US Army Corps of Engineers
Nashville District

Upper Cumberland River Basin
Harlan Diversion Project
Harlan Kentucky
Contract No. DACW62-89-C-0092

AD-A277 556

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Harlan Diversion Project Construction Foundation Report

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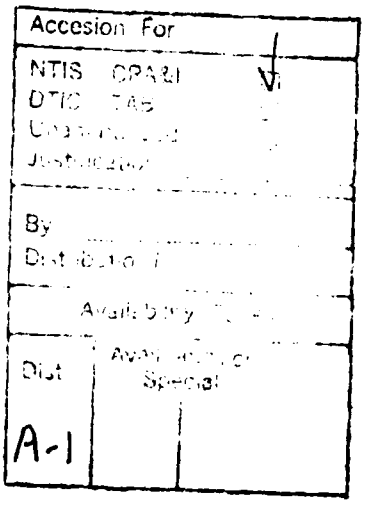
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Construction Foundation Report
Harlan Diversion Project
Harlan, Kentucky

February 1994



U.S. Army Corps of Engineers
Nashville District
P.O. Box 1070
Nashville, Tennessee 37202-1070

Harlan Diversion Project
Construction Foundation Report

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Harlan Diversion Project

Foundation Report

1. Introduction.

1.1 Location and Description of Project. The southeastern Kentucky community of Harlan is located in a flood prone area near the confluence of three major forks of the Cumberland River. The project consists of four parallel tunnels which divert Clover Fork through Ivy Hill and away from the Harlan central business district. Each tunnel is 32 feet high, 34 feet wide, and approximately 2,000 feet long. The tunnels are reinforced by rock bolts and lined with shotcrete.

Near the upstream portals a diversion structure diverts Clover Fork into the tunnels. The diversion embankment is approximately 30 feet high, with a maximum height of 50 feet. It is 200 feet wide at the base and 600 feet long. A slurry trench and sheet pile cutoff prevents seepage beneath the embankment. A floodwall and a closure structure across a single track railroad line are incorporated into the left abutment of the diversion embankment.

Changes in the flow of Clover Fork required two highway relocations, one at either end of the diversion tunnels. Upstream, Kentucky Highway 38 was relocated away from the existing Clover Fork channel through road cuts and over a 316 feet long, two span, post-tensioned, I-beam bridge which spans the diverted channel as it enters the tunnels. On the downstream side Kentucky Highway 72 was re-built over a 450 feet long, four span, pre-tensioned, I-beam bridge which spans Clover Fork as it exits the tunnels.

1.2 Construction Authority and Project History. Initial studies for this project were authorized by the Energy and Water Development Act of 1981 (PL 96-367, Section 202.) This act authorized the design and construction, at full Federal expense, of flood control measures in the portions of the Cumberland River Basin damaged by severe flooding in April 1977.

The Supplemental Appropriations Act of 1982 (PL 97-257 of September 1982) further required that high levees and floodwalls constructed to comply with the Energy and Water Development Act of 1981 shall provide for a standard project flood (SPF) level of protection where the consequences from overtopping caused by large floods would be catastrophic. Similar language was contained in the Energy and Water Development Appropriation Bill of 1983 (HR Report 97-850 of September 1982), which also specifically directed the Army Corps of Engineers to study and design protection for several Upper Cumberland River Basin communities, including Harlan, Kentucky.

House Joint Resolution 492 (PL 98-3222 of July, 1984) directed the Corps of Engineers to implement immediately "nonstructural flood control measures such as relocation sites, flood-proofing and flood plain acquisition, and evacuation as described in the General Plan for Section 202 Program Implementation."

An Environmental Impact Statement was published in April 1988.

A sealed-bid solicitation (No. DACW62-89-B-0026) was issued on 1 June 1989 with a 2 August 1989 deadline.

On 1 September 1989 Contract No. DACW62-89-C-0092 was awarded to Grassetto USA Construction, Inc. and Incisa USA, Inc., Joint Venture, for the sum of $ 28,781,458.55. The Government Estimate was $ 31,305,500. The final construction cost, including all contract modifications, was $ 31,430,719.49. Notice to proceed was given on 21 September 1989. The originally scheduled completion date was 20 September 1992, and was extended to 7 March 1993.

The Harlan Flood Control Project Groundbreaking Ceremony was held on 9 October 1989 at the downstream portal site. Ceremony participants included Congressman Harold Rogers, Colonel James A. Ward, Colonel James King, Area Engineer J.C. McDaniels, Contractor Representative Massimo Rossi, and Harlan Mayor L.C. Howard.

1.3 Purposes of Report. This Harlan Diversion Project Foundation Report was prepared to insure the preservation of records of foundation conditions encountered during construction and of methods used to adapt structures to these conditions. The Foundation Report along with referenced preconstruction reports and construction progress reports will provide a complete record of project foundation conditions. As stated in Engineering Regulation No. 1110-1-1801, the potential uses of this Report include:

1. Planning additional foundation treatment should the need arise after project completion.
2. Evaluating the cause of stress, deformation or failure of a structure.
3. Planning remedial action should failure of a structure occur as a result of foundation deficiencies.
4. Planning foundation explorations and anticipating foundation problems for future comparable construction projects.
5. Determining the validity of claims made by construction contractors in connection with difficulties arising from alleged foundation conditions or from alleged changed conditions.
6. Serving as part of the permanent collection of project engineering data required by ER 1110-2-100, Appendix A.

1.4 Resident Construction Staff.

J.C. McDaniels.....Area Engineer
Capt. Allyn Allison...Assistant Area Engineer
Ed Robertson.....Construction Representative
Charles Melton.....Office Engineer
Paul A. Ross.....Geologist
Tim Shy.....Geologist
Ronnie Boswell.....Materials Engineering Technician
Dan Ferrell.....Contract Administrator
Tommy Clayton.....Construction Inspector
James Forrester.....Construction Inspector
Robert Marshall.....Construction Inspector
Orville Wicker.....Construction Inspector
Debbie Klinger.....Secretary
Teresa Perkins.....Secretary

1.5 Design Staff.

Marvin Simmons.....Chief of Geology Section
John Stanton.....Geology Section
Paul Booth.....Soils Section
Daphne Jackson.....Soils Section
Jesse Perry.....Chief of Design Branch
Gordon McClellan.....Chief of Civil-Structural Section
William Wilson.....Civil-Structural Section
Buddy Abbott.....Chief of Relocations Section
Hank Phillips.....Chief of Hydraulics Section
Don Getty.....Hydrology and Hydraulics Branch
Tommy Allen.....Hydrology and Hydraulics Branch
Charles Davis.....Instrumentation and Inspection Section
Ray Hedrick.....Environmental Branch
Rob Karwedsky.....Environmental Branch
Sandra Martin.....Waterways Experiment Station
Richard Humphries.....Tunnel Design Consultant (Golder Assc.)
Don Mills.....Bridge Design Consultant (Kroboth Eng.)

1.6 Prime Contractor's Supervision and Quality Control.

Renatto Bozetti.....Project Manager
Lou Case.....Project Engineer
Hank Leatherman.....General Superintendent
Jerry Haney.....Tunnel Superintendent (1st Shift)
Roy Hill.....Tunnel Superintendent (2nd Shift)
Tom Trapp.....Chief QC & Instrumentation Specialist

1.7 List of Major Subcontractors.

Company	Responsibility
Codell Construction Co..... Winchester, Kentucky	Surface Excavations, Roads, & Diversion Embankment
London Bridge..... London, Kentucky	Hwy 38 & Hwy 7[illegible] Bridges, Upstream Portal Nosing Concrete, Railroad Closure Structure and Floodwall
Hayes Drilling Inc..... Lexington, Kentucky	Hwy 38 Bridge Caisson Drilling
GeoCon Inc. ..... Lakeland, Florida	Slurry Trench
Underground Petroleum..... Equipment Company Lexington, Kentucky	Underground Tank Removal

2. Contract Modifications Related To Foundation Conditions

No.	Date	Description	Cost
22	Sep 90	Clearing U/S Portal- Extended clearing limits uphill because portal slopes were revised.	$ 3,546
25	Nov 90	Nosing Reinforcement U/S and D/S- Install additional angled and vertical bolts, up to 40 feet long, to reinforce corners and nosings prior to blasting.	99,576
37	Apr 91	Hwy 72 Bridge Revision- Additional concrete required to provide pier footing embedment into rock.	39,925
39	Jun 91	Hwy 38 Bridge Revision- Revise caissons and wing walls because rock was lower than anticipated.	164,135
40	Jun 91	Hwy 38 Slide Removal and Trim Nosings- Remove landslide material from slope and roadway between stations 55+00 and 57+00. Trim overhanging rock from upstream portal nosings.	24,550
45	Aug 91	Trim Nosings and Additional Concrete- Trimming and additional concrete was required because nosings shifted during blasting.	119,710
56	Apr 92	Reinforce D/S portal slope and cracked shotcrete above tunnels 3 and 4.	10,634
63	Sep 92	Extend diversion embankment seepage cutoff farther into the right abutment by adding sheet pile wall section, because rock was lower than anticipated.	122,547
66	Oct 92	Remove and replace cracked shotcrete above downstream portal of tunnel 4.	35,209
76	Jun 93	Additional test blasting and engineering control for U/S portal noses; redrill pre-split holes cut off because of blasting; remove boulders outside of Hwy 38 template between stations 49+00 and 72+00.	61,541

3. Contract Quantities - Estimated and As-Built

Estimated and as-built quantities and unit prices are shown on pages 6 through 12.

PAYMENT ESTIMATE - CONTRACT PERFORMANCE SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
0C.1	MOBILIZATION & PREPARATORY WRK	LS	1	**********	2,300,000.00	1.00	2,300,000.00
2A.1	CLEARING,GRUBBING & REMOV STR	LS	1	140,305.39	140,305.39	1.00	140,305.39
2C.1	DIVERSION & CARE OF WATER	LS	1	356,465.96	356,465.96	1.00	356,465.96
2D.1	EXCAVATION	CY	380000	6.62	2,515,600.00	446,628.00	2,956,677.36
2D.2	PRESPLITTING	SF	133360	2.76	368,073.60	136,184.00	375,867.84
2E.1	TUNNEL EXCAVATION	CY	283100	34.53	9,775,443.00	283,578.20	9,791,955.25
2F.1	ROCK DOWELS	LF	1600	4.34	6,944.00	1,442.00	6,258.28
2F.2	ROCK BOLTS (SURFACE)	LF	11000	6.24	68,640.00	20,286.00	126,584.64
2F.3	TESTING ROCK BOLTS	EACH	10	1,551.28	15,512.80	10.00	15,512.80
2F.4	DRILLING DRAIN HOLES	LF	9000	8.13	73,170.00	11,233.00	91,340.55
2F.5	SLOTTED PVC PIPE FOR DRAIN HLS	LF	1680	1.68	2,822.40	1,636.00	2,748.48
2F.6	STRIP DRAINS	LF	1800	2.76	4,932.00	4,347.00	11,910.78
2F.7	SHOTCRETE	SY	18750	21.52	403,500.00	21,193.90	456,092.73
2F.8	SHOTCRETE TEST SAMPLES	EACH	380	111.04	42,195.20	347.00	38,530.88
2H.1	SHOTCRETE, FIBER REINFORCED	SY	72500	23.87	1,730,575.00	73,066.10	1,744,087.81
2H.2	ROCK BOLTS (TUNNEL)	LF	108000	4.91	530,280.00	108,876.00	534,581.16
2H.3	SLURRY TRENCH modfn 63	SF	13640	16.43	224,105.20	13,646.70	224,215.28
2I.1	COMPACTED FILL	CY	67000	3.48	233,160.00	77,012.00	268,001.76
2I.2	8-INCH SLOTTED PIPE	LF	700	8.25	5,775.00	712.00	5,874.00
2I.3	8-INCH SOLID PIPE	LF	80	5.12	409.60	80.00	409.60
2I.4	BACKFILL MATERIAL	TON	100	20.20	2,020.00	305.30	6,167.06
2J.1	CLEARING & GRUBBING FOR ROADS	LS	1	59,035.80	59,035.80	1.00	59,035.80
2J.2	ROADWAY EXCAVATION	CY	352000	6.62	2,330,240.00	371,876.00	2,461,819.12
2J.3	EMBANKMENT-IN-PLACE	CY	28400	4.04	114,736.00	28,400.00	114,736.00
2J.4	SPECIAL EXCAVATION	CY	15700	6.32	99,224.00	13,348.00	84,359.36
2J.5	DENSE GRADED AGGREGATE BASE	TON	9600	20.20	193,920.00	9,003.81	181,876.96
2J.6	BIT CONCRETE SURFACE CLASS 1	TON	580	39.34	22,817.20	886.66	34,881.20
2J.7	BIT CONCRETE SURFACE CLASS A	TON	380	40.66	15,450.80	507.14	20,620.31
2J.8	BIT CONCRETE BASE CLASS 1	TON	7340	33.13	243,174.20	7,720.48	255,779.50
2J.9	BIT MATERIAL FOR TACK	TON	3.5	308.72	1,080.52	3.50	1,080.52
2J.10	SLOPED & FLARED BOX 1-0 18-IN	EACH	6	2,351.35	14,108.10	6.00	14,108.10
2J.11	SLOPED & FLARED BOX 1-0 30-IN	EACH	1	3,749.95	3,749.95	1.00	3,749.95
2J.12	CURB BOX INLET, TYPE A	EACH	3	752.95	2,258.85	3.00	2,258.85
2J.13	CURB BOX INLET, TYPE B	EACH	2	3,192.18	6,384.36	2.00	6,384.36
2J.14	JUNCTION BOX, TYPE B	EACH	1	1,882.38	1,882.38	1.00	1,882.38
2J.15	MANHOLE, TYPE A	EACH	1	2,253.30	2,253.30	1.00	2,253.30
2J.16	MANHOLE, TYPE C	EACH	1	4,197.65	4,197.65	0.00	0.00
2J.17	PIPE CULVERT, 15-INCH	LF	140	37.65	5,271.00	149.00	5,609.85
2J.18	PIPE CULVERT, 18-INCH	LF	250	40.66	10,165.00	250.00	10,165.00
2J.19	PIPE CULVERT, 24-INCH	LF	100	52.71	5,271.00	126.00	6,641.46
2J.20	PIPE CULVERT, 30-INCH	LF	72	69.00	4,968.00	72.00	4,968.00
2J.21	PIPE CULVERT, 48-INCH	LF	84	125.00	10,500.00	84.00	10,500.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

P.4/12
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PAYMENT ESTIMATE - CONTRACT PERFORMANCE SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE: 22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
2J.22	PIPE CULVERT, 60-INCH	LF	144	152.65	21,981.60	148.00	22,592.20
2J.23	CONCRETE, CLASS A	CY	28	123.23	3,450.44	27.98	3,447.98
2J.24	STEEL REINFORCEMENT	LB	1650	0.89	1,468.50	1,650.00	1,468.50
2J.25	STEEL "W" BEAM GUARDRAIL modif= 44	LF	2800	17.43	48,804.00	3,212.50	55,993.88
2J.26	TERMINAL SECTION NO. 1	EACH	1	42.17	42.17	8.00	337.36
2J.27	END TREATMENT, TYPE 2A	EACH	2	430.70	861.40	4.00	1,722.80
2J.28	END TREATMENT, TYPE 3	EACH	2	451.79	903.58	2.00	903.58
2J.29	END TREATMENT, TYPE 4	EACH	1	691.37	691.37	1.00	691.37
2J.30	END TREATMENT, TYPE 7 modif= 44	EACH	4	677.68	2,710.72	4.00	2,710.72
2J.31	BRIDGE END CONNECTORS, TYPE A	EACH	8	821.43	6,571.44	8.00	6,571.44
2J.32	15-INCH ENTRANCE PIPE	LF	68	27.38	1,861.84	83.00	2,272.54
2J.33	EDGE KEY	LF	90	9.59	863.10	90.00	863.10
2J.34	CONCRETE BARRIER TYPE 12L (TEM modif= 22	LF	0	41.07	0.00	0.00	0.00
2J.35	PERFORATED PIPE 8-INCH	LF	100	8.25	825.00	100.00	825.00
2J.36	NON-PERFORATED PIPE 8-INCH	LF	20	5.12	102.40	20.00	102.40
2J.37	CONCRETE ENTRANCE PAVEMENT	SY	16	29.03	464.48	32.00	928.96
2J.38	R-OF-WAY MARKERS, RURAL TYPE 1	EACH	50	60.24	3,012.00	50.00	3,012.00
2J.39	P.CEMENT CONCRETE PAVEMENT 8-IN	SY	70	29.03	2,032.10	70.00	2,032.10
2J.40	CHANNEL LINING, CLASS II	TON	190	26.01	4,941.90	246.94	6,422.91
2J.41	STANDARD CURB AND GUTTER	LF	380	12.87	4,890.60	380.00	4,890.60
2J.42	STANDARD INTEGRAL CURB	LF	35	9.04	316.40	35.00	316.40
2J.43	SILT TRAP, TYPE B	EACH	5	281.62	1,408.10	3.00	844.86
2J.44	SILT CHECKS	EACH	25	78.03	1,950.75	13.00	1,014.39
2J.45	MAINTENANCE & CONTROL OF TRAFFI	LS	1	23,000.13	23,000.13	1.00	23,000.13
2K.1	KY. HIGHWAY 38 BRIDGE	LS	1	628,627.23	628,627.23	1.00	628,627.23
2K.2	KY. HIGHWAY 72 BRIDGE	LS	1	**********	1,458,453.98	1.00	1,458,453.98
2K.3	STEEL TEST PILES HP 14x73 (BRG	LF	108	43.18	4,879.44	107.81	4,870.86
2K.4	CAST STEEL PILE POINTS	EACH	87	143.07	12,447.09	87.00	12,447.09
2K.5	STEEL PILES 14x73 (BRIDGE)	LF	1650	37.65	62,122.50	1,799.78	67,761.72
2K.6	CYCLOPIAN STONE PROTECTION modif= 37	TON	0	30.12	0.00	0.00	0.00
2K.7	STR EXCAV (UNCLASS) KY HWY 38 modif= 39	CY	715	24.86	17,774.90	619.00	15,388.34
2K.8	STR EXCAV (UNCLASS) KY HWY 72 modif= 37	CY	1720	24.05	41,366.00	1,416.00	34,054.80
2K.9	DRILLED FOUND OVB CAISSONS modif= 39	LF	150	422.30	63,345.00	138.70	58,573.01
2K.10	DRILLED FOUND ROCK CAISSONS modif= 39	LF	225	544.36	122,481.00	241.40	131,408.50
2K.11	PROOF TEST HOLES	LF	360	17.25	6,210.00	416.00	7,176.00
2L.1	STEEL SHEET PILING, TYPE PZ 22	LF	160	47.78	7,644.80	176.07	8,412.62
2L.2	STEEL SHEET PILING, TYPE PSZ27.5	LF	1360	56.80	77,248.00	1,625.86	92,348.85
2M.1	STEEL H-PILES (HP 12x74)	LF	1540	37.65	57,981.00	1,265.40	47,642.31
2M.2	PILE POINTS (HP 12x 74)	EACH	46	143.07	6,581.22	46.00	6,581.22
2N.1	TYPE 1 STONE PROTECTION modif= 37	TON	13410	37.65	504,886.50	14,129.30	531,968.15
2O.1	SEEDING W/ SEED MIX NO. 1	MSF	690	41.07	28,338.30	882.75	36,254.54
2O.2	SEED MIX NO. 1 PLUS CROWN VETCH	MSF	130	54.76	7,118.80	118.38	6,483.44

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

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JUN 28 '93 11:12 HARLAN (606)573-3457 P.5/12

PAYMENT ESTIMATE - CONTRACT PERFORMANCE SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	CONTRACT QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
20.3	SEED MIX NO.1 PLUS RED CANARY	MSF	40	68.45	2,738.00	0.00	0.00
20.4	SEED & PROTECT, METHOD 2	MSF	400	54.76	21,904.00	543.60	29,767.54
20.5	VEGETATIVE MULCH	TON	40	150.60	6,024.00	70.93	10,682.06
20.6	AGRICULTURAL LIMESTONE	TON	90	32.86	2,957.40	107.68	3,538.36
20.7	FERTILIZER (10-20-20)	TON	8.5	423.04	3,595.84	10.10	4,272.70
20.8	FERTILIZER (20-10-10)	TON	2.2	425.78	936.72	0.00	0.00
20.9	TOPSOIL, 12 INCH THICK	SY	103340	3.01	311,053.40	75,939.88	228,579.04
20.10	SOD	SY	1000	2.74	2,740.00	519.00	1,422.06
20.11	PLANTING	LS	1	41,070.93	41,070.93	1.00	41,070.93
29.1	INSTRUMENTATION	LS	1	45,092.83	45,092.83	1.00	45,092.83
28.1	CHAIN-LINK FENCE	LF	1800	60.24	108,432.00	2,096.00	126,263.04
28.2	GATES	EACH	4	752.98	3,011.92	4.00	3,011.92
28.1	GEOTEXTILE mod= 37	SY	19000	5.51	104,690.00	24,957.17	137,514.01
28.2	GEOCOMPOSITE	SY	6000	13.23	79,380.00	6,439.35	85,192.60
28.3	GEOMEMBRANE LINER	SY	15100	11.16	168,516.00	15,896.43	177,404.16
26.1	UNDERGROUND TANK REMOV & DISP	LS	1	6,317.75	6,317.75	1.00	6,317.75
27.1	GOVERNMENT OFFICE COMPLEX	LS	1	172,499.55	172,499.55	1.00	172,499.55
23.1	8-INCH PVC WATERLINE	LF	240	27.59	6,621.60	242.10	6,679.54
23.2	8-INCH GATE VALVES	EACH	2	750.00	1,500.00	2.00	1,500.00
21.3	16-INCH STEEL CASING PIPE	LF	190	50.00	9,500.00	190.00	9,500.00
3E.1	TUNNEL BASE SLAB	LF	7740	148.54	1,149,699.60	7,751.00	1,151,333.54
3E.2	NORTH & SOUTHSIDE I-WALL	LS	1	17,853.43	17,853.43	1.00	17,853.43
3E.3	NORTH & SOUTHSIDE T-WALL	LS	1	36,078.70	36,078.70	1.00	36,078.70
3E.4	RAILROAD CLOSURE STRUCTURE	LS	1	52,083.05	52,083.05	1.00	52,083.05
3E.5	PORTAL HOSING	LS	1	**********	1,023,469.95	1.00	1,023,469.95
3E.6	CONCRETE HEADWALLS	EACH	2	1,981.35	3,962.70	2.00	3,962.70
5C.1	SWING GATE	LS	1	128,060.70	128,060.70	1.00	128,060.70
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00
0		0 0	0	0.00	0.00		0.00

TOTAL ORIGINAL CONTRACT AMOUNT w/ORIG BID ITEM MODS ********** $29,530,875.67

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

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JUN 28 '93 11:12 HARLAN (606)573-3457

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
APPROVED MODIFICATIONS(ie.NEW ITEMS NOS.)							
----	FUNDS ALLOCATION modif= 1	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 2	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 3	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 4	0	0	$0.00	$0.00		$0.00
2T.2	OVERHAUL & PLACE FILL modif= 5	CY	3146	$2.30	$7,235.80	3,146.00	$7,235.80
2T.3	SEPTIC SYSTEM modif= 5	LS	1	$3,156.00	$3,156.00	1.00	$3,156.00
2T.4	12-INCH CMP modif= 5	LF	90	$21.90	$1,935.00	92.00	$1,978.00
2T.5	#2 & #610 AGGREGRATE modif= 5	TON	1000	$14.53	$14,530.00	1,559.29	$22,656.48
2T.6	BITUMINOUS SURFACE (RE) modif= 5	TON	400	$59.56	$23,824.00	420.60	$25,050.94
2T.7	CHAIN LINK FENCE (RE) modif= 5	LF	794	$15.92	$12,640.48	791.40	$12,599.09
2T.8	FLAG POLE modif= 5	LS	1	$2,350.00	$2,350.00	1.00	$2,350.00
----	TIME EXTENSION - WEATHER 18DAY modif= 6	0	0	$0.00	$0.00		$0.00
2T.9	6-INCH DIAMETER WELL modif= 7	LF	650	$8.90	$5,785.00	765.00	$6,806.50
2T.10	8-INCH CASING modif= 7	LS	1	$2,716.00	$2,716.00	1.00	$2,716.00
2T.11	1-1/4 INCH WATER LINE modif= 7	LF	500	$4.29	$2,145.00	302.00	$1,295.58
2T.12	FURNISH & INSTALL PUMP SYSTEM modif= 7	LS	1	$8,900.00	$8,900.00	1.00	$8,900.00
----	FUNDS ALLOCATION modif= 8	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 9	0	0	$0.00	$0.00		$0.00
----	ALTERNATE DISPOSAL AREA GEORGE modif= 10	0	0	$0.00	$0.00		$0.00
----	ADMINISTRATIVE MOD REV SCOPE 5 modif= 11	0	0	$0.00	$0.00		$0.00
2B.2	REMOVE CONTAMINATED MATERIAL modif= 12	CY	250	$92.00	$23,000.00	610.00	$56,120.00
----	FUNDS ALLOCATION modif= 13	0	0	$0.00	$0.00		$0.00
2V.1	8-INCH PVC PIPE modif= 14	LF	936	$112.33	$105,139.60	963.00	$108,193.05
2V.2	ERR	EA	7	$3,815.00	$26,705.00	7.00	$26,705.00
2V.3	CONCRETE ENCASEMENT modif= 14	CY	4.5	$395.00	$1,777.50	5.25	$2,073.75
2V.4	CONCRETE ANCHOR modif= 14	EA	7	$617.00	$4,319.00	7.00	$4,319.00
----	TIME EXTENSION WEATHER 17 DAYS modif= 15	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 16	0	0	$0.00	$0.00		$0.00
2B.3	SHOTCRETE BARRIER WALL modif= 17	LS	1	$13,500.00	$13,500.00	1.00	$13,500.00
2B.5	REMOVE CONTAMINATED WATER modif= 18	GAL	20000	$2.10	$42,000.00	19,601.00	$41,162.10
2B.4	LAB TEST modif= 18	EA	6	$365.00	$2,190.00	6.00	$2,190.00
----	FUNDS ALLOCATION modif= 19	0	0	$0.00	$0.00		$0.00
----	TIME EXTENSION WEATHER 4 DAYS modif= 21	0	0	$0.00	$0.00		$0.00
2A.2	ASBESTOS REMOVAL OLD MAR SCH modif= 20	LS	1	$290,745.00	$290,745.00	1.00	$290,745.00
2A.4	DISP other than 3-Cty FILL (b) modif= 20	LS	1	$64,250.00	$64,250.00	1.00	$64,250.00
2T.13	MISCELLANEOUS REVISIONS modif= 23	LS	1	$11,441.00	$11,441.00	1.00	$11,441.00
2A.3	ADDITIONAL CLEARING modif= 22	LS	1	$5,344.00	$5,344.00	1.00	$5,344.00
2A.2	GROUTED CHANNEL LINING modif= 22	LS	1	$7,848.00	$7,848.00	1.00	$7,848.00
2A.46	GOVT BARRIER WALL modif= 22	LS	1	$7,904.00	$7,904.00	1.00	$7,904.00
----	FUNDS ALLOCATION modif= 24	0	0	$0.00	$0.00		$0.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

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JUN 28 '93 11:13 HARLAN (606)573-3457

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PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
----	TIME EXTENSION WEATHER 1 DAY modif= 26	0	0	$0.00	$0.00		$0.00
27.9	ANCHOR BOLTS U/S modif= 25	LF	6040	$11.15	$67,346.00	6,056.00	$67,524.40
27.10	ANCHOR BOLTS D/S modif= 25	LF	3265	$9.85	$32,160.25	3,264.00	$32,150.40
27.5	SEWER LINE TIE IN modif= 27	LS	1	$36,000.00	$36,000.00	1.00	$36,000.00
----	FUNDS ALLOCATION modif= 28	0	0	$0.00	$0.00		$0.00
----	DELETE DISPOSAL ALT "A" modif= 29	LS	1	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 30	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 31	0	0	$0.00	$0.00		$0.00
2K.1	ERR	LS	1	$0.00	$0.00		$0.00
----	TIME EXTENSION WEATHER 4 DAYS modif= 33	0	0	$0.00	$0.00		$0.00
30.4	HARLAN WATERLINE RELOCATION modif= 35	LS	1	$9,440.00	$9,440.00	1.00	$9,440.00
----	FUNDS ALLOCATION modif= 36	0	0	$0.00	$0.00		$0.00
2J.47	SIZE 57 STONE modif= 37	TON	150	$23.75	$3,562.50	130.55	$3,100.56
2K.12	ERR	CY	120	$108.00	$12,960.00	182.00	$19,656.00
2K.13	CONCRETE OUTSIDE 18 IN LIMIT modif= 37	CY	65	$106.00	$6,890.00	65.00	$6,890.00
2K.14	DECK DRAINS modif= 37	LS	1	$9,812.00	$9,812.00	1.00	$9,812.00
2K.15	ERR	TON	1040	$30.12	$31,324.80	961.63	$28,964.30
----	TIME EXTENSION WEATHER 17 DAYS modif= 38	0	0	$0.00	$0.00		$0.00
2K.16	DRILL FOUND OVB 60 IN CAISSON modif= 39	LF	75	$830.00	$62,250.00	55.70	$46,231.00
2K.17	DRILL FOUND ROCK 60 IN CAISSON modif= 39	LF	90	$1,150.00	$103,500.00	106.60	$122,590.00
2K.18	REVISE HWY 38 BRIDGE ABUTMENTS modif= 39	LS	1	$27,700.00	$27,700.00	1.00	$27,700.00
2J.48	SLIDE REMOVAL HWY 38 modif= 40	LS	1	$8,200.00	$8,200.00	1.00	$8,200.00
2J.49	TRIM U/S MOSINGS modif= 40	LS	1	$6,030.00	$6,030.00	1.00	$6,030.00
2J.50	CONCRETE BARRIERS HWY 38 modif= 40	LS	1	$1,350.00	$1,350.00	1.00	$1,350.00
29.12	APPALON WITH NETTING modif= 40	SY	6500	$1.38	$8,970.00	6,938.00	$9,574.44
----	FUNDS ALLOCATION modif= 41	0	0	$0.00	$0.00		$0.00
----	TIME EXTENSION WEATHER 9 DAYS modif= 42	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 43	0	0	$0.00	$0.00		$0.00
2E.7	ROCK TRIMMING modif= 45	LS	1	$33,230.00	$33,230.00	1.00	$33,230.00
2E.8	HAUL ROCK TO D/A modif= 45	LS	1	$4,570.00	$4,570.00	1.00	$4,570.00
2E.9	SURFACE PREPARATION modif= 45	LS	1	$12,250.00	$12,250.00	1.00	$12,250.00
2E.10	CONCRETE MOSING modif= 45	CY	300	$195.00	$58,500.00	625.30	$121,933.50
2E.11	SHOTCRETE (SIDES) modif= 45	CY	80	$107.00	$8,560.00	149.50	$15,996.50
2E.12	SHOTCRETE (TOP) modif= 45	CY	20	$130.00	$2,600.00	80.00	$10,400.00
2E.13	12-INCH CORRUGATED METAL PIPE modif= 46	LS	1	$4,800.00	$4,800.00	1.00	$4,800.00
2J.51	BITUMINOUS SEAL MATERIALS modif= 47	TON	12	$615.00	$7,380.00	11.65	$7,164.75
2J.52	BITUMINOUS SEAL AGGREGATE modif= 47	TON	100	$61.50	$6,150.00	227.94	$14,018.31
----	FUNDS ALLOCATION modif= 48	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 49	0	0	$0.00	$0.00		$0.00
2E.2	CUTOFF/PIPE INTERSECTION modif= 50	LS	1	$15,000.00	$15,000.00	1.00	$15,000.00
----	WEATHER 2 DAY EXTENSION modif= 51	0	0	$0.00	$0.00		$0.00
2E.3	ACCESS ROAD RELOCATION modif= 52	LS	1	$13,465.00	$13,465.00	1.00	$13,465.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

JUN 28 '93 11:14 HARLAN (606)573-3457 P.8/12

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 23-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
24.53	ABUTMENT DRAINAGE modf= 53	LS	1	$3,692.00	$3,692.00	1.00	$3,692.00
36.14	GEOMEMBRANE CONNECTION modf= 53	LS	1	$582.00	$582.00	1.00	$582.00
27.11	D\S SLOPE REPAIR modf= 56	LS	1	$10,634.00	$10,634.00	1.00	$10,634.00
----	TIME WEA OCT - MAR 92 2 DAYS modf= 57	0	0	$0.00	$0.00		$0.00
22.15	SURVEY HARLAN ROAD modf= 58	LS	1	$3,132.00	$3,132.00	1.00	$3,132.00
30.4	BLASTING CONSULTANT modf= 58	LS	1	$8,057.00	$8,057.00	1.00	$8,057.00
27.14	MISC & RESIDENT OFFICE modf= 58	LS	1	$8,261.00	$8,261.00	1.00	$8,261.00
----	FUNDS ALLOCATION modf= 59	0	0	$0.00	$0.00		$0.00
05.19	EXCAVATION (BRIDGE) modf= 60	CY	300	$52.00	$15,600.00	88.48	$4,600.96
27.12	SHOTCRETE D/S modf= 60	CY	75	$208.00	$15,600.00	108.00	$22,464.00
27.13	SHOTCRETE U/S modf= 60	LS	1	$4,055.00	$4,055.00	1.00	$4,055.00
29.3	REMOVE BARRIER PIPE modf= 60	LS	1	$1,370.00	$1,370.00	1.00	$1,370.00
22.2	EXCAVATION (SPLASH) modf= 60	LS	1	$10,839.00	$10,839.00	1.00	$10,839.00
22.3	TYPE I STONE (SPLASH) modf= 60	TN	450	$23.00	$10,350.00	352.87	$8,116.01
22.4	CONCRETE B (SPLASH) modf= 60	CY	50	$108.00	$5,400.00	67.00	$7,236.00
----	WEATHER APR-JUN 92 6 DAYS modf= 61	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modf= 62	0	0	$0.00	$0.00		$0.00
28.3	STEEL SHEETPILING modf= 63	LF	3000	$43.70	$131,100.00	2,526.35	$110,401.50
28.4	PILING EXTRACTION modf= 63	LF	300	$22.00	$6,600.00	105.00	$2,310.00
28.5	STANDBY TIME (EQUIP) modf= 63	HR	40	$40.00	$1,600.00	45.00	$1,800.00
28.6	KOMATSU 180 modf= 63	HR	20	$92.00	$1,840.00	22.00	$2,024.00
28.7	CAT D-4 DOZER modf= 63	HR	20	$69.00	$1,380.00	15.00	$1,035.00
28.8	HITACHI 181 modf= 63	HR	20	$140.00	$2,800.00	68.50	$9,590.00
28.9	BYMAPAC COMPACTOR modf= 63	HR	20	$85.00	$1,700.00	0.00	$0.00
28.10	PC-150 W/TAMPER modf= 63	HR	20	$105.00	$2,100.00	0.00	$0.00
28.11	KOMATSU 155A modf= 63	HR	20	$155.00	$3,100.00	19.50	$3,022.50
28.12	MOBILIZATION modf= 63	EA	4	$430.00	$1,720.00	2.00	$860.00
28.13	ERR	LS	1	$0.00	$0.00		$0.00
28.3	H-2, CHANNEL LINING modf= 64	LS	1	$39,200.00	$39,200.00	1.00	$39,200.00
28.4	TYPE I DITCH, STONE modf= 64	TN	200	$30.00	$6,000.00	261.33	$7,839.90
28.5	GROUT, CHANNEL LINING modf= 64	CY	40	$132.00	$5,280.00	52.00	$6,864.00
27.14	MISC ITEMS MOD 66 modf= 66	LS	1	$16,200.00	$16,200.00	1.00	$16,200.00
27.15	REMOVE SHOTCRETE modf= 66	CN	30	$207.00	$6,210.00	38.50	$7,969.50
27.16	PLACE SHOTCRETE modf= 66	CY	22	$138.00	$3,036.00	15.00	$2,070.00
27.17	LOAD AND HAUL MATERIAL modf= 66	HR	10	$271.00	$2,710.00	14.00	$3,794.00
24.54	HIGHWAY 38 REPAIRS modf= 66	LS	1	$7,053.00	$7,053.00	1.00	$7,053.00
----	FUNDS ALLOCATION modf= 65	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modf= 67	0	0	$0.00	$0.00		$0.00
21.6	REMOVE AND REPLACE COFFERDAM modf= 68	LS	1	$33,938.00	$33,938.00	1.00	$33,938.00
----	WEATHER DELAY 10 DAYS modf= 69	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modf= 70	0	0	$0.00	$0.00		$0.00
----	ADMIN REVISE MOD 22 COST CODE modf= 71	0	0	$0.00	$0.00		$0.00

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P.9/12
JUN 28 '93 11:14 HQRLSN (606)573-3457

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	CONTRACT QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
----	FUNDS ALLOCATION mod#= 72		0	0 $0.00	$0.00		$0.00
20.14	MEMBRANE CONNECTION mod#= 73	LS	1	$3,341.00	$3,341.00	1.00	$3,341.00
20.15	RELOCATE WATERLINES mod#= 73	LS	1	$2,890.00	$2,890.00	1.00	$2,890.00
21.7	CLEAN UP TRACTS 614,615 mod#= 73	LS	1	$10,263.00	$10,263.00	1.00	$10,263.00
21.8	EMBANKMENT HAUL mod#= 75	LS	1	$48,216.00	$48,216.00	1.00	$48,216.00
29.6	MISCELLANEOUS EXCAVATION mod#= 76	LS	1	$61,541.00	$61,541.00	1.00	$61,541.00
----	FUNDS ALLOCATION mod#= 74		0	0 $0.00	$0.00		$0.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

P.10/12
JUN 28 '93 11:15 HORGAN (606)573-3457
RECEIVED 06/28 09:27 1993 MI 615 726 4713 PAGE 10 (PRINTED PAGE 10)]

4. Foundation Exploration and Testing.

4.1 Investigations Prior to Construction. During the period from 1984 through early 1989, numerous investigations were conducted in the areas of the portals, tunnels, bridge abutments, roadways, and diversion structure.

Soils testing included USCS classification, Standard Penetration Testing, determination of moisture content, Atterberg limits, and gradations. Rock testing included determination of unconfined compressive strength, elastic moduli, seismic velocity, point load index, Poisson's ratio, direct shear strength, and unit weight. Rock properties and test data graphs and tables, taken from Feature Design Memorandum No. 3, are presented in Section 5.3, "Engineering Characteristics of Foundation Materials".

The locations of preconstruction borings are shown on PLATES B-2, C-2, and D-2. All boring logs and test data are included in the Harlan Diversion Project Feature Design Memorandum No. 3 and in the construction Specifications for the Harlan Diversion Project-Appendices A and B.

4.2 Investigations During Construction. Investigations during construction consisted of exploratory air-track and jack-hammer drilling, core drilling, and trenching. Testing included determination of unconfined compressive strength, slake durability, and gradations.

4.2.1 Downstream Portal Investigations.

4.2.1.1 Drilling and Trenching. On 7 November 1989 seven exploratory air-track holes were drilled to locate top of rock in the downstream portal area. On 13 November five more air-track holes were drilled to determine top of rock along Kentucky Highway 72 near future bridge abutment number 2. These holes indicated a steeply dipping top of rock surface, on approximately the same slope as the original ground surface. Elevations at which rock was encountered did not differ significantly from information presented in the contract drawings.

On 16 January 1990 three backhoe trenches were dug to determine the depth to rock along the planned ten-feet-wide bench above the tunnels. The actual rock surface was found to be 7½ to 9 feet lower than the estimated rock line. On 23 January 1990 five nearly horizontal air-track holes were drilled to determine distance to unweathered rock on the 1V:1H slope above the ten-feet-wide bench. Harder rock was found 9 to 13 feet behind the existing slope. Because rock at the design bench level was lower than estimated and because of slides in the overburden and weathered siltstone 1V:1H slopes, adjustments were made to the backslope. These changes are discussed further in Section 6 of this report.

4.2.1.2 Testing. In September 1990 samples of rock blasted from the downstream portal area were tested for slake durability. The samples were taken by the contractor and tested by C.V.E. Testing of Harlan. All material exceeded the minimum SDI of 95% required for use in the Kentucky Highway 72 roadway embankment.

Slake Durability Index (SDI)

Tunnel	Station	Elev.	Rock Type	SDI
1	D/S Portal	1175	Siltstone	98.9%
2	D/S Portal	1175	Siltstone	97.9%
3	D/S Portal	1175	Siltstone	98.8%

All samples were described as dark gray, massive, sandy shale, elsewhere described as siltstone, and tested with Kentucky method #64-513-79 (ASTM D 4644-87). This test method covers the determination of the durability index of a shale or other similar rock after two drying and wetting cycles with abrasion. Slake durability index is defined as the percentage of dry mass retained of a collection of shale pieces on a No. 10 sieve after two cycles of oven drying and 10 minutes of soaking in water with a standard tumbling and abrasion action. Despite the high test results, siltstone roadheader cuttings used as fill on the diversion embankment broke down significantly during the placement, leveling, and compaction processes. Wet material pumped under equipment load and it became necessary to control the moisture content in constructing the embankment.

4.2.2 Upstream Portal Investigations. Seven air-track holes were drilled to determine the elevation of hard rock across the top of the vertical portal backslope from baseline A to baseline C. See Plate C-8 for baseline locations. Harder rock was found to be about ten feet below the design bench elevation. Based on drilling results the upstream portal slopes were changed as described in Section 7.1.

4.2.3 Highway 72 Bridge Investigations.

4.2.3.1 Drilling. Three five-feet-deep jackhammer holes were drilled in each pier foundation to determine it's suitability, as required by Kentucky Standard Specifications for Road and Bridge Construction and the Division of Construction Guidance Manual. All nine holes indicated moderately hard siltstone, with no voids below foundation level.

4.2.3.2 Testing. From December 1990 through February 1991, more siltstone samples from the Highway 72 bridge pier foundations were tested to determine slake durability. Material from this area was used as backfill around the bridge abutments. Test results are tabulated on the next page.

Slake Durability Index

Pier No.	Location	Elev.	Rock Type	SDI
1	20 ft. from U/S end	1150	Siltstone	96.6%
1	14 ft. from D/S end	1148	Siltstone	96.3%
2	Not Recorded	1149	Siltstone	97.9%
3	Not Recorded	1148	Siltstone	97.2%

4.2.4 Highway 38 Bridge Investigations.

4.2.4.1 Drilling. Each of the Highway 38 bridge abutments is supported by eight caissons. Before the caisson holes were augered, proof test NX core holes were drilled to a level five feet below the proposed bottom of each caisson. Bedrock was lower than expected in some areas, requiring modification to caisson design. Where revisions deepened and relocated caissons, jackhammer proof test holes were drilled five feet below the bottom of the completed caisson hole. The Highway 38 bridge foundation is discussed in detail in Section 11 of this report. Logs of drill holes are included in Appendix H, PLATES H-3 and H-4.

4.2.4.2 Testing. In documenting foundation conditions the Corps of Engineers tested cores from the proof test holes to determine unconfined compressive strength. Test results, in pounds per square inch (PSI), are recorded below.

Caisson No.	Sample Elev.	Rock Type	PSI
A2-1	1197.7	Sdy siltstone	12,891
A2-2	1172.0	Sdy siltstone	8,435
A2-3	1182.0	Siltstone	6,605
A2-4	1189.5	Siltstone	4,647
A2-4	1179.5	Sdy siltstone	10,822
A2-4	1174.5	Sdy siltstone	9,549
A1-7	1172.0	Siltstone	4,535
A2-5	1175.0	Siltstone	7,162
A1-5	1160.5	Sdy siltstone	12,700

4.2.5 Tunnel Investigations. To provide documentation of tunneling conditions, rock cores from the tunnels were tested to determine unconfined compressive strength. The samples were cored by the contractor and tested by both the contractor and the Corps of Engineers project laboratory. Test results in pounds per square inch (PSI) are tabulated below.

Unconfined Compressive Strength Test Results

Tunnel	Station	Rock Type	PSI	Date Tested
2	10+71	Siltstone	2,200*	9- -90
2	10+71	Siltstone	3,750	9- -90
2	10+71	Siltstone	6,262	9- -90
2	10+71	Siltstone	5,375	9- -90

Unconfined Compressive Strength Test Results

Tunnel	Station	Rock Type	PSI	Date Tested
2	10+71	Siltstone	2,812	9- -90
1	19+80	Sandstone	18,125	1-09-91
1	19+80	Sandstone	13,875	1-09-91
1	19+80	Sandstone	+17,800**	1-10-91
1	20+86	Siltstone	3,062	1-09-91
1	20+86	Siltstone	6,062	1-09-91
1	20+86	Sdy siltstone	10,350	1-10-91
2	13+42	Siltstone	5,500	1-09-91
2	13+42	Siltstone	5,750	1-09-91
2	13+42	Siltstone	4,725	1-10-91
2	18+86	Siltstone	4,500	4-12-91
3	14+10	Sdy siltstone	10,250	4-12-91
3	14+10	Sdy siltstone	9,000	4-12-91
2	19+85	Siy Sandstone	11,250	4-30-91
3	17+47	Siltstone	2,500	5-01-91
3	17+47	Siltstone	3,000	5-01-91
3	19+80	Sdy siltstone	10,750	5-20-91
3	20+70	Sdy siltstone	8,750	5-29-91
3	22+30	Sdy siltstone	8,500	5-29-91

* Test results believed to be inaccurate because of a bad cap.
** Sample not taken to failure.

The number of cores taken in different materials may be biased toward the higher strength sandy material which occurs in widely spaced bands and beds ranging from less than 0.1 foot to 2.4 feet thick. Material excavated from the tunnels is about 92 per cent siltstone with a compressive strength ranging from about 4,000 to 6,000 PSI. The actual extent of the different materials is shown on tunnel geology maps in Appendix D, Plates D-12 through D-169.

4.2.6 Slurry Trench Investigations.

4.2.6.1 Backfill Borrow Site. In August and September 1991, several backhoe pits were dug in the alluvium upstream of the embankment and adjacent to Clover Fork to locate the best borrow site for slurry trench backfill material. Gradation test results indicated that, although on the fine side of the specification requirement, suitable backfill material was available from the upper four to six feet of the alluvium. Details of slurry trench construction are presented in Section 9.2 of this report. A test pit location plan and gradation results are included in Appendix E, PLATES E-8 through E-10.

4.2.6.2 Right Abutment of Diversion Embankment. In June 1992, the contractor drilled four air-track holes to determine depth to bedrock in the right abutment area. Indications were that the top of rock surface was lower than the estimated top of rock line. A Corps of Engineers drill crew drilled three additional SPT/core holes which confirmed

the preliminary findings. This led to a modification extending the foundation seepage cutoff farther into the right abutment with the addition of a sheet pile wall section. See Section 9.2, "Slurry Trench".

5. Geology

5.1 Regional Geology. The Cumberland River basin upstream of Pineville, Kentucky comprises the northwestern two-thirds of the Cumberland Mountains region, a subdivision of the Cumberland Plateau physiographic province. The region is about 25 miles wide by 125 miles long and lies entirely within the Pine Mountain Overthrust. It is bounded on the northwest by Pine Mountain and on the southeast by Cumberland Mountain, two asymmetric ridges with general crest elevations of 2,500 and 2,800 feet above mean sea level respectively. The topography of the area is in early maturity typified by rugged mountainous terrain dissected by a well developed drainage system which varies from rectangular to dendritic in form. The highest point in Kentucky, The Double on Black Mountain (Elev. 4,150), is located in the headwaters of the Cumberland River. The valleys are steep sided and narrow.

5.2 Site Geology.

5.2.1 Physiography. The tunnels were excavated through Ivy Hill, a southwesterly trending spur which extends from the southwest end of Black Mountain. Generally, elevations range between 1,152 feet above mean sea level (stream bed elevation at the downstream portal) to over 3,300 feet at the closest peak on Black Mountain. The maximum elevation above the tunnels is 1524 feet. The average depth of cover over the crown of the tunnels is approximately 218 feet with the maximum being 324 feet. The hillside slopes are variable but generally are very steep, varying between 1V:1H to 1V:3H. The Cawood Sandstone member forms prominent cliffs in many areas around the project site. The floodplains of the Cumberland River and its major tributaries are irregular in width due to migration of channels. This migration produces an alternating wide and narrow floodplain. The banks of the river are steep, sloping about 1V:3H.

5.2.2 Description of Overburden. Overburden soils and soil-like materials in the project area are generally one of four types: residuum, colluvium, alluvium, or artificial fill. Residuum, or residual soil, is decomposed bedrock characterized by its clayey and sandy clay nature and relict bedding texture. Colluvium, found on hill slopes and at the base of slopes, is generally loose accumulations of sandy soils containing boulders, cobbles, and rock fragments which have fallen from outcroppings of the overlying Cawood Sandstone. Alluvial soils are found at the lower elevations of the project where they have been deposited by the waters of Clover Fork. Alluvial materials range from silts to gravels, and may be mixed with colluvium and artificial fill. Artificial fill is

found throughout the project area primarily in association with railroad, highway, or dwelling construction. The upstream area, most notably the H-2 disposal site and the diversion embankment site, contained large amounts of trash, scrap metal, and other waste materials classified as artificial fill.

5.2.3 Bedrock Stratigraphy. The Harlan Diversion project is located entirely within the outcrop area of the Hance formation. The material immediately below the tunnels is part of the upper Hance coal zone. It is marked in the tunnel exploration at about elevation 1140 in borings C-200, C-201, and C-207. Above this is 160 to 180 feet of slightly micaceous, moderately hard gray siltstone through which the tunnels were driven. This material varies in character across the site being more shaly in some areas and more massive in others. This has led to variations in the description of this material between the two extremes of siltstone and shale. X-ray analysis and the appearance of most of the core tends to support a classification as siltstone however the bedding characteristics in some locations suggest a shale. It is generally referred to as a siltstone since this seems to represent the majority of the material. Within the tunnels, bedding is generally massive except for thin to thick (0.1 foot to 2.4 feet thick) beds of hard, light gray, very fine grained, quartzose sandstone and sandy siltstone. These were confined mainly to the middle one-third of the tunnels. They were all hard and continuous to discontinuous. At most they constitute about 8% of the tunnel excavation.

The upper contact of the siltstone facies is transitional with the Cawood Sandstone member becoming interbedded and commonly cross-bedded, variably silty, micaceous, and carbonaceous, moderately hard to hard, fine to medium grained, well cemented, light gray to tan with occasional carbonaceous or shaly zones. The sandstone forms low cliffs on the flanks of Ivy Hill about 140 feet above the crown of the tunnels. These cliffs are the source of the abundant large blocks of sandstone which are found in the colluvium at the base of the slopes.

5.2.4 Bedrock Structure. Bedding is nearly horizontal, with dips ranging between 0 and 7 degrees to the southwest. Bedding thickness varies across the site being more shaly in some areas and more massive in others. Within the tunnels, bedding is generally massive except for thin to thick beds of hard, light gray, very fine grained, quartzose sandstone and sandy siltstone. These were confined mainly to the middle one-third of the tunnels.

Joints spacing ranges from very closely spaced to extremely widely spaced and are usually extremely widely spaced. Most joints are generally planar to slightly curved, of moderate to high continuity, tight, clean, slightly rough to smooth, not healed, and dry. Joints located near the original ground surface are sometimes stained or contain a moderately thin filling of silty clay, and show water seepage. Zones of curved

joints, up to 2½ feet thick, occur in the portal areas and along the Hwy 38 road cut. These zones are composed of very closely spaced, parallel, tight joints with a moderately thin, very soft, residual silty-clay filling. The joint surfaces are smooth, not healed, and commonly show water seepage. The strike of these features is often nearly parallel to the adjacent river channel and the dip is high angle, curved, and irregular. They are difficult to project downward because they often step riverward along bedding planes.

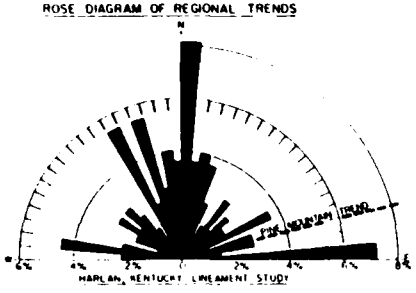
Occurrance of prominent joints in the tunnels is confined to an area within about 100 feet of either portal, relatively near the original ground surface. These are typically of moderate continuity, tight to wide open, smooth to slightly rough, not healed, and stained. There was no evidence of faulting in any of the tunnel or portal excavations. Graphical representation of discontinuity data is included in Section 5.3.

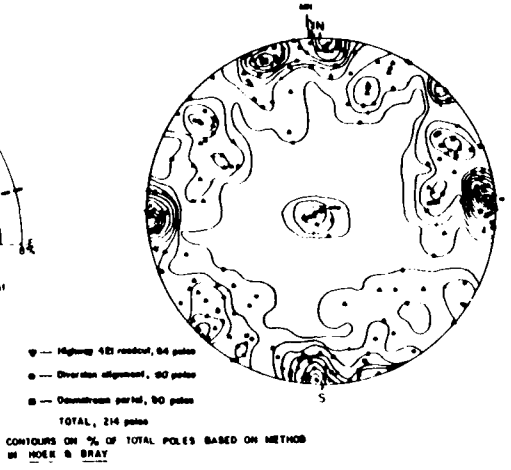
5.2.5 Bedrock Weathering. At the overburden/bedrock contact and along near surface discontinuities the bedrock is highly weathered to decomposed with the siltstone reduced to a soft soil with relict rock texture (residuum). Depth of weathering varies but is usually limited to less than ten feet below top of rock.

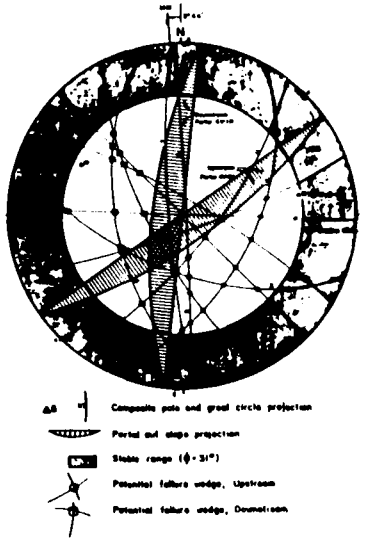
5.2.6 Groundwater. Within the Harlan project area groundwater occurs in both the alluvial soils and in the bedrock. The groundwater in the alluvium is at or slightly above the adjacent river level. The permeability of the bedrock is low and the occurrance of groundwater is more dependent upon fracturing of the rock. For this reason well yields are extremely variable.

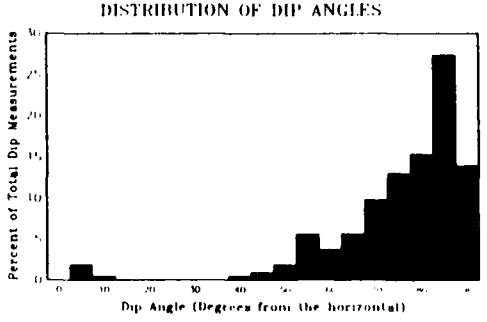
Observation well C-204 located on Ivy Hill near tunnel 4 was monitored throughout the tunnel construction contract. Water levels in this well remained stable throughout construction. A graph of water levels is included in Appendix I, PLATE I-23.

5.3 Engineering Characteristics Foundation Materials. Engineering characteristics of the foundation rock are presented on pages 20 through 24. These graphs and tables were taken from Feature Design Memorandum No. 3. Complete data from testing conducted during the project design phase are presented in the Harlan Diversion Project Feature Design Memorandum No. 3, Engineering Features and in the construction specifications for the Harlan Diversion Project, Appendices A and B. Design of the diversion tunnels and characteristics of foundation materials was the subject of an article by Marvin Simmons and John Stanton, published in the Bulletin of the Association of Engineering Geologists, No. 1, 1991.



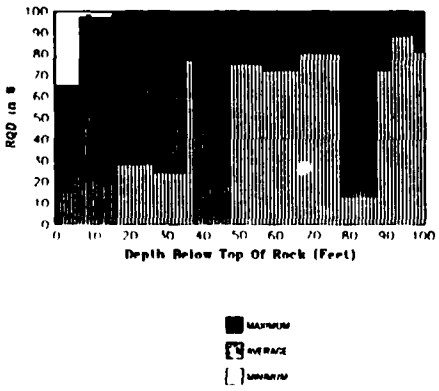




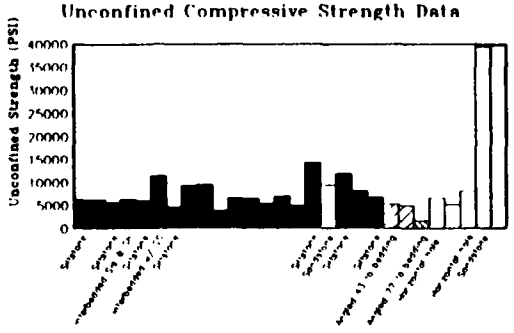


Results of discontinuity studies.

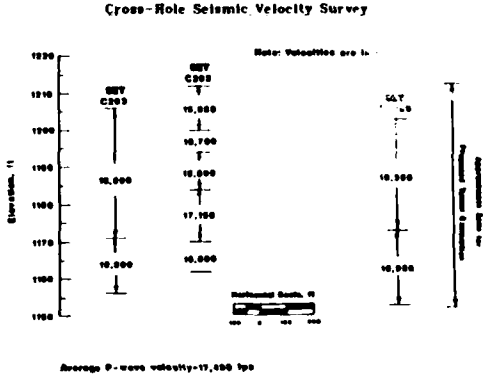
RQD's in the Upstream Portal



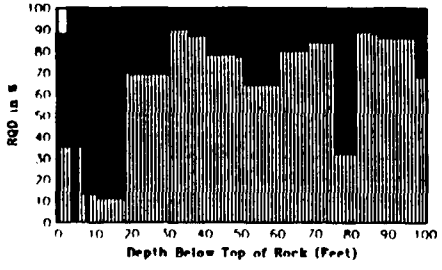
Unconfined Compressive Strength Data



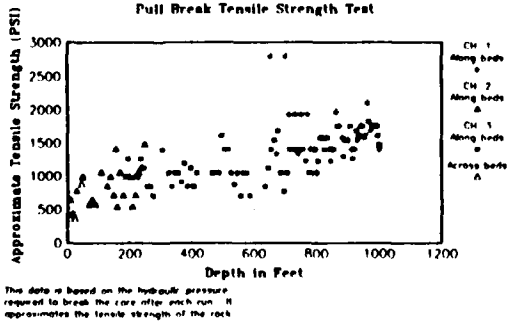
Cross-Hole Seismic Velocity Survey



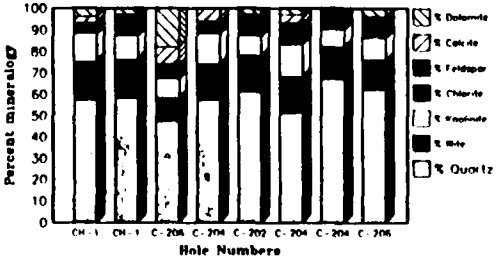
RQD's in the Downstream Portal



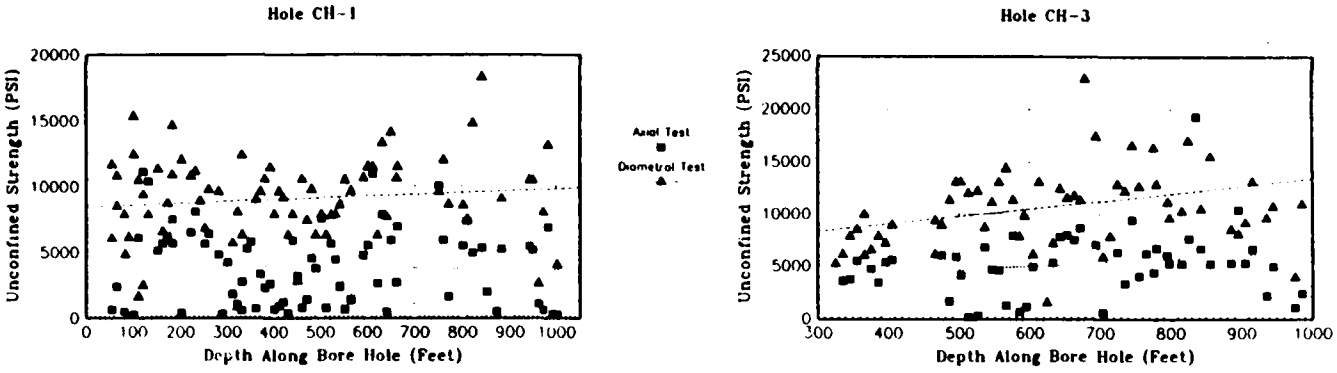
Pull Break Tensile Strength Test



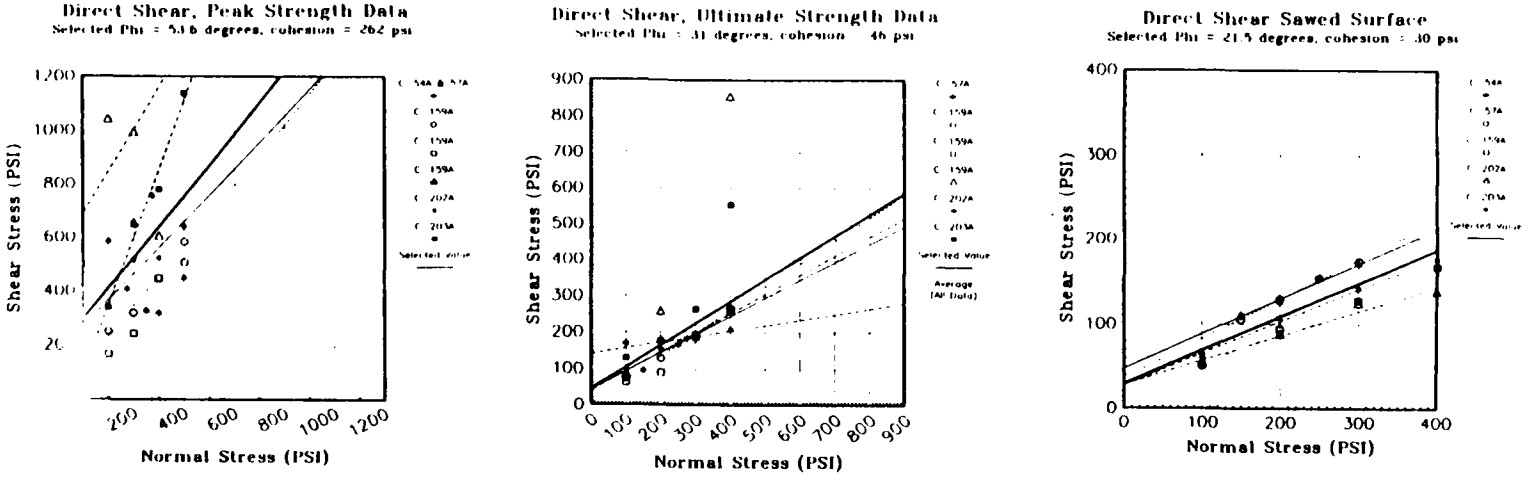
Mineralogy



Rock mass properties and test data.



Point load test data from horizontal borings, performed with an SBEL model PLT-10. The lines shown are a best fit linear regression analysis. Unconfined strength is based on the point load index multiplied by 24.



Direct shear strength test data.

Rock properties and triaxial strength test data.

Hole Number	Material	Sample Elevation	Unconfined Compressive Strength	Modulus of Elasticity x 10^6 psi	Poisson's Ratio	Triaxial Compressive Strength ϕ (degrees)	Triaxial Compressive Strength C psi	Tensile Strength psi	Orientation of Loading to Bedding (degrees)	Unit weight #/cu ft
C-54A	Siltstone	1,424.9	6,250	0.710	0.250				90	168.7
C-54A	Siltstone	1,424.1	5,620	0.677	0.259				90	167.3
C-54A	Shaly Sandstone	1,389.3	8,620	1.127	0.183				90	163.3
C-54A	Shaly Sandstone	1,386.2	12,580	3.150	0.146				90	163.2
C-54A	Sandstone	1,384.9	18,070	5.191	0.146				90	159.5
C-57	Siltstone	1,291.5	6,290	0.772	0.241				90	167.3
C-57	Shale & Siltstone	1,290.6	6,290	1.007	0.209				90	167.3
C-200	Siltstone	1,200.3	4,950						42	
C-200	Siltstone	1,199.0	5,200						42	
C-200	Siltstone	1,187.4				39	190		42	
C-200	Siltstone	1,177.5				37	400		42	
C-202	Siltstone	1,195.1						1,060	90	
C-202	Siltstone	1,194.7	4,600						90	
C-202	Siltstone	1,187.4	9,280						90	
C-202	Siltstone	1,182.5	9,430	6.410					90	
C-203	Siltstone	1,180.2	8,120						90	
C-204	Siltstone	1,209.8						1,750	90	
C-204	Siltstone	1,179.7	9,500						90	
C-204	Siltstone	1,168.2	14,250	6.529	0.186				90	
C-204	Siltstone	1,156.9	3,750						90	
C-206	Siltstone	1,165.7	6,520						90	
C-206	Siltstone	1,165.3	6,520						90	
C-206	Siltstone	1,153.7	11,830	4.511	0.255				90	
C-285	Siltstone	1,192.2				38	1,800		90	
OC-293	Siltstone	1,164.4	6,680						90	
C-296	Siltstone	1,208.6	1,600						77	
CH-1	Siltstone	1,208.9	5,260						0	
CH-1	Siltstone	1,205.8						530	0	
CH-1	Siltstone	1,205.7	6,560						0	
CH-1	Siltstone	1,198.9	8,130						0	
CH-1	Siltstone	1,198.8						530	0	
CH-3	Siltstone	1,168.7				35	1,000		0	

Summary of direct shear test data.

Hole Number	Material	Sample Elevation	Intact Rock Peak φ (degrees)	Intact Rock Peak C psi	Intact Rock Ultimate φ (degrees)	Intact Rock Ultimate C psi	Bedding Plane Ultimate φ (degrees)	Bedding Plane Ultimate C psi	Sawed Surface Ultimate φ (degrees)	Sawed Surface Ultimate C psi
C-54A	Siltstone	1,424.5	58	165						
C-54A	Shaly Sandstone	1,383.9					30	5		
C-55A	Shaly Sandstone	1,383.2	69	197	29	27				
C-55A	Shaly Sandstone	1,383.0					35	22		
C-55A	Shaly Sandstone	1,373.3							31	4
C-55A	Shaly Sandstone	1,373.1							26	12
C-57	Siltstone & Shale	1,282.5	65	190	26	45				
C-57	Siltstone	1,281.1					26	30		
C-57	Siltstone	1,279.4					28	17		
C-159A	Siltstone	1,197.2	45	37	29	2				
C-159A	Siltstone	1,184.3	53	40	30	16				
C-159A	Siltstone	1,178.6							21	12
C-159A	Siltstone	1,179.5	50	35	33	0				
C-202A	Siltstone	1,179.4							19	18
C-202A	Siltstone	1,166.4	36	36	22	3				
C-202A	Siltstone	1,160.6			17	92				
C-202A	Siltstone	1,156.4	23	109	14	31				
C-203A	Siltstone	1,341.3	72	35	32	0				
C-203A	Siltstone	1,203.0	40	115	26	35				
C-203A	Siltstone	1,194.2	69	80						

6. Downstream Portals

6.1 Excavation Grades - Design and As-Built.

6.1.1 Overburden. Overburden slopes were designed to be 1V:1H along the left side slope and above the tunnel portals, and 1V:2H along the right side slope, as shown on the general plan of the downstream portal, PLATE B-1. During construction, slides developed on the 1V:1H overburden slopes, some of them extending back to joint faces in highly weathered rock. Treatment consisted of laying back the slope to 1V:1½H in overburden, or to the joint faces which had been exposed in rock. As a result, some of the overburden slopes were flatter or set back farther into the hillside than originally planned. An increase in excavation quantities resulted. Design and as-built cross-sections are included in Appendix B.

6.1.2 Rock. All finished rock slopes were presplit. The specifications allowed a one foot offset between lifts and limited lift depth to 30 feet. Approval was given to the contractor's request to offset slopes three feet between lifts to accommodate drilling equipment, as shown on PLATE B-8.

A ten-feet-wide bench was to be constructed at the top of rock. To establish the bench, a 2V:1H slope was presplit from top of rock down to bench level. Below this bench, rock slopes were designed to be 4V:1H and vertical. Because of low rock at the

bench level and continuing development of slides in the 1V:1H slopes, the bench at top of rock was set back 15 feet into the hillside. A new 1V:1H backslope was laid out. Rock was encountered at approximately elevation 1290. A 2V:1H presplit slope was developed from approximately 1290 to 1270. This allowed final slopes to be constructed in harder, less weathered rock. An extra bench was created and the design bench was lowered and widened.

Overbreakage resulted in areas where joints occurred behind the presplit surfaces. The rock was often too fractured to bolt effectively. In such areas loose blocks were removed and joint faces, rather than presplit faces, form the finished slope.

Below elevation 1230, blasting caused the rock to shift along smooth, nearly horizontal bedding planes and high angle joints which crossed the outside corners. Displaced rock was either pinned with additional rock bolts, or removed. Because of this, in some areas the final excavated surfaces were below and behind design lines.

PLATE B-10 illustrates plan and as-built slope configurations as well as overburden/soft-rock/hard-rock contacts as determined from contractors survey data, exploratory pits, and drill holes.

6.2 Dewatering Provisions. Groundwater entering the downstream portal excavation was limited to small seeps occurring primarily at the overburden/rock contact and along bedding planes and joints. The total amount of groundwater seepage was negligible compared to surface runoff.

Control of surface water runoff was necessary to prevent flooding of the work area during periods of rainfall. An intermittent stream entered the area above the tunnel 1 portal. A shotcrete dam was constructed to divert the stream into an 18-inch diameter corrugated polyethylene pipe which carried it down the slope and away from the work area. Water which collected in the work area was processed through a water treatment plant to remove suspended solids, and then pumped into Clover Fork.

6.3 Overburden Excavation.

6.3.1 Dates. Surveyors began layout at the downstream portal area during the last week of September 1989. Overburden excavation began in November 1989 and continued in conjunction with rock excavation until July 1990.

6.3.2 Methods and Equipment. Excavation began at the top of the portal area. Two D-8 Caterpillar dozers and a Komatsu PC150LC backhoe cut the 1V:1H slope and moved the material to an existing bench at approximately elevation 1215. Large sandstone boulders which were uncovered during overburden removal were blasted so they could be loaded and hauled to

disposal. A John Deere 844 and a Fiat Allis 745H rubber-tired endloader loaded material into 16 cubic yard capacity highway dump trucks which transported it to disposal area L-11 by way of Route 72 and US 119.

6.3.3 Construction Summary, Problems, and Treatment. The general treatment of the portal slopes included installation of rock anchors on an 8 by 8 feet pattern, strip drains, and a four-inches-thick, welded-wire-fabric reinforced, shotcrete covering.

Occasionally, shotcreting of the 1V:1H backslope was delayed beyond contract specified time limits, for two reasons, (1) slides required repositioning of finish slopes and (2) design slopes were dependent upon an estimated top of rock line. When rock was encountered lower than anticipated, benches and backslopes had to be lowered or set back into the hillside. Both of these conditions were unpredictable and required that shotcrete application be delayed so that benches and slopes could be adjusted as the excavation progressed. For these reasons overburden slopes were not shotcreted.

