SECTION 25

SEDIMENT AND DRAINAGE CONTROL

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SECTION 25

SEDIMENT AND DRAINAGE CONTROL

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SECTION 25

SEDIMENT AND DRAINAGE CONTROL

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FIGURE NUMBER	FIGURE TITLE
25-1	Topdressing Regolith Stockpile Berm Typical Section
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SECTION 25

SEDIMENT AND DRAINAGE CONTROL

LIST OF EXHIBITS

EXHIBIT NUMBER	EXHIBIT TITLE
25-1	Typical Diversion Berm Plan and Sections
25-2	Area 1 Revegetated Areas
25-3	Area 2 Revegetated Areas
25-4	Area 3 Revegetated Areas

SECTION 25

SEDIMENT AND DRAINAGE CONTROL

LIST OF APPENDICES

APPENDIX NUMBER	APPENDIX TITLE
25.A	Diversion Berm Design Data
25.B	Dixon Test Plot Spoil Mitigation Study

SECTION 25

SEDIMENT AND DRAINAGE CONTROL

LIST OF REVISIONS DURING PERMIT TERM

REV. NUMBER	REVISION DESCRIPTION	DATE APPROVED

25. SEDIMENT CONTROL PLAN

25.1 **Mining and Reclamation Practices and Methods to Control Erosion and Sediment**

25.1.1 Surface Water Control Measures

Surface water controls used at Navajo Mine perform two basic functions. First, impoundments and diversions keep surface flows that originate outside the permit area (upstream) from entering active mining areas. Section 26 – Drainage Control Plan describes these impoundments and the performance standards they are designed to meet

Other surface water controls are designed, constructed, and maintained, using the best technology currently available, to prevent additional contributions of sediment to stream flow or to runoff outside the permit area. The specific controls vary according to the category of mining or reclamation operations from which the drainage is to be controlled. All surface water controls are designed and constructed to reduce, where possible, the waste of water through evaporation. Table 25-1 summarizes the controls used at Navajo Mine. Following the table is a description of each sediment control method and its application in specific mining and reclamation operations.

It is very important to recognize that site specific conditions may require the limited application of a control method listed in Table 25-1 to a mining or reclamation operation for which a different method is listed. In any case, the control methods will be designed, constructed and maintained according to prudent engineering practices and the best technology currently available.

25.1.1.1 Operation 1: Topdressing Stockpiles

The berms and/or ditches that encircle the topdressing stockpiles will divert the surface runoff along the stockpile to a point where it can either be retained and/or dewatered, see Section 26 – Drainage Control for additional detail. The berms are normally constructed by dozers or front end loaders, while the ditches are usually formed with motor graders. The berms and ditches are inspected on a routine basis and repaired as needed.

The typical berm and/or ditch shown on Figure 25-1 and typical dewatering system shown on Figure 25-2 will be used on stockpiles that have other surface drainage controls downstream, such as sediment pond, impoundments or the mining pit. It will not be used on the stockpiles near the permit boundary where there would be potential for a discharge to occur off the permit area. If, such is the case a site specific design certified by a professional engineer will be submitted for approval.

25.1.1.2 Operation 2: Immediate Mining and Active Grading Areas

Surface runoff from immediate mining and active grading areas (includes topdressing removal, overburden drilling, storage, stripping, spoil piles, pits and primary/final regrading of the last spoil row) is contained by

berms (See Exhibit 25-1). Water is conveyed to the pit or a ramp, a depression in ungraded spoils, or a depression along a berm or sediment pond. Water may be evaporated, used for dust suppression, or it may be discharged if NPDES permit conditions are met. There will be no discharge from precipitation events up to and including the 10-yr., 24-hr event.

Diversion berms will be used in situations where runoff from the immediate mining areas or active grading areas must be prevented from leaving the permit area or entering a reclaimed (topsoiled) area. The berm in these situations function as diversion structure. The diversion berms are used on permanent, interim, and pre-law lands. There are three known situations where the berms are required.

1. In advance of mining where the general slope of the land will allow water to flow away from the advancing highwall and away from existing drainage control structures;
2. Following mining where the final grading is occurring and the general slope of the land allows water to flow toward reclaimed or off the permit areas; and
3. Areas at the end of the pits where drainage from topsoil stripped areas, spoils, or regraded areas has potential to leave the permit area or enter reclaimed lands.

Several factors are considered in the design criteria for diversion berms, the most important dimension of the immediate mining area diversion berm is its height. There are two water drainage conditions which determine the height, and they are; (1) water flowing along a berm, thus the berm functions as a diversion, and (2) water is contained by the berm in areas of relatively small depression. The maximum height of the diversion berm will be four feet, except in areas where the berm crosses topographical lows in which case the berm may be seven feet. A diversion berm may impound water in low areas. The maximum depth of water impounded by a diversion berm will be six feet (three feet of running water and three feet of standing water). See Exhibit 25-1 for a typical design layout of a diversion berm.

The assumptions and design criteria used for diversion berms are as follows:

- A minimum of 1 foot of freeboard will be maintained at all times
- The 10 year, 24 hour design storm event (1.6 inches of rainfall) will be used
- Type II-65 storm type
- Maximum delta Z is 125’ to calculate Tc
- Areas have a Curve Number of 89
- Maximum area of concern is 300 acres
- Minimum area of concern is 25 acres
- Areas are approximated as squares (conservative for calculating Tc)
- Areas have a flow length equal to the square root of the area times 1.5

- Berm serves as an erodible channel
- Mannings number (n) assumed at 0.03
- Berm side grade = 2:1
- Regraded slope of 1% - 15% adjacent
- Flowline grade 1% - 15%
- Berm Height can be calculated from the following reformatted Mannings equation:

$$b = ([Q \times n \times \{C_2^{2/3}\}] / [1.486 \times \{FS / 100\}^{1/2} \times \{C_1^{5/3}\}])^{3/8}$$

where;

b	=	berm height
Q	=	peak flow cfs form drainage area
n	=	mannings number
FS	=	flowline grade in percent
C_1	=	1 + 50/IS
IS	=	internal embankment grade
C_2	=	$(5)^{1/2} + ([IS^2 + 100^2]^{1/2}\ IS)$

From the above the minimum calculated height for the berm is 1.29 feet and the maximum is 3.14 feet. From this equation it was also noted that some flows will exceed the erosive velocity of the soil however, since the channels are generally in spoil, they will self armor over time. Sediment will be retained within the disturbed areas not yet reclaimed and will not leave the permit area. For supporting data see Appendix 25.A of the mine permit.

25.1.1.3 Operation 3: Coal Handling and Ancillary Areas

Runoff from coal handling and ancillary areas (including coal stockpiles, the coal plant, maintenance shops and associated areas) is conveyed to sediment ponds. Additional information on sediment ponds can be found in Section 26 – Drainage Control Plan.

25.1.1.4 Operation 4: Reclamation Areas

Runoff from reclamation areas (graded spoils with topdressing in place) is controlled by a series of measures that, in combination, limit contributions of sediment to stream flow outside the permit area to levels no greater than the levels found in background conditions.

The sequence in which reclamation area sediment controls are put into place is important to the functioning of the controls. The sequence is as follows:

a. Spoils are recontoured by grading with dozers (see Section 34 – Post-Reclamation Topography, for a complete description of the backfilling and grading operation),

b. The berms and ditches, which were placed around spoils before grading (see Operation 2, above), are removed,
c. Topdressing is placed on the spoils immediately following removal of the berms (see b., above),
d. Mulch is applied to the topdressed area and crimped,
e. The area is seeded, and the remaining steps of the revegetation plan are carried out to establish a diverse, effective vegetation cover.

As mining progresses, active mining areas (Operation 2, above) are reclaimed as described here. Lease-wide revegetated areas are shown on Exhibit 25-2, Exhibit 25-3, and Exhibit 25-4. To prevent possible degradation, topdressing replacement operations will begin within five days following removal of the active mining area berms and ditches.

The sediment control methods described above in a. through e (i.e., re-contouring, and grass/straw mulch,) are designed and installed at Navajo Mine according to the specifications found in M.A.R.C. and Hess and Fisher Engineers, Inc. (1985). A copy of the report is found in Permit NM-0003C, Chapter 27, Appendix 27-J.

As part of the surface water control plan, a monitoring scheme as outlined in Section 42 – Monitoring, Maintenance, Inspections and Examinations will be instituted. Also see Permit NM-0003C; Chapter 27, Appendices G and K for additional documentation on the surface water monitoring program.

25.1.1.5 Operation 5: Miscellaneous Areas

There are some facilities that are not included in the previous sections. These areas include, but are not limited to, railroad maintenance storage yards, irrigation pumping facilities, electrical substations, MET stations, and temporary rail storage yards for replacement materials. In these instances a variety of BTCA's or BMP's may be used individually or in combination to ensure compliance with applicable regulations. These controls include, but are not limited to, siltation fences, rock mulch, plant mulch, and fiber logs, straw bales, and rock check dams. New or enhanced technologies and practices will be used where deemed a more viable option.

References

M.A.R.C. and Hess and Fisher Engineers, Inc. 1985. Handbook of Alternative Sediment Control Methodologies for Mined land, for USDOI/OSMRE. [Permit NM-0003C, Chapter 27, Appendix 27-J]

Table 25-1 Sediment Controls

Operation	Control Method	Performance Standard; Design Criteria	Refer To:
1. Topdressing Stockpiles	Berms, Ditches, Dewatering	Reference[1]; zero discharge[2]	Section 26.2
2. Immediate Mining Areas (includes topdressing removal, overburden drilling, equipment storage, stripping, spoils prior to completion of top-dressing placement)	Berms, Ditches, Dewatering, Sediment Ponds[3]	Reference[1]; zero discharge[2], 10 yr-24 hr storm event[6], PE certification, NPDES criteria (as approved)	Section 26.2
3. Coal Handling & Ancillary Areas (coal stockpiles, coal preparation plant, shops)	Sediment Ponds	Minimum 10-yr., 24-hr. event, P.E. certification, NPDES criteria (as approved)	Sections 22.1 and 26.2
3a. Railroad & Haulroad Transportation Corridors	Alternative Sedimentation Control (BTCA's and BMP's); Siltation fences, mulching, low gradient ditches, riprap channels, etc.	Refer to Section 26.1 of the PAP for design criteria.	Sections 23.4, 23.5, 26.1, 26.2 and 37.1

Table 25-1 (Continued)

Operation	Control Method	Performance Standard; Design Criteria	Refer To:
4. Reclamation Areas (graded with topdressing in place)	Recontouring[4], mulching[5], revegetation, terraces, Sediment Ponds[7]	Background Surface Water quality[9], 10 yr-24 hr storm event[8], PE certification, NPDES criteria (as approved),	Sections 26.2 and 37.1
5. Miscellaneous Areas (rail storage yards, irrigation pumping facilities, electrical substations, MET stations, temporary rail storage areas for replacement materials)	Berms, ditches, BTCA's and BMP's; (siltation fences, rock mulch, plant mulch, fiber logs, straw bales, rock check dams other technologies deemed suitable for the application)	Reference [10]	Section 26.2

1 30 CFR 701.5, 780.21(h), and 816.45.

2 Zero discharge means "no discharge" for any event up to the 10-yr., 24-hr. precipitation event; P.E. certified structures will be built only where a discharge resulting from an event greater than the 10-yr., 24-hr. event could leave the permit area.

3 Used only if the surface runoff is not retained in the Immediate Mining Area and there is a potential for the runoff to leave the permit area or enter a reclaimed area.

4,5 "Handbook of Alternative Sediment Control Methodologies for Mined Lands", Mining and Reclamation Council of America and Hess and Fisher Engineers, Inc., March 1985; contained in Permit NM-0003C, Chapter 27, Appendix 27-J, pages 5-17 and 79-81.

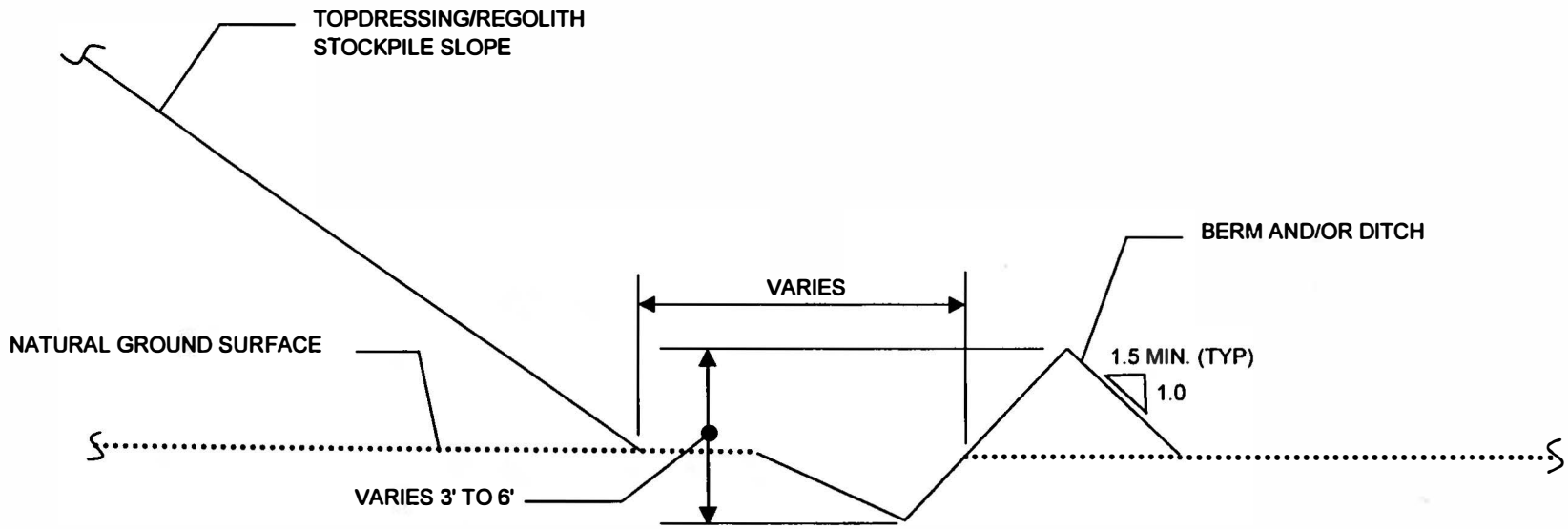
6 This criteria applies only to structures that control the surface runoff which may have the potential of leaving the permit area or entering a reclaimed area.

7 Used only if the surface runoff has the potential of leaving the permit area.

8 This criteria applies only to siltation structures at the NPDES discharge points. The "Reclamation Surface Stabilization Handbook" in the PAP outlines the design criteria for structures within the reclamation areas.

9 30 CFR 816.42 and 40 CFR Part 434 Subpart H Western Alkaline Coal Mining Subcategory.

10 30CFR 816.45 and 816.46.



TYPICAL SECTION
NTS

NOTES:

1. THE TYPICAL BERM AND/OR DITCH SHOWN WILL BE USED AROUND ONLY THE TOPDRESSING/REGOLITH STOCKPILES HAVING OTHER SURFACE RUNOFF CONTROLS DOWNSTREAM, SUCH AS SEDIMENT PONDS, IMPOUNDMENTS OR THE PIT. IT WILL NOT BE USED IF THE STOCKPILE IS LOCATED NEAR THE PERMIT BOUNDARY AND THERE IS A POTENTIAL FOR A DISCHARGE OFF THE PERMIT AREA OCCURRING. FOR THE LATTER CASE A SITE SPECIFIC DESIGN WILL BE SUBMITTED FOR APPROVAL.

