ADDENDUM II

Crossland- July 1995
Drainage Area Calculation
&
Channel Design

WESTERN
STATES
MINERALS
CORPORATION

26 July, 1995

TO: Mr. E.M. Gerick

FROM: D.J. Crossland

SUBJECT: DESIGN OF FEEDER DITCH #3 - J.B. KING MINE

cc:

As requested, you will find calculation summaries for the design of J.B. King Feeder Ditch #3 attached.

My understanding for this design is: 1.) that Feeder Ditch #3 was built for the same purpose as the other 'Feeder Ditches' constructed on the property - that is, it was built across a recently roughened and reseeded area of the J.B. King Mine (through erosional monitoring stations 14 &14A) in order to protect that area from the naturally occurring off-site water flows from Drainage Area 7 which are naturally funneled to the reclaimed area; 2.) that the as constructed Feeder Ditch #3 tail end is just at the 1994 reclaimed disturbed area boundaries and the ditch design will use this same limit; 3.) the as-built configuration for Feeder Ditch #3 should be compared to the calculated design for conformity; 3.) design calculations for Feeder Ditch #3 should use the same assumptions and calculation methods as previously used at the site in the designs of Feeder Ditches #1 &2, in order to maintain design continuity for the J.B. King site as a whole.

Certification: I certify that the as built Feeder Ditch #3 meets or exceeds the design calculations for same, and that said design conservatively estimates the requirements to contain the expected flows from the 100 year, 6 hour design event of 1.8".

Dwight A. Crossland
26 July 95

250 S. Rock Blvd., Ste. 130 · Reno, Nevada 89502 · (702) 856-3339 · FAX (702) 856-1818

AREA 7 — d.j.c. 7/25/95

CALCULATIONS PERFORMED AS PER APPENDICES 1 & 3 OF "J.B. KING MINE RECLAMATION PLAN REVISION", FEB. '94, TO MAINTAIN SITE CONTINUITY OF DESIGN PROCEDURES.

RUNOFF CALCULATIONS:

CONTOUR LENGTH = 10" x 300'/IN. = 3,000'

CONTOUR INTERVAL = 25'

AREA = 6.0 ACRES = 261,110 ft.^{2}

$$\text{SLOPE} = \frac{3000 \times 25 \times 100}{261{,}110} = 28.7\%$$

HYDRAULIC LENGTH = 800'

100 YR., 6 HR. STORM = 1.8"

TIME TO PEAK FLOW = 2.51 HRS.

ACCUMULATED RAINFALL INCHES @ P.F. = 1.09"

RUNOFF INCHES @ P.F. = 0.38"

RAINFALL EXCESS INCHES @ P.F. = 0.0135"

HYDROGRAPH PEAK = 5.28 CFS.

RUNOFF VOLUME = 0.38 ACRE FT.

Dwight J. Crossland
26 JULY 95

[Con't]

AREA 7 (CON'T.) d.j.c. 7/25/95

DITCH CALCULATIONS: MANNINGS EQUATION SOLUTION
FOR "NORMAL DEPTH" FLOWRATE – TRAPEZOIDAL CHANNEL

FLOW = (Q) = 5.28 C.F.S.

MANNING # = n = 0.03

BOTTOM WIDTH = b = 5'

SIDESLOPE = 1h:1v

SLOPE = S_0 = 0.05

NORMAL DEPTH = 0.2451'

FLOW X-SECT AREA = 1.2856 ft^2

FLOW TOP WIDTH = 5.4902'

WETTED PERIMETER = 5.8485'

FLOW VELOCITY = 4.1070 FT./SEC.

CHECKS:

FREEBOARD = 1.9167 – 0.2451 = 1.67 ⇒ OK

VELOCITY: 2 ≦ 4.1 ≤ 6 ⇒ OK

Dwight J. Crosland
26 JULY '95

UMC 817.45 - HYDROLOGIC BALANCE: SEDIMENT CONTROL MEASURES

All previous sediment control measures described in the November 1990 revision sheets contained in this section have shown limited success at the site. These were intended to serve as temporary erosion control measures until the slopes were stabilized by vegetation. However, based upon several vegetation monitoring surveys conducted between 1989 and 1993, and an Ecological Monitoring and Environmental Characterization study performed by Bamberg Associates in 1994; it appears that at this specific reclaimed site that it is not possible to stabilize erosion entirely by vegetation alone.

Therefore, some contour furrows and previous silt fences have been eliminated. However, remnant furrows can still be seen, such as the existing furrows that have been allowed to breach. Also, the maintenance practices of filling rills and gullies with straw mulch and rock has been added to slow erosion. The present plan calls for surface roughing and rock mulch (gravel) placement on the side slopes of the refuse pile as the primary erosion control measure. The side slopes will also receive biosolids to improve the existing soil nutrients, and provide a reasonable plant growth media for revegetation.

A silt fence will be erected between the covered vegetation test plot and the undisturbed drainage ditch, where needed, to prevent sediment runoff.

Straw and rock filling of areas in the newly disturbed ground where rilling becomes excessive, may be used until natural stabilization occurs.

A more detailed discussion of actual work accomplished in late 1994 is covered in Section UMC 817.22, under the subsection entitled Soil Stabilization. In addition, results of the testwork on the gravel material (rock mulch) used to cover the Refuse Pile slope, is attached to Section UMC 817.22 as Addendum II.

UMC 817.46 - HYDROLOGIC BALANCE : SEDIMENTATION POND

WSMC proposes to retain the current sediment impoundment facility as a permanent impoundment during the post reclamation phase of the project. The current landowner, State of Utah - Trust Lands Administration, agrees with this proposal as documented in section UMC 784.15 of this permit.

Please note, as stated previously, the current design and existing structure will comply with the requirements for permanent impoundments as described in section UMC 817.49 and UMC 817.56 of this permit.

UMC 817.81 - COAL PROCESSING WASTE BANKS : GENERAL REQUIREMENTS

Refuse Pile Covering-

Note that two modifications have been made to the requirements for refuse pile covering as follows:

1. For the test plot portion of refuse pile, a variance from the four feet of cover is recommended by Mr. Henry Sauer of the Division staff in a memorandum to the file dated March 21, 1994.

2. Due to a surface roughening planned for the side slopes of the refuse pile, as an erosional control measure. The previous language of "... a minimum of four (4) feet cover..." will be changed to "... an average of four (4) feet cover..." for the side slopes of the refuse pile.

UMC 817.103 - BACKFILLING AND GRADING : COVERING COAL AND ACID AND TOXIC FORMING MATERIALS

As noted in section UMC 817.81 of this permit, a variance from the four feet of cover to two feet for the vegetation test plot area has been recommended by a Division staff member.

As a result of this approved variance, the vegetation test plot was covered with an average of 2 ft. of cover; the surface roughened; and reseeded during Nov./Dec. 1994 at the direction of the Division.

UMC 817.110 Erosion Monitoring Plan and Standard for Bond Release

The site, since reclamation was completed in late 1985 and early 1986, has undergone some accelerated erosion during the early years following reclamation. A few of the procedures that personnel from WSMC used to slow the erosion process included: installing contour furrows and silt fences; and using straw and rock to patch larger rills or gullies as they occurred. These erosion retarding measures were required during those early years when insufficient vegetation and other protective cover was not available to reduce the erosional forces of nature to a normal erosion state.

However, vegetation cover has shown progressive improvement between 1989 through 1993; and this, along with the development of surface litter and natural rock armoring of the surface, has probably brought the site to a normal erosion state which is comprable with the surrounding, undisturbed land areas, or at least within tolerance levels of normal erosion. Understandably, this statement requires validation, and the proposed erosion monitoring plan is designed to help make that determination.

The current regulation governing erosion control or soil stabilization is not specific as to how an operator can seek bond release for this element of liability. The parts of the Utah Coal Mine Regulation that deal with this are;

1. R645-301-244.100 "All exposed surface areas will be protected and stabilized to effectively control erosion..."

2. R645-301-244.300 "Rills and gullies which form in areas that have been regraded and topsoiled and which either;..."

3. R645-301-244.310 "Disrupt the approved postmining land use or the reestablishment of the vegetative cover, or..."

4. R645-301-244.320 "Cause or contribute to a violation of water quality standards for receiving streams will be filled, regraded, or otherwise stabilized;..."

Since all of the regulations pertaining to erosion control or soil stabilization are so vague and subjective, WSMC has attempted to outline an erosion monitoring plan and and specific criteria for bond release associated with this element of responsibility.

It is the belief of WSMC that the vast majority of existing erosional features on the site, carry off-site drainage run-off across the site to the sedimentation pond. This will be elaborated upon in the discussion that follows.

To begin, the erosion monitoring plan will have the following key elements: 1) a series of on-site erosion monitoring transects that will be regularly recorded quantitatively and qualitatively for change; 2) a recording rain monitoring stating on site; and 3) a series of comparable off-site erosional transects that will be recorded on the same schedule as 1) above.

The details of the erosion monitoring plan are described in the following text.

1. On-Site Erosion Monitoring Transects-

Approximately 90% of the significant erosional features that exist on-site are covered by the transects that have been established. These erosional monitoring transects are located on Drawing JBK-3 (AS BUILT), and each transect is individually shown in plan and cross-sectional view on the attached drawings that are an Addendum to this section. It should be noted that the other area that previously contained significant erosional features was the west and southwest side slopes of the refuse pile, but these features were eliminated during the 1994 site reclamation work.

These two areas: the slide slopes of the refuse pile; and the area of the erosional transects, are distinctly different with respect to the elements causing erosion. Firstly, the side slope of the refuse pile is approximately a 4 to 1 slope (horizontal to vertical), and the water that caused the rills and gullies fell directly within the site. In addition, the area of the erosion transects has an overall flatter slope (however, some localized slopes are as steep as the 4 to 1 on the refuse pile) but more importantly, the water causing the rilling comes from **outside sources** (multiple off-site drainage basins contribute run-on across the site at this location).

The erosion monitoring transects are strategically placed to intersect surface run-on flow patterns generated by off-site drainage from areas 3 and 4 specifically.

Drainage area 4 contains the following transects:

F-O to F-OA, F-1 to F-1A, F-2 to F-2A, F-3 to F-3A, F-4 to F-4A, F-4B, F-1B to F-1C, F-2B to F-2C, F-1D to F-3B, F-3B to F-3C, F-11 to F-11A, F-12 to F-12A, and F-10 to F-10A

Drainage area 3 contains the following transects:

F-5 to F-5A, F-6 to F-6A, F-7 to F-7A, F-5B to F-5C, F-6B to F-6C, F-7B to F-7C, F-8 to F-8A, and F-9 to F-9A

Drainage area 2 contains the following transects:

C to C' and D to D'

Drainage area 1 contains the following transects:

A to A' and B to B'

Drainage area 7 contains the following transects:

F-14 to F-14A and F-13 to F-13A

Each transect has been established in the field with a 3/8 inch rebar stake driven into the ground at each end, and an aluminum tag identifying each point. All erosional features were measured and are marked on the cross-sectional view with VR or FR, which stands for a "V" shaped rill or "Flat" shaped rill (flat is defined as a rill with a generally flat shaped bottom). Other geographical features or remnants are shown were thought to be beneficial to the monitoring program.

In addition to the physical measurement of the erosional features, a photographic record will also be collected. The first set of photographs of each transect will be taken during August 1995 and this will establish the location of each photographic viewpoint. Subsequent photos will utilize these same locations, as well as camera settings, in order to maintain continuity in the photographic data assemblage. Note that other photographic points or angles may also be added, as site conditions warrent.

It is planned that data will be collected twice each year for the first two years after installation- probably in the Spring (April-May) and Fall (Oct.-Nov.).

2. Recording Rain Gauge-

WSMC is willing to install a recording rain gauge and data logger at the site for the next two years, if the Division will commit to downloading the data on a regular basis (every one to two months) and sending WSMC a copy on diskette. WSMC reserves the right to discontinue this portion of the monitoring plan if, in its opinion, vandalism or other related equipment or monitoring costs render the further collection of climate data unrealistic.

3. Establish Off-Site Erosional Monitoring Transects

WSMC will establish off-site erosional transects for monitoring purposes, that are comparable to on-site conditions. These will be monitored by similar methods, and on a similar schedule to the on-site erosion transects.

Once these off-site transects are established, they will be marked in the field and the same pertinent data that was submitted to the Division for the on-site transects, will be submitted. As monitoring proceeds, additional transects may be added as appropriate.

Standard for Bond Release-

Upon the demonstrated establishment of Normal Erosion (as defined in the OSM document entitled "Technical Note - Method for Evaluation of Erosion on Reclaimed Coal Lands in Western United States" draft dated 12/5/90), WSMC will be eligible for release from site liability and surety bonding as related to erosion control. It is understood that Natural Erosion (ibid.) will be determined by the data developed from the off-site monitoring, and that the mine site will be evaluated as a whole.

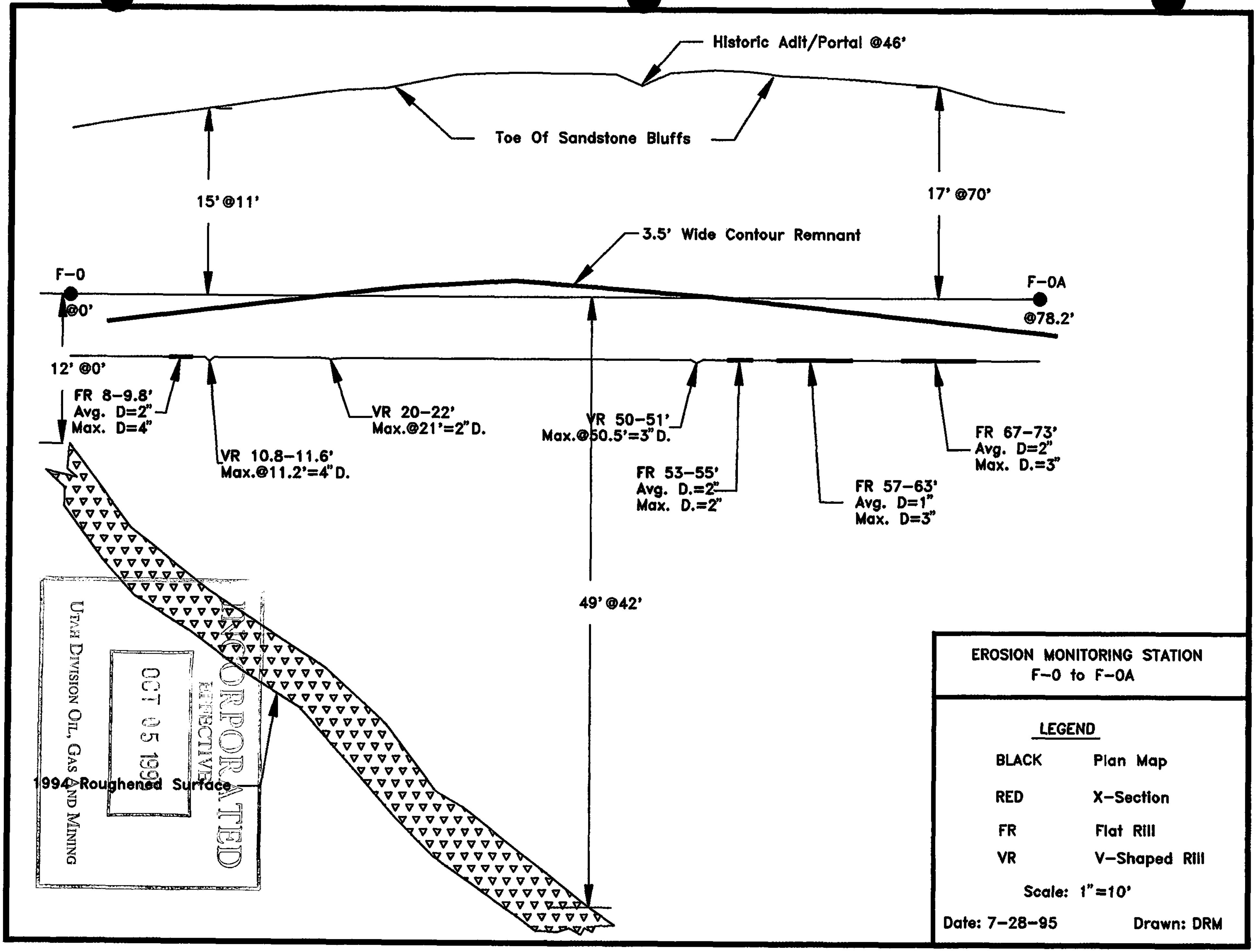
Three documents are attached for reference:

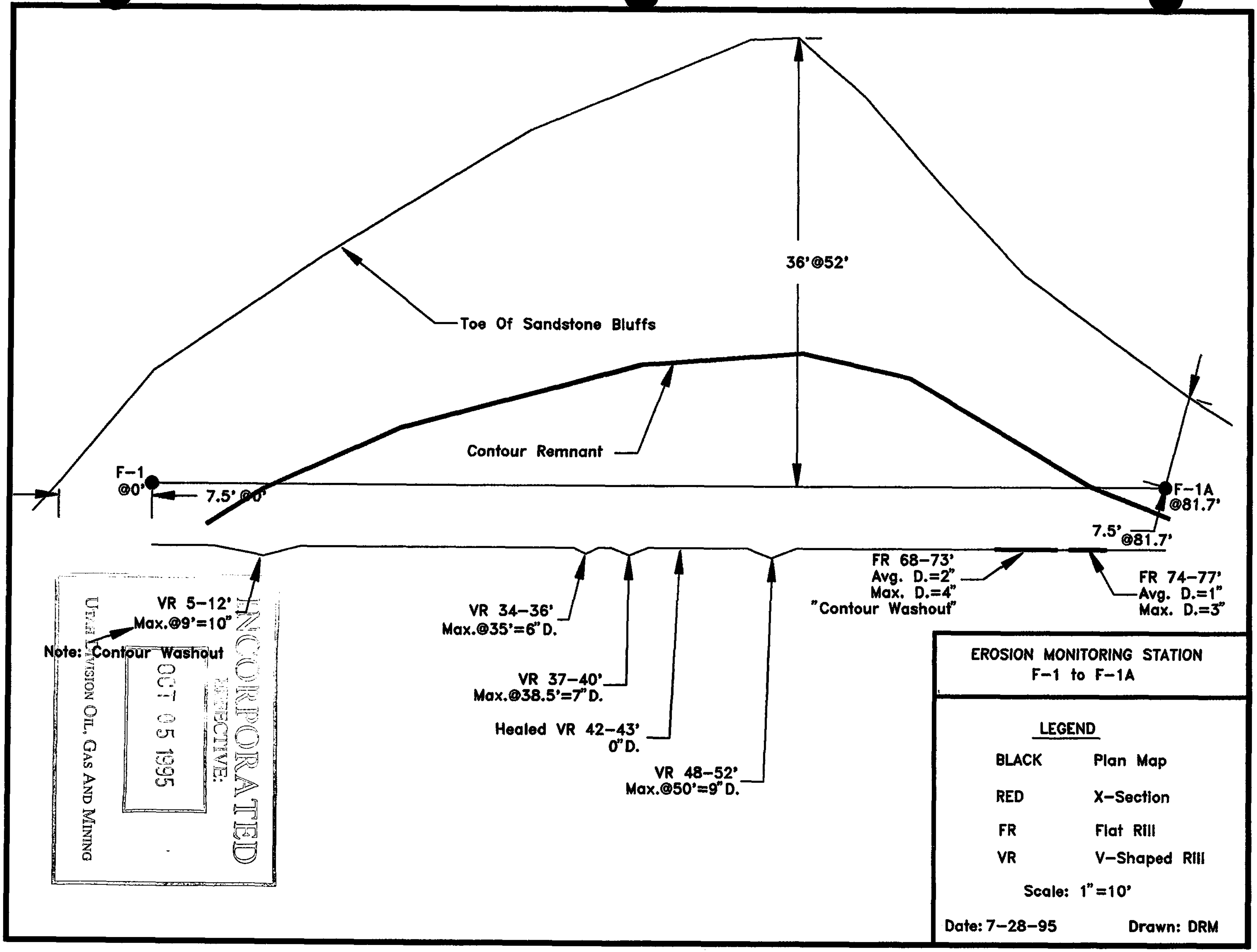
Addendum I- Erosional Monitering Transects

Addendum II- OSM document entitled "Technical Note- Method for Evaluation of Erosion on Reclaimed Coal Lands in Western United States," dated draft 12/5/90.

Addendum III- Bamberg report entitled "Ecological Monitoring and Environmental Characterization," dated August 1994.

ADDENDUM I


Historic Adit/Portal @46'
Toe Of Sandstone Bluffs
15'@11'
17' @70'
3.5' Wide Contour Remnant
F-0
@0'
F-0A
@78.2'
12' @0'
FR 8-9.8'
Avg. D=2"
Max. D=4"
VR 10.8-11.6'
Max.@11.2'=4"D.
VR 20-22'
Max.@21'=2"D.
VR 50-51'
Max.@50.5'=3"D.
FR 53-55'
Avg. D.=2"
Max. D.=2"
FR 57-63'
Avg. D=1"
Max. D=3"
FR 67-73'
Avg. D=2"
Max. D.=3"
49'@42'
1994 Roughened Surface
INCORPORATED
EFFECTIVE
UTAH DIVISION OIL, GAS AND MINING
EROSION MONITORING STATION
F-0 to F-0A
LEGEND
BLACK Plan Map
RED X-Section
FR Flat Rill
VR V-Shaped Rill
Scale: 1"=10'
Date: 7-28-95
Drawn: DRM



Toe Of Sandstone Bluffs
36'@52'
Contour Remnant
F-1
@0'
7.5' @0'
F-1A
@81.7'
7.5' @81.7'
VR 5-12'
Max.@9'=10"
Note: Contour Washout
VR 34-36'
Max.@35'=6" D.
VR 37-40'
Max.@38.5'=7" D.
Healed VR 42-43'
0" D.
VR 48-52'
Max.@50'=9" D.
FR 68-73'
Avg. D.=2"
Max. D.=4"
"Contour Washout"
FR 74-77'
Avg. D.=1"
Max. D.=3"
EROSION MONITORING STATION
F-1 to F-1A
LEGEND
BLACK Plan Map
RED X-Section
FR Flat Rill
VR V-Shaped Rill
Scale: 1"=10'
Date: 7-28-95
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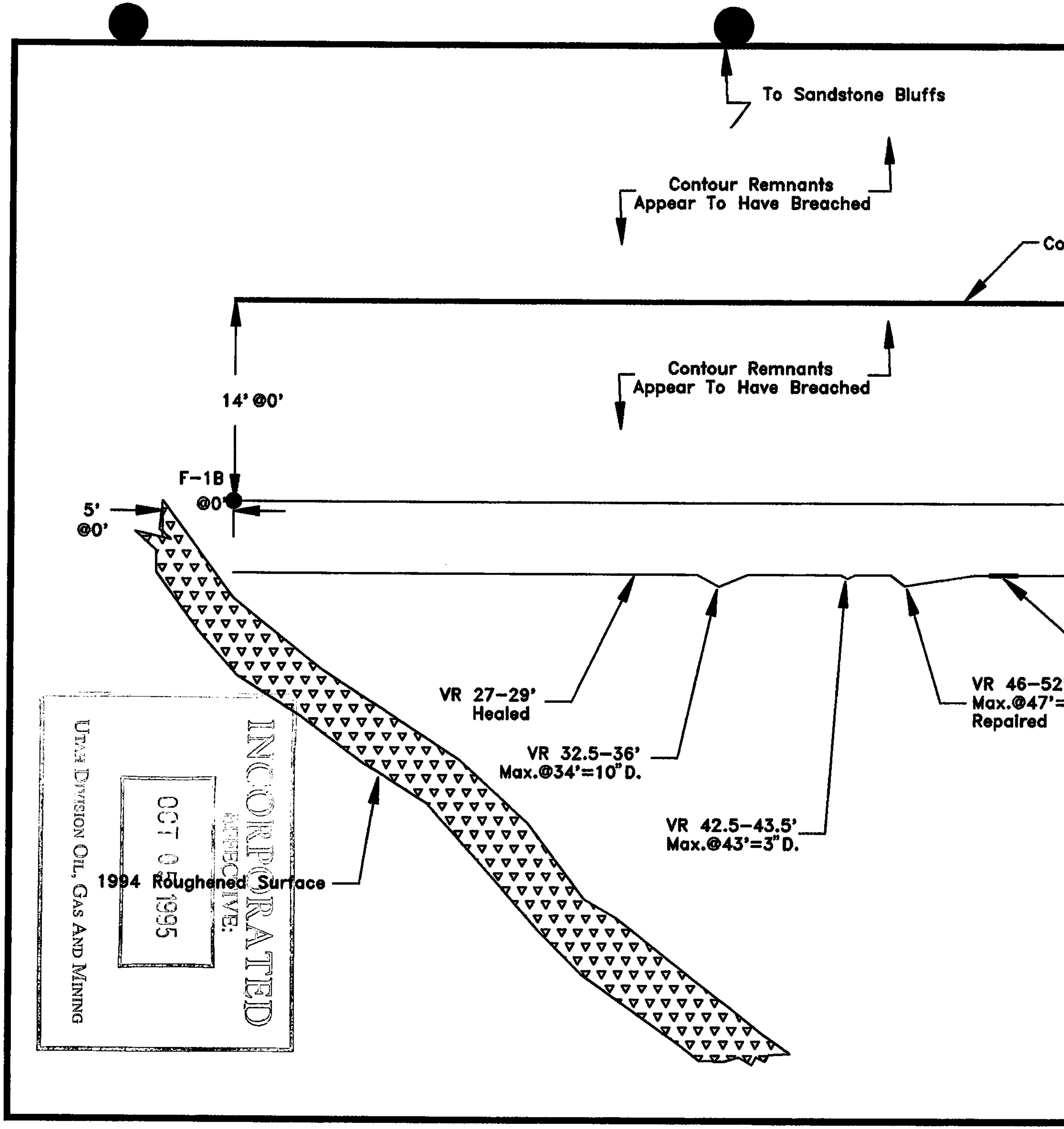