In December 1989, excavation of the 1V:1H backslope began along the left portal slope between stations 7+00 and 9+80. A slide began developing along the top of this 1V:1H slope, between station 8+25 and 8+75 on 15 December, 1989. Tension cracks developed 15 feet upslope from the top at the 1V:1H cut, accompanied by bulging and cracking in the overburden and weathered rock portion of the slope. The material was removed and the slope stabilized by laying it back to 1V:1½H. The slope was warped into the steeper 1V:1H slopes on either side. Removing the slide and laying back the slope moved the top of the cut uphill and outside project limits, requiring the acquisition of additional property.

During January 1990, slides continued to develop on 1V:1H backslopes. Two slides located along the left side slope from station 8+10 to 8+60 and from 9+30 to 9+75 occurred along joint planes which trend N15°W, 60° SW; nearly parallel to the cut slope. Seepage along the overburden/siltstone contact and along the joint planes saturated the overburden and contributed to slope failure. Treatment consisted of removing slide material back to the joint face using a D-8 dozer and backhoe.

Slides also developed along the 1V:1H backslope above tunnels 2 and 3. Cracks appeared in the ground surface above the top of the cut- slope, accompanied by cracking and outward movement in the weathered siltstone along a nearly horizontal bedding plane. After heavy rains on 10 and 11 February 1990, an overburden slide occurred from station 7+50 to 8+00 on the left side slope. Saturated soil continued to slide along a joint face which intersected the cut slope. Cracking in the overburden extended 13 feet upslope of the clearing line. A backhoe was used to remove slide material back to the joint face.

6.3.4 Disposition of Materials. Most of the overburden excavated from the downstream portal area was hauled to disposal area L-11. In December 1989, a small amount was used as fill at the Corps of Engineers office site.

6.4 Rock Excavation.

6.4.1 Dates. Rock excavation began at the downstream portal in January 1990 and was completed on 14 September 1990.

6.4.2 Methods and Equipment. Blasting began at the top of rock, about elevation 1290 at its highest point, and continued to the finished grade near elevation 1155. Ingersoll Rand ECM 350 air-track drills with 750 CFM air compressors were used to drill blast holes. A Gardner-Denver RDC 16 rotary drill was used briefly, during May 1990, to drill 5⅛-inch diameter blast holes for ten production blasts. A Caterpillar D-8 dozer pushed material to a John Deere 844 and a Fiat Allis 745H endloader for loading into trucks which transported it to the disposal area.

6.4.3 Blasting. All finished rock slope surfaces were presplit. Presplit drilling and blasting began in February 1990 on the 2V:1H slope from top of rock down to bench level, approximately elevation 1290 to 1270. During March 1990, blasting continued with development of the 4V:1H presplit slope and production blasting from approximately elevation 1270 to 1245. In April blasting continued on the right side slope along Baseline "A", along the backslope above the tunnel portals, and along the outside corners of tunnels 1 and 2. Details of initial presplit (PS) and production (Prod) blasting are shown on the next page.

Type	Dia.	Spacing	Depth	Stem	Powder	lbs/delay
PS	2½-3"	36"	15-30'	2-4'	Detagel, Iresplit 200 grain Primacord	-----
Prod	4"	5x5,6x6, 7x7	8-15'	6-7'	ANFO, Iremite	40-65

Presplit blasts were detonated with electric blasting caps. Production blasts were detonated with the Nonel system. The first presplit shot across the face of tunnel 1 was loaded with 200-grain detonating cord only and failed to produce good breakage. The holes were cleaned out and reloaded with detonating cord and Detagel which produced satisfactory results.

Excavation continued on the downstream portals to approximately elevation 1200 during May 1990. This included presplitting adjacent to tunnels 1, 3, and 4. Production blasting continued in front of tunnel 2. Experimentation with different materials and techniques were conducted in an effort to reduce blast damage to the outside corners. Additional vertical rock bolts and pattern rock bolts were installed before adjacent blasts

were fired. Despite the precautions that were taken, some damage did occur and this resulted in final excavated surfaces that were below and behind design lines.

Presplit (one 30-feet lift) and production blasting (two 15-feet lifts) continued from elevation 1230 to 1200 in front of tunnels 3 and 4. The left side slope, along baseline C from station 11+00 to 11+66, was presplit in one lift from elevation 1215 to 1186. Details of typical blasts are shown below.

Type	Dia.	Spacing	Depth	Stem	Powder
PS	2½"	36-18"	30'	1½-4'	Primacord (200 gr), Detagel, Unigel, Iresplit. EB Caps.
Prod	3-5"	6x6,9x9'	15'	3-8'	ANFO, Iregel, Iremite primers Nonel initiation.

Experimentation with different presplit materials, hole spacing, and deck loading was done in an effort to reduce blast damage to the outside corners of the downstream portals. To reinforce the corners, ten and twenty feet long vertical rock bolts were installed on the outside corners of tunnels 1 and 3 prior to blasting. Pattern rock bolts were installed in vertical faces before adjacent blasting. Installation of anchor bars, welded wire fabric, and shotcrete continued within the time restraints set forth in the specifications. Despite the precautions damage occurred as rock shifted along smooth, nearly horizontal bedding planes and high angle joints which cross the outside corners. Displaced rock was secured with additional rock bolts, or removed. Blast damage to shotcrete also became a problem. A production blast in front of tunnel 3 from elevation 1215 to 1200 resulted in shifting of the tunnel 2 corner along a joint and bedding planes and damaged shotcrete on the face of tunnel 2.

The Contractor employed Dr. James Mahar, a rock mechanics consultant, to evaluate conditions at the downstream portal. Dr. Mahar presented his findings and recommendations at a meeting held at the Pineville Area Office on 1 June 1990. The recommendations included the installation of 40-feet long, vertical, stressed anchors on two-feet centers around the corners and two feet inside the presplit lines. Extra length rock bolts installed normal to joints which cut across the corners were also recommended. It was suggested that the blasting plan be re-evaluated and modified if necessary.

Presplitting the remaining 45 feet in one single lift was discussed, this being a way of preserving more of the rock corner by eliminating a horizontal offset which would be required if two separate presplit shots were made.

A modified version of Dr. Mahar's plan was used. Additional bolts up to 40 feet long were installed on each side of the corners, angled to intersect and anchor behind cross-cutting joint planes. Vertical bolts up to 40 feet long were installed from the elevation 1200 level, on four-feet-centers around the

outside corners. The layout of additional bolts is shown on PLATES B-14 and B-15.

The blasting plan was revised to reduce the overall size of the blasts and reduce presplit hole spacing to 18 inches. Presplitting from elevation 1200 to 1155 was completed in one lift. Other details of the revised blasting plan were:

Type	Dia.	Spacing	Depth	Stem	Powder
PS	3"	18"	45'	4'	Detagel and Unigel
Prod	3½	7'x 7'	15'	6'	ANFO

Blasting resumed on 19 June below elevation 1200 with much improved results. Excavation was completed to invert level by 26 June. Installation of pattern rock bolts, drains, and shotcrete was completed around the portal corners. Blasted rock was pushed back up to the portal faces to a level four feet below springline to form an access ramp and work platform for construction equipment. The two roadheaders were moved into position in front of tunnels 1 and 2 with excavation of the top headings scheduled to begin in early September 1990.

6.4.4 Disposition of Excavated Materials. Initially rock excavated from the downstream portal was placed in disposal area L-11. Beginning in February 1990 the material was hauled to the proposed site for the new Harlan High School. Blasted rock was also used as fill in the Highway 72 bridge abutment approach ramps.

6.5 Foundation Preparation and Clean-up. Slopes were cleaned using compressed air and water, and hand tools. Water was used sparingly on the more weathered siltstone surfaces. Scaling of loose rock from the surface slopes was accomplished with the excavating equipment as the cut was brought down. The contractor proposed to use high pressure water sprayers (green-cutting), rather than sandblasting, to remove latency and rebound material which accumulated at the bottom of the slope during shotcrete application. This method was used with good results. Cleaning of the cold-joint was further improved upon by placing two-by-eight- feet plywood sheets along the bottom of the slopes being shotcreted. The plywood reduced the accumulation of rebound material and kept the exposed bottom edge of the welded wire reinforcement cleaner. About 15 minutes after shotcrete application, the plywood was removed and the joint area was green-cut. This procedure worked very well and green-cutting, instead of sandblasting, was approved for continued use.

6.6 Rock Reinforcement. Downstream portal slopes were reinforced with rock dowels and rock bolts as shown on PLATES B-11 through B-15. Both rock dowels and rock bolts were epoxy coated No. 7, grade 60, fully threaded steel bars manufactured by the Dywidag Company.

Rock dowels were installed on ten feet spacing along the more weathered, upper portion, of the rock slopes. Dowels were grouted with Conbextra-S non-shrink grout and were not stressed. Dowels were installed within 24 hours of exposure of the excavated face.

Pattern rock bolts, were installed on a 10 by 10 feet staggered pattern. Additional bolts, up to 25 feet in length, were installed as necessary. Rock bolts were anchored with Fosroc Lokset resin cartridges and stressed to 30 kips. Bolts were installed within 48 hours of exposure of the excavated face. The resin manufacturer's data indicated that with ⅞-inch bolts and 1¼-inch holes, the 1⅛-inch resin cartridges would "yield", or encapsulate, 16 inches of bolt per 12-inch cartridge including a 15% loss which was considered to be typical. In practice, however, a 12-inch cartridge would yield only about 12 inches of bolt encapsulation. At first it was suspected that the resin loss was occurring as resin was forced into cracks in the rock. While that may have been true in some instances, the difference was attributed primarily to variations in hole diameter. Measurements with a hole gauge indicated holes to be the correct 1¼-inch diameter at the bottom of the hole, with the diameter increasing slightly toward the collar. This lower than anticipated yield was obvious from the beginning, when resin failed to show at the rock surface as a bolt was inserted. Nine 12-inch cartridges were required for each ten feet long bolt. For longer bolts, the number of resin cartridges was increased accordingly.

6.6.1 Rock Bolt Testing. Specifications required two types of rock bolt testing, pull-out tests and load cells. Two pull-out tests were conducted at the upstream portal area early in the bolting program to check the strength of the anchorage system and insure the adequacy of bolting procedures. Three load cells were installed on downstream portal surface bolts to monitor long-term performance. For both types of tests, only the fast-set anchor zone resin cartridges were used. Results of the pull-out tests are shown below. Load cells are discussed in Section 6.9.

6.6.1.1 Pull-Out Tests. Test bolts were to be stressed to 1½ times the yield strength of the bolt, or to failure, whichever was less. The yield strength of a No. 7 grade 60 bolt is 36 kips, therefore the maximum test load was to be 54 kips. In the first two tests elastic deformation of the bolts occurred before failure of the anchorage. Since the ultimate strength of this type of bolt is 52½ kips, the maximum load applied to the remaining three test bolts at the upstream portal was reduced to 42 kips. The tensioning jack was calibrated against a load cell before each test. Both tests were conducted in hard, unweathered, siltstone using ten feet long, No. 7, grade 60 bolts. Bolt elongation was measured, where recorded, using a hand held scale. Drill hole diameters were 1¼-inches. Resin cartridges were 1⅛-inches in diameter by 12 inches long. Mr. Gary Greenfield of the Fosroc/Celtite

Company was on site to observe the first two pull-out tests. Test results are tabulated below.

Test No.	Bond* Length	Stress* Length	Jack PSI	Load (Kips)	Strain (Ins)	Remarks
S-1	36-in.	76-in.	1300	10	---	Elastic deform-
			2800	20	---	ation began at
			4100	30	0.47	50 kips, testing
			5600	40	0.59	discontinued
			7000	50	---	
S-2	36-in.	76-in.	1300	10	---	Elastic deform-
			2800	20	---	ation began at
			4100	30	0.30	47.5 kips, test-
			5600	40	0.40	ing discontinued
			7000	50	---	

*Bond and stress lengths are calculated based on the observed yield of 12 inches of bolt encapsulation per 12-inch resin cartridge.

Rock bolt pull-out test results confirmed the adequacy of the 36-inch bond zone used for all surface bolts. All surface bolts were tensioned to 30 kips. Three more rock bolt pull-out tests were made at the upstream portal. Details of these tests are included in Section 7.6.1 of this report.

6.7 Rock Protection. Even though SDI test results were in the 97% to 99% range, some deterioration occurs when this siltstone is subjected to repeated wetting and drying cycles, over a period of a few months. A four-inch minimum thickness of welded-wire-fabric reinforced wet-mix shotcrete was applied within 96 hours of exposure of the excavated face to protect against slaking and weathering.

6.7.1 Shotcrete Mix Design. All shotcrete was the wet-mix type. A water reducing admixture was added to a mix having a one-inch slump. The resulting mix had a slump of about 2½-inches measured at the hopper.

The typical shotcrete mix used on surface slopes was:

Mix SG-6

Cement 850 lbs.	AEA 2 oz. (air-entraining admixture)
Sand 1715 lbs.	WRA 51 oz. (water-reducing admixture)
Stone 1010 lbs.	Water 302 lbs.

Accelerator was added at the nozzle as conditions required.

6.8 Drainage Provisions. Drain holes were drilled and slotted PVC pipes installed on a 12-by-12 feet pattern before shotcrete was applied. Drain holes were 15 feet deep and angled 5° upward. Strip drains were installed as necessary.

Strip drains were Hitek 6, a 10-inch wide by ¼-inch thick geocomposite drain, described as a cuspated high density polyethylene core wrapped in a geotextile filter sleeve, produced by Burcan Industries.

6.9 Instrumentation. Three load cells were installed on downstream portal slopes. Two load cells, L1DS and L2DS, were installed near the downstream portals of tunnels 2 and 3 respectively, on 12 July 1990. These first two installations were observed by Mr. Bill Jewsberry of Slope Indicator Company, the load cell manufacturer. A third load cell L3DS was installed on 14 August 1990. Load cells were monitored daily for the first 60 days after installation and while excavation was within 80 feet, and weekly thereafter for the duration of all tunnel excavation.

The contractor was required to give immediate notification if a load cell reading was five kips greater than the previous reading. Load cells 1, 2, and 3 were installed with a 20 to 25 kip lock-off load, and showed total increases of only about four kips during the monitoring period. Graphs of load cell readings are included in Appendix I, PLATES I-24 through I-31.

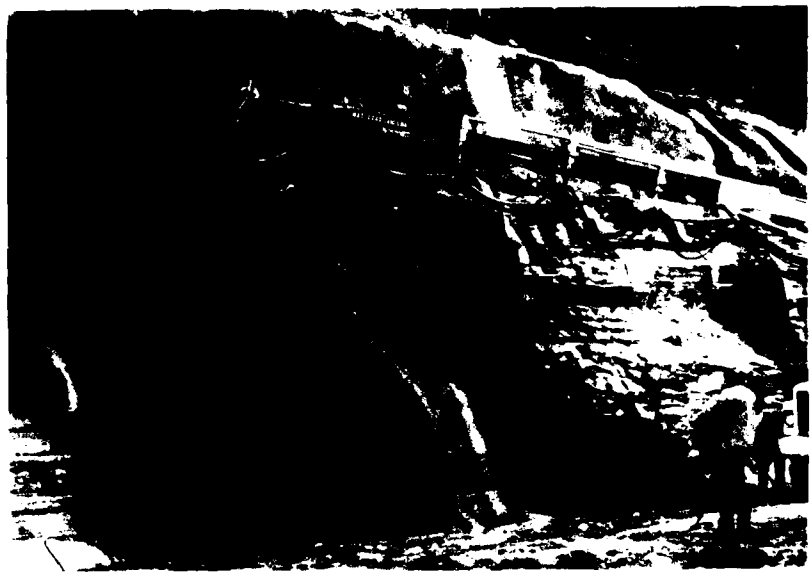
6.10 Foundation Approval and Mapping. Immediately after exposure, portal slopes were inspected by a Corps of Engineers geologist, at which time additional scaling and rock bolting was directed as necessary. Foundation approval was given after final clean-up, before shotcrete was applied. Maps of the downstream portal slopes are included on PLATES B-16 through B-20.

6.11 Possible Future Problems and Recommended Observations. On 23 January 1992 cracks were first noticed in the shotcreted backslope above the tunnel 3 corner, from about elevation 1260 to 1240. Study of geologic maps and construction photographs indicated the cracking occurred along a smooth, high-angle joint face. The cracked shotcrete showed about five inches displacement, which was apparently caused by a buildup of water pressure due to frozen drain holes. The location of the electrical substation, which supplied power to the tunnels, blocked access by shotcrete equipment. As a preliminary fix, the slope was reinforced with 15 additional rock dowels in May 1992. The area became accessible for completion of the remedial work in October 1992. Laborers used jackhammers to remove cracked shotcrete. Inspection of the underlying rock surface indicated that the shotcrete had cracked and separated from the rock surface along the smooth joint face, and no rock movement was involved. The rock surface had remained mostly unweathered and fresh. Additional drains were installed and new shotcrete applied.

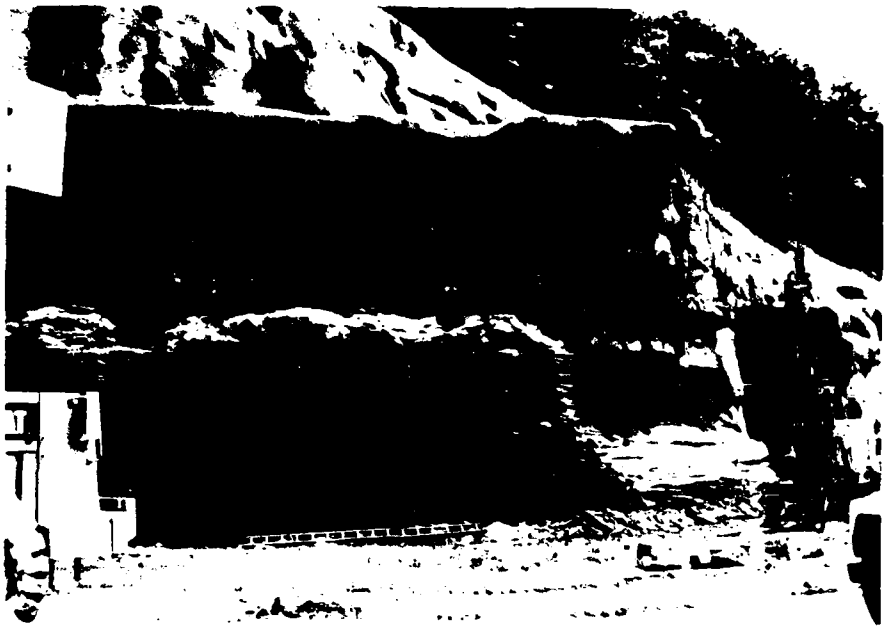
Similar shotcrete cracking can be expected in the future. Repair may be dangerous and difficult because of the steepness of the slopes and limited access.



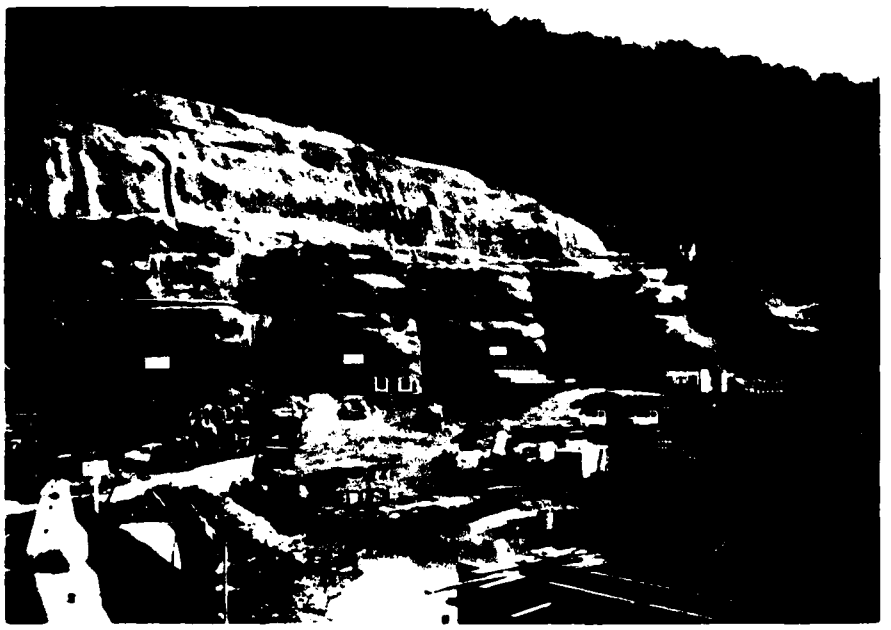








[illegible] corner, from [illegible] tunnel centerline and elevation 12' are painted on face. Note loss of corner back to the joint line. May [illegible]



[illegible] Arch [illegible]

7. **Upstream Portals.**

7.1 Excavation Grades - Design and As-Built. The contractor's surveyor developed a stationing system whereby cross-sections could be made perpendicular to the vertical backslope. All layout and mapping above elevation 1210 utilized this stationing system. Baseline locations are shown on PLATE C-1.

Baseline A = Station 3+20.5
Baseline B = Station 2+00
Baseline C = Station 0+79.5

7.1.1 Overburden. Overburden slopes were designed and constructed at 1V:1H, as shown on the general plan of the upstream portal, PLATE C-1. Because of changes to the underlying rock slopes, the overburden slope extended slightly higher up-hill than originally planned.

7.1.2 Rock.

7.1.2.1 Backslope. The slope was designed to be 2V:1H in weathered rock. A 10-feet-wide bench was to be created where the top of rock line intersected the vertical slope near elevation 1270. Below this bench the vertical slope extended down to tunnel invert at elevation 1168.

Seven air-track holes were drilled to determine the elevation of harder rock along the vertical portal backslope. Harder rock was found to be about 10 feet below the design bench elevation. Based upon these findings, the upstream portal design was changed in the following ways:

1. Vertical slope remained in design location, but lowered approximately 10 feet, to begin in harder rock.
2. The bench, where the vertical slope intersected the hard rock surface, was widened from 10 to 15 feet.
3. 2V:1H slopes were created in hard siltstone and the overlying sandstone, upslope from the 15-ft. bench.
4. On 2V:1H slopes, a 10-feet-wide bench was created at the top of each lift.
5. In continuing development of the vertical face which extended down to tunnel invert level, vertical presplit lines were offset three feet at the top of each lift.

Lowering the bench to begin in less weathered rock was, in large part, a safety consideration. The intent was to reduce the chances of slope failures and rock fall from the top of the vertical slope, which would eventually be about 100 feet directly above the working surface. These changes increased the amount of clearing and excavation above the portals, and increased the tunnel lengths by about three feet. Design and as-built cross-sections are shown on PLATE C-10.

7.1.2.2 Side Slopes. Side slopes were designed and constructed on 4V:1H.

7.1.2.3 Nosings. Three nosings project from the backslope to channel water flow into the tunnels. Each nosing is about 34 feet wide at the back, 20 feet wide at the tip, and 130 feet long. Nosings are about 42 feet high with nearly vertical sides. Nosings consist of rock left in placed during portal excavation, protected by a covering of shotcrete or concrete. The concrete portion of nosing 2 also supports the Highway 38 bridge. Nosing sections and details are included on PLATES C-11 through C-13.

7.2 Dewatering Provisions. Groundwater entering the upstream portal excavation was limited to small seeps occurring at the overburden/rock contact and along bedding planes and joints. The total amount of groundwater seepage was negligible compared to surface runoff.

As the excavation progressed downward below the level of existing Highway 38, about elevation 1200, control of surface runoff became more difficult. Water collected in the portal area during periods of rainfall. Ponded water interfered with work activities, including instrumentation readings, since the muddy water could not be disposed of in the river. After waiting for the suspended solids to settle out, the water was pumped into Clover Fork. Eventually, as the tunnels top headings were completed, water was piped through a tunnel to the downstream portal area and processed through the water treatment plant, before being discharged into Clover Fork.

7.3 Overburden Excavation. Initial clearing of the upstream portal area was done in January and February 1990. Additional clearing which was required because of changes to the rock slopes was done in May 1990. Much of the overburden was removed in conjunction with adjacent Highway 38 excavation which began in March and was completed by the end of July 1990.

7.3.1 Disposition of Excavated Material. Overburden materials from the upstream portal area were placed in the H-2 disposal area.

7.4 Rock Excavation. Rock excavation began at the upstream portal on 28 June 1990 and was completed on 4 April 1991. Blasting began at the top of the slope in sandstone at about elevation 1321, and continued down to tunnel invert level at elevation 1168. Ingersoll Rand ECM 350 air-track drills with 750 CFM air compressors were used to drill blast holes.

Above elevation 1210, blasting methods were similar to those used on the Highway 38 road-cut on either side of the portal. Below elevation 1210, more controlled blasting techniques were used to minimize blast damage to the portal nosings.

7.4.1 Disposition of Excavated Materials. A Caterpillar 977L endloader loaded shot rock directly onto Euclid R50 dump trucks. The material was hauled to the H-2 disposal area, stockpiled for later use as embankment fill, or used to backfill areas in the Highway 38 subgrade which were over-excavated to remove unsuitable material.

7.4.2 Blasting Above Elevation 1230.

7.4.2.1 Presplit Blasting. In developing the upstream portal back slope, the angled presplit holes ran approximately parallel to the existing ground surface only a short distance away. Firing the presplit line in a separate operation before the production blast disturbed the remaining rock and made it difficult to drill the production blast holes. If production holes were drilled before the presplit shot, holes were cut off and could not be loaded. For these reasons, the presplit and production blasts were usually fired in one operation, separated by millisecond delays.

Presplit holes were 2¾-inches in diameter, drilled on 36-inch centers, with a maximum depth of 30 feet. A typical presplit blast contained 30 holes. To keep blast vibrations down, a maximum of 15 holes were fired per delay period, with a 17-millisecond surface delay between groups of holes. Holes were loaded with Detagel, primed with detonating cord, and initiated with an instantaneous electric blasting cap. Using four feet of crushed gravel stemming, this resulted in 100.9 pounds of explosives per delay period.

The condition of the final slopes formed by presplit blasting was generally good. Back break occurred in areas where joints intersected the rock face at an angle of about 15° or less. Several blocks fell out from the face leaving overhangs which were removed or bolted.

7.4.2.2 Production Blasting. Production holes were 3½ and 4-inches in diameter, drilled on a six-by-six, seven-by-seven, or eight-by-eight feet square pattern, with a maximum depth of 30 feet. The number of holes per shot varied. Holes drilled adjacent to the presplit lines were shortened so that they would be no closer than six feet to the presplit line at the bottom of the hole. Holes were loaded with Iremite and ANFO with one pound cast primers and non-electric caps. Holes were stemmed with six to seven feet of crushed gravel. Powder factors ranged from 1.2 to 1.7 pounds per cubic yard. To keep blast vibrations down, the amount of explosives was limited to less than 85 pounds per delay period. Seismographs were set up for all blasts to monitor vibration levels at nearby structures.

7.4.2.3 Excavation Summary, Problems, and Treatment. Blasting exposed joints of very high continuity which intersected the portal backslope at a 15° angle, and dipped toward the open excavation (N 40°E, 75°SE). Zones, up

to 2.4 feet thick, of very closely spaced (approximately ½-inch) joints were noted. These are shown as joints number 15, 16, and 20 on the geologic map of the upstream portal slopes, Plate C-10. The joints are coated with very soft, residual silty clay, are slightly rough to smooth and are not healed.

A revised bolting plan, developed with the assistance of District Engineering and Construction Divisions, was implemented to provide additional support for rock prone to spalling and down-dip gravity sliding along joint faces. Bolt spacing was reduced from ten-by-ten feet to five-by-five feet, and bolts were angled 5° above horizontal. Bolts were lengthened as necessary, up to a maximum 25 feet length, to provide anchorage about five feet behind the joint planes. As-built bolt locations are shown on PLATES C-14 and C-15.

Joint mapping and projection of strike identified advantages for the use of longer bolts between stations 0+60 and 1+00, elevations 1237 and 1242. 15-feet long bolts were installed to anchor three to five behind the joint plane. Joint filling caused difficulty for resin insertion, clogging the drill hole and requiring repeated reaming to clear the hole. Drilling holes without water produced better results.

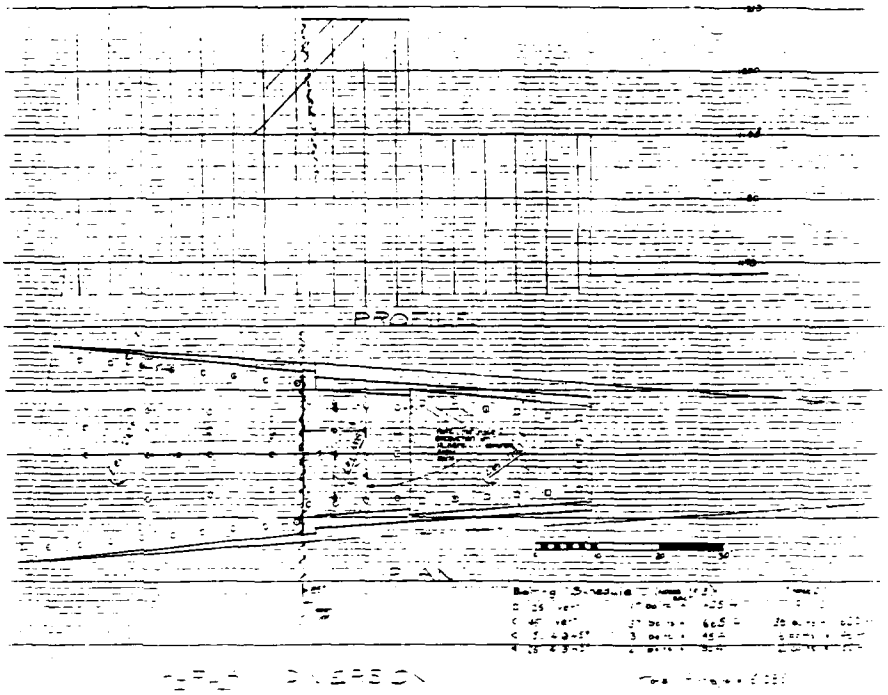
Although no actual damage to the shotcrete was observed during blasting, several shotcrete undercuts developed behind template. One occurred near station 1+85 in an area where fallouts had occurred during previous excavation. Other fallouts were noted at stations 1+00, 2+00 and 2+30. Short rock dowels were installed in each fallout area prior to shotcrete backfilling. A five-by-five feet pattern of bolts up to 25 feet long, was installed as in the previous lift.

7.4.3 Blasting Below Elevation 1230.

7.4.3.1 Nosing Reinforcement Prior to Blasting.

Nosings were reinforced with vertical bolts ranging in length from 15 to 45 feet, anchored below tunnel invert level to elevation 1165-1163. Bolts were installed on five feet centers around the perimeter of the nosings, and on approximately six-by-ten feet spacing on interior surfaces of the nosings. Bolts were also installed on 45° angles to anchor behind high angle joints.

The bolt installation procedure required 2½-inch diameter drill holes with a five feet anchor zone at the base. A threaded coupling was used on bolts longer than 40 feet. After grout in the bond zone had cured, the remainder of the hole was filled with grout. Finally, the bolt was tensioned to 30 kips and the load locked off.



Reinforcement plan for upstream portal nosings.

7.4.3.2 Blasting Plan. Dr. Calvin Konya of Precision Blasting Services in Montville, Ohio was called in as a blasting consultant. Controlled blasting techniques were implemented to minimize damage to the upstream portal nosings. Blasting methods and results are summarized below.

7.4.3.3 Blasting Sequence. Presplit holes were drilled for the full 42 feet depth of the nosings and, after stemming the lower portion of these holes, presplit and production blasts were fired in two lifts of about 21 feet each. Following presplitting one, two, and three row production blasts were used to excavate rock between the nosings.

7.4.3.4 Presplit Blasting. Presplit holes were 2½- inches in diameter, drilled on 18-inch centers. Initially holes were loaded with eight sticks of ⅞-inch diameter by 12-inch long cartridges of "Red-E-Split A" taped onto 50-grain detonating cord and spaced 34 inches center-to-center. With two feet of stemming this produced a weight of 0.116 pounds of explosives per foot of hole. Because of excessive fly rock and heaving, loading was later reduced to 0.10 and eventually 0.07 pounds per foot by increasing spacing between sticks and leaving a four feet air space above the upper stick. Presplit holes were fired simultaneously with high precision blasting caps.

7.4.3.5 Production Blasting. Production holes were three-inches in diameter, drilled on a five-by-seven feet rectangular pattern, and 20 to 22 feet deep. Production holes

were loaded with two-inch diameter Iremite E, and stemmed with about four feet of crushed stone. A row of buffer holes was used between the production holes and the finished slope. These were drilled on four feet centers parallel to, and three feet away from, the presplit wall. The buffer holes were 2½-inches in diameter and depths varied depending upon the slope of the adjacent presplit wall. Buffer holes were loaded with 1½-inch diameter Iremite E. Production shots were fired with non-electric caps and delayed to open near the center and fire progressively toward each side.

7.4.3.6 Problems and Solutions. Blasting and excavation was complicated by frequent movements of nosing blocks sideways along bedding planes and high angle joints. Extensive bolting and changes to the blasting plan resulted in some improvement.

As blasting began between nosing 1 and 2, lateral movement of the rock mass of nosing 1 occurred along a bedding plane at elevation 1190. The nosing tip rotated in an upstream direction and offsets as much as 1.4 feet were measured. The horizontal movement cut off presplit drill holes which had not been loaded and fired. Portions of the two-inch thick shotcrete "flash-coat" cracked during blasting and had to be removed.

The tip of nosing 2 also shifted during blasting. The displaced block contained very closely spaced joints which dipped 70 degrees toward the open excavation. Unlike the other two nosings, nosing 2 had no bench out in front at elevation 1190 which would serve to stabilize the displaced block. The disturbed rock was determined to be a safety hazard and a backhoe was used to remove it. About 120 cubic yards of additional concrete was required to replace it. Ten additional 20-feet-long bolts were installed in the end of the nosing between elevations 1200 and 1190.

Two smaller blasts of one row each were made in an attempt to reduce movements of adjacent nosings, without significant improvement. Blasting consultant Dr. Konya recommended returning to two row breakup shots between nosings, and this was done.

Two other changes were made to reduce movement of the nosings during blasting. To reduce bolt breakage, stressing of bolts was discontinued. Bolt angles were increased to 30° downward from horizontal to provide better anchorage across bedding planes. These changes may have helped slightly, but rock displacements continued to occur.

As excavation of the nosings progressed, it became apparent that the contract requirement of shotcreting the exposed rock surface within 96 hours would have to be waived. When shotcrete was applied before blasting on the opposite side of a nosing, shifting of the rock mass would crack the shotcrete

to the extent that it had to be removed and new shotcrete applied. For this reason, shotcrete was delayed until adjacent blasting was complete. To prevent weathering of the siltstone a "flash coat", an approximately one-inch-thick layer of protective shotcrete, was applied as soon as possible after exposure, to be followed by installation of rock anchors, welded wire fabric, and the full four-inch thickness of shotcrete at a later time. Blasting of the upstream nosings was completed in April 1991. The nosings were surveyed so that final trimming requirements could be determined. Trimming was necessary and the contract was modified to accomplish this. A hoe-ram was used to trim nosings to within required lines to allow clearance for concrete forms. To reduce trimming requirements, the position of nosing 1 was rotated one degree upstream from its design position. Nosings 2 and 3 were not changed.

7.5 Foundation Preparation and Clean-up. Loose rock was removed by a backhoe as the slopes were brought down. Final cleaning was by compressed air and water, and hand tools.

7.6 Rock Reinforcement. Pattern rock dowels and bolts were installed as at the downstream portals, except that horizontal spacing was decreased from 10 feet to 8.6 feet. The general bolting details are shown on Plate C-16. In some areas the bolting pattern was changed and longer bolts installed, as described in Section 7.6 of this report. Rock bolt materials were the same as used elsewhere on the project.

7.6.1 Rock Bolt Testing. Three rock bolts were pull tested to confirm the adequacy of the anchorage system. Test results are shown below.

Test No.	Bond Length	Stress Length	Jack PSI	Stress (Kips)	Strain (Ins)	Remark.
S-3	36 in.	76 in.	----	10	0.10	No failure.
			----	20	0.22	
			----	30	0.40	
			----	40	0.81	
			----	42	1.15	
S-4	24 in.	88 in.	----	10	0.13	No failure.
			----	20	0.32	
			----	30	0.50	
			----	40	0.90	
			----	42	1.40	
S-5	26 in.	110 in.	----	10	0.25	No failure.
			----	20	0.38	
			----	30	0.52	
			----	40	0.78	
			----	42	0.94	

Bond and stress lengths are calculated based on the observed yield of 12 inches bolt encapsulation per 12-inch resin cartridge. No failures resulted with bond zones as short as 24 inches and loads as high as 42 kips. Pull-out tests confirmed the adequacy of the 36-inch bond zone used for surface bolts. All surface bolts were tensioned to 30 kips.

7.7 Rock Protection. As at the downstream portals, siltstone slopes were shotcreted to protect against weathering. The Cawood sandstone exposed at the top of the slope was not shotcreted.

7.8 Drainage Provisions. As at the downstream portal, slotted PVC pipe lined drain holes were installed 15 feet deep, angled 5° upward, on a 12-by-12 feet pattern. Strip drains were installed as needed to drain joints which intersected the slope face.

7.9 Instrumentation. Load cells L4US, L5US, and L16US were installed with a lock-off load of about 25 kips. L4US and L5US showed gradual increases and leveled off at 30 to 34 kips. L16US showed a gradual decrease and leveled off at 19 kips. Graphs of load cell readings are included in Appendix I, PLATES I-24 through I-31.

7.10 Foundation Approval and Mapping. Immediately after exposure, portal slopes were inspected and additional scaling and rock bolting was done if necessary. Slopes were mapped before wire mesh shotcrete reinforcement was installed. Foundation approval was given after final cleanup, immediately before shotcrete application. Geologic maps of the upstream portal slopes are included on PLATES C-19 through C-23.

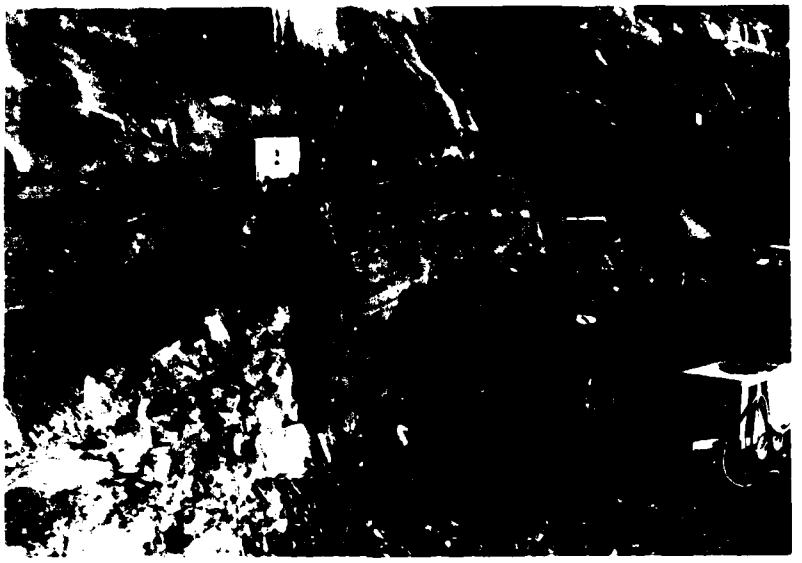
7.11 Possible Future Problems and Recommended Observations. As has already occurred at the downstream portal, freezing of drain holes could lead to shotcrete cracking.



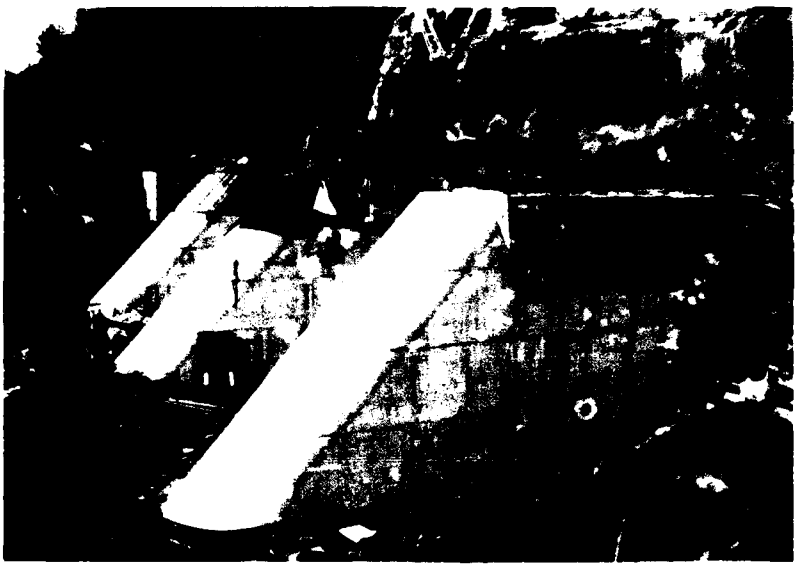
Upstream portal slope. Strip drains installed along joints, elevation 1275 to 1260. 31 July 1990

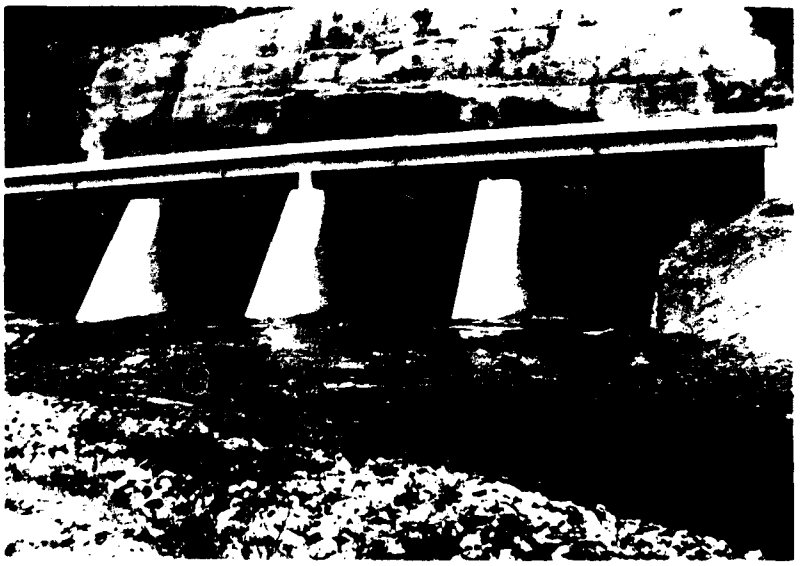


Top of nosing 1, elevation 1210, with vertical bolts laid out. View southwest across upstream portal area. 13 November 1990









8. Tunnels

8.1 Excavation Grades - Design and As-Built. Each of the four tunnels is an inverted "U" shape, 34 feet wide and 32 feet high. An over-excavation tolerance of six-inches outside the "B" line was allowed. When surveys indicated that an area had been undercut, it was trimmed with a roadheader. Overcut areas were filled with shotcrete to within the six-inch tolerance.

The tunnels range from 1836 to 2059 feet and average 1941.5 feet in length. Having a uniform grade of one foot vertically in 162.5 feet horizontally, the tunnels slope about 12 feet from upstream to downstream.

8.2 Overburden Excavation. All overburden was removed during development of the tunnel portals.

8.3 Rock Excavation-Top Headings. To minimize disturbance of rock in the tunnel crown, specifications required that the top heading be excavated by a roadheader. The top heading consisted of the semi-circular area above the tunnel spring line and two feet below spring line for the Dosco roadheader, and four feet below spring line for the Paurat roadheader. The Dosco roadheader excavated a total of 32,841 cubic yards and the Paurat a total of 132,329 cubic yards of rock from the top headings of the tunnels.

8.3.1 Dates. Roadheader excavation of the top headings began on 4 September 1990 and was completed on 23 March 1992. The chart "Tunnel Excavation Methods and Dates" on page 65 summarizes the dates of all excavation activities in the tunnels.

8.3.2 Methods and Equipment. The tunnels were driven from the downstream end up slope to ensure that water would drain away from the face. An electrical substation to supply power to the roadheaders was established at about elevation 1230, on the backslope above tunnel 4.

The contractor selected the size and type of roadheader based upon rock test data provided in the specifications, roadheader manufacturers recommendations, production rates, and scheduling requirements among other factors. A 120-ton Paurat E-242-B and an 83-ton Dosco Mk3 roadheader were used for excavating the top heading and trimming the sides of the bottom headings. During the time that both roadheaders were in use excavating the top headings, September 1990 through August 1991, the larger Paurat outperformed the Dosco by about 2.7 to 1 in total cubic yards of rock excavated. Because of excessive downtime the Dosco roadheader was removed from top heading excavation 1490 feet into tunnel 2. The Paurat completed the remainder of the top headings, and the Dosco was used only in trimming the bottom headings to finish grade.

Roadheader specifications are shown on the following chart.

Roadheader Data		
Manufacturer	Dosco	Paurat
Model No.	MK3	E 242B
Weight	83 metric tons (91.5 short tons)	120 metric tons (132 short tons)
Length	12.2 meters (40 ft)	16.6 meters (54.4 ft)
Height (Main Body)	2.95 meters (9.7 ft)	3.94 meters (12.9 ft)
Max. Cutting Height	6.1 meters (20 ft)	7.5 meters (24.6 ft)
Utilized Cutting Height (Approx)	5.8 meters (19 ft)	6.4 meters (21 ft)
Max. Cutting Width	7.2 meters (23.6 ft)	8.9 meters (29.2 ft)
Cutter Motor Size	276 kW (370 hp)	300 kW (402 hp)
Max. Torque at Cutting Head	49.6 kNm (36,586 ft lb)	132.4 kNm (97,653 ft lb)

8.3.3 Roadheader Excavation Rates. In calculating roadheader excavation rates, if a roadheader was in use for any part of a day, it was considered as a full operating day with no adjustment for rock bolting time, shotcrete time, or equipment downtime. Actual excavation rates would be slightly higher than indicated.

8.3.3.1 Dosco Excavation Rates. The Dosco roadheader worked 207 days (4010 hours) during the period from 4 September 1990 to 15 August 1991, excavating a total of 32,841 cubic yards of rock.

32,841 CY / 4010 hours = 8.19 CY / hour

Assuming full utilization of the 370 horsepower cutter motor:

$$\frac{8.19 \text{ CY / hour}}{370 \text{ Hp}} = 0.022 \text{ CY / hour / hp}$$

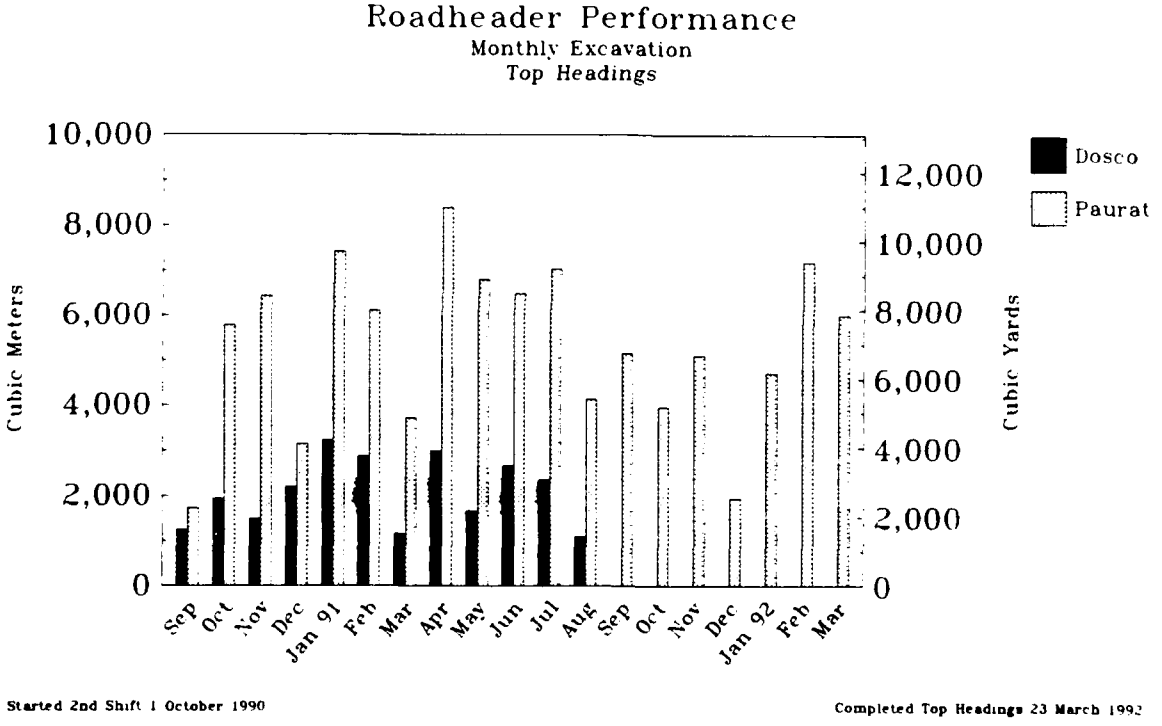
8.3.3.2 Paurat Excavation Rates. The Paurat roadheader worked 348 days (6820 hours) during the period from 4 September 1990 to 23 March 1992, excavating a total of 132,329 cubic yards of rock.

132,329 CY / 6820 hours = 19.40 CY / hour

Assuming full utilization of the 402 horsepower cutter motor:

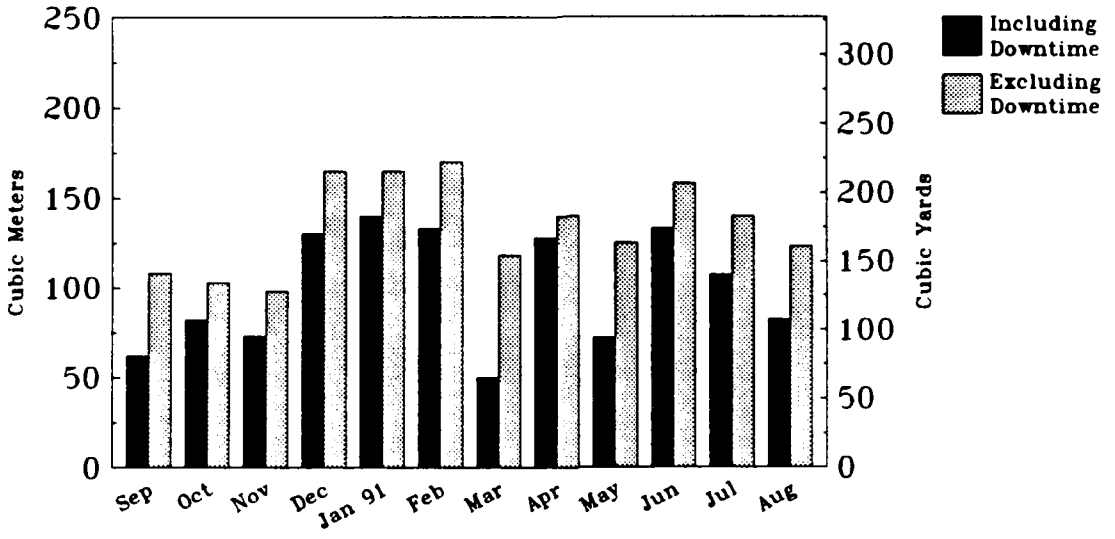
$$\frac{19.40 \text{ CY / hour}}{402 \text{ Hp}} = 0.048 \text{ CY / hour / hp}$$

8.3.4 Roadheader Performance Graphs and Chart. Roadheader performance graphs, which illustrate daily and monthly excavation data, are shown below.



Dosco Roadheader

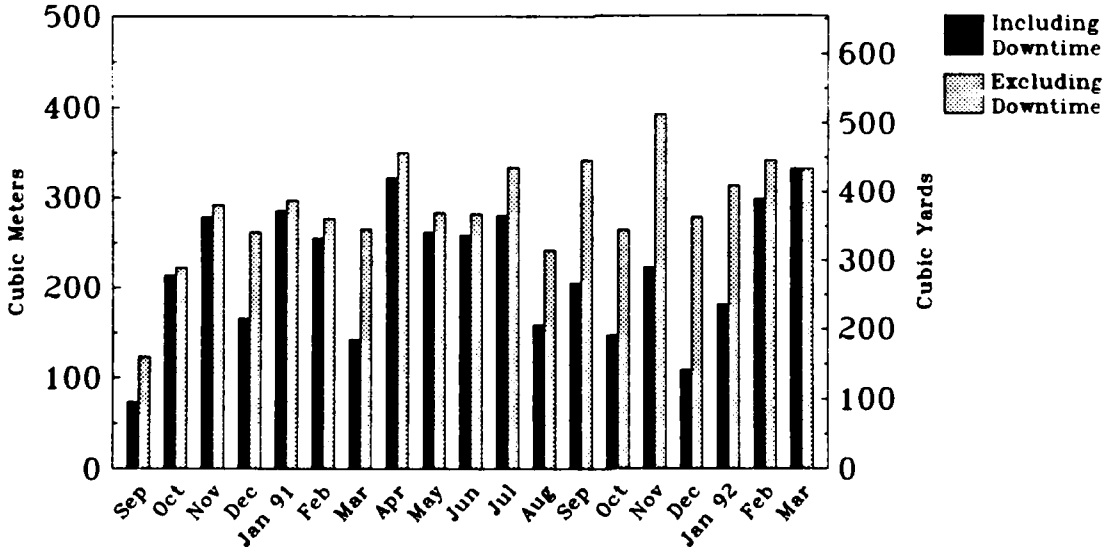
Average Daily Excavation
Top Headings



Started 2nd Shift 1 October 1990.

Paurat Roadheader

Average Daily Excavation
Top Headings



Started 2nd Shift 1 October 1990.

Completed Top Headings 23 March 1992

The total linear feet of tunnel and cubic yards excavated by each machine are shown on the following chart.

Roadheader Excavation
Top Headings

	Dosco Model Mk3			**Paurat** Model E242B		
Month	Linear Feet	Cubic Yards	CY/hp	Linear Feet	Cubic Yards	CY/hp
Sept (90)	84	1,624	4.4	103	2,250	5.6
Oct	131	2,532	6.8	346	7,557	18.8
Nov	101	1,952	5.3	385	8,408	20.9
Dec	148	2,861	7.7	188	4,106	10.2
Jan (91)	218	4,214	11.4	444	9,697	24.1
Feb	194	3,750	10.1	366	7,993	19.9
Mar	78	1,508	4.1	222	4,848	12.1
Apr	201	3,885	10.5	503	10,986	27.3
May	112	2,165	5.9	407	8,889	22.1
Jun	199	3,847	10.4	388	8,474	21.1
Jul	159	3,073	8.3	421	9,195	22.9
Aug	74	1,430	3.9	247	5,394	13.4
Sep	--	---	--	308	6,727	16.7
Oct	--	---	--	237	5,176	12.9
Nov	--	---	--	306	6,683	16.6
Dec	--	---	--	117	2,555	6.4
Jan (92)	--	---	--	282	6,159	15.3
Feb	--	---	--	430	9,391	23.4
Mar	--	---	--	359	7,841	19.5
TOTALS	1,699	32,841	--	6,059	132,329	---

8.3.5 Pick Consumption. Most of the picks used were manufactured by Kennemetal, Inc. Experiments with a longer pick manufactured by American GTE, Inc. proved unsuccessful. While the longer pick cut more rock per operating hour, the added leverage with the longer pick caused damage to the bit block. In addition, the carbide cutting elements were frequently damaged. Any gains realized from use of the longer picks were offset by longer periods of downtime and fewer operating hours. The experiment was abandoned and the use of shorter picks resumed.

Picks located at the tip and back of the cutting head received the most wear and were the most frequently replaced. At times the contractor replaced completely worn out picks with used, but less worn, picks and this made pick usage rates difficult to determine. A pick usage rate, believed to be indicative of overall rates, was recorded in February 1992 when the Paurat roadheader used 301 picks in excavating 9,391 cubic yards (430 linear feet) of rock. This equals 31.2 cubic yards of rock excavated per pick.

It was anticipated that, when excavating through the beds of hard very-fine-grained sandstone, the roadheader operator would "sump-in" above and below the bed and then break off the hard layers. In practice this was not often done. To avoid having to back-up the roadheader, the operator cut "head-on" into the hard beds. This resulted in increased wear on the picks and increased the pick usage rates.

8.3.6 Construction Summary. The downstream portal face was prepared to begin roadheader excavation by painting the 17-feet radius of the B-line. Crown bolts, 16 feet long No. 8 bolts, were then installed as shown on Plate B-15. Following crown bolt installation, the typical sequence of operations for the top headings was:

1. Advance roadheader five feet to establish tunnel brow
2. Remove loose rock
3. Conduct initial profile and X-section mapping
4. Trim with roadheader if necessary
5. Remove loose rock
6. Install rock bolts
7. Install instrumentation, if required
8. Conduct final profile and X-section mapping for "as-built" documentation
9. Wash rock surfaces
10. Perform geologic mapping
11. Apply shotcrete

The above procedure was repeated until 10 to 25 feet of heading and a safe working area had been established, after which time the heading was advanced in increments of about 25 feet.

Following the completion of the first 100 feet of top heading the ventilation, electric power, and lighting were installed.

The laser alignment system was also installed to provide line and grade control for roadheader operation.

The roadheader automatic guidance system was never operative on this project. Control of top heading excavation was maintained using five to seven lasers, mounted one foot inside the tunnel B-line, to assist with the manual operation of the roadheader.

Upon completion of the first 100 linear feet of tunnel, normal shift work was initiated for the various activities; two 10-hour production shifts per day. Normal hours of activity were from 0700 to 1730 hours for the day shift, and from 1900 to 0530 hours for the night shift, with scheduled maintenance between shifts.

The original excavation plan provided for roadheader excavation and rock bolt installation during both shifts, and the application of shotcrete during the day shift only. The general procedure which gradually evolved was to rock bolt once each day, at the end of the night shift or the beginning of the day shift. This met the contract criteria for installing bolts without post-tensioning, and also kept the roadheader operator under a bolted roof at all times.

8.3.7 Disposition and Processing of Materials. Roadheader cuttings were disposed of at the L-11 disposal area and the new Harlan High School site, or were utilized as fill for the Hwy 72 bridge abutment, the Hwy 38 road subgrade, or the diversion embankment. The only processing necessary was moisture control, allowing the material to air dry after rainfall before continuing the placement of compacted fill.

8.4 Rock Excavation-Bottom Headings.

8.4.1 Dates. Bottom heading excavation began on 13 April 1991 and was completed on 26 June 1992. The chart "Tunnel Excavation Methods and Dates" on page 65 summarizes the dates of all excavation activities in the tunnels.

8.4.2 Methods and Equipment. The contractor was allowed to choose the method of bottom heading excavation, subject to the approval of the Contracting Officer. To prevent blast damage to the downstream portal corners, the outermost few feet of each bottom heading was excavated with a roadheader. The remainder of the bottom heading was blasted. Ingersoll Rand ECM 350 air-track drills were used to drill the blast holes. A side-dump endloader loaded muck onto 16-cubic yard dump trucks for transport to stockpile or disposal areas, or directly to placement as fill in the diversion embankment.

About two feet of rock was left along the sidewalls which was later trimmed to final grade with a roadheader. Where necessary, the tunnel floors were also trimmed with a hoe ram or a roadheader.

Bottom heading construction normally followed this sequence:

1. Excavate outermost few feet with roadheader
2. Drill and blast
3. Remove muck with end-loader and trucks
4. Trim sides with roadheader
5. Conduct initial cross-section survey
6. Complete additional trimming if necessary
7. Conduct final cross-section surveys for "as-built" documentation
8. Wash rock surfaces
9. Complete geologic mapping
10. Apply shotcrete
11. Prepare invert for concrete slab placement (trim with roadheader or hoe ram if necessary, install reinforcement and anchor bars, place concrete)

8.4.3 Blasting. Bottom bench blasting began at the downstream end of a tunnel upon completion of the top heading. Test blasting was performed under the direction of Michael Muth of Blasting Consultants Inc., Lyndon, Kentucky. Results were evaluated to establish a general plan for all subsequent tunnel blasting operations. A total of about 100,000 cubic yards of rock were excavated by blasting in the bottom headings.

Blast holes were 2½-inches in diameter. Holes were drilled on a five-by-five feet square pattern with no hole closer than three feet to the finished excavation limit. Blast holes were 10 to 12 feet deep with 4½ to 5 feet of No. 8 crushed gravel stemming.

Wet holes were loaded with 2 by 16-inch Iremite 42 emulsion slurry cartridges. Dry holes were loaded with ANFO. Due to water remaining in the tunnel from construction of the top heading and to surface runoff entering the tunnels from the upstream portal areas, few blasts were dry enough to allow the use of ANFO.

Blast holes were primed with 2 x 8-inch cartridges of Iremite 42 cap-sensitive emulsion with a detonation velocity of 17,000 feet per second. Blast holes were charged with Primadet Nonel non-electric detonators. The shock tubes on the detonators were hooked up to a trunkline of 25 grain E-Cord and initiated with a non-electric device.

The contractor's original blasting plan submittal called for six row blasts. To allow for evaluation of blasting results, a test program was initiated. The first blasts contained only two rows, with blasts gradually increasing in size up to six rows. A seismograph was set up to monitor peak particle velocities at the closest house on Ivy Hill. The heaviest load used was a six row blast with 37 pounds of explosives per delay, which produced good breakage and registered a maximum peak particle velocity of only 0.18 inches per second measured 195 feet away.

With the good results obtained by the first nine blasts, the contractor requested approval to make larger blasts, up to ten rows into a muck pile. Blast No. 10 in tunnel 1 began another test program to show that this could be done without producing excessive vibration and damage to the tunnel walls. Recorded peak particle velocities are dependent upon the distance from the blast to the seismograph and the pounds of explosives per delay period. In designing the blasts, the goal was to keep velocities low by minimizing the pounds of explosives per delay period. To obtain comparable results a seismograph was set up at relatively constant distances, 45 to 65 feet, in tunnel 2.

Through the test program it was demonstrated that ten row blasts containing up to 42 pounds of explosives per delay period could be used without damage to the tunnels. The maximum peak particle velocity recorded was 2.95 inches per second at a distance of 55 feet from the blast. Seismograph readings indicated that the vertical vibration component was usually the largest for any given blast, while the transverse vibration was usually the smallest. There was no damage to shotcrete observed on any tunnel or surface exposures.

The remaining tunnel blasting plan used eight and nine rows of holes with a maximum of 36 pounds of explosives per delay period. Cubic yards per blast ranged from 450 to 533. Powder factors ranged from 1.01 to 1.08 pounds per cubic yard. After a good sequence of operation had been established, two or three blasts were fired each working day.

Depths of blast holes varied. In tunnel 1 blast holes were drilled to two feet above finish grade. The portion of tunnel 2 which was excavated by the Dosco roadheader, from station 10+48 to 25+38, was left four feet above finish grade because the contractor failed to take the Dosco's shallower cut into consideration and drilled blast holes the same depth as in tunnel 1. This left four feet of rock above invert level which was trimmed with a hoe ram. Tunnel 3 blast holes were drilled to two feet above finish grade. Tunnel 4 blast holes were drilled to finish grade to reduce final trimming requirements.

A typical tunnel blasting plan is shown on page 56.

8.4.4 Disposition of Excavated Materials. All blasts larger than two rows produced good breakage and the shot rock was used as fill material for the Hwy 38 subgrade and the diversion embankment. Excess material was hauled to disposal area L-11 and the Harlan High School site.

8.5 Foundation Preparation. Foundation preparation in the tunnels consisted of removing loose rock, installing rock bolt reinforcement (top headings), and washing the rock surface immediately prior to shotcrete and floor slab application.

8.6 Rock Reinforcement.

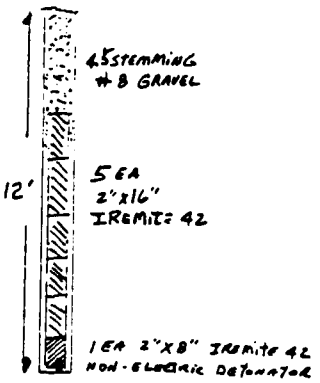
8.6.1 Crown Bolts. Two rows of 16-feet-long crown bolts were installed from the downstream portal face, before roadheader excavation began. Upstream portal crown bolts were installed after roadheader trimming of the bell mouths. Crown bolts were No. 8, epoxy-coated, Dywidag bars grouted with Lokset resin. Crown bolt locations and details are shown on PLATE B-12

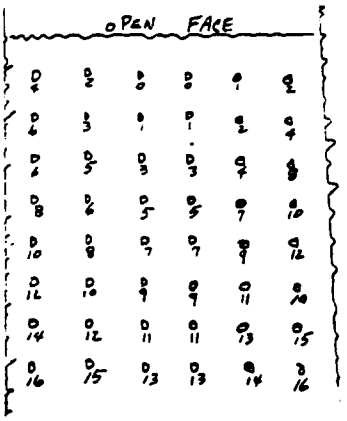
TUNNEL # 4

PROPOSED BLASTS

BOTTOM HEADING

HOLE SIZE	2½"
SPACING	5'
BURDEN	5'
TOTAL DEPTH OF EXCAVATION	12'-14'
DRILLED DEPTH	10'-12'
SUB-DRILL	NONE
STEMMING	4.5' #8 GRAVEL
HOLES PER BLAST	48
HOLES PER DELAY	3
LBS PER HOLE	11.49
LBS PER DELAY	34.3
LBS PER BLAST	550
CY PER BLAST	533
POWDER FACTOR	1.03





DELAYED AS SHOWN

8.6.2 Rock Bolts. The tunnels top headings were reinforced with 12-feet long rock bolts installed on a six-by-six feet pattern (six feet between rows of bolts and six feet between bolts within each row) as shown on PLATE D-6. Holes were drilled and the bolts installed by a Tamrock auto rock bolt machine equipped with hydraulic hammer. The automatic resin cartridge insertion system on the rock bolt machine did not work as intended and resin cartridges had to be inserted manually by a laborer working from an elevated work platform. Resin cartridges were held in place in the nearly vertical holes by square plastic clips placed on each cartridge.

Bolt installation was normally accomplished within the time and distance limitations specified, within 20 feet of the advancing face and within 24 hours of exposure, so that stressing of the bolts was not necessary. Each row of seven roof bolts typically took about 30 minutes to install. Bolts which were installed outside these time and distance requirements were stressed to 22 kips, which approximately doubled the installation time.

8.6.2.1 Rock Bolt Testing. Specifications required two types of rock bolt testing. Pull-out tests were conducted early in the bolting program to check the strength of the anchorage system and insure the adequacy of bolting procedures. Load cells were installed to monitor long term performance on ten tunnel bolts. See Section 8.9.1, "Instrumentation", for discussion of load cells.

Five tunnel bolts were pull tested to a maximum load of 42 kips. The tensioning jack was calibrated against a load cell before each test. All tests were conducted in hard, unweathered, siltstone using twelve feet long, No. 7, grade 60 bolts. Bolt elongation was measured, where recorded, using a hand held scale. Drill hole diameters were 1¼-inches. Only fast-set anchor zone cartridges were used. Two different sized resin cartridges were used: 1⅛-inches diameter by 12-inches long, and 1⅛-inches by 26-inches long. Bond and stress lengths shown below are calculated based on the observed yield of 12 inches of bolt encapsulation per 12-inch resin cartridge.

At the time of pull-out test T-3, on 30 November 1990, low temperatures had begun to cause excessively long gel times for the H-90 fast set resin. Some tunnel roof bolts actually slipped back out of the hole because the resin was not gelling quickly enough. Replacement bolts were installed at the contractor's expense. The contractor elected to change to H-35 fast set resin which has a much faster gel time. Test T-3 was intended to be the first bolt tested using the newly acquired H-35 resin. The bolt failed in the bond zone, pulling out 2.4 inches (the limit of the jack ram) with little resistance. After testing it was determined that some of the left over H-90 resin had been placed into an H-35 box. The resin had not gelled when pull tested five minutes after installation. Because of this error, test T3-A was conducted.

Tunnel Bolt Pull-Out Tests

Test No.	Bond Length	Stress Length	Jack PSI	Stress (Kips)	Strain (In.)	Remarks
T-1	24 in.	88 in.	----	10	----	No failure.
			----	20	----	
			----	30	----	
			----	40	----	
			----	42	----	
T-2	12 in.	100 in.	----	10	0.40	Vert. roof bolt, failed at 20 kips due to lack of resin confinement
			----	20	----	
T-3	26 in.	110 in.	----	--	----	Bond zone failed, resin not gelled
T-3A	26 in.	110 in.	1800	10	0.10	Failed at 42 kips
			3050	20	0.20	
			4500	30	0.30	
			6000	40	0.50	
			----	42	----	
T-4	26 in.	110 in.	1700	10	0.05	No failure
			2900	20	0.15	
			4300	30	0.30	
			5900	42	0.55	
T-5	26 in.	110 in.	500	10	0.13	Failed at 32 kips
			2050	20	0.25	
			2400	22	0.30	
			3300	30	0.50	
			----	--	----	

The lowest legitimate pull-out force recorded occurred in test T-5, which failed at 32 kips with a 26-inch bond zone. Tunnel bolts were installed with a minimum 36-inch bond zone and none of the bolts which required stressing failed during stressing to the specified 22 kips. Most tunnel bolts were installed within specified time and distance requirements, so that stressing was not necessary.

8.7 Rock Protection. Shotcreting of finished tunnel surfaces was required within seven days of exposure. A remotely controlled Finn "Robocon" ES-1000, mobile shotcrete rig was used for shotcrete application on all tunnel rock surfaces. A four-inch minimum thickness of steel-fiber-reinforced shotcrete was applied, sometimes in one application, and sometimes in two separate applications. The shotcrete was cored at regular intervals for testing purposes, and these

cores usually indicated actual shotcrete thickness of five to six inches. Over-cut areas were backfilled with shotcrete to within the allowable six-inch tolerance. Shotcrete was usually scheduled to be applied once each week, early on Saturday morning, though roadheader downtime often allowed more frequent application.

The floor of the completed tunnels is protected by a minimum eight-inches-thick concrete slab. Due to over-trimming by the roadheaders and hoe rams, the slab ranges from eight-inches up to about two feet, and averages about one foot in thickness. The floor slab is reinforced with No. 5 reinforcing bars spaced on 18-inch centers. The slab is anchored by No. 6 bars grouted two-feet into rock and placed on seven feet spacing. No drain holes were installed. Details of floor slab reinforcement are shown on PLATE C-13.

8.7.1 Shotcrete Mix Designs. Different mix designs were developed for overhead and side-wall applications. The most significant difference was the use of microsilica in overhead locations. Tunnel shotcrete mix design work sheets are shown below.