CERTIFICATION STATEMENT

I, LEONARD RAYMOND, HEREBY CERTIFY THAT THIS FIGURE WAS REVIEWED BY ME AND THE INFORMATION SHOWN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

LEONARD RAYMOND
NEW MEXICO
6600
REGISTERED PROFESSIONAL ENGINEER
7-15-98

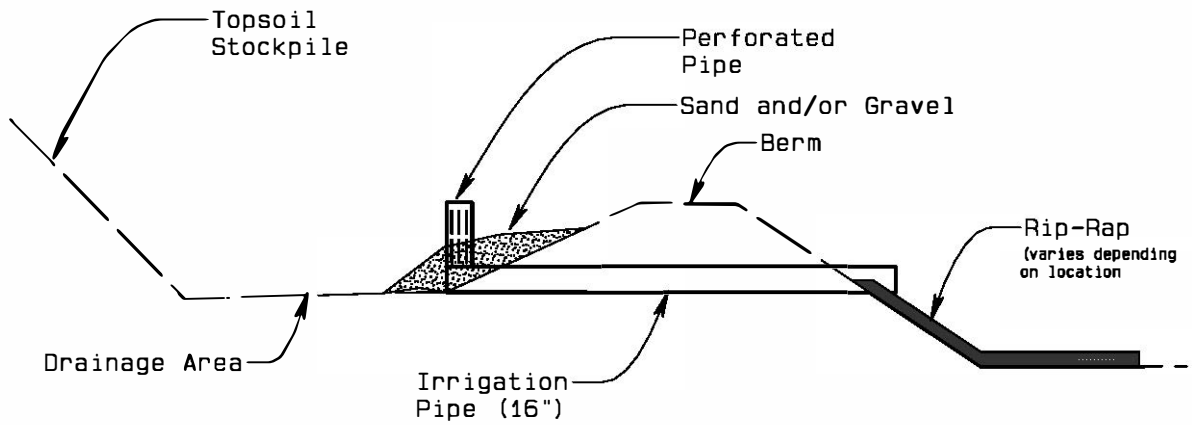
FIGURE 25-1

REV. NO.	DATE	REVISIONS:	APPROVALS ENGR.	E.Q.	P.E.	CHIEF ENGR
1	6/4/98	MIDTERM UPDATES & REVISIONS	LR		LR	

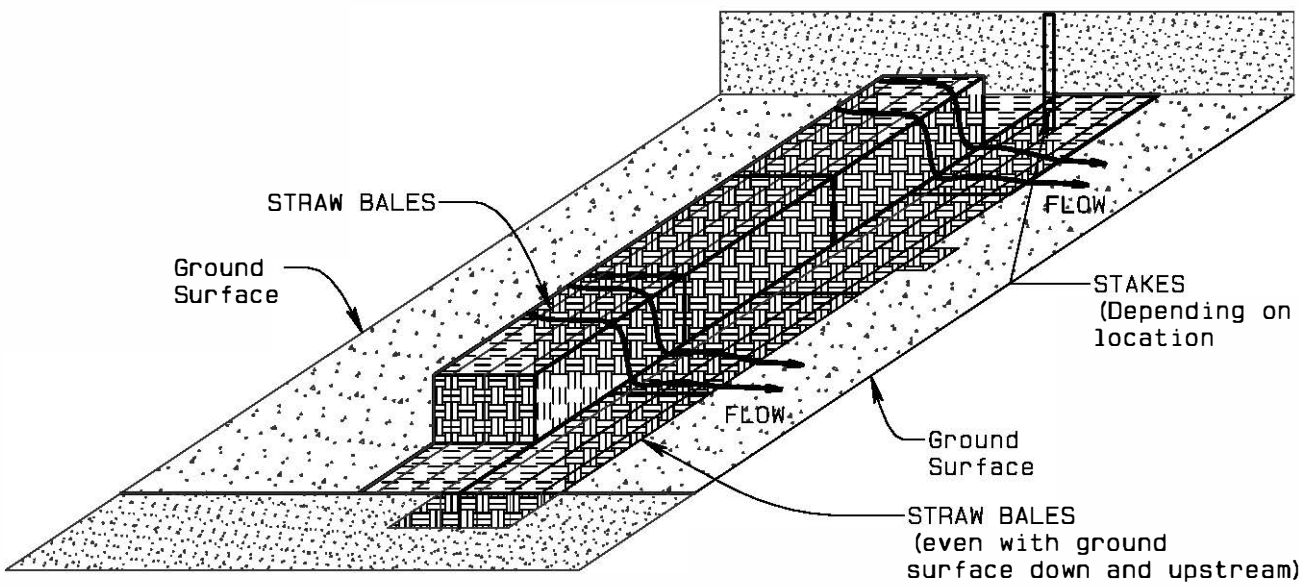
BHP NAVAJO COAL COMPANY
NAVAJO MINE
SAFETY PAYS
PO BOX 1717 FRUITLAND, NM 87416

TOPDRESSING/REGOLITH STOCKPILE BERM - TYPICAL SECTION

Drawn By: LR | Approved By: LR | Date: 6/3/98



TYPICAL DRAINAGE AREA
PERFORATED PIPE STRUCUTURE



TYPICAL DRAINAGE AREA
STRAW BALE STRUCTURE

FIGURE 25-2

NAVAJO COAL COMPANY

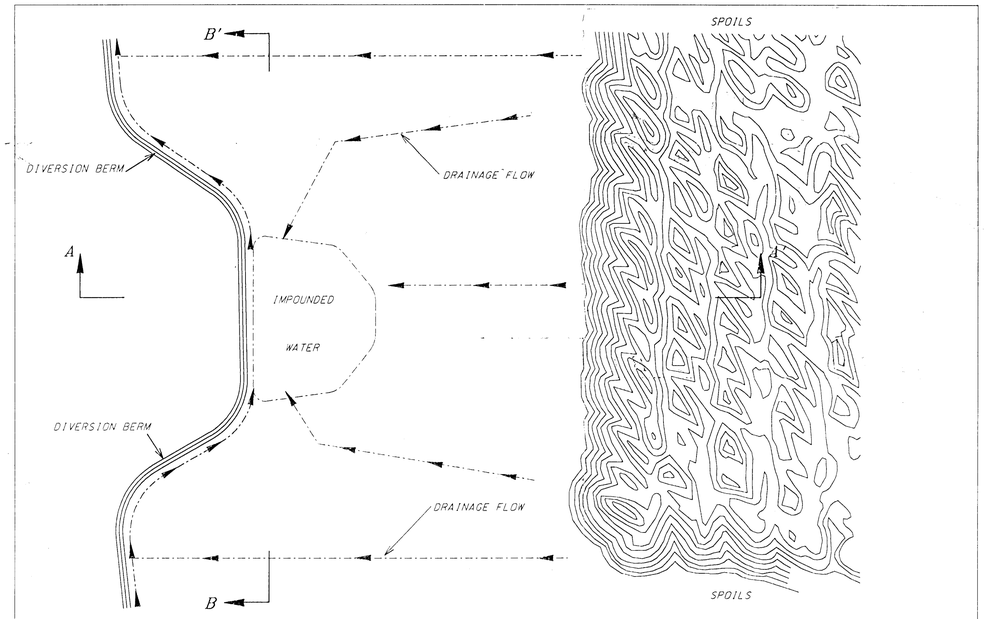
bhpbilliton

P.O.BOX 1717 FRUITLAND, NEW MEXICO 87416/PHONE 505-598-3209/FAX 505-598-3361

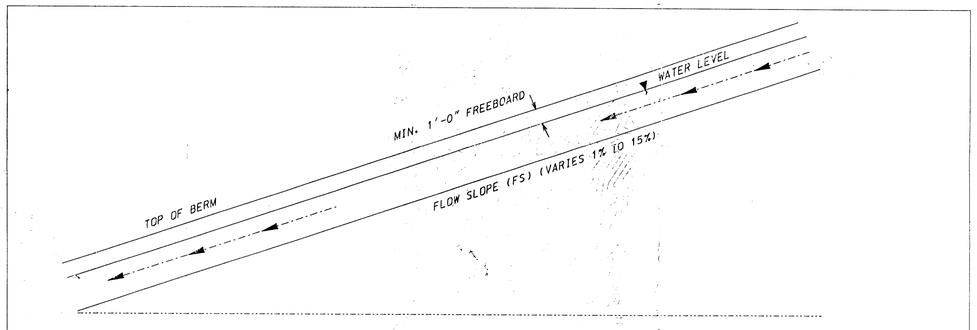
NAVAJO MINE
TYPICAL DEWATERING
STRUCTURE

PREPARED BY Shawn Smith	DRAWN BY PJF	SCALE N.T.S.
APPROVED BY	DATE 8-15-08	

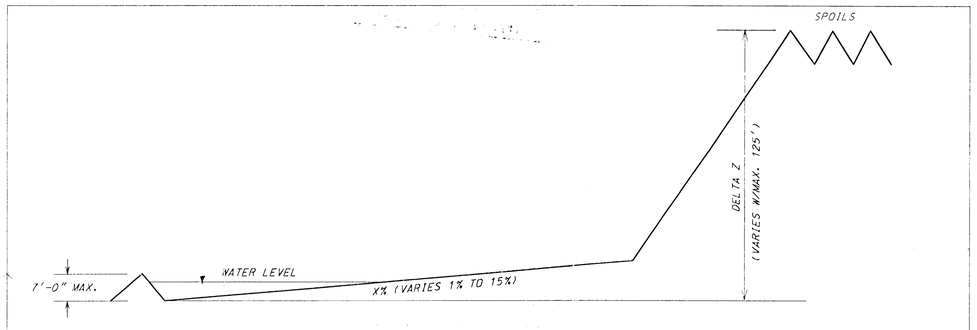
PATH: \\ENGNMCFMN-SRV02\Data\Departments\Eng_EQ\Engineering New Structure\ENGTECH\OTHER'S\SSMITH\Typical TS_Berm Drainage.pro



DIVERSION BERM
PARTIAL PLAN-SPOILS SIDE
N.T.S.



SIMILAR TO SECTION B-B'
N.T.S.



SECTION A-A' SPOILS SIDE
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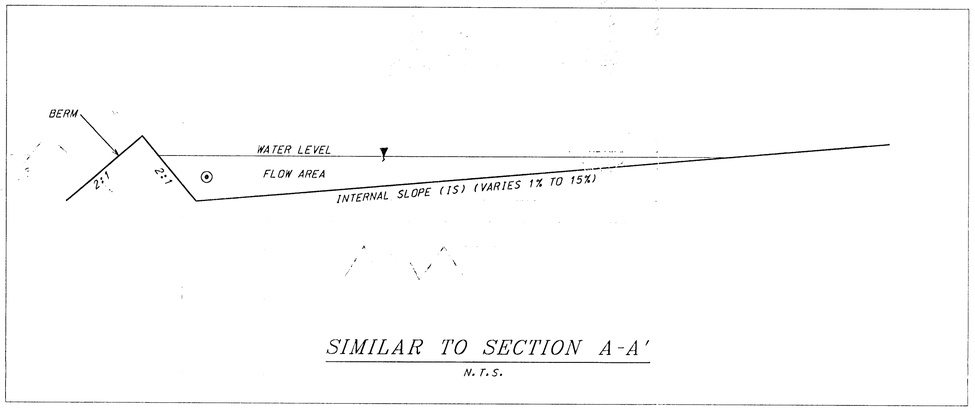
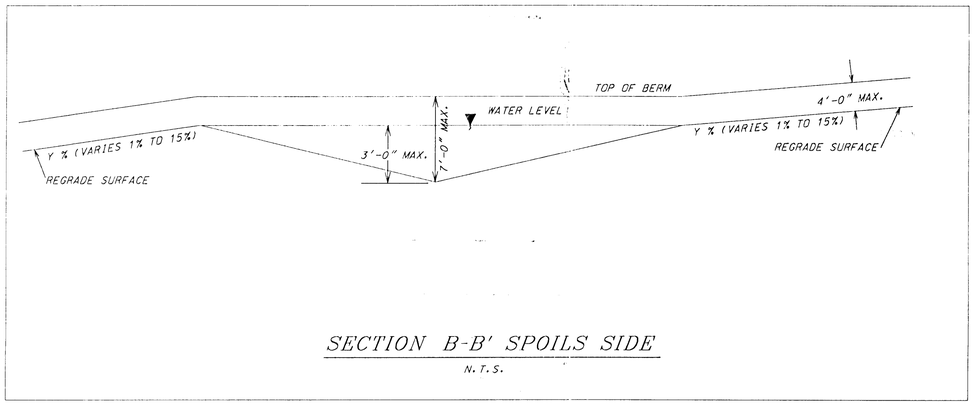


SIMILAR TO SECTION A-A'
N.T.S.



SECTION B-B' SPOILS SIDE
N.T.S.

LEGEND

	DRAINAGE FLOW
WATER LEVEL	WATER SURFACE
	HORIZONTAL ORIGIN
⊙	WATER FLOW OUT OF PAGE

NOTE:
FOR SUPPORTING DESIGN DATA REFER TO SECTION 11.2.10 AND APPENDIX 11-N IN THE MINE PERMIT.

CERTIFICATION STATEMENT
I, Leonard Raymond, hereby certify that this drawing was reviewed by me and that the information shown is accurate and complete to the best of my knowledg.

LEONARD RAYMOND NEW MEXICO 6600 PROFESSIONAL ENGINEER
4-1-97

REV. NO.	DATE	DRAFT. BY	REVISION DESCRIPTION	ENG.	E.D.	P.E.	P.S.	CHIEF ENG.
A	3-31-97	PJF	SUBMITTED TO OSM FOR APPROVAL					

APPROVALS

APR 1997 APPROVED

EXHIBIT 25-1

BHP NAVAJO COAL COMPANY
NAVAJO MINE
P.O. BOX 155 FRUITLAND, NEW MEXICO 87416

TYPICAL DIVERSION BERM PLAN AND SECTIONS

PREPARED BY	LR	DRAWN BY	PJF	SCALE	AS NOTED
APPROVED BY	LR	DATE	MAR. 29, 1997	MYLAR LOC.	A11-4

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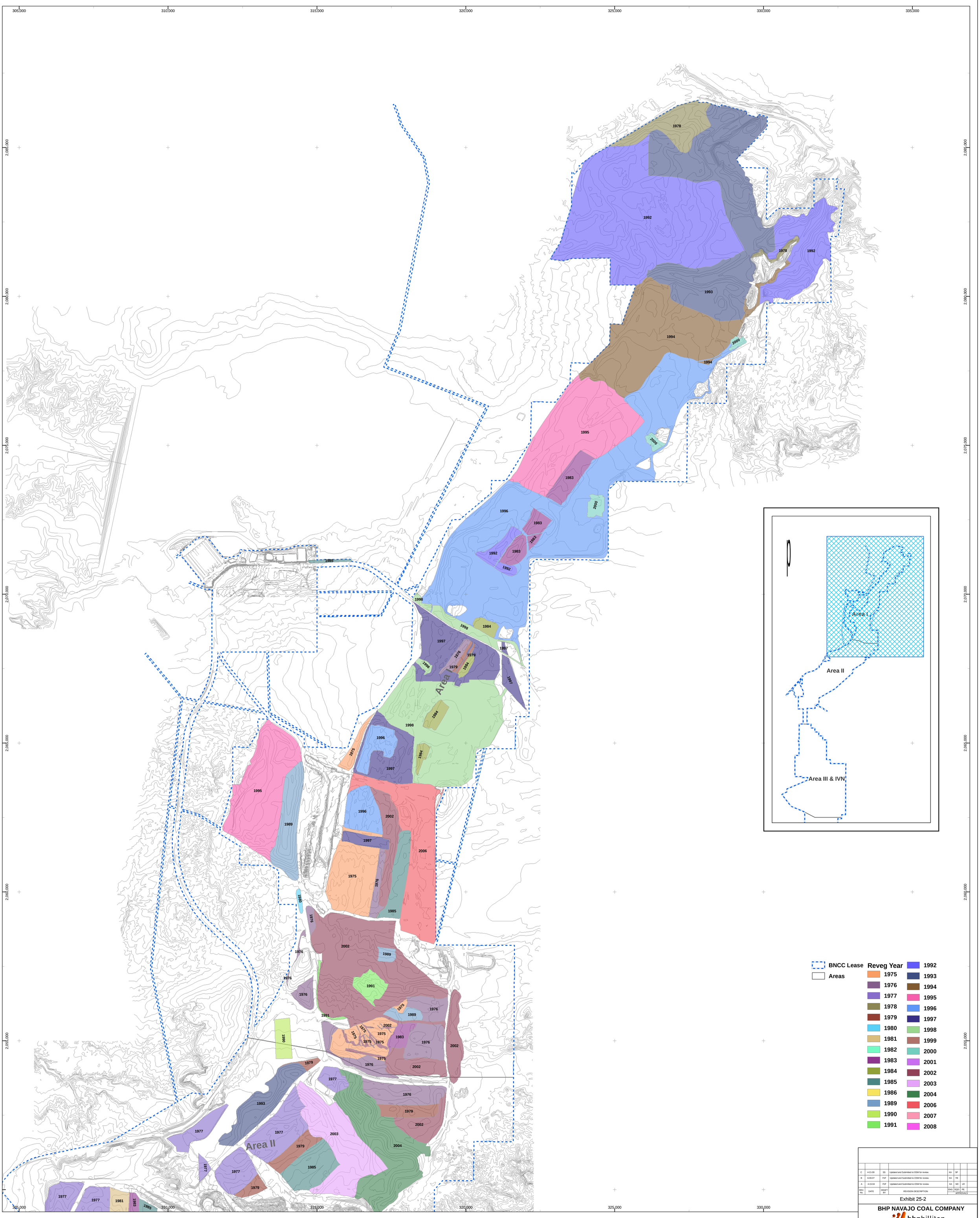

