GEOMAT INC
2060 Afton Place ◆ Farmington, NM 87401 ◆ Tel (505) 327-7928 ◆ Fax (505) 326-5721

August 27, 2009

Ron C. Van Valkenburg, P.E.
BHP Billiton
BHP Navajo Coal Company
P.O. Box 1717
Fruitland, New Mexico 87416

RE: Proposed Area 4 North Coal Haulage/Small Vehicles Road
Pond Embankment Slope Stability Analysis
Ponds 401, 402, 403, 404, and 405
GEOMAT Project No. 92-0893

GEOMAT Inc. (GEOMAT) has completed geotechnical engineering analyses to evaluate the stability of the proposed roadway embankments which will form the dams of the Navajo Mine Area 4 North Ponds 401, 402, 403, 404, and 405 at the referenced project site. As shown on the Plan and Profile sheets (provided by BHP Billiton) in Appendix A, Ponds 401 through 405 will be located along the south side of Cottonwood Wash between Stations 157+00 and 108+00 on the south side of the proposed Area 4 North Road. The pond embankments will range from approximately 200 to 900 feet in length and 12 to 50 feet in height. We understand the embankments will be constructed of compacted materials obtained from two on-site borrow areas as shown on the Site Plan in Appendix A. The ponds will retain sediment from storm runoff. The maximum depth of water retained in the ponds will range from approximately eight feet in Ponds 401 and 405 to 18 feet in Pond 404. We also understand the topsoil present at the embankment sites will be removed and stockpiled prior to construction of the ponds.

Our scope of services for this project included a site reconnaissance by a geotechnical engineer, a subsurface exploration program, laboratory analyses, and slope stability analyses. Our services were performed in general accordance with our Proposal No. 92-08-04 dated August 5, 2009.

SITE RECONNAISSANCE

A geotechnical engineer from our office performed a site reconnaissance on August 6 and 10, 2009. Selected photographs taken during the reconnaissance trips are presented in Appendix B.

SUBSURFACE EXPLORATION

Subsurface conditions were explored on August 10, 2009 by drilling one exploratory boring at each of the five proposed pond embankment sites as shown on the Site Plan in Appendix C. The borings were advanced with a CME-45 truck-mounted drill using a combination of 4-inch O.D. solid stem and 7-inch O.D. hollow-stem augers. Each boring was advanced to a depth of approximately 20 feet below existing ground surface, with the exception of boring B-5, which was terminated at a depth of about 13 feet due to auger refusal on sandstone.

The borings were continuously monitored by a geologist from our office who examined and

SLOPE STABILITY ANALYSIS

Both the pond side and the non-pond sides of the embankments at Ponds 401 through 405 were analyzed. The embankments were analyzed with the ponds full and empty and with and without pseudo-static earthquake forces of 0.1g. The configurations of the embankments, properties of the native soils/rock and imported soils that will be used to construct the embankments, and surcharge loading conditions which were used in the analyses are as follows:

- Slopes of both the pond and non-pond sides of the embankments were analyzed,
- Slopes of safety berms: 1.5:1 H:V,
- Elevations of the embankments were provided to us by BHP,
- Embankment material to be used: compacted on-site clayey sand and gravel: compacted density 130 pcf; cohesion 250 psf; angle of internal friction (phi) 35 degrees,
- Material type and strength data for the soil to be used in the embankments are based on information obtained by GEOMAT for this project from the exploratory borings and laboratory tests.
- The shoe ground pressure of 25.3 psi imposed by the Marion 7920 Dragline while traveling on the haul road was the design surcharge used for all the analyses.

The location and configuration of the embankments and ponds are depicted on the Plan and Profile sheets in Appendix A. Appendix A also contains a sheet (provided by BHP Billiton) showing the embankment cross-sections.

We understand that the ponds will be used to retain sediment from storm runoff water. The ponds are not expected to impound water for long periods of time.

The Galena Slope Stability Analysis System computer software, version 4.02 was used to analyze the stability of both sides (the pond-side and non-pond-side) of the embankments. It should be noted that due to requirements of the program, all the slopes are plotted ascending to the right. Both the pond-side and non-pond sides were analyzed with and without water. The analyses were also performed with and without a pseudo-static earthquake force of 0.1g. The analyses were performed using the soil strength/density parameters that were obtained by GEOMAT and that are presented in Appendix C of this report.

In our analysis, we assumed removal of the top five feet of soil (topsoil) before construction of the embankments. The underlying layers of sandstone were defined as having a cohesion ranging from about 100,000 to 200,000 psf and a phi angle of approximately 2 to 4 degrees. The coal seam was modeled with a unit weight of 80 pcf, a cohesion of 2,000 psf (approximately 14 psi) and a phi angle of 3 degrees. These values are estimates intended to be conservative for these material types.

Rapid drawdown conditions were not analyzed, since a phreatic surface should not develop during the short time the water is expected to be impounded.

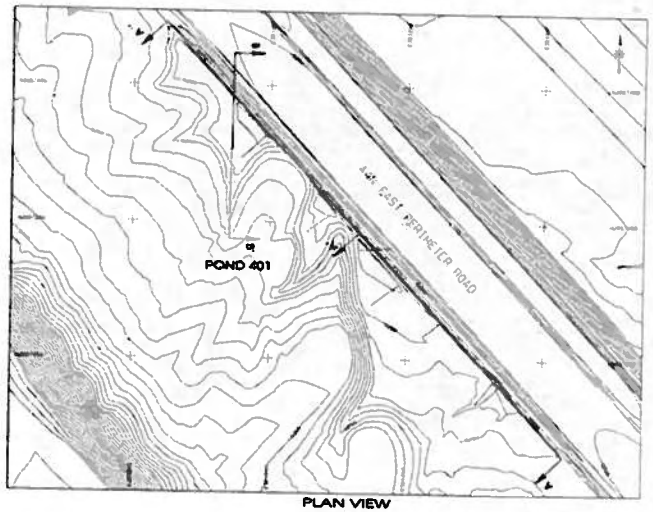
Pond Area	Side	Water Condition	Pseudo Static Earthquake (%g)	Calculated Factor of Safety
404	Pond	Reservoir empty	0.0	2.1
404	Pond	Reservoir empty	0.1	1.7
404	Pond	Reservoir full	0.1	1.5
404	Non-Pond	Reservoir empty	0.0	1.7
404	Non-Pond	Reservoir empty	0.1	1.5
404	Non-Pond	Reservoir full	0.1	1.2
405	Pond	Reservoir empty	0.0	1.7
405	Pond	Reservoir empty	0.1	1.4
405	Pond	Reservoir full	0.1	1.3
405	Non-Pond	Reservoir empty	0.0	1.6
405	Non-Pond	Reservoir empty	0.1	1.4
405	Non-Pond	Reservoir full	0.1	1.2

As shown in the above table, the calculated factors of safety range from 1.2 to 2.2 for the 1.5:1 H:V embankment slope. All of the slopes and conditions met what we understand is the Office of Surface Mining (OSM) required factor of safety of 1.3, except for the non-pond side of 404 and the non-pond side of 405. The factors of safety for these two embankments were 1.2 under the conditions of the reservoirs being full at the time there was an earthquake. Since the conditions of the earthquake and high water occurring at the same time are unlikely and the factors of safety are within 0.1 of the 1.3 value, it is our opinion that the design conditions are adequate. If higher factors of safety are required, the slopes could be reduced from 1.5:1 H:V to 2:1 H:V.