Top Headings

SHOTCRETE MIX DESIGNS

Project: Harlan Diversion Contractor: Granite/Tucker Date: 9/18/91

Design Strength: 4000 Mix Design No.: TDIG-1 Supplier: Mountain Construction Concrete Diversion

Material	Source	Specific Gravity x 62.4	
Cement	Dixie	3.15 x 62.4 = 196.56	✓
Fly Ash	Southeastern	2.30 x 62.4 = 143.52	
Micro Silica	Elchem	2.40 x 62.4 = 149.76	
Sand	Whitewater Aggregates	2.66 x 62.4 = 165.98	✓
Sand (Mfg.)	Rogers Group	2.77 x 62.4 = 169.73	
Stone	Kelly & Haydon	2.77 x 62.4 = 169.73	✓
Steel Fiber	Novocon	7.30 x 62.4 = 455.52	✓

Material	Weight per C.Y.	Solid Volume	% Moisture	Actual Weight
Cement	800	4.07		800
Fly Ash	-	-		-
Micro Silica	75	.30		75
Sand (Natural)	1700	10.24	5.7%	1770
Stone	800	4.71	2.7%	810
Steel Fiber	100	0.32		100
Air (6 %)	-	1.62		-
Water (43gal)	360	3.77		250
Total	3835	27.13		3835

Admixtures		Manufacturer/Type	Break Data	
AEA	oz./cwt		7-day	psi
WRA	oz./cwt		28-day	psi
	oz./cwt		28-day	psi
	oz./cwt		Other	psi

Shotcrete Data

Shotcrete Temperature: Air Temperature: W/C Ratio 0.45

Percent Coarse Aggregate: 32 Slump: 2½ Air Content: 7%

Bottom Headings

SHOTCRETE MIX DESIGNS

Project: Marian Diversion Contractor: Granetto/Incisa Date: 1/24/91

Design strength: 4000psi Mix Design No.: SFG8 Supplier: Mountain construction Concrete Division

Material	Source	Specific Gravity x 62.4
Cement	Davis	Bulk Sp = 3.15 x 62.4
Fly Ash	[illegible]	Bulk Sp = [illegible] x 62.4
Micro Silica		x 62.4
Sand	Wildwater Aggregate	Bulk Sp = 2.46 x 62.4
Stone	Kelly + Memphis	Bulk Sp = 2.72 x 62.4
Steel Fiber	Novocon	Bulk Sp = 7.3 x 62.4

Material	Weight per C. Y.	Solid Volume	% Moisture	Actual Weight
Cement	750	3.82		
Fly Ash	100	.70		
Micro Silica	—	—		
Sand	1600	9.64		
Stone	1100	5.48		
Steel Fiber	105	0.22		
Air (6 %)	—	1.62		
Water (35gal)	297	4.67		
Total	3942	27.15		

Admixtures		Manufacturer/Type	Test Panel No.
AEA	oz./cwt		
WRA	oz./cwt		
	oz./cwt		
	oz./cwt		

Shotcrete Data	

Concrete Temperature: Air Temperature: W/C Ratio:

Percent Coarse Aggregate: Slump: Air Content:

8.7.2 Shotcrete Problems. The fall-out of wet shotcrete from the tunnel crown presented a safety hazard and resulted in much wasted shotcrete. The contractor brought in several consultants in an effort to solve this problem. Changes suggested by representatives of product manufacturers and the American Concrete Institute did not produce significant improvement.

Shotcrete consultant Mr. Neil McAskill of HBT AGRA Limited in Burnaby, British Columbia visited the project to observe the entire shotcrete operation and try to determine the cause of shotcrete fallout. Tests indicated that the initial set was taking as long as one hour and 15 minutes. One of Mr. McAskill's suggestions was to change accelerators. The contractor switched from Accela-Set II Liquid to QSL-100. With QSL-100 the shotcrete began to take its initial set in 10 to 15 minutes. Shotcrete was applied in two-inch layers, waiting about fifteen minutes between applications. These changes greatly reduced fall-out and produced a smoother finished shotcrete surface.

8.8 Water Occurrance and Drainage Provisions. Groundwater occurrence was limited to small seeps from joints and bedding planes, and to intermittent flows through fractures in response to rainfall. Most of the water encountered in the

tunnels was a by-product of construction activities - dust control sprays on the roadheaders and washing of rock surfaces before shotcrete application. Surface runoff entered the tunnels from the upstream portal area and was allowed to flow to the downstream portals where it was directed to a sediment pond. When necessary to comply with state regulations, water was treated to remove suspended solids before being pumped into Clover Fork.

Water pressure tests conducted during tunnel design showed little or no take in the tunnel zones. No significant groundwater flows were anticipated and none were encountered during construction.

8.9 Instrumentation. The Corps of Engineers installed eight multiple-position borehole extensometers (MPBX's) and an observation well (OW) on Ivy Hill above the tunnels before construction began. The contractor installed single-position borehole extensometers (SPBX's), tape extensometer (TX) anchor points, and load cells. Some of the instruments were grouped in the following arrays, at five locations in the first 1,000 feet of tunneling:

1. Two rock bolt load cells (one in the crown and one in the haunch).
2. Four TX anchor points (one at each side of the tunnel at spring line and two in the haunch). One of these arrays coincided with the location of MPBX-8. TX anchor points were also installed at the other MPBX locations, and at six other selected locations.
3. Six SPBX's, two each in lengths of one foot, five feet, and ten feet (three in the crown and three in the haunch).

Instrument Array Locations

Array	Tunnel	Station	Array	Tunnel	Station
A	1	10+77	J	3	22+11
B	1	13+67	K	3	11+36
C	1	15+98	L	2	26+52
D	2	11+26	M	4	13+82
E	1	18+68	N	4	15+97
F	2	15+33	O	4	19+23
G	1	25+55	P	4	23+96
H	1	9+95	Q	4	27+37
I	3	18+23	R	4	29+05

Arrays A through E were full instrumentation arrays with load cells, SPBX's, and five point TX's. Arrays F through R had 3-point TX's only. Tunnel instrumentation details are included in Appendix I.

8.9.1 Load Cells. Fifty-ton capacity electrical resistance strain gage type load cells, manufactured by Slope Indicator Company, were installed on ten tunnel bolts to

monitor long term performance of the bolt anchorage system and any increases in load which occurred because of volume changes in the rock surrounding the tunnels. Only the fast-set resin bond zone cartridges were used in load cell installations.

Load cells were read immediately after installation, daily for the first 60 days after installation and while tunnel excavation was within 80 feet of the load cell, and weekly thereafter for the duration of all tunnel excavation. Load cell bolts were locked off at loads ranging from about 1½ to 6 kips, the load created by tightening the nut with a pneumatic impact wrench. Tunnel load cells indicated cumulative increases up to about 1½ kips during their monitoring period. Upon completion of tunnel excavation, load cells were removed, the annular space filled with cement grout, and the area covered with shotcrete.

Most of the load cells performed very well for the life project. The major problem was with occasional wet connections which produced erroneously high readings.

8.9.2 Multiple-Position Borehole Extensometers. The Corps of Engineers installed eight multiple-position borehole extensometers, each having five anchor points, to monitor displacement during construction. Installations were as shown on PLATES I-1 and I-2.

The initial readings were made before tunnel excavation began. Reading frequency was daily when tunnel excavation was within 300 feet of the instrument, three times per shift (four times in a 24 hour period) when tunnel excavation was within 50 feet of the instrument, and weekly thereafter. Displacements, measured to the thousandth of an inch, were graphed to illustrate changes from the initial reading. The contractor was required to provide immediate notification if displacements exceeded the following:

Anchor No.	Displacement @100%	Displacement @130%	Displacement @ 160%	Displacement @190%
6	0.247 in.	0.321 in.	0.395 in.	0.469 in.
5	0.217 in.	0.282 in.	0.347 in.	0.412 in.
4	0.177 in.	0.230 in.	0.283 in.	0.336 in.
3	0.125 in.	0.162 in.	0.200 in.	0.237 in.
2	0.090 in.	0.117 in.	0.144 in.	0.171 in.

The MPBX's however, showed very little movement throughout construction, and never exceeded the notification level. Readings generally remained stable as the tunnel headings advanced past them. Displacements ranging from +0.1 to -0.09 inches were indicated. The lowest anchors should have shown the greatest displacements, though this was not always the case. Questionable data is indicated when higher anchors show more displacement than lower ones, and in cases of negative displacement. MPBX graphs are included in Appendix I, PLATES I-12 through I-23. Monitoring of MPBX's was discontinued upon

completion of tunnel excavation. The above ground portions were dismantled in February 1992.

8.9.3 Single-Position Borehole Extensometers. In each array, two anchors were set at one foot, two at five feet, and two at ten feet depths. SPBX's were read immediately after installation, daily for the first 60 days and while excavation was within 80 feet of the instrument, and weekly thereafter for the duration of all tunnel excavation.

The contractor was required to provide immediate notification if displacements exceeded the following:

Anchor Embedded	Displacement @ 100%	Displacement @130%	Displacement @160%	Displacement @190%
1 ft.	0.267 in.	0.347 in.	0.427 in.	0.507 in.
5 ft.	0.217 in.	0.282 in.	0.347 in.	0.412 in.
10 ft.	0.177 in.	0.230 in.	0.283 in.	0.336 in.

Generally the deeper anchors should have shown the greatest displacements, though this was not always true. The SPBX readings ranged from +0.125 to -0.05 inches and never exceeded the notification level. Repeatability of the readings varied by about 0.005 inches. Abrupt changes and negative deflections indicate readings of questionable accuracy. SPBX graphs are included in Appendix I, PLATES I-41 through I-48.

Even simple mechanical instruments are subject to providing questionable and erroneous readings. Review of the instrumentation graphs indicates that the SPBX readings were the most erratic. The fluctuations shown on these graphs probably reflect the degree of accuracy of the depth gauge used to measure these instruments.

8.9.4 Tape Extensometers. Tape extensometers were read immediately after installation, weekly for the first 60 days and while excavation was within 80 feet, and as directed thereafter. Measured TX deflections generally ranged from +.025 to -.02 feet, with no discernable pattern to the changes. Tape extensometer graphs are included in Appendix I, PLATES I-32 through I-40. Tape extensometer anchors planned for installation on centerline in the crown of the tunnels were relocated, to provide clearance for the 60-inch diameter tunnel ventilation line.

8.10 Foundation Mapping and Approval Process. All tunnel surfaces were inspected and mapped by a Corps of Engineers geologist. Preliminary inspections were made immediately after exposure to determine if additional rock bolts and drain holes were needed. A geologist re-inspected and mapped the rock surfaces after they were washed and just prior to shotcrete application. Final foundation approval was given before shotcrete was applied. Mapping was as described by Engineer Technical Letter No. 1110-1-37, "Geologic Mapping of Tunnels

and Shafts by the Full Periphery Method." Mylar base maps were prepared in advance. Using a scale of one inch equals ten feet, each sheet represents 50 linear feet of tunnel. Tunnel maps are included in Appendix D.

8.11 Possible Future Problems and Recommended Observations. The only anticipated problem is the possibility of shotcrete cracking near the portals. Very little seepage was observed during construction. That which did occur was located along bedding planes and joints near the portal areas. Since these areas are more exposed to outside temperatures, some freezing and cracking of shotcrete could occur.

TUNNEL EXCAVATION METHODS AND DATES

Tunnel No.	Heading	Excavation Method	Station From		Station To	Dates From	Dates To
1	Top	Paurat	9+80	-	30+39	9-04-90	3-19-91
	Bottom	Paurat	9+80	-	10+51	4-13-91	4-14-91
		Blasting	10+51	-	30+39	4-29-91	6-20-91
		Trimming w/Dosco	9+80	-	30+39	8-16-91	11-21-91
2	Top	Dosco	10+48	-	10+71	9-04-90	9-10-90
		Dosco	10+71	-	10+96	9-19-90	9-22-90
		Dosco	10+96	-	25+38	11-12-90	8-14-91
		Paurat	25+38	-	30+24	8-15-91	9-20-91
	Bottom	Paurat	10+48	-	11+75	9-26-91	10-01-91
		Blasting	11+75	-	30+24	10-02-91	12-02-91
		Trimming w/Dosco	11+75	-	30+24	11-21-91	2-27-92
3	Top	Dosco	11+16	-	11+59	9-25-90	10-04-90
		Dosco	11+59	-	12+20	10-17-90	10-26-90
		Paurat	12+20	-	14+16	4-02-91	4-13-91
		Paurat	14+16	-	30+13	4-15-91	8-08-91
	Bottom	Paurat	11+18	-	11+81	8-12-91	8-13-91
		Blasting	11+81	-	30+13	8-19-91	9-25-91
		Trimming w/Dosco	11+81	-	30+13	2-28-92	4-17-92
4	Top	Dosco	11+69	-	11+91	9-11-90	9-17-90
		Dosco	11+91	-	12+20	10-05-90	10-16-90
		Dosco	12+20	-	12+72	10-26-90	11-07-90
		Paurat	12+72	-	30+05	10-02-91	3-23-92
	Bottom	Paurat	11+69	-	11+83	3-31-92	3-31-92
		Blasting	11+83	-	30+05	4-01-92	5-01-92
		Trimming w/Paurat	11+69	-	30+05	5-04-92	6-26-92





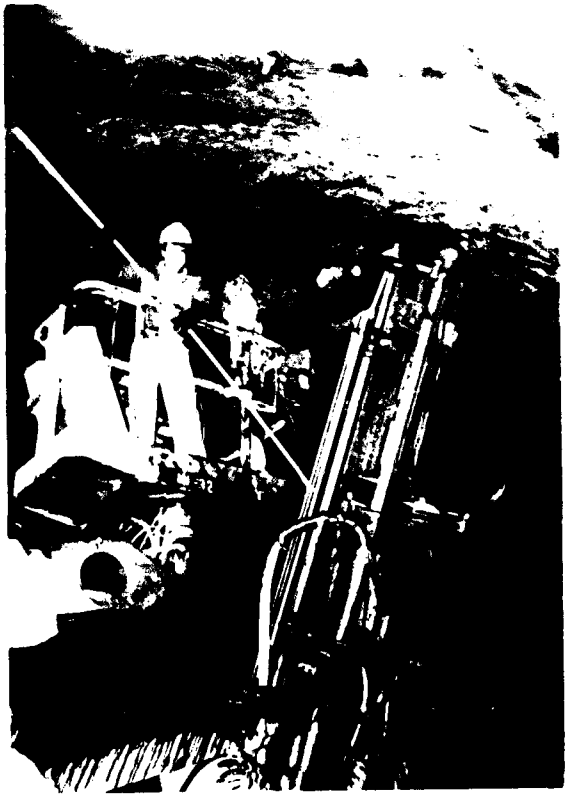


...m' ...ay, very fine grain sandstone beds in.
...nnel 4, station 22+00. February 1992



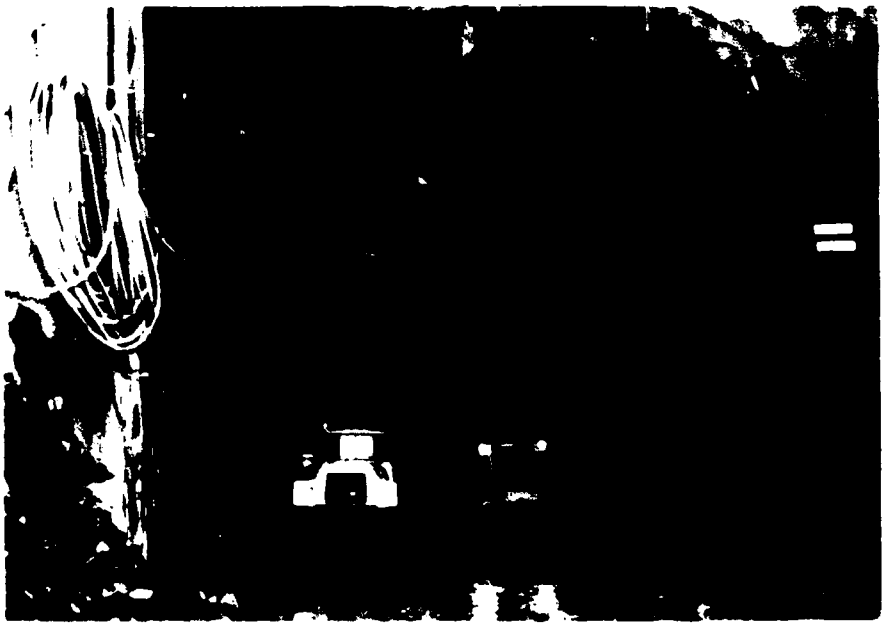
...m' ... ...-meter cutting tunnel 1 bell mouth.
20 March 19...



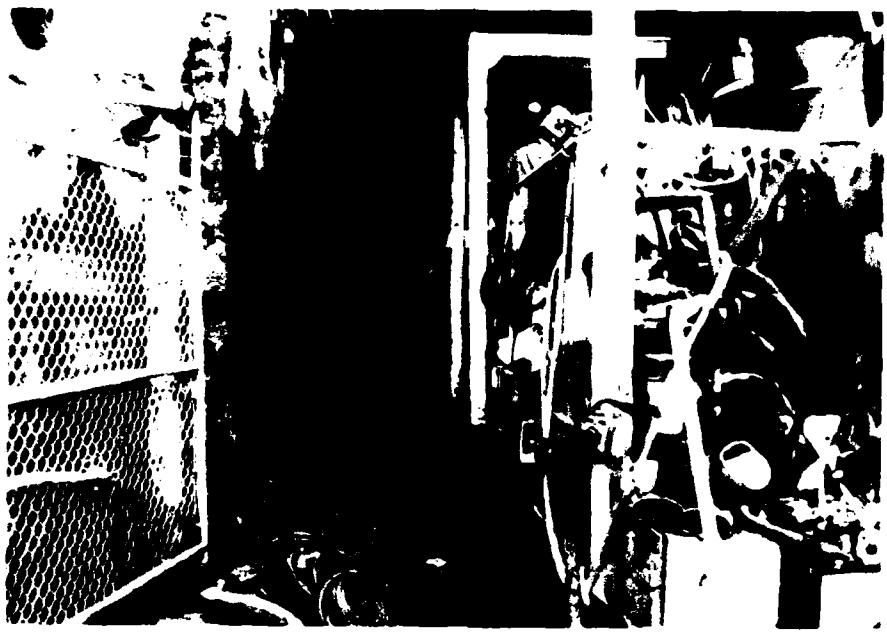




[illegible] after blasting in tunnel [illegible], sta [illegible]
May [illegible]



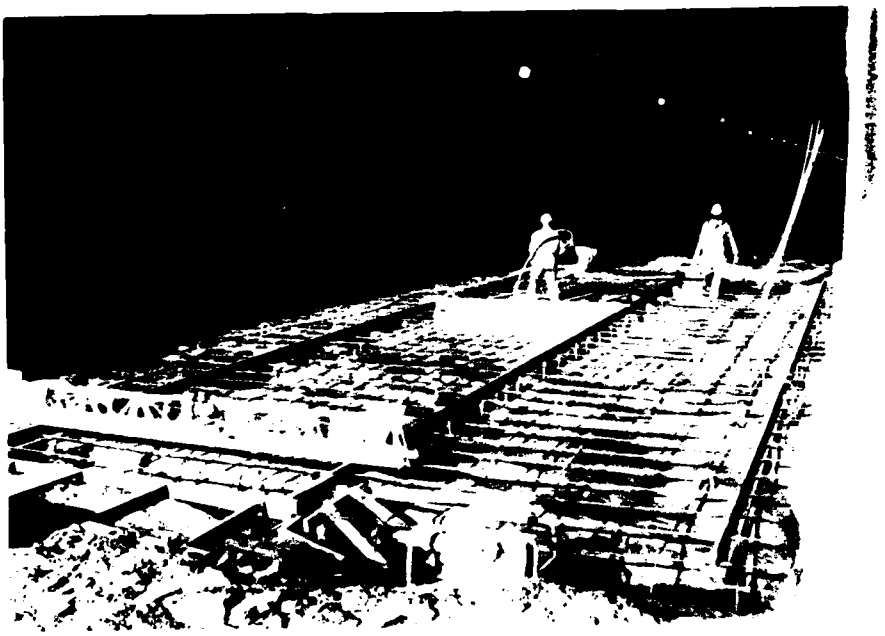
[illegible] under loading mark from blast in tunnel
April [illegible]



View from behind Dosco roadheader, preparing to trim bottom heading in tunnel 1. August 199.



Dosco roadheader trimming left side of tunnel 1. 20 November 199



9. Diversion Structure.

Located immediately adjacent to and downstream of the upstream portals, the diversion structure serves to divert flows of the Clover Fork from the natural river channel into the four tunnels. With a total length of about 710 feet, the structure is comprised of 580 feet of embankment with a slurry trench cutoff along it's upstream toe, 66 feet of concrete floodwall, and a 50-feet-long closure structure at the railroad crossing. Under a contract modification, a sheet pile seepage cut-off installed at the right abutment. This is described in section 9.2.8. Construction of the diversion embankment, slurry trench, floodwall and closure structure are discussed individually in this report.

The diversion structure was completed in two phases. The floodwall, railroad closure structure, and the embankment and slurry trench from station 7+25 to station 4+55 were constructed first, while the tunnels were being excavated. Phase 1 stopped at station 4+55 in order to maintain an eighty feet wide floodway along Clover Fork. Phase 2, from station 4+55 across the river channel, was constructed after Clover Fork had been diverted through the tunnels.

9.1 Embankment. Longitudinally, the crest elevation of the embankment is sloped, from elevation 1211.8 on the right abutment to elevation 1212.1 at the tie-in with the floodwall. With an average foundation elevation of 1182.0, the embankment has an average height of 30 feet. Embankment slopes are 1V:3H for both the upstream and downstream sides, and the crest width is ten feet. The embankment was constructed primarily of material from the tunnel excavation.

The embankment was made more seepage resistant by a covering of 40-mils-thick PolyFlex high density polyethylene geomembrane. Covering this geomembrane is a minimum two-feet-thick layer of fine (minus three-inch) tunnel cuttings and a one-foot-thick layer of topsoil. The geomembrane was anchored at the bottom of the slurry trench on the upstream side, extended up and over the embankment, and was buried in an anchor trench ten feet beyond the downstream toe of the embankment.

9.1.1 Excavation Grades. Specifications required at least one foot of stripping below original ground level in the flood plain, and at least three feet of excavation across the river channel. To remove unsuitable material, an additional 1½ to 4 feet of excavation was required in the flood plain, on the south side of the river.

9.1.2 Engineering Characteristics of Foundation Materials. The major portion of the embankment is founded upon floodplain deposits up to approximately 20 feet thick. The soils are mainly alluvial silts, sands, and gravels. The alluvium typically has a very loose to loose, silty sand

layer immediately below the surface that ranges from 3.0 to 10.4 feet in thickness, with an average thickness of 5.5 feet. Below this silty sand layer the soil grades to a sandy gravel which ranges from 7.0 to 9.7 feet in thickness. Below this gravel layer lies the siltstone bedrock. Preconstruction drive sample investigations recovered an average of 2.1 feet of siltstone before refusal was met. This is indicative of the depth and degree of weathering of the bedrock surface. PLATES E-5 and E-6 present cross-sections through the embankment foundation area, and include boring logs.

During design, permeabilities of the embankment and foundation materials were assumed as shown below:

Material	Horizontal Permeability cm/sec	Vertical Permeability cm/sec
Embankment	1×10^{-1}	1×10^{-2}
Silts and Silty Sands	1×10^{-3}	1×10^{-4}
Gravel	1×10^{-2}	1×10^{-3}

A soil-bentonite slurry trench cutoff, with a specified maximum permeability of 1×10^{-6} cm/second, was installed along the upstream toe of the embankment. Slurry trench construction is discussed in Section 9.2 of this report.

9.1.3 Drainage Provisions. An eight-inch diameter perforated polyethylene pipe was installed along the downstream toe of the embankment, sloping towards the existing channel. Mirafi polypropylene geotextile and Mirafi Miradrain 6000 geocomposite sheets were installed just beneath the impervious geomembrane on the downstream side of the embankment. The geotextile and geocomposite are tied into the downstream toe drain.

9.1.4 Dewatering Requirements. The ground water level was about the same as nearby Clover Fork, elevation 1172.5. This was about six feet below the deepest excavation for foundation preparation and dewatering was not necessary.

9.1.5 Embankment Phase 1 (Station 7+25 to 4+55) - Construction Summary. The Harlan Gas Road was closed on 10 April 1991 to start construction of the first phase of the diversion embankment and associated structures. A water line relocation for the Black Mountain Utility District was completed on 3 May. Topsoil stripping and excavation of unsuitable foundation material began on 18 April. Foundation soils were compacted and about seven feet of embankment fill was placed in building up to the slurry trench working surface, about elevation 1184. Construction of the first

phase of the slurry trench started on 18 October and ended on 18 November 1991. Uninterrupted placement of embankment fill resumed on 15 January and the first phase of the embankment was complete by the end of March 1992.

Two relocated water lines owned by the Black Mountain Utilities District extend beneath the diversion dam in an upstream to downstream direction, adjacent and parallel to the old Harlan Gas Road. Water line locations are shown on Plate E-12. The pipe trench was backfilled with two feet of #8 gravel and tunnel roadheader cuttings. Seepage cutoff was provided by a geomembrane boot installed around the pipes and welded to a surrounding geomembrane liner, and by the soil-bentonite slurry trench located along the upstream toe of the embankment.

Topsoil was stripped using a D8K dozer. The cleaner topsoil was stockpiled nearby for later use on the embankment. The more contaminated material was hauled to the H-2 disposal area. Overexcavation was required to remove a 1½ to 4-feet thick layer of unsuitable organic material and trash across the entire embankment foundation area between Clover Fork and the Harlan Gas Road. This area was reportedly used as a city landfill in the past. After stripping the unsuitable material, the entire surface of the embankment foundation area was compacted by six passes of a 15-ton vibratory roller.

Rock excavated from the tunnels, having a maximum size of 12-inches, was used as fill for construction of the diversion embankment. Shot rock from the bottom heading of tunnel 1 was used for the first lift. Subsequent lifts utilized shot rock from tunnel 1 and roadheader cuttings from tunnels 2 and 3. Rockfill was spread into one-foot layers using a D8K dozer, then compacted by six passes of a 15-ton vibratory roller. Any oversize rock fragments were reduced to minus 12-inches as the material broke down under the leveling and compaction processes. Tunnel cuttings which could not be placed directly on the embankment were stockpiled for later use.

Up to eight feet of rockfill was placed in building up to elevation 1187-1189, the working level for slurry trench construction. The slurry trench working surface was completed in June, 1991. Fill placement was interrupted to allow construction of the first phase of the slurry trench and work on the railroad closure structure.

Uninterrupted placement and compaction of embankment fill resumed on 15 January, 1992 from the north side of the railroad closure structure to station 4+55. It was noted that roadheader cuttings pumped under equipment load if placed too wet, behaving more like soil than rock. The Corps of Engineers tested in-place embankment fill. Assuming a standard density of 167.0 lbs/ft^3 (the density of siltstone),

compaction of about 82% was obtained with six passes of the vibratory roller. Optimum moisture content was about 5%. A test data sheet which indicates densities obtained with varying moisture contents and compactive efforts is included in Appendix E, PLATE E-11.

Moisture was controlled by placing only the drier Paurat roadheader cuttings directly on the embankment. The wetter Dosco cuttings were stockpiled. Rain caused delays in embankment fill placement and compaction.

Placement of fill between the railroad closure structure and embankment station 4+55 continued throughout February. By the end of March 1992, the first section of the diversion embankment had been topped out, except for final filling around the closure structure, and plating with topsoil was in progress. Construction of the remaining section of embankment across Clover Fork awaited completion of the slurry trench which, in turn, was dependent upon diversion of Clover Fork through the tunnels.

9.1.6 Embankment Phase 2 (Station 4+55 to 1+00) - Construction Summary. Clover Fork was diverted through the tunnels on 21 September, 1992. The remainder of the embankment foundation was stripped, and up to six feet of weathered siltstone was removed in the Clover Fork channel, down to elevation 1162-1163. Embankment fill was then placed up to elevation 1186 to provide a working surface for completion of the slurry trench. Phase 2 of the slurry trench was constructed in October 1992. Embankment fill placement resumed immediately thereafter and was completed in December 1992.

9.1.7 Instrumentation. No instrumentation was installed in the diversion structure.

9.1.8 Possible Future Problems and Recommended Observations. Erosion of topsoil and fill could expose the geomembrane, leading to its deterioration. Vehicular traffic on the embankment would aggravate embankment erosion problems.

9.2 Slurry Trench. To provide a barrier to foundation seepage, a slurry trench cutoff was constructed along the upstream toe of the embankment. The trench extends downward from the base of the embankment and is embedded two feet into the siltstone bedrock. The trench has vertical sidewalls and is a minimum of 36-inches wide. An impervious geomembrane liner was installed on the upstream side and the trench filled with soil-bentonite backfill. The total depth of the slurry trench is about twenty feet.

The slurry trench was constructed in two phases. Phase I began at station 7+25 near the railroad tracks and extended toward the river to station 4+55. Phase 1 stopped at station

4+55 in order to maintain an eighty-feet-wide floodway along Clover Fork. Phase 2, from station 4+55 across the river channel to station 1+65 was constructed after Clover Fork had been diverted through the tunnels.

9.2.1 Construction Equipment - Phase 1. The first section of the trench was excavated by a track mounted Link Belt LS-5800 backhoe equipped with a 46-inch or a 36-inch wide bucket which was capable of excavating both the overburden and bedrock. This backhoe was also used to lower the geomembrane sheets into the trench. A Caterpillar D-8 dozer excavated backfill material from it's borrow site and a Caterpillar 950B rubber tired endloader hauled it from the borrow site to the backfill mixing area. A Dresser TD-15C dozer mixed the soil-bentonite backfill and pushed it into the trench.

9.2.2 Construction Equipment - Phase 2. A Komatsu PC300LC track mounted backhoe was used to excavate the second phase of the trench. This backhoe was smaller and less effective than the Link Belt LS-5800 used during Phase 1. A Komatsu D63E-1 dozer mixed the soil-bentonite backfill and pushed it into the trench.

9.2.3 Excavation Grades - Design and As-Built. The design minimum elevation of the slurry trench working surface was 1184 across the Clover Fork channel, and 1186 elsewhere, as shown on PLATE E-1. The slurry trench was constructed below a work surface ranging from elevation 1187.1 to 1184.8. PLATE E-2 shows as-built elevations for the entire slurry trench.

The slurry trench was constructed as designed, with the following exceptions:

1) The geomembrane liner was installed on the upstream side of the trench.
2) A sheet pile seepage cutoff was added in the right abutment area, from station 1+80 to station 0+15. See Section 9.2.8 for details of this modification.

9.2.4 Slurry. To support the walls of the trench during excavation, the trench was kept filled with a water-bentonite slurry. Slurry was mixed in a slurry batch plant to produce a colloidal suspension of bentonite in water. The specifications required that water losses not be greater than 20 cubic centimeters as determined by API Test 13A, Section 5. This criteria was used to determine whether water softening agents were needed in the slurry mixture. Based upon passing test results, water softeners were not used.

9.2.5 Geomembrane Liner. A 30-mils-thick Polyflex high density polyethylene geomembrane liner was installed the full depth of the slurry trench. To seal the geomembrane around the relocated water pipes a geomembrane "boot" was

placed around the pipes, secured with a band clamp. The base of the boot was welded to overlapping sheets of geomembrane placed flat against the trench wall. Geomembrane installation is described in Sections 9.2.7 and 9.2.8.

9.2.6 Backfill. Specifications for the soil-bentonite backfill required an average permeability of no greater than 1 x 10^{-6} centimeters per second, and a bentonite content of at least four per cent. As-built permeabilities were much lower than required, ranging from 3.1 x 10^{-9} to 96.1 x 10^{-9} centimeters per second.

The contractor's permeability testing was done by Soil Testing Engineers, Inc. of Baton Rouge, Louisiana. The Corps of Engineers also tested samples at it's Ohio River Division laboratory. Backfill permeability test results are summarized below.

Trench Station	Permeability	Tested By
6+70	9.4 x 10^{-9}	Contractor
5+90	7.8 x 10^{-9}	Contractor
4+85	4.3 x 10^{-9}	Contractor
6+80 - 5+80	15.1 x 10^{-9}	CE
6+70	3.1 x 10^{-9}	CE
5+90	96.1 x 10^{-9}	CE
4+85	16.8 x 10^{-9}	CE

Backfill was prepared by mixing suitable material excavated from the trench (estimated to be 20% of the total excavated quantity), borrow material (silty sand), bentonite powder, and a slurry composed of bentonite powder and Harlan city water. A three to six-inch slump was specified. For the first phase the contractor elected to use a six-inch slump. For the second phase a three-inch slump was used with improved results. The lower slump allowed greater control over the movement of the advancing backfill toe, and it's position relative to the geomembrane sheets.

9.2.6.1 Backfill Borrow Site - Phase 1.
Several backhoe pits were dug in the alluvium upstream of the embankment and adjacent to Clover Fork to locate the best borrow site for slurry trench backfill material. Gradation test results indicated that, although on the fine side of the specification requirement, suitable backfill material was available. This silty sand occurred in a four feet thickness near the ground surface. Over-size rock and debris were removed by hand. Gradation results are included in Appendix E, PLATES E-9 and E-10.

9.2.6.2 Backfill Borrow Site - Phase 2.
Eight- hundred cubic yards of material, which had been excavated from beneath the old Highway 38, was stockpiled for use in completing the slurry trench backfill.

9.2.7 Slurry Trench, Phase 1 (Station 7+25 to 4+55) - Construction Summary. Phase 1 trench excavation began on 18 October and backfilling was completed on 18 November 1991. The subcontractor had originally estimated about two weeks, but repair of damaged water lines extended construction time. Excavation began alongside the railroad embankment and progressed toward the river. This provided the excavator more solid ground on which to maneuver, and prevented interference with railroad traffic.

The LinkBelt LS-5800 backhoe used a standard 46-inch wide bucket to excavate the trench. A surveyor's level was set up to provide vertical control. Stakes, offset well away from the work area, were used for horizontal control. After breaking a bucket tooth on 25 October, the 46-inch wide bucket was replaced with a 36-inch wide bucket. The replacement bucket was also equipped with ripping teeth mounted on the outside, and proved more efficient at excavating in rock.

Prior to the placement of geomembrane and eventual backfilling, the subcontractor sounded the trench to verify that it was clear and free of sediment. When sounding revealed that sediment had accumulated, the backhoe was used to clean the trench before backfilling began.

Geomembrane placement began on 29 October. Placing the geomembrane sheets on the upstream side of the trench allowed the exposed flap of geomembrane to lie clear of the soil-bentonite backfill mixing area which was located on the downstream side of the trench. Specially notched sheets of geomembrane were placed around water lines which crossed the trench. Placement of the material was difficult, as the geomembrane tended to be buoyant in the slurry. The bottom edge had to be forced into place despite re-bar woven into the geomembrane bottom to act as a sinker. Once backfilling began, the six-inch slump backfill was expected to assume a 1V:8H slope in the trench. This was later measured and was found to range from about 1V:8H to 1V:10H. For this reason over-lapping geomembrane sheets had to be installed well ahead of the backfill operations. Backfilling began at a 1V:1H lead-off trench near the railroad tracks. As the advancing backfill flowed past the geomembrane sheets, the bottom was dragged laterally along with it. Upper edges pulled loose from the top of the trench, and the geomembrane sagged under the weight of the backfill material. Sheets of geomembrane were staked on their upper edge, and additional sheets placed to cover the gaps which opened as the original sheets were dragged apart. It was apparent that a better method of geomembrane installation would have to be devised.

Backfilling of the freshly-excavated trench was completed to station 4+55 on 2 November. The backfill was excavated to expose the water lines where they crossed through the trench. The water lines were exposed and found to have been damaged

by the backhoe during excavation of the slurry trench. The water lines were repaired and the trench subcontractor began installation of the pipe boot. A backing sheet of geomembrane was placed under the pipes, slit at the pipe locations, and pulled up and around the water lines. The bottom of this backing sheet of geomembrane was driven to rock using angle iron attached to the bottom edge of the material with welded sockets, and steel pipes inserted into the sockets as push rods. A backhoe then pushed the geomembrane sheet to the bottom of the trench. The geomembrane boot was welded to this backing sheet. Around the pipes, the geomembrane was gathered and secured with two hose-type clamps on each pipe. Fresh backfill material was mixed, and the trench completed on 16 November. A layer of filter fabric was placed to cover the exposed top of slurry trench backfill. Fill placement resumed, covering the slurry trench on 25 November.

9.2.8 Slurry Trench, Phase 2 (Station 1+70 to 4+55) - Construction Summary. In June 1992, the contractor drilled four air-track holes to determine depth to bedrock at the northwest end of the trench, in the right abutment. Indications were that the top of rock surface was much lower than estimated. A Corps of Engineers crew drilled three additional SPT/core holes which confirmed the preliminary findings. Drill logs for these three holes are included on PLATE E-7.

The contract was modified to extend the foundation seepage cutoff further into the right abutment. A sheet pile cutoff was added, extending from station 1+70 to station 0+15, the centerline of the relocated Highway 38. After the slurry trench was completed, the piling cutoff was extended an additional 10 feet into the slurry trench, to station 1+80. See PLATES E-2 and E-3.

Phase 2 slurry trench excavation began on 22 October and backfilling was completed by 31 October 1992. A much improved method was used to install the geomembrane liner. Geomembrane sheets were attached to rigid frames constructed of four-inch pipes and six-inch steel I-beams. Frames and attached geomembrane sheets were installed in 30 feet high and 35 feet wide sections. Four frames were used, each frame installed to lap about four feet behind the previously placed frame. When backfill reached a depth of ten feet along a section, a frame was pulled, leaving the geomembrane sheet in the trench.

Excavation for the two feet embedment into rock was slow, about 40 linear feet per day. The upper six feet of weathered rock had been removed before fill placement began. The rock which remained was difficult to excavate with a backhoe.

9.3 Floodwall and Closure Structure. Floodwalls and a railroad closure structure were constructed at the left abutment of the diversion embankment. These structures are founded on HP 12 x 74 piles driven through artificial fill and alluvium, to refusal in the siltstone bedrock. The closure structure has a single-leaf swing gate with a span of 30 feet and a height of 14.25 feet. The floodwall consists of a 12-feet long section of T-wall on each side of the closure structure and 42 feet of I-wall. A sheet pile seepage cutoff was driven to refusal in bedrock beneath these structures.

9.3.1 Construction Summary. An alternate access road to nearby homes was constructed on the landward side of the railroad right-of-way in December 1991. This replaced the existing road which was blocked by the railroad closure structure. H-piles and sheet piles were driven on both sides of and under the railroad tracks in January 1992. The railroad was out of service for about ten hours while sections of the track were removed on 22 January. Sheet piles 42 and 43 failed to go to refusal on the first attempt. Both these piles were pulled and were successfully driven to refusal on the second attempt. During pile driving operations a seismograph was set up ten feet from the corner of a nearby church, 75 feet from the pile driver. The highest recorded reading was 0.04 inches per second.

Pile driving hammer for sheet piling:

Model MKT-9B3
Ram Wt. 1600 lbs.
Stroke Rated-17 inch
Energy Rated 8750 Ft/lbs.
Speed Rated 145
Air Pressure 100

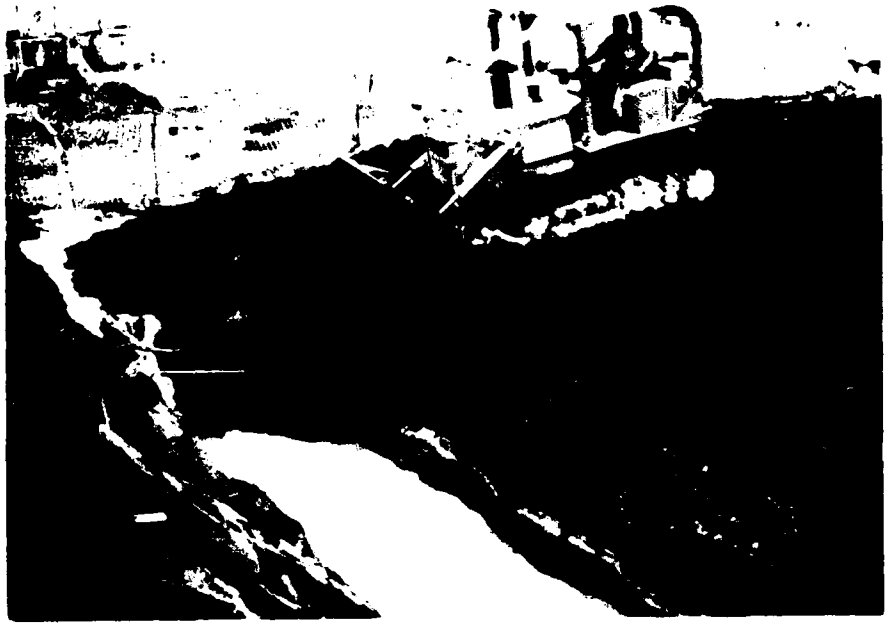
Pile driving hammer for H-piling:

Model Vulcan 506
Ram Wt. 6500 lbs.
Stroke Rated-48 inch
Energy Rated 26,000 Ft/lbs.
Speed Rated 52
Air Pressure 120

Closure structure footings were placed in February 1992. General details of the closure structure and floodwalls are shown on Plate F-2. Pile driving records are included on PLATE F-3.







Dozer pushing soil-bentonite backfill into 1V:1H lead-off trench. 31 October 1991



Backfilling phase 1 of the slurry trench. View looking toward right abutment. 31 October 1991





10. Highway 72 Bridge.

At the downstream portal area, Highway 72 was re-routed over a 450-feet-long bridge which spans Clover Fork as it exits the tunnels.

10.1 Abutments. Construction of the bridge abutments started in October 1990 and was completed in May 1991. The bridge abutments are supported by 14-inch structural steel H-piles driven through the overburden to refusal in bedrock. All piles were fitted with cast steel driving points furnished by Versabite Foundation Accessories of Matthews, North Carolina. Piles were driven to refusal, which was defined as "when measurable penetration under five blows of the approved hammer and system is one-quarter inch or less and where the pile tip is in bedrock and the installation is approved by the Contracting Officer."

London Bridge Company used a 60-ton Link-Belt 118 crane with a fixed lead system. The pile driver was a Vulcan model #506 single acting hammer with 6500 pound ram weight, 690 pound anvil weight, and a 48-inch stroke for 26,000 foot-pounds of energy. The hammer speed was 52 blows per minute with air pressure of 120 PSI. A 750-pound Vulcan pile driving cap and a 12-inch diameter by 2½-inch aluminum and Micarta cushion block were used.

Abutment 1 piles were driven in October 1990. Pile lengths ranged from about 16 to 30 feet. Tip elevations ranged from about 1147 to 1160, which is consistent with preconstruction exploratory boring top of rock data.

Abutment 2 pile driving began on 23 October 1990. Piles 11 and 43 hit an obstacle approximately 18 feet below the surface. The piles were skewed in opposite directions, suggesting that the obstruction lay between the piles. The angle of skew was within permissible limits, and no corrective action was necessary. Piles ranged from about 19 to 24 feet in length. Tip elevations ranged from about 1142 to 1146. Pile records are provided on PLATE G-2.

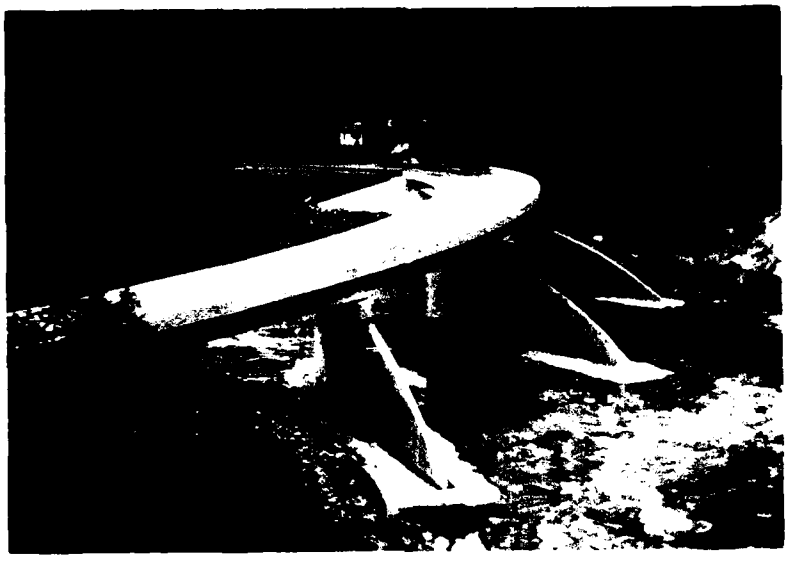
10.2 Piers.

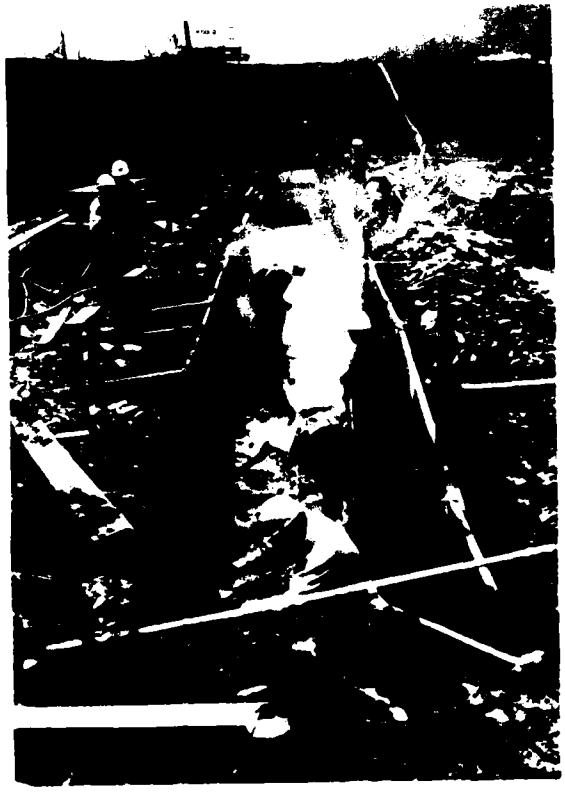
10.2.1 Pier 1. Excavation for pier 1 began on 21 November 1990. A D-8 dozer equipped with a single-tooth ripper was used to make the initial cut into rock. The trench was then trimmed to final dimensions using a backhoe and jackhammers. Rock samples were collected from the pier foundations and tested for slake durability, with test results ranging from 96.3% to 97.9%. Three five-feet-deep test holes confirmed rock competency. Contract modification 37 provided for a design change which was recommended by the bridge designer. The footing was expanded in size so that concrete would be in contact with the sides of the excavated trench.

10.2.2 Pier 2. A dike was built around the pier 2 excavation to control surface water. Excavation began on 29 January 1991 using a backhoe and jackhammers. The dozer and ripper were not used in order to reduce overbreakage similar to that which occurred on the pier 1 footing excavation. Slake-durability testing on rock sampled below pier 2 footing indicated an SDI of 97.95%. Three test holes drilled five feet into rock below the footing confirmed rock competency. The pier 2 footing was placed on 13 February.

10.2.3 Pier 3. Excavation of pier 3 foundation began on 9 February 1991. As on pier 2, only a backhoe and jackhammers were used. The pier footing was separated from the main channel of Clover Fork by an earthen berm. Seepage through the berm entered the excavation and required continuous pumping. Concrete was completed on 22 March.

Pre-stressed concrete I-beams for the bridge were placed during May 1991. Ivy Hill Road was re-opened to traffic on 23 August, permitting traffic to enter Harlan from the north side of Ivy Hill. The Highway 72 bridge was opened to traffic on 2 October 1991.





11. Highway 38 and Bridge.

11.1 Excavation Grades - Design and As-Built. In developing the 1V:1H slope at the top of the road cut, hard sandstone was encountered higher than expected in some areas. Where this occurred the slopes were changed from a 1V:1H dozer cut to a 2V:1H presplit cut. This necessitated the addition of an extra bench at the upper part of the slope so that the lower slopes could be constructed according to design. These changes increased excavation quantities.

Jointing runs approximately parallel to the road cut and in some areas the presplit blasts broke back to expose joint faces. Since there was no provision for rock bolting the road cut, and in many cases the rock was too fractured to be bolted effectively, loose rock was removed behind the design line. This also increased excavation quantities.

11.2 Overburden Excavation. Utility lines were relocated around the work area from October 1989 through January 1990. Overburden excavation began in March 1990. Excavation of the 1V:1H slope in overburden began in March and was essentially complete by the end of July 1990. Additional excavation is described in Section 11.2.2.

11.2.1 Methods and Equipment. Overburden was excavated using a Caterpillar D-8 dozer. A Caterpillar 977L endloader loaded material onto Euclid R50 dump trucks which hauled it to the H-2 disposal area.

11.2.2 Construction Summary, Problems, and Treatment. Between stations 67+50 and 69+00 organic material unsuitable for the road subgrade was overexcavated. The area was backfilled with rock from the upstream portal excavation.

In January 1991, overburden in a hollow at station 56+50 to 57+00 slid to the bottom of the excavated cut. Headward erosion reached to within eight feet of the project property boundary, and left remaining overburden on the slope excessively steep and prone to further sliding. Laying the slope back away from the cut would result in encroachment outside the project property boundary. The Pineville real estate office made arrangements to purchase this additional property. Excavation of slide material and laying back of the slope was completed in March 1991.

By April 1991 road cuts were excavated to grade on either side of the tunnel portals. Between stations 52+50 and 55+00, four to nine feet of unsuitable organic overburden material was overexcavated. The area was backfilled with shot rock, from the upstream portal excavation. A surface leveling course of tunnel roadheader cuttings was placed to complete the backfilling. Organic material, unsuitable for road subgrade, was also removed between stations 70+50 to 71+50. The overexcavated area, 15 feet wide and four feet

deep, was backfilled with tunnel cuttings. Other unsuitable material was removed by a cut 20 feet wide and three feet deep from station 68+75 to 70+00. Several large boulders were removed from the subgrade near abutment 1 in August 1991.

11.2.3 Disposition of Excavated Materials. Overburden from the highway 38 excavation was placed in the H-2 disposal area.

11.3 Rock Excavation. Blasting for the highway 38 relocation began near station 66+00 in March 1990.

11.3.1 Methods and Equipment. Presplit blasting methods were similar to those used at the downstream portal and at the upstream portal above elevation 1230. Holes were 3-inches in diameter, on 36-inch centers, and up to 30 feet deep. ⅞-inch diameter Detagel was initiated with electric blasting caps. In developing the cut-slopes, presplit lines ran approximately parallel to the existing ground surface only a short distance away. Firing the presplit line in a separate operation before the production blast disturbed the remaining rock to the extent that it was difficult to drill the production blast holes. If production holes were drilled before the presplit shot, holes were cut off and could not be loaded. For these reasons, the presplit and production blasts were usually fired in one operation, separated by millisecond delays.

11.3.2 Construction Problems and Treatment. Blasting broke back to expose joint planes where they intersected design slopes. Fractured rock and detached blocks were removed, leaving natural joint faces to form the finished slope in these areas. This backbreak added to over-runs in surface excavation quantities.

11.3.3 Disposition of Excavated Material. Rock from the highway 38 excavation was placed in the H-2 disposal area.

11.4 Rock Reinforcement. Reinforcement of the slopes was not required by the contract. Some rock bolts were installed as needed and paid at unit prices. Five 25-feet-long rock dowels were installed, from station 69+60 to 70+00 elevation 1330 to secure an overhanging sandstone block. A nearby utility pole and construction limits prevented removal of the entire block. Six rock bolts, three 10-feet long and three 15-feet long, were installed between stations 50+00 and 50+50 for support of a small overhang.

11.5 Bridge Foundation - Caisson Construction. Proposed caisson locations for the Highway 38 bridge were core drilled during March 1991. NX core holes were drilled through the approximate center of each caisson to a target depth of five feet below the proposed bottom. Augers

advanced the holes through overburden to top of rock where coring began. Cores were logged, photographed, and discarded. In some holes, a sample of core was taken for compressive strength testing. Test results are included in Section 4.2.4, "Investigations During Construction." Drilling logs are included in Appendix H, PLATES H-3 and H-4.

Drilling results on abutment 1 essentially confirmed the depth of the overburden/rock contact indicated in the plans. Abutment 2 results, however, revealed the overburden/rock contact in two holes to be substantially (14 to 18 feet) deeper than expected. Rock Quality Designations were also lower on several abutment 2 cores. Since some change in caisson design would probably be necessary, core holes were deepened so that at least 20 feet of rock was recovered, to a depth five feet below the anticipated base. Core drilling was completed on 26 March, 1991, and the results forwarded to the bridge designer.

The bridge abutment caissons were re-designed, with the most significant changes being:

- --Enlarge caissons A2-2 and A2-3 to 60-inches in diameter.
- --Add one 60-inch diameter caisson along the A2-1 to A2-4 row and change spacing of caissons in that row.
- --Enlarge caisson A1-1 to 60-inches in diameter.
- --Increase rock embedment length to a minimum of 15 feet for all 48-inch diameter caissons and 20 feet for 60-inch diameter caissons.

The revised drilled shaft notes, schedule, and layout are enclosed in Appendix H, PLATE H-2.

A Hughes LDH-70 drill rig arrived on site on 18 June and caisson hole drilling started on 24 June. Rock augering was slowed by occasional bands and beds up to 1½ feet thick, of very-fine-grained sandstone, sometimes descibed as coarse-grained siltstone. Drilling rates slowed to fractions of an inch per hour with very high auger tooth consumption. When this very hard rock was encountered, a 1350 pound drop hammer was used. The general procedure was to drop the hammer eight to ten times. Although not advancing the hole measurably, this would slightly fracture and roughen the rock surface, allowing the rock auger or core barrel to cut through it. A coring bit was sometimes used instead of the rock auger to provide additional cutting action around the margins of the hole. Once the very hard beds were penetrated, rock augering continued at normal rates of approximately one foot per hour.

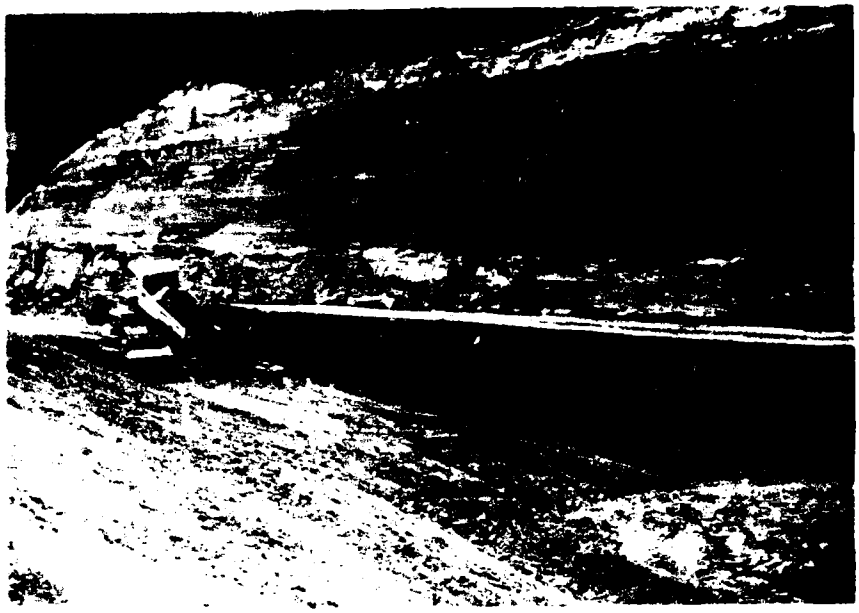
All completed caisson holes were proof tested by drilling a five-feet-deep jackhammer hole in the bottom. Proof testing of hole A2-5 revealed a void approximately one foot below the bottom. The caisson hole was deepened an additional 3.9 feet and re-inspected. A fracture, open 1.6 feet and oriented

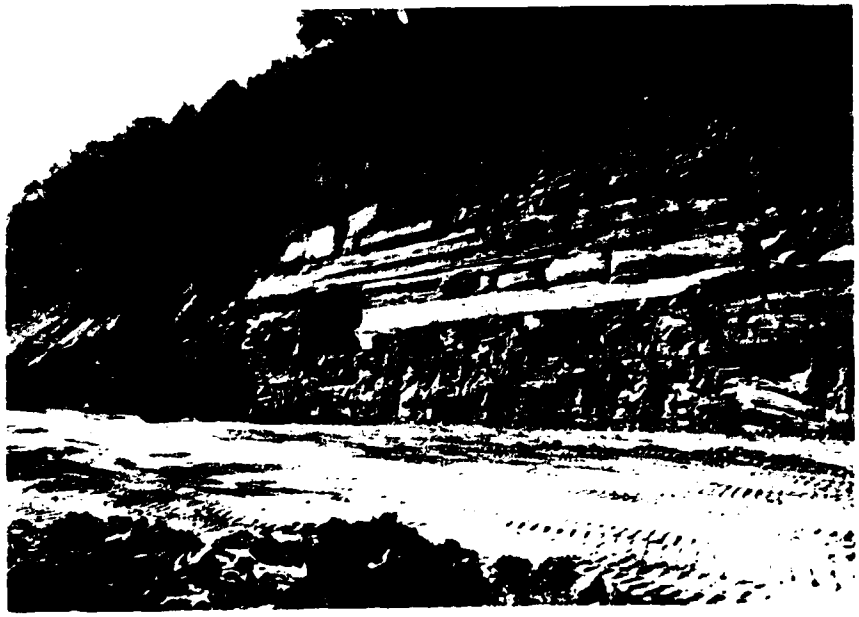
N20°E, 80°NW, was observed in the side of the hole. The wall rock and hole bottom beneath the fracture appeared to be competent with no evidence of further voids. Additional proof testing indicated good rock for a depth of five more feet. The open fracture was plugged to limit concrete flow to six inches inside the feature, and non-reinforced concrete was placed up to the original design bottom. Reinforcing steel was then placed in the hole, and concrete placed following normal procedures.

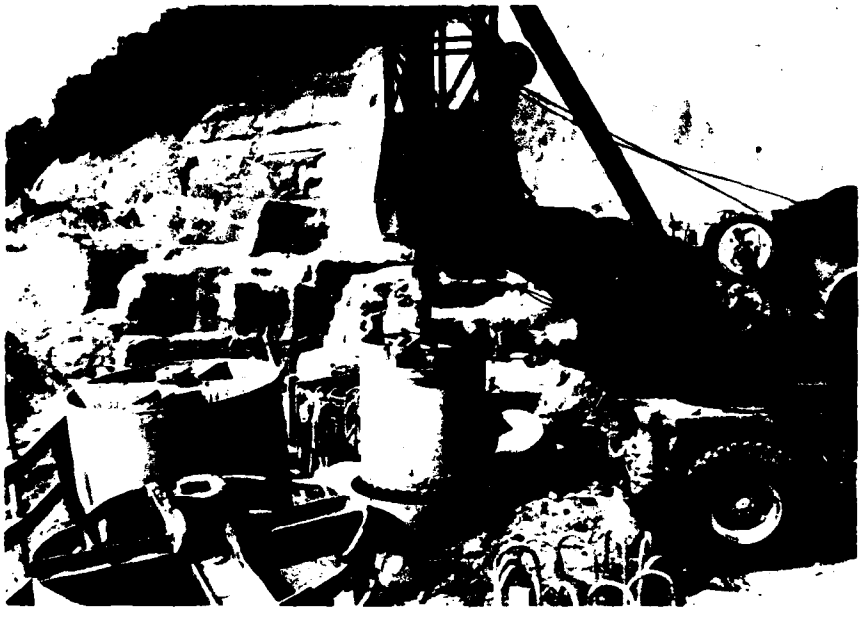
Caisson hole A2-4 was started on 15 August. Fill material around the collar of the hole caved-in and forced temporary abandonment of the drilling. Additional fill was placed and compacted as well as possible in the confined area. A 20-feet-long section of temporary casing was installed and drilling resumed. Caisson construction was completed on 11 September, when concrete for caissons A2-4 and A2-6 was placed.

Completed caisson holes were checked for verticality, and all were within the specified tolerances which were (1) the top no more than three-inches from centerline location, and (2) a maximum deviation, from top to bottom, of 1.5% of caisson height.

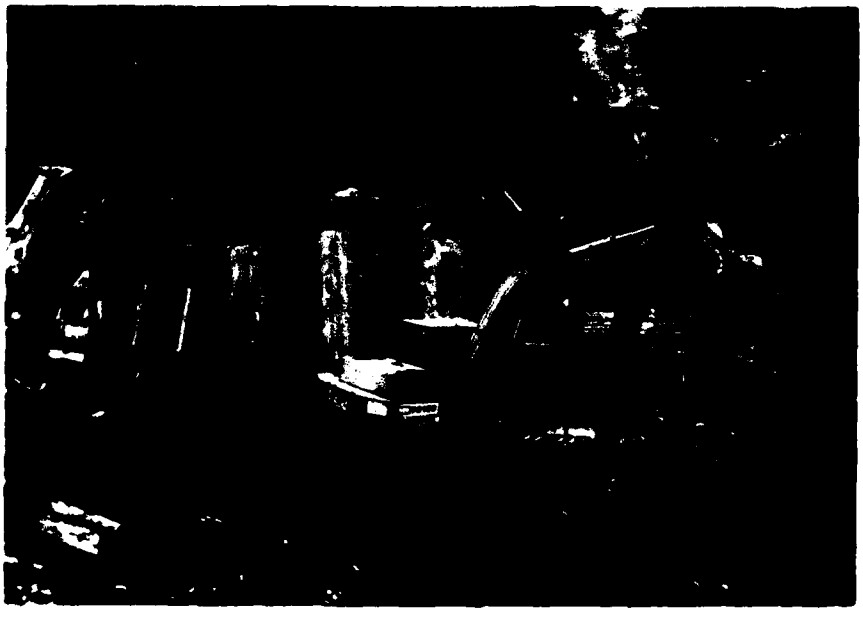
All caisson holes except A1-6 were mapped peripherally prior to placement of reinforcing steel and concrete. That hole was proof tested, and the jackhammer operator reported good rock at the base of the caisson, and no visible fractures in the wall rock. Caisson hole maps are included in Appendix H, PLATES H-5 through H-19.







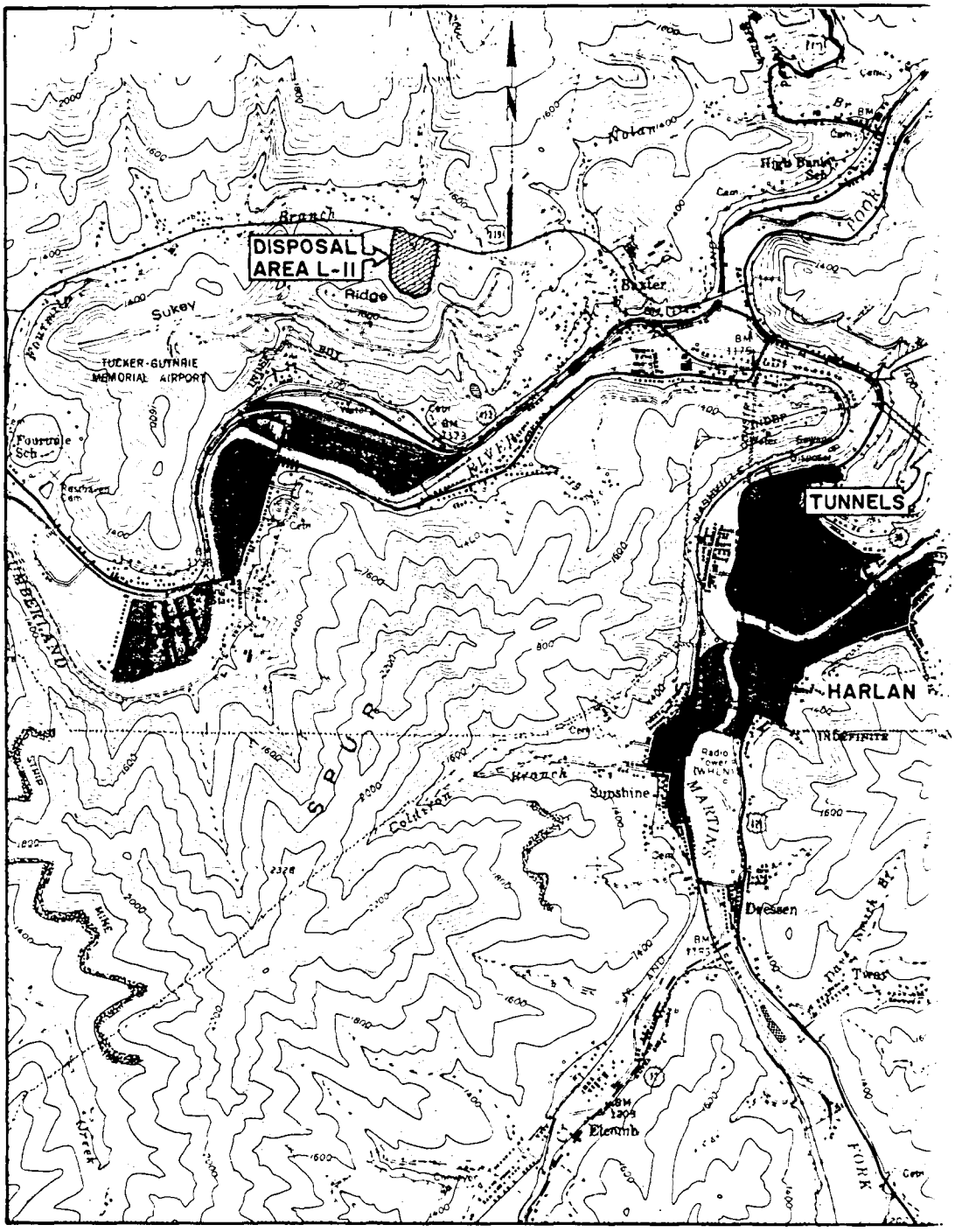
[illegible] drill rig with spring bit, [illegible]
[illegible] August [illegible]



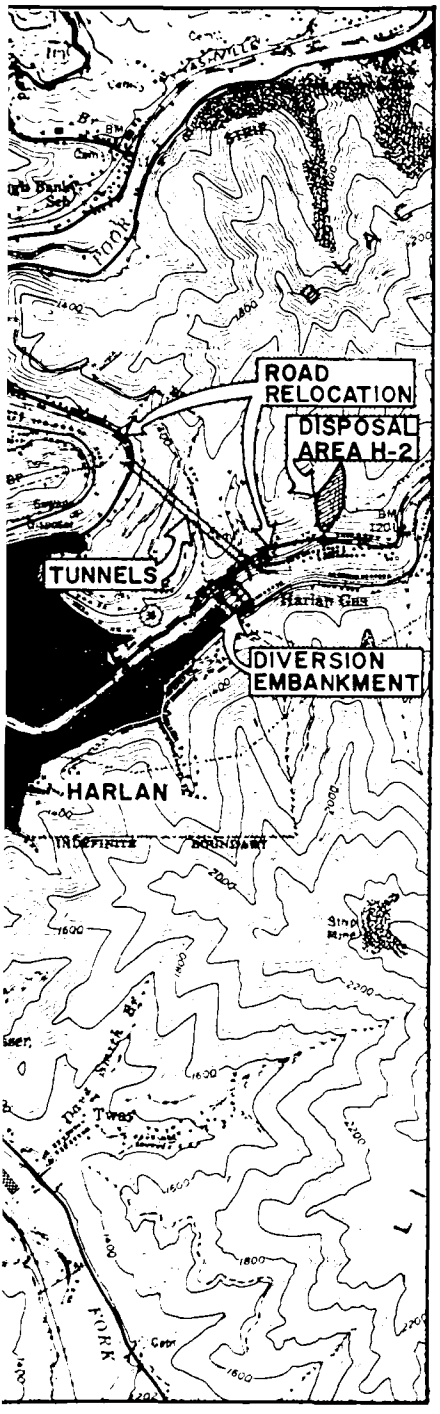
[illegible] ram used to excavate rock alongside the completed caissons for wing wall embedment. View [illegible] looking downstream. January [illegible]

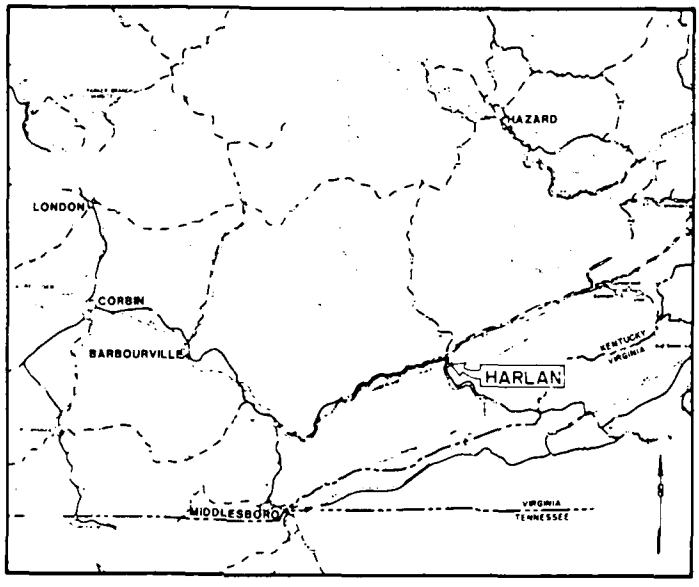
Appendix A - General

Plate No.	Drawing No.	Description
A-1	Q1A-64/1	Project Location Map
A-2	Q1A-4/382	Boring Legend
A-3 thru 5	------	Geologic Descriptions



PROJECT LOCATION MAP





VICINITY MAP
NOT TO SCALE

Revisions	Date	Descriptions	By	Checked

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Designed by:
Drawn by:
Checked by:
Approved by:

U.S. Army Corps of Engineers

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

PROJECT LOCATION MAP

Date:
Sheet _ _ of _
Scale:
Drawing Number QIA-64/1
Record Drawing as constructed dated

Plate A-1

UNIFIED SOIL CLASSIFICATION

1	2 Major Divisions		3 Group Symbols	4 Typical Names	5 Field Identification Procedures (Excluding particles larger than 3 inches and basing fractions on estimated weights)	6 Information Required for Describing Soils	Laboratory
Coarse-grained Soils (more than half of material is larger than No. 200 sieve size)	Gravels (more than half of coarse fraction is larger than No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.	Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	Give typical name; indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information, and symbol in parentheses.	Less than 5% — GW, GP, SW, SP. More than 12% — GM, GC, SM, SC. 5% to 12% — Borderline cases requiring use of dual symbols.
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size. For visual classification, the 1/4 inch size may be used as equivalent to the No. 4 sieve size.)	Clean Sands (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.	Example: Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-inch maximum size, rounded and subangular sand grains coarse to fine, about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).	
			SP	Poorly graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.		
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).		
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).		
Fine-grained Soils (more than half of material is smaller than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.)	Silts and Clays (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	Identification Procedures on Fraction Smaller than No. 40 Sieve Size: Dry Strength (Crushing characteristics): None to slight. Dilatancy (Reaction to shaking): Quick to slow. Toughness (Consistency near PL): None.	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage condition. Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).	Plasticity Chart: Determining Soils Toughness and Dry with Increasing...
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high. None to very slow. Medium.		
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium. Slow. Slight.		
	Silts and Clays (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium. Slow to none. Slight to medium.		
			CH	Inorganic clays of high plasticity, fat clays.	High to very high. None. High.		
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high. None to very slow. Slight to medium.		
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U.S. Standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/8 inch. For field classification purposes screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

DILATANCY (Reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction, whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

DRY STRENGTH (Crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

TOUGHNESS (Consistency near plastic limit)

After removing particles larger than the No. 4 sieve size, as described for the dilatancy test, a specimen of soil with a volume of about one-half cubic inch should be prepared. If necessary, add water to the soil until it has the consistency of putty, so soft that it should be rolled into a thread. After the specimen is rolled into a thread, it should be folded and rerolled repeatedly. During this manipulation the specimen stiffens, finally losing its plasticity and crumbling when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles.