REV. No.	DATE	DRAFT BY	REVISION DESCRIPTION	ENG.	EQD.	PE.
				APPROVALS		
C	4-21-09	SS	Updated and Submitted to OSM for review.	KA	SP	
B	6-06-07	PJF	Updated and Submitted to OSM for review.	KA	YB	
A	4-15-04	PJF	Updated and Submitted to OSM for review.	KA	MC	LR

Exhibit 25-2

BHP NAVAJO COAL COMPANY

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Area I-Revegetated Areas

PREPARED BY: KApplegate/ PJFoster	DRAWN BY: PJFoster	PAPER SIZE: ANSI E
APPROVED BY: KApplegate	DATE: March 23, 2004	1"=1000'

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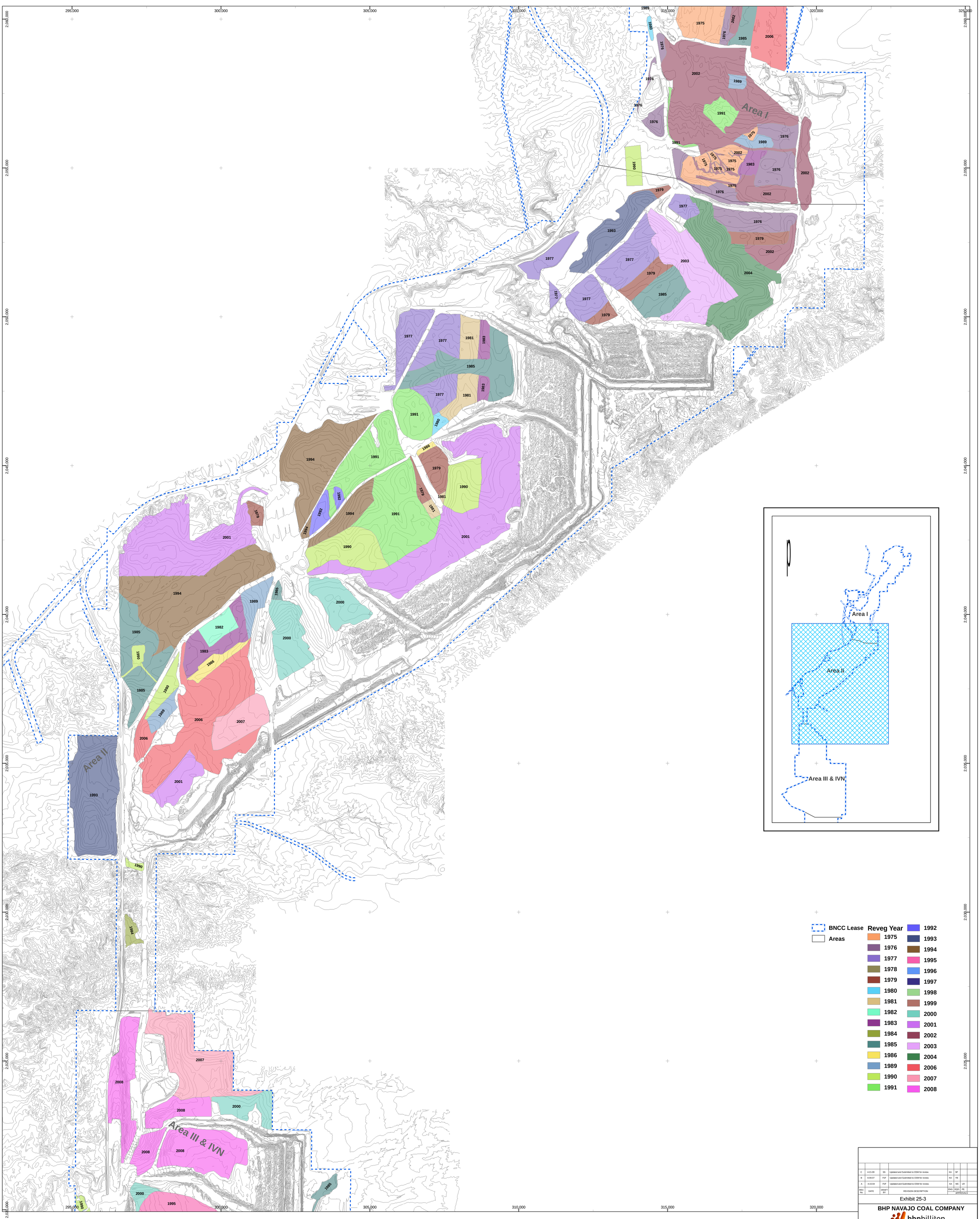
1:12,000



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C	4-21-09	SS	Updated and Submitted to OSM for review.	KA	SP	
B	6-06-07	PJF	Updated and Submitted to OSM for review.	KA	YB	
A	4-15-04	PJF	Updated and Submitted to OSM for review.	KA	MC	LR

APPROVALS:

Exhibit 25-3

BHP NAVAJO COAL COMPANY

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Area II-Revegetated Areas

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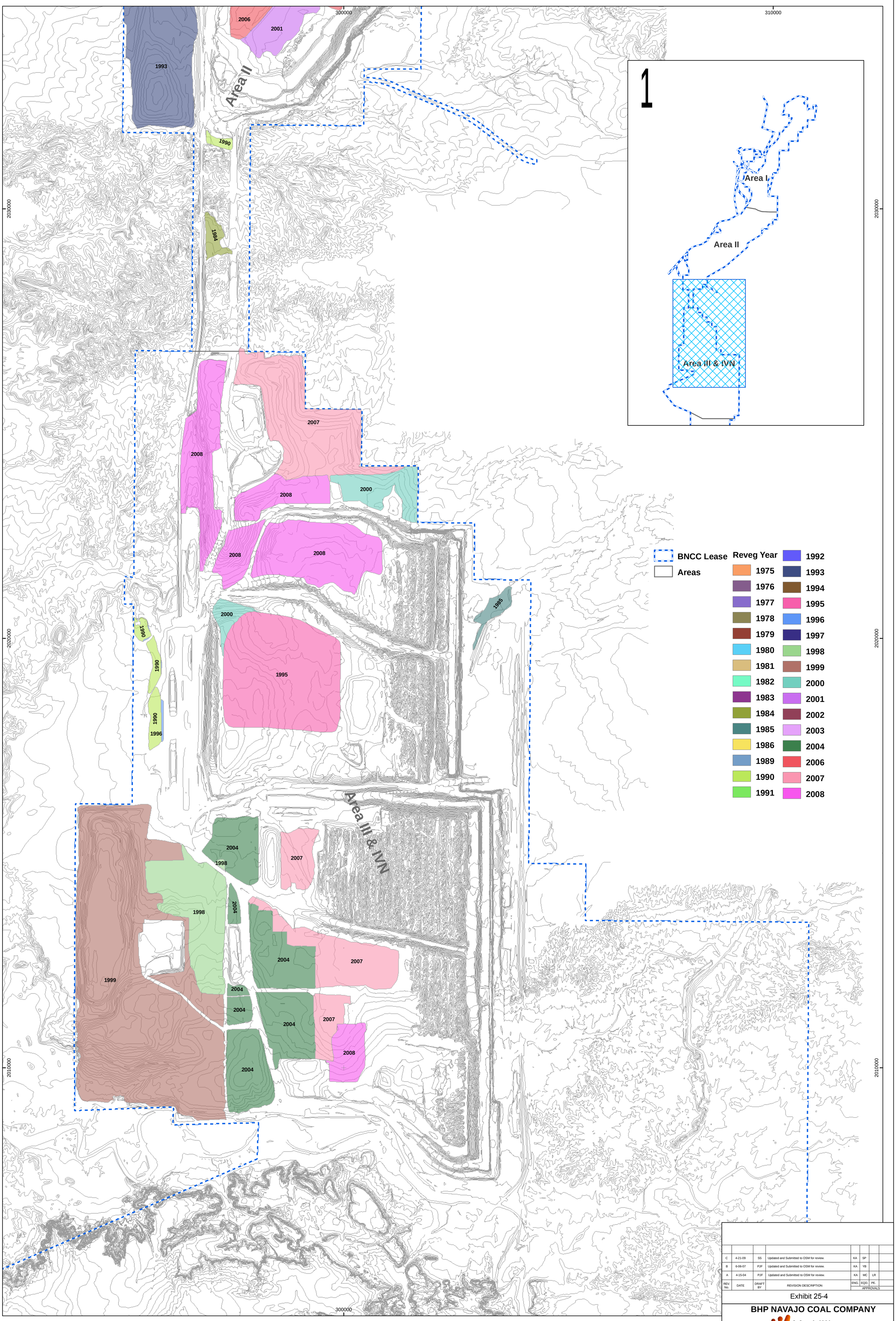
APPROVED BY: KApplegate	DATE: March 23, 2004	1"=1000'



REV. No.	DATE	DRAFT BY	REVISION DESCRIPTION	ENG.	EQD.	PE.	
C	4-21-09	SS	Updated and Submitted to OSM for review.	KA	SP		
B	6-06-07	PJF	Updated and Submitted to OSM for review.	KA	YB		
A	4-15-04	PJF	Updated and Submitted to OSM for review.	KA	MC	LR	

APPROVALS

Exhibit 25-4

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Area III-Revegetated Areas

PREPARED BY: KApplegate/ PJFoster	DRAWN BY: PJFoster	PAPER SIZE: ANSI E
APPROVED BY: KApplegate	DATE: March 23, 2004	1"=1000'

Appendix 25.A

Diversion Berm Design Data

April 1, 1997

Diversion Berm Design Data
Table of Contents

Berm Height Calculations 1

SEDCAD Runs
(Worst Case Scenarios for 25-300 ac. Watersheds) 11

DIVERSION BERM

BERM HEIGHT CALCULATIONS

MARCH 27, 1997

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
1	1	25	21.69	11.45	48.45	0.03	0.47	1.47	1.89
1	3	25	21.69	8.81	25.13	0.03	0.71	1.71	2.46
1	6	25	21.69	7.54	17.01	0.03	0.90	1.90	2.88
1	9	25	21.69	6.92	13.76	0.03	1.03	2.03	3.13
1	12	25	21.69	6.55	11.96	0.03	1.13	2.13	3.31
1	15	25	21.69	6.29	10.81	0.03	1.20	2.20	3.45
1	1	50	36.31	16.86	58.78	0.03	0.57	1.57	2.15
1	3	50	36.31	12.96	30.48	0.03	0.86	1.86	2.80
1	6	50	36.31	11.09	20.64	0.03	1.09	2.09	3.27
1	9	50	36.31	10.19	16.70	0.03	1.25	2.25	3.56
1	12	50	36.31	9.63	14.51	0.03	1.37	2.37	3.77
1	15	50	36.31	9.25	13.12	0.03	1.46	2.46	3.92
1	1	75	47.71	20.69	65.12	0.03	0.64	1.64	2.31
1	3	75	47.71	15.91	33.77	0.03	0.95	1.95	3.00
1	6	75	47.71	13.61	22.86	0.03	1.21	2.21	3.51
1	9	75	47.71	12.50	18.50	0.03	1.38	2.38	3.82
1	12	75	47.71	11.82	16.08	0.03	1.51	2.51	4.04
1	15	75	47.71	11.35	14.53	0.03	1.62	2.62	4.20
1	1	100	56.84	23.59	69.54	0.03	0.68	1.68	2.41
1	3	100	56.84	18.14	36.06	0.03	1.01	2.01	3.13
1	6	100	56.84	15.52	24.41	0.03	1.29	2.29	3.66
1	9	100	56.84	14.26	19.75	0.03	1.47	2.47	3.99
1	12	100	56.84	13.48	17.17	0.03	1.62	2.62	4.22
1	15	100	56.84	12.95	15.52	0.03	1.73	2.73	4.39
1	1	150	71.37	27.98	75.73	0.03	0.74	1.74	2.55
1	3	150	71.37	21.52	39.27	0.03	1.10	2.10	3.32
1	6	150	71.37	18.41	26.59	0.03	1.40	2.40	3.88
1	9	150	71.37	16.91	21.51	0.03	1.61	2.61	4.22
1	12	150	71.37	15.99	18.70	0.03	1.76	2.76	4.46
1	15	150	71.37	15.36	16.90	0.03	1.88	2.88	4.65
1	1	200	82.7	31.25	80.03	0.03	0.78	1.78	2.65
1	3	200	82.7	24.03	41.50	0.03	1.17	2.17	3.44
1	6	200	82.7	20.56	28.10	0.03	1.48	2.48	4.02
1	9	200	82.7	18.89	22.73	0.03	1.70	2.70	4.38
1	12	200	82.7	17.86	19.76	0.03	1.86	2.86	4.63
1	15	200	82.7	17.15	17.86	0.03	1.99	2.99	4.82
1	1	250	92.17	33.90	83.36	0.03	0.82	1.82	2.72
1	3	250	92.17	26.07	43.23	0.03	1.21	2.21	3.54
1	6	250	92.17	22.30	29.27	0.03	1.55	2.55	4.13
1	9	250	92.17	20.49	23.68	0.03	1.77	2.77	4.50
1	12	250	92.17	19.37	20.58	0.03	1.94	2.94	4.76
1	15	250	92.17	18.61	18.60	0.03	2.07	3.07	4.95
1	1	300	100.54	36.18	86.12	0.03	0.84	1.84	2.78
1	3	300	100.54	27.82	44.66	0.03	1.25	2.25	3.61
1	6	300	100.54	23.81	30.24	0.03	1.60	2.60	4.22

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
1	9	300	100.54	21.87	24.46	0.03	1.83	2.83	4.60
1	12	300	100.54	20.68	21.26	0.03	2.00	3.00	4.86
1	15	300	100.54	19.86	19.22	0.03	2.14	3.14	5.06
3	1	25	21.69	7.59	39.43	0.03	0.39	1.39	2.86
3	3	25	21.69	5.83	20.45	0.03	0.57	1.57	3.72
3	6	25	21.69	4.99	13.85	0.03	0.73	1.73	4.35
3	9	25	21.69	4.59	11.20	0.03	0.84	1.84	4.73
3	12	25	21.69	4.34	9.74	0.03	0.92	1.92	5.00
3	15	25	21.69	4.16	8.80	0.03	0.98	1.98	5.21
3	1	50	36.31	11.16	47.84	0.03	0.47	1.47	3.25
3	3	50	36.31	8.59	24.81	0.03	0.70	1.70	4.23
3	6	50	36.31	7.35	16.80	0.03	0.89	1.89	4.94
3	9	50	36.31	6.75	13.59	0.03	1.01	2.01	5.38
3	12	50	36.31	6.38	11.81	0.03	1.11	2.11	5.69
3	15	50	36.31	6.13	10.68	0.03	1.19	2.19	5.93
3	1	75	47.71	13.70	52.99	0.03	0.52	1.52	3.48
3	3	75	47.71	10.54	27.48	0.03	0.77	1.77	4.53
3	6	75	47.71	9.01	18.61	0.03	0.98	1.98	5.29
3	9	75	47.71	8.28	15.05	0.03	1.12	2.12	5.76
3	12	75	47.71	7.83	13.09	0.03	1.23	2.23	6.09
3	15	75	47.71	7.52	11.83	0.03	1.32	2.32	6.34
3	1	100	56.84	15.62	56.59	0.03	0.55	1.55	3.64
3	3	100	56.84	12.02	29.35	0.03	0.82	1.82	4.73
3	6	100	56.84	10.28	19.87	0.03	1.05	2.05	5.53
3	9	100	56.84	9.44	16.07	0.03	1.20	2.20	6.02
3	12	100	56.84	8.93	13.97	0.03	1.31	2.31	6.37
3	15	100	56.84	8.58	12.63	0.03	1.41	2.41	6.63
3	1	150	71.37	18.53	61.63	0.03	0.60	1.60	3.85
3	3	150	71.37	14.25	31.96	0.03	0.90	1.90	5.01
3	6	150	71.37	12.19	21.64	0.03	1.14	2.14	5.85
3	9	150	71.37	11.20	17.51	0.03	1.31	2.31	6.37
3	12	150	71.37	10.59	15.22	0.03	1.43	2.43	6.74
3	15	150	71.37	10.17	13.75	0.03	1.53	2.53	7.02
3	1	200	82.7	20.70	65.14	0.03	0.64	1.64	4.00
3	3	200	82.7	15.92	33.78	0.03	0.95	1.95	5.20
3	6	200	82.7	13.62	22.87	0.03	1.21	2.21	6.07
3	9	200	82.7	12.51	18.50	0.03	1.38	2.38	6.61
3	12	200	82.7	11.83	16.08	0.03	1.51	2.51	6.99
3	15	200	82.7	11.36	14.54	0.03	1.62	2.62	7.28
3	1	250	92.17	22.45	67.84	0.03	0.66	1.66	4.11
3	3	250	92.17	17.27	35.18	0.03	0.99	1.99	5.34
3	6	250	92.17	14.77	23.82	0.03	1.26	2.26	6.24
3	9	250	92.17	13.57	19.27	0.03	1.44	2.44	6.79
3	12	250	92.17	12.83	16.75	0.03	1.58	2.58	7.18
3	15	250	92.17	12.32	15.14	0.03	1.69	2.69	7.48

