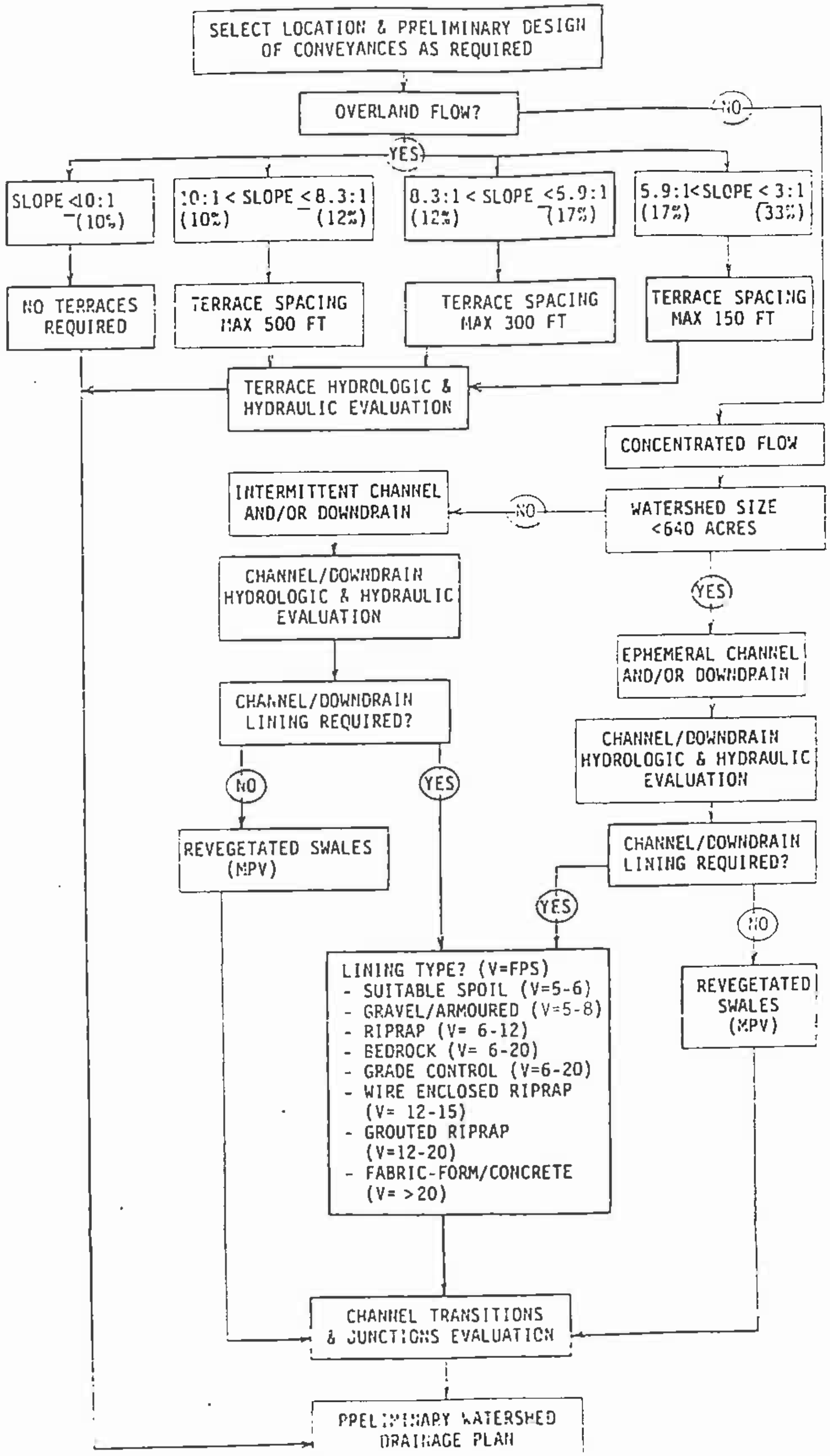
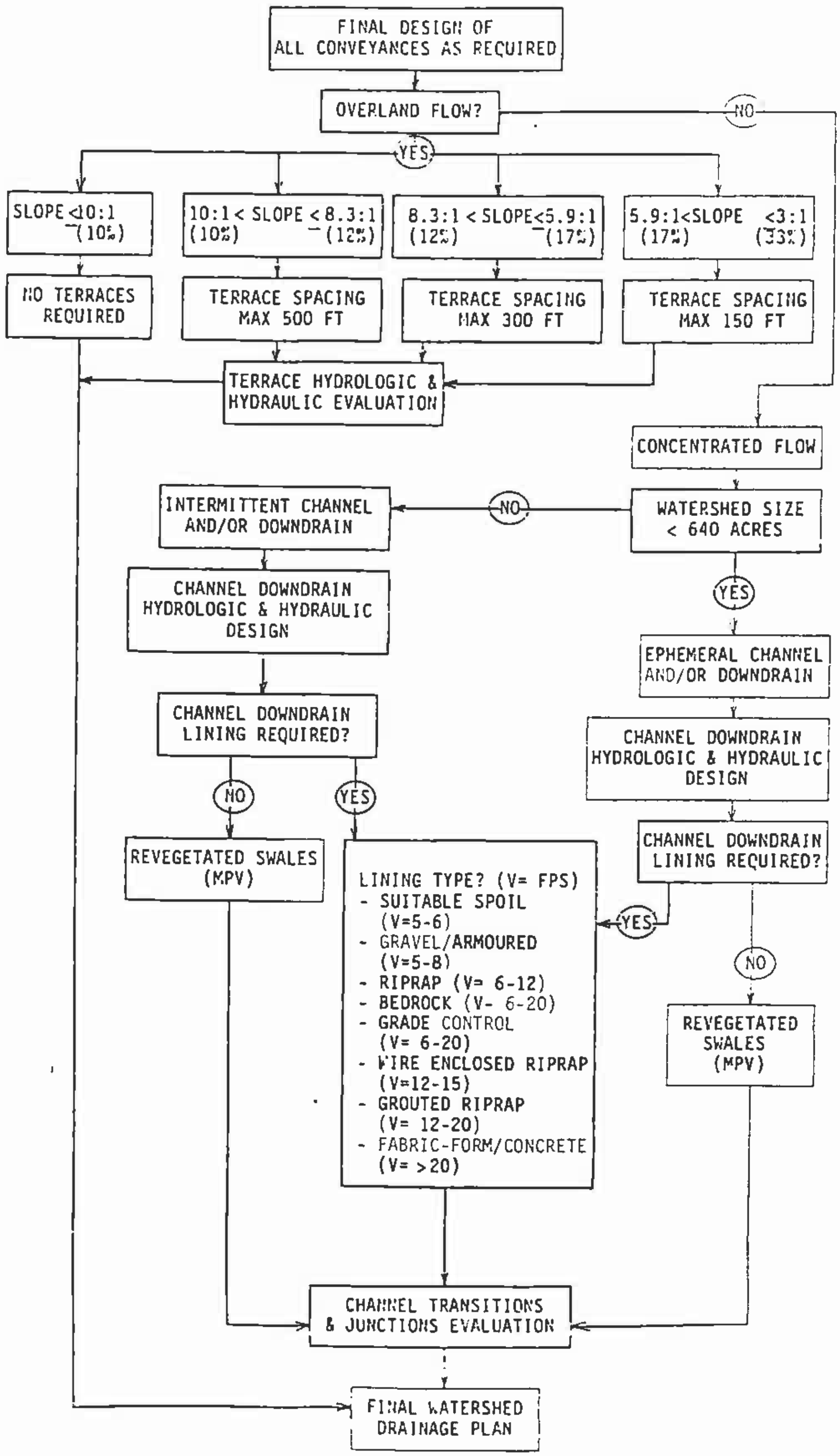


Figure 3


FINAL DESIGN OF
ALL CONVEYANCES AS REQUIRED
OVERLAND FLOW?
YES
NO
SLOPE ≤10:1 (10%)
10:1 < SLOPE < 8.3:1 (10%) (12%)
8.3:1 < SLOPE < 5.9:1 (12%) (17%)
5.9:1 < SLOPE <3:1 (17%) (33%)
NO TERRACES REQUIRED
TERRACE SPACING MAX 500 FT
TERRACE SPACING MAX 300 FT
TERRACE SPACING MAX 150 FT
TERRACE HYDROLOGIC & HYDRAULIC EVALUATION
CONCENTRATED FLOW
WATERSHED SIZE < 640 ACRES
NO
INTERMITTENT CHANNEL AND/OR DOWNDRAIN
CHANNEL DOWNDRAIN HYDROLOGIC & HYDRAULIC DESIGN
CHANNEL DOWNDRAIN LINING REQUIRED?
NO
YES
REVEGETATED SWALES (MPV)
YES
EPHEMERAL CHANNEL AND/OR DOWNDRAIN
CHANNEL DOWNDRAIN HYDROLOGIC & HYDRAULIC DESIGN
CHANNEL DOWNDRAIN LINING REQUIRED?
YES
NO
REVEGETATED SWALES (MPV)
LINING TYPE? (V= FPS)
- SUITABLE SPOIL (V=5-6)
- GRAVEL/ARMOURED (V=5-8)
- RIPRAP (V= 6-12)
- BEDROCK (V- 6-20)
- GRADE CONTROL (V= 6-20)
- WIRE ENCLOSED RIPRAP (V=12-15)
- GROUTED RIPRAP (V= 12-20)
- FABRIC-FORM/CONCRETE (V= >20)
CHANNEL TRANSITIONS & JUNCTIONS EVALUATION
FINAL WATERSHED DRAINAGE PLAN

is placed and initial rough grading of the spoil peaks begin, the engineer will begin the preliminary design of conveyances as outlined in Figure 2. This design will provide the preliminary drainage conveyance plan for each watershed, which will be used by the field reclamation crew for guidance in rough grading the spoil in and around the conveyance structure locations (i.e., primary reclamation channels, downdrains, and terraces). This drainage plan will be based on the engineers estimate of the reclaimed watershed size, time of concentration, conveyance geometry, and other appropriate site-specific watershed characteristics. These watershed characteristics and the preliminary drainage conveyance plan will be developed by gathering the following basic design data:

<u>Topographic Data</u>. Topographic data would include the premining topographic maps, current site survey data, current aerial photos, current topographic maps, the "Estimated Postmining Topographic Map" - Drawing Nos. 85350 and 85352, "Mine Plan Map" - Drawing No. 85210, "Drainage Area and Facilities Map" - Drawing No. 85400, "Sediment and Water Control Structure Map" - 85405, "Jurisdictional Permit and Affected Lands Map" - Drawing No. 85360, and such other information which would assist the engineer in determining the approximate size of the reclaimed watershed and the potential drainage patterns within the watershed. In addition to the above, a site reconnaissance will be necessary to evaluate the watershed and land form characteristics.

Once all of the preliminary topographic data has been evaluated, a preliminary rough grading plan for the conveyance channels will be generated in order to develop the preliminary drainage conveyance plan. The preliminary rough grading plan will conform with the backfilling and grading requirements discussed in Chapter 21. The preliminary sizing of the main conveyances' width, slope, and location will be of primary concern.

Conveyance Shape, Alignment, and Drainage Patterns. The preliminary conveyance shape, alignment and drainage pattern development will be based on the site reconnaissance and the experience and engineering judgment of the design engineer. The factors affecting the planned alignment and shape of a conveyance channel include topography, size of the proposed channel, the existing channel, tributary junctions, geologic conditions, channel stability, rights-of-way, required stabilization measures, and other physical features. General guidelines to follow in determining conveyance channel alignment include:

1) follow the general direction of natural drainageways

2) provide relatively straight channels with gradual curves

3) make use of natural or existing channels when possible

4) avoid unstable soils and other natural conditions that increase construction and maintenance costs (Schwab et al., 1966).

Channel alignment and the use of gradual curves are particularly important. Gradual curves minimize possible bank erosion. Alternate alignment should be considered in areas where geologic conditions present a stability problem. An alternate alignment may locate the channel in more stable soils.

Hydrologic Data. The hydrologic data and design methods will be similar to the methods discussed in Chapter 6. All applicable conveyance structures will be designed according to acceptable engineering practices and applicable regulatory requirements. Specific design criteria and procedures considered applicable are described in this design handbook.

All hydrological design methods have certain conditions and limitations affecting their use. Experience and judgment are required on the part of the design engineer regarding both the selection of methods and interpretation of the results obtained. It should be emphasized that empirical surface water hydrology is not an exact science, and that equally valid approaches may give differing results. Sound engineering judgment is, therefore, a key ingredient in hydrologic analysis. Peabody's design program is conducted under the direct supervision of professional engineers experienced in the field of water and sediment control facility design who attempt to apply such judgment to all projects they undertake.

Hydrological Methods. Hydrological methods developed by organizations such as the SCS, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation and the U.S. Department of Transportation are utilized by Peabody. Since SCS methods are widely used domestically and internationally for analysis of both rural and urban watersheds, these methods are used for most hydrological analysis. For most specialized hydrological problems, computer programs such as HEC-1 developed by the Corps of Engineers and SEDIMOT II or SEDCAD, developed by the University of Kentucky, may be used.

However, Peabody's engineers may, on occasion, use methods which differ from the design procedures submitted herein if, in their judgment, such deviation is warranted. Methodologies other than described herein will be explained and justified. These alternative design procedures will be submitted to the regulatory agency and approved prior to construction.

Design Frequency. Design frequency as it is commonly used in hydrologic design, describes how often a storm runoff event of a particular magnitude or larger is likely to occur. This event is usually expressed in terms of years, meaning that a storm runoff event will be equaled or exceeded on the average of one time during the interval. The probability of an event occurring in any one year is the reciprocal of the frequency. Conversely, further probability analyses can determine the required design frequency when the design life and an acceptable probability of the structure design capacity being exceeded during the design life is specified.

The minimum design frequency for each type of conveyance channel has been specified by the regulatory agency. The following minimum frequencies will be used to design reclamation conveyance structures.

TABLE 1

Minimum Design Frequencies

Conveyance Structure Type	Minimum Frequency
Terraces	100-year, 6-hour
Ephemeral Downdrains (<640 ac.)	10-year, 6-hour
Intermittent Downdrains (≥ 640 ac.)	100-year, 6-hour
Ephemeral Reclamation Channels (<640 ac.)	10-year, 6-hour
Intermittent Reclamation Channels (≥ 640 ac.)	100-year, 6-hour

Precipitation Data. Rainfall amounts for the Black Mesa mining complex are obtained from "NOAA Atlas 2, Precipitation Frequency Atlas of the Western United States, Volume VIII, Arizona". The 6-hour and 24-hour return periods for applicable precipitation events obtained from the atlas are as follows:

TABLE 2

Return Period/Precipitation

Return Period (years)	Precipitation (Inches) 6-Hour	24-Hour
2	1.05	1.4
5	1.4	1.8
10	1.6	2.1
25	1.9	2.5
50	2.2	2.7
100	2.4	3.0

Curve Number Selection. Perhaps no parameter in hydrology is as subjective as the selection of the proper runoff curve number for a given watershed. Traditional methods of curve number estimation involve the engineer or hydrologist, with some soils and vegetation information, visiting the watershed in question, observing the vegetation and soils, and then selecting a curve number. Curve number selection relies heavily upon the judgment of the designer, but this selection process usually performs satisfactorily in practice. Curve numbers are a function of three principal variables: vegetation type and cover; and the hydrologic soil group of the watershed soils. The curve numbers are weighted, based on major soil groups and vegetation types in the watershed. Table 3 is the basis for all curve numbers used at the Black Mesa Complex. These curve numbers are part of the revised S.C.S., TR-55 publication (see Chapter 6, Attachment G).

Peabody Coal Company will primarily be using the curve numbers within the range land use. The reclaimed areas will be evaluated using the herbaceous land use. The predominant vegetation cover in the reclaimed areas will be grasses or a herbaceous type cover. The reclaimed areas will on the average have a 35 percent vegetative cover and be contoured. This will be equivalent to a fair hydrologic cover. Therefore, based on the SCS information, a curve number of 81 was selected for the reclamation areas. This appears to be conservative based on studies done at Black Mesa by WWL, who estimated curve numbers in the 75 to 80 range, (see Chapter 6, Appendix D, Volume 27) and studies conducted by Dadkhad (1979) who determined the presence of rock fragment on the surface reduces the raindrop impact and in effect lowers the curve number up to ten percent depending on rock cover.

TABLE 3

SCS Curve Numbers

Kayenta and Black Mesa Mines, Arizona

Cover Type	Vegetation Cover	Hydrologic Conditions	Hydrologic Soil Type B	C	D
Reclaimed Areas (Herbaceous)					
Pre-law (1977)		poor	-	87	-
Post-law (1977) Contoured		fair	-	81	-
Undisturbed Areas					
Pinon-Juniper					
Poor Conditions	0-30%	poor	75	85	89
Average Mine Conditions*	35%	-	65	78	83
Fair Conditions	30-70%	fair	58	73	80
Sagebrush-Grass					
Poor Conditions	0-30%	poor	67	80	85
Average Mine Conditions*	30%	-	60	73	79
Fair Conditions	30-70%	fair	51	63	70
Disturbed Areas					
Paved w/open ditches (including right-of-way)		-	89	92	93
Gravel roads (including right-of-way)		-	85	89	91
Dirt roads (including right-of-way)		-	82	87	89
Newly graded areas or bare ground		-	86	91	94

Sources: Revised SCS Technical Release No. 55.

Communication with Colorado and Arizona SCS State Hydrologist (8-5-85).

Note:

*Interpolated from Figure S-3, SCS's publication "Procedures for Determining Peak Flows in Colorado", March 1980 (see Chapter 6, Attachment G).

The undisturbed areas will be evaluated using the Pinon-Juniper and the sagebrush-grass land use. Peabody Coal Company's lease area is approximately 70-75 percent pinon-juniper and 25-30 percent sagebrush-grass ground cover in the undisturbed areas (Chapter 9). These curve numbers correspond closely to Figure S-3 from the S.C.S.'s publication "Procedures for Determining Peak Flows in Colorado", March, 1980, which is also provided in Chapter 6, Attachment G. Curve numbers for disturbed areas will mainly be based on the curve numbers for "Street and Roads", curve numbers for "Newly Graded Areas", and a review of the site specific land use during the life of mining and reclamation.

The calculated values for curve numbers reflect an Antecedent Moisture Condition (AMC) II. SCS criteria defines AMC II as between 0.5 inches and 1.1 inches of rainfall in the five days prior to the design event for the vegetation "dormant" season and between 1.4 inches and 2.1 inches during the growing season. As the most intense precipitation events are summer thunderstorms during the growing season, using AMC II requires that a minimum 2-year, 24-hour event occurs in the five days preceding the design event in question. To insure conservatism in design, Peabody utilizes AMC II, a condition that may be atypical for the mine site. This procedure adds conservativeness to Peabody's runoff calculations.

Time of Concentration. The runoff time of concentration is calculated using the following equation (USBR, 1977):

$$T_c = \left[\frac{11.9\,(L)^3}{H}\right]^{0.385}$$

Where: L = length of longest water course in miles

H = watershed elevation difference in feet

T_c = time of concentration in hours

The time of concentration is defined as the time it takes water to flow from the hydraulically most remote point on a basin to the basin outlet. An alternative method to calculate the time of concentration is to use the SCS Upland Curve Method as described in the SEDCAD User Manual and applicable SCS publications.

Storm Type/Unit Hydrograph. Typically, a SCS Type II storm type will be used to represent the temporal storm pattern. A "Medium" surface response type will be used which is similar to the unit hydrograph response shapes. A "Medium" surface response type would be similar to an agricultural land use or a reclaimed watershed.

Routing Methods. Typically, the routing method will be the method used in the hydrologic model (i.e., Muskingham Method for SEDIMOT II and SEDCAD or Modified Puls for HEC-1, etc.).

Input parameters will be discussed in later sections for each conveyance structures.

Hydraulic Data. Hydraulic data will be necessary for the design of the conveyance and grade control structures. Typically, the unlined channels will be designed for subcritical flow (i.e., Froude Number 1) or the permissible velocity will be less than 5 to 6 fps depending on channel material. Erosion will be controlled with a channel liner when the flow is supercritical and causes the channel to be unstable.

Manning Equation. Typically, the Manning Equation will be used to determine the velocity and depth of flow. The Manning Equation is as follows:

$$V = \frac{1.49}{n} [R]^{2/3} [S]^{1/2}$$

where n = Manning roughness coefficient

R = Hydraulic radius

S = Channel slope

V = Velocity

Manning's "n" selection. The following Manning's coefficient of channel roughness will be used:

TABLE 4

Manning's "n"

Conveyance Structure	Channel Condition	Values of n
Terraces	Small earth channel in good condition	0.025
Downdrains:		
(Unlined)	Lined with graded suitable spoil	0.03
(Rock-lined)	Riprapped (calculated "n" values)	0.04-0.05
Reclamation Channels:		
(Unlined)	Lined with graded suitable spoil	0.03
(Rock-lined)	Riprapped (calculated "n" values)	0.04-0.05

Velocity and Channel Lining Criteria. The velocity and Froude Number calculations will be the primary considerations when selecting a stable channel lining. The following is the recommended channel lining material and permissible velocity ranges.

TABLE 5

Velocity and Channel Lining Criteria

Channel Lining Type	Permissible Velocity Range (fps)
Graded Suitable Spoil	5-6
Gravel/Armoured Coat	5-8
Rock Riprap	6-12
Shale to Sandstone Bedrock	6-20
Wire-Enclosed Riprap	12-15
Grouted Riprap	12-20
Fabriform/Concrete	Greater than 20

The Froude Number equation is:

$$F = \frac{V}{\sqrt{gL}}$$

V = Velocity (fps)

g = 32 ft/sec² (Gravitational Acceleration)

L = Characteristic Length (ft)

The Froude Number relates the inertia forces to the gravitational effects. The channel lining, permissible velocities, and Froude Number should be evaluated on a site specific basis to assure an adequate channel lining material is chosen which will result in a stable channel.

Allowable Freeboard Criteria. Typically, one foot of freeboard, plus or minus 0.2 foot, will be added to the design flow depth of all conveyance structures. For gradient terraces,this will be measured from the low spot in the channel to the elevation where there is a minimum of three feet of width on top of the containment berm or dike. This will allow localized construction variances in the containment berm or dike without the potential of overtopping. For terraces longer than 3500 feet long, two foot of freeboard, plus or minus 0.2 foot, will be added to the design flow depth. A relatively smooth transition of the containment berm or dikes when the freeboard is increased from one foot to two feet at a length of 3500 feet will be incorporated in the terrace berm.

Sideslope Values. Sideslopes will vary with material and should be a consideration during a site reconnaissance. The following is the steepest sideslope (z) values recommended, based on the nature of the bank material:

TABLE 6

Recommended Sideslopes

Nature of Bank Material	Z
Rock	0.2
Smooth or Weathered Rock	0.5-1.0
Soil (clay, silt and sand mixtures)	1.5
Compacted Clay	1.5
Sandy Soil	1.5
Silt and Loam (loose sandy earth)	2
Graded Suitable Spoil	2
Fine Sand	3

Procedures for the Design of Reclamation Drainage Structures

Once the basic design data has been collected and the rough grading has been progressing according to the preliminary drainage plan, the engineer will develop the final design (Figure 3) for all conveyances as the backfilling and grading operations approach finish grading. After the graded spoil has been field checked for suitability criteria and before the topsoil is spread onto the graded spoil, the engineer will determine the watershed size and final location of all conveyances. Conveyance structures' size, slope, and lining type will be designed based on updated topography data.

As part of the finish grading, all conveyance structures begun during the rough graded process will be completed in accordance with the final design plan. The main types of conveyance structures to be designed are the gradient terraces, downdrains, primary reclaimed channels, and grade control structures. Each of these types of structures require the width, depth and channel lining to be evaluated in order to establish a stable channel. Figure 3 outlines the decision process for the type of conveyance, size of conveyance structure and the type of channel lining material to use during the final design process.

Design and Inspection Files. A design file for each conveyance structure will be maintained by watershed at the mine site that contains calculations utilizing the procedures, design criteria and format described in this handbook. Each conveyance structures' design will be a part of a master file for each of the 68 primary reclamation watersheds which are generally described in a later section. Other structures which might be used in the associated reclaimed watersheds will also be included in the appropriate file.

Typically, the watershed file will contain the following data, depending on the stage of backfilling and grading operations.

1. Preliminary Watershed Drainage Plan
2. Final Watershed Drainage Plan
3. Subwatershed Area Calculations
4. Time of Concentration Calculations
5. Hydrologic Model Input and Output Data Sheets
6. Hydraulic Calculations
7. Topographic or Site Data
8. Certified As-Built Watershed Maps and Calculations
9. Periodic Structure Maintenance and Monitoring Inspection/Rill and Gully Inspection Reports
10. Annual Reports
11. Photographs
12. Other Data Relative to the Design, Construction, and Maintenance Process

As-Built Certification. The as-built certification for each reclamation watershed will be submitted to OSMRE within 60 days after reclamation of the watershed is completed. Any major deviations from the approved design which occur during construction will be noted in the certified "as-built" report to the regulatory authorities. In all cases, a professional engineer will review and evaluate the deviations and regulation requirements during construction. This will allow the flexibility required by Peabody to make field decisions during construction without unduly interrupting the construction schedule for each structure.

In addition, on an annual basis, final construction inspection reports (certified as-builts) will be submitted to OSMRE in the annual rill and gully, and conveyance structure maintenance status report, for all subwatersheds reclaimed in the previous year.

Design and Inspection Forms

During the design and construction of conveyance and grade control structures, the engineer will use several forms to document the design analysis and field inspections. Attachment B-2 contains the typical forms used for computer input (i.e., design assumptions), computer output (i.e., design results), structure design summary sheets, field inspections, etc.

Following is a list of the blank forms:

1. Conveyance Structure Design Summary
2. Typical SEDIMOT II Input File and Forms
3. Routing Worksheet I (SEDIMOT II)
4. Typical SEDIMOT II Output Forms
5. Normal Depth Computations (Dodson & Associates)
6. Critical Depth Computation (Dodson & Associates)
7. Channel Rating Curve Computation (Dodson & Associates)
8. Nonerodible Channel Design (SEDCAD)
9. Eordible Channel Design (SEDCAD)
10. Rock Riprap Channel Design (SEDCAD)
11. Am. Soc. Civil Engineers Proc. June, 1948 Riprap Sizing Chart
12. Design Comments Form
13. Field Monitoring and Maintenance Inspection Form

Typically, these will be the more common forms found in the watershed files at the mine site. The total contents of the watershed files could vary depending on site-specific conditions, types of structures designed and constructed, hydrologic and hydraulic procedures utilized, and stage of reclamation in the watershed.

Gradient Terrace. A gradient terrace is a small earthen embankment and channel, or a combination of dike and channel, constructed to intercept surface runoff. Terraces are used to break up the slope length by providing channels at predetermined intervals that are approximately perpendicular to the overland flow direction. The terraces intercept the runoff, decrease the flow velocity, and allow a percentage of the settleable sediment sizes to deposit, while the remaining suspended sediment is carried off the slope. Collected flows are conveyed safely off the reclaimed slopes and into the downdrains or reclaimed drainage channels (see Figures 4 and 5).

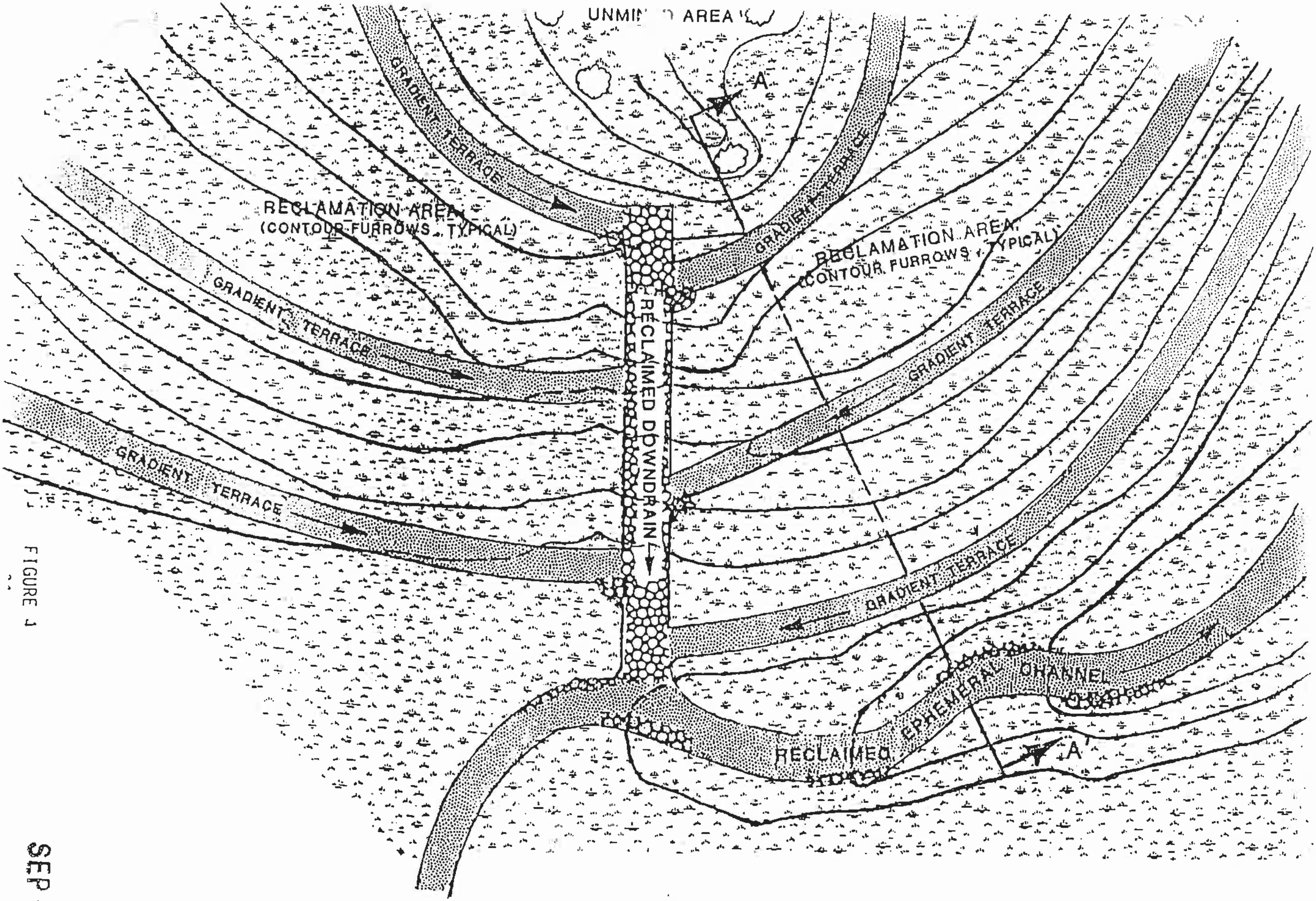


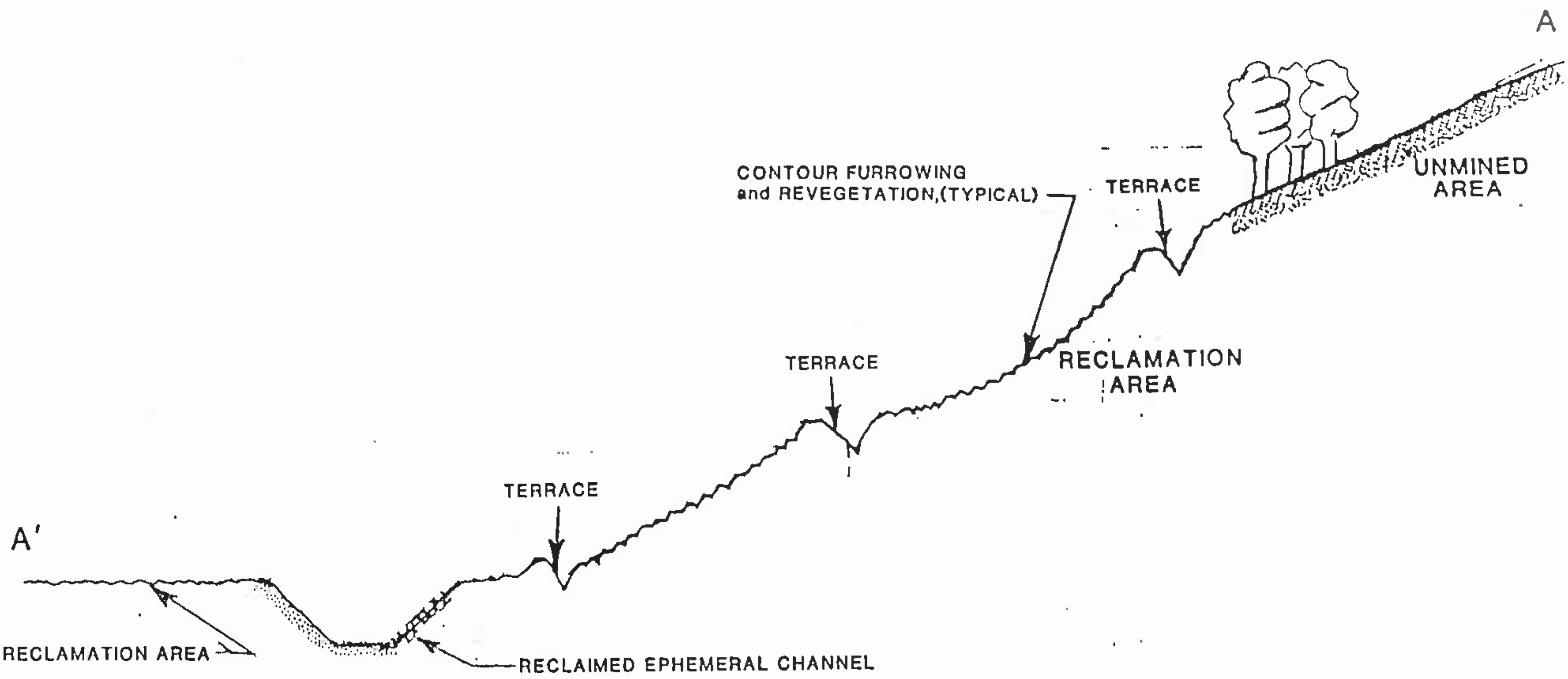
FIGURE 1

TYPICAL RECLAMATION OUTSLOPE AREA

Date:12/04/87
NOT TO SCALE
FIGURE

SEP 15 1989

FIGURE 5



PEABODY COAL COMPANY BLACK MESA-KAYENTA MINE P.O. BOX 026 KAYENTA,ARIZONA 86033				
TYPICAL RECLAMATION OUTSLOPE AREA SECTION A-A'				
FIG. NO.	APP'D BY. J.S.	DRAWN BY. M.B.	DATE: 12/04/87	SCAL N/A

The reclaimed landscape will contain some areas of potentially steep and long rolling slopes. These areas include outslopes of reclaimed box cut spoils, final pit and highwall reclamation, areas adjacent to ramps and haul roads, and areas which blend into adjacent natural steep topography.

Selection Criteria. The following criteria are used to define gradient terraces.

Location - terraces will be installed on graded slopes greater than ten percent.

Length - terraces can be extended, as needed, to a maximum length of approximately 7,000 feet in order to provide the coverage required to intercept runoff.

Spacing - Horizontal spacing between terraces is based on specific landform slope criteria identified in Table 7. Documentation for terrace spacing is provided in Chapter 26, Attachment A.

TABLE 7

Gradient Terrace Spacing Criteria

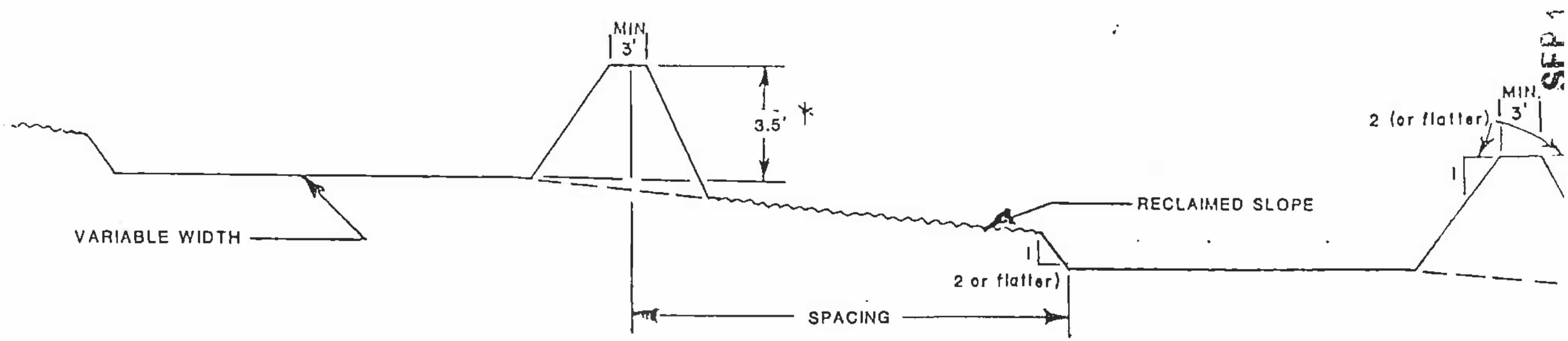
Slope Category (percent)	Horizontal Spacing (feet)
10 - 12	500
12 - 17	300
17 - 33	150

Geometry - Utilize either V-ditch or flat bottom terrace channel as site conditions and equipment availability dictate. The gradient terrace designs are based on the more conservative V-ditch configuration; whereas, the flat bottom terrace will have a larger cross sectional area; therefore, these terraces would have additional capacity or freeboard. See Figure 6.

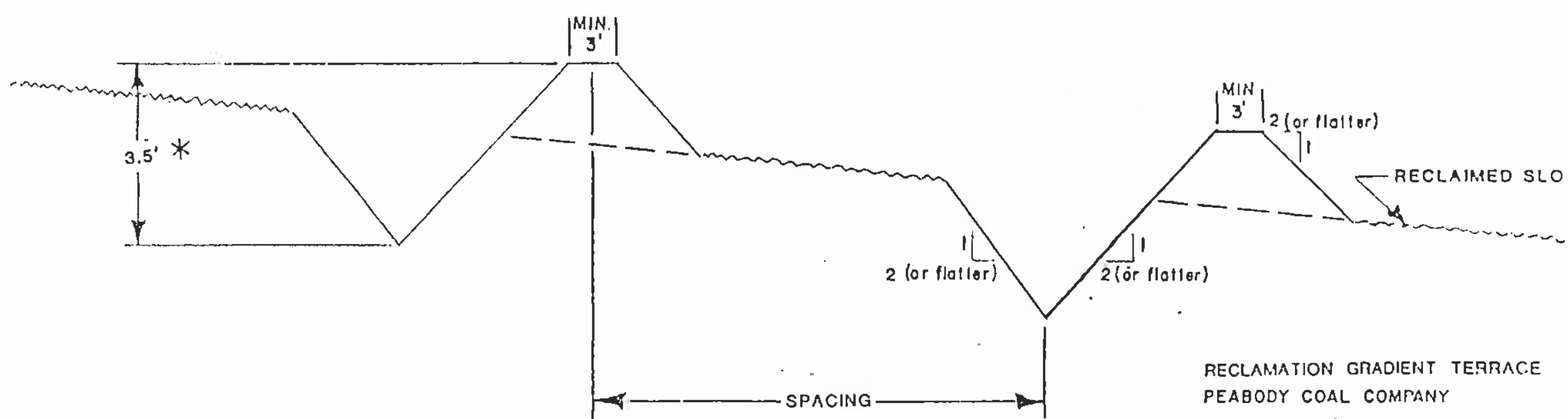
Sediment Storage - Assume 1.5 feet of sediment storage in a V-ditch terrace (Figure 7) to reduce maintenance as summarized in Table 8. This is a conservative assumption and is very unlikely to occur; therefore, longer sediment storage life may be possible.

Design Procedure. Hydrologic and hydraulic analyses have been performed for each reclaimed slope category and associated terrace spacings at various terrace lengths for both the 100-year, 6-hour and 10-year, 6-hour events. The specified lengths, terrace watershed area, time of concentration, Froude Number, and terrace hydraulic parameters have been calculated. The 10-year, 6-hour results are also calculated for comparison to lower flow events. Additional analyses were performed for terraces with 1.5 feet of accumulated sediment and without sediment. The analyses without sediment is performed to compare hydraulic results if sediment does not accumulate. Terrace geometry would approximate a V-ditch in this case. The results of each set of analyses are presented in Tables 9 and 10.

FLAT BOTTOM GRADIENT TERRACE (TYPICAL)



V-DITCH GRADIENT TERRACE (TYPICAL)



RECLAIMED SLOPE	LENGTH (ft.)	SPACING (ft)	TERRACE DEPTH (ft.) *
>10 - <12	0-3500	500	3.5
> 12 - ≤17	0-3500	300	3.5
> 17 - ≤33	0-3500	150	3.5

RECLAMATION GRADIENT TERRACE
PEABODY COAL COMPANY
BLACK MESA/KAYENTA MINE
FIGURE NO.
DATE: 01/20/89
(NOT TO SCALE)

DEPTH WILL VARY WITH LENGTH AND AREA. TYPICALLY, FREEBOARD WILL BE 1'(0-3500) & 2'(>3500'). ALSO SEE CHAPTER 26, ATTACHMENT B

FIGURE 6

SEP 1 0

TABLE 8

Terrace Sediment Storage

Assumptions: Sediment Density = 94 lb/ft^3

Max. Allowable Sediment Storage = 1.5 ft.

Average Annual Soil Loss = 5 ton/ac/yr

Uniform Distribution of Sediment Storage

Sediment Storage per 1,000 ft. of Terrace:

$$\frac{2(1.5' \times 3')}{2} \times 1000' = 4{,}500\ ft^3$$

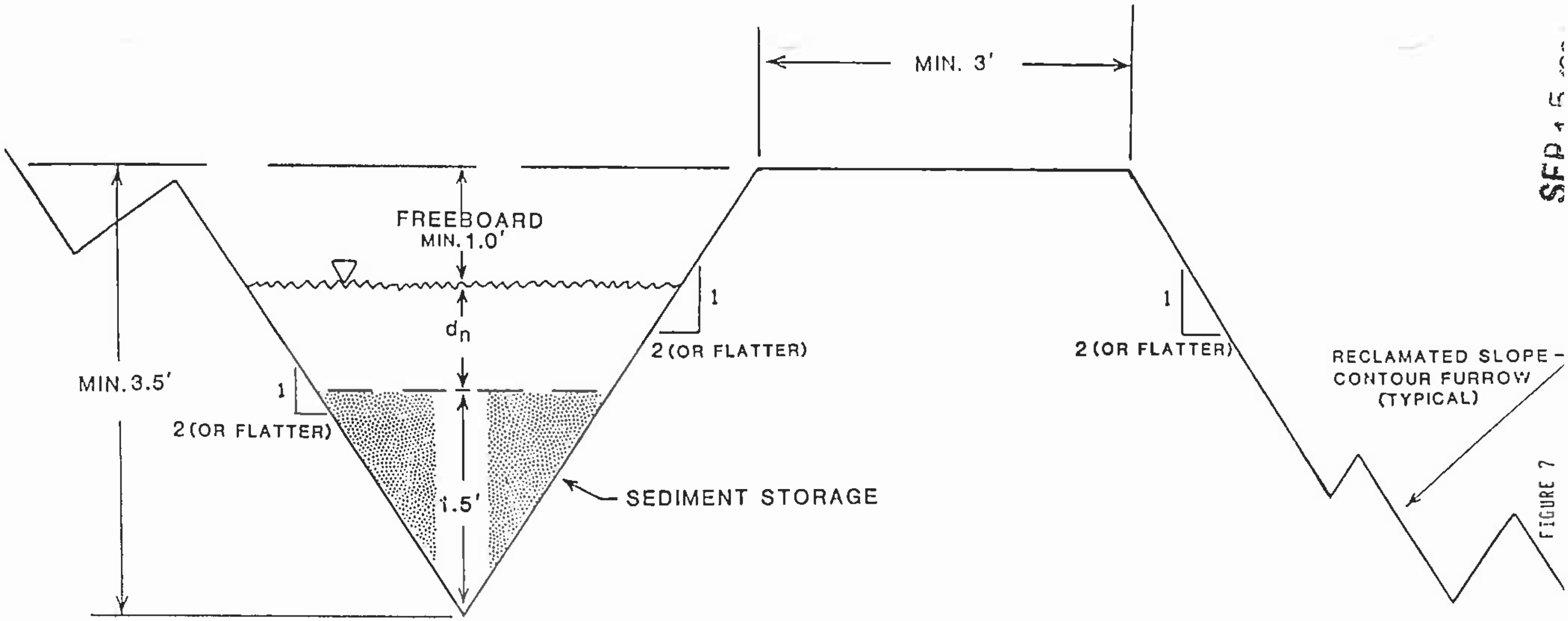
$$\text{Available Sediment Storage} = \frac{4500\ ft^3 \times 94\ lb/ft^3}{2000\ lb/ton} = 211.5\ \text{tons per 1000 ft.}$$

Years of Sediment Storage per 1000 ft of Terrace

Slope Category	Area (Ac)	Sediment Storage (tons)	Avg Annual Soil Loss	Yrs of Sediment Storage*
10 - ≤12%	11.5	211.5	5 T/A/Y	3.7 yrs
12 - ≤17%	6.9	211.5	5 T/A/Y	6.1 yrs
17 - ≤33%	3.4	211.5	5 T/A/Y	12.4 yrs

Note: The above assumes all of the 5 T/A/Y is deposited in the Terrace Ditch and none is transported off site.

$$^{*}\text{Years of Sediment Storage} = \frac{211.5\ \text{tons}}{\text{Area} \times 5\ T/A/Y} = \text{Years}$$



Reclaimed Slope (%)	Sediment Storage Depth (ft.)	100yr.-6hr. dn (ft.)	Available Freeboard (ft.)	Terrace Depth (ft.) *
> 10- ≤ 12%	1.5	1.1	0.9	3.5
> 12- ≤ 17%	1.5	0.8	1.2	3.5
> 17- ≤ 33%	1.5	0.6	1.4	3.5

* SEE CHAPTER 26, ATTACHMENT B FOR ADDITIONAL DESIGN GUIDELINES.

PEABODY COAL COMPANY BLACK MESA-KAYENTA MINE P.O. BOX 625 KAYENTA, ARIZONA 86033				
TYPICAL GRADIENT TERRACE				
FIG. NO.	APP'D BY.	DRAWN BY.	DATE:	SCALE:
.	J.S.	M.B.	12/04/87	N/A

ᴊLE 9

1.5 Ft. of Sedimen. ,torage - Gradient Terrace

Hydrologic and Hydraulics Summary

Reclaimed Slope (%)	Terrace Length (ft)	Terrace Spacing Width (ft)	Watershed Area (ac)	Curve Number	Time of Concentration (hrs)	100 Yr-6 Hr Storm Outlet Q_{100} (cfs)	Outlet Vel (fps)	Outlet dn (ft)	$Froude_{100}$ No.	10 Yr-6 Hr Storm Outlet Q_{10} (cfs)	Outlet Vel (fps)	Outlet dn (ft)	$Froude_{10}$ No.
>10 - ≤12	1000	500	11.5	81	0.118	16.6	3.0	0.7	0.67	7.5	2.3	0.5	0.63
	2000	500	23.0	81	0.203	22.8	3.3	0.9	0.68	9.3	2.5	0.5	0.64
	3000	500	34.4	81	0.286	29.7	3.6	1.0	0.69	11.9	2.7	0.6	0.65
	3500	500	40.2	81	0.326	32.8	3.7	1.1	0.70	13.1	2.8	0.7	0.66
	4000	500	45.9	81	0.366	35.5	3.8	1.1	0.70	14.1	2.8	0.7	0.66
	5000	500	57.4	81	0.445	40.3	3.9	1.2	0.71	15.8	2.9	0.7	0.67
	6000	500	68.9	81	0.522	44.4	4.0	1.3	0.71	17.2	3.0	0.8	0.67
	7000	500	80.3	81	0.598	47.8	4.1	1.3	0.72	18.5	3.1	0.8	0.67
>12 - ≤17	1000	300	6.9	81	0.106	10.0	2.5	0.6	0.64	4.5	1.9	0.4	0.60
	2000	300	13.8	81	0.193	14.0	2.8	0.7	0.66	5.7	2.1	0.4	0.62
	3000	300	20.7	81	0.278	18.1	3.1	0.8	0.67	7.3	2.3	0.5	0.63
	3500	300	24.1	81	0.320	19.8	3.2	0.8	0.68	7.9	2.3	0.5	0.63
	4000	300	27.5	81	0.360	21.4	3.2	0.9	0.68	8.5	2.4	0.5	0.64
	5000	300	34.4	81	0.441	24.3	3.4	0.9	0.69	9.5	2.5	0.5	0.64
	6000	300	41.3	81	0.519	26.7	3.5	1.0	0.69	10.3	2.6	0.6	0.64
	7000	300	48.2	81	0.596	28.8	3.5	1.0	0.69	11.1	2.6	0.6	0.65
>17 - ≤33	1000	150	3.4	81	0.093	4.9	2.0	0.4	0.61	2.2	1.5	0.2	0.57
	2000	150	6.9	81	0.180	7.2	2.3	0.5	0.63	2.9	1.7	0.3	0.58
	3000	150	10.3	81	0.265	9.2	2.5	0.5	0.64	3.7	1.8	0.3	0.60
	3500	150	12.1	81	0.307	10.1	2.5	0.6	0.64	4.1	1.9	0.3	0.60
	4000	150	13.8	81	0.348	10.9	2.6	0.6	0.65	4.3	1.9	0.3	0.60
	5000	150	17.2	81	0.429	12.3	2.7	0.6	0.65	4.8	2.0	0.4	0.61
	6000	150	20.7	81	0.508	13.5	2.8	0.7	0.66	5.3	2.0	0.4	0.61
	7000	150	24.1	81	0.584	14.6	2.9	0.7	0.66	5.6	2.1	0.4	0.62

Empty (No Sediment Storage) - Gradient Terrace

Hydrologic and Hydraulics Summary

Reclaimed Slope (%)	Terrace Length (ft)	Terrace Spacing Width (ft)	Watershed Area (ac)	Curve Number	Time of Concentration (hrs)	100 Yr-6 Hr Storm Outlet Q_{100} (cfs)	100 Yr-6 Hr Storm Outlet Vel (fps)	100 Yr-6 Hr Storm Outlet dn (ft)	$Froude_{100}$ No.	10 Yr-6 Hr Storm Outlet Q_{10} (cfs)	10 Yr-6 Hr Storm Outlet Vel (fps)	10 Yr-6 Hr Storm Outlet dn (ft)	$Froude_{10}$ No.
>10 - ≤12	1000	500	11.5	81	0.118	16.6	3.3	1.6	0.66	7.5	2.7	1.2	0.63
	2000	500	23.0	81	0.203	22.8	3.6	1.8	0.68	9.3	2.9	1.3	0.64
	3000	500	34.4	81	0.286	29.7	3.9	2.0	0.69	11.9	3.1	1.4	0.65
	3500	500	40.2	81	0.326	32.8	4.0	2.0	0.69	13.1	3.1	1.5	0.65
	4000	500	45.9	81	0.366	35.5	4.0	2.1	0.69	14.1	3.2	1.5	0.66
	5000	500	57.4	81	0.445	40.3	4.2	2.2	0.70	15.8	3.3	1.6	0.66
	6000	500	68.9	81	0.522	44.4	4.3	2.3	0.70	17.2	3.4	1.6	0.66
	7000	500	80.3	81	0.598	47.8	4.3	2.4	0.71	18.5	3.4	1.6	0.67
>12 - ≤17	1000	300	6.9	81	0.106	10.0	2.9	1.3	0.64	4.5	2.4	1.0	0.61
	2000	300	13.8	81	0.193	14.0	3.2	1.5	0.65	5.7	2.5	1.1	0.62
	3000	300	20.7	81	0.278	18.1	3.4	1.6	0.67	7.3	2.7	1.2	0.63
	3500	300	24.1	81	0.320	19.8	3.5	1.7	0.67	7.9	2.8	1.2	0.63
	4000	300	27.5	81	0.360	21.4	3.6	1.7	0.67	8.5	2.8	1.2	0.63
	5000	300	34.4	81	0.441	24.3	3.7	1.8	0.68	9.5	2.9	1.3	0.64
	6000	300	41.3	81	0.519	26.7	3.8	1.9	0.68	10.3	3.0	1.3	0.64
	7000	300	48.2	81	0.596	28.8	3.8	1.9	0.69	11.1	3.0	1.4	0.64
>17 - ≤33	1000	150	3.4	81	0.093	4.9	2.5	1.0	0.61	2.2	2.0	0.7	0.58
	2000	150	6.9	81	0.180	7.2	2.7	1.2	0.63	2.9	2.2	0.8	0.59
	3000	150	10.3	81	0.265	9.2	2.9	1.3	0.64	3.7	2.3	0.9	0.60
	3500	150	12.1	81	0.307	10.1	2.9	1.3	0.64	4.1	2.4	0.9	0.61
	4000	150	13.8	81	0.348	10.9	3.0	1.4	0.64	4.3	2.4	1.0	0.61
	5000	150	17.2	81	0.429	12.3	3.1	1.4	0.65	4.8	2.4	1.0	0.61
	6000	150	20.7	81	0.508	13.5	3.2	1.5	0.65	5.3	2.5	1.0	0.62
	7000	150	24.1	81	0.584	14.6	3.2	1.5	0.66	5.6	2.5	1.1	0.62

Gradient terraces can be determined by utilizing the following general guidelines.

1. Determine the slope of the reclaimed land from mapping or field measurements.
2. Define terrace spacing for reclaimed watershed slope, in Table 7.
3. Define the length of terrace(s) required within the watershed.
4. Determine flow depth for the 100-year, 6-hour event from Table 9.
5. Add allowable freeboard to flow depth to define total depth of terrace to construct or use Table 11 to determine a total depth of either 3.5 or 4.5 feet, as appropriate for the length of terrace.
6. Check terrace length and spacing to assure terrace watershed area does not exceed the area value shown in Table 9. If the area is exceeded, adjust terrace design.
7. Check terrace design with Table 10 to evaluate hydraulic characteristics if the absence of sediment stored in the terrace will require further design adjustments.

An alternate procedure may be undertaken if the terrace lengths defined in Tables 9 and 10 are not utilized. The analyses used to develop Tables 9 and 10 must be performed. This alternative procedure would be used to define terrace design parameters for lengths between those specified in the above tables.

Construction. The designed gradient terraces will be constructed by using scrapers, dozers, track loaders, or motor graders. The terrace berm or the cut and fill method based on SCS-type procedures will be utilized. The terraces will be constructed on slopes steeper than 10 percent after the supplemental plant growth media or topsoil has been placed (see Figure 1).

The layout and field staking of the terraces will be performed under the direct supervision of the engineer in order to fit the terraces to the reclaimed topography and geological conditions. Typically, terraces will be layed out parallel to permanent features such as ridges, major drainage divides, public roads, major drainage patterns, rock outcrops, property lines. The "control slope", measured from the topographic data, will dictate what terrace spacing is required. Within any terrace spacing area, there may be slopes that fall in several slope categories; therefore, where a significant portion of steeper slope areas occur, the steeper "control slope" is used to determine the terrace spacing.

Once the terrace layout has been staked, the site should be inspected to assure objectionable materials or obstructions such as brush, large rock, gullies, ditches, etc.

TABLE 11

Gradient Terrace Depth (Ft.) Summary

100-Yr, 6-Hour Storm

	Empty			With 1.5 ft. of Sediment Storage				Maximum
Slope Category	Dn	Freeboard	Total Depth	Sed Storage	Dn	Freeboard	Total Depth	Drainage Area
(>10 - ≤12%)								
≤3500' long	2.0	1.5	3.5	1.5	1.1	0.9	3.5	40.2
≤7000' long	2.4	2.1	4.5	1.5	1.3	1.7	4.5	80.3
(>12 - ≤17%)								
≤3500' long	1.7	1.8	3.5	1.5	0.8	1.2	3.5	24.1
≤7000' long	1.9	2.6	4.5	1.5	1.0	2.0	4.5	48.2
(>17 - ≤33%)								
≤3500' long	1.3	2.2	3.5	1.5	0.6	1.4	3.5	12.1
≤7000' long	1.5	3.0	4.5	1.5	0.7	2.3	4.5	24.1

are removed or buried to prevent endangering the performance of the terrace. The foundation of the terrace berm or dike will be stripped of objectionable material. The terraces will be constructed to the staked alignment, grade and cross section as directed by the engineer. The alignment will be staked on the average of a 0.5 to 1.0 percent slope and will not be steepened to cause the Froude Number to be greater than or equal to 0.8 nor will the slope be flat or negative, causing the terrace to overtop. A positive grade will be maintained along points of the terrace bottom to prevent overtopping. Typically, the terraces will be constructed to the minimum cross-sections shown on Figures 6 and 7. Larger cross-sections than those shown will be conservative if utilized, because of the larger storage capacity and lower resultant velocities. The terrace berms will be constructed to assure adequate bonding and compaction of the material. Compaction will be performed by normal routing or wheel-rolling of equipment over the berm. All fill material will have adequate moisture such that a sample taken in the hand and squeezed will remain intact. Due to the berm's low height, compaction should be adequate to maintain a stable berm. Irregularities in the berm will be adequately graded or rounded to prevent weak points and to minimize erosion. The top width of the berm shall be at least three feet wide. Once all construction is completed, the adjacent areas will be revegetated in accordance with the Surface Stabilization and Reclamation Plans.

Reclamation Downdrains. Reclamation downdrains are erosion-resistant, trapezoidal grade control structures, which will perform as ephemeral or intermittent channels in steep reclaimed areas. The Black Mesa topography is very rolling and steep in certain areas. When these areas are mined and the reclamation grading is completed, it is necessary to blend the reclaimed areas into this natural topography; therefore, erosion-resistant downdrains may be required if the reclaimed watershed size is large and steep enough to cause significant concentrated runoff. Figure 5 shows a typical, generic outslope area which might be on an exterior reclaimed slope, adjacent to a reclaimed ramp, in the final highwall area, or in an isolated reclaimed area, etc. where the topography would not allow the gradient terraces to be graded directly into a primary reclamation channel. The gradient terraces will intercept the overland runoff and direct drainage into the downdrains, which drain into primary reclamation channels. The increase in travel time of the runoff to the primary channel will significantly reduce the peak runoff in the channel and thus reduce the peak velocities and reduce erosion. Typically a downdrain would be located in a reclaimed ramp area, or where significant concentrated flow is entering the reclaimed area and a conveyance structure is required to drain the area into a primary channel.

Due to the estimated nature of the postmining topography and the potential for variations in the actual postmining graded surface, the best location for the reclaimed downdrains would be field located based on site-specific conditions and the volume of anticipated peak runoff from the upstream areas. When the design peak velocity exceeds critical velocity, the appropriate surface protection measure will be provided.

If the location of the downdrain is known prior to topsoil redistribution activities, topsoil will not be placed in the downdrain. Should the location of a downdrain be defined after topsoil replacement, the topsoil will be removed in the immediate vicinity of the downdrain. The minimum width along the downdrain alignment which will not be topsoiled is approximately 45 feet. This is based on a minimum estimated channel bottom width of 15 feet with an additional 15 feet of width each side of the primary downdrain channel as shown on Figure 8. Topsoil material loss will be minimized.

If adequate natural erosion-resistant material does not exist in the channel bottom or meanders are anticipated to develop that exceed the 45-feet minimum width of the non-topsoiled channel, Peabody will use riprap, or grade control structures to prevent the channel from eroding into the adjacent topsoiled reclamation areas. The channel lining and permissible velocities should be evaluated on a site-specific basis to assure an adequate channel lining material is chosen which will result in a stable channel.

Selection Criteria. The following criteria are used to define reclamation downdrains.

- Location - Areas of concentrated runoff within reclaimed area, at transitions from natural or reclaimed area to reclaimed or natural areas, respectively, or at locations where both the reclaimed area and natural areas join.
- Length - As needed to convey concentrated runoff to reclaimed primary channel or until a permissible velocity is achieved.
- Spacing - Minimize number of downdrains.
- Geometry - Trapezoidal channel with sideslope values based upon bank materials.

Design Procedure. Reclamation downdrains will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines.

1. Field inspect the site before and during reclamation backfilling and grading operations to determine the most logical locations for reclamation downdrains (i.e., low areas in the postmining topography, locations necessary to reestablish drainages upstream and downstream of the reclamation area, steep outslopes, etc.).

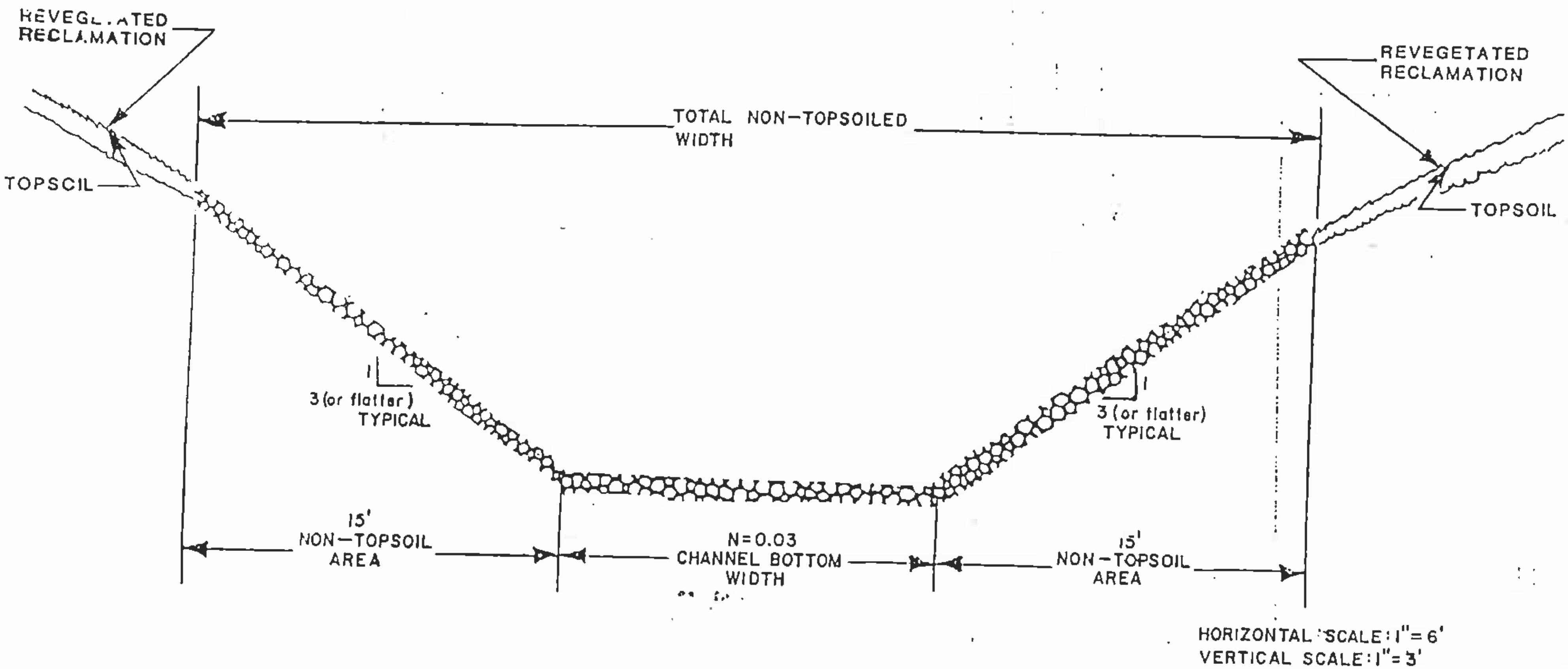


FIGURE 8

SEP 10 1989

PEABODY COAL COMPANY BLACK MESA-KAYENTA MINE P.O. BOX 020 KAYENTA, ARIZONA 00000				
RECLAMATION DOWNDRAIN CHANNEL CROSS-SECTION				
FIG. NO.	APP'D BY. J.S.	DRAWN BY. M.B.	DATE: 12/04/87	SCALE: AS SHOWN

Gather the appropriate topographic data as the rough and finish grading is finalized (see Figures 1, 2, and 3).