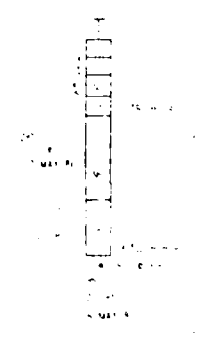
The toughness of the thread near the plastic limit and of the lump are indicative of the quality of the colloidal clay fraction contained in the soil. Highly plastic clays have a very tough thread near the plastic limit and a very tough lump when dry. Fat clays of medium to high plasticity have a moderate toughness. Inorganic clays of low plasticity, or organic clays which occur below the A-line, have a soft and spongy thread and crumble quickly near the plastic limit. Highly organic clays have a very weak and spongy

Adapted by Corps of Engineers and Bureau of Reclamation, January 1952.

LEGEND FOR BORING TYPE SHOWN ON EXPLORATION PLANS

LETTER	SYMBOL	DESCRIPTION
DC		Diamond Core Hole
		Diamond Core Hole
		Auger Hole
		Auger Hole
		Test Pit
		Test Pit
		Diamond Core Hole or Auger Hole with Piezometer Installation

LEGEND FOR LOGS OF BORINGS AND SUBSURFACE PROFILES AND SECTIONS



Laboratory Classification Criteria

$$C_u = \frac{D_{60}}{D_{10}} \text{ Greater than 6}$$

$$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} \text{ Between 1 and 3}$$

Not meeting all gradation requirements for GW

Atterberg limits below "A" line or PI less than 4 — Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.

Atterberg limits above "A" line with PI greater than 7

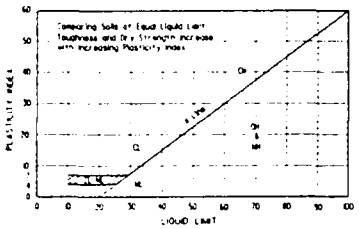
$$C_u = \frac{D_{60}}{D_{10}} \text{ Greater than 4}$$

$$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} \text{ Between 1 and 3}$$

Not meeting all gradation requirements for SW

Atterberg limits below "A" line or PI less than 4 — Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.

Atterberg limits above "A" line with PI greater than 7



PLASTICITY CHART

for laboratory classification of fine-grained soils

...chart are U.S. standard.

Consistency near plastic limit

...passing particles larger than the No. 40 sieve size, a specimen of soil about one-half ...ze in size, is added to the consistency of putty. If too dry, water must be added ...ntially, the specimen should be spread out in a thin layer and allowed to lose some ...e by evaporation. Then the specimen is rolled out by hand on a smooth surface or ...tween the palms into a thread about one eighth inch in diameter. The thread is then folded ...ed repeatedly. During the augmentation the moisture content is gradually reduced ...e specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit ...ched.

...e thread crumbles, the pieces should be lumped together and a slight kneading action ...ued until the lump crumbles.

...ver the thread near the plastic limit and the stiffer the lump when it finally crumbles, ...re patient in the rolling) any fraction in the soil. Weakness of the thread at the ...limit and quick loss of coherence of the lump below the plastic limit indicate either ...nic clay of low plasticity, or materials such as kaolin-type clays and organic clays ...ccur below the A line.

...ganic clays have a very weak and spongy feel at the plastic limit.

ABBREVIATIONS

@	at	drv	drive	LL	liquid limit	scat	scattered
accum	accumulated	DWR	drillwater retained	*lm	lense	sd	sand
AH	ahead	el	elevation	lo	loose	sdy	sandy
alt	alternating	est	estimate, -ed	ls	limestone	sh	shale
ang	angular	excl	excluding	lt	light	shy	shaly
approx	approximate, -mately	extr	extremely	med	medium	sl	silt
argil	argillaceous	f	fine, finely	mic	micaceous	sls	siltstone
bbl	barrel	fe	iron	min	mineralized, -ization	sly	silty
bdd	bedded, bedding	fld	filled	mod	moderate, moderately	sl	slight, slightly
bdr	bedrock	fm	formation	mot	mottling, mottled	slcs	siliceous
bifur	bifurcating	fos	fossil, fossiliferous	mss	massive	*slick	slickenside
BK	back	*frac	fracture	mst	moist	sml	small
blky	blocky	*frag	fragment	*mtl	material	smpl	sample
*bl	black	frl	friable	mtx	matrix	sft	soft
bldr	boulder	fsl	fissle	*nod	nodule	soln	solution, -tioned, -tioning
BOH	bottom of hole	gen	generally	NR	no recovery	SPT	std. penetration test
br	brown	glau	glauconite, -itic	num	numerous	ss	sandstone
brec	brecciated	gr	gray	ob	overburden (unclassified)	st	stain, -ed, -ing
brk	broken	gra	grain, grained	occ	occasional, -ally	stf	stiff
c	coarse	grad	gradational	ool	oolite, oolitic	*strg	stringer
cal	calcite	grn	green	op	open, opened	*styl	stylolite
calc	calcareous	grt	grout	org	organic	stylc	stylolitic
carb	carbonaceous	gvl	gravel, gravelly	part	partially	sur	surface
*cav	cavity	gyp	gypsum	*pbl	pebble	tt	tight
*cbl	cobble	h/a	high angle	petro	petroleum, petroliferous	TR	top of rock
CD	corrected depth	hd	hard	PI	plasticity index	tr	trace
cem	cement	hem	hematite	*pit	pit, pitted, pitting	UL	unaccountable loss
CH	core in hole	hld	headed	PL	plastic limit	unacct	unaccountable
cht	chert	hor	horizontal	pl	plastic	var	variable
circ	circulation	imbdd	imbedded	pla	platy	v	very
cl	clay	incl	including	*pln	plane	vert	vertical
cly	clayey	intbdd	interbed, interbedded	pwdr	powder, powdered	vgy	vuggy
cmtd	cemented	intlam	interlaminated	prob	probable, probably	w/	with
col	columnar	irr	irregular, irregularly	pt	paper-thin	wea	weathered
conc	concrete	*jt	joint	PT	pressure test	wht	white
*congl	conglomerate	l/a	low angle	*ptg	parting	WL	water level
crm	crumbly	lam	lamina, -nae, -nated	qtz	quartz	WT	water table
d	dense	LC	lost core	rec	recovered	x-bdd	cross-bedded
dis	disseminated	LDW	lost drillwater	REF	refusal	xl	crystal
dk	dark	lea	leached	rk	rock	xln	crystalline
damp	damp	lg	large	rnd	round	yel	yellow
dol	dolomite, dolomitic	lig	lignitic	RQD	rock quality designation		
drl	drilling	lim	limonite	sat	saturated		

* When using as the plural form add "s"

TERMS FOR THICKNESS OF BEDDING

Parting	< 0.02'
Band	0.02' - 0.2'
Thin Bed	0.2' - 0.5'
Medium Bed	0.5' - 1.0'
Thick Bed	1.0' - 2.0'
Massive	> 2.0'

TERMS FOR HARDNESS OF BEDROCK

SCALE OF HARDNESS	DESCRIPTION
Very soft or plastic	Can be indented easily with thumb
Soft	Can be scratched with fingernail
Moderately hard	Can be scratched easily with knife; cannot be scratched with fingernail
Hard	Difficult to scratch with knife
Very hard	Cannot be scratched with knife

GENERAL NOTES

1. A BLOW COUNT OF HIGHER THAN 50 BLOWS PER HALF FOOT IS NORMALLY DEFINED AS REFUSAL FOR STANDARD PENETRATION HOLES. FOR ALL OTHER HOLES DRILLED THROUGH OVERBURDEN, REFUSAL IS DEFINED AS THE POINT BEYOND WHICH FURTHER PENETRATION WAS IMPRACTICABLE WITH THE EXPLORATION METHOD USED.
2. WATER ELEVATIONS INDICATED (WIN CORE (C), DENSION (D), DRIVE SAMPLED (D), AUGER (A), AND WASHBORINGS (WB) MAY HAVE BEEN INFLUENCED BY TRAPPED DRILLING FLUID OR AN INSUFFICIENT PASSAGE OF TIME TO PERMIT BORING TO REFLECT ACTUAL GROUND WATER ELEVATION.
3. GROUNDWATER LEVELS WILL VARY IN ACCORDANCE WITH RAINFALL AND STREAM STAGES. THEREFORE ACTUAL LEVEL OF GROUNDWATER ON ANY DATE OTHER THAN THAT SHOWN ON THE LOGS MUST BE DETERMINED BY SEPARATE OBSERVATIONS. WATER LEVEL READINGS WERE NOT TAKEN ON EVERY HOLE FOR VARIOUS REASONS. THE ABSENCE OF A READING DOES NOT INDICATE THE ABSENCE OF GROUNDWATER.
4. WHEREVER THE METHOD OF EXPLORATION PRECLUDED THE POSSIBILITY OF RECOVERING SAMPLES ABOVE ROCK, SUITABLE FOR EXAMINATION OR TESTS, THE MATERIAL IS DENOTED AS OVERBURDEN.
5. SOME OF THE EXPLORATORY BORINGS ARE PROJECTED ON THE SOIL AND ROCK PROFILES, FOR DISTANCES, SEE PLANS OF EXPLORATION.
6. ALL ELEVATIONS ARE IN FEET AND REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD).
7. RQD IS A MEASURE OF THE ROCK QUALITY. ALL LENGTHS OF CORE RECOVERED OVER 4 INCHES IN LENGTH ARE ADDED THEN DIVIDED BY THE TOTAL LENGTH OF CORE WHICH SHOULD HAVE BEEN RECOVERED AND EXPRESSED AS A PERCENTAGE.
8. ADDITIONAL GEOLOGIC STANDARDS ARE INCLUDED ON PLATES A-3 THRU A-5.

GENERAL BEDROCK DESCRIPTION

...HANCE FORMATION SILTSTONE: Thick bedded to massive, moderately hard to soft, argillaceous to sandy, ...unweathered to highly weathered, variably micaceous and carbonaceous, gray, with occasional lenses ...of hard siltstone, very fine grained sandstone.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: AJ
Checked By: PP
Submitted By: [illegible]

UPPER CUMBERLAND RIVER BASIN
LOCAL PROTECTION PROJECT
HARLAN COUNTY, KENTUCKY
DIVERSION TUNNELS

BORING LEGEND

Recommended: [illegible] — Date: [illegible]
CHIEF, GEOTECHNICAL BRANCH
CHIEF, ENGINEERING DIVISION
Approved: [illegible] — Date: [illegible]
Drawing Number: Q1A-4382

Computer Sheet A&E Section Design & Drafting

PLATE A-2

Standard Descriptions and Descriptive Criteria for Rock

Hardness

H1	Very Soft.....	Can be deformed by hand
H2	Soft.....	Can be scratched by fingernail
H3	Moderately Hard.....	Can be scratched easily with a knife
H4	Hard.....	Can be scratched with difficulty with a knife
H5	Very Hard.....	Cannot be scratched with a knife

Weathering

W1	Unweathered.....	No evidence of any mechanical or chemical alteration
W2	Slightly Weathered....	Slight discoloration on surface, slight alteration along discontinuities, less than 10% of the rock volume is altered, strength is substantially unaffected
W3	Moderately Weathered..	Discoloring is evident, surface is pitted and altered with alteration penetrating well below rock surfaces, 10% to 50% of the rock is altered, strength is noticeably less than fresh rock
W4	Highly Weathered.....	Entire mass is discolored, alteration nearly complete, some pockets of slightly weathered rock noticeable, some minerals leached away, retains only a fraction of original strength

Bedding

B1	Massive.....	Greater than 2 ft.
B2	Thick Bedded.....	1 to 2 ft.
B3	Medium Bedded.....	0.5 to 1 ft.
B4	Thin Bedded.....	0.2 to 0.5 ft.
	Band.....	0.02 to 0.2 ft.
	Parting.....	Less than 0.02 ft.

Void Conditions

Pore (porous).....	Less than .003 ft. (1/32 in.)
Pit (pitted).....	.003 to .02 ft. (1/32 to 1/4 in.)
Vug (vuggy).....	.02 to .33 ft. (1/4 to 4 in.)
Cavity.....	Greater than 4 in.

Standard Descriptions and Descriptive Criteria for Discontinuities

Fracture Spacing

SP1	Extremely widely spaced....	Greater than 10 ft.
SP2	Very widely spaced.....	3 to 10 ft.
SP3	Widely spaced.....	1 to 3 ft.
SP4	Moderately spaced.....	0.3 to 1 ft.
SP5	Closely spaced.....	0.1 to 0.3 ft.
SP6	Very closely spaced.....	Less than 0.1 ft.

Fracture Continuity

C1	Very low continuity.....	Less than 3 ft.
C2	Low continuity.....	3 to 10 ft.
C3	Moderate continuity.....	10 to 30 ft.
C4	High continuity.....	30 to 100 ft.
C5	Very high continuity.....	Greater than 100 ft.

Fracture Openness

O0	Tight.....	No visible separation
O1	Slightly open.....	Less than .003 ft. (1/32 in.)
O2	Moderately open.....	.003 to .01 ft. (1/32 to 1/8 in.)
O3	Open.....	.01 to .03 ft. (1/8 to 3/8 in.)
O4	Moderately wide.....	.03 ft. (3/8 in.) to 0.1 ft.
O5	Wide.....	Greater than 0.1 ft., actual opening recorded

Fracture Filling Thickness

T0	Clean.....	No film or coating
T1	Very thin.....	Less than .003 ft. (1.32 in.)
T2	Moderately thin....	.003 to .01 ft. (1/32 to 1/8 in.)
T3	Thin.....	.01 to .03 ft. (1/8 to 3/8 in.)
T4	Moderately thick...	.03 ft. (3/8 in.) to 0.1 ft.
T5	Thick.....	Greater than 0.1 ft., actual thickness recorded

Fracture Surface (Roughness)

R1	Stepped.....	Near normal steps and ridges occur on fracture surfaces
R2	Rough.....	Large, angular asperities can be seen
R3	Moderately rough.....	Asperities are clearly visible and fracture surface feels abrasive
R4	Slightly rough.....	Small asperities on the fracture surface are visible and can be felt
R5	Smooth.....	No asperities, smooth to the touch
R6	Polished.....	Extremely smooth and shiny

Standard Descriptions and Descriptive Criteria For Discontinuities

Fracture Healing

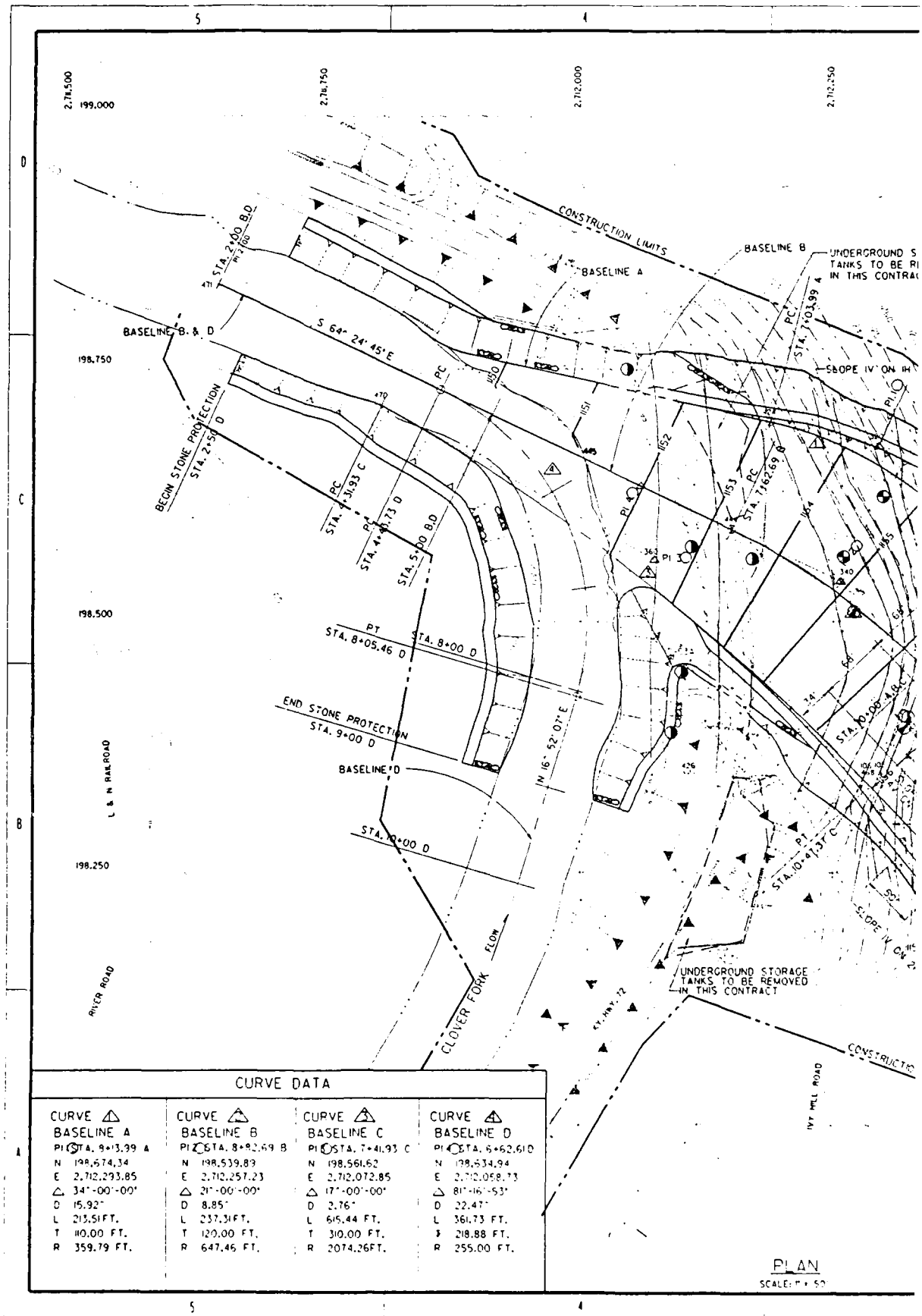
HL1	Totally healed.....	Fracture is completely healed or recemented
HL2	Moderately healed....	Greater than 50 percent of fractured material, fracture surfaces, or filling is healed or recemented
HL3	Partly healed.....	Less than 50 percent of fractured material, filling, or fracture surface is healed or recemented
HL4	Not healed.....	Fracture surface, fracture zone, or filling is not healed or recemented

Fracture Moisture Conditions

M1.....	The fracture is dry. It is tight or filling (where present) is of sufficient density or composition to impede water flow. Water flow along the fracture does not appear possible.
M2.....	The fracture is dry with no evidence of previous water flow. Water flow appears possible.
M3.....	The fracture is dry but shows evidence of water flow such as staining, leaching, and vegetation.
M4.....	The fracture filling (where present) is damp, but no free water is present.
M5.....	The fracture shows seepage. It is wet with occasional drops of water.
M6.....	The fracture emits a continuous flow (estimate flow rate).

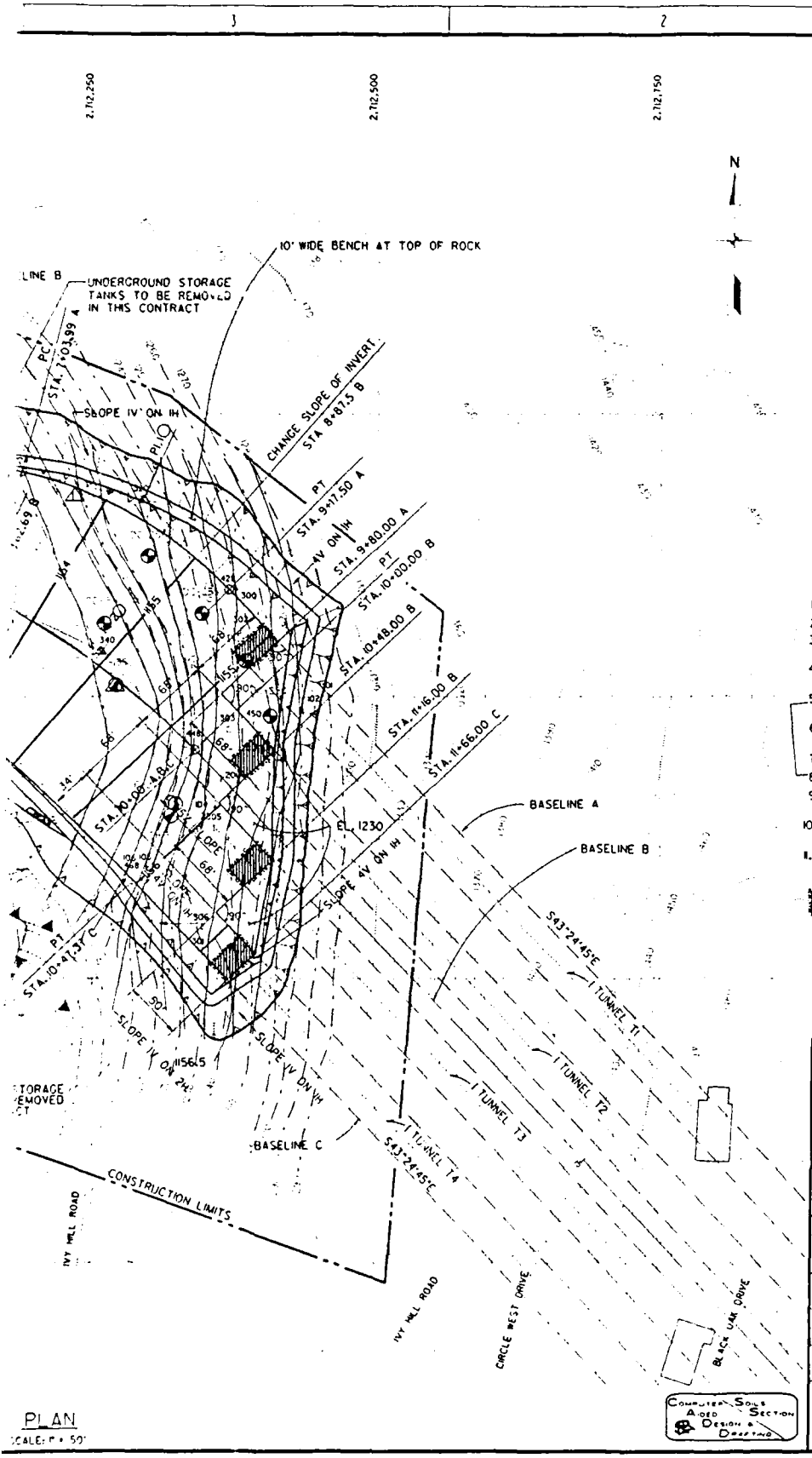
Appendix B - Downstream Portal

Plate No.	Drawing No.	Description
B-1	Q1A-64/61.3	General Plan
B-2	Q1A-64/39.1	Boring Plan
B-3	Q1A-64/40.1	Geologic Section I-I
B-4	Q1A-64/41.1	Geologic Section J-J
B-5	Q1A-64/42.1	Geologic Section K-K
B-6	Q1A-64/43.1	Geologic Section L-L
B-7	Q1A-64/44.1	Geologic Section M-M
B-8	Q1A-4/383	Excavation Sections
B-9	Q1A-4/384	Section Location Plan
B-10	Q1A-4/385	Excavation Sections
B-11	Q1A-64/60.3	Rock Slope Treatment
B-12	Q1A-64/69.2	Rock Slope Treatment
B-13	Q1A-64/70.2	Rock Slope Treatment
B-14	-------	Added Rock Reinforcement
B-15	-------	Added Rock Reinforcement
B-16	Q1A-4/386	Geologic Map
B-17	Q1A-4/387	Geologic Map, T-4 Portal
B-18	Q1A-4/388	Geologic Map, T-3 Portal
B-19	Q1A-4/389	Geologic Map, T-2 Portal
B-20	Q1A-4/390	Geologic Map, T-1 Portal



CURVE DATA

CURVE △ BASELINE A	CURVE △ BASELINE B	CURVE △ BASELINE C	CURVE △ BASELINE D
PI STA. 9+13.39 A	PI STA. 8+82.69 B	PI STA. 7+41.93 C	PI STA. 6+62.610
N 198,674.34	N 198,539.89	N 198,561.62	N 198,634.94
E 2,712,293.85	E 2,712,257.23	E 2,712,072.85	E 2,712,058.73
△ 34°-00'-00"	△ 21°-00'-00"	△ 17°-00'-00"	△ 81°-16'-53"
D 15.92°	D 8.85°	D 2.76°	D 22.47°
L 213.51 FT.	L 237.31 FT.	L 615.44 FT.	L 361.73 FT.
T 110.00 FT.	T 120.00 FT.	T 310.00 FT.	T 218.88 FT.
R 359.79 FT.	R 647.46 FT.	R 2074.26 FT.	R 255.00 FT.



PLAN
SCALE: 1" = 50'

NOTES

1. FOR GENERAL PLAN OF PROJECT, SEE DWG. NO. 64/2.
2. FOR BORINGS IN AREA OF DOWNSTREAM PORTAL, SEE DWG. NO. 64/39.
3. FOR CROSS SECTIONS ALONG RIGHT BANK (BASELINE C) SEE DWG. NO. 64/62.
4. FOR CROSS SECTIONS ALONG LEFT BANK (BASELINE A) SEE DWG. NO. 64/63 & /64.
5. FOR CROSS SECTIONS ALONG BACKWALL AT TUNNEL EXIT, SEE DWG. NO. 64/65.
6. FOR CROSS SECTIONS OF STREAMBANK PROTECTION IN EXISTING CLOVER FORK CHANNEL, SEE DWG. NO'S. 64/66, /67, & /68.
7. FOR DETAILS OF SLOPE TREATMENT, SEE DWG. NO'S. 64/69 & /70.
8. FOR PLANS OF RELOCATED HIGHWAY 72, SEE SEPARATE FOLIO.
9. FOR INSTRUMENTATION IN AREA OF DOWNSTREAM PORTAL. SEE DWG. NO. 64/79.
10. ALL SLOPES TO BE DEVELOPED PERPENDICULAR TO THE BASE OF THE APPLICABLE CUTS.
11. ALL CUT SLOPES IV ON IH OR STEEPER ADJACENT TO PORTALS SHALL BE SHOTCRETED.

TYPE I STONE SPLASH PADS WITH SLUSH GROUT TYPICAL 4 TUNNELS

Revisions	Date	Description	By	Checked
.3	11-24-93	REVISED AS CONSTRUCTED	S.B.D	
.2	6-30-89	ADDED SLOPE DATA, CONSTRUCTION LIMITS, STORAGE TANK AREAS, AND NOTE 11.	E.P.D.	J.L.S.
.1	5-31-89	CONFORMING TO REVIEW COMMENTS	L.L.	P.E.B.

50' 0 50'
Graphic Scale

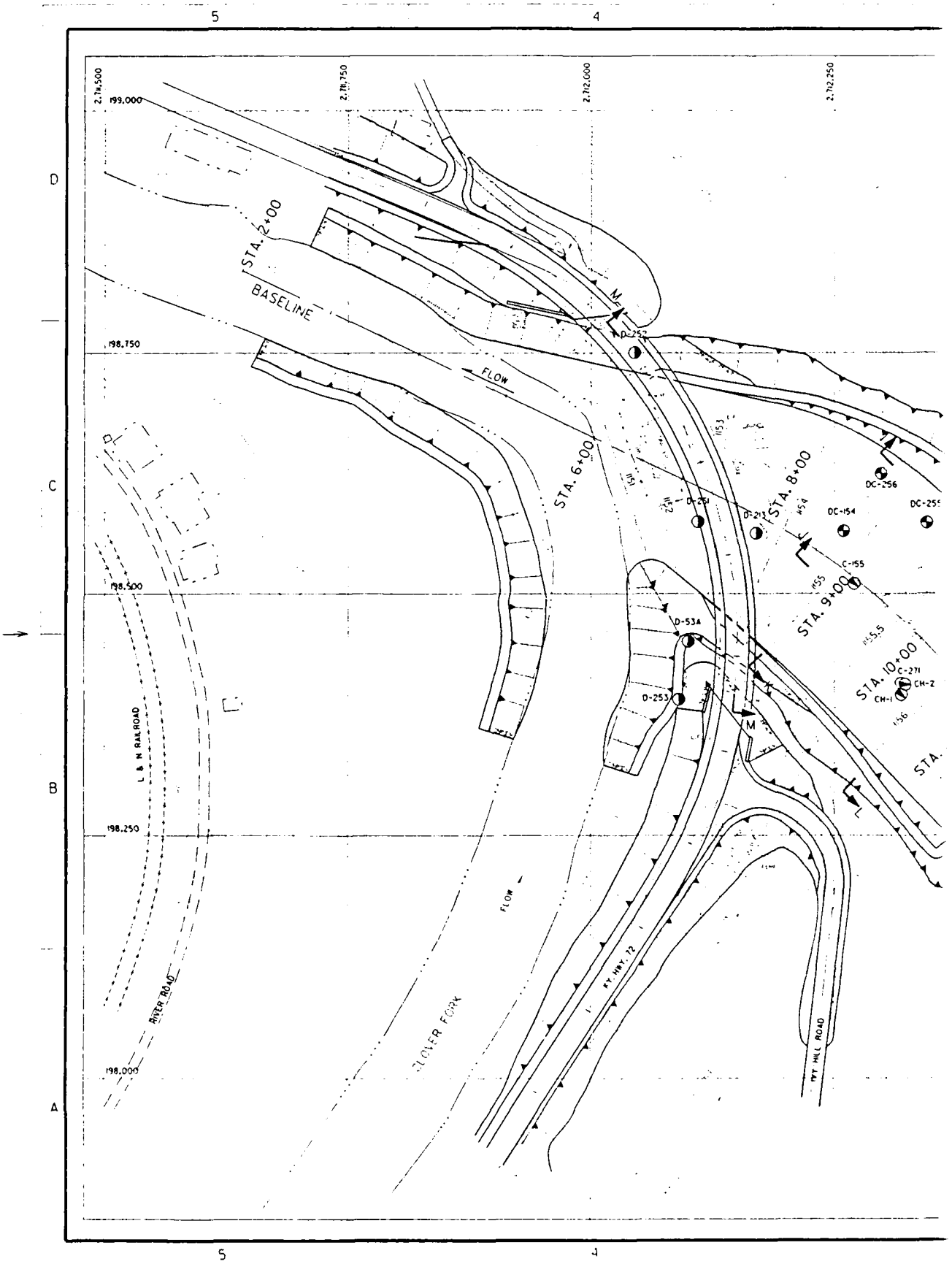
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Designed By: P.E.R.
Drawn By: W. LISON
PAUL ENBERRY
Checked By:
Approved By:
CHIEF, GEOTECHNICAL BRANCH
CHIEF, ENGINEERING DIVISION

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION
GENERAL PLAN
DOWNSTREAM PORTAL

Date: FEB. 1989
Scale: 1" = 50'
Sheet of
Drawing Number 01A-64/61.3
Record Drawing as constructed dated

PLATE B-1


5
4
2,711,500
2,711,750
2,712,000
2,712,250
199,000
198,750
198,500
198,250
198,000
D
C
B
A
STA. 2+00
BASELINE
FLOW
STA. 6+00
STA. 8+00
STA. 9+00
STA. 10+00
D-252
D-251
D-213
D-534
D-253
DC-256
DC-255
DC-154
C-155
C-271
CH-1
CH-2
M
L & N RAILROAD
RIVER ROAD
CLOVER FORK
KY. HWY. 72
PAT HILL ROAD

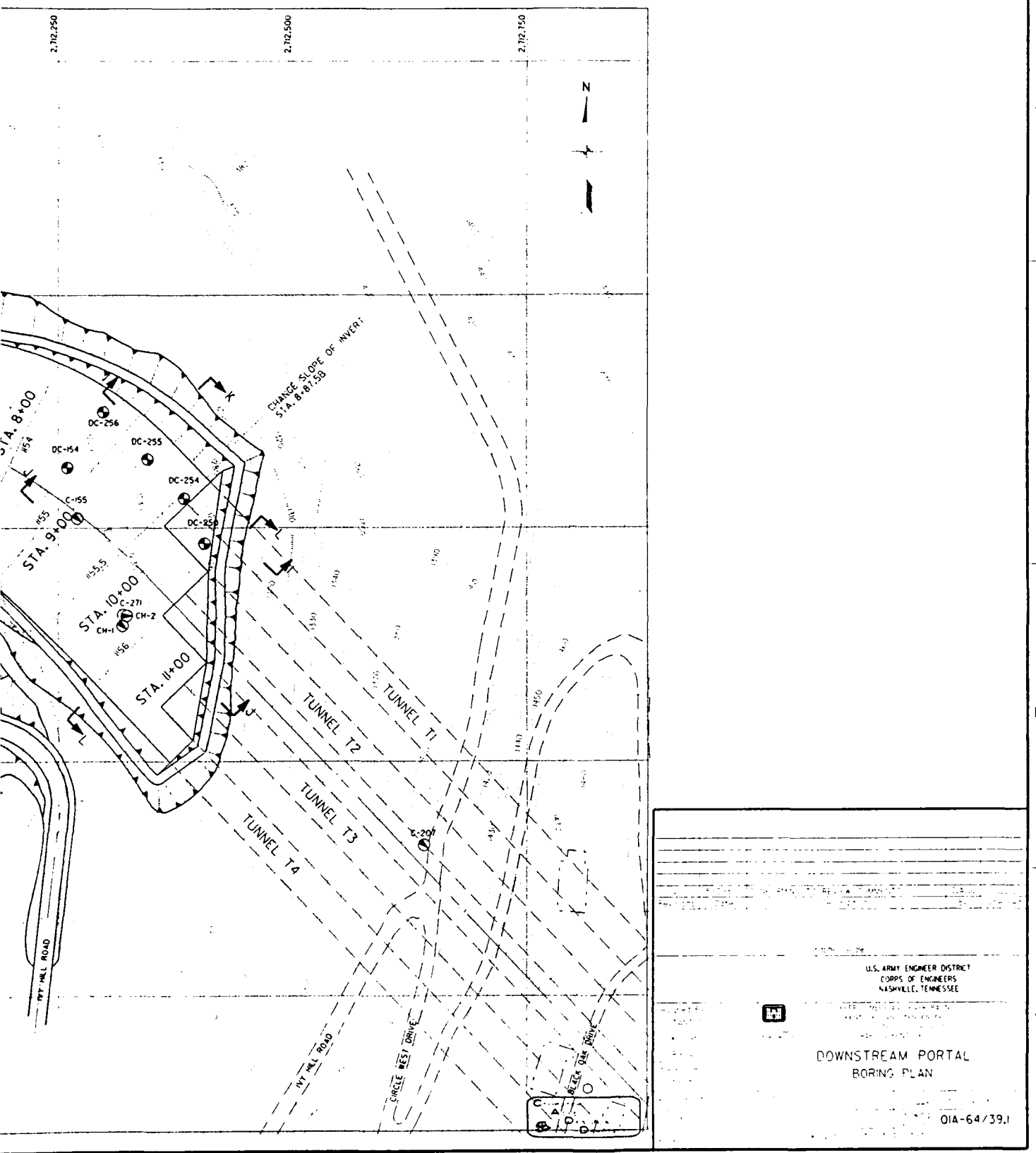
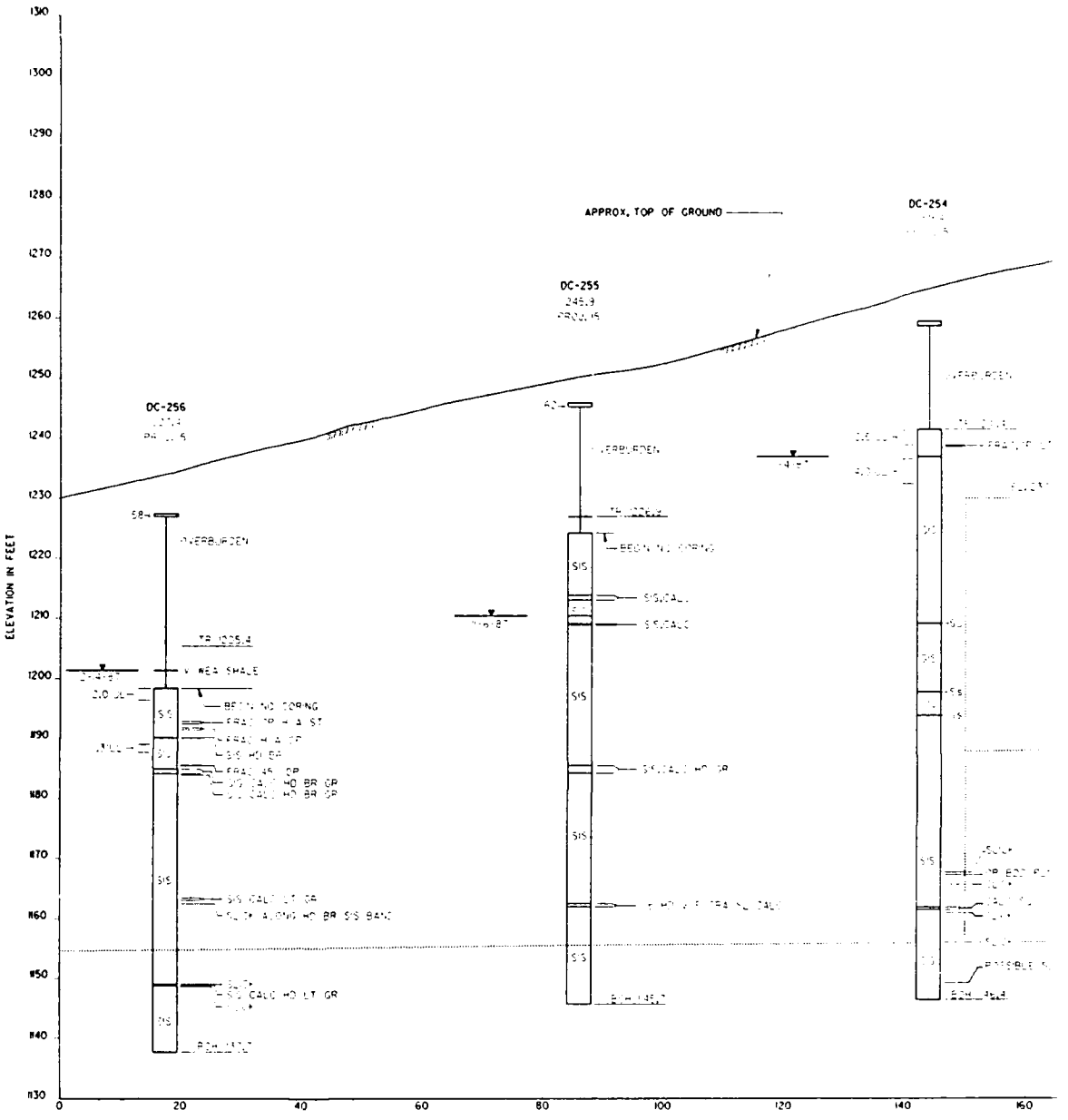
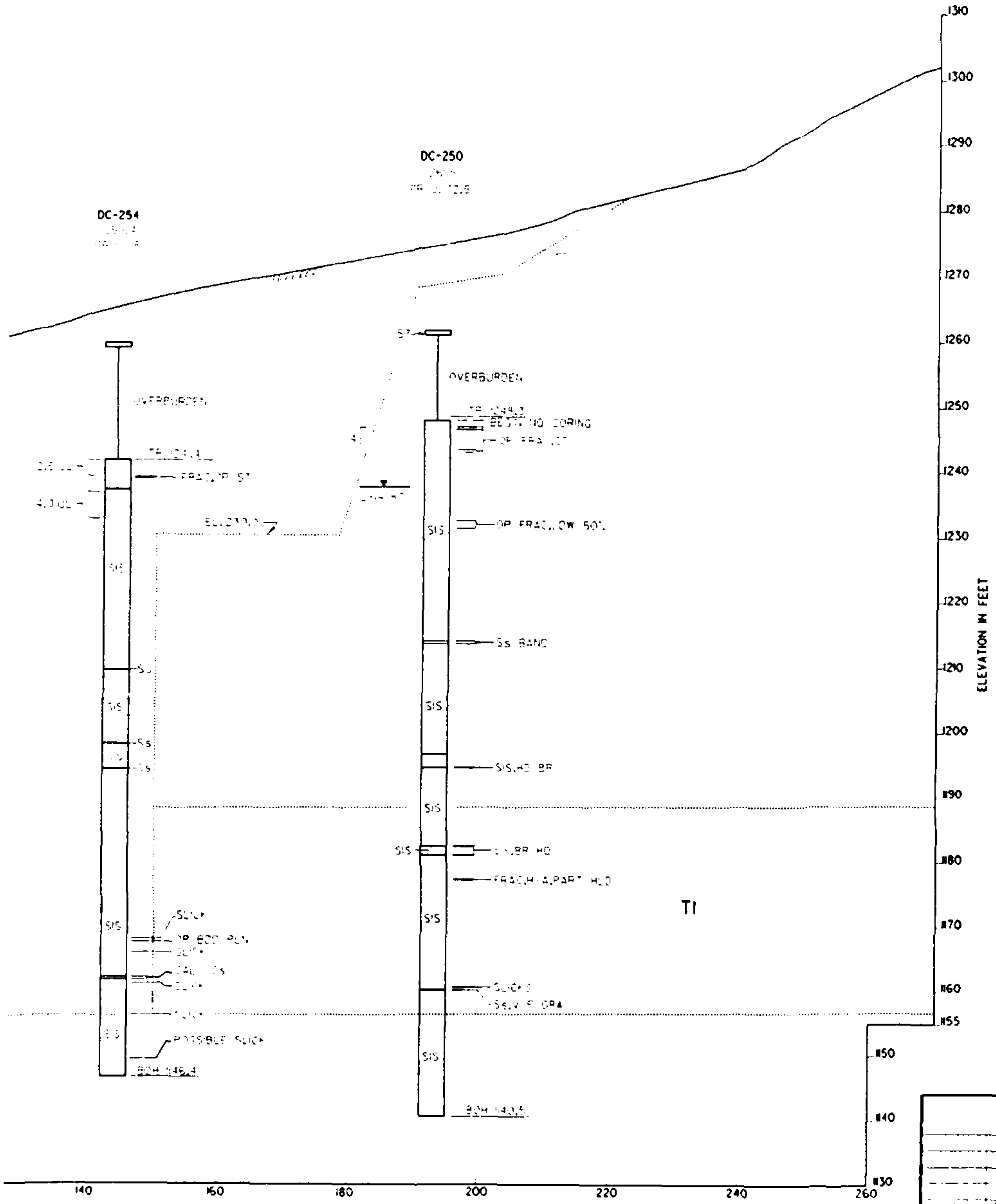

2,712,250
2,712,500
2,712,750
N
CHANGE SLOPE OF INVERT
STA. 8+87.58
STA. 8+00
STA. 9+00
STA. 10+00
STA. 11+00
DC-256
DC-255
DC-254
DC-154
C-155
DC-253
C-271
CH-1
CH-2
TUNNEL T1
TUNNEL T2
TUNNEL T3
TUNNEL T4
C-204
INT HILL ROAD
CIRCLE WEST DRIVE
BEECH OAK DRIVE
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
DOWNSTREAM PORTAL
BORING PLAN
01A-64/39.1

PLATE B-2


APPROX. TOP OF GROUND
DC-256
DC-255
DC-254
OVERBURDEN
BEGIN NO CORING
SHALE
SLTSTONE
SS
SLTY SS
SILTY SS
SS/CALC
SLTY SS/CALC
SS/CALC HD BR
SLTY SS/CALC HD BR
SLTY SS/CALC HD LT GR
SLTY SS/CALC HD BR SLTY SS BAND
SLTY SS/CALC HD LT GR
ELEVATION IN FEET
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
0
20
40
60
80
100
120
140
160

SECTION 1-1



TION I-I

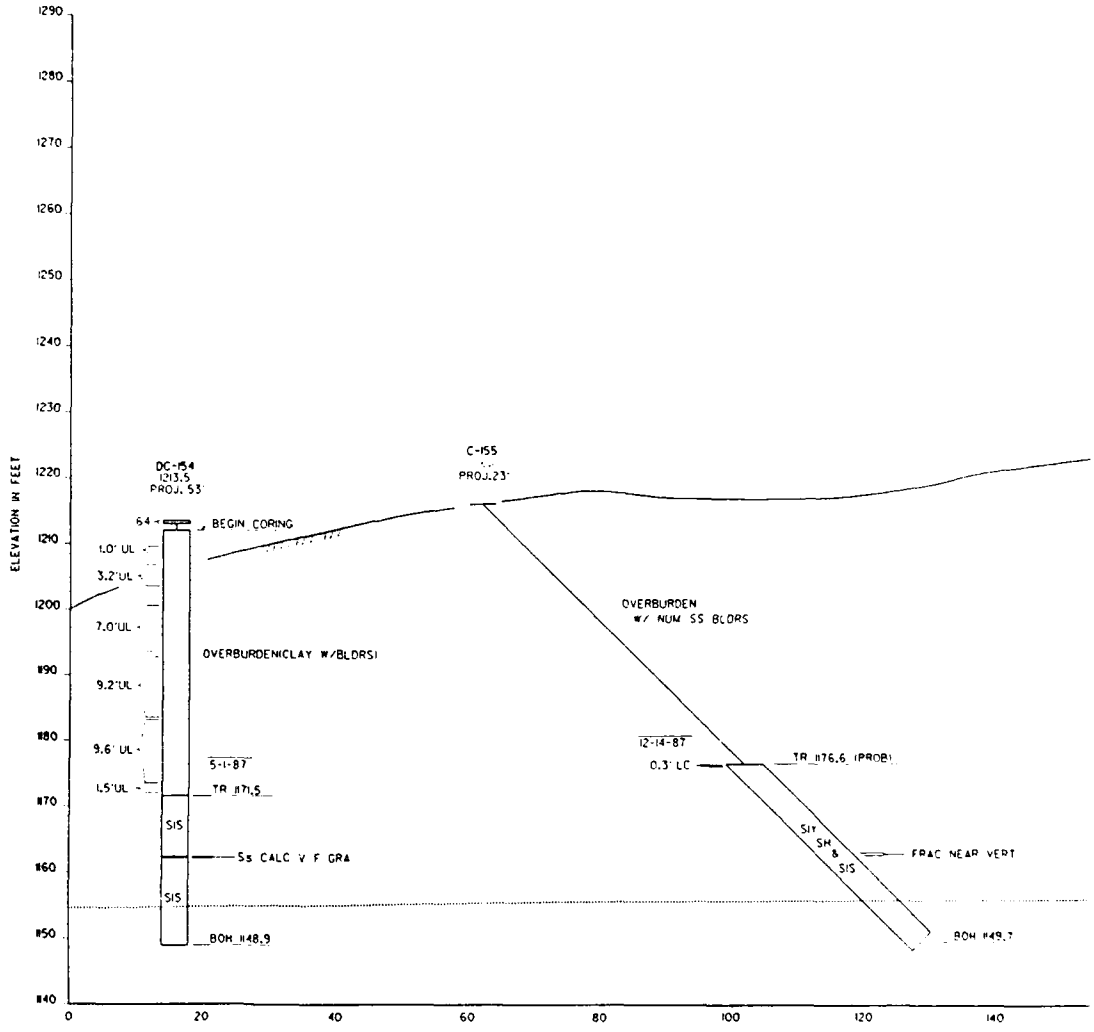
NOTES:
1. FOR LOCATION OF SECTION AND BORING PLAN, SEE DRAWING OIA-64/39.
2. FOR DETAILED LOGS OF BORINGS, SEE DRAWING OIA-64/7 THRU OIA-64/29.
3. FOR GENERAL NOTES, SEE DRAWING OIA-64/7.

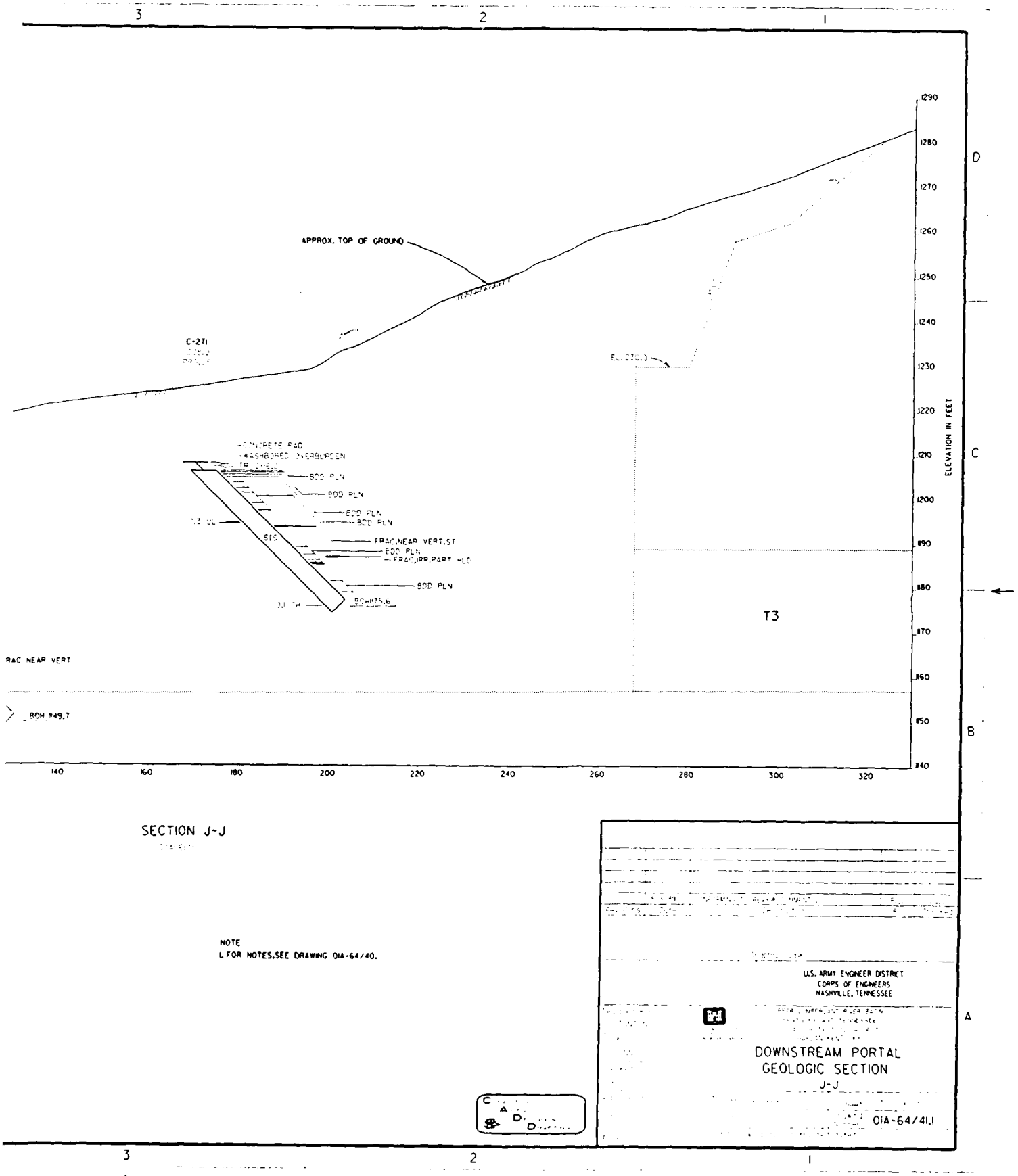
	5-31-89	CONFORMING TO REVIEW COMMENTS	C.A.G.	J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
GEOLOGIC SECTION
I-I

OIA-64/40.1


ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
80
100
120
140
DC-154
1313.5
PROJ. 53'
C-155
PROJ.23'
64'
BEGIN CORING
1.0' UL
3.2' UL
7.0' UL
9.2' UL
9.6' UL
1.5' UL
OVERBURDEN/CLAY W/BLDRS
OVERBURDEN
W/ NUM SS BLDRS
5-1-87
TR 1171.5
SIS
Ss CALC V F GRA
SIS
BOH 1148.9
12-14-87
0.3' LC
TR 1176.6 (PROB)
SIL
SH
&
SIS
FRAC NEAR VERT
BOH 1149.7
D
C
B
A
5
4



SECTION J-J

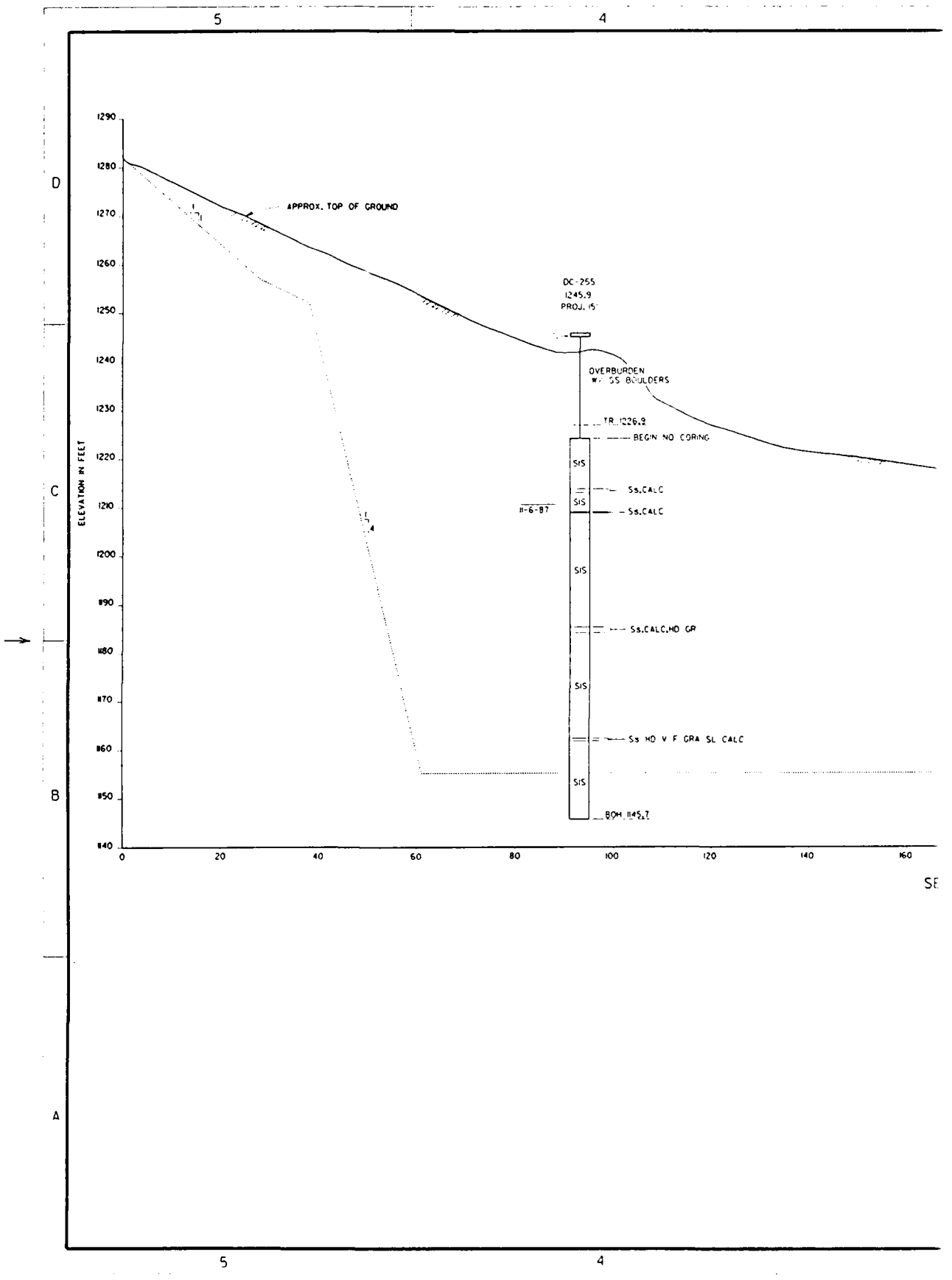
NOTE
1. FOR NOTES, SEE DRAWING 01A-64/40.

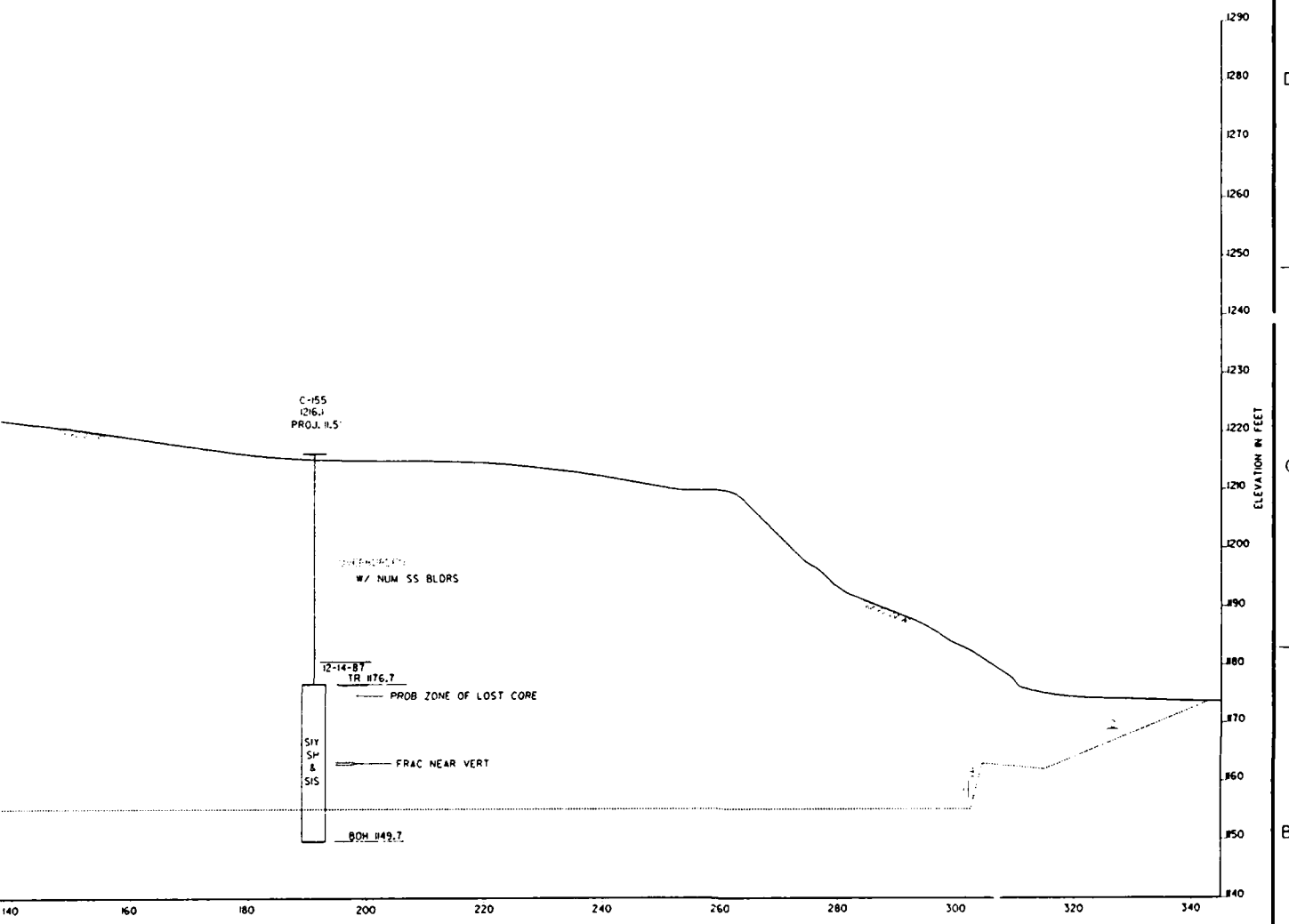
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
GEOLOGIC SECTION
J-J

01A-64/41.1

PLATE B-4


5
4
D
C
B
A
ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
APPROX. TOP OF GROUND
DC-255
1245.9
PROJ. 15'
OVERBURDEN
W/ SS BOULDERS
TR. 1226.2
BEGIN NO CORING
SIS
Ss,CALC
Ss,CALC
11-6-87
SIS
SIS
Ss,CALC,MD GR
SIS
Ss MD V F GRA SL CALC
SIS
BOH 1145.7
0
20
40
60
80
100
120
140
160
SE



SECTION K-K

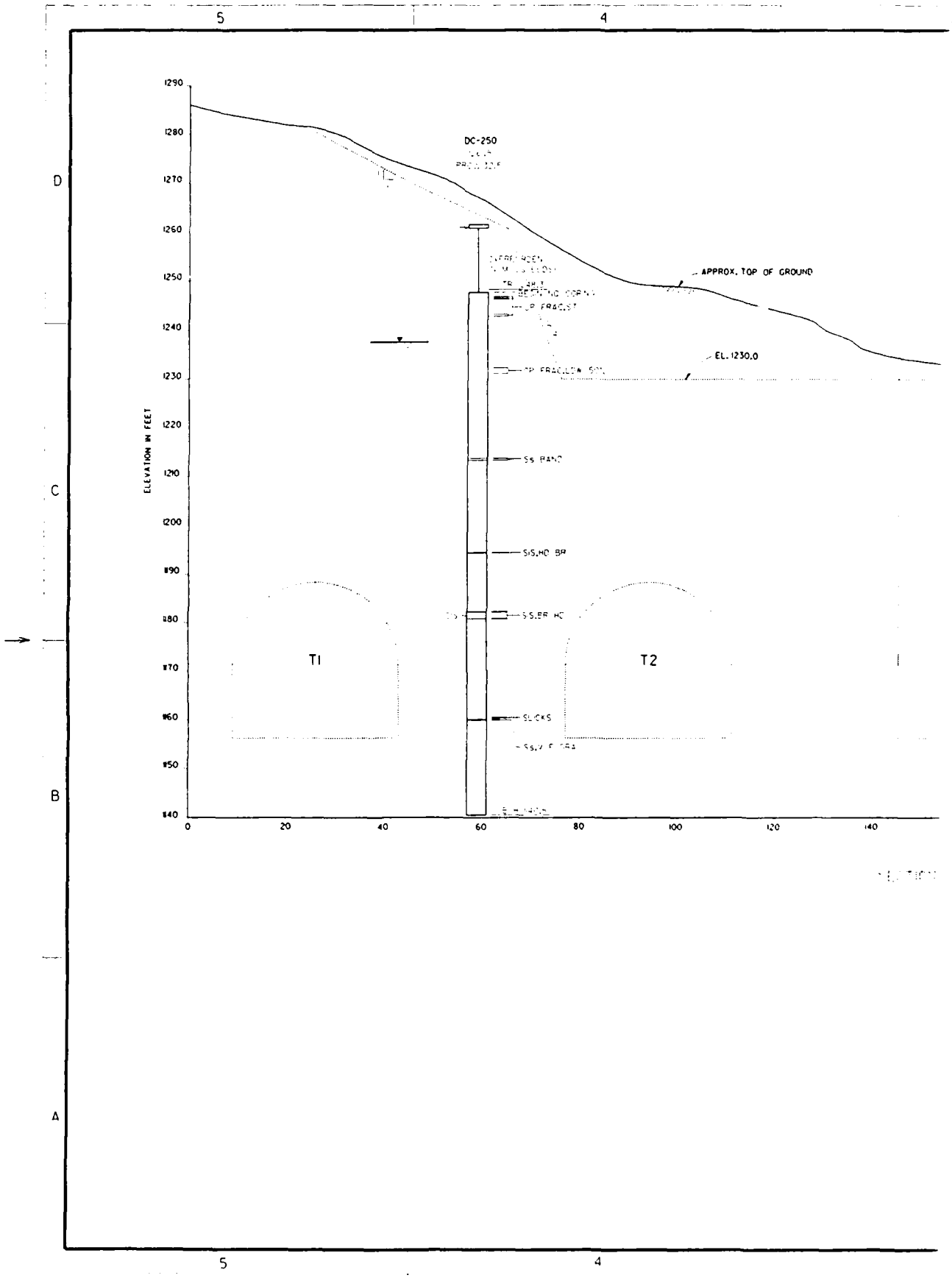
NOTE
1. FOR NOTES, SEE DRAWING 01A-64/40.

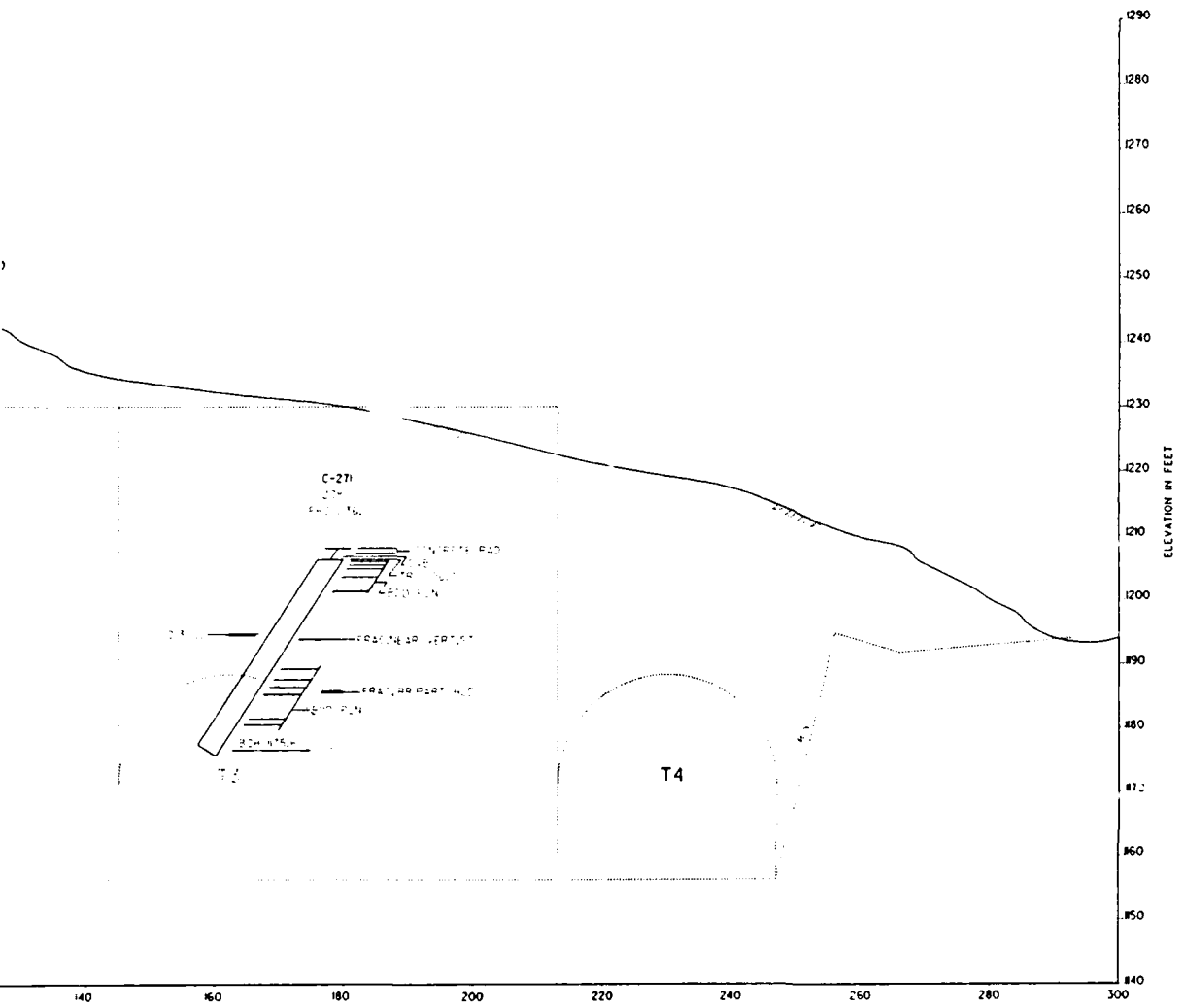
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
GEOLOGIC SECTION
K-K

01A-64/42.1

PLATE B-5


5
4
D
C
B
A
ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
80
100
120
140
DC-250
APPROX. TOP OF GROUND
EL. 1230.0
SS SAND
SS,HD BR
SS,ER HC
SLICKS
T1
T2



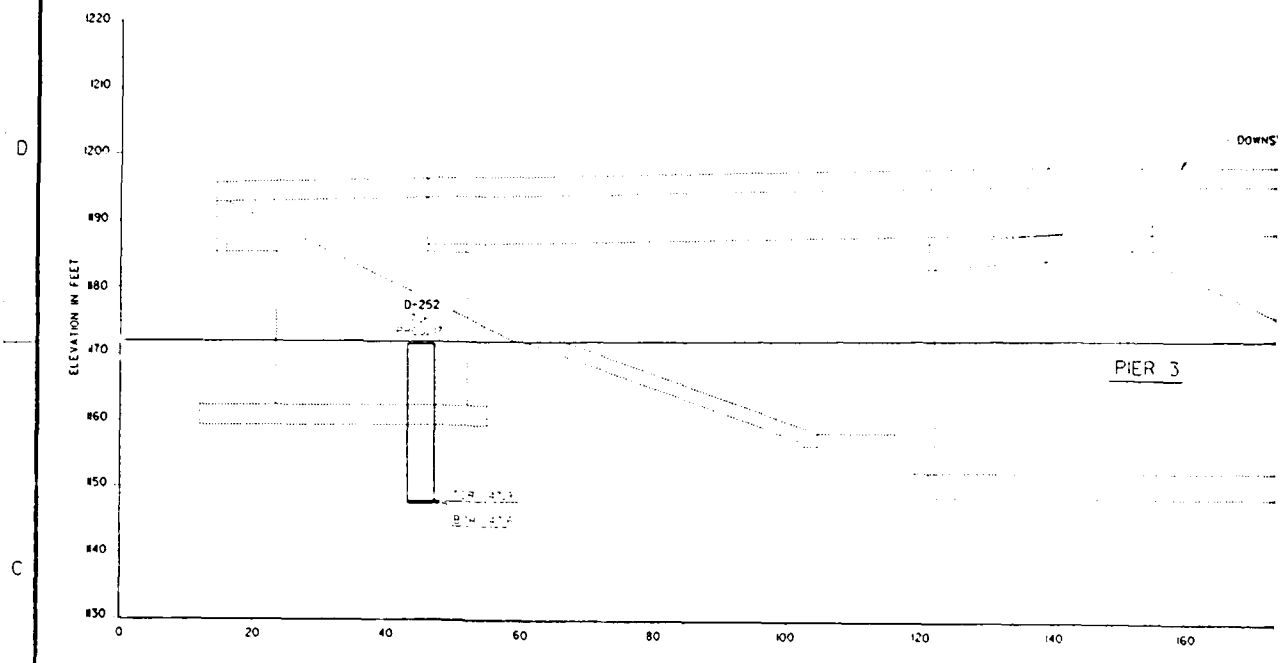
NOTE
1. FOR NOTES, SEE DRAWING 01A-64/40.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

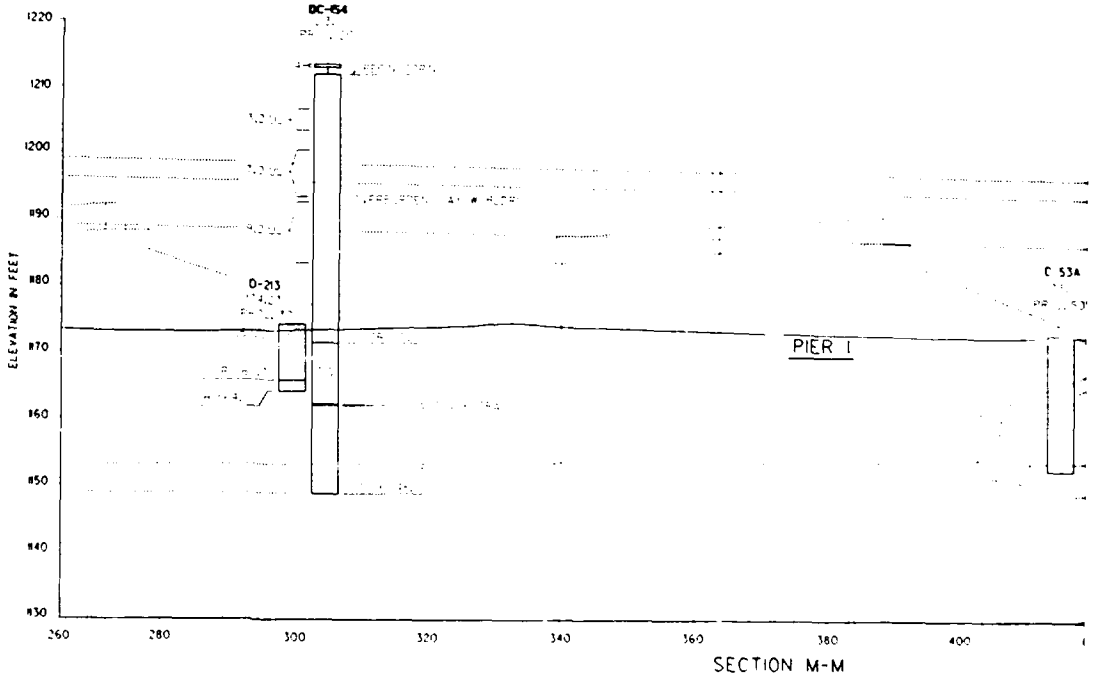
DOWNSTREAM PORTAL
GEOLOGIC SECTION

01A-64/43.1

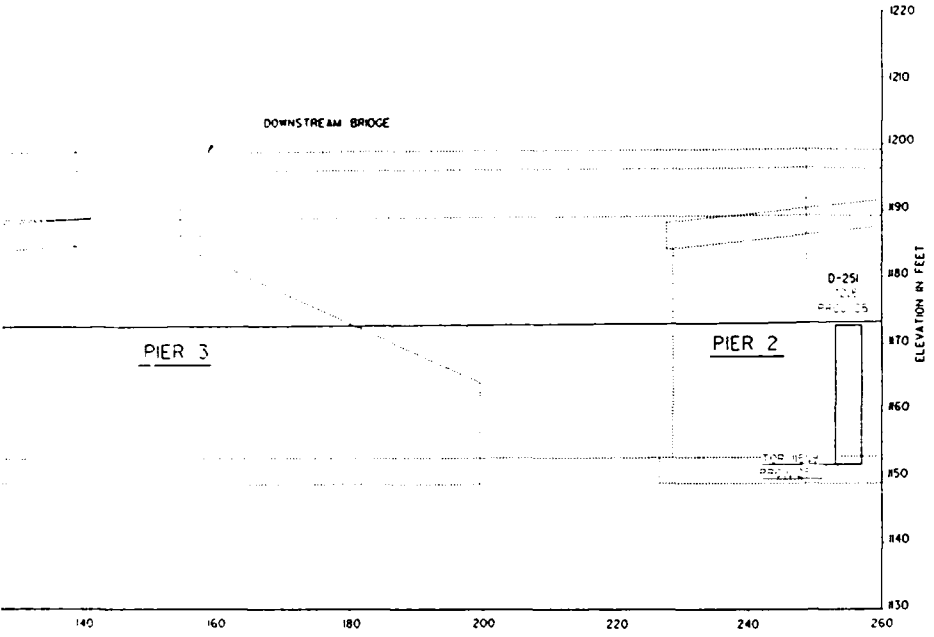
PLATE B-6



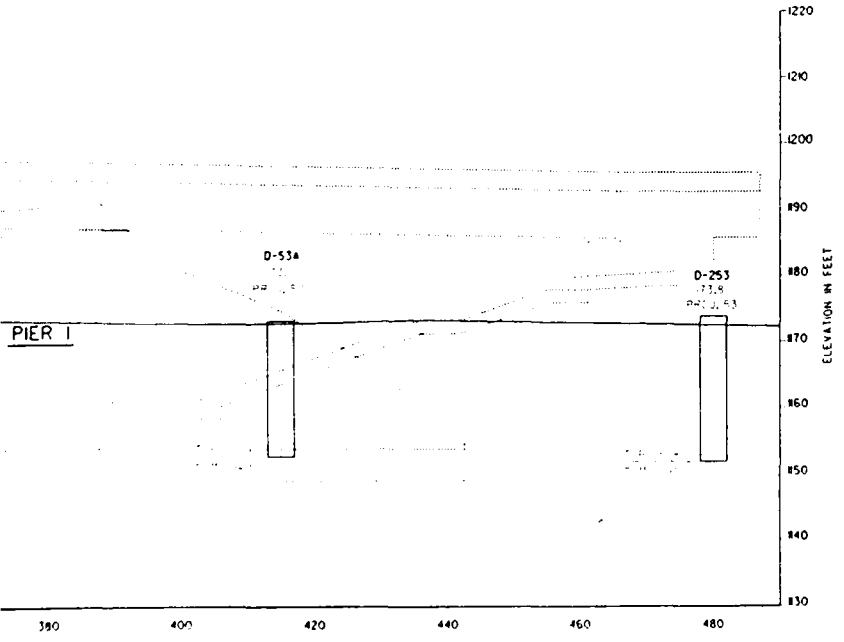
SECTION M-M



SECTION M-M



SECTION M-M



N M-M

NOTE
1. FOR NOTES, SEE DRAWING 01A-64/40.