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
3	1	300	100.54	23.97	70.09	0.03	0.69	1.69	4.20
3	3	300	100.54	18.43	36.34	0.03	1.02	2.02	5.46
3	6	300	100.54	15.77	24.61	0.03	1.30	2.30	6.38
3	9	300	100.54	14.49	19.91	0.03	1.49	2.49	6.94
3	12	300	100.54	13.70	17.31	0.03	1.63	2.63	7.34
3	15	300	100.54	13.15	15.64	0.03	1.74	2.74	7.64
5	1	25	21.69	6.26	35.83	0.03	0.35	1.35	3.46
5	3	25	21.69	4.82	18.58	0.03	0.52	1.52	4.50
5	6	25	21.69	4.12	12.58	0.03	0.66	1.66	5.26
5	9	25	21.69	3.79	10.18	0.03	0.76	1.76	5.73
5	12	25	21.69	3.58	8.85	0.03	0.83	1.83	6.06
5	15	25	21.69	3.44	8.00	0.03	0.89	1.89	6.31
5	1	50	36.31	9.22	43.47	0.03	0.43	1.43	3.94
5	3	50	36.31	7.09	22.54	0.03	0.63	1.63	5.12
5	6	50	36.31	6.06	15.26	0.03	0.81	1.81	5.99
5	9	50	36.31	5.57	12.35	0.03	0.92	1.92	6.52
5	12	50	36.31	5.27	10.73	0.03	1.01	2.01	6.89
5	15	50	36.31	5.06	9.70	0.03	1.08	2.08	7.18
5	1	75	47.71	11.31	48.15	0.03	0.47	1.47	4.22
5	3	75	47.71	8.70	24.97	0.03	0.70	1.70	5.48
5	6	75	47.71	7.44	16.91	0.03	0.89	1.89	6.41
5	9	75	47.71	6.84	13.68	0.03	1.02	2.02	6.98
5	12	75	47.71	6.47	11.89	0.03	1.12	2.12	7.38
5	15	75	47.71	6.21	10.75	0.03	1.20	2.20	7.68
5	1	100	56.84	12.90	51.42	0.03	0.50	1.50	4.41
5	3	100	56.84	9.92	26.67	0.03	0.75	1.75	5.73
5	6	100	56.84	8.49	18.05	0.03	0.95	1.95	6.70
5	9	100	56.84	7.80	14.61	0.03	1.09	2.09	7.29
5	12	100	56.84	7.37	12.70	0.03	1.19	2.19	7.71
5	15	100	56.84	7.08	11.48	0.03	1.28	2.28	8.03
5	1	150	71.37	15.30	56.00	0.03	0.55	1.55	4.66
5	3	150	71.37	11.77	29.04	0.03	0.82	1.82	6.06
5	6	150	71.37	10.07	19.66	0.03	1.04	2.04	7.09
5	9	150	71.37	9.25	15.91	0.03	1.19	2.19	7.72
5	12	150	71.37	8.75	13.83	0.03	1.30	2.30	8.16
5	15	150	71.37	8.40	12.50	0.03	1.39	2.39	8.50
5	1	200	82.7	17.09	59.19	0.03	0.58	1.58	4.84
5	3	200	82.7	13.14	30.69	0.03	0.86	1.86	6.29
5	6	200	82.7	11.24	20.78	0.03	1.10	2.10	7.35
5	9	200	82.7	10.33	16.81	0.03	1.26	2.26	8.01
5	12	200	82.7	9.77	14.61	0.03	1.37	2.37	8.47
5	15	200	82.7	9.38	13.21	0.03	1.47	2.47	8.82
5	1	250	92.17	18.54	61.64	0.03	0.60	1.60	4.97
5	3	250	92.17	14.26	31.97	0.03	0.90	1.90	6.47
5	6	250	92.17	12.20	21.64	0.03	1.14	2.14	7.56

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
5	9	250	92.17	11.21	17.51	0.03	1.31	2.31	8.23
5	12	250	92.17	10.60	15.22	0.03	1.43	2.43	8.70
5	15	250	92.17	10.17	13.76	0.03	1.53	2.53	9.06
5	1	300	100.54	19.79	63.68	0.03	0.62	1.62	5.08
5	3	300	100.54	15.22	33.02	0.03	0.93	1.93	6.61
5	6	300	100.54	13.02	22.36	0.03	1.18	2.18	7.72
5	9	300	100.54	11.96	18.09	0.03	1.35	2.35	8.41
5	12	300	100.54	11.31	15.73	0.03	1.48	2.48	8.89
5	15	300	100.54	10.86	14.21	0.03	1.58	2.58	9.26
7	1	25	21.69	5.52	33.64	0.03	0.33	1.33	3.93
7	3	25	21.69	4.25	17.44	0.03	0.49	1.49	5.11
7	6	25	21.69	3.63	11.81	0.03	0.62	1.62	5.97
7	9	25	21.69	3.34	9.56	0.03	0.71	1.71	6.50
7	12	25	21.69	3.16	8.31	0.03	0.78	1.78	6.87
7	15	25	21.69	3.03	7.51	0.03	0.84	1.84	7.16
7	1	50	36.31	8.13	40.81	0.03	0.40	1.40	4.47
7	3	50	36.31	6.25	21.16	0.03	0.59	1.59	5.81
7	6	50	36.31	5.35	14.33	0.03	0.76	1.76	6.79
7	9	50	36.31	4.91	11.59	0.03	0.87	1.87	7.39
7	12	50	36.31	4.64	10.08	0.03	0.95	1.95	7.82
7	15	50	36.31	4.46	9.11	0.03	1.01	2.01	8.14
7	1	75	47.71	9.97	45.21	0.03	0.44	1.44	4.78
7	3	75	47.71	7.67	23.44	0.03	0.66	1.66	6.22
7	6	75	47.71	6.56	15.87	0.03	0.84	1.84	7.27
7	9	75	47.71	6.03	12.84	0.03	0.96	1.96	7.92
7	12	75	47.71	5.70	11.16	0.03	1.05	2.05	8.37
7	15	75	47.71	5.47	10.09	0.03	1.12	2.12	8.72
7	1	100	56.84	11.37	48.28	0.03	0.47	1.47	5.00
7	3	100	56.84	8.74	25.04	0.03	0.70	1.70	6.50
7	6	100	56.84	7.48	16.95	0.03	0.90	1.90	7.60
7	9	100	56.84	6.87	13.71	0.03	1.02	2.02	8.27
7	12	100	56.84	6.50	11.92	0.03	1.12	2.12	8.75
7	15	100	56.84	6.24	10.77	0.03	1.20	2.20	9.11
7	1	150	71.37	13.49	52.58	0.03	0.51	1.51	5.29
7	3	150	71.37	10.37	27.27	0.03	0.77	1.77	6.88
7	6	150	71.37	8.87	18.46	0.03	0.98	1.98	8.04
7	9	150	71.37	8.15	14.94	0.03	1.12	2.12	8.75
7	12	150	71.37	7.71	12.98	0.03	1.22	2.22	9.26
7	15	150	71.37	7.40	11.73	0.03	1.31	2.31	9.64
7	1	200	82.7	15.06	55.57	0.03	0.54	1.54	5.49
7	3	200	82.7	11.58	28.82	0.03	0.81	1.81	7.14
7	6	200	82.7	9.91	19.51	0.03	1.03	2.03	8.34
7	9	200	82.7	9.11	15.78	0.03	1.18	2.18	9.08
7	12	200	82.7	8.61	13.72	0.03	1.29	2.29	9.61
7	15	200	82.7	8.27	12.40	0.03	1.38	2.38	10.00

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
7	1	250	92.17	16.34	57.87	0.03	0.57	1.57	5.64
7	3	250	92.17	12.57	30.01	0.03	0.84	1.84	7.33
7	6	250	92.17	10.75	20.32	0.03	1.07	2.07	8.57
7	9	250	92.17	9.88	16.44	0.03	1.23	2.23	9.33
7	12	250	92.17	9.34	14.29	0.03	1.34	2.34	9.87
7	15	250	92.17	8.97	12.92	0.03	1.44	2.44	10.28
7	1	300	100.54	17.44	59.79	0.03	0.58	1.58	5.76
7	3	300	100.54	13.41	31.01	0.03	0.87	1.87	7.50
7	6	300	100.54	11.48	20.99	0.03	1.11	2.11	8.76
7	9	300	100.54	10.54	16.98	0.03	1.27	2.27	9.54
7	12	300	100.54	9.97	14.76	0.03	1.39	2.39	10.09
7	15	300	100.54	9.57	13.34	0.03	1.49	2.49	10.50
9	1	25	21.69	5.02	32.09	0.03	0.31	1.31	4.32
9	3	25	21.69	3.86	16.64	0.03	0.47	1.47	5.61
9	6	25	21.69	3.31	11.27	0.03	0.60	1.60	6.56
9	9	25	21.69	3.04	9.12	0.03	0.68	1.68	7.14
9	12	25	21.69	2.87	7.92	0.03	0.75	1.75	7.55
9	15	25	21.69	2.76	7.16	0.03	0.80	1.80	7.87
9	1	50	36.31	7.39	38.93	0.03	0.38	1.38	4.91
9	3	50	36.31	5.69	20.19	0.03	0.57	1.57	6.39
9	6	50	36.31	4.87	13.67	0.03	0.72	1.72	7.46
9	9	50	36.31	4.47	11.06	0.03	0.83	1.83	8.12
9	12	50	36.31	4.23	9.61	0.03	0.90	1.90	8.59
9	15	50	36.31	4.06	8.69	0.03	0.97	1.97	8.95
9	1	75	47.71	9.08	43.13	0.03	0.42	1.42	5.26
9	3	75	47.71	6.98	22.37	0.03	0.63	1.63	6.84
9	6	75	47.71	5.97	15.14	0.03	0.80	1.80	7.99
9	9	75	47.71	5.49	12.25	0.03	0.91	1.91	8.70
9	12	75	47.71	5.19	10.65	0.03	1.00	2.00	9.20
9	15	75	47.71	4.98	9.62	0.03	1.07	2.07	9.58
9	1	100	56.84	10.35	46.06	0.03	0.45	1.45	5.49
9	3	100	56.84	7.96	23.88	0.03	0.67	1.67	7.14
9	6	100	56.84	6.81	16.17	0.03	0.85	1.85	8.35
9	9	100	56.84	6.26	13.08	0.03	0.98	1.98	9.09
9	12	100	56.84	5.91	11.37	0.03	1.07	2.07	9.61
9	15	100	56.84	5.68	10.28	0.03	1.14	2.14	10.01
9	1	150	71.37	12.28	50.16	0.03	0.49	1.49	5.81
9	3	150	71.37	9.44	26.01	0.03	0.73	1.73	7.56
9	6	150	71.37	8.08	17.61	0.03	0.93	1.93	8.84
9	9	150	71.37	7.42	14.25	0.03	1.06	2.06	9.62
9	12	150	71.37	7.02	12.39	0.03	1.17	2.17	10.17
9	15	150	71.37	6.74	11.19	0.03	1.25	2.25	10.59
9	1	200	82.7	13.71	53.01	0.03	0.52	1.52	6.03
9	3	200	82.7	10.54	27.49	0.03	0.77	1.77	7.84
9	6	200	82.7	9.02	18.61	0.03	0.98	1.98	9.17

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
9	9	200	82.7	8.29	15.06	0.03	1.12	2.12	9.98
9	12	200	82.7	7.84	13.09	0.03	1.23	2.23	10.55
9	15	200	82.7	7.52	11.83	0.03	1.32	2.32	10.99
9	1	250	92.17	14.87	55.21	0.03	0.54	1.54	6.20
9	3	250	92.17	11.44	28.63	0.03	0.80	1.80	8.06
9	6	250	92.17	9.78	19.38	0.03	1.02	2.02	9.42
9	9	250	92.17	8.99	15.68	0.03	1.17	2.17	10.25
9	12	250	92.17	8.50	13.63	0.03	1.28	2.28	10.84
9	15	250	92.17	8.16	12.32	0.03	1.37	2.37	11.29
9	1	300	100.54	15.87	57.04	0.03	0.56	1.56	6.33
9	3	300	100.54	12.21	29.58	0.03	0.83	1.83	8.24
9	6	300	100.54	10.44	20.03	0.03	1.06	2.06	9.63
9	9	300	100.54	9.59	16.20	0.03	1.21	2.21	10.48
9	12	300	100.54	9.07	14.08	0.03	1.33	2.33	11.08
9	15	300	100.54	8.71	12.73	0.03	1.42	2.42	11.54
11	1	25	21.69	4.66	30.91	0.03	0.30	1.30	4.65
11	3	25	21.69	3.58	16.03	0.03	0.45	1.45	6.05
11	6	25	21.69	3.07	10.85	0.03	0.57	1.57	7.07
11	9	25	21.69	2.82	8.78	0.03	0.66	1.66	7.70
11	12	25	21.69	2.66	7.63	0.03	0.72	1.72	8.14
11	15	25	21.69	2.56	6.90	0.03	0.77	1.77	8.48
11	1	50	36.31	6.86	37.49	0.03	0.37	1.37	5.29
11	3	50	36.31	5.27	19.44	0.03	0.55	1.55	6.88
11	6	50	36.31	4.51	13.16	0.03	0.70	1.70	8.05
11	9	50	36.31	4.15	10.65	0.03	0.80	1.80	8.76
11	12	50	36.31	3.92	9.26	0.03	0.87	1.87	9.26
11	15	50	36.31	3.76	8.37	0.03	0.93	1.93	9.65
11	1	75	47.71	8.42	41.54	0.03	0.41	1.41	5.67
11	3	75	47.71	6.47	21.54	0.03	0.61	1.61	7.37
11	6	75	47.71	5.54	14.58	0.03	0.77	1.77	8.61
11	9	75	47.71	5.09	11.80	0.03	0.88	1.88	9.38
11	12	75	47.71	4.81	10.26	0.03	0.96	1.96	9.92
11	15	75	47.71	4.62	9.27	0.03	1.03	2.03	10.33
11	1	100	56.84	9.60	44.36	0.03	0.43	1.43	5.92
11	3	100	56.84	7.38	23.00	0.03	0.65	1.65	7.70
11	6	100	56.84	6.32	15.57	0.03	0.82	1.82	9.00
11	9	100	56.84	5.80	12.60	0.03	0.94	1.94	9.80
11	12	100	56.84	5.49	10.95	0.03	1.03	2.03	10.36
11	15	100	56.84	5.27	9.90	0.03	1.10	2.10	10.79
11	1	150	71.37	11.39	48.31	0.03	0.47	1.47	6.27
11	3	150	71.37	8.76	25.05	0.03	0.70	1.70	8.15
11	6	150	71.37	7.49	16.96	0.03	0.90	1.90	9.53
11	9	150	71.37	6.88	13.72	0.03	1.02	2.02	10.37
11	12	150	71.37	6.51	11.93	0.03	1.12	2.12	10.97
11	15	150	71.37	6.25	10.78	0.03	1.20	2.20	11.42