The analysis and recommendations submitted in this report are contingent upon proper compaction of the fill material used to construct the embankments. Soils should be compacted to at least 95 percent of the maximum dry density as determined by ASTM D1557 (modified proctor) at a moisture content between two (2.0) percent below and four (4.0) percent above the optimum moisture content. Fill should be placed in lift thicknesses that can be compacted to the required density by the type of compaction equipment being used.

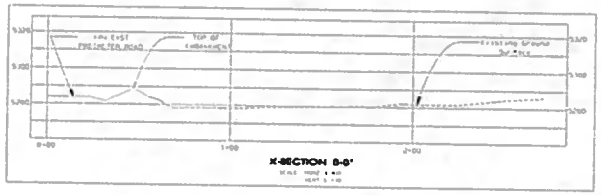
The nature and variation of the native materials and the materials to be used to construct the embankment may not become evident until construction or until the final source location and type

Appendix A

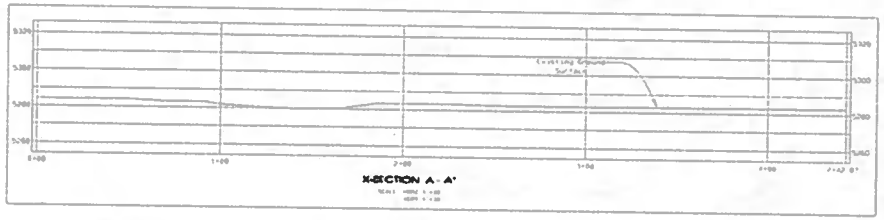


PLAN VIEW

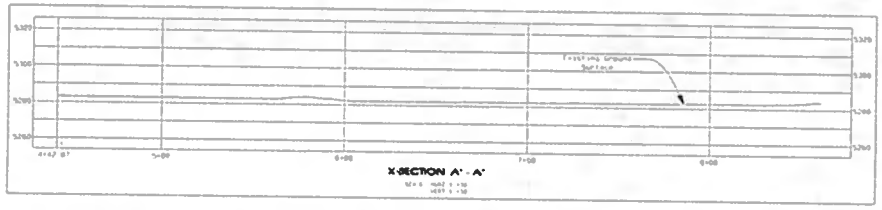
CONTOUR INT 2 FT
SCALE 1 =80



X-SECTION B-B'



X-SECTION A - A'



X-SECTION A' - A'

LEGEND

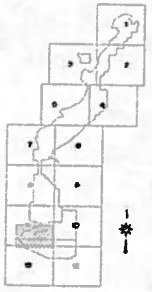
- ROAD
- BUILDING
- FENCE
- CULVERT
- DRAINAGE
- POWERLINE
- 5,280 INDEX CONTOUR
- 5,280 INTERMEDIATE CONTOUR
- PERMIT/LEASE BOUNDARY

NOTES

1. For location of drainage control structures and embankments refer to exhibit 11-1-1F
2. The hydrology and supporting design data for the drainage control structures are referenced on Table 11-1-1 of the report

STAGE STORAGE DATA

ELEV feet	AREA acres	VOLUME ac-ft	CUM VOLUME ac-ft
5274	0.026	0.00	0.00
5276	0.199	0.20	0.20
5278	0.574	0.70	0.90
5280	0.909	1.40	2.30
5282	1.237	2.20	4.50



SCALE AS NOTED

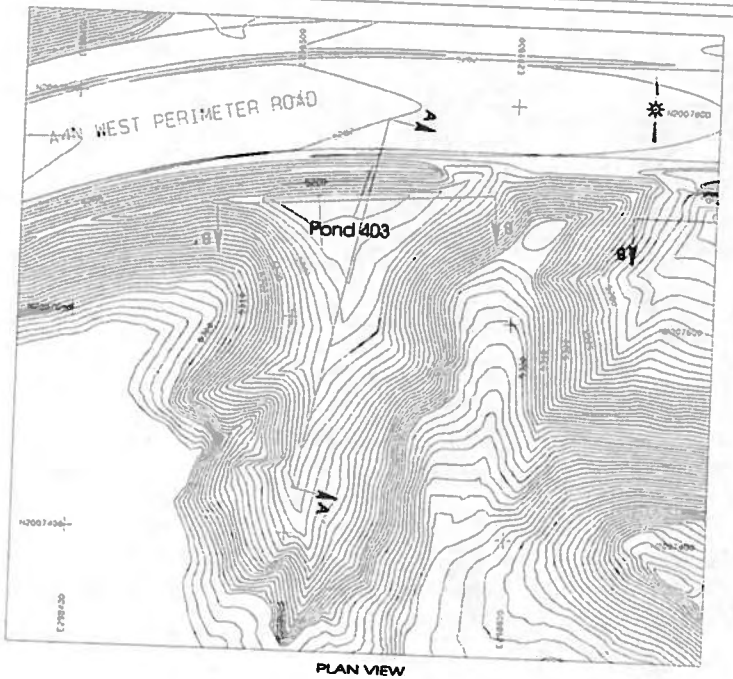
CERTIFICATION STATEMENT

I Ron G. Van Valkenburg hereby certify that this drawing was reviewed by me and that the information shown is complete and accurate to the best of my knowledge

bhpbilliton
NAVAJO COAL COMPANY
NAVAJO MINE

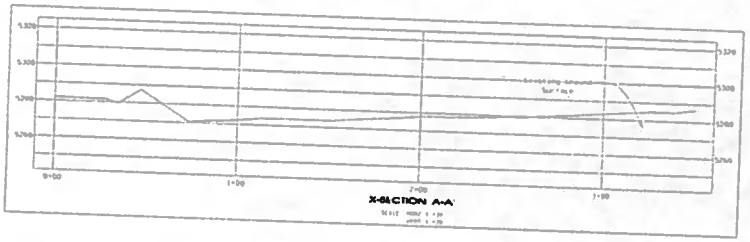
PLAN, PROFILE AND SECTION

EXHIBIT 11-001
AREA 4 NORTH
POND 401
Design

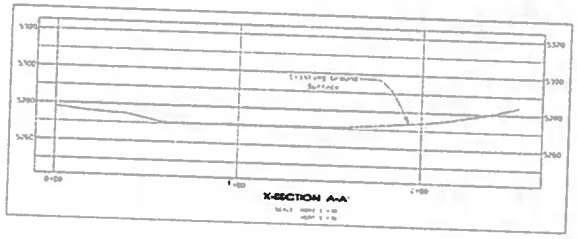


PLAN VIEW

SCALE 1" =60



X-SECTION A-A



X-SECTION A-A

LEGEND

ROAD

BUILDING

FENCE

CULVERT

DRAINAGE

POND LINE

INDEX CONTOUR

INTERMEDIATE CONTOUR

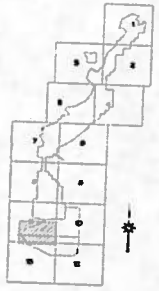
PERMIT/LEASE BOUNDARY

NOTES

1. For location of drainage control structures and surroundings refer to Exhibit 11-19
2. The hydrology and supporting design data for the drainage control structures are referenced on Table 11-5aa at the end