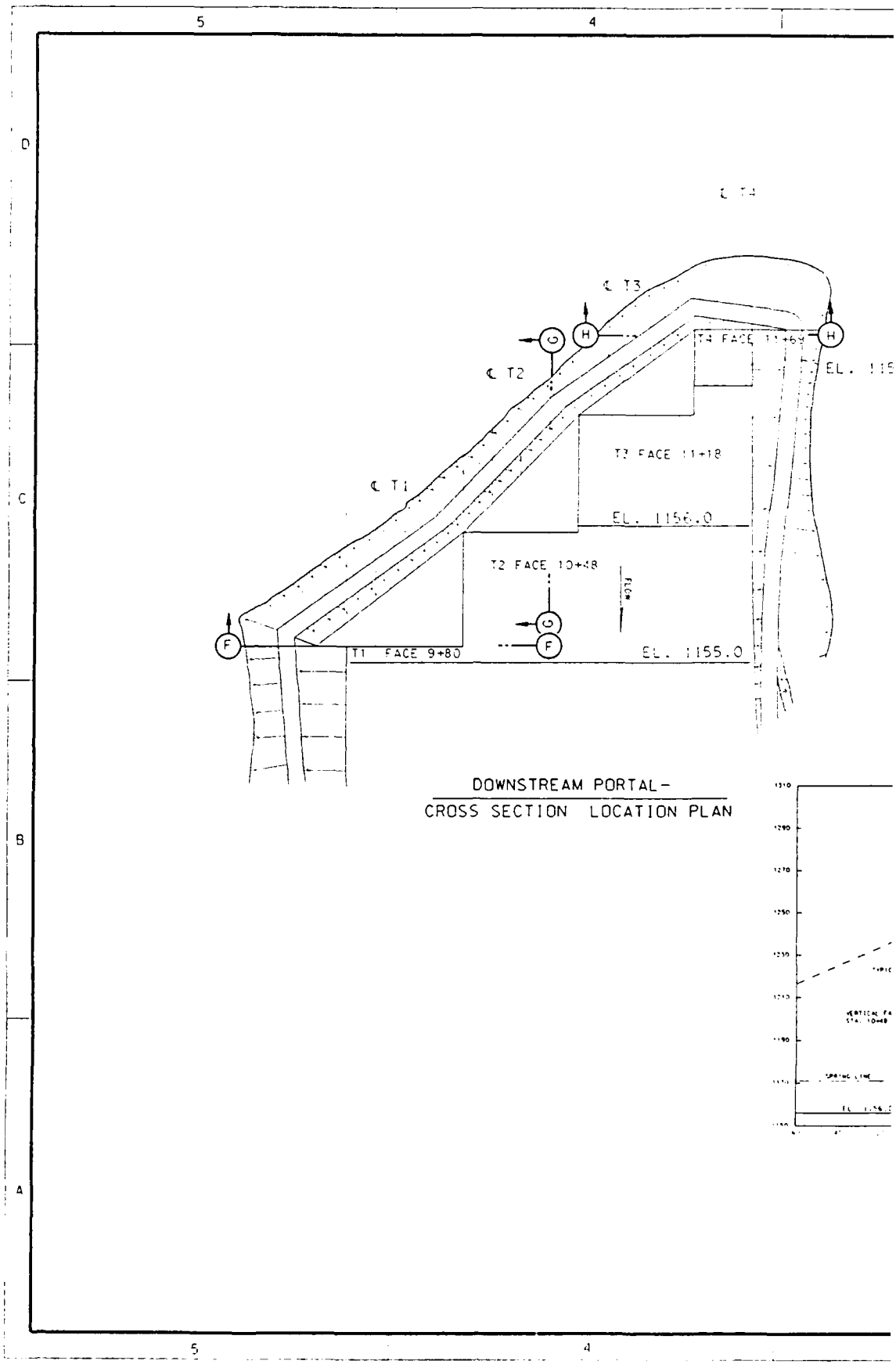
1	5-31-89	CONFORMING TO REVIEW COMMENTS	C.A.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
GEOLOGIC SECTION
M-M

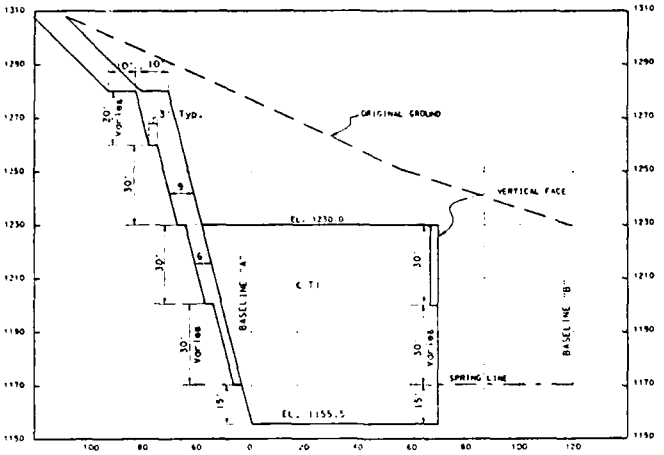
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PLATE B-7

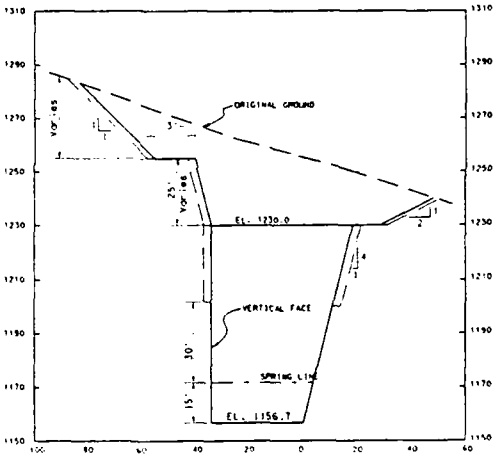

5
4
D
C
B
A
℄ T4
℄ T3
℄ T2
℄ T1
G
H
F
T4 FACE 11+64
EL. 115
T3 FACE 11+18
EL. 1156.0
T2 FACE 10+48
FLOW
T1 FACE 9+80
EL. 1155.0
DOWNSTREAM PORTAL-
CROSS SECTION LOCATION PLAN

REVISIONS				
NO.	DESCRIPTION	DATE	BY	APPROVED

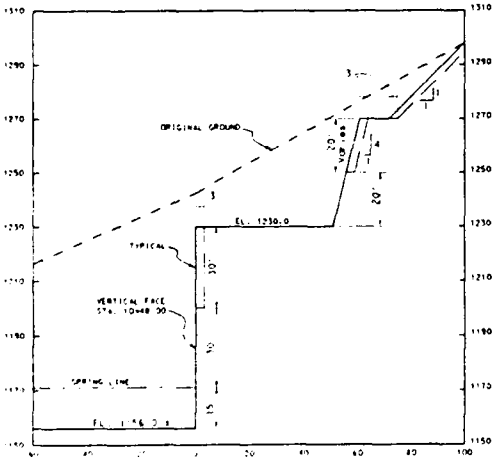




DOWNSTREAM PORTAL
SECTION F



DOWNSTREAM PORTAL
SECTION H



DOWNSTREAM PORTAL
SECTION G

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: CAG
Checked By: PB
Approved By:
CHIEF, GEOTECHNICAL BRANCH
CHIEF, ENGINEERING DIVISION

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

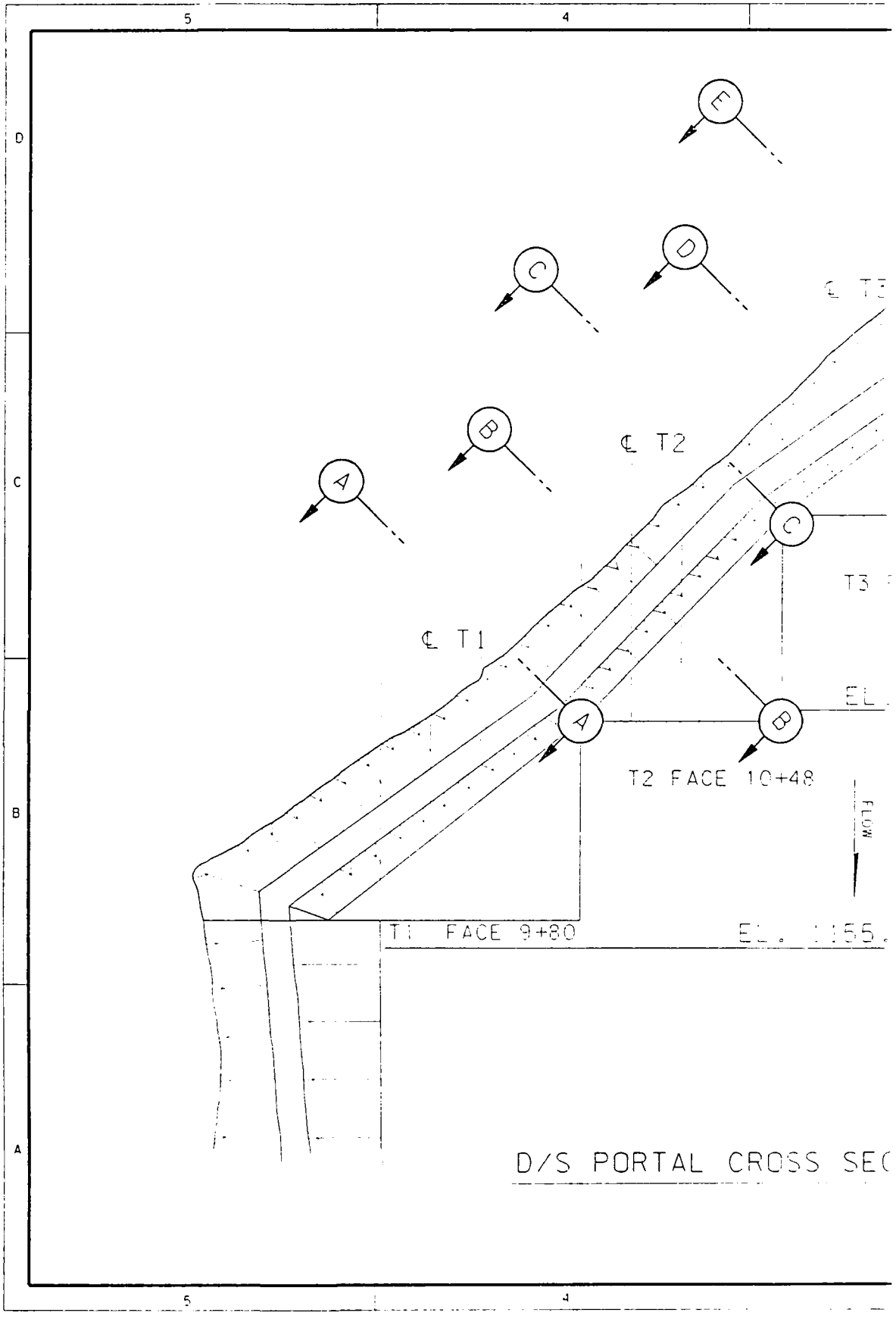
DOWNSTREAM PORTAL
EXCAVATION PLAN, CROSS SECTIONS AND CROSS SECTION LOCATIONS

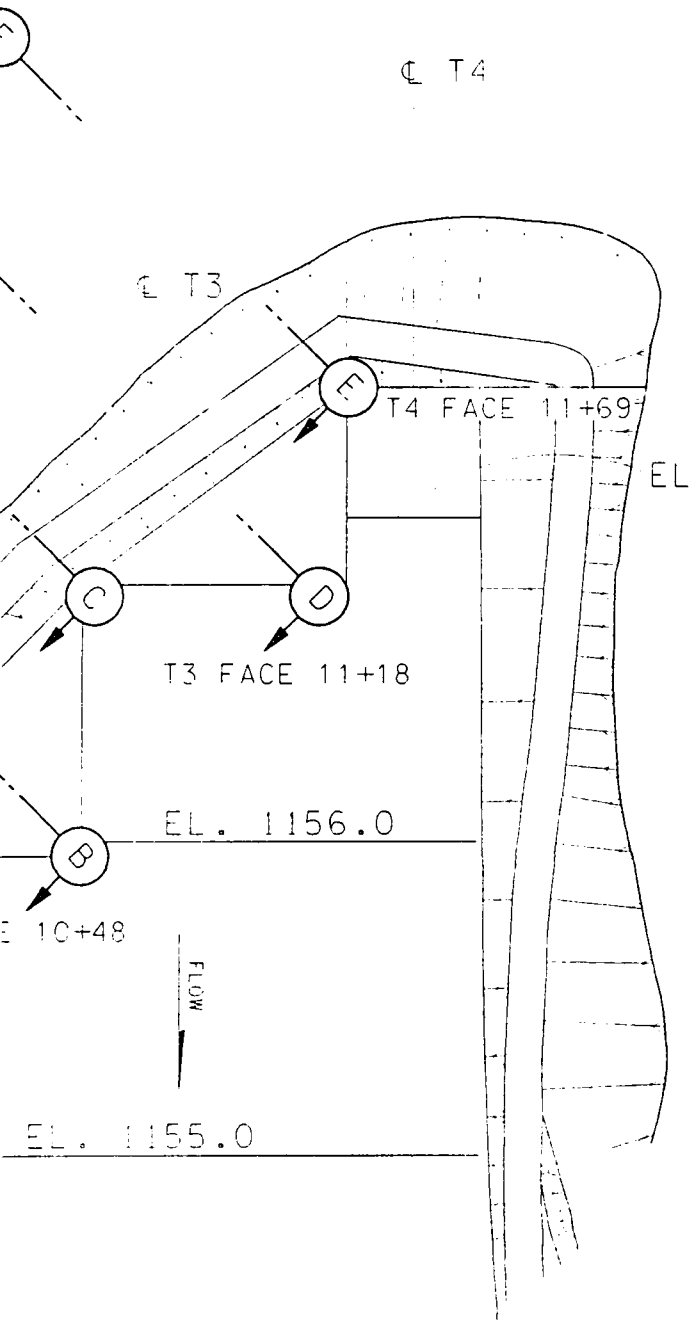
Scale: 1"=20'

Computer Aided Design & Drafting Section

Q1A-4383

PLATE B-8


5
4
D
C
B
A
E
C
D
B
A
℄ T2
℄ T1
T3
EL
T2 FACE 10+48
FLOW
T1 FACE 9+80
EL. 1155.
D/S PORTAL CROSS SEC



NOTE:
THESE CROSS-SECTIONS SHOWN ON PLATE B-10.

40' 0 40'

Graphic Scale

CROSS SECTION LOCATION PLAN

REVISIONS				
REV.	DESCRIPTION	DATE	BY	APPROVED

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

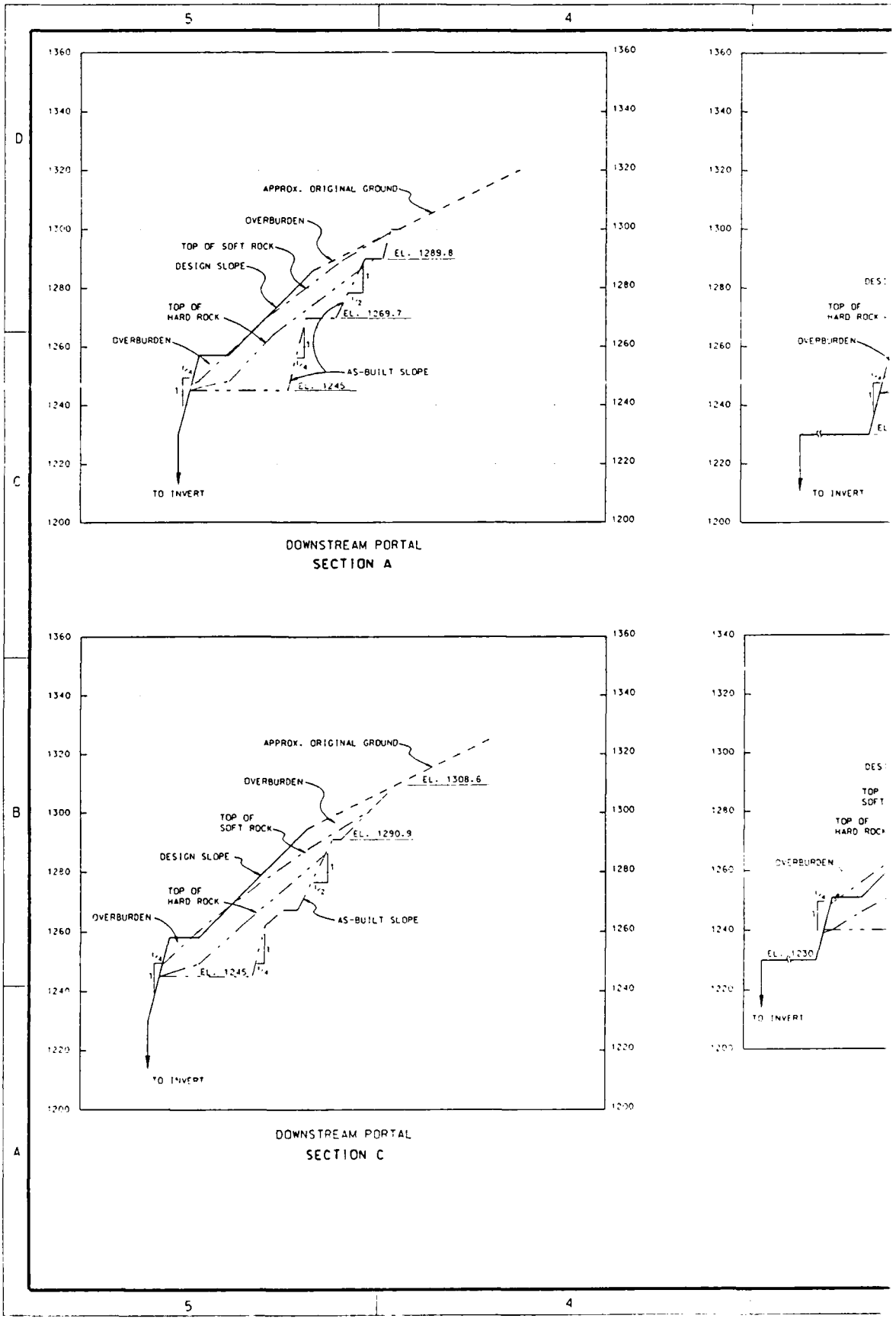
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

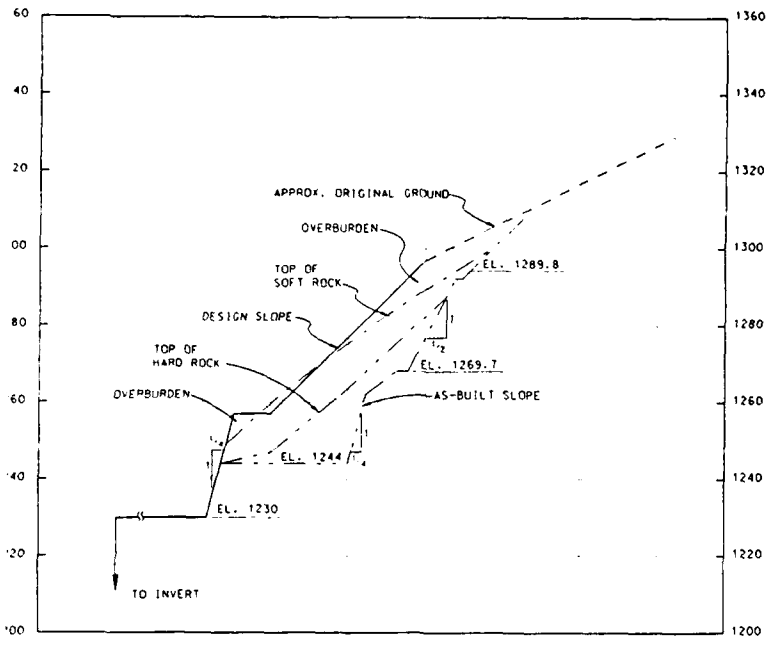
CROSS SECTION LOCATION PLAN
DOWNSTREAM PORTAL

Drawn By:
Checked By:
Date: FEB 1994
Record Drawing as constructed dated
Drawing Number: Q1A-4384

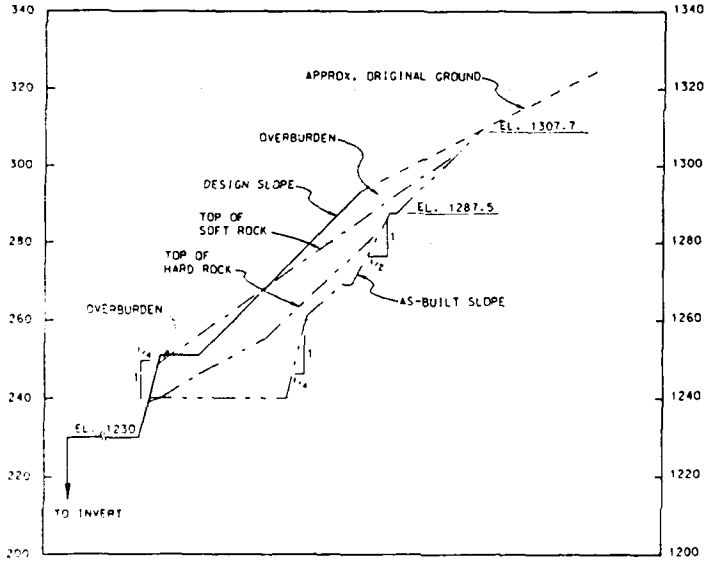
Computer Solids Aided Design & Drafting Section

PLATE B-9

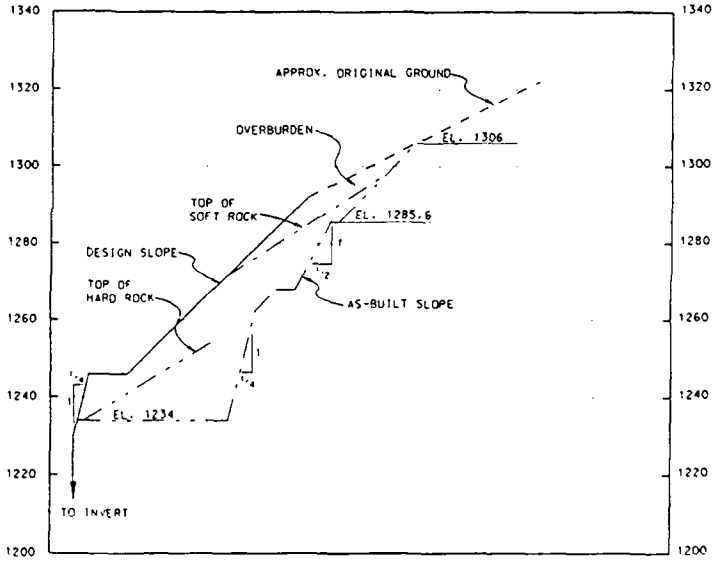

5
4
D
C
B
A
1360
1340
1320
1300
1280
1260
1240
1220
1200
APPROX. ORIGINAL GROUND
OVERBURDEN
TOP OF SOFT ROCK
DESIGN SLOPE
TOP OF HARD ROCK
OVERBURDEN
EL. 1289.8
EL. 1269.7
AS-BUILT SLOPE
EL. 1245
TO INVERT
DOWNSTREAM PORTAL
SECTION A
APPROX. ORIGINAL GROUND
OVERBURDEN
TOP OF SOFT ROCK
DESIGN SLOPE
TOP OF HARD ROCK
OVERBURDEN
EL. 1308.6
EL. 1290.9
AS-BUILT SLOPE
EL. 1245
TO INVERT
DOWNSTREAM PORTAL
SECTION C



DOWNSTREAM PORTAL
SECTION B



DOWNSTREAM PORTAL
SECTION D



DOWNSTREAM PORTAL
SECTION E

NOTE:
SEE CROSS-SECTION LOCATION PLAN, PLATE B-9.

20' 0 20'
Graphic Scale

REVISIONS				
REV.	DESCRIPTION	DATE	BY	APPROVED

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

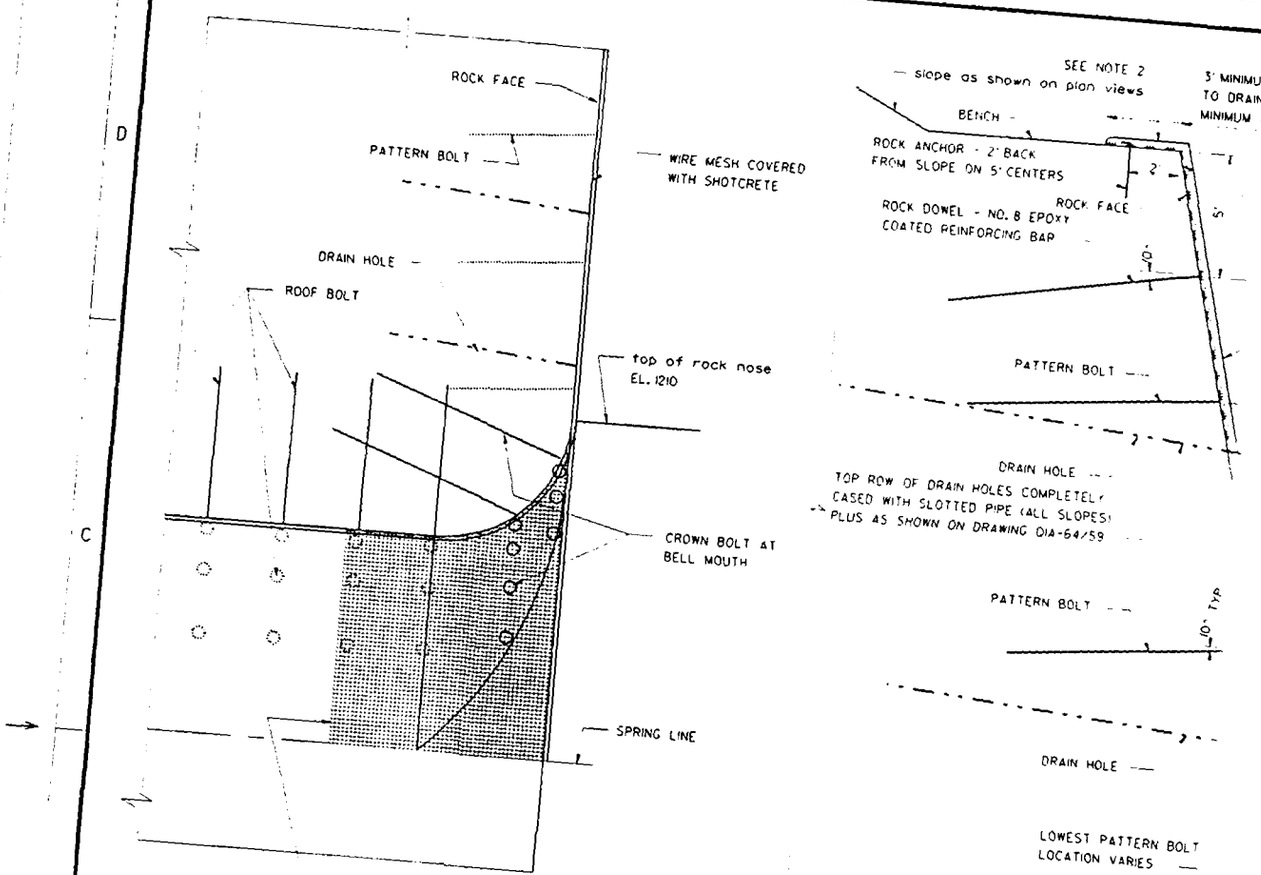
Drawn By: CAG
Checked By: PR
PR Geologist
Approved By:
Chief, Geotechnical Branch
Chief, Engineering Division

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTALS
DESIGN & AS-BUILT CROSS-SECTIONS PERPENDICULAR TO BACKSLOPE

Date: FEB 1994
Scale: 1"=20'
Record Drawing as constructed 22?-?
Drawing Number: Q1A-4385

Computer Solid Aided Section Design & Drafting

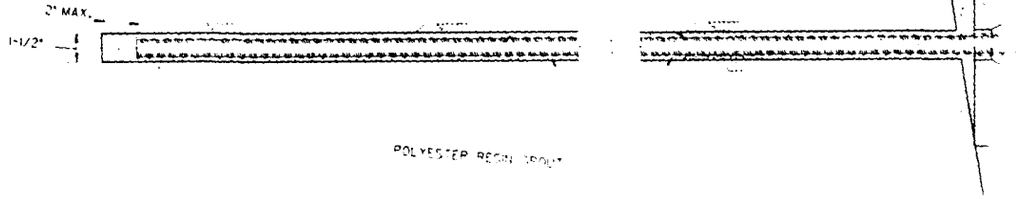
PLATE B-10



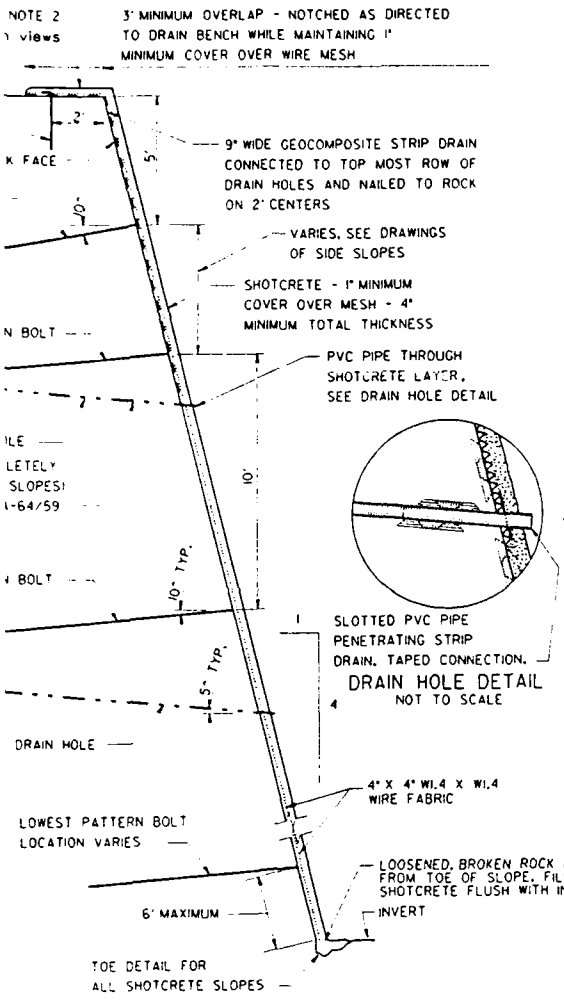
DETAIL
WIRE MESH INSTALLATION
AT BELL MOUTH
(UPSTREAM PORTAL ONLY)
SCALE: 1" = 5'

TOE DETAIL F
ALL SHOTCRE

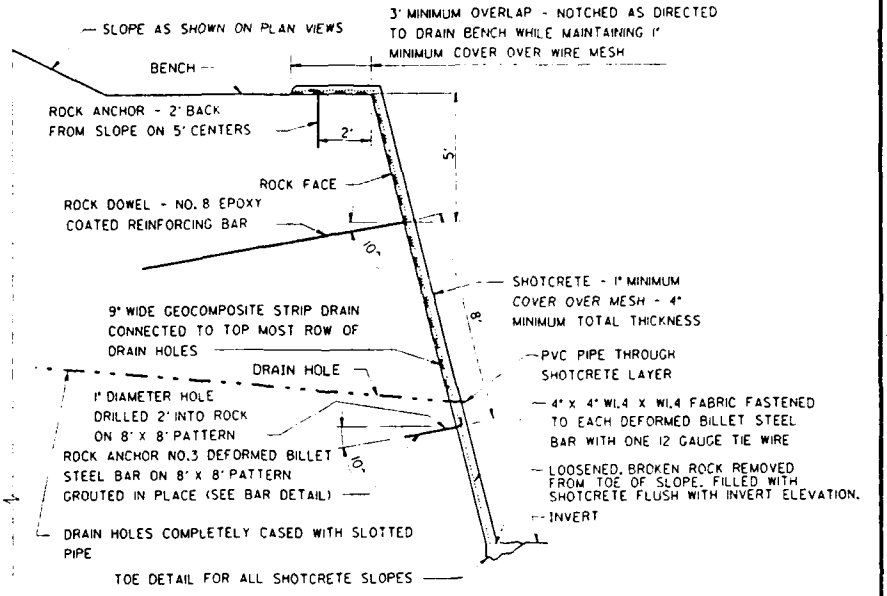
DETAIL
SLOPE TREATMENT FOR 4 ON 1
AND ROCKNOSE SIDE SLOPES TO RECEIVE S
SCALE: 1" =



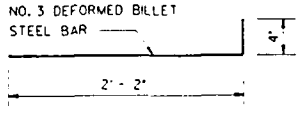
DETAIL
ROCK BOLT
NOT TO SCALE



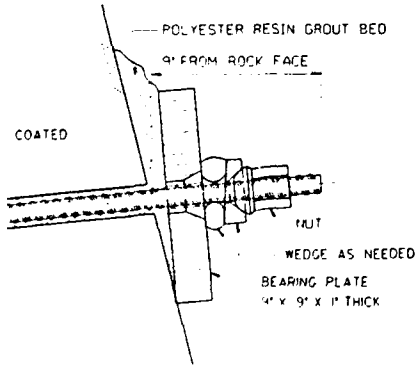
DETAIL
MENT FOR 4 ON 1 SLOPES OVER 40' HIGH
ES TO RECEIVE SHOTCRETE (STEEPER THAN 4V ON 1H)
SCALE: 1" = 2.5'



DETAIL
SLOPE TREATMENT FOR SLOPES UNDER 40' HIGH - SHOTCRETE, DOWELS AND DRAINAGE ONLY
SCALE: 1" = 2.5'



ROCK ANCHOR BAR DETAIL
NOT TO SCALE



NOTE:
CONICAL NUT AND WEDGE ASSEMBLY SHOWN. OTHER SYSTEM AS APPROVED MAY BE USED

NOTES:

1. SPACING ON ROCK DOWELS AND ROCK BOLTS TYPICAL EXCEPT AS MODIFIED IN OTHER DRAWINGS.
2. SHOTCRETE WAS EXTENDED UP-SLOPE TO COVER ALL SILTSTONE SURFACES.

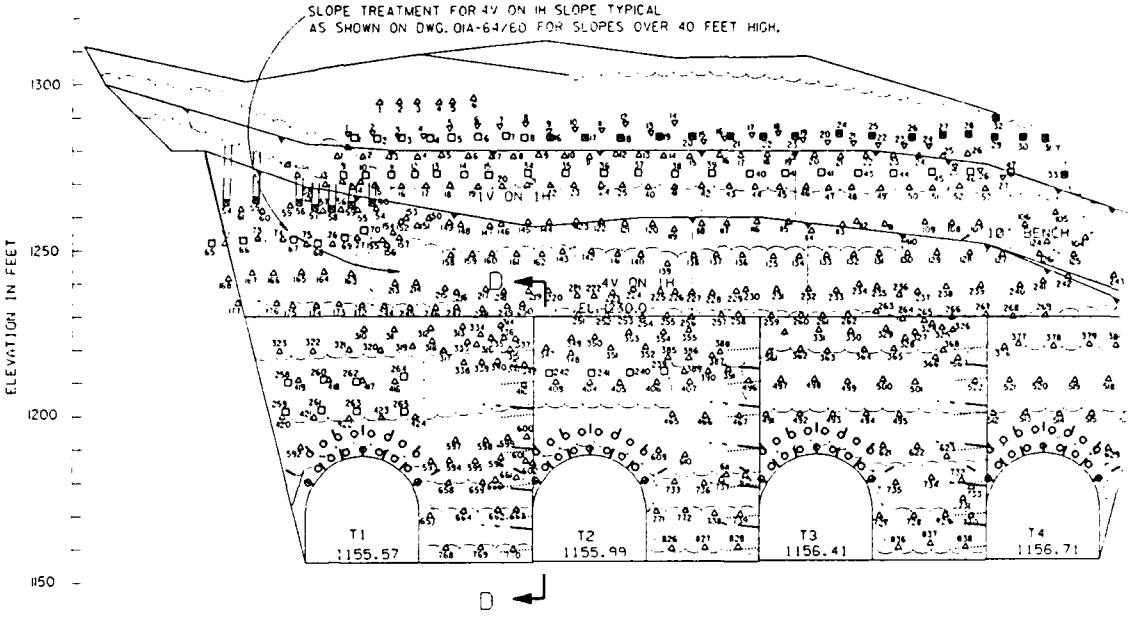
.3	2-2-94	AS CONSTRUCTED	MAR	
.2	6-30-89	ADDED DRAIN HOLE DETAIL	E.P.D.	J.L.S.
.1	5-31-89	CONFORMING TO REVIEW COMMENTS	E.P.D.	J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

PORTAL
ROCK SLOPE TREATMENT DETAILS

01A-64/60.3

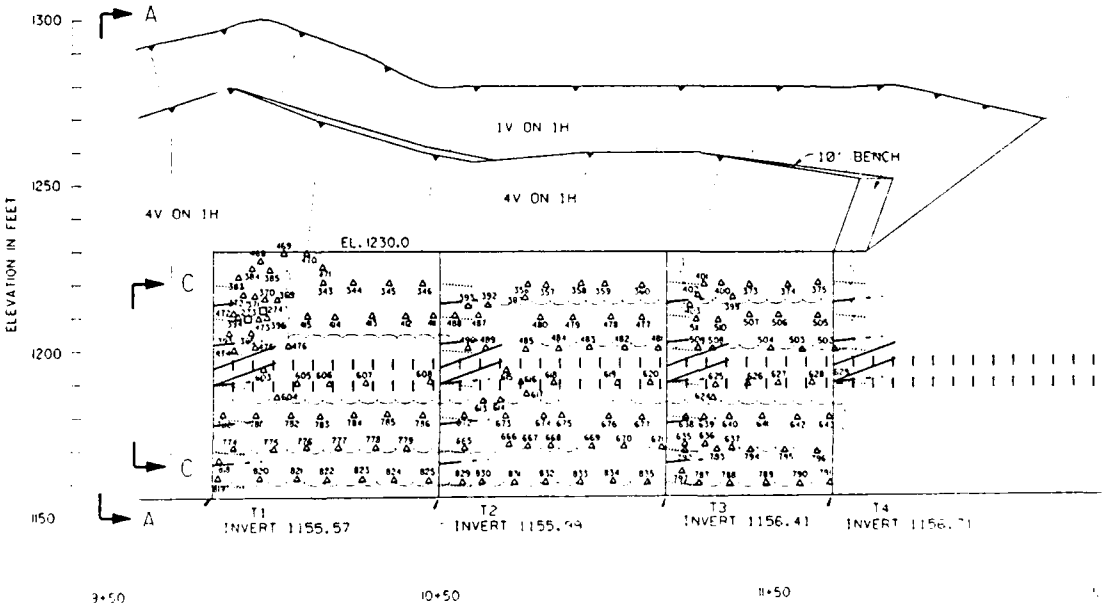
PLATE B-11



SECTION A-A

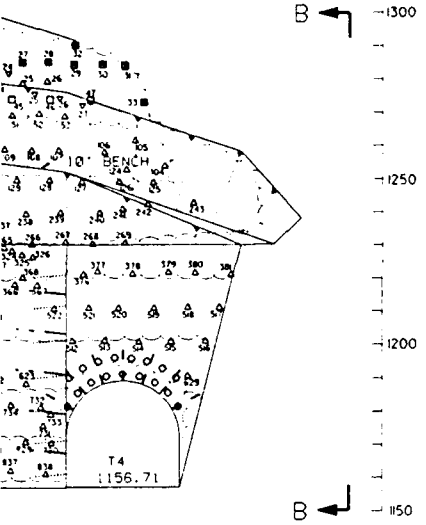
SCALE: 1" = 20'

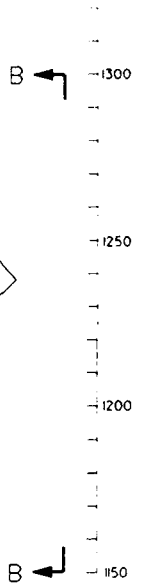
INVERT ELEVATION SHOWN AT TOP OF 8" CONCRETE BASE SLAB.

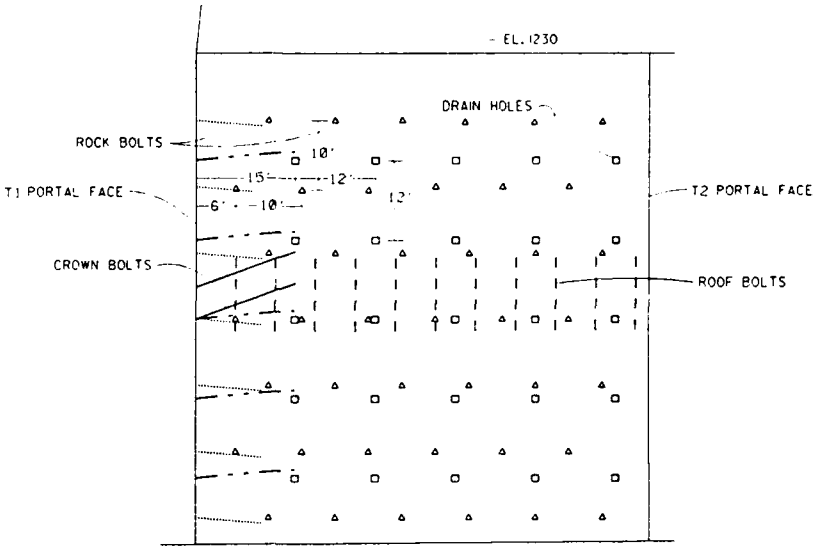


SECTION B-B

SCALE: 1" = 20'





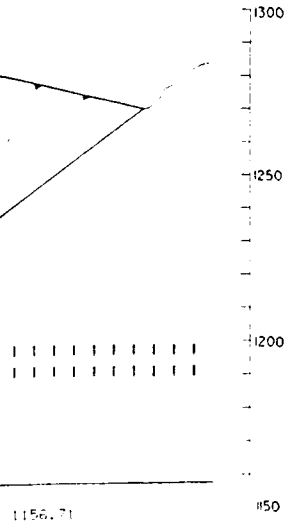


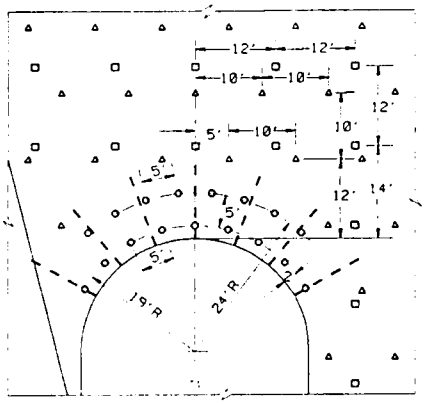
SECTION D-D

SCALE: 1" = 10'

SPACING SHOWN TYPICAL.

8.





SECTION C-C

SCALE: 1" = 10'

NOTES:

1. GENERAL NOTES ON DRAWING 01A-64/2.
2. SLOPE TREATMENT DETAILS AS SHOWN ON DRAWING 01A-64/60.
3. GENERAL PLAN OF D/S PORTAL SHOWN ON DRAWING 01A-64/61.
4. SUPPORT DETAILS FOR TUNNELS SHOWN ON DRAWING 01A-64/72.
5. LOCATION, NUMBER, & LENGTH OF ROCK BOLTS, DOWELS & DRAINS MAY BE VARIED AT THE DIRECTION OF CONTRACTING OFFICER TO SUIT ROCK CONDITIONS EXPOSED AS EXCAVATION PROGRESSES.
6. ALL VERTICAL AND 1H ON 4V ROCK FACES TO BE COVERED WITH WIRE MESH OR FIBER REINFORCED SHOTCRETE.

LEGEND

- DRAIN HOLES: 15' DEEP, 3" DIAMETER, ANGLED UP AT 5 DEGREES ON A 12' X 12' SQUARE PATTERN BEGINNING ON THE CENTERLINE OF EACH TUNNEL 14' ABOVE THE CROWN.
- PATTERN BOLTS: 10' LONG, ANGLED DOWN AT 5 DEGREES ON 10' X 10' STAGGERED PATTERN BEGINNING 12' ABOVE THE TUNNEL CROWN AND 5' LEFT AND RIGHT OF THE TUNNEL CENTERLINE.
- ROOF BOLTS: INSIDE TUNNEL 12' LONG ON 6' CENTERS RADIALLY OUT FROM CENTER AND ALONG TUNNEL AXES.
- CROWN BOLTS: 15' LONG ANGLED UP AT 20 DEGREES TO TUNNEL AXIS AS SHOWN ON DRAWING.
- DRAIN HOLES FULLY CASED WITH SLOTTED PVC PIPE.
- STRIP DRAINS.

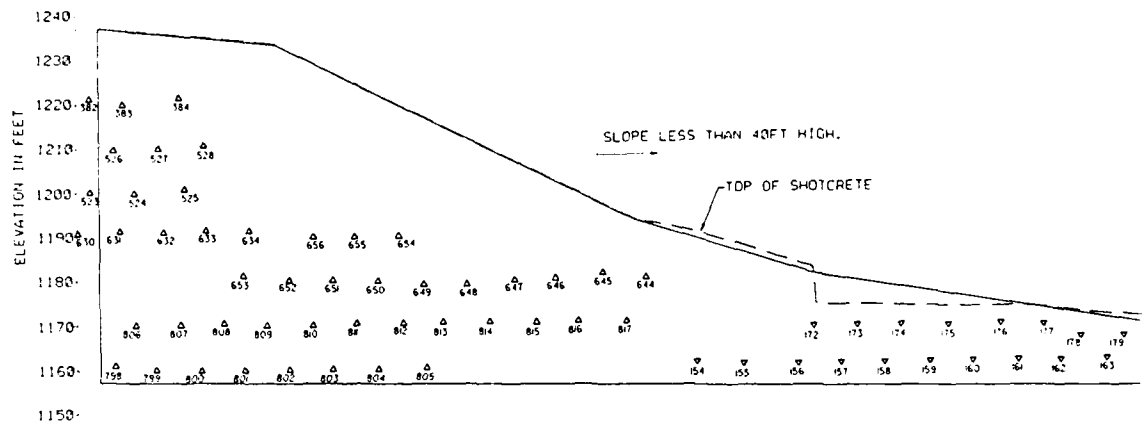


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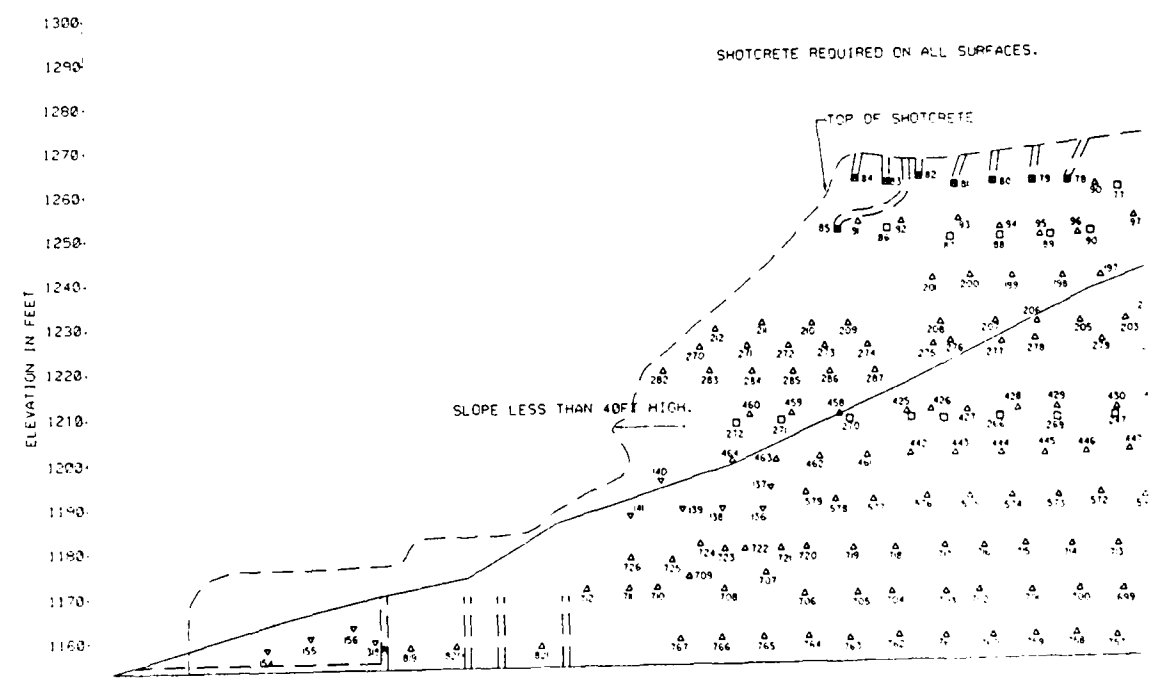
DOWNSTREAM PORTAL
ROCK SLOPE TREATMENT

01A-64 60/1

PLATE B-12

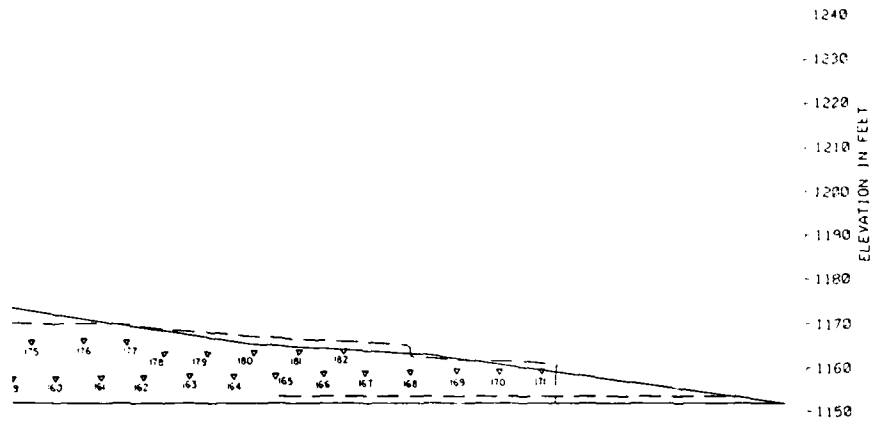


RIGHT BANK
LOOKING UP STATION



LEFT BANK
LOOKING UP STATION

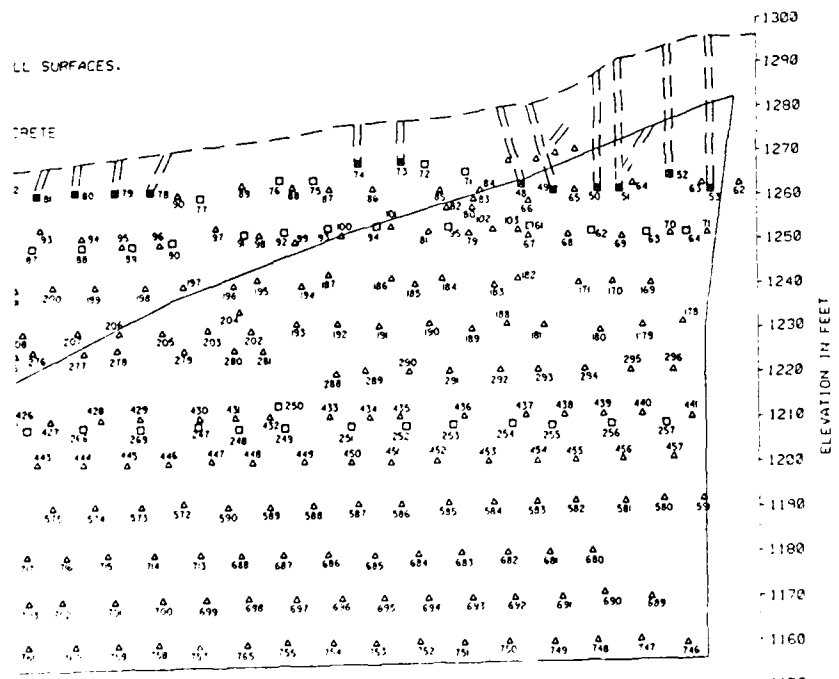
L SURFACES.



ON

LL SURFACES.

CRETE



LEGEND

- □ DRAIN HOLES: 15' DEEP, 3" DIAMETER, ANGLED UP AT 5 DEGREES ON A 12' X 12' SQUARE PATTERN.
- △ PATTERN BOLTS: 10' LONG, ANGLED DOWN AT 5 DEGREES ON 10' X 10' STAGGERED PATTERN.
- ⊠ DRAIN HOLES FULLY CASED WITH SLOTTED PVC PIPE.
- ▽ ROCK DOWELS.
- = = STRIP DRAINS.

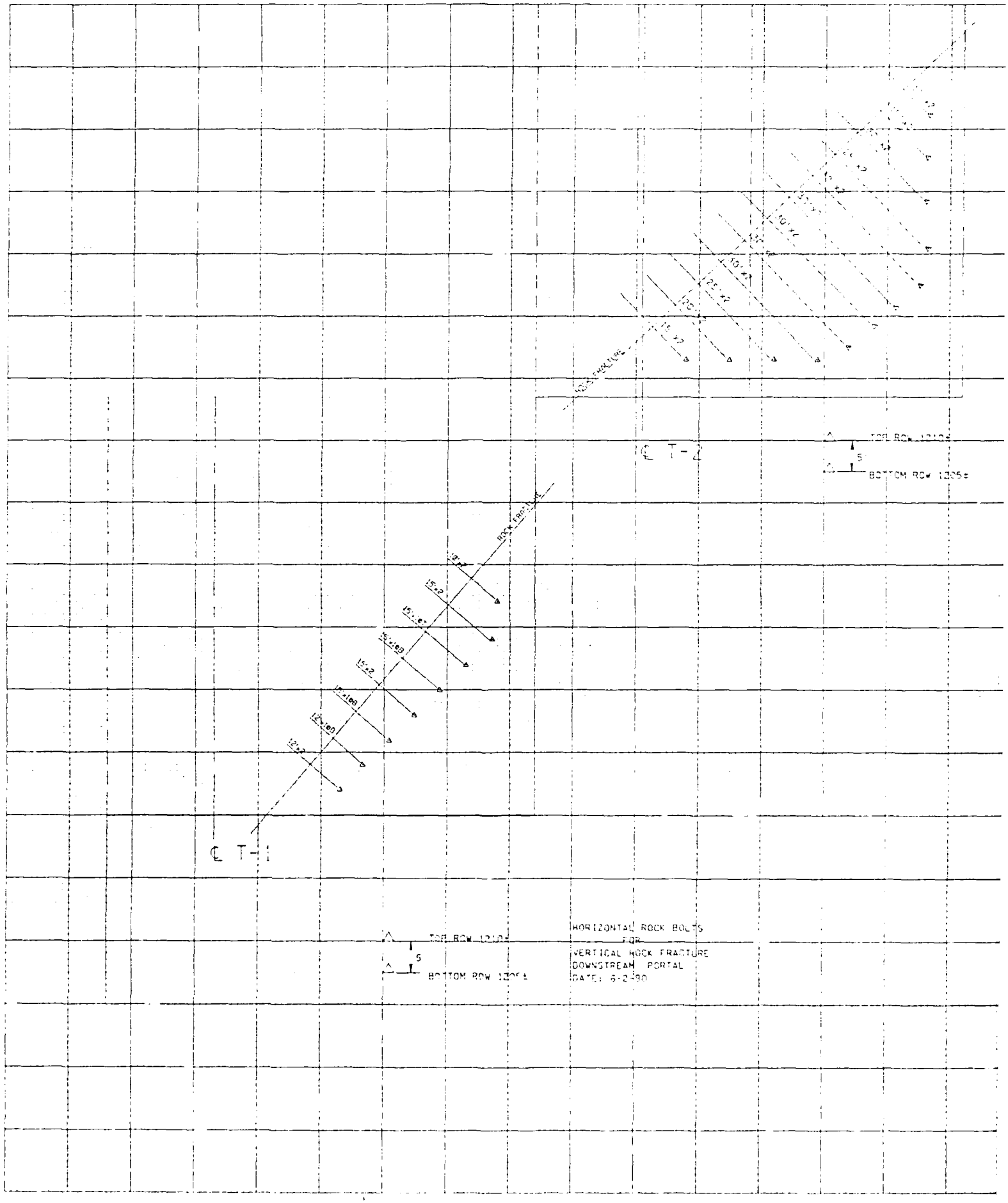
FOR NOTES SEE DRAWING 01A-64/58.