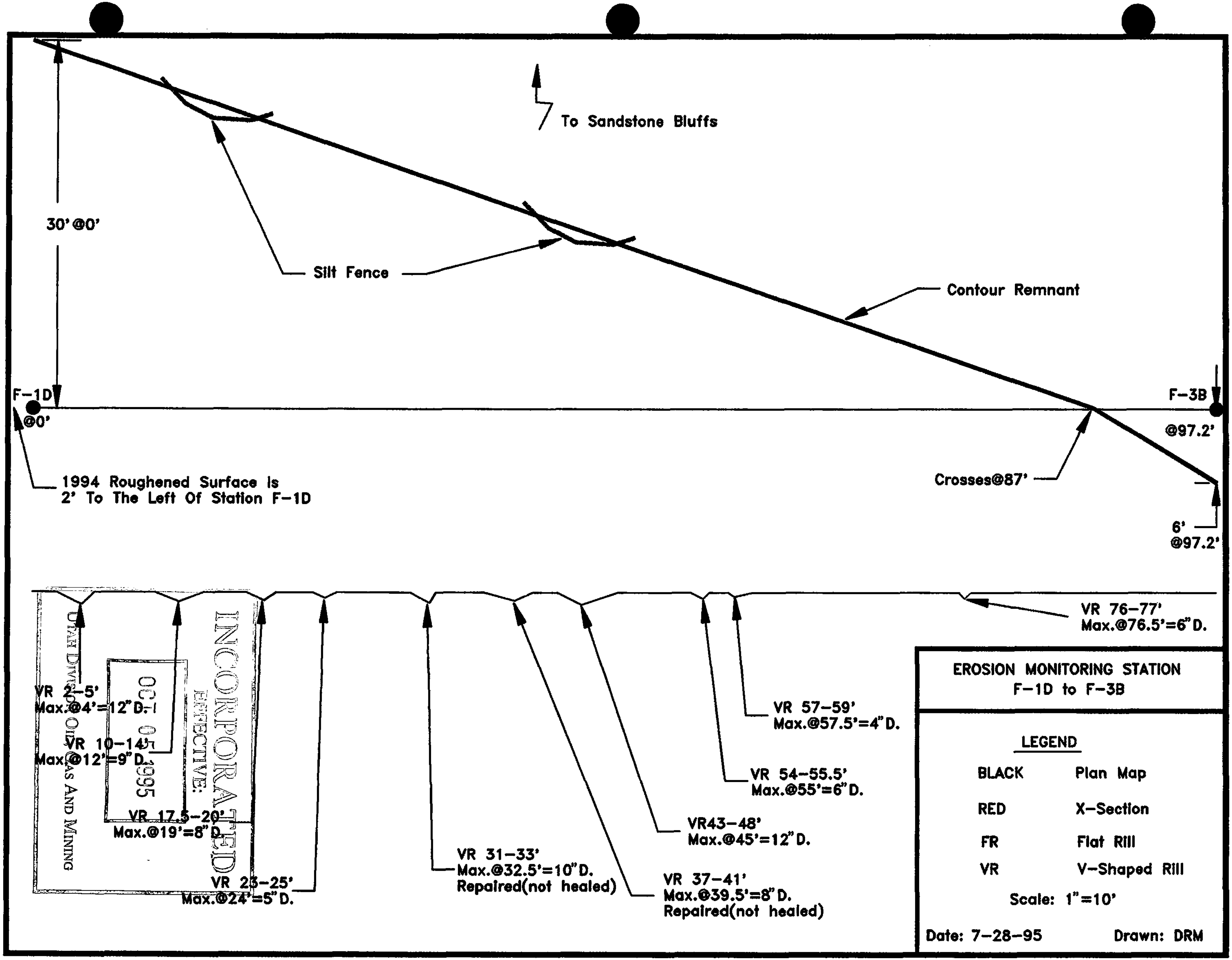
EROSION MONITORING STATION
F-1B to F-1C

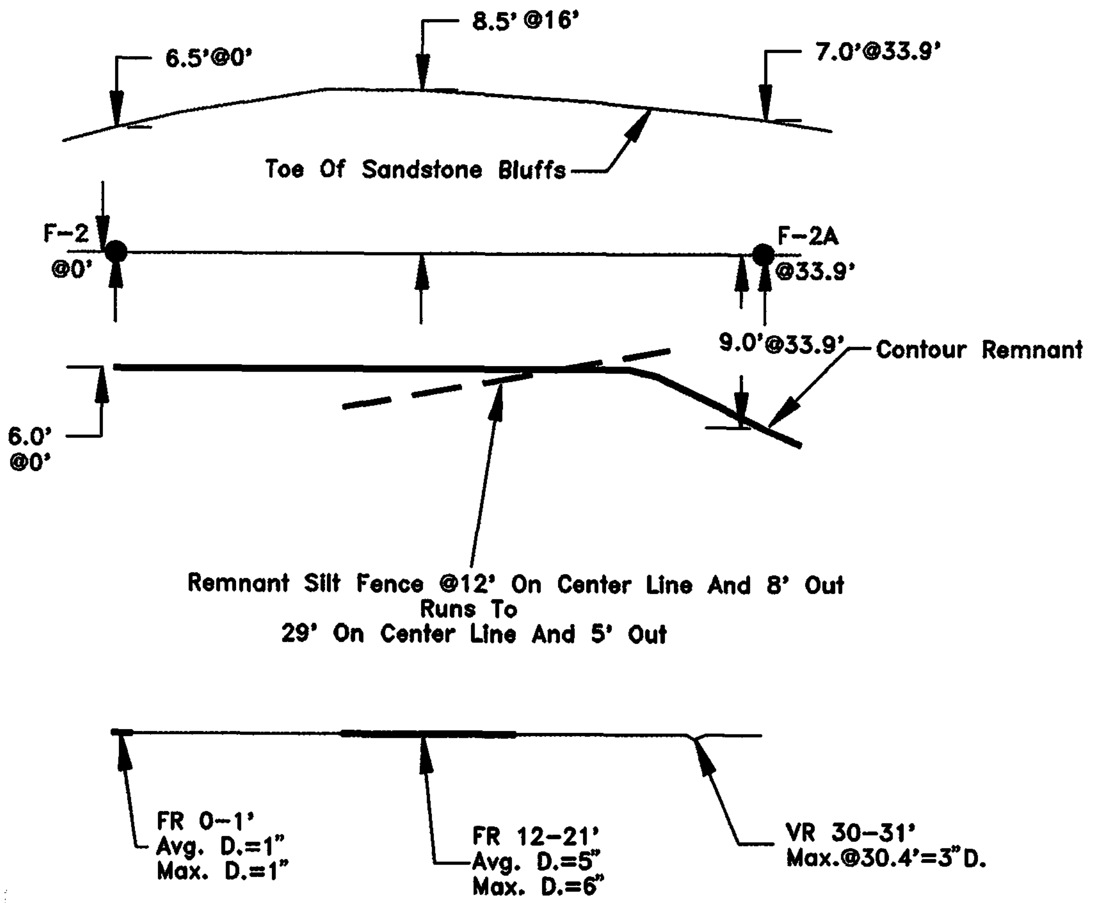
LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM


To Sandstone Bluffs
30' @0'
Silt Fence
Contour Remnant
F-1D
@0'
F-3B
@97.2'
1994 Roughened Surface Is
2' To The Left Of Station F-1D
Crosses@87'
6'
@97.2'
VR 76-77'
Max.@76.5'=6" D.
VR 2-5'
Max.@4'=12" D.
VR 10-14'
Max.@12'=9" D.
VR 17.5-20'
Max.@19'=8" D.
VR 23-25'
Max.@24'=5" D.
VR 31-33'
Max.@32.5'=10" D.
Repaired(not healed)
VR 37-41'
Max.@39.5'=8" D.
Repaired(not healed)
VR43-48'
Max.@45'=12" D.
VR 54-55.5'
Max.@55'=6" D.
VR 57-59'
Max.@57.5'=4" D.
INCORPORATED
EFFECTIVE:
OCT 05 1995
UTAH DIVISION OIL GAS AND MINING
EROSION MONITORING STATION
F-1D to F-3B
LEGEND
BLACK Plan Map
RED X-Section
FR Flat Rill
VR V-Shaped Rill
Scale: 1"=10'
Date: 7-28-95
Drawn: DRM



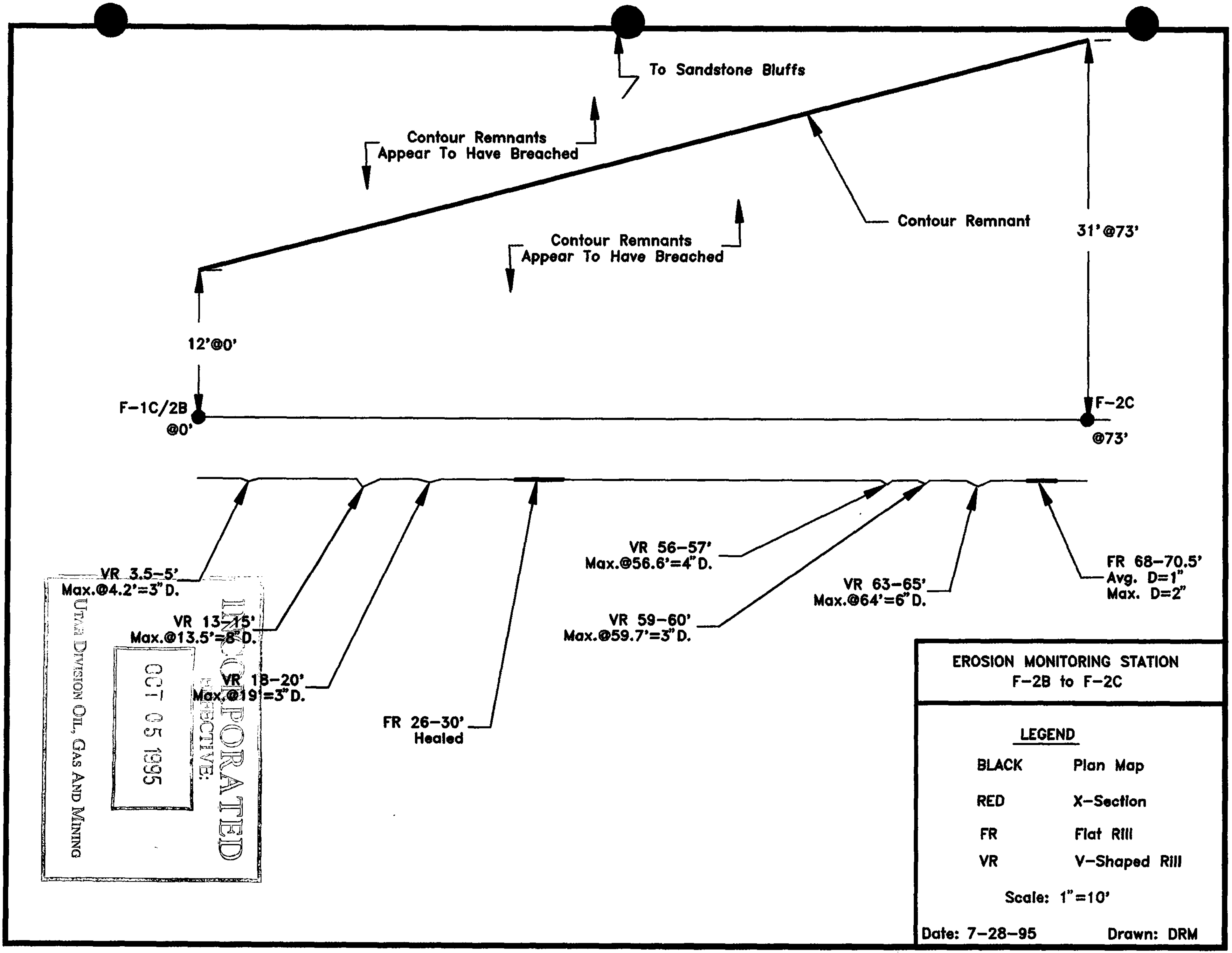
EROSION MONITORING STATION
F-2 to F-2A

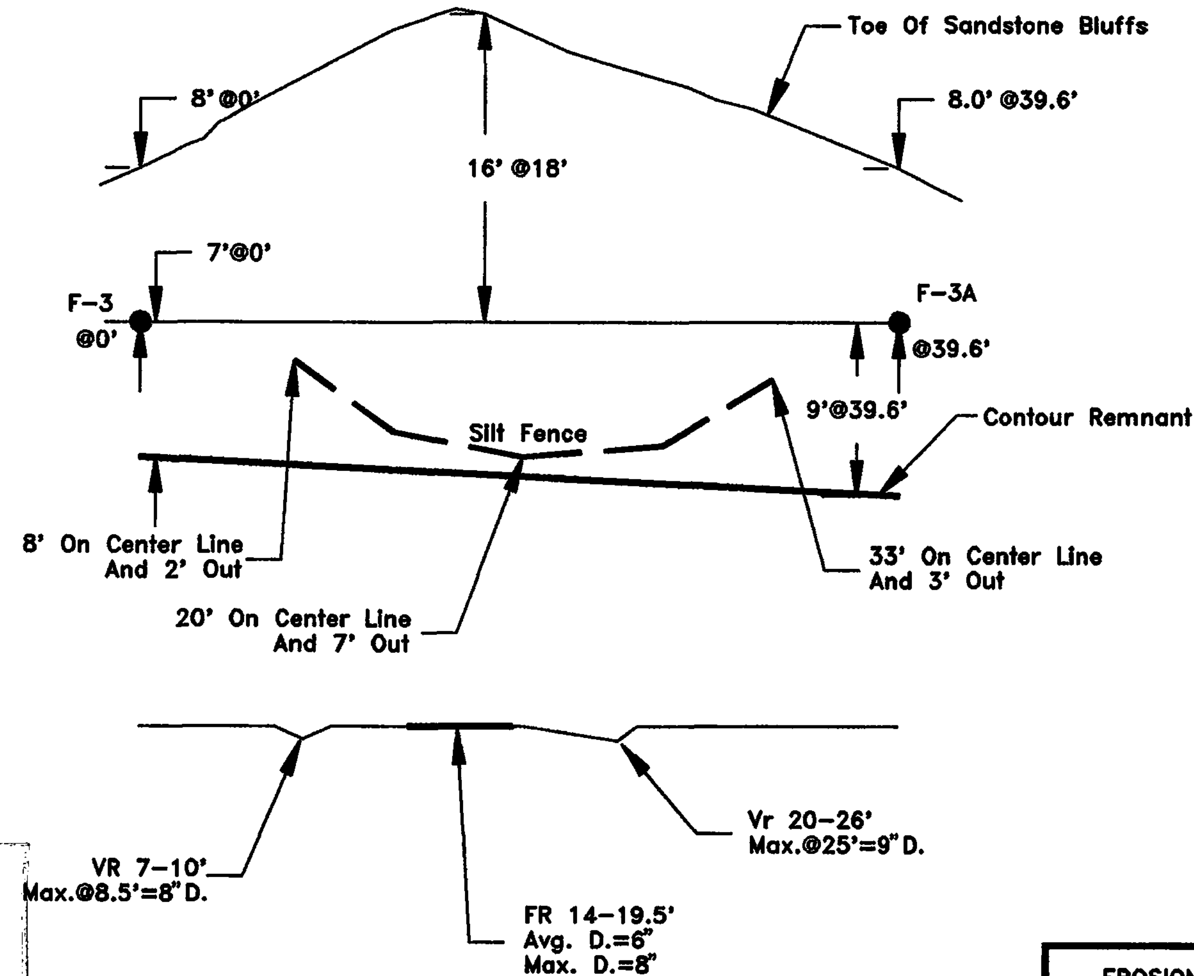
LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM


To Sandstone Bluffs
Contour Remnants Appear To Have Breached
Contour Remnant
Contour Remnants Appear To Have Breached
31'@73'
12'@0'
F-1C/2B @0'
F-2C @73'
VR 3.5-5' Max.@4.2'=3" D.
VR 13-15' Max.@13.5'=8" D.
VR 18-20' Max.@19'=3" D.
FR 26-30' Healed
VR 56-57' Max.@56.6'=4" D.
VR 59-60' Max.@59.7'=3" D.
VR 63-65' Max.@64'=6" D.
FR 68-70.5' Avg. D=1" Max. D=2"
EROSION MONITORING STATION
F-2B to F-2C
LEGEND
BLACK Plan Map
RED X-Section
FR Flat Rill
VR V-Shaped Rill
Scale: 1"=10'
Date: 7-28-95
Drawn: DRM



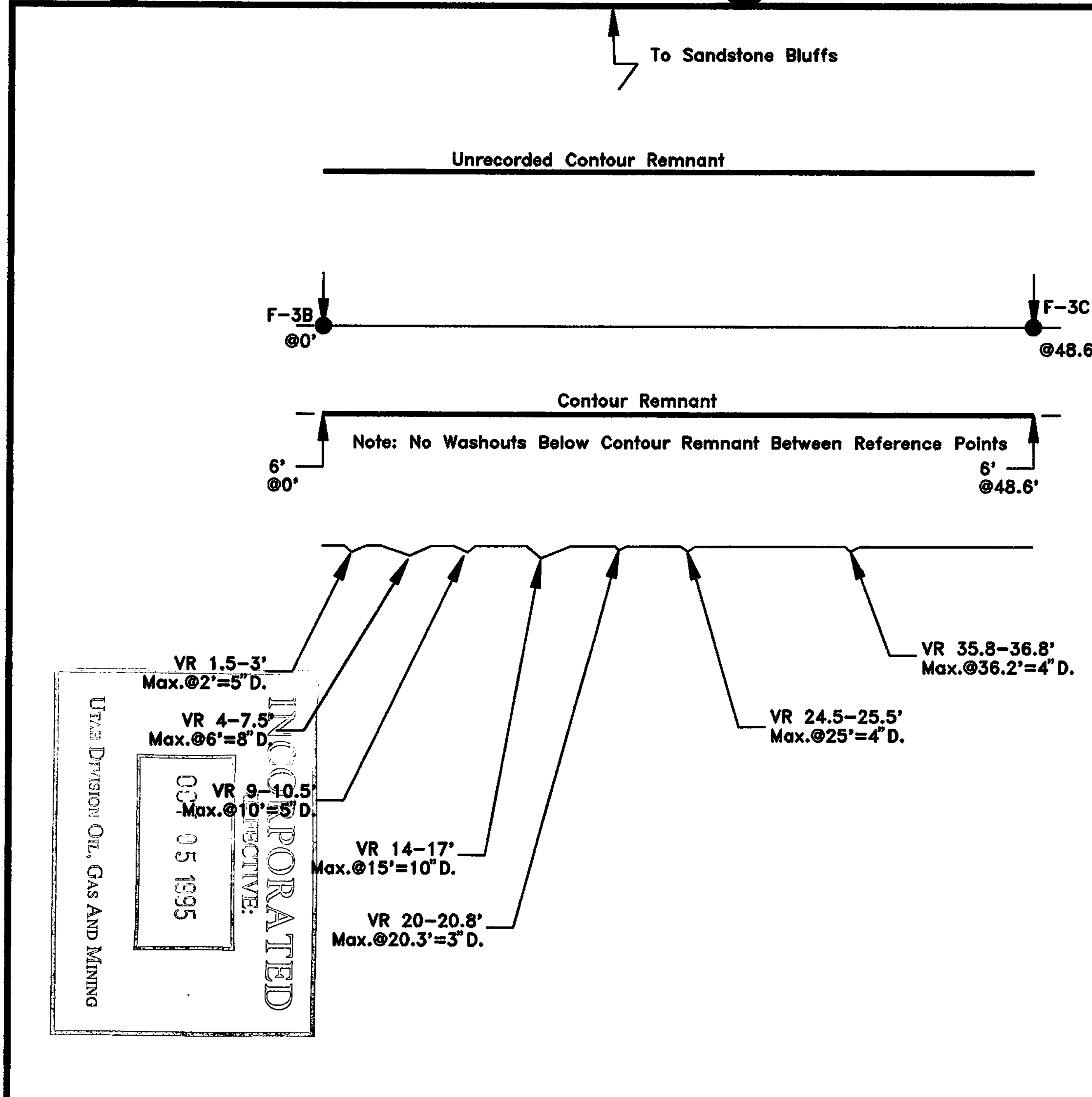
EROSION MONITORING STATION
F-3 to F-3A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



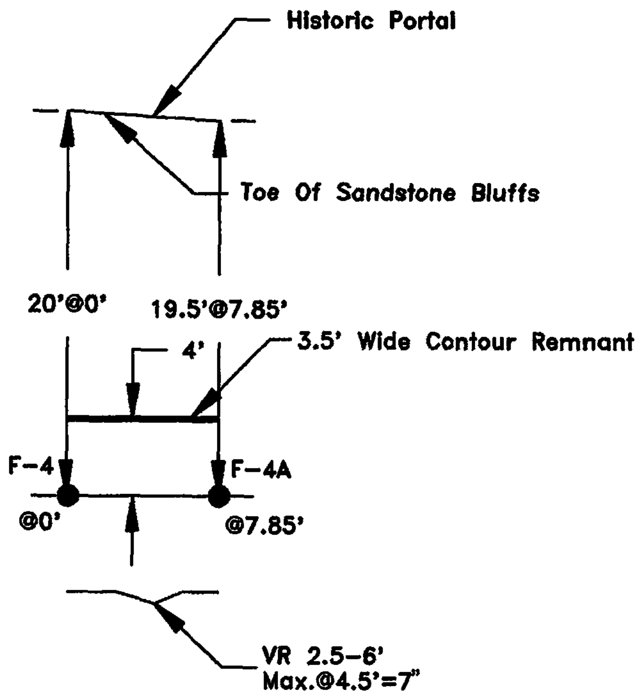
EROSION MONITORING STATION
F-3B to F-3C

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



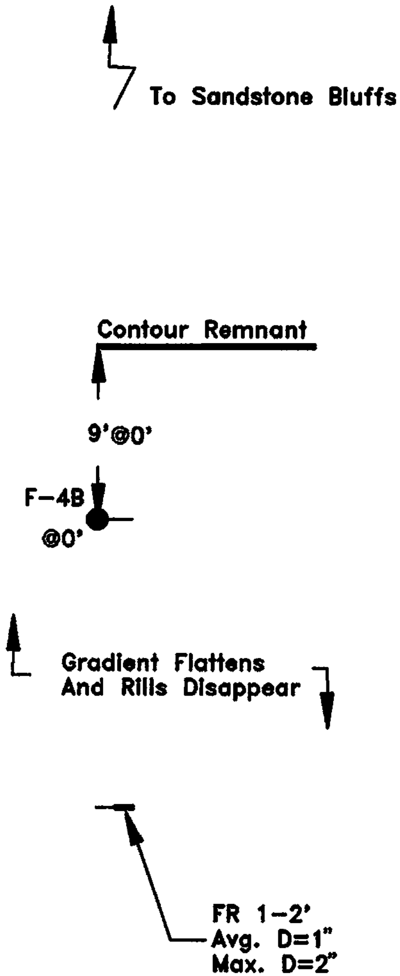
EROSION MONITORING STATION
F-4 to F-4A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



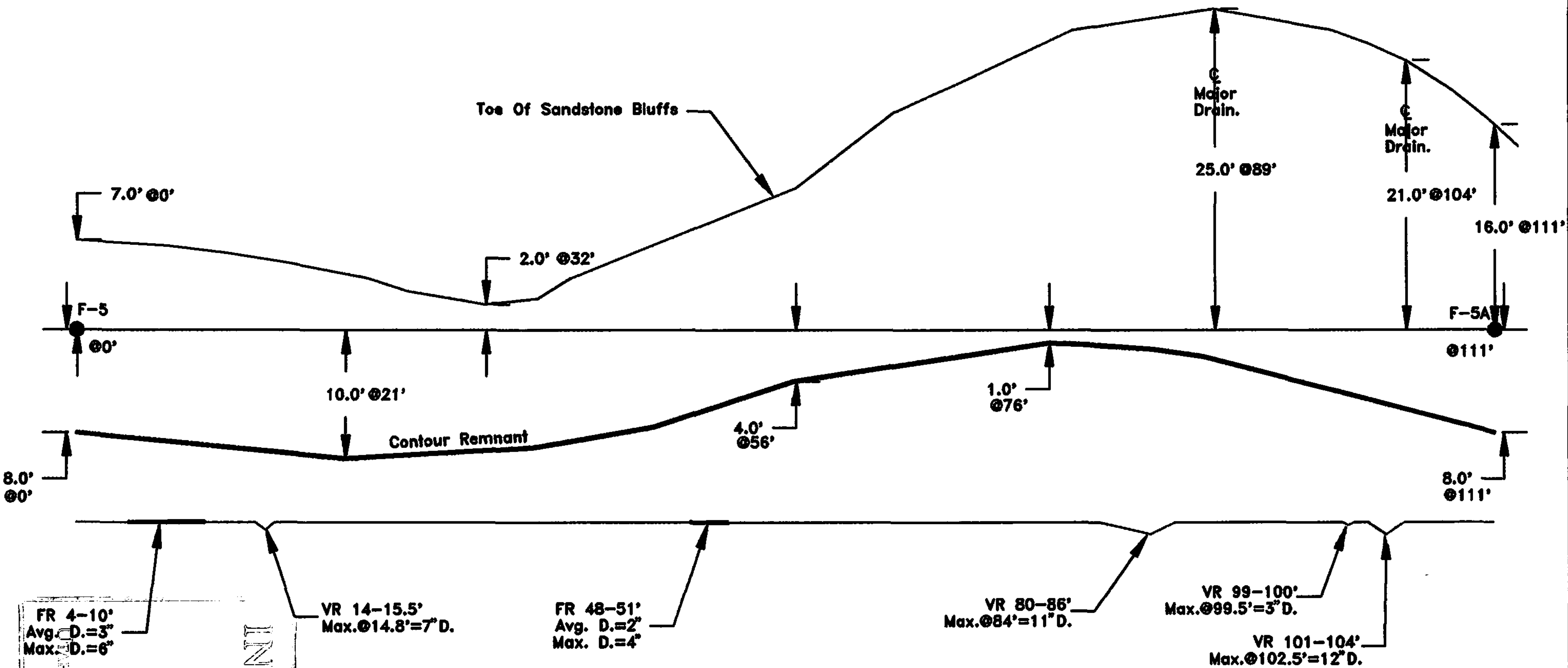
EROSION MONITORING STATION
F-4B

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



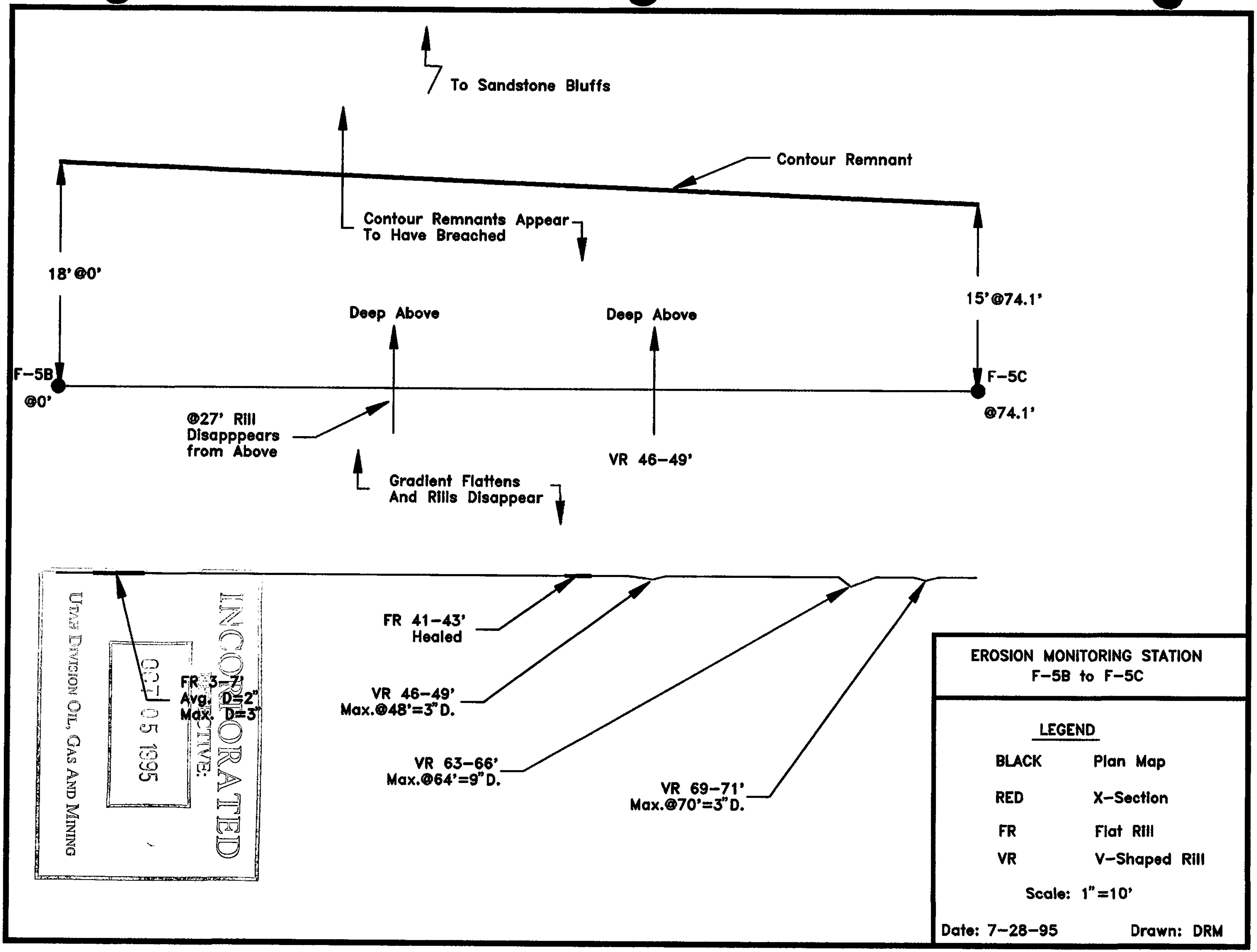
EROSION MONITORING STATION
F-5 to F-5A

LEGEND

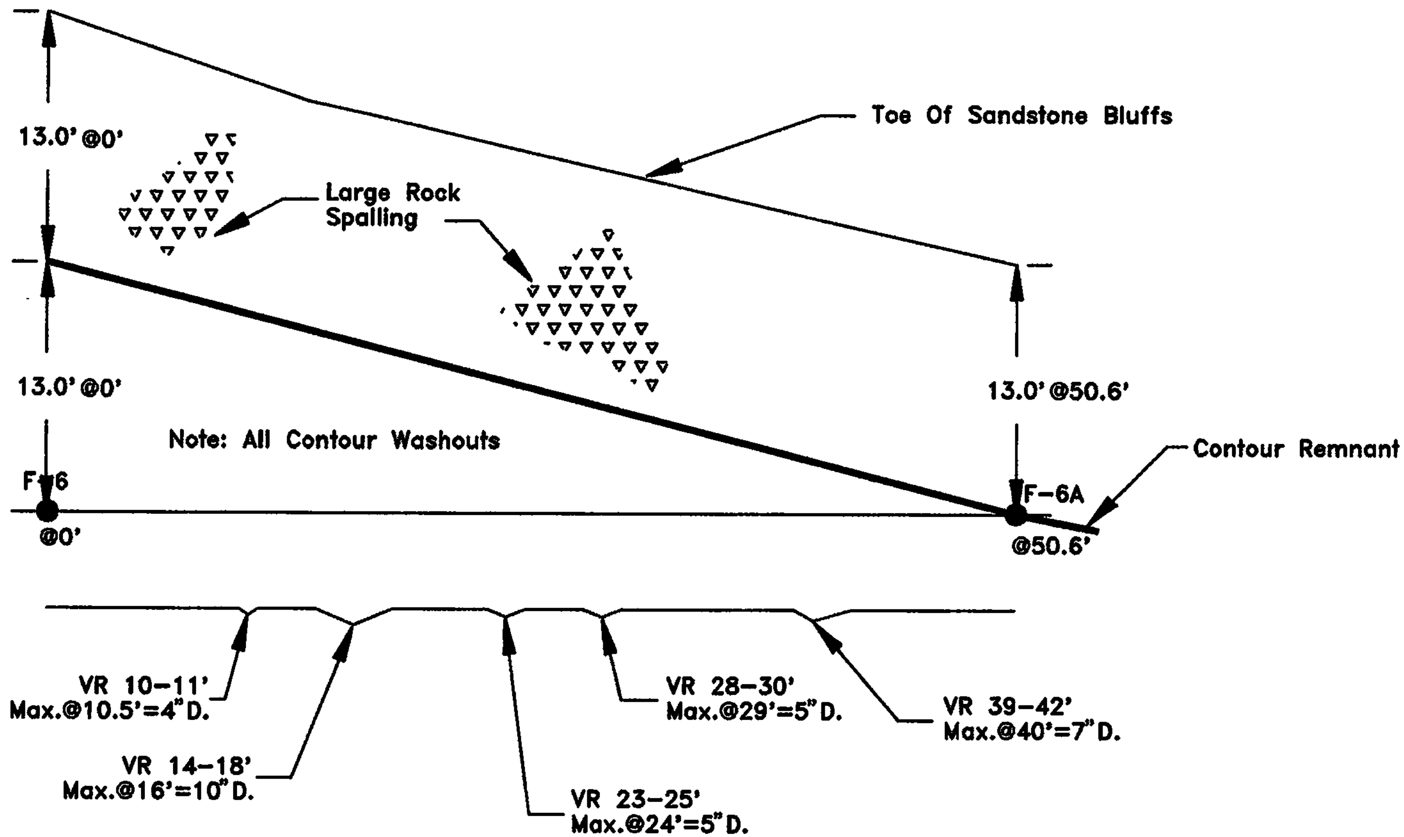
BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=12'