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
11	1	200	82.7	12.72	51.05	0.03	0.50	1.50	6.50
11	3	200	82.7	9.78	26.47	0.03	0.74	1.74	8.46
11	6	200	82.7	8.37	17.93	0.03	0.95	1.95	9.88
11	9	200	82.7	7.69	14.50	0.03	1.08	2.08	10.76
11	12	200	82.7	7.27	12.61	0.03	1.19	2.19	11.38
11	15	200	82.7	6.98	11.39	0.03	1.27	2.27	11.85
11	1	250	92.17	13.79	53.17	0.03	0.52	1.52	6.68
11	3	250	92.17	10.61	27.57	0.03	0.77	1.77	8.69
11	6	250	92.17	9.07	18.67	0.03	0.99	1.99	10.16
11	9	250	92.17	8.34	15.10	0.03	1.13	2.13	11.06
11	12	250	92.17	7.88	13.13	0.03	1.24	2.24	11.69
11	15	250	92.17	7.57	11.87	0.03	1.32	2.32	12.18
11	1	300	100.54	14.72	54.93	0.03	0.54	1.54	6.83
11	3	300	100.54	11.32	28.49	0.03	0.80	1.80	8.88
11	6	300	100.54	9.69	19.29	0.03	1.02	2.02	10.38
11	9	300	100.54	8.90	15.60	0.03	1.17	2.17	11.30
11	12	300	100.54	8.41	13.56	0.03	1.28	2.28	11.95
11	15	300	100.54	8.08	12.26	0.03	1.37	2.37	12.44
13	1	25	21.69	4.38	29.95	0.03	0.29	1.29	4.96
13	3	25	21.69	3.37	15.53	0.03	0.44	1.44	6.44
13	6	25	21.69	2.88	10.52	0.03	0.56	1.56	7.53
13	9	25	21.69	2.65	8.51	0.03	0.64	1.64	8.20
13	12	25	21.69	2.50	7.40	0.03	0.70	1.70	8.67
13	15	25	21.69	2.40	6.68	0.03	0.74	1.74	9.03
13	1	50	36.31	6.44	36.34	0.03	0.36	1.36	5.64
13	3	50	36.31	4.95	18.84	0.03	0.53	1.53	7.33
13	6	50	36.31	4.24	12.76	0.03	0.67	1.67	8.57
13	9	50	36.31	3.89	10.32	0.03	0.77	1.77	9.32
13	12	50	36.31	3.68	8.97	0.03	0.84	1.84	9.86
13	15	50	36.31	3.54	8.11	0.03	0.90	1.90	10.27
13	1	75	47.71	7.91	40.26	0.03	0.39	1.39	6.03
13	3	75	47.71	6.08	20.88	0.03	0.59	1.59	7.85
13	6	75	47.71	5.20	14.13	0.03	0.75	1.75	9.17
13	9	75	47.71	4.78	11.43	0.03	0.85	1.85	9.98
13	12	75	47.71	4.52	9.94	0.03	0.94	1.94	10.56
13	15	75	47.71	4.34	8.98	0.03	1.00	2.00	10.99
13	1	100	56.84	9.02	42.99	0.03	0.42	1.42	6.30
13	3	100	56.84	6.93	22.29	0.03	0.63	1.63	8.20
13	6	100	56.84	5.93	15.09	0.03	0.80	1.80	9.58
13	9	100	56.84	5.45	12.21	0.03	0.91	1.91	10.43
13	12	100	56.84	5.15	10.61	0.03	1.00	2.00	11.03
13	15	100	56.84	4.95	9.59	0.03	1.07	2.07	11.49
13	1	150	71.37	10.69	46.82	0.03	0.46	1.46	6.67
13	3	150	71.37	8.22	24.28	0.03	0.68	1.68	8.68
13	6	150	71.37	7.04	16.44	0.03	0.87	1.87	10.14

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
13	9	150	71.37	6.46	13.30	0.03	0.99	1.99	11.04
13	12	150	71.37	6.11	11.56	0.03	1.09	2.09	11.68
13	15	150	71.37	5.87	10.45	0.03	1.16	2.16	12.16
13	1	200	82.7	11.94	49.48	0.03	0.48	1.48	6.92
13	3	200	82.7	9.18	25.66	0.03	0.72	1.72	9.00
13	6	200	82.7	7.86	17.37	0.03	0.92	1.92	10.52
13	9	200	82.7	7.22	14.05	0.03	1.05	2.05	11.46
13	12	200	82.7	6.83	12.22	0.03	1.15	2.15	12.12
13	15	200	82.7	6.56	11.04	0.03	1.23	2.23	12.62
13	1	250	92.17	12.96	51.53	0.03	0.50	1.50	7.11
13	3	250	92.17	9.96	26.72	0.03	0.75	1.75	9.25
13	6	250	92.17	8.52	18.09	0.03	0.96	1.96	10.81
13	9	250	92.17	7.83	14.64	0.03	1.09	2.09	11.77
13	12	250	92.17	7.40	12.72	0.03	1.20	2.20	12.45
13	15	250	92.17	7.11	11.50	0.03	1.28	2.28	12.96
13	1	300	100.54	13.83	53.24	0.03	0.52	1.52	7.27
13	3	300	100.54	10.63	27.61	0.03	0.78	1.78	9.45
13	6	300	100.54	9.10	18.69	0.03	0.99	1.99	11.05
13	9	300	100.54	8.36	15.12	0.03	1.13	2.13	12.03
13	12	300	100.54	7.90	13.15	0.03	1.24	2.24	12.72
13	15	300	100.54	7.59	11.88	0.03	1.32	2.32	13.25
15	1	25	21.69	4.15	29.16	0.03	0.29	1.29	5.23
15	3	25	21.69	3.19	15.12	0.03	0.42	1.42	6.80
15	6	25	21.69	2.73	10.24	0.03	0.54	1.54	7.95
15	9	25	21.69	2.51	8.28	0.03	0.62	1.62	8.65
15	12	25	21.69	2.37	7.20	0.03	0.68	1.68	9.15
15	15	25	21.69	2.28	6.51	0.03	0.72	1.72	9.53
15	1	50	36.31	6.11	35.38	0.03	0.35	1.35	5.95
15	3	50	36.31	4.70	18.34	0.03	0.52	1.52	7.73
15	6	50	36.31	4.02	12.42	0.03	0.66	1.66	9.04
15	9	50	36.31	3.69	10.05	0.03	0.75	1.75	9.84
15	12	50	36.31	3.49	8.74	0.03	0.82	1.82	10.41
15	15	50	36.31	3.35	7.89	0.03	0.88	1.88	10.84
15	1	75	47.71	7.49	39.19	0.03	0.38	1.38	6.37
15	3	75	47.71	5.76	20.32	0.03	0.57	1.57	8.28
15	6	75	47.71	4.93	13.76	0.03	0.73	1.73	9.68
15	9	75	47.71	4.53	11.13	0.03	0.83	1.83	10.53
15	12	75	47.71	4.28	9.68	0.03	0.91	1.91	11.14
15	15	75	47.71	4.11	8.75	0.03	0.97	1.97	11.60
15	1	100	56.84	8.54	41.85	0.03	0.41	1.41	6.65
15	3	100	56.84	6.57	21.70	0.03	0.61	1.61	8.65
15	6	100	56.84	5.62	14.69	0.03	0.78	1.78	10.11
15	9	100	56.84	5.16	11.89	0.03	0.89	1.89	11.01
15	12	100	56.84	4.88	10.33	0.03	0.97	1.97	11.64
15	15	100	56.84	4.69	9.34	0.03	1.04	2.04	12.12

DIVERSION BERM HEIGHT CALCULATION									
Flow Slope (FS) (%)	Internal Slope (IS) (%)	Watershed Area (acres)	Peak Discharge (Q10) (cfs)	Flow Area (ft^2)	Wetted Perimeter (ft)	Mannings Coefficient	Berm Height (B) (ft)	Berm + 1 foot of Freeboard	Velocity (ft/s)
15	1	150	71.37	10.14	45.58	0.03	0.45	1.45	7.04
15	3	150	71.37	7.79	23.64	0.03	0.66	1.66	9.16
15	6	150	71.37	6.67	16.00	0.03	0.85	1.85	10.70
15	9	150	71.37	6.13	12.95	0.03	0.97	1.97	11.65
15	12	150	71.37	5.79	11.25	0.03	1.06	2.06	12.32
15	15	150	71.37	5.56	10.17	0.03	1.13	2.13	12.83
15	1	200	82.7	11.32	48.17	0.03	0.47	1.47	7.31
15	3	200	82.7	8.70	24.98	0.03	0.70	1.70	9.50
15	6	200	82.7	7.45	16.91	0.03	0.89	1.89	11.10
15	9	200	82.7	6.84	13.68	0.03	1.02	2.02	12.09
15	12	200	82.7	6.47	11.89	0.03	1.12	2.12	12.78
15	15	200	82.7	6.21	10.75	0.03	1.20	2.20	13.31
15	1	250	92.17	12.28	50.17	0.03	0.49	1.49	7.51
15	3	250	92.17	9.44	26.01	0.03	0.73	1.73	9.76
15	6	250	92.17	8.08	17.61	0.03	0.93	1.93	11.41
15	9	250	92.17	7.42	14.25	0.03	1.06	2.06	12.42
15	12	250	92.17	7.02	12.39	0.03	1.17	2.17	13.13
15	15	250	92.17	6.74	11.20	0.03	1.25	2.25	13.68
15	1	300	100.54	13.11	51.83	0.03	0.51	1.51	7.67
15	3	300	100.54	10.08	26.88	0.03	0.76	1.76	9.98
15	6	300	100.54	8.62	18.20	0.03	0.96	1.96	11.66
15	9	300	100.54	7.92	14.72	0.03	1.10	2.10	12.69
15	12	300	100.54	7.49	12.80	0.03	1.20	2.20	13.42
15	15	300	100.54	7.19	11.57	0.03	1.29	2.29	13.98

DIVERSION BERM

SEDCAD+ COMPUTER RUNS

WORST CASE SENERIOS
FOR 25 TO 300 ACRE WATERSHEDS

MARCH 27, 1997

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DEVERSION BERM - WORST CASE SENERIO FOR 25 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\25AC

Date: 03-27-1997

Civil Software Design -- SEDCAD+ Version 3.1
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Company Name: BHP MINERALS
Filename: C:\LR\BERM\25AC User: LR
Date: 03-27-1997 Time: 08:18:37
DEVERSION BERM - WORST CASE SENERIO FOR 25 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	25.00	89	M	0.153	0.000	0.000	0.0	1.47	21.69
			Type: Null			Label: BERM				
111	Structure	25.00							1.47	
111	Total IN/OUT	25.00							1.47	21.69

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\25AC User: LR
Date: 03-27-1997 Time: 08:18:37
DEVERSION BERM - WORST CASE SENERIO FOR 25 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	1565.00	7.99	2.83	0.15	0.153		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 50 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\50AC

Date: 03-27-1997

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\50AC User: LR
Date: 03-27-1997 Time: 08:18:39
DIVERSION BERM - WORST CASE SENERIO FOR 50 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

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SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE
==========

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	50.00	89	M	0.258	0.000	0.000	0.0	2.95	36.31
			Type: Null			Label: BERM				
111	Structure	50.00							2.95	
111	Total IN/OUT	50.00							2.95	36.31

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\50AC User: LR
Date: 03-27-1997 Time: 08:18:39
DIVERSION BERM - WORST CASE SENERIO FOR 50 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	2214.00	5.65	2.38	0.26	0.258		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 75 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\75AC

Date: 03-27-1997

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\75AC User: LR
Date: 03-27-1997 Time: 08:18:41
DIVERSION BERM - WORST CASE SENERIO FOR 75 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	75.00	89	M	0.350	0.000	0.000	0.0	4.42	47.71
			Type: Null			Label: BERM				
111	Structure	75.00							4.42	
111	Total IN/OUT	75.00							4.42	47.71

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\75AC User: LR
Date: 03-27-1997 Time: 08:18:41
DIVERSION BERM - WORST CASE SENERIO FOR 75 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	2711.00	4.61	2.15	0.35	0.350		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 100 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\100AC

Date: 03-27-1997

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\100AC User: LR
Date: 03-27-1997 Time: 08:18:43
DIVERSION BERM - WORST CASE SENERIO FOR 100 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	100.00	89	M	0.435	0.000	0.000	0.0	5.89	56.84
			Type: Null			Label: BERM				
111	Structure	100.00							5.89	
111	Total IN/OUT	100.00							5.89	56.84

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\100AC User: LR
Date: 03-27-1997 Time: 08:18:43
DIVERSION BERM - WORST CASE SENERIO FOR 100 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	3131.00	3.99	2.00	0.44	0.435		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 150 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\150AC

Date: 03-27-1997

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\150AC User: LR
Date: 03-27-1997 Time: 08:18:45
DIVERSION BERM - WORST CASE SENERIO FOR 150 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

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SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE
==========

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	150.00	89	M	0.589	0.000	0.000	0.0	8.84	71.37
			Type: Null		Label: BERM					
111	Structure	150.00							8.84	
111	Total IN/OUT	150.00							8.84	71.37

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\150AC User: LR
Date: 03-27-1997 Time: 08:18:45
DIVERSION BERM - WORST CASE SENERIO FOR 150 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	3834.00	3.26	1.81	0.59	0.589		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 200 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\200AC

Date: 03-27-1997

Civil Software Design -- SEDCAD+ Version 3.1
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Company Name: BHP MINERALS
Filename: C:\LR\BERM\200AC User: LR
Date: 03-27-1997 Time: 08:18:47
DIVERSION BERM - WORST CASE SENERIO FOR 200 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

==========
SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE
==========

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	200.00	89	M	0.731	0.000	0.000	0.0	11.78	82.70
			Type: Null		Label: BERM					
111	Structure	200.00							11.78	
111	Total IN/OUT	200.00							11.78	82.70

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\200AC User: LR
Date: 03-27-1997 Time: 08:18:47
DIVERSION BERM - WORST CASE SENERIO FOR 200 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	4427.00	2.82	1.68	0.73	0.731		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 250 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\250AC

Date: 03-27-1997

Civil Software Design -- SEDCAD+ Version 3.1
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Company Name: BHP MINERALS
Filename: C:\LR\BERM\250AC User: LR
Date: 03-27-1997 Time: 08:18:33
DIVERSION BERM - WORST CASE SENERIO FOR 250 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	250.00	89	M	0.865	0.000	0.000	0.0	14.73	92.17
			Type: Null		Label: BERM					
111	Structure	250.00							14.73	
111	Total IN/OUT	250.00							14.73	92.17

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\250AC User: LR
Date: 03-27-1997 Time: 08:18:33
DIVERSION BERM - WORST CASE SENERIO FOR 250 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	4950.00	2.53	1.59	0.87	0.865		

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

DIVERSION BERM - WORST CASE SENERIO FOR 300 AC WATERSHED

by

Name: LR

Company Name: BHP MINERALS
File Name: C:\LR\BERM\300AC

Date: 03-27-1997

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\300AC User: LR
Date: 03-27-1997 Time: 08:18:35
DIVERSION BERM - WORST CASE SENERIO FOR 300 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	300.00	89	M	0.991	0.000	0.000	0.0	17.67	100.54
			Type: Null			Label: BERM				
111	Structure	300.00							17.67	
111	Total IN/OUT	300.00							17.67	100.54

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Company Name: BHP MINERALS
Filename: C:\LR\BERM\300AC User: LR
Date: 03-27-1997 Time: 08:18:35
DIVERSION BERM - WORST CASE SENERIO FOR 300 AC WATERSHED
Storm: 1.60 inches, 10 year-24 hour, Type II-65
Hydrograph Convolution Interval: 0.1 hr

DETAILED SUBWATERSHED INPUT/OUTPUT TABLE

J	B	S	SWS	Seg. #	Land Flow Condition	Distance (ft)	Slope (%)	Velocity (fps)	Segment Time (hr)	Time Conc. (hr)	Muskingum K (hr)	Muskingum X
1	1	1	1	-a	5	5422.00	2.31	1.52	0.99	0.991		

Appendix 25.B

Dixon Test Plot Spoil Mitigation Study

Root Zone Suitability Study – Dixon Ramp 1 and 2 Areas, Navajo Mine

Introduction

Spoil material at BHP Navajo Coal Company (BNCC), in Dixon Ramps 1 and 2, was regraded in 2005 in preparation for reclamation. These materials were sampled to determine their suitability as root-zone material prior to the application of a coversoil. Approximately 50% of the root-zone material did not meet the suitability guidelines for Navajo Mine. The spoil material had an EC/SAR relationship that was unsuitable according to the established guidelines for Navajo Mine. Based on observations and research at this mine, the Dixon spoil material has characteristics that are known to maintain appropriate chemical and physical conditions supporting plant establishment and production. Previous work has shown that similar reclaimed soils will maintain good water flow characteristics and a chemical environment that will support plant growth required to meet bond release requirements. BNCC is proposing to develop approximately 68 acres (48 %) of the reclaimed ramps 1 and 2 in Dixon as a test plot to demonstrate the soils ability to maintain good water flow and soil characteristics that will support plant growth, Figures 1 and 2. The area will not be mitigated according to current root-zone criteria but will be topsoiled, seeded and irrigated per normal permit standards. The test plot will be monitored through the irrigation stage. At the end of irrigation, if the spoil between 0-15cm below the topsoil-spoil interface does not demonstrate a significant change in the EC or SAR values towards a more favorable condition (increases in EC or decreases in SAR), the area will be mitigated and reseeded.