2. Divide the reclaimed areas into appropriate watersheds based on the topography and the ability of the adjacent downstream channels to handle the peak runoff. Ephemeral channels will be designed for the peak runoff from a 10-year, 6-hour precipitation event. Intermittent and perennial channels will be designed for the peak runoff from a 100-year, 6-hour precipitation event.

3. Calculate and input the appropriate information into SEDIMOT II, SEDCAD, HEC-1, or other appropriate hydrological models (see Table 12). Run the model and output the peak runoff. Additional routing procedures may be utilized on complex watersheds.

4. Using the peak runoff and the appropriate topographic data, use Manning's equation (i.e., Dodson & Associates software) to calculate peak velocity, normal depth, Froude Number, top width of flow, etc.

   Size the reclamation downdrain channel width to prevent the peak runoff from encroaching into adjacent topsoiled and revegetated areas. Size the channel adequately to maintain the peak velocity less than critical velocity or install an erosion resistant liner to maintain a stable channel. Add freeboard of approximately one foot to define total channel depth.

5. Incorporate the channel designs into the finish grading of the spoil material. Take advantage of any geological control structures if they are available during finish grading to stabilize the channel.

Construction. The downdrains will be constructed using scrapers, dozers, track loaders or motor graders to the alignment, grade and shape as directed by the engineer. The layout and field staking of the downdrain will be performed under the direct supervision of the engineer in order to fit the downdrain to the reclaimed topographic and geological conditions. Whenever practicable, the downdrain will be constructed to maintain subcritical flows or velocities that will not cause excessive erosion based on the channel lining material (Table 5).

Once the downdrain layout has been staked, the site will be inspected to assure objectionable materials or obstructions such as brush, large rock, gullies, ditches, etc. are removed or buried to prevent endangering the performance of the downdrain. If a berm or dike is required to maintain the downdrain alignment, the foundation of the berm or dike will be stripped of objectionable material. The berm or dike will be constructed to the staked alignment, grade and cross-section as directed by the engineer. A positive

TABLE 12

Typical SEDIMOT II Input File

(Downdrain Sizing)

Card Code 1	Watershed Identification Code
Card Code 2	Storm Type
	I Type: SCS's Type II = 2
	NRPIV : No. of Depth Time Values = 2
Card Code 3	Storm Data
	P_{100}: Rainfall Depth (inch) = 2.4
	(or) P_{10} : Rainfall Depth (inch) = 1.6
	SDUR: Storm Duration (hr) = 6
	DELTSW: Storm Time Increment = 0.10
	P30INT: Max 30 Min. Intensity = 1.0
Card Code 4	Number of Junctions
	NOJ: Number of Junctions = 1
	IHYDR: Hydrology only = 1
Card Code 5	Number of Branches/Junctions
	NOB(I): Number of Branches per Junction = 1
Card Code 10	Number of Structures per Branch
	NOS (I,J): Number of Structures per Branch (I) for each Junction (J) = 1
Card Code 11	Between Structure Routing Parameters
	Time (I,J,K): Travel Time Between Structures = 0.0
	RK (I,J,K): Muskingum's K Between Structures (hr) = 0.0
	RX (I,J,K): Muskingum's X Between Structures (hr) = 0.0
Card Code 12	Subwatershed/Structure Information
	NSWS: Number of Subwatersheds per Structure = 1
	CNTROL: Type of Sediment Control Structure = 1 (Null)
	IPRINT: Print Control Variable = 1 (Summary Table)
	ISUBSP: Print Control Variable for the Drainage Area Between Previous Structure or Junction = 1 (Summary)
	IPRINZ: Print Option for Subwatershed Inputs = 1 (Input Tables)
Card Code 13	Subwatershed Data
	PARAH (I,1): Subwatershed Area (acres) = (Length x Width or from topography map)

TABLE 12 (Cont.)

Typical SEDIMOT II Input File

(Downdrain Sizing)

PARAH (I,2): Curve Number (Reclaimed) = 81

PARAH (I,3): Time of Concentration (hr) = (Calculated)

PARAH (I,4): Travel Time (to Structure) = 0.0

PARAH (I,5): Muskingum's K (to Structure) = 0.0

PARAH (I,6): Muskingum's X (to Structure) = 0.0

PARAH (I,7): Hydrology Print Option = 1.0

PARAH (I,8): Hydraulic Surface Condition = 2.0 (Medium or Agricultural)

PARAH (I,9): Number of Flow Segments = 0.0

grade will be maintained on all points of the downdrain channel to prevent overtopping. The berm or dike will be constructed to assure adequate bonding and compaction of the material. Compaction will be performed by normal routing or wheel-rolling of equipment over the berm. All fill material will have adequate moisture such that a sample taken in the hand and squeezed will remain intact when released. Compaction should be adequate to maintain a stable berm. Irregularities in any berm will be adequately graded or rounded to prevent weak points and to minimize erosion. The top width of the berm or dike will be at least three feet wide. Once all construction is completed, the adjacent areas will be revegetated in accordance with the Surface Stabilization and Reclamation Plans.

Primary Reclamation Channels. The postmining topography maps were reviewed to determine the magnitude of the reclaimed drainage networks, evaluate the estimated drainage watersheds, and identify potential conditions within the watersheds to develop potential drainage controls and methodologies for providing those controls. This evaluation provided a preliminary indication of the number and characteristics of watersheds and their drainage channels in the reclaimed areas (Table 13). Approximately 68 primary watersheds were delineated in the postmining areas and are shown on Drawing No. 85350. A primary watershed, which contains more than 30 acres, is chosen on the basis of containing at least one primary, well-defined, reclamation drainage channel which could collect runoff from within the watershed and transport the flow into adjacent natural channels. Primary drainage channels would receive concentrated flows directly from gradient terraces, or via reclamation downdrains (see Figures 9 and 10).

In order to determine the drainage characteristics of the postmining topography, each of the 68 primary postmining watersheds were evaluated using the Hydrologic Computer Model SEDIMOT II to predict runoff from each watershed. Table 14 lists both the input parameters and output results of the analysis for each watershed. The estimated maximum size of the reclaimed ephemeral or intermittent channels that could potentially develop was determined. The peak runoff from a 10-year, 6-hour precipitation event was calculated at the outlet of the reclaimed postmining watershed for the ephemeral channels and the peak runoff from a 100-year, 6-hour precipitation event was calculated for intermittent channels.

The bottom width of the reclamation channel is chosen based on limiting the velocities of the peak runoff and channel lining material. This velocity limit is well within the range of natural channels (see Chapter 6, Table 2 and Chapter 15); therefore, the postmining channels should have hydraulic characteristics similar or better than the natural channels.

TABLE 13

Black Mesa/Kayenta Mines

Postmining Primary Reclamation Channels Summary

Watershed	Area (Ac)	Curve Number	Time of Concentration (Hrs)	Peak Flow (cfs)
J7-1w	76.6	81	0.182	32.35
J7-2w	148.7	81	0.458	40.13
J7-3w	110.0	81	0.238	41.56
J7-4w	107.3	81	0.186	44.90
J7-5w	123.3	81	0.268	44.10
J7-6w	231.5	81	0.357	71.91
J7-7w	40.80	81	0.148	17.84
J7-8w	152.1	81	0.015	63.30
J7-9w	120.2	81	0.273	42.63
J7-10w	281.4	81	0.220	95.13
J7-11w	39.2	81	0.168	17.09
J16-1w	170.1	81	0.360	52.60
J16-2w	111.5	81	0.202	44.97
J16-3w	209.1	81	0.404	60.73
J16-4w	182.7	81	0.407	52.85
J16-5w	122.3	81	0.250	45.18
J16-6w	203.4	81	0.269	72.62
J16-7w	254.9	81	0.327	82.87
J19-1w	1036.1	81	0.790	554.28*
J19-1.1w	220.9	81	0.349	69.46
J19-1.2w	289.5	81	0.422	82.03
J19-2w	1235.4	81	0.859	585.86*
J19-3w	164.2	81	0.317	54.21
J19-4w	211.0	81	0.262	76.23
J19-5w	926.7	81	0.704	498.97*
J19-6w	94.7	81	0.189	39.35
J19-7w	107.1	81	0.184	45.03
J19-8w	58.6	81	0.141	25.63

TABLE 13 (Cont.)

Black Mesa/Kayenta Mines

Postmining Primary Reclamation Channels Summary

Watershed	Area (Ac)	Curve Number	Time of Concentration (Hrs)	Peak Flow (cfs)
J19-9w	42.7	81	0.084	27.81
J19-10w	137.9	81	0.204	55.40
J19-11w	339.1	81	0.388	100.69
J19-12w	106.2	81	0.243	39.75
J19-13w	37.90	81	0.135	16.58
J21-1w	413.4	81	0.436	114.93
J21-2w	94.9	81	0.199	38.52
J21-3w	562.1	81	0.680	119.88
J21-4w	137.4	81	0.248	50.95
J21-5w	702.7	81	0.523	452.16*
J21-6w	152.5	81	0.317	50.35
J21-7w	185.8	81	0.213	73.42
J21-8w	225.9	81	0.251	83.30
J21-9w	238.0	81	0.284	82.83
J21-10w	506.6	81	0.380	152.09
J21-11w	203.9	81	0.261	73.79
J21-12w	217.4	81	0.321	71.33
J21-13w	471.4	81	0.541	115.10
N6-1w	507.2	81	0.377	152.90
N6-2w	1649.1	81	0.732	866.66*
N6-3w	147.5	81	0.404	42.84
N6-4w	704.5	81	0.761	361.23*
N6-5w	509.2	81	0.480	133.74
N6-6w	87.5	81	0.259	31.79
N10-1w	467.7	81	0.449	157.44
N10-2w	605.5	81	0.519	151.65
N11-1.1w	466.9	81	0.344	128.70
N11-1.2w	151.2	81	0.311	50.37

TABLE 13 (Cont.)

Black Mesa/Kayenta Mines

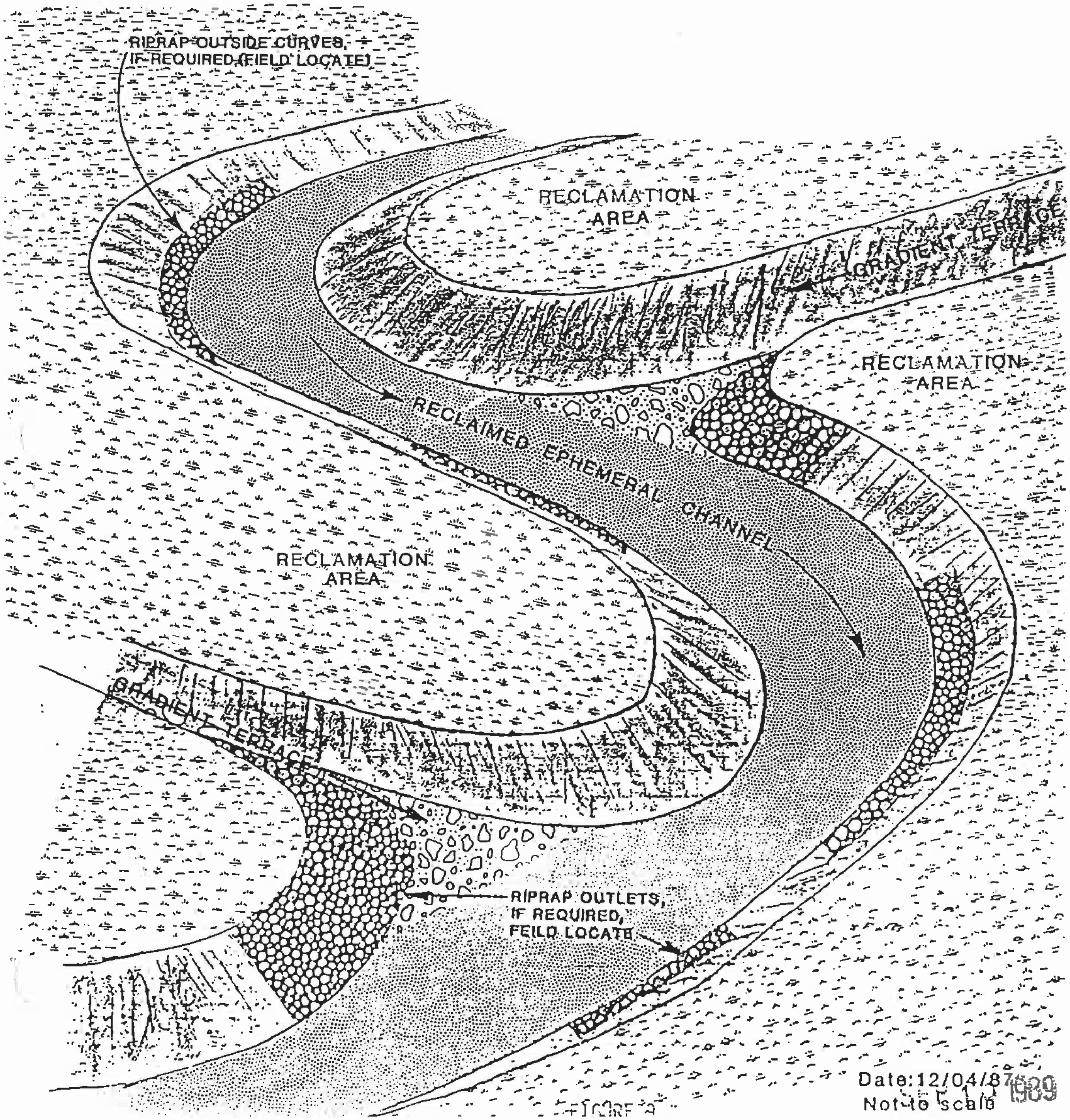
Postmining Primary Reclamation Channels Summary

Watershed	Area (Ac)	Curve Number	Time of Concentration (Hrs)	Peak Flow (cfs)
N11-1.3w	134.6	81	0.283	46.92
N11-2w	75.5	81	0.127	33.02
N11-3w	72.6	81	0.158	31.75
N11-4.1w	964.6	81	0.131	718.05*
N11-4.2w	181.3	81	0.337	58.05
N11-4.3w	142.9	81	0.311	47.63
N11-4.4w	555.3	81	0.397	162.85
N14-1w	514.8	81	0.526	127.87
N14-2w	411.4	81	0.498	105.70
N14-3w	226.6	81	0.349	71.25
N14-4w	1440.0	81	0.851	687.10*
N14-5w	1507.2	81	1.005	645.99*

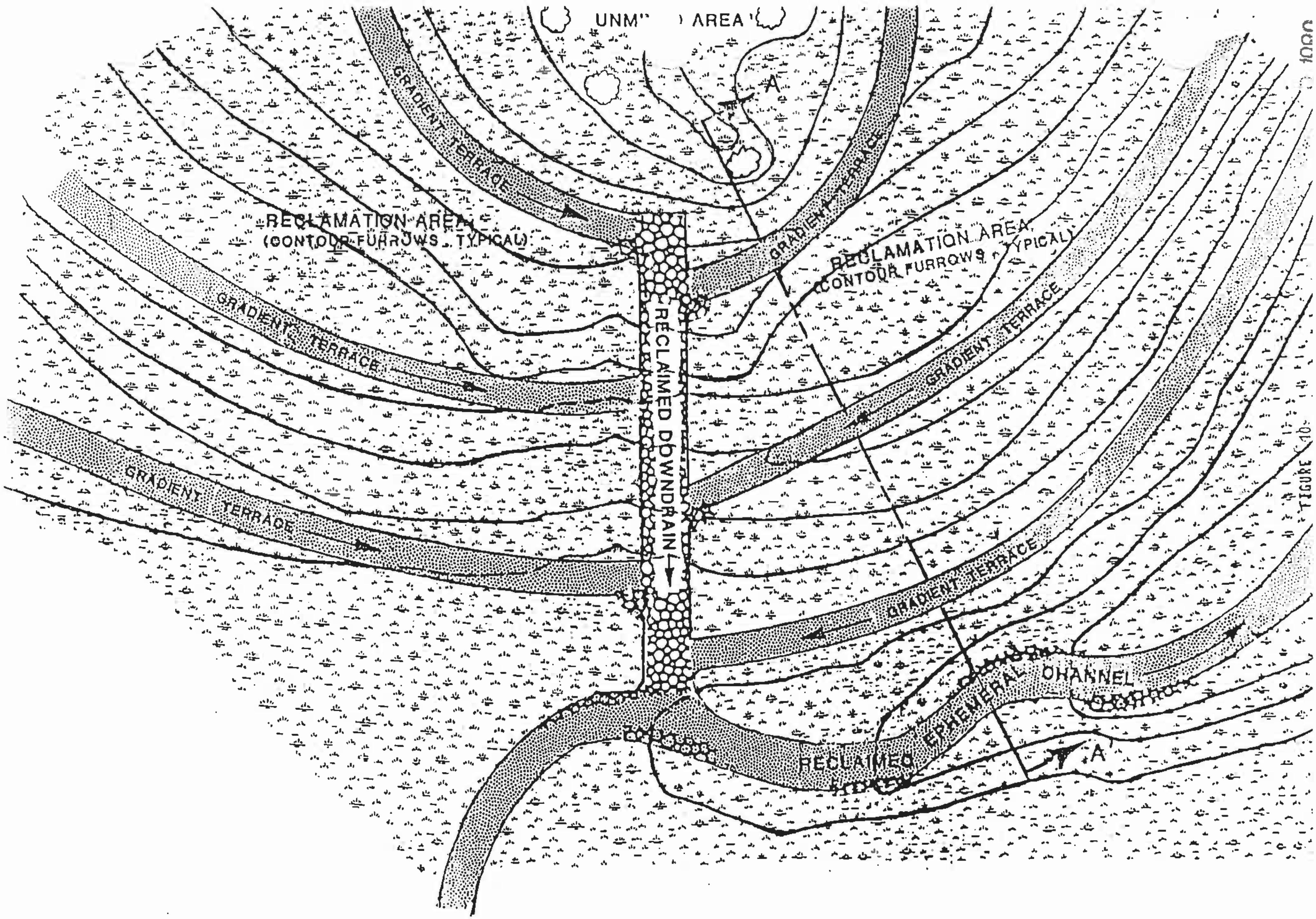
Note: See Drawing No. 85350 for location

*100-year, 6-Hour Storm Event

TYPICAL RECLAMATION CHANNEL



Date: 12/04/87
Not to scale



TYPICAL RECLAMATION OUTSLOPE AREA
-RECLAMATION CHANNEL

Date:12/04/87
NOT TO SCALE
FIGURE

In order to prevent loss of topsoil resources, the reclaimed channels will not be topsoiled. Rather, suitable plant growth spoil material will be left in the drainage channel. This material, due to its moderate coarse fragment or rock content, will form an armoured surface, increasing the potential for channel stabilization. Also, an additional 15 feet on each side of the designed reclaimed channel bottom will not be topsoiled to allow for containment of the high flows and to confine the low meandering flow, if any, within the channel area and away from the topsoiled and revegetated areas (see Figure 11). Revegetation of this 30-foot width will be carried out only as a means of providing opportunities for vegetation establishment based on channel characteristics that will develop over time.

Generally, the gradient terraces and grass-lined swales will be graded to drain into the reclaimed main channels on a non-erodible slope. Depending on the nature of the material at the exits of the gradient terraces, erodible material will be stabilized with appropriate surface protection measures which may include rock riprap, straw mulch or bales, geotextile fabrics, and/or organic fiber matting. On the outside curves or points along the reclamation channel where excessive erosion might cause the channel to encroach into adjacent topsoiled and revegetated areas, Peabody will use an appropriate surface protection mechanism. The channel lining and permissible velocities will be evaluated on a site-specific basis to assure an adequate channel lining material is chosen which will result in a stable channel.

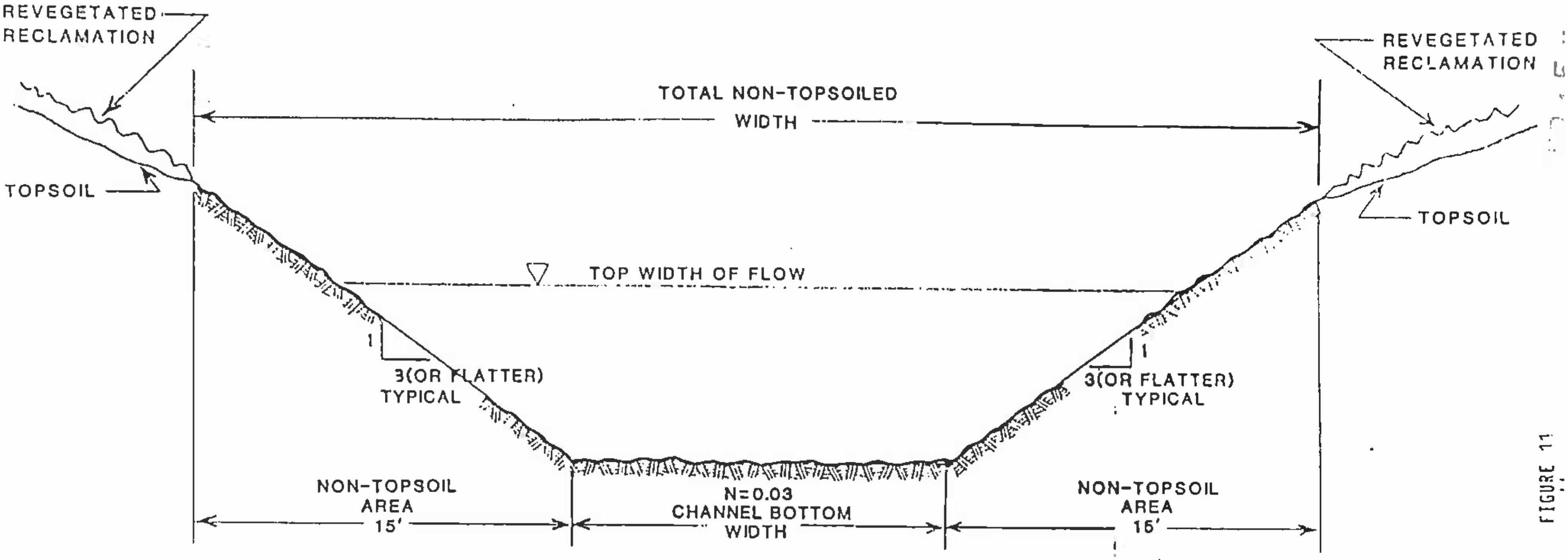
Selection Criteria. The following criteria is used to identify a primary reclamation channel.

Location - A primary watershed, which contains more than 30 acres, is chosen on the basis of containing at least one primary, well-defined, reclamation drainage channel which could collect runoff from within the watershed and transport the flow into adjacent natural channels.

Design Procedure. Primary reclamation channels will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines:

1. Field inspect the site before and during reclamation backfilling and grading operations to determine the most logical locations for a primary reclamation channel (i.e., low areas in the postmining topography, or a location necessary to reestablish drainages upstream and downstream of the reclamation area, etc.). Gather the appropriate topographic data as the rough and finish grading is finalized (see Figure 1).

FIGURE 11



HORIZONTAL SCALE: 1"=6'
VERTICAL SCALE: 1"=3'

EXAMPLE: (J7-3W) WATERSHED NO. IDENTIFICATION (SEE DRAWING 85350)

PEABODY COAL COMPANY BLACK MESA-KAYENTA MINE P.O. BOX 626 KAYENTA, ARIZONA 86033				
TYPICAL RECLAMATION CHANNEL CROSS-SECTION				
FIG. NO.	APP'D BY.	DRAWN BY.	DATE:	SCALE:
	J.G.S.	J.H.	01/23/09	N/A

2. Divide the reclaimed areas into appropriate watersheds based on the topography, existing conveyance designs, and the ability of the adjacent downstream channels to handle the peak runoff. Ephemeral channels will be designed for the peak runoff from a 10-year, 6-hour precipitation event. Intermittent and perennial channels will be designed for the peak runoff from a 100-year, 6-hour precipitation event.
3. Calculate and input the appropriate information into SEDIMOT II, SEDCAD, HEC-1, or other appropriate hydrological models (Table 14). Run the model and output the peak runoff. Additional routing procedures may be utilized on complex watersheds.
4. Using the peak runoff and the appropriate topographic data, use Manning's equation (i.e., Dodson & Associates software) to calculate peak velocity, normal depth, Froude Number, top width of flow, etc.

   Size the primary reclamation channel width to prevent the peak runoff from encroaching into adjacent topsoiled and revegetated areas. Size the channel adequately to maintain the peak velocity less than critical velocity or design appropriate grade control structures to stabilize the channel. Add freeboard of approximately one foot to define total channel depth.
5. Incorporate the channel designs into the finish grading of the spoil material. Take advantage of any geological control structures if they are available during finish grading to stabilize the channel.

Construction. The reclamation channels will typically be a trapezoidal-shaped channel graded into the suitable spoil material. The reclamation channels will be constructed using scrapers, dozers, track loaders or motor graders to the alignment, grade and shape as directed by the engineer. This layout and field staking of the reclamation channel will be performed under the direct supervision of the engineer in order to fit the channel to the reclaimed topographic and geological conditions. Whenever practicable, the reclamation channel will be constructed to maintain subcritical flow or velocities that will not cause excessive erosion based on the channel lining material (Table 5).

Once the reclamation channel layout has been staked, the site will be inspected to assure objectionable materials or obstructions such as brush, large rock, gullies, ditches, etc. are removed or buried to prevent endangering the performance of the reclamation channel. If a berm or dike is required to maintain the reclamation channel alignment, the foundation of the berm or dike will be stripped of objectionable material. The berm or dike will be constructed to the staked alignment, grade, and cross section as directed by the engineer. A positive grade will be maintained on all points of the downdrain channel

TABLE 14

Typical SEDIMOT II Input File

(Primary Reclamation Channel Sizing)

Card Code 1	Watershed Identification Code
Card Code 2	Storm Type
	I Type: SCS's Type II = 2
	NRPIV: No. of Depth Time Values = 2
Card Code 3	Storm Data
	P_{100}: Rainfall Depth (inch) = 2.4
	(or) P_{10} : Rainfall Depth (inch) = 1.6
	SDUR: Storm Duration (hr) = 6
	DELTSW: Storm Time Increment = 0.10
	P30INT: Max 30 Min. Intensity = 1.0
Card Code 4	Number of Junctions
	NOJ: Number of Junctions = 1
	IHYDR: Hydrology only = 1
Card Code 5	Number of Branches/Junctions
	NOB(I):Number of Branches per Junction = 1
Card Code 10	Number of Structures per Branch
	NOS (I,J): Number of Structures per Branch (I) for each Junction (J) = 1
Card Code 11	Between Structure Routing Parameters
	Time (I,J,K): Travel Time Between Structures = 0.0
	RK (I,J,K): Muskingum's K Between Structures (hr) = 0.0
	RX (I,J,K): Muskingum's X Between Structures (hr) = 0.0
Card Code 12	Subwatershed/Structure Information
	NSWS: Number of Subwatersheds per Structure = 1
	CNTROL: Type of Sediment Control Structure = 1 (Null)
	IPRINT: Print Control Variable = 1 (Summary Table)
	ISUBSP: Print Control Variable for the Drainage Area Between Previous Structure or Junction = 1 (Summary)
	IPRINZ: Print Option for Subwatershed Inputs = 1 (Input Tables)

TABLE 14 (Cont.)

Typical SEDIMOT II Input File

(Primary Reclamation Channel Sizing)

Card Code 13 — Subwatershed Data

PARAH (1,1): Subwatershed Area (acres) = (Length x Width or a topography map)

PARAH (1,2): Curve Number (Reclaimed) = 81

PARAH (1,3): Time of Concentration (hr) = (Calculated)

PARAH (1,4): Travel Time (to Structure) = 0.0

PARAH (1,5): Muskingum's K (to Structure) = 0.0

PARAH (1,6): Muskingum's X (to Structure) = 0.0

PARAH (1,7): Hydrology Print Option = 1.0

PARAH (1,8): Hydraulic Surface Condition = 2.0 (Medium or Agricultural)

PARAH (1,9): Number of Flow Segments = 0.0

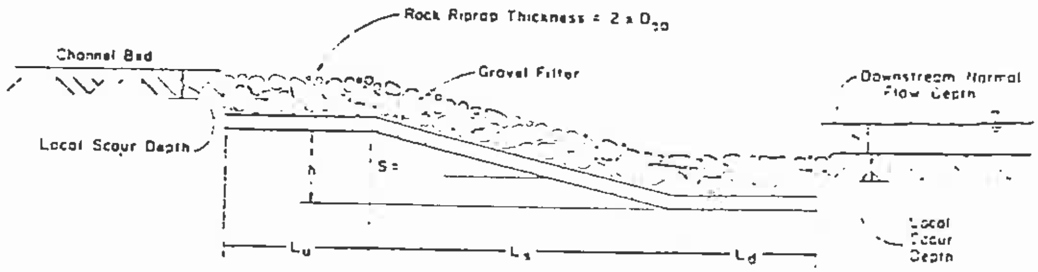
to prevent overtopping. The berm or dike will be constructed to assure adequate bonding and compaction of the material. Compaction will be performed by normal routing or wheel-rolling of equipment over the berm. All fill material will have adequate moisture such that a sample taken and squeezed will remain intact when released. Compaction will be adequate to maintain a stable berm. Irregularities on the berm will be adequately graded or rounded to prevent weak points and to minimize erosion. The top width of the berm or dike shall be at least three feet. Once all construction is completed, the adjacent areas will be revegetated in accordance with the Surface Stabilization and Reclamation Plans.

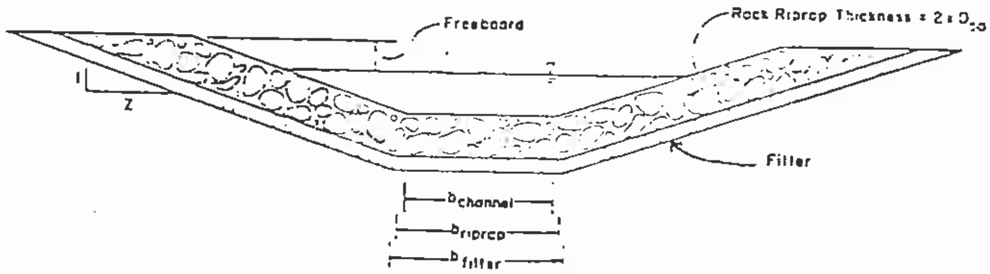
Grade Control Structures. The use of grade control structures permits adjustment of a channel slope which is too steep for design conditions or controls the potential development of headcutting which could migrate upstream. Typically, these structures will be used in conjunction with conveyance structures. A grade control structure includes drop structures, erosion-resistant liners, check dams, level spreaders, sediment traps, or other types of structures which reduces the velocities, attentuate the volume of flow, stabilize the channel, or traps the sediment.

Drop Structures. A drop structure is a riprap-lined structure or a structure constructed over an erosion-resistant ledge rock which outcrops in the channel. The ledge rock acts as a grade control structure. An erosion-resistant stilling basin will be provided at the outlet. The structure can be either vertical drops or sloped drops and can vary depending on material type and anticipated design velocities (Figures 12). Where large quantities of excavation are required to reduce the existing profile of the land surface to the equilibrium slope, drop structures will be located to minimize excavation costs and minimize disturbance. Sloped drops can also be designed to fit the channel topography needs with little difficulty.

The height of drop structures will be governed by a quantitative assessment of the available construction material, required excavation quantities, and cost. Small drop structures are usually more economical than large structures; however, to account for the same overall drop in a given channel reach, more structures would be required. This may increase the construction costs depending on the location of available sites and the rock riprap and excavation quantities required at each site. Consequently, a decision on the height of the structures must consider all possible alternatives.

The number of drop structures required to achieve the equilibrium slope is based on analyzing the total drop height required and the height of the individual drop structures.





Drop structure

FIGURE 12

The combined height of all the drop structures must equal the total drop height.

Selection Criteria.

Location - Control potential headcutting sites or where channel slopes are too steep for design conditions. Take advantage of any geologic conditions. Utilize small, rather than large structures. Place in locations with reasonably straight sections of channel with neither upstream or downstream curves with 100 to 200 feet of the structure.

Spacing - Space structures to minimize excavation and construction costs.

Design Procedure. The velocity of flow on the downstream side of a drop structure can be quite high, creating the potential for local scour at the toe and possible undercutting of the structure. Consequently, protection is required in a transition length between the steep slope of the riprapped drop structure and the mild sloped channel. Protection is also required at the entrance to the drop structure due to the drawdown and increased velocity that results as flow transitions from a mild to a steep slope (see Figure 12). For simplicity, the length of protection estimated for the more critical exit section is also specified for entrance protection. Model studies and field observations of sandbed channels conveying relatively small discharges indicate the depth of local scour is generally no larger than the uniform flow depth computed for the downstream channel section. Therefore, the transition length will be equal to five times the downstream uniform flow depth; however, in no case less than 15 feet. Additional energy dissipation measures are usually not required at the base of rock riprap drop structures since the flow velocity is typically not very large.

Drop structures will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines:

1. Define drop structure locations.
2. Determine necessary drop height at each location.
3. Calculate design discharge using procedures defined for downdrains and reclamation channels.
4. Define a slope for the structure based on riprap availability and construction costs.
5. Assume scour depths up and downstream will be equal to the normal depth of flow in downstream channel.

6. Calculate length of structure based on the equation:

$$L = L_u + L_s + L_d$$

where L_u = 5 x downstream normal flow depth, d (15 ft minimum)

$L_s = h/S$

L_d = 5 x downstream normal flow depth, d (15 ft minimum)

h = the height of the drop

S = slope of the drop structure (ft/ft)

7. Perform the hydraulic and riprap design using the SEDCAD channel utility computer software or Manning's Equation (i.e., Dodson Associates computer software) to solve for velocity or the Federal Highway Administration's HEC No. 11, "Use of Riprap for Bank Protection" or other published engineering riprap guidelines will be used to size the riprap. When using the SEDCAD channel utility computer software, the following input and output parameters will be used:

Discharge (cfs)	=	(Calculated from Hydrologic Model)
Bottom Width	=	(Based on site conditions)
Side Slopes	=	(3:1 or flatter depending on material)
Bed Slope	=	(Based on site conditions)
Manning's n	=	(Calculated for Riprap)
Specific Gravity	=	2.30
Safety Factor	=	1.20
Depth	=	(Calculated)
Top Width	=	(Calculated)
Velocity	=	(Calculated Based on Channel Lining Material)

The velocity will be in the permissible velocity range (Table 5) to maintain a stable channel; otherwise, the slope or shape of the structure will be revised.

If the D50 for the bottom or bank is larger than two feet, revise the structure's design to reduce the size of the riprap or wire enclosed riprap or grouted riprap will be utilized.

Construction. Rock drop structures are easily constructed by various mechanized equipment and generally result in relatively low cost installations. The construction of the grade control structures will follow the guidelines discussed in the construction of downdrains, reclamation channels, and general riprap consideration sections of this handbook.

Erosion-Resistant Liners. An erosion-resistant liner is a surface protection measure provided in critical portions of the channel to maintain a stable channel (see Figures 13 and 14).

Selection Criteria.

Location - Based on velocity and channel lining criteria (see Table 5).

Design Procedures. Erosion-resistant liners will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines:

1. Define location of required conveyance liner.
2. Calculate design discharge using procedures defined for downdrains and reclamation channels.
3. Perform the hydraulic and riprap design using procedures defined for drop structures.

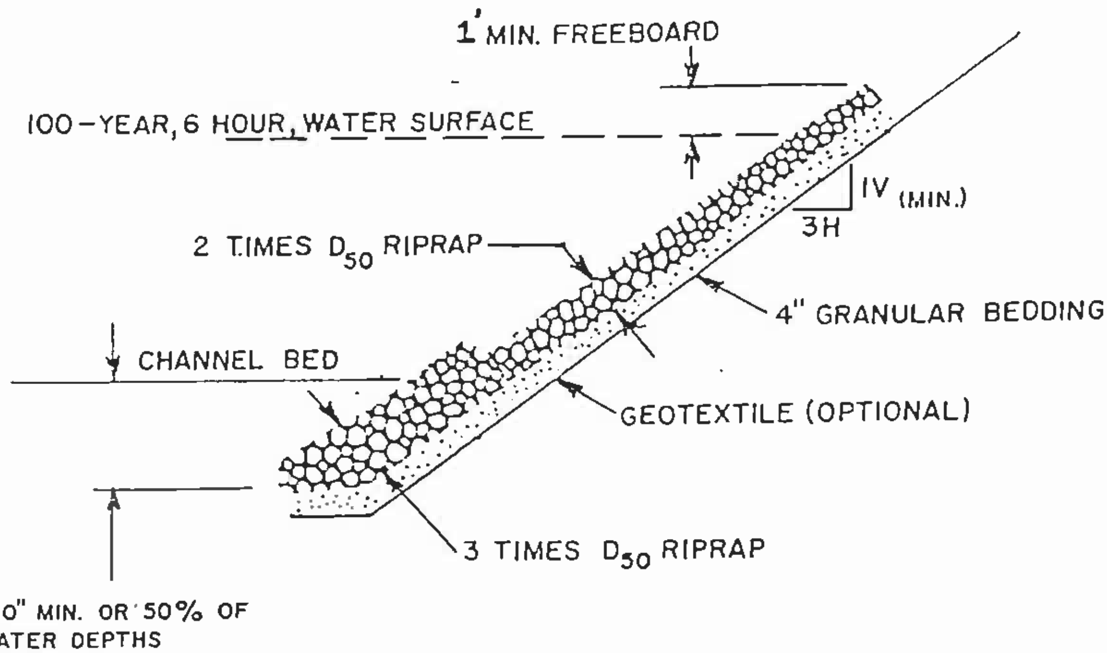
Construction. Erosion-resistant liners are constructed with various mechanized equipment. Construction of the liner will follow the guidelines discussed in the construction of downdrains, reclamation channels, and general riprap consideration sections of this handbook.

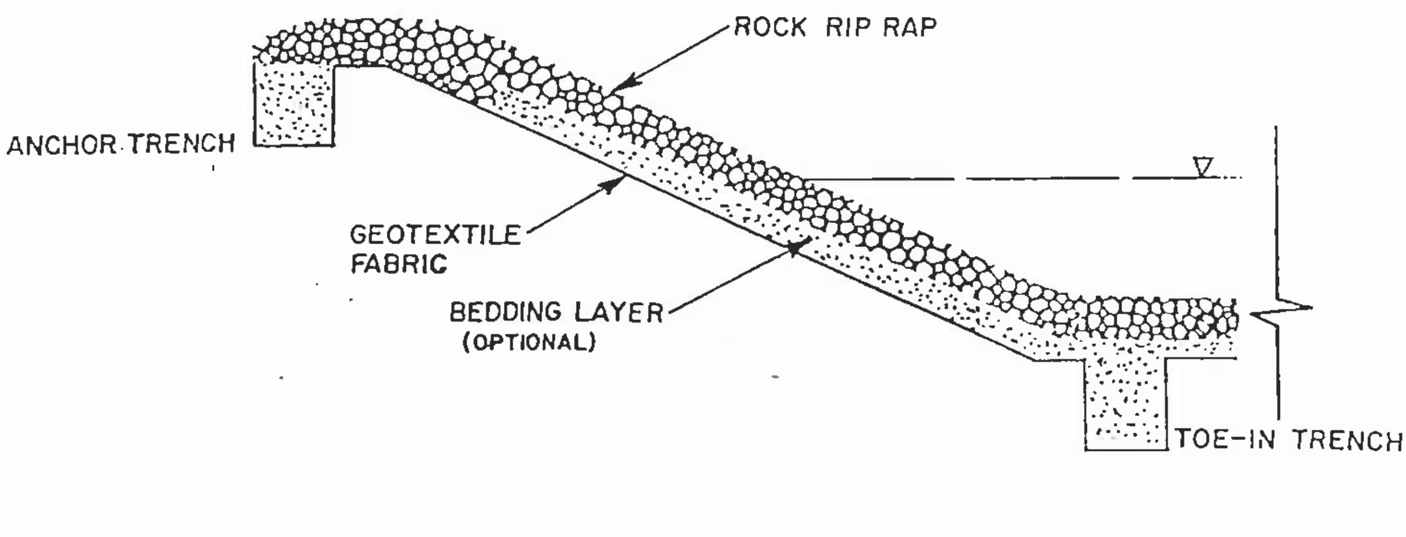
Check Dams. A check dam is a low-head structure constructed across a channel to stabilize the grade or to control head cutting in natural or constructed channels (Figure 15). Check dams are used to reduce or prevent excessive erosion by reducing velocities in diversions, conveyances, and sedimentation pond inlets, provide minor attentuation of the flow volume, or by providing partially-lined channel sections or structures that can withstand high flow velocities. Check dams are used where the capability of earth and/or vegetative measures is exceeded in the safe handling of water at permissible velocities, or sections with excessive grade.

Selection Criteria.

Location - Based on topography and geologic conditions.

Size - Large enough to prevent flow from cutting around the end of the rock dam. Rock sized in accordance with the riprap design procedures.





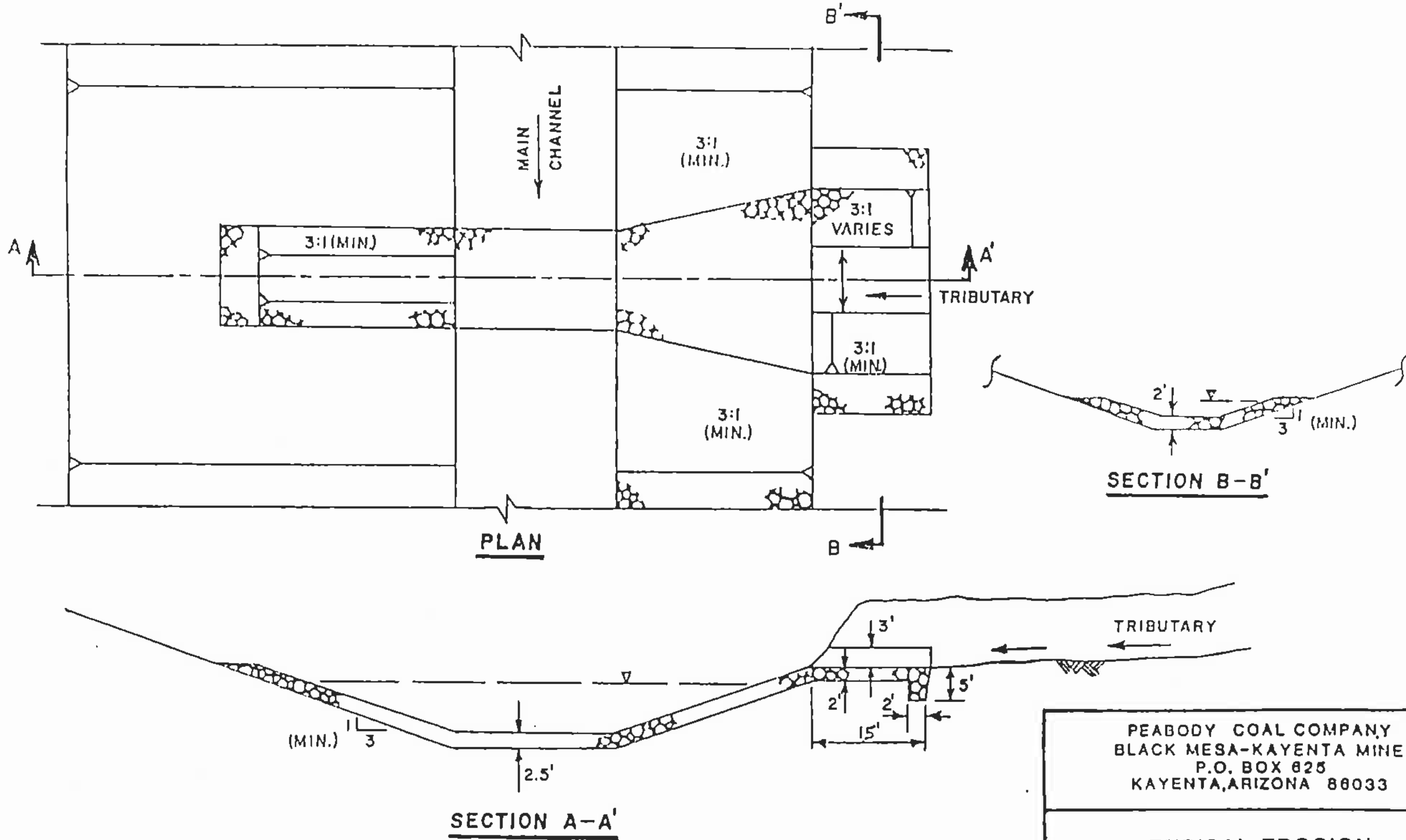
PEABODY COAL COMPANY
BLACK MESA-KAYENTA MINE
P.O. BOX 626
KAYENTA, ARIZONA 86033

TYPICAL EROSION RESISTANT LINER (A)

FIG. NO.	APP'D BY.	DRAWN BY.	DATE:	SCALE
	LS	MB	12/04/87	N/A

SEP 15 1989

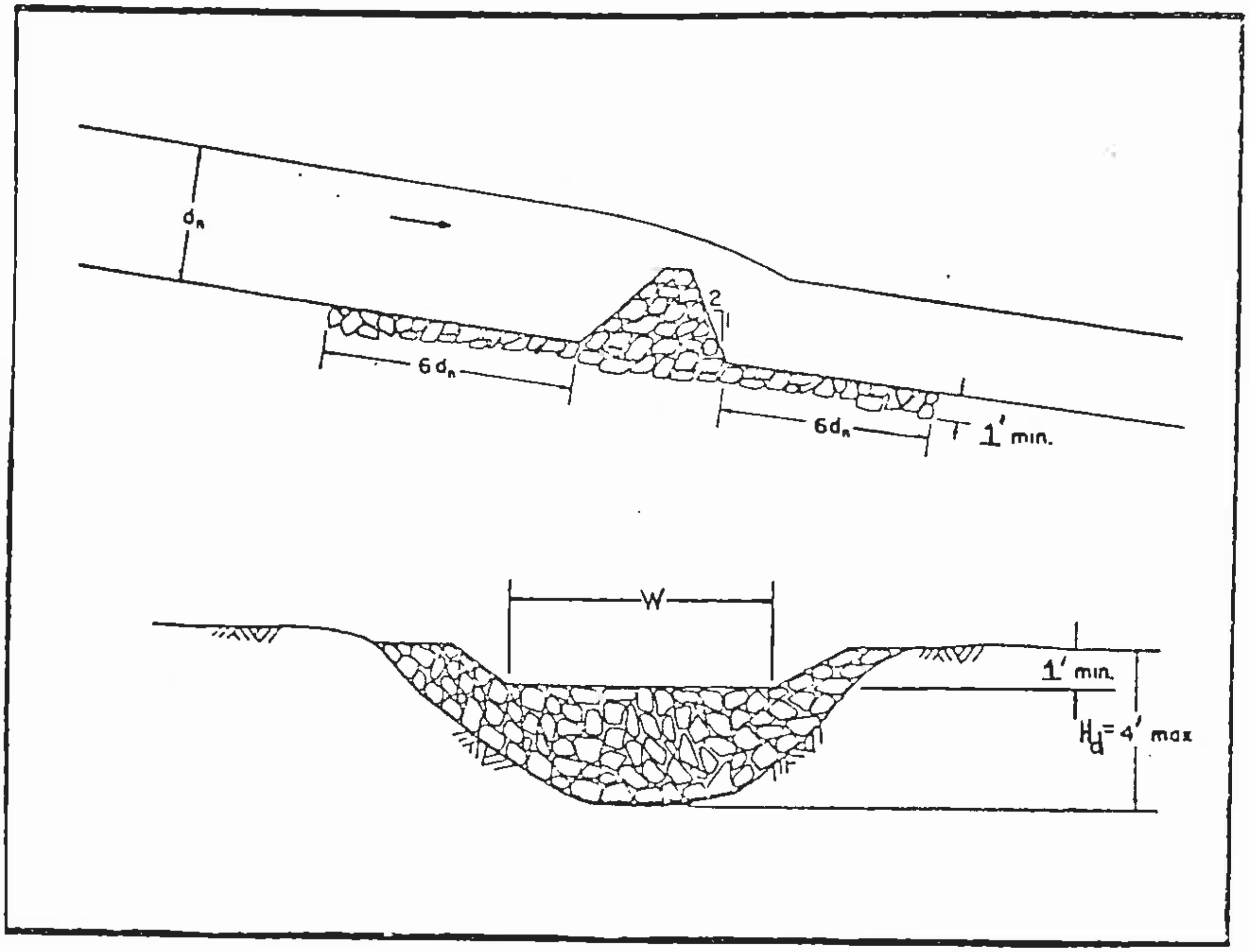
FIGURE 13



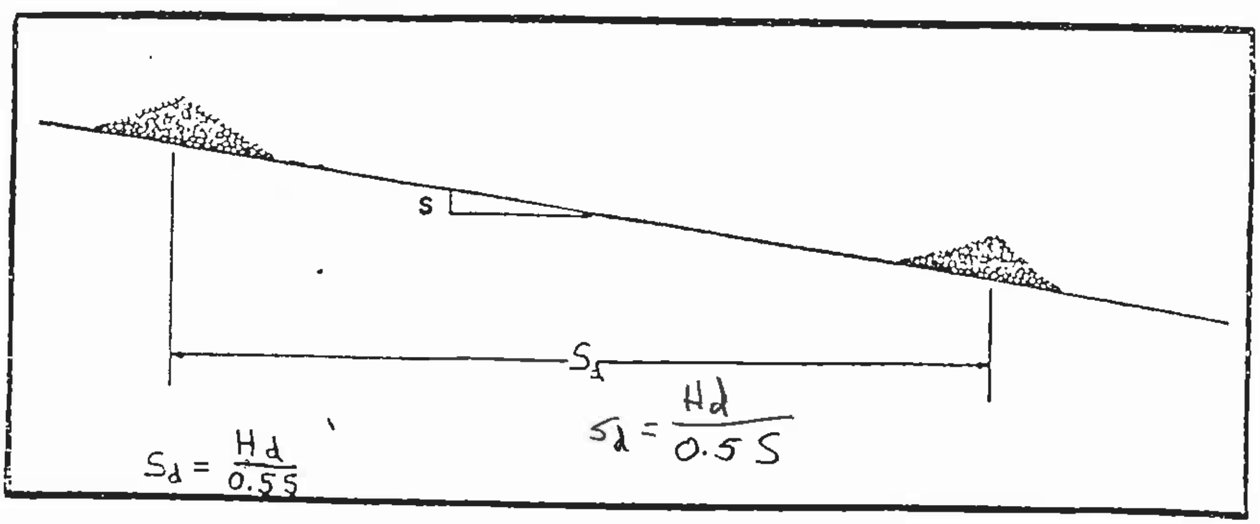
PEABODY COAL COMPANY
BLACK MESA-KAYENTA MINE
P.O. BOX 625
KAYENTA, ARIZONA 86033

TYPICAL EROSION RESISTANT LINER (B)

FIG. NO.	APP'D BY.	DRAWN BY.	DATE:	SCALE
	J.S.	M.B.	12/04/87	N/A



Rock Check Dam Sketch



Spacing between Check Dams

Typical Check Dam

Figure 15

Design Procedures. Check dams will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines:

1. Define location of required check dam.
2. Calculate design discharge using procedures defined for downdrains and reclamation channels and the procedures for check dams in SEDCAD.
3. Perform the hydraulic analyses and riprap design using procedures defined for drop structures.

Construction. Check dams will be constructed of durable rock at dimensions recommended as shown in Figure 15.

Level Spreaders. A level spreader is an outlet constructed at zero percent grade across the slope. The purpose of the structure is to convert a concentrated flow of runoff into sheet flow and to discharge it at non-erosive velocities onto areas stabilized by existing vegetation, or erosion-resistant material (see Figure 16).

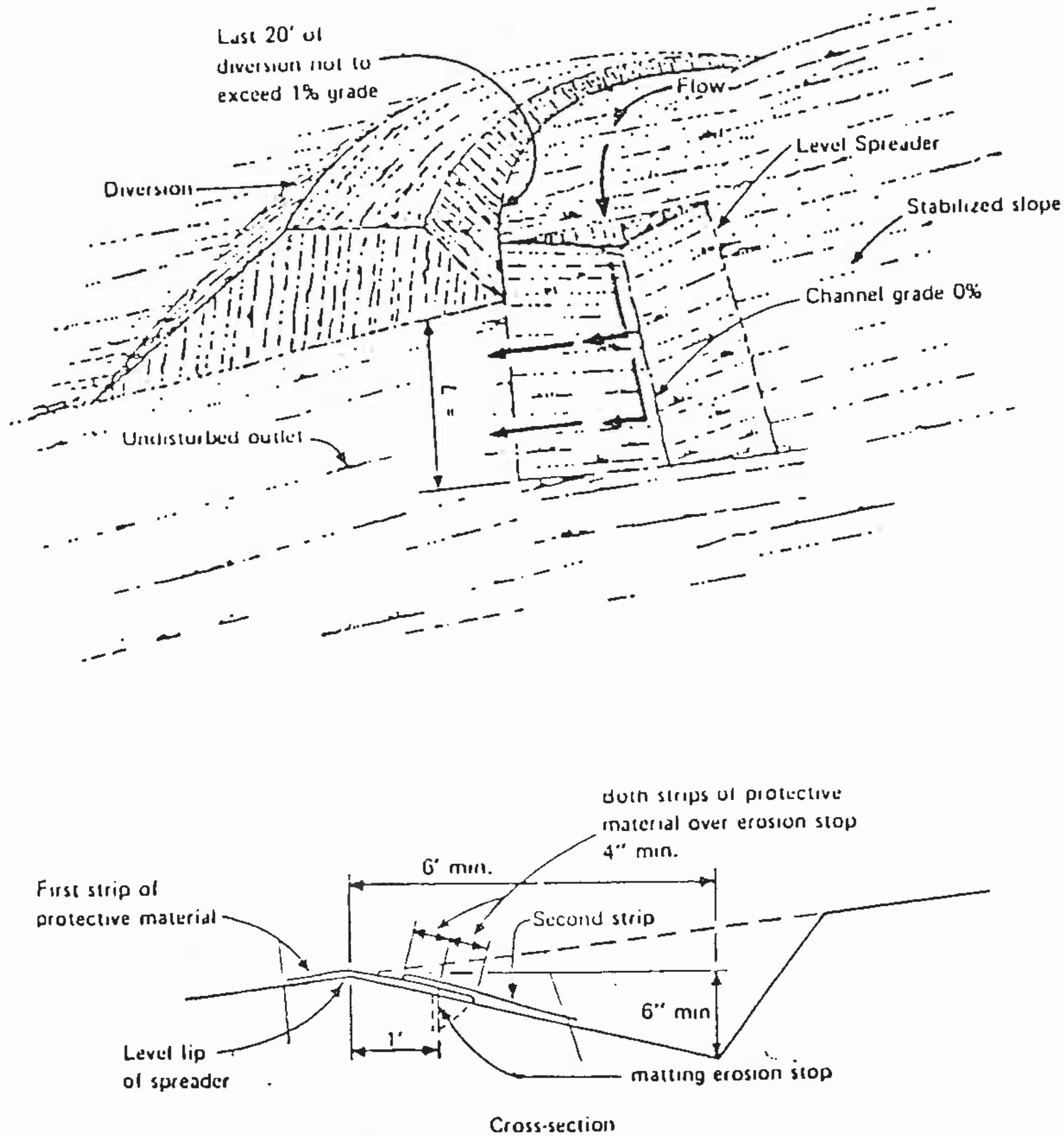
Selection Criteria.

Location - Construct on undisturbed soil or in conjunction with another grade control or conveyance structure where the area directly below the level lip is stabilized and where the water will continue in a sheet flow below the point of discharge. It is used as a stable outlet for concentrated flows such as in gradient terraces or in revegetated swales.

Sizing - The level spreader will have a maximum flow rate of one cfs per foot of length, based on the peak rate of flow from the design storm. An acceptable practice indicates the length of the level spreader to be equal to five feet per acre of drainage area. The minimum length of level spreader will be 5 feet and the maximum length 20 feet.

Design Procedures. Level spreaders will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines:

1. Define location of the level spreader.
2. Calculate design discharge using procedures defined for downdrains and reclamation channels.
3. Determine length based on sizing criteria above.



Level Spreader

FIGURE 16

4. Perform the hydraulic design for the level spreader and outflow channel using procedures defined for downdrains and reclamation channels.

5. Final discharge will be over the level lip, which will be protected with matting, erosion stops, jute, or excelsior materials, onto an existing stabilized area. The stabilized area will have a complete vegetative cover sufficiently established to be erosion resistant or other suitable erosion-resistance liner.

Construction. The construction will be performed by various mechanized equipment available at the mine site. Construction procedures will be similar to drop structures.

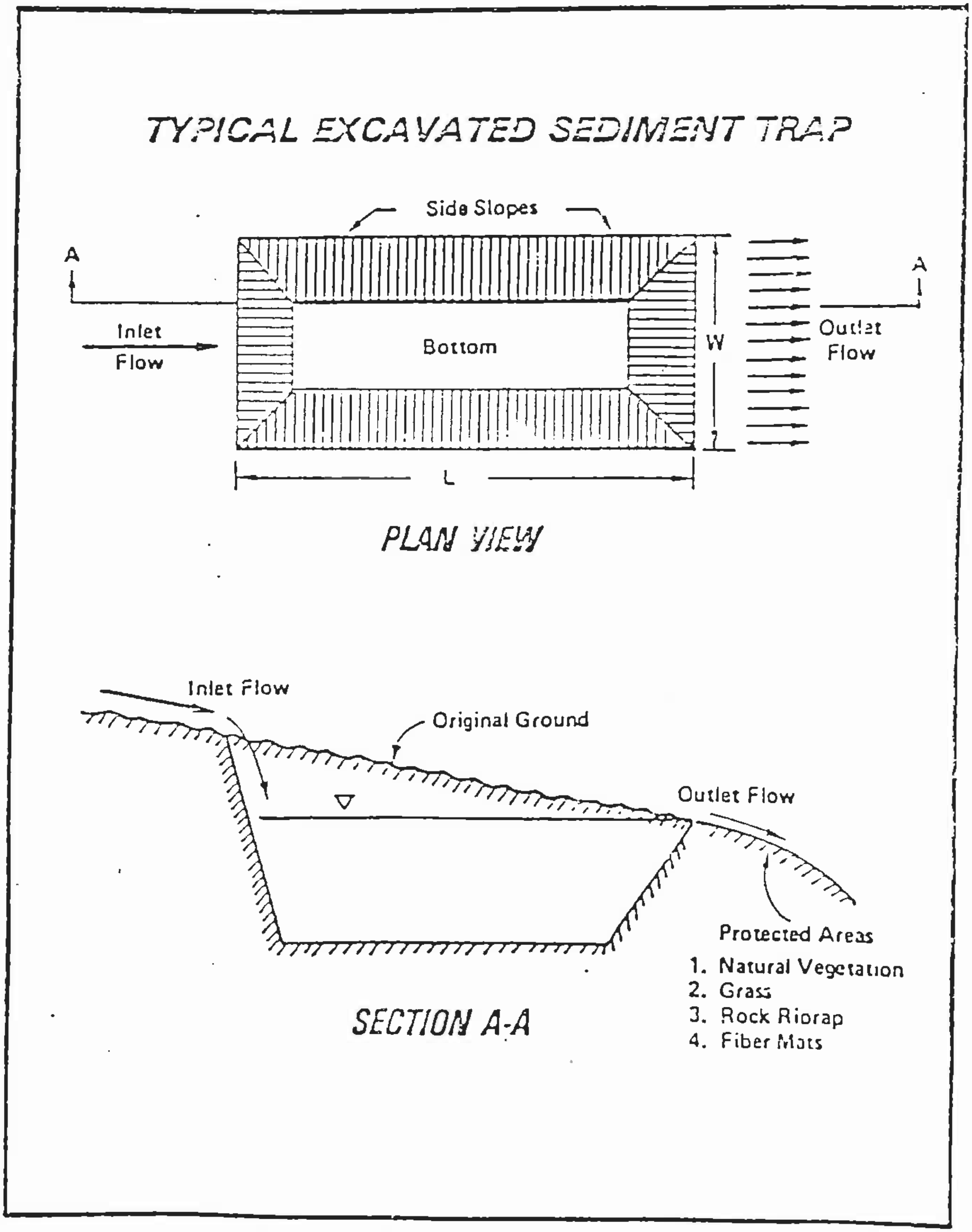
Sediment Traps. A sediment trap is a small storage or dentention area without special inlet and outlet controls or specific sideslopes. Sediment traps are typically constructed by excavation (Figure 17) or by creating an impoundment with logs, silt fence, or brush barrier/filter fabric as a low head dam. Typically, the sediment trap will only be a temporary measure, utilized until the upstream revegetated area has been stabilized.

Location - Sediment traps will be built as close as possible to the source of sediment. In most cases, the trap will be built outside of an existing watercourse to minimize the quantity of sediment to be trapped. The traps will never be constructed in a primary reclamation channel. Natural depressions adjacent to the disturbance area will be used for sediment traps where possible, and the area affected by the trap's construction and maintenance will be minimized.

Sizing - Based on the USLE calculations, a minimum of one year of sediment storage, or based on the Modified USLE calculations, the sediment runoff from a minimum one 10-year, 24-hour storm event.

Design Procedures. Sediment traps will be designed under the direct supervision of a Registered Professional Engineer using procedures and criteria discussed in this design handbook and utilizing the following general guidelines:

1. Define location of the sediment trap.
2. Calculate design discharge using procedures defined for downdrain and reclamation channels.
3. Calculate sediment yield based on procedures discussed in Chapter 26, Attachment A or use the SEDIMOT II/SEDCAD procedures discussed in Chapter 6.
4. Perform the hydraulic and lining design of the outflow channel using procedures defined for downdrains and reclamation channels.



Excavated Sediment Trap

FIGURE 17

Typical Excavated Sediment Trap

Construction. If a trap is constructed by excavation, it will be necessary to remove surrounding vegetation so that equipment can remove sediment from the trap. The area under the embankment will be cleared, grubbed, and stripped of any vegetation, root mat, and undesirable material.

To facilitate clean-out, the pool area will be cleared. Fill material for the embankment will be free of roots or other woody vegetation, organic material, large stones, and other objectionable material. The embankment will be compacted in 12-inch layers by traversing with construction equipment. The earthen embankment will be seeded with temporary or permanent vegetation and mulched. The structure will be removed and the area stabilized when the upslope drainage area has been stabilized. All cut and fill slopes will be 2:1 or flatter.

Grade Control Structures - Conclusion. In conclusion, the primary structures used in conjunction with conveyance structures will be drop structures and erosion-resistant liners. Check dams, level spreaders, and sediment traps will be minor structures and utilized in smaller, specialized applications.

General Riprap Considerations. Riprap consists of a layer of discrete fragments of durable rock possessing sufficient size to withstand the dynamic, erosive forces generated by the flow of water. The protective qualities of a riprap-lined channel lie somewhere between those of a grassed waterway and a concrete-lined channel. Dumped riprap is extensively used on surface mine sites due to the availability of rock, and the conduciveness of this method to placement by readily available mechanized equipment. When available in sufficient size, dumped rock riprap is usually the most economical material for bank protection. Dumped riprap has many advantages over other types of protection, including its flexibility and the ease of local damage repair.

The important factors to be considered in designing rock riprap protection are:

1. Durability of the rock
2. Density of the rock
3. Shape and angularity of the rock
4. Size and weight of the rock
5. Angle of repose for the rock
6. Filter considerations
7. Slope of the bed or bankline being protected

8. Velocity (both magnitude and direction) of the flow in the vicinity of the rock

Rock riprap should (Soil Conservation Service, 1977):

1. Assure stability of the protected bank as an integral part of the channel as a whole. For this major objective, the ideal condition for stability is a straight channel or a gently curved channel with its outer bank rougher and more erosion resistant than the inner bank.
2. Tie to stable natural bank or other fixed improvements with transitions designed to ease differentials in alignment, grade, slope, and roughness of banks.
3. Eliminate or ease local irregularities so as to streamline the protected bank.

Rocks used for riprap will be blocky in shape, as they will tend to "nest" together, providing greater resistance to movement. Riprap consisting of angular stones is more suitable than that consisting of rounded stones due to their greater angle of repose. These criteria are reflected in stone shape limitations given by the U.S. Army Corps of Engineers (1970) which specify:

1. The stone shall be predominantly angular in shape.
2. Not more than 25 percent of the stones reasonably well distributed throughout the gradation shall have a length more than 2.5 times the breadth or thickness.
3. No stone shall have a length exceeding 3.0 times its breadth or thickness.