Date: 7-28-95 Drawn: DRM



To Sandstone Bluffs
Contour Remnant
Contour Remnants Appear To Have Breached
18'@0'
15'@74.1'
Deep Above
Deep Above
F-5B
@0'
F-5C
@74.1'
@27' Rill Disapppears from Above
VR 46-49'
Gradient Flattens And Rills Disappear
FR 41-43' Healed
FR 3-7' Avg. D=2" Max. D=3"
VR 46-49' Max.@48'=3" D.
VR 63-66' Max.@64'=9" D.
VR 69-71' Max.@70'=3" D.
EROSION MONITORING STATION
F-5B to F-5C
LEGEND
BLACK Plan Map
RED X-Section
FR Flat Rill
VR V-Shaped Rill
Scale: 1"=10'
Date: 7-28-95
Drawn: DRM



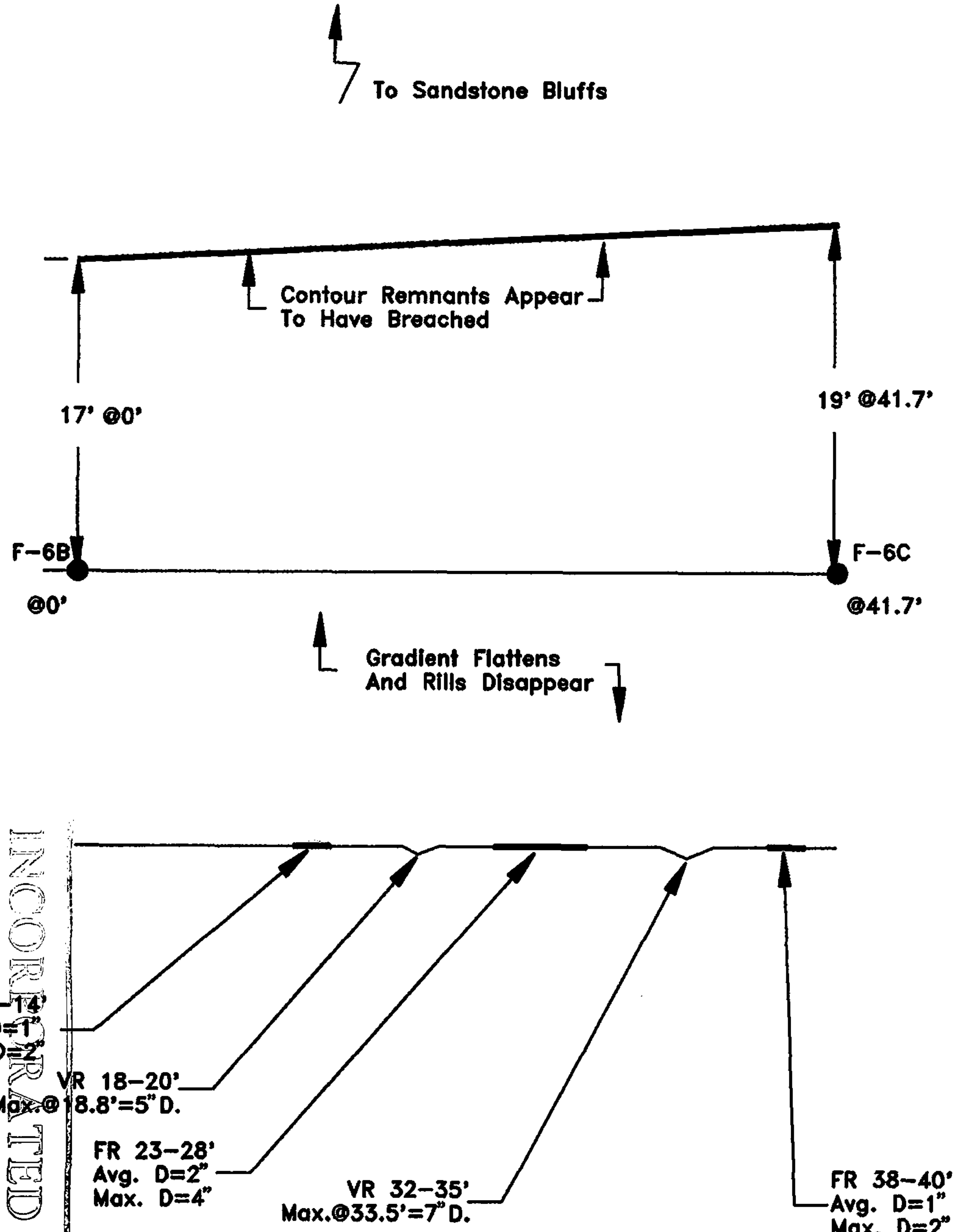
EROSION MONITORING STATION
F-6 to F-6A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



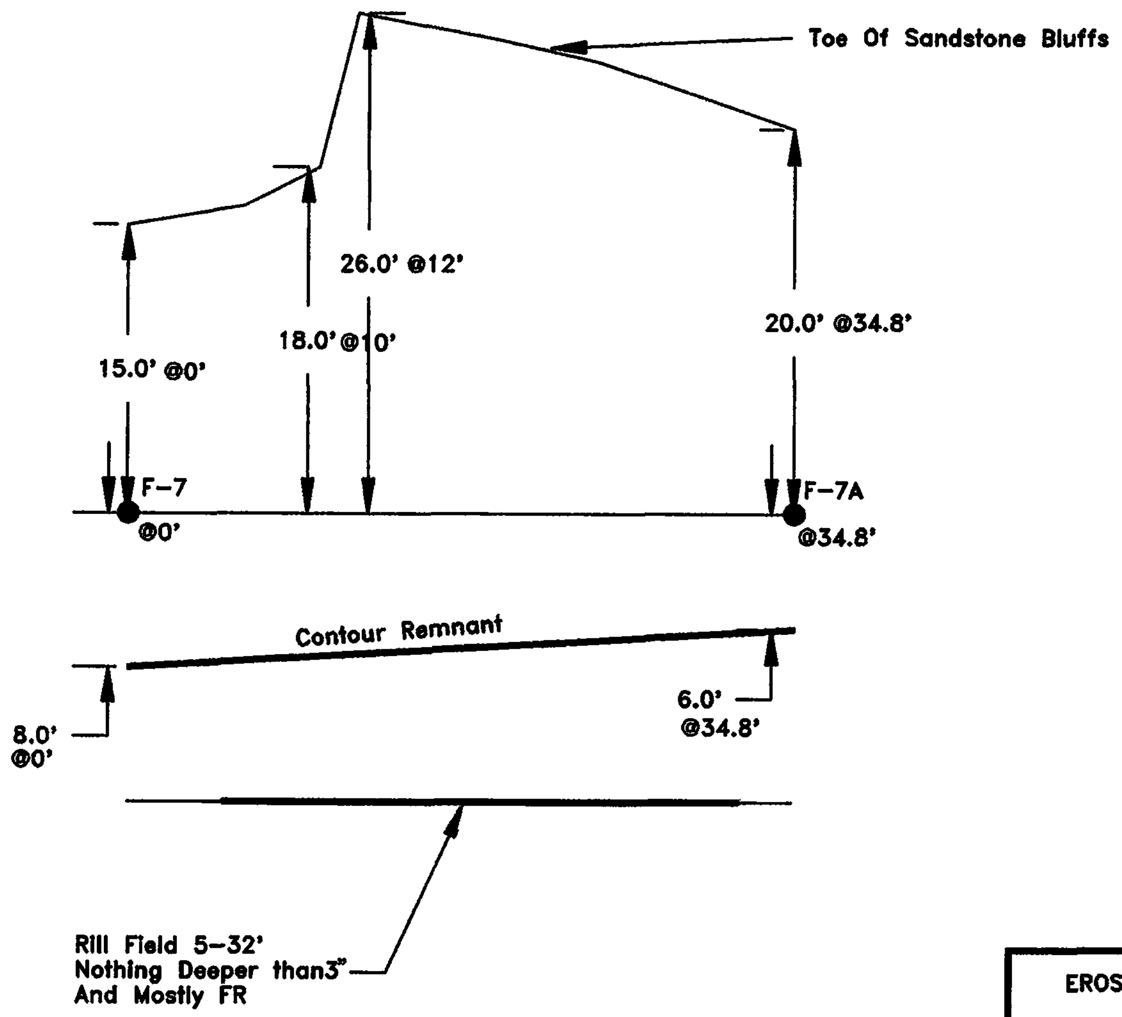
EROSION MONITORING STATION
F-6B to F-6C

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



EROSION MONITORING STATION
F-7 to F-7A

LEGEND

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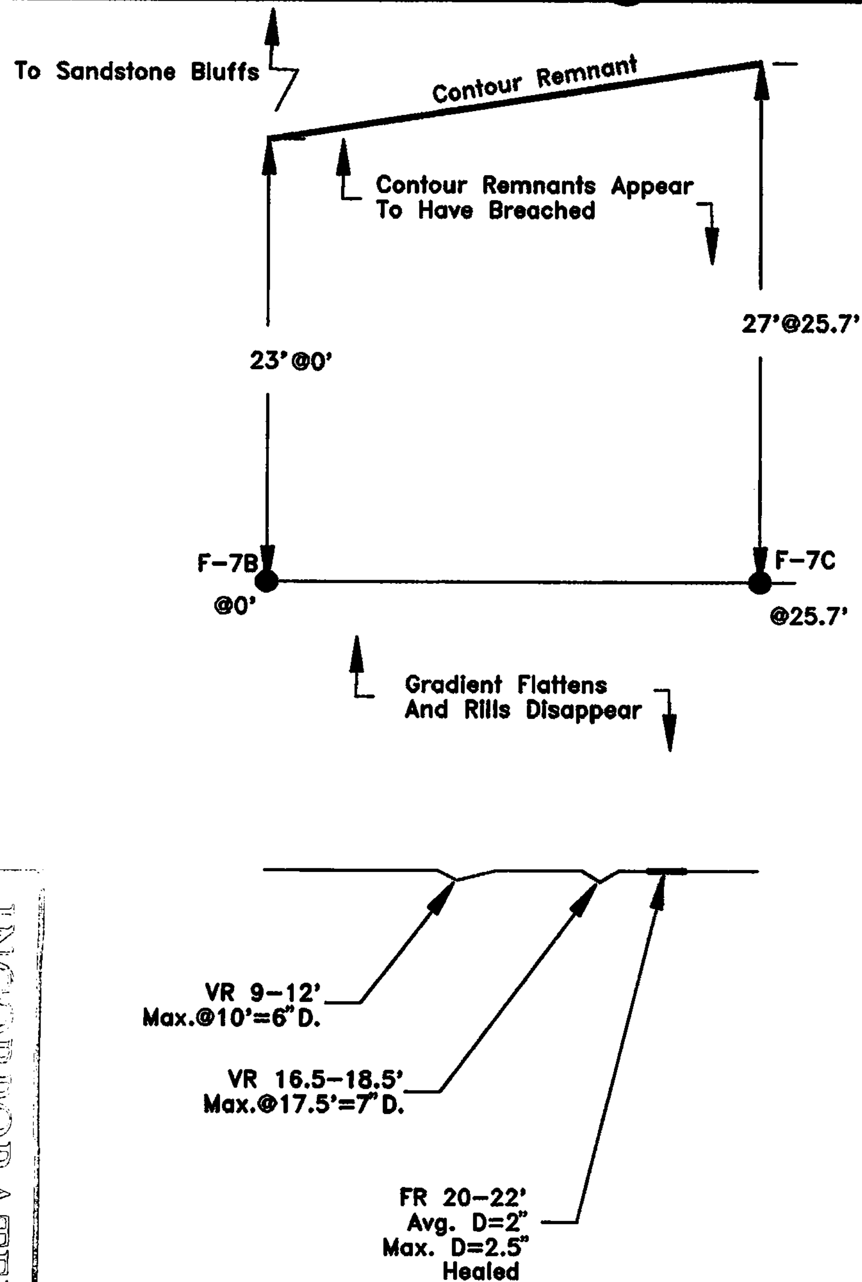
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



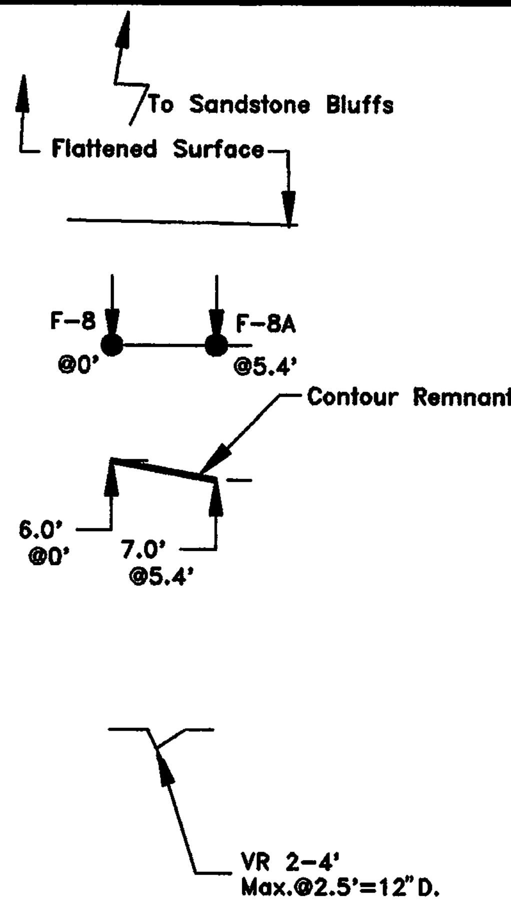
EROSION MONITORING STATION
F-7B to F-7C

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



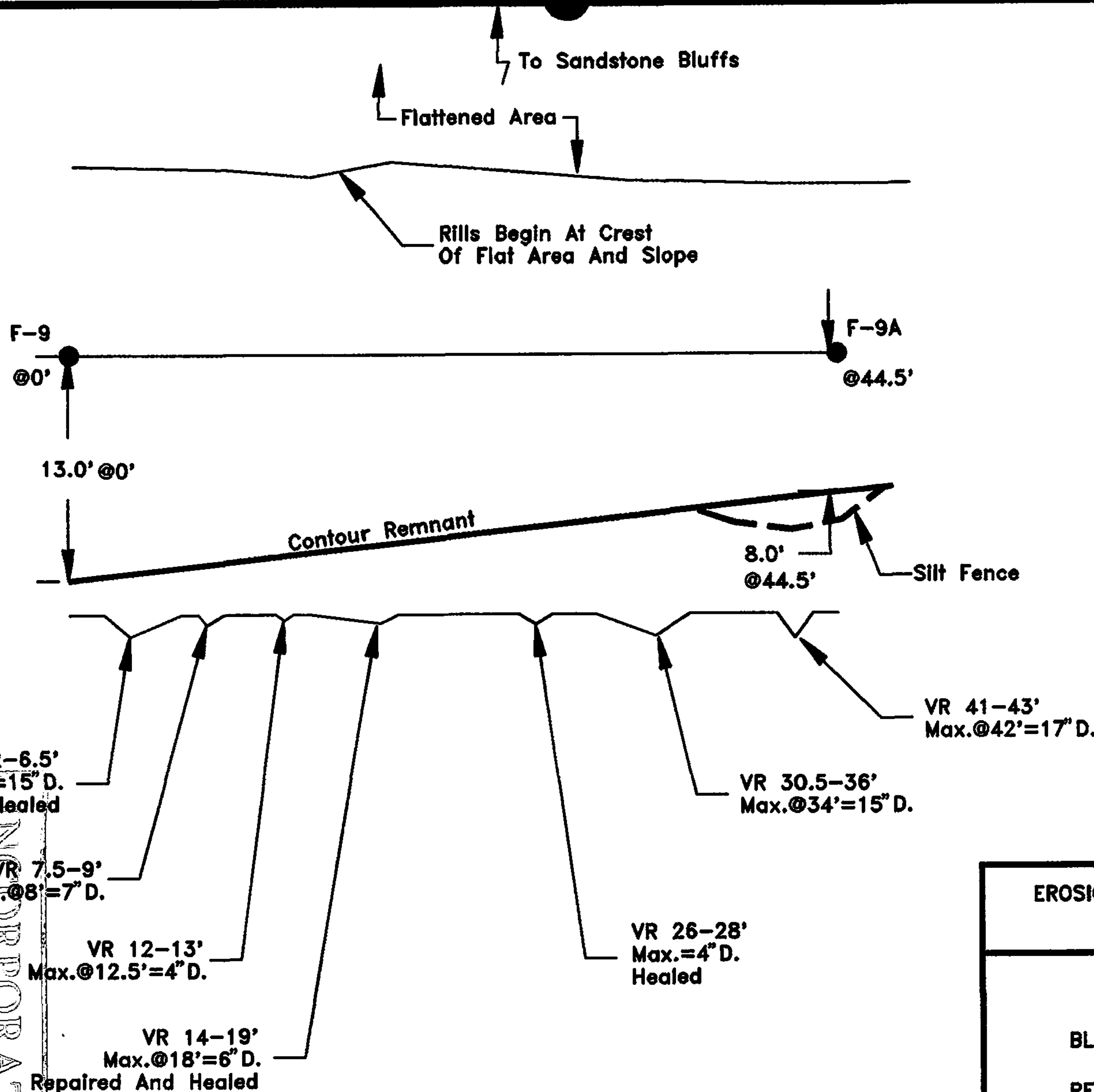
EROSION MONITORING STATION
F-8 to F-8A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



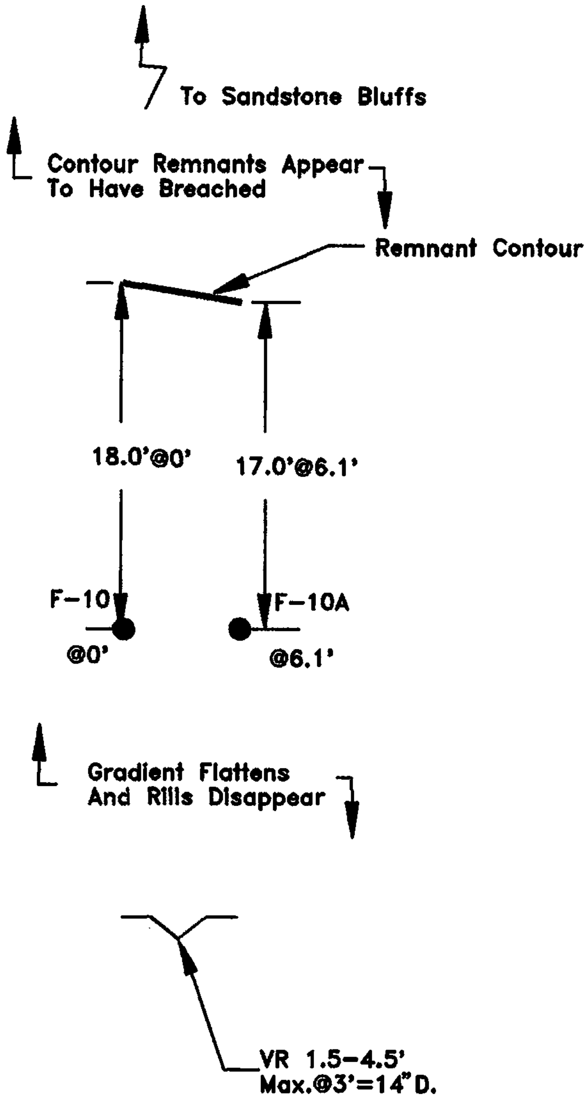
EROSION MONITORING STATION
F-9 to F-9A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

DATE: 7-28-95 Drawn: DRM



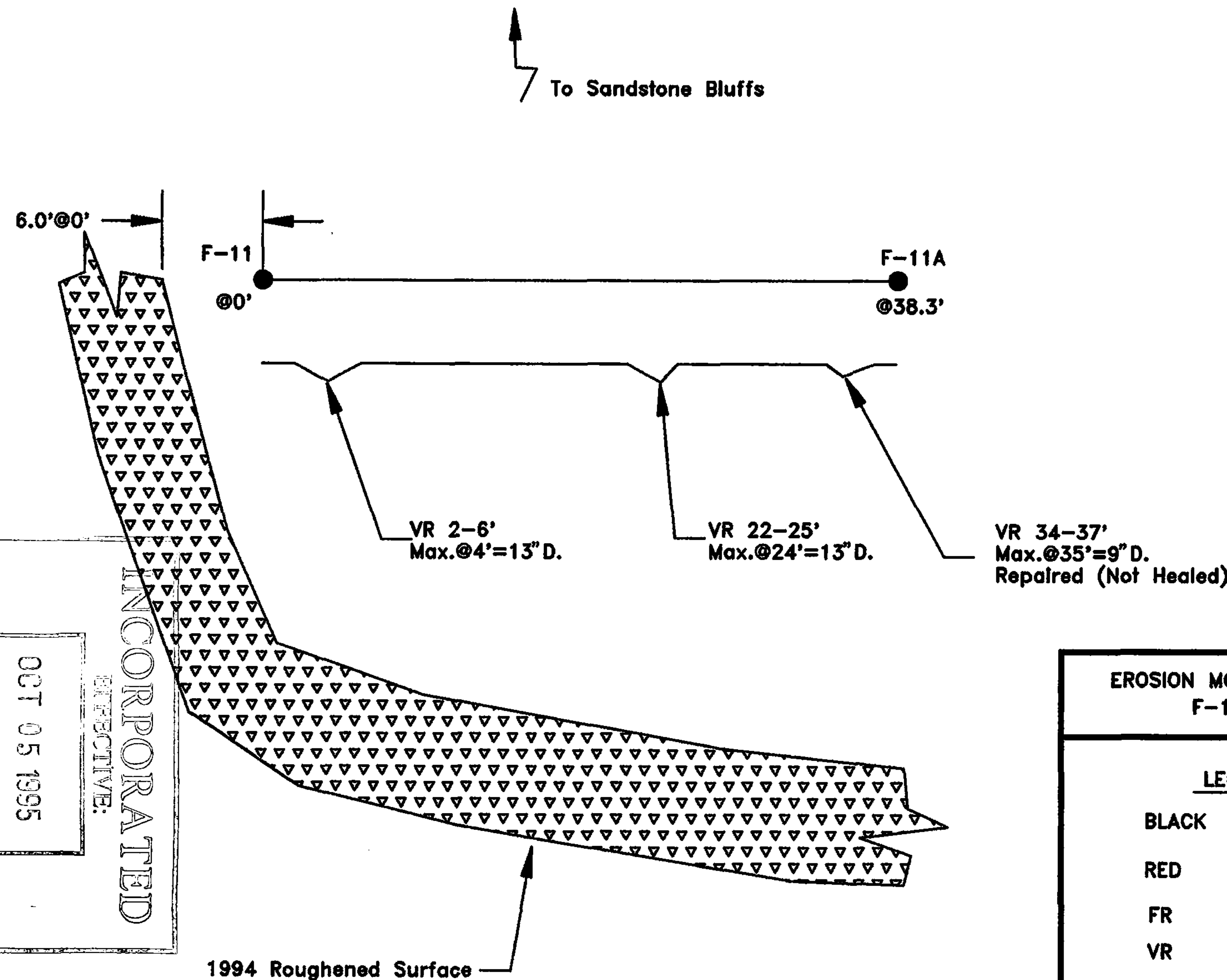
EROSION MONITORING STATION
F-10 to F-10A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



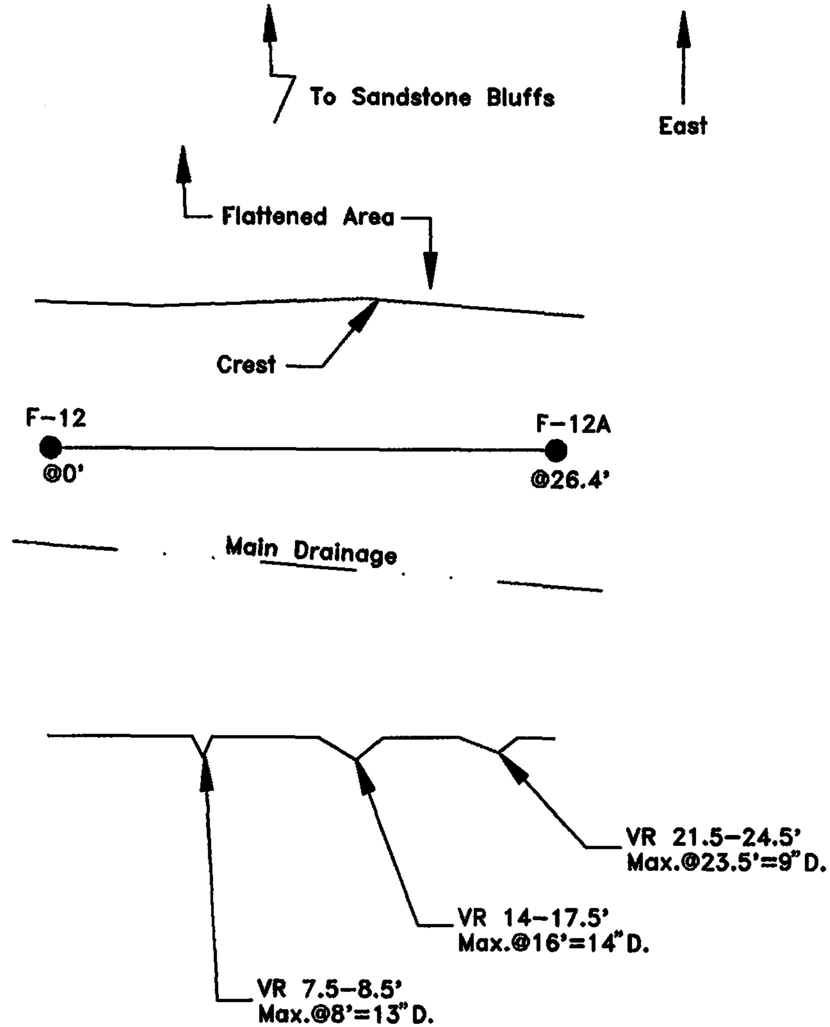
EROSION MONITORING STATION
F-11 to F-11A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