STAGE STORAGE DATA

ELEV (feet)	AREA (acres)	VOLUME (acre-ft)	CUM VOLUME (acre-ft)
5266	0.00	0.00	0.00
5268	0.02	0.00	0.00
5270	0.05	0.10	0.10
5272	0.05	0.10	0.20
5274	0.05	0.10	0.30
5276	0.24	0.40	0.90
5278	0.37	0.60	1.42
5280	0.45	0.60	2.02



SCALE AS NOTED

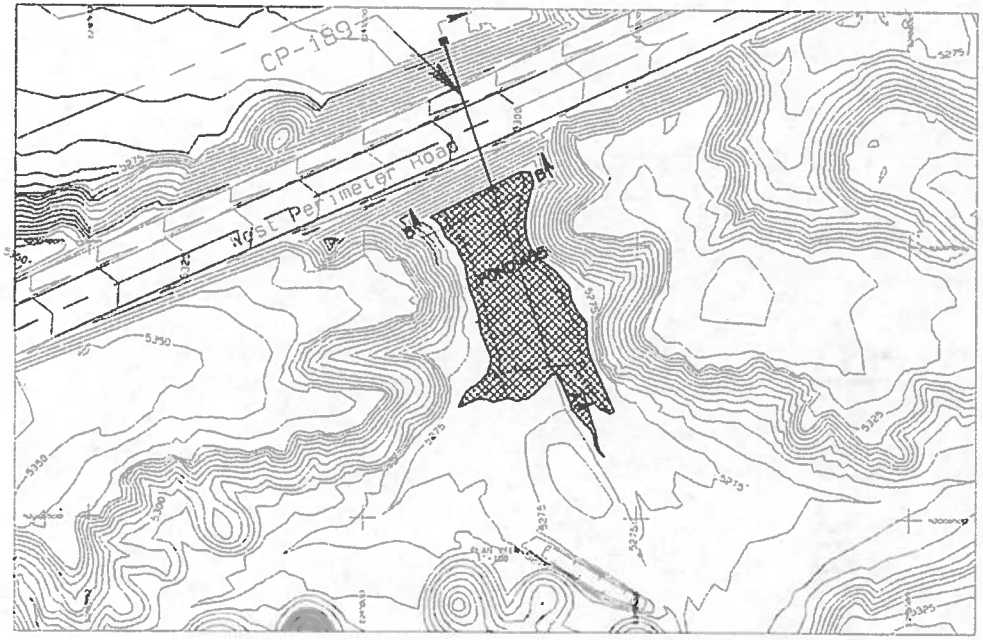
CERTIFICATION STATEMENT

I, Ron C. Van Valkenburg, hereby certify that this drawing was reviewed by me and that the information shown is complete and accurate to the best of my knowledge

bhpbilliton
NAVAJO COAL COMPANY
NAVAJO MINE

PLAN, PROFILE AND SECTION

EXHIBIT 11-03
AREA 4 NORTH
POND 403
Design



LEGEND

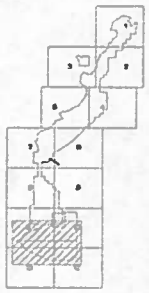
- ROAD
- WATERSHED
- BUILDING
- FENCE
- IRRIGATION LINE
- CULVERT
- DAM
- DRAINAGE
- RAILROAD
- TREES
- POWERLINE
- 5,300 SPOT ELEVATION
- 5,300 INDEX CONTOUR
- 5,310 INTERMEDIATE CONTOUR
- 718 / 5,420 ↗ / 1-30 LEASE CORNER
- PERMIT/LEASE BOUNDARY

NOTES

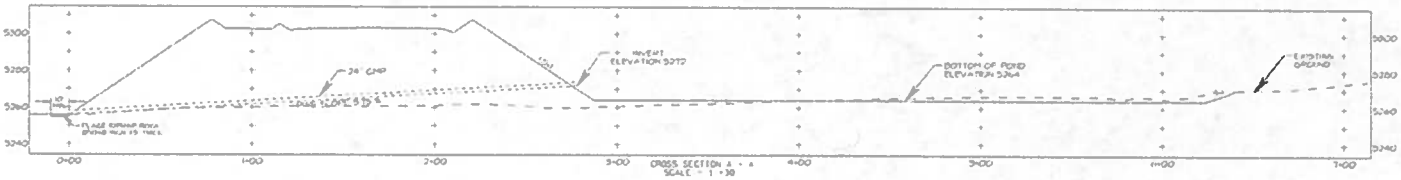
1. For hydrology and design information refer to appendix 11-J, pond supporting par.
2. The watershed areas for culverts are shown on Exhibit 11-5A.
3. The watershed areas and Stage-Vol for Ponds are shown on Exhibit 11-5B.

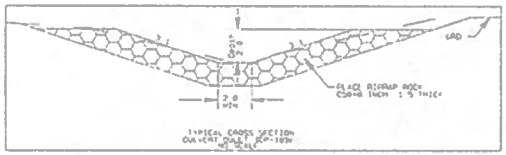
STAGE STORAGE DATA

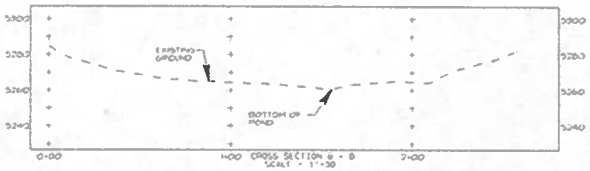
ELEV. feet	AREA acres	VOLUME ac-ft	CUM VOLUME ac-ft
5264	0.93	0.0	0.00
5266	1.87	2.8	2.8
5268	1.24	2.1	4.9
5270	1.46	2.8	7.7
5272	2.12	3.7	10.8



SCALE AS NOTED







CERTIFICATION STATEMENT

I, Ron C. van Valkenburg hereby certify that this drawing was reviewed by me and that the information shown is complete and accurate to the best of my knowledge.