These limitations apply only to the stone within the riprap gradation and not to any other durable rock that may be allowed. When a high percentage of durable rock is used that does not meet the above-listed limitations, an increase in riprap thickness will be provided.

Riprap Gradation and Placement. Riprap gradation simply implies that the riprap should be composed of a distributed size range of rock. With distributed size range, the interstices formed by the larger stones are filled with the smaller sizes in an interlocking fashion that prevents formation of open pockets.

Recommended values for the D_{max} size range from 1.3 to 2.0 times the D_{50} size, with 2.0 being the most commonly used. The value for the D_{10} to D_{20} size ranges from 0.20 to 0.30 times the D_{50} size.

These guidelines were developed for use with mild slope riprap design procedures where the

D_{50} size is usually relatively small. Consequently, they produce adequate designs with a well distributed size range and D_{max} sizes that are reasonable. However, applying this D_{max} criteria to a steep slope riprap design does not produce reasonable results. Due to the large D_{50} sizes typical of the steep slope riprap design procedure, the resultant D_{max} sizes are unrealistic and impractical, particularly considering placement and channel excavation requirements. Additionally, the recommended steep slope riprap design procedure produces a conservative estimate of the D_{50} size. Therefore, the stability of the riprap should not require a large gradation above this size. In this situation, it is more important to establish a smooth gradation to the smaller sizes to avoid large voids.

Therefore, the recommended riprap gradation for protection on steep slopes is that the maximum rock size D_{max} be no larger than 1.25 times the median size D_{50}. On mild slopes, the upper limit for D_{max} should be increased to two times D_{50}. To maintain a large safety factor and a conservative design, the ratio between the median diameter and the 10 to 20 percent size should be in a range of 2 to 3 for both steep and mild.

Following are the suggested riprap gradation limits:

	Steep Slope	Mild Slope
$\frac{D_{max}}{D50}$	1.25	2
$\frac{D_{50}}{D_{10-20}}$	2-3	2-3

Example: If D_{50} is 12 inches for a steep slope riprap, then

$$\left[\frac{D_{max}}{D_{50}}\right] = 1.25; \; D_{max} = 1.25 \, (D_{50})$$

$$= 1.25 \, (12) = 15 \text{ inches.}$$

Note: Steep Slope is when Froude Number 1

Mild Slope is when Froude Number 1

Riprap Thickness. The thickness of the riprap layer should be sufficient to accommodate the largest rock in the riprap material. Maximum resistance to the erosive forces of flowing water is obtained when individual stones are contained within the riprap layer thickness. The actual thickness of a riprap channel lining depends to a large extent upon experience and engineering judgment. Similar to gradation specification, recommendations of layer thickness vary from about 1.3 to 2.0 times the median rock diameter D_{50} of the riprap in order to accommodate the D_{max} size. Therefore, for riprap linings on steep slopes, a design value of 1.25 is recommended. A conservative riprap layer thickness of 2.0 times D_{50} is recommended for riprap applications on mild slopes. In constructing the channel, the depth of excavation will be adequate to accommodate the thickness of the riprap and filter layers.

Riprap Durability. Rock riprap will consist of hard, durable, well-graded rock. The rock will be free of claystone, vegetation, organic matter, debris, and other deleterious material as required by the engineer. Typically, riprap will be well-cemented sandstones and siltstones.

Filter Layers/Geotextiles. Typically, geotextile filter fabric will be used beneath the riprap. A six to nine-inch layer of bedding material will be placed over the geotextile filter fabric to protect the fabric during riprap placement. Typically, a Mirafi 700x or equivalent will be used for the filter fabric. All joints between rolls of the fabric will consist of an approximate 18 inches of overlap. The fabric will be placed on the channel bottom and side slopes up to the top of the design depth of the channel. Loose edges of the fabric will be turned down and buried a minimum of one foot.

If geotextile filter fabric is not available, a granular filter layer will be installed beneath the riprap. The granular filter will be a minimum of one foot thick and consist of well-graded gravel placed over the channel bed. No more than approximately five percent by weight of the granular filter should pass through a 200-mesh sieve.

Channel Transitions and Junctions. Transitions may be defined as a change in either direction, slope or cross section of the channel that produces a change in the state of flow (Henderson, 1966). Erosion protection will be provided both up and downstream of a transition reach when supercritical or excessive velocities are anticipated based on the channel lining material. Lined distances will be at least three feet upstream of the entrance and at least five feet downstream of the transition exit.

Where a confluence between a primary reclamation channel or downdrain and a natural stream channel occurs, the junction will be oriented to provide a good transition of the channel flow into the natural streamflow and adequate bank protection provided.

The natural angle of juncture between tributary stream and main streams has been observed to be in a range of 45 to 55 degrees. At a junction between a channel and a natural stream channel, the channel is essentially a tributary. Therefore, orientation of major channel junctions at angles no larger than 45 to 55 degrees will provide a reasonable transition and assimilation of diverted flows into stream channels. Where topography restricts the angle at junctions of downdrains, reclamation channels and natural stream channels to greater than 55 degrees, erosion protection will be provided. A major channel, such as one carrying the flow of a diverted tributary stream, will be constructed so that the channel enters at the invert level of the natural channel. Smaller channels may be brought in at some point on the channel bank above the stream bed level. When this is the case, adequate protection of the channel banks will be provided by placement of localized riprap.

Generic Watershed Design Example

Based on discussions with OSMRE's staff, a request was made by OSMRE to apply the typical design of terrace, downdrains, reclamation channels, grade control structures, and riprap design to a "generic watershed" which represents those expected during mining/reclamation operations at the Black Mesa Mine site. The design only had to be a preliminary design plan, but representative of the application of this design manual. Peabody selected, with OSMRE's staff concurrence, this generic watershed. This was accomplished after a meeting with OSMRE's staff on November 10, 1988. Watershed No. N14-4W, within the N-14 mine area, was chosen because this watershed was one of the largest watersheds of the 68 reclaimed watersheds, the N-14 mine area will complete coal removal operations by 1993, this watershed could possibly contain many of the conveyance structures discussed in this handbook, and the watershed contains significant areas that have been reclaimed and that will remain undisturbed.

Based on the Surface Stabilization Plan presented in Figure 1, this generic watershed design example would be similar to the preliminary watershed plan produced during preliminary rough grading activities. This watershed plan would be developed to assist the reclamation crews during the rough grading phase (see Figure 2). Once the area gets closer to be finished graded, updated topographic data would be obtained and this exercise would be repeated in order to finalize the design of all conveyances as required (Figure 3), and to lay out the alignments in the field.

Using the Estimated Postmining Topography Map as a topographic basis, a Generic Watershed Map was generated (Drawing No. 85354). Watershed No. N14-4W was divided into ten subwatersheds. Table 15 is a summary of the reclamation channels, downdrains, and terraces found within each subwatershed.

The following is the general procedures which were followed to develop this preliminary "Generic Watershed" design:

1. Assemble basic design data.
2. Locate terraces based on terrace spacing criteria. Table 16 is a summary of the terrace data. The drainage area and terrace length should always be checked to assure the terrace depth is adequate.
3. Layout and design the downdrains and reclamation channels. Table 17 summarizes the hydrologic and hydraulic data for each subwatershed. The watershed (i.e., N14-4w) is subdivided into ten subwatersheds at a junction where the peak discharge is to be determined (see Drawing No. 85354). The hydrologic and hydraulic calculations follows the precedures discussed in this handbook for downdrains and primary reclamation channels. The hydraulic calculations were performed at critical slope and at the anticipated average slope of the channel shown on Drawing No. 85354. Following is a summary of what analysis the engineer would typically perform for each subwatershed. Calculations and hydraulic model output is provided in Attachment B-1 to this Attachment.

   a) Subwatershed No. I - This is an undisturbed watershed located upstream of the mining area. Based on site specific conditions and the latest estimated topographic data, find the area, CN, time of concentration, and peak discharges. This is an undisturbed watershed so no further analysis is necessary.

   b) Subwatershed No. II - This subwatershed contains areas that are undisturbed and disturbed. This analysis will size the primary reclamation channel - 2C. The initial design indicates the channel will need several sloped drop structures at a 7 percent slope in order to allow the remaining portion of the channel to be constructed at a 1.1 percent slope or flatter. This will create subcritical flow at the design channel width of 40 feet. The channel may

TABLE 15

Generic Watershed - Subwatershed Summary

Subwatershed ID	Reclamation Channel ID	Reclamation Downdrain ID	Gradient Terrace ID
IS	1C	-	-
IIS	2C	-	24T
IIIS	-	1D	18T
	-	-	20T
	-	-	21T
IVS	3C	-	19T
	-	-	22T
	-	-	23T
VS	-	2D	1T
	-	-	2T
	-	-	9T
	-	-	11T
	-	-	13T
VIS	-	3D	-
VIIS	-	4D	10T
	-	-	12T
	-	-	14T
	-	-	15T
	-	-	16T
	-	-	17T
VIIIS	-	5D	3T
	-	-	4T
	-	-	5T
	-	-	6T
IXS	-	6D	25T
	-	-	26T
	-	-	27T
	-	-	28T
	-	-	29T
	-	-	30T

TABLE 15

(Cont.)

Generic Watershed - Subwatershed Summary

Subwatershed ID	Reclamation Channel ID	Reclamation Downdrain ID	Gradient Terrace ID
	-	-	31T
	-	-	33T
	-	-	34T
	-	-	35T
	-	-	36T
	-	-	37T
	-	-	38T
	-	-	39T
	-	-	40T
	-	-	41T
	-	-	42T
XS	4C	-	7T
	-	-	8T

Note: Terrace 32T flows into Watershed No. N14-2W.

TABLE 16

Generic Watershed (N14-4W)

Terrace Data

Terrace ID No.	Drainage Area (Ac)*	Slope[1] Category (%)	Terrace Length (ft)*	Terrace Depth at Outlet (ft)
1T	17.63	12-17	4360	4.5
2T	26.01	10-12	3560	4.5
3T	11.83	17-33	3360	3.5
4T	8.60	17-33	3160	3.5
5T	9.33	17-33	3160	3.5
6T	11.53	17-33	3280	3.5
7T	4.85	17-33	2040	3.5
8T	3.67	17-33	1400	3.5
9T	18.37	12-17	3960	4.5
10T	14.03	10-12	3840	4.5
11T	6.46	10-12	1560	3.5
12T	6.54	17-33	1400	3.5
13T	3.16	17-33	1040	3.5
14T	2.79	17-33	960	3.5
15T	9.33	17-33	3160	3.5
16T	10.58	17-33	2920	3.5
17T	7.35	17-33	2680	3.5
18T	8.82	17-33	2320	3.5
19T	3.75	17-33	1120	3.5
20T	6.24	17-33	720	3.5
21T	3.60	17-33	720	3.5
22T	2.57	12-17	560	3.5
23T	5.95	17-33	1240	3.5
24T	6.54	17-33	2240	3.5
25T	10.14	17-33	3240	3.5
26T	8.45	17-33	3320	3.5
27T	7.93	17-33	3520	4.5
28T	11.16	17-33	3800	4.5
29T	23.07	12-17	4000	4.5

TABLE 16 (Cont.)

Generic Watershed (N14-4W)

Terrace Data

Terrace ID No.	Drainage Area (Ac)*	Slope[1] Category (%)	Terrace Length (ft)*	Terrace Depth at Outlet (ft)
30T	6.54	17-33	1360	3.5
31T	9.62	17-33	2240	3.5
32T	8.82	10-12	3560	4.5
33T	1.76	17-33	440	3.5
34T	2.06	17-33	640	3.5
35T	2.57	12-17	840	3.5
36T	4.78	17-33	1080	3.5
37T	14.69	12-17	1520	3.5
38T	16.24	12-17	2840	3.5
39T	6.17	17-33	2600	3.5
40T	11.68	17-33	3760	4.5
41T	9.33	17-33	2440	3.5
42T	17.41	12-17	2400	3.5

*(See Table 11 for Area and Length Limits)

[1] Exact slope categories are:

$>10 - \leq 12$

$>12 - \leq 17$

$>17 - \leq 33$

TABLE 17

Generic Watershed Hydrology and

Hydraulic Data Summary

Sub-Watershed ID No.	Area (ac)	CN	Tc (hrs)	Q_{10} (cfs)	Q_{100} (cfs)	Structure	Slope (%)	Width (ft)	Lining[1] Type	Channel Vel_{10} (fps)	Dn_{10} (ft)	Vel_{100} (fps)	Dn_{100} (ft)
IS	902.8	81	0.587	210.4	543.4	Null	-	-	-	4.9	1.0	7.0	1.8
IIS	971.9	81	0.635	216.0	557.8	Channel	1.1	40	Suitable (OB)	5.0	1.0	7.1	1.8
							7	40	Riprap	7.4	0.7	9.9	1.3
IIIS	52.9	81	0.175	22.7	55.8	Downdrain	1.5	15	Suitable (OB)	3.2	0.4	4.4	0.7
							8.5	15	Riprap	5.0	0.3	6.6	0.5
IVS	1048.9	81	0.725	215.0	554.5	Channel	1.1	40	Suitable (OB)	5.0	1.0	7.1	1.8
							7	40	Riprap	7.4	0.7	9.9	1.3
VS	76.1	81	0.302	25.7	64.2	Downdrain	1.5	15	Suitable (OB)	3.3	0.4	4.7	0.8
							5	15	Riprap	4.7	0.3	6.1	0.6
VIS	82.0	81	0.380	24.6	62.2	Downdrain	1.5	15	Suitable (OB)	3.3	0.4	4.6	0.8
							3.3	15	Riprap	4.7	0.4	5.5	0.7
VIIS	57.9	81	0.284	20.2	50.2	Downdrain	1.6	15	Suitable (OB)	3.1	0.4	4.4	0.7
							5.5	15	Riprap	4.4	0.3	5.8	0.5
VIIIS	188.0	81	0.430	52.7	134.3	Downdrain	1.3	15	Suitable (OB)	4.1	0.7	5.8	1.3
							6.5	15	Riprap	6.1	0.5	7.9	0.9
IXS	200.9	81	0.425	56.7	144.4	Downdrain	1.3	15	Suitable (OB)	4.3	0.7	5.9	1.3
							5.5	15	Riprap	6.0	0.6	7.8	1.0
XS	1492.5	81	0.851	277.0	712.2	Channel	1.1	40	Suitable (OB)	5.5	1.2	7.7	2.1
							5.0	40	Riprap	7.5	0.9	9.8	1.6

Note 1: OB = Overburden

require a gravel lining if the channel does not have sufficient roughness to reduce the velocities during the 100 year storm event.

c) Subwatershed No. III - This subwatershed contains areas that are undisturbed and disturbed. An undisturbed ephemeral channel will flow through the proposed reclamation area. This flow is routed to an ephemeral downdrain in the reclamation, downdrain - 1D. If the entire downdrain has an average slope of 8.5 percent, then a channel 15 feet wide will need to be riprapped. If portions of the channel can be flattened to 1.5 percent or flatter, then only the steeper portions will require channel lining protection.

d) Subwatershed No. IV - This subwatershed will contain the primary reclamation channel - 3C. The initial design indicates the channel will need several sloped drop structures at a 7 percent slope in order to allow the remaining portion of the channel to be constructed at a 1.1 percent slope or flatter. This will create subcritical flow at the design channel width of 40 feet. The channel may require a gravel lining if the channel does not have sufficient roughness to reduce the velocities during the 100 year storm event.

e) Subwatershed No. V - This subwatershed contains a small area which is undisturbed; the remaining area will be reclaimed. The runoff will flow into downdrain - 2D. If the entire downdrain has an average slope of 5 percent, then a channel 15 feet wide will need to be riprapped at least a minimum of 15 feet beyond the end of the downdrain where the slope is 1.5 percent or flatter (i.e., subcritical). If portions of the channel can be flattened from 5 percent to 1.5 percent or flatter, then only the steeper portions will require channel lining protection.

f) Subwatershed No. VI - This subwatershed will be totally reclaimed. The upper portion of downdrain - 3D is flat enough where a channel lining is not required; whereas, the last portion would be steeper than 1.5 percent and require riprap at the outlet to Subwatershed No. 6.

g) Subwatershed No. VII - This subwatershed will be totally reclaimed except for a small portion at the lease boundary. The runoff will flow into downdrain - 4D. If the entire downdrain has an average slope of 5.5 percent, then a channel 15 feet wide will need to be riprapped. If portions of the channel can be flattened to 1.6 percent or flatter, then only the steeper portions will require channel lining protection.

h) Subwatershed No. VIII - This subwatershed receives the flow from Subwatershed Nos. 5, 6, and 7. The runoff will flow into downdrain 5D. If the entire downdrain has an average slope of 6.5 percent, then a channel 15 feet wide will need to be riprapped. If portions of the channel can be flattened to 1.3 percent or flatter, then only the steeper portions will require channel lining protection.

i) Subwatershed No. IX - This subwatershed will be totally reclaimed except for a small portion at the lease boundary. The runoff will flow into downdrain 6D. If the entire downdrain has an average slope of 5.5 percent, then a channel 15 feet wide will need to be riprapped. If portions of the channel can be flattened to 1.3 percent or flatter, then only the steeper portions will require channel lining protection.

j) Subwatershed No. X - This subwatershed receives the runoff from the entire watershed. The runoff will flow into the primary reclamation channel 4C. The initial design indicates the channel will need several sloped drop structures at a 5 percent slope in order to allow the remaining portion of the channel to be constructed at a 1.1 percent or flatter slope. This will create subcritical flow at the design channel width of 40 feet. The channel may require a gravel lining if the channel does not have sufficient roughness to reduce the velocities during the 100 year storm event. The end of the channel will be blended into the surrounding topography to allow a smooth transition into the downstream N14-G Dam's ponding area.

In conclusion, the above Generic Watershed Design Example represents the preliminary calculations performed to develop a Preliminary Watershed Drainage Plan (see Figures 1 and 2). These design slopes and channel widths will be used as a guideline by the reclamation crew in the rough grading phase of the backfilling and grading operations. As the subwatershed areas become finish graded, then a Final Watershed Drainage Plan will be developed (see Figures 1 and 3). Between the Preliminary and Final Watershed Drainage Plan, the engineer can be working with the reclamation crew at the site to modify the plan as necessary to fit the drainage pattern to the grading operation and to the local geological conditions.

Once the topographic data has been updated, the Final Watershed Drainage Plan will be finalized for each conveyance structure (see Figure 3). The locations and alignments are then staked and the reclamation crew completes the finish grading and lining of the structures as necessary.

Watershed Structure Maintenance and Monitoring. Two types of monitoring and maintenance will be conducted on reclaimed lands. Both types are illustrated on Figure 1. The watershed structure maintenance and monitoring is primarily conducted to determine if the conveyance structures are performing as designed and are stable. The associated activities are described below. The second type of inspection conducted is the general reclamation maintenance and monitoring that is described in the Rill and Gully Plan presented in Chapter 26. This plan should be reviewed concurrently. Both inspection activities which may be conducted concurrently will ensure the success of the surface stabilization plan.

Maintenance, Monitoring and Reporting. Reclaimed conveyance structures will be monitored for instability during routine engineering and reclamation inspections and when revegetation sampling is conducted. Emphasis will be placed on periods following heavy snowmelt or rains. The conveyance structures will also be monitored for unstable channel lining material, reduced freeboard, and other conditions that would effect the performance of the structures. If the monitoring shows evidence of instability or it appears likely that the structure's integrity is compromised, the following action will be taken. The first step will involve determination of the source or cause of the problem. This will in turn provide the basis or approach to be taken for remedial action. If it is determined that the source or cause is related to the construction of a properly engineered and designed structure, the structure will be properly repaired or reconstructed to meet specifications. Any rill and gully areas which may have resulted from instability will be backfilled, graded, topsoiled, mulched, and reseeded or allowed to stabilize naturally if this action is feasible and will result in less associated disturbance. If it is determined that the topography or drainage characteristics of the affected portion of the reclaimed landscape is such that drainage is concentrated in an area not controlled by a designed conveyance, then the area will be redesigned for the proper conveyance structure, the structure will be built, and any adjacent area affected by rills and gullies will be repaired or allowed to stabilize naturally as stated in Chapter 26.

The locations of rill and gully areas, conveyance structure maintenance areas, and the causes of their formations and remedial activities performed will be documented in watershed files maintained at the Black Mesa Complex. In addition, an annual rill and gully, and conveyance structure maintenance status report will be submitted to the regulatory authority by June 1.

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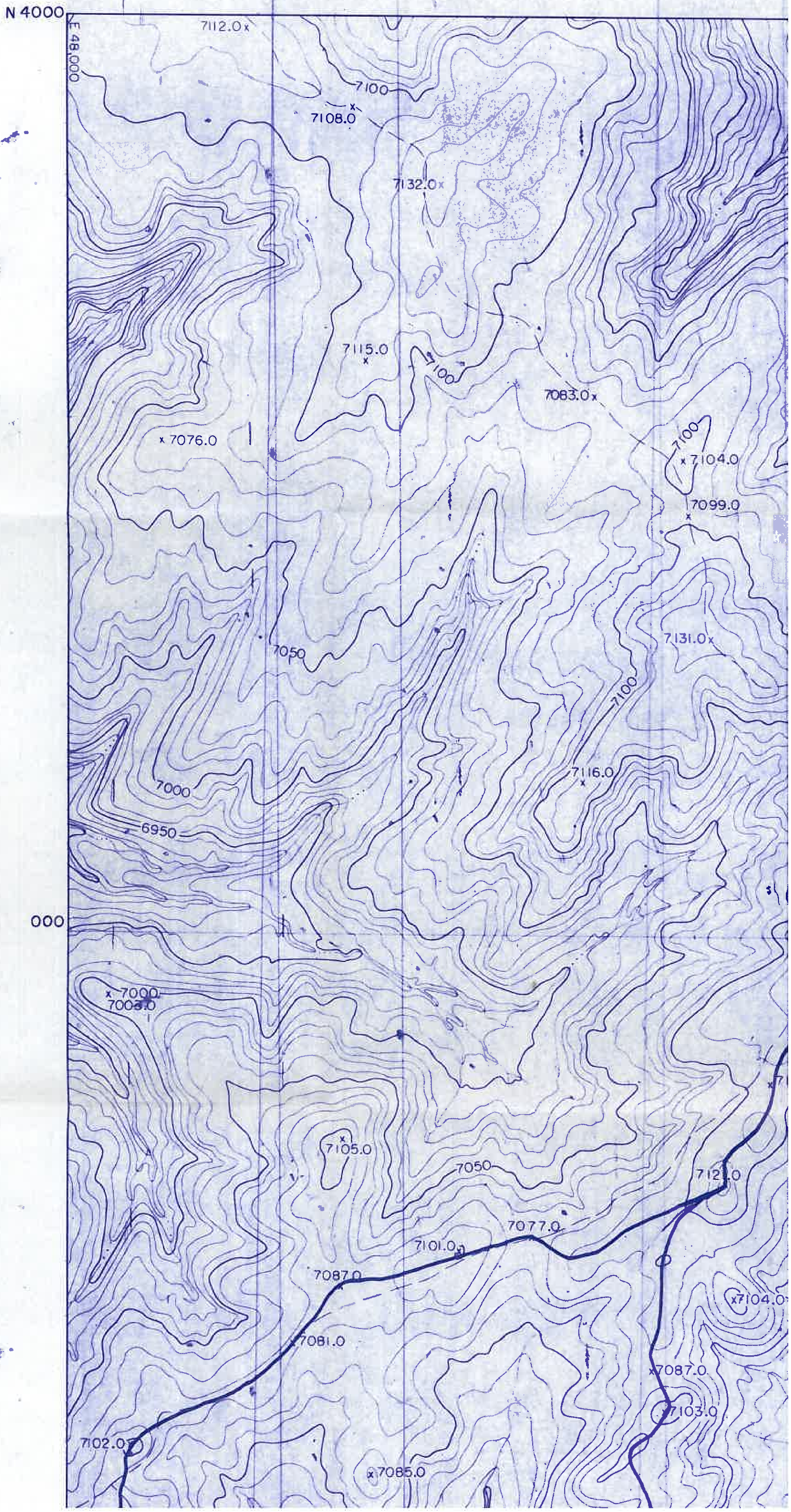
ATTACHMENT B-1

GENERIC WATERSHED DESIGN EXAMPLE

GENERIC WATERSHED MAP

DRAWING 85354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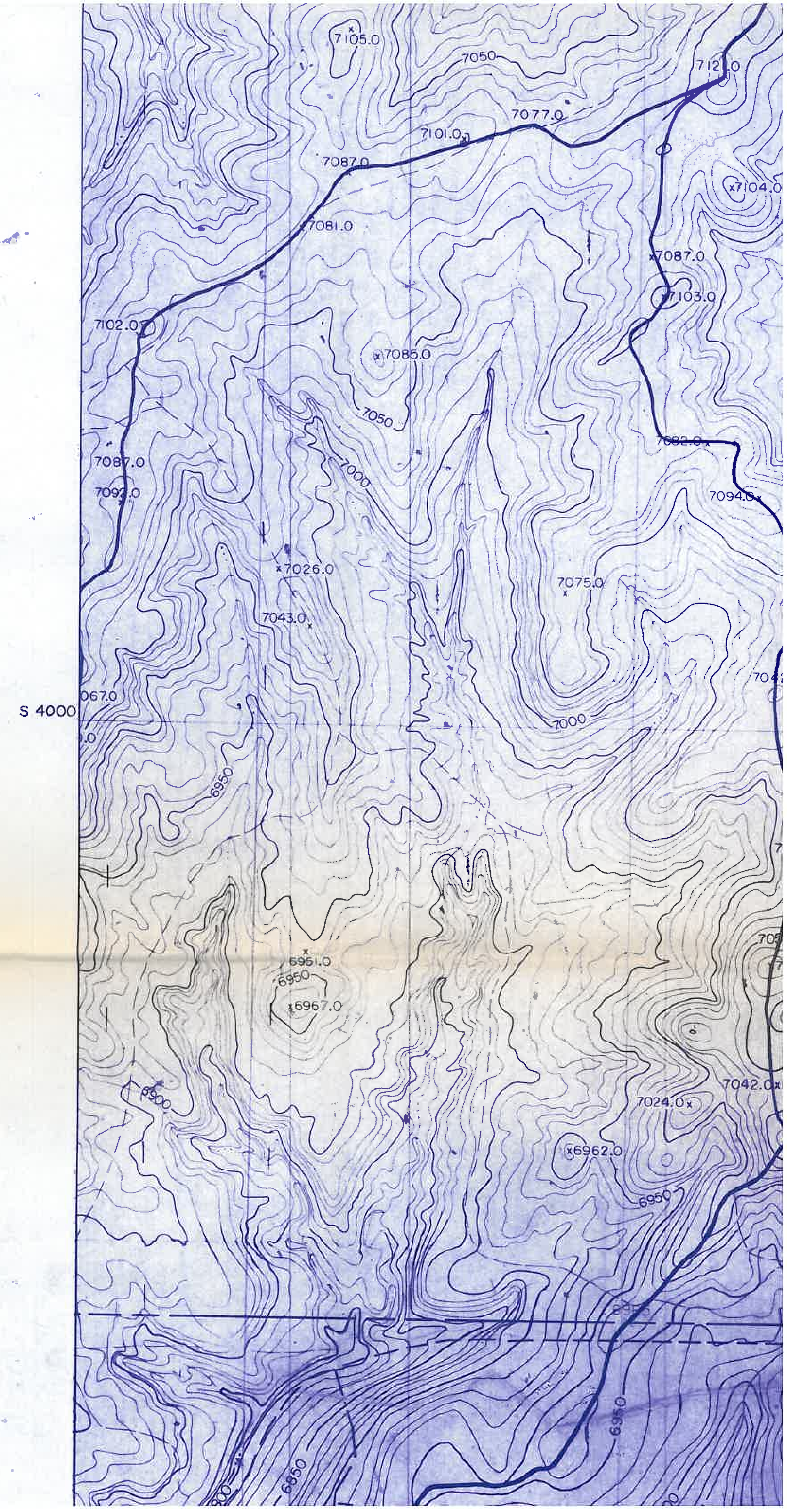

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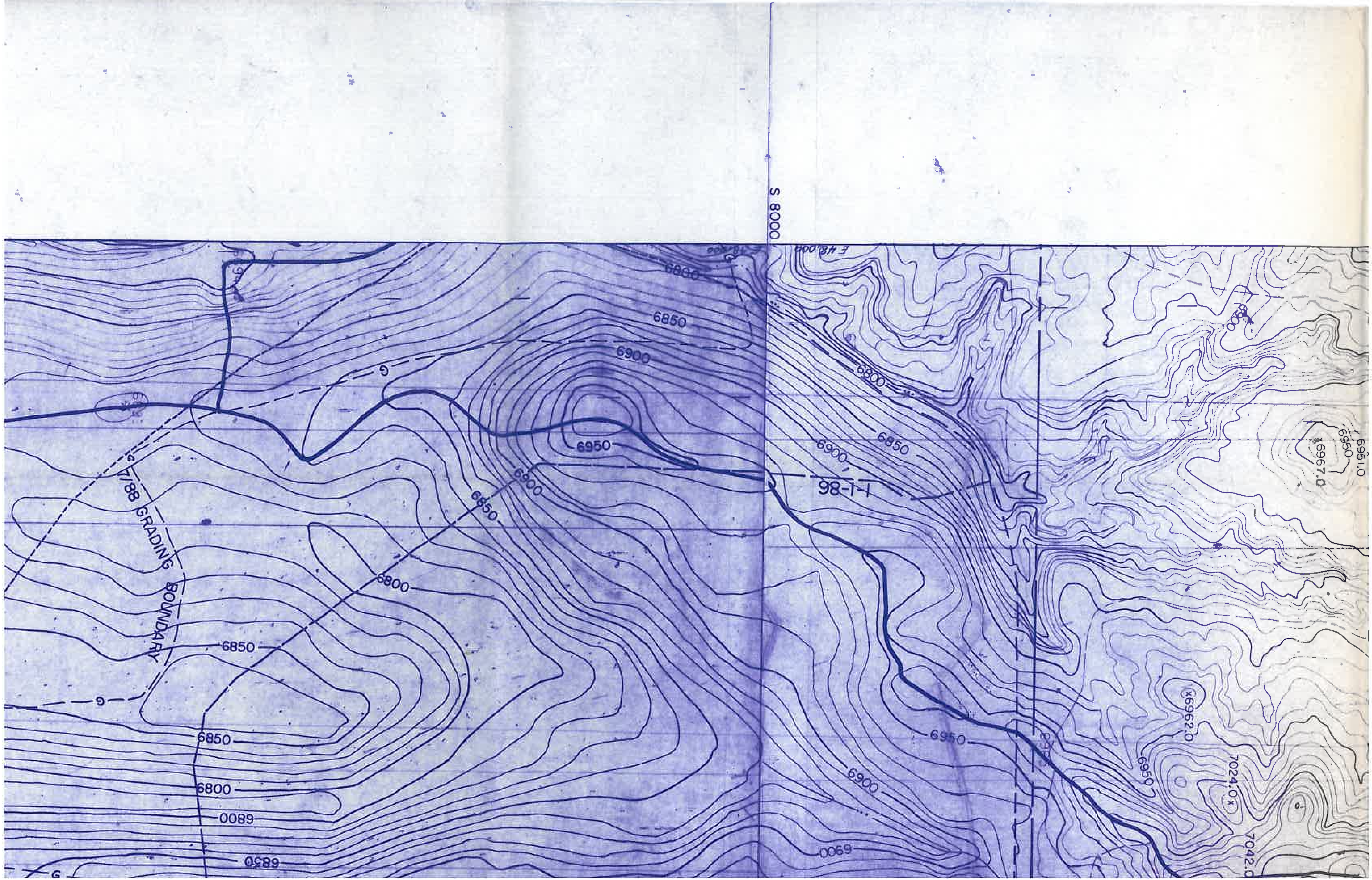
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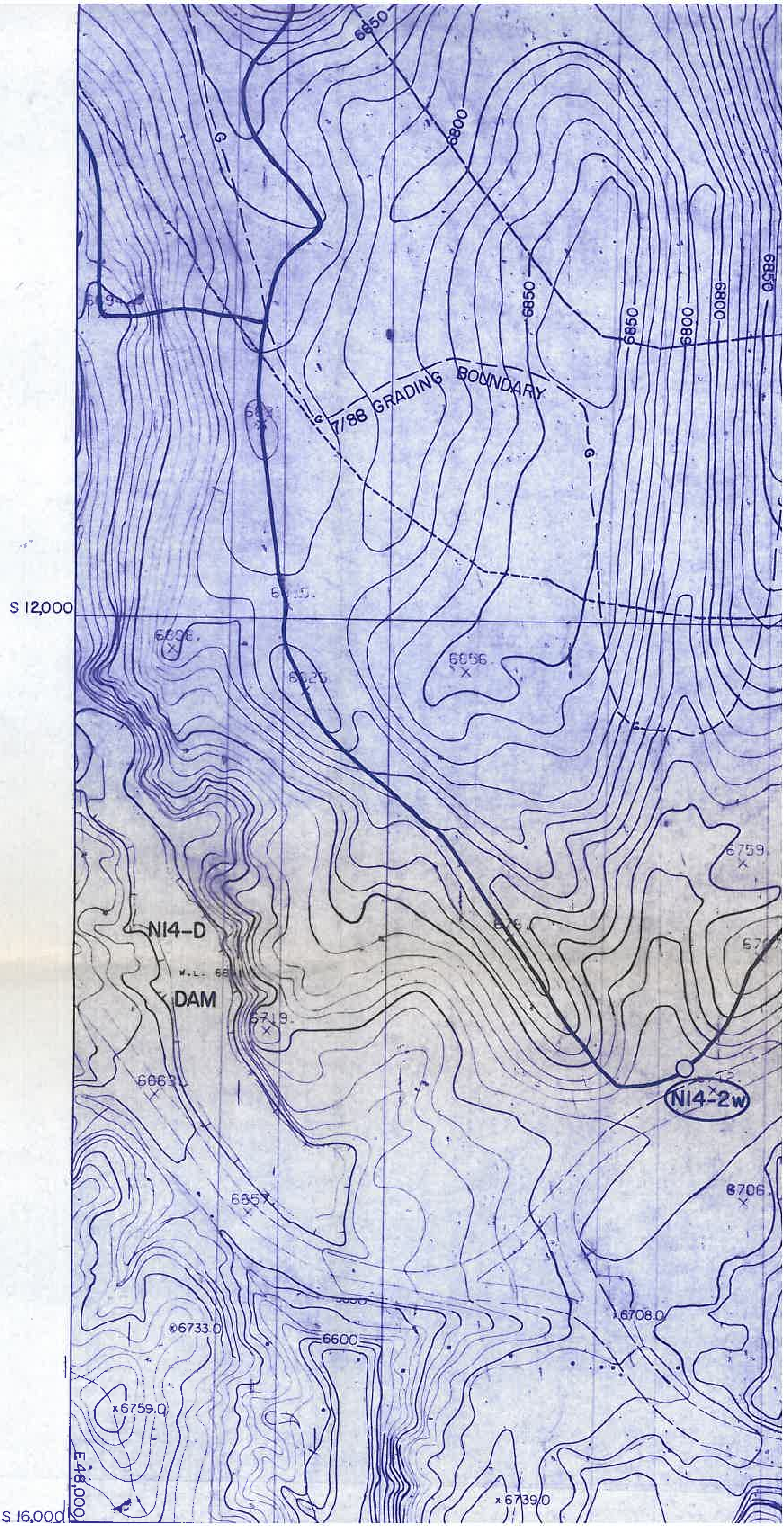
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S 16,000
E 48,000
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DAM
N14-2W
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6856.
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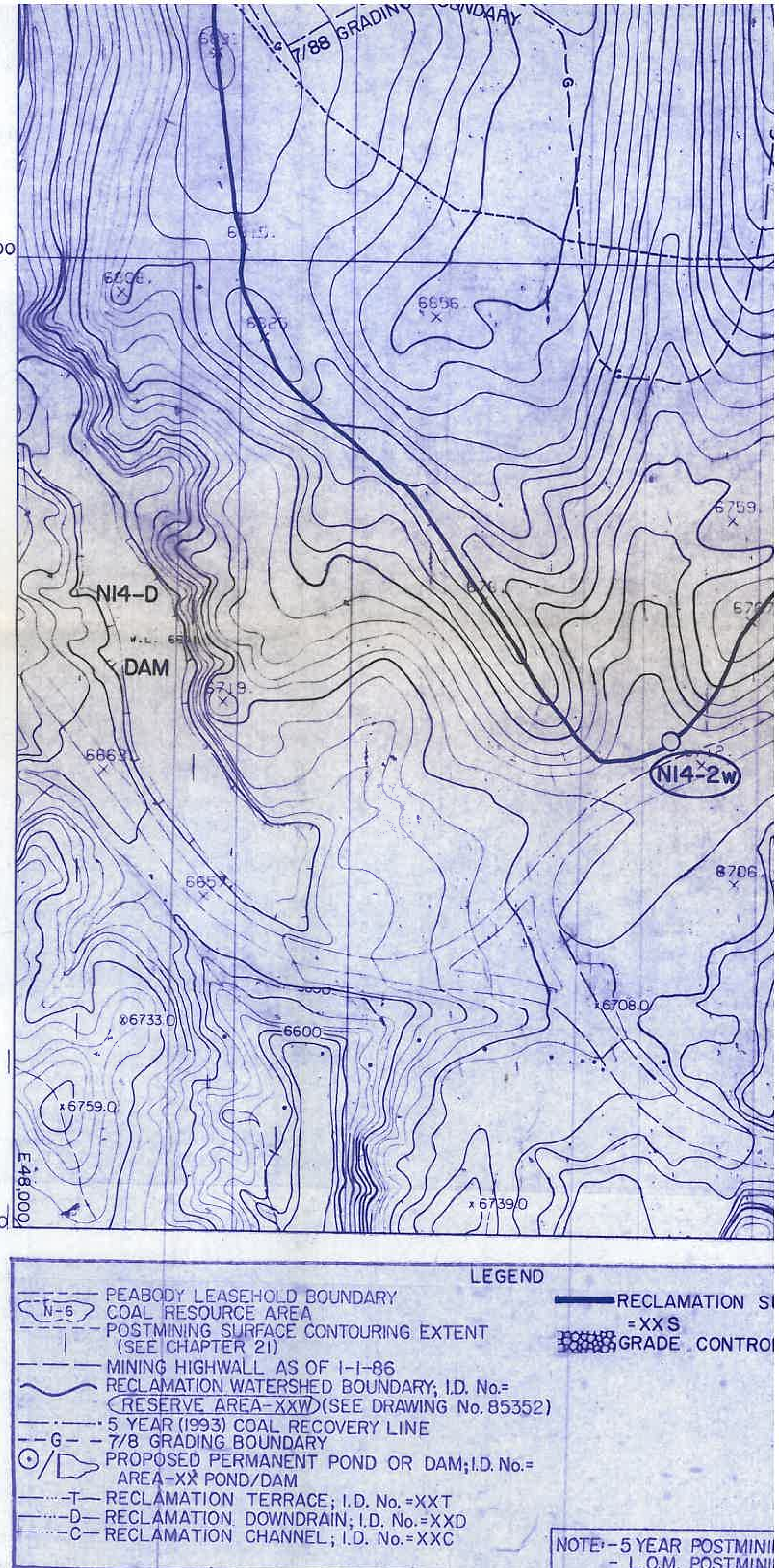

7/88 GRADING BOUNDARY
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NI4-D
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NI4-2W
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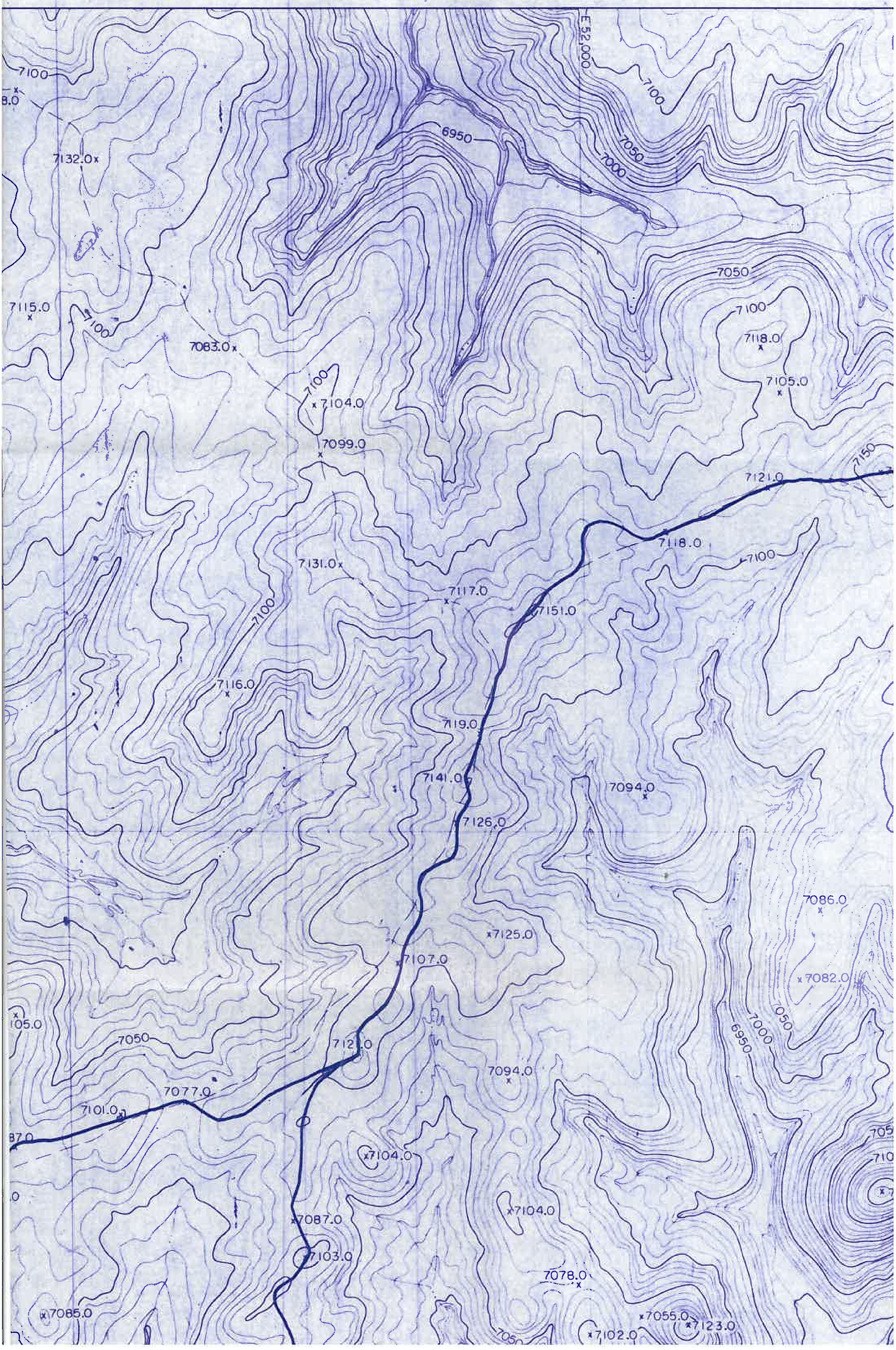
6759.0
E 48,000
S 16,000
6739.0
LEGEND
PEABODY LEASEHOLD BOUNDARY
N-6 COAL RESOURCE AREA
POSTMINING SURFACE CONTOURING EXTENT (SEE CHAPTER 21)
MINING HIGHWALL AS OF 1-1-86
RECLAMATION WATERSHED BOUNDARY; I.D. No.=
RESERVE AREA-XXW (SEE DRAWING No. 85352)
5 YEAR (1993) COAL RECOVERY LINE
G 7/8 GRADING BOUNDARY
PROPOSED PERMANENT POND OR DAM; I.D. No.= AREA-XX POND/DAM
T RECLAMATION TERRACE; I.D. No.=XXT
D RECLAMATION DOWNDRAIN; I.D. No.=XXD
C RECLAMATION CHANNEL; I.D. No.=XXC
RECLAMATION S
=XXS
GRADE CONTRO
NOTE: -5 YEAR POSTMINI
- L.O.M. POSTMINI



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7100
7151.0
7116.0
7119.0
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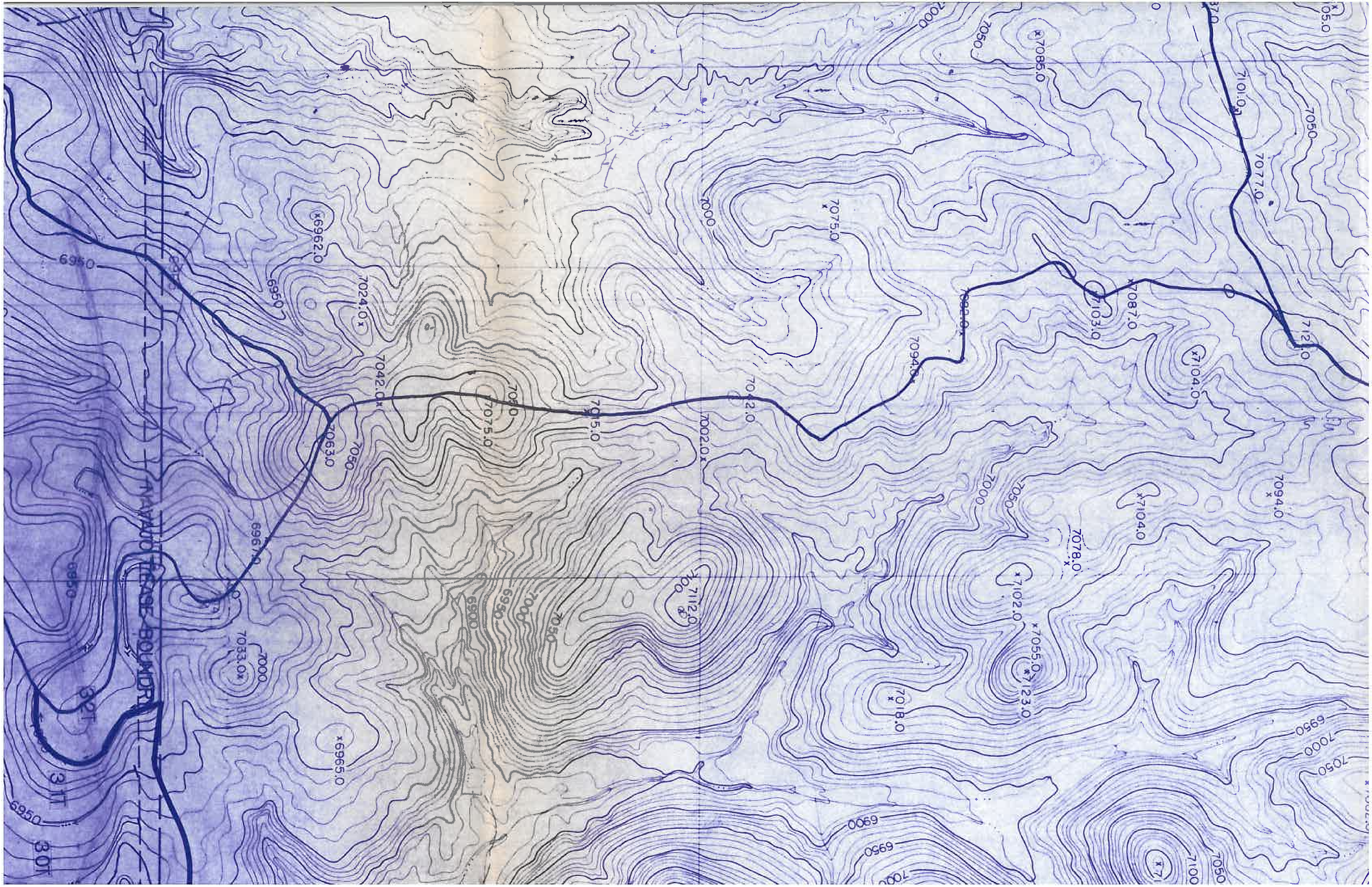

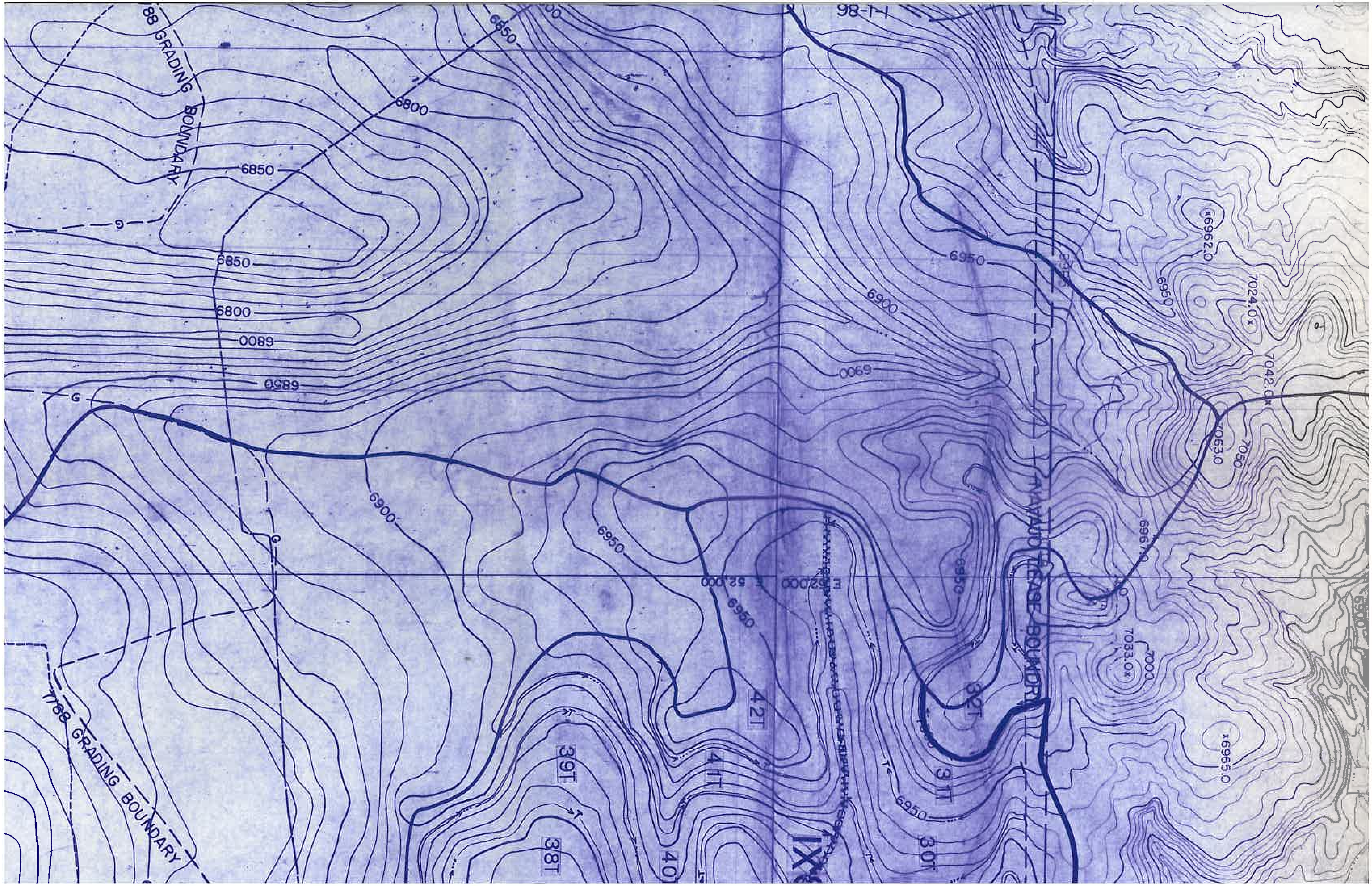
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NAVAJO LEASE BOUNDARY
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7050
7033.0x
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31T
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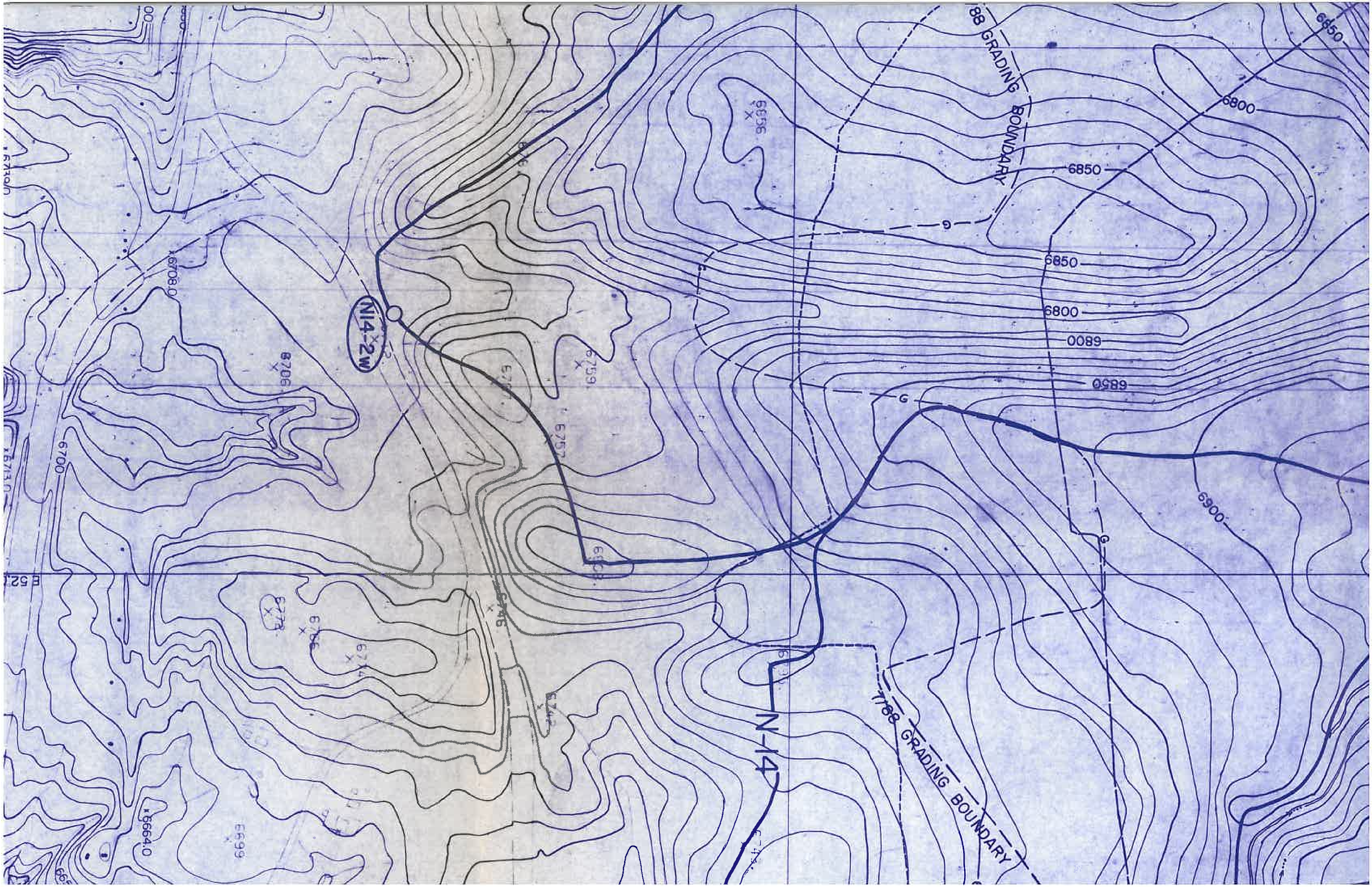
GRADING BOUNDARY



88 GRADING BOUNDARY
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6800
6850
6900
N14-2W
N-14
7/88 GRADING BOUNDARY
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6757
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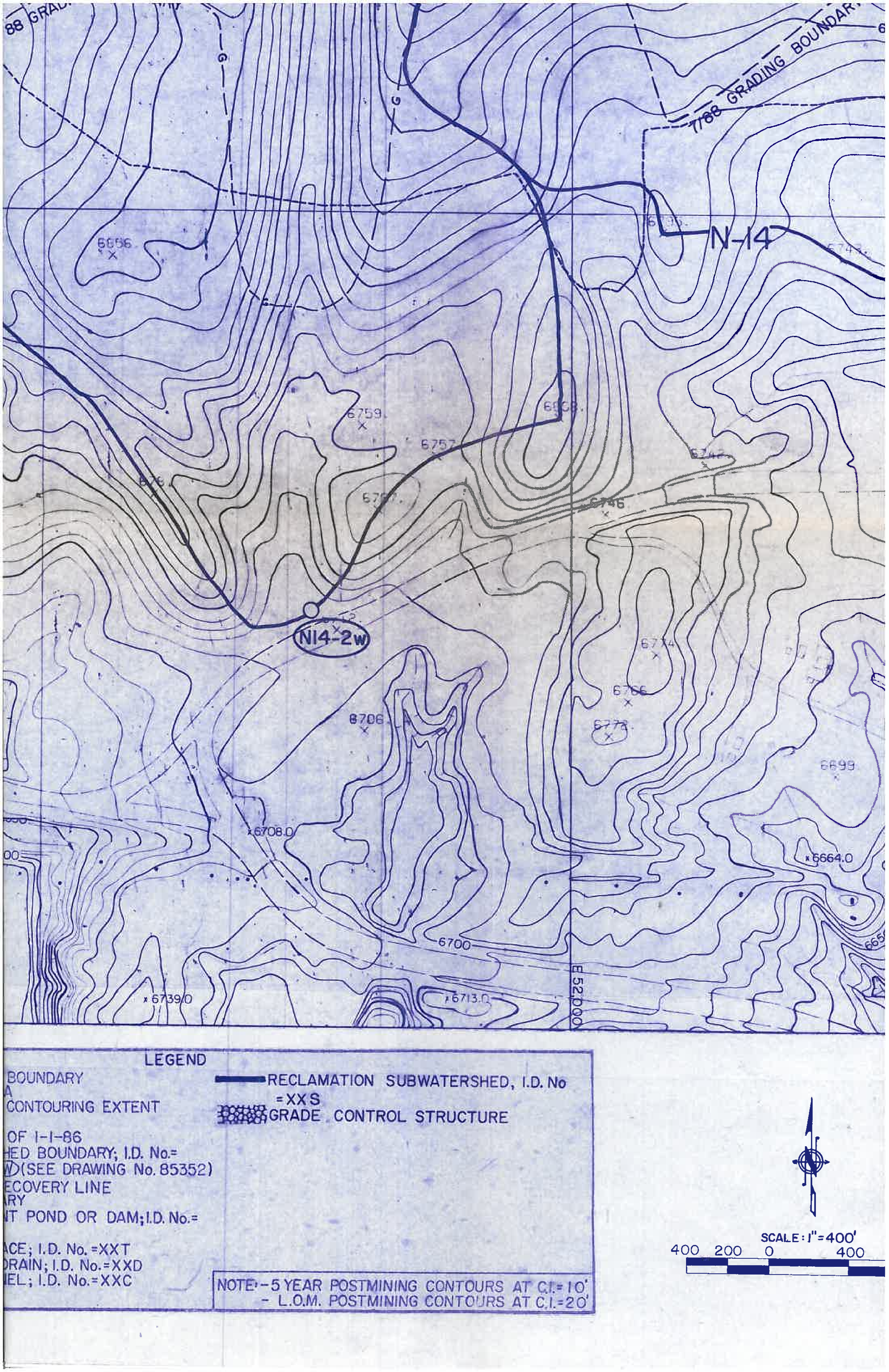
6699
6774
6706



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N14-2W
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6766
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6699
6708.0
6664.0
6700
6739.0
6713.0
E 52,000
LEGEND
BOUNDARY
A
CONTOURING EXTENT
OF 1-1-86
HED BOUNDARY; I.D. No.=
W(SEE DRAWING No. 85352)
ECOVERY LINE
ARY
IT POND OR DAM; I.D. No.=
ACE; I.D. No. =XXT
DRAIN; I.D. No.=XXD
NEL; I.D. No.=XXC
RECLAMATION SUBWATERSHED, I.D. No =XXS
GRADE CONTROL STRUCTURE
NOTE: - 5 YEAR POSTMINING CONTOURS AT C.I.= 10'
- L.O.M. POSTMINING CONTOURS AT C.I.= 20'
SCALE: 1"= 400'
400 200 0 400


E 52,000
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7164.0
7041.0
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7122.0
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7128.0
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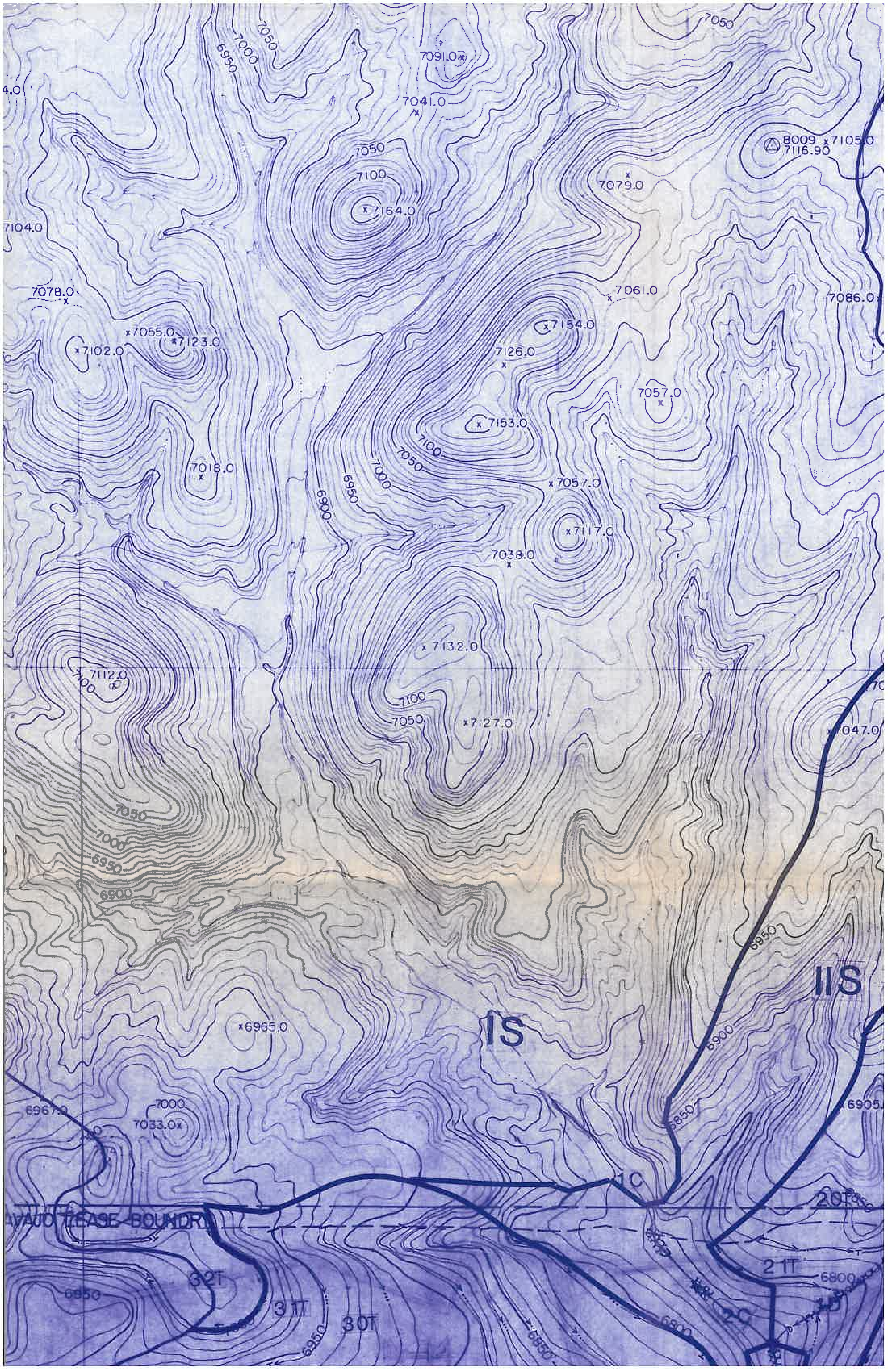
7157.0