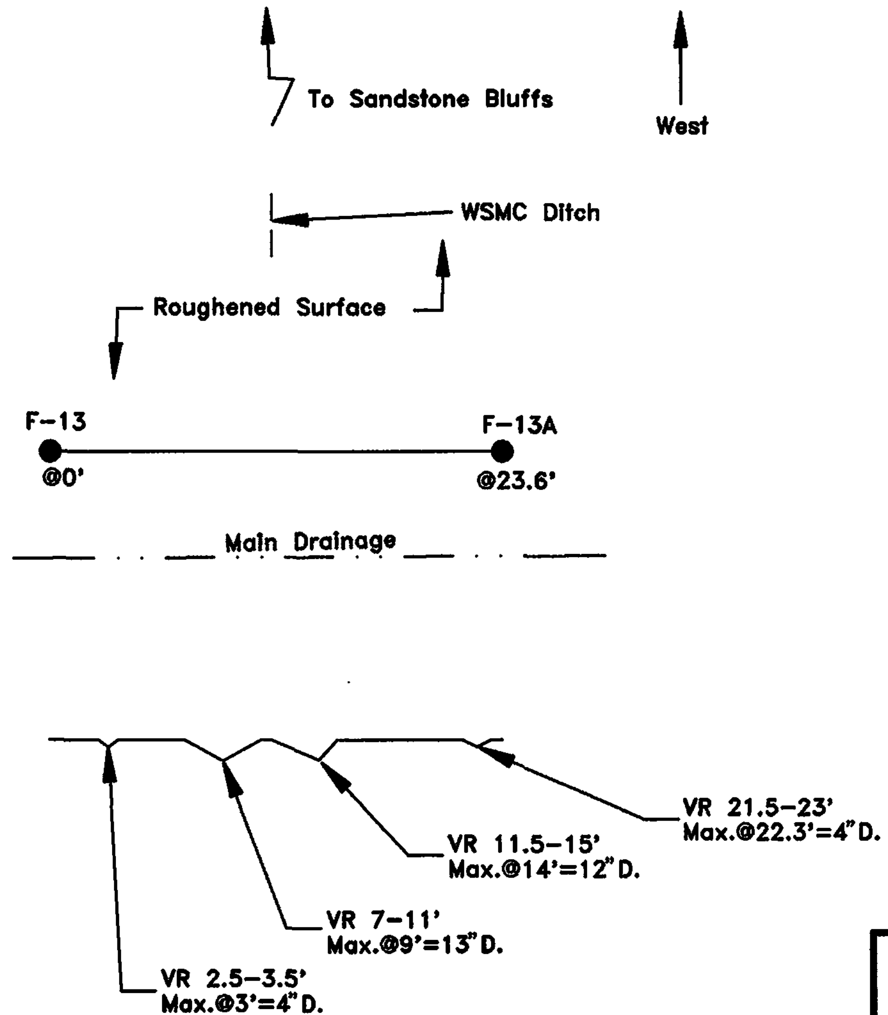
EROSION MONITORING STATION
F-12 to F-12A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



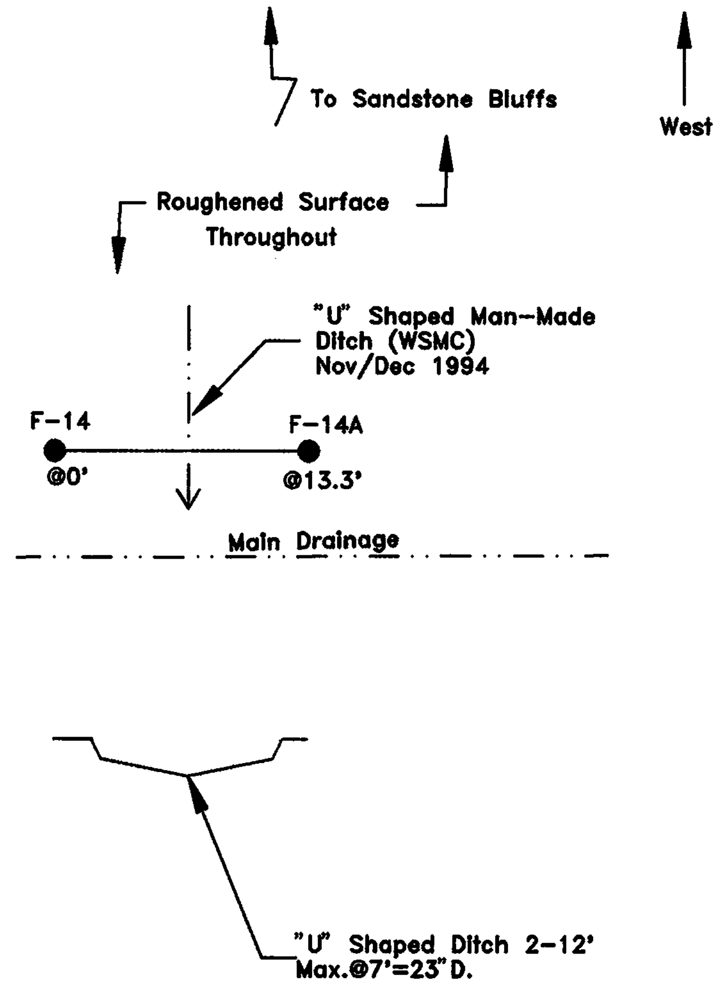
EROSION MONITORING STATION
F-13 to F-13A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM



EROSION MONITORING STATION
F-14 to F-14A

LEGEND

BLACK	Plan Map
RED	X-Section
FR	Flat Rill
VR	V-Shaped Rill

Scale: 1"=10'

Date: 7-28-95 Drawn: DRM

ADDENDUM II

EROSION CONDITION CLASSIFICATION SYSTEM

TECHNICAL NOTE

METHOD FOR EVALUATION OF EROSION ON RECLAIMED COAL LANDS IN WESTERN UNITED STATES

Prepared by
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Technical Assistance Division
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Office of Surface Mining Reclamation and Enforcement

DRAFT 12/5/90

This Technical Note is based on the Bureau of Land Management's Erosion Condition Classification System, by Ronnie Clark (BLM Technical Note - Number 346). The Office of Surface Mining Reclamation and Enforcement wishes to acknowledge Mr. Clark's work on development of this system. OSM's Technical Note incorporates BLM classification system with some adaptation for use on reclaimed coal lands.

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INTRODUCTION

Erosion is the wearing away and deposition of the land surface by moving water, wind, ice, or other geological agents, including such processes as gravitational creep. As a natural geologic process, it is a primary agent of geologic change. For instance, sedimentary rocks are a result of erosional and depositional processes. The Grand Canyon was created by erosion, most of the croplands in the valleys of the Western States are on alluvium, the results of the deposition of materials eroded in upstream areas.

Vegetation protects the soil, reducing its tendency to move under the impact of falling raindrops, flowing water, and wind. Removal of vegetation increases the rate of erosion above that under natural conditions. This increased rate of erosion is called "accelerated erosion". Accelerated erosion occurs primarily as a result of the activities of man. Accelerated erosion is detrimental to the productivity of the land and water quality. It often reduces the productivity of the land use and also increases the sediments in the water courses and the flood plains.

Man cannot completely stop erosion, but his goal should be to keep accelerated erosion to a minimum. If the rate of erosion is greater than the rate of soil formation, the productivity of the land will diminish and managing the soil on the basis of sustained yields will not be possible. Where accelerated erosion has been excessive, remedial action must be taken to slow the rate to a level approaching the natural situation. Land use and management practices, which keep erosion losses at a natural rate, will not only keep the soils permanently productive, but they will also maintain the natural quality of the water resources. This will benefit the aquatic and riparian plants and animals, as well as, the terrestrial wildlife and domestic livestock. Land uses such as grazing land, forestry, wildlife habitat, recreation, and developed water resources can be maintained under a system which controls erosion to a level that maintains a soil productivity.

In order to determine whether the extent of accelerated erosion on the reclaimed lands is excessive, or within tolerance levels, it is necessary to make an inventory of the degree of erosion that has taken place. A prerequisite of the inventory is a system for defining and classifying the degrees of erosion. The purposes of this technical note are to: (1) present the erosion condition classification system and (2) to give guidance for the inventory procedures.

BACKGROUND

The Office of Surface Mining Reclamation and Enforcement (OSM) has been inspecting reclaimed lands since 1978. One of the difficulties encountered by OSM inspectors has been evaluating erosion on mined lands reclaimed under the permanent regulatory program. In issuing a notice of violation (NOV), an inspector must demonstrate that the erosion on a reclaimed minesite is caused by ineffective methods for protection and stabilization of the soil surface and, that the erosion is disruptive to the postmining land use or the reestablishment of the vegetative cover, or that erosion causes or contributes to the violation of water quality standards (30 CFR 816.95). The inspectors currently do not have a method for determining when reclaimed areas are not adequately protected or stabilized to control erosion, or when erosion is disruptive to the postmining land use.

Under the Initial (or interim) Federal program, numerous notices of violation had been issued for failure to control erosion, and many of these had gone to hearing before an Administrative Law Judge. Many of these cases have been lost due to OSM's lack of quantitative data to prove that vegetation was not adequate to control erosion, or that erosion was disruptive of the postmining land use (30 CFR 715.14(i)). The Solicitors representing OSM have expressed the need for an established procedure to be employed by inspectors for evaluating the erosional condition on reclaimed lands and determining disruption of the proposed postmining land use.

The Bureau of Land Management (BLM) was required under the Federal Land Policy and Management Act of 1976 (Public Law 94-579) to inventory and evaluate the condition of public lands under its control. BLM had developed an erosion inventory procedure for evaluating the condition of watersheds. The inventory was utilized to evaluate 2,264 watersheds which encompassed 135 million acres of arid and semiarid lands in the western United States. The procedure utilized numerical values describing the erosion condition classes called soil surface factors (SSF). The factors vary from a value of 1 to 100 and are obtained with an accuracy of 90%. The procedure is currently being used by the BLM and has been incorporated into their Manual as the standard procedure for evaluating erosional condition.

Many of the western mine lands are located in the watersheds that were evaluated by the BLM. These areas offer a premine comparison with the postmine reclaimed erosion factors. However, a comparison of premine with postmine erosional factors are not necessary to determine the erosion condition classes. The adaptation of BLM's procedures have been slightly modified to be utilized on reclaimed mine lands.

OBJECTIVES

The objectives of this technical note are: (1) to present a system for classifying the erosional condition; (2) to provide guidance on a field method for measuring the erosional condition class for a sample area; and, (3) to identify when reclamation efforts fail to adequately protect and stabilize the soil surface and, when erosional conditions are disruptive to the approved postmining land use. The classification system evaluates the condition of seven specific erosional features. For example, the degree of rilling and gully is to be evaluated for every case where water is the dominant erosional agent and rills or gullies are present. Rilling and gulling will not be used in the evaluation of areas in which wind is the dominant erosional agent. The use of this system should result in a higher degree of accuracy of results between individuals evaluating the same area, and a higher degree of uniformity in measured results for comparable conditions between different areas.

Accuracy

Experience indicates that the accuracy of consistently estimating the SSF for a given area on a general erosion inventory is ±5 SSF value. Some individuals are not able to reach this consistency and may be ±10 in their estimates without additional training.

Uses of Data

Some of the uses of these procedures are:

1. Erosion condition and/or trends can be determined.

2. The gully rating provides input to channel characteristics.

3. Stabilization goals can be set for erosion control programs.

4. Present erosion activity can be evaluated by soil type, management system, land treatment practice, and other comparable conditions.

5. Through a system of "comparison areas" it is possible to estimate erosion reduction potentials with alternative land management treatments.

6. Estimates of sediment yield or ~~soil loss could be~~ determined on areas where no hydrologic monitoring stations are available.

7. Treatment effectiveness on changes in SSF's can be made

for use in justifications statements.

8. Input can be made into livestock grazing suitability criteria.

Problems

Some of the problems experienced with the procedure are:

1. Accuracy is not consistently closer than ±5 SSF value.

2. Variations among individual field inspectors following the procedure is commonly ±5 SSF value.

3. Variations in the measured SSF value within a geographic area may be ±5 SSF value among small areas having the same actual erosional activity.

IDENTIFICATION OF EROSIONAL FEATURES

Seven indicators of soil movement are described and their reliability for indicating soil loss (erosion) are explained. The indicators are: (1) soil movement, (2) pedestalling, (3) surface litter and organic mulch, (4) surface rock fragments, (5) flow patterns, (6) rills, and (7) gullies. The qualitative approximation of soil movement due to erosion has been proven to be reasonably reliable.

Soil Movement

The real cause of soil movement on watersheds lies in soil instability. Some of the factors affecting soil instability are: (1) splash erosion, wind velocity; (2) soil texture, structure, infiltration, and permeability; (3) slope gradient and length; and (4) cover, such as vegetation, liter, mulch, and stones. However, any reduction of cover, can accentuate the natural soil instability.

Soil movement is most obvious during windstorms, heavy rainstorms, sudden snowmelt or when intensive land uses (i.e., trampling by livestock) are occurring on loose soils. Dust clouds and muddy stream runoff are examples of obvious soil movement, but much of the soil movement occurs without such obvious signs.

A certain amount of soil movement is natural on most land surfaces. However, soil movement is accelerated if the soil mantle and parent material is disturbed to create soil losses in excess of those which occurred under natural conditions.

A single feature of soil loss cannot be used to accurately determine the erosion condition, it must be supported by additional evidence. For example, soil movement alone is a poor indicator of ecological trend. By the time erosion is apparent, profound changes usually have taken place in cover, or disturbance of the soil mantle (as shown in Fig. 6). Inadequate soil cover may be obvious as an indicator of accelerated soil movement. Where ground cover is depleted to less than the minimum density required to protect the soil mantle, soil movement from relatively small areas may increase at an accelerated rate. A fourfold increase in soil loss as bulk density increases from 0.8 to 1.4 may occur if ground cover is significantly decreased.

Other indicators of unstable soil may be gullied drainageways with active bank cutting and sediment deposition in water bodies and at channel confluences.

Soil and litter (and mulch) movement on steeper slopes is obvious when significant accumulations of soil and litter material occur at lower levels. This churning changes the soil structure and contributes to subsequent soil displacement during wind or rainstorms.

Soil movement usually becomes more obvious as slope steepness increases and occurs most readily when antecedent soil mixture is very low or very high. However, two items may be necessary to minimize soil erosion: (1) a ground cover of at least 70 percent and, (2) a soil bulk density of 0.70 or less (Packer, 1961).

Lichen lines or breaks, are indicators of soil movement. These lines appear if the surface soil has eroded around stones and rocks covered with lichen. Since lichen only grows on the above ground portion of stones and rocks, there will be an abrupt, horizonal, break between lichen and rock area that originally was below the soil surface. This may not always be true on newly reclaimed sites where the soil had recently been placed on the regraded spoil. Lichen growth occurring from after reclamation should be used. Old lichen growth will show discoloration over time and will eventually decay.

Lichen growth will keep pace with normal geologic erosion and may slightly accelerate erosion. Pronounced lichen lines on stones and rocks are reliable evidence of soil movement at a moderate to severe rate. The space between the lichen lines and the present soil surface indicates the amount of soil movement that has occurred.

Lichen lines are more obvious on elevated terrain, such as ridges, and terraces. They may not appear on lower slope areas where soil losses may be replaced by deposition of soil or litter that has moved from farther upslope.

Caution: Frost heaving of stones and rocks may create lichen lines, giving a false indication of soil losses.

<u>Pedestalling</u>

Pedestalling may be observed as small soil pinnacles or plains, which like miniature mesas, remain in position after the soil between mesas has been eroded away.

Pedestals are formed under the protection of stones or pebbles, residue, or vegetation that may consist of a single plant or a small island of a plant community. The latter are more positive indicators of pedestals than are single-plants because in certain soils single plants often are elevated on a pedestal by frost heaving.

This indicator has value where a former soil surface can be established by the uniform height of pedestals or islands. Similarities of the soil layers in sections of surface soil (including underlying overburden) materials of pedestals and islands are excellent for establishing the reliability of this erosional feature. The reliability is good where the soil profile characteristics between the pedestals and islands resemble the soil characteristics at the same depth within the pedestals and islands.

Elevated islands and pedestals may be caused jointly by erosion and deposition, where a part of the eroded area in the locality may supply loose soil to be deposited by wind in clumps of vegetation. The identification of aeolian deposits is discussed under Flow Patterns (in Wind Erosion Prone Areas).

Soil pedestals under stones or litter are formed on some kinds of soil by the impact of raindrops and sheet waterflow over barren, adjacent areas. Where a pebble or stick protects the soil from the impact of raindrops, the original soil under the protecting object is retained, whereas the soil in bare areas is churned by raindrop impacts and easily washes away. Pedestals are also formed on certain soils where the soil ped (a unit of soil structure) is resistant, whereas the soil material in the fracture between peds is less cohesive and susceptible to erosion. Close observation soon after the storm usually is needed to denote these soil pedestals because after a few hours or days of sunshine they may crumble. These pedestals formed during a known period are clues to the sheet erosion rate that has occurred. This indicator is especially valuable as convincing evidence of current soil movement during storms of moderate intensity or duration, which may not form gullies or alluvial deposits.

Frost heaving is common in many soils. Care must be exercised to distinguish between soil remnants that are solely the result of erosion from those that are at least partially the result of frost heaving. Distinguishing precisely how much pedestal evaluation is due to heaving and how much to erosion is difficult and probably impossible.

Frost heaving often occurs following decimation of the vegetational stand and organic ground cover between plants, which in turn exposes the soil to the effects of periodic low air temperatures. With frost heaving, single plants elevated on pedestals usually characterize the vegetation. These plants commonly are tilted; the crown is not horizontal as it was when it grew as a part of a stable plant community.

The probability that frost heaving has occurred also can be supported by the soil type. The following soils are highly susceptible to frost heaving:

(1) Clay subsoils fairly close to surface.
(2) Pumice (ash) soils.
(3) Soils with greater than 3 percent of material smaller than 0.02 mm.
(4) Soils of high silt (0.05-0.002 mm) and very fine sandy (0.10-0.05 mm) if a soil water supply is available.
(5) Soils having a large capillary water capacity if antecedent moisture is available to move to the freezing point. (U.S. Department of Agriculture, 1971).

Surface Litter and Organic Mulch

Litter and organic mulch movement on moderate to steeper slopes is obvious when significant buildup of soil and litter material have moved downslope and accumulated on the upslope side of vegetation and rocks. This relocation of litter and mulch reduces the soil moisture retention potential from which they were removed and increase the potential of soil movement by rainstorms on the unprotected soil surface (see Soil Movement).

Surface Rock Fragments (Erosional Pavement)

Surface rock fragments or erosion pavement being referred to here consist of gravel or cobbles concentrated on the surface due to the moving of finer soil particles that formerly surrounded them. This surface rock appearance is normal if there is no truncated soil profile, and subsurface soil consists of altered rock fragments and parent material. Surface rock relocation due to erosion is substantiated by erosion indicators nearby.

> **Caution:** Differentiate between eroded soils and soils that naturally have a high gravel or cobble content in the soil surface layers.

It is important to note that evenly distributed surface rock effectively protects the soil surface and slows soil movement. If surface rock does not exceed 50 percent of ground cover, it curtails evaporation, promotes greater moisture holding capacity and reduces runoff velocity. It may have an effect similar to vegetation in reducing erosion.

These are shallow basins varying from a few inches to several feet across in bare soil between vegetated sites from which wind has carried away fine soil particles. This wind action is easily recognized by a residue of small pebbles or sand particles that are too large to be transported by wind, and that remain on the scoured surface of the shallow basin. Fresh scouring by wind on the shallow basins appears as lines etched in the soil surface paralleled by tiny streamlined ridges of fine soil in the leeward side of obstructions (vegetation, litter, pebbles).

> **Caution:** Do not confuse barren areas or disks caused by ant colonies with wind-scoured depressions. A collection of sand particles is common and removal of fine soil material by wind from ant disks does occur. Particles of coarse sand and pebbles will occur quite uniformly over a wind-scoured depression; whereas in an ant disks, coarse particles will be aggregated near the center of ant habitation.

The material from wind-scoured depressions or basins is transported to other areas to form aeolian deposits. These deposits, known as dunes, mounds, or hummocks usually occur adjacent to the eroded basin or within the eroding area. Airborne material, because of air current patterns, may occasionally be dumped on distant non-eroding areas such as leeward slopes.

On a smaller scale, deposits may be observed on the leeward side of plants or other obstructions. Such deposits consist of fine, well-sorted soil particles. However, rodent activity may have introduced coarse fragments to the site.

Depositional volume may be determined by cutting a vertical section through a mound and the obstructing material to expose the original soil surface. A comparison should be made to differentiate between the adjacent scoured area and the deposition volume. Relative deposit age may be determined by decomposition rate or buried organic material (vegetation and litter). In older deposits, it may be impossible to identify buried vegetation (organic material).

<u>Flow Patterns (in Areas Subject to Water Erosion)</u>

Soil materials that been dislodged, transported and redeposited over the watershed by water are known as alluvial deposits. These deposits are easily discernible as little fans at the end of small channels or behind obstructions in channels (flow paths) where the velocity of runoff has been reduced. They also may be formed as accumulations of soil material or litter on the uphill side of obstructions on the soil surface. As used in this inventory, they are referenced as deposits on the site writeup area (inventory unit), not to fans at major channel mouths.

<u>Rills</u>

Rills are small channels, less than 6 inches deep, which are formed by flowing water. They are so small as to be obliterated by surface soil disturbance or during soil movement associated with weathering. The soil profile may be gradually truncated by rilling. If obliterated, the next storm will cause a new set of rills to form, and these in turn may be obliterated by excessive soil surface disturbance. A high volume of soil can be moved in a short time frame by this process. Often, "sheet erosion" precedes rill erosion.

The presence of rills is an excellent indicator of current erosional activity when evaluating changes in erosion produced by land management treatments. Rills can be measured to produce a quantitative estimate of soil loss by use of the Alutin Method (Hill and Kaiser, 1965).

<u>Gullies</u>

Channels, called gullies, of greater than 6 inches in depth, may be cut into the soil mantle by runoff. Gullies within the sample site generally will be tributaries of intermittent or permanent stream channels that continue outside of the sample site delineation. An active gully is easily detected by unstable sidewalls with little or no vegetation or recent soil loss by erosion. Active cutting, which is called "head-cutting," may be occurring at the channel head.

A healing gully is easily detected by the reestablishment of vegetation on the sidewall and reduction in soil loss in the channel bottom and by the absence of head-cutting activity.

A rill enlarges into a gully if repeated cutting and entrenchment occurs. Negligible channel blockage or filling occurs with soil movement during storm runoff.

CLASSIFICATION SYSTEM

For the past ten years, BLM has used this classification system for erosion condition inventory work. This system was developed so that it is easily understood by range conservationists, foresters, wildlife and fishery biologists, botanists, recreational specialists, hydrologists and soil scientists.

There are five erosion classes: stable, slight, moderate, critical and severe. Erosion classes of critical and severe are considered disruptive of all land uses (as defined under 30 CFR 701.5). The moderate erosion class is considered to be disruptive only to the forestry and cropland uses. Erosion classes stable and slight are not considered disruptive of any land uses. Accelerated erosion results in lower erosional condition classes. When erosion is disruptive to the land use, it is considered to have be an accelerated erosion.

Field observations are made visually on seven surface features that are visibly affected by recent wind and water erosional activity: areas of soil movement, surface litter, surface rock fragments, pedestalling, flow patterns, rills, and gullies. These field observations are recorded on a specially designed field sheet. All of the features are not expected to be present on all sites. For example, in certain situations surface rock fragments may not be potentially present. When this occurs, adjustments are made as indicated in Illustrations 1 through 3. While observing these features, the total area to be represented must be kept in mind, as significant variation may occur within the area.

The meaning of terms used in this procedure may not be the same to all of us. To assist you in understanding the procedure, these terms are defined in Appendix 1, Glossary of Terms.

Procedure

The procedure for determining the erosional condition and potential adverse impacts to postmining land uses consist of six steps: 1. Determine the site writeup area (SWA) for the erosion inventory; 2. Determine if each of the seven erosional features is present; 3. Determine an average condition for each of the seven erosional features that exist in SWA; 4. For those features present, the description should be reviewed and a numerical value should be indicated on the field sheet; 5. Total both the weighted values and the potential values for each erosional feature indicated on the field sheet, and calculate the percentage of the total weighted value to potential values to determine the soil surface factor (SSF); and, 6. Determine the erosional condition class using the SSF and the chart on the bottom of the field sheet and determine if the erosion on the SWA is potentially disruptive of the postmining land use.

The following is a detailed discussion of each of the six steps for determining the erosional condition and potential adverse impacts to postmining land uses:

1. Determine the site writeup area for the erosion inventory. This may vary from a general erosion inventory on a large area (i.e., watershed, bond release areas, etc.), to a specific erosion inventory on a small area of localized erosion. The inventory may be applied to areas less than an acre to several hundred acres. The inspector conducting the inventory needs to decide the limits of the area to be sampled. It is necessary to stratify the inventory area into homogeneous units--called site writeup areas-the basic unit for collecting data on the vegetation and soil resources. Stratification is necessary since the areas of concern are those areas currently eroding.

   The stratified SWA (site writeup area) sampling technique may be delineated by slope (e.g. 10%, 1:4, etc.), aspect (east, west, north, south, etc.), soils (e.g. texture), vegetative cover, or drainage area within a reclaimed area. Sufficient area must be included in the SWA to represent the problem area. For example, a 50 yard section of an east facing aspect of a slope of 4 horizontal to 1 vertical is showing signs of erosion activity. Areas both north and south of this eroded section have fewer signs of erosion activity. Upon observing the entire aspect it is discovered that the eroding section has a sandy textured soil, while adjacent to this area, the soil texture is a clay-loam. In this case, the SWA would include only the area having sandy soil.

   Frequently, accelerated erosion results in lower vegetative cover and productivity. However, not all areas with low vegetative cover and productivity are a result of accelerated erosion. Other surface features that indicate water erosion activity must be present to diagnose accelerated erosion.

   The inspector that encounters a reclaimed area that displays any of the seven surface conditions or features that are effects of water erosion activity, must first evaluate the size of the area affected. The perimeter of the area should be staked on the ground for future reference and photographs taken to document the location and condition of erosion within the SWA. One photograph should be taken from a point where the entire SWA will be included in the photograph (if possible). Also, photographs showing examples of the erosional features should be taken which includes a measuring scale such as a ruler, tape measure, or a ball-point pen. Position from which photographs are taken on the ground should be marked with a stake labeled as a photo point, indicating the direction the photo was taken (ie. north south, east, west), the date, and the individual conducting the inventory. The inspector's notes should also include this information.

2. **Determine if each of the seven erosional features is potentially present.** There seven erosional feature evaluated in this inventory: 1. Soil movement; 2. Surface litter and organic mulch movement; 3. Surface rock fragment; 4. Flow patterns; 5. Pedestals; 6. Rills; and, 7. Gullies. Any combination of these features can exist on the same SWA. Where the potential for an erosional feature (e.g., rock fragments) does not exist, those erosional features are not a valid factor to consider in the evaluation, as shown in Illustration 2 and 3. Only those features that exist in the SWA should be considered.