RON C. VAN VALKENBURG
STATE OF ARIZONA
9653

BHP NAVAJO COAL CO.
NAVAJO MINE

EXHIBIT 11-5
JREA NORTH
POND
DESIGN

PLAN, PROFILE AND SECTIONS

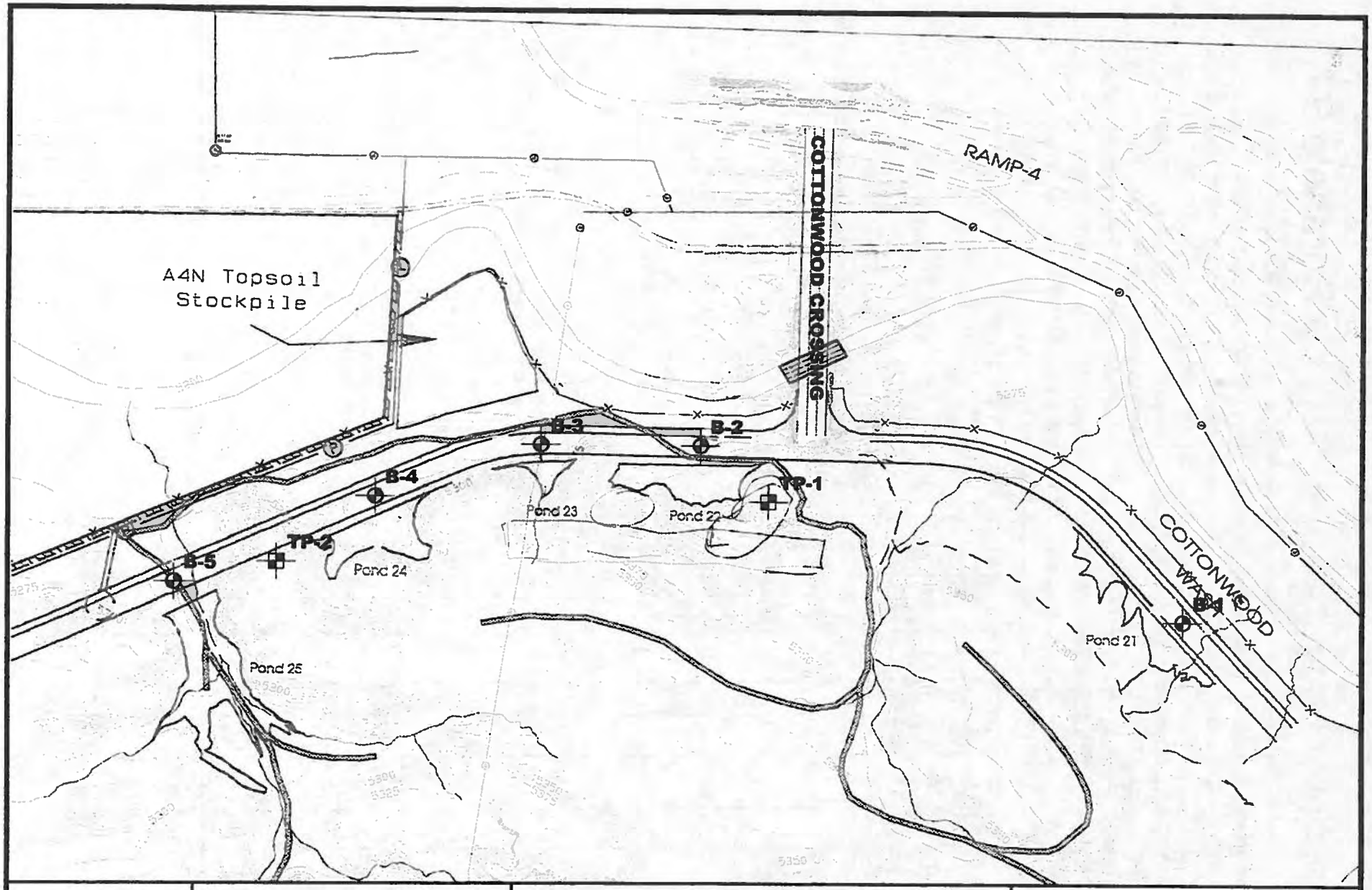
SITE PHOTOGRAPHS

Test Pit TP-1 (Borrow Site)

Borrow Material from Test Pit TP-1

Drill Rig at Pond 405

Test Pit TP-2 (Borrow Site)



Approximate

Not to Scale

SITE PLAN	PROJECT
Boring Locations (approximate)	A4N Pond Embankment Stability Analysis Navajo Mine Area 4 North San Juan County, New Mexico
GEOMAT Project No. 92-0893 Date Test Pits Excavated: 8-10-09 Date Borings Drilled: 8-10-09	GEOMAT INC Appendix 11-I

GEOMAT INC.
2060 Afton Place
Farmington, NM 87401
Tel (505) 327-7928
Fax (505) 326-5721

Borehole B-2

Project Name:	A4N Pond Embankment Stability	Date Drilled:	8/10/2009
Project Number:	92-0893	Latitude:	Not Determined
Client:	BHP Billiton	Longitude:	Not Determined
Site Location:	Navajo Mine Area 4 North	Elevation:	Not Determined
Rig Type:	CME-45	Boring Location:	See Site Plan
Drilling Method:	4" O.D. Solid Stem Auger	Groundwater Depth:	20.5 feet (approx) during drilling
Sampling Method:	Modified California with Rings	Logged By:	Don Baldwin
Hammer Weight:	140 lbs	Remarks:	Pond 402
Hammer Fall:	30 inches		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Recovery	USCS	Soil Symbol	Depth (ft)	Soil Description
									1	SILTY SAND, brown, fine- to medium-grained, loose to medium dense, dry to moist, weak cementation
									2	
									3	
									4	
96.2	13		2.3	7-11-16	MC 18				5	
									6	
									7	
									8	
									9	
				2-4-10	MC 18		SM		10	
									11	
									12	
									13	
									14	
				2-5-12	MC 18				15	
									16	fine- to coarse-grained
									17	
									18	
									19	
				5-12-11	MC 18				20	
									21	▽ groundwater at approximately 20.5 foot depth during drilling
									22	Total Depth 21.5 feet
									23	
									24	
									25	

A = Auger Cuttings GRAB = Hand Sample MC = Modified California (Ring Sample) SS = Split Spoon

GEOMAT 92-0893.GPJ GEOMAT.GDT 08/26/09

GEOMAT INC
2060 Afton Place
Farmington, NM 87401
Tel (505) 327-7928
Fax (505) 326-5721

Borehole B-4

Project Name:	A4N Pond Embankment Stability	Date Drilled:	8/10/2009
Project Number:	92-0893	Latitude:	Not Determined
Client:	BHP Billiton	Longitude:	Not Determined
Site Location:	Navajo Mine Area 4 North	Elevation:	Not Determined
Rig Type:	CME-45	Boring Location:	See Site Plan
Drilling Method:	4" O.D. Solid Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Modified California with Rings	Logged By:	Don Baldwin
Hammer Weight:	140 lbs	Remarks:	Pond 404
Hammer Fall:	30 inches		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Recovery	USCS	Soil Symbol	Depth (ft)	Soil Description
							SC		1–5	CLAYEY SAND with gravel, gray, fine- to medium-grained, loose, dry to moist, no cementation
				4-9-15	MC 18					
							RK		6	SHALE, gray, moderately weathered, moderately soft
							RK		7–13	SANDSTONE, gray, fine- to coarse-grained, slightly weathered, moderately hard, moderately cemented
				9-29-50/5	MC 17					
							RK		14–18	COAL, black, fresh, moderately hard, fractured
				9-50/4	MC 10					
							RK		19–20	SILTSTONE grading to SHALE, gray, fresh, moderately hard
				19-50/2	MC 8					
									21–25	Total Depth 20.7 feet

A = Auger Cuttings GRAB = Hand Sample MC = Modified California (Ring Sample) SS = Split Spoon

GEOMAT 92-0893.GPJ GEOMAT.GDT 08/26/09

PROJECT A4N Pond Embankment Stability
Navajo Mine Area 4 North

JOB NO. 92-0893 **DATE** 08/10/09

LOG OF TEST PIT NO. TP-1

LOGGED BY George Madrid
BACKHOE TYPE JD 310SJ
LOCATION See Site Plan
SURFACE ELEV. Not Determined **DATUM** N/A

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0					SC		CLAYEY SAND, brown, fine- to medium-grained, loose, dry, no cementation
1			D				PI = 16 -200 = 30%
2							
					RK		SANDSTONE, brown, fine- to medium-grained, moderately weathered, moderately soft, moderate cementation, fractured
3							
					RK		SILTSTONE, gray, moderately weathered, moderately soft (PARTING)
4							
5							
6			D				PI = 15 -200 = 32
7							
8							
9							
10							Test pit completed at 10 foot depth No groundwater encountered

GEOTECH TP2 92-0893 TP.GPJ AGRA ALB.GDT 09/26/09

SAMPLE TYPE

B - Undisturbed Block Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample

GEOMAT INC.