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7018.0
7057.0
7117.0
7038.0
7132.0
7112.0
7127.0
7047.0
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IIS
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21T
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LEASE BOUNDRY
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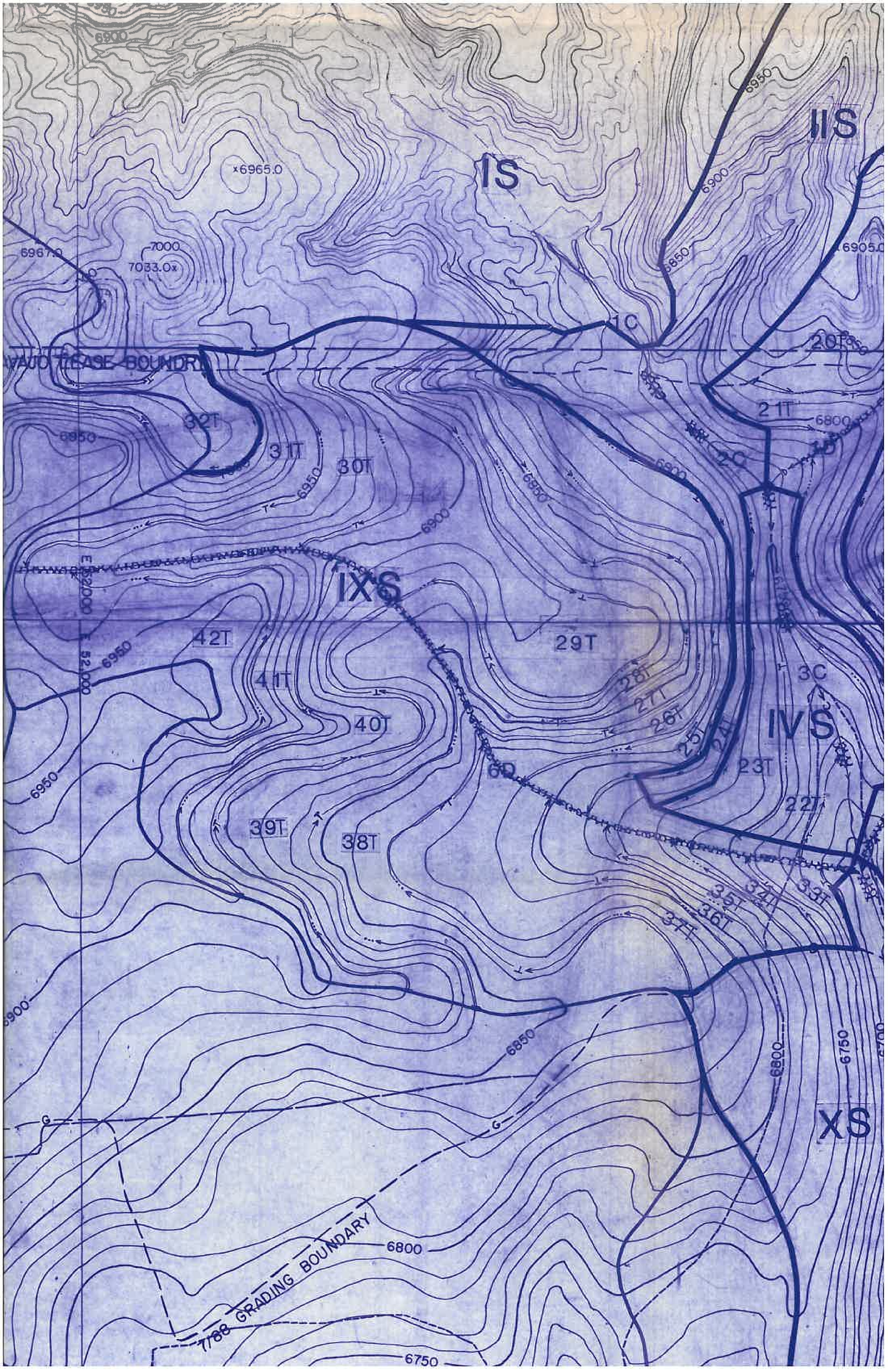

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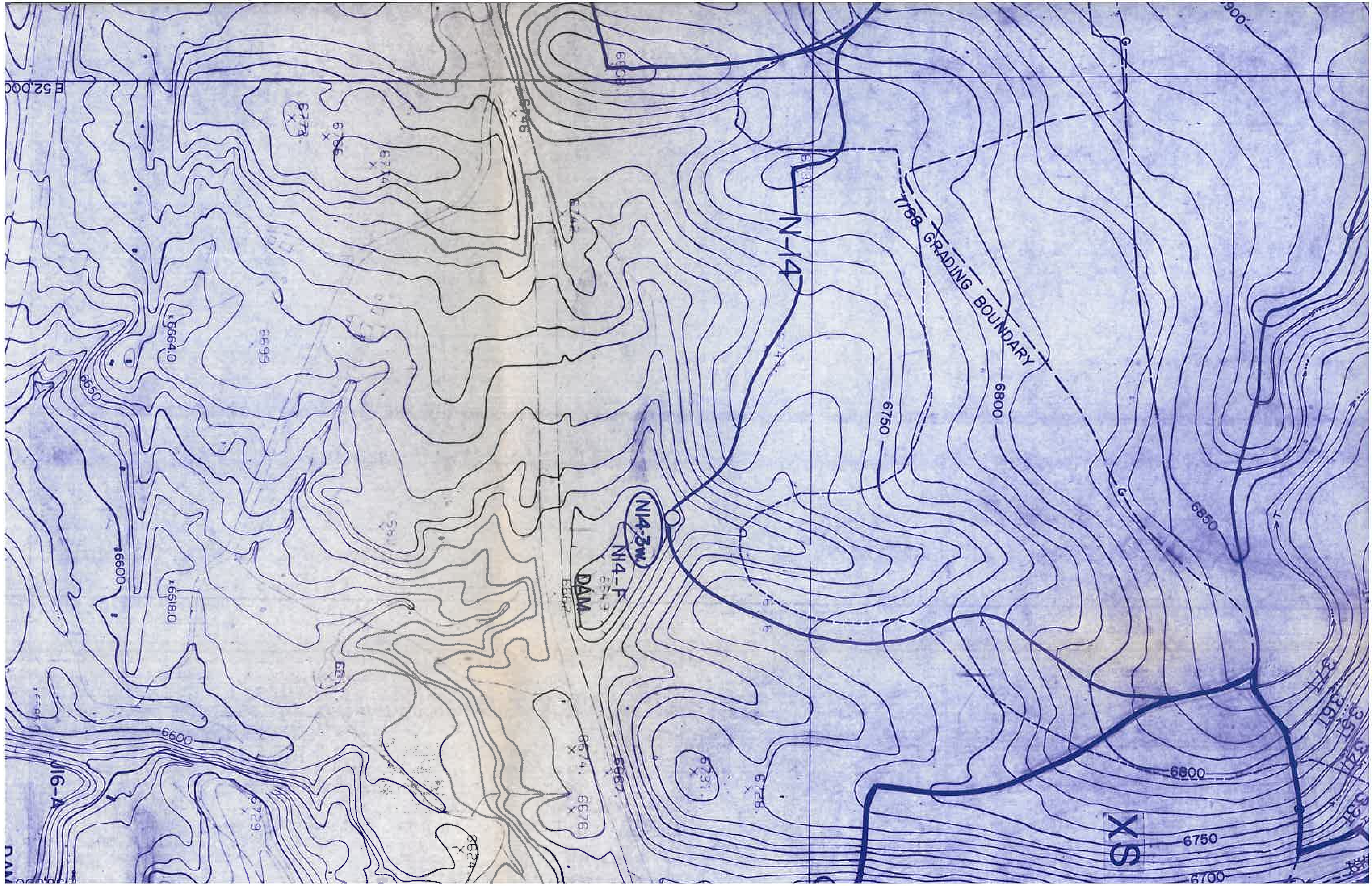
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7788 GRADING BOUNDARY
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N14-F
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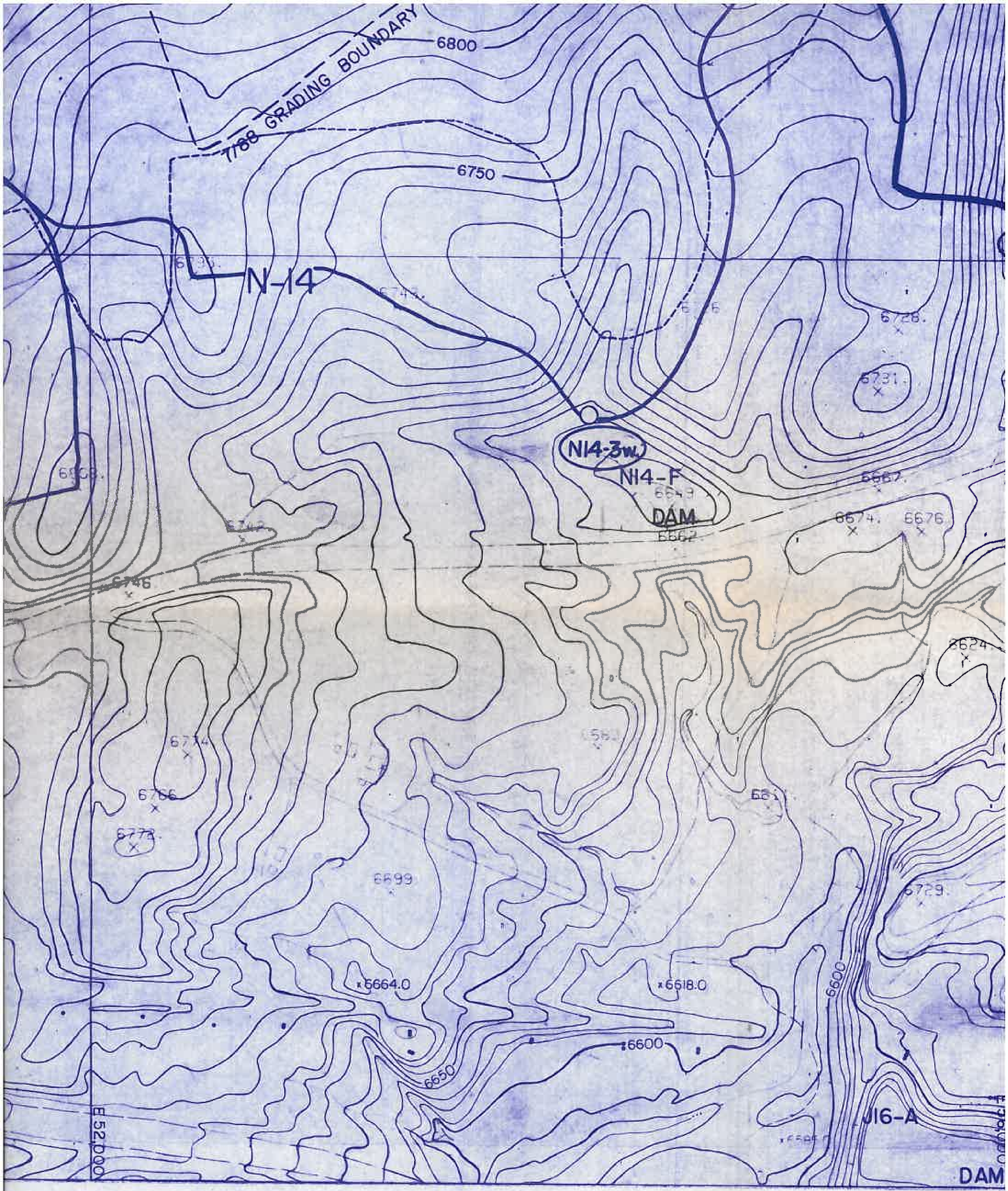


ED, I.D. No

RE

S AT C.I.= 10'
S AT C.I.=20'

SCALE: 1"=400'

400 200 0 400 800

ENGINEER'S CERTIFICATION

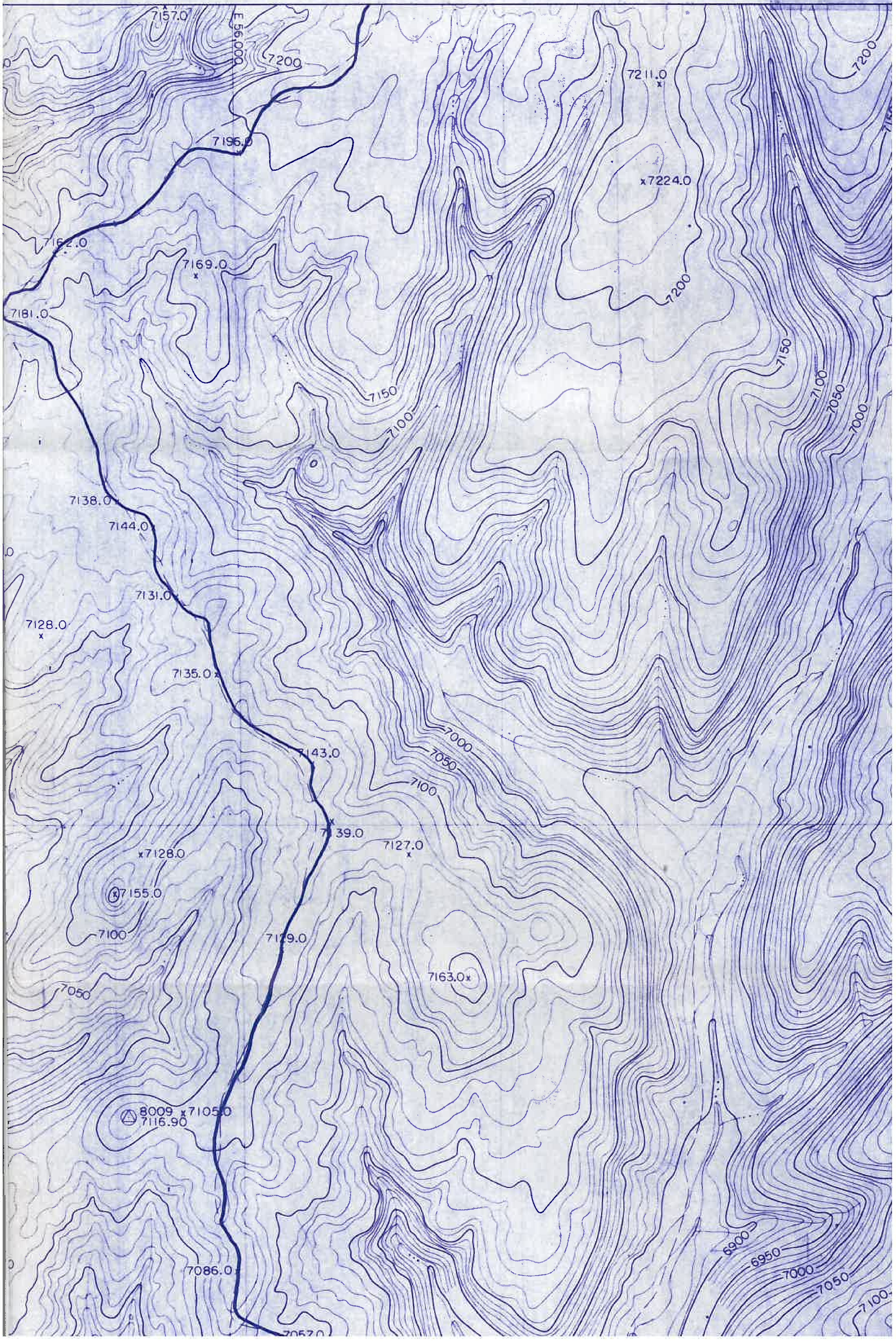
JAMES G. SCHLENVOGT
SENIOR ENGINEER
Peabody Coal Company

ARIZONA P.E. 18782

DATE: JAN 1 4 1989

Registered Professional Engineer (Civil) · Certificate No. 18782 · JAMES GARY SCHLENVOGT · ARIZONA, U.S.A.

(SEE DRAWING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7138.0
7144.0
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7135.0
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7050
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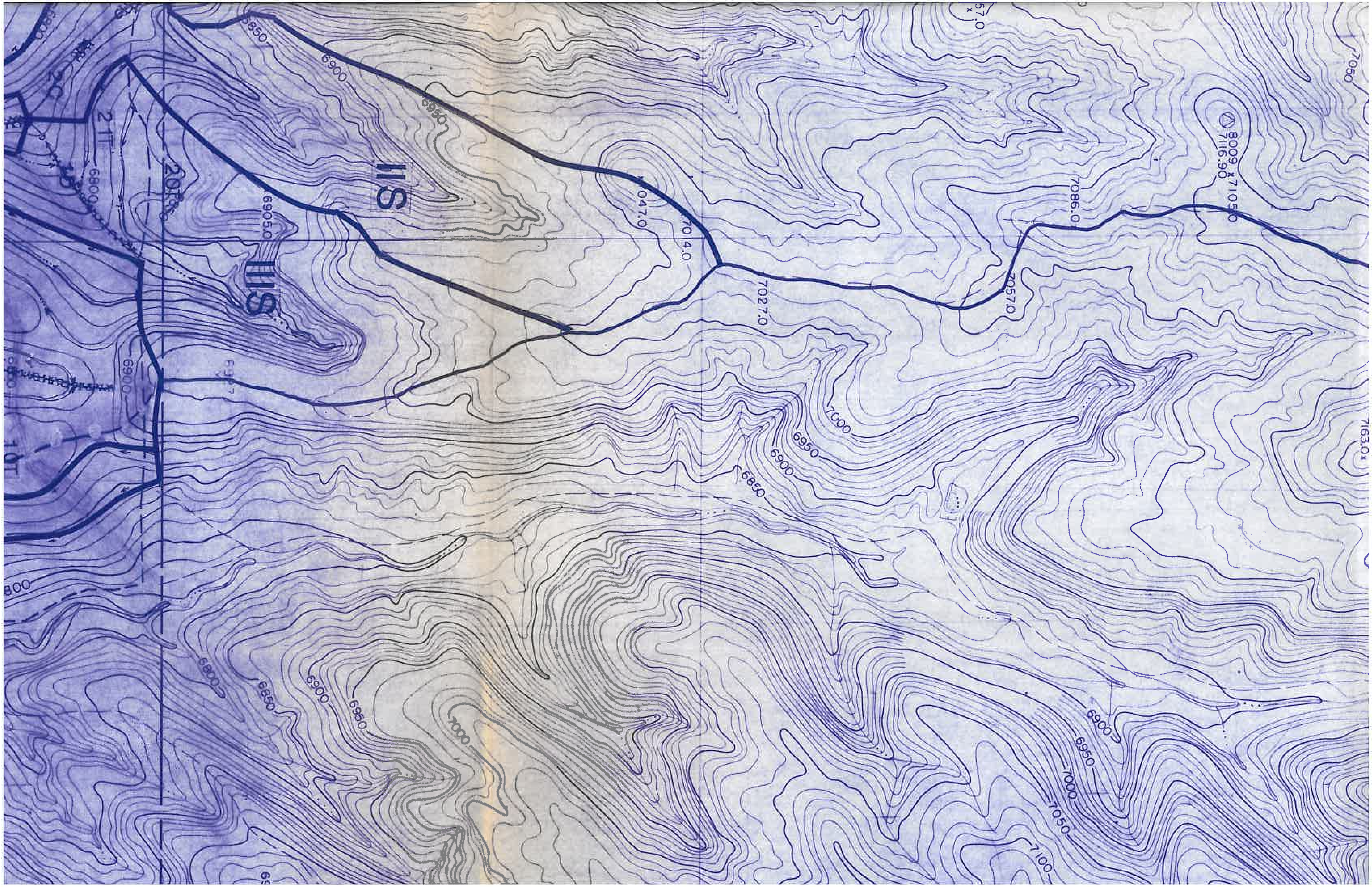

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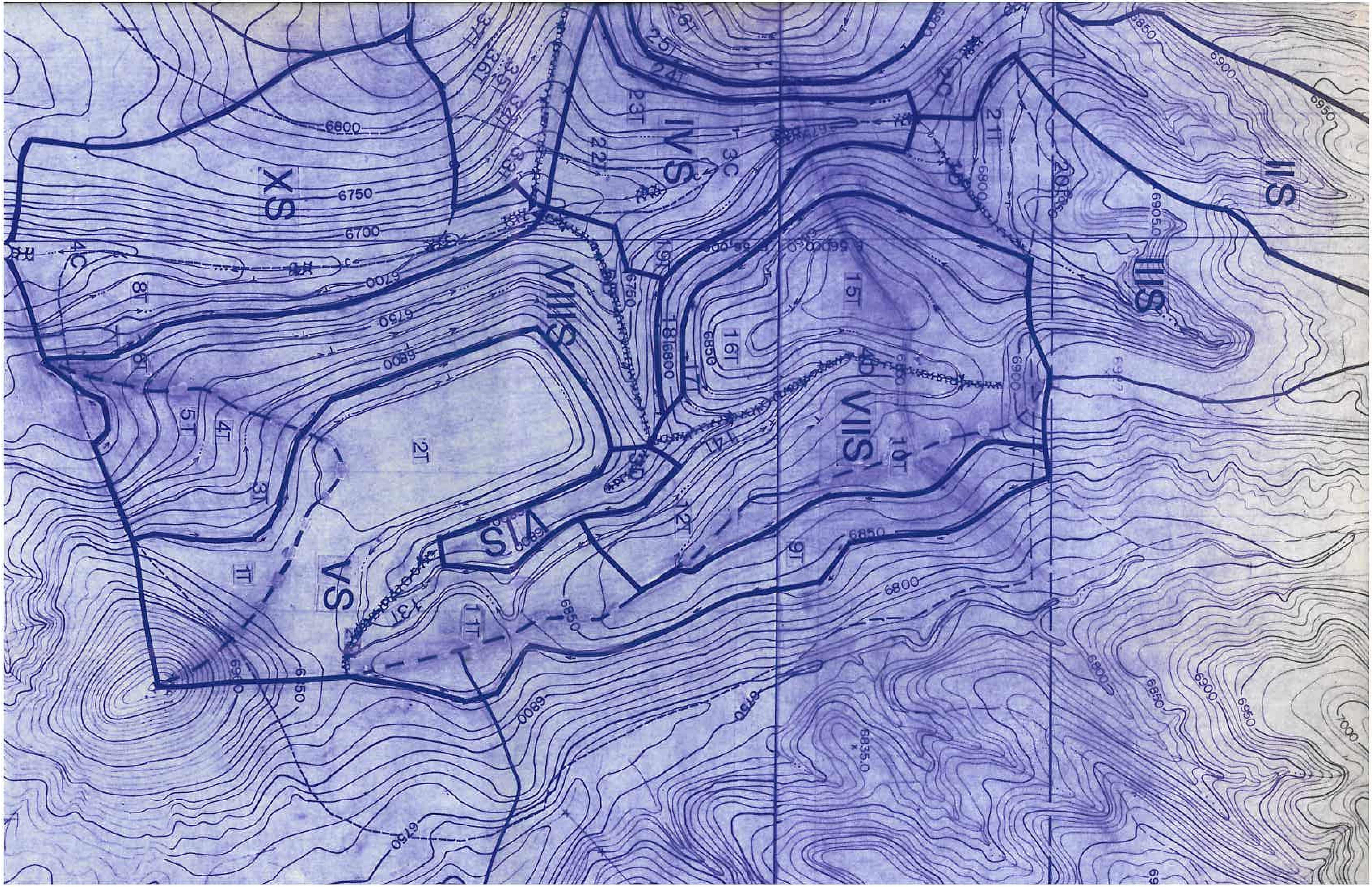

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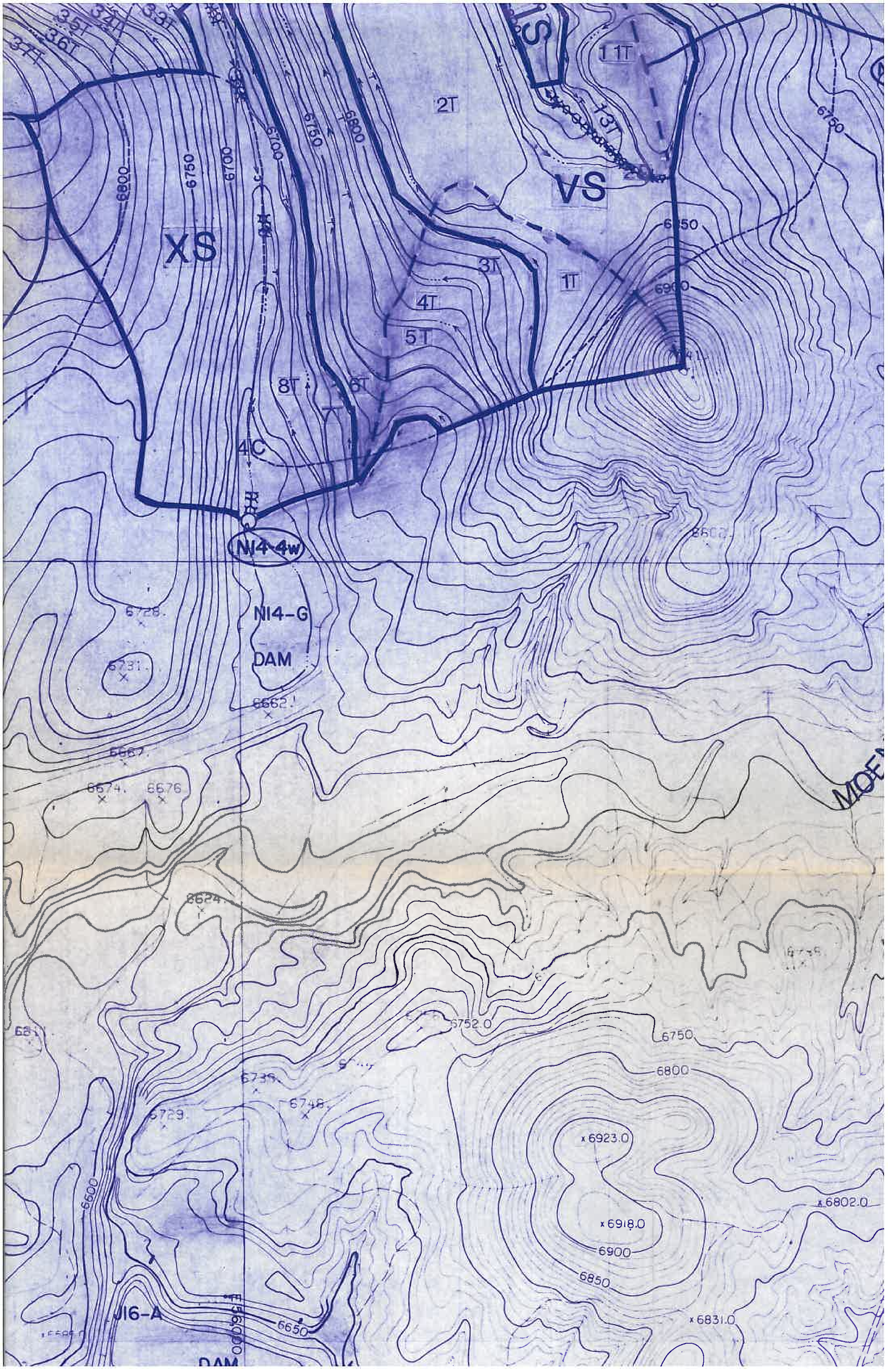
3C
4C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4C
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NI4-4w
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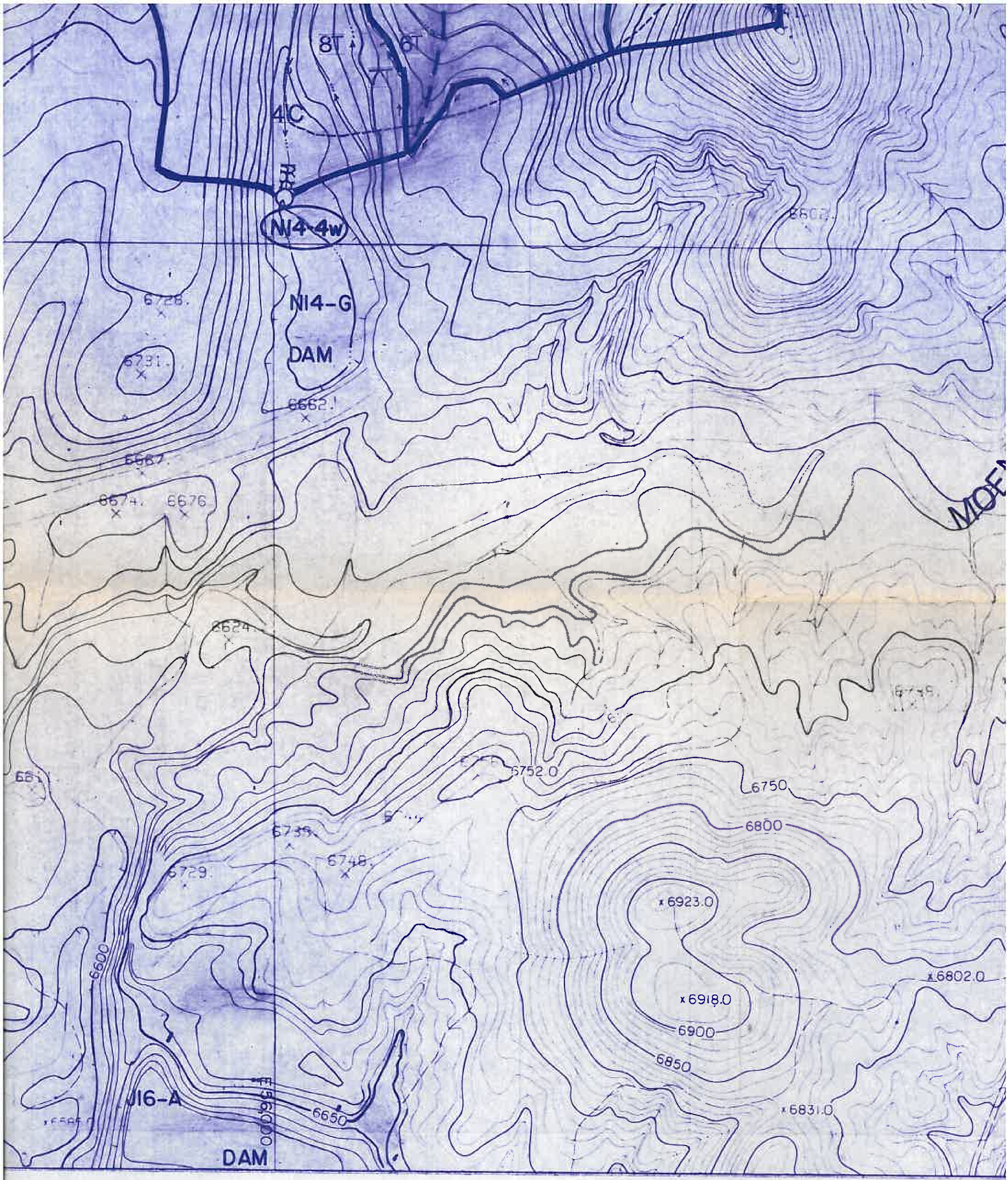


S CERTIFICATION

ARIZONA P.E. 18782

DATE: JAN 1 4 1989

PEABODY COAL C
BLACK MESA - KAYE
P.O. BOX 6
KAYENTA, ARIZONA

GENERIC
WATERSHE
(ESTIMATED POSTMINING TOPOGRA

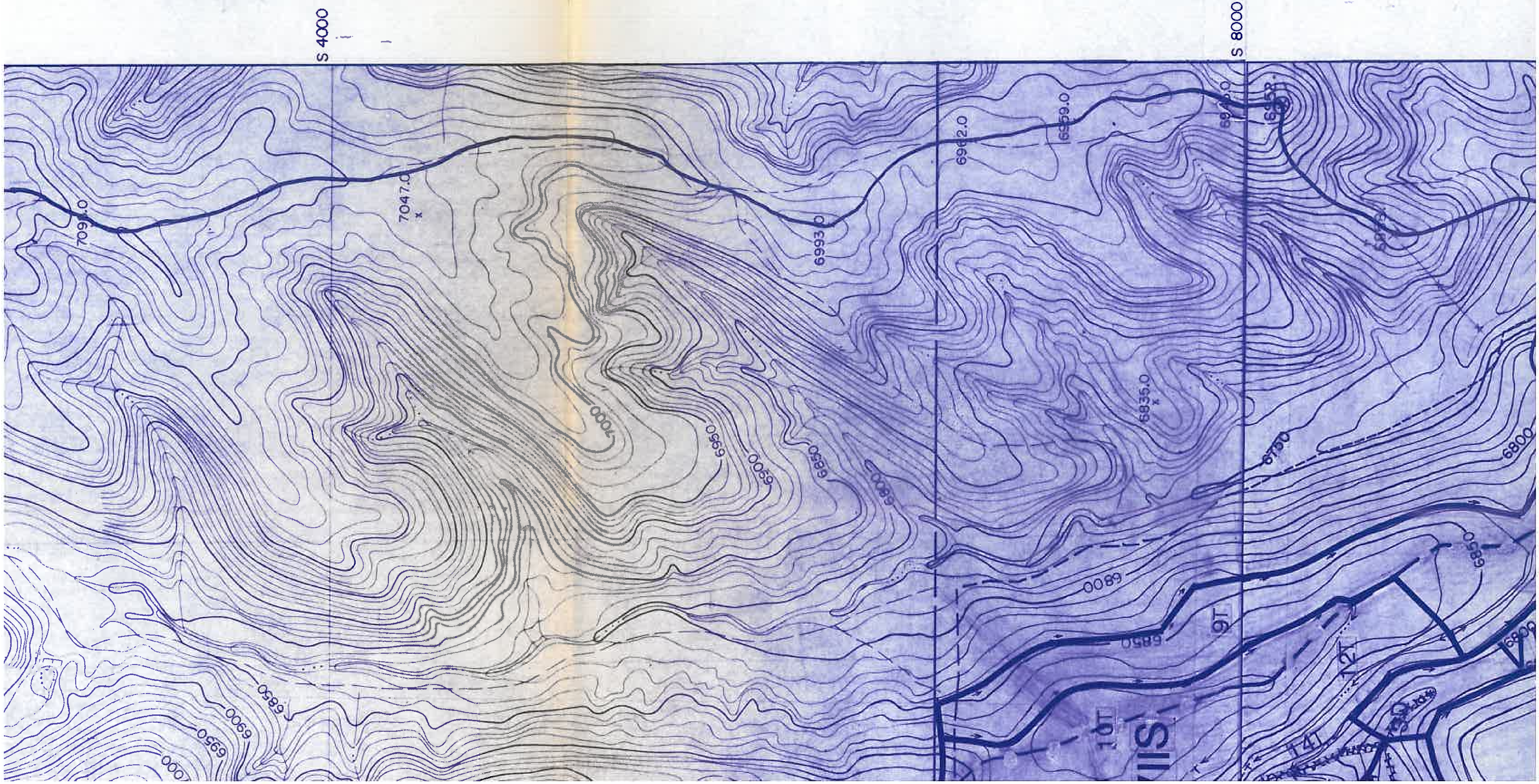
DRAWN BY	APP'D BY	DATE	REVISION DESCRIP

PEABODY COAL COMPANY
BLACK MESA – KAYENTA MINE
P.O. BOX 625
KAYENTA, ARIZONA 86033

GENERIC WATERSHED (ESTIMATED POSTMINING TOPOGRAPHIC MAP)	DRG. No. 85354
	SHEET No. M-7,M-8
	DRAWN BY: G.A.
	DATE: 1/10/89
	SCALE: 1"=400'
	C.I. 10'

DRAWN BY	APP'D BY	DATE	REVISION DESCRIPTION

S 8000
S 12,000
MOENKOPI WASH
DAM
N14-H
N14-5W
6750
6800
6850
VS
VIS
IS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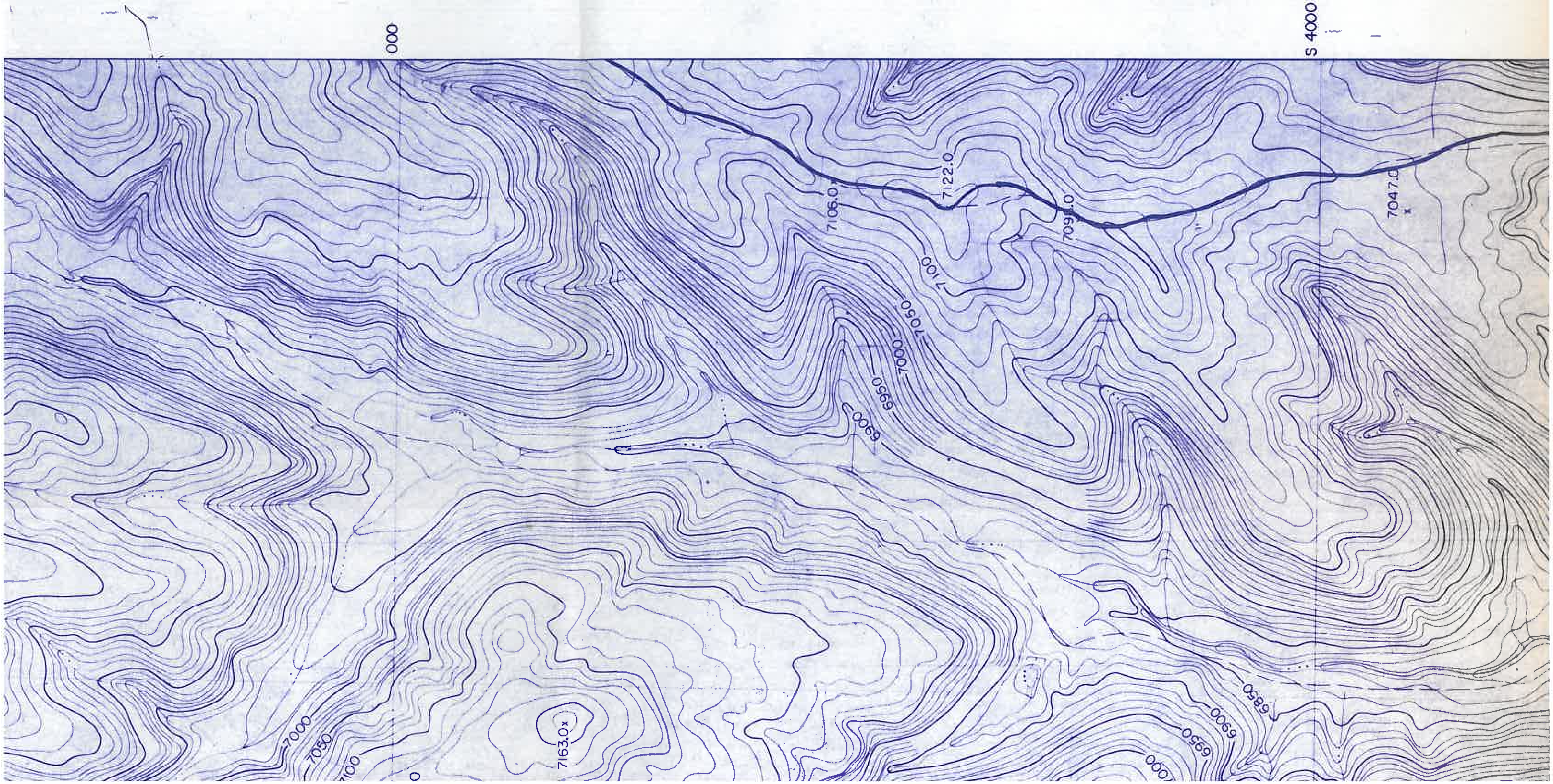
6900
6850
6800
6750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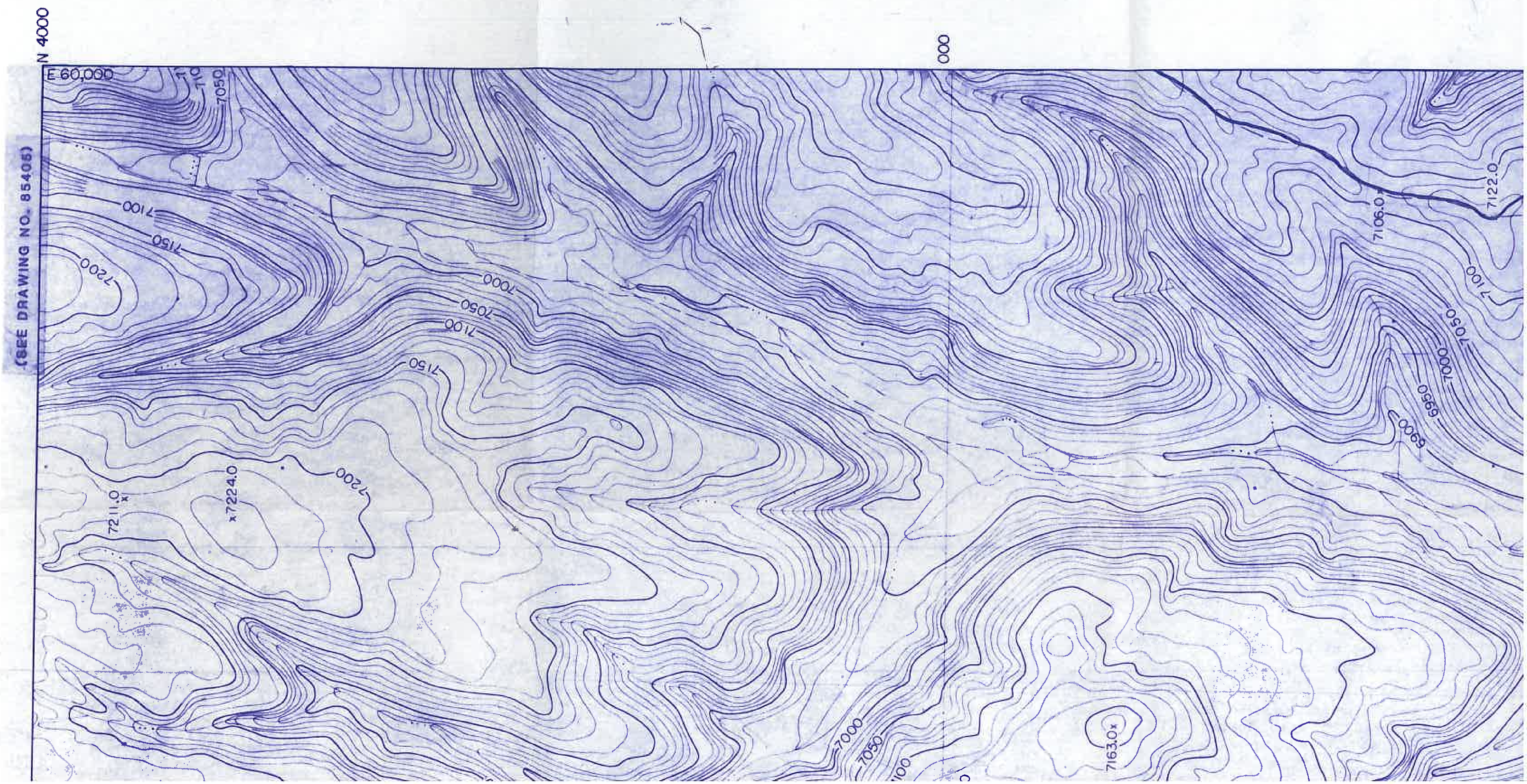
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7224.0
7200
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7050
7163.0

ATTACHMENT B-1

GENERIC WATERSHED EXAMPLE

WORKSHEETS

GENERIC WATERSHED DESIGN EXAMPLE

TIME OF CONCENTRATION CALCULATIONS

GENERIC WATERSHED

N14-4W

$$tc = \left[\frac{11.9(L)^3}{H}\right]^{0.385}$$

Subwatershed #1

L = 10840' = 2.053 miles

H = 7181' - 6770' = 411'

$$tc = \left[\frac{11.9\ (2.053)^3}{411}\right]^{0.385} = 0.587 \text{ hrs.}$$

Subwatershed #2

L = 10840' + 900' = 11,740 = 2.224 miles

H = 7181' - 6755' = 426'

$$tc = \left[\frac{11.9\ (2.224)^3}{426}\right]^{0.385} = 0.635 \text{ hrs.}$$

Subwatershed #3

L = 3200' = 0.606 miles

H = 7000' - 6755' = 245'

$$tc = \left[\frac{11.9\ (0.606)^3}{245}\right]^{0.385} = 0.175 \text{ hrs.}$$

Subwatershed #4

L = 11740' + 2000' = 13740' = 2.602 miles

H = 7181' - 6697' = 484'

$$tc = \left[\frac{11.9\ (2.603)^3}{484}\right]^{0.385} = 0.725 \text{ hrs.}$$

Subwatershed #5

L = 5100' = 0.966 miles

H = 7041' = 6800' = 241'

$$tc = \left[\frac{11.9\ (0.966)^3}{241}\right]^{0.385} = 0.302 \text{ hrs.}$$

Subwatershed #6

L = 5100' + 1300' = 6400' = 1.212 miles

H = 7041' - 6780' = 261'

$$tc = \left[\frac{11.9\ (1.212)^3}{261}\right]^{0.385} = 0.380 \text{ hrs.}$$

Subwatershed #7

L = 3100' = 0.606 miles

H = 6850' - 6780' = 70'

$$tc = \left[\frac{11.9\ (0.606)^3}{70}\right]^{0.385} = 0.284 \text{ hrs.}$$

Subwatershed #8

L = 6400' + 1400' = 7800' = 1.477 miles

H = 7041' - 6697' = 344'

$$tc = \left[\frac{11.9\ (1.477)^3}{344}\right]^{0.385} = 0.430 \text{ hrs.}$$

Subwatershed #9

L = 7400' = 1.402 miles

H = 7000' - 6697' = 303'

$$tc = \left[\frac{11.9\ (1.402)^3}{303}\right]^{0.385} = 0.425 \text{ hrs.}$$

Subwatershed #10

L = 13740' = 2540' = 16280' = 3.083 miles

H = 7181' - 6651' = 530'

$$tc = \left[\frac{11.9\ (3.083)^3}{530}\right]^{0.385} = 0.851 \text{ hrs.}$$

GENERIC WATERSHED DESIGN EXAMPLE

10-Year, 6-Hour Storm Event

Input and Output

GENERIC WATERSHED(N14-4W):SUBWATERSHED #1

2	2							
1.60	6.00	0.10	1.00					
1	1							
1								
1								
0.0	0.0	0.0						
1	1	1	1	1				
902.8	81.0	0.587	0.0	0.0	0.0	1.0	2.0	0.0

```
*****************************************************************
*****************************************************************

       UNIVERSITY OF KENTUCKY COMPUTER MODEL
       OF SURFACE MINE HYDROLOGY AND SEDIMENTOLOGY
       FOR MORE INFORMATION CONTACT THE AGRICULTURAL
       ENGINEERING DEPARTMENT

       THE UK MODEL IS A DESIGN MODEL DEVELOPED TO PREDICT
       THE HYDRAULIC AND SEDIMENT RESPONSE FROM SURFACE
       MINED LANDS FOR A SPECIFIED RAINFALL EVENT (SINGLE STORM)

       VERSION DATE 5-25-83

       DISCLAIMER: NEITHER THE UNIVERSITY NOR ANY OF ITS EMPLOYEES
       ACCEPT ANY RESPONSIBILITY OR LEGAL LIABILITY FOR THE
       CONCLUSIONS DRAWN FROM THE RESULTS OF THIS MODEL

*****************************************************************
*****************************************************************


            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #1

            *********************************************


  *********************INPUT VALUES*********************

  STORM DURATION                    =      6.00   HOURS
  PRECIPITATION DEPTH               =      1.60   INCHES
```

* *

JUNCTION 1, BRANCH 1, STRUCTURE 1

* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	902.80	81.00	0.587	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	210.36	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	27.6747	ACRE-FT
PEAK DISCHARGE	=	210.3598	CFS
AREA	=	902.8000	ACRES
TIME OF PEAK DISCHARGE	=	3.40	HRS

* * * * * * * * * * * *

NULL STRUCTURE

* * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #2

```
     2       2
  1.60    6.00    0.10    1.00
     1       1
     1
     1
   0.0     0.0     0.0
     1       1       1       1       1
 971.9    81.0   0.635     0.0     0.0     0.0     1.0     2.0     0.0
```

```
*****************************************************************
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             *********************************************

                  WATERSHED IDENTIFICATION CODE
                  ------------------------------
                  GENERIC WATERSHED(N14-4W):SUBWATERSHED #2

             *********************************************


  *********************INPUT VALUES********************

  STORM DURATION                     =       6.00   HOURS
  PRECIPITATION DEPTH                =       1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	971.90	81.00	0.635	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	216.00	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	29.7929	ACRE-FT
PEAK DISCHARGE	=	215.9967	CFS
AREA	=	971.8999	ACRES
TIME OF PEAK DISCHARGE	=	3.40	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #3
      2        2
   1.60     6.00     0.10     1.00
      1        1
      1
      1
    0.0      0.0      0.0
      1        1        1        1        1
   52.9     81.0    0.175      0.0      0.0      0.0      1.0      2.0      0.0
```

```
*****************************************************************
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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #3

            *********************************************


 *********************INPUT VALUES********************

 STORM DURATION                     =        6.00   HOURS
 PRECIPITATION DEPTH                =        1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	52.90	81.00	0.175	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	22.71	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	1.6216	ACRE-FT
PEAK DISCHARGE	=	22.7063	CFS
AREA	=	52.9000	ACRES
TIME OF PEAK DISCHARGE	=	3.10	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #4
        2        2
     1.60     6.00     0.10     1.00
        1        1
        1
        1
      0.0      0.0      0.0
        1        1        1        1        1
   1048.9     81.0    0.725      0.0      0.0      0.0      1.0      2.0      0.0
```

```
****************************************************************
****************************************************************

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****************************************************************
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            ********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #4

            ********************************************


  *********************INPUT VALUES********************

  STORM DURATION                    =       6.00   HOURS
  PRECIPITATION DEPTH               =       1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	******	81.00	0.725	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	215.05	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	32.1533	ACRE-FT
PEAK DISCHARGE	=	215.0471	CFS
AREA	=	1048.8999	ACRES
TIME OF PEAK DISCHARGE	=	3.50	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #5

```
       2       2
    1.60    6.00    0.10    1.00
       1       1
       1
       1
     0.0     0.0     0.0
       1       1       1       1       1
    76.1    81.0   0.302     0.0     0.0     0.0     1.0     2.0     0.0
```

```
**********************************************************************
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            ************************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #5

            ************************************************


  *********************INPUT VALUES*********************

  STORM DURATION                      =       6.00   HOURS
  PRECIPITATION DEPTH                 =       1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	76.10	81.00	0.302	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	25.72	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	2.3328	ACRE-FT
PEAK DISCHARGE	=	25.7226	CFS
AREA	=	76.1000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * * Ж
NULL STRUCTURE
* * * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #6

```
       2       2
    1.60    6.00    0.10    1.00
       1       1
       1
       1
     0.0     0.0     0.0
       1       1       1       1       1
    82.0    81.0   0.380     0.0     0.0     0.0     1.0     2.0     0.0
```

```
*****************************************************************
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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #6

            *********************************************


  *********************INPUT VALUES*********************

  STORM DURATION                     =       6.00   HOURS
  PRECIPITATION DEPTH                =       1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	82.00	81.00	0.380	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	24.62	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	2.5137	ACRE-FT
PEAK DISCHARGE	=	24.6176	CFS
AREA	=	82.0000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #7
       2       2
    1.60    6.00    0.10    1.00
       1       1
       1
       1
     0.0     0.0     0.0
       1       1       1       1       1
    57.9    81.0   0.284     0.0     0.0     0.0     1.0     2.0     0.0
```

```
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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #7

            *********************************************


 *********************INPUT VALUES*********************

 STORM DURATION                      =       6.00   HOURS
 PRECIPITATION DEPTH                 =       1.60   INCHES
```

*
JUNCTION 1, BRANCH 1, STRUCTURE 1
*

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	57.90	81.00	0.284	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	20.15	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	1.7749	ACRE-FT
PEAK DISCHARGE	=	20.1505	CFS
AREA	=	57.9000	ACRES
TIME OF PEAK DISCHARGE	=	3.10	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #8
       2        2
    1.60     6.00     0.10     1.00
       1        1
       1
       1
     0.0      0.0      0.0
       1        1        1        1        1
   188.0     81.0    0.430      0.0      0.0      0.0      1.0      2.0      0.0
```

```
******************************************************************
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             *********************************************

                  WATERSHED IDENTIFICATION CODE
                  ------------------------------
                  GENERIC WATERSHED(N14-4W):SUBWATERSHED #8

             *********************************************


  *********************INPUT VALUES********************

  STORM DURATION                      =       6.00   HOURS
  PRECIPITATION DEPTH                 =       1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	188.00	81.00	0.430	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	52.69	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	5.7630	ACRE-FT
PEAK DISCHARGE	=	52.6936	CFS
AREA	=	188.0000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #9

2	2							
1.60	6.00	0.10	1.00					
1	1							
1								
1								
0.0	0.0	0.0						
1	1	1	1	1				
200.9	81.0	0.425	0.0	0.0	0.0	1.0	2.0	0.0

```
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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #9

            *********************************************


  *********************INPUT VALUES*********************

  STORM DURATION                     =       6.00   HOURS
  PRECIPITATION DEPTH                =       1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	200.90	81.00	0.425	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	56.69	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	6.1585	ACRE-FT
PEAK DISCHARGE	=	56.6944	CFS
AREA	=	200.9000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #10
       2       2
    1.60    6.00    0.10    1.00
       1       1
       1
       1
     0.0     0.0     0.0
       1       1       1       1       1
  1492.5    81.0   0.851     0.0     0.0     0.0     1.0     2.0     0.0
```

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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #10

            *********************************************


 *********************INPUT VALUES*********************

 STORM DURATION                     =        6.00   HOURS
 PRECIPITATION DEPTH                =        1.60   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	******	81.00	0.851	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	277.03	0.37

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	45.7516	ACRE-FT
PEAK DISCHARGE	=	277.0286	CFS
AREA	=	1492.5000	ACRES
TIME OF PEAK DISCHARGE	=	3.50	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED DESIGN EXAMPLE

100-Year, 6-Hour Storm Event

Input and Output

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #1
      2       2
   2.40    6.00    0.10    1.00
      1       1
      1
      1
    0.0     0.0     0.0
      1       1       1       1       1
  902.8    81.0   0.587     0.0     0.0     0.0     1.0     2.0     0.0
```

```
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           ******************************************

               WATERSHED IDENTIFICATION CODE
               -----------------------------
               GENERIC WATERSHED(N14-4W):SUBWATERSHED #1

           ******************************************


 ********************INPUT VALUES********************

 STORM DURATION                    =       6.00   HOURS
 PRECIPITATION DEPTH               =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	902.80	81.00	0.587	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	543.45	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	65.5874	ACRE-FT
PEAK DISCHARGE	=	543.4497	CFS
AREA	=	902.8000	ACRES
TIME OF PEAK DISCHARGE	=	3.30	HRS

* * * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #2

2	2							
2.40	6.00	0.10	1.00					
1	1							
1								
1								
0.0	0.0	0.0						
1	1	1	1	1				
971.9	81.0	0.635	0.0	0.0	0.0	1.0	2.0	0.0

```
*****************************************************************
*****************************************************************

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*****************************************************************
*****************************************************************


            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #2

            *********************************************


  *********************INPUT VALUES********************

  STORM DURATION                   =       6.00   HOURS
  PRECIPITATION DEPTH              =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	971.90	81.00	0.635	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	557.84	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	70.6074	ACRE-FT
PEAK DISCHARGE	=	557.8386	CFS
AREA	=	971.8999	ACRES
TIME OF PEAK DISCHARGE	=	3.40	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #3
       2         2
    2.40      6.00      0.10      1.00
       1         1
       1
       1
     0.0       0.0       0.0
       1         1         1         1         1
    52.9      81.0     0.175       0.0       0.0       0.0       1.0       2.0       0.0
```

```
*****************************************************************
*****************************************************************

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*****************************************************************
*****************************************************************


            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #3

            *********************************************


 *********************INPUT VALUES********************

 STORM DURATION                    =        6.00   HOURS
 PRECIPITATION DEPTH               =        2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	52.90	81.00	0.175	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	55.76	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	3.8431	ACRE-FT
PEAK DISCHARGE	=	55.7560	CFS
AREA	=	52.9000	ACRES
TIME OF PEAK DISCHARGE	=	3.10	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #4

```
      2      2
   2.40   6.00   0.10   1.00
      1      1
      1
      1
    0.0    0.0    0.0
      1      1      1      1      1
 1048.9   81.0  0.725    0.0    0.0    0.0    1.0    2.0    0.0
```

```
*****************************************************************
*****************************************************************

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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #4

            *********************************************


 *********************INPUT VALUES********************

 STORM DURATION                     =       6.00   HOURS
 PRECIPITATION DEPTH                =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	******	81.00	0.725	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	554.54	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	76.2014	ACRE-FT
PEAK DISCHARGE	=	554.5439	CFS
AREA	=	1048.8999	ACRES
TIME OF PEAK DISCHARGE	=	3.40	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #5
     2       2
  2.40    6.00    0.10    1.00
     1       1
     1
     1
   0.0     0.0     0.0
     1       1       1       1       1
  76.1    81.0   0.302     0.0     0.0     0.0     1.0     2.0     0.0
```

```
******************************************************************
******************************************************************

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******************************************************************


            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #5

            *********************************************


 *********************INPUT VALUES*********************

 STORM DURATION                       =       6.00   HOURS
 PRECIPITATION DEPTH                  =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	76.10	81.00	0.302	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	64.19	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	5.5286	ACRE-FT
PEAK DISCHARGE	=	64.1866	CFS
AREA	=	76.1000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #6
        2         2
     2.40      6.00      0.10      1.00
        1         1
        1
        1
      0.0       0.0       0.0
        1         1         1         1         1
     82.0      81.0     0.380       0.0       0.0       0.0       1.0       2.0       0.0
```

```
*****************************************************************
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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #6

            *********************************************


 *********************INPUT VALUES*********************

 STORM DURATION                      =       6.00   HOURS
 PRECIPITATION DEPTH                 =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	82.00	81.00	0.380	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	62.19	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	5.9572	ACRE-FT
PEAK DISCHARGE	=	62.1950	CFS
AREA	=	82.0000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED(N14-4W):SUBWATERSHED #7

```
       2       2
    2.40    6.00    0.10    1.00
       1       1
       1
       1
     0.0     0.0     0.0
       1       1       1       1       1
    57.9    81.0   0.284     0.0     0.0     0.0     1.0     2.0     0.0
```

```
************************************************************************
************************************************************************

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             **************************************************

                  WATERSHED IDENTIFICATION CODE
                  ------------------------------
                  GENERIC WATERSHED(N14-4W):SUBWATERSHED #7

             **************************************************


 *********************INPUT VALUES*********************

 STORM DURATION                      =       6.00   HOURS
 PRECIPITATION DEPTH                 =       2.40   INCHES
```

```
* * * * * * * * * * * * * * * * * * * * * * *
    JUNCTION  1, BRANCH  1, STRUCTURE  1
* * * * * * * * * * * * * * * * * * * * * * *
```

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	57.90	81.00	0.284	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	50.16	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	4.2064	ACRE-FT
PEAK DISCHARGE	=	50.1589	CFS
AREA	=	57.9000	ACRES
TIME OF PEAK DISCHARGE	=	3.10	HRS

```
* * * * * * * * * * * *
    NULL STRUCTURE
* * * * * * * * * * * *
```

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #8
      2       2
   2.40    6.00    0.10    1.00
      1       1
      1
      1
    0.0     0.0     0.0
      1       1       1       1       1
  188.0    81.0   0.430     0.0     0.0     0.0     1.0     2.0     0.0
```

```
****************************************************************
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            ********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #8

            ********************************************


 *********************INPUT VALUES*********************

 STORM DURATION                   =       6.00   HOURS
 PRECIPITATION DEPTH              =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	188.00	81.00	0.430	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	134.35	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	13.6580	ACRE-FT
PEAK DISCHARGE	=	134.3468	CFS
AREA	=	188.0000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #9
       2       2
    2.40    6.00    0.10    1.00
       1       1
       1
       1
     0.0     0.0     0.0
       1       1       1       1       1
   200.9    81.0   0.425     0.0     0.0     0.0     1.0     2.0     0.0
```

```
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            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #9

            *********************************************


 *********************INPUT VALUES*********************

 STORM DURATION                     =       6.00   HOURS
 PRECIPITATION DEPTH                =       2.40   INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	200.90	81.00	0.425	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	144.43	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	14.5952	ACRE-FT
PEAK DISCHARGE	=	144.4300	CFS
AREA	=	200.9000	ACRES
TIME OF PEAK DISCHARGE	=	3.20	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

```
GENERIC WATERSHED(N14-4W):SUBWATERSHED #10
       2        2
    2.40     6.00     0.10     1.00
       1        1
       1
       1
     0.0      0.0      0.0
       1        1        1        1        1
  1492.5     81.0    0.851      0.0      0.0      0.0      1.0      2.0      0.0
```

```
*****************************************************************
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*****************************************************************
*****************************************************************


            *********************************************

                 WATERSHED IDENTIFICATION CODE
                 ------------------------------
                 GENERIC WATERSHED(N14-4W):SUBWATERSHED #10

            *********************************************


 *********************INPUT VALUES********************

 STORM DURATION                    =       6.00    HOURS
 PRECIPITATION DEPTH               =       2.40    INCHES
```

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	******	81.00	0.851	0.000	0.000	0.00	2.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	712.15	0.87

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	108.4285	ACRE-FT
PEAK DISCHARGE	=	712.1514	CFS
AREA	=	1492.5000	ACRES
TIME OF PEAK DISCHARGE	=	3.50	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

GENERIC WATERSHED DESIGN EXAMPLE

Hydraulic Design Calculations

N14-4W

Subwatershed No. 1S

Reclamation Channel 1C

RECLAMATION CHANNEL 1C

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	543.4
Manning's Roughness Coefficient (n-value)	0.03
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	40

*** RESULTS ***

CRITICAL DEPTH (FEET)	1.71
Critical Slope (feet per foot)	0.0115
Flow Velocity (feet per second)	7.[illegible]
Froude Number	1.000[illegible]
Velocity Head (feet)	[illegible]
Energy Head (feet)	[illegible].58
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible].17

RECLAMATION CHANNEL 1C

10-YEAR, 6-HOUR STORM EVENT

HYDRAULIC CALCULATIONS

RECLAMATION CHANNEL 1C

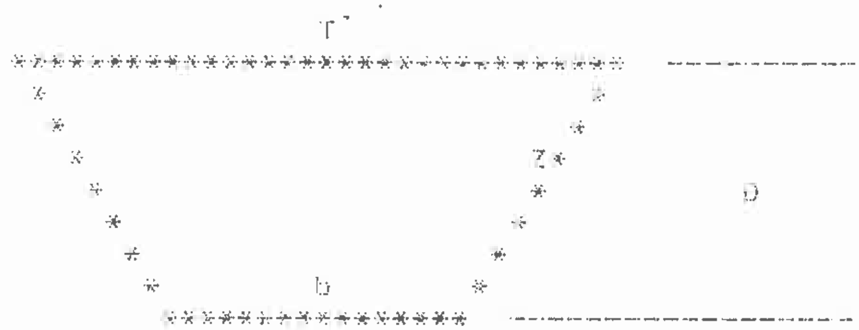
:

10-YEAR, 6-HOUR STORM

HYDRAULIC CALCULATIONS

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL



Discharge	= 210.40 cfs		Depth (D)	=	0.99 feet
Bottom (b)	= 40.00 feet		Top width (T)	=	45.94 feet
Side slopes (Z)	= 3.0:1		Velocity	=	4.93 ft/sec
Bed Slope	= 1.100 %		Hydraulic Radius	=	0.92 feet
Manning's n	= 0.030				