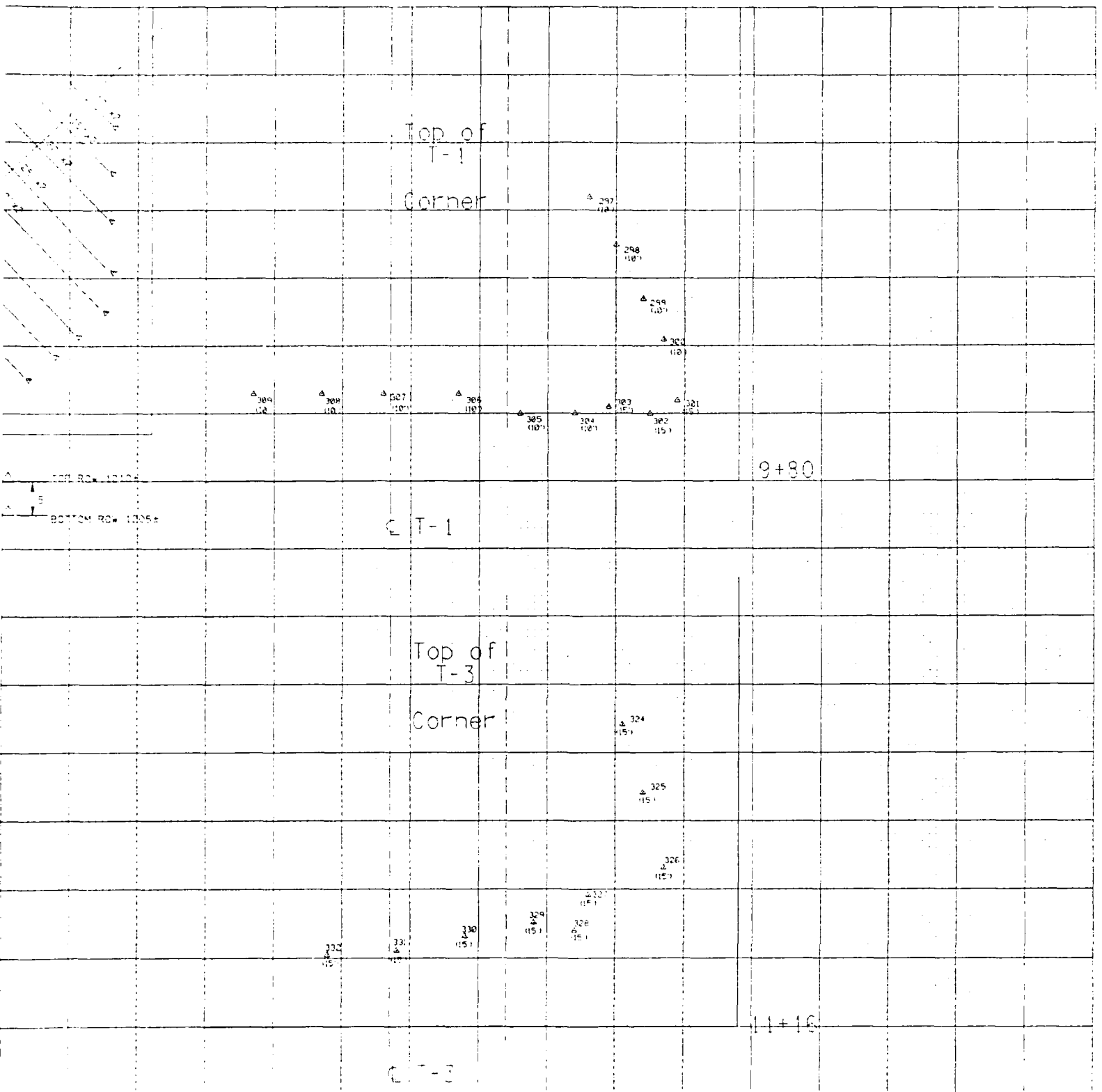
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
SIDE SLOPE ROCK TREATMENT

01A-64/70.2

PLATE B-13

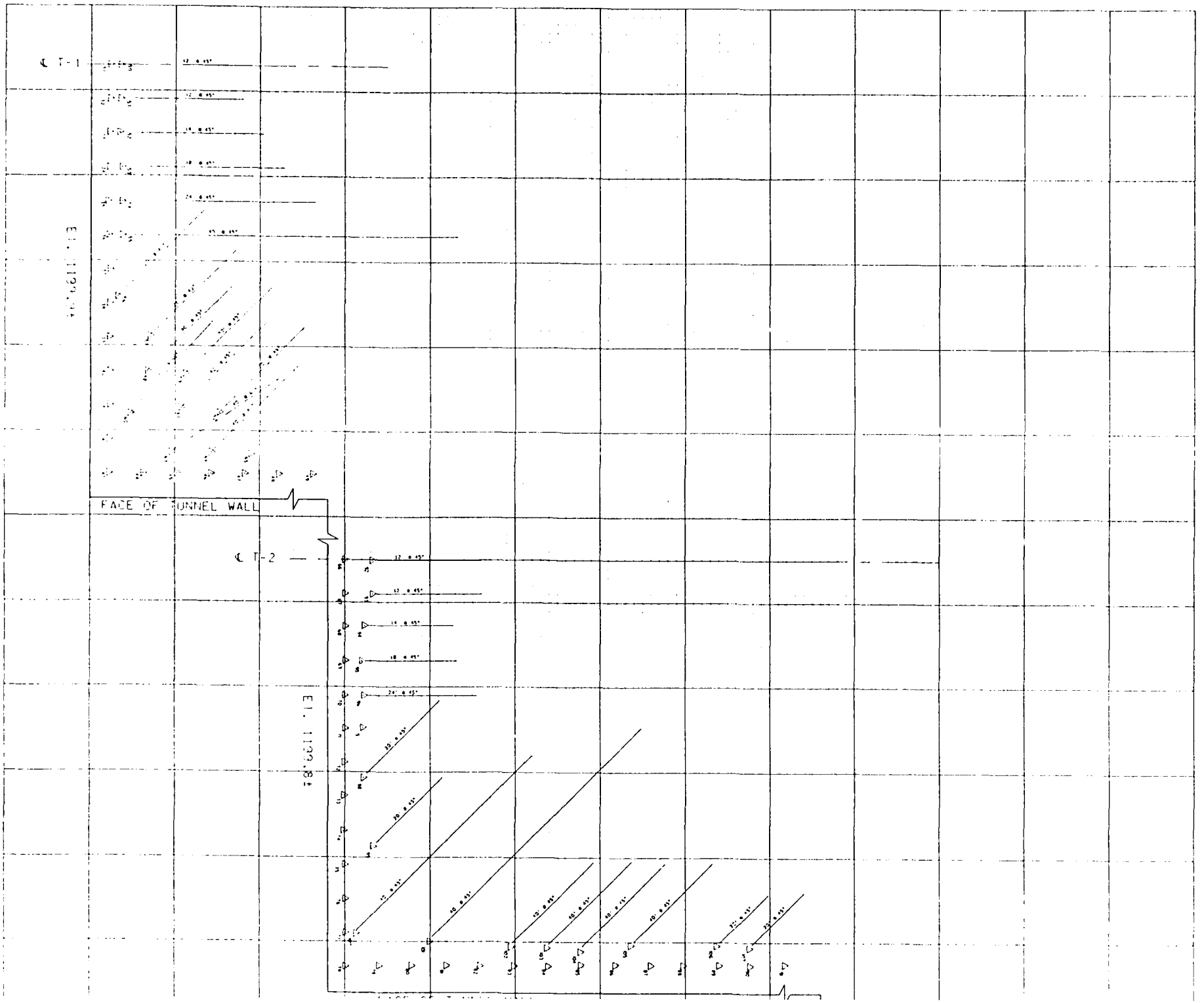

ROCK FRACTURE
℄ T-2
TOP ROW 1210±
5
BOTTOM ROW 1205±
ROCK FRACTURE
℄ T-1
TOP ROW 1210±
5
BOTTOM ROW 1205±
HORIZONTAL ROCK BOLTS
FOR
VERTICAL ROCK FRACTURE
DOWNSTREAM PORTAL
DATE: 6-2-80

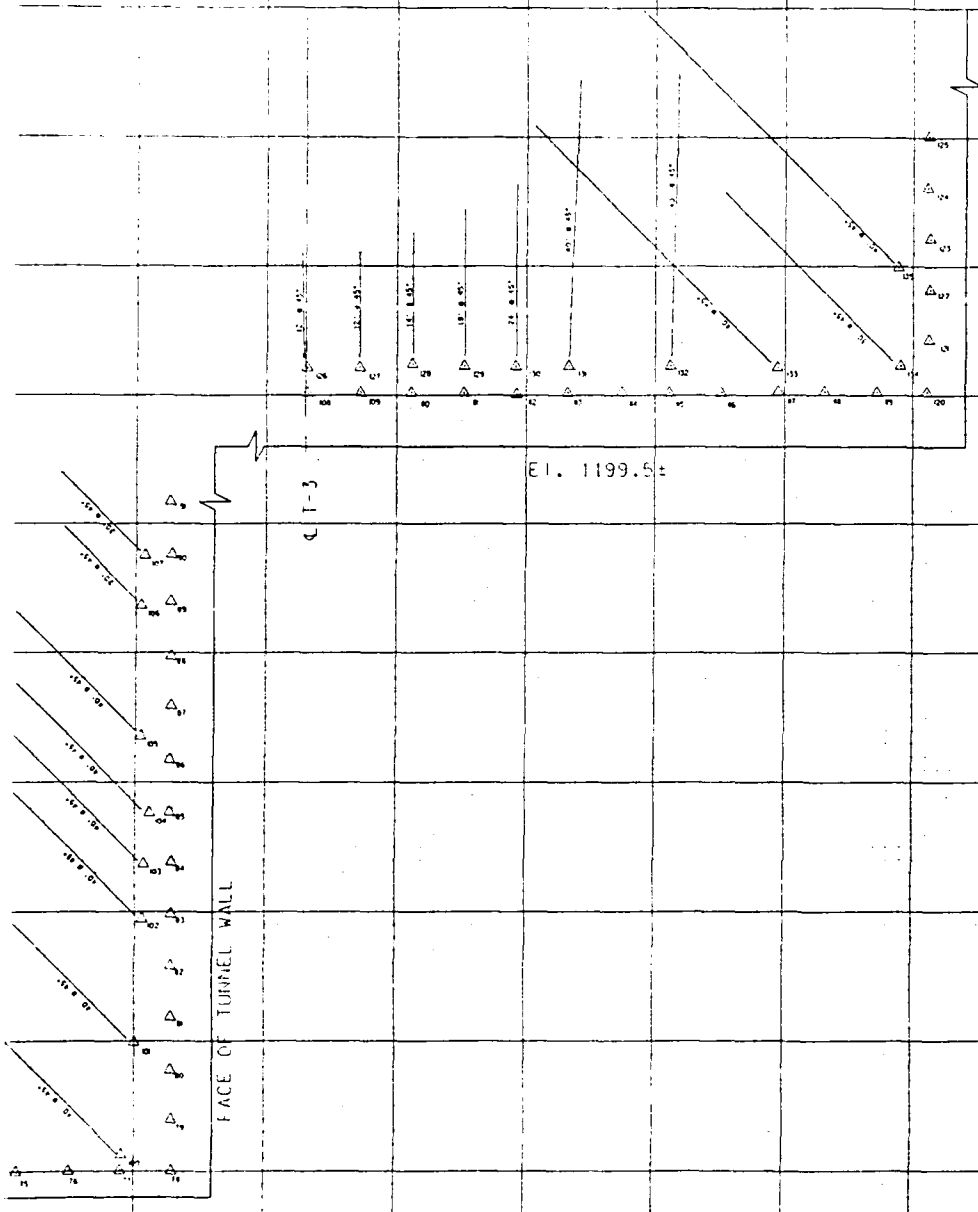


VERTICAL ROCK BOLTS
DOWNSTREAM PORTAL
DATE: 5-11-90

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: JTM	HARLAN DIVERSION PROJECT
Designed By:	AS CONSTRUCTED
ENGINEER	DOWNSTREAM PORTAL
	HORIZONTAL & VERTICAL ROCK BOLTS
Approved By:	Date: JAN 1994
CHIEF, BRANCH	PLATE B-14
CHIEF, ENGINEERING DIVISION	Record drawing as constructed dated


℄ T-1
EL. 1194.4
FACE OF TUNNEL WALL
℄ T-2
EL. 1193.84



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: JTM

Checked By:

ENGINEER

Approved By:

CHIEF, E BRANCH

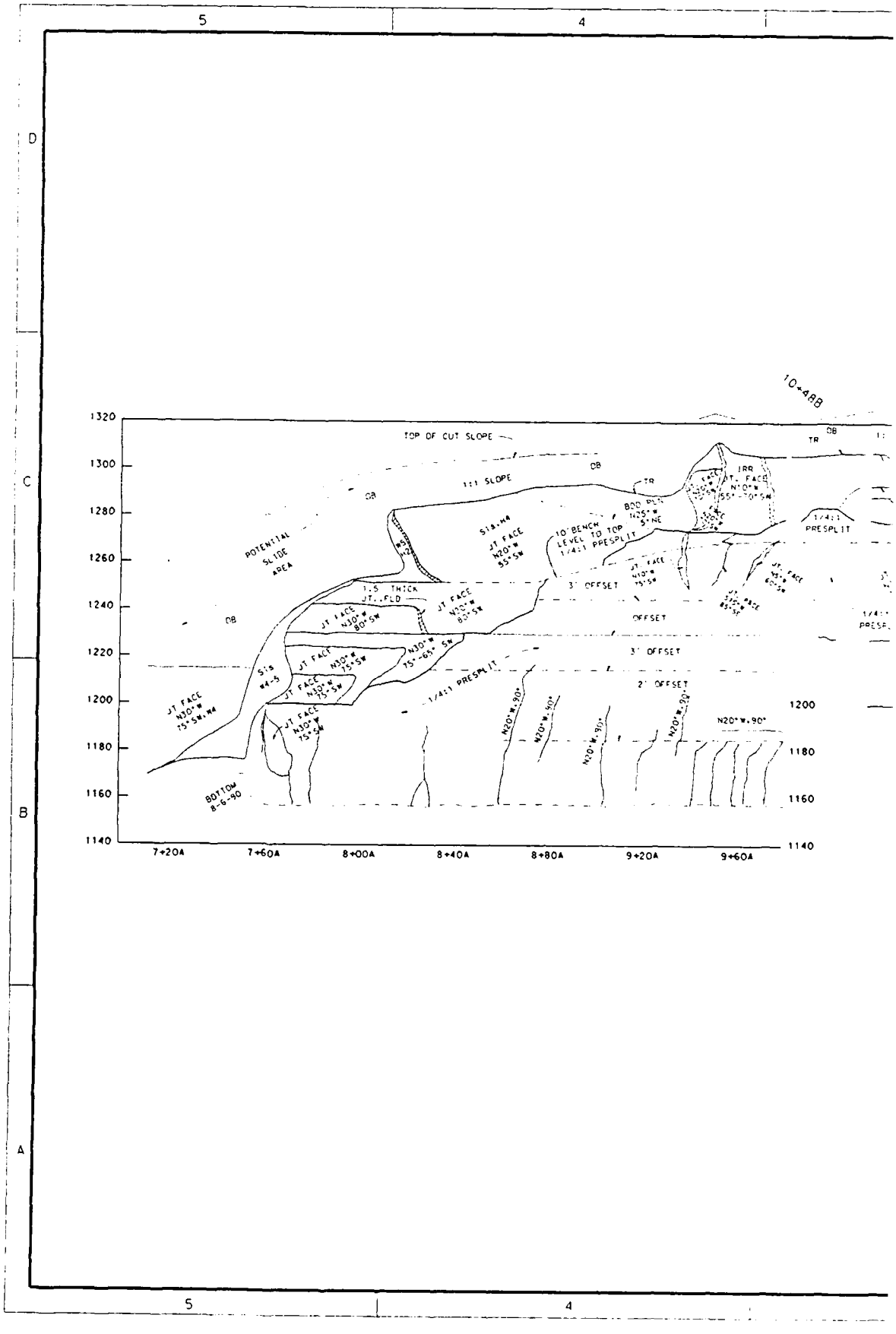
CHIEF, ENGINEERING DIVISION

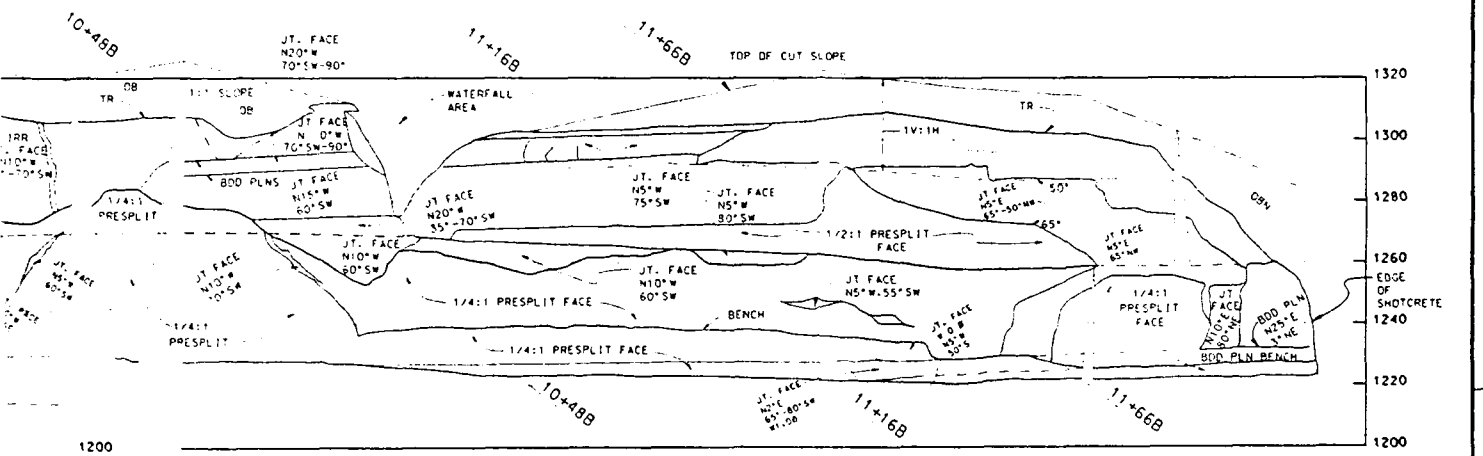
HARLAN DIVERSION PROJECT
AS CONSTRUCTED
DOWNSTREAM PORTAL
AS BUILT DOWELS

Date: JUL 1994

Scale: NOT TO SCALE

PLATE B-15


5
4
D
C
B
A
10+488
1320
1300
1280
1260
1240
1220
1200
1180
1160
1140
TOP OF CUT SLOPE
1:1 SLOPE
DB
TR
POTENTIAL SLIDE AREA
10' BENCH LEVEL TO TOP 1/4:1 PRESPLIT
3' OFFSET
OFFSET
2' OFFSET
1/4:1 PRESPLIT
BOTTOM 8-6-90
7+20A
7+60A
8+00A
8+40A
8+80A
9+20A
9+60A



NOTES:

1. MAPPED IN THE PLANE OF THE SLOPE. EXCEPT FOR HORZONITAL BENCHES WHICH ARE NOT SHOWN.
2. ROCK REINFORCEMENT AND DRAINAGE NOT SHOWN.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

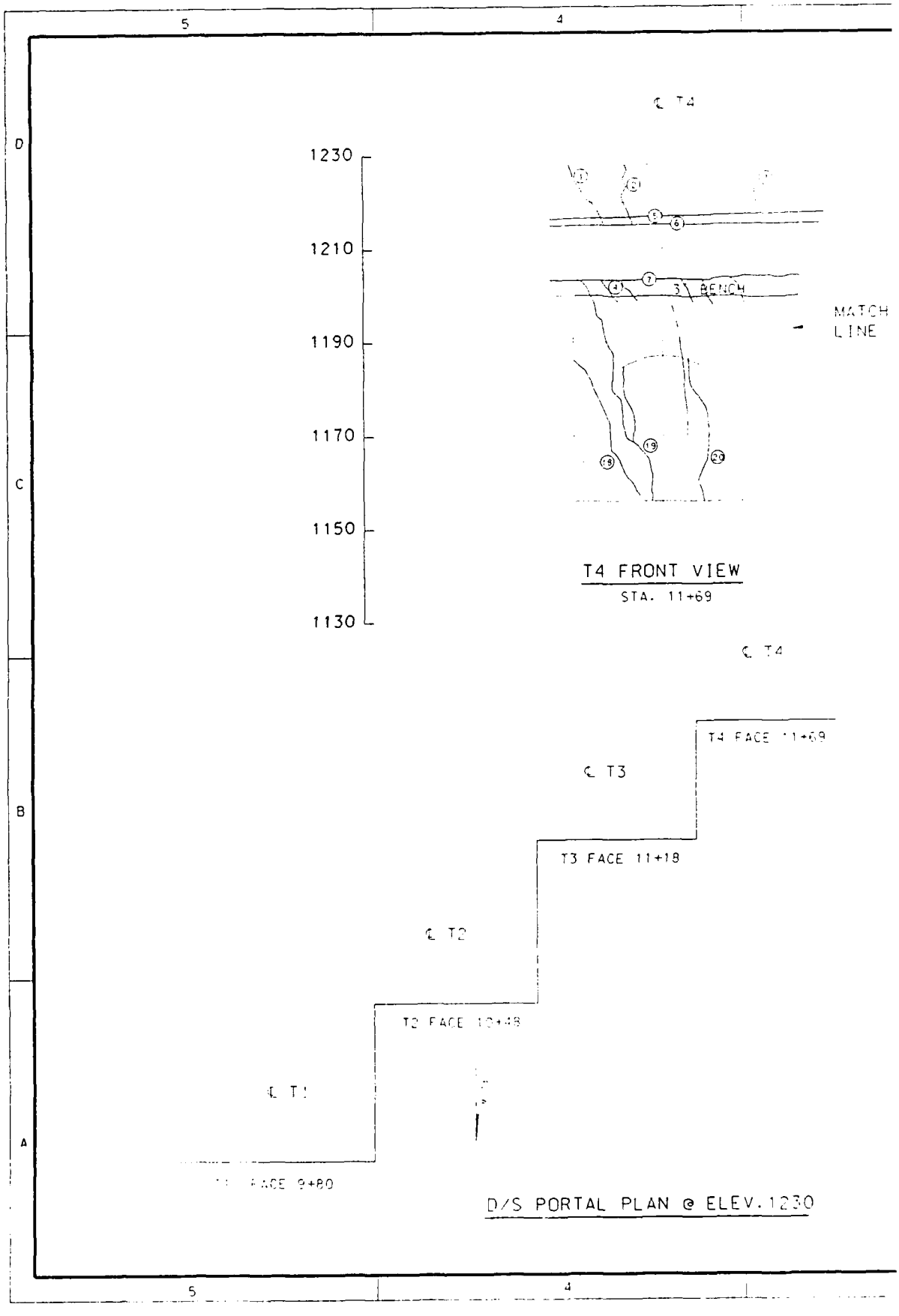
Drawn By: C.A.G.
Checked By: P.R.

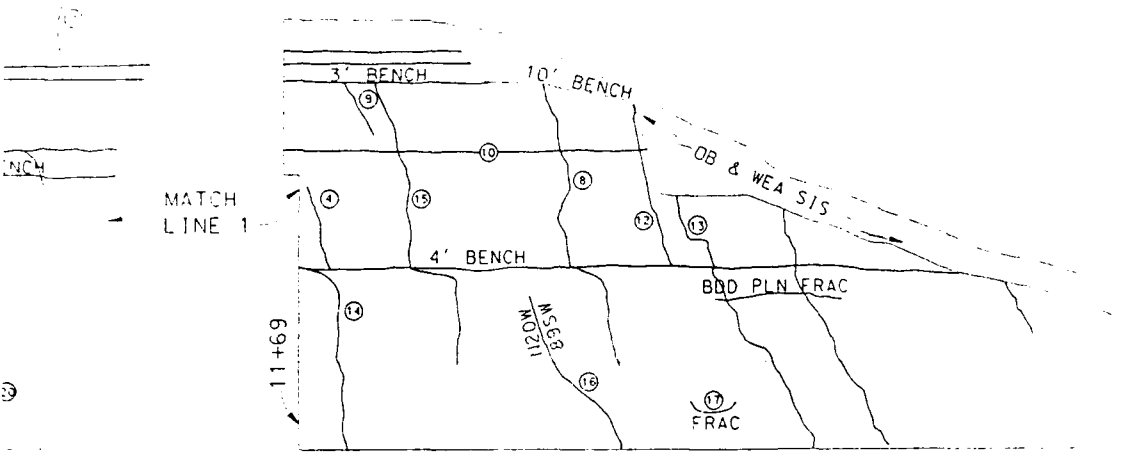
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL AREA
GEOLOGIC MAP OF SURFACE SLOPES

Computer Aided Design & Drafting

Drawing Number: Q1A-4386

PLATE B-16


5
4
D
C
B
A
℄ T4
1230
1210
1190
1170
1150
1130
3' BENCH
MATCH LINE
T4 FRONT VIEW
STA. 11+69
℄ T4
T4 FACE 11+69
℄ T3
T3 FACE 11+18
℄ T2
T2 FACE 10+48
℄ T1
T1 FACE 9+80
D/S PORTAL PLAN @ ELEV. 1230



T4 SIDE VIEW

T4 JOINT DESCRIPTIONS

① Jt.N20°E 65°-75°W-NW
② Jt.N20°E 80°NW
③ Jt.N10°E 75°SE
④ jts. N15°W 75°SW
⑤ Bdd pln N70°W 2°NE
⑥ Bdd pln N70°W 2°NE
⑦ Bdd pln 0°ø
⑧ Jt. N10°E 90°-80°NW
⑨ Jt. N10°E 90° 0ø
⑩ Bdd plns.hor.0ø
⑪ Jt. N10°E 90°ø
⑫ Jt.N10°E 80°-70°NW 0ø
⑬ Jt.N10°E 90° 0ø
⑭ Jt.N10°E 90° 0ø
⑮ Jt.N12°E 90° 0ø
⑯ Jt.N20°W 89°SW
⑰ Blast Frac
⑱ Jt.N5°E 60°W 90° 0ø
⑲ Jt.N10°E 70°-[illegible]°NW 0ø
⑳ Jt.N15°E 90° 0ø

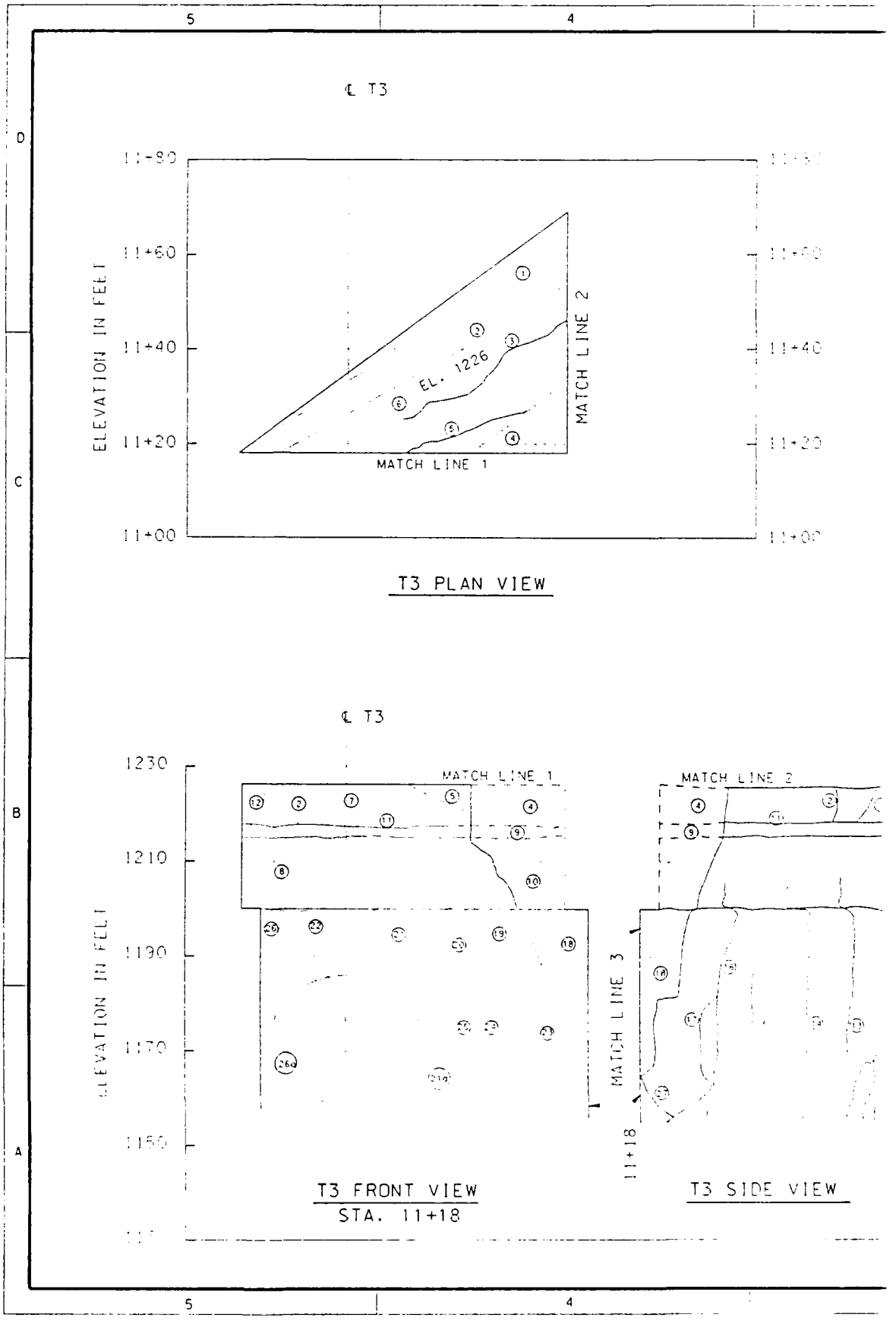
20' 0 20'
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL-TUNNEL 4
GEOLOGIC MAP

Drawing No. Q1A-4387

PLATE B-17

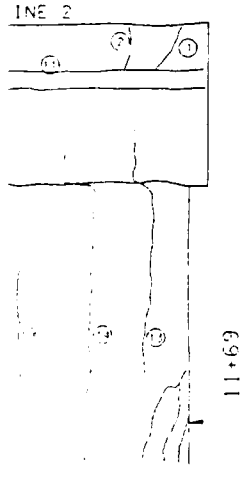

℄ T3
11+80
11+60
11+40
11+20
11+00
ELEVATION IN FEET
EL. 1226
MATCH LINE 1
MATCH LINE 2
T3 PLAN VIEW
℄ T3
1230
1210
1190
1170
1150
ELEVATION IN FEET
MATCH LINE 1
MATCH LINE 2
MATCH LINE 3
11+18
T3 FRONT VIEW
STA. 11+18
T3 SIDE VIEW

REVISIONS				
REV.	DESCRIPTION	DATE	BY	APPR.

T-3 JOINT DESCRIPTIONS

① JT N20°E 75°NW-90°,.04'(op½"-3/4" by blast),ti
② JT N20°E 75°NW-90°,.04'(op½"-3/4" by blast),ti
③ Irreg.BF
④ Jt face N10°E 70°NW
⑤ Jt,N20°E,60°NW (cly si)
⑥ Bdd pln,N20°W 3°NE
⑦ Jt N20°E 80°NW
⑧ Jt,N20°E 90,ti
⑨ Blast fractured face
⑩ Jt face,N5E,80NW-90°
⑪ Bdd pln,0ø,cly si
⑫ Jt face,N20°E 75°NW
⑬ Jt, N5°E 75°NW-90°(op½"-3/4" by blast)
⑭ Jt,N10°E 90°,ti
⑮ Jt N20°W 90°,ti
⑯ Jt,N10°E 90°,ti
⑰ Jt,N10°W 90°,ti
⑱ Jt face N20°E 70°NW 90°,ti
⑲⑳㉑ Jt,N5°E 90°,ti
㉒ Jt,N10°W70°SW,ti
㉓ Jt,N15°E 90° .04
㉔ Jt, N10°W 85°SW,ti
㉕ Jt, N15°E 80°NW,ti
㉖ Jt, N0°E 80°W,ti
㉗ Jt, N65°E 75°SE

11+80
11+60
11+40
11+20
11+00



1230
1210
1190
1170
1150

IDE VIEW

Graphic Scale

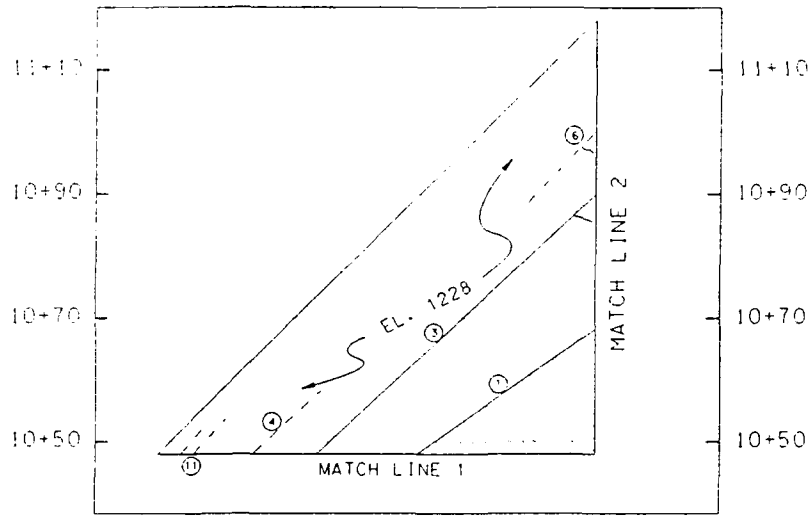
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENN. 37

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL-T3 CORNER
GEOLOGIC MAPS

DATE: FEB 1994
Record Drawing as constructed dated
Q1A-4388

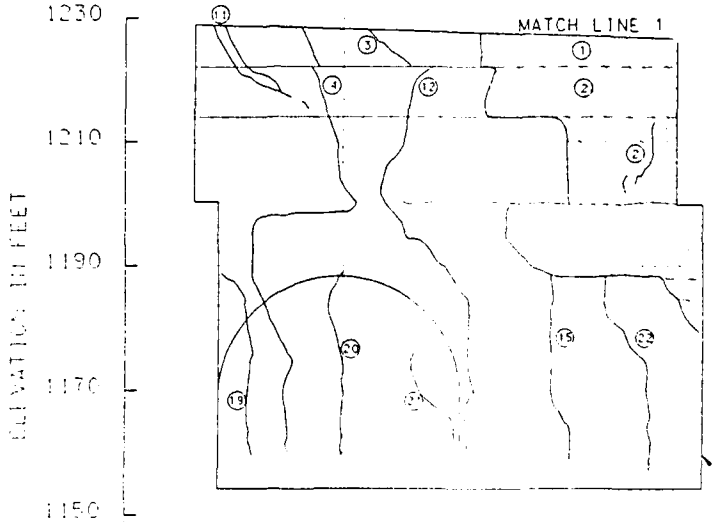
COMPUTER-SYSTEMS AIDED DESIGN & DRAFTING SECTION

PLATE B-18



T2 PLAN VIEW

℄ T2



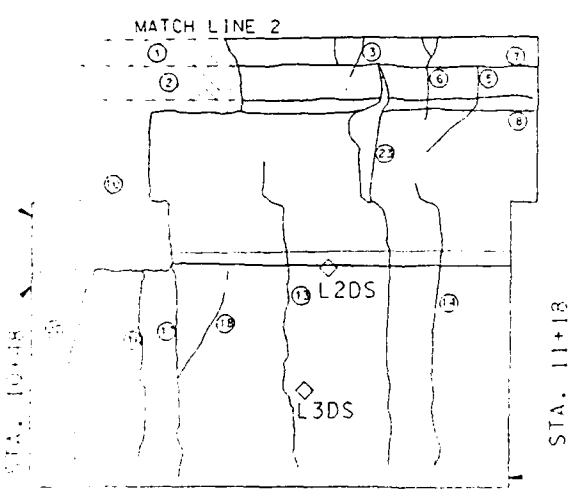
T2 FRONT VIEW
STA. 10+48

T2

REVISIONS				
REV.	DESCRIPTION	DATE	BY	APPROVED

T-2 JOINT DESCRIPTIONS

① Blast fractured.irr. N20°E
② Jt Face N10°E 90°
③ Jt.N5°E65°NW
④ Jt.N2°E 90°
⑤ Jt.N10°E 90°(op 1" by blast)
⑥ Jt.N10°E 90°(op 1" by blast)
⑦ Bdd pln.hor
⑧ Bdd pln.hor
⑩ Jt face N15°E 90°
⑪ Jts. N20°E 30°NW
⑫ Jt.N0°E V
⑬⑭ Jts.N10°E 90°
⑮ Jt.N10°W 80°SW
⑯ Jt.N10°E 90°
⑰ Jt.N20°W 80°SW
⑱ Jt
⑲ Jt.N24°E 84°NE
⑳ Jt.N25°E 81°SE
㉑ Jt.N35°E 85°SE
㉒ Jt.face N20°E 90°-75°NW



T2 SIDE VIEW

LEGEND

L3DS ◇ LOAD CELL

Graphic Scale

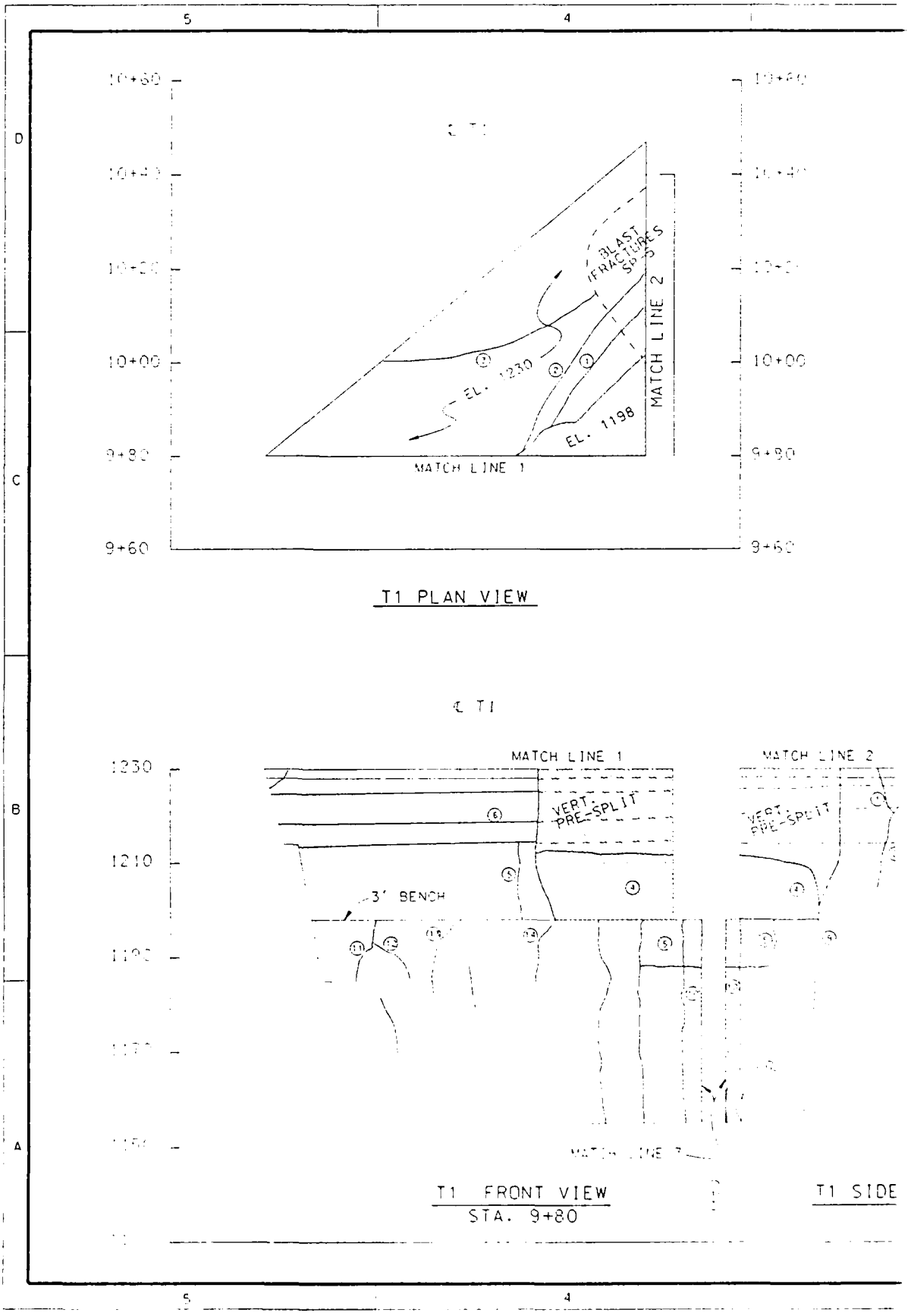
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL-T2 CORNER
GEOLOGIC MAPS

Date: FEB 1994
Drawing Number: Q1A-4389

Computer Aided Design & Drafting Section

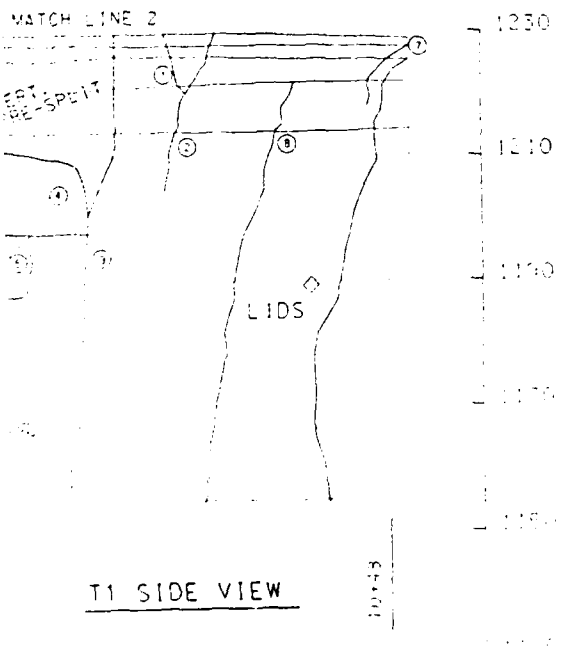
PLATE B-19


5
4
D
C
B
A
10+60
10+40
10+20
10+00
9+80
9+60
℄ T1
BLAST FRACTURES
MATCH LINE 2
MATCH LINE 1
EL. 1230
EL. 1198
T1 PLAN VIEW
℄ T1
1230
1210
MATCH LINE 1
MATCH LINE 2
VERT. PRE-SPLIT
3' BENCH
T1 FRONT VIEW
STA. 9+80
T1 SIDE

REV.	DESCRIPTION	DATE	BY	APPR'VD

T1 JOINT DESCRIPTIONS

① J1,N15°W 90°..03(open¾" by blast)
② J1,N15°W 90°..03(open¾" by blast)
③ Blast fractured,open¼"
④ J1,N5°E 60°SE-70°NW
⑥ Bed pln,N80°W 3°NE
⑦ J1s,N20°E20°-30°NW
⑧ J1,N10°W 80°SW
⑨ J1,N10°E 90°-80°NW
⑩ J1 face, N10°E 90°
⑪ J1,N10°E 70°NW
⑫ J1,N10°E 30°NW
⑬ J1 N-S 90°-80°SW
⑭ J1 N10°E 90°
⑮ J1,N15°E 90°
⑯ J1,N5°E 84°NW



T1 SIDE VIEW

LEGEND
LIDS ◇ LOAD CELL

20' 0 20'
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

WOLF CREEK DAM
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL-T1 CORNER
GEOLOGIC MAPS

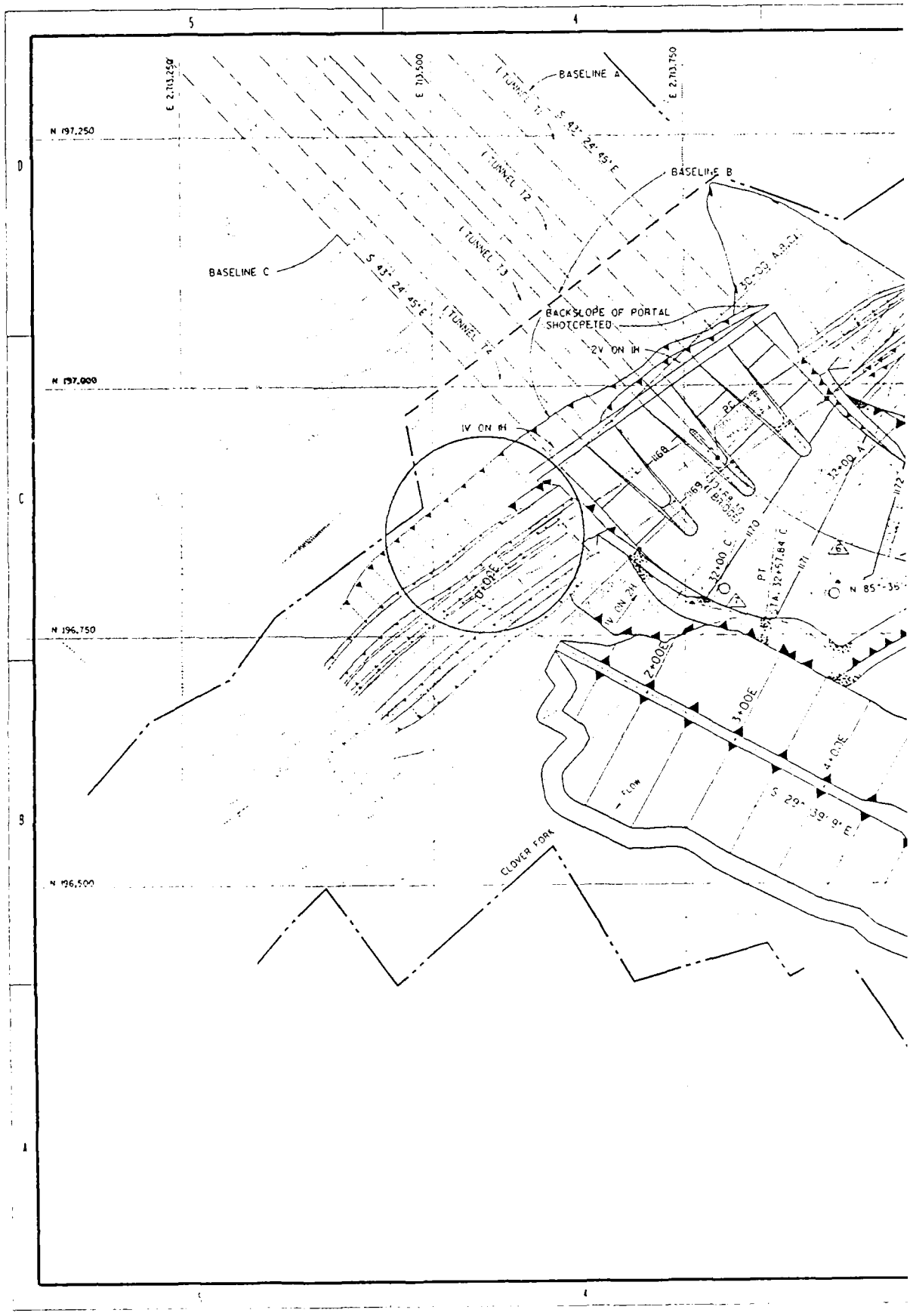
Computer Support & Design Section

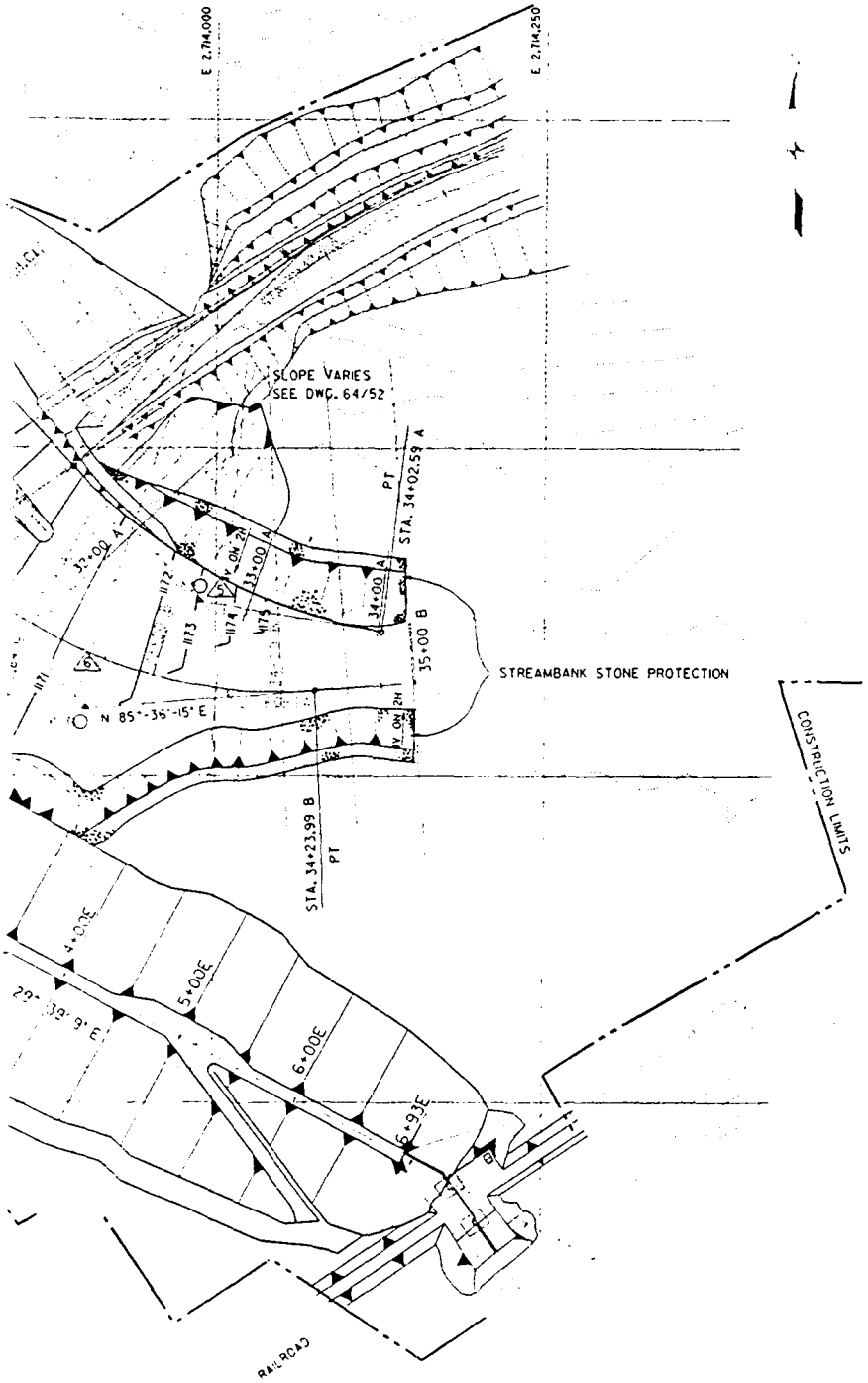
Drawing No. 96-1A-4390

PLATE B-20

Appendix C - Upstream Portal

Plate No.	Drawing No.	Description
C-1	Q1A-64/51.2	General Plan
C-2	Q1A-64/32.1	Boring Plan
C-3	Q1A-64/33.2	Geologic Section C-C
C-4	Q1A-64/34.1	Geologic Section D-D
C-5	Q1A-64/35.1	Geologic Section E-E
C-6	Q1A-64/36.1	Geologic Section F-F
C-7	Q1A-64/3 .2	Geologic Section G-G
C-8	Q1A-64/38.2	Geologic Section H-H
C-9	Q1A-64/54	Cross Sections
C-10	Q1A-4/391	Back-Slope Cross-Sections
C-11	Q1A-64/103.1	Nosing Plan
C-12	Q1A-64/104.1	Nosing Sections
C-13	Q1A-64/106.1	Nosing and Base Slab Detail
C-14	Q1A-59.3	Rock Slope Treatment
C-15	Q1A-64/58.1	Rock Slope Treatment
C-16	-------	Nosing 1 Reinforcement
C-17	-------	Nosing 2 Reinforcement
C-18	-------	Nosing 3 Reinforcement
C-19	Q1A-4/ 33	Geologic Map
C-20	Q1A-4/392	Nosing Surface Map
C-21	Q1A-4/394	Nosing 1 Map
C-22	Q1A-4/395	Nosing 2 Map
C-23	Q1A-4/396	Nosing 3 Map


BASELINE A
BASELINE B
BASELINE C
E 2,713,250
E 713,500
E 2,713,750
N 197,250
N 197,000
N 196,750
N 196,500
S 43° 24' 45" E
TUNNEL T1
TUNNEL T2
TUNNEL T3
TUNNEL T4
BACKSLOPE OF PORTAL SHOTCPETED
2V ON 1H
1V ON 1H
0+00E
2+00E
3+00E
4+00E
S 29° 39' 9" E
FLOW
CLOVER FORK
PC
PT
32+00 A
32+00 C
N 85°-35
A
B
C
D
5
4
3



CURVE DATA		
CURVE 5 BASELINE A	CURVE 6 BASELINE B	CURVE 7 BASELINE C
PI STA. 32+72.41 A	PI STA. 32+72.41 B	PI STA. 31+87.27 C
N 196,883.77	N 196,801.98	N 196,781.95
E 2,713,987.84	E 2,713,901.40	E 2,713,756.54
△ 37°-00'-00"	△ 51°-00'-00"	△ 34°-00'-00"
D 13.69°	D 15.62°	D 23.36°
L 270.18 FT.	L 326.58 FT.	L 145.31 FT.
T 140.00 FT.	T 175.00 FT.	T 75.00 FT.
R 418.42 FT.	R 366.90 FT.	R 245.31 FT.

NOTES:

1. FOR GENERAL NOTES SEE DWG. 64/2.
2. FOR DETAILED GEOMETRY OF PORTAL NOSES, SEE DWGS. 64/103 AND 64/104.
3. FOR DETAILS OF EMBANKMENT, SEE DWG. 64/74.
4. FOR DETAILS OF CLOSURE STRUCTURE, SEE DWG. 64/87.
5. FOR ROAD AND BRIDGE DETAILS SEE SEPERATE FOLIO.

Revisions	Date	Description	By	Checked
2	5-10-89	CHANGED CONSTRUCTION LIMITES, ADDED SLOPE DATA & NOTE 5	B.E.	D.J.
1	5-3-89	CONFORMING TO REVIEW COMMENTS	L.L.	P.E.B.

50 0 50
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

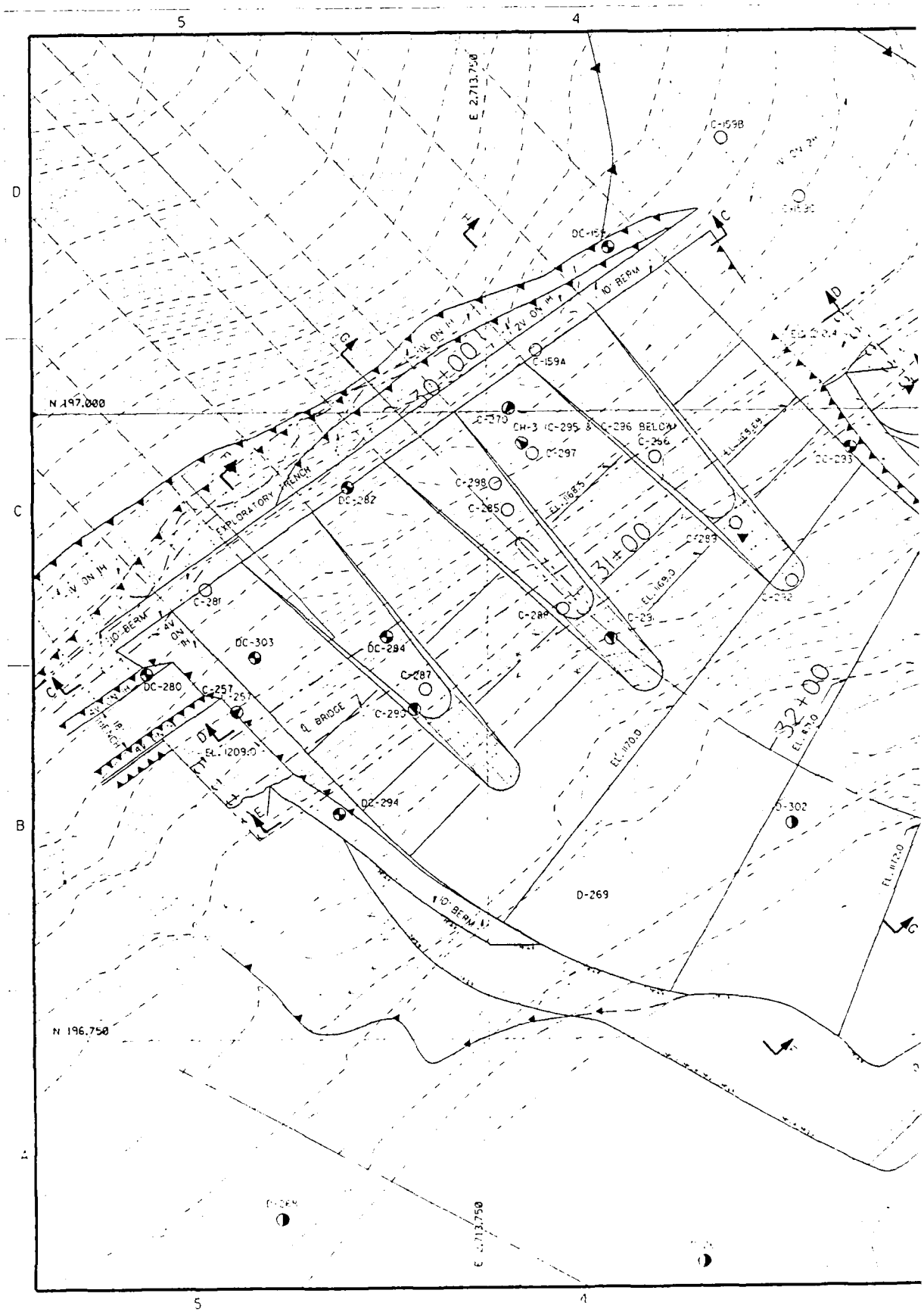
Designed By: P.E.B.
Drawn By: P.E.B.

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HAPLAN, KENTUCKY
DIVERSION
GENERAL PLAN
UPSTREAM PORTAL

Approved By: ENGINEER
Date: FEB. 1989
Scale: 1" = 50'
Sheet No. of
Drawing Number: 01A-64/51.2
Record Drawing as Constructed 5-1989

Computer Support Aided Design & Drafting Section

PLATE C-1


5
4
D
C
B
A
E 2,713,750
N 197,000
N 196,750
30+00
31+00
32+00
EXPLORATORY TRENCH
10' BERM
2V ON 1H
4V ON 1H
DC-280
DC-281
DC-282
DC-293
DC-294
DC-303
C-159B
C-159A
C-257
C-270
C-285
C-286
C-287
C-288
C-293
C-296
C-297
C-298
CH-3 (C-295 & C-296 BELOW)
EL. 1209.0
EL. 1169.0
EL. 1170.0
EL. 1172.0
D-269
D-302
℄ BRIDGE

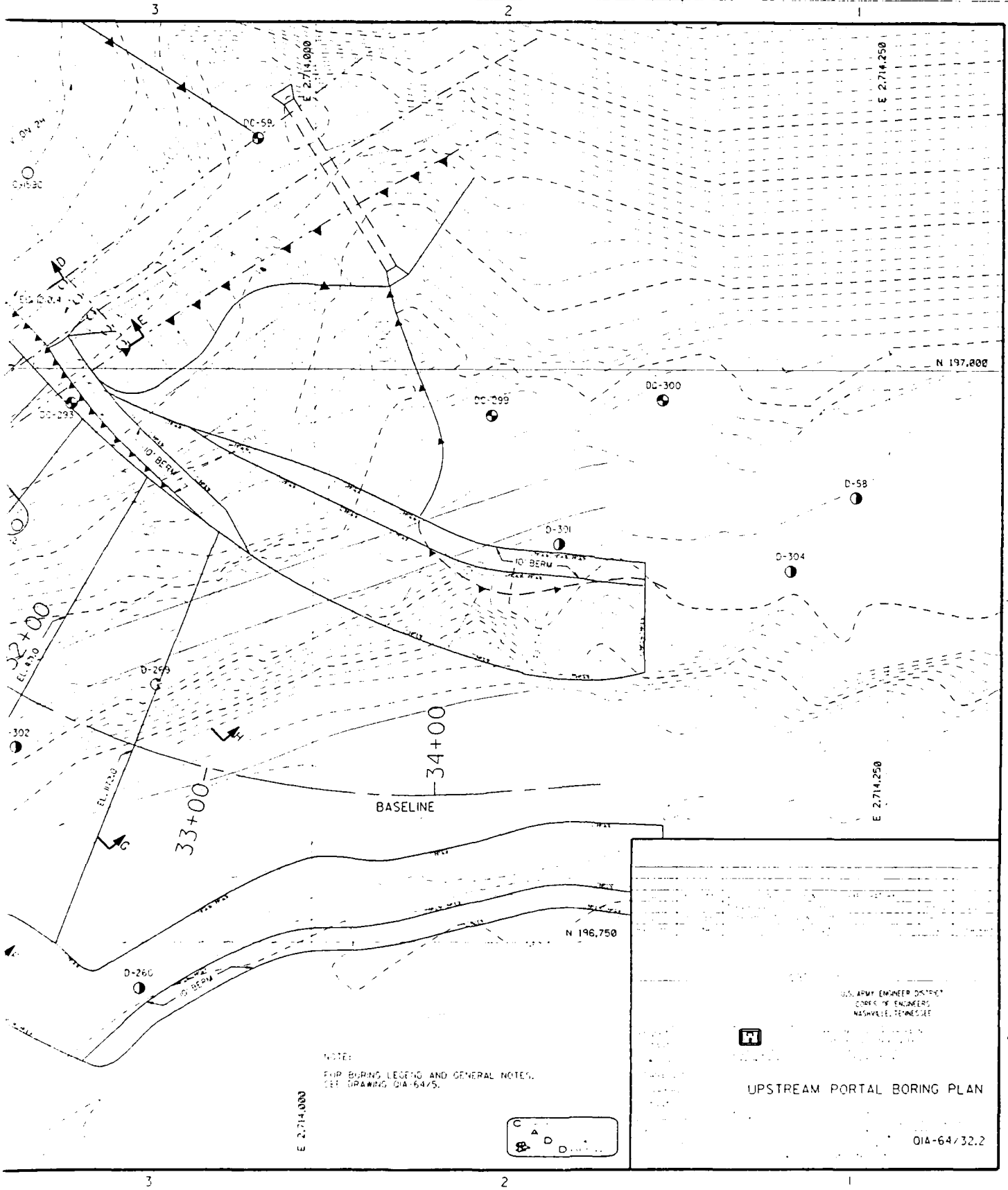
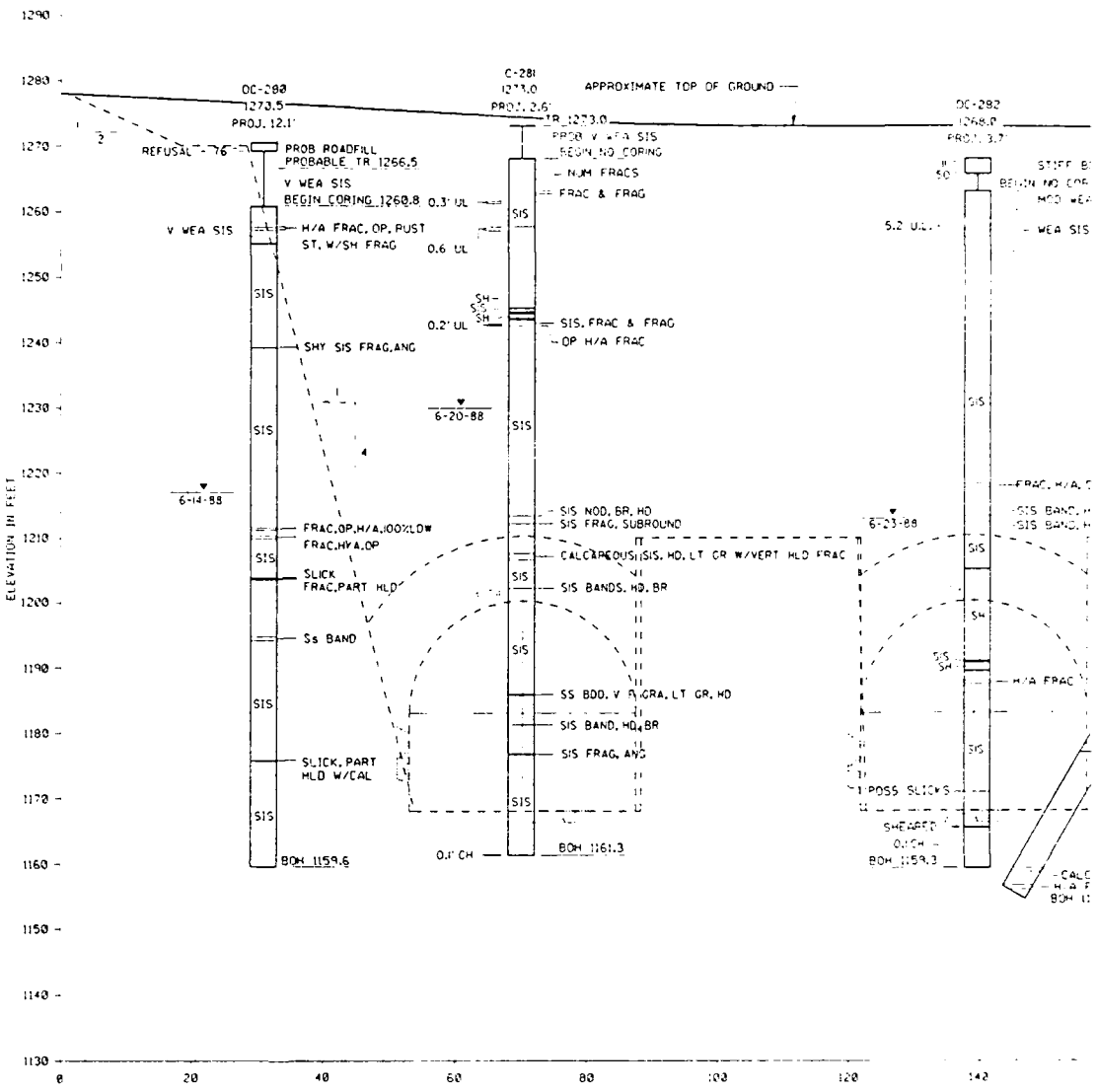
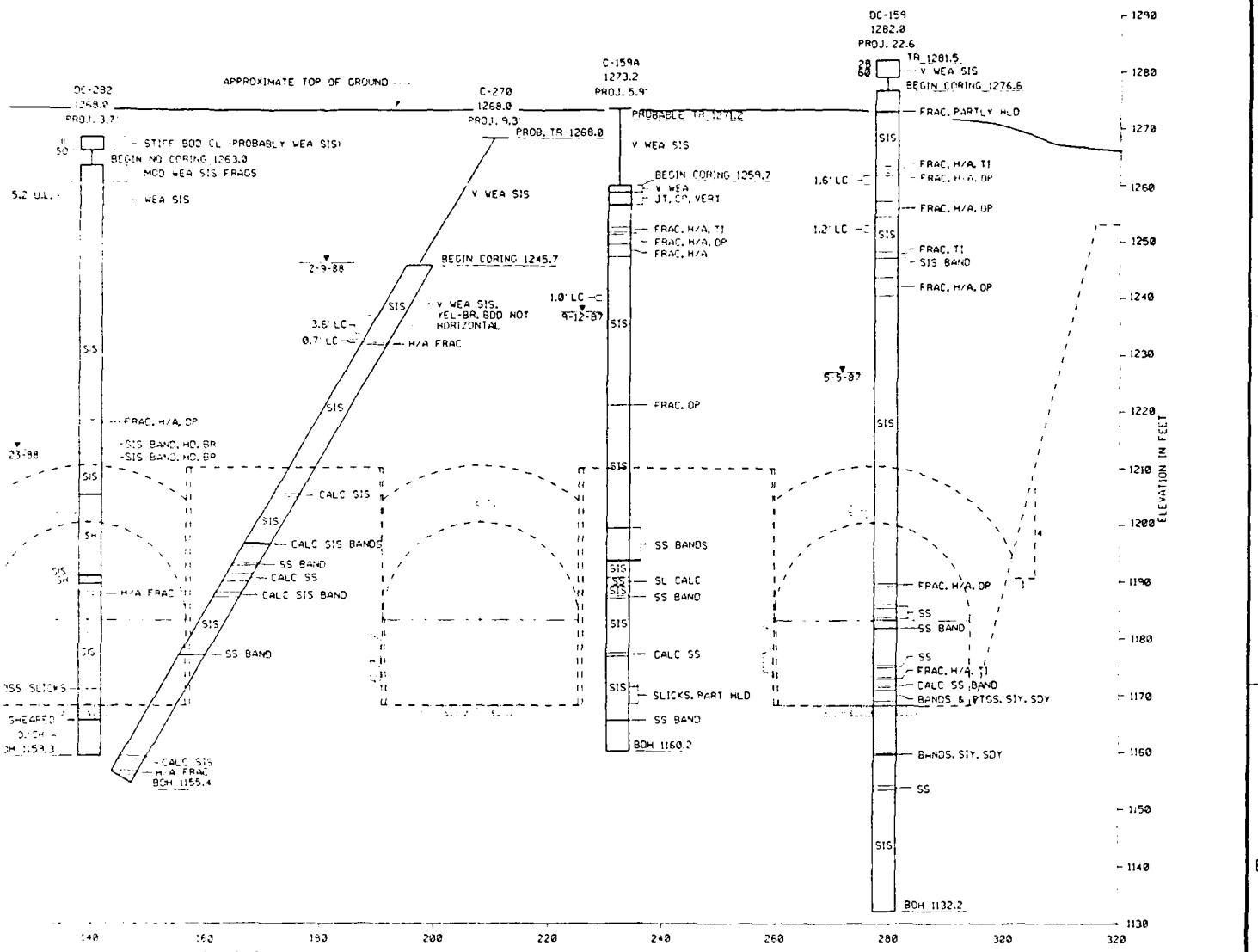

3
2
1
D
C
B
A
E 2,714,000
E 2,714,250
N 197,000
N 196,750
DC-58
DC-299
DC-300
D-58
D-301
D-304
D-260
10' BERM
32+00
33+00
34+00
BASELINE
NOTE:
FOR BORING LEGEND AND GENERAL NOTES,
SEE DRAWING 01A-64/5.
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
UPSTREAM PORTAL BORING PLAN
01A-64/32.2

PLATE C-2


APPROXIMATE TOP OF GROUND
OC-280
1273.5
PROJ. 12.1'
REFUSAL
PROB ROADFILL
PROBABLE TR 1266.5
V WEA SIS
BEGIN CORING 1260.8
H/A FRAC, OP, RUST
ST, W/SH FRAG
SHY SIS FRAG,ANG
FRAC,OP,H/A,100%LOW
FRAC,H/A,OP
SLICK
FRAC,PART HLD
Ss BAND
SLICK, PART
HLD W/CAL
BOH 1159.6
6-14-88
6-20-88
6-23-88
0.3' UL
0.6 UL
0.2' UL
0.1' CH
SIS, FRAC & FRAG
OP H/A FRAC
SIS NOD, BR, HD
SIS FRAG, SUBROUND
SIS BANDS, HD, BR
SS BDD, V FGRA, LT GR, HD
SIS BAND, HD, BR
SIS FRAG, ANG
BOH 1161.3
NUM FRACS
FRAC & FRAG
PROB V WEA SIS
BEGIN NO CORING
POSS SLICKS
SHEARED
BOH 1159.3
ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
0
20
40
60
80
100
120
140
D
C
B
A
5
4



SECTION C-C

SCALE: 1" = 10'

NOTES:

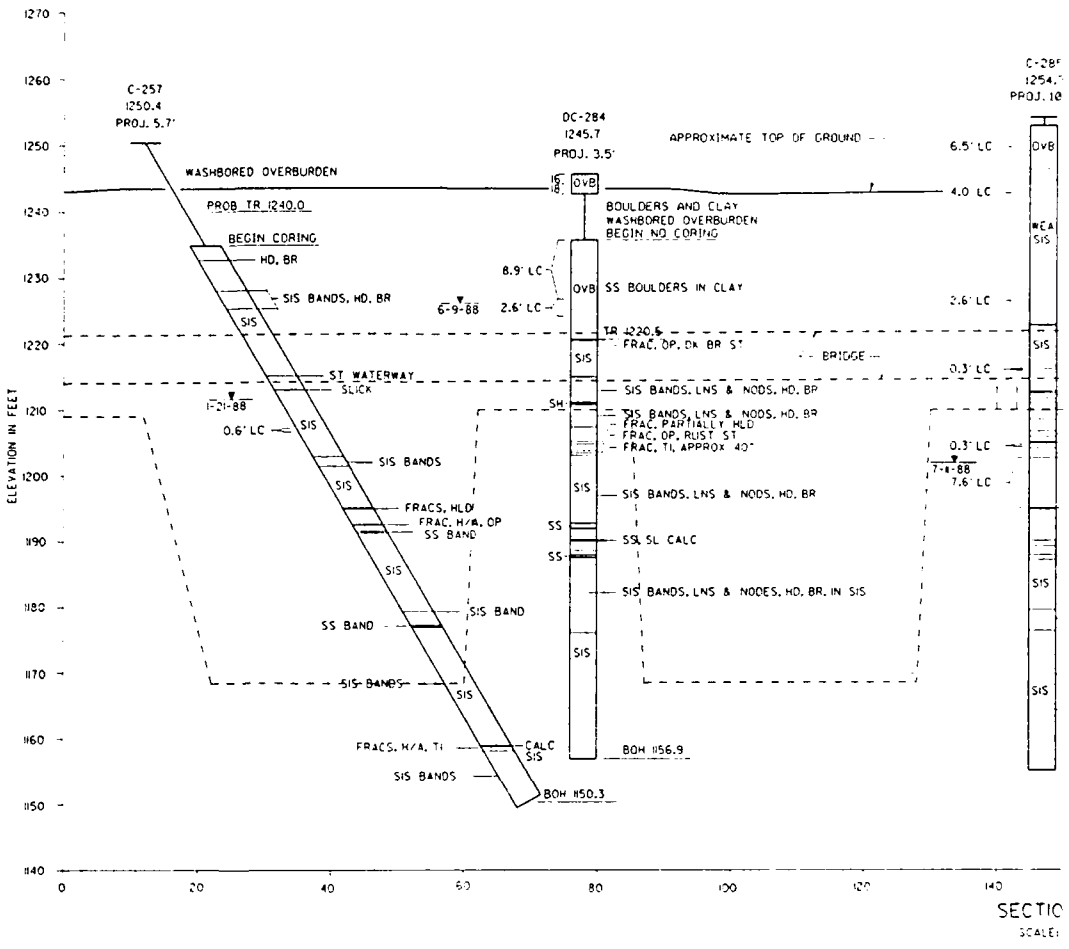
1. FOR LOCATIONS OF SECTIONS AND BORING PLAN, SEE DRAWING 01A-64/32.
2. FOR DETAILED LOGS OF BORINGS, SEE DRAWINGS 01A-64/7 THROUGH 01A-64/29.
3. FOR GENERAL NOTES, SEE DRAWING 01A-64/7.

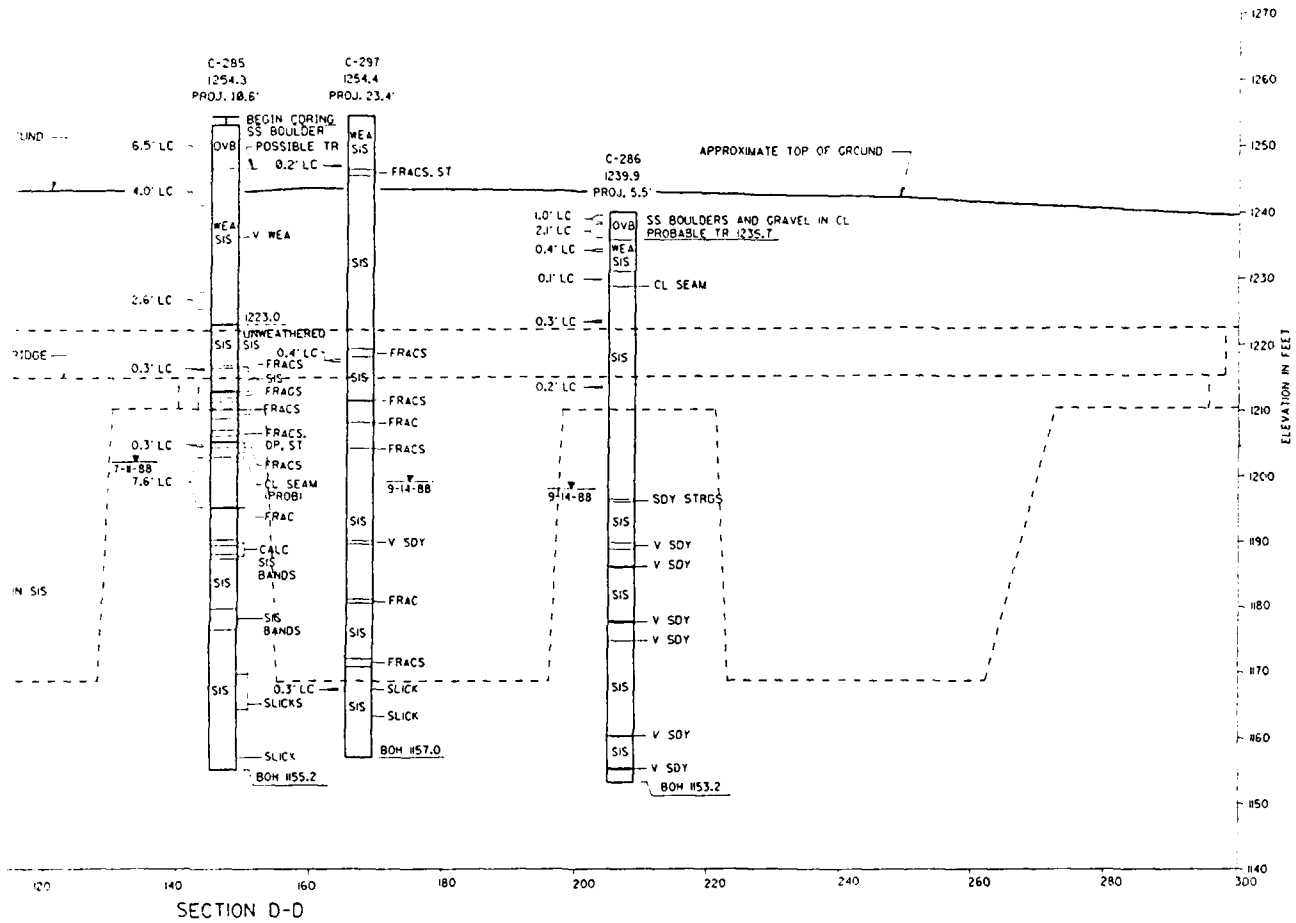
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
C-C

01A-64/33.2

PLATE C-3


C-257
1250.4
PROJ. 5.7'
WASHBORED OVERBURDEN
PROB TR 1240.0
BEGIN CORING
HD, BR
SIS BANDS, HD, BR
SIS
ST WATERWAY
SLICK
1-21-88
0.6' LC
SIS BANDS
FRACS, HLO
FRAC, H/A, OP
SS BAND
SS BAND
SIS BANDS
FRACS, H/A, TI
CALC SIS
SIS BANDS
BOH 1150.3
DC-284
1245.7
PROJ. 3.5'
APPROXIMATE TOP OF GROUND
OVB
BOULDERS AND CLAY
WASHBORED OVERBURDEN
BEGIN NO CORING
8.9' LC
OVB
SS BOULDERS IN CLAY
6-9-88
2.6' LC
TR 1220.6
FRAC, OP, DK BR ST
BRIDGE
SIS
SH
SIS BANDS, LNS & NODS, HD, BR
SIS BANDS, LNS & NODS, HD, BR
FRAC, PARTIALLY HLO
FRAC, OP, RUST ST
FRAC, TI, APPROX 40°
SIS BANDS, LNS & NODS, HD, BR
SS
SS, SL CALC
SS
SIS BANDS, LNS & NODES, HD, BR, IN SIS
BOH 1156.9
6.5' LC
4.0' LC
3.6' LC
0.3' LC
7-6-88
7.6' LC
0.3' LC
ELEVATION IN FEET
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
80
100
120
140
SECTIO
SCALE:



SECTION D-D

SCALE: 1" = 10'

NOTE:

FOR NOTES, SEE DRAWING 01A-64/33.