UNIFIED SOIL CLASSIFICATION SYSTEM					CONSISTENCY OR RELATIVE DENSITY CRITERIA
Major Divisions			Group Symbols	Typical Names	
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Standard Penetration Test Density of Granular Soils
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Penetration Resistance, N (blows/ft.) — Relative Density
		Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures	0-4 Very Loose
			GC	Clayey gravels, gravel-sand-clay mixtures	5-10 Loose
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines	11-30 Medium Dense
			SP	Poorly graded sands and gravelly sands, little or no fines	31-50 Dense
		Sands with Fines	SM	Silty sands, sand-silt mixtures	>50 Very Dense
			SC	Clayey sands, sand-clay mixtures	Standard Penetration Test Density of Granular Soils
Fine-Grained Soils 50% or more passes No. 200 sieve	Silts and Clays Liquid Limit 50 or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	Penetration Resistance, N (blows/ft.) — Consistency — Unconfined Compressive Strength (Tons/ft2)
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	<2 Very Soft <0.25
			OL	Organic silts and organic silty clays of low plasticity	2-4 Soft 0.25-0.50
	Silts and Clays Liquid Limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous free sands or silts, elastic silts	4-8 Firm 0.50-1.00
			CH	Inorganic clays of high plasticity, fat clays	8-15 Stiff 1.00-2.00
			OH	Organic clays of medium to high plasticity	15-30 Very Stiff 2.00-4.00
Highly Organic Soils			PT	Peat, mucic & other highly organic soils	>30 Hard >4.0

U.S. Standard Sieve Sizes	3"	3/4"	#4		#10		#40	#200
Unified Soil Classification	Cobbles	Gravel		Sand				Silt or Clay
		coarse	fine	coarse	medium	fine		

MOISTURE CONDITIONS	
Dry	Absence of moist, dusty, dry to the touch
Slightly Damp	Below optimum moisture content for compaction
Moist	Near optimum moisture content, will moisten the hand
Very Moist	Above optimum moisture content
Wet	Visible free water, below water table

MATERIAL QUANTITY	
trace	0-5%
few	5-10%
little	10-25%
some	25-45%
mostly	50-100%

OTHER SYMBOLS
R Ring Sample
S SPT Sample
B Bulk Sample
▼ Ground Water

BASIC LOG FORMAT:

Group name, Group symbol, (grain size), color, moisture, consistency or relative density. Additional comments: odor, presence of roots, mica, gypsum, coarse particles, etc.

EXAMPLE:

SILTY SAND w/trace silt (SM-SP), Brown, loose to med. Dense, fine to medium grained, damp

UNIFIED SOIL CLASSIFICATION SYSTEM

LAB NO.	BORING NO.	SAMPLE DEPTH (ft)	ASTM D698		MOISTURE CONT. (%)	DENSITY		ATTERBERG LIMITS			SWELL (%)	PHI ANGLE (degrees)	% PASS #200 SIEVE	CLASSIFICATION	
			Density	Moisture		WET (pcf)	DRY (pcf)	LL	PL	PI					
7959	TP-1	0 - 2.5	111.8	15.9				34	18	16			30	SC	Clayey SAND w/ trace gravel
7960	TP-1	3.5 - 10.0	107.6	18.3				36	21	15			32	GC	Clayey GRAVEL w/ sand
7978	B-1	5.0			2.9	109.5	106.4						24	SM	Silty SAND
7979	B-1	10.0										33.9		SM	Silty SAND
7980	B-2	5.0			2.3	98.4	96.2	NLL	NPL	NP			13	SM	Silty SAND
7981	B-2	10.0										33.0		SM	Silty SAND
7982	B-3	5.0			6.7	103.7	97.2	29	17	12			50	SC/CL	Clayey SAND/Sandy CLAY

GEOMAT INC.

SUMMARY OF SOIL TESTS

Project	Area 4 North Pond Embankments
Job No.	92-0893
Location	BHP Navajo Mine
Date Drilled	8/10/2009

amec

Client: Geomat, Inc
2060 Afton Place
Farmington, NM 87401-

Attn: George Madrid

Project Name: GeoMat 2008 Miscellaneous Testing
Various Locations
Farmington, NM

Project Manager: Robert Romero

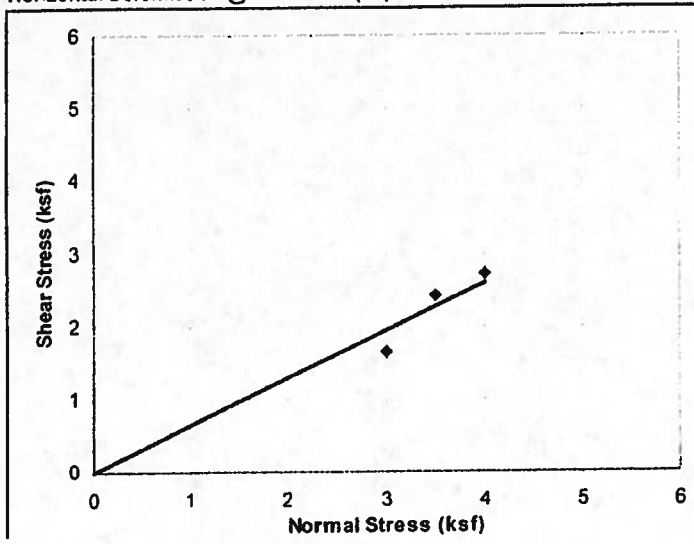
Report Date: August 21, 2009

Project #: 8-519-005130
Work Order #: 11
Lab #: 9-0928-02
Sampled By: D. Baldwin
Date Sampled: 08/10/2009
Visual Description of Material: Geomat/Soil Sample #7981
Sample Source: Area 4 North Pond Embankments/ BH B-2 @ 10' Project #92-0893

SOILS / AGGREGATES

Direct Shear Test of Soils Under Consolidated Drained Conditions (ASTM D3080-04)

Direct Shear Point Number:	1	2	3
Initial Diameter of specimen (in.):	2.42	2.42	2.42
Initial Thickness of specimen (in.):	1.00	1.00	1.00
Dry Mass of Specimen (g):	132.7	129.2	129.3
Initial Moisture (%):	2.9%	3.0%	2.5%
Initial Wet Density (pcf):	113.5	110.7	110.2
Initial Dry Density (pcf):	110.3	107.4	107.5
Final Thickness of specimen (in.)::	0.99	1.00	0.99
Final Moisture (%):	2.0%	2.3%	1.9%
Final Wet Density (pcf):	113.8	110.2	110.3
Final Dry Density (pcf):	111.6	107.8	108.2
Normal Stress (ksf):	3.00	3.50	4.00
Maximum Shearing Stress (ksf):	1.6	2.4	2.7
Vertical Deformation @ Max Shear (in.):	0.001	0.007	0.013
Horizontal Deformation @ Max Shear (in.):	0.225	0.150	0.210