3. **Determine an average condition for each of the seven erosional features that exist in SWA.** The degree of erosion, as manifested by each of the seven erosional features, is assigned a numerical score ranging between 0 and 14 for all features, except flow pattern and gullies, which have a range of 0 to 15. Two of the features were assigned a maximum score of 15 simply to give a maximum composite score of 100 for all seven features. These numerical scores are called soil surface factor (SSF) values. When used for all the erosional features evaluated together for a SWA, they are called composite SSF values. These are shown on Table 1, along with the potential weighted value assigned to each feature.

4. **For those features observed, the description of the degree of erosion should be reviewed and a numerical value should be indicated on the field sheet.** Tables 2 through 8 indicate five magnitudes of erosion activity within each of the seven items.

   The total range of SSF values of 0 to 14, or 0 to 15, is divided into five more or less equal classes to conform with the five erosion condition classes.

Table 1. Determining Erosion Condition Class.

Erosional Features	Potential Weighted Value
Soil Movement	14
Surface Litter	14
Surface Rock Fragments	14
Pedestalling	14
Flow Patterns	15
Rills	14
Gullies	15
TOTAL:	100

Table 2. Classes for Degree of Recent Soil Movement.

Class	Description	SSF Values
Stable	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between 0 and .1 in. (0 to 2.5 mm).	0 1 2 3
Slight	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between .1 and .2 in. (2.5 to 5 mm).	4 5
Moderate	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between .2 and .4 in. (5 to 10 mm).	6 7 8
Critical	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between .4 and .8 in. (10 to 20 mm).	9 10 11
Severe	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas is over .8 in. (20 mm).	12 13 14

Table 3. Classes for Degree of Surface Litter Movement.[1]**

Class	Description	SSF Values
Stable	No movement, or if present, less than 2 percent of the litter has been translocated and redeposited against obstacles.	0 1 2 3
Slight	Between 2 and 10 percent of the litter has been translocated and redeposited against obstacles.	4 5 6
Moderate	Between 10 and 25 percent of the litter has been translocated and redeposited against obstacles, or removed from the area.	7 8
Critical	Between 25 and 50 percent of the litter has been translocated and redeposited against obstacles, or removed from the area.	9 10 11
Severe	More than 50 percent of the litter has been translocated and redeposited against obstacles, or removed from the area.	12 13 14

** Use judgement on surface litter movement when evaluating low vegetative production sites, as litter may be accumulating in place and very little is evident.

[1] Surface litter includes organic mulch.

Table 4. Classes for Degree of Surface Rock Fragment Disturbance*

Class	Description	SSF Values
Stable	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is less than .1 in. (2.5 mm).	0 1 2
Slight	Depth of soil removal around the fragments, and/or depth or recent deposits around the fragments is between .1 and .2 in. (2.5 to 5 mm).	3 4 5
Moderate	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is between .2 and .4 in. (10 to 20 mm).	6 7 8
Critical	Depth of soil removal around the fragments, and/or depth or recent deposits around the fragments is between .4 and .8 in. (10 to 20 mm).	9 10 11
Severe	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is over .8 in. (20 mm).	12 13 14

* Surface rock fragment disturbance is not evaluated where they are more than 40 in. (1 m.) apart or cover less than 0.2 percent of the surface area.

Table 5. Classes for Degree of Pedestalling.*

Class	Description	SSF Values
Stable	Pedestals are mostly less than .1 in. (2.5 mm) high and 1 or less frequent than 2 pedestals per 100 sq. ft.	0 1 2 3
Slight	Pedestals are mostly between .1 to .3 in. (2.5 to 8 mm) high, and/or have a frequency of 2 to 5 pedestals per 100 sq. ft.	4 5 6
Moderate	Pedestals are mostly between .3 to .6 in. (8 to 15 mm) high, and/or have a frequency of 5 to 7 pedestals per 100 sq. ft.	7 8 9
Critical	Pedestals are mostly between .6 to 1 in. (15 to 25 mm) high, and/or have a frequency of 7 to 10 pedestals per 100 sq. ft.	10 11
Severe	Pedestals are mostly over 1 in. (25 mm) high, and/or have a frequency of over 10 pedestals per 100 sq. ft.	12 13 14

* Pedestals due to erosion are not to be confused with those caused by frost-heaving. Examination of the roots and crowns of vegetation will assist in this determination.

Table 6. Classes for Degree of Flow Pattern Development.

Class	Description	SSF Values
Stable	None, or if present, less than 2 percent of the surface area shows evidence of recent translocation and deposition of soil and litter[2].	0 1 2 3
Slight	Between 2 and 10 percent of the surface area shows evidence of recent translocation and deposition of soil and litter.	4 5 6
Moderate	Between 10 and 25 percent of the surface area shows evidence of recent translocation and deposition of soil and litter.	7 8 9
Critical	Between 25 and 50 percent of the surface area shows evidence of recent translocation and deposition of soil and litter.	10 11 12
Severe	Over 50 percent of the surface area shows evidence of recent translocation and deposition of soil and litter.	13 14 15

[2] Litter include organic mulch.

Table 7. Classes for Frequency and Distribution of Rills

Class	Description	SSF Values
Stable	Rills, if present, are mostly less than .5 in. (13 mm) deep, and generally at infrequent intervals over 10 ft.	0 1 2 3
Slight	Rills are mostly .5 to 1 in. (13 to 25 mm) deep, and generally at infrequent intervals over 10 ft.	4 5 6
Moderate	Rills are mostly 1 to 1.5 in. (25 to 38 mm) deep, and at 10 ft. intervals.	7 8 9
Critical	Rills are mostly 1.5 to 3 in. (38 to 76 mm) deep; and at intervals of 5 to 10 ft.	10 11 12
Severe	Rills are mostly 3 to 9 in. (76 to 229 mm) deep, and at intervals of less than 5 ft.	13 14

See Illustration 3 for calculation of SSF if there is no potential for rills.

Table 8. Classes for Frequency and Distribution of Gullies

Class	Description	SSF Values
Stable	No gullies, or if present, less than 2 percent of the channel bed and walls show active erosion (are not vegetated) along their length, and/or gullies make up less than 2 percent of the total area.	0 1 2 3
Slight	Between 2 and 5 percent of the channel bed and walls show active erosion (are not vegetated) along their length, and/or gullies make up between 2 and 5 percent of the total area.	4 5 6
Moderate	Between 5 and 10 percent of the channel bed and walls show active erosion (are not vegetated) along their length, and/or gullies make up between 5 and 10 percent of the total area.	7 8 9
Critical	Between 10 and 50 percent of the channel bed and walls show active erosion (are not vegetated) along their length, and/or gullies make up between 10 and 50 percent of the total area.	10 11 12
Severe	Over 50 percent of the channel bed and walls show active erosion (are not vegetated) along their length, and/or gullies make up over 50 percent of the total area.	13 14 15

If gullies are not potentially present, deduct 15 rating points from a possible value of 100 (shown in Illustration 3).

Table 9. Erosion Condition Classes and Soil Surface Factors.

Class	Soil Surface Factor
Stable	1 - 20
Slight	21 - 40
Moderate	41 - 60
Critical	61 - 80
Severe	81 - 100

5. Total both the observed values and the potential values for each erosional feature indicated on the field sheet, and calculate the percentage of the total observed value relative to the potential values to determine the soil surface factor (SSF). This becomes the numerical expression of erosion activity and is a unitless number which indicates the percentage of the total potential erosion activity. No attempt is made to differentiate between accelerated or natural erosion activity.

   A classification system has been developed to separate the degree of erosion into five erosion condition classes. Table 9 shows the relation of numerical values (SSF's) to one of the erosion condition classes.

   Tables 2 through 8 provide a narrative descriptions having similar meaning throughout the Western States. Table 9 summarizes these narrative descriptions into universal classes of erosion condition. If the procedure is used properly and an individual says he has a moderate erosion condition class on the Powder River Basin of Montana, anyone familiar with moderate erosion in Arizona will understand what he is describing. Without this or a similar procedure, an individual using a term like slight or critical erosion will likely be the only one who really knows what he is describing.

6. Determine the erosional condition class using the SSF and the chart on the bottom of the field sheet and determine if the erosion on the SWA is potentially disruptive of the postmining land use. The field sheet has a chart at the bottom of the first page that converts the SSF into erosional condition

class (i.e., stable, slight, moderate, critical, or severe). The erosion condition class then can be used to determine if the erosion on the SWA is potentially disruptive of the postmining land use (i.e., moderate is disruptive to cropland and forestry land uses, and critical and severe are disruptive to all land uses).

Field Sheet

Field sheet (Figure 1) is utilized to provide the field inspector with information needed to compute the SSF as a basis for estimating erosion condition class.

Examples

Three examples, Illustrations 1 through 3, have been prepared to help demonstrate how to determine the SSF representing a given area. Each example has a rating for soil movement, surface litter, pedestalling, and flow patterns. In addition, for Illustration 1, the area has surface rock fragments and a potential for rill and gully formation. In Illustration 2, the area has gullies, but no potential for surface rock fragments or rill formation. For Illustration 3, the area has no potential for surface rock fragments, or for rill or gully formation.

When water is the dominant erosional agent, and rills and/or gullies are absent, the factors are given a value of zero, but are included in the calculation of the composite value for degree of erosional activity.

When all seven potential erosional features are measured for an area, the sum of the observed SSF values for all seven features is divided by 100 (the sum of the seven potential erosional features), and that quotient is multiplied by 100 to express the composite SSF values on a percentage basis. One hundred is used in the denominator of the fraction in this equation simply because it is the maximum SSF sum obtainable in this method. Therefore, as shown in Illustration 1, when all seven features are evaluated the composite SSF value is equal to the sum of the individual SSF values. The numerical value for the composite SSF value of 50 obtained for example one, in Illustration 1, puts that area in the moderate erosion condition class which is defined by SSF composite value limits between 41 and 60. If the postmining land use is cropland or forestry, the erosion condition is disruptive to the postmining land use, which is in violation of 30 CFR 816.95. However, the erosion condition is not disruptive to other land uses (e.g., grazingland, fish and wildlife habitat, industrial and commercial, etc.) defined under 30 CFR 701.5. ~~A moderate class should be monitored by the inspector over the next year or annual precipitation period (rainy season) to determine if the erosion condition is not deteriorating.~~

Figure 1.
Determination of Erosion Condition Class

OBSERVER: ____________ DATE: ____________ MINE: ____________

LOCATION: ____________

OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT
DETERMINATION OF EROSION CONDITION
SOIL SURFACE FACTOR (SSF)

DESCRIPTION OF EROSION CONDITIONS

EROSION FACTORS						TOTALS OBSERVED / POTENTIAL
SOIL MOVEMENT	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between 0 and .1 in. (0 to 2.5 mm). 0 or 1 2 3	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated area, is between .1 and .2 in. (2. to 5 mm). 4 5 6	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between .2 and .4 in. (5 to 10 mm). 7 8 9	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is between .4 and .8 in. (10 to 20 mm). 10 11 12	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas is over .8 in. (20 mm). 13 14	____ / ____
SURFACE LITTER & MULCH	No movement, or if present, less than 2 percent of the litter has been translocated and redeposited against obstacles. 0 or 1 2 3	Between 2 and 10 percent of the litter has been translocated and redeposited against obstacles. 4 5 6	Between 10 and 25 percent of the litter has been translocated and redeposited against obstacles. 7 8 9	Between 25 and 50 percent of the litter has been translocated and redeposited against obstacles or removed from that area. 10 11 12	More than 50 percent of the litter has been translocated and redeposited against obstacles or removed from the area. 13 14	____ / ____
SURFACE ROCK FRAGMENT	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is less than .1 in. (2.5 mm). 0 or 1 2 3	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is between .1 and .2 in. (2.5 to 5 mm). 4 5 6	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is between .2 and .4 in. (5 to 10 mm). 7 8 9	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments, is between .4 and .8 in. (10 to 20 mm). 10 11 12	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is over .8 in. (20 mm) 13 14	____ / ____
PEDESTALING	Pedestals are mostly less than .1 in. (2.5 mm) high and/or less frequent than 2 pedestals per 100 sq. ft. 0 or 1 2 3	Pedestals are mostly between .1 to .3 in. (2.5 to 8 mm) high and/or have a frequency of 2 to 5 pedestals per 100 sq. ft. 4 5 6	Pedestals are mostly between .3 to .6 in. (8 to 15 mm) high, and/or have a frequency of 5 to 7 pedestals per 100 sq. ft. 7 8 9	Pedestals are mostly between .6 and 1 in. (15 to 25 mm) high, and/or have a frequency of 7 to 10 pedestals per 100 sq. ft. 10 11 12	Pedestals are mostly over 1 in. (25 mm) high, and/or have a frequency of over 10 pedestals per 100 sq. ft. 13 14	____ / ____
FLOW PATTERNS	None, or if present, less than 2 percent of the surface area shows evidence of recent trans - location and deposition of soil and litter. 0 or 1 2 3	Between 2 and 10 percent of the surface area shows evidence of recent translocation and deposition of soil and litter. 4 5 6	Between 10 and 25 percent of the surface area shows evidence of recent translocation and deposition of soil and litter. 7 8 9	Between 25 and 50 percent of the surface area shows evidence of recent translocation and deposition of soil and litter. 10 11 12	Over 50 percent of the surface area shows evidence of recent translocation and deposition of soil and litter. 13 14 15	____ / ____
RILLS	Rills, if present, are mostly less than .5 in. (13 mm) deep, and generally at infrequent intervals over 10 ft. 0 or 1 2 3	Rills are mostly .5 to 1 in. (13 to 25 mm) deep, and generally at infrequent intervals over 10 ft. 4 5 6	Rills are mostly 1 to 1.5 in. (25 to 38 mm) deep, and generally at 10 ft. intervals. 7 8 9	Rills are mostly 1.5 to 3 in. (38 to 76 mm) deep, and at intervals of 5 to 10 ft. 10 11 12	Rills are mostly 3 to 6 in. (76 to 152 mm) deep, and at intervals of less than 5 ft. 13 14	____ / ____
GULLIES	No gullies, or if present, less than 2 percent of the channel bed and walls show active erosion (are not vegetated), gullies make up less than 2 percent of the total area. 0 or 1 2 3	Between 2 and 5 percent of the channel-bed and walls show active erosion (are not vegetated), or gullies make up between 2 and 5 percent of the total area. 4 5 6	Between 5 and 10 percent of the channel bed and walls show active erosion (are not vegetated), or gullies make up between 5 and 10 percent of the total area. 7 8 9	Between 10 and 50 percent of the channel bed and walls show active erosion (are not vegetated), or gullies make up between 10 and 50 percent of the total area. 10 11 12	Over 50 percent of the channel bed and walls show active erosion (are not vegetated) along their length, or gullies make up over 50 percent of the total area. 13 14 15	____ / ____

TOTAL SSF= ______ = ______ / ______ X 100
(SSF=Observed/Potential x 100)

POSTMINE LAND USE: ____________

EROSION CONDITION CLASSES:
STABLE 0-20 SSF, SLIGHT 21-40 SSF, MODERATE 41-60 SSF, CRITICAL 61-80 SSF, SEVERE 81-100 SSF

SSF's DISRUPTIVE TO POSTMINING LAND USES: Cropland and Forestry 41-100 SSF, All Other Uses 61-100 SSF

INCORPORATED
EFFECTIVE:
OCT 05 1995
UTAH DIVISION OIL, GAS AND MINING

In examples two and three shown in Illustrations 2 and 3, fewer than the maximum of seven erosional features were represented in the areas and, therefore, could not be measured. When such is the case, the composite SSF value is calculated by dividing the sum of the SSF values of those features actually measured by the sum maximum possible SSF values, and multiplying that quotient by 100. By this method the composite SSF value for example two is 33, which places the area in the middle portion of the slight erosion condition class whose limits are between 21 and 40. Had the sum of the SSF values divided by 100 instead of 72, the composite SSF value would have been 24, and the area would have been classified as more stabilized. Likewise, for example 3, the composite SSF value is 66 based on the exclusion of the three features not measured, whereas it would have only been 37 if the sum of the SSF values for the four items measured would have been divided by 100.

Example 2, a composite SSF value of 33 is not disruptive to any postmining land uses, while Example 3, a composite value of 66 is disruptive to all postmining land uses.

Illustration 1. Computation of SSF with All Potential Items.

EROSIONAL FEATURE	EXAMPLE ONE*		
	POTENTIALLY PRESENT	IDENTIFIED FACTORS	POSSIBLE FACTOR
Soil Movement	Yes	11	14
Surface Litter	Yes	8	14
Surface Rock Fragments	Yes	8	14
Pedestalling	Yes	11	14
Flow Patterns	Yes	12	15
Rills	Yes	0	14
Gullies	Yes	0	15
TOTAL		50	100

Total SSF $\frac{50}{100} \times 100 = 50$

* Example one represents an area where all seven erosional features are potentially present. (Example one is shown in Figure 2.)

Note: Surface litter includes organic mulch

Illustration 2. Computation of SSF with No Surface Rock Fragments or Rill Potential.

EROSIONAL FEATURE	EXAMPLE TWO**		
	POTENTIALLY PRESENT	IDENTIFIED FACTORS	POSSIBLE FACTOR
Soil Movement	Yes	3	14
Surface Litter	Yes	6	14
Surface Rock Fragments	No	--	--
Pedestalling	Yes	6	14
Flow Patterns	Yes	6	15
Rills	No	--	--
Gullies	Yes	3	15
TOTAL		24	72

Total SSF $\frac{24}{72} \times 100 = 33$

**Example two represents erosion developed on vast alluvial fan containing no surface rock fragments or probability for rills. (Figure 3 is the example area.)

Note Surface litter includes organic mulch

Illustration 3. Computation of SSF with No Surface Rock Fragments, Rills, or Gully Potential.

EROSIONAL FEATURE	EXAMPLE THREE***		
	POTENTIALLY PRESENT	IDENTIFIED FACTORS	POSSIBLE FACTOR
Soil Movement	Yes	14	14
Surface Litter	Yes	8	14
Surface Rock Fragments	No	--	--
Pedestalling	Yes	6	14
Flow Patterns	Yes	9	14
Rills	No	--	--
Gullies	No	--	--
TOTAL		37	56

Total SSF $\frac{37}{56} \times 100 = 66$

*** Example three represents a soil where wind erosion is the only eroding agent and no surface rock fragments are potentially present. (See figure 4).

Note: Surface litter includes organic mulch

SUMMARY

The objectives of this technical note were: (1) to present a system for classifying the erosional condition; (2) to provide guidance on a field method for measuring the erosional condition class for a sample area; and, (3) to identify when reclamation efforts fail to adequately protect and stabilize the soil surface and, when erosional conditions are disruptive to the approved postmining land use. The classification system evaluates the condition of seven specific erosional features. These features include:

1. Soil movement
2. Surface litter (and organic mulch) movement
3. Surface rock fragment disturbance
4. Flow pattern development
5. Pedestalling
6. Rilling
7. Gully

The use of this system should provide the inspectors with a evaluation method that has a high degree of accuracy of results between individuals evaluating the same area, and a high degree of uniformity in measured results for comparable conditions between different areas.

APPENDIX 1. Glossary of Terms.

<u>aeolian or eolian</u>: Pertaining to deposits such as loess and dune sand, eroded from sedimentary structures such as sandstone, or other erosion and deposition accomplished by wind.

<u>antecedent moisture condition (AMC)</u>: Amount of soil moisture at the storm beginning.

<u>bare ground</u>: All land surface that is not covered by vegetation, litter, gravel, cobbles, stones or rock outcrop.

<u>bulk density</u>: (Of a soil). The oven-dry weight of measured volume of soil including pore spaces. Expressed in grams per cubic centimeter.

<u>cover</u>: Material covering soil and providing protection from, or resistance to, the impact of raindrops and the energy of overland flow. Expressed in percent of the area covered. Composed of vegetation, litter, gravel, cobbles, stones and rock outcrop, which are lying on or within 20 feet or the ground surface.

<u>erosion</u>: Wearing away of land surface by running water, wind, ice, or other geologic agents. Includes such processes as gravitational creep, detachment and movement of soil or rock by water, wind, ice, or gravity.

> <u>accelerated erosion</u>: Primarily as result of influence of man's activities or, in some cases, of animals.
>
> <u>erosion pavement</u>: Layer of coarse fragments of gravel and cobbles on ground surface remaining after removal of fine particles by erosion.
>
> <u>erosion condition class</u>: Condition or grouping of erosion conditions based on degree of erosion or on characteristic erosion patterns applied to total erosion situation. No attempt is made to differentiate among accelerated, normal, natural, or geological erosion. Five classes are recognized (stable, slight, moderate, critical, and severe). Water and wind erosion are both considered.
>
> <u>geologic erosion</u>: Normal or natural erosion caused by geologic processes. (See <u>natural erosion</u>.)
>
> <u>gully erosion</u>: Erosion process whereby water accumulates in narrow channels and, over short periods, removes soil from narrow area to considerable depths, ranging form 6 inches to as much as 75 to 100 feet.
>
> <u>natural erosion</u>: Wearing away of earth's surface by water,

ice, or other natural agents under natural environmental conditions of climate or vegetation, undisturbed by man. Synonymous with geologic erosion.

normal erosion: Gradual erosion of land used by man which does not greatly exceed natural erosion and is not greater than the rate of formation of the soil mantle by natural weathering processes.

rill erosion: Erosion process in which small channels of less than 9 inches are formed.

sheet erosion: Removal of a fairly uniform layer of soil from land surface by runoff water flowing in a sheet instead of in defined channels.

splash erosion: Spattering of small soil particles caused by impact of raindrops on soils. Loosened and spattered particles may or may not be subsequently transported by surface runoff.

flow patterns: Arrangement of soil particles, surface litter, coarse rock fragments, and pedestals which reflect surface-water flow or wind movement.

gullies: Distinction between gullies and rills is depth. Gullies are over six inches deep. A gully is a channel or miniature valley cut into soil mantle by concentrated runoff through which water only flows during and (immediately after) rains or during snowmelt.

infiltration: Water passage into soil surface.

litter: Organic debris composed of freshly fallen or slightly decomposed organic materials. Includes all undecomposed dead organic matter (including organic mulch) either lying on the surface or standing within 20 feet of ground surface. Litter includes lichens and moss less than 1/16 inch thick unless they are growing on rock fragments or rock outcrop.

microterraces: Small terraces that form within the erosional feature.

overland flow: Rain water or snowmelt over land surface toward channels.

pedestalling: The process of forming a small elevated plane by the erosion of adjacent areas form around an object. Does not pertain to pedestals created by heaving from frost action.

rills: Small, intermittent watercourse in soil mantle, equal to or less than nine inches deep with steep sides. It may be obliterated easily by surface disturbance or slight soil movement associated with weathering. Yet in the process the soil profile is gradually truncated.

scour: To abrade and wear away; the wearing away of terraces, diversion channels, or streambeds.

sediment load: Total sediment, including bedload, being moved by flowing water in a stream at a specified cross section.

soil movement: Displaces of the soil mantle by water, wind, ice, gravity, or land use.

soil surface factor (SSF): Numerical expression of surface erosion activity caused by wind and water as reflected by soil movement, surface litter, erosion pavement, pedestalling, rills, flow patterns, and gullies. Values vary form 0 for stable erosion condition to 100 for a severe condition.

surface litter: Nondecomposed dead organic matter (including organic mulch) lying on ground surface or near enough to it to be affected by water or wind acting on eroding surface.

surface rock fragments: Rock fragments of all sizes lying on or in soil surface; those of primary concern are small enough to reflect movement by water and wind. Includes gravel, cobbles, and stones.

truncated areas: Having lost all or part of the upper soil horizon(s) or topsoil.

vegetation: Includes all living vegetation within 20 feet of the ground surface, such as the canopy of trees and shrubs, and lichens and moss, more than 1/16 inch thick and only the basal area of grasses and forbs. All live organic floral materials, regardless of form, are to be grouped into vegetation; exceptions to this are the lichens and mosses that are growing on rocks. For the purpose of this survey if the lichens and/or moss has not accumulated a thickness in excess of 1/16 inch, it should be recorded as rock fragments. Lichens and moss on bare ground having a thickness less than 1/16 inch should be recorded as litter rather than vegetation.

APPENDIX 2.

SELECTED REFERENCES

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ADDENDUM III

ECOLOGICAL MONITORING
AND ENVIRONMENTAL CHARACTERIZATION

J.B. KING MINE
EMERY COUNTY, UTAH

Submitted to:
WESTERN STATES MINERALS CORPORATION
290 S. Rock Blvd.
Reno, Nevada 89502

Prepared by:
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Location of –
2 soil sample
pts. off-site

August 1994

TABLE OF CONTENTS

1.0 INTRODUCTION

The J.B. King Mine is a reclaimed underground coal mine located approximately 10 linear miles south of the town of Emery in Emery County, Utah in Range 6 East, Township 23 South, Section 32, SLBM. The J.B. King coal mine, reclaimed by Western States Minerals Corporation (WSMC), is in its eighth year of reclamation bonding. Reclamation and revegetation of the approximately thirty acre site was initiated in the fall of 1985, and the following spring, 1986, shrub were transplanted into the area. The site has been periodically monitored since 1986 for vegetation cover and density, and site conditions. This monitoring has allowed the conditions and trends in the vegetation to be assessed.

There have been recent Notices of Violation (NOVs) issued by the Utah Division of Oil, Gas, and Mining (Division) that cited failure to minimize erosion and properly construct ditches. These types of conditions have occurred repeatedly in the past, and WSMC has instituted corrective measure and rebuilt and installed control structures. These measures and reconstructions have, in general, not controlled the erosion processes on site resulting in a perpetuation of numerous NOVs by the Division. Recent NOVs have been issued concerning a perceived lack of revegetation success as it relates to erosion control and the size and extent of areas bare of vegetation.

The specific concerns on the site expressed by the Division are: (1) areas with uncovered coal refuse or having limited cover of soil on the top of the refuse pile (this was left at the request of the Division as a revegetation test plot), (2) rate of erosion on the sides of the refuse pile, and (3) low vegetative cover on small, local areas of the site. These conditions were detailed in a series of NOVs issued by the Division.

There has been a need to reassess the erosion control and related revegetation conditions experienced at the J.B. King Mine during the last several years to analyze for trends and ecological conditions. This analysis needed to be done both on the site and in the immediate areas surrounding the site to develop a full understanding of the trends and conditions. Vegetation has been monitored four times on the site during the past five years (1989, and 1990 through 1993) as required by Utah regulations and because of good moisture in 1991 and 1992. In addition, recent documentation and reports have been prepared for proposed modifications on the site relating to erosion control and vegetation enhancement (RA Consultants, 1992; Hansen Allen & Luce, 1994).

The criteria in the present reclamation standards and general requirements being used for determining success on the site does not account for site specific and regional environmental conditions. The general requirements in R645-301-353.140 state that "The vegetative cover will be: ....diverse, effective, and permanent; and ....capable of stabilizing the soil surface from erosion". In this arid region, vegetation does not stabilize the soil surface. In addition, "diverse, effective, and permanent" are non-specific and subject to interpretation. There are no standards for erosion control except that sediment control measures will minimize erosion to the extent possible (R645-301-742.113). The performance standards for reclamation may not be appropriate for conditions in this arid region with high rates of erosion and low vegetation cover.

Western States Mineral's proposed solution is to determine if ecological and erosional factors on the site are in balance with the natural environmental conditions. To determine this, it was necessary to learn these factors and how they interrelate on the natural surrounding landscape. These can then be applied to conditions on the reclaimed mine site. The landscape patterns and scale for vegetation in the arid western US are related to regional and local climate, topographic, and other environmental factors (Carlile, et.al., 1989). Methods have been developed for examining landscape and ecological scale (Cullinan and Thomas, 1992; Simmons, et al., 1992).