Our hypothesis is that the application of irrigation and natural precipitation occurring at Navajo Mine will provide sufficient weathering conditions that will promote the development of a favorable EC/SAR relationship. These conditions have been observed and documented at both the Navajo Mine and San Juan Mine by Buchanan (unpublished reports) and by Musslewhite and others in New Mexico and Arizona. The findings have shown that both the coversoil and the upper portion of the root-zone material have weathered during the initial two-year period when irrigation is administered. The depth of weathering is associated with the depth of water movement. It is well established that the depth of water also controls the depth of rooting. As water moves through the profile, either due to irrigation or precipitation, salts will leach. This process of weathering (leaching) affects the EC/SAR relationship such that favorable physical and chemical conditions are maintained. Following the irrigation, the root zone material will continue to weather, resulting in further leaching of salts to levels controlled by the local climatic conditions. These pedogenetic processes will produce soils that resemble the natural undisturbed soils that have salt accumulation zones below the solum (A and B horizons).

The purpose of this study is to demonstrate that the root-zone material determined to be unsuitable based on levels of EC and SAR is, in fact, suitable and will not negatively impact the water movement capabilities of the root-zone. The water movement capability will be maintained due to its ability to produce salt levels from weathering processes that will maintain flocculation. The information collected from this study will provide guidance to make changes in EC/SAR root-zone suitability criteria specific to conditions at Navajo Mine.

Background

Relationships between sodium adsorption ratio (SAR), electrical conductivity (EC), and mineralogy in agricultural soil systems have been extensively researched. However, minimal work has been completed to understand these relationships in minesoils and to develop appropriate EC/SAR evaluation methods to assess root-zone suitability. The chemical and physical properties of minesoils are unique and quite different from natural soils formed through pedogenesis. This difference is associated with the presence of unweathered overburden and interburden materials as the root-zone material. These materials are often classified as sodic (SAR>13) by some standards even though they are characterized by levels of soluble ions adequate to maintain flocculation of soil particles. In addition, weatherable minerals are present in such materials that can effectively ameliorate problems associated with elevated levels of exchangeable sodium.

The impact of SAR on the physical character of a soil is greatly dependent on soil salinity. It is impossible to estimate the impact of SAR values on the physical state of a soil or spoil material without evaluating the EC or electrolyte concentration of the system (Shanmuganathan and Oades, 1983). Any attempt to set critical ESP (SAR) values for land management would be arbitrary unless total cation concentration or EC is taken into consideration simultaneously (Sumner, et al., 1998). Research has shown that extremely high SAR values do not cause physical degradation of soil materials if the system also contains high levels of soluble salts. This fact was first shown by research done by Quirk and Schofield (1955). Their work demonstrated that a soil with an ESP of 40 maintained a stable permeability with an electrolyte concentration of about 30 mmol/L (about EC = 2.9 dS/m). McNeal and Coleman (1966) pointed out that typical arid land soils (having clay mineralogy dominated by 2:1 layer silicates with only moderate amounts of montmorillonite) could tolerate ESP values of 15 or greater before serious reductions in hydraulic conductivity occur, if salt concentration of the percolating solution exceeds 3 mmol/L (0.3 dS/m). Gardner et al. (1959) came to the same conclusion dealing with unsaturated soils. This phenomenon has since been demonstrated on numerous occasions by a number of investigations and is well documented in the literature. Sumner et al. (1998) discussed the SAR/EC relationship very thoroughly in their publication titled "Sodic Soils: Distribution, Properties, Management, and Environmental Consequences." Much of their discussion addressed the fact that the USDA Soil Salinity Laboratory did not adequately address this topic even though they were well aware of it. In fact, the definition of sodic soils was published by Bower et al. (1958) without mention of electrolyte concentration in the definition. Sumner et al. (1998) noted that if the work of Quirk and Schofield (1955) had been adopted in the United States, a much clearer understanding of sodic soils and sodicity would have resulted. Instead of using electrolyte concentration as an important component of the definition of sodic soils, Handbook 60, which was published in 1954 and reprinted in 1969 with limited mention of salinity, continues to be used as an authority addressing salinity and sodicity issues. It is not surprising that many sites are not correctly diagnosed for sodicity relative to suitability for reclamation.

The impact of sodicity on soil physical properties is dependent on the electrolyte concentration associated with the system. If salt is added to a dispersed clay in a suspension, the increased electrolyte concentration causes the clay particles to stick together forming flocculated particles that settle. The minimum electrolyte concentration required to cause flocculation is referred to

as the threshold electrolyte concentration (TEC) or flocculation value (FV). This value is dependent on counter-ion valence and clay type. The TEC values for sodium-montmorillonite were shown to be about 12 mol/m^3 NaCl or 0.86 dS/m and 0.25 mol/m^3 $CaCl_2$ or 0.02 dS/m for calcium-montmorillonite (Van Olphen, 1977). Corresponding values for sodium and calcium illites were found to be 40 mol/m^3 to 50 mol/m^3 NaCl and 0.25 mol/m^3, respectively (Arora and Coleman, 1979). These data show that a sodium montmorillonite can be maintained in a flocculated condition if the salt levels of the same ion (Na) are about 1 dS/m and sodium illites will tend to remain flocculated if salt levels with the same ion (Na) are about 3.6 dS/m. Sposito (1989) indicated through his discussion of the literature that a fully Na-saturated smectite suspension will flocculate if the electrolyte concentration is > 8 mol/m^3 (0.6 dS/m) and a suspension of Na-illite will do the same if the electrolyte concentration reaches about 50 mol/m^3 (3.6 dS/m). His conclusion is that soil salinity tends to counteract the effect of exchangeable sodium on soil structure. The presence of divalent ions such as Ca reduces the TEC to lower salt concentrations. In summary, research shows if salinity is maintained at or above the TEC value for a specific material, the physical condition of the material will be maintained in a flocculated state no matter how high the SAR.

Objectives:

The general objective of this project is to provide guidance for the development of appropriate EC/SAR standards at the Navajo Mine. The specific objective of the salinity study is to demonstrate that both the salinity and sodicity of the root-zone interface (0-15cm below the topsoil-spoil interface) material will significantly (statistically) change if either natural precipitation or irrigation water influences the upper 15 cm of the spoil profile. The hypothesis is that movement of water over a two season irrigation period will change the salinity and sodicity to conditions that will maintain flocculation or conditions toward flocculation. Following are specific tasks to complete the objectives:

1. to monitor the salinity/sodicity relationships in the reclaimed profile.
2. to demonstrate that these systems maintain suitable chemical characteristics that support reclamation.
3. to monitor the hydrologic functions of the soil profile.
4. to demonstrate that the existing reclaimed system is well-drained and maintains water movement through the profile.
5. to demonstrate the magnitude of change in the soil chemistry that occurs during the period of irrigation.
6. to develop guidelines specifying the EC/SAR relationship levels required for suitable spoil materials at Navajo Mine.

These objectives will be achieved using information from a sampling and monitoring program that will evaluate the chemical condition and the water movement capability of reclaimed soils at locations in the Dixon Ramps 1 and 2. The study will include (1) sampling coversoil and root-zone materials over a two year period to assess changes of EC and SAR in the profile; and (2) monitoring of water content in the reclaimed soil profile over time.

Scope of Work

Task 1: Document Review. A review of current and pertinent literature will be completed. The primary areas of study include the chemistry of sodium enriched soils and overburden materials that are used for minesoil reconstruction. Mineral weathering characteristics of such materials will be an important component of the review. Also included will be a summary of unpublished studies and data from various mine sites in the Southwest.

Task 2: Establishment of Study Area Sampling Locations. Sampling sites will be established at thirty-four (34) locations, Table 1 and Figures 1 and 2. Twenty-eight (28) of the sampling locations were chosen based on the soil suitability sample grid from March 2006, Figures 1 and 2. Six additional targeted samples were chosen based on the extreme EC and SAR values from the March 2006 sampling. Due to variability in the composition of the spoil material, it is expected that the sample locations chosen will not mirror the results of the previous sampling, except for the six targeted samples. Instead it is assumed that the neighboring underlying spoil material will only be similar to the previously sampled material. It is expected that the selected sites will represent EC and SAR values covering the range of conditions found at Dixon Ramps 1 & 2.

Task 3: Sampling Site Profile Characterization. A monitoring program will be conducted on reclaimed sites located in the Dixon Ramp 1 and 2 areas. Each of the study sites will be sampled to establish baseline conditions prior to irrigation and at the end of the two year study period. Soon after coversoil has been placed over the root-zone material, the site will be sampled to a depth of 90 cm. Each sampling location will be located by the Navajo Mine Survey team. They will pin-flag the sampling point and mark the extents (corners) of the pit. Each pit will be 36 (thirty-six) inches wide, 5.5 (five and a half) feet deep, and approximately 8 (eight) feet long, with 18 (eighteen) inch benches along the sides of the east and west walls of the pit, Figure 3. They will be oriented on a north-south axis. Sampling will be conducted on the north edge of the pit at the intervals described below. The pit will be backfilled and the extent of the disturbance documented. Pinflags will be used to identify the location of the pit as well as the location of the pit boundaries for the subsequent pit.

Subsequent soil sampling will be conducted 2 linear feet directly north of the previous pit's north wall, Figure 3. 75% of the pit will be dug over the previous pit. The pit will have the same dimensions as the initial pit, but will be shifted 2 feet north of the extents of the initial pit disturbance. The 2 foot shift north will allow the sampling team to recover material that has not been disturbed by sampling, and the material will have similar composition at depth as the initial sample.

Samples will be collected from the 34 sampling sites at the following depth intervals: (1) 0 to 10 cm above the topsoil-spoil interface; (2) 0 to 5 cm below the topsoil-spoil interface; (3) 5 to 10 cm below the topsoil-spoil interface; (4) 10 to 15 cm below the topsoil-spoil interface; (5) 15 to 30 cm below the topsoil-spoil interface; (6) 30 to 60 cm below the topsoil-spoil interface; and (7) 60 to 90 cm below the topsoil-spoil interface, Figure 3. Samples will be analyzed for the following parameters: (1) pH; (2) EC; (3) SAR; (4) Saturation percentage; (5) Particle size analysis; (6) cations (including Ca, Mg, Na); and (7) anions (including SO_4^{-2}, HCO_3^{-1}). Samples

will consist of approximately one (1) kilogram of material that will be passed through a .25 inch screen with only material less than .25 inches being crushed and sent for analysis.

Task 4: Sampling Site Instrumentation for Soil Water Content. Sampling sites will be fitted with access points for monitoring equipment to measure soil water content at depth. A neutron probe will be used to measure moisture content of the spoil at depth. The neutron probe will be calibrated using gravimetric samples taken from the sampling locations, approximately 1 meter south of the neutron probe access tube. The access points will be installed so that the first probe measurement will be at 10 cm above the topsoil-spoil interface, the second measurement at the interface, and the subsequent measurements at 10, 20, 40, and 80 cm below the interface. The neutron probe will be lowered to these set depths to take measurements. Each sampling location will be monitored once every week during the irrigation periods and once monthly throughout the rest of the study period. These data will be available for time-series analysis and for use as a covariate in the statistical analysis.

Task 5: Irrigation Plan. The study site will receive approximately 13 inches of irrigation during a two-year period following reclamation, Table 2. About 11 inches of water will be applied during the first growing season, and approximately 2 inches of water will be applied during year 2 of the study. The irrigation is separated into a germination cycle with an initial 1 inch application followed by four 0.5 inch applications every forth day. Following the germination cycle the support cycle begins with 0.5 inch applications about every 9 days. Each sampling location will be equipped with a calibrated Rainwise 8" rain gauge and Hobo event data logger that will measure and record each precipitation or irrigation event. These data will be recorded and potentially be used as covariates in the statistical analysis. The irrigation will be monitored by a scientist to ensure that the equipment is functioning properly and the irrigation plan is being followed.

Task 6. Field Study Plot Sampling and Analysis. The sampling sites established in Task 2 will be monitored at the end of the growing season in 2008. Samples will be collected at the depth intervals and analyzed for the parameters described in Task 3. Data collected will be analyzed using statistical methods as described in Task 7.

Task 7. Statistical Experimental Design. The data collected from the spoil samples will be analyzed using standard paired t-tests. In the case that the underlying assumptions of t-tests are not appropriate, a non-parametric test (such as the Wilcoxon Rank Sum) will be used. The two measured parameters, EC and SAR, at the depth of 0-15cm below the topsoil-spoil interface will be statistically analyzed for differences between the initial collection and the final collection using paired tests. Because the 0-15 cm interval is not being sampled or sent for analysis as a unit, the 0-5 cm, 5-10 cm, and 10-15 cm sample EC and SAR values from each sample location will be averaged and used as the 0-15 cm composite EC and SAR values for the sample location. The null hypothesis that there are no differences between what was measured initially and what was measured at the end of the two year period will be tested against the alternative hypothesis that the EC or SAR values of the samples at the end of the study period are more suitable than the paired sample from the first year of sampling ($\alpha = 0.10$). More suitable signifies that the values of EC have increased and the SAR values have decreased. Multiple regression will also be used to model the impact of the covariates on the change in the sample EC and SAR values. Specifically, the covariates for analysis will be the amount of surface water at the location and

the average amount of soil moisture from the neutron probe at the 10cm depth (below the interface). The time series data from the sampling locations will be used to illustrate the presence of and water at different depths with corresponding irrigation cycles and levels noted along the timeline.

Success Standard

Success of this test plot will be determined by a statistical test of the 0-15 cm composite EC or SAR values in the spoil samples. Success will be demonstrated when the difference between the EC or SAR values before and after the study period are statistically significant at the $p<.10$ level, or if 100% of the samples remain or become suitable during the course of the study using the current guidelines.