Shearing Device Used:
Geomatic Direct Shear Apparatus, Model 8914

Rate of Deformation (in./min.): 0.015

Internal Friction Angle (deg.): 33.0

Cohesion (kips/sq.ft.): 0.0000

Reviewed By: for Bob R.
hg

Distribution: Client ✓ File: ✓ Supplier: ✓ Other: Addressee (1)
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GEOMAT INC
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January 14, 2010

Ron C. Van Valkenburg, P.E.
BHP Billiton
BHP Navajo Coal Company
P.O. Box 1717
Fruitland, New Mexico 87416

RE: Proposed Area 4 North Coal Haulage/Small Vehicles Road
Pond Embankment Slope Stability Analysis – Addendum No. 1 (Final)
Ponds 401, 402, 403, 404, and 405
GEOMAT Project No. 92-0893

GEOMAT Inc. (GEOMAT) has performed additional slope stability analyses on the proposed Area 4 North road embankments at the five pond locations. These additional slope stability analyses should be considered as Addendum No. 1 (Final) to our original Pond Embankment Slope Stability Analysis report dated August 27, 2009 (GEOMAT Project No. 92-0893). These additional analyses were performed in general accordance with our Scope of Work and Cost Estimate dated September 21, 2009 and results of a meeting held at the mine on November 6, 2009 and phone conference held on January 4, 2010. The meeting held at the mine was attended by Ron Van Valkenburg, Greg Perkins, Ferguson Gorman, WJ Napoleon, and Joe Haas of Navajo Mine and Brian Tsingine and George Madrid of GEOMAT. The phone conference participants were Ron Van Valkenburg, Greg Perkins, Ferguson Gorman, and WJ Napoleon of Navajo Mine and Brian Tsingine and George Madrid of GEOMAT. The purpose of these analyses was to determine the factor of safety of the embankments using 2:1 (H:V) slopes and assuming the embankment fills are placed in approximate 5-foot lifts without moisture and density control. It is also assumed that each 5-foot lift would be placed along the whole length and width of the roadway prior to adding the subsequent 5-foot lift.

On December 17, 2009, we performed density testing on a prototype area where a fill had been placed in an approximate 6-foot lift with similar material and in a similar fashion to that planned for the Area 4 North road. Tests were performed with a portable nuclear density gage at seven different locations; six of the seven tests were performed in the top one foot of the fill and the other test was performed in the bottom one foot of the fill in a backhoe-excavated pit . In-place wet densities ranged from an average of approximately 121 pounds per cubic foot (pcf) in the top one foot of the fill to 103 pcf in the bottom one foot of the fill. Based on these test results, 103 pcf was used as the embankment fill unit weight in our analyses. Due to the gravely, rocky nature of the material direct shear testing to determine the cohesion and angle of internal friction (phi) could not be performed. A cohesion value of 230 psf and phi angle of 30 degrees was selected for use in the analyses based on data in the Naval Facilities Engineering Command Design Manual 7.02.

The Galena Slope Stability Analysis System computer software, version 5.02 was used to analyze the stability of both sides (the pond-side and non-pond-side) of the embankments. The results of the analyses are shown in the following table.

Pond Area	Side	Water Condition	Pseudo Static Earthquake (%g)	Calculated Factor of Safety
401	Pond	Reservoir empty	0.0	2.2
401	Pond	Reservoir empty	0.1	1.8
401	Pond	Reservoir full	0.1	1.4
401	Non-Pond	Reservoir empty	0.0	2.1
401	Non-Pond	Reservoir empty	0.1	1.7
401	Non-Pond	Reservoir full	0.1	1.3
402	Pond	Reservoir empty	0.0	2.1
402	Pond	Reservoir empty	0.1	1.7
402	Pond	Reservoir full	0.1	1.3
402	Non-Pond	Reservoir empty	0.0	2.2
402	Non-Pond	Reservoir empty	0.1	1.7
402	Non-Pond	Reservoir full	0.1	1.3
403	Pond	Reservoir empty	0.0	2.1
403	Pond	Reservoir empty	0.1	1.6
403	Pond	Reservoir full	0.1	1.4
403	Non-Pond	Reservoir empty	0.0	1.9
403	Non-Pond	Reservoir empty	0.1	1.4
403	Non-Pond	Reservoir full	0.1	1.2
404	Pond	Reservoir empty	0.0	2.0
404	Pond	Reservoir empty	0.1	1.6
404	Pond	Reservoir full	0.1	1.4
404	Non-Pond	Reservoir empty	0.0	1.8
404	Non-Pond	Reservoir empty	0.1	1.4
404	Non-Pond	Reservoir full	0.1	1.1
405	Pond	Reservoir empty	0.0	1.8
405	Pond	Reservoir empty	0.1	1.5
405	Pond	Reservoir full	0.1	1.3
405	Non-Pond	Reservoir empty	0.0	1.8
405	Non-Pond	Reservoir empty	0.1	1.4
405	Non-Pond	Reservoir full	0.1	1.2

As shown in the above table, the calculated factors of safety range from 1.1 to 2.2 for embankment slopes of 2:1 (H:V). All of the slopes and conditions met what we understand is the Office of Surface Mining (OSM) required factor of safety of 1.3, except for the non-pond sides of 403, 404 and 405. The factors of safety for these three embankments were 1.1 for Pond 404 and 1.2 for Ponds 403 and 405 under the conditions of the reservoirs being full at the time there was an earthquake. It was decided during the phone conference of January 4th to reduce the height of the embankment fill and water level at each of these three ponds as necessary to attain the required factor of safety of 1.3 on the non-pond sides under the conditions of the ponds being full at the time there was an earthquake. A factor of safety of 1.3 was attained by reducing the embankment fill and water level by 8, 9 and 3 feet for Ponds 403, 404, and 405, respectively.

The individual sheets showing the details of the calculations and the configurations of the slopes used in the calculations are available upon request.

Any information in our original report not specifically modified herein remains unchanged.

Thank you for the opportunity to work with you on this project. If you have any questions or need additional information, please let us know.

Sincerely yours,
GEOMAT Inc.

Brian Tsingine
Engineering Staff Professional

GEORGE A. MADRID
NEW MEXICO
9110
REGISTERED PROFESSIONAL ENGINEER

1.14.10

George A. Madrid, P.E.
President, Principal Engineer

Distribution: Addressee (1)

APPENDIX 11-I

STABILITY ANALYSES

(9/93)

APPENDIX 11-I

SLOPE STABILITY SUMMARY

To demonstrate that all cut and fill slopes, regraded areas and embankments are stable, representative structures were selected on which to conduct stability analyses. Criteria for site selection included foundation material, embankment material, slope angle, safety and environmental concerns and use of the structure.