The objective of the present monitoring study was to determine the ecological relationships of biological and erosional factors on the site and in nearby areas of similar topographic position. The approach was to measure biological conditions and environmental factors concurrently on the same areas. This study was designed to provided information on the general regional and site specific factors of the climatic and geomorphologic processes that affect vegetation establishment and erosion rates. A detailed site and surrounding area reconnaissance and observational surveys were followed by linear transects of quantitative plot surveys. The linear transect and plot design allowed adequate amounts of data for statistical analysis to be collected from each topographic position. The data was then statistically analyzed for ecological relationships. This information was to determine if site specific biological conditions have a predictor value for vegetation on site. WSM also is proposing use this technique to comply with reclamation standards, criteria, and stipulations for erosion and vegetation on the J.B. King site. This report presents results of the ecological monitoring and in addition assessed site and surrounding area ecological conditions.

2.0 REGIONAL AND SITE CHARACTERISTICS

This section was abstracted from an earlier report on erosion and topographic characteristics at the J.B. King site (RA Consultants, 1992). The J.B. King reclaimed site is located in the western Canyonlands section of the Colorado Plateau in central Utah on the western edge of the San Rafael Swell and the eastern edge of High Plateaus section at the southern end of the Coal Cliffs.

2.1 Regional Setting

This part of the Colorado Plateau is characterized by many high plateaus that are drained by the Green and Colorado Rivers. On the Colorado Plateau, the distinguishing features are elevated plateaus underlain by near-horizontal bedrock weathered into a stepped landscape with many cliffs and escarpments separated by wide gentle slopes as a result of differential weathering (Morrison 1991). In the Canyonland section, the easily eroded Cretaceous shales and sandstones are cut into canyons in flat-lying older strata. This region is well known historically for the great significance of erosion in creating the unique topography and landforms of this area. Much of the sediment produced by mass wasting of landslides and mechanical weathering in source areas has been transported and result in aggradation of downstream valleys. Differential weathering of different strata has produced scarps that retreat by rockfall and slab-failure processes. Natural coal seams are common throughout the area.

This intermountain region has a continental type climate with warm summers and cold winters and wide contrasts and fluctuations in temperature and moisture. The climate is semiarid with averages of 6 to 16 inches of annual precipitation and a range of 45 to 55° F average annual temperature. The area is subject to "summer monsoon" type thunderstorms, winter frontal storms as snow or rain, and is noted for the intensity of the summer rainfall. Vegetation in the central and northern section is a shrub-grassland at lower elevation grading into pinyon-juniper woodlands on intermediate areas with coniferous forests at higher elevations.

Studies on the Colorado Plateau stress the importance of erosion process and the denudation of an area subject to widespread erosion and sediment transport. The main temporal actions in the erosion cycle are:

- loosening or detachment of particles by weathering to produce sediment
- water detachment of particle by rain splash, impact or shear
- infiltration followed by runoff

- lateral movement by sheet erosion
- rill (<8") and gully (>8") formation
- sediment transport and downslope movement
- deposition in an aggradation zone

The delivery rate is equal to the yield of sediment production divided by the erosion rate. Unconsolidated sediment is subject to detachment and will be transported at the first opportunity.

Numerous exposed coal seams outcrop in this "Coal Cliffs" portion of the Plateau, and are a part of the natural environment. These coal seams vary in thickness but are generally exposed at the base of shale slopes and are easily erodible. Coal material is naturally part of the sediment production, and is transported and deposited in drainage and alluvial materials. Some local plant species are adapted to grow in this material and are common. Coal exposed at the surface has been weathered and altered by microbial action, mainly fungus.

2.2. Specific Characteristics on the J.B. King Site.

The J.B. King Mine is located along the eastern edge of the Dog Valley Wash at 6240 to 6375 feet elevation. The area and vicinity of the site has the typical continental climate and receives about 8-10 inches annual precipitation with intense summer thunderstorms. The site forms a northwestern-facing amphitheater with resistant sandstone cliffs around an eroded alcove formed on Mancos Shale which underlies the sandstone and contains the coal. The reclaimed site has about 30 acres with a covered refuse pile, a main drainage, open flats and slopes, and a barrow area. The constructed ditches across the site have received large volumes of water as runoff from the drainage above and outside the site boundaries. Thunderstorms have produced splash erosion and sheet erosion on unprotected soil surfaces.

The soils and range sites in the vicinity of the site are in the Travessilla-Gerst badlands type according to the Soil Conservation Service (pers. comm., Leland Sasser, Soil Scientist, SCS, Price). This is considered a non-soil complex with shallow sandy material over bedrock on the sandstone flats and cliffs, and a clay loam on the Manchos Shale slopes. The erosion and weathering is too rapid for typical soil profiles to develop, and the soil is weathered bedrock materials with low vegetation cover. The alluvial slopes and bottoms below the cliffs and slopes has a variable non-defined colluvial or alluvial soils material with layers of coarse sand mixed with finer loams and clays.

There is a broad pattern of vegetation types related to soils and topography around the site. The sandstone flats above and east of Dog Valley are a pinyon-juniper woodland interspersed with shrub-grass on deeper sandy soils. Vegetation on the alluvial flats in the broad Dog Valley is dominated by greasewood (*Sarcobatus vermiculatus*) with a few scattered grass clumps. Grazing has reduced grass cover and an annual weedy flora covers sandy flats. Vegetation on the intermediate slopes between the sandstone outcrops and flats and the alluvial valley floors is a mixed shrub-scrub on the shaley and sandy slopes. The J.B. King reclaimed site is topographically located in this intermediate zone on slopes between the upper sandstone flats and the alluvial valleys. This zone does not have a well defined vegetation type due to differences in skeletal soils, rock outcrops, and steep topography with fairly rapid erosion.

Typical plant cover values are 8-10% on the shale slopes, and 18-20% on the alluvial slopes and flats, and about 12-15% on the sandstone outcrops and flats. There is a large variability in vegetation and ecological factors in the escarpment and sloping areas between sandstone bluffs (pinyon/juniper) and alluvial flats (greasewood shrub)

The area is grazed by cattle as winter rangeland except for the 30 acre reclaimed site which is fenced to exclude cattle. The grazing has been intense and has increased erosion and runoff by reducing the sparse plant cover and loosening and breaking the soil surface by trampling. The last several years until 1992 have had low rainfall and increased the effects of grazing by further reducing plant cover. Grazing of cattle has altered the dominant plants species on all areas around the site and introduced a large annual weedy component. The extent of this alteration in vegetative composition is unknown since there are no ungrazed reference areas.

Several soil and topographic conditions were altered on the mine site during active mining and later reclamation related activities. These mining and reclamation activities changed the conditions on the site from the premining state, and the site differs in these characteristics from slopes adjacent to the mine site. The main changes were: (1) a reduction in slopes so that the site is flatter than adjacent areas (except for the southwest side of the covered refuse pile), (2) the soil substrates are a mixed and transported material that is deeper than the in-place soils and rock outcrop on adjacent areas, ~~and (3) the soils are~~ heterogenous mixed weathered and parent material that in places have a high nutrient content or may have a high salt content. Observations on surrounding landforms determined that the ~~reclaimed site has mixed~~ substrate and topographic conditions intermediate between the bluffs and upper slopes ~~and the alluvial fans~~

and flats downslope in Dog Valley.

The conditions for plant growth and productivity, in general, are favorable but variable. There are a variety of substrates and slopes for different types of vegetation. The resulting vegetation types and patterns are somewhat similar to the flatter alluvial valley sections of Dog Valley where large clumps of greasewood are interspersed with bare, flat, compacted soils. However, vegetation on the reclaimed site is varied with more species and higher productivity than observed on the flats in Dog Valley where grazing has reduced grass cover to less than a few percent, and a large part of the annual vegetation is weedy.

There are several contributing factors and conditions around Dog Valley that have affected and controlled erosion both on and off site. These factors have increased or altered the already high rates of erosion and sedimentation due to natural geomorphologic and climatic conditions. They include: (1) cycles of drought followed by increased rainfalls causing variations in vegetative growth and plant cover both on and off site, (2) unmanaged cattle grazing during this drought cycle resulting in decreased plant cover and loosened soil surfaces (cattle were grazed on the reclaimed site until 1989 coinciding with the early reclamation period), and (3) the drought was interrupted in 1991 and 1992 by a series of thunderstorms on and off the site, however 1993 and 1994 have been drier than normal again. The thunderstorms in 1991 and 1992 were of a gentler, soaking type that did excessively erode and move sediment, although large volumes of water entered the site in the drainage control ditches.

Other site conditions that have contributed to changes in vegetation growth and erosion control include location and previous history. The site is located in a landform configuration with slopes, substrate conditions, and drainage that are naturally not in equilibrium and result in erosion. Mining and initial reclamation temporarily increased surface instability. The previous mining and reclamation activities left loose unconsolidated material on the site that was easily eroded and acted as a sediment source. This unconsolidated material (refuse pile, and other flats and slopes) requires a period of time for armoring of loose surface and adjustment of micro-topography for drainage into rills and gullies on smooth slopes and flats. This process of soil armouring and stabilization has started on the site. The rate of these processes are unknown and depend on local episodic weather patterns. The sedimentation rate during the past eight years has been fairly slow as evidenced by the lack of deposition of sediment into the sediment pond. Sediment control measures by WSM further inhibited erosion on site.

The consequences of the site conditions for erosion control are that natural conditions and reclamation activities have resulted in a short period of instability of the slopes, surfaces, and unconsolidated sediment on site, followed by increasing stability. The current study was designed to help determine if the erosional conditions and vegetational bare patterns on the J.B. King mine site exceed natural conditions in the surrounding environment. Permanently marked transects have been set up to monitor trends in vegetation and erosion (See Section 3.0 for methodology).

3.0 SAMPLING PROTOCOL

This sampling protocol has been developed for sampling vegetation cover and densities, and vegetative community patterns in relationship to topographic, soils, and erosional factors. The present reference area does not address the pattern of vegetation and size or percentage of bare, non-vegetated areas versus vegetated areas. The topography and soils on the reclaimed site are complex and disturbed, and the vegetation established is in a successional status and not uniform. This specific type of sampling determines the relationship of vegetation patterns to soils and topography on undisturbed natural areas in the vicinity of the mine site. The purpose of this sampling was to determine if the natural patterns and ecological factors affecting vegetation in this specific region of Utah can be determined, and if they will serve as a guide to predict present and future conditions (as it reflects on potential revegetation) on the reclaimed site.

The types of field analyses that were used are not a part of ordinary procedures covered in the Division's guidelines which uses fixed reference areas, range sites, or baseline data prior to mining. The guidelines suggest the use of belt transects or plots, but treats each randomly located plot as one sample. This type of sampling does not allow the determination of vegetation patterns and bare areas, nor relationships of vegetation types to environmental factors, such as erosion. Under R645-301-456.100 of the Coal Mining Rules "other approved success standards" may be used to judge the effectiveness of the vegetation. The requirement that the sampling techniques for measuring success using a 90% statistical confidence interval assumes a normally distributed population of samples, which may not be met in this highly variable and heterogenous landscape.

Linear coupled plots in transects were established on and off the site. These were linear plots (2 x 10 meters in size) laid end to end along a straight compass line and oriented roughly parallel to the sandstone escarpments. The general areas surveyed were the western and northern facing escarpments and slopes of Dog Valley. Vegetative, topographic, erosional, and soil variables were recorded in each plot. The transects were then analyzed for the type of vegetation and patterns of vegetation types as they relate to topography, soils, and erosional features. Large bare areas were noted but not sampled by the transect method.

A general field reconnaissance was conducted in the vicinity of the reclaimed mine to observe and record topographic, drainage conditions, and other environmental factors along the sandstone escarpments in a topographic position similar to the site. The downslope and drainage features in the alluvial wash below the site were characterized and photographed. These procedures used for the field program did not change significantly from an earlier proposed sampling protocol document. All minor changes to these procedures are documented in this report, and an explanation and rationale for the change included.

The down-gradient drainage in the Dog Valley Wash was evaluated for present conditions, and the potential for effects from sedimentation from the J.B. King site. The drainage along Dog Valley, starting at the western edge of the site, was walked west and then north approximately 2 miles to the Interstate 70 freeway. The drainage was observed for major vegetation types, dominant plant species, and soil and topographic conditions.

3.1 Specific Procedures

The procedures are detailed in this section for the variables measured, the sampling locations and marking, number of samples, and analysis of the data.

Sampling location and marking: Two sampling sets were conducted: a set of four lines off site, and a set of four lines on the reclaimed site. See Figures 1 and 2, which are maps of the transect locations. Two of the off site linear transects were run north and one west from numbered perimeter fence posts chosen randomly; the fourth transect was down-valley from the site. The transects were run from the random points (fence posts) on the north edge of the site in a northerly direction (azimuths 15° and 17°) along gradients at the same elevation as the site, and roughly parallel to the escarpment face. This was repeated running west at an azimuth of 270° from the western edge of the site along and below the sandstone bluffs. Transects were permanently marked with 3' lengths of #3 rebar driven 2' (or until refusal) into the ground at 30 meter intervals. A 30 meter steel tape was stretched between markers, and 3 plots (each 2x10 meters) recorded at 10 meter intervals. Similarly, three transects were run inside the perimeter fence on the reclaimed site from randomly chosen fence posts. A fourth transect was located on the steeper south and west facing portion of the refuse pile, this was not marked with rebar for the erosional study because of the uncertainty of future plans for the surface of the refuse pile.

The following table is a summary of the transects:

Location	Number	Azimuth	No. of Plots	Permanent Erosion Stakes
On site	A1	53°	35	Yes
On site	A2	160°	33	Yes
On site	A3	130°	45	Yes
On site - Refuse pile (2 parallel lines)	R1	followed contour	36	No
North of site	N1	15°	45	Yes
North of site	N2	17°	36	Yes
West of site	W1	270°	34	Yes
Valley floor (below site)	V1	260°	30	No

Variables: The variables chosen were considered to be those ecologically significant for measuring biological responses to environmental conditions. These variables are specifically related to established reclamation procedures and situations on the reclaimed mine site. The dependent (response) variables in the transects measured for vegetation were: (1) total percent desirable plant cover, (2) dominant species, and (3) total number of shrubs (for shrub density). The length of the center line that was vegetated was not recorded since no large bare areas were encountered along the transects. ~~This aspect of the~~ observations will be discussed in the vegetation patterns section (see Section 4.3). Instead of bare areas, the distance between areas with low cover was determined by inspection of the data ~~for large scale~~ pattern analysis.

The independent (predictor) variables measured were: (1) topographic features (degree and aspect of the slope), (2) soil surface features (type of substrate and percentage rock cover), (3) erosion features (depth and width of gullies and rills) and estimation of overall erosion factor, and (4) an estimated moisture factor. Surface moisture and the aggradation/degradation (erosional status) was a qualitative factor estimated for each plot using scalars of 1 to 5. Three additional measurements on the stake were recorded: (1) the length of stake above ground, and the height above ground of a point parallel to and level with the stake in (2) front and (3) back of the stake at a one foot distance from the stake along the transect line (see diagram below). These last three measurements can be repeated at intervals over a period of years to determine erosion status around the stakes.

Specific field forms were used during the field measurements. Records from these forms were transferred to computer spreadsheets for general analysis and statistical tests. The following are the measurements for each variable that were measured in the field:

VARIABLES	FIELD MEASUREMENTS
DEPENDENT	
Vegetation	dominant species as a record
	total cover as a percent
	shrub density as a count
INDEPENDENT	
Topography	degree of slope
	aspect for 8 cardinal points on a compass
Soil type	a descriptive term that gives the general texture in the field by inspection: from sand to clay
Substrate type	a descriptive term for the substrate from with the soil was derived; sandstone, shale, coal, alluvium, colluvium, aeolian, mixed
Rock	type as a rock type: sandstone, shale, coal
	surface rock cover of the soil as a percent
Moisture	moisture regime: scaler of 1 (moist) to 5 (dry)
Erosion	present status: scaler of 1 (severe erosion) to 5 (obvious deposition)

Number of samples: The number of samples (minimum of 30 plots) was determined by the general length of the transects off site which covered the topographic position being sampled. The four lines off site were run until either an obstacle was encountered (such as a sandstone bluff) or the line was about 450 meters in length. Sample adequacy for the number of factors being measured was not of concern, but a large number of samples were needed for correlation and statistical analysis. The number of 10 meter plots sampled in the four lines off site was 145, and the number of plots in the four lines on site was 149.

Analysis: The purpose of the preliminary analysis was first, to characterize the vegetation and environmental parameters for each transect line, and then determine correlations and relationships. The results of the transects were first analyzed for: (1) the vegetative dominant species, percent cover, and shrub densities, (2) the aspect and slopes of topographic features, (3) the types of soil and substrates, and (4) rock types and percent cover. The parameters developed were statistical means and standard deviations, and other standard parameters.

The second major analysis was to develop a matrix of correlation coefficients between the dependent and independent variables. These correlations were determined using computer statistical programs, Statgraphics Plus and Microsoft Excel. If significant correlations were found, then the third statistic performed was a multiple regression analysis. Based on these correlations, only one multiple regression analysis has been run for this report; that was for plant cover as a function of moisture, rock cover, and gully width. The plot data can be analyzed for other relationships, but the one regression analysis run is illustrative of the method.

The vegetative cover for each set of transect plots was compared to all other sets using the *T*-test distribution. This test measures whether the means of the two sets of plots are similar, and if one set of samples can be used as a predictor of expected parameters of the other.

The results presented here are a partial statistical analysis of the large data base from the linear transects. Other more detailed analysis can be conducted in the future when this methodology has been accepted as the basis for performance standards. The results of the analysis are discussed for the ecological characteristics that can be used as predictors of vegetation parameters and erosion processes.

4.0 RESULTS

The results of the field sampling procedures and partial statistical analysis showed that, in general, the vegetation cover and density is highly variable both on and off site. There was no highly significant correlation of the vegetation to the soil, substrate, erosional, and topographic factors measured that would indicated a strong association. The single exception was a higher correlation between vegetation cover and the moisture factor. The results of the preliminary data analysis are presented, and the general conditions in Dog Valley reviewed followed by a discussion of their significance on the site.

4.1 Analysis of Transect Data

Standard statistical parameters: These parameters were calculated for the variables to determine the average, range, and standard deviation. The vegetation and environmental parameters are presented in Table 4.1 for the four on site transects (A-1, A-2, A-3, R-1) and four off site transects (N-1, N-2, W-1, V-1). Average vegetative cover was 17.2% (20.1, 16.5, 23.2, and 9.1%) for on site vegetation; and for off site varied from 11.0% for N1, 15.9% for N2, 16.1% for V1, and 17.8% for W1 for an overall average of 15.2%. The standard deviation of the vegetation data was high for all plots in each transect, but was higher for the transects on site. Analysis of the plot data for variance and standard deviation indicate that the variability of all the measured variables is high. The sample adequacy of 30% was generally acceptable using a precision calculation of the width of the 95% confidence intervals.

Dominant plants species: The plant species recorded in the plots differed on the reclaimed mine from species off site. The reclaimed site was seeded with a species composition that differed from the off site natural vegetation. The dominant shrub species on site were four-wing saltbush (*Atriplex confertifolia* - a seeded and transplanted species) and greasewood (*Sarcobatus vermiculatus* - seeding naturally from nearly plants). Dominant grasses were the seeded species and hybrids of wheatgrass (*Agropyron* sp.), and Indian ricegrass (*Oryzopsis hymenoides*). The dominant shrub species off site were more varied with two species of saltbush, one sagebrush (*Artemisia nova*), and greasewood; grass species were also varied, although grass cover was low. Table 4.2 presents the dominant species in the transects by frequency. The type of vegetation based on dominant species is a shrub-scrub with a small grass component. The species dominance from area to area changes at the topographic locations at the base of the escarpments

Simple correlation analysis: Simple correlation coefficients were calculated for dependent versus independent variables. A correlation coefficient value of greater than 0.5 or higher was considered highly significant (i.e. a strong association existed). Plant cover and shrub density (dependent variables) were each run independently against slope, percent of rock cover, erosion factor, moisture factor, depth and width of rills/gullies, soil type, substrate type, and aspect. The last three variables were recorded as alphanumeric, but were converted to numeric entries for analysis. The results of the correlations are given in Table 4.3.

The strongest associations (high correlation coefficients) indicate that vegetative cover is positively correlated with moisture, and negatively correlated with rock cover. Except for one off site transect (N-2), plant cover was positively correlated with shrub density. The vegetation cover is higher with better moisture regimes, and lower with increased rock cover. Within the independent variables, erosion is negatively correlated with degree of slope. Very few strong correlation exists between the other dependent variables that show strong association that can be used as predictor variable for on versus off site relationships. There was some correlation between the independent variables. For example, slope was consistently negatively correlated with erosion, that is, the flatter the slope, the lower the erosion potential. This general lack of correlation indicates that the vegetation and ecological factors do not show strong association are not in equilibrium. The vegetation does not tend toward a "climax" community or similar types. Most environmental factors cannot be used to predict vegetation conditions.

A *T*-test was used to determine if there is similarity in the vegetative cover values for pairs of transects. For the site the most similar off site transects was N-2, which had fairly high values. Although the cover values were similar, other environmental factors and plant species composition differed. Table 4.4 presents the results of the *T*-test.

Vegetation patterns: Occurrence of vegetation types and patterns of low vegetative cover were analyzed for both on site and off site transects. Nodes (repeat patterns) of low to high vegetation cover along the transects were determined to vary from 80 to 200 meters and had no consistent pattern on or off site. Other patterns of species dominance were not readily observable from the transect data. Some species were more prevalent on naturally exposed coal seams and soil derived from shale and coal, but the vegetation did not form a distinctive community on these locations. This result of a lack of vegetation patterns on the scarps and slopes around Dog Valley was consistent with the general lack of observable correlations with environmental or ecological factors. There was little predictable repeat patterns based on the results of our study. Large changes in the topography and soils within short distances probably account for the lack of predictable patterns. The broader scale vegetation patterns around the site are discussed in Section 2.2. Areas with consistent high soil moisture and a high vegetative cover from springs, seeps, or permanent streams are conspicuously lacking in Dog Valley. The vegetation was patchy and heterogeneous.

4.2 Description of Dog Valley Drainage Around and Below Mine Site

The alluvial flats in Dog Valley below the J.B. King site is a broad drainage that in not incised for about one-half mile below the down drainage edge of the site. The soils are a dense, compacted sandy clay loam, that do not easily erode. The vegetation cover is composed principally of large greasewood shrubs and sparse clumps of grass (see Transect V1 for vegetation parameters). Ground cover is of weedy annuals, mainly halogeton (*Halogen glomeratus*), African mustard (*Malcomia africana*), and Russian thistle (*Salsola iberica*). The channel begins as a sudden incision (about an 8 foot drop) in a small scarp 0.5 miles down stream of the site, and the channel gradually becomes broader and deeper as it continues down valley (north) toward I-70. At the freeway, the Dog Valley drainage is channelized by the road construction and drops steeply to another broad valley to the east in the drainage of Middle Creek. Both drainages were dry in June of 1994.

There were natural coal seams on the sides of the valley and also in portions of the channel that were cut into the shale. These coal seams were eroding and contributing sediment to the soils. Noticeable coal debris was observed in the channel and in the alluvial soils in the valley. The species of plants most noted growing on exposed coal seams off the site were buckwheat (*Eriogonum corymbosum*), Gardner saltbush (*Atriplex gardneri*), pricklypear (*Opuntia polyacantha*), and Indian ricegrass (*Oryzopsis hymenoides*). Some of these same plants had become established in the coal refuse test plots on the site. There was a total of 16 species of plants observed growing in the exposed coal refuse test plot. Several large rubber rabbitbrush (*Chrysothamnus nauseosus*) plants were growing directly in the coal refuse.

There were no wetlands observed, nor any seeps or springs along the valley floor. All of the channels were dry during early June and there was no standing water. Tamarisk was the only hydrophytic plant observed that grew near two deep plunge pools that were also dry. There were no special or sensitive habitats observed along the length of the drainage that was walked and observed.

4.3 Bare (Non-Vegetated) Area Comparisons On and Off Site

Observations in the area to determine where bare areas existed in the natural vegetation showed occurrences in two general areas: (1) on the sandstone and shale bluffs and upper flats where large rock outcrops are present and (2) on the lower alluvial flats in Dog Valley. The lower flats are dominated by greasewood and the soil is a compacted sandy clay loam. The size and locations of these bare areas were related to natural features of severe erosion and dense soil types. These bare areas were estimated to cover about 2% of the areas around Dog Valley. Some bare areas have been created or enlarged by cattle grazing and bedding, or related to roads and other disturbance. A large stock pond in the alluvial flat below the site has resulted in an area of major disturbance and denuding by cattle.

Bare areas on the reclaimed site were concentrated in the area of repeated disturbance by access roads and the reconstruction of the upper drainage ditches. These areas had seedlings and some vegetation, indicating a trend of increase in vegetative cover. The ridge extending southwest from the refuse pile also had some bare areas, probably as a result of soil compaction and poor moisture retention. These areas on site were identified using the following criteria: (1) less than or equal to 1 percent of desirable vegetative cover overall in a contiguous area, (2) greater than or equal to 20 feet on the shortest side, and (3) greater than or equal to 625 square feet total footage within each bare area. Areas meeting these criteria were counted and their general size recorded. A total of 34 bare areas (see Table 4.5) were found on site, comprising approximately 41,000 square feet or 3 percent of the entire 30 acre reclaimed site.

In general, the reclaimed site had a somewhat higher percentage of large bare areas (3% on site versus 2% off site) as compared to the surrounding sandstone bluffs and flat areas and the alluvial portions of Dog valleys. These on site bare areas were neither larger nor more conspicuous than off site areas, and are balanced by areas on the site with higher than normal cover (see Table 4.1). The reclaimed site consistently had a higher overall plant cover and density as compared to the adjacent off site areas, as measured in the linear transects.