RECLAMATION CHANNEL 1C

100-YEAR, 6-HOUR STORM

HYDRAULIC CALCULATIONS

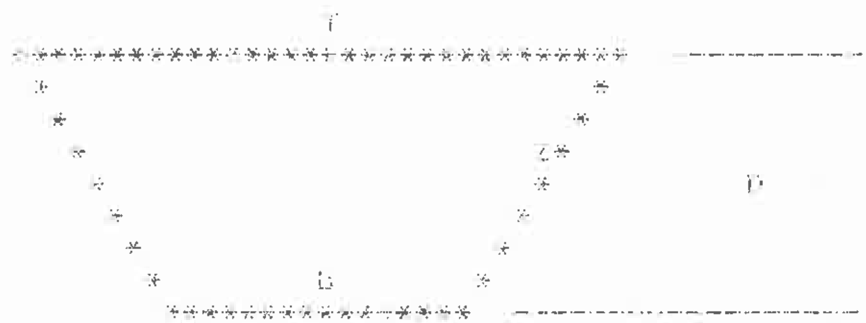
RECLAMATION CHANNEL 1C

100-YEAR, 6-HOUR STORM EVENT

HYDRAULIC CALCULATIONS

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL



Discharge	= 543.10 cfs		Depth (D)	=	1.76 feet
Bottom (B)	= 40.00 feet		Top width (T)	=	50.56 feet
Side slopes (Z)	= 3.0:1		Velocity	=	7.01 ft/sec
Bed Slope	= 1.100 %		Hydraulic Radius	=	1.56 feet
Manning's n	= 0.030				

N14-4W

Subwatershed No. 11S

Reclamation Channel 2C

Gradient Terrace 24T

RECLAMATION CHANNEL 2C

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	557.8
Manning's Roughness Coefficient (n-value)	0.03
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	40

*** RESULTS ***

CRITICAL DEPTH (FEET)	1.74
Critical Slope (feet per foot)	0.0115
Flow Velocity (feet per second)	7.09
Froude Number	1.000
Velocity Head (feet)	0.78
Energy Head (feet)	2.52
Cross-Sectional Area of Flow (square feet)	78.70
Top Width of Flow (feet)	50.44

(Enter : Repeat, (R)ecord, or (Esc) End

RECLAMATION CHANNEL 2C

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

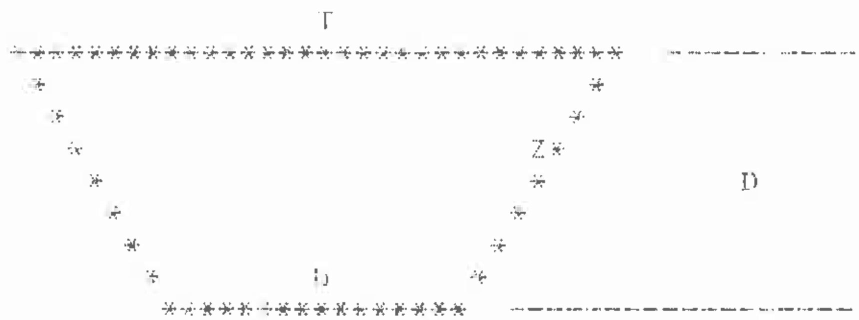
HYDRAULIC CALCULATIONS

AT

1.1% AND 7.0% SLOPES

SEDCAD+ CHANNEL UTILITY

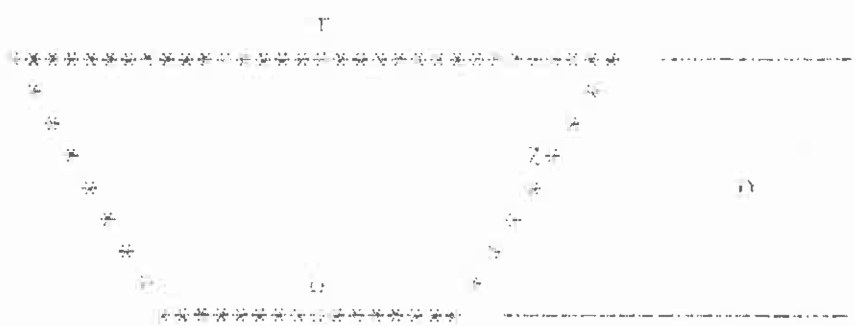
NONERODIBLE CHANNEL



Discharge	=	216.00 cfs	Depth (D)	=	1.01 feet
Bottom (b)	=	40.00 feet	Top width (T)	=	46.04 feet
Side slopes (Z)	=	3.0:1	Velocity	=	4.98 ft/sec
Bed Slope	=	1.100 %	Hydraulic Radius	=	0.93 feet
Manning's n	=	0.030			

SEDCAD+ CHANNEL UTILITY

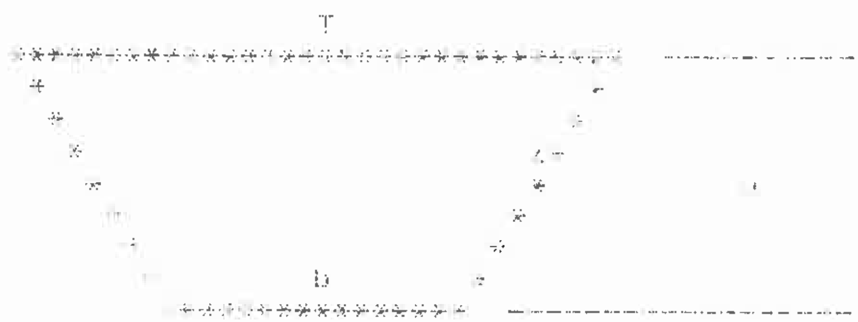
NONERODIBLE CHANNEL



Discharge	=	557.80 cfs	Depth (D)	=	[illegible].79 feet
Bottom (b)	=	40.00 feet	Top Width (T)	=	50.76 feet
Side slopes (Z)	=	[illegible].0:1	Velocity	=	7.08 ft/sec
Bed Slope	=	1.100 %	Hydraulic Radius	=	[illegible].68 feet
Manning's n	=	0.030			

[illegible] CHANNEL UTILITY

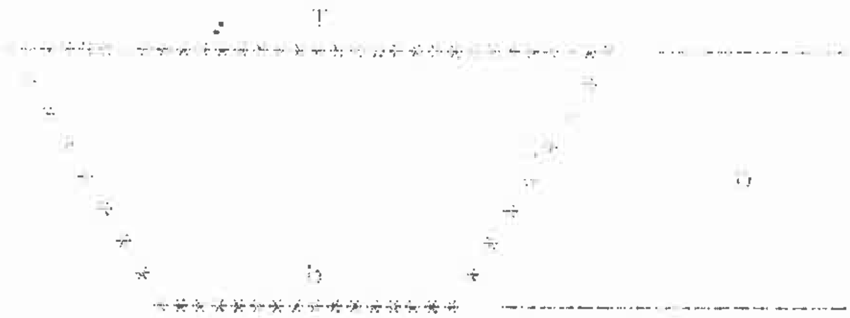
ROCK RIPRAP CHANNEL



Discharge	=	216.00 cfs	Depth (d)	=	0.68 feet
Bottom (b)	=	40.00 feet	Top Width (T)	=	44.10 feet
Side slopes (Z)	=	3.0:1	Velocity	=	7.43 ft/sec
Bed Slope	=	7.000 %	Hydraulic Radius	=	0.63 feet
Manning's n	=	0.040			
Specific Gravity	=	2.30	Bottom D50	=	1.04 feet
Safety Factor	=	1.20	Bank D50	=	0.75 feet

[illegible] CHANNEL [illegible]

ROCK RIPRAP CHANNEL



Discharge	=	357.30 cfs	Depth (D)	=	1.27 feet
Bottom (b)	=	40.00 feet	Top width (T)	=	[illegible] feet
Side slopes (Z)	=	[illegible]	Velocity	=	[illegible].37 ft/sec
Bed Slope	=	[illegible] %	Hydraulic radius	=	1.16 feet
Manning's n	=	[illegible]			
Specific Gravity	=	2.30	Bottom D50	=	1.94 feet
Safety Factor	=	1.20	Bank D50	=	1.79 feet

N14-4W

Subwatershed No. IIIS

Reclamation Downdrain 1D

Gradient Terraces 18T, 20T, 21T

RECLAMATION DOWNDRAIN 10

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	55.8
Manning's Roughness Coefficient (n-value)	0.03
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	15

*** RESULTS ***

CRITICAL DEPTH (FEET)	0.72
Critical Slope (feet per foot)	0.0155
Flow Velocity (feet per second)	4.53
Froude Number	1.000
Velocity Head (feet)	0.32
Energy Head (feet)	1.04
Cross-Sectional Area of Flow (square feet)	12.31
Top Width of Flow (feet)	19.31

[illegible]

RECLAMATION DOWNDRAIN 1D

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

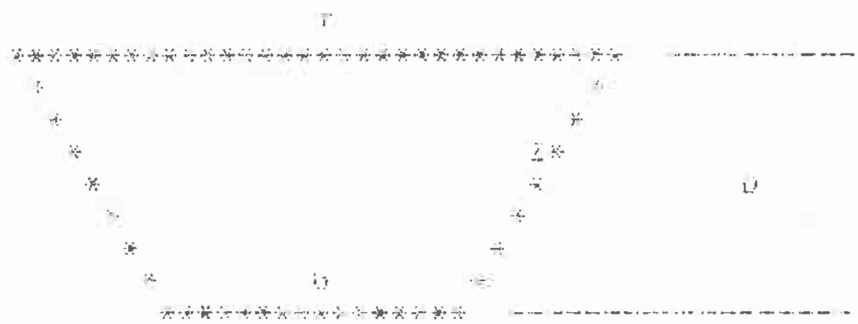
HYDRAULIC CALCULATIONS

AT

1.5% AND 8.5% SLOPES

SEDCAD+ CHANNEL UTILITY

ERODIBLE CHANNEL



Discharge	= 22.70 cfs	Depth (D)	=	0.44	feet
Bottom (b)	= 15.00 feet	Top width (T)	=	17.47	feet
Side slopes (Z)	= 3.0:1	Velocity	=	3.19	ft/sec
Bed slope	= [illegible]	Hydraulic Radius	=	0.43	feet
Manning's n	= 0.030				

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL

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   *                          *
    *                       Z *
     *                        *             D
      *                      *
       *                    *
        *        b         *
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Discharge	= 55.80 cfs		Depth (D)	=	0.70 feet
Bottom (b)	= 15.00 feet		Top width (T)	=	19.20 feet
Side slopes (Z)	= 3.0:1		Velocity	=	[illegible] ft/sec
Bed slope	= 1.500 %		Hydraulic Radius	=	0.62 feet
Manning's n	= 0.030				

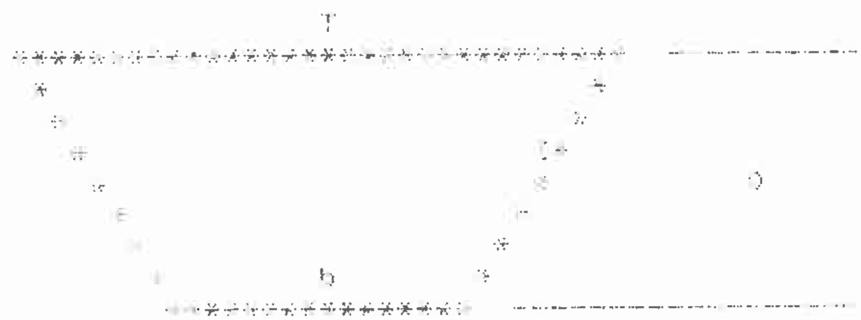
SEDCAD+ CHANNEL UTILITY

ROCK RIPRAP CHANNEL

Discharge	=	22.70 cfs	Depth (D)	=	[illegible] feet
Bottom (B)	=	15.00 feet	Top width (T)	=	[illegible] feet
Side slopes (Z)	=	3.0:1	Velocity	=	5.04 ft/sec
Bed Slope	=	[illegible] %	Hydraulic Radius	=	[illegible] feet
Manning's n	=	0.036			
Specific Gravity	=	2.50	Bottom D50	=	[illegible] feet
Safety Factor	=	1.20	Bank D50	=	[illegible] feet

[illegible] CHANNEL UTILITY

ROCK RIPRAP CHANNEL



Discharge	=	[illegible] cfs	Depth (D)	=	[illegible] feet
Bottom (b)	=	[illegible] feet	Top width (T)	=	[illegible] feet
Side slopes (Z)	=	[illegible]:1	Velocity	=	[illegible] ft/sec
Bed Slope	=	[illegible] %	Hydraulic Radius	=	[illegible] feet
Manning's n	=	0.039			
Specific Gravity	=	[illegible]	Bottom D50	=	[illegible] feet
Safety Factor	=	1.20	Bank D50	=	[illegible] feet

N14-4W

Subwatershed No. IVS

Reclamation Channel 3C

Gradient Terraces 19T, 22T, 23T

RECLAMATION CHANNEL 3C

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	554.5
Manning's Roughness Coefficient (n-value)	0.03
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	40
*** RESULTS ***	
CRITICAL DEPTH (FEET)	1.73
Critical Slope (feet per foot)	0.0115
Flow Velocity (feet per second)	7.09
Froude Number	1.000
Velocity Head (feet)	0.78
Energy Head (feet)	2.51
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible]

<Enter> Repeat, <Report>, or <Esc> Exit

RECLAMATION CHANNEL 3C

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

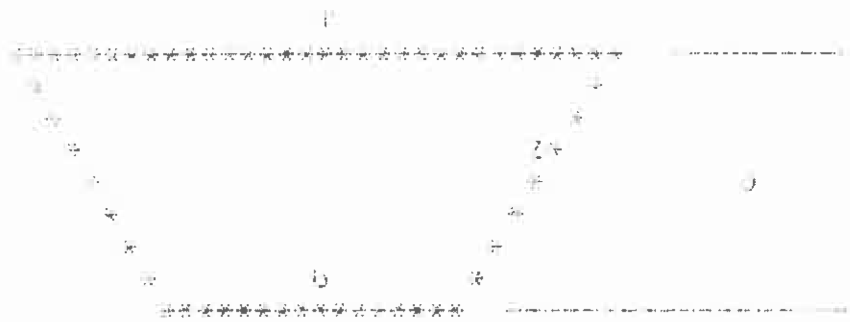
HYDRAULIC CALCULATIONS

AT

1.1% AND 7.0% SLOPES

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL



Discharge	=	215.00 cfs	Depth (d)	=	[illegible].00 feet
Bottom (b)	=	40.00 feet	Top Width (T)	=	46.02 feet
Side Slopes (Z)	=	3.0:1	Velocity	=	[illegible].77 ft/sec
Bed Slope	=	1.100 %	Hydraulic Radius	=	[illegible] feet
Manning's n	=	0.030			

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL

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   *                           *
    *                         *
     *                       *          D
      *                     *
       *                   *
        *        b        *
         *****************   ------------------
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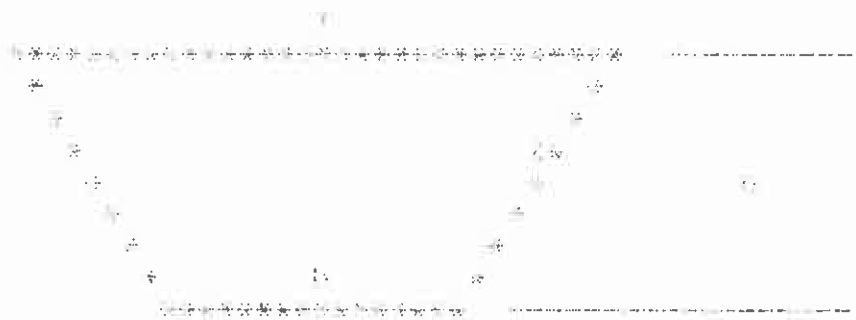
Discharge	= 554.38 cfs	Depth (D)	=	1.79	feet
Bottom (b)	= 40.00 feet	Top width (T)	=	50.72	feet
Side slopes (Z)	= 3.0:1	Velocity	=	7.06	ft/sec
Bed Slope	= 1.100 %	Hydraulic Radius	=	1.58	feet
Manning's n	= 0.030				

DESIGN CHANNEL RESULTS

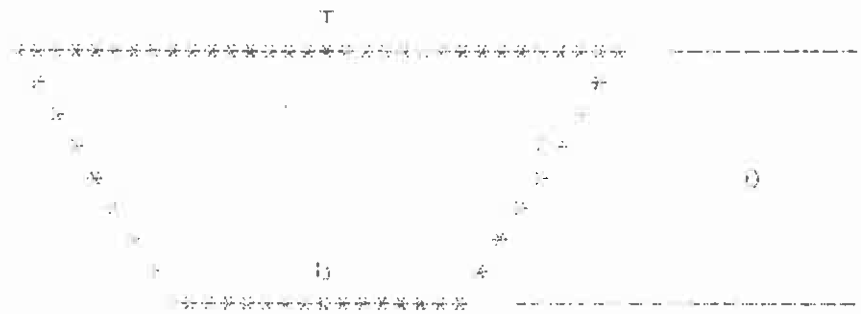
ROCK RIPRAP CHANNEL



Discharge	= 215.00 cfs	Depth (D)	= 0.68 feet
Bottom (b)	= 40.00 feet	Top Width (T)	= 44.09 feet
Side Slope (Z)	= 3.0:1	Velocity	= 7.42 ft/sec
Bed Slope	= 7.000 %	Hydraulic Radius	= 0.65 feet
Manning's n	= 0.040		
Specific Gravity	= 2.20	Bottom D50	= 1.04 feet
Safety Factor	= 1.20	Bank D50	= 0.97 feet

RIPRAP CHANNEL UTILITY

ROCK RIPRAP CHANNEL



Discharge	=	554.30 cfs	Depth (D)	=	1.27 feet
Bottom (b)	=	40.00 feet	Top Width (T)	=	47.61 feet
Side slopes (Z)	=	3.0:1	Velocity	=	9.85 ft/sec
Bed slope	=	1.000 %	Hydraulic Radius	=	1.16 feet
Manning's n	=	0.044			
Specific Gravity	=	2.34	Bottom D50	=	1.93 feet
Safety Factor	=	1.20	Bank D50	=	1.79 feet

N14-4W

Subwatershed No. VS

Reclamation Downdrain 2D

Gradient Terraces 1T, 2T, 9T, 11T, 13T

RECLAMATION DOWNDRAINS 2D

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL [illegible]

CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	[illegible]
Manning's Roughness Coefficient (n-value)	0.03
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	15
*** RESULTS ***	
CRITICAL DEPTH (FEET)	0.78
Critical Slope (feet per foot)	[illegible]
Flow Velocity (feet per second)	[illegible]
Froude Number	[illegible]
Velocity Head (feet)	[illegible]
Energy Head (feet)	[illegible]
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible]

[illegible]

RECLAMATION DOWNDRAIN 2D

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

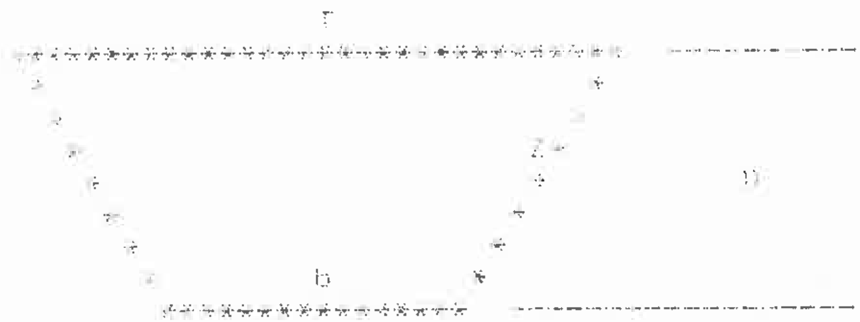
HYDRAULIC CALCULATIONS

AT

1.5% AND 5.0% SLOPES

SEDCAD+ CHANNEL UTILITY

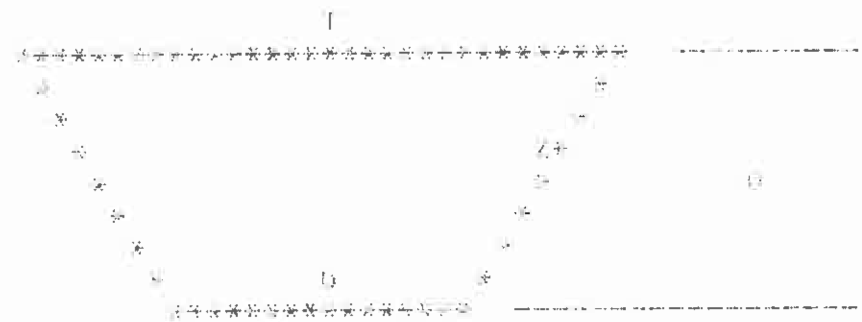
NONERODIBLE CHANNEL



Discharge	= 25.70 cfs	Depth (d)	= 0.44 feet
Bottom (b)	= 15.00 feet	Top width (T)	= 17.66 feet
Side slopes (Z)	= 3.0:1	Velocity	= 3.34 ft/sec
Bed Slope	= 1.500 %	Hydraulic Radius	= 0.41 feet
Manning's n	= 0.030		

[illegible] CHANNEL UTILITY

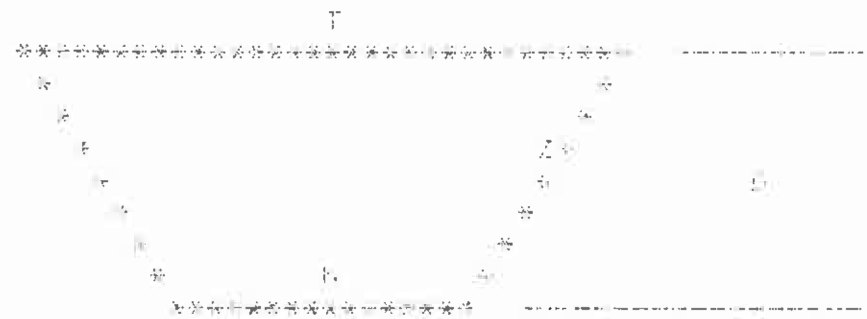
NONERODIBLE CHANNEL



Discharge	=	64.20 cfs	Depth (D)	=	0.77 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	[illegible].40 feet
Side slopes (Z)	=	3.0:1	Velocity	=	4.65 ft/sec
Bed Slope	=	1.5000 %	Hydraulic Radius	=	0.67 feet
Manning's n	=	0.030			

FLOOD+ CHANNEL UTILITY

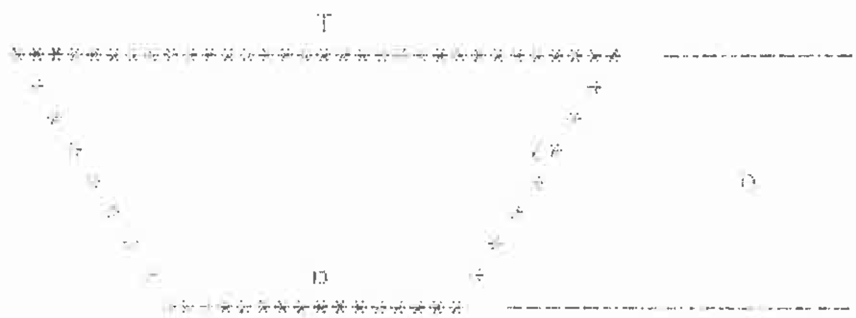
ROCK RIPRAP CHANNEL



Discharge	=	23.70 cfs	Depth (D)	=	0.34 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	17.05 feet
Side slopes (Z)	=	3.0:1	Velocity	=	4.67 ft/sec
Bed Slope	=	3.000 %	Hydraulic Radius	=	0.32 feet
Manning's n	=	0.033			
Specific Gravity	=	2.50	Bottom D50	=	0.26 feet
Safety Factor	=	1.20	Bank D50	=	0.27 feet

[illegible] CHANNEL UTILITY

ROCK RIPRAP CHANNEL



Discharge	=	64.20 cfs	Depth (D)	=	0.[illegible] feet
Bottom (b)	=	15.00 feet	Top width (T)	=	[illegible] feet
Side slopes (Z)	=	[illegible].0:1	Velocity	=	[illegible] ft/sec
Bed Slope	=	[illegible].000 %	Hydraulic Radius	=	[illegible] feet
Manning's n	=	0.037			
Specific Gravity	=	[illegible].30	Bottom D50	=	[illegible] feet
Safety Factor	=	1.20	Bank D50	=	0.6[illegible] feet

N14-4W

Subwatershed No. VIS

Reclamation Downdrain 3D

RECLAMATION DOWNDRAIN 3D

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	32.2
Manning's Roughness Coefficient (n-value)	0.03
Channel Side Slope - Left Side (horizontal/vertical)	2
Channel Side Slope - Right Side (horizontal/vertical)	2
Channel Bottom Width (feet)	15

*** RESULTS ***

CRITICAL DEPTH (FEET)	0.77
Critical Slope (feet per foot)	0.0[illegible]
Flow Velocity (feet per second)	[illegible]
Froude Number	1.[illegible]
Velocity Head (feet)	0.[illegible]
Energy Head (feet)	[illegible]
Cross-Sectional Area of Flow (square feet)	1[illegible]
Top Width of Flow (feet)	1[illegible]

Enter [illegible]

RECLAMATION DOWNDRAIN 3D

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

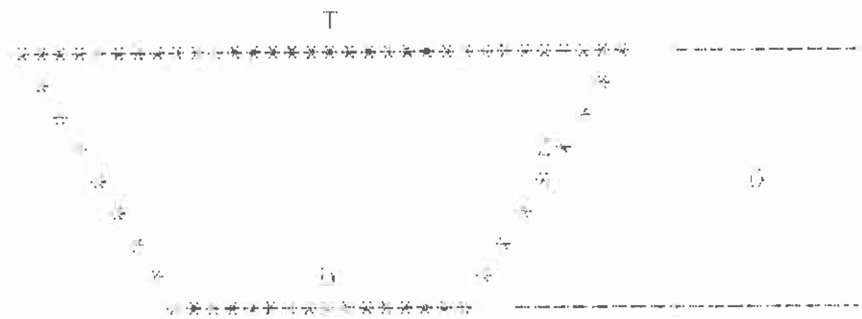
HYDRAULIC CALCULATIONS

AT

1.5% AND 3.3% SLOPES

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL



Discharge	= 24.60 cfs		Depth (D)	=	0.43 feet
Bottom (b)	= 15.00 feet		Top width (T)	=	17.59 feet
Side slopes (Z)	= 3.0:1		Velocity	=	3.28 ft/sec
Bed Slope	= 1.500 %		Hydraulic Radius	=	0.40 feet
Manning's n	= 0.030				

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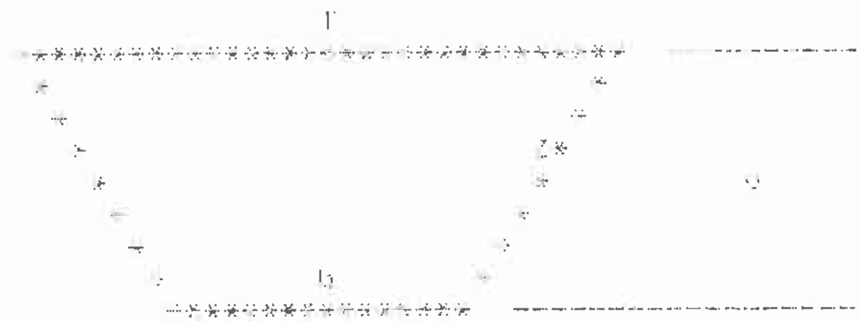
SEDCAD+ CHANNEL UTILITY

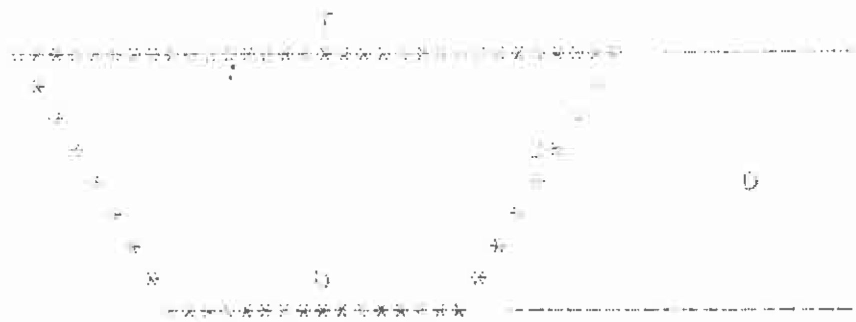
NONERODIBLE CHANNEL



Discharge	=	62.20 cfs	Depth (D)	=	0.75 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	19.51 feet
Side slopes (Z)	=	3.0:1	Velocity	=	4.60 ft/sec
Bed Slope	=	1.500 %	Hydraulic Radius	=	0.66 feet
Manning's n	=	0.030			

[illegible]

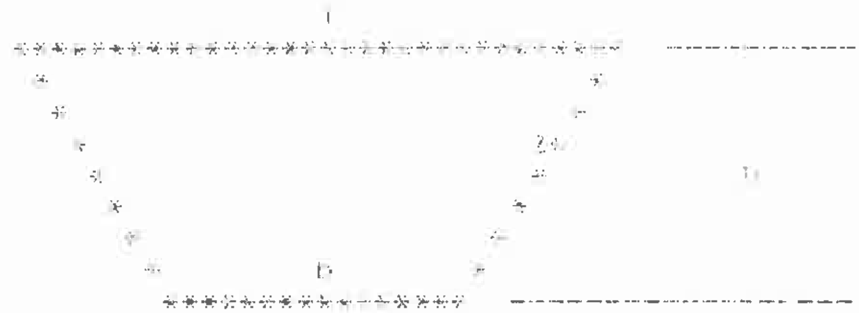
ROCK RIPRAP CHANNEL



Discharge	=	24.60 cfs	Depth (Y)	=	[illegible] feet
Bottom (B)	=	10.00 feet	Top width (T)	=	[illegible] feet
Side slopes (Z)	=	[illegible]:1	Velocity	=	[illegible] ft/sec
Bed Slope	=	[illegible] %	Hydraulic Radius	=	0.54 feet
Manning's n	=	[illegible]			
Specific Gravity	=	[illegible]	Bottom D50	=	0.24 feet
Safety Factor	=	[illegible]	Bank D50	=	0.24 feet

** [illegible] CHANNEL [illegible]

ROCK RIPRAP CHANNEL



Discharge	= 62.20 cfs		Depth (D)	=	0.66 feet
Bottom (b)	= 15.00 feet		Top width (T)	=	18.9? feet
Side slopes (Z)	= 3.0:1		Velocity	=	5.50 ft/sec
Bed Slope	= 3.300 %		Hydraulic Radius	=	0.55 feet
Manning's n	= 0.035				
Specific Gravity	= 2.30		Bottom D50	=	0.2[illegible] feet
Safety Factor	= 1.20		Bank D50	=	0.[illegible] feet

N14-4W

Subwatershed No. VIIS

Reclamation Downdrain 4D

Gradient Terraces 10T, 12T, 14T,

15T, 16T, 17T

RECLAMATION DOWNDRAIN 40

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	[illegible]
Manning's Roughness Coefficient (n-value)	0.05
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	15

*** RESULTS ***

CRITICAL DEPTH (FEET)	0.67
Critical Slope (feet per foot)	0.0158
Flow Velocity (feet per second)	[illegible]
Froude Number	1.000
Velocity Head (feet)	[illegible]
Energy Head (feet)	[illegible]
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible]

RECLAMATION DOWNDRAIN 4D

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

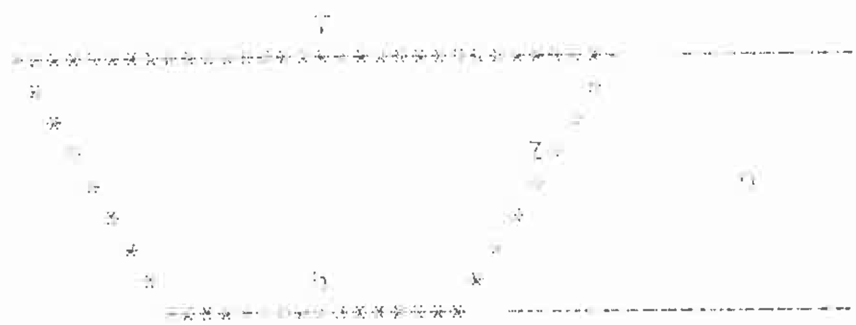
HYDRAULIC CALCULATIONS

AT

1.6% AND 5.5% SLOPES

SOUND CHANNEL UTILITY

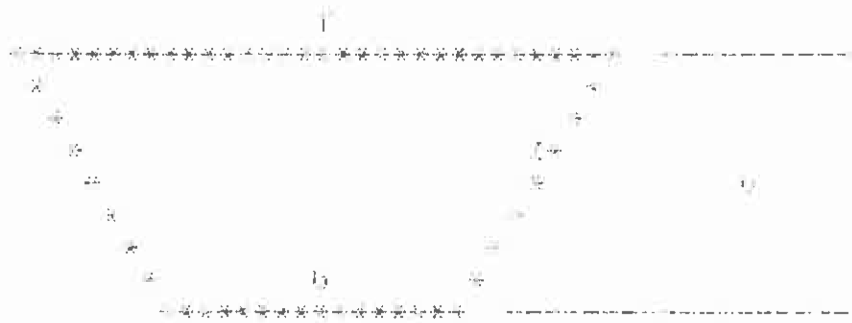
NONERODIBLE CHANNEL



Discharge	=	20.20 cfs	Depth (d)	=	0.38 feet
Bottom (b)	=	15.00 feet	Top Width (T)	=	17.26 feet
Side slopes (Z)	=	3.0:1	Velocity	=	3.12 ft/sec
Bed Slope	=	1.000 %	Hydraulic Radius	=	0.35 feet
Manning's n	=	0.030			

SEDCAD+ CHANNEL UTILITY

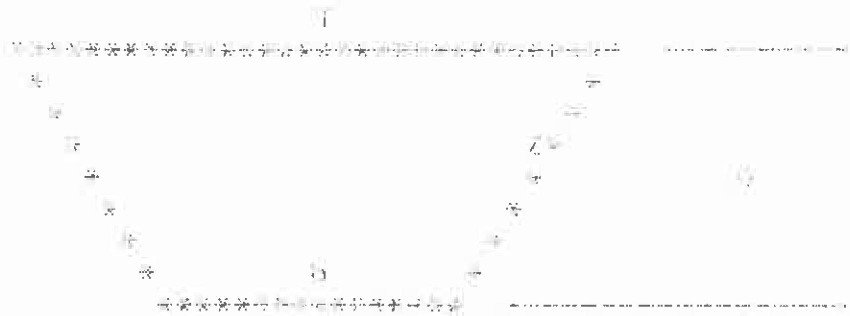
NONERODIBLE CHANNEL



Discharge	= 30.20 cfs		Depth (d)	=	0.65 feet
Bottom (b)	= 15.00 feet		Top Width (T)	=	18.89 feet
Side slopes (Z)	= 3.0:1		Velocity	=	4.23 ft/sec
Bed Slope	= 1.500 %		Hydraulic Radius	=	0.58 feet
Manning's n	= 0.030				

[illegible]

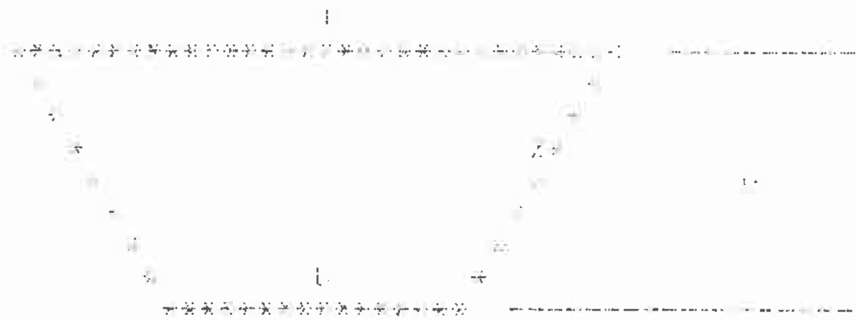
ROCK RIPRAP CHANNEL



Discharge	=	[illegible] cfs	Depth (d)	=	[illegible] feet
Bottom (b)	=	15.[illegible] feet	Top width (T)	=	[illegible] feet
Side slopes (Z)	=	3.0:1	Velocity	=	[illegible] ft/sec
Bed Slope	=	[illegible] %	Hydraulic Radius	=	[illegible] feet
Manning's n	=	0.033			
Specific Gravity	=	2.30	Bottom D50	=	[illegible] feet
Safety Factor	=	1.20	Bank D50	=	[illegible] feet

[illegible]

[illegible]



Discharge	=	[illegible] cfs	Depth (D)	=	0.52 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	18.11 feet
Side slopes (Z)	=	3.00:1	Velocity	=	[illegible] ft/sec
Bed Slope	=	[illegible] %	Hydraulic Radius	=	0.47 feet
Manning's n	=	0.0[illegible]			
Specific Gravity	=	2.[illegible]	[illegible]	=	[illegible] feet
Safety Factor	=	[illegible]	[illegible]	=	[illegible] feet

N14-4W

Subwatershed No. VIIIS

Reclamation Downdrain 5D

Gradient Terraces 3T, 4T, 5T, 6T

RECLAMATION DOWNDRAIN 5D

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

TRAPEZOIDAL CHANNEL ANALYSIS

CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	[illegible]
Manning's Roughness Coefficient (n-value)	[illegible]
Channel Side Slope - Left Side (horizontal/vertical)	[illegible]
Channel Side Slope - Right Side (horizontal/vertical)	[illegible]
Channel Bottom Width (feet)	[illegible]

*** RESULTS ***

CRITICAL DEPTH (FEET)	[illegible]
Critical Slope (feet per foot)	[illegible]
Flow Velocity (feet per second)	[illegible]
Froude Number	[illegible]
Velocity Head (feet)	[illegible]
Energy Head (feet)	[illegible]
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible]

RECLAMATION DOWNDRAIN 5D

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

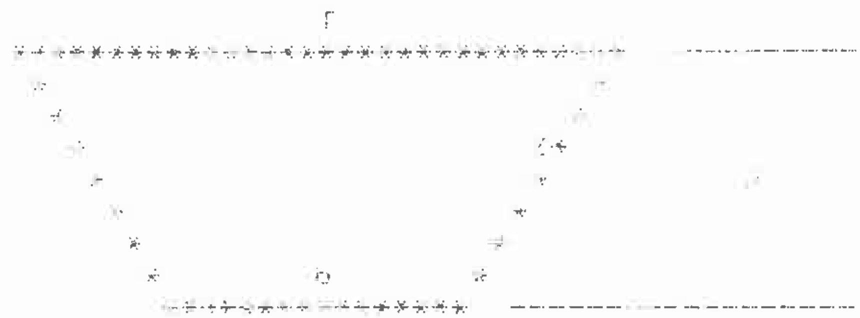
HYDRAULIC CALCULATIONS

AT

1.3% AND 6.5% SLOPES

ROCKY CHANNEL UTILITY

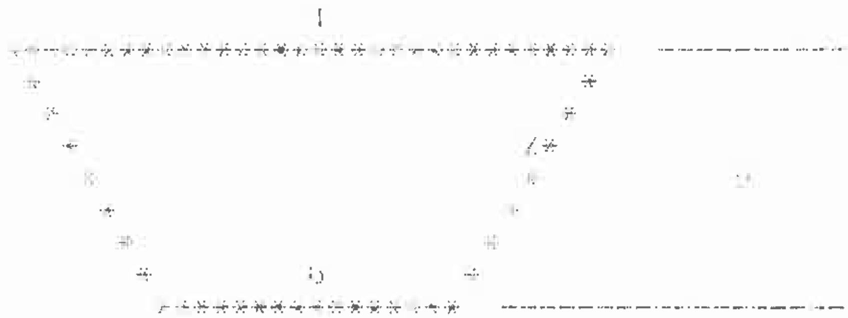
NONERODIBLE CHANNEL



Discharge	=	52.70 cfs	Depth (d)	=	0.71 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	19.27 feet
Side slopes (z)	=	3.0:1	Velocity	=	4.14 ft/sec
Bed slope	=	[illegible]	Hydraulic radius	=	0.62 feet
Manning's n	=	[illegible]			

[illegible]

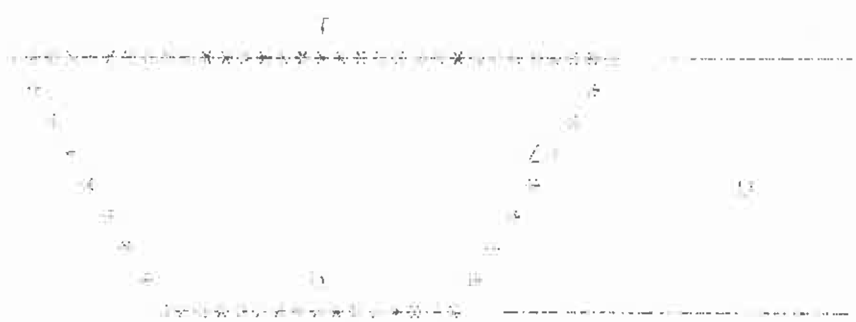
[illegible] CHANNEL



Discharge	=	134.70 cfs	Depth (D)	=	1.25 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	22.50 feet
Side slopes (Z)	=	3.0:1	Velocity	=	5.75 ft/sec
Bed Slope	=	1.500 %	Hydraulic Radius	=	1.02 feet
Manning's n	=	0.032			

UDFCD CHANNEL UTILITY

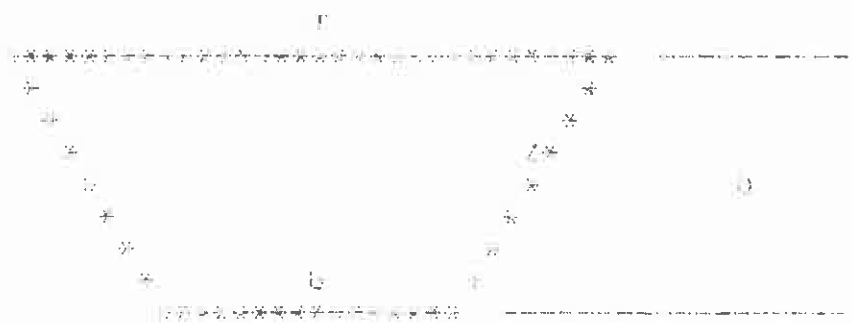
ROCK RIPRAP CHANNEL



Discharge	=	[illegible]2.70 cfs	Depth (D)	=	[illegible] feet
Bottom (B)	=	[illegible].00 feet	Top Width (T)	=	[illegible]5.09 feet
Side Slopes (Z)	=	[illegible]:1	Velocity	=	[illegible].12 ft/sec
Bed Slope	=	[illegible].500 %	Hydraulic Radius	=	0.[illegible]7 feet
Manning's n	=	0.037			
Specific Gravity	=	2.30	Bottom D50	=	0.72 feet
Safety Factor	=	1.20	Bank D50	=	0.68 feet

SEDCAD+ CHANNEL UTILITY

ROCK RIPRAP CHANNEL



Discharge	=	114.30 cfs	Depth (D)	=	2.94 feet
Bottom (b)	=	13.00 feet	Top Width (T)	=	20.65 feet
Side Slopes (Z)	=	3.0:1	Velocity	=	7.22 ft/sec
Bed Slope	=	5.300 %	Hydraulic Radius	=	1.80 feet
Manning's n	=	0.041			
Specific Gravity	=	2.30	Bottom D50	=	1.32 feet
Safety Factor	=	1.20	Bank D50	=	1.24 feet

N14-4W

Subwatershed No. IXS

Reclamation Downdrain 6D

Gradient Terraces 25T, 26T, 27T, 28T, 29T,

30T, 31T, 33T, 34T, 35T, 36T, 37T,

38T, 39T, 40T, 41T, 42T

RECLAMATION DOWNDRAIN 6D

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

Flow Rate (cubic feet per second)	[illegible]
Manning's Roughness Coefficient (dimensionless)	[illegible]
Channel Side Slope - Left Side (horizontal/vertical)	[illegible]
Channel Side Slope - Right Side (horizontal/vertical)	[illegible]
Channel Bottom Width (feet)	15

*** RESULTS ***

CRITICAL DEPTH (FEET)	[illegible]
Critical Slope (feet per foot)	0.01[illegible]
Flow Velocity (feet per second)	[illegible]
Froude Number	[illegible]
Velocity Head (feet)	[illegible]
Energy Head (feet)	[illegible]
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible]

RECLAMATION DOWNDRAIN 6D

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

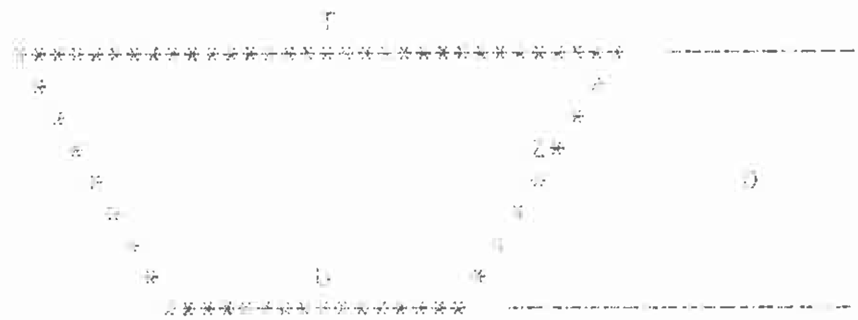
HYDRAULIC CALCULATIONS

AT

1.3% AND 5.5% SLOPES

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL



Discharge	=	56.70 cfs	Depth (D)	=	0.74 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	19.45 feet
Side slopes (Z)	=	3.0:1	Velocity	=	4.25 ft/sec
Bed Slope	=	1.500 %	Hydraulic Radius	=	0.65 feet
Manning's n	=	0.030			

SEDCAD+ CHANNEL UTILITY

NONERODIBLE CHANNEL

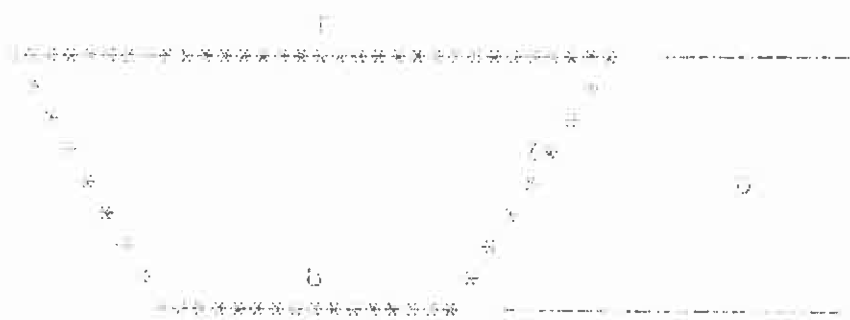
```
                         T
 ***** **************************      ---------------
  *                              *
   *                            *
    *                         Z*
     *                         *              D
      *                       *
       *                     *
        *         b         *
         *****************      ------------------
```

Discharge	=	144.40 cfs	Depth (D)	=	1.31 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	22.84 feet
Side Slopes (Z)	=	3.0:1	Velocity	=	5.90 ft/sec
Bed Slope	=	1.300 %	Hydraulic Radius	=	1.06 feet
Manning's n	=	0.030			

:

SEDCAD+ CHANNEL UTILITY

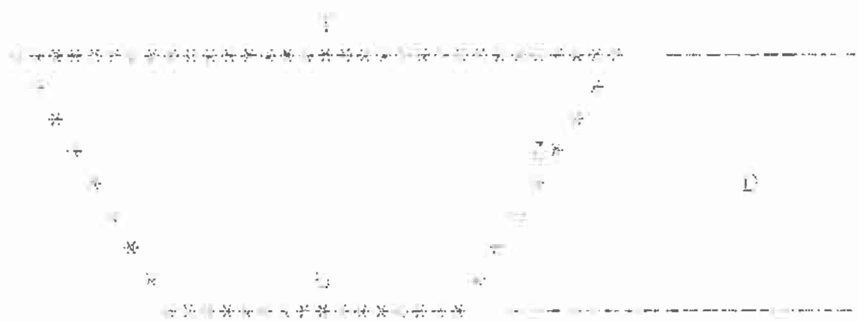
ROCK RIPRAP CHANNEL



Discharge	=	56.70 cfs	Depth (D)	=	0.56 feet
Bottom (b)	=	15.00 feet	Top width (T)	=	18.36 feet
Side slopes (Z)	=	3.0:1	Velocity	=	6.01 ft/sec
Bed Slope	=	5.500 %	Hydraulic Radius	=	[illegible] feet
Manning's n	=	0.037			
Specific Gravity	=	2.30	Bottom D50	=	0.66 feet
Safety Factor	=	1.20	Bank D50	=	0.63 feet

SECONDARY CHANNEL [illegible]

ROCK RIPRAP CHANNEL



Discharge	=	144.40 cfs	Depth (D)	=	1.02 feet
Bottom (B)	=	15.00 feet	Top Width (T)	=	21.12 feet
Side Slopes (Z)	=	3.0:1	Velocity	=	7.77 ft/sec
Bed Slope	=	3.000 %	Hydraulic Radius	=	0.86 feet
Manning's n	=	0.041			
Specific Gravity	=	2.30	Bottom D50	=	1.19 feet
Safety Factor	=	1.20	Bank D50	=	1.13 feet

N14-4W

Subwatershed No. XS

Reclamation Channel 4C

Gradient Terraces 7T, 8T

RECLAMATION CHANNEL 4C

100-YEAR, 6-HOUR STORM EVENT

CRITICAL SLOPE CALCULATIONS

[illegible]

CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	[illegible]
Manning's Roughness Coefficient (n-value)	[illegible]
Channel Side Slope - Left Side (horizontal/vertical)	[illegible]
Channel Side Slope - Right Side (horizontal/vertical)	[illegible]
Channel Bottom Width (feet)	40

*** RESULTS ***

CRITICAL DEPTH (FEET)	2.03
Critical Slope (feet per foot)	0.0110
Flow Velocity (feet per second)	[illegible]
Froude Number	[illegible]
Velocity Head (feet)	[illegible]
Energy Head (feet)	[illegible]
Cross-Sectional Area of Flow (square feet)	[illegible]
Top Width of Flow (feet)	[illegible]

RECLAMATION CHANNEL 4C

10-YEAR, 6-HOUR STORM EVENT

&

100-YEAR, 6-HOUR STORM EVENT

HYDRAULIC CALCULATIONS

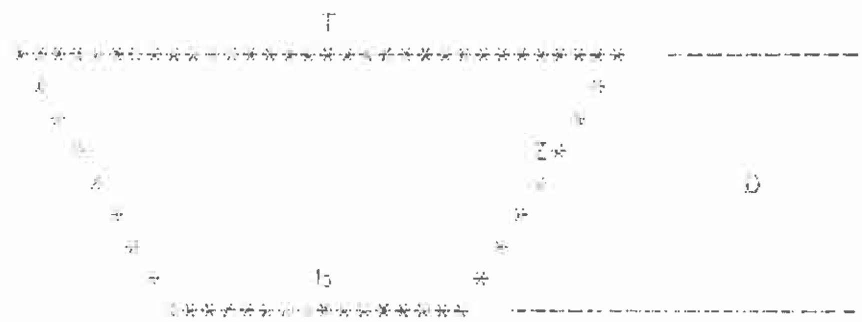
AT

1.1% AND 5.0% SLOPES

SEDCAD+ CHANNEL UTILITY

:

NONERODIBLE CHANNEL

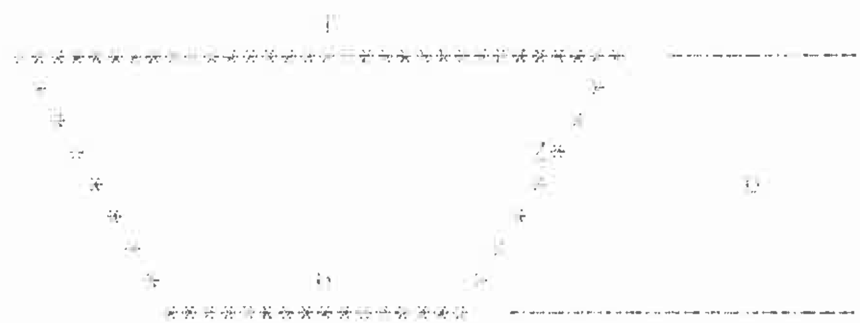


Discharge	=	277.00 cfs	Depth (D)	=	1.17 feet
Bottom (b)	=	40.00 feet	Top width (T)	=	47.02 feet
Side slopes (Z)	=	3.0:1	Velocity	=	5.46 ft/sec
Bed slope	=	1.100 %	Hydraulic Radius	=	1.07 feet
Manning's n	=	0.030			

SECTION CHANNEL UTILITY

:

NONERODIBLE CHANNEL



Discharge	=	712.20 cfs	Depth (D)	=	2.08 feet
Bottom (B)	=	40.00 feet	Top width (T)	=	52.49 feet
Side slopes (Z)	=	3.0:1	Velocity	=	7.74 ft/sec
Bed Slope	=	1.100 %	Hydraulic Radius	=	1.81 feet
Manning's n	=	0.030			

SEDCAD+ CHANNEL UTILITY

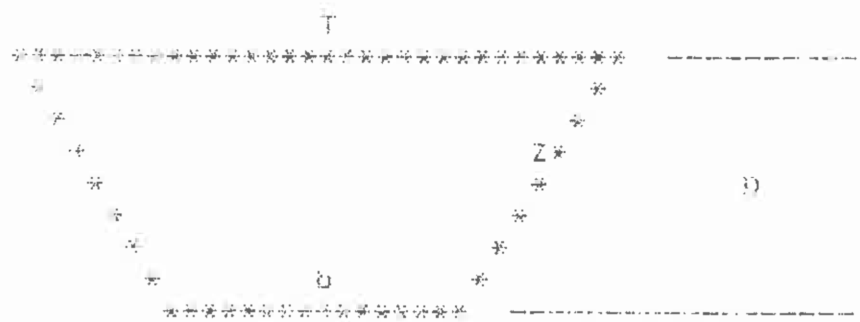
ROCK RIPRAP CHANNEL

```
                          T
*******************************************     ----------------
 *                                         *
  *                                       *
   *                                   Z*
    *                                    *                 D
     *                                  *
      *                                *
       *            b                 *
        ****************       ------------------------------
```

Discharge	=	[illegible]77.00 cfs	Depth (D)	=	0.87 feet
Bottom (b)	=	10.00 feet	Top width (T)	=	15.20 feet
Side slopes (Z)	=	3.0:1	Velocity	=	7.45 ft/sec
Bed slope	=	[illegible].000 %	Hydraulic Radius	=	0.[illegible] feet
Manning's n	=	0.039			
Specific Gravity	=	2.30	Bottom D50	=	0.91 feet
Safety Factor	=	1.20	Bank D50	=	0.87 feet

[illegible] CHANNEL UTILITY

ROCK RIPRAP CHANNEL



Discharge	=	712.20 cfs	Depth (D)	=	1.60 feet
Bottom (B)	=	40.00 feet	Top width (T)	=	49.62 feet
Side slopes (Z)	=	3.00	Velocity	=	9.84 ft/sec
Bed Slope	=	5.000 %	Hydraulic Radius	=	1.43 feet
Manning's n	=	0.043			
Specific Gravity	=	2.30	Bottom D50	=	1.68 feet
Safety Factor	=	1.20	Bank D50	=	1.61 feet

ATTACHMENT B-2

BLANK FORMS

CONVEYANCE STRUCTURE DESIGN SUMMARY

Date: ______________

Conveyance Structure Design Summary

Watershed ID: ______________________________

Structure ID: ______________________________

Location: ______________________________

Map Number: ______________________________

Structure Type: ______________________________

Design Rainfall Depth (In): ____________________

Drainage Area (Ac): ______________________________

Curve Number: ______________________________

Time of Concentration (Hr): ____________________

Peak Discharge (cfs): ______________________________

(Attach input and output printouts)

Channel Bottom Slope (%): ____________________

Manning's Roughness Coefficient: ____________________

Channel Side Slope: (L)______________ (R)____________

Channel Bottom Width (Ft): ____________________

Flow Depth (Ft): ______________________________

(Attach channel analysis input and output printouts)

Flow Velocity (Fps): ______________________________

Froude Number: ______________________________

Is Channel Lining Requied? (Y)__________ (N)__________

Channel Lining Type: ______________________________

Optional:

Riprap Specific Gravity: ______________________________

Riprap Safety Factor: ______________________________

Riprap Bottom D_{50}: ______________________________

Riprap Bank D_{50}: ______________________________

TYPICAL HYDROLOGIC CALCULATION FORMS

Typical SEDIMOT II Input File

(Gradient Terrace Sizing)

Card Code 1	Watershed Identification Code
Card Code 2	Storm Type
	I Type: SCS's Type II =
	NRPIV : No. of Depth Time Values =
Card Code 3	Storm Data
	P_{100}: Rainfall Depth (inch) =
	(or) P_{10} : Rainfall Depth (inch) =
	SDUR: Storm Duration (hr) =
	DELTSW: Storm Time Increment =
	P30INT: Max 30 Min. Intensity =
Card Code 4	Number of Junctions
	NOJ: Number of Junctions =
	IHYDR: Hydrology only =
Card Code 5	Number of Branches/Junctions
	NOB(I): Number of Branches per Junction =
Card Code 10	Number of Structures per Branch
	NOS (I,J): Number of Structures per Branch (I) for each Junction (J) =
Card Code 11	Between Structure Routing Parameters
	Time (I,J,K): Travel Time Between Structures =
	RK (I,J,K): Muskingum's K Between Structures (hr) =
	RX (I,J,K): Muskingum's X Between Structures (hr) =
Card Code 12	Subwatershed/Structure Information
	NSWS: Number of Subwatersheds per Structure =
	CNTROL: Type of Sediment Control Structure =
	IPRINT: Print Control Variable =
	ISUBSP: Print Control Variable for the Drainage Area Between Previous Structure or Junction =
	IPRINZ: Print Option for Subwatershed Inputs =
Card Code 13	Subwatershed Data
	PARAH (I,1): Subwatershed Area (acres) =

Typical SEDIMOT II Input File

(Gradient Terrace Sizing)

PARAH (I,2): Curve Number (Reclaimed) =

PARAH (I,3): Time of Concentration (hr) =

PARAH (I,4): Travel Time (to Structure) =

PARAH (I,5): Muskingum's K (to Structure) =

PARAH (I,6): Muskingum's X (to Structure) =

PARAH (I,7): Hydrology Print Option =

PARAH (I,8): Hydraulic Surface Condition =

PARAH (I,9): Number of Flow Segments =

Typical SEDIMOT II Input File

(Downdrain Sizing)

Card Code 1	Watershed Identification Code
Card Code 2	Storm Type
	I Type: SCS's Type II =
	NRPIV : No. of Depth Time Values =
Card Code 3	Storm Data
	P_{100}: Rainfall Depth (inch) =
	(or) P_{10} : Rainfall Depth (inch) =
	SDUR: Storm Duration (hr) =
	DELTSW: Storm Time Increment =
	P30INT: Max 30 Min. Intensity =
Card Code 4	Number of Junctions
	NOJ: Number of Junctions =
	IHYDR: Hydrology only =
Card Code 5	Number of Branches/Junctions
	NOB(I): Number of Branches per Junction =
Card Code 10	Number of Structures per Branch
	NOS (I,J): Number of Structures per Branch (I) for each Junction (J) =
Card Code 11	Between Structure Routing Parameters
	Time (I,J,K): Travel Time Between Structures =
	RK (I,J,K): Muskingum's K Between Structures (hr) =
	RX (I,J,K): Muskingum's X Between Structures (hr) =
Card Code 12	Subwatershed/Structure Information
	NSWS: Number of Subwatersheds per Structure =
	CNTROL: Type of Sediment Control Structure =
	IPRINT: Print Control Variable =
	ISUBSP: Print Control Variable for the Drainage Area Between Previous Structure or Junction =
	IPRINZ: Print Option for Subwatershed Inputs =
Card Code 13	Subwatershed Data
	PARAH (I,1): Subwatershed Area (acres) =

Typical SEDIMOT II Input File

(Downdrain Sizing)

PARAH (1,2): Curve Number (Reclaimed) =

PARAH (1,3): Time of Concentration (hr) =

PARAH (1,4): Travel Time (to Structure) =

PARAH (1,5): Muskingum's K (to Structure) =

PARAH (1,6): Muskingum's X (to Structure) =

PARAH (1,7): Hydrology Print Option =

PARAH (1,8): Hydraulic Surface Condition =

PARAH (1,9): Number of Flow Segments =

Typical SEDIMOT II Input File

(Primary Reclamation Channel Sizing)

Card Code 1	Watershed Identification Code
Card Code 2	Storm Type
	I Type: SCS's Type II =
	NRPIV: No. of Depth Time Values =
Card Code 3	Storm Data
	P_{100}: Rainfall Depth (inch) =
	(or) P_{10} : Rainfall Depth (inch) =
	SDUR: Storm Duration (hr) =
	DELTSW: Storm Time Increment =
	P30INT: Max 30 Min. Intensity =
Card Code 4	Number of Junctions
	NOJ: Number of Junctions =
	IHYDR: Hydrology only =
Card Code 5	Number of Branches/Junctions
	NOB(I):Number of Branches per Junction =
Card Code 10	Number of Structures per Branch
	NOS (I,J): Number of Structures per Branch (I) for each Junction (J) =
Card Code 11	Between Structure Routing Parameters
	Time (I,J,K): Travel Time Between Structures =
	RK (I,J,K): Muskingum's K Between Structures (hr) =
	RX (I,J,K): Muskingum's X Between Structures (hr) =
Card Code 12	Subwatershed/Structure Information
	NSWS: Number of Subwatersheds per Structure =
	CNTROL: Type of Sediment Control Structure =
	IPRINT: Print Control Variable =
	ISUBSP: Print Control Variable for the Drainage Area Between Previous Structure or Junction =
	IPRINZ: Print Option for Subwatershed Inputs =

Typical SEDIMOT II Input File

(Primary Reclamation Channel Sizing)

Card Code 13

Subwatershed Data

PARAH (I,1): Subwatershed Area (acres) =

PARAH (I,2): Curve Number (Reclaimed) =

PARAH (I,3): Time of Concentration (hr) =

PARAH (I,4): Travel Time (to Structure) =

PARAH (I,5): Muskingum's K (to Structure) =

PARAH (I,6): Muskingum's X (to Structure) =

PARAH (I,7): Hydrology Print Option =

PARAH (I,8): Hydraulic Surface Condition =

PARAH (I,9): Number of Flow Segments =

Typical SEDIMOT II Input File

(Primary Reclamation Channel Sizing)

Card Code 1	Watershed Identification Code
Card Code 2	Storm Type
	I Type: SCS's Type II =
	NRPIV: No. of Depth Time Values =
Card Code 3	Storm Data
	P_{100}: Rainfall Depth (inch) =
	(or) P_{10} : Rainfall Depth (inch) =
	SDUR: Storm Duration (hr) =
	DELTSW: Storm Time Increment =
	P30INT: Max 30 Min. Intensity =
Card Code 4	Number of Junctions
	NOJ: Number of Junctions =
	IHYDR: Hydrology only =
Card Code 5	Number of Branches/Junctions
	NOB(I):Number of Branches per Junction =
Card Code 10	Number of Structures per Branch
	NOS (I,J): Number of Structures per Branch (I) for each Junction (J) =
Card Code 11	Between Structure Routing Parameters
	Time (I,J,K): Travel Time Between Structures =
	RK (I,J,K): Muskingum's K Between Structures (hr) =
	RX (I,J,K): Muskingum's X Between Structures (hr) =
Card Code 12	Subwatershed/Structure Information
	NSWS: Number of Subwatersheds per Structure =
	CNTROL: Type of Sediment Control Structure =
	IPRINT: Print Control Variable =
	ISUBSP: Print Control Variable for the Drainage Area Between Previous Structure or Junction =
	IPRINZ: Print Option for Subwatershed Inputs =

Typical SEDIMOT II Input File

(Primary Reclamation Channel Sizing)

Card Code 13

Subwatershed Data

PARAH (I,1): Subwatershed Area (acres) =

PARAH (I,2): Curve Number (Reclaimed) =

PARAH (I,3): Time of Concentration (hr) =

PARAH (I,4): Travel Time (to Structure) =

PARAH (I,5): Muskingum's K (to Structure) =

PARAH (I,6): Muskingum's X (to Structure) =

PARAH (I,7): Hydrology Print Option =

PARAH (I,8): Hydraulic Surface Condition =

PARAH (I,9): Number of Flow Segments =

WORK SHEET I

for
Routing Hydrographs
Between Junctions and/or Structures

From Junction or Structure _____ to Structure _____

(1) Seg-ment	(2) Surf. Cond.	(3) Horizontal Distance (ft.)	(4) Vertical Distance (ft.)	(5) Diagonal Distance (ft.)	(6) Slope (%)	(7) Velocity (ft./sec.)	(8) Travel Time (hr.)
1							
2							
3							
		Σ _____		Σ _____			Σ _____

$\overline{V}_w$ = _______ , X = _______ , K = _______

From Junction or Structure _____ to Structure _____

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1							
2							
3							
		Σ _____		Σ _____			Σ _____

$\overline{V}_w$ = _______ , X = _______ , K = _______

From Junction or Structure _____ to Structure _____

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1							
2							
3							
		Σ _____		Σ _____			Σ _____

$\overline{V}_w$ = _______ , X = _______ , K = _______

$$\overline{V}_w = \sum_{i=1}^{N} \frac{\text{col. } 3_{(i)} \times \text{col. } 7_{(i)}}{\Sigma \text{ col. } 3}, \quad \text{OR} \quad \overline{V}_w = \sum_{i=1}^{N} \frac{\text{col. } 5_{(i)} \times \text{col. } 7_{(i)}}{\Sigma \text{ col. } 5};$$

where N = segment numbers

$$X = \frac{.5\overline{V}_w}{1.7 + \overline{V}_w} \qquad K = \Sigma \text{ col. } 8$$

TYPICAL SEDIMOT II

OUTPUT FILE

```
************************************************************************
************************************************************************

        UNIVERSITY OF KENTUCKY COMPUTER MODEL
        OF SURFACE MINE HYDROLOGY AND SEDIMENTOLOGY
        FOR MORE INFORMATION CONTACT THE AGRICULTURAL
        ENGINEERING DEPARTMENT

        THE UK MODEL IS A DESIGN MODEL DEVELOPED TO PREDICT
        THE HYDRAULIC AND SEDIMENT RESPONSE FROM SURFACE
        MINED LANDS FOR A SPECIFIED RAINFALL EVENT (SINGLE STORM)

        VERSION DATE 5-25-83

        DISCLAIMER: NEITHER THE UNIVERSITY NOR ANY OF ITS EMPLOYEES
        ACCEPT ANY RESPONSIBILITY OR LEGAL LIABILITY FOR THE
        CONCLUSIONS DRAWN FROM THE RESULTS OF THIS MODEL

************************************************************************
************************************************************************


              ********************************************

                   WATERSHED IDENTIFICATION CODE
                   ------------------------------

              ********************************************


**********************INPUT VALUES**********************

STORM DURATION                    =                 HOURS
PRECIPITATION DEPTH               =                 INCHES
```

* *
JUNCTION BRANCH STRUCTURE
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	ACRE-FT
PEAK DISCHARGE	=	CFS
AREA	=	ACRES
TIME OF PEAK DISCHARGE	=	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

TYPICAL HYDRAULIC CALCULATION FORMS

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)
Channel Bottom Slope (feet per foot)
Manning`s Roughness Coefficient (n-value)
Channel Side Slope - Left Side (horizontal/vertical)
Channel Side Slope - Right Side (horizontal/vertical)
Channel Bottom Width (feet)

*** RESULTS ***

NORMAL DEPTH (FEET)
Flow Velocity (feet per second)
Froude Number
Velocity Head (feet)
Energy Head (feet)
Cross-Sectional Area of Flow (square feet)
Top Width of Flow (feet)

<Enter>: Repeat, <R>eport, or <Esc>: End

TRAPEZOIDAL CHANNEL ANALYSIS
NORMAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)
Channel Bottom Slope (feet per foot)
Manning`s Roughness Coefficient (n-value)
Channel Side Slope - Left Side (horizontal/vertical)
Channel Side Slope - Right Side (horizontal/vertical)
Channel Bottom Width (feet)

*** RESULTS ***

NORMAL DEPTH (FEET)
Flow Velocity (feet per second)
Froude Number
Velocity Head (feet)
Energy Head (feet)
Cross-Sectional Area of Flow (square feet)
Top Width of Flow (feet)

<Enter>: Repeat, <R>eport, or <Esc>: End

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)
Manning`s Roughness Coefficient (n-value)
Channel Side Slope - Left Side (horizontal/vertical)
Channel Side Slope - Right Side (horizontal/vertical)
Channel Bottom Width (feet)

*** RESULTS ***

CRITICAL DEPTH (FEET)
Critical Slope (feet per foot)
Flow Velocity (feet per second)
Froude Number
Velocity Head (feet)
Energy Head (feet)
Cross-Sectional Area of Flow (square feet)
Top Width of Flow (feet)

<Enter>: Repeat, <R>eport, or <Esc>: End

TRAPEZOIDAL CHANNEL ANALYSIS

RATING CURVE COMPUTATION

Channel Bottom Slope (feet per foot)

Manning`s Roughness Coefficient (n-value)

Channel Side Slope - Left Side (horizontal/vertical)

Channel Side Slope - Right Side (horizontal/vertical)

Channel Bottom Width (feet)

*** RESULTS ***

Depth (ft)	Flow Rate (cfs)	Velocity (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq ft)	Top Widt (ft

Enter Depth of Flow, or Press the <Esc> Key to End

NONERODIBLE CHANNEL DESIGN

What shape channel will you be designing for?
    1 - TRAPEZOIDAL
    2 - PARABOLIC
    3 - TRIANGULAR
? 1

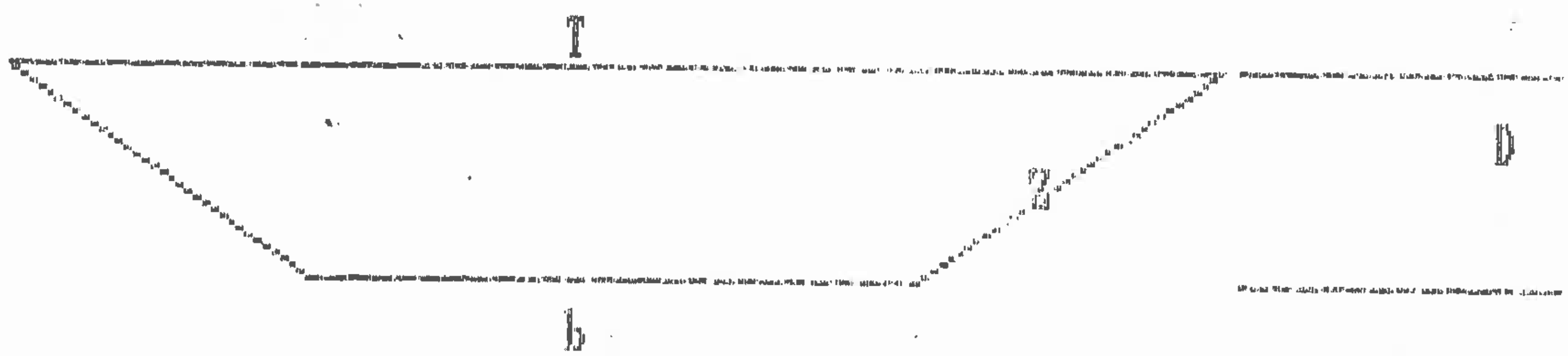
Will you INPUT:
   1 - DISCHARGE
   2 - DEPTH OF FLOW
? 1

What is the Design Discharge (cfs) ?
What is the average channel bed slope (%) ?
What are the side slopes (Z:1 - enter Z)?
What is the bottom width (in feet)?