An inventory was made of all ponds, impoundments, embankments (cut and fill) and regrade areas. These structures were all examined in the field to determine their status. Notes were made as to the presence or absence of water, spillways, slope failures, seepage, and piping. The relative size of each structure was noted along with any potential safety or environmental hazards if the structure were to fail. Excessively steep slopes were also noted as were any conditions resulting from erosion. An assessment was made of the soil types forming both the structure itself and its foundation. All of this information, along with any unusual conditions seen during the field visits, was compiled to allow selection of representative structures for analysis.

It was originally thought that soil types would be useful in cataloging the structures. However, almost all of the structures were found to be composed of and sitting on a sandy clay type soil. Little difference is visible in the field from one structure to the next. Since this criteria is important, the soils section of the Permit Application Package (PAP) was examined to determine the soil types and their relative

proportions. This information was combined with data from "Soil Survey of San Juan County" by the Soil Conservation Service in which the various soils were evaluated as to their ability to form embankments, dikes and levees. Soils which received unfavorable comments as to their suitability for use as embankments, etc. were found to cover more than eighty percent of the permit area. A decision was made to treat all of the structures as if they were built on and of material which is not normally considered satisfactory. Hence, soil type was not used as a selection criterion. Selections were made based on size, steepness of slope, existence of seepage or other visible concerns and on potential safety and environmental problems. Ponds whose designs had already been examined and approved by OSMRE were eliminated. Totally incised structures were also eliminated as they have no dam or other structure to fail. A listing of the structures considered, their associated selection criteria and a brief description of why or why they were not selected for testing is given on TABLE 11-I-1. A steeply slope regrade area was selected as a worst case representative of the regraded spoils. The structures selected for stability analyses are listed below.

STRUCTURE AND REASON FOR SELECTION

Big Fill

Largest fill on permit area. Fill was not compacted and structure has had previous problem with piping and has had a small surficial slope failure. Drainage pipes were installed to keep water from ponding on and soaking into the structure.

Stub 17 Large Impoundment

Largest dam structure of the impoundments. Structure was not compacted.

Elms Embankment 2

Largest impounding haulroad embankment.

Area III Shop Pond

Dam has steep sides and has had significant erosional damage. The largest of the two sediment ponds which have not been previously approved.

Lowe Impoundment 13

Structure is representative of those built by Comstock and other pond-like impoundments and has the largest dam structure.

Lowe Railroad

Largest embankment (fill) on permit area Embankment 1 without a culvert. Water has previously impounded to a maximum depth of 5 feet. Embankment forms part of the railroad. Seepage from base occurs when water is present.

Barber Regrade

Steep regraded spoils with no compaction. Area is located by the railroad near North Barber.

Big Fill Stability Analysis

Two different stability analyses have been conducted on the Big Fill and are included in the permit package. The first is kept on file at the Environmental Quality Department of the Navajo Mine, and is a determination of static stability. The report indicates that the Big Fill would have a minimum static stability safety factor greater than 1.5 if certain remedial actions were taken. Those actions were all completed in 1985. The second stability analysis is kept on file at the Environmental Quality Department of the Navajo Mine and is a seismic stability analysis of the structure. The minimum seismic safety factor was found to be 1.2 under conservative assumptions.

The Big Fill stands alone and is not representative of any other structure on the mine. It was built using a dragline which excavated nearby material and placed it without compaction in the desired location. This construction method led to the problems experienced by the structure in subsequent years. The other fill structures associated with the railroad were compacted and have all retained their integrity over the years.

Stub 17 Large Impoundment

Stub 17 Large Impoundment was chosen for stability analysis because it is the largest of the impoundment structures constructed without compaction along the Barber highwall. Structures of like construction include Stub 17 small Impoundment and Stub 18 Impoundment. Results of the analysis, as detailed on file at the Environmental Quality Department of the Navajo Mine, indicate a minimum static factor of 1.2 and a minimum seismic factor of safety of 1.0.

No plans have been made to modify the structures to increase the safety factors as all of them will be mined through in the next few years.

Elms Embankment 2 (Standpipe)

Elms Embankment 2 (Standpipe) was selected for analysis because it is the largest of the impounding haulroad embankments. Other haulroad embankments also impound water along the same stretch of road. Results of the analysis, as detailed on file at the Environmental Quality Department of the Navajo Mine, shows a minimum static factor of safety of 1.2 and a minimum seismic factor of safety of 1.1.

The road has been modified since the analysis was made and is now approximately 70 feet wide at the crest. This widening also affected the other haulroad embankments which impound water.

Area III Shop Pond

Area III Shop Pond is representative of the sediment control ponds constructed when facilities were built for Area III development.

Those ponds include Area III Shop Pond, Area III Complex Pond and Lowe Stockpile Pond. Since Area III Shop Pond is the only one to have suffered any damage over the years it was analyzed for stability. Results of the analysis, as detailed on file at the Environmental Quality Department of the Navajo Mine, indicates that the structure has a minimum static factor of safety of 1.5 and a minimum seismic factor of safety of 3.7.

To control overtopping, an additional pond was constructed upstream of the structure to reduce runoff into the structure. The new pond is off the permit area and was built to Bureau of Indian Affairs specifications and now serves as a stock watering pond.

Lowe Impoundment 13

When Lowe pit was opened, five impoundments were constructed upstream of the workings to prevent water from flowing into the pit. The impoundment with the largest dam structure, Lowe Impoundment 13, was selected as a worst case representative of these impoundments and was subjected to stability analysis. Results of the analysis, as detailed on file at the Environmental Quality Department of the Navajo Mine, shows a minimum static factor of safety of 4.0 and a minimum seismic factor of safety of 2.9.

Lowe Railroad Embankment 1

Lowe Railroad Embankment 1 is directly representative of the two culvertless railroad embankments and is worse case representative of the embankments with culvert as they will not impound water. Unlike the Big Fill, these structures were compacted and the results of the stability analysis reflect the better construction practice. The stability analysis, as detailed on file at the Environmental Quality Department of the Navajo Mine, indicates that the embankment has a minimum static factor of safety of 3.4. Seismic stability was not determined.

North Barber Regrade

North Barber Regrade, a steep (4:1) regraded spoil slope, was selected as a worst case representative to determine static stability on regraded spoils. Results of the analysis, as detailed on file at the Environmental Quality Department of the Navajo Mine, shows that the slope is very stable with a minimum factor of safety of 9.7.