Table 4.1 Statistical Parameters for Vegetation and Ecological Parameters

Transect A-1

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	35	35	35	35	35	35	35	35
Average	20.1	6.4	2.8	8.7	5.4	11.7	2.7	2.1
Median	15	5	0	0	5	10	3	2
Mode	18	5	0	0	3	3	3	2
Geometric mean	14.9	--	--	--	4.6	9.4	2.7	1.9
Variance	238.0	17.3	65.0	681.4	11.3	60.0	0.4	0.5
Std deviation	15.4	4.2	8.0	26.1	3.4	7.7	0.6	0.7
Standard error	2.6	0.7	1.4	4.4	0.6	1.3	0.1	0.1
Minimum	2	0	0	0	2	3	2	1
Maximum	65	16	29	110	15	30	4	3
Range	63	16	29	110	13	27	2	2

Transect A-2

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	33	33	33	33	33	33	33	33
Average	16.5	5.8	1	3.6	5.4	12.4	2.5	2.4
Median	15	5	0	0	3	10	3	2
Mode	15	6	0	0	1	2	3	1
Geometric mean	12.9	--	--	--	--	7.8	2.3	2.1
Variance	107.9	22.2	16.1	236.4	30.2	126.6	0.7	1.5
Std deviation	10.4	4.7	4.0	15.4	5.5	11.3	0.8	1.2
Standard error	1.8	0.8	0.7	2.7	1.0	2.0	0.1	0.2
Minimum	2	0	0	0	0	1	1	1
Maximum	40	20	18	80	20	45	4	5
Range	38	20	18	80	20	44	3	4

Table 4.1 (continued)

Transect A-3

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	45	45	46	46	45	45	45	45
Average	23.2	6.2	4.1	10.4	6.2	6.3	2.5	2.6
Median	20	6	0	0	6	5	3	3
Mode	20	6	0	0	5	10	3	3
Geometric mean	18.3	--	--	--	--	5.0	2.4	2.5
Variance	182.6	13.6	365.9	1933	19.4	17.7	0.3	0.6
Std deviation	13.5	3.7	19.1	44.0	4.4	4.2	0.6	0.7
Standard error	2.0	0.5	2.8	6.5	0.7	0.6	0.1	0.1
Minimum	1	0	0	0	0	1	1	1
Maximum	60	16	125	280	18	20	4	4
Range	59	16	125	280	18	19	3	3

Transect R-1

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	36	36	42	42	36	36	36	36
Average	9.1	6.2	9.4	29.5	14.9	18.1	1.8	1.6
Median	9.5	6.0	12.0	40.0	14.5	15	2	2
Mode	10	5	0	0	15	15	2	2
Geometric mean	8.0	--	--	--	14.7	16.0	1.8	1.6
Variance	13.5	11.0	61.8	677.8	6.3	82.8	0.1	0.2
Std deviation	3.7	3.3	7.9	26.0	2.5	9.1	0.4	0.5
Standard error	0.6	0.6	1.2	4.0	0.4	1.5	0.1	0.1
Minimum	1	0	0	0	12	5	1	1
Maximum	16	12	22	70	20	45	2	2
Range	15	12	22	70	8	40	1	1

Table 4.1 (continued)

Transect N-1

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	45	45	46	46	45	45	45	45
Average	11.0	6.7	8.6	28.7	13.0	49.1	1.9	1.6
Median	10	6	0	0	12	50	2	2
Mode	12	3	0	0	12	60	2	1
Geometric mean	9.1	--	--	--	10.1	43.4	1.7	1.5
Variance	37.2	26.8	584.8	5264	77.4	430.1	0.6	0.4
Std deviation	6.1	5.2	24.2	72.6	8.8	20.7	0.8	0.6
Standard error	0.9	0.8	3.6	10.7	1.3	3.1	0.1	0.1
Minimum	1	0	0	0	2	8	1	1
Maximum	26	25	120	300	30	90	4	3
Range	25	25	120	300	28	82	3	2

Transect N-2

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	39	39	39	39	37	39	39	39
Average	15.9	7.5	10.4	18.3	8.2	42.8	2.2	1.9
Median	15	7	0	0	5	50	2	2
Mode	25	7	0	0	3	60	2	1
Geometric mean	14.1	--	--	--	5.1	30.8	2.1	1.7
Variance	53.3	16.1	955.8	1853	79.4	573.5	0.7	0.9
Std deviation	7.3	4.0	30.9	43.0	8.9	23.9	0.8	0.9
Standard error	1.2	0.6	5.0	6.9	1.5	3.8	0.1	0.1
Minimum	5	0	0	0	1	1	1	1
Maximum	28	18	150	200	32	80	4	4
Range	23	18	150	200	31	79	3	3

Table 4.1 (continued)

Transect W-1

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	39	39	41	41	39	39	39	39
Average	17.8	9.4	31.6	71.8	10.1	36.9	2.3	2.2
Median	17	7	12	40	6	40	2	2
Mode	12	5	0	0	3	65	2	2
Geometric mean	15.4	7.4	--	--	7.2	21.8	2.2	2.0
Variance	78.5	45.8	10207	20655	75.4	657.2	0.5	0.6
Std deviation	8.9	6.8	101.0	143.7	8.7	25.6	0.7	0.7
Standard error	1.4	1.1	15.8	22.4	1.4	4.1	0.1	0.1
Minimum	3	2	0	0	2	1	1	1
Maximum	35	30	630	700	30	80	4	4
Range	32	28	630	700	28	79	3	3

Transect V-1

Parameter	Plant cover	Shrub density	Rill depth	Rill width	Slope	Rock cover	Erosion	Moisture
Sample size	30	30	30	30	30	30	30	30
Average	16.1	4.2	0.8	3.3	1.2	0.5	2.9	3.0
Median	11	3	0	0	1	0	3	3
Mode	5	1	0	0	1	0	3	3
Geometric mean	11.3	--	--	--	--	--	2.8	2.9
Variance	170.8	15.1	20.8	333.3	0.5	1.6	0.1	0.2
Std deviation	13.1	3.9	4.6	18.3	0.7	1.3	0.3	0.5
Standard error	2.4	0.7	0.8	3.3	0.1	0.2	0.1	0.1
Minimum	2	0	0	0	0	0	2	2
Maximum	45	14	25	100	3	5	3	4
Range	43	14	25	100	3	5	1	2

Table 4.2 Dominant Plants On and Off Site by Frequency

On Site

SHRUBS	Frequency
Atriplex confertifolia	89%
Sarcobatus vermiculatus	34%
Atriplex canescens	25%
FORBS/SUBSHRUBS	
Ceratoides lanata	9%
GRASSES	
Agropyron spp	54%
Oryzopis	17%

Off Site

SHRUBS	Frequency
Atriplex canescens	46%
Atriplex gardneri	25%
Artemesia nova	26%
Sarcobatus vermiculatus	27%
FORBS/SUBSHRUBS	
Gutierrezia sarothrae	51%
GRASSES	
Sporobolus sp.	26%
Hilaria jamesii	29%

Table 4.3 Correlation Coefficient Matrix for All Variables Measured

Variables	A-1	A-2	A-3	R-1	N-1	N-2	W-1	V-1
plant cover vs. shrub density	0.52	0.62	0.78	0.79	0.26	-0.08	0.25	0.87
plant cover vs. rill width	0.39	0.10	0.02	0.35	0.10	-0.03	0.38	0.46
plant cover vs. rill depth	0.39	0.19	0.02	0.42	0.09	0.07	0.38	0.46
plant cover vs. slope	0.02	-0.03	-0.17	-0.08	0.06	-0.46	-0.17	0.09
plant cover vs. rock cover	-0.24	-0.31	-0.39	-0.21	-0.23	-0.70	-0.20	-0.03
plant cover vs. moisture	0.75	0.66	0.73	0.53	0.61	0.65	0.70	0.40
plant cover vs. erosion	0.07	0.35	0.18	-0.05	0.08	0.46	0.31	-0.45
shrub dens. vs. rill width	0.20	0.15	0.07	0.37	0.08	0.10	0.03	0.40
shrub dens. vs. rill depth	0.32	0.23	0.05	0.48	0.07	0.30	0.05	0.40
shrub dens. vs. slope	0.25	0.48	-0.04	-0.36	-0.36	0.07	0.39	0.15
shrub dens.vs rock cover	-0.18	0.27	-0.35	-0.07	-0.48	-0.01	0.04	-0.08
shrub dens. vs. moisture	0.53	0.6	0.59	0.57	0.13	-0.16	0.48	0.28
shrub density vs. erosion	-0.07	-0.23	0.04	-0.11	0.11	-0.32	-0.06	-0.25
rill width vs. slope	0.07	0.41	-0.02	0.09	0.12	0.12	-0.23	-0.13
rill width vs. rock cover	-0.19	0.02	0.49	-0.14	-0.02	0.07	-0.26	-0.06
rill width vs. moisture	0.24	-0.01	-0.12	0.34	0.17	-0.08	0.27	0.45
rill width vs. erosion	-0.22	-0.33	-0.17	-0.16	-0.37	-0.14	-0.33	-0.55
rill depth vs. slope	0.15	0.48	-0.03	0.05	0.16	0.06	-0.19	-0.13
rill depth vs. rock cover	-0.17	0.01	0.48	-0.09	0.02	0.07	-0.26	-0.06
rill depth vs. moisture	0.24	0.01	-0.10	0.32	0.15	0.11	0.24	0.45
rill depth vs. erosion	-0.29	-0.32	-0.15	-0.21	-0.34	-0.06	-0.18	-0.55
slope vs. rock cover	0.46	0.49	0.10	-0.40	0.52	0.52	0.68	-0.07
slope vs. moisture	0.03	-0.47	-0.32	-0.08	-0.23	-0.43	0.11	-0.04
slope vs. erosion	-0.38	-0.70	-0.35	-0.05	-0.59	-0.67	-0.36	0.19
rock cover vs. moisture	-0.05	-0.69	-0.50	-0.27	-0.20	-0.63	0.02	0.05
rock cover vs. erosion	-0.16	-0.65	-0.33	-0.18	-0.11	-0.32	-0.24	0.11
moisture vs. erosion	0.03	0.66	0.28	-0.03	0.35	0.51	0.19	0.56

Table 4.4. *T*-Test for Similarity of Vegetative Cover for Paired Transects

Transects	*T*-Test	Transects	*T*-Test	Transects	*T*-Test
A-1 to A-2	0.2610	A-2 to N-2	0.7951	R-1 to N-2	0.0000
A-1 to A-3	0.3514	A-2 to W-1	0.5782	R-1 to W-1	0.0000
A-1 to R-1	0.0002	A-2 to V-1	0.9070	R-1 to V-1	0.0075
A-1 to N-1	0.0019	A-3 to R-1	0.0000	N-1 to N-2	0.0013
A-1 to N-2	0.6871	A-3 to N-1	0.0000	N-1 to W-1	0.0001
A-1 to W-1	0.4387	A-3 to N-2	0.0027	N-1 to V-1	0.0497
A-1 to V-1	0.2677	A-3 to W-1	0.0312	N-2 to W-1	0.3185
A-2 to A-3	0.0157	A-3 to V-1	0.0275	N-2 to V-1	0.9373
A-2 to R-1	0.0004	R-1 to N-1	0.0969	W-1 to V-1	0.5584
A-2 to N-1	0.0088				

Table 4.5 Statistical Summary of Bare Area Determination On Site

Parameter	Bare Area (ft^2)
Sample size	34
Average	1203
Median	995
Mode	936
Geometric mean	1070
Variance	549,081
Standard deviation	741
Standard error	127
Minimum	644
Maximum	4212
Range	3568

5.0 DISCUSSION AND RECOMMENDATIONS

The vegetation and ecological factors measured in and around the J.B. King site are highly variable and showed little correlation with environmental factors, except moisture. This is a disclimax vegetation on azonal soils in a "badlands topography" as defined by the Soil Conservation Service (SCS). The vegetation in the specific topographic position of the mine site is a variable shrub-scrub of mixed species that has been altered by grazing off site, and by disturbance and reclamation procedures on site. The reclaimed site is situated in a topographic position of great diversity, and in an area where rapid natural geomorphologic processes are constantly altering the landscape. The vegetation was heterogeneous as to species composition and cover, and formed small patches on the slopes and ridges around Dog Valley. The scale of vegetation change can often be measured within a few feet, and changes are abrupt.

There is little predictor value of the natural soils, topography, and other factors measured that can be used to predict what specific type of vegetation or pattern, including bare spots, will eventually develop on the site. Vegetative cover and shrub density are not highly dependent on most measurable environmental factors, or on each other. Moisture regime was the highest predictor of vegetative cover, but not of shrub density or vegetative type and pattern. Soil moisture is generally low with few areas where moisture is retained on the slopes and drainages either on or off site. There are a few flat and depressed areas on site at the base of the refuse pile where moisture collects. Most areas off site on the slopes and ridges are well drained and there are few areas where moisture collects. The Dog Valley drainages are dry with no wetlands, pools, or permanent water as streams or seeps. As rock cover increases, vegetative cover decreases, but there is not a strong association. However, rock outcrop and rock rubble and shaley slopes have very little vegetation. Shaley slopes have low vegetative cover values, but are not prominent in this area.

The use of a single small reference area or areas would be inappropriate based on the results of this quantitative study of ecological factors, vegetation parameter, and vegetation type patterns. The general vegetation parameters measured showed vegetative cover values of 10 to 23% during the growing season for 1994, and a variable shrub and grass component. The statistical analysis showed that although sample adequacy could be met using a modified confidence interval, there were no areas similar to the conditions or vegetation on the site for use as reference areas off site. The transects off site, although not representative, could be used as a general basis for vegetation standards of cover and density. Production has not been measured, but is estimated to vary from 200 to 600 pounds/acre based on previous SCS surveys. Production on and off site are not comparable, and comparisons could be based on ocular estimations by the SCS.

We suggest range condition, trend, and estimated production be conducted on the site specifically to determine if the vegetation and habitats are compatible with site conditions. Reference to off site conditions could be handled by resampling the permanently marked transects during the final bond period for general vegetation parameters. The upper and lower bounds of vegetative composition, cover, and density could be determined (but not at a 90% confidence limit due to natural large variations in vegetation). The use of a statistical confidence interval for measuring success is difficult in this vegetation type due to the heterogeneity of the vegetation. The site determination could be done in conjunction with an independent third party, such as the SCS. Based on the general vegetative conditions at the time of sampling or estimations, the site can be determined to have equal or better vegetation and habitat conditions as compared to the surrounding areas based on trends, sampling, and analysis the past five years, and on the results on the present sampling and permanently marked transects.

Erosion is variable and rapid depending on degree of slope, soils, and topographic situation. There are no discernable trends or differences on site versus off site based on our short field study. As noted earlier, reclamation procedures and sediment control measured have reduced slopes and altered soil conditions such that erosion is less than other areas at the same topographic position. There were fewer and smaller rills and gullies on the reclaimed site, including the face of the refuse pile. The stakes and measurements of erosion factors can be continued to determine trends in erosion both on and off site.

The soils on the site, due to disturbance and soil placement practices during reclamation, resemble the upper portions of the adjacent alluvial valley in the Dog Valley drainage. However, the vegetation is a diverse mixture of seeded and naturally reseeding species.

Recommendations are as follows:

1. WSM should request a variance on the stipulation that vegetation should stabilize the soil surface and control erosion.

2. WSM should request that the vegetation standards on the site be based on the linear transect method (not on a single reference area), and:

- for sample adequacy, substitute the formula given below for the present requirement for a 90% confidence level with a 10% change in the mean (since the sample parameters for all the transects sampled do not meet this criteria). Sample adequacy can be meet using a precision estimate that the width of the 95% confidence interval is no greater than 30% of the mean (using a D' = [2(SE÷X)]100),

- the site be analyzed for productivity and range condition (forage value) with reference to off site linear transects using an SCS method of estimating productivity and evaluating range condition, and

- the site be treated as a single unit for evaluation of cover, density, and productivity (cannot be segregated into vegetation or management units)

3. WSM should request that a determination that sedimentation rates and erosion controls on the site are equal to or better than conditions off site in similar topographic situations, and that erosion has been controlled to the extent possible.

We further recommend that based on the analysis of ecological and vegetation parameters, no further actions be taken on site to increase or enhance vegetation or control erosion. The top of the refuse pile has exposed coal refuse that is revegetating, and is similar to exposed coal seams in the immediate vicinity of the reclaimed mine. This portion of the refuse pile could be left indefinitely as a test plot with no impacts on plants or animals. The hazards to plant or animal communities from physical or chemical conditions on the reclaimed mine site have no apparent differences to conditions off the site.

REFERENCES:

Carlile, D.W., et. al. 1989. Determination of Ecological Scale. Landscape Ecology 2(4):203-213.

Cullinan, V.I., and J.M. Thomas. 1992. A comparison of quantitative methods of examining landscape pattern and scale. Landscape Ecology 7(3):211-227.

Hansen, Allen & Luce. 1994. J.B. King Mine: Reclamation Plan Revision. Proposed Appendix to Permit ACT/015/002, submitted to the State of Utah, Division of Oil, Gas, and Mining. 24 pp, plus Appendices.

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Simmons, M.A., et. al. 1992. Satellite imagery as a tool to evaluate ecological scale. Landscape Ecology 7(2):77-85.

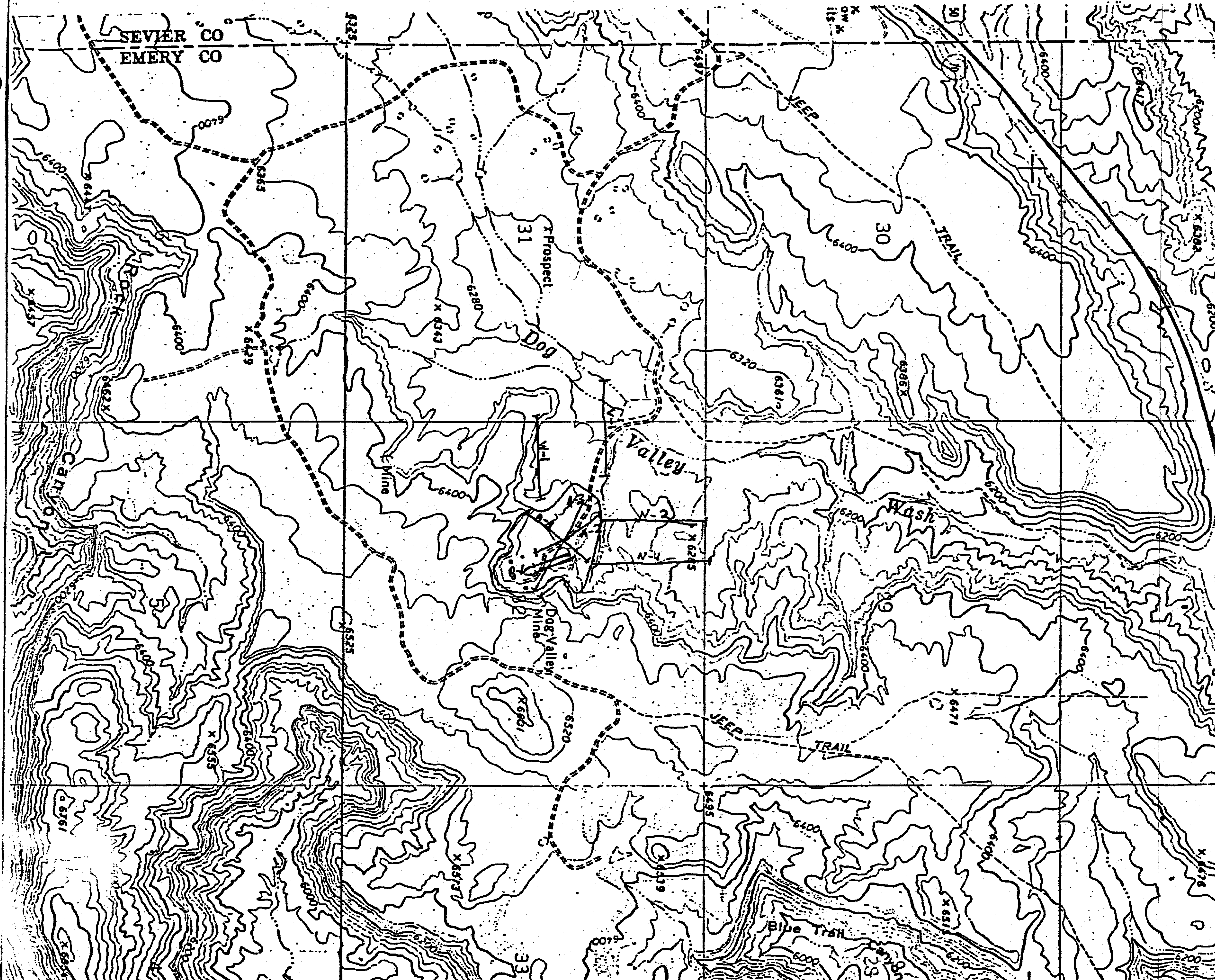

Figure 1. Topographic map showing approximate locations of off site linear transects. Transects N1, N2, and W1 are permanently marked with rebar. See Figure 2 for locations of on site transects.

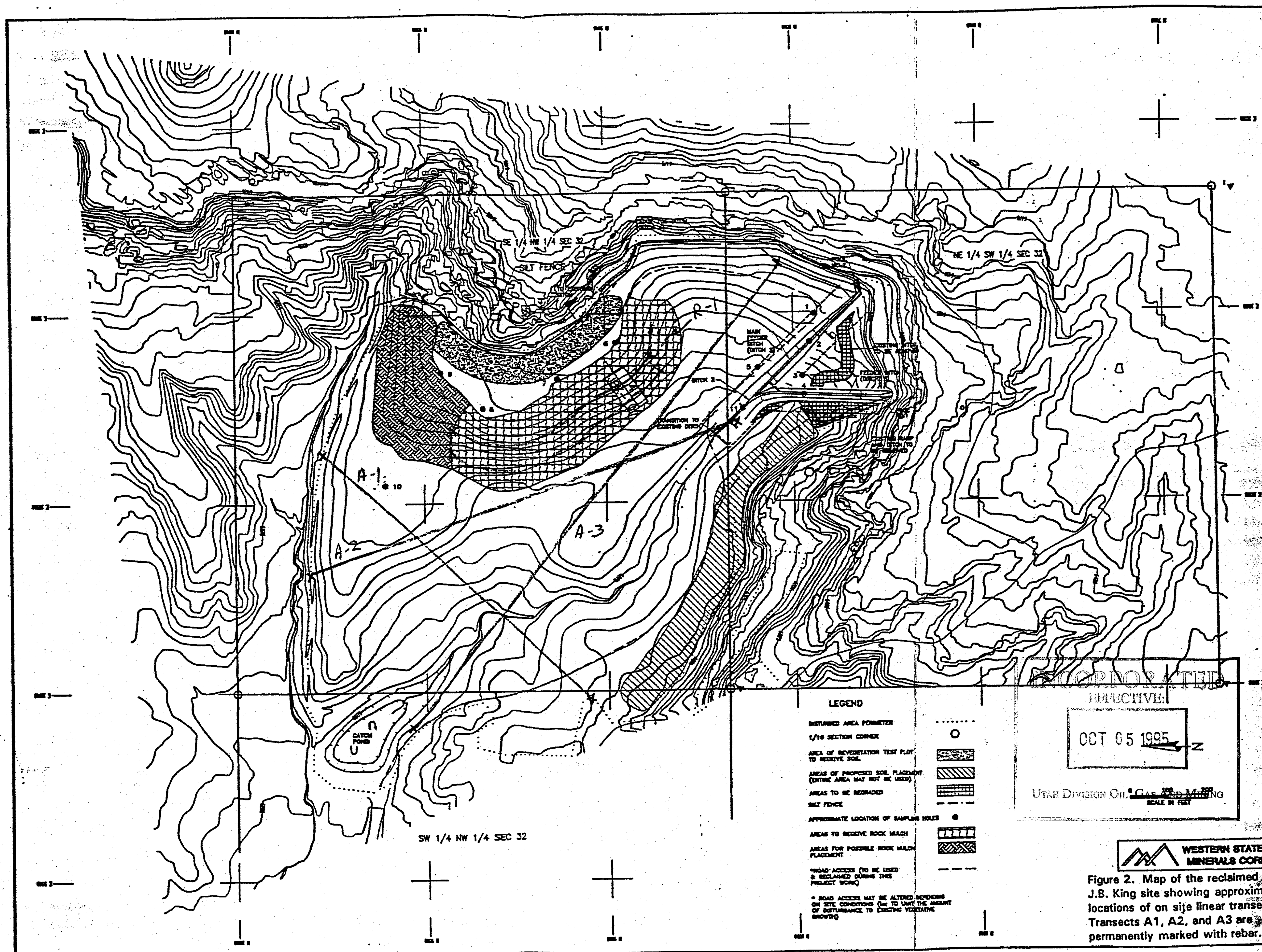

Figure 2. Map of the reclaimed J.B. King site showing approximate locations of on site linear transects. Transects A1, A2, and A3 are permanently marked with rebar.

UMC 817.112 - REVEGETATION : USE OF INTRODUCED SPECIES

The following summarizes the recommended seed mix, application methods, and sowing rates proposed to be utilized during the 1994 revegetation activities planned for the J.B. King reclaimed minesite, as well as the actual revegetation practices that were performed.

Seed Mix

The recommended seed mix has been adjusted based on the monitoring results of the past four years for growth of plant species in the original seed mixture. Some species that were planted did not germinate or grow, such as joint fir, blue grama and big bluestem, and these plants will not be seeded again. The attached Table ["Recommended Seed Mix for Revegetation"] gives the presently recommended seed mix.

Approximately 206 lbs. of pure live seed was purchased from Plummer Seed Co., Inc. in Ephraim, Ut for the 1994 reclamation activities. Please find attached a specification sheet for the seed used. In addition to this purchased seed, other native seed was collected from site plants and used in the reseeding process.

Application Methods and Rates

The general seed mix will be applied at 14 to 18 pounds per acre by the broadcast method. Seeds germinate best when applied immediately on freshly worked soil, therefore seeds will be applied as soon as (within 24 hours) a portion of the site is finished and roughened. Seed will be broadcast either by hand or using a hand-held mechanical spreader.

In actual practice, approximately 26 lbs. of pure live seed per acre was applied to the redisturbed lands (8 acres total). In addition, the native seed collected from the site was applied at a rate of about 3 to 5 lbs. per acre. The location of that application is shown on Drawing JBK-3 (AS BUILT), and includes all land within the perimeter of the 1994 redisturbed lands. Application was via hand broadcast only, and was completed daily, following surface roughening.

FROM: Plummer Seed Co., Inc.
P.O. Box 70
Ephraim, Utah 84627

Mix No.: Western States Fall -94

DELIVER TO: Gayland Cropper
2500 South 3100 West
Delta, Utah 84624

SPECIES	VARIETY	%PURE SEED	%GERM.	%HARD SEED	%GERM. & HARD	ORIGIN	TESTED	LOT NO.
Shadscale Saltbush	V.N.S.	15.39	40 TZ	0	40 TZ	UT	4-94	P-93
Western Wheatgrass	Rosanna	13.68	90 TZ	0	90 TZ	WA	1-94	LH-1
Winterfat	V.N.S.	10.26	40 TZ	0	40 TZ	UT	3-94	330
Galleta Grass	Viva	8.79	70	0	70	NM	2-94	BS-94
Fourwing Saltbush	V.N.S.	7.89	39 TZ	0	39 TZ	UT	4-94	ATCA-3
Gardner Saltbush	V.N.S.	6.84	45 TZ	0	45 TZ	UT	4-94	ATGA-2
Thickspike Wheatgrass	Critana	6.83	90	0	90	WA	1-94	AGDA-2
Indian Ricegrass	Nezpar	6.69	92 TZ	0	92 TZ	WA	1-94	NLL-1
Sanddrop Seed	V.N.S.	4.40	68	2	70	NM	4-94	SPCR-1
Gooseberryleaf Globemallow	V.N.S.	1.89	81 TZ	0	81 TZ	UT	8-94	SPGR-94
Needle and Thread Grass	V.N.S.	1.77	87 TZ	0	87 TZ	UT	2-94	STCO-93
Yellow Sweet Clover	V.N.S.	1.71	80	10	90	Canada	4-94	M-1
Palmer Penstemon	V.N.S.	.88	87 TZ	0	87 TZ	UT	8-94	PEPA-94

Net Weight/Bag: 50 lbs. PLS lbs.: 28.86 PLS lbs. In Mix: 150 lbs Bulk lbs. In Mix : 259.85

% WEED SEED: .16 % OTHER CROP: .23 % INERT MATTER: 12.59 NOXIOUS WEEDS: None Found

UMC 817.114 - REVEGETATION : MULCHING AND OTHER SOIL STABILIZING PRACTICES

During 1993, soil samples from the site were collected and analyzed for chemical and physical characteristics. The results of this work are summarized in a report entitled **Analysis of Soil Samples of the J.B. King Mine, June 1993** by Samuel A. Bamberg, Ph.d, Bamberg Associates. This report and the soil nutrient laboratory reports are attached as documentation.

The outcome of these studies indicated that use of inorganic soil fertilizers and soil supplements would probably be inappropriate at this time. However, it was found that the best amendment for improving the nutrient status and moisture regime of the soil is heavy textured organic matter (such as sewage sludge). This will also improve tilth and water holding capacity. Hay and straw can be used to protect the reclaimed soil surface after seeding, but will not greatly improve the soil conditions or enhance plant growth. The organic sludge also contains large amounts of nitrogen that will slowly release over a period of years, having a persistent positive effect on the soil fertility. The rate of sludge application is being recommended in a range of 12 to 18 tons per acre. However, the actual application rate was higher and is discussed in section UMC 817.25.

A source of these biosolids (sewage sludge) has been located and procured from the Price River Water Improvement District (PRWID). All required permitting approvals have been received from EPA, Region VIII and State of Utah, Dept. of Environmental Quality, Division of Water Quality and are documented in section UMC 782.19 of this permit.

In actual practice, biosolids procured from the PRWID were applied to the 1994 redisturbed lands as described in Section UMC 817.25.

ANALYSIS OF SOIL SAMPLES ON THE J.B. KING MINE, JUNE 1993

The soil chemical and physical characteristics on the J.B. King mine have a large influence on revegetation success, and affect the subsequent types of vegetation that will persist on the site. The soil texture and chemical nutrient status is of particular importance for plant growth and species composition. Heavy, textured clay soils have very low plant growth in this part of the Colorado Plateau due to poor soil moisture conditions. Large concentrations of salts or alkali conditions in the soils can inhibit plant germination and growth. The sedimentary shales and sandstone around the coal beds typically are high in salts and some metals, and low in the plant nutrients of nitrogen, potassium and phosphorus.