Table 1. Dixon study plot sample locations

Label	Northing	Easting	Elevation
206S-95W	2012010.02	301157.80	5389.25
205S-95W	2012340.25	301153.31	5390.69
204S-95W	2012669.54	301153.69	5388.42
203S-96W	2012806.40	300823.90	5389.39
204S-96W	2012669.30	300823.66	5390.90
205S-96W	2012340.10	300824.20	5391.26
205S-96W-B	2012421.51	300906.16	5389.93
206S-96W	2012010.80	300824.17	5390.64
206S-97W	2012008.07	300491.92	5387.37
205S-97W	2012340.69	300493.75	5389.49
204S-97W	2012669.43	300494.62	5390.00
203S-97W	2012870.83	300492.63	5386.70
203S-98W	2012895.69	300163.53	5389.03
204S-98W	2012674.09	300195.37	5387.19
204S-98W-B	2012753.57	300248.13	5387.16
205S-98W	2012339.53	300163.46	5388.33
206S-98W	2012011.05	300162.70	5387.41
206S-99W	2012010.37	299832.67	5381.85
206S-99W-A	2012151.05	299671.93	5381.44
205S-99W	2012338.71	299833.89	5384.32
204S-99W	2012669.27	299834.17	5386.07
203S-99W	2012999.89	299834.76	5387.17
203S-100W	2012998.41	299503.87	5375.89
204S-100W	2012668.56	299504.24	5376.51
204S-100W-A	2012751.10	299423.30	5374.81
203S-100W-A	2013098.95	299394.01	5375.51
205S-100W	2012428.58	299498.78	5381.74
206S-100W	2012009.11	299505.47	5379.44
202S-101W	2013203.62	299163.58	5373.66
203S-101W	2012998.02	299173.45	5370.79
203S-101W-C	2012919.19	299094.26	5371.52
202S-102W	2013200.08	298853.25	5365.02
203S-102W	2012994.54	298872.69	5369.38
202S-103W	2013329.35	298513.85	5380.09

Milestones

Table 2. Dixon study plot milestones

Date	Irrigation amount (inches)	Action
		Survey sample locations at Dixon
30-Oct-06		Collect soil samples for baseline measures, install rain gauges, install neutron probe access points, and pin flag 34 sampling locations
15-Nov-06		Send soil samples to IML for analysis
15-Dec-06		Analyze soil sample data
1-Jan-07		Draft preliminary report
15-Feb-07		Send progress report and distribution of soil characteristics to OSM
1-Apr-07		Seed Dixon areas
15-Apr-07	1	Irrigation
19-Apr-07	0.5	Irrigation
23-Apr-07	0.5	Irrigation
27-Apr-07	0.5	Irrigation
1-May-07	0.5	Irrigation
10-May-07	0.5	Irrigation
19-May-07	0.5	Irrigation
28-May-07	0.5	Irrigation
6-Jun-07	0.5	Irrigation
15-Jun-07	0.5	Irrigation
24-Jun-07	0.5	Irrigation
3-Jul-07	0.5	Irrigation
12-Jul-07	0.5	Irrigation
21-Jul-07	0.5	Irrigation
30-Jul-07	0.5	Irrigation
8-Aug-07	0.5	Irrigation
17-Aug-07	0.5	Irrigation
26-Aug-07	0.5	Irrigation
4-Sep-07	0.5	Irrigation
13-Sep-07	0.5	Irrigation
22-Sep-07	0.5	Irrigation
1-Oct-07	0.5	Irrigation
15-Apr-08	0.5	Irrigation
26-Apr-08	0.5	Irrigation
5-May-08	0.5	Irrigation
23-Oct-08		Survey sampling locations
30-Oct-08		Collect spoil samples at 34 locations
5-Nov-08		Send samples to IML for analysis

Table 2. Continued

Date	Irrigation amount (inches)	Action
End of 2008 or Early 2009		Statistical analysis and report drafting
Early 2009		Final report to OSM

Preliminary Data Analysis

A preliminary data analysis was conducted on the March 2006 samples. The purpose of this analysis was to determine the EC-SAR relationship and distribution of the initial samples and of the twenty–eight sample sites selected for this study. The results of preliminary analysis are provided on the following scatter plot diagrams, histograms, and tables.

Scatter plots of the EC-SAR relationship in the sampled locations

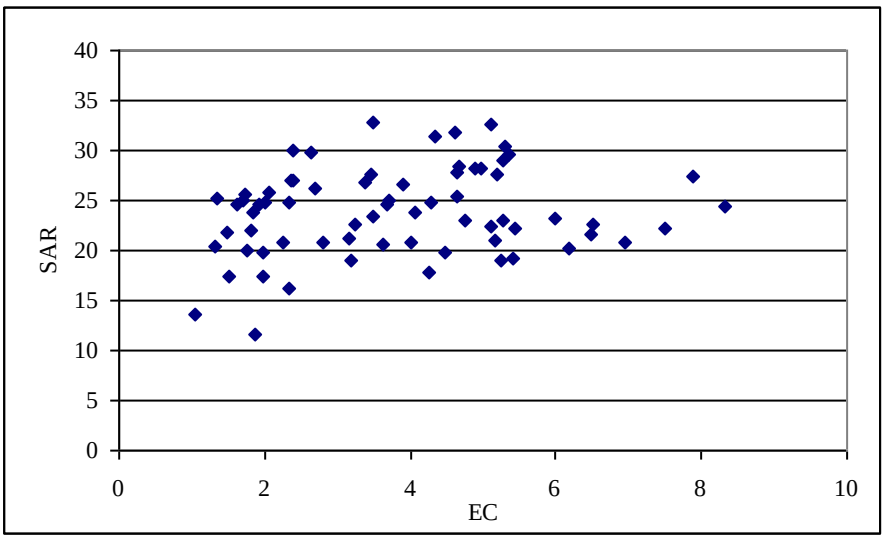

Figure 4. EC-SAR distribution of all March 2006 sample locations at the 0-1 foot depth

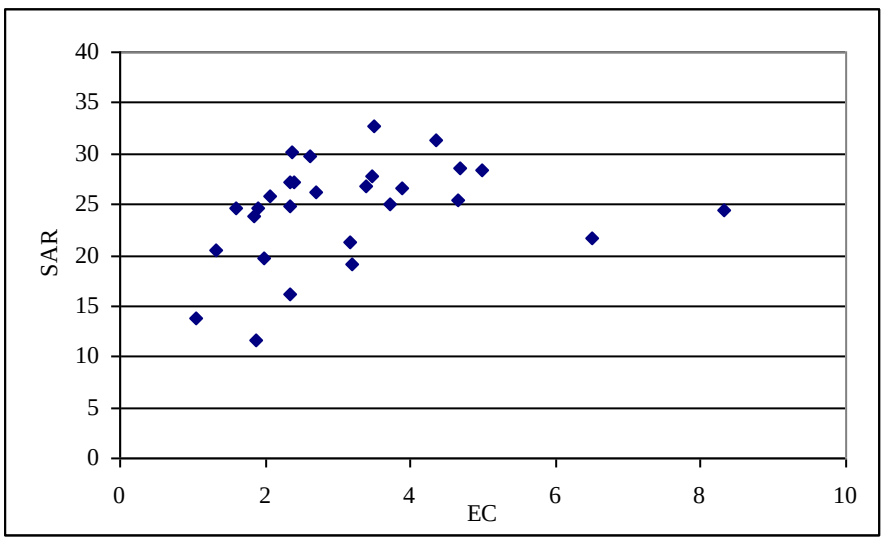

Figure 5. EC-SAR distribution of the selected twenty-eight sample locations at the 0-1 foot depth

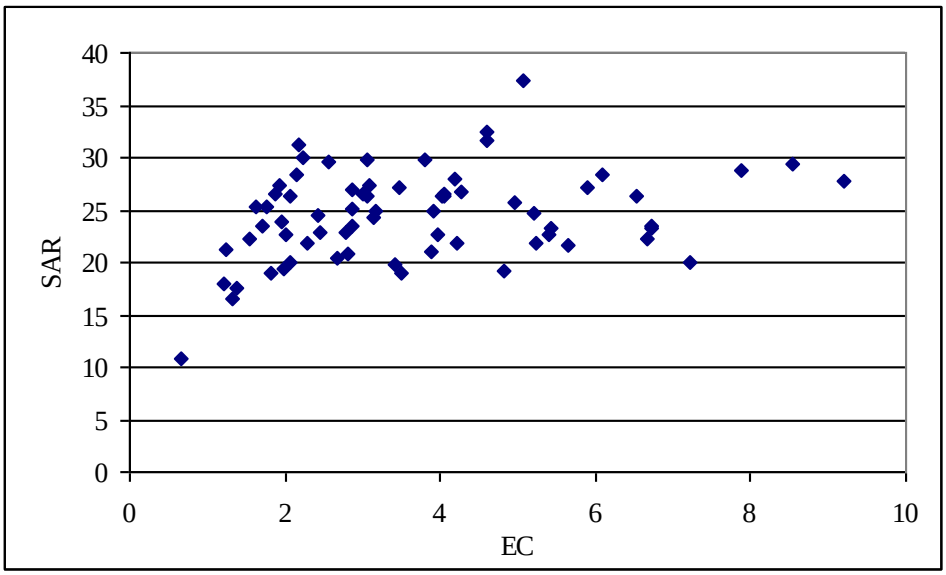

Figure 6. EC-SAR distribution of all March 2006 sample locations at the 1-4 feet depth

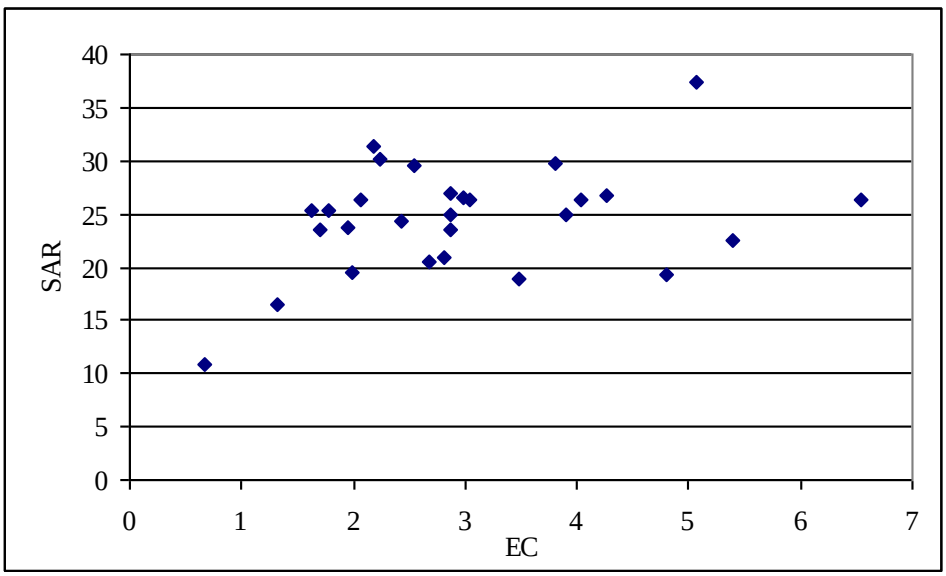

Figure 6. EC-SAR distribution of the selected twenty-eight sample locations at the 1-4 feet depth

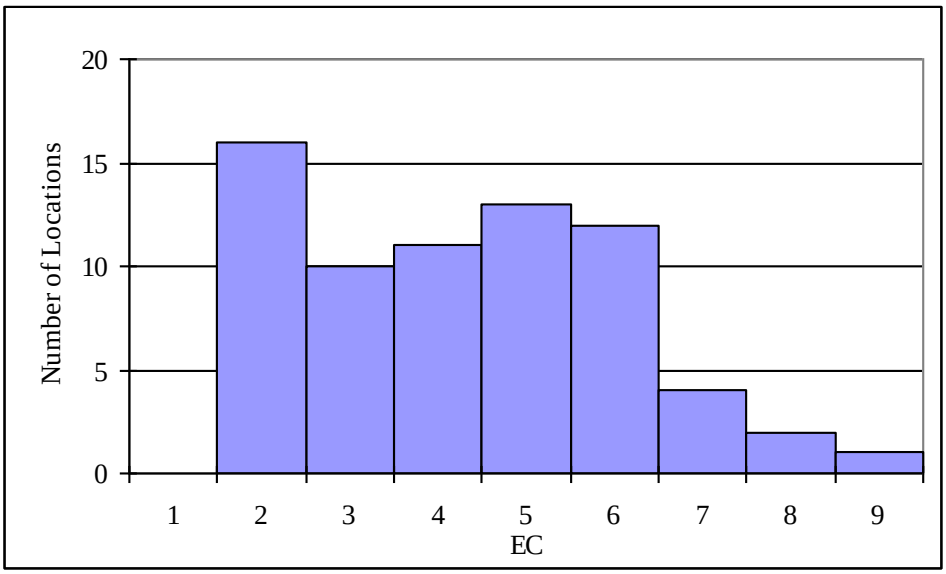

Figure 7. EC values of all March 2006 sampled locations at the 0-1 foot depth

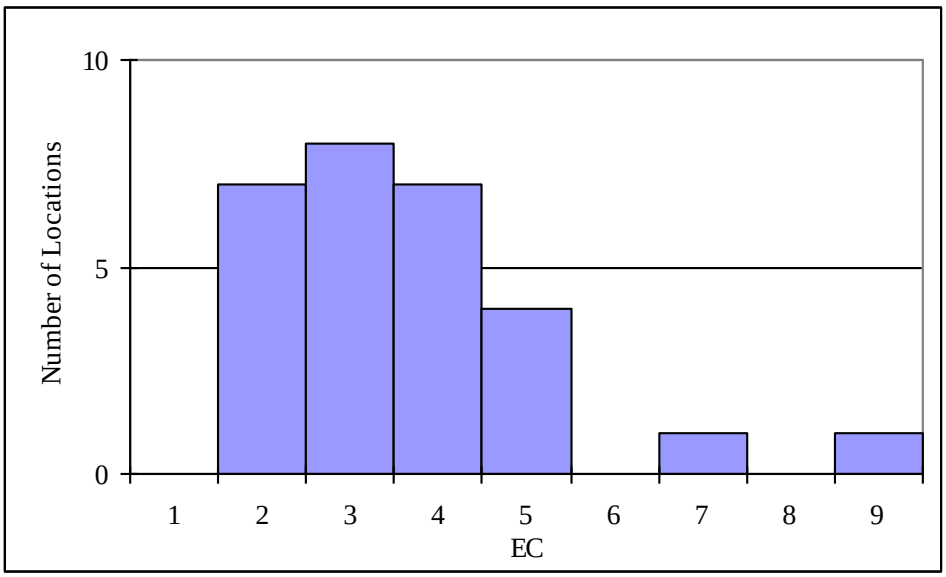

Figure 8. EC values of the selected twenty-eight sample locations at the 0-1 foot depth

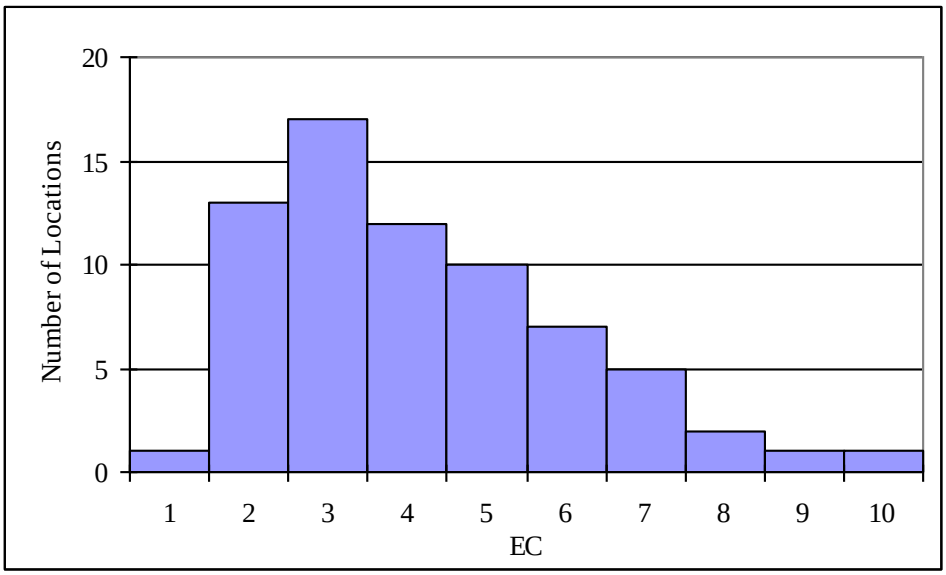

Figure 9. EC values of all March 2006 sampled locations at the 1-4 feet depth

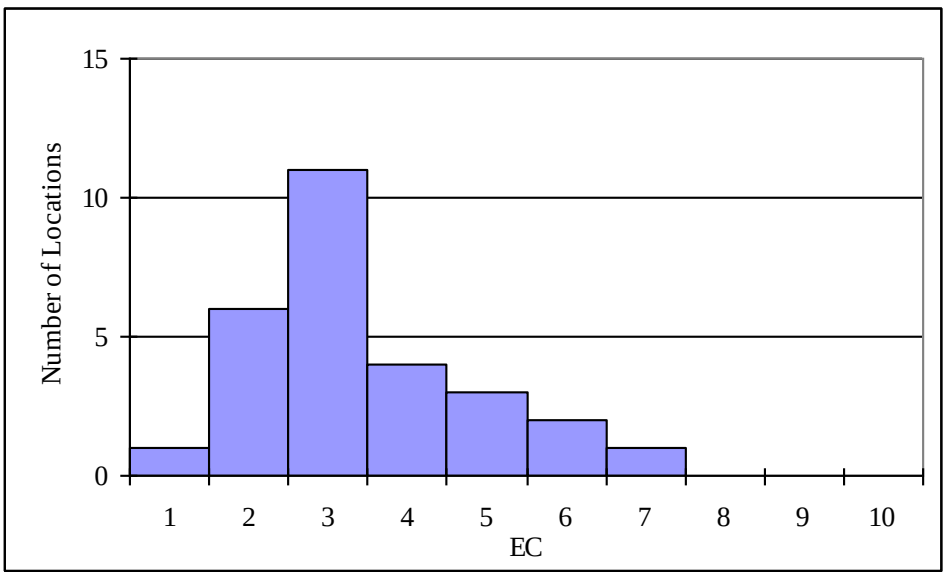

Figure 10. EC values of the selected twenty-eight sample locations at the 1-4 feet depth