Table 11-I-1 (1 of 6)
SLOPE STABILITY STRUCTURES

NAME	SOIL TYPE SURROUNDING	FOUNDATION	SIZE	COMMENTS	TEST: REASONING
North Sewer Pond	Sandy Clay	Same	Medium	Lined, well engineered mostly incised pond	No. Previously approved.
Area III Sewer	Sandy clay	Same	Large	Lined, well engineered, mostly incised pond.	No, well engineered, lined, incised.
Barber Loadout Pond	Sandy clay	Same	Large	Pond is totally incised.	No, well engineered
Sediment Pond 1, Cell A	Sandy clay	Same	Medium	Design accepted by OSMRE.	No. Previously approved.
Sediment Pond 1, Cell B	Sandy clay	Same	Medium	Design accepted by OSMRE.	No. Previously approved.
Sediment Pond 1, Cell A	Sandy clay	Same	Large	Design accepted by OSMRE.	No. Previously approved.
Sediment Pond 5	Sandy clay	Same	Small	Design accepted by OSMRE.	No. Previously approved.
Emma's Pond	Sand with some clay	Same	Small	Standpipe type spillway behind small dam structure.	No. Previously approved.
Pinto Pond	Sand, sandstone	Same	Small	Pond is incised.	No. Previously approved.
Hosteen Stockpile	Sandy clay	Coal seam	Large	Dam is 4-5 times higher than on other sedimentation pond Pond is large and has some sandy clay soil. Design has already been accepted by OSMRE.	No. Previously approved

Table 11-I-1 (2 of 6)
SLOPE STABILITY STRUCTURES

NAME	SOIL TYPE SURROUNDING	FOUNDATION	SIZE	COMMENTS	TEST: REASONING
Barber Stock-pile Pond 1	Sandy Clay	Same	Medium	Incised pond with mild slopes.	No. Previously approved.
Barber Stock-pile Pond 2	Sandy clay	Same	Medium	Incised pond with mild slopes.	No. Previously approved.
Area III Shop Pond	Sandy clay	Same	Medium	Dam structure has steep Slopes.	Yes. Possible steep slope failure.
Area III Comples Pond	Sandy clay	Same	Small	Small dam with moderately steep slope.	No. Small incised.
Lowe Stock-pile Pond	Badlands	Same	Small	Partially incised, max height 6 feet slopes not excessively steep.	No. Small incised.
Stub 17 Impoundment	Sandy clay	Same	Small	Impounded only slight amounts of water in the past, dam is approximately 15' high with steep sides.	No. Small structure and drainage basin.
Stub 17 Large Impoundment	Sandy clay	Same	Large	Has failed to meet seismic stability requirements in the past. Slope will be modified.	Stability tested
Stub 18 Impoundment	Sandy clay	Same	Medium	Spillway has never passed any water.	No.
Lowe Impoundment 10	Sandy clay	Same	Medium	Largely incised, no water, small drainage basin.	No, Small drainage, engineered

Table 11-I-1 (3 of 6)
SLOPE STABILITY STRUCTURES

NAME	SOIL TYPE SURROUNDING	FOUNDATION	SIZE	COMMENTS	TEST: REASONING
Lowe Impoundment 11	Sandy Clay	Same	Medium	Totally incised, no failures of any type.	No. Totally incised, well engineered.
Lowe Impoundment 12	Sandy clay	Same	Medium	Totally incised, no failures of any type.	No. Totally incised well engineered
Lowe Impoundment 13	Sandy clay	Same	Medium	Maximum dam height of 7', no failures of any type.	Yes. Largest Lowe impoundment not incised.
Lowe Impoundment 14	Sandy clay	Same	Large	Totally incised, no failures of any type.	No. Totally incised well engineered
Area III Diversion Impoundment 1	Sand, Sandy clay	Shale, Sandy clay	Large	Structure has already been approved by OSMRE.	No. Previously approved.
Area III Diversion Impoundment 2	Sandy clay	Shale	Large	Structure has already been approved by OSMRE.	No. Previously approved.
Area III Diversion Impoundment 3	Sandy clay	Shale	Large	Structure has already been approved by OSMRE.	No. Previously approved.
Elms Embankment 1	Sandy clay	Same	Small	Embankment formed road, very wide. No culvert	No. Small

Table 11-I-1 (4 of 6)
SLOPE STABILITY STRUCTURES

NAME	SOIL TYPE SURROUNDING	FOUNDATION	SIZE	COMMENTS	TEST: REASONING
Elms Embankment 2	Sandy Clay	Same	Large	Has been analyzed for seismic stability. No culvert.	Stability tested.
Elms Embankment 3	Sandy clay	Same	Small	Embankment formed by road, very wide. No culvert.	No. Small
Elms Embankment 4	Sandy clay	Same	Small	Embankment formed by road, very wide. No culvert.	No. Small
Elms Embankment 5	Sandy clay	Same	Small	Embankment formed by road. No culvert.	No. Small
Elms Embankment 6	Sandy clay	Same	Small	Embankment formed by road. No culvert.	No. Small
Area III Embankment	Sandy clay	Same	Large	Embankment is 20' high and more than 170' wide. No culvert.	No. Very similar to Elms Embankment 2
Lowe Railroad Embankment 2	Sandy clay	Same with sandstone layers	Large	Large embankment, water seepage from base, small drainage area. No culvert.	No.
Lowe Railroad Embankment 1	Sandy clay	Same	Large	Large embankment, water seepage from base, small drainage area, no culvert.	Yes. Largest culvertless fill.
Neck Road Embankment 1	Sandy clay	Badlands	Large	Large, steep sided, 7' dia. culvert at base.	No. Compacted fill.

Table 11-I-1 (5 of 6)
SLOPE STABILITY STRUCTURES

NAME	SOIL TYPE SURROUNDING	FOUNDATION	SIZE	COMMENTS	TEST: REASONING
Neck Road Embankment 2	Sandy Clay	Badlands	Large	Large, steep sided, 30' dia. culvert at base.	No. Fill was compacted.
Pinto RR Embankment 1	Sandy clay	Same	Small	Two culvert; 4'drain and a 7' dia. livestock access.	No. Small
Pinto RR Embankment 2	Clayey sand	Sand, some sandstone	Medium	4' dia. drain culvert in excellent shape.	No. Small
Pinto RR Embankment 4	Sandy clay	Same	Small	Concrete drain culvert in excellent shape.	No. Small compacted fill.
Big Fill	Sandy clay	Same	Huge	Concrete drain culvert in excellent shape. Fill was not compacted.	Tested for static and seismic stability.
Hosteen RR Embankment	Sandy clay	Badlands	Large	Concrete drain culvert in excellent shape 5' diameter.	No. Compacted fill
Barber RR Embankment 1	Sandy clay	Same with sandstone	Small	Concrete drain culvert in excellent shape 4' diameter.	No. Compacted fill
Barber RR Embankment 2	Sandy clay	Same	Small	18" diameter culvert excellent shape.	No. Small
Updip Barber RR Embankment 1	Sandy clay	Same	Small	24" diameter culvert excellent shape.	No. Small
Updip Barber RR Embankment 2	Sand	Sandy clay	Small	30" diameter culvert excellent shape.	No. Small

Table 11-I-1 (6 of 6)
SLOPE STABILITY STRUCTURES

NAME	SOIL TYPE SURROUNDING	FOUNDATION	SIZE	COMMENTS	TEST: REASONING
Updip Barber RR Embankment 3	Sandy Clay Sandstone	Same	Small	30" diameter culvert excellent shape.	No. Small
Updip Barber RR Embankment 4	Sandy clay	Same	Small	24" diameter culvert excellent shape.	No. Small
Updip Barber RR Embankment 5	Sandy clay	Same	Large	Culvert exit end tends to silt in.	No. Compacted fill.
Neck RR Embankment 1	Sandy clay	Badlands	Large	10' diameter culvert in excellent condition.	No. Compacted fill.
Neck RR Embankment 2	Sandy clay	Badlands	Large	30' diameter culvert in excellent condition.	No. Compacted fill.