Six soil samples were collected on and around the mine site for laboratory analysis of the chemical and physical features important for plant growth. The major soil substrates in the region are sand to sandy loam derived from sandstone, and silt loam to silty clay derived from shales. Two samples were collected offsite immediately to the northeast of the reclaimed mine site on each of these substrates, sandstone and shale. Four samples were collected onsite; one on the north side of the mine in subsoil that had the topsoil removed on shaley sand, two from the mixed substrate on the refuse pile soil cover, and one from a shaley area that was borrowed for soil to cover the refuse pile on the west side of the property. For each sample, 6 to 10 collections were composited from a depth ranging from 0 to 6 inches.

In the soils laboratory, samples were analyzed for the following variables:

General:

- pH (standard units)
- salts (mmhos/cm)
- cation exchange capacity (meq/100g)
- lime (%)
- organic matter (%)
- organic nitrogen (lbs/acre)
- sodium (meq/100g)
- sodium adsorption ratio (SAR)
- texture (% each of sand, silt, and clay) expressed as USDA texture

Available nutrients (ppm): nitrate-n, phosphorus, potassium, calcium, magnesium, sulfur, boron zinc, iron, manganese, and copper.

The results of the analyses are presented in Tables A4-1 to A4-3. Soil textures were a sandy loam to a silt loam on substrates derived from sandstone and limy sands, and a loam to a silty clay on soils derived from shaley bedrock. The soils on the site were derived from mixed substrates and were a silt loam on the north side, loam on the west portion of the refuse pile and the borrow (shaley) area, and a silty clay on the central part of the refuse pile. The soil pH was basic with a range from 8.2 to 9.0, and lime was medium to high. Salts and alkali were highest in the soil onsite derived from shaley bedrock and were excessive on the refuse pile and shaley area. Alkali, in general, was high on the soils from shaley bedrock. Nitrogen and phosphorus were low to medium in the soils, however potassium was average. Straw and other organic matter was observed in the top layers of soil but, in general, nitrogen was deficient. The other elements that were high and in excessive amounts in these soils were sulfur, boron, iron, and manganese or magnesium.

The factors in these soils that are severely limiting for plant growth in this arid climate are the high amounts of clay, high salts and alkali, and the high mineral content of some elements. The textures of the shaley substrates onsite are loams to silty clays with a clay percentage up to about 40%. These textures are generally not that limiting for plant growth, but coupled with high salt and alkali content do severely limit plant growth. Nutrients and fertilizer, if added as a soil amendment, are not effective for plant growth without adequate soil moisture conditions. This explains the poor growth and productivity of vegetation during drought years. During years of adequate moisture, plant cover and productivity will double as compared to dry seasons. The nature of the soils on the mine site and in this region requires plant species that are adapted to poor soil textures, high salts and excess alkali, and can withstand periods of drought. The plants observed that do well in this area on soils derived from shaley substrates are species of saltbush (*Atriplex* spp.), greasewood (*Sarcobatus vermiculatus*), grasses such as galleta (*Hilaria jamesii*) and sand dropseed (*Sporobolus cryptandrus*), and a numbers of forbs. On the sandstone derived soils, other plants species thrive that are adapted to drought conditions and generally low soil moisture.

The majority of the soils observed on the reclaimed minesite are derived from a mixed substrate including large amounts of shale, some sandstone, and other soil materials left over from coal mining. The soils analyzed all contained some excess salt and alkali, and require adequate soil moisture for good plant growth. The plant growth, as measured during the past four years, is adequate for the region, and is what can be expected given the soil conditions, climate in the area, and the topography of the site.

Table A4-1 Soil Sample Locations and Textural Properties, J.B. King Mine

Sample No.	Location	USDA texture	%		
			Sand	Silt	Clay
Onsite					
JBK01	N of Refuse Pile	silt loam	24	61	15
JBK02	Refuse Pile (N-S)	loam	26	48	26
JBK05	Refuse Pile (E-W)	silty clay	17	42	41
JBK06	Shaley area	loam	28	46	26
Offsite					
JBK03	Sandstone	sandy loam	77	13	10
JBK04	Shale slope	loam	33	47	20

Table A4-2 Soil Sample Physical Properties, J.B. King Mine

Sample No.	Salt (MMHOS/cm)	CEC (MEQ/100g)	Na (MEQ/100g)	SAR	pH	OM (%)
Onsite						
JBK01	2.98	10.2	0.50	2.1	8.4	0.7
JBK02	9.00	11.0	4.46	9.3	8.3	1.1
JBK05	3.94	23.6	3.29	4.6	8.3	0.7
JBK06	10.80	12.3	2.84	4.5	8.2	1.8
Offsite						
JBK03	0.43	6.9	0.09	0.3	9.0	0.8
JBK04	4.14	10.7	0.85	3.3	8.2	1.0

Table A4-3 Soil Sample Available Nutrients (Units in ppm), J.B. King Mine

Sample No.	N	P	K	Ca	Mg	S	B	Zn	Fe	Mn	Cu
Onsite											
JBK01	5.1	9.2	140	2720	502	717	2.3	1.1	24.7	3.4	1.1
JBK02	25.6	7.0	127	3390	932	1708	3.4	0.9	2.7	18.1	1.1
JBK05	0.9	9.1	146	4300	1701	4157	5.1	1.1	10.2	1.8	1.4
JBK06	39.9	9.8	181	3080	1775	6662	5.8	1.6	27.1	6.5	1.4
Offsite											
JBK03	7.4	9.4	96	1500	181	342	1.2	0.5	5.5	1.7	0.4
JBK04	2.9	7.8	129	2760	442	1162	2.1	0.8	31.0	9.5	0.9

COLORADO ANALYTICAL LABORATORY

SOIL WATER ENVIRONMENTAL

SOIL NUTRIENT LABORATORY REPORT

LAB NO: 3538.1 DATE RCVD: 06/30/93 REPORTED: 07/23/93	REPORT TO: SAM BAMBERG	BILL TO: SAM BAMBERG 26050 E. JAMISON CR. AURORA, CO 80016

SAMPLE ID: SAMPLE JBK 01 PROJECT: JB KING

Nol relive pile - scraped area 0-6 inches 10

LABORATORY RESULTS:	SAMPLE RESULT	LOW——AVE——HIGH
FIELD TEXTURE (USDA)	SILT LOAM	
pH (UNITS)	8.4	***********************
SALTS (MMHOS/CM)	2.98	****************************
CEC EST. (MEQ/100G)	10.2	**********
LIME (%)	MEDIUM	**********************
ORGANIC MATTER (%)	0.7	******
ORGANIC N (LBS/ACRE)	19.5	******
SODIUM (MEQ/100G SOIL)	0.50	***********
AVAILABLE NUTRIENTS (PPM)		
NITRATE-N	5.1	*****
PHOSPHORUS	9.2	*********
POTASSIUM	140	***************************
CALCIUM	2720	*********************
MAGNESIUM	502	***************************************
SULFUR	717.5	***
BORON	2.3	***
ZINC	1.1	*********************
IRON	24.7	***
MANGANESE	3.4	***
COPPER	1.1	*********************

NOTE: *AVERAGE VALUES ARE FOR COLORADO SOILS*

FERTILIZER RECOMMENDATIONS (LBS/ACRE)		ADDITIONAL TESTING	
CROP	NOT REQUESTED	SODIUM ADSORPTION RATIO (SAR)	2.1
YIELD GOAL		SAND (%)	24
MANURE APPLIED		SILT (%)	61
		CLAY (%)	15
NITROGEN		USDA TEXTURE	SILT LOAM
PHOSPHORUS - P2O5			
POTASSIUM - K2O			
SULFUR - SO4-S			

COMMENTS

FERTILIZATION WILL BE MOST EFFECTIVE IF ADEQUATE MOISTURE CONDITIONS PREVAIL.

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Mailing Address: P.O. Drawer 507, Brighton, CO 80601

COLORADO ANALYTICAL LABORATORY

SOIL WATER ENVIRONMENTAL

SOIL NUTRIENT LABORATORY REPORT

LAB NO: 3538.2 DATE RCVD: 06/30/93 REPORTED: 07/23/93	REPORT TO: SAM BAMBERG	BILL TO: SAM BAMBERG 26050 E. JAMISON CR. AURORA, CO 80016

SAMPLE ID: SAMPLE JBK 02 PROJECT: JB KING

W slope - refuse pile 6 composite N-S transect

LABORATORY RESULTS:	SAMPLE RESULT	LOW——AVE——HIGH
FIELD TEXTURE (USDA)	LOAM	
pH (UNITS)	8.3	************************
SALTS (MMHOS/CM)	9.00	**
CEC EST. (MEQ/100G)	11.0	***********
LIME (%)	HIGH	**
ORGANIC MATTER (%)	1.1	***********
ORGANIC N (LBS/ACRE)	33.0	***********
SODIUM (MEQ/100G SOIL)	4.46	**
AVAILABLE NUTRIENTS (PPM)		
NITRATE-N	25.6	*************************
PHOSPHORUS	7.0	******
POTASSIUM	127	*************************
CALCIUM	3390	***************************
MAGNESIUM	932	**
SULFUR	1708.3	**
BORON	3.4	**
ZINC	0.9	*****************
IRON	2.7	******************
MANGANESE	18.1	**
COPPER	1.1	*********************

NOTE: *AVERAGE VALUES ARE FOR COLORADO SOILS*

FERTILIZER RECOMMENDATIONS (LBS/ACRE)		ADDITIONAL TESTING	
CROP	NOT REQUESTED	SODIUM ADSORPTION RATIO (SAR)	9.3
YIELD GOAL		SAND (%)	26
MANURE APPLIED		SILT (%)	48
		CLAY (%)	26
NITROGEN		USDA TEXTURE	LOAM
PHOSPHORUS - P2O5			
POTASSIUM - K2O			
SULFUR - SO4-S			

INCORPORATED EFFECTIVE: OCT 05 1995 UTAH DIVISION OIL, GAS AND MINING

COMMENTS

FERTILIZATION WILL BE MOST EFFECTIVE IF ADEQUATE MOISTURE CONDITIONS PREVAIL.
SOME YIELD REDUCTION IS POSSIBLE DUE TO HIGH SALTS
SOIL CONTAINS EXCESS ALKALI

COLORADO ANALYTICAL LABORATORY

SOIL WATER ENVIRONMENTAL

SOIL NUTRIENT LABORATORY REPORT

LAB NO: 3538.5 DATE RCVD: 06/30/93 REPORTED: 07/23/93	REPORT TO: SAM BAMBERG	BILL TO: SAM BAMBERG 26050 E. JAMISON CR. AURORA, CO 80016

SAMPLE ID: SAMPLE JBK 05 PROJECT: JB KING

refuse pile W to E transect 6 comps 0-6

LABORATORY RESULTS:	SAMPLE RESULT	LOW—AVE—HIGH
FIELD TEXTURE (USDA)	SILTY CLAY	
pH (UNITS)	8.3	***********************
SALTS (MMHOS/CM)	3.94	*************************************
CEC EST. (MEQ/100G)	23.6	**********************
LIME (%)	LOW	**********
ORGANIC MATTER (%)	0.7	******
ORGANIC N (LBS/ACRE)	20.1	******
SODIUM (MEQ/100G SOIL)	3.29	***
AVAILABLE NUTRIENTS (PPM)		
NITRATE–N	0.9	
PHOSPHORUS	9.1	*********
POTASSIUM	146	****************************
CALCIUM	4300	*********************************
MAGNESIUM	1701	***
SULFUR	4157.0	***
BORON	5.1	***
ZINC	1.1	*********************
IRON	10.2	***
MANGANESE	1.8	**********************************
COPPER	1.4	***************************

NOTE: *AVERAGE VALUES ARE FOR COLORADO SOILS*

FERTILIZER RECOMMENDATIONS (LBS/ACRE)		ADDITIONAL TESTING	
CROP	NOT REQUESTED	SODIUM ADSORPTION RATIO (SAR)	4.6
YIELD GOAL		SAND (%)	17
MANURE APPLIED		SILT (%)	42
		CLAY (%)	41
NITROGEN		USDA TEXTURE	SILTY CLAY
PHOSPHORUS – P2O5			
POTASSIUM – K2O			
SULFUR – SO4-S			

INCORPORATED
EFFECTIVE:
JUN 05 1995
DIVISION OIL, GAS AND MINING

COMMENTS

FERTILIZATION WILL BE MOST EFFECTIVE IF ADEQUATE MOISTURE CONDITIONS PREVAIL.

COLORADO ANALYTICAL LABORATORY

SOIL WATER ENVIRONMENTAL

SOIL NUTRIENT LABORATORY REPORT

LAB NO: 3538.6 DATE RCVD: 06/30/93 REPORTED: 07/23/93	REPORT TO: SAM BAMBERG	BILL TO: SAM BAMBERG 26050 E. JAMISON CR. AURORA, CO 80016

SAMPLE ID: SAMPLE JBK 06 PROJECT: JB KING

tested area 10 composite 0-6

LABORATORY RESULTS:

	SAMPLE RESULT	LOW——AVE——HIGH
FIELD TEXTURE (USDA)	LOAM	
pH (UNITS)	8.2	**********************
SALTS (MMHOS/CM)	10.80	**
CEC EST. (MEQ/100G)	12.3	************
LIME (%)	MEDIUM	*********************
ORGANIC MATTER (%)	1.8	****************
ORGANIC N (LBS/ACRE)	52.5	****************
SODIUM (MEQ/100G SOIL)	2.84	***
AVAILABLE NUTRIENTS (PPM)		
NITRATE-N	39.9	**************************************
PHOSPHORUS	9.8	*********
POTASSIUM	181	***********************************
CALCIUM	3080	***********************
MAGNESIUM	1775	***
SULFUR	6662.5	***
BORON	5.8	***
ZINC	1.6	******************************
IRON	27.1	***
MANGANESE	6.5	***
COPPER	1.4	***************************

NOTE: *AVERAGE VALUES ARE FOR COLORADO SOILS*

FERTILIZER RECOMMENDATIONS (LBS/ACRE)		ADDITIONAL TESTING	
CROP	NOT REQUESTED	SODIUM ADSORPTION RATIO (SAR)	4.5
YIELD GOAL		SAND (%)	28
MANURE APPLIED		SILT (%)	46
		CLAY (%)	26
NITROGEN		USDA TEXTURE	LOAM
PHOSPHORUS - P2O5			
POTASSIUM - K2O			
SULFUR - SO4-S			

INCORPORATED EFFECTIVE: OCT 05 1995 UTAH DIVISION OIL, GAS AND MINING

COMMENTS

FERTILIZATION WILL BE MOST EFFECTIVE IF ADEQUATE MOISTURE CONDITIONS PREVAIL.
SOME YIELD REDUCTION IS POSSIBLE DUE TO HIGH SALTS
SOIL CONTAINS EXCESS ALKALI

COLORADO ANALYTICAL LABORATORY

SOIL WATER ENVIRONMENTAL

SOIL NUTRIENT LABORATORY REPORT

LAB NO: 3538.3 DATE RCVD: 06/30/93 REPORTED: 07/23/93	REPORT TO: SAM BAMBERG	BILL TO: SAM BAMBERG 26050 E. JAMISON CR. AURORA, CO 80016

SAMPLE ID: SAMPLE JBK 03 PROJECT: JB KING

Sandy loam on sandstone surface NE of area 100 yards

LABORATORY RESULTS:	SAMPLE RESULT	LOW——AVE——HIGH
FIELD TEXTURE (USDA)	SANDY LOAM	
pH (UNITS)	9.0	***
SALTS (MMHOS/CM)	0.43	****
CEC EST. (MEQ/100G)	6.9	******
LIME (%)	MEDIUM	**********************
ORGANIC MATTER (%)	0.8	********
ORGANIC N (LBS/ACRE)	25.2	********
SODIUM (MEQ/100G SOIL)	0.09	*
AVAILABLE NUTRIENTS (PPM)		
NITRATE-N	7.4	*******
PHOSPHORUS	9.4	*********
POTASSIUM	96	*******************
CALCIUM	1500	************
MAGNESIUM	181	**************
SULFUR	341.8	**
BORON	1.2	************************
ZINC	0.5	**********
IRON	5.5	**********************************
MANGANESE	1.7	********************************
COPPER	0.4	*******

NOTE: *AVERAGE VALUES ARE FOR COLORADO SOILS*

FERTILIZER RECOMMENDATIONS (LBS/ACRE)		ADDITIONAL TESTING	
CROP	NOT REQUESTED	SODIUM ADSORPTION RATIO (SAR)	0.3
YIELD GOAL		SAND (%)	77
MANURE APPLIED		SILT (%)	13
		CLAY (%)	10
NITROGEN		USDA TEXTURE	SANDY LOAM
PHOSPHORUS - P2O5			
POTASSIUM - K2O			
SULFUR - SO4-S			

INCORPORATED EFFECTIVE: OCT 05 1995 DIVISION OIL, GAS AND MINING

COMMENTS

FERTILIZATION WILL BE MOST EFFECTIVE IF ADEQUATE MOISTURE CONDITIONS PREVAIL.

COLORADO ANALYTICAL LABORATORY

SOIL WATER ENVIRONMENTAL

SOIL NUTRIENT LABORATORY REPORT

LAB NO: 3538.4 DATE RCVD: 06/30/93 REPORTED: 07/23/93	REPORT TO: SAM BAMBERG	BILL TO: SAM BAMBERG 26050 E. JAMISON CR. AURORA, CO 80016

SAMPLE ID: SAMPLE JBK 04 PROJECT: JB KING

shaly loam - off to NE drainage Far composite 0-6

LABORATORY RESULTS:	SAMPLE RESULT	LOW———AVE———HIGH
FIELD TEXTURE (USDA)	LOAM	
pH (UNITS)	8.2	***********************
SALTS (MMHOS/CM)	4.14	***
CEC EST. (MEQ/100G)	10.7	**********
LIME (%)	HIGH	**
ORGANIC MATTER (%)	1.0	*********
ORGANIC N (LBS/ACRE)	28.8	*********
SODIUM (MEQ/100G SOIL)	0.85	******************
AVAILABLE NUTRIENTS (PPM)		
NITRATE-N	2.9	**
PHOSPHORUS	7.8	*******
POTASSIUM	129	*************************
CALCIUM	2760	**********************
MAGNESIUM	442	***********************************
SULFUR	1161.8	***
BORON	2.1	**
ZINC	0.8	****************
IRON	31.0	***
MANGANESE	9.5	***
COPPER	0.9	*****************

NOTE: *AVERAGE VALUES ARE FOR COLORADO SOILS*

FERTILIZER RECOMMENDATIONS (LBS/ACRE)		ADDITIONAL TESTING	
CROP	NOT REQUESTED	SODIUM ADSORPTION RATIO (SAR)	3.3
YIELD GOAL		SAND (%)	33
MANURE APPLIED		SILT (%)	47
		CLAY (%)	20
NITROGEN		USDA TEXTURE	LOAM
PHOSPHORUS - P2O5			
POTASSIUM - K2O			
SULFUR - SO4-S			

INCORPORATED
EFFECTIVE:
OCT 05 1995
Utah Division Oil, Gas And Mining

COMMENTS

FERTILIZATION WILL BE MOST EFFECTIVE IF ADEQUATE MOISTURE CONDITIONS PREVAIL.
SOME YIELD REDUCTION IS POSSIBLE DUE TO HIGH SALTS

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<u>UMC 817.116 - REVEGETATION : STANDARDS FOR SUCCESS</u>

The following summarizes revegetation trends, based upon 1989 to present monitoring results; and discusses substrate and topographic considerations in relationship to the vegetative trends.

<u>Present Revegetation Conditions and Trends</u>

The general condition and phenology of the vegetation on site has improved due to moderately favorable precipitation during 1992 and 1993, as opposed to the previous drought years 1989-91. Plant species cover has increased from 1989, and some shrubs and grassed have germinated to produce numerous seedlings. Grasses and shrubs have increased in size and cover. The plant cover on the reclaimed site is comparable to the region, and 1993's increased growth was proportional to the reference area. The general trend in vegetation on the site has been a gradual increase in shrub density, also an increase of plant species of desirable forage quality with a simultaneous decrease in weedy species. There has also been a general increase in total plant cover of desirable plants (from 13% in 1989 to 25% in 1993). The reclaimed site does not have the same dominant species as the natural vegetation, but the species present provide good cover and quality habitat for animals. The reclaimed site has become a functional ecosystem with a diverse assemblage of plants and animals, and habitats in good condition. Due to the vegetation seeded and planted during reclamation, the J.B. King mine site contains more desirable vegetation for grazing than the surrounding areas, which has been heavily utilized as winter pasture for many years.

The perimeter fence surrounding the reclaimed site is in good condition and is being maintained on a continuous basis by a local contractor. The erosion control features including the catch pond, and rills filled with straw and rock are intact and operating. Erosion has not been excessive during the past two years of greater precipitation. Soil surfaces have stabilized through natural processes of armor plating with residual rock and compaction. The silt fences have been removed since their function of catching sediment during the early mine reclamation is no longer needed. The site is continuing to be monitored and maintained to promote revegetation and erosion control. Grazing rights to the site were obtained by WSMC through 1999 to exclude cattle. Vegetation and general site conditions were monitored during 1989, 1991, 1992, and 1993, and show a positive progressive trend in reclamation results.

Monitoring during 1993 showed that four-wing saltbush (Ariplex canescens) was the most abundant woody plant species measured in the sample plots at 45% of the total number of shrubs, and an average density of 1304 shrubs per acre. Shadscale (Atriplex confertifolia) was the second most abundant with a density of 22% of the total and 632 shrubs per acre. Winterfat (Ceratoides lanata) and greasewood (Sarcobatus vermiculatus) each were 11% of the total with 328 and 320 shrubs per acre respectively. Rubber rabbitbrush (Chrysothamnus nauseosus) was the last shrub species with a significant density at 9% of the total and 272 shrubs per acre.

During 1993, the average percent cover of all monitored plots for shrubs, grasses, and forbs was 17.2, 6.8, and 0.9 respectivelly, for an average desirable vegetative cover of 24.9%. Weeds (three species) had an average percent cover of 7.4. Bare ground comprised an average of 38.7% of the ground cover; litter, 17.4%; and rock, 11.6%.

The trends of the shrub density and total vegetation cover at the reclaimed J.B. King site can be analyzed from the surveys and monitoring conducted during the past four years from 1989 to 1993. The changes are related to two major factors: (1) natural plant succession on disturbed substrates with gradual changes in species composition, cover, and density over a period of time, and (2) responses to climatic conditions and local weather patterns, particularly amounts and timing of precipitation. The natural trend in plant succession in this region is from a weedy annual forb to perennial shrubs and grasses. The

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planting of seeds and seedlings during early revegetation activities (1985 and 1986) partially shortcut the weedy seral stage of succession. However, the site has had various amounts of weedy cover depending on rainfall, the degree of soil and substrate disturbance, and the amount of desirable vegetative cover. In the local weather conditions, a three-year drought from 1988 to late 1991 has been followed with normal snow and rainfall during the growing season in 1992 and 1993.

Shrub density increased from the three earlier surveys, but there was little apparent increase in total shrubs between 1992 and 1993. The previously noted change in shrub density and percentage composition has continued. The trend in shrub density was 1970 shrubs per acre in 1987, 2146 in 1989, 2430 in 1991, and 2224 in 1992. The 2880 shrubs per acre calculated in 1993 was somewhat denser, probably as a result of a large number of seedlings, only some of which were large enough to be counted as shrubs in ground cover. The number of shrub species has stayed fairly constant, but the composition has been changing. Four-wing saltbush (Atriplex canescens) decreased in numbers and percentage of shrubs from 70% in 1987, to 47% in 1989, to 37% in 1991; then increased to 47% in 1992. The density and percentage was approximately the same in 1993 at 45%. The number of four-wing saltbush shrubs decreased during the earlier drought, and have been partially replaced as a result of new germination. Over the past two years, there were increased noted in winterfat (Ceratoides lanata) and shadscale (Atriplex confertifolia) as seedlings generally over the whole site, and in greasewood (Sarcobatus vermiculatus) in areas with clay or saline soils.

In summary, since the site was first revegetated, shrub denisty and percent composition has changed in the kinds and numbers of shrubs. The composition change has been the result of natural succession and replacement of shrubs, and as a result of the drought cycle followed by plentiful moisture. The past two years has resulted in numerous shrub seedlings which were measured in the plant cover, but not in shrub density. Portions of the reclaimed areas had greater density, and some shrubs are germinating in specific soils. Greasewood was noted in the clay soils, and Gardner's saltbush in shaley slopes.

The average total plant cover including weeds was measured at approximately 21.0% (12.9% exluding weeds) in 1989, 14.8% (13.2% excluding weeds) in 1991, and 50.1% (22.0% excluding weeds) in 1992; and in the latest survey, the total plant cover measured in 1993 was averaged 32.3% (24.9% excluding weeds). This increase in vegetative cover the past two years was due to the more nearly normal amount of precipitation the site received and the resultant increase in plant growth and germination. Variance in plant microcommunities was still high due to the differences in soils, moisture, and other ecological conditions. The dominate lifeform of the vegetative cover was shrubs although, during years of low moisture, grasses and forbs increase in amount of plant cover. Three species of plants were considered weeds and were excluded when calculating total desirable cover. Halogeton (Halogeton glomeratus) was the most abundant weed on the site, and is generally not considered desirable as forage and can be poisonous to sheep when constituting a large portion of their diet. However, in the fairly early successional stage present on the site, it promotes soil stability and its annual growth provides ground cover (litter) for the following year. Summer cypress (Kochia scoparia), and Russian thistle (Salsola paulsenii) were the other common weeds. As the vegetation on the site proceeds through natural succession, weeds will decrease as the disturbance factors decrease and soil surfaces change. A more natural vegetation will become established that resembles the surrounding plant community types, this trend can already be seen between 1989 and 1993.

Although the grass percent cover did not increase greatly from the previous year, many young grass seedlings were observed in the past two years. Much of the grass was recorded as trace occurrences. Several grass species that are common in the natural communities near the mine site are becoming established onsite. Some of the grass species were in the original seed mixture, but are now becoming large enough to be observed in the plots. The grasses noted as increasing onsite were needle and thread (Stipa comata), galleta (Hilaria jamesii), and ricegrass (Oryzopsis hymenoides). Wheatgrasses (Agropyron spp) are common, but difficult to identify due to extensive hybridization. Hybrids were common throughout the site, and all hybrids of wheatgrasses were simply classified as one hybrid.

The other onsite condition undergoing change was the establishment of animal and invertebrate populations. Elk have overwintered on the site the past two years, and use by insects, birds, and small mammal burrows were observed. Ant hills were numerous on site, and are easily seen because ants denude vegetation surrounding their hills.

Substrate and Topographic Considerations

The soil chemical and physical characteristics on the J.B. King mine have a large influence on revegetation plant cover, and affect the subsequent types of vegetation that persist on the site. The soil texture and chemical nutrient status is of particular importance for plant growth and species composition. Heavy, clay textured soils have very low plant growth in this part of the Colorado Plateau due to poor soil moisture conditions. Large concentrations of salts or alkali conditions in the soils can inhibit plant germination and growth. The sedimentary shale and sandstone around the coal beds typically are high in salts and some metals, and low in the plant nutrients of nitrogen, potassium, and phosphorus.

The majority of the soils observed on the reclaimed mine site are derived from a mixed substrate including large amounts of shale, some sandstone, and other miscellaneous soil materials. The soils tested on the site had a silty loam to silty clay texture, were basic, and had a high content of salts and alkali. In general, shaley bedrock soils were high in alkalinity. Nitrogen and phosphorus concentrations were low to medium, and potassium was average. Straw and other organic matter was observed in the top layers of soil but nitrogen was generally deficient. Other elements in excessive amounts in these soils were sulfur, boron, and iron; and either manganese or magnesium was also high. The onsite soils factors that are severely limiting for arid climate plant growth include the high content of clay, salt, alkali, and other minerals. The soil textures generally do not limit plant growth, but coupled with high salinity and alkalinity, they can contribute to the problem.

Nutrients and fertilizer, as a soil amendment, are not effective for promoting plant growth if adequate soil moisture conditions are not present. This explains the poor growth and productivity of vegetation during drought years. During years of adequate moisture, plant cover and productivity will double when compared to dry seasons. The nature of the soils on the mine site ~~and in this region requires~~ plant species that are adapted to soils with poor textures, high salt content, and ~~excess alkali and are~~ drought tolerant. The soils analyzed all contained some excess salt and alkali ~~and required adequate soil~~ moisture for good plant growth. ~~The nutrient requirements for revegetation to native plants has not been~~ established in this region.

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