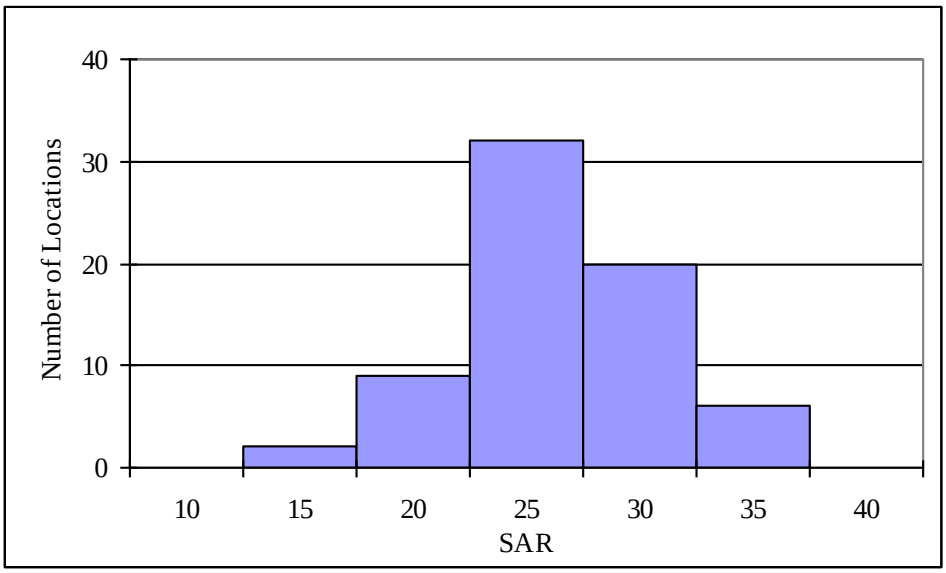

Figure 11. SAR values of all March 2006 sampled locations at the 0-1 foot depth

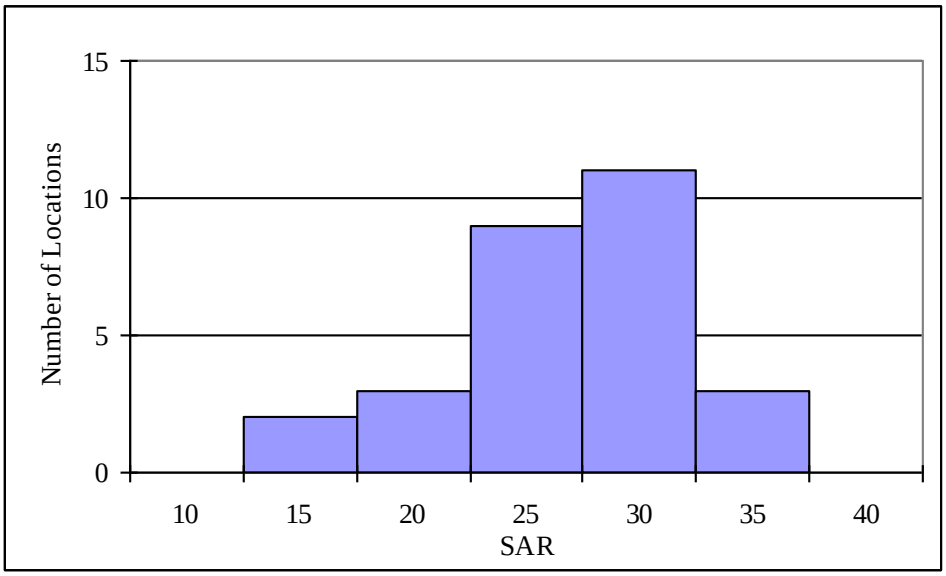

Figure 12. SAR values of the selected twenty-eight sample locations at the 0-1 foot depth

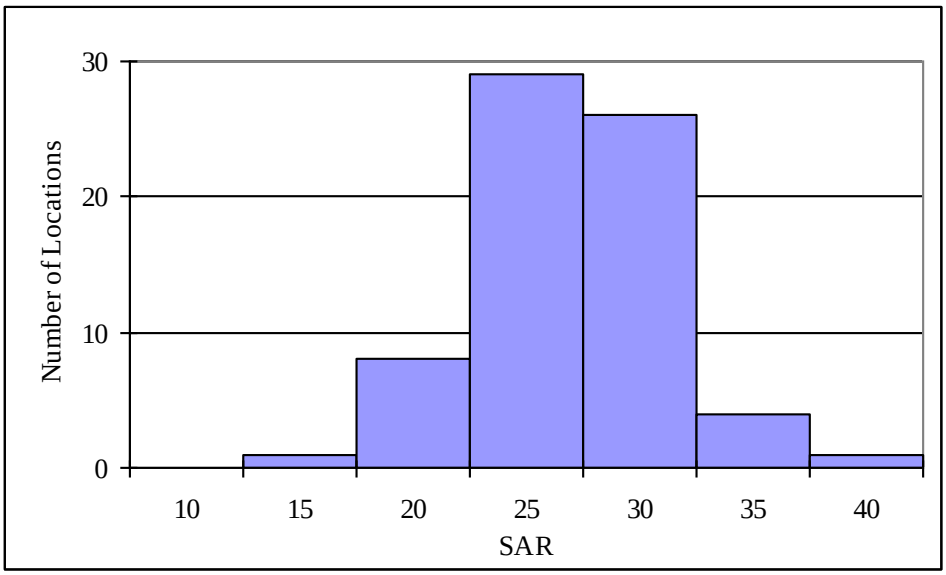

Figure 13. SAR values of all March 2006 sampled locations at the 1-4 feet depth

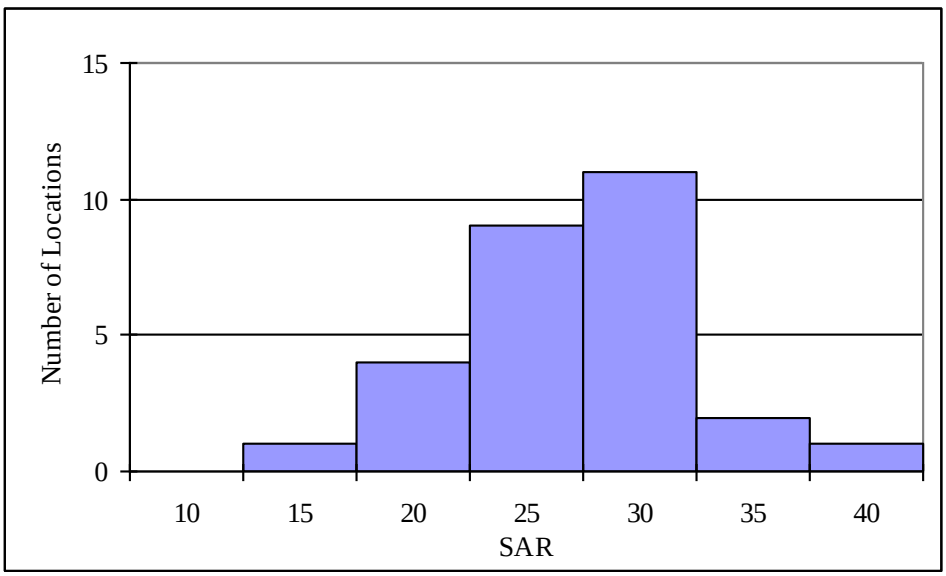

Figure 14. SAR values of the selected twenty-eight sample locations at the 1-4 feet depth

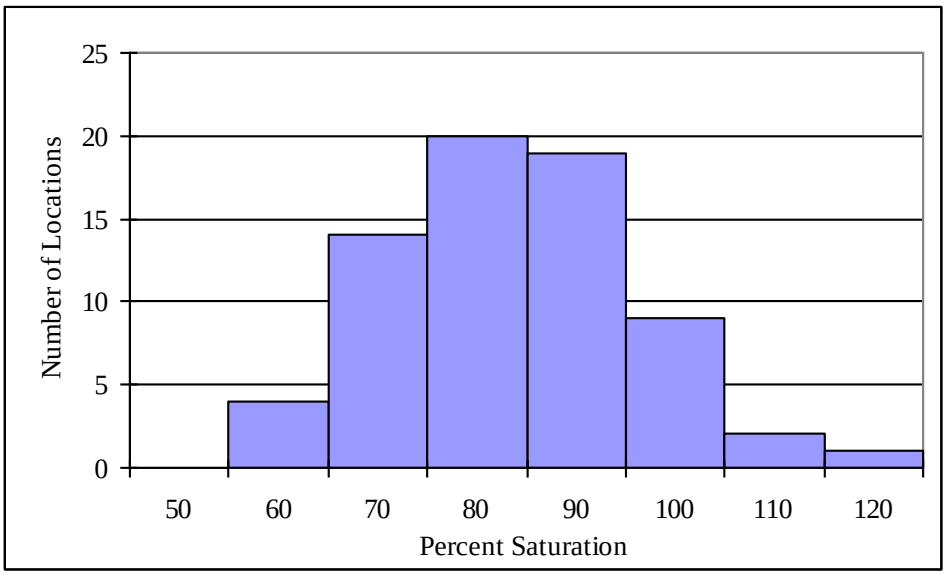

Figure 15. Percent saturation of all March 2006 sampled locations at the 0-1 foot depth

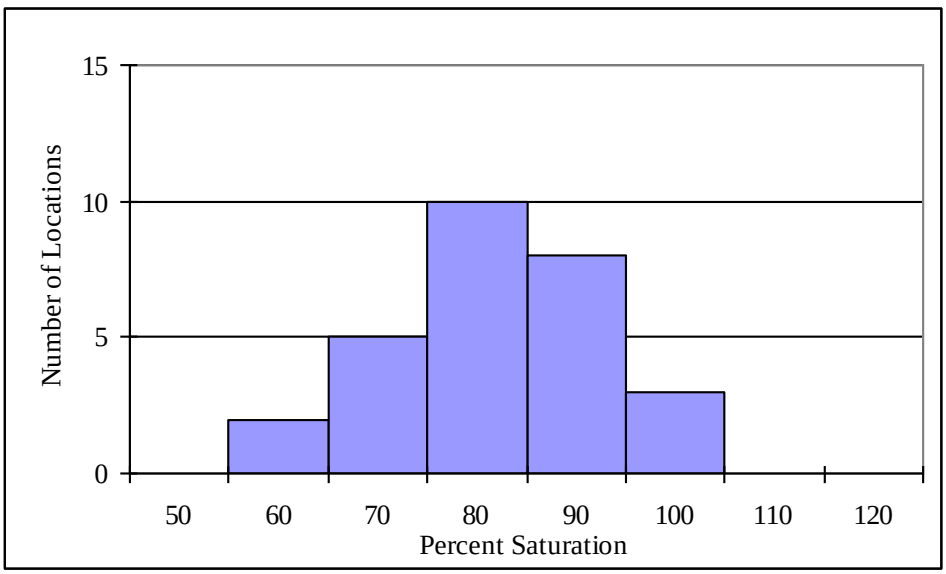

Figure 16. Percent saturation of the selected twenty-eight sample locations at the 0-1 foot depth

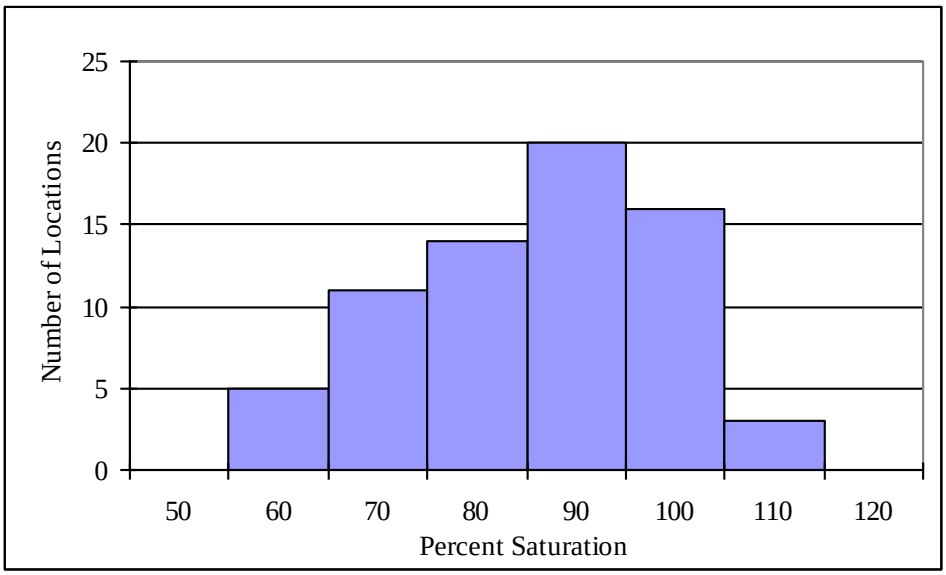

Figure 17. Percent saturation of all March 2006 sampled locations at the 1-4 feet depth

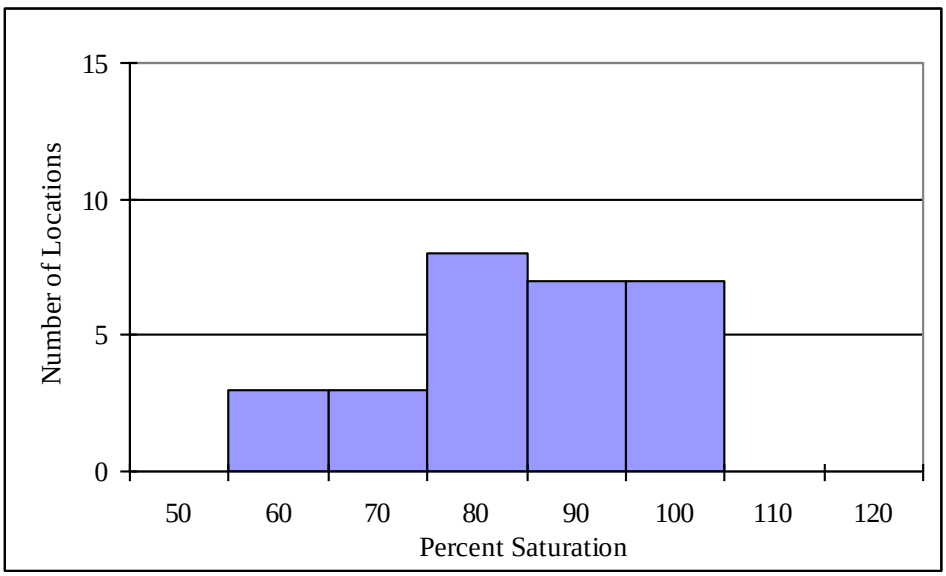

Figure 18. Percent saturation of the selected twenty-eight sample locations at the 1-4 feet depth

Summary statistics for the sampled locations

Table 3. Summary for all sampled locations in Dixon at the 0-1 foot depth

Variable	Obs	Mean	Std. Dev.	Min	Max
EC	69	3.80	1.76	1.04	8.33
SAR	69	23.92	4.35	11.70	32.80
SAT %	69	78.80	12.64	50.90	111.00

Table 4. Summary for selected sample locations at Dixon at the 0-1 foot depth

Variable	Obs	Mean	Std. Dev.	Min	Max
EC	28	3.16	1.61	1.04	8.33
SAR	28	24.47	5.03	11.70	32.80
SAT %	28	76.86	11.17	50.90	96.80

Table 5. Summary for all sampled locations in Dixon at the 1-4 feet depth

Variable	Obs	Mean	Std. Dev.	Min	Max
EC	69	3.67	1.90	1.04	8.33
SAR	69	24.49	4.26	10.80	37.30
SAT %	69	81.02	12.89	54.50	107.00

Table 6. Summary for selected sample locations at Dixon at the 1-4 feet depth

Variable	Obs	Mean	Std. Dev.	Min	Max
EC	28	3.00	1.34	0.67	6.54
SAR	28	24.58	5.08	10.80	37.30
SAT %	28	79.49	12.24	56.30	97.80