CHANNEL MATERIAL	MANNING'S N	RANGE MIN.	MAX
1 - ASPHALTIC CONCRETE, MACHINE PLACED	[.014]	***	***
2 - ASPHALT, EXPOSED PREFABRICATED	[.015]	***	***
3 - CONCRETE	[.015]	.012	.018
4 - CONCRETE, RUBBLE	[.022]	.016	.029
5 - METAL, SMOOTH (FLUMES)	[.013]	.011	.015
6 - METAL, CORRUGATED	[.024]	.021	.026
7 - PLASTIC	[.013]	.012	.014
8 - SHOTCRETE	[.017]	.016	.017
9 - OTHER	????		

Enter Number Corresponding to Channel Material Used
[Brackets indicate default Manning's n value used]? 9
Enter the Manning's n value?

NONERODIBLE CHANNEL



TRAPEZOIDAL SECTION

Discharge	=	cfs	Depth (D)	=	feet
Bottom (b)	=	feet	Top width (T)	=	feet
Side slopes (Z)	=		Velocity	=	ft/sec
Bed Slope	=	%	Hydraulic Radius	=	feet
Manning's n	=				

ERODIBLE CHANNEL DESIGN

What shape channel will you be designing for?
  1 - TRAPEZOIDAL
  2 - PARABOLIC
  3 - TRIANGULAR
? 1
What is the design discharge (cfs)?
What is the average channel bed slope (%) ?
What are the side slopes (Z:1 - enter Z)?
What is the bottom width (in feet)?
Are you designing for:
  1 - CLEAR WATER
  2 - WATER TRANSPORTING COLLODIAL SILTS
? 2
Enter the method:
  1 - LIMITING VELOCITY
  2 - TRACTIVE FORCE
? 1

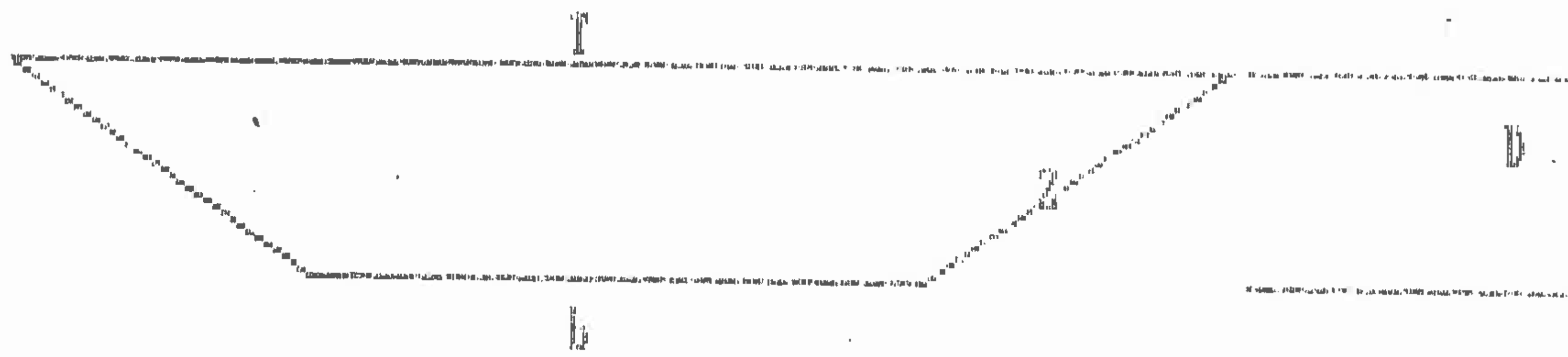
Enter the number corresponding to channel material:

LIMITING VELOCITIES AND TRACTIVE FORCES FOR OPEN CHANNELS

N	Material	(n)	For Clear Water Velocity (fps)	For Clear Water Tractive Force (psf)	Water Transporting Colloidal Silts Velocity (fps)	Water Transporting Colloidal Silts Tractive Force (psf)
1	FINE SAND COLLOIDAL	0.020	1.50	0.027	2.50	0.075
2	SANDY LOAM NONCOLLOIDAL	0.020	1.75	0.037	2.50	0.075
3	SILT LOAM NONCOLLOIDAL	0.020	2.00	0.037	3.00	0.075
4	ALLUVIAL SILTS NONCOLLOIDAL	0.020	2.00	0.048	3.50	0.150
5	ORDINARY FIRM LOAM	0.020	2.50	0.075	3.50	0.150
6	VOLCANIC ASH	0.020	2.50	0.075	3.50	0.150
7	STIFF CLAY VERY COLLOIDAL	0.025	3.75	0.260	5.00	0.460
8	ALLUVIAL SILTS COLLOIDAL	0.025	3.75	0.260	5.00	0.460
9	SHALES AND HARDPANS	0.025	6.00	0.670	6.00	0.670
10	FINE GRAVEL	0.020	2.50	0.075	5.00	0.320
11	GRADED LOAM-COBBLES NONCOLLOIDAL	0.030	3.75	0.380	5.00	0.660
12	GRADED SILTS-COBBLES COLLOIDAL	0.030	4.00	0.430	5.50	0.[illegible]
13	COARSE GRAVEL NONCOLLOIDAL	0.025	4.00	0.300	6.00	0.[illegible]
14	COBBLES AND SHINGLES	0.035	5.00	0.910	5.50	1.100

?

ERODIBLE CHANNEL



TRAPEZOIDAL SECTION

Discharge	=	cfs	Depth (D)	=	feet
Bottom (b)	=	feet	Top width (T)	=	feet
Side slopes (Z)	=		Velocity	=	ft/sec
Bed Slope	=	%	Hydraulic Radius	=	feet
Manning's n	=				

ROCK RIPRAP DESIGN

What is the design discharge (cfs)?
What is the average channel bed slope (%) ?
What are the side slopes (Z:1 - enter Z)?
What is the bottom width (in feet)?
What is the Specific Gravity of the rock [2.65]?
What is the design Safety Factor [1.5]?

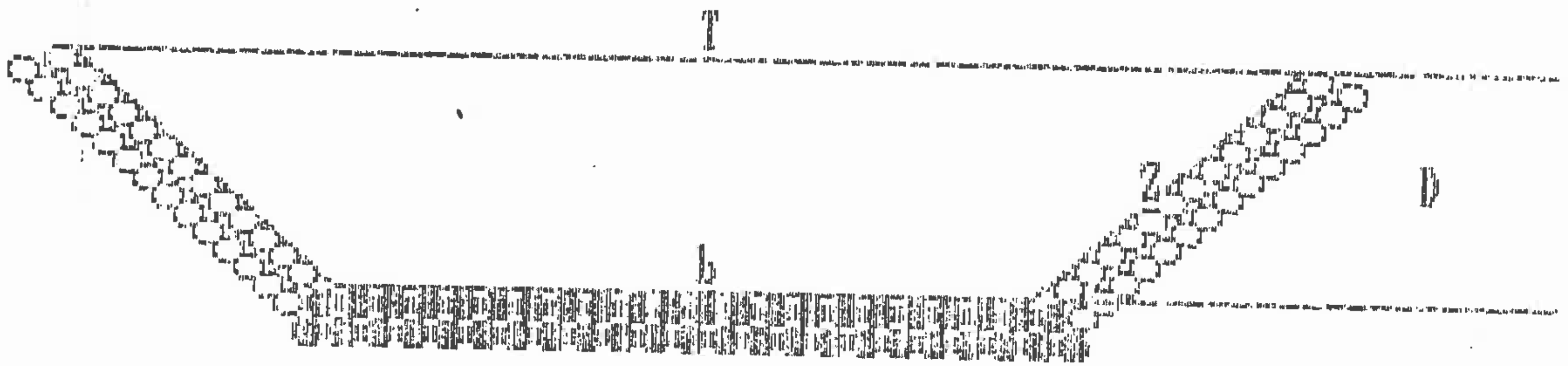
SEDCAD+ CHANNEL UTILITY

ROCK RIPRAP CHANNEL

```
                T
 ********************************     ----------
  *                            *
   *                          *
    *                       Z*
     *                       *              D
      *                     *
       *                   *
        *       b         *
         ****************     ------------------
```

Discharge	=	cfs	Depth (D)	=	feet
Bottom (b)	=	feet	Top width (T)	=	fee
Side slopes (Z)	=		Velocity	=	ft/
Bed Slope	=	%	Hydraulic Radius	=	feet
Manning's n	=				
Specific Gravity	=		Bottom D50	=	feet
Safety Factor	=		Bank D50	=	feet

ROCK RIPRAP CHANNEL



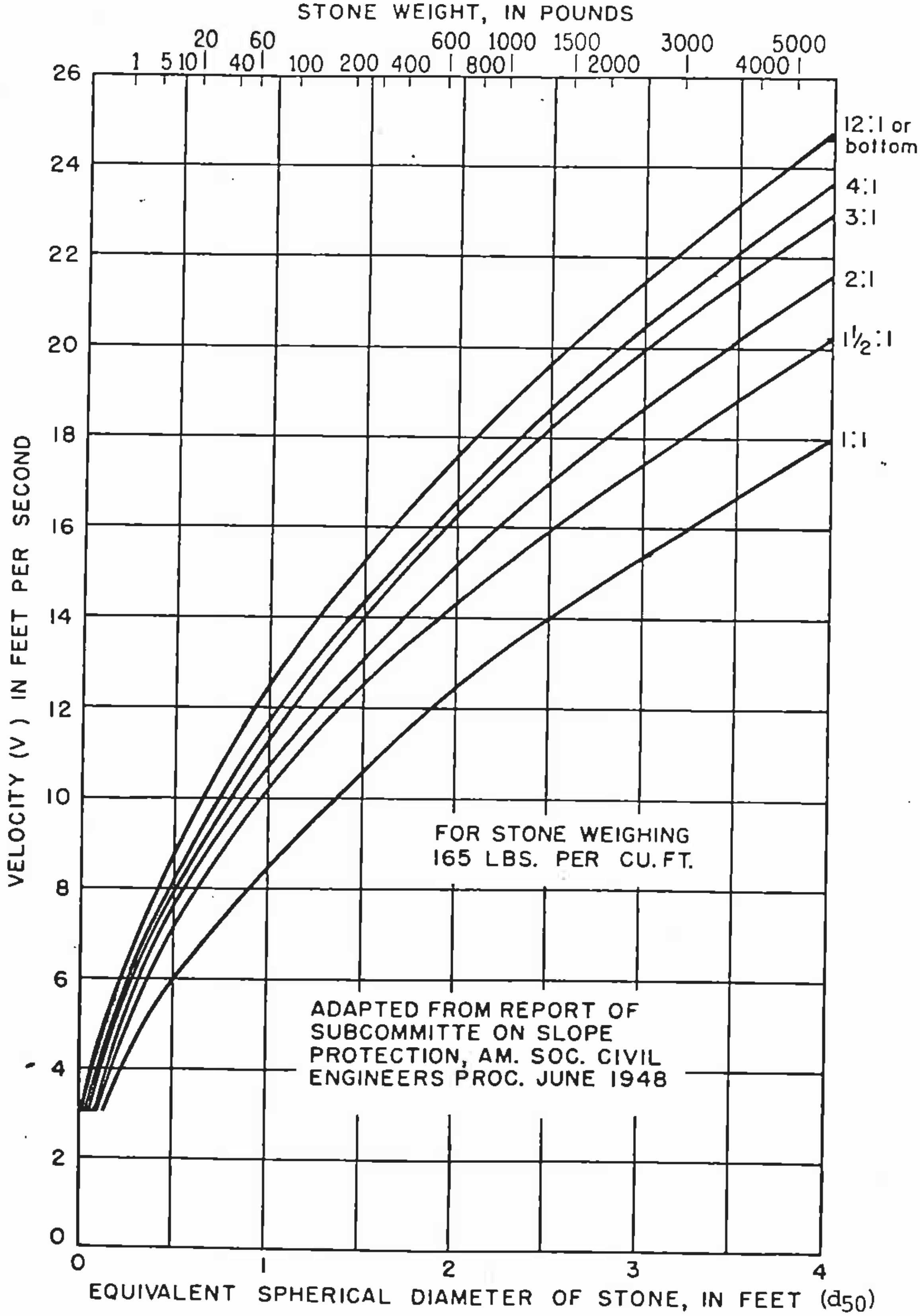
TRAPEZOIDAL SECTION

Discharge	=	cfs	Depth (D)	=	feet
Bottom (b)	=	feet	Top width (T)	=	feet
Side slopes (Z)	=		Velocity	=	ft/sec
Bed Slope	=	%	Hydraulic Radius	=	feet
Manning's n	=				
Specific Gravity	=		Bottom D50	=	feet
Safety Factor	=		Bank D50	=	feet

AM. SOC. CIVIL ENGINEERS

PROC. JUNE, 1984

RIPRAP SIZING CHART



SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES

DESIGN COMMENTS

Date: ____________

Watershed ID: ____________________

Structure ID: ____________________

Designer: ____________________

FIELD MONITORING AND MAINTENANCE INSPECTION FORM

Peabody

INSPECTION FORM

PEABODY COAL COMPANY
Western Division

DATE ____________

DAY

S	M	T	W	TH	F	S

PROJECT ____________
JOB NO. ____________
CLIENT ____________
CONTRACTOR ____________
PROJECT MANAGER ____________

WEATHER	Brite Sun	Clear	Overcast	Rain	Snow
TEMP.	To 32	32 50	50 70	70 85	85 up
WIND	Still	Moder	High	Report No	
HUMIDITY	Dry	Moder	Humid		

AVERAGE FIELD FORCE

Name of Contractor	Non-manual	Manual	Remarks

VISITORS

Time	Representing	Representing	Remarks

EQUIPMENT AT THE SITE

CONSTRUCTION ACTIVITIES

DISTRIBUTION
1. Proj. Mgr.
2. Field Office
3. File
4. Client

PAGE 1 OF ____ PAGES

BY ____________ TITLE ____________

Wiley-Fisk Form 8-1

Peabody

INSPECTION FORM
(Continuation Sheet)

PEABODY COAL COMPANY
Western Division

PROJECT ____________________ REPORT NO. __________

JOB NO. ____________________ DATE __________

CONSTRUCTION ACTIVITIES (Continued)

Discussions

Inspectors Comments

DISTRIBUTION:
1. Proj. Mgr.
2. Field Office
3. File
4. Client

SHEET ______ OF ______

BY ____________________ TITLE __________

ATTACHMENT C

SUPPORTING INFORMATION FOR THE SURFACE STABILIZATION PROGRAM

ATTACHMENT C

INDEX

LIST OF FIGURES

LIST OF TABLES

ATTACHMENT C

INDEX (Cont.)

LIST OF TABLES (Cont.)

Introduction

The following information is presented to provide support for the concepts, methods and plans developed by Peabody Western Coal Company (PWCC) to ensure reclaimed landscapes at the Black Mesa Complex are established effectively with regard to long term erosional stability. Surface stabilization concepts, methods and plans are described in Chapter 26, Surface Stabilization Program.

Regional Environmental and Geomorphologic Setting

A brief review of the more important processes that influence regional land surface stability is provided.in this section. Such a review is necessary because the inherent nature of the region, which includes the Black Mesa leasehold, is conducive to high erosional potential. Past and present reclamation practices related to surface stabilization have, to a large degree, been dictated by the processes inherent to the region where the leasehold is situated. The surface stabilization program contained in this chapter evolved through monitoring the response of the reclaimed lands to the processes that effect surface stability, gaining a better understanding of the processes themselves, and applying this knowledge to select the appropriate techniques needed to insure sustained surface stability.

Chapter 15 (Hydrologic Description) contains detailed information on the regional and local hydrology of Black Mesa. It includes descriptions of the geologic and hydrologic features and processes that determine basin responses to the semi-arid climate. The interrelationships among the various independent and dependent variables which characterize drainage basin geomorphology on Black Mesa are complex and typical of semi-arid conditions. Native drainage basin morphologies are characterized by high drainage densities, moderate to steep upland hillslopes that feature shallow, highly erosive soils, and prominently entrenched channels in the higher order streams. These drainage basin characteristics are indicative of the typical Black Mesa watershed responses to the high energy rainfall events over time. The climate of Black Mesa is semi-arid, and typically produces from 8 to 12 inches of precipitation annually (Chapter 11). Most rainfall occurs as intense summer thunderstorms that produce high kinetic energies. Thunderstorms result in large amounts of soil detachment and collected on reclaimed lands follows. This evaluation reflects directly on the degree of success that reclamation practices applied to interim lands have had with regard to surface stabilization.

Surface Water Standards. Water quality standards include suspended sediment (mg/l), which is an integral part of the sediment yield from a reclaimed drainage basin. Water quality criteria to be used for bond release purposes necessarily involve determinations regarding whether reclaimed area runoff diminishes or degrades the water quality of receiving streams. This implies that suspended sediment concentrations in reclaimed area runoff must be comparable to receiving stream concentrations. Also, it follows that sediment yields from reclaimed areas must be comparable with yields from similar, undisturbed watersheds.

Peabody has intensively monitored surface water quality within and adjacent to the Black Mesa leasehold since 1981. Chapter 16 (Hydrologic Monitoring Program) describes in detail surface water monitoring objectives, instrumentation, and frequencies. Chapter 15, Hydrologic Description, presents interpretations of the data collected from this program, and includes discussions of drainage basin characteristics (stream orders, channel geomorphology), runoff, and sediment loads. The program is designed to collect, interpret, and report baseline surface water monitoring data for the purpose of evaluating the impacts of mining on the local and regional hydrology. This baseline data will eventually be used to evaluate the success of Peabody's reclamation in meeting bond release criteria (surface water quality of runoff from reclaimed area).

In order to further assess the effects of mining and reclamation on the water quality and sediment balance of the receiving streams and to compare the erosion potential of the reclaimed areas to undisturbed areas, a Small Watershed Study was designed and implemented in June of 1985. The Small Watershed Study was discontinued in 1992. The term "small watershed" is used to distinguish this study from the larger scale, stream (main channel) monitoring program. In this program, surface water data from small watersheds was collected under both reclaimed and undisturbed conditions for the purpose of calibrating a predictive hydrologic model that can be applied to future reclaimed areas. The overland flow component as well as the channelized runoff component of reclaimed and undisturbed watersheds was quantified. Data generated from this study can provide a basis for evaluating whether reclaimed areas have been restored to a condition

TABLE 1

Drainage Areas, Drainage Relief Ratios and Average Watershed Slopes for Watersheds Monitored by Small Watershed Study Flumes on Black Mesa

Monitoring Area	Monitoring Sites	Drainage Area (acres)	Drainage Relief Ratio	Average Watershed Slope (%)
N-2	227	11.6	.0827	9.4
	228	2.7	.1323	12.8
J-1/N-6	267	4.9	.0614	7.6
	268	11.0	.0541	9.3
J-27	277	19.8	.0614	6.6
Undisturbed (J-3)	309	40.7	.0564	14.6

and the undisturbed watershed area. Hydrologic cover includes canopy cover, vegetative litter, and rock. Hydrologic cover percentages within the monitored reclaimed areas ranged between 15.4 (N-2) and 30.6 (J-1/N-6) while the undisturbed watershed had a hydrologic cover of 36.6 percent. The greatest range in k-factors determined from selectively sampled soils in the four areas occurred in the undisturbed watershed (.14-.29). The three reclaimed areas showed less variability among sampled k-values, but the overall means were higher than the mean determined for the undisturbed area.

Flume Rating Curve Comparisons. Figures 1 through 6 are sediment rating curves for each Small Watershed Study flume site. The curves were developed from automated sampler suspended sediment data and discharge values collected at the flumes during runoff events monitored from 1985 through 1988. Suspended sediment and discharge values were converted to tons per day using the relationship:

$$\text{tons/day} = Q \times C \times k$$

where,

Q = discharge (cfs)

C = suspended sediment concentration (mg/l)

and,

k = is a constant (.0027) for converting English units to tons per day and assumes a specific weight of 2.65 for sediment

Least-squares equations defining the "best fit" lines through each set of data were calculated after transforming each sediment (tons per day) and discharge (cfs) value into logarithms. Table 3 presents the equations defining the regression lines determined for each flume's sediment rating curve.

For comparison purposes, the sediment rating curve and corresponding regression relationship developed from sediment and runoff data collected through 1988 in the undisturbed watershed (Site 309) was considered to be representative of small-sized watersheds on Black Mesa (< 50 acres). This watershed had a relatively moderate relief ratio (.0564), a moderate average watershed slope, vegetation typical of undisturbed watersheds on Black Mesa (pinyon-juniper and sagebrush grassland), and comparable percent hydrologic cover to regional native vegetation. Soil development on the hillslopes was

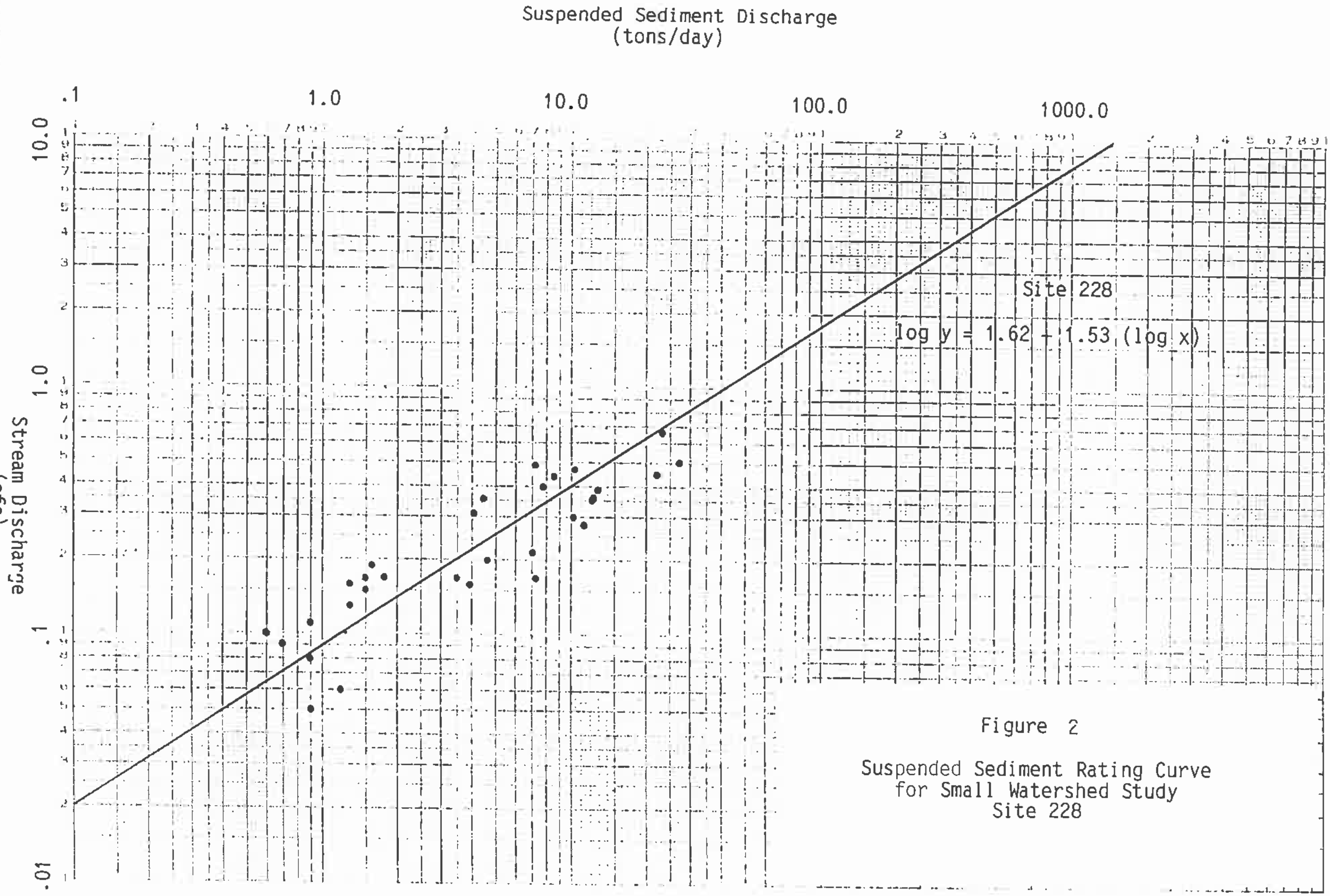


Figure 2

Suspended Sediment Rating Curve
for Small Watershed Study
Site 228

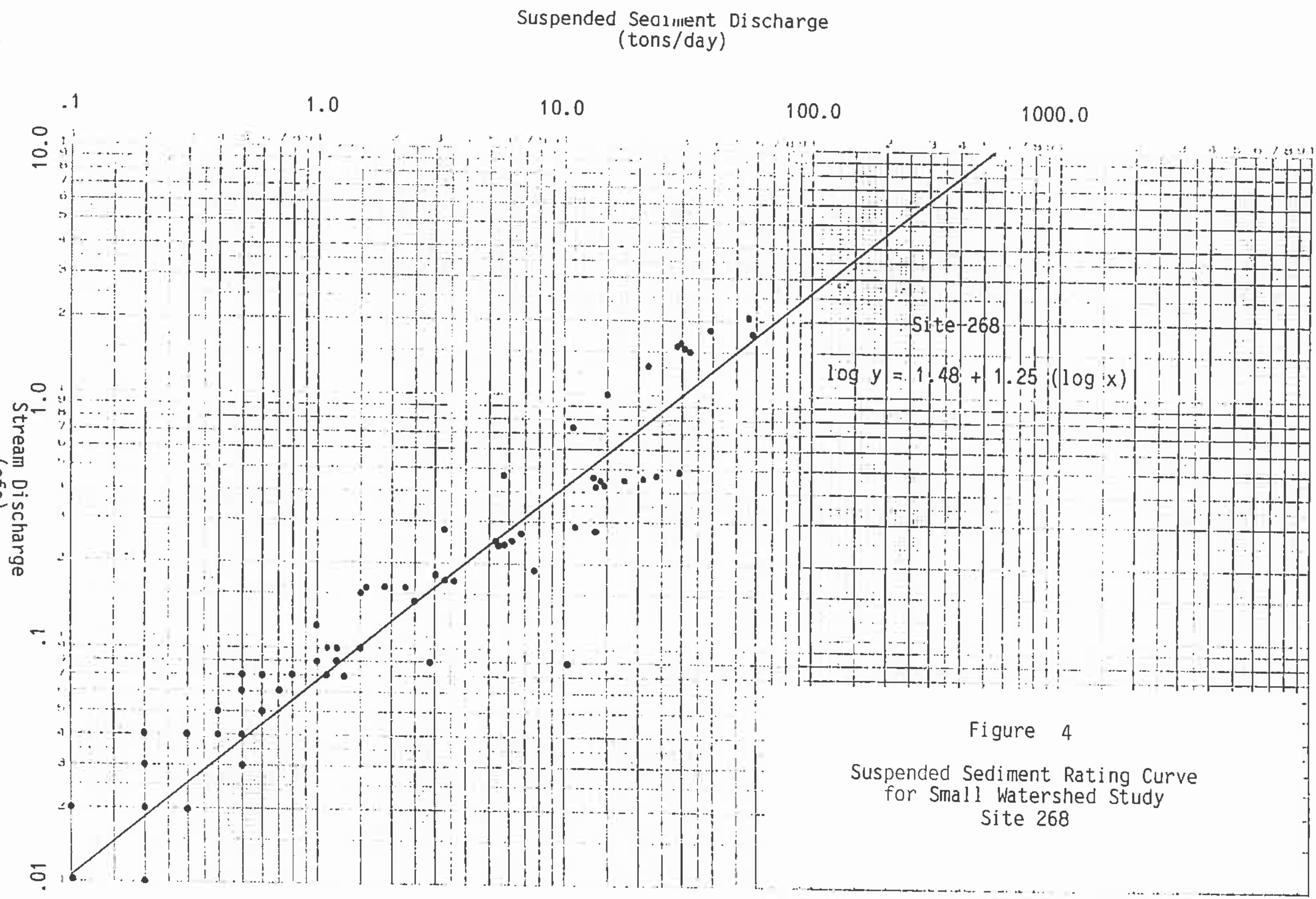


Figure 4

Suspended Sediment Rating Curve
for Small Watershed Study
Site 268

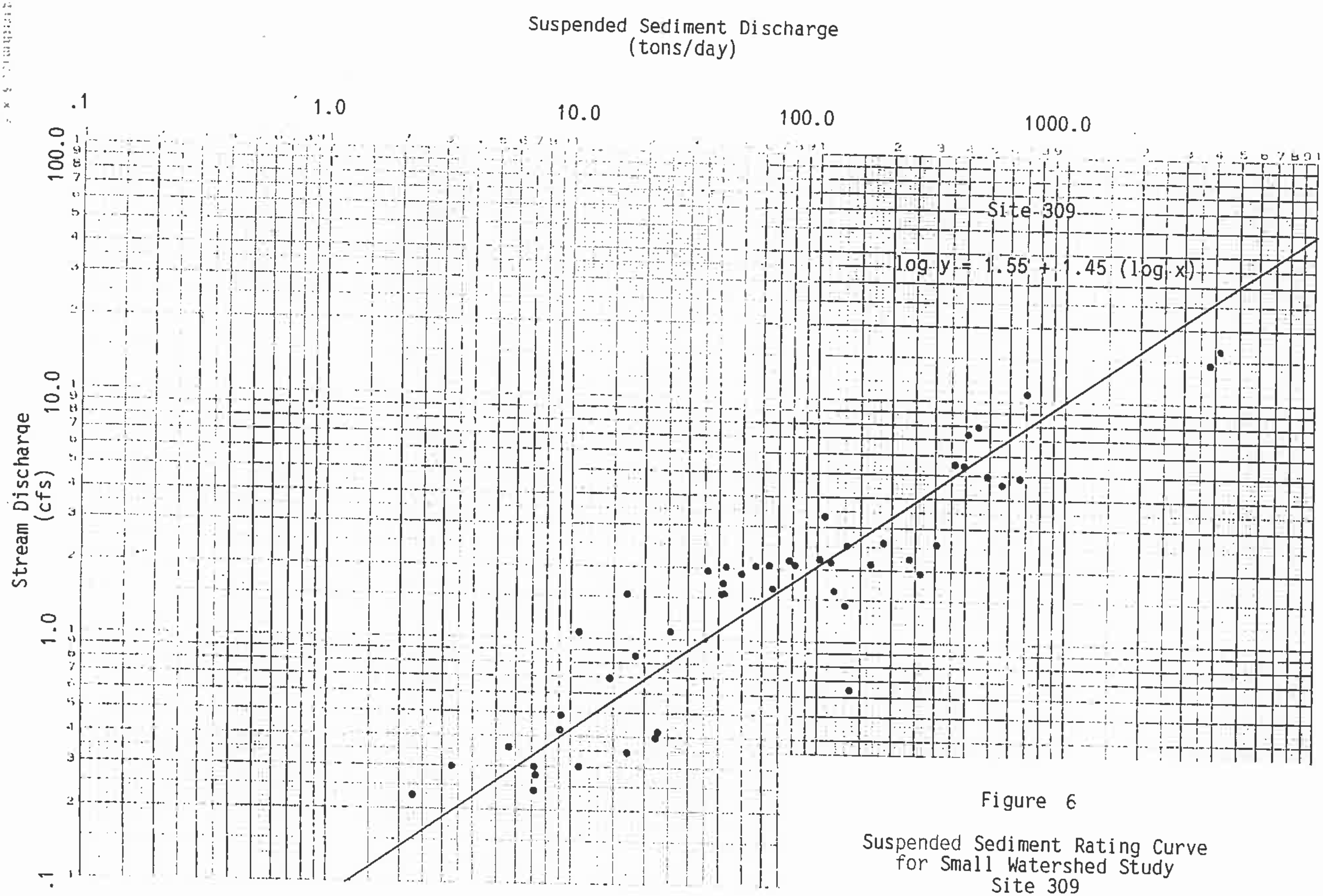


Figure 6

Suspended Sediment Rating Curve
for Small Watershed Study
Site 309

shallow and sparse. Soil types were variable in distribution, and possessed a relatively large range of field determined k-factors. The watershed produced runoff with suspended sediment concentrations of 10^4 to 10^5 mg/l. The sediment rating curve for this watershed (Site 309, Figure 6) and corresponding regression equation (see Table 3) are compared with rating curves from reclaimed watersheds in the following discussion.

The small watersheds that were monitored in reclaimed areas had all undergone topsoil replacement and revegetation at least three years prior to the onset of monitoring in 1985. Topsoil was replaced with scrapers to a minimum depth of six inches. Revegetation was accomplished using an approved seed mixture. Shallow contour furrowing of the topsoil was the only sediment-control/surface-stabilization technique used in these areas during the reclamation process. Regrading of spoil and subsequent reclamation created little to no drainage density, resulting in a landscape largely dominated by overland runoff.

A comparison between the regression equations for each reclaimed watershed rating curve and Site 309 show the sediment rating curve regression lines for Sites 267, 268, and 277 all lie just to the left of the regression line for Site 309. The slopes and intercepts of the regression line equations for these three reclaimed area sediment rating curves are all less than the regression equation for Site 309. The rating curves show that, for a discharge of 10 cfs, the 3 reclaimed watersheds produced about half of the sediment discharge than the undisturbed watershed at the same discharge. This indicates that, in the monitored reclaimed watersheds in the J-1/N-6 (Sites 267, 268) and J-27 (Site 277) coal resource areas, sediment yield and transport was lower for comparable discharges than in the undisturbed watershed.

The sediment rating curve comparisons between Sites 267, 268, and 277, and Site 309 indicate that, through 1988, the reclaimed watersheds recreated in the two coal resource areas (J-1/N-6 and J-27) produced no greater sediment loads than a typical undisturbed watershed. The reclaimed watersheds monitored in J-1/N-6 and J-27 underwent final reseeding in 1981 and 1982, respectively. Watersheds monitored in both areas are typical of interior graded spoil with hillslopes no greater than 4:1. Topsoil replacement, surface manipulation (contour furrowing), and vegetation reestablishment, were conducted in each area using contemporaneous approved techniques. The sediment rating curve comparisons suggest that the monitored reclaimed watersheds were as geomorphically stable shallow slopes, in combination with past minesoil reconstruction and timely revegetation in the J-1/N-6 and J-27 reclaimed areas appear to have resulted in sediment discharges less than or equal to undisturbed conditions. If vegetation reestablishment is slow, contour furrows may weather faster on the steeper slopes commonly found in reclaimed areas formed of outslope spoils, ramps, or reduced highwalls. Convex slopes commonly formed in these areas are susceptible to rilling and gullying, which may result in higher reclaimed area sediment loads than similar undisturbed watersheds. In conclusion, these outslope spoils, ramps, or reduced highwall reclaimed areas which may experience higher erosion rates will require additional reclamation techniques (i.e., contour terraces, reclaimed downdrains, concave slope grading, etc.) to reduce peak velocities of runoff, control drainage development (channelized flow) and thus, to reduce erosion.

Runoff Plot Data Comparisons. Attachment 4 of Chapter 16 (Hydrologic Monitoring Program) presents a detailed description of runoff plot monitoring conducted from 1985 through 1992 as part of the Small Watershed Study. The plots collected total eroded sediment mass and runoff volume on a storm basis from 24 bordered plots of equal area (350 square feet each). In the following sections, data collected from these 24 plots through 1988 provides a basis for investigating the overland flow portions of runoff and sediment yield from small watersheds.

Eighteen of the plots were located on a range of slopes and percent hydrologic cover within the post-law reclaimed areas (N-2, J-1/N-6, and J-27). The remaining six were located on similar slopes with varying cover types and percent cover in the undisturbed watershed. Table 4 presents plot site numbers and corresponding percent slopes, hydrologic cover, and k-factors measured in each of the 24 plots.

Attachment D presents graphs (Figures 1 to 34) of total eroded sediment (tons) versus total runoff volume (liters) measured in Small Watershed Study plots on a storm basis from 1985 through 1988. Figures 1 through 24 present graphs for individual runoff plots. Figures 25 through 27 are graphs of eroded sediment versus runoff for each reclaimed monitoring area (25, N-2; 26, J-1/N-6; and 27, J-27). Figure 28 is a graph of eroded sediment versus runoff data collected in all plots located in reclaimed areas. Figure 29 presents eroded sediment versus runoff for all plot sites (six) in the undisturbed watershed (J-3). For all graphs, a "least-squares" regression equation was determined by first transforming each data value (total eroded sediment and corresponding runoff) into logarithms. Each figure in Attachment D includes the equation and the line defining the measured eroded sediment and runoff relationship, unless there were insufficient points to allow a meaningful regression. The reader should refer to the aforementioned figures presented in Attachment D while reading the following discussion.

Eighteen runoff plots (10'x35') installed as nine pairs (for replication and comparison purposes) in the N-2, J-1/N-6, and J-27 post-law reclaimed areas were located on a range of slopes (see Table 4). Topsoil replacement, contour furrowing, and revegetation conducted in each reclaimed area monitored by the 18 plots were consistent with previously-approved reclamation techniques. Measured percent hydrologic cover varied among the plots. K-factors determined from field measurements varied less than cover in the 18 reclaimed area runoff plots.

The six runoff plots installed in the undisturbed watershed were located on similar slopes (14 to 18 percent), varying in cover type and percent hydrologic cover (Sites 303 and 308, sagebrush grassland; 304 through 307, pinyon-juniper woodland). Measured k-factors among each of the six undisturbed watershed runoff plots varied greatly, ranging between .14 and .29. Plot locations selected in the undisturbed watershed were considered representative of unmined, natural areas on Black Mesa. The least-squares regression lines and corresponding equations were used to compare overland flow sediment production on reclaimed areas with undisturbed conditions.

Figures 1 through 6 in Attachment D are sediment versus runoff graphs for the plots located in the N-2 post-law reclaimed area. Based on the regression lines, Sites 221 and 222 showed the highest total eroded sediment versus runoff relationship. These plots were situated on the highest slope range monitored in N-2 (18 to 20 percent). Sites 223 and 224 showed less eroded sediment for comparable runoff values, while having measured cover percentages almost half of the percentage measured in Plots 221 and 222. This suggests that slope accounted for much of the increased eroded sediment measured at Sites 221 and 222 in comparison with Sites 223 and 224. The regression line for Site 225 (Figure 5) indicates a trend to higher sediment than Sites 223 and 224 for higher runoff values, but a similar eroded sediment versus runoff relationship to Plots 221 and 222. This can be attributed to the relatively high k-factor representative of the soil in Plot 225. Lack of data through 1988 due to instrumentation malfunctions precluded fitting a meaningful regression line to the data collected at Site 226. Comparisons among the plot located in the J-27 post-law reclaimed area. Adequate regression lines and equations were not determined for Sites 271 and 272 due to the scant data collected at both plots through 1988. Among Sites 273 through 276, Plot 275 data resulted in the highest sediment versus runoff relationship. Although the slope for Plot 275 is relatively low (5 percent), the high sediment production at similar runoff volumes can probably be attributed to the slightly lower percent cover measured in the plot in comparison to the other three, and to the fact that only four data points define the plot. Site 276 (paired with Site 275) agrees well with Sites 273 and 274, so it is likely that additional data collected at Site 275 may show close agreement with Sites 273, 274, and 276.

Regression plots for the J-27 sites suggest that at lower slopes a larger change in slope is necessary to show significant changes in sediment yield for the range of runoff volumes. The lack of significant sediment yield differences for sites with slopes ranging from five to ten percent was partly due to the fact that the sites with the lowest slopes also had the lowest cover. All J-27 plot regression lines showed less sediment yield for the range of runoff volumes than the J-3 regressions.

Figures 19 through 24 (Attachment D) present sediment versus runoff graphs of the six plots that monitored overland runoff and sediment in the undisturbed watershed. Plots 303 and 308 had sagebrush-grassland type of cover, whereas the other four plots were the pinon-juniper woodland type of cover. The range in slope for the J-3 plots was fairly close (14 percent to 18 percent), so further resolution of the sensitivity of cover and k-factors may be made because the effects from differences in slope should be very minimal. In addition, any biases introduced by some plots having rainfall data from more storms than others was removed by only plotting those points for storms measured at all the J-3 plots. Thus, Figures 19 to 24 are presented to show all the data collected through 1988 at each J-3 plot, but for the following discussion, Figures 30 to 33 and 23 and 24 (showing only those data points collected from common storms) should be referred to.

Comparing Site 303 with Site 304, Site 304 showed a trend toward more sediment yield for higher runoff events. A comparison of Sites 303 and 305 indicates that Plot 305 yielded more sediment at lower runoff volumes. Plots 304 and 305 had hydrologic covers of 27 and sediment versus runoff relationships. Plots located on less steep slopes with almost 50 percent less cover (Sites 223, 224, 265, and 266), showed less sediment production. Percent cover variability accounted for some differences in overland sediment production in reclaimed areas, as seen by the higher sediment versus runoff relationship in Plot Site 225 compared with 221, 222, 223, and 224. Variation in reclaimed soil k-factors showed an even slighter effect on overland sediment production in reclaimed areas except where high k-factors are combined with low cover.

Comparisons among the combined data graphs for each reclaimed area (Figures 25, 26 and 27) with runoff plot data collected in the undisturbed area indicate that all three reclaimed areas (N-2, J-1/N-6, and J-27) produced less eroded sediment from overland runoff than the undisturbed area. This suggests that, for overland flow sediment yields, the interim post-law reclaimed areas are stable with regard to the surrounding undisturbed hillslopes.

The previously-discussed comparisons between the flume sediment rating curves and runoff plot data demonstrate that past reclamation efforts conducted in the J-27 and J-1/N-6 interim post-law reclaimed areas created small watersheds and drainages that were geomorphically stable and in equilibrium compared with the representative undisturbed watershed. Sediment production from overland flow in the N-2 post-law reclaimed area was less than the undisturbed area, while the sediment rating curves for the two flume sites in N-2 (227 and 228) showed higher sediment yields for comparable discharges than the undisturbed watershed. The data collected in N-2 compared with the undisturbed watershed indicated that the channelized portion of runoff that occurred in the monitored watersheds above the two flumes was contributing to the higher sediment yields. Both watersheds above Sites 227 and 228 had relatively high relief ratios, low overall hydrologic cover, and exhibited the beginnings of natural, uncontrolled drainage density development (small gullies and rills). Uncontrolled development of drainages in reclaimed areas on Black Mesa could result in small watersheds that are geomorphically unstable with regard to similar sized undisturbed basins. Utilizing the surface stabilization techniques and drainage design procedures outlined in Chapter 26 will help ensure that future coal resource areas are reclaimed to geomorphically stable conditions.

Figure 34 (Attachment D) is introduced at this point to reemphasize the importance of the proposed reclamation practices (ripping, contour furrowing, cover, etc.) to the stability applicable for characterizing the effects of land disturbance and reclamation activities conducted at surface coal mine sites (WET, 1990). In August of 1993, RCE finalized a report entitled "Surface Water Modeling of Reclaimed Parcels at the Black Mesa Complex" (RCE, 1993). The report includes data descriptions, summaries, sensitivity analyses, and model calibration and validation results achieved using the Small Watershed Study data. This report was incorporated in its entirety within PWCC's liability release application package for the N1/N2 and J27 interim program reclaimed areas (PWCC, 1994), which was submitted to the Albuquerque Field Office - Office of Surface Mining in March of 1994. Chapter 3, Protection of the Hydrologic Balance, in the application references the report and includes additional analysis of Small Watershed Study data.

Vegetation Standards. The standards for revegetation success are defined in accordance with the approved postmining land uses of grazing land and wildlife habitat. Specific criteria relating to diversity, effectiveness, and permanence must be applied to the postmining vegetation to judge its success. Ground cover, productivity (above ground vegetation biomass), woody plant stocking rates, and species diversity are criteria used to evaluate the utility of reclaimed landscapes for livestock grazing, wildlife habitat, soil stability, and species diversity on the Black Mesa leasehold. The specific criteria for making revegetation success determinations and the methods used in the derivation of each are described under Revegetation Success Standards in Chapter 23. The methods for collecting data necessary for revegetation success determinations are described in Volume 8, Chapter 9, Page 87 and Attachment 2.

The Permanent Program Performance Standards require that the cover established on reclaimed areas is effective in stabilizing the soil surface from accelerated erosion. In this context, ground cover as defined at 30 CFR 701.5, appropriately satisfies the intent of the regulations. The ground cover standard, as presented in Chapter 23, was derived from data collected in native sagebrush communities which occur on the Black Mesa leasehold. Therefore, if the ground cover standard is met, then it can reasonably be assumed that the reclaimed vegetation is no less effective than the native vegetation for preventing soil loss.

Table 5 summarizes the total nonstratified ground cover that was measured in 1995, 1997, and 1998 at representative reclaimed areas. The results represent mean ground cover values from reclaimed areas. The sampled areas were reclaimed five or more years ago at the time of sampling. These areas also represent a significant portion of the total reclaimed acreage. The data for these areas, and the sagebrush reference areas which formed the basis for the cover revegetation success standard, may be found in annual vegetation monitoring reports submitted to OSMRE from 1992 through 1998.

The information in Table 5 shows that an effective vegetative cover has been achieved in the sampled reclaimed units. The reclaimed area total nonstratified ground cover was greater than the revegetation success standard for cover in nearly all cases, spring or fall. This illustrates two important points that pertain to surface stability analysis.

First, substantial progress is being made toward achieving the proposed ground cover standard. This indicates that the vegetation that has been established on the reclaimed areas has equal or greater level of effectiveness with respect to surface stabilization as the natural vegetation. Second, the minor amount of rilling and gullying that has been experienced on the Black Mesa leasehold has not been sufficient to effect the results of vegetation cover samples. If a significant amount of erosion was occurring, the randomly-conducted cover samples would reflect lower cover values as the number of bare areas caused by erosion increased. The data and qualitative monitoring indicates that this is not the case. Therefore, any rills and gullies that may be apparent on the Black Mesa are not hindering the postmining land use objectives as they relate to vegetation establishment and effectiveness.

Literature Cited

Fullerton, W.T. Water and Sediment Routing from Complex Watersheds. MS Thesis, Colorado State University, Fort Collins, Colorado, 1983, 285 pp.

Peabody Western Coal Company (PWCC). Application for Release of Reclamation Liability N1/N2 and J27 Interim Program Indian Lands Black Mesa and Kayenta Mines. 1994.

Piest, R.F. The Role of the Large Storm as a Sediment Contributor. In Proceedings of the Federal Intra-Agency Sedimentation Conference, Jackson, Mississippi, 1963: USDA, ARS Miscellaneous Publication 970, (1963) p. 98-108.

ATTACHMENT # D

GRAPHS OF TOTAL ERODED SEDIMENT VERSUS RUNOFF VOLUME FOR SMALL WATERSHED STUDY RUNOFF PLOTS

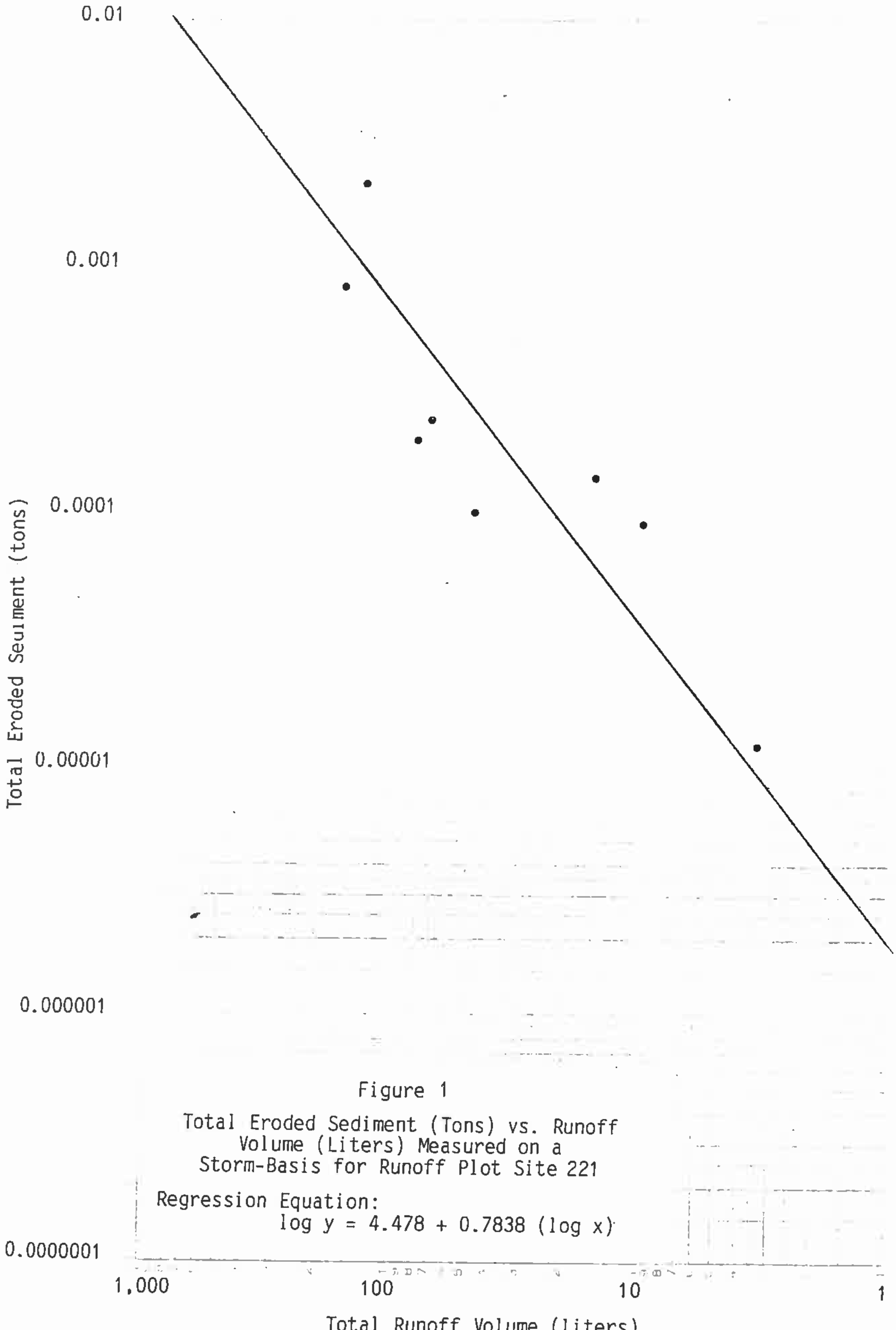


Figure 1

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 221

Regression Equation:

$$\log y = 4.478 + 0.7838 (\log x)$$

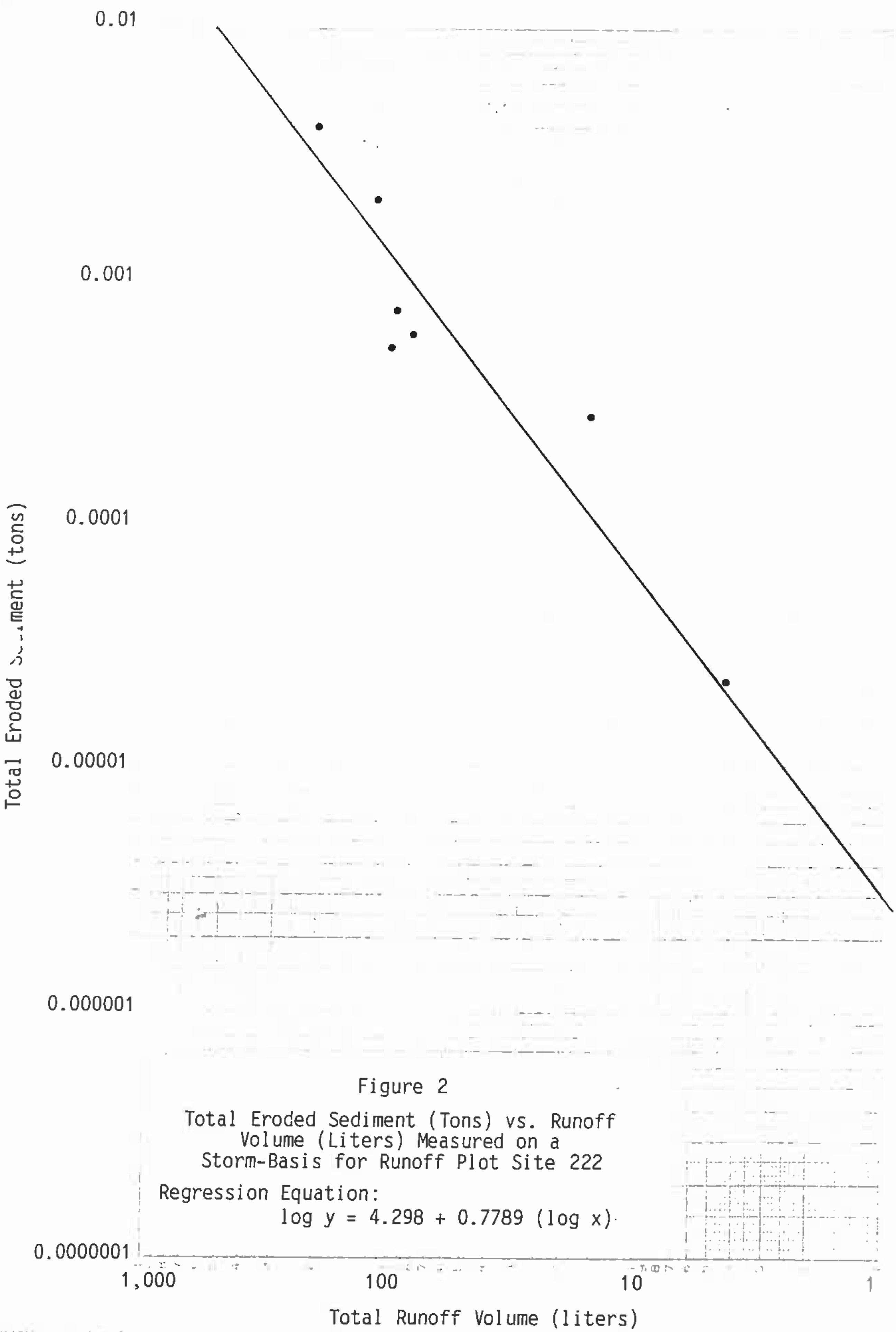


Figure 2

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 222

Regression Equation:

$$\log y = 4.298 + 0.7789 (\log x)$$

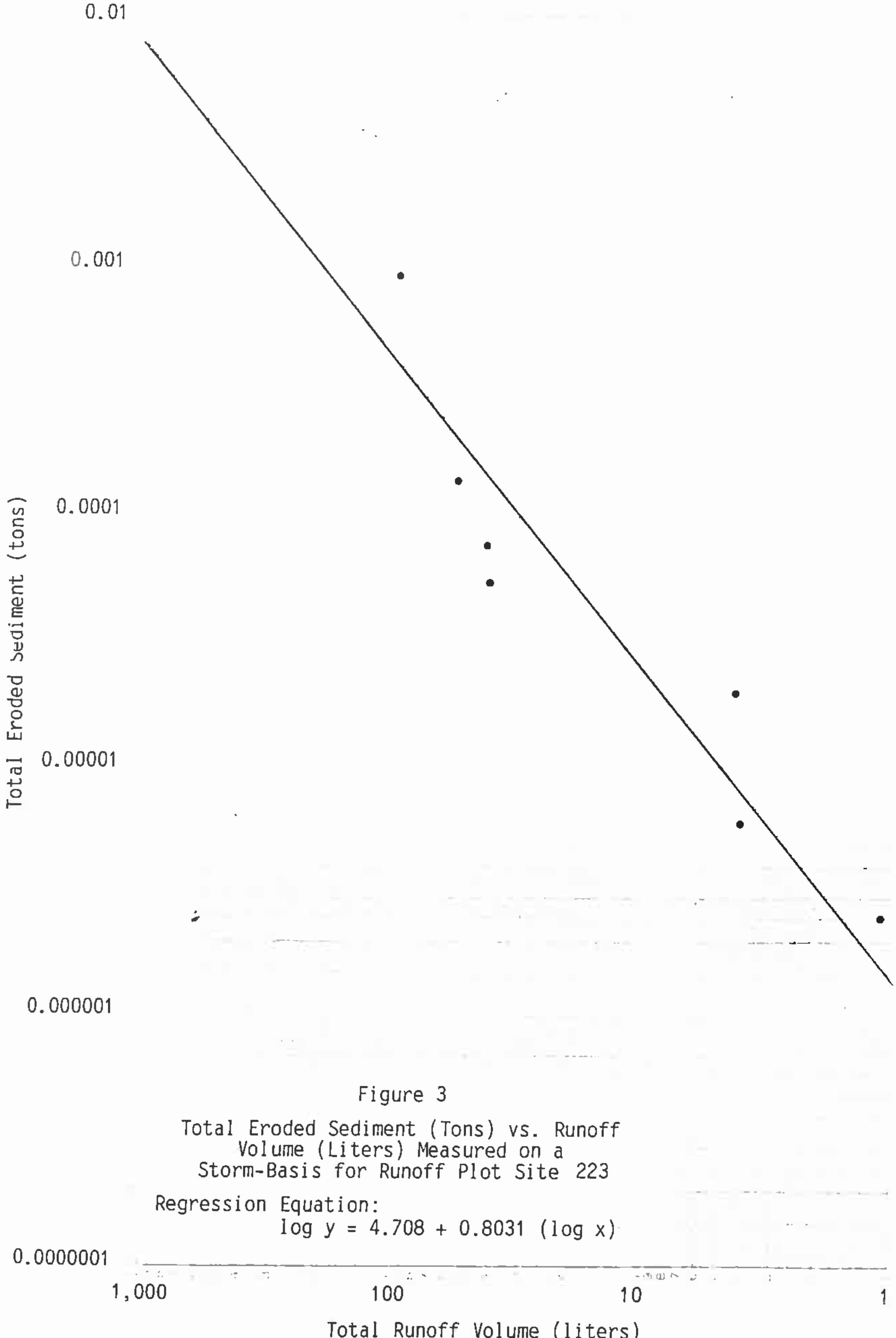


Figure 3

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 223

Regression Equation:

$$\log y = 4.708 + 0.8031 (\log x)$$

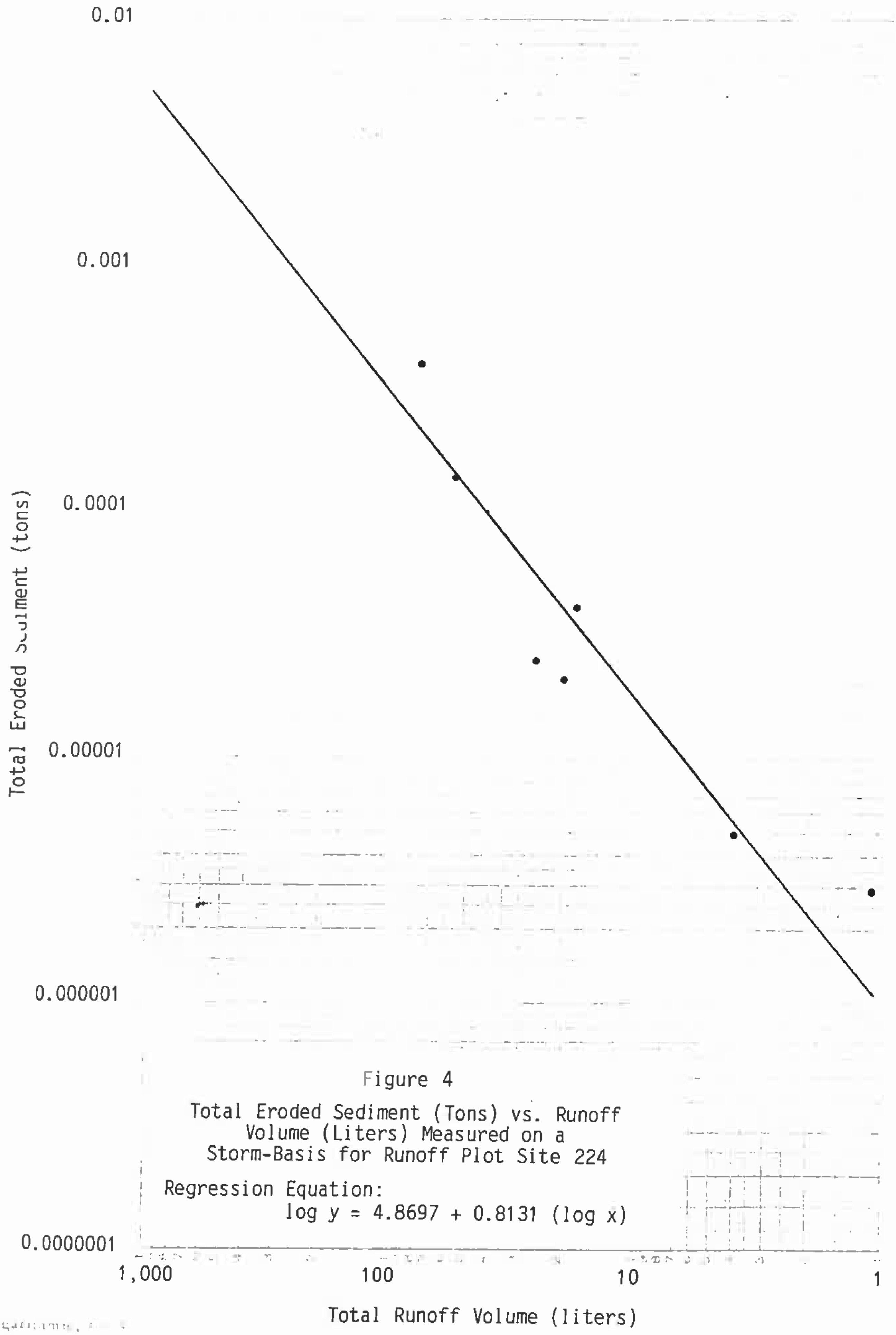


Figure 4

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 224

Regression Equation:

$$\log y = 4.8697 + 0.8131 (\log x)$$

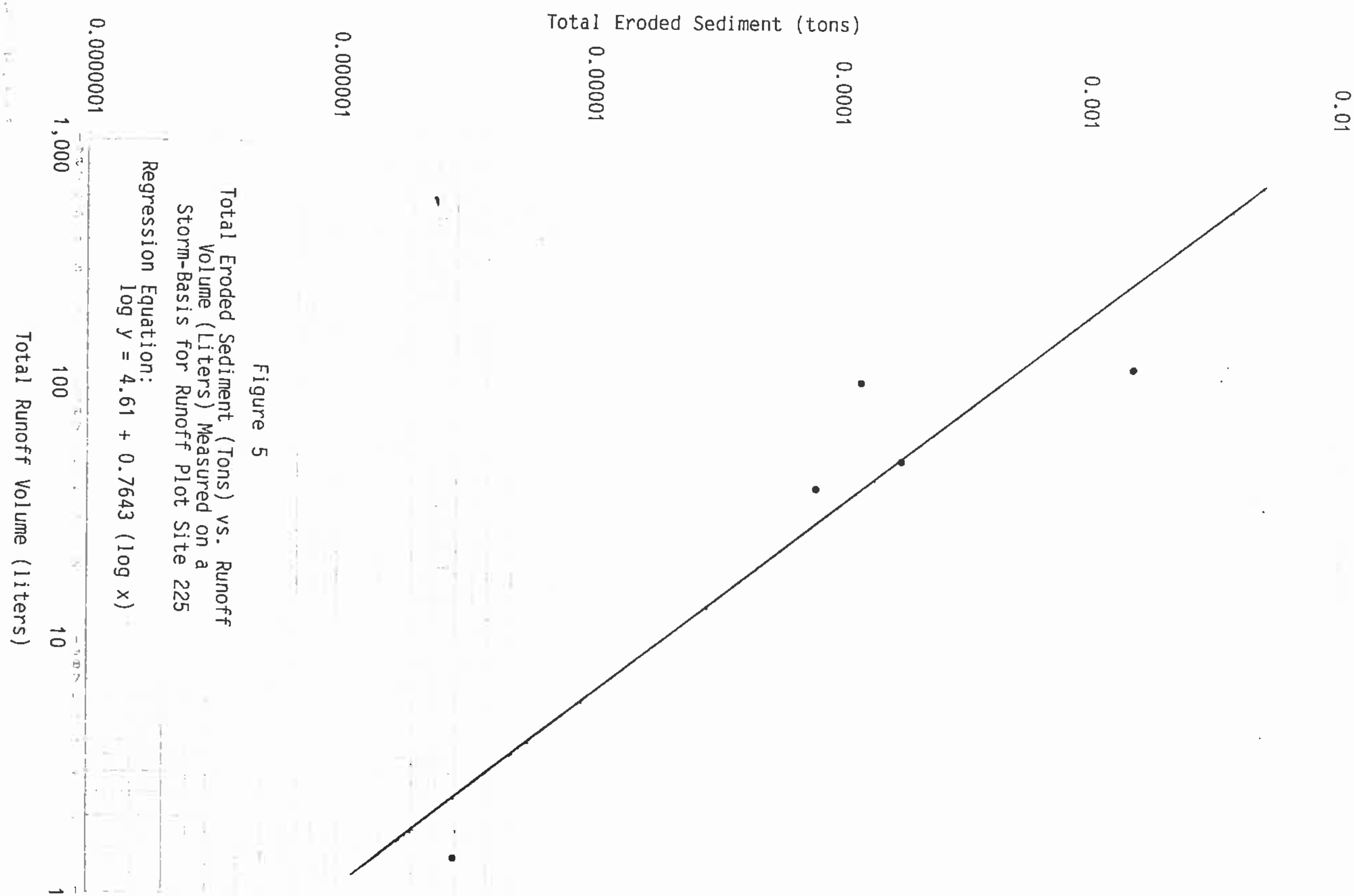


Figure 5

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 225

Regression Equation:
$\log y = 4.61 + 0.7643 (\log x)$

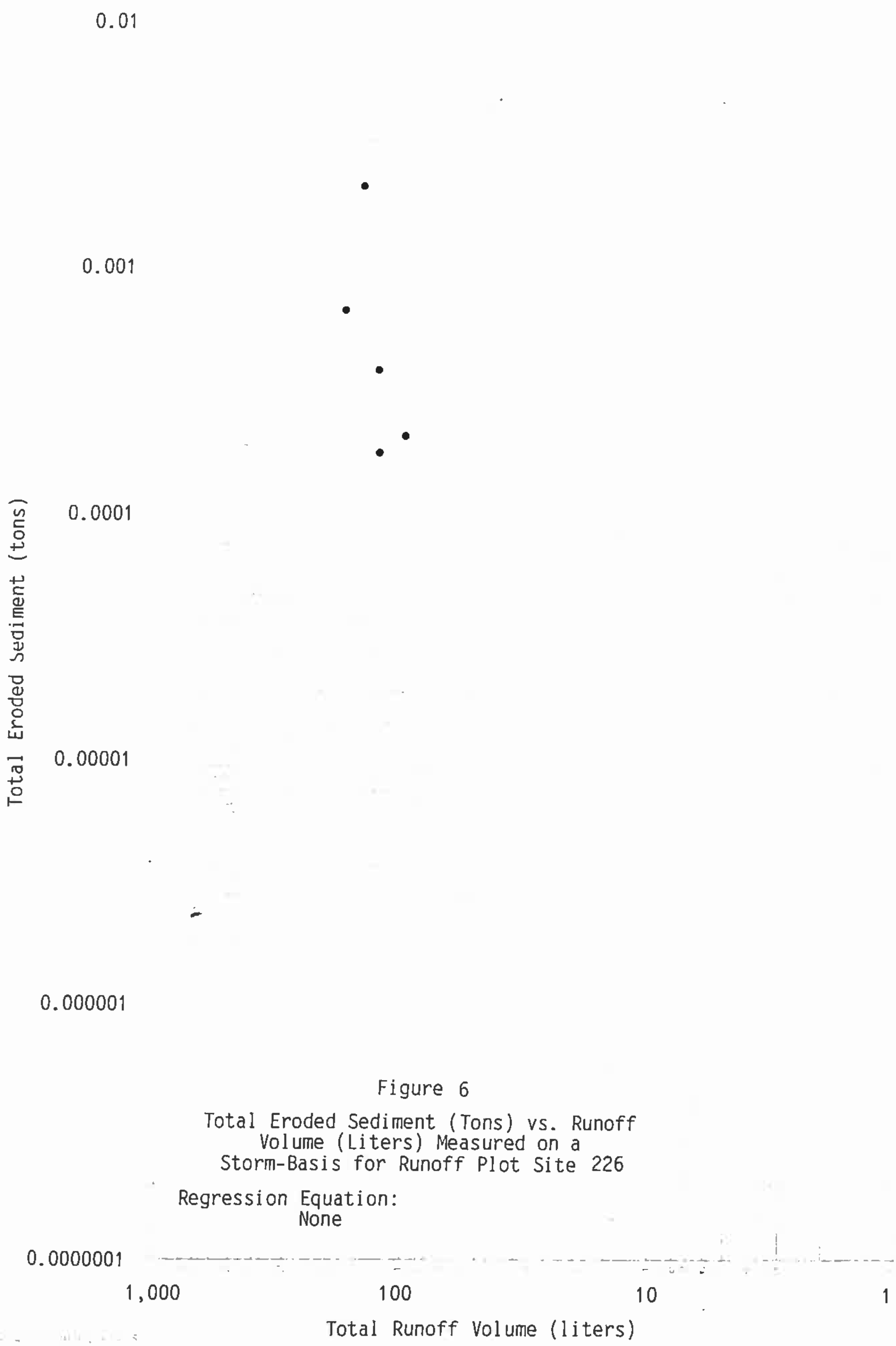


Figure 6

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 226

Regression Equation:
None

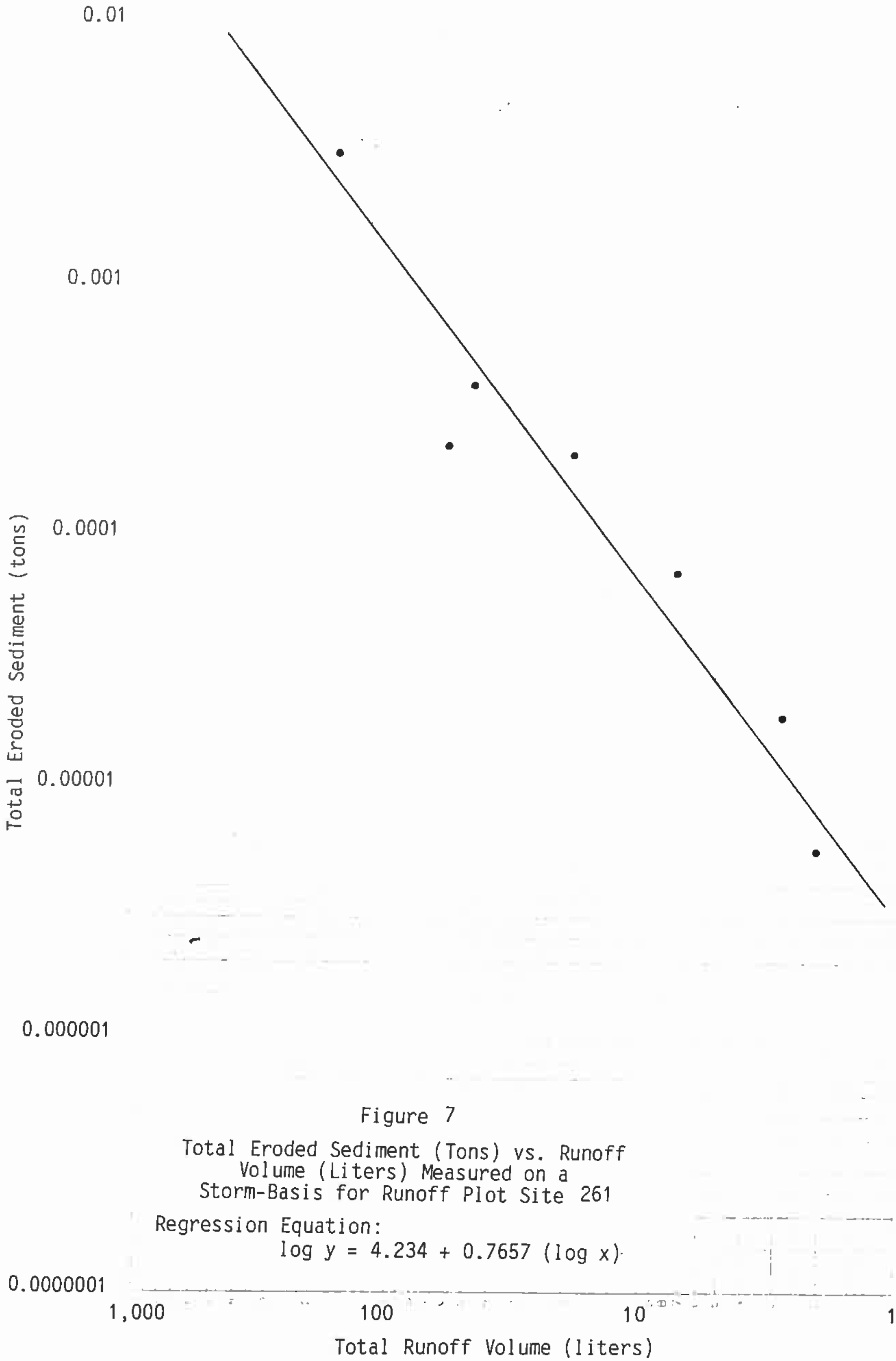


Figure 7

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 261

Regression Equation:

$$\log y = 4.234 + 0.7657 (\log x)$$

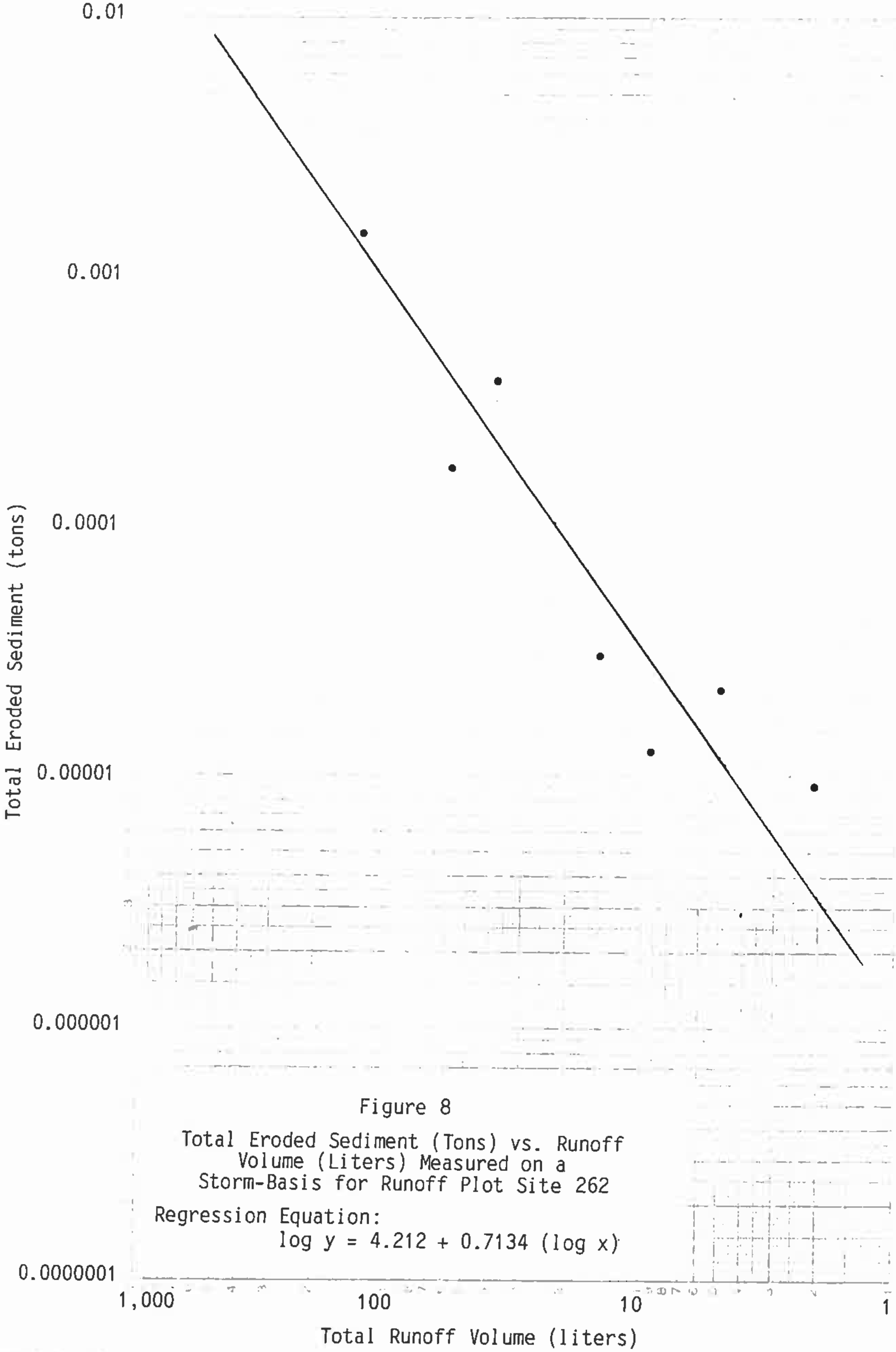


Figure 8

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 262

Regression Equation:

$$\log y = 4.212 + 0.7134 (\log x)$$

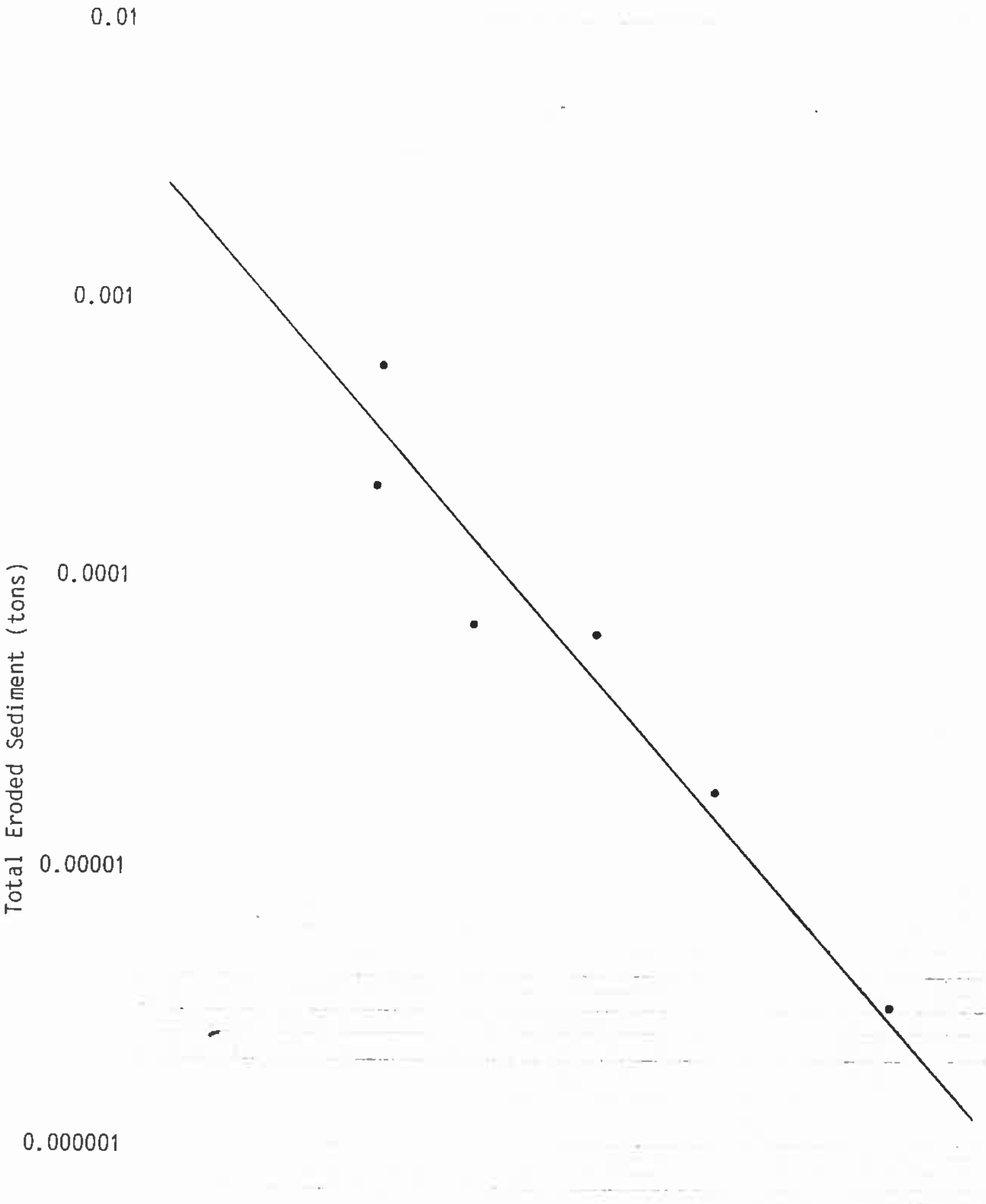


Figure 9

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 263

Regression Equation:

$$\log y = 5.217 + 0.8733 (\log x)$$

0.0000001

1,000 100 10 1

Total Runoff Volume (liters)

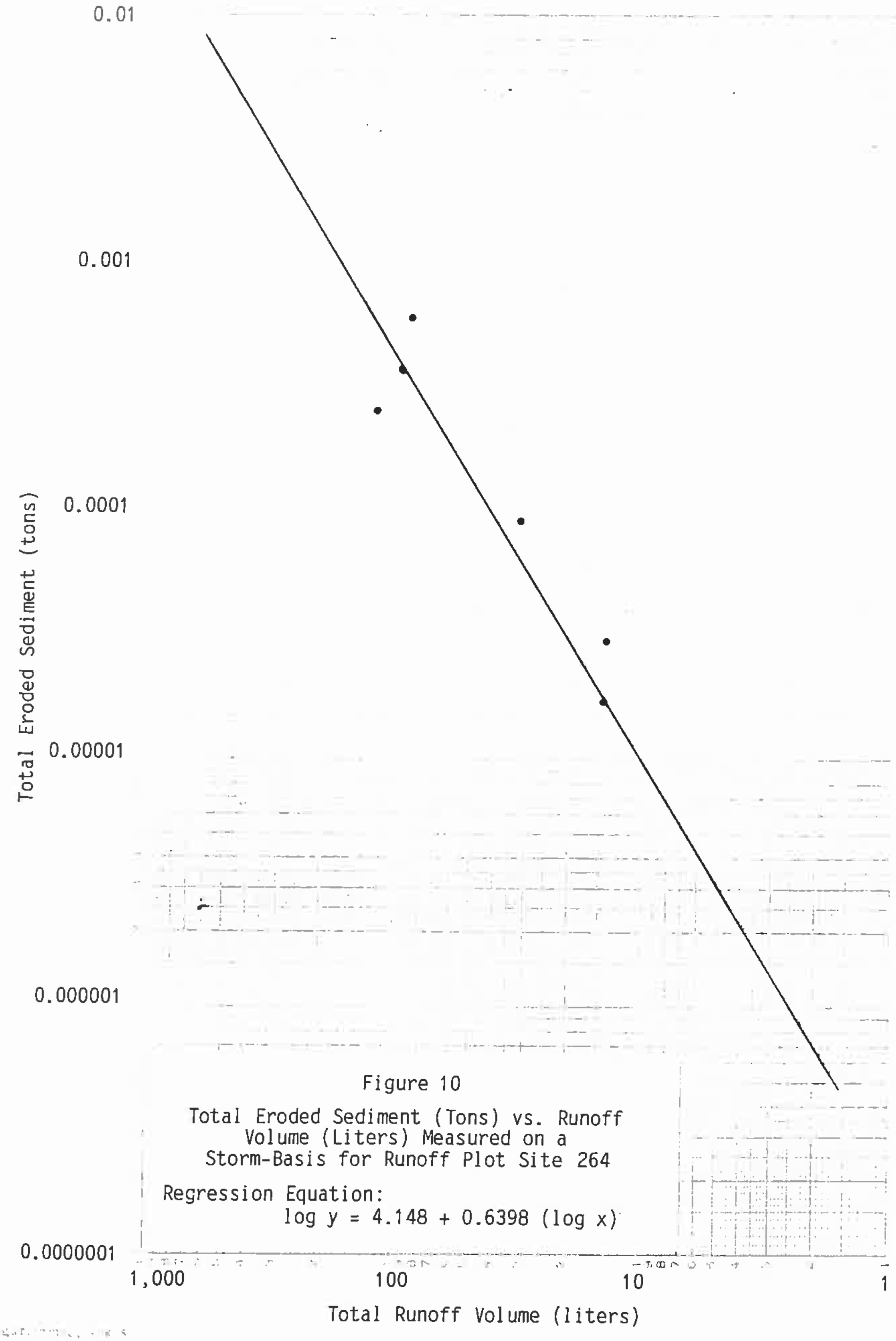


Figure 10

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 264

Regression Equation:

$$\log y = 4.148 + 0.6398 (\log x)$$

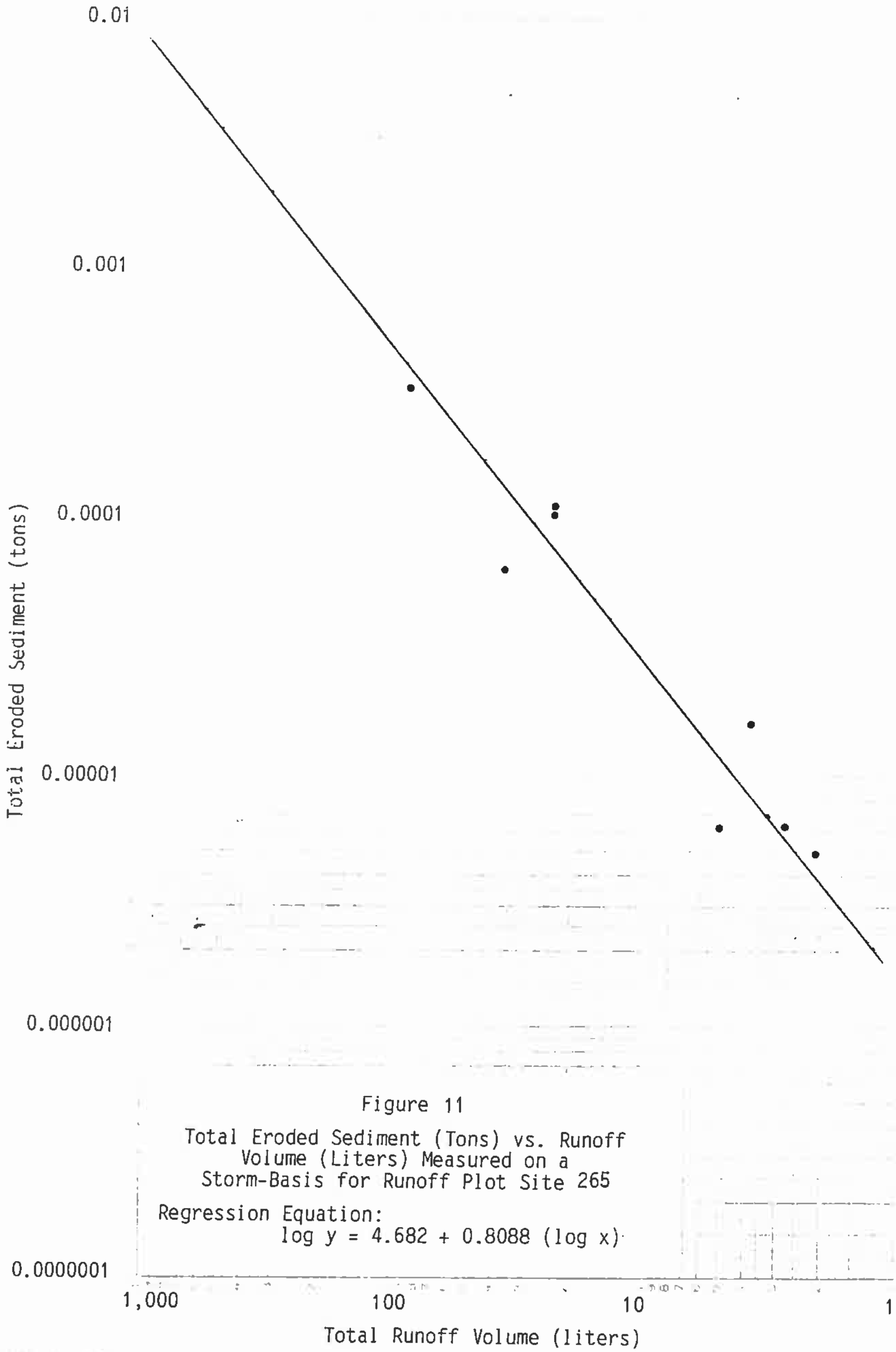


Figure 11

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 265

Regression Equation:
$\log y = 4.682 + 0.8088 (\log x)$

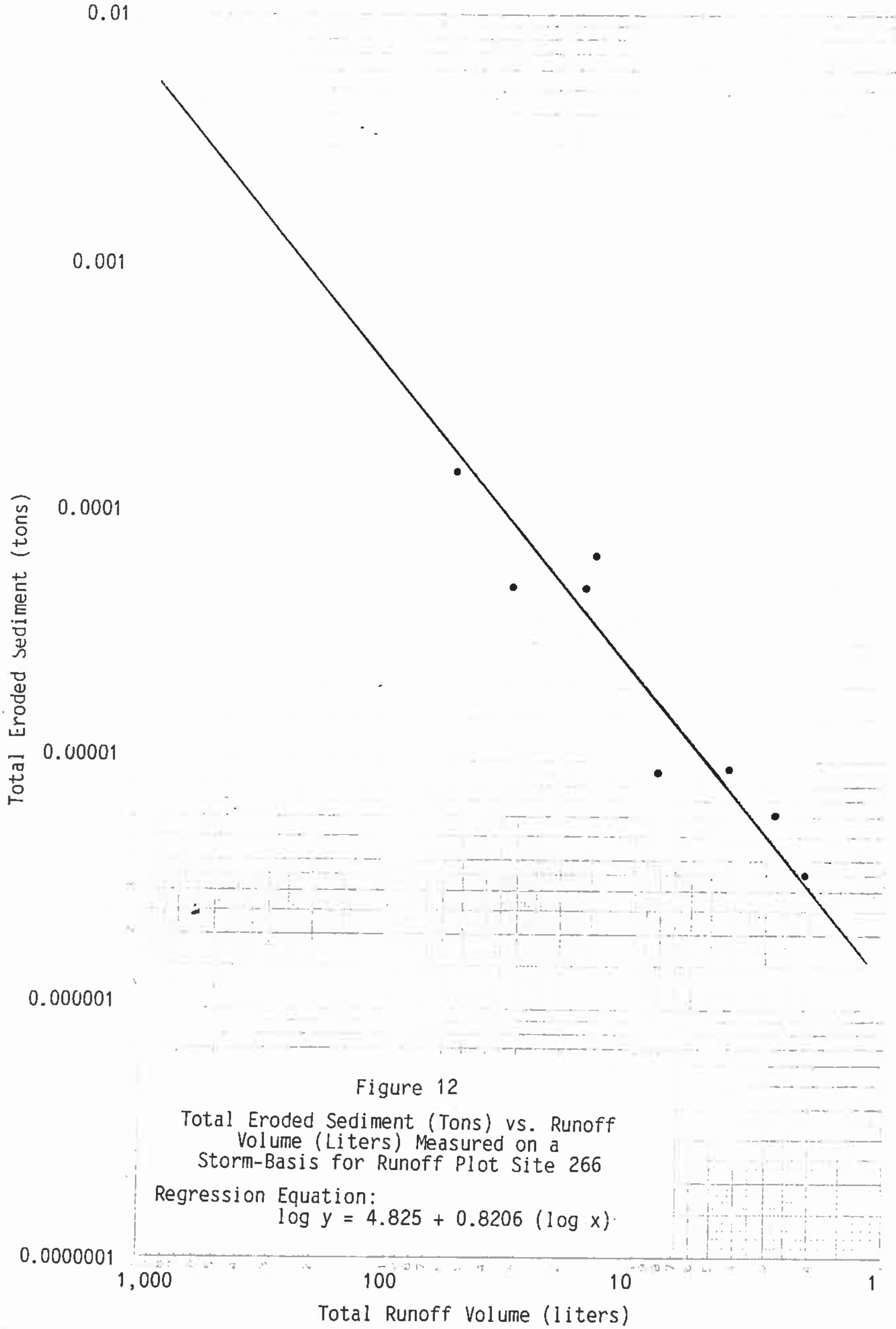


Figure 12

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 266

Regression Equation:

$$\log y = 4.825 + 0.8206 (\log x)$$

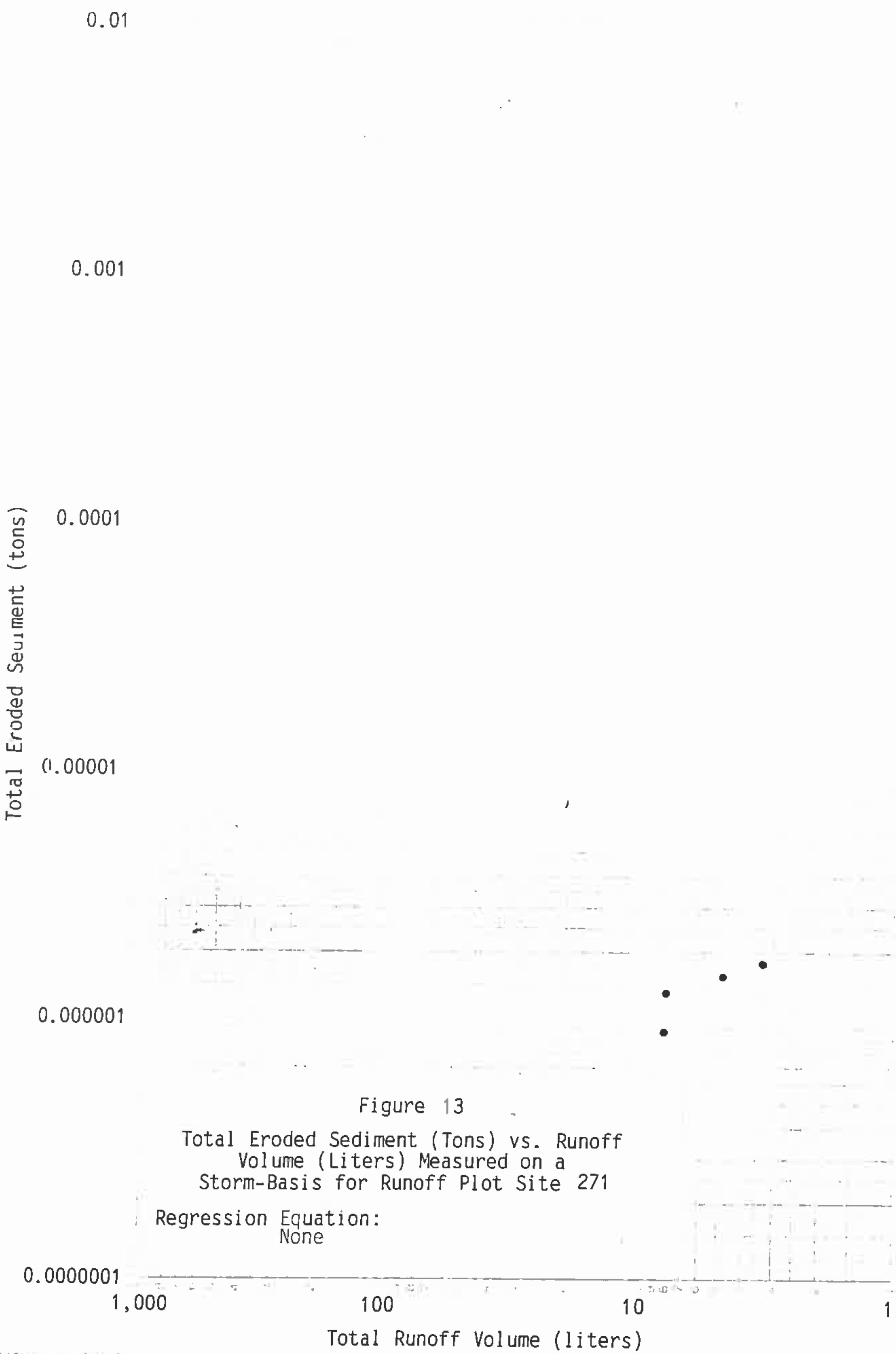


Figure 13

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 271

Regression Equation:
None

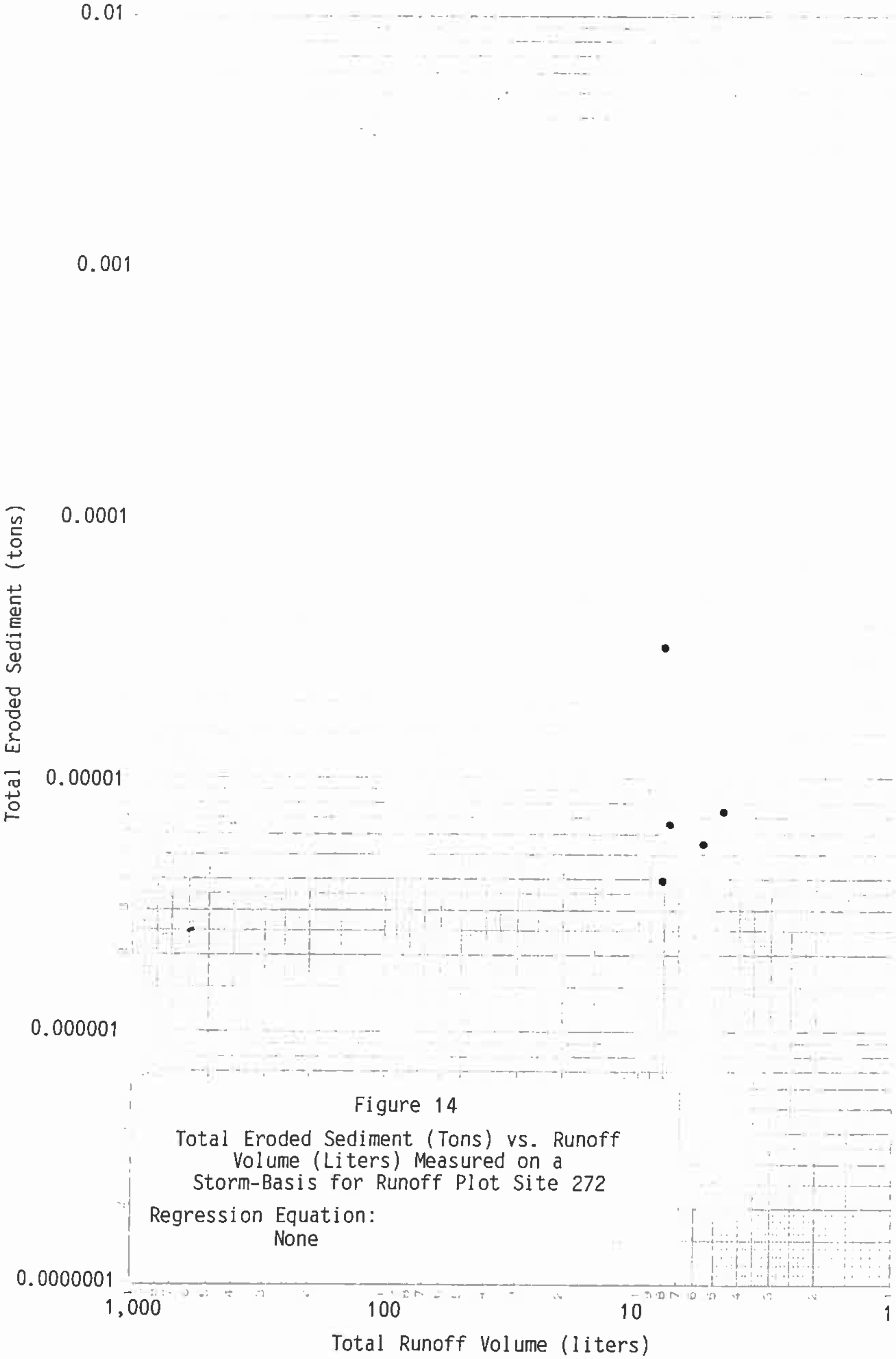


Figure 14

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 272

Regression Equation:
None

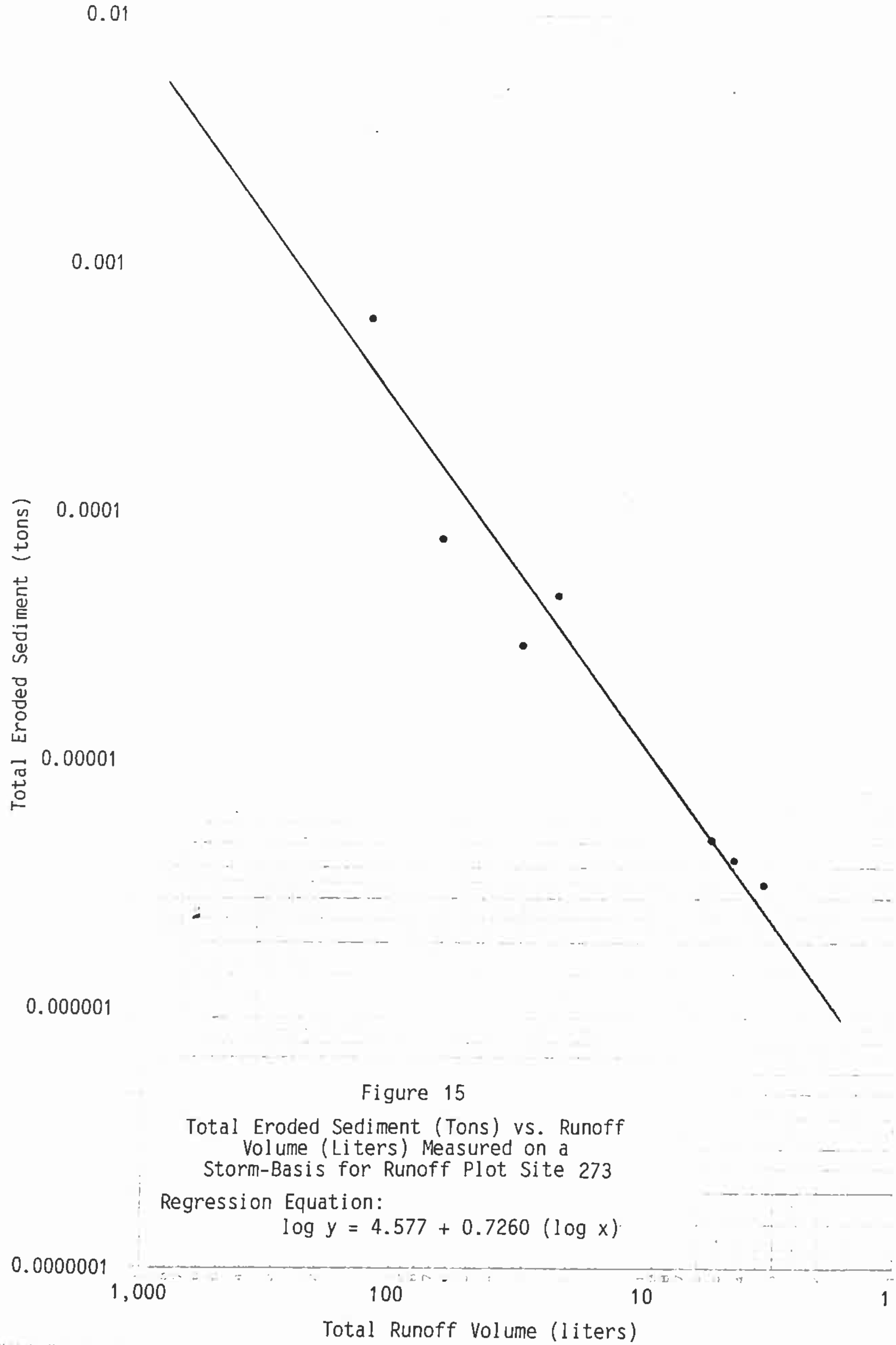


Figure 15

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 273

Regression Equation:

$$\log y = 4.577 + 0.7260 (\log x)$$

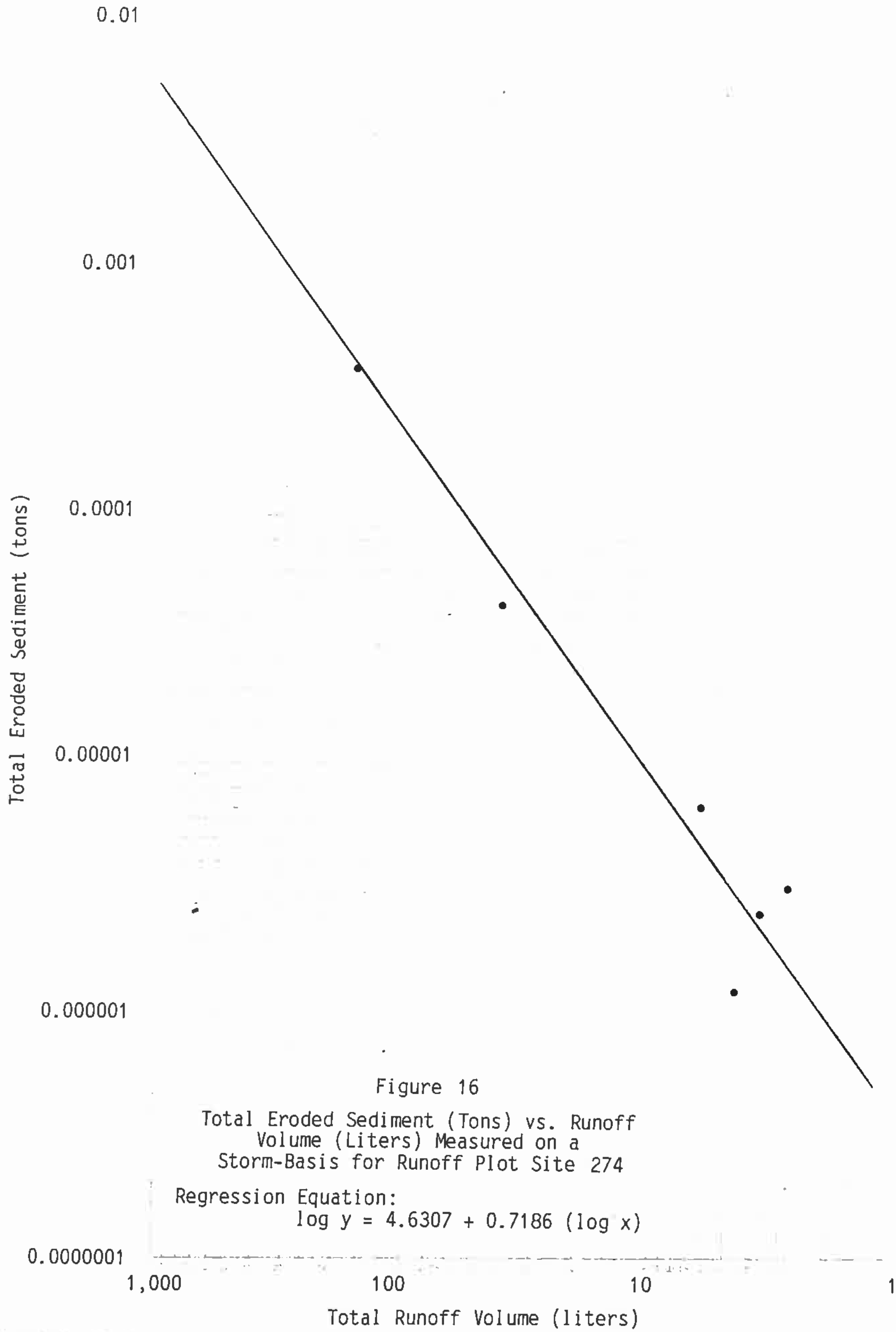


Figure 16

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 274

Regression Equation:

$$\log y = 4.6307 + 0.7186 (\log x)$$

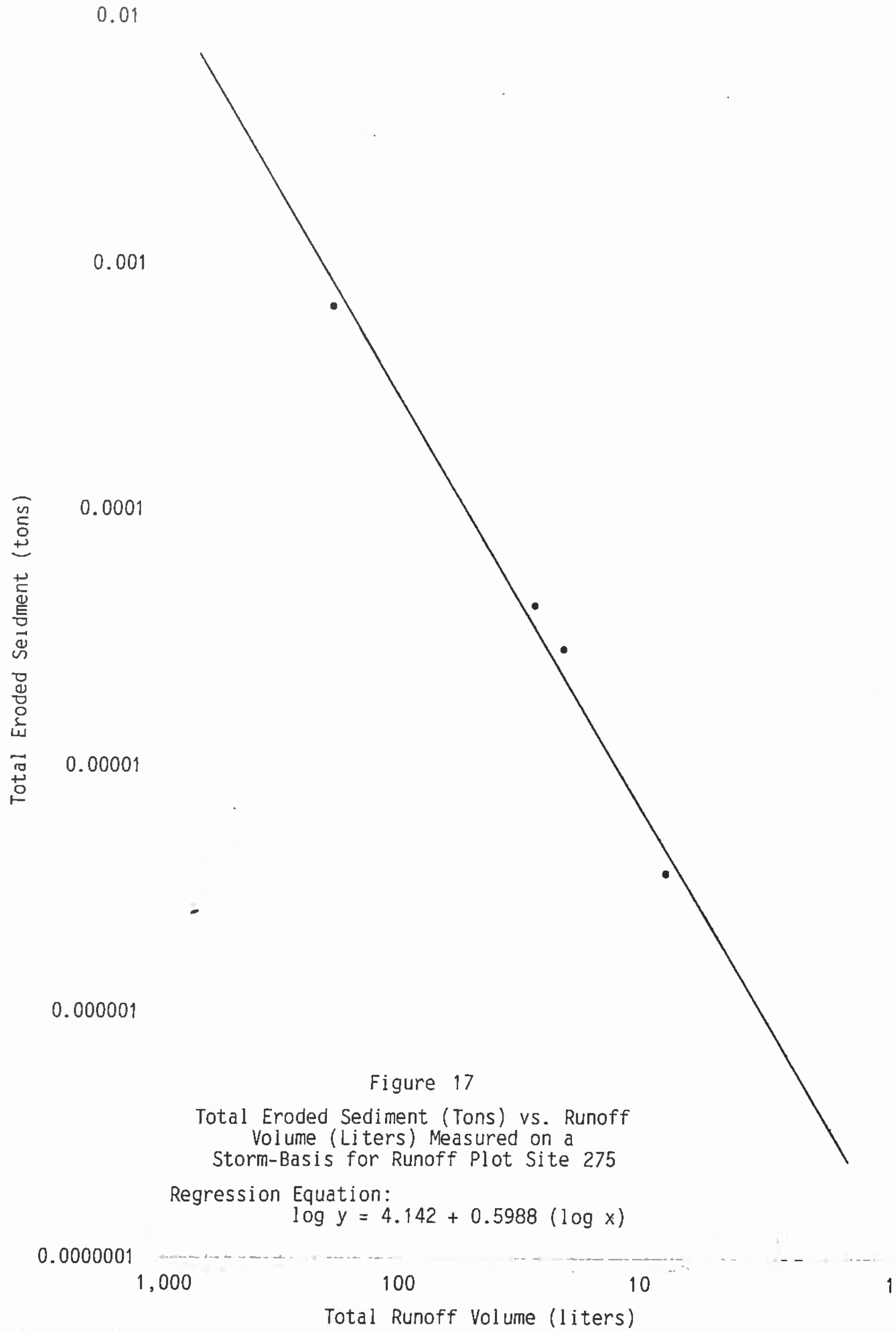


Figure 17

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 275

Regression Equation:

$$\log y = 4.142 + 0.5988 (\log x)$$

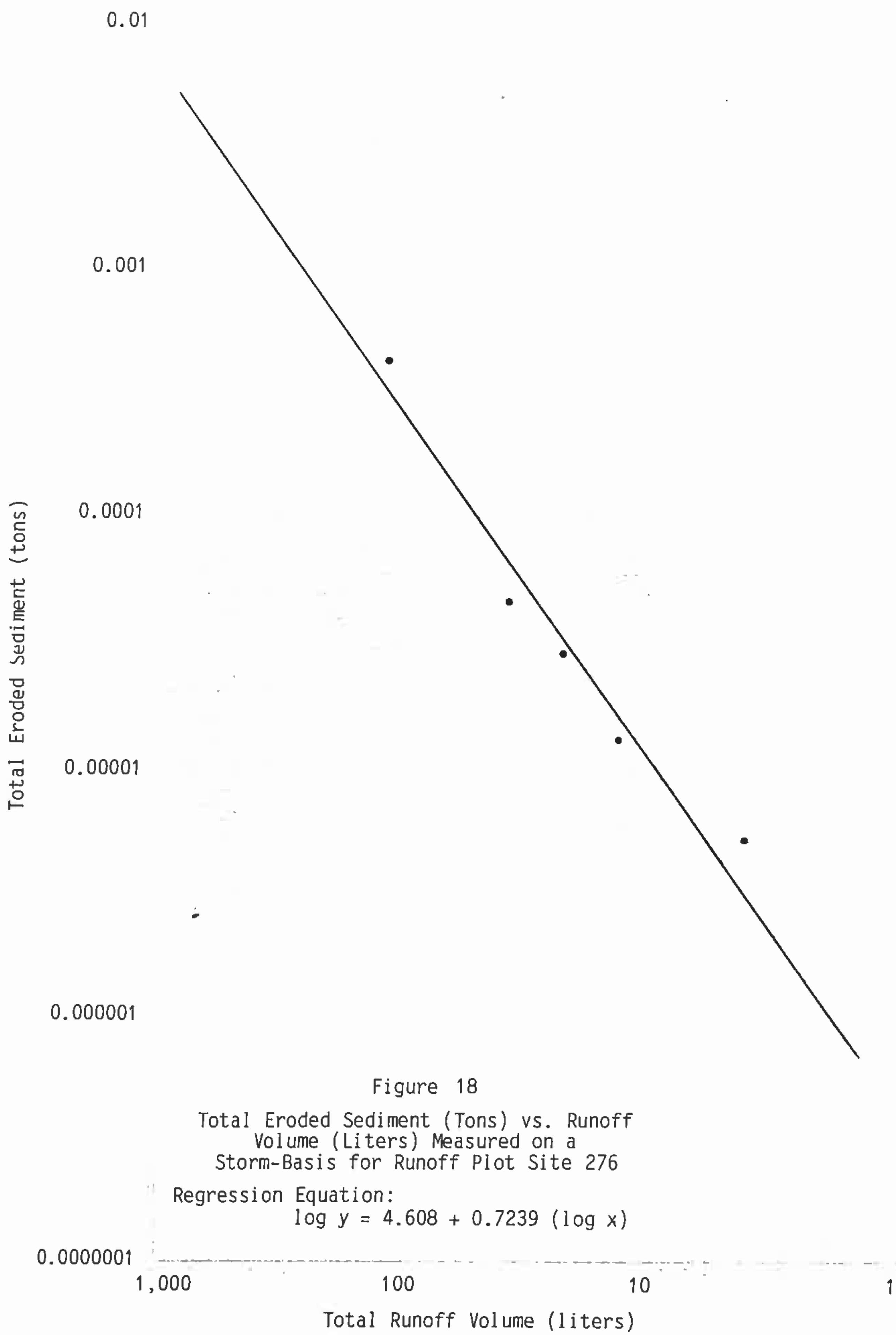


Figure 18

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 276

Regression Equation:

$$\log y = 4.608 + 0.7239 (\log x)$$

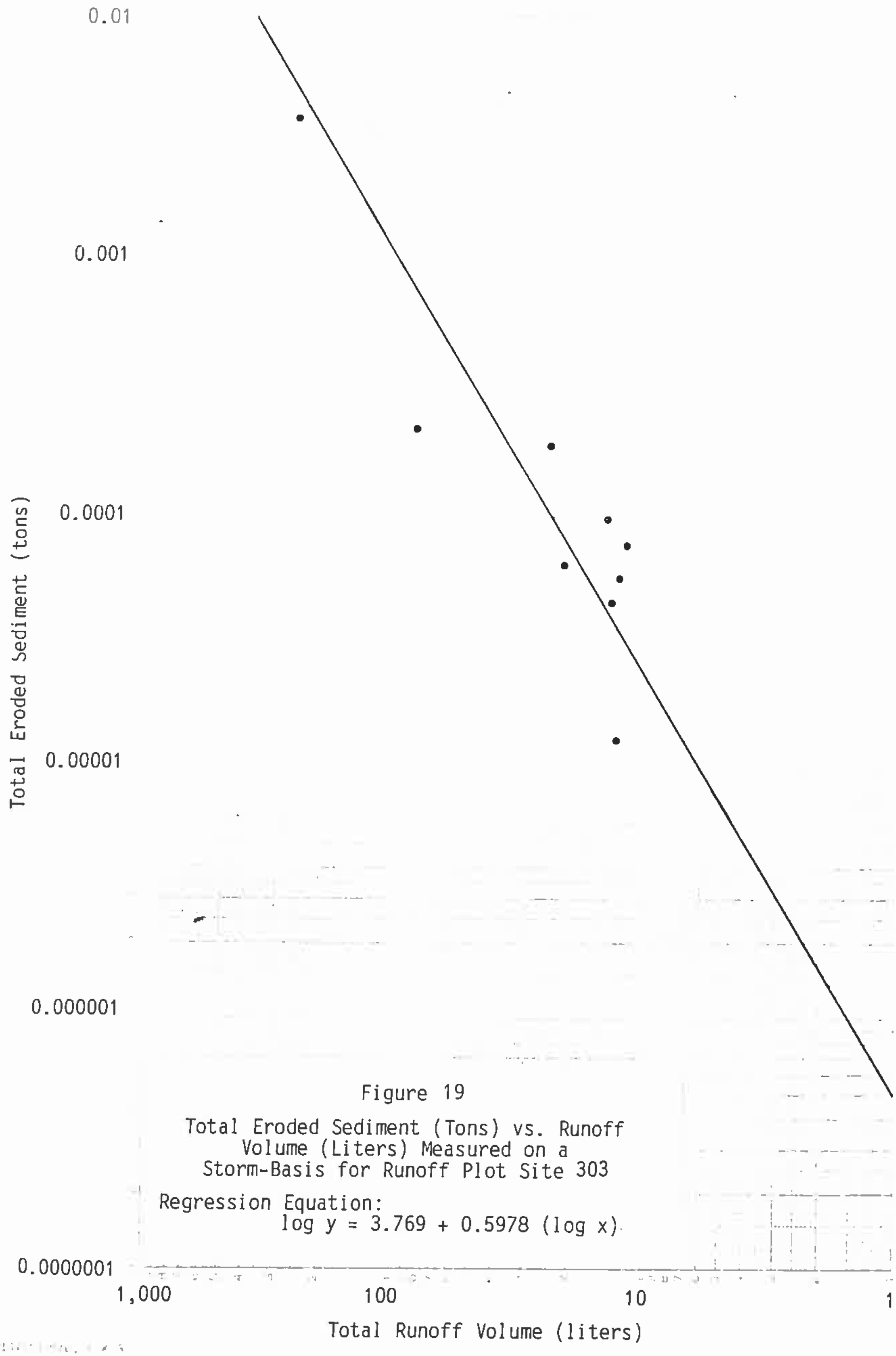


Figure 19

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 303

Regression Equation:

$$\log y = 3.769 + 0.5978 (\log x)$$

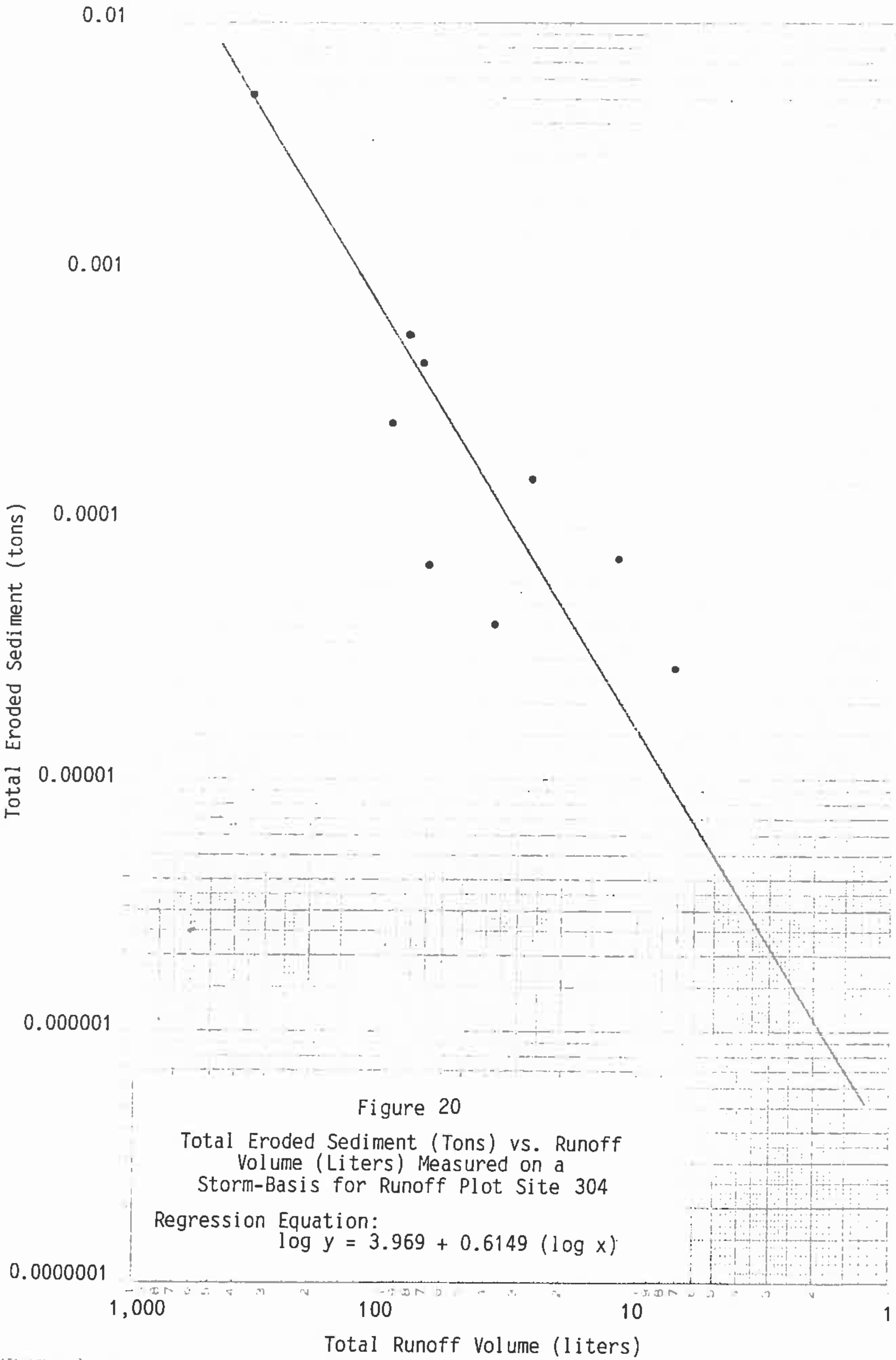


Figure 20

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 304

Regression Equation:

$$\log y = 3.969 + 0.6149 (\log x)$$

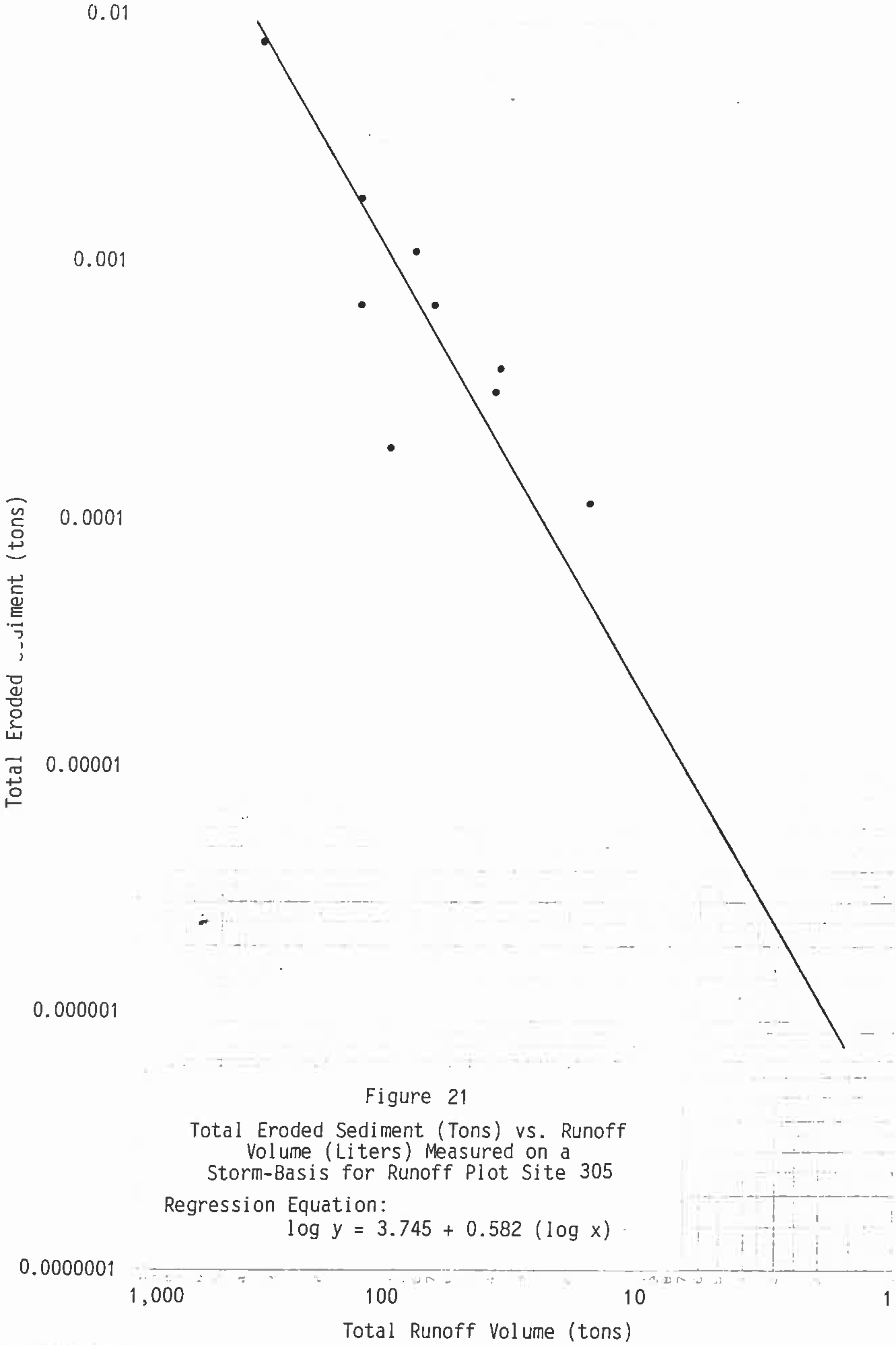


Figure 21

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 305

Regression Equation:

$$\log y = 3.745 + 0.582 (\log x)$$

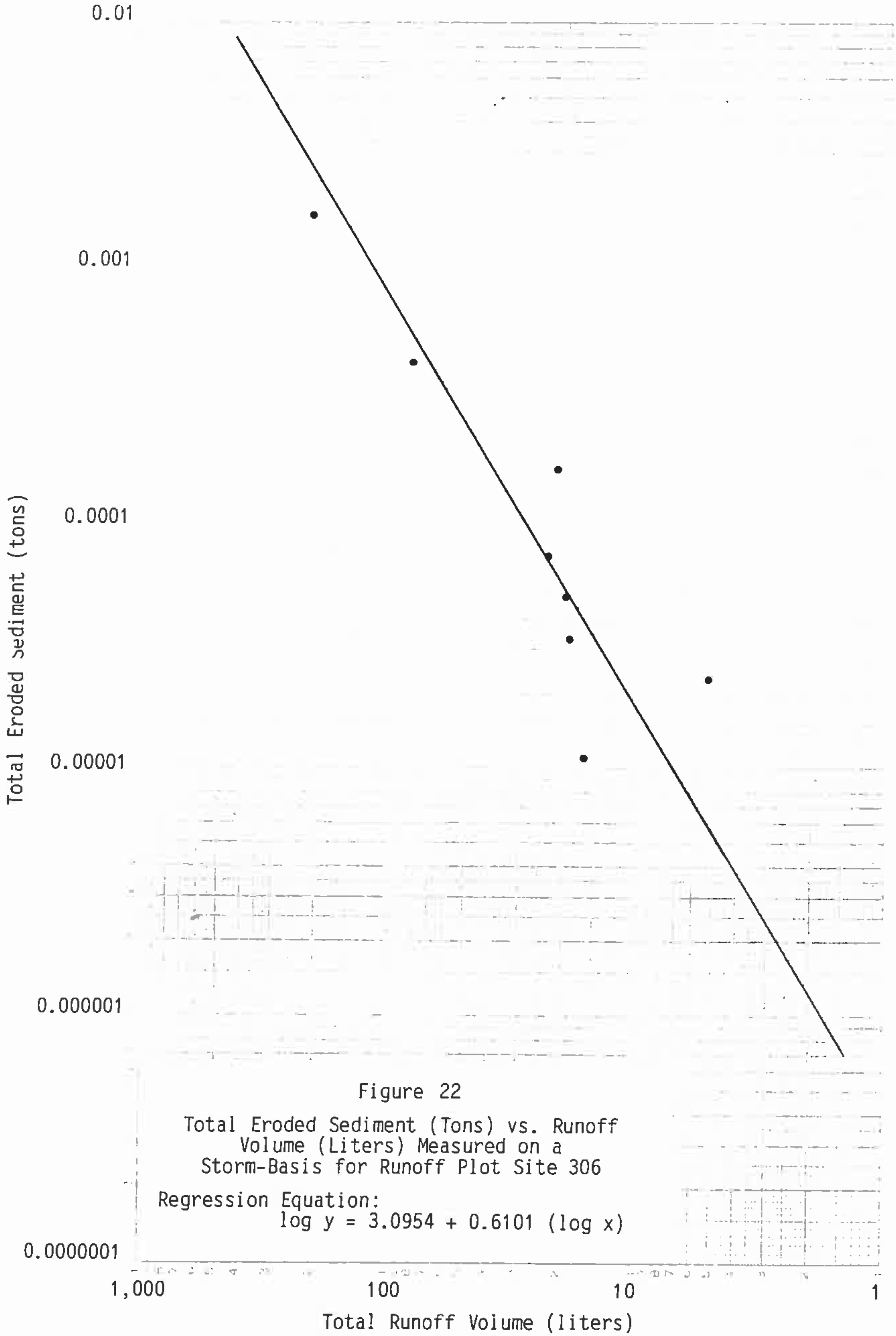


Figure 22

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 306

Regression Equation:

$$\log y = 3.0954 + 0.6101 (\log x)$$

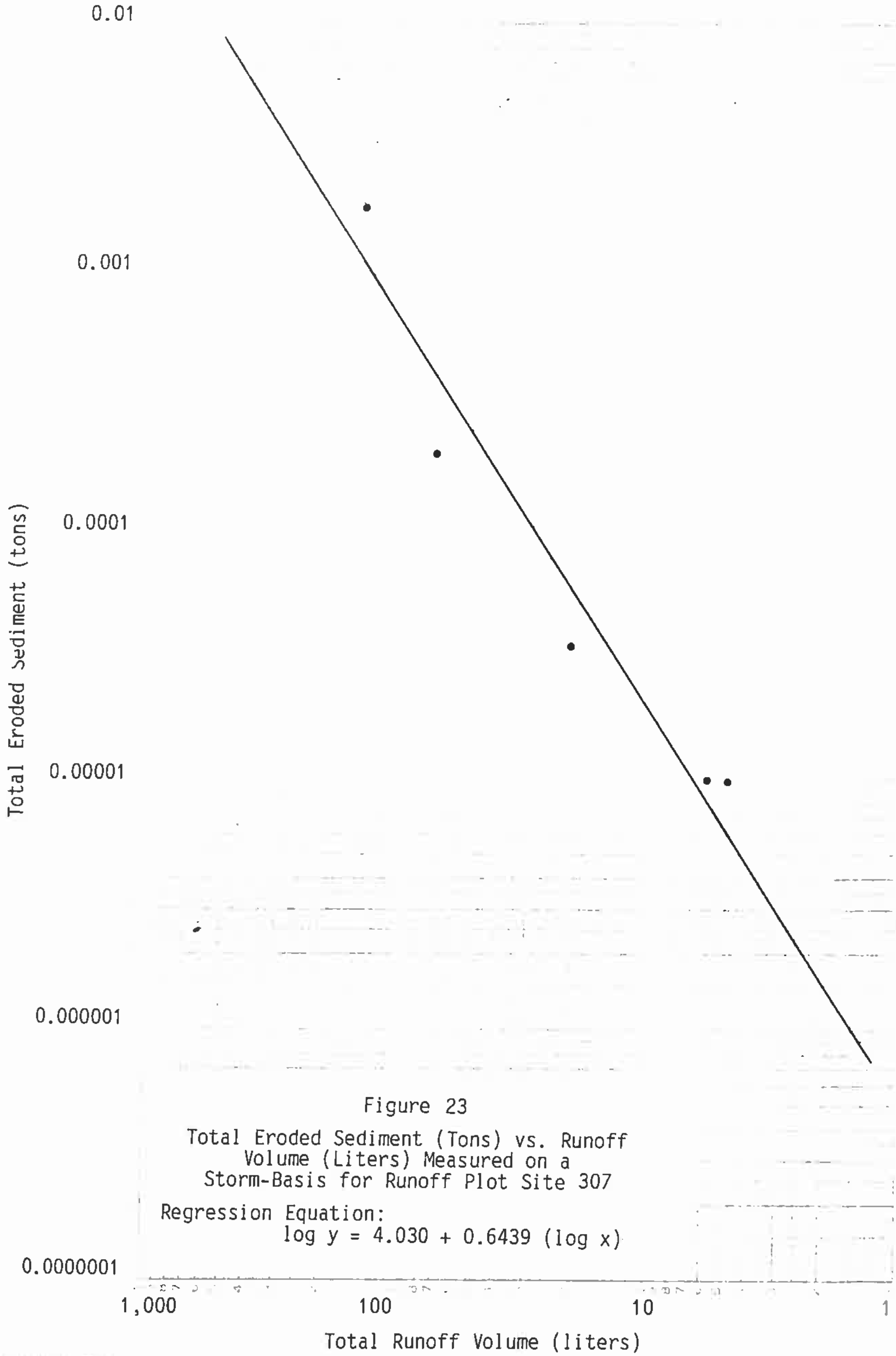


Figure 23

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 307

Regression Equation:

$$\log y = 4.030 + 0.6439 (\log x)$$

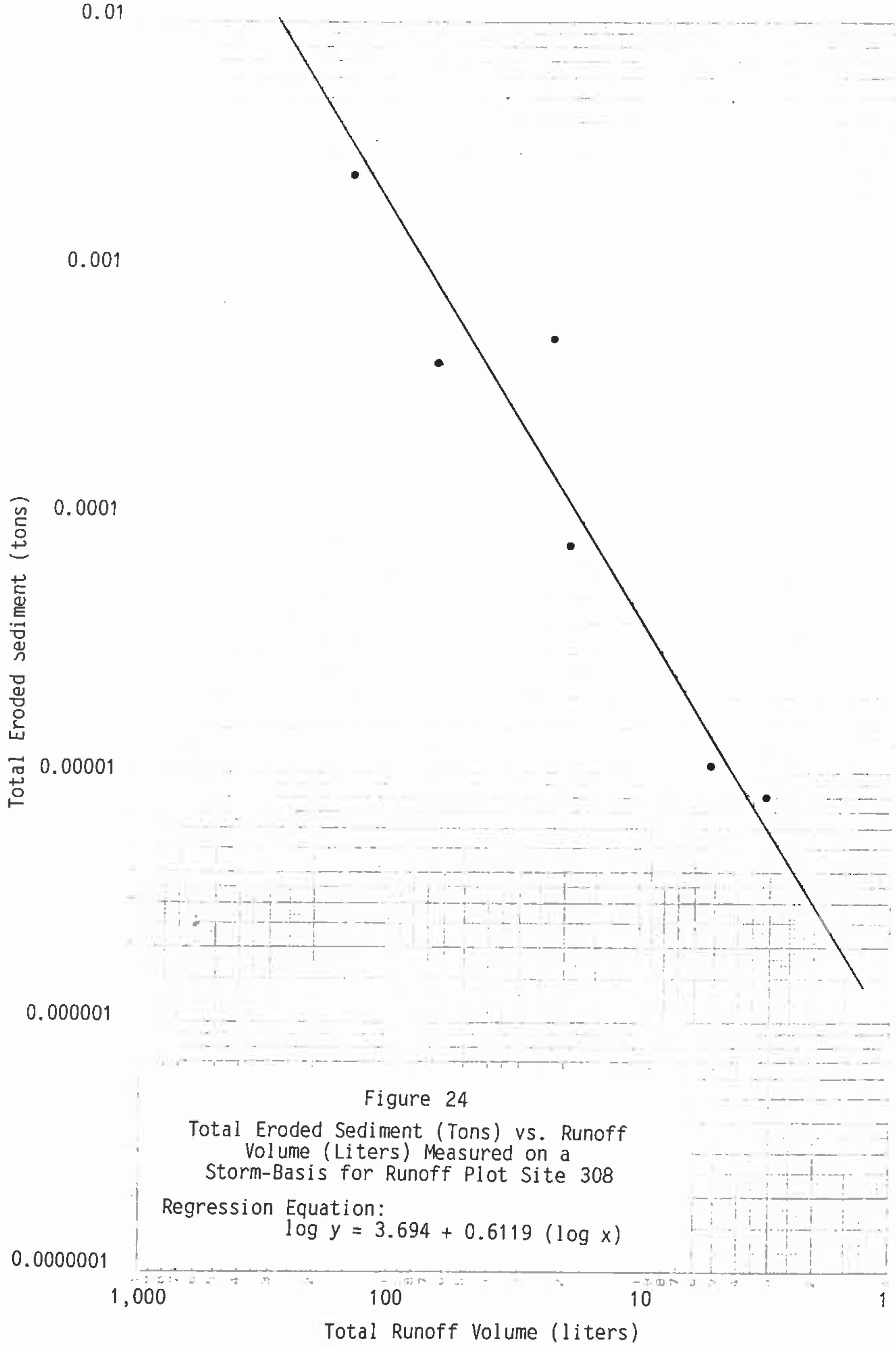


Figure 24

Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for Runoff Plot Site 308

Regression Equation:

$$\log y = 3.694 + 0.6119 (\log x)$$

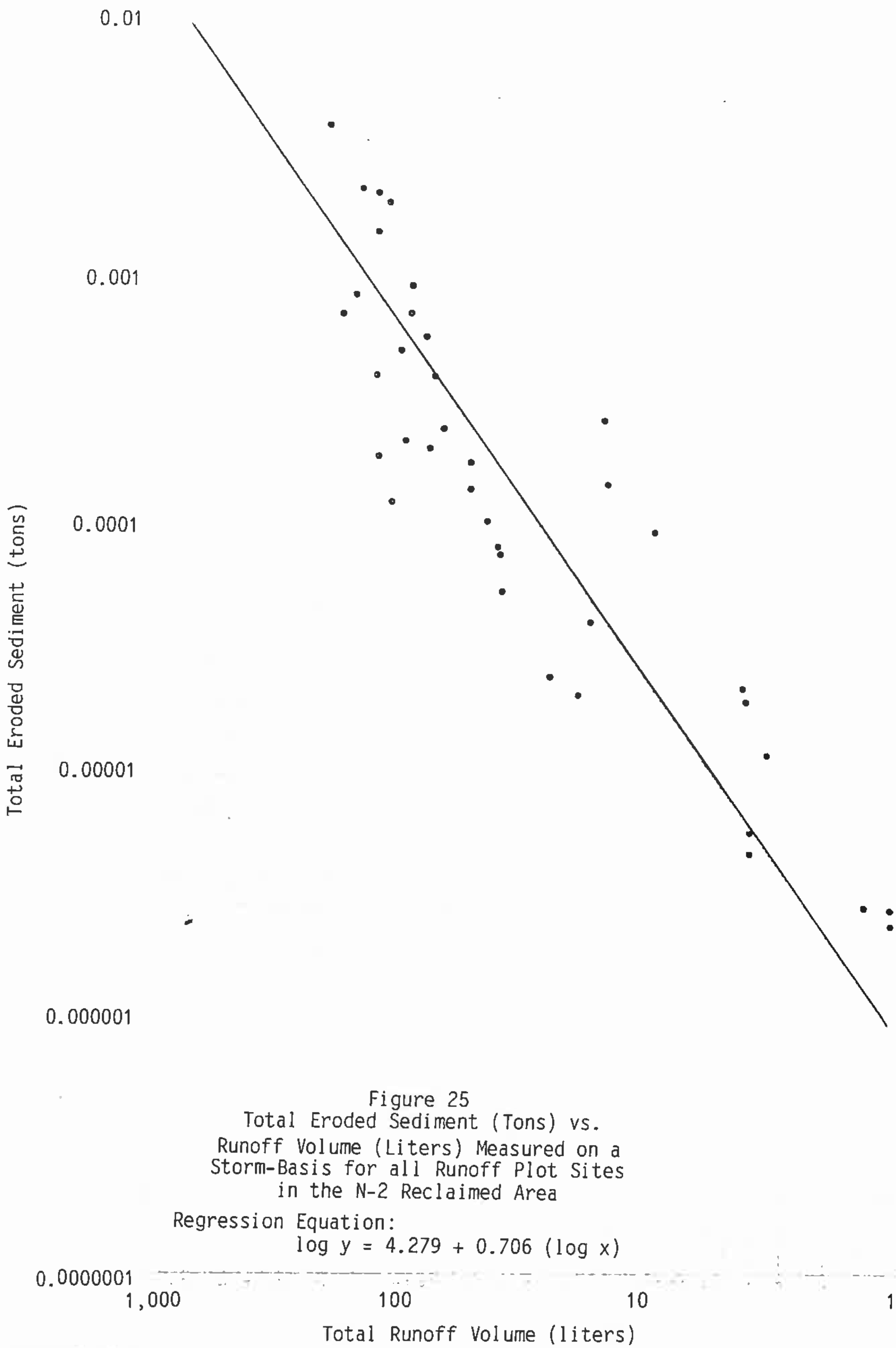


Figure 25
Total Eroded Sediment (Tons) vs.
Runoff Volume (Liters) Measured on a
Storm-Basis for all Runoff Plot Sites
in the N-2 Reclaimed Area

Regression Equation:

$$\log y = 4.279 + 0.706 (\log x)$$

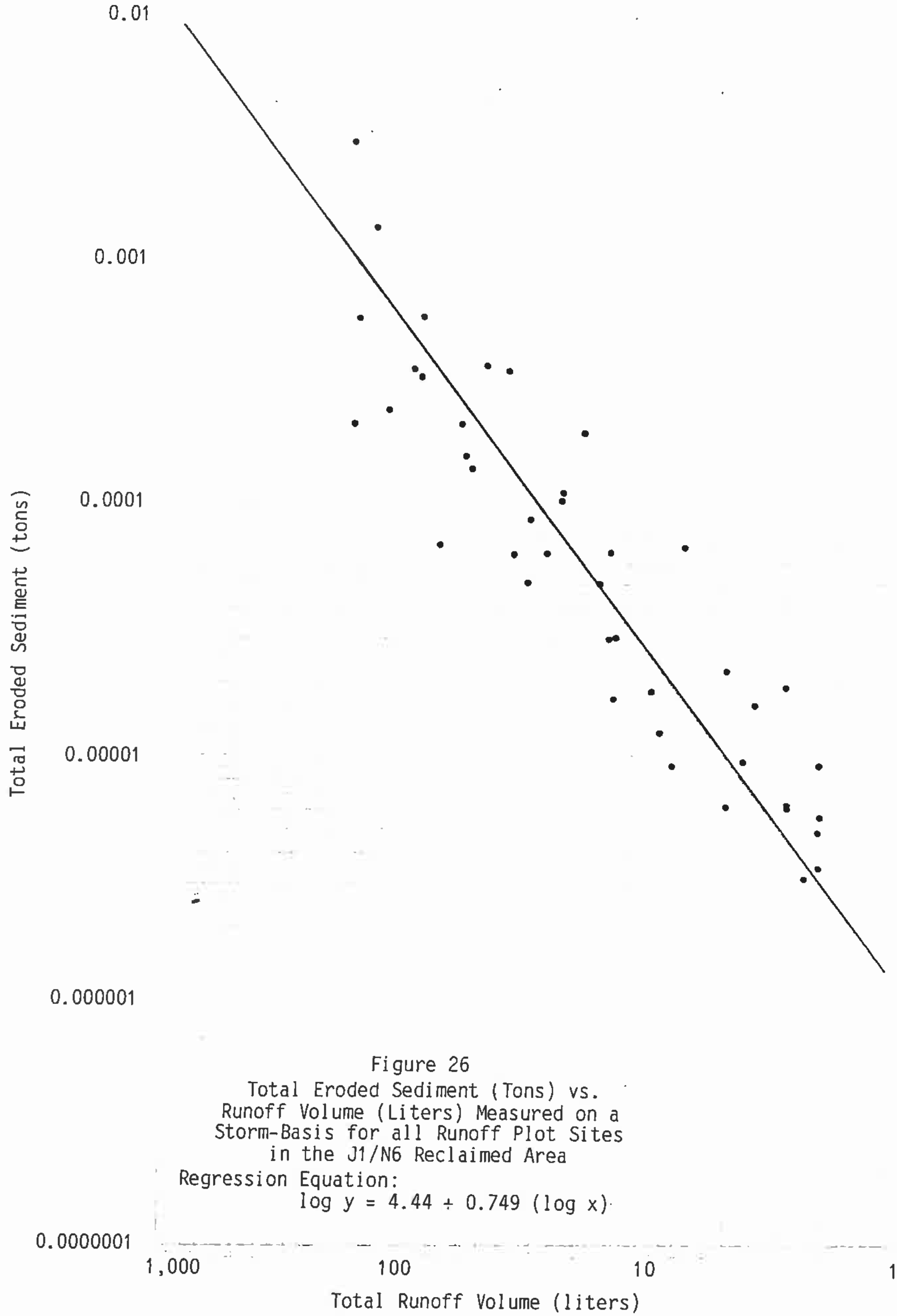


Figure 26
Total Eroded Sediment (Tons) vs.
Runoff Volume (Liters) Measured on a
Storm-Basis for all Runoff Plot Sites
in the J1/N6 Reclaimed Area

Regression Equation:

$$\log y = 4.44 + 0.749 (\log x)$$

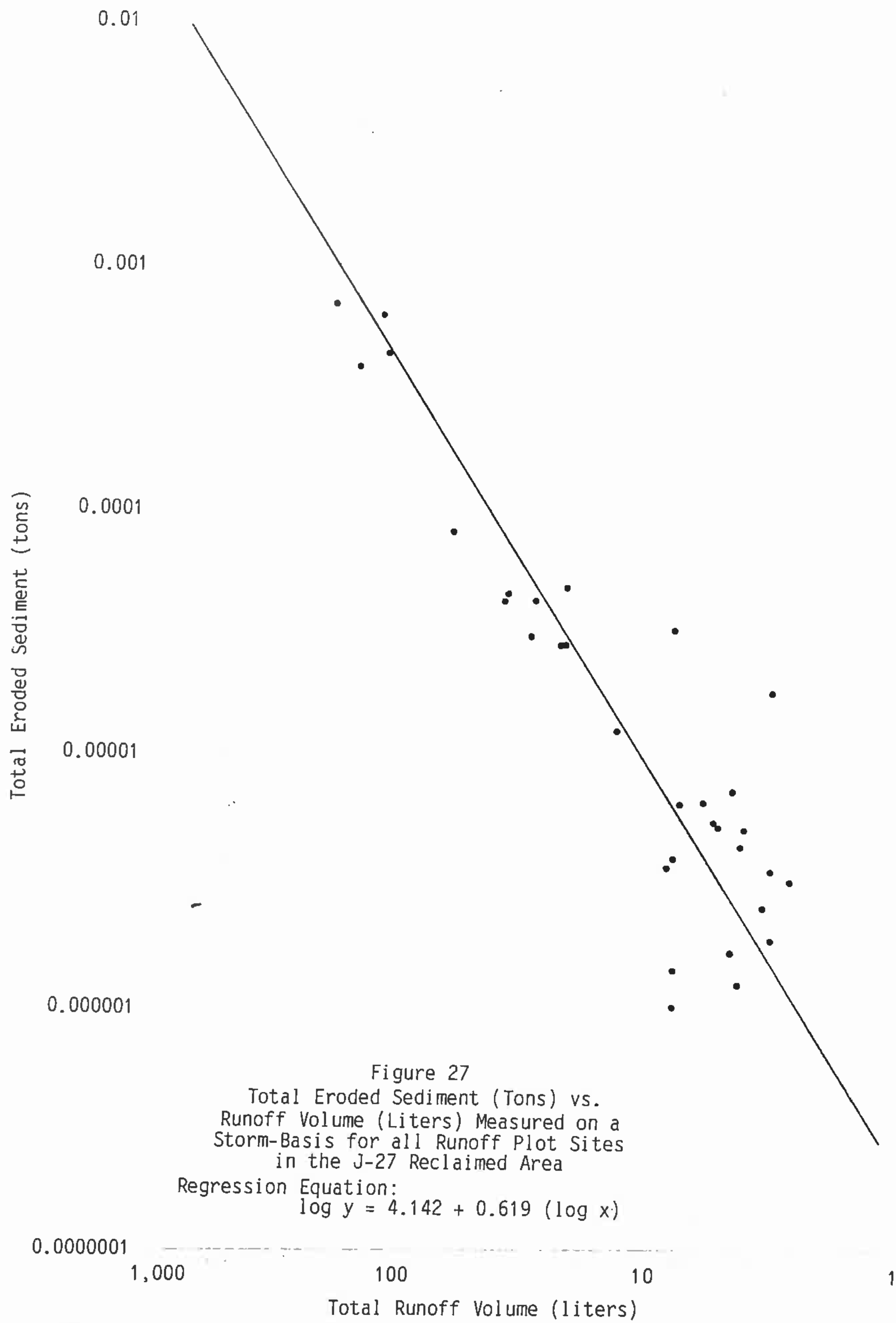


Figure 27
Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) Measured on a Storm-Basis for all Runoff Plot Sites in the J-27 Reclaimed Area

Regression Equation:

$$\log y = 4.142 + 0.619 (\log x)$$

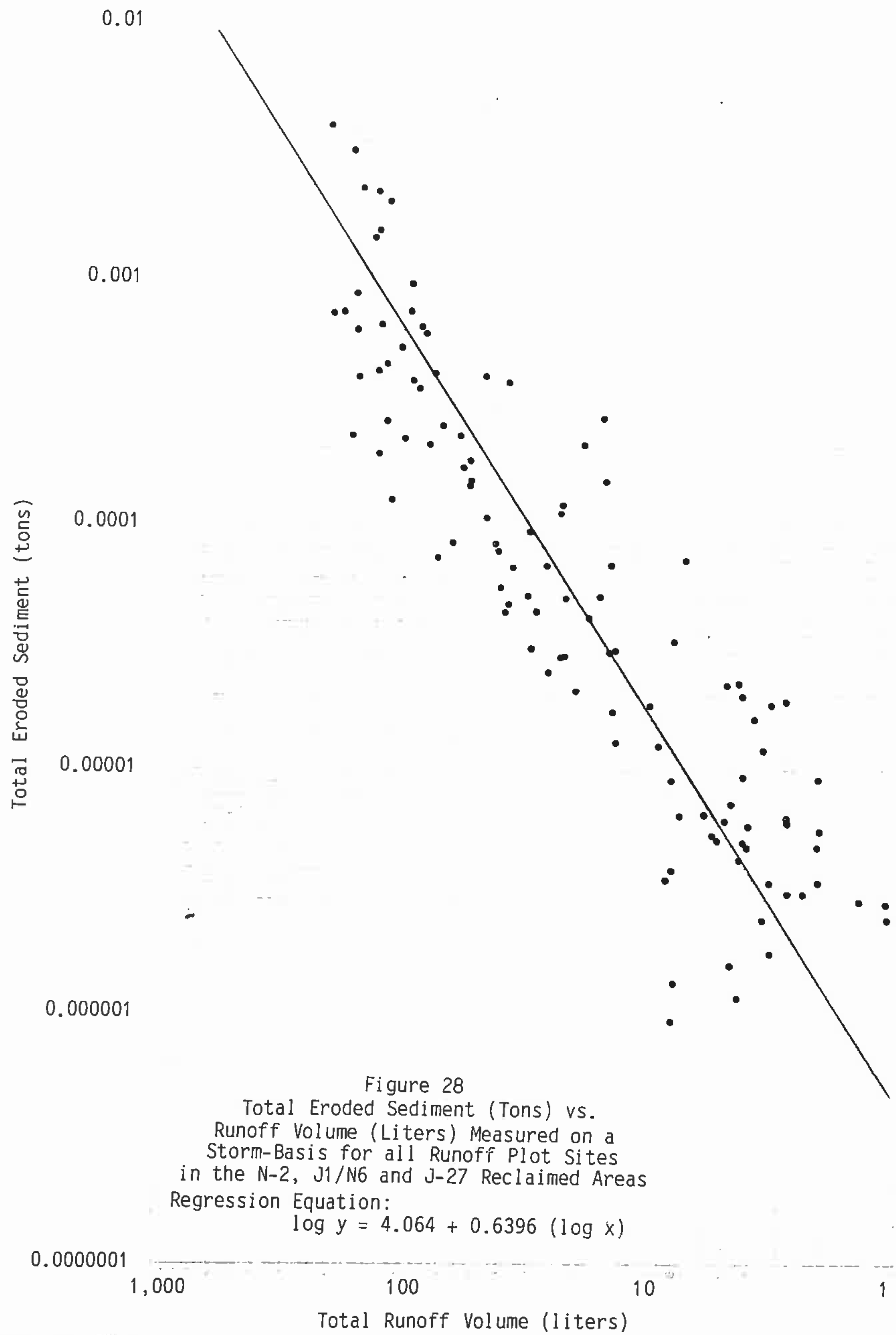


Figure 28
Total Eroded Sediment (Tons) vs.
Runoff Volume (Liters) Measured on a
Storm-Basis for all Runoff Plot Sites
in the N-2, J1/N6 and J-27 Reclaimed Areas

Regression Equation:

$$\log y = 4.064 + 0.6396 (\log x)$$

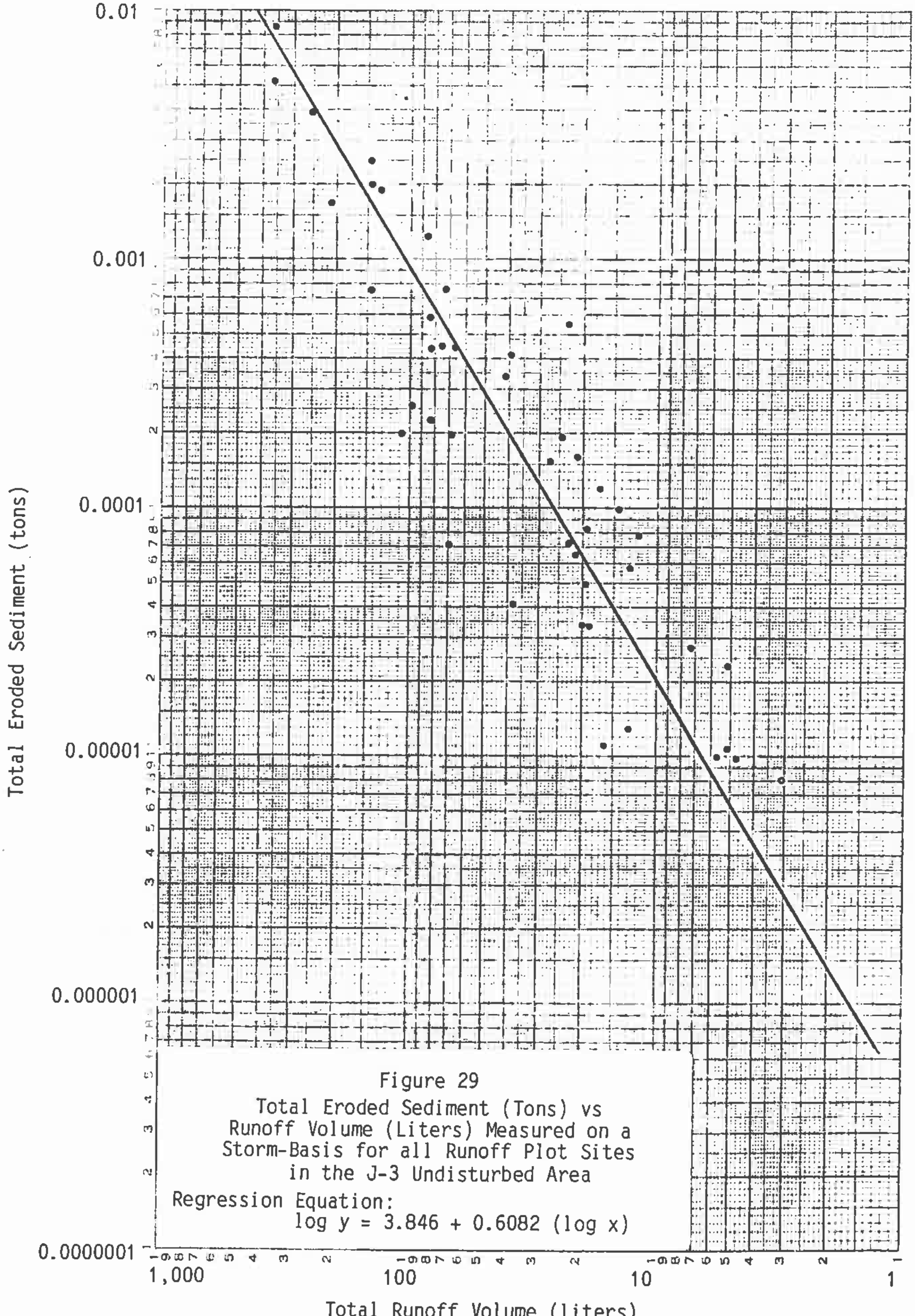


Figure 29
Total Eroded Sediment (Tons) vs Runoff Volume (Liters) Measured on a Storm-Basis for all Runoff Plot Sites in the J-3 Undisturbed Area

Regression Equation:
$\log y = 3.846 + 0.6082 (\log x)$

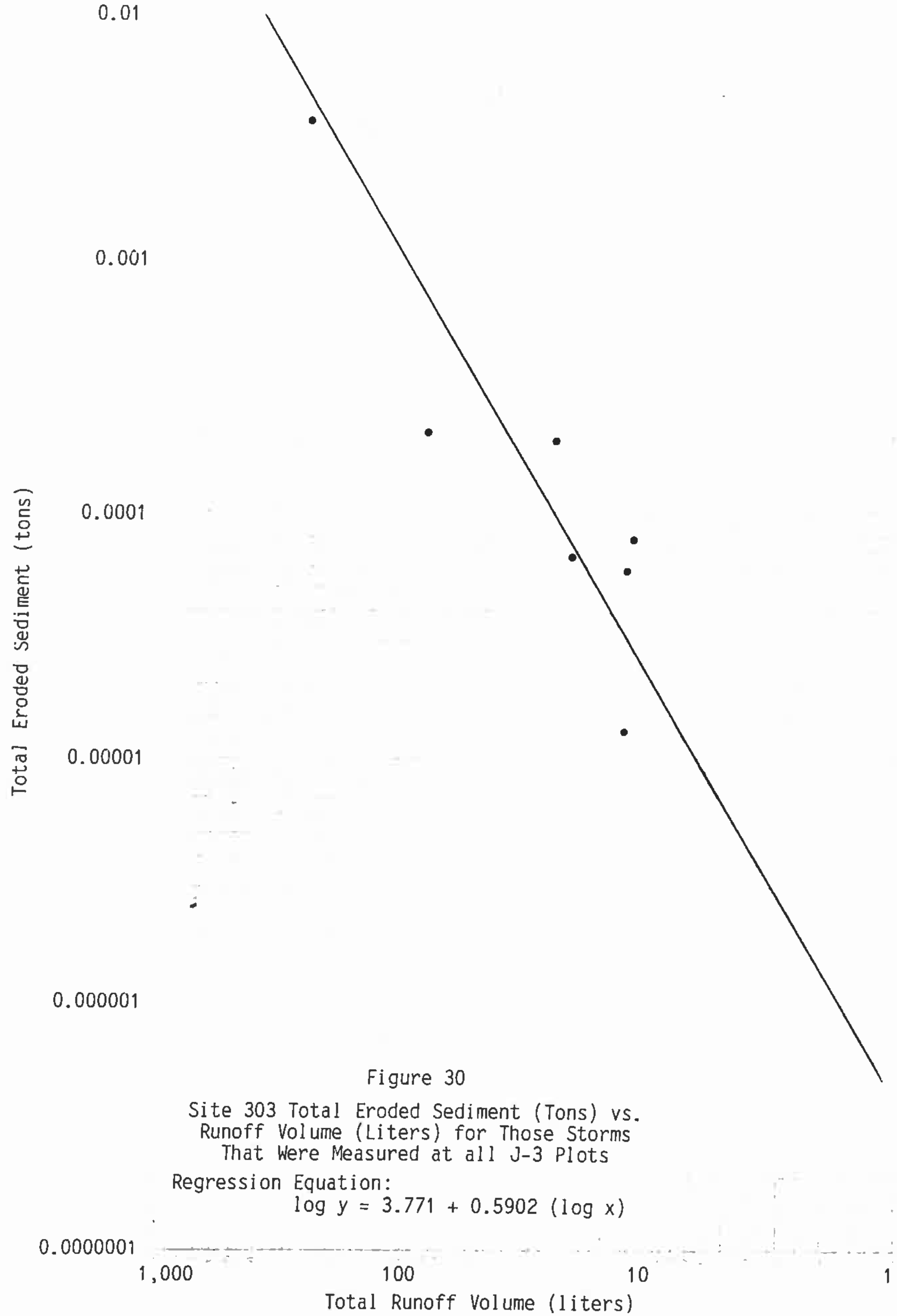
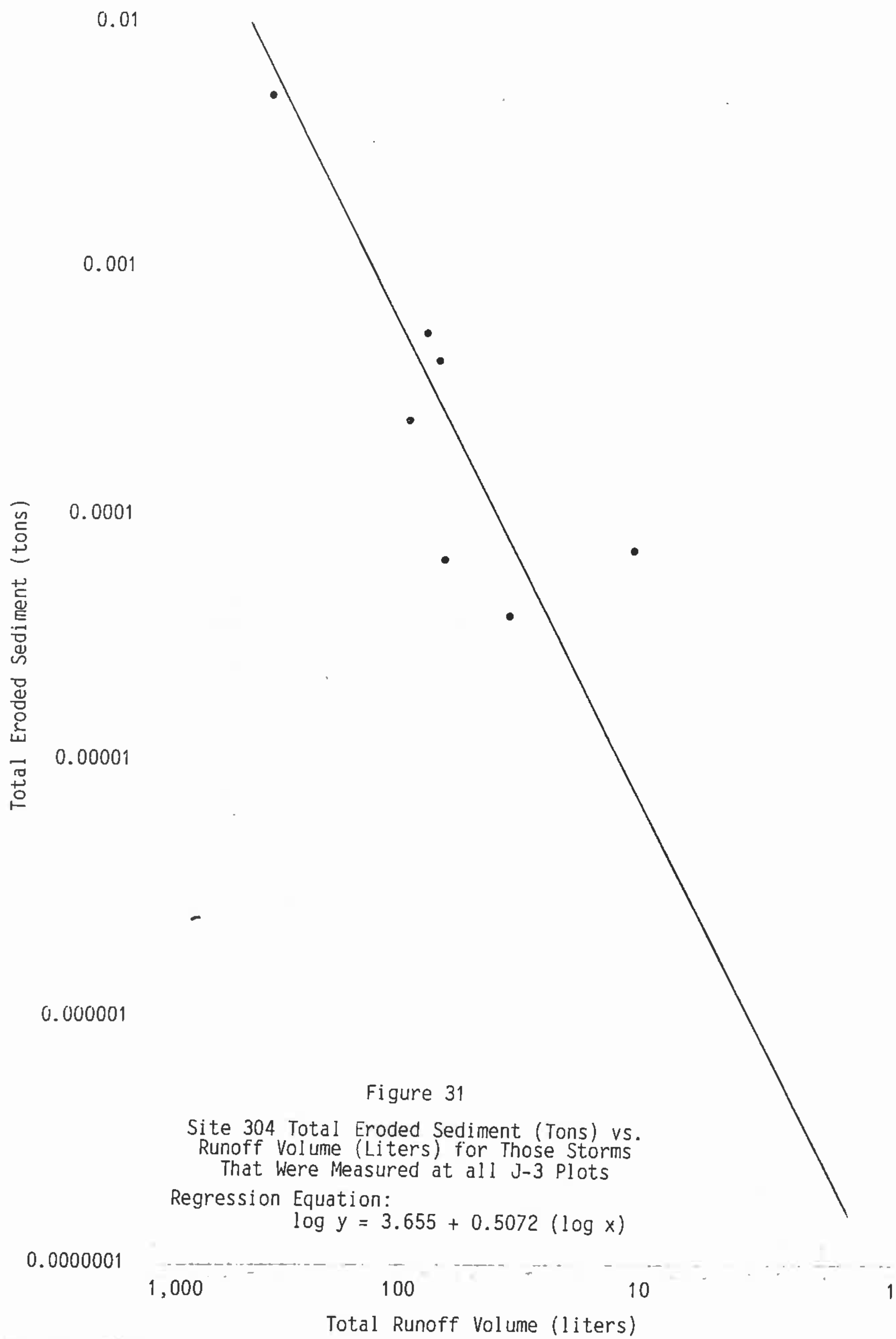


Figure 30

Site 303 Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) for Those Storms That Were Measured at all J-3 Plots

Regression Equation:

$$\log y = 3.771 + 0.5902 (\log x)$$


0.01
0.001
0.0001
0.00001
0.000001
0.0000001
Total Eroded Sediment (tons)
1,000
100
10
1
Total Runoff Volume (liters)
Figure 31
Site 304 Total Eroded Sediment (Tons) vs.
Runoff Volume (Liters) for Those Storms
That Were Measured at all J-3 Plots
Regression Equation:
log y = 3.655 + 0.5072 (log x)

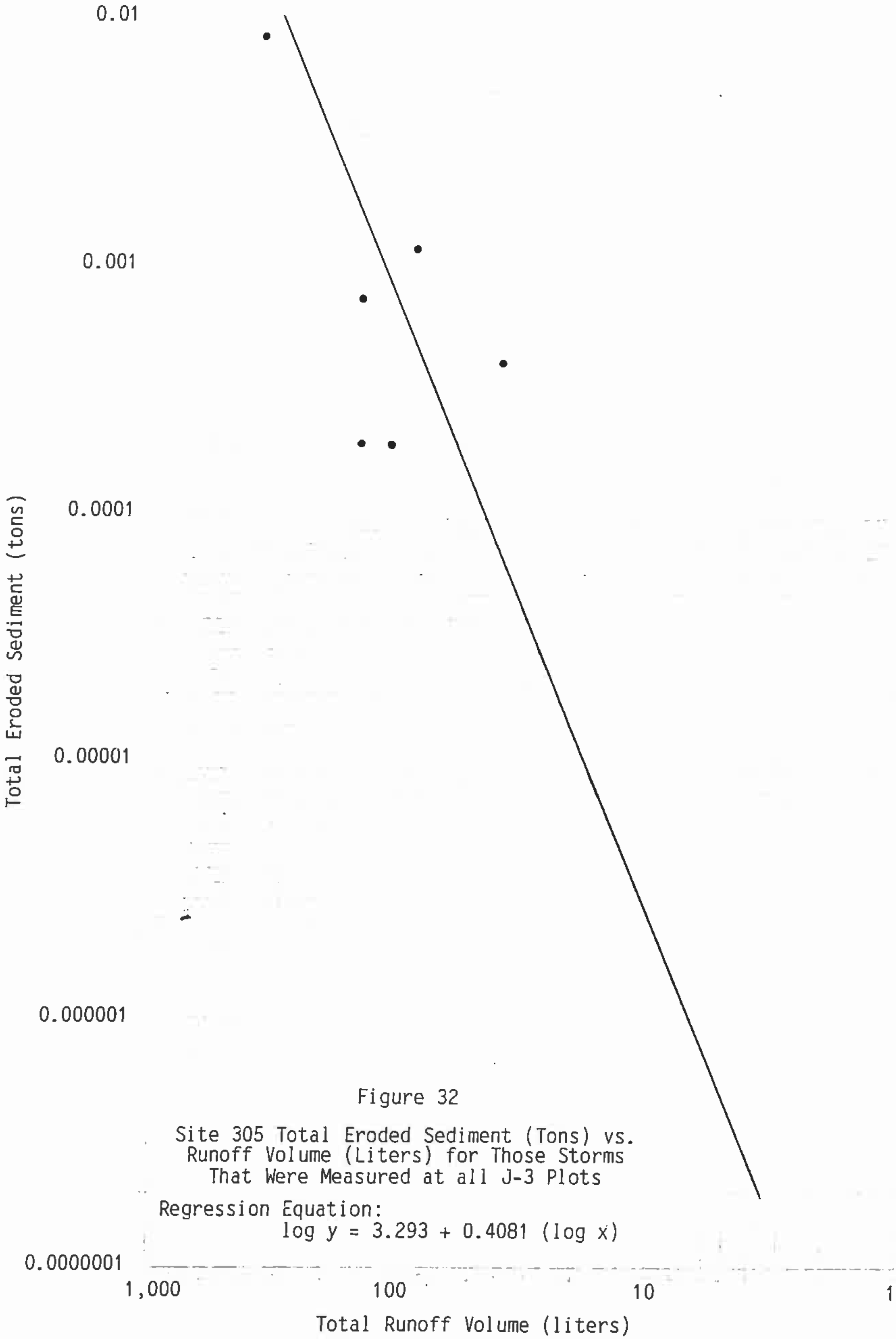


Figure 32

Site 305 Total Eroded Sediment (Tons) vs. Runoff Volume (Liters) for Those Storms That Were Measured at all J-3 Plots

Regression Equation:

$$\log y = 3.293 + 0.4081 (\log x)$$

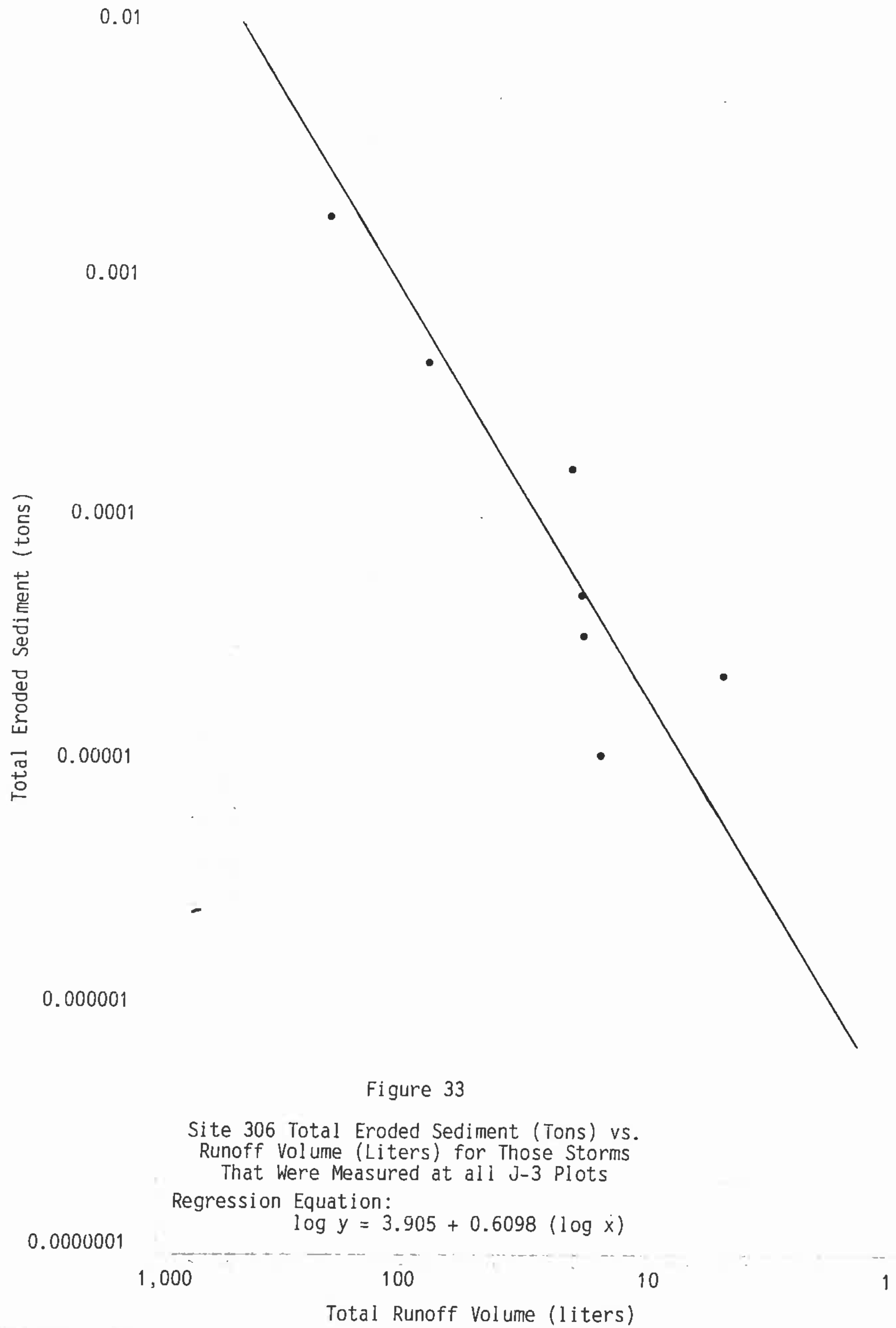


Figure 33

Site 306 Total Eroded Sediment (Tons) vs.
Runoff Volume (Liters) for Those Storms
That Were Measured at all J-3 Plots

Regression Equation:

$$\log y = 3.905 + 0.6098 (\log x)$$

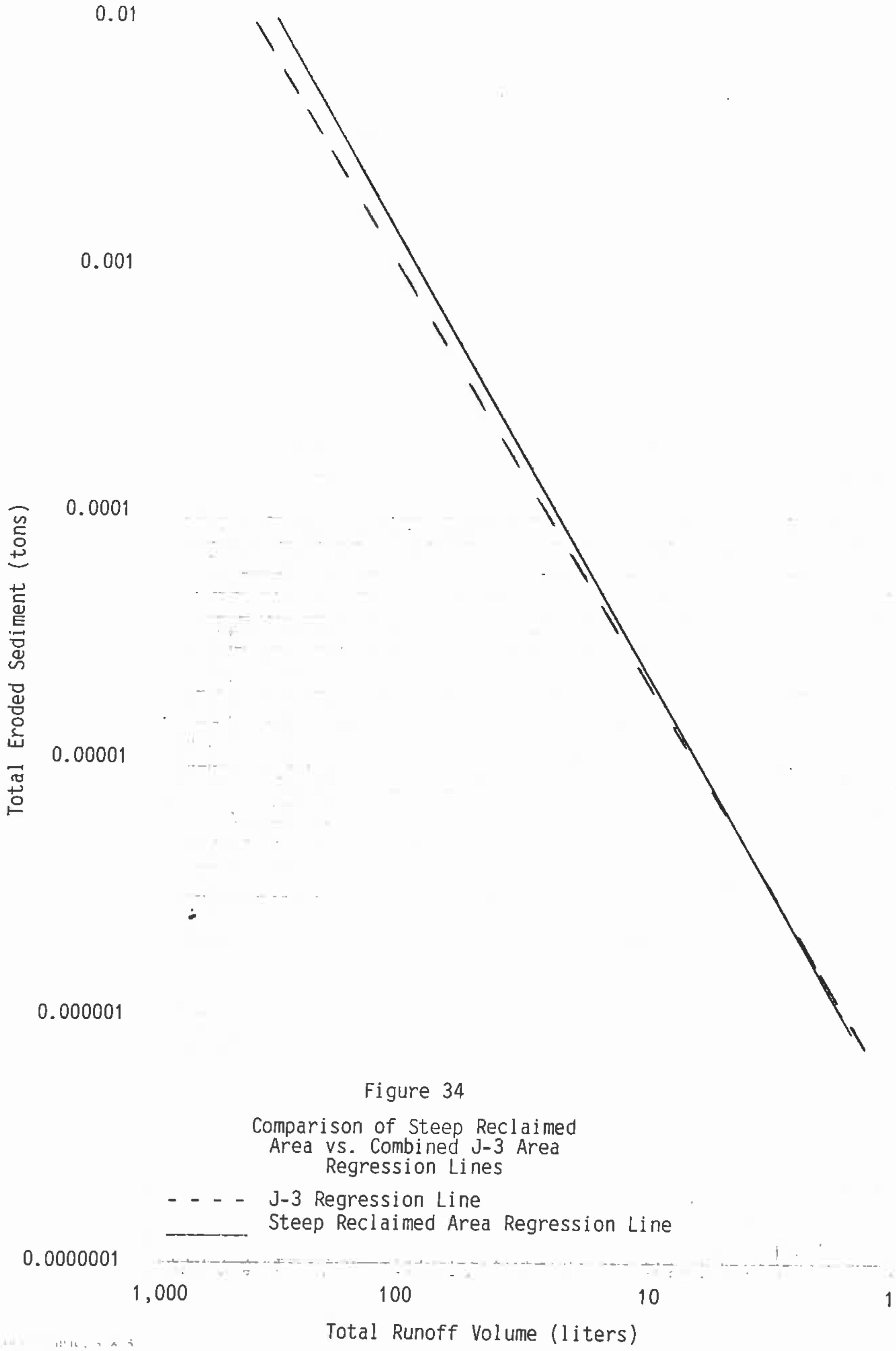


Figure 34

Comparison of Steep Reclaimed Area vs. Combined J-3 Area Regression Lines

ATTACHMENT E

J-16 WHITE GRASS HILLS DRAINAGE PLAN

INCLUDING TERRACES & DOWNDRAINS

PERMIT REVISION

Revised 07/22/2003

J16 WHITEGRASS HILLS
SLOPE DESIGN
WATERSHED I

APPROVED JUN 2003

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	2.790	2.790	4.11	0.20

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	2.790	0.044	0.000	0.000	81.000	F	4.11	0.203
	Σ	**2.790**						**4.11**	**0.203**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	5.11	55.00	1,076.00	6.780	0.044
#1	**1**	**Time of Concentration:**					**0.044**

J16 WHITEGRASS HILLS SLOPE DESIGN WATERSHED II

APPROVED JUN 2003

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

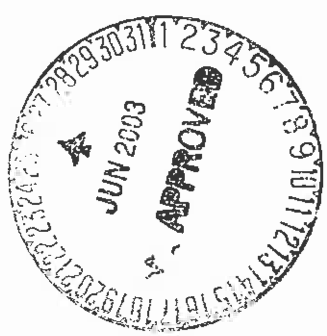
General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	2.410	2.410	3.55	0.18



Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	2.410	0.029	0.000	0.000	81.000	F	3.55	0.175
	Σ	**2.410**						**3.55**	**0.175**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	7.35	63.00	857.00	8.130	0.029
#1	**1**	**Time of Concentration:**					**0.029**

J16 WHITEGRASS HILLS

SLOPE DESIGN

WATERSHED III

APPROVED
JUN 2003

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	2.740	2.740	4.04	0.20

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	2.740	0.021	0.000	0.000	81.000	F	4.04	0.199
	Σ	**2.740**						**4.04**	**0.199**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	10.38	76.30	735.00	9.660	0.021
#1	**1**	**Time of Concentration:**					**0.021**

J16 WHITEGRASS HILLS
SLOPE DESIGN
WATERSHED I-IV

APPROVED
JUN 2003

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	10.940	10.940	16.12	0.79

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	10.940	0.030	0.000	0.000	81.000	F	16.12	0.795
	Σ	**10.940**						**16.12**	**0.795**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	17.52	239.30	1,366.00	12.550	0.030
#1	**1**	**Time of Concentration:**					**0.030**

J16 WHITEGRASS HILLS
SLOPE DESIGN
WATERSHED V

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	0.910	0.910	1.34	0.07

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	0.910	0.014	0.000	0.000	81.000	F	1.34	0.066
	Σ	**0.910**						**1.34**	**0.066**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	10.18	50.00	491.00	9.570	0.014
#1	**1**	**Time of Concentration:**					**0.014**

J16 WHITEGRASS HILLS
SLOPE DESIGN
WATERSHED VI

APPROVED
JUN 2003

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	0.450	0.450	0.66	0.03

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	0.450	0.007	0.000	0.000	81.000	F	0.66	0.033
	Σ	**0.450**						**0.66**	**0.033**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	14.17	42.50	300.00	11.290	0.007
#1	**1**	**Time of Concentration:**					**0.007**

J16 WHITEGRASS HILLS
SLOPE DESIGN
WATERSHED V-VI

Gary Altsisi

Peabody Western Coal
P.O. Box 650
Kayenta, AZ 86033

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	100 yr - 6 hr
Rainfall Depth:	2.400 Inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	1.360	1.360	2.00	0.10

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	1.360	0.014	0.000	0.000	81.000	F	2.00	0.099
	Σ	**1.360**						**2.00**	**0.099**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	8. Large gullies, diversions, and low flowing streams	15.42	92.50	600.00	11.770	0.014
#1	**1**	**Time of Concentration:**					**0.014**

OUTFLOW CHANNEL DESIGN - WATERSHED I-IV

Material: Riprap

Triangular Channel

Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)
3.0:1	3.0:1	33.3	1.00		

PADER Method - Steep Slope Design

	w/o Freeboard	w/ Freeboard
Design Discharge:	16.12 cfs	
Depth:	0.80 ft	1.80 ft
Top Width:	4.78 ft	10.78 ft
Velocity:	8.48 fps	
X-Section Area:	1.90 sq ft	
Hydraulic Radius:	0.378	
Froude Number:	2.37	
Manning's n:	0.0530	
Dmin:	3.00 in	
D50:	6.00 in	
Dmax:	9.00 in	

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OUTFLOW CHANNEL DESIGN - WATERSHED V-VI

Material: Coarse gravel noncolloidal

Triangular Channel

Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Manning's n	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
3.0:1	3.0:1	33.3	0.0250	1.00			9.0

	w/o Freeboard	w/ Freeboard
Design Discharge:	2.00 cfs	
Depth:	0.28 ft	1.28 ft
Top Width:	1.65 ft	7.65 ft
Velocity:	8.86 fps	
X-Section Area:	0.23 sq ft	
Hydraulic Radius:	0.131	
Froude Number:	4.21	

TYPICAL V-DITCH TERRACE DESIGN - using max. flow

Material: Stiff clay very colloidal

Triangular Channel

Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Manning's n	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
2.0:1	2.0:1	1.5	0.0250	1.00			3.8

	w/o Freeboard	w/ Freeboard
Design Discharge:	4.11 cfs	
Depth:	0.76 ft	1.76 ft
Top Width:	3.04 ft	7.04 ft
Velocity:	3.56 fps	
X-Section Area:	1.16 sq ft	
Hydraulic Radius:	0.340	
Froude Number:	1.02	

Whitegrass Hills Slope Stabilization
Revegetation Plan

The slopes will be contour furrow disked or ripped on the contour with a chisel plow or a small dozer equipped with triple shank rippers. If necessary, after a site-by-site evaluation, soil may be redistributed to ensure successful vegetation establishment and stabilization. In some areas, rocky or coarse textured plant growth media may be placed on slopes as a stabilization measure. These areas will be hand broadcast seeded if equipment access is restricted. Following terrace construction, tillage and seedbed preparation, the soiled areas will be drill seeded on the contour with the mix listed below. Broadcast seeded areas will receive an application of double the drilled rate.

Species		PLS lbs	Seeds/ft^2
Tall wheatgrass	(Agropyron elongatum)	3.0	5.4
Thickspike wheatgrass	(Agropyron dasystachyum)	4.0	14.0
Western wheatgrass	(Agropyron smithii)	4.0	10.0
Pubescent wheatgrass	(Agropyron trichophorum)	3.0	6.6
Fourwing saltbush	(Atriplex canescens)	3.0	3.6
Total (drilled rate)		17.0	39.6

The mix contains 3 sod forming wheatgrass species and tall wheatgrass, a tall and coarse grass with very low palatability to discourage livestock grazing. Fourwing saltbush is included at a high rate to provide additional structural cover, soil binding benefits, and provide some restriction to livestock access. The reseeded areas will be mulched with grass hay at 2 tons per acre and crimped. Any areas where high rock or coarse fragment materials were placed will not be mulched.