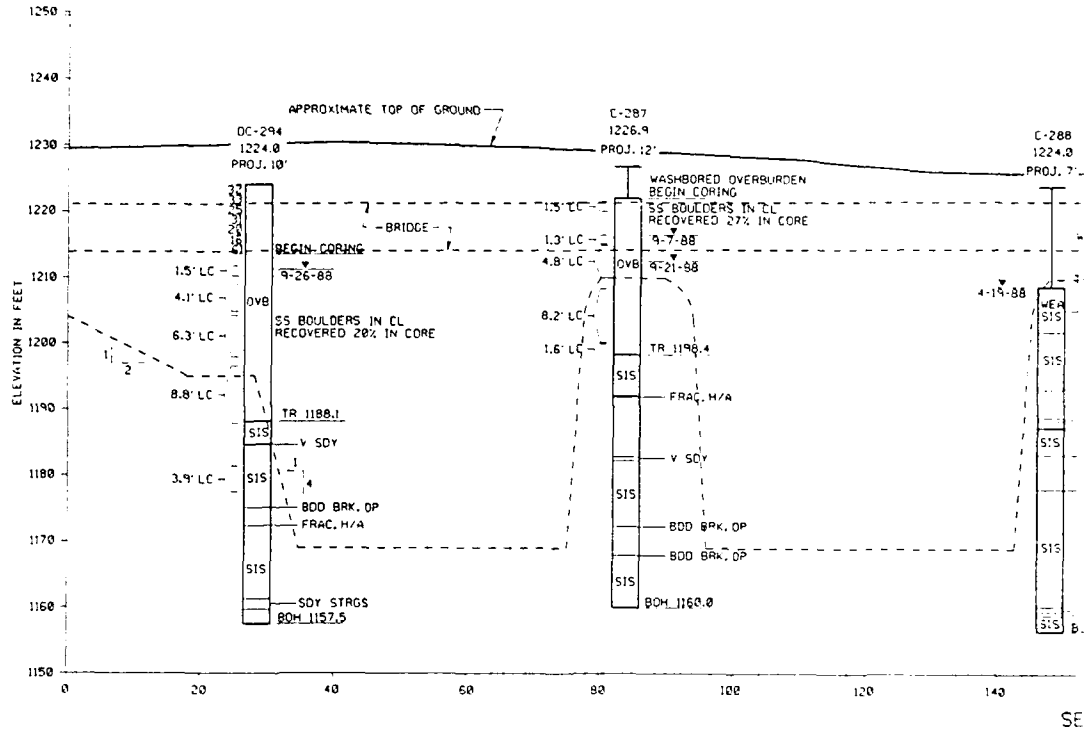
1	5-31-89	CONFORMING TO REVIEW COMMENTS E.P.O. J.L.S.

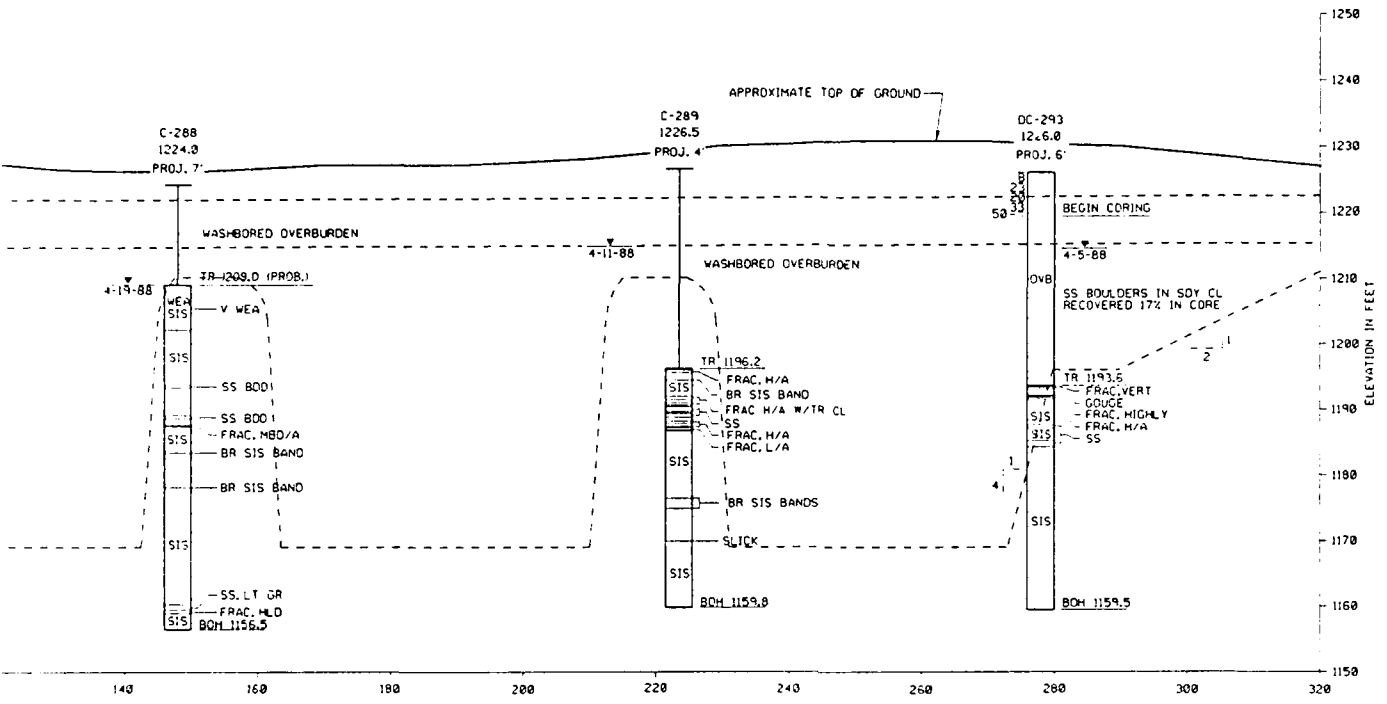
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
D-D

01A-64/34.1

PLATE C-4


APPROXIMATE TOP OF GROUND
DC-294
1224.0
PROJ. 10'
C-287
1226.9
PROJ. 12'
C-288
1224.0
PROJ. 7'
ELEVATION IN FEET
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
0
20
40
60
80
100
120
140
BRIDGE
BEGIN CORING
9-26-88
1.5' LC
4.1' LC
6.3' LC
8.8' LC
3.9' LC
OVB
SS BOULDERS IN CL
RECOVERED 20% IN CORE
TR 1188.1
SIS
V SDY
BDD BRK. OP
FRAC. H/A
SDY STRGS
BOH 1157.5
WASHBORED OVERBURDEN
BEGIN CORING
SS BOULDERS IN CL
RECOVERED 27% IN CORE
9-7-88
9-21-88
1.5' LC
1.3' LC
4.8' LC
8.2' LC
1.6' LC
TR 1198.4
BDD BRK. OP
BOH 1160.0
4-19-88
WEA
SE



SECTION E-E
SCALE: 1" = 10'

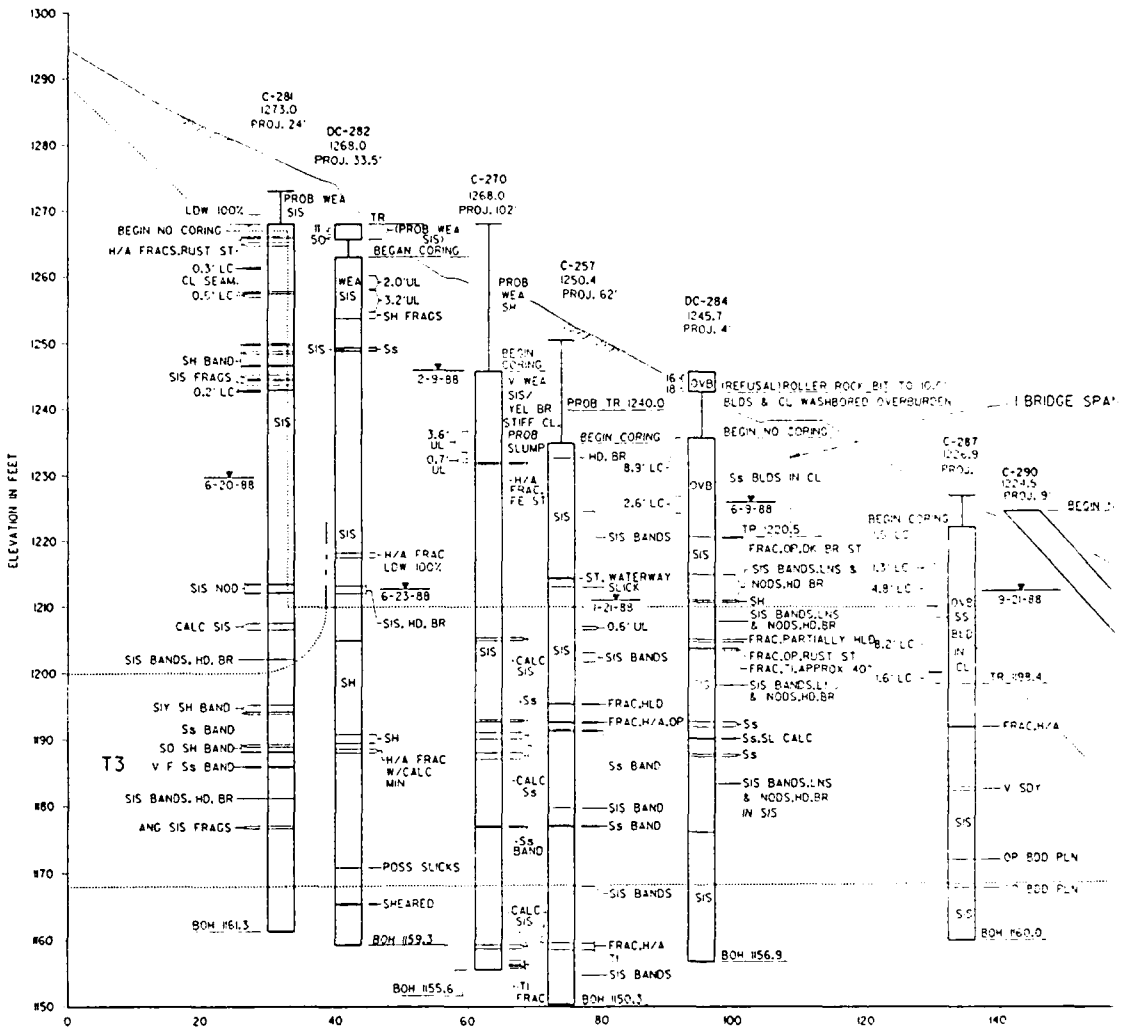
NOTE:
FOR NOTES, SEE DRAWING 01A-64/33.

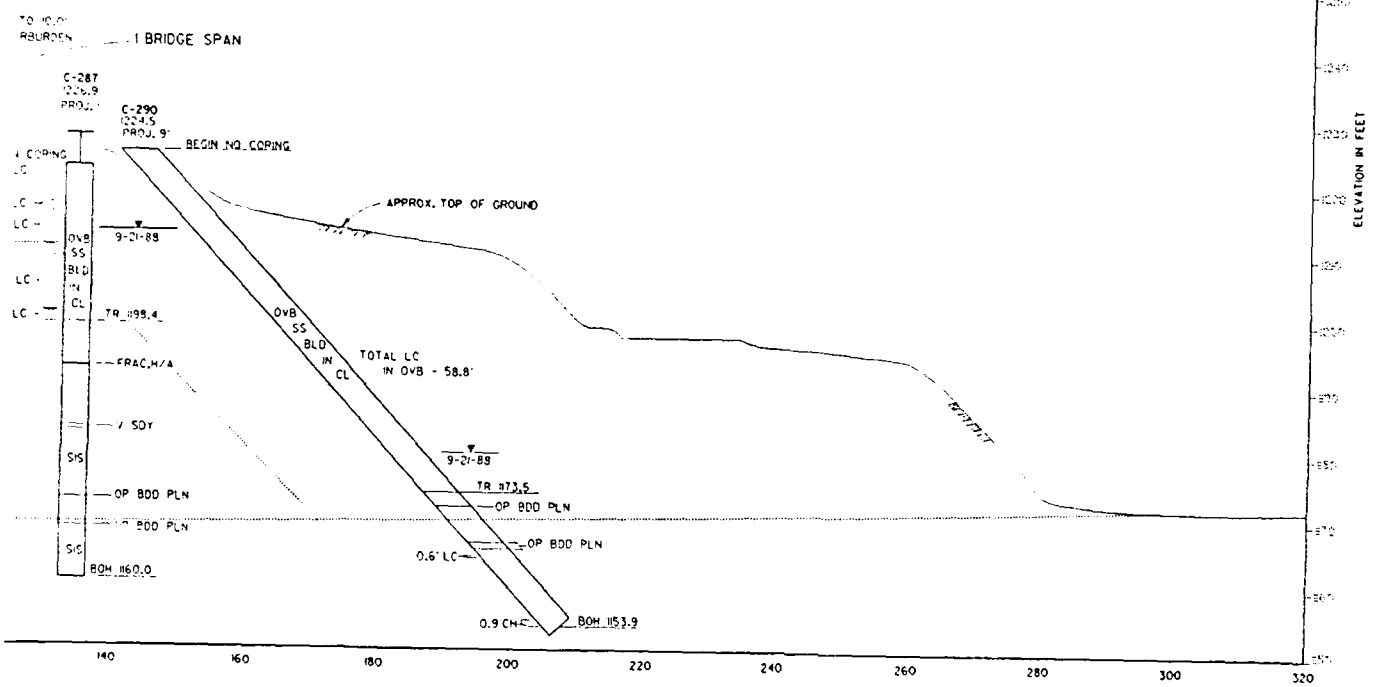
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGR
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
E-E

01A-64/35.1

PLATE C-5


ELEVATION IN FEET
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
0
20
40
60
80
100
120
140
C-284
1273.0
PROJ. 24'
DC-282
1268.0
PROJ. 33.5'
C-270
1268.0
PROJ. 102'
C-257
1250.4
PROJ. 62'
DC-284
1245.7
PROJ. 4'
C-287
1226.9
PROJ.
C-290
1224.5
PROJ. 9'
PROB WEA SIS
LDW 100%
BEGIN NO CORING
H/A FRACS, RUST ST
0.3' LC
CL SEAM
0.5' LC
SH BAND
SIS FRAGS
0.2' LC
6-20-88
SIS NOD
CALC SIS
SIS BANDS, HD, BR
SIY SH BAND
Ss BAND
SO SH BAND
V F Ss BAND
SIS BANDS, HD, BR
ANG SIS FRAGS
BOH 1161.3
T3
TR
(PROB WEA SIS)
BEGAN CORING
WEA SIS
2.0' UL
3.2' UL
SH FRAGS
SIS
Ss
2-9-88
3.6' UL
0.7' UL
H/A FRAC LDW 100%
6-23-88
SIS, HD, BR
SH
SH
H/A FRAC W/CALC MIN
POSS SLICKS
SMEARED
BOH 1159.3
BOH 1155.6
PROB WEA SH
BEGIN CORING
V WEA SIS/ YEL BR STIFF CL PROB SLUMP
H/A FRAC, FE ST
CALC SIS
Ss
CALC Ss
Ss BAND
CALC SIS
TI FRAC
PROB TR 1240.0
BEGIN CORING
HD. BR
8.3' LC
2.6' LC
SIS BANDS
ST. WATERWAY SLICK
1-21-88
0.6' UL
SIS BANDS
FRAC, HLD
FRAC, H/A, OP
Ss BAND
SIS BAND
Ss BAND
SIS BANDS
FRAC, H/A
TI
SIS BANDS
BOH 1150.3
OVB
(REFUSAL) ROLLER ROCK BIT TO 10
BLDS & CL WASHBORED OVERBURDEN
BEGIN NO CORING
Ss BLDS IN CL
6-9-88
TR 1220.5
FRAC, OP, DK BR ST
SIS BANDS, LNS & NODS, HD BR
4.8' LC
SH
SIS BANDS, LNS & NODS, HD, BR
FRAC, PARTIALLY HLD
8.2' LC
FRAC, OP, RUST ST
FRAC, APPROX 40°
1.6' LC
SIS BANDS, LNS & NODS, HD, BR IN SIS
Ss
Ss, SL CALC
Ss
SIS BANDS, LNS & NODS, HD, BR IN SIS
SIS BANDS
BOH 1156.9
OVB
SS
BLD IN CL
TR 1198.4
FRAC, H/A
V SDY
SIS
OP BDD PLN
BDD PLN
S S
BOH 1160.0
BEGIN
9-21-88
BRIDGE SPA
SEC



SECTION F-F

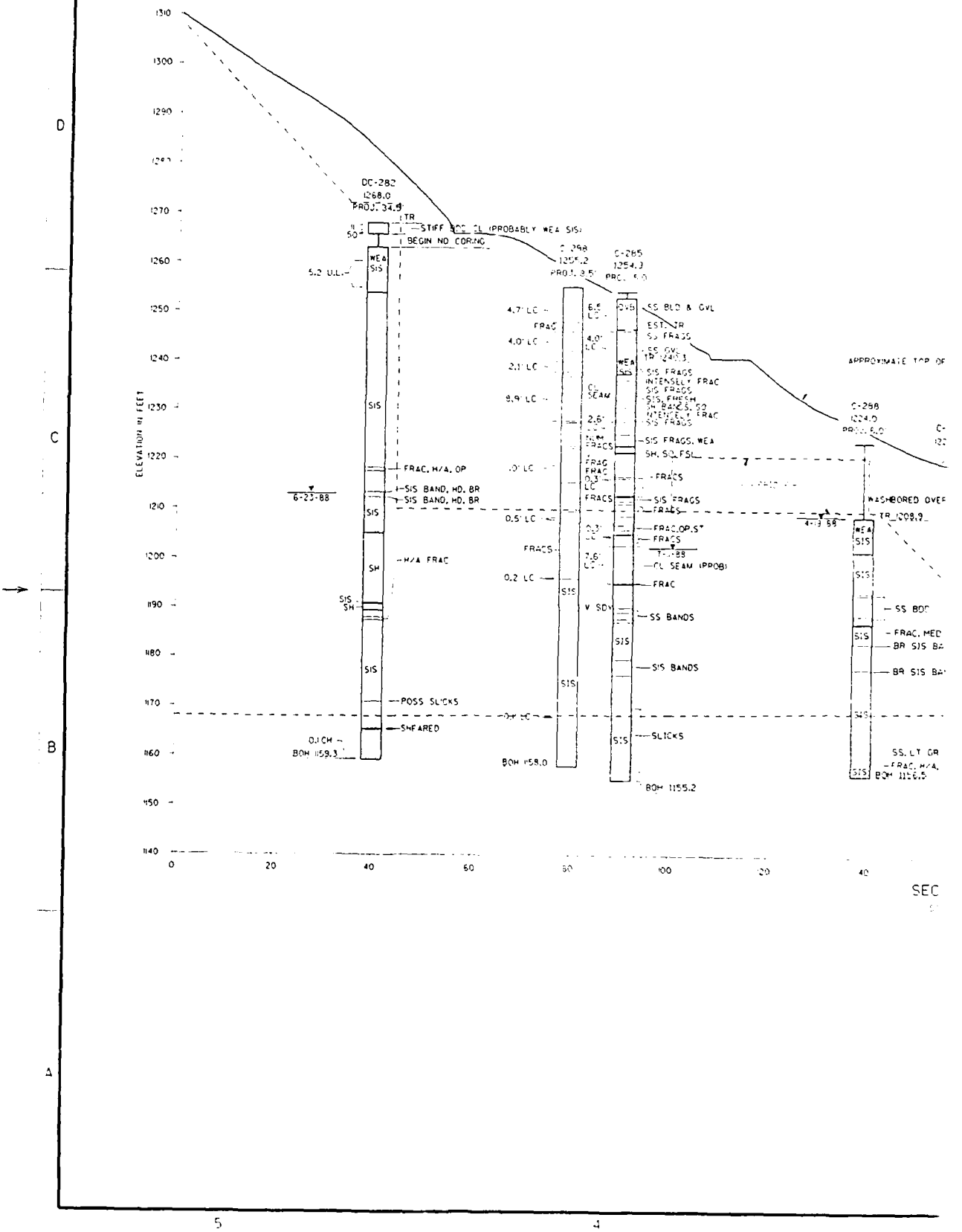
NOTE
1. FOR NOTES SEE DRAWING 01A-64/33.

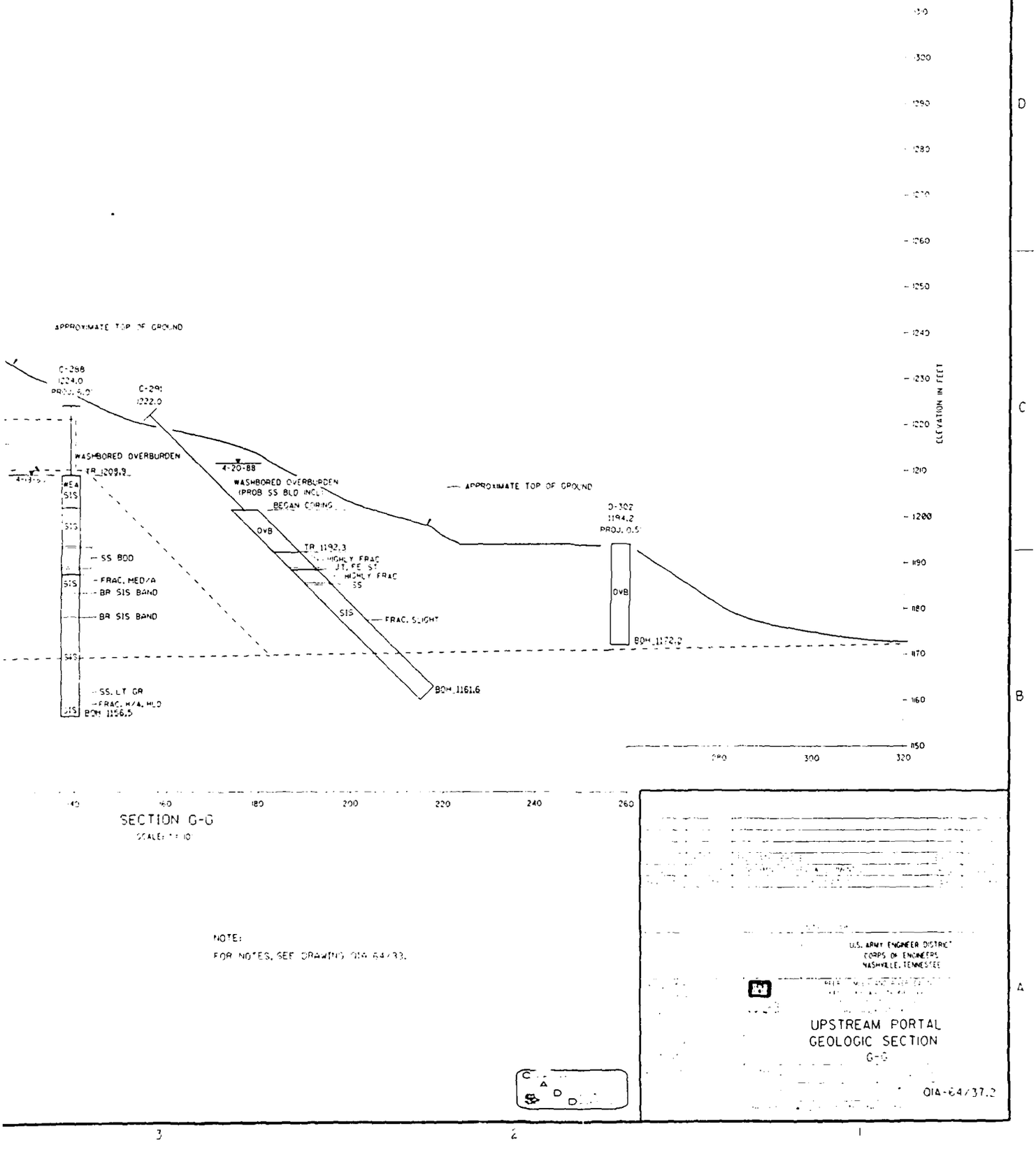
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
F-F

01A-64/36.1

PLATE C-6


ELEVATION IN FEET
1310
1300
1290
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
80
100
120
140
DC-282
1268.0
PROJ. 34.9'
TR
STIFF SCC SL (PROBABLY WEA SIS)
BEGIN NO CORING
WEA
SIS
6.2 U.L.
SIS
FRAC, H/A, OP
SIS BAND, HD. BR
SIS BAND, HD. BR
6-23-88
SIS
SH
H/A FRAC
SIS
SH
SIS
POSS SLICKS
SHEARED
O.I CH
BOH 1159.3
C-298
1255.2
PROJ. 3.5'
4.7' LC
FRAC
4.0' LC
2.1' LC
9.9' LC
OL SEAM
2.6' LC
NUM FRACS
FRAC
FRAC
0.3' LC
FRACS
0.5' LC
FRACS
0.6' LC
0.2 LC
SIS
V SDY
SIS
SIS
BOH 1158.0
C-285
1254.3
PROJ. 5.0'
SS BLD & GVL
EST. TR
SS FRAGS
SS GVL
TR 1240.3
WEA
SIS
SIS FRAGS
INTENSELY FRAC
SIS FRAGS
SIS, FRESH
IN BANDS, SO
INTENSELY FRAC
SIS FRAGS
SIS FRAGS, WEA
SH, SO, FSL
FRACS
SIS FRAGS
FRACS
FRAC, OP, S*
FRACS
7-7-88
OL SEAM (PPOB)
FRAC
SS BANDS
SIS
SIS BANDS
SIS
SLICKS
SIS
BOH 1155.2
APPROXIMATE TOP OF
C-258
1224.0
PROJ. 6.0'
WASHBORED OVER
TR 1208.9
4-13-88
WEA
SIS
SIS
SS BOD
SIS
FRAC, MED
BR SIS BA
BR SIS BA
SIS
SS, LT GR
FRAC, H/A,
BOH 1156.5
SEC



SECTION G-G

SCALE: 1" = 10'

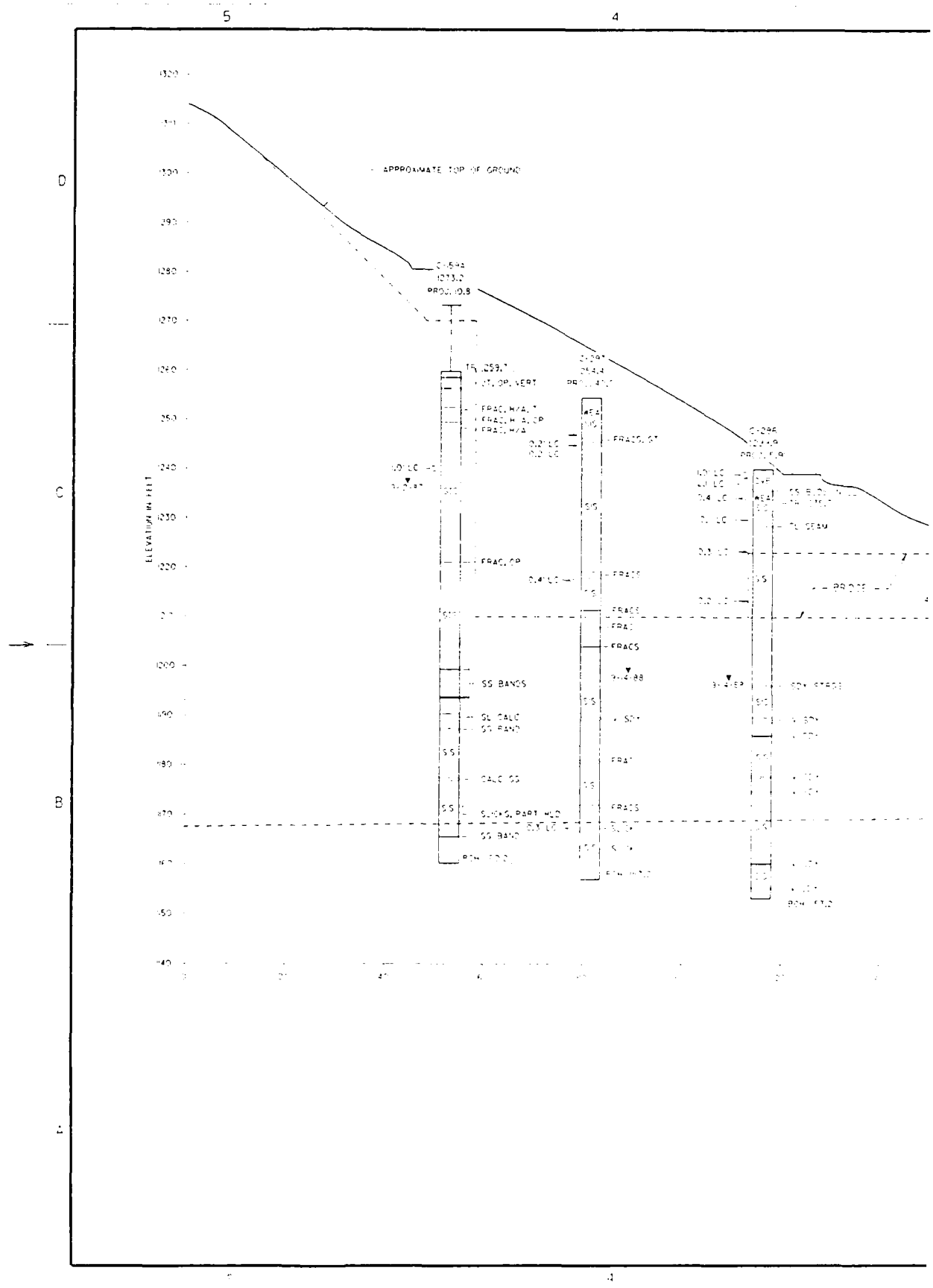
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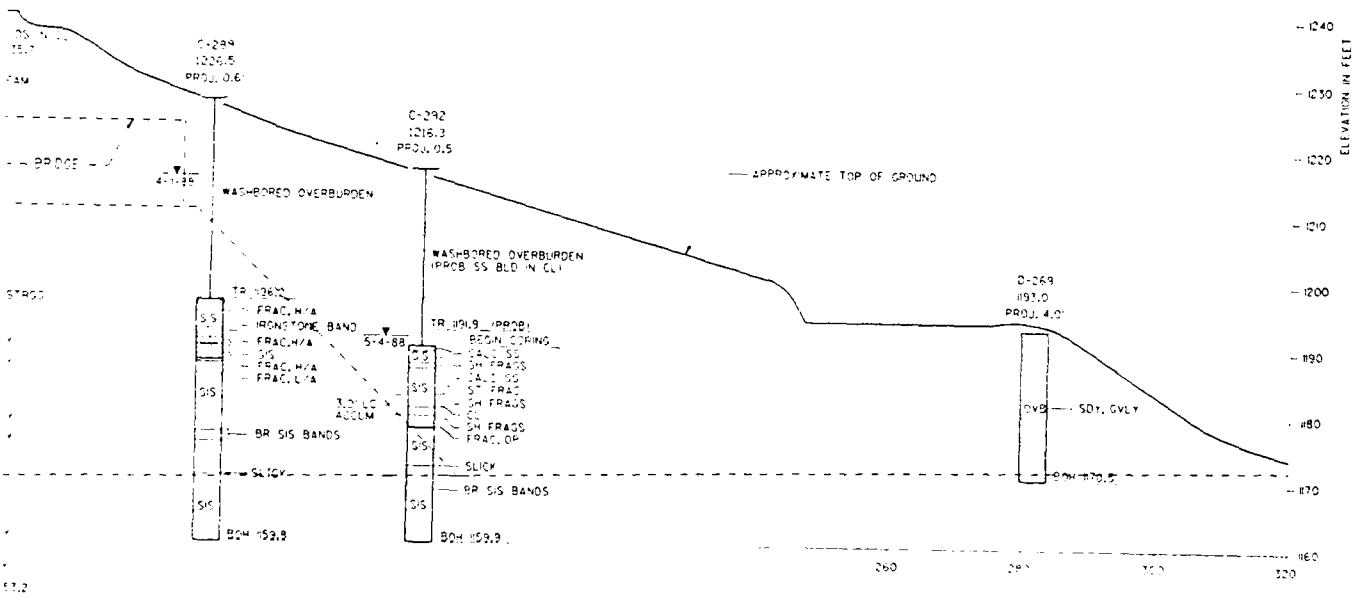
FOR NOTES, SEE DRAWING 01A-64/33.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
G-G

01A-64/37.2


5
4
D
C
B
APPROXIMATE TOP OF GROUND
ELEVATION IN FEET
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
FRAC CP
SS BANDS
SL CALC
SS BAND
CALC SS
FRAC
FRACS
SL SEAM



SECTION H-H

NOTE:

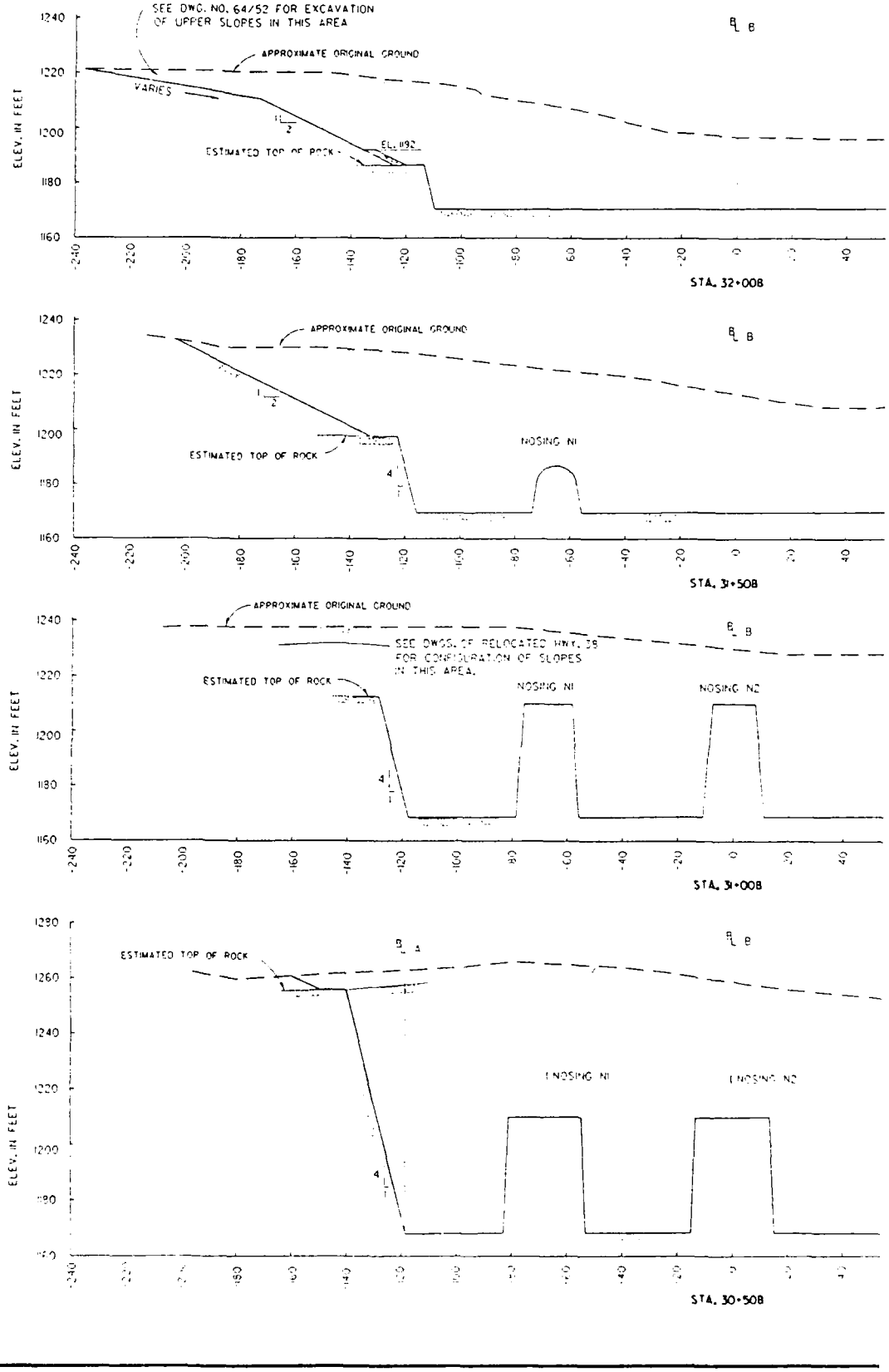
FOR NOTES, SEE DRAWING 01A-64433.

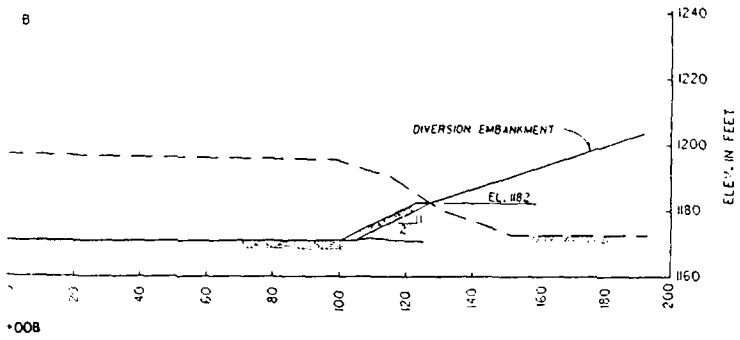
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION

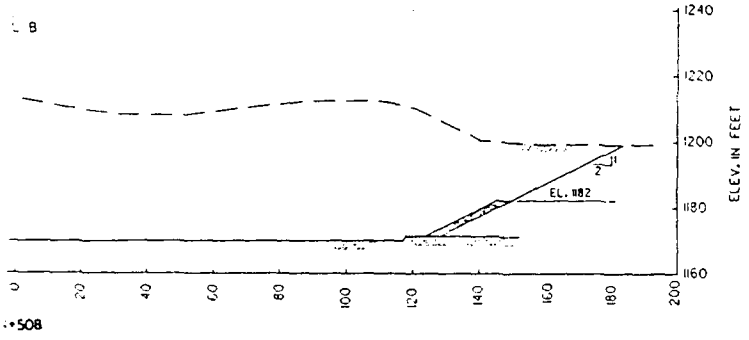
01A-64433.2

PLATE C-9

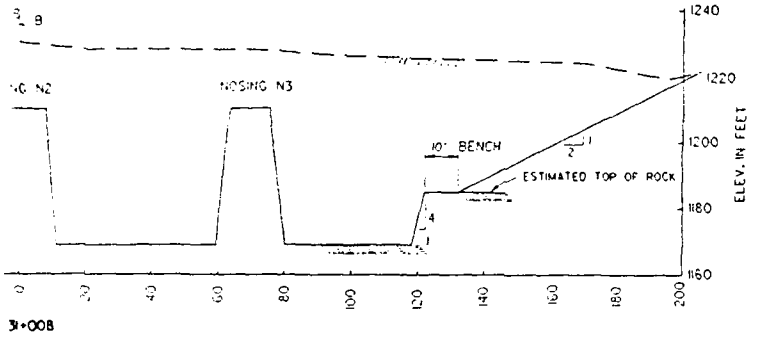

SEE DWG. NO. 64/52 FOR EXCAVATION OF UPPER SLOPES IN THIS AREA
APPROXIMATE ORIGINAL GROUND
VARIES
ESTIMATED TOP OF ROCK
EL. 1192
ELEV. IN FEET
STA. 32+008
NOSING N1
STA. 31+508
SEE DWGS. OF RELOCATED HWY. 39 FOR CONFIGURATION OF SLOPES IN THIS AREA.
NOSING N2
STA. 31+008
STA. 30+508



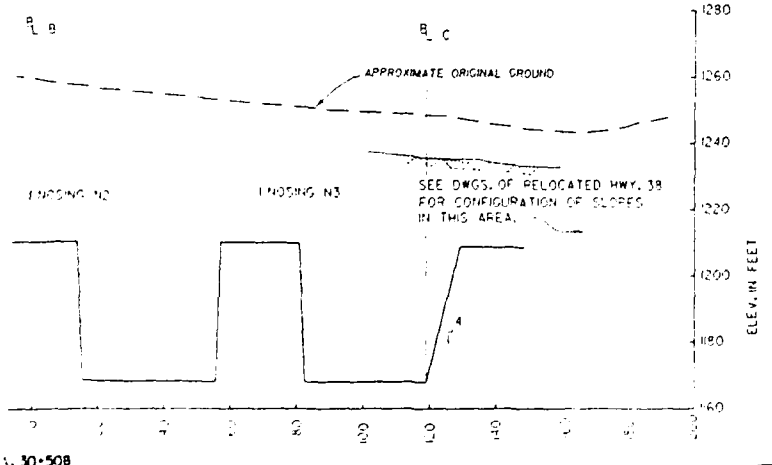
+008



+508



31+008



30+508

NOTES:

1. FOR PLAN OF UPSTREAM PORTAL, SEE DWG. NO. 64/51.
2. FOR DETAILS OF STONE PROTECTION, SEE DWG. NO. 64/56.
3. FOR DETAILS OF NOSES, SEE DWG. NO. 64/104.
4. FOR DIVERSION EMBANKMENT, SEE DWG. NO. 64/73.
5. ALL SLOPES, DIMENSIONS, AND ELEVATIONS ARE TYPICAL FOR THIS SHEET UNLESS OTHERWISE NOTED.
6. FOR CHANNEL INVERTS, SEE UPSTREAM PORTAL PLAN.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

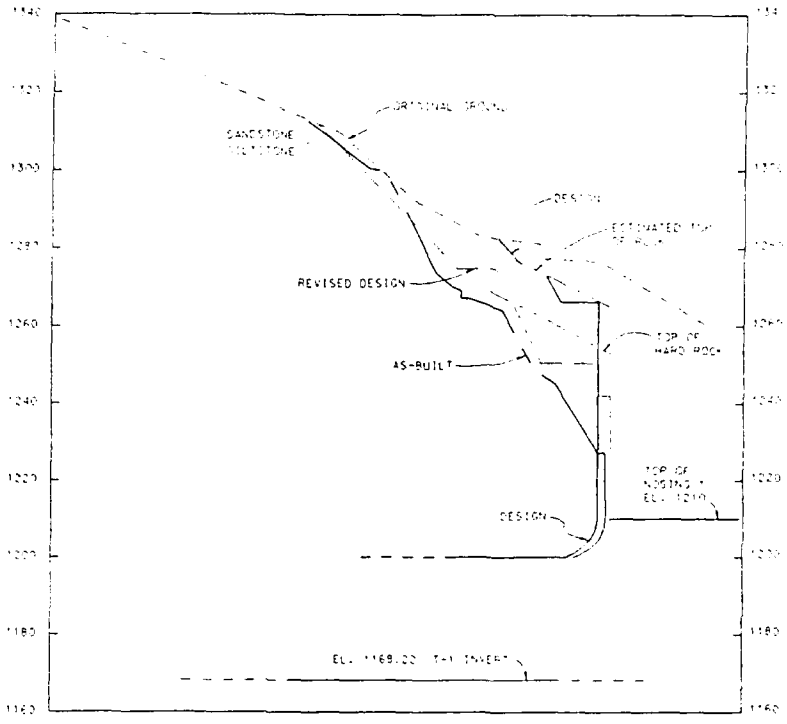
CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE

DIVERSION TUNNELS

UPSTREAM PORTAL CROSS SECTIONS
STA. 30+508 THRU STA. 32+008

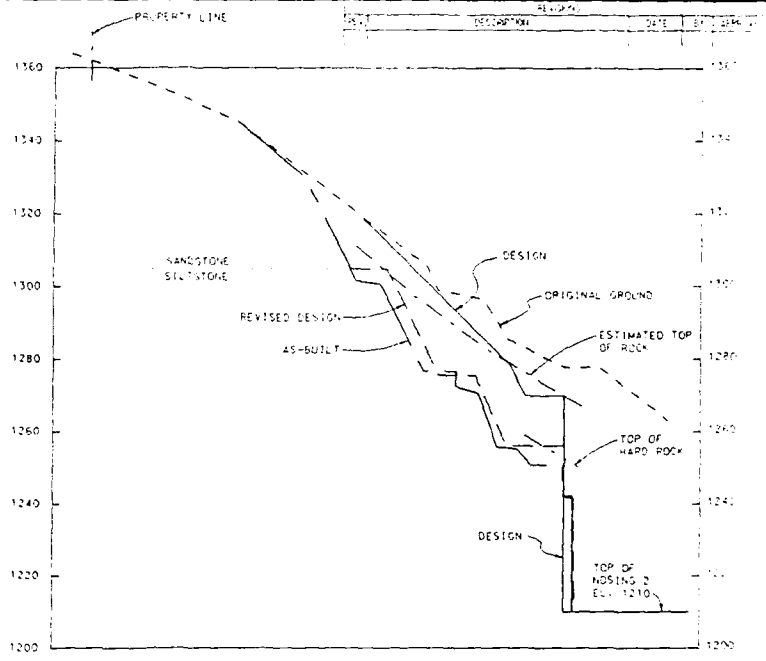
DIA-64/54

PLATE C-9

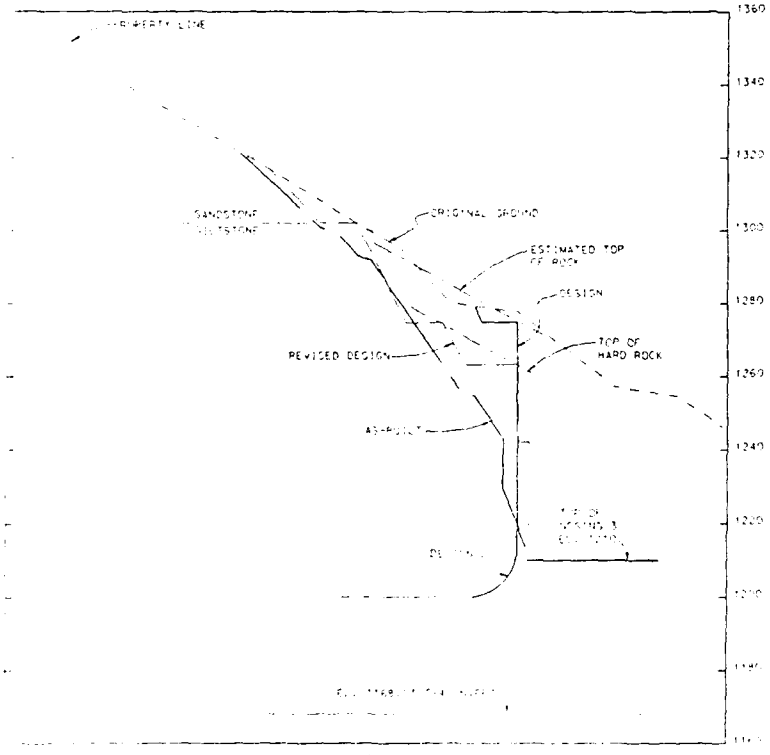


SECTION 1
UPSTREAM PORTAL

CROSS-SECTION (100' LEFT OF BASELINE B.DESIGN AND AS-BUILT)



SECTION K
UPSTREAM PORTAL
CROSS-SECTION AT BASELINE B.
DESIGN AND AS-BUILT SLOPE



SECTION J
UPSTREAM PORTAL
CROSS-SECTION (100' RIGHT OF BASELINE B. DESIGN AND AS-BUILT)

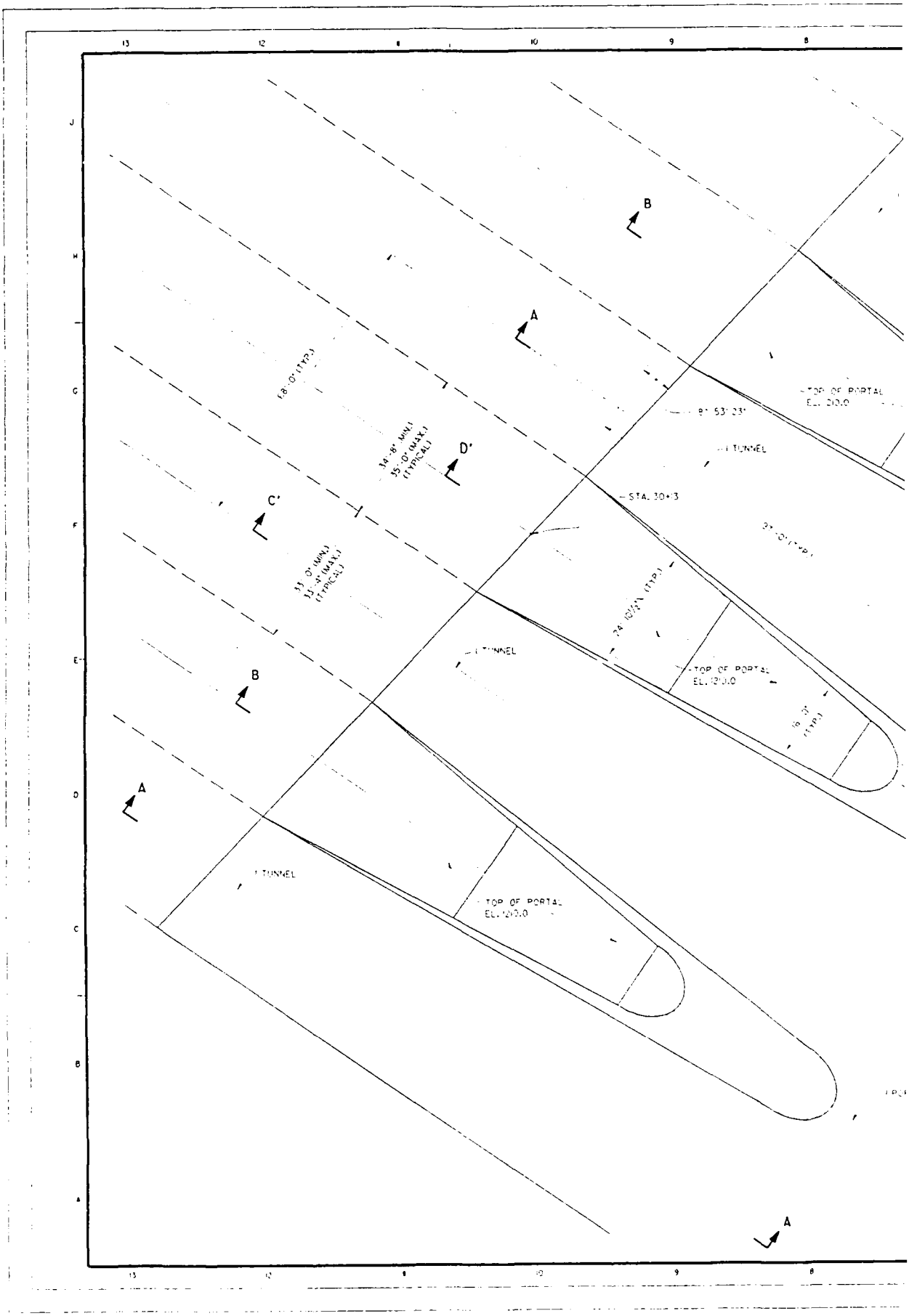
NOTE:
SEE PLATE C-10 FOR CROSS SECTION LOCATIONS.

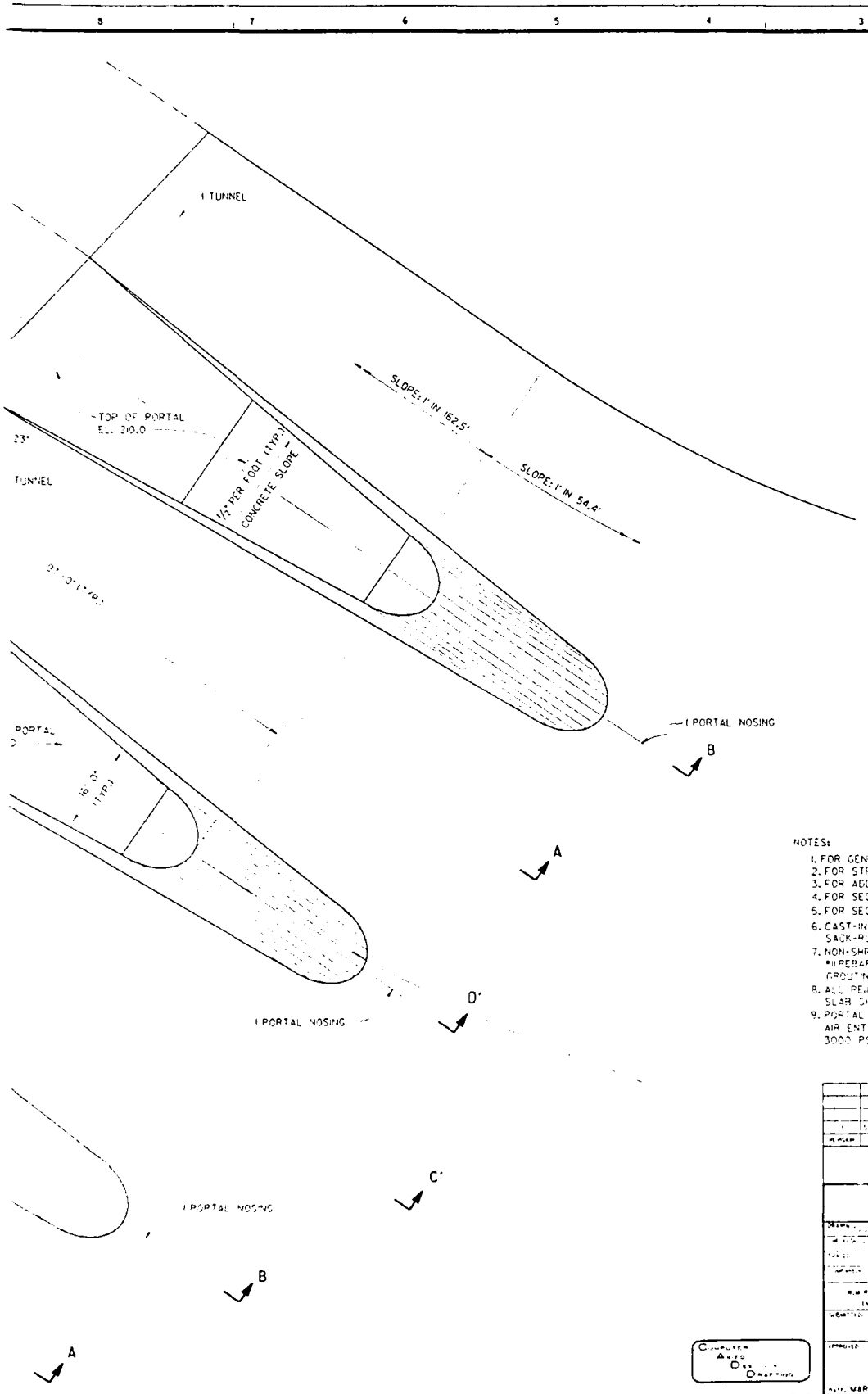
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL BACKSLOPE
DESIGN & AS-BUILT CROSS SECTIONS

Q1A-4391

PLATE C-10


13
12
11
10
9
8
J
H
G
F
E
D
C
B
A
B
A
C'
D'
B
A
(8'-0" (TYP.)
34'-8" MIN.)
35'-0" (MAX.)
(TYPICAL)
33'-0" MIN.)
33'-9" MAX.)
(TYPICAL)
TOP OF PORTAL
EL. 210.0
8° 53' 23"
TUNNEL
STA. 30+3
24 (8'-0") (TYP.)
TOP OF PORTAL
EL. 210.0
TUNNEL
TOP OF PORTAL
EL. 210.0
TUNNEL



NOTES:

1. FOR GENERAL NOTES, SEE DWG. 64/2.
2. FOR STRUCTURAL NOTES, SEE DWG. 64/82.
3. FOR ADDITIONAL PORTAL AND TUNNEL GEOMETRY, SEE DWG. 64/91.
4. FOR SECTION A-A AND B-B, SEE DWG. 64/104.
5. FOR SECTION C'-C' AND D'-D', SEE DWG. 64/106.
6. CAST-IN-PLACE PORTAL NOSING CONCRETE SHALL HAVE A SACK-RUBBED FINISH.
7. NON-SHRINK GROUT SHALL BE USED FOR GROUTING THE #11 REBARS IN THE PORTAL NOSING INTO ROCK AND FOR GROUTING THE #6 REBARS IN THE TUNNEL SLAB INTO ROCK.
8. ALL REINFORCING IN THE PORTAL NOSINGS AND THE TUNNEL SLAB SHALL BE CONTINUOUS THRU CONSTRUCTION JOINTS.
9. PORTAL NOSING AND TUNNEL SLAB CONCRETE SHALL BE AIR ENTRAINMENT WITH A MIN. COMPRESSIVE STRENGTH OF 3000 PSI @ 28 DAYS.

REVISION	DATE	DESCRIPTION	BY	CHKD
1	5/27/83	GENERAL REVISIONS	D.J.V.	M.R.

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

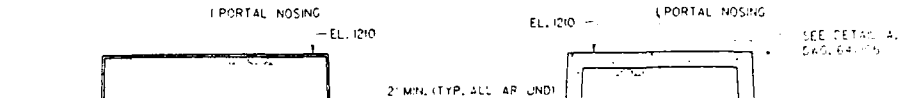
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

UPSTREAM PORTAL NOSINGS
PLAN

DRAWING NUMBER
01A-64/103.1

DATE: MARCH 1983

PLATE C-11

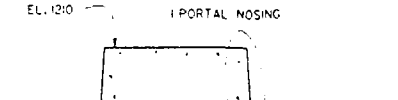


SECTION C-C

SCALE: 1/8" = 1'-0"

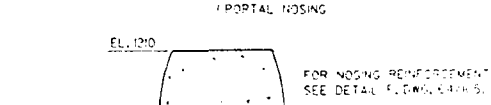
SECTION D-D

SCALE: 1/8" = 1'-0"



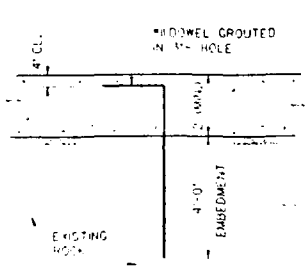
SECTION E-E

SCALE: 1/8" = 1'-0"

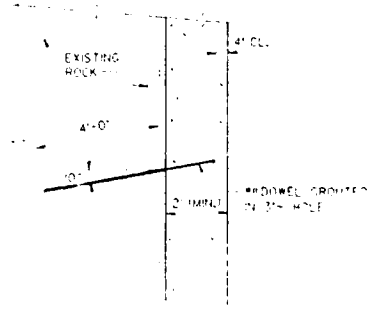


SECTION F-F

SCALE: 1/8" = 1'-0"



VERTICAL



HORIZONTAL

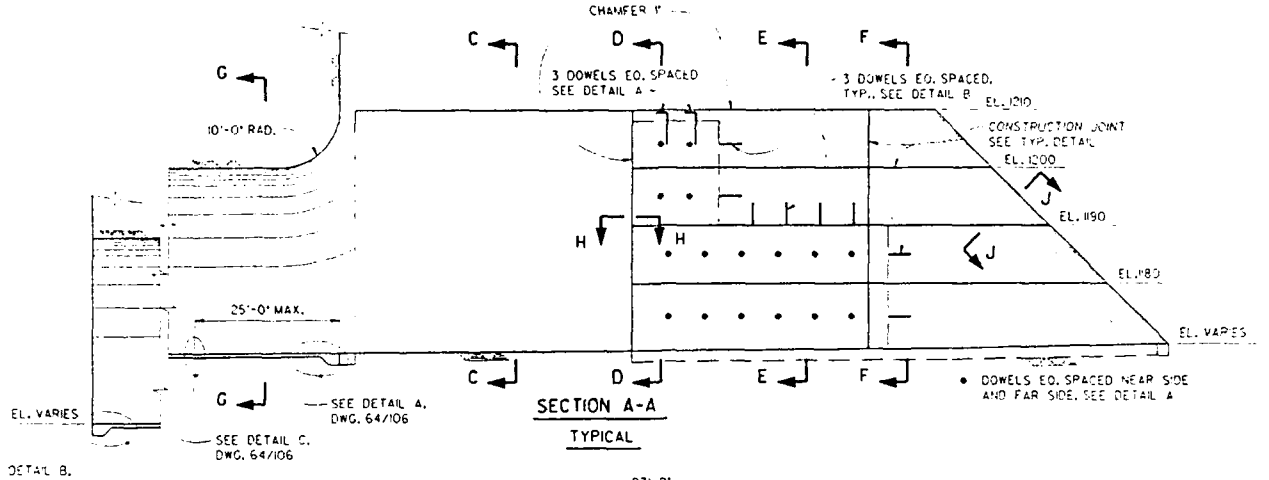
DETAIL A

SCALE: 1/8" = 1'-0"

TYPICAL CO

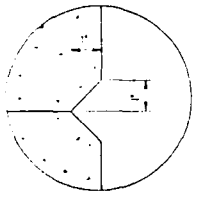
PO

VERTICAL



SECTION A-A

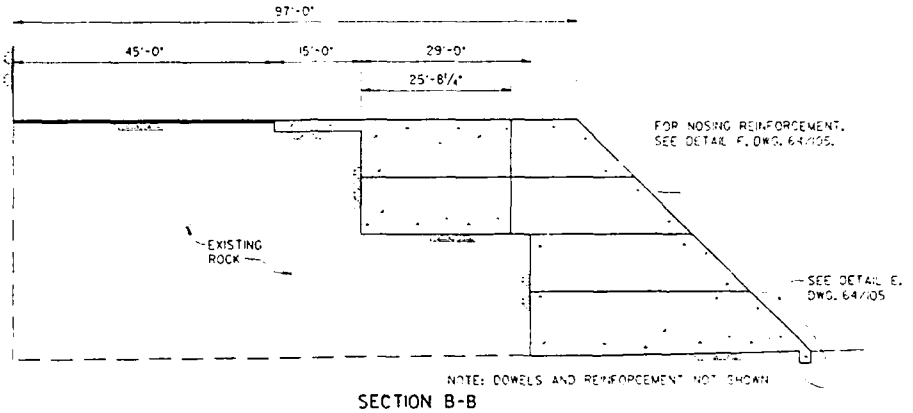
TYPICAL



TYPICAL CONSTRUCTION JOINT

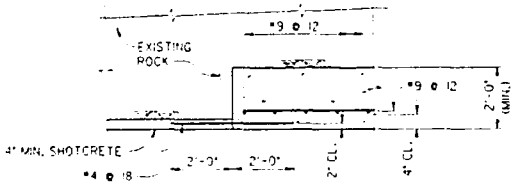
PORTAL NOSING

SCALE: 6" = 1'-0"



NOTE: DOWELS AND REINFORCEMENT NOT SHOWN

SECTION B-B



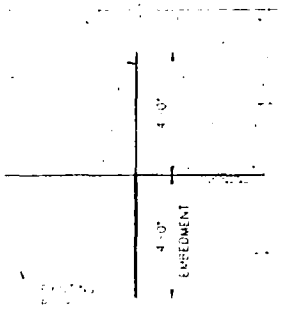
SECTION H-H

SCALE: ½" = 1'-0"

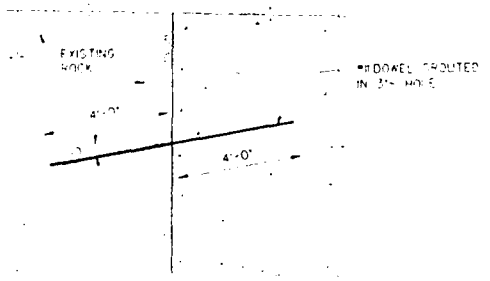
NOTES:

1. FOR CONCRETE AND REINFORCING NOTES, SEE DWG. 64/103.
2. FOR SECTION J-J, SEE DWG. 64/105.
3. FOR SECTION G-G, SEE DWG. 64/[illegible].
4. FOR LOCATION OF SECTIONS A-A AND B-B, SEE DWG. 64/103.

* DOWEL GROUTED IN 2½" HOLE



VERTICAL



HORIZONTAL

DETAIL B

SCALE: ½" = 1'-0"

	7-22-89	GENERAL REVISIONS	E.J. M.W.
REVISION	DATE	DESCRIPTION	BY CHKD

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

TENNESSEE-TOMBIGBEE WATERWAY BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

UPSTREAM PORTAL NOSINGS
SECTIONS AND DETAILS

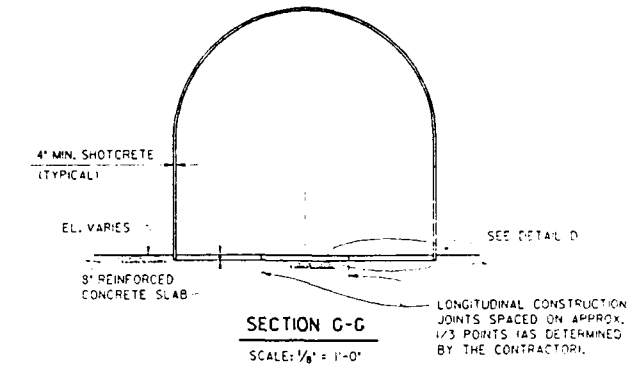
APPROVED

DATE MARCH 1989

01A-64/104.1

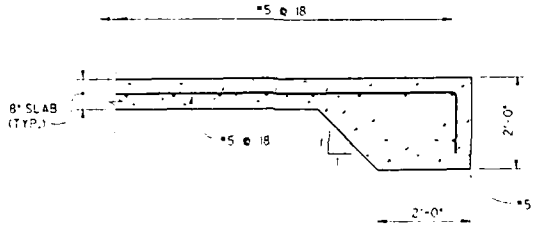
COMPUTER AIDED DESIGN & DRAFTING

PLATE C-12



SECTION C-C

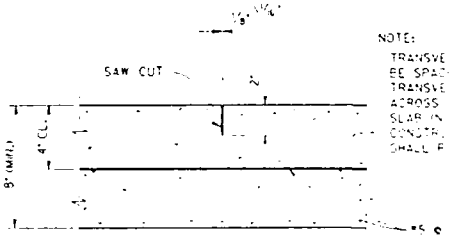
SCALE: 1/8" = 1'-0"



DETAIL A - AS SHOWN

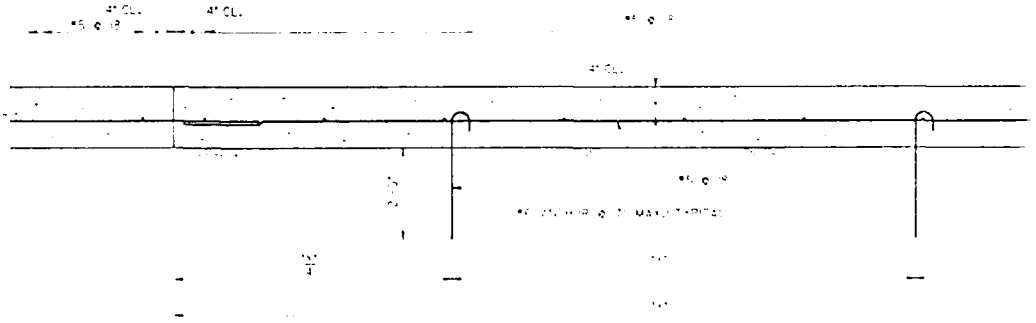
DETAIL B - OPP. HAND

SCALE: 3/4" = 1'-0"

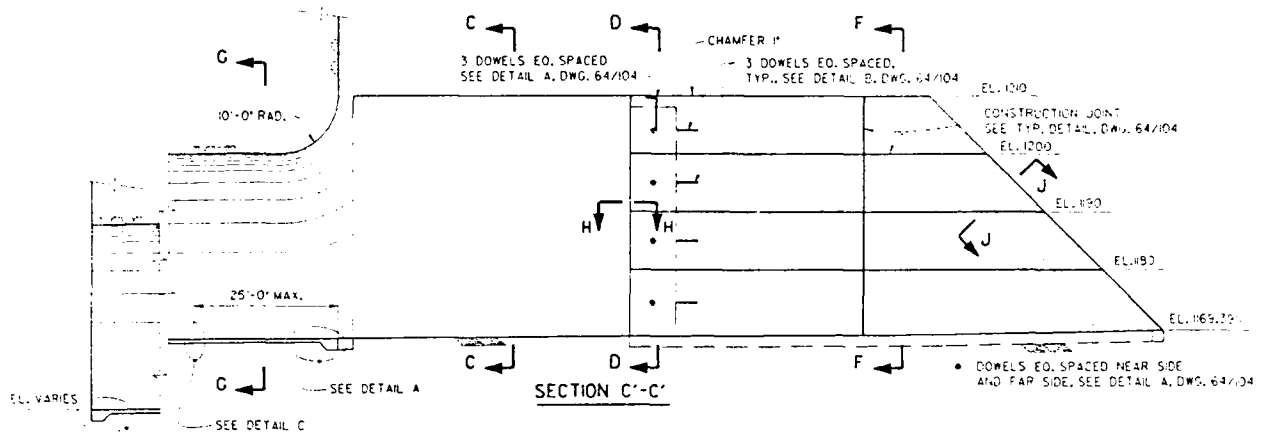


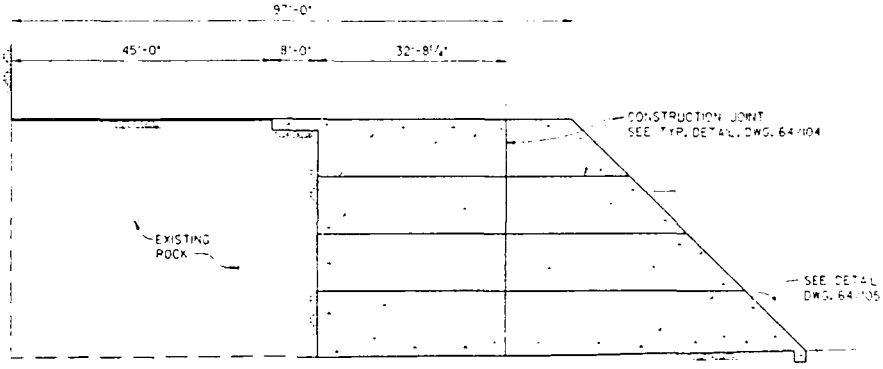
DETAIL C

TYPICAL CONTRACTION JOINT



DETAIL D





SECTION D'-D'

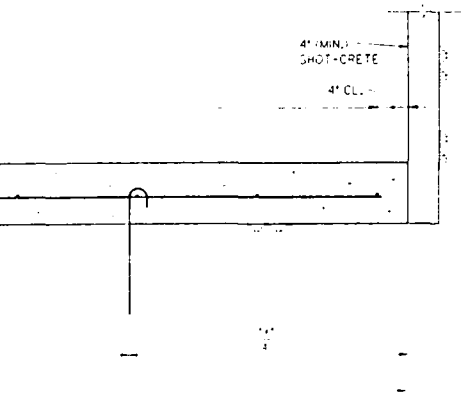
NOTE:
TRANSVERSE CONTRACTION JOINTS SHALL BE SPACED ON 25' CTRS. (MAX.). TRANSVERSE JOINTS SHALL BE CONTINUOUS ACROSS ALL 3 LANES OF TUNNEL SLAB (NOT OFFSET). TOOLED TRANSVERSE CONSTRUCTION JOINTS, WHEN REQUIRED, SHALL REPLACE CONTRACTION JOINTS.

#5 @ 18

TAIL C

NTRACTION JOINT

NOTES:
1. FOR CONCRETE AND REINFORCING NOTES, SEE DWG. 64/103.
2. FOR LOCATION OF SECTION C-C' AND D-D', SEE DWG. 64/103.
3. FOR SECTION C-C, D-D, AND H-H, SEE DWG. 64/104.
4. FOR SECTION J-J, AND DETAIL F, SEE DWG. 64/105.



DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

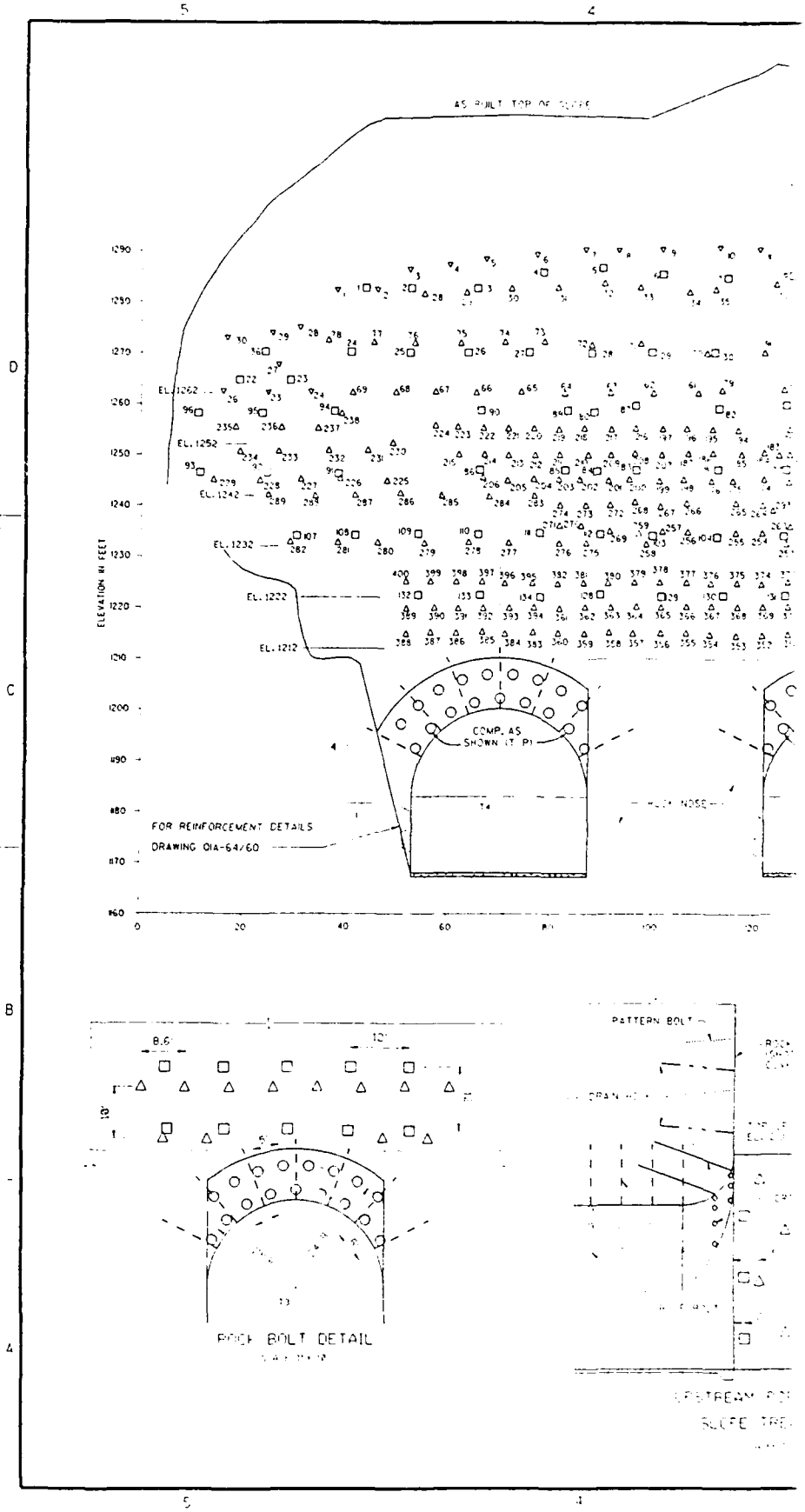
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

UPSTREAM PORTAL NOSING AND TUNNEL BASE SLAB DETAILS

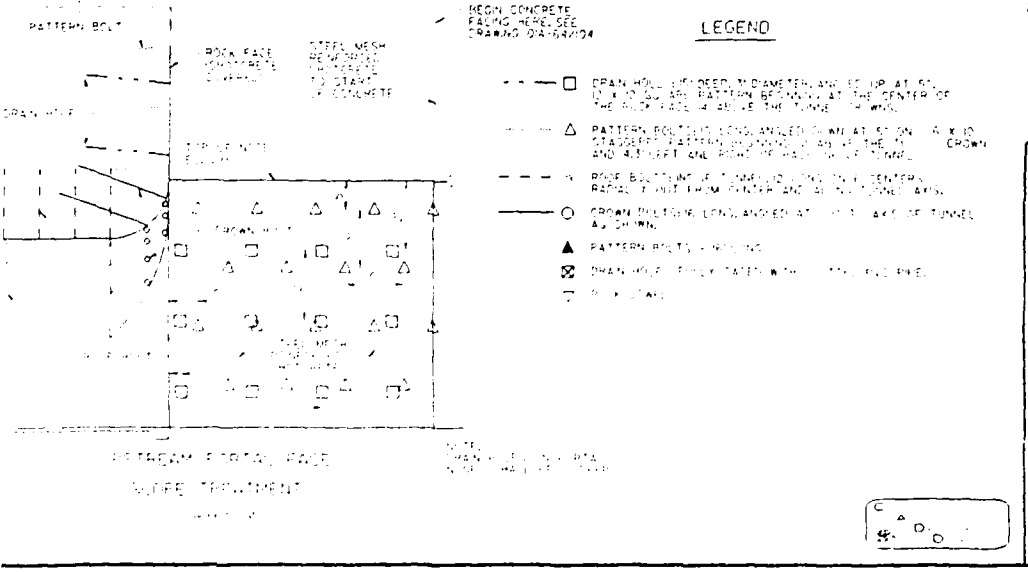
MARCH 1983

01A-64/106.1

PLATE C-13


AS BUILT TOP OF SLOPE
ELEVATION IN FEET
EL. 1262
EL. 1252
EL. 1242
EL. 1232
EL. 1222
EL. 1212
COMP. AS SHOWN (T P)
FOR REINFORCEMENT DETAILS
DRAWING 01A-64/60
ROCK BOLT DETAIL
PATTERN BOLT
0
20
40
60
80
100
120





BEGIN CONCRETE FACING HERE, SEE DRAWING 01A-64/104

LEGEND

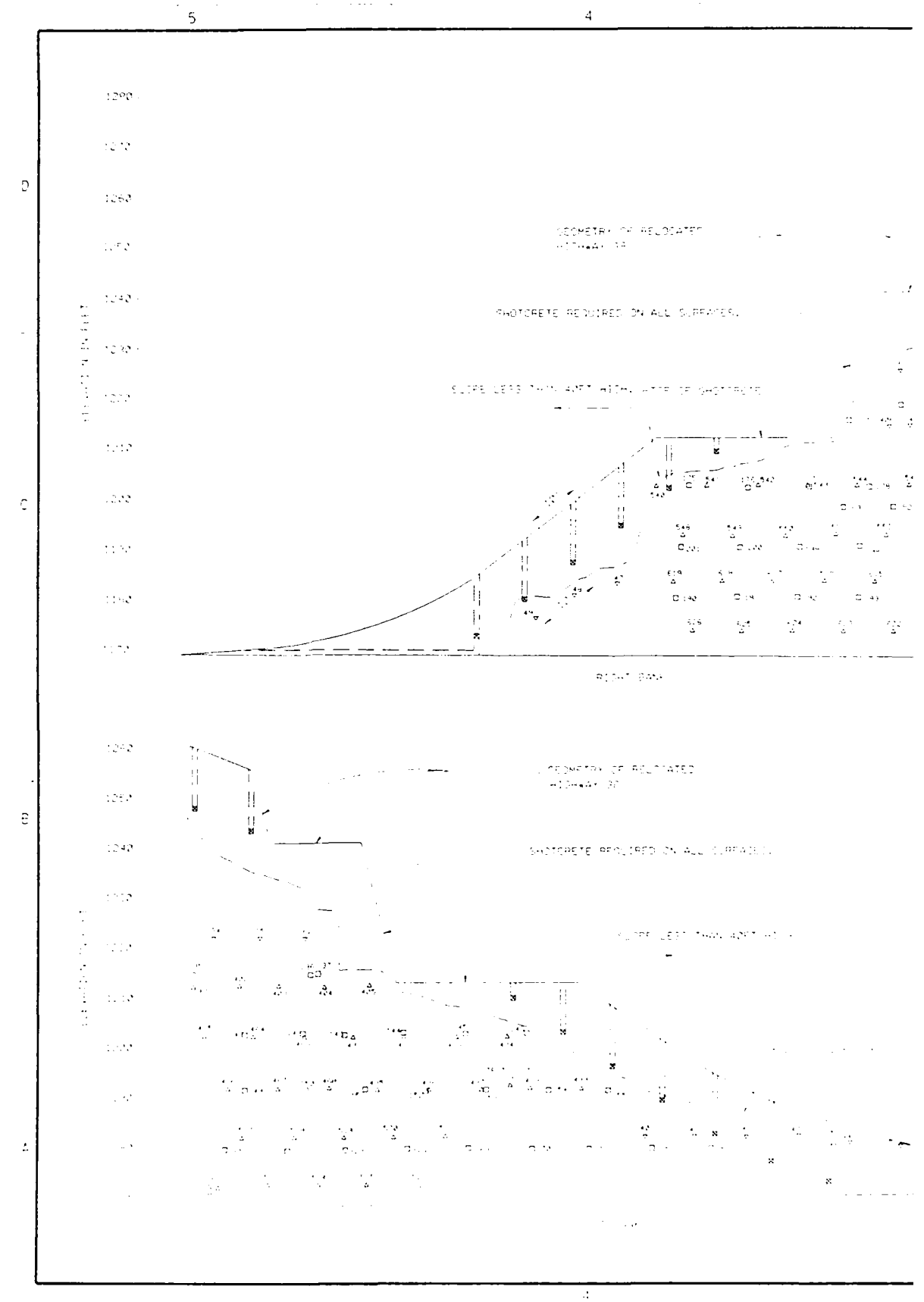
NOTES:

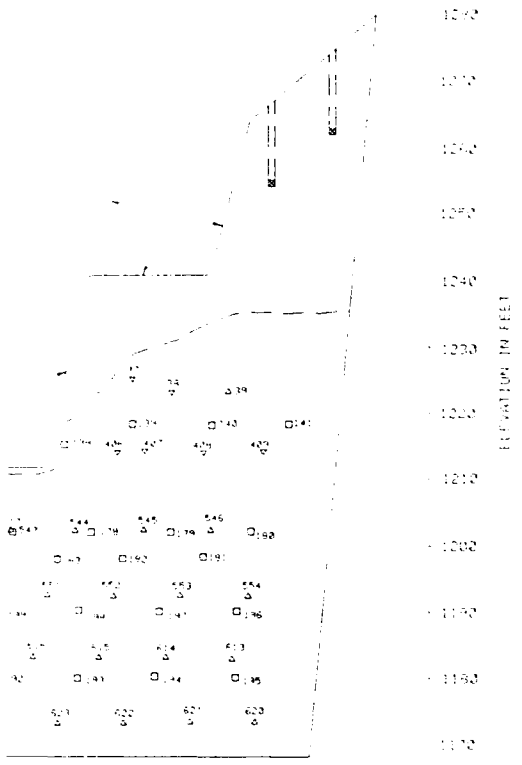
1. FOR SUPPORT DETAILS, SEE DRAWING NUMBER 01A-64/60.
2. FOR STRUCTURAL DETAILS OF PORTAL NOSES AND CONCRETE BASE SLAB, SEE DRAWINGS 01A-64/103 THROUGH 01A-64/106.
3. LOCATION, NUMBER AND LENGTH OF ROCK BOLTS AND DRAINS MAY BE VARIED AT THE DIRECTION OF THE CONTRACTING OFFICER TO SUIT ROCK CONDITIONS ENCOUNTERED IN THE EXCAVATION AS IT PROGRESSES.

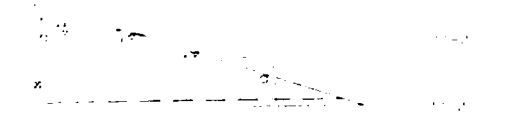
UPSTREAM PORTAL

01A-64/59.3

PLATE C-14


5
4
D
C
B
A
GEOMETRY OF RELOCATED
SHOTCRETE REQUIRED ON ALL SURFACES.
SLOPE LESS THAN 60FT HIGH, USE OF SHOTCRETE
RIGHT BANK
GEOMETRY OF RELOCATED
SHOTCRETE REQUIRED ON ALL SURFACES.
SLOPE LESS THAN 60FT HI





LEGEND

□ DRAIN HOLES: 15' DEEP, 3" DIAMETER, ANGLED UP AT 5 DEGREES IN A 10' x 10' SQUARE PATTERN.

△ PATTERN BOLTS: 10' LONG, ANGLED DOWN AT 5 DEGREES ON 10' x 10' STAGGERED PATTERN.

⊠ DRAIN HOLES FULLY CASED WITH SLOTTED PVC PIPE.

▽ ROCK DOWELS.

STRIPDRAINS.

NOTE

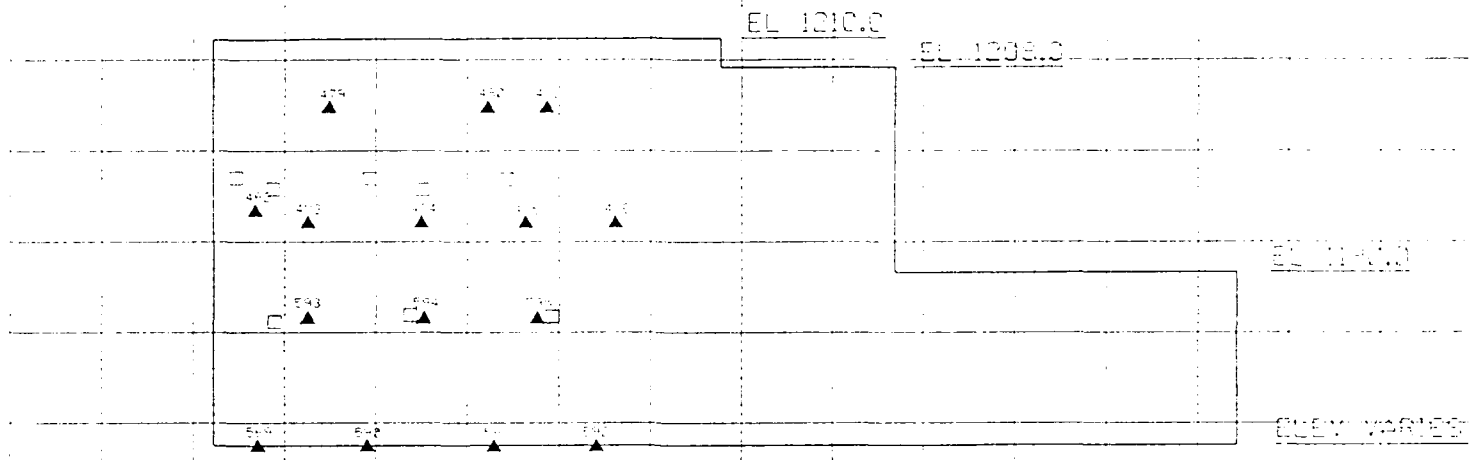
1. THE LOCATIONS FOR ROCK BOLTS, DOWELS, AND DRAIN HOLES ON THIS DRAWING ARE APPROXIMATE AND MAY BE ADJUSTED IN THE FIELD.
2. FOR DETAILS OF SLOPE TREATMENT SEE DRAWING DIA-84/E2.
3. TOP OF SLOPE SHOWN IS AT ESTIMATED BENCH ELEVATION.

[redacted]

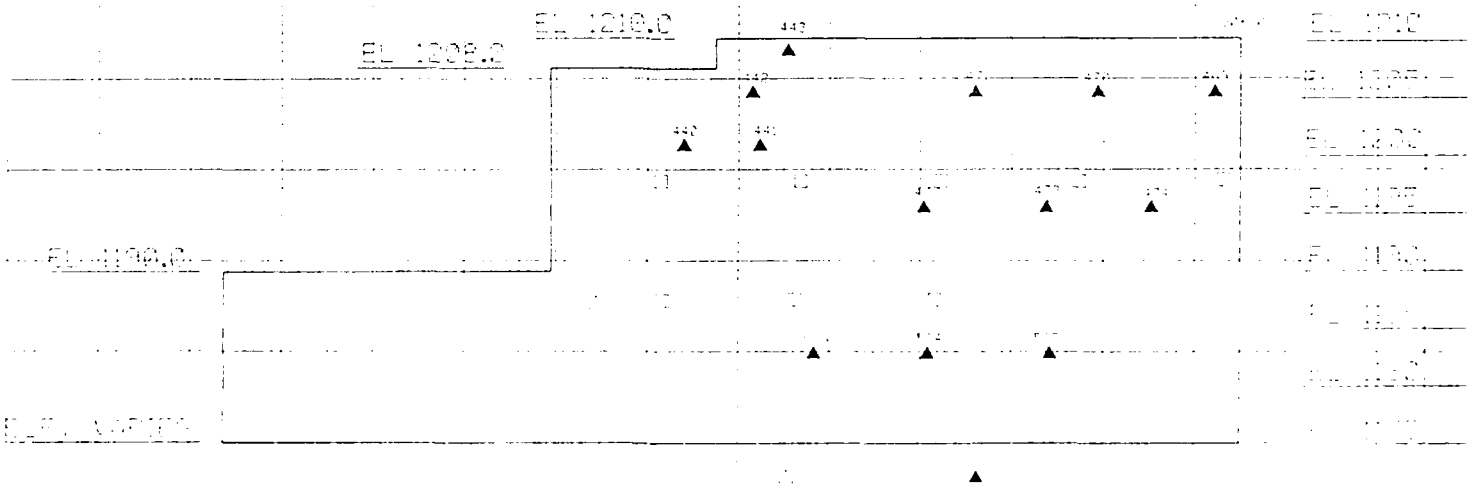
[redacted]STREAM PORTAL
[redacted] SLOPE ROCK TREATMENT

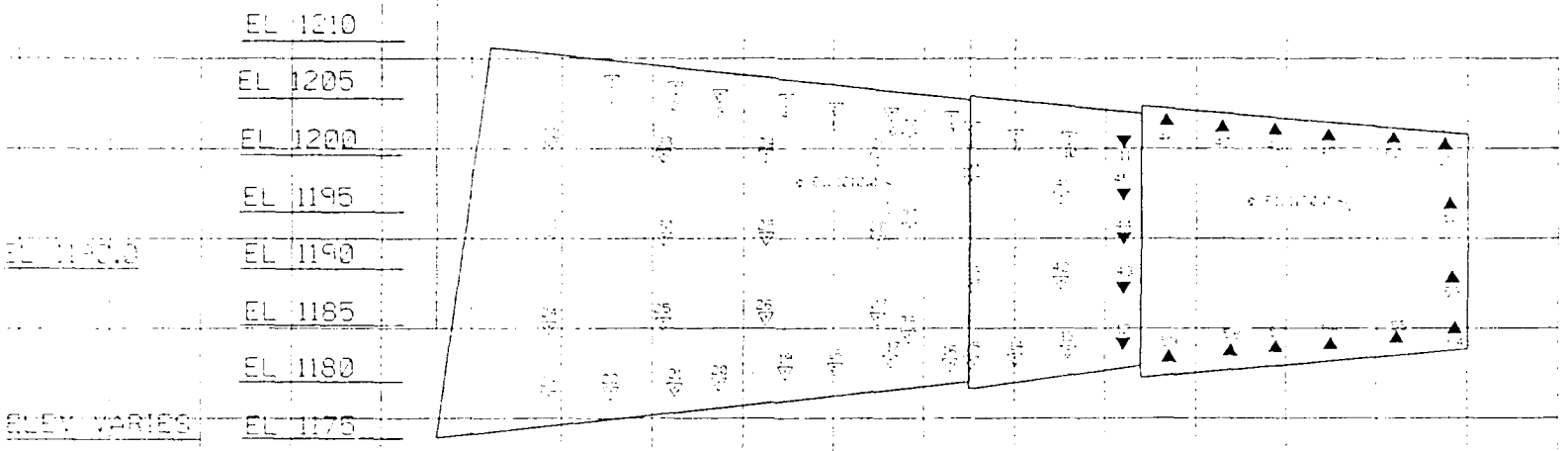
DIA-84/[redacted]

PLATE C-15

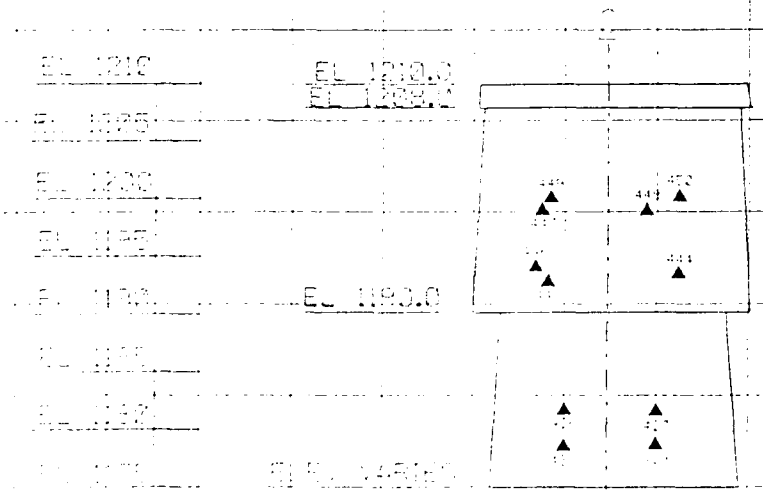


RIGHT SIDE VIEW





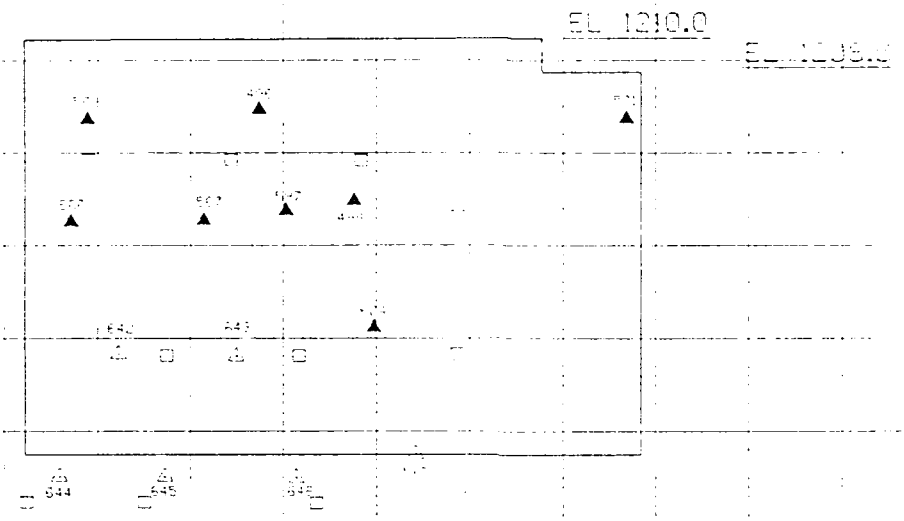
TOP VIEW



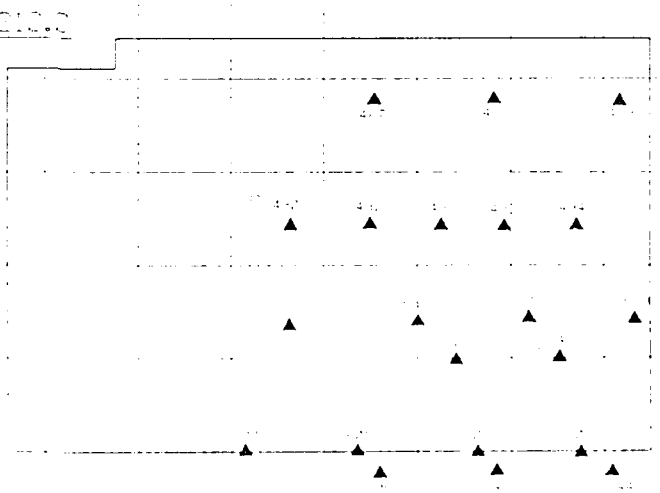
U.S. ARMY ENGINEER DISTRICT

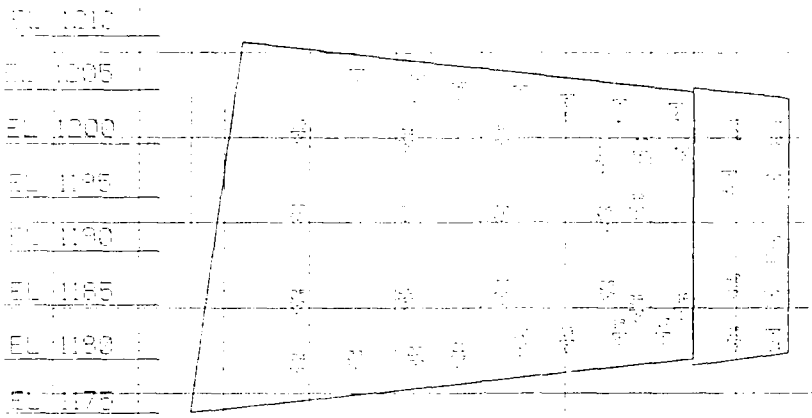
HARLAN DIVERSION PROJECT
AS CONSTRUCTED

PLATE C-16

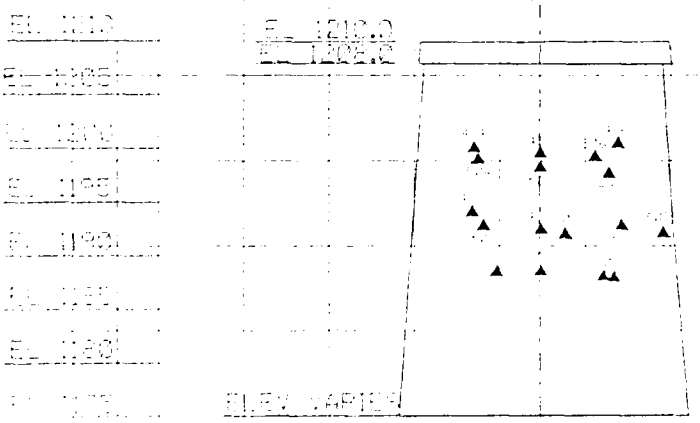


RIGHT SIDE VIEW





TOP VIEW

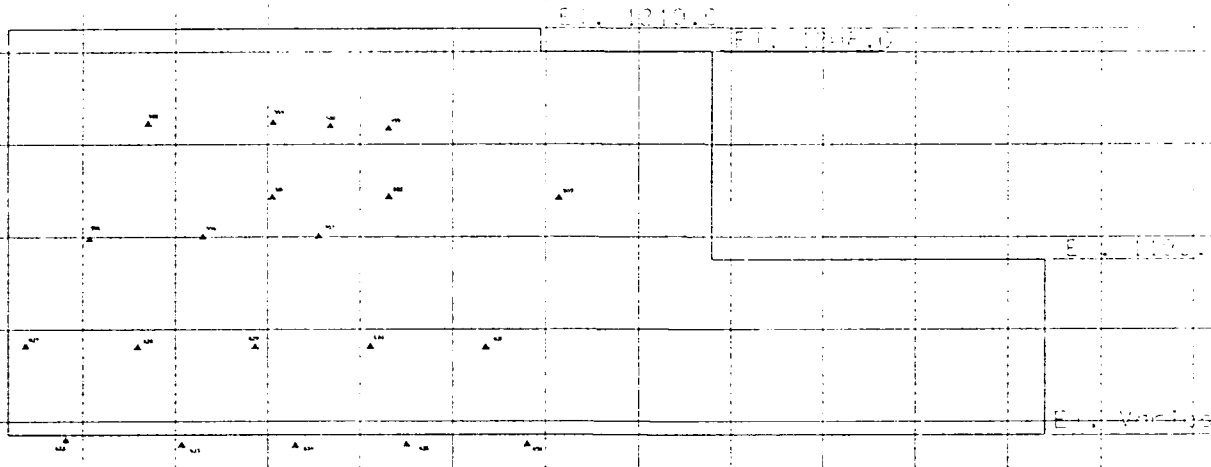


VIEW

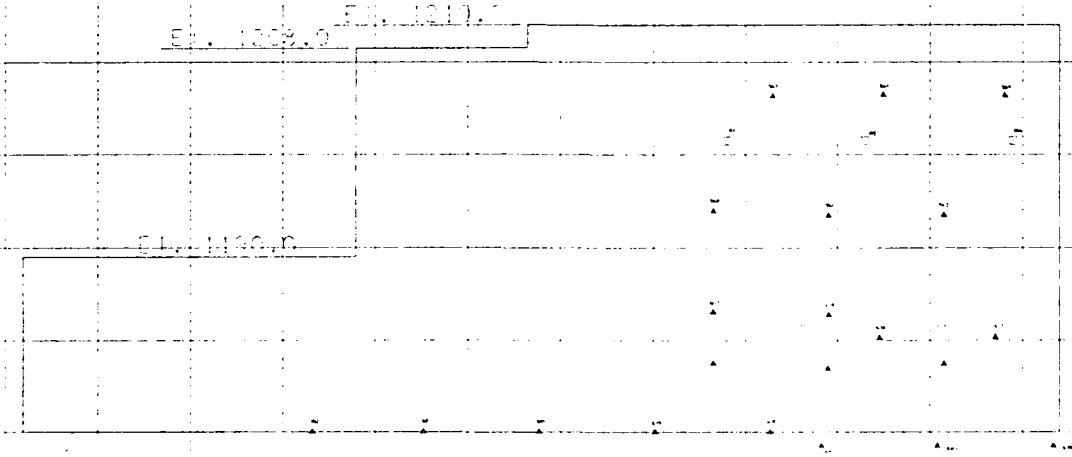
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

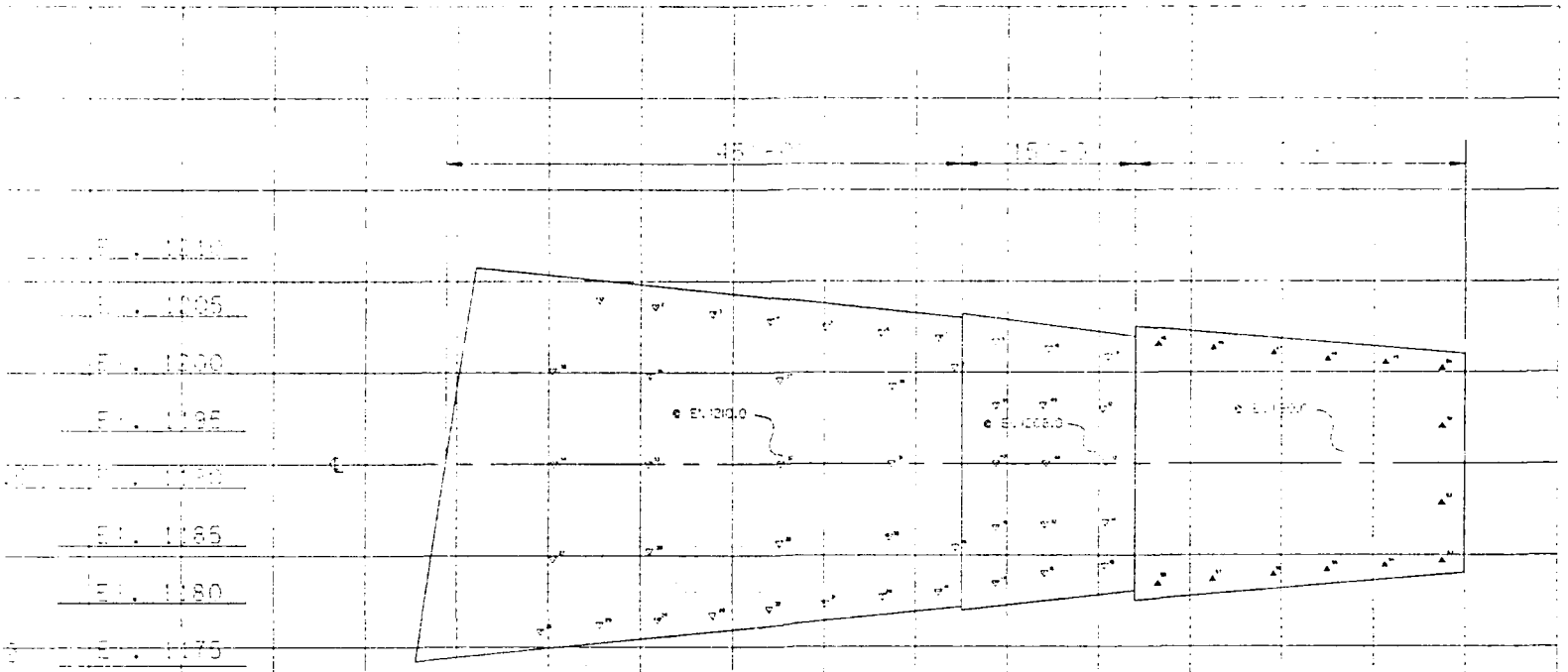
HARLAN DIVERSION PROJECT
AS CONSTRUCTED
INTAKE NO. 1
UPSTREAM PORTAL
ANCHOR BLOCK & END PLATE

PLATE C-17

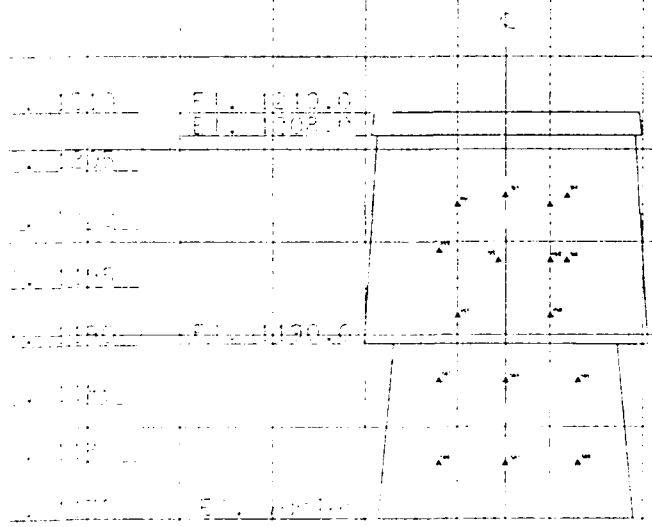


RIGHT SIDE VIEW





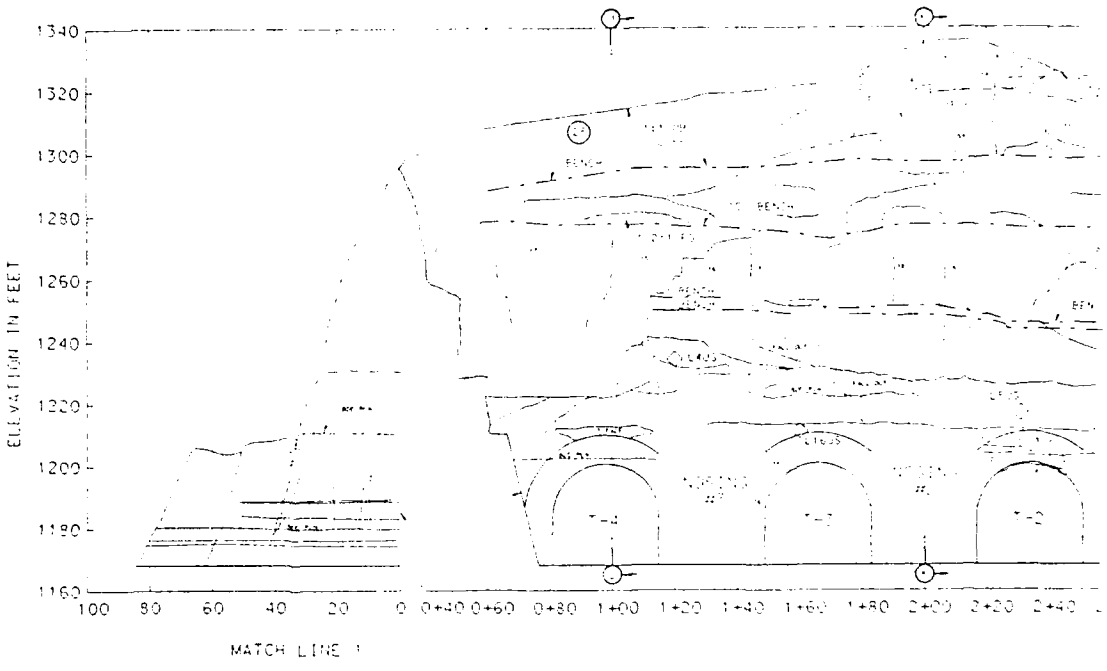
LEGEND

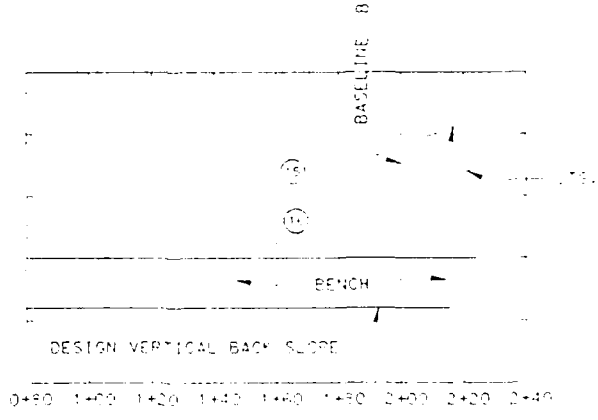


U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

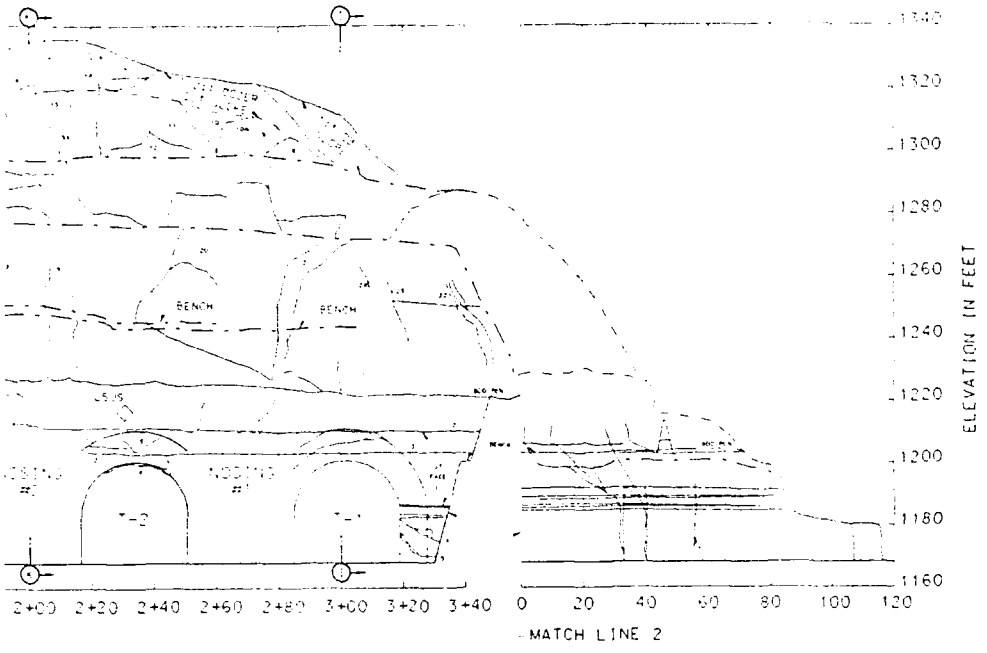
HARLAN DIVERSION PROJECT
AS CONSTRUCTED
PORTAL NOSE #3
UPSTREAM PORTAL
ANCHOR BOLTS & ROCK BOLTS

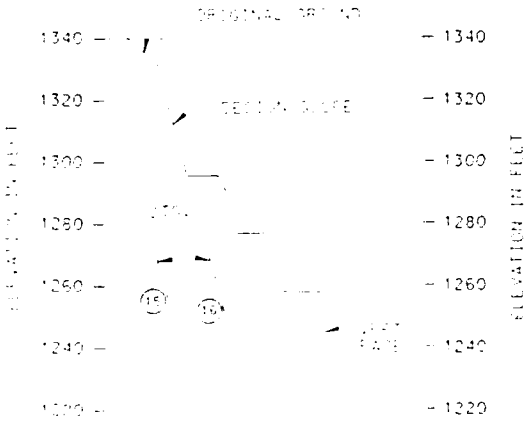
PLATE C-18





HORIZONTAL SECTION
AT ELEVATION 1260





VERTICAL SECTION
AT STATION 2+00

JOINT DESCRIPTIONS

T1 BELL JOINT DESCRIPTIONS

T2 BELL JOINT DESCRIPTIONS

T3 BELL JOINT DESCRIPTIONS

LEGEND

L4US LOAD CELL

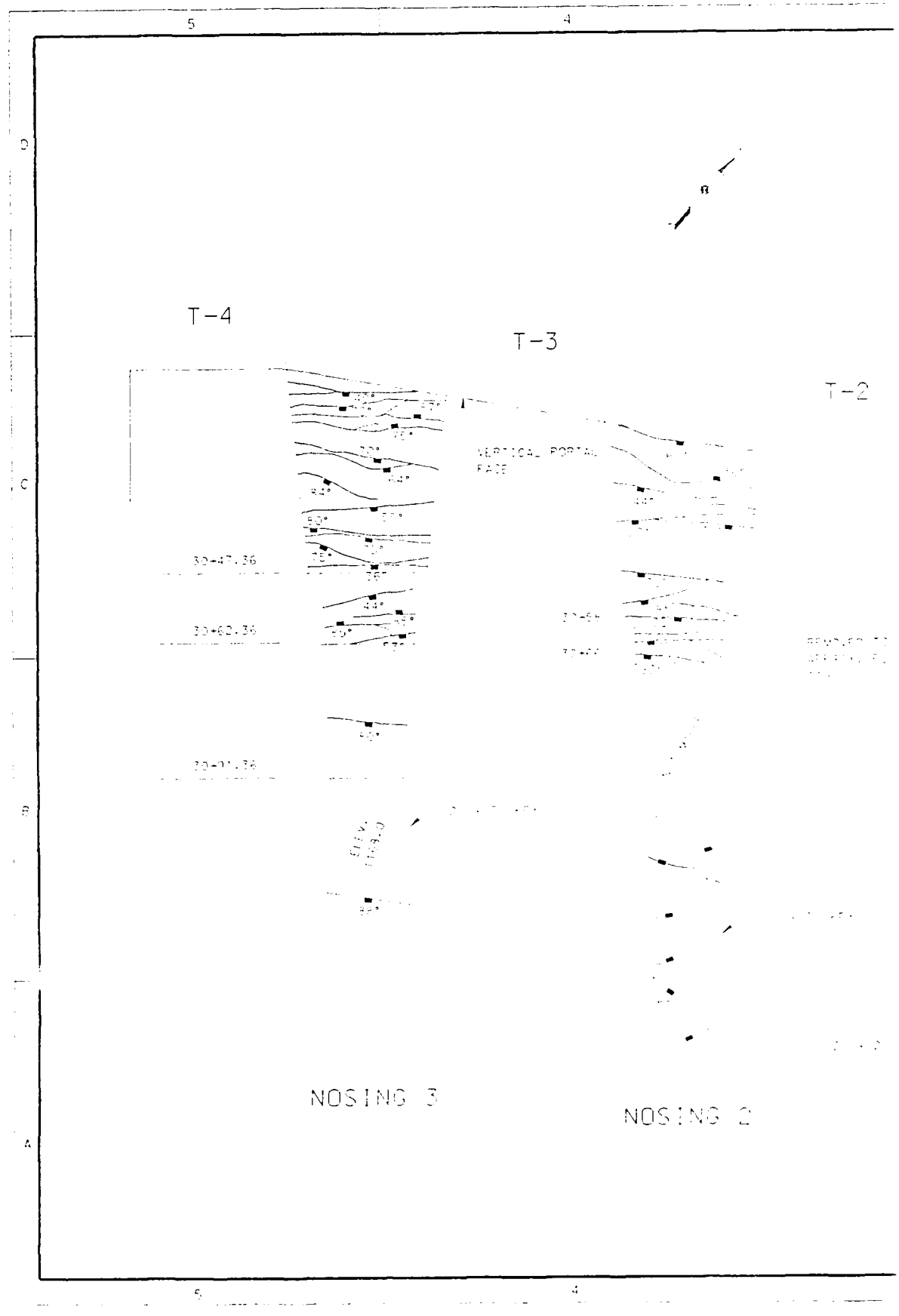
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

UPPER CUMBERLAND RIVER BASIN

LOCAL FLOOD PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL
GEOLOGIC MAP AND
CROSS-SECTION LOCATIONS

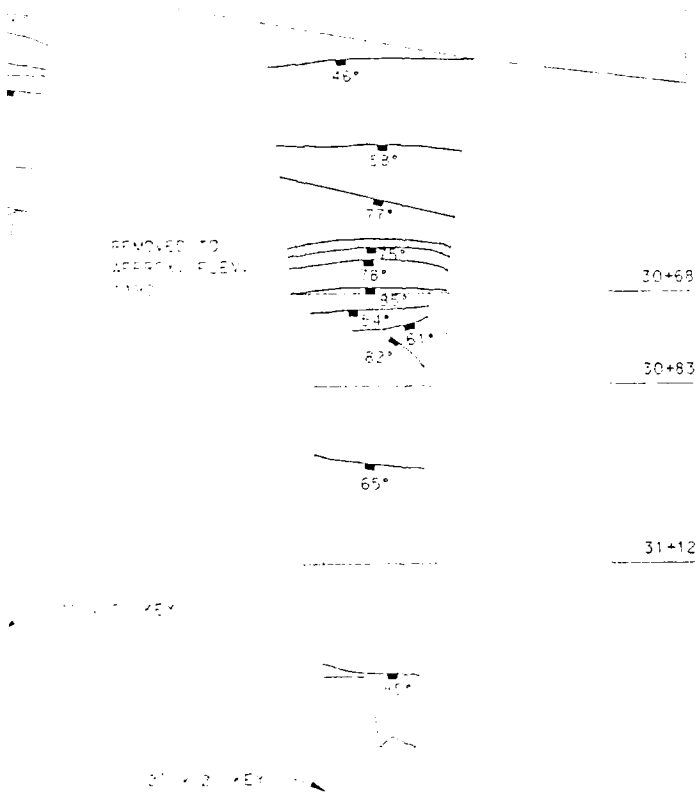
Q1A-4393

PLATE C-19


5
4
D
C
B
A
T-4
T-3
T-2
VERTICAL PORTAL FACE
30+47.36
30+82.36
30+91.36
NOSING 3
NOSING 2

T-2

T-1



LEGEND

77° JOINT WITH DIP INDICATED

VERTICAL JOINT

ZONES OF CLOSELY SPACED JOINTS WITH BROWN, CLAYEY-SILT FILLING.

NOTES:

1. JOINTS ARE TYPICALLY TIGHT, NOT HEALED, AND SMOOTH.
2. SEE PLATES C-19 AND C-20 FOR NOSING SECTIONS AND DETAILS.
3. SEE PLATES C-13, C-18, AND C-03 FOR MAPS OF NOSING SIDES.

NOSING 1

REVISION				
NO.	DESCRIPTION	DATE	BY	APPROVED

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

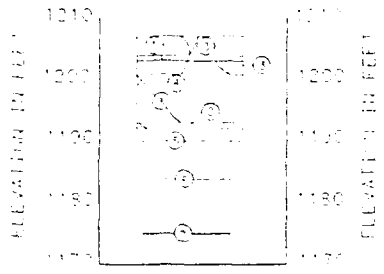
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN KENTUCKY
DIVERSION TUNNELS

UPSTREAM PORTAL NOSINGS
SURFACE MAP

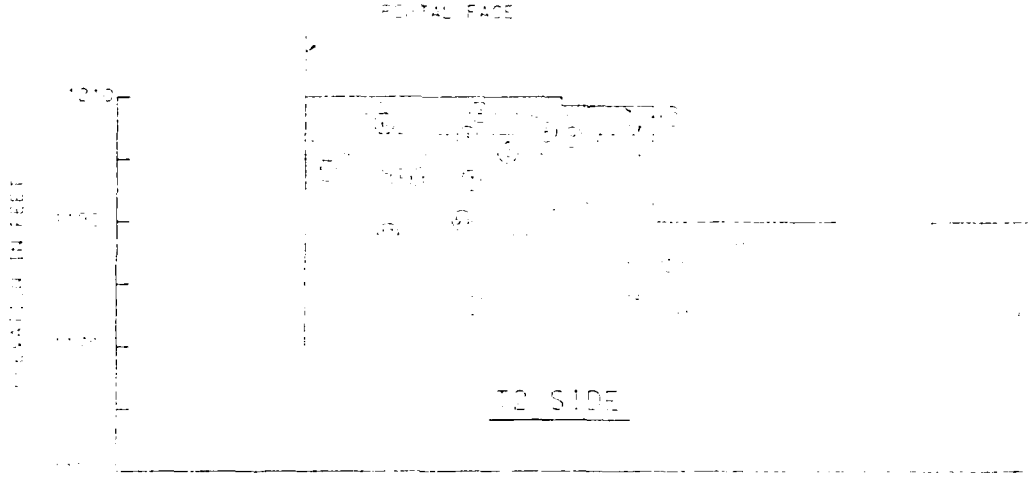
Q1A-4392

PLATE C-20

N1 FRONT JOINT DESCRIPTIONS



N1 FRONT

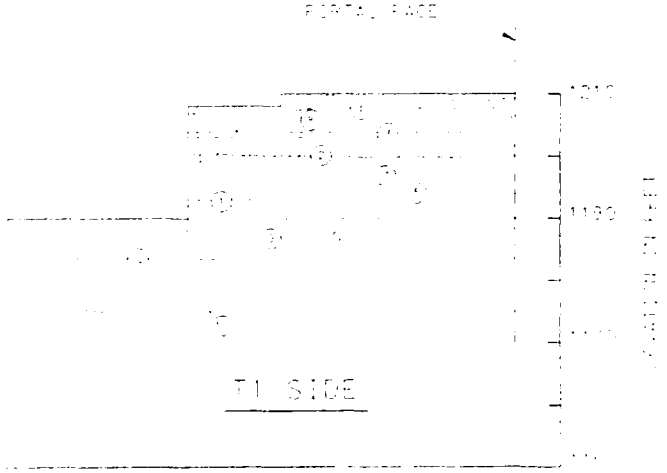


T2 SIDE

T0 (SIDE) JOINT DESCRIPTIONS

T1 (SIDE) JOINT DESCRIPTIONS

ESTIMATED COST MATERIAL, DLE TI
BLASTING AND/OR ACM MATERIAL

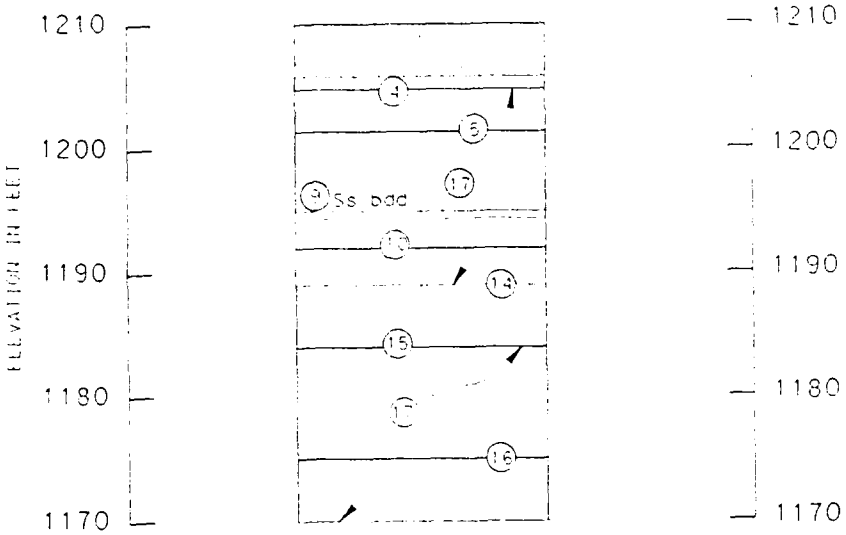


U.S. ARMY ENGINEER DISTRICT

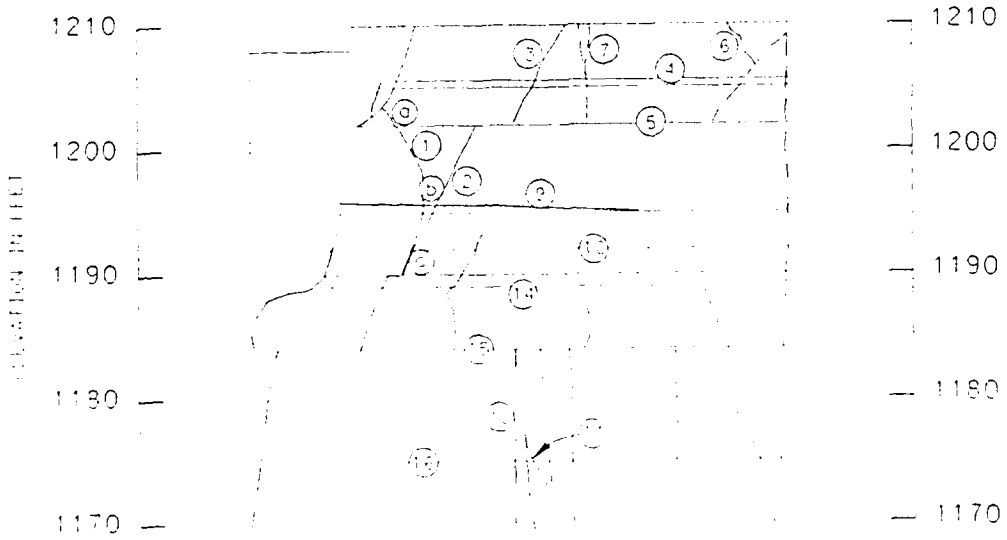
UPSTREAM PORTAL MOORING NI

PROFILE MAP

01A-4/394



FRONT



T2 SIDE

JOINT DESCRIPTIONS

① J1,irr,op,fe s'
(a) N45°E 46°SE
(b) N45°E 90°
(c) N45°E 45°NW

② J1,ir N45°E 46°SE

③ J',op,N45°E 46°SE

④ fe bdd,hd,v f grd,

⑤ Bdd pln,op,hor

⑥ J1,N50°E 70°SE

⑦ J's,op,fe s1,N40°E 60

⑧ J1s,N30°E 60°SE

⑨ Ss bdd,hd,v f gr

⑩ J1,N65°E 70°NW-67°SE,

⑪ J1,op,fw s1,N65°E 70°

⑫ J1,op,fw s1,N65°E 80°

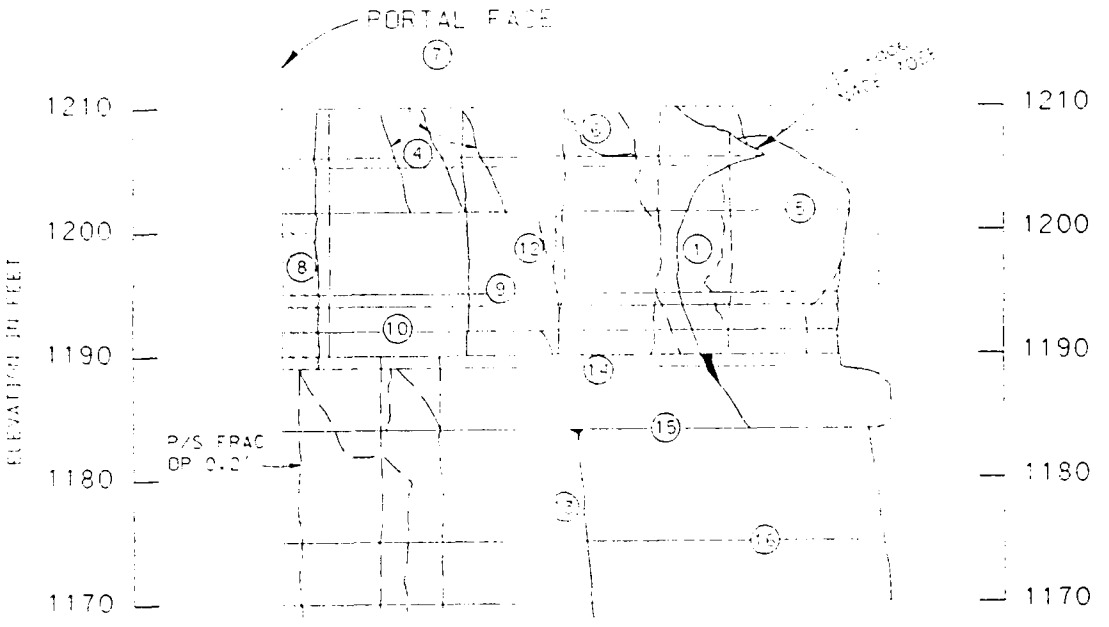
⑬ J1,N,fw s1,N65°E 70°

⑭ Bdd pln, op,hor

⑮ Bdd pln, op,hor

⑯ Bdd pln, op,hor

⑰ J1 irr,op,fe s1,45°E



T3 SIDE

JOINT DESCRIPTIONS

① Jt.iff.op.fe st
(a) N45°E 46°SE
(b) N45°E 90°
(c) N45°E 45°NW
② Jt.ff N45°E 46°SE
③ Jt.op.N45°E 46°SE
④ Sh bdd.hdv f grd.ff gr
⑤ Bdd pln.op.bar
⑥ Jt.N50°E 70°SE
⑦ Jt's.op.fe st.N40°E 60°-75°SE
⑧ Jt.N40°E 60°SE
⑨ Sh bdd.hdv f gr. f gr
⑩ Jt.N45°E 70°NW-84°SE..op.fe st
⑪ Jt.op.fe st.N45°E 74°NW
⑫ Jt.op.fe st.N65°E 84°SE
⑬ Jt.op.fe st.N60°E 70°SE
⑭ Bdd plnr.op.bar
⑮ Bdd plnr.op.bar
⑯ Bdd plnr.f.grav
⑰ f.fract.N40°E 84°SE

LEGEND

P/S PRESPLIT HOLE FRACTURES

BROKEN BEHIND DESIGN LINES

NOTES:

1. SEE PLATE A-2 FOR GEOLOGIC ABBREVIATIONS.
2. SEE PLATES A-3 THRU A-5 FOR EXPLANATION OF DESCRIPTIVE TERMS.
3. SEE PLATES C-15 AND C-16 FOR NOSING SECTIONS AND DETAILS.

0 10'

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL NOSING 2
GEOLOGIC MAP

Q1A-4395

Computer Support & Technical Section
Design & Drafting

PLATE C-22



N3 FRONT VIEW

N3 FRONT (JOINT DESCRIPTIONS)

① Bdd pln,ti,0¢

② Bdd hor

③ Bdd hor

④ Bdd hor

⑤ Bdd pln,slop .01'

⑥ Bdd-Sls w/Ss strgs slop .01'

T4 SIDE (JOI

⑦ [illegible]

⑧ [illegible]

⑨ Bdd ≈ hor

⑩ Bdd pln. ≈ ho

⑪ Bdd pln. ≈ hor

⑫ Bdd ≈ hor

⑬ Prep [illegible] bdd pln. of ≈

⑭ J1.N85°E [illegible]

⑮ J1.,05 [illegible] to N85°E [illegible]

⑯ J1.[illegible] to [illegible] @ wea rock

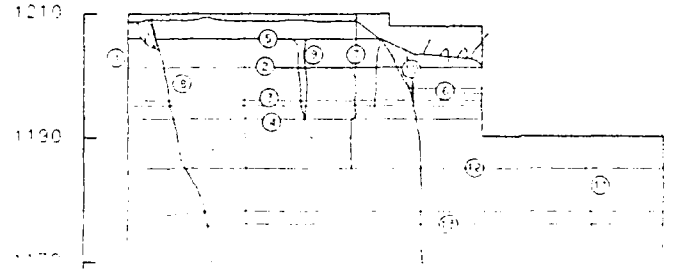
⑰ J1.N85°E 80°S fe 3'

⑱ Bdd pln. ≈ hor

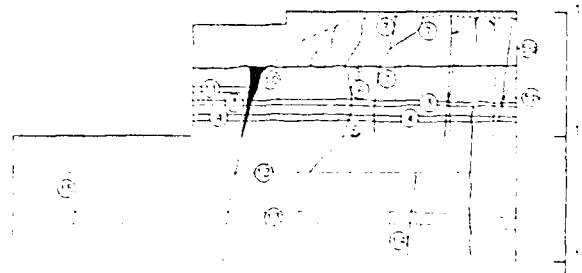
⑲ Bdd.Sls w/Ss

PORTAL FACE

P/S



T4 SIDE



T3 SIDE

T4 SIDE (JOINT DESCRIPTIONS)

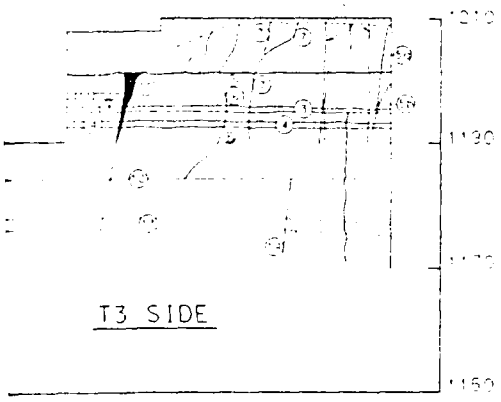
1. Stiff, tan, [illegible] ≈0.05' thickness of grouts
2. Bdd pln. ≈ hor..0'
3. Bdd ≈ hor
4. Bdd pln. ≈ hor
5. Bdd pln. ≈ hor
6. Bdd ≈ hor
7. Pre-split, moving movement along bdd pln. of ≈0.4'
8. Jt.N45°E 70°SE..04', st fe st
9. Jt..05' @ top,.0' @ bottom
   (a) N55°E 85°SE
   (b) N55°E 80°SE
10. Jt.(>1.0' to 0.4' @ bottom)- c & wkd rock mix-fill
11. Jt.N65°E 80°SE..05' to (>1.0'), fe st
12. Bdd pln. ≈ hor..01'
13. Bdd.Sls w/Ss strgs. ≈ hor..01'

T3 SIDE (JOINT DESCRIPTIONS)

6. Bdd.≈ hor. lt gr.ark
7. Bdd.≈ hor.dk gr.ss mix
8. Bdd. Sls/Ss strgs. ≈ hor
9. Bdd.Sls. ≈ hor
10. Jts..01,possibly due to blasting
    (a) N60°E 85°SE
    (b) N60°E 75°SE
11. Jt.N45°E 63°NW
12. Frac possibly due to P/s
13. Jts.curved..05
    (a) N65°E 65°NW
    (b) N65°E 50°SE
14. Jt.N45E 60°SE
15. Jt.N80°E 65SE ≈ 90°,.0'(>1.0' near top,0.4' @ bottom,cl & wkd rock frags-fill
16. Bdd. ≈ hor
17. Bdd pln..01'
18. Bdd.Sls w/Ss strgs
19. Jt.N65°E 85°SE.03',fe st
20. Jt.N65E 826Se..05'(>1.0') fe st

PORTAL FACE

P/S



T3 SIDE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: D.A.S.
Checked By: P.P.
P.P.

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVISION TUNNELS

UPSTREAM PORTAL NOSING 3
GEOLOGIC MAP

Approved By:
Chief, Geotechnical Branch
Chief, Engineering Division

Computer Solid Section Aided Design & Drafting

Date: FEB 1994

Scale: 1"=10'

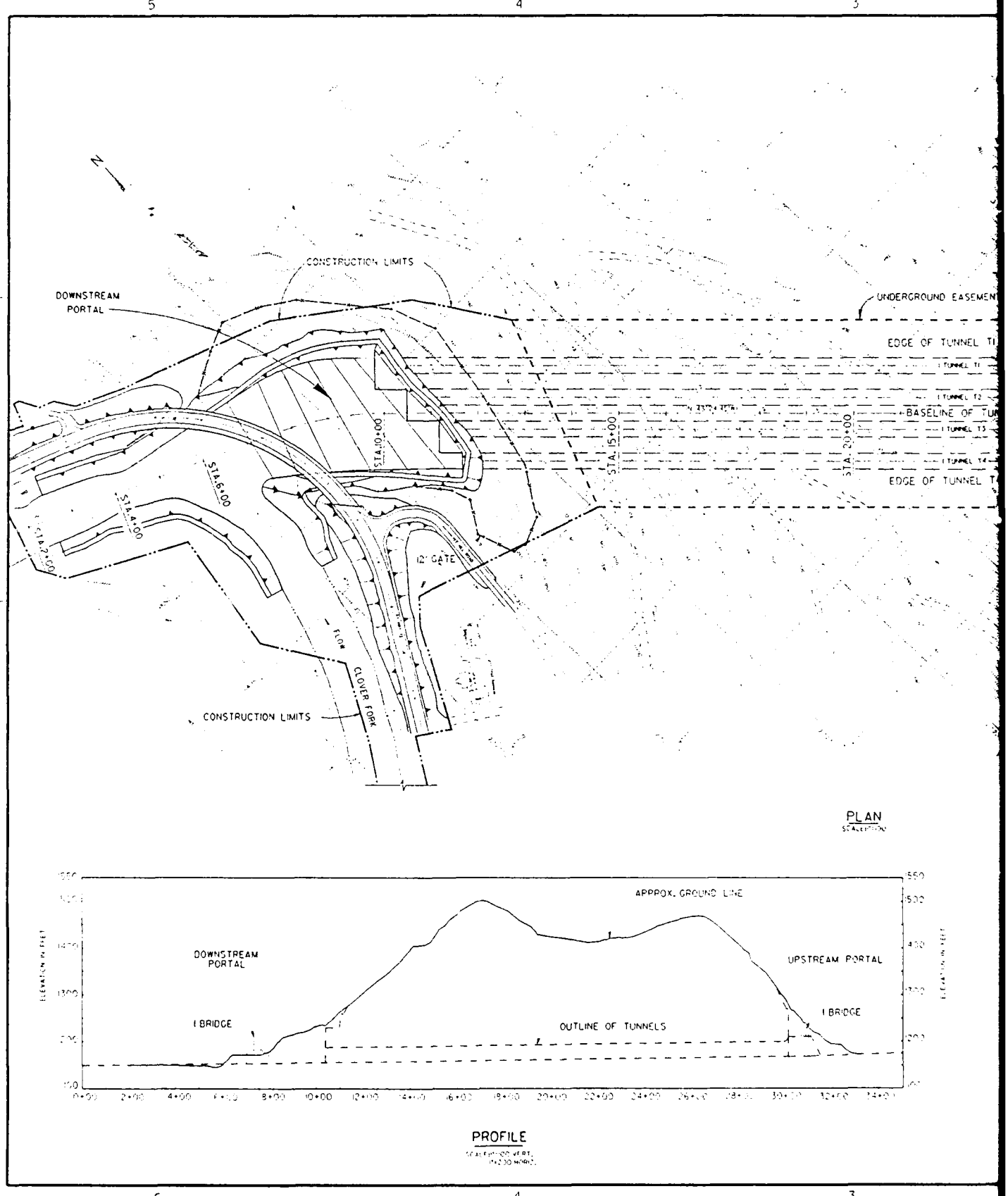
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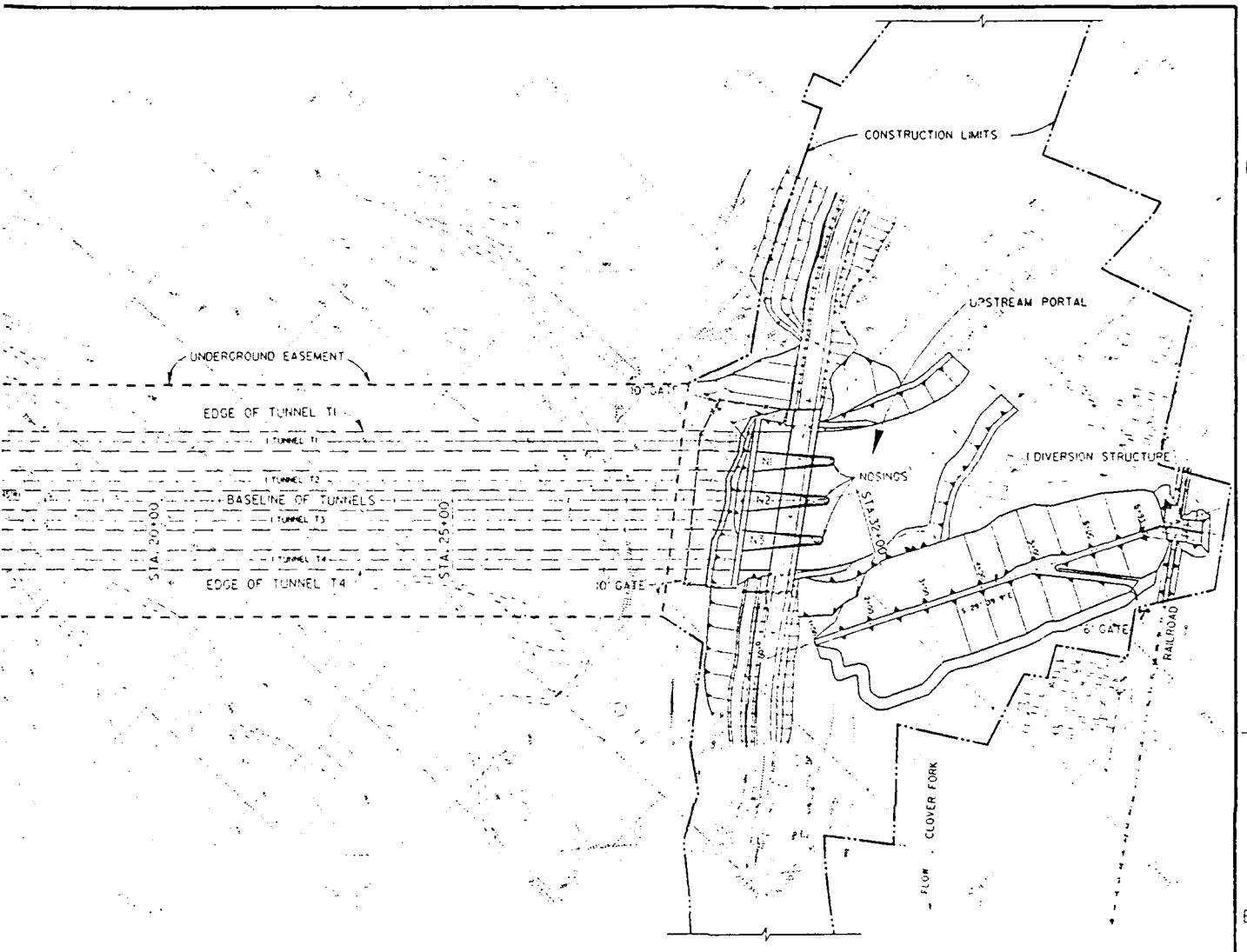
File No. Q1A-4396

PLATE C-23

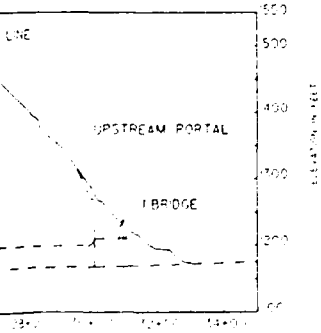
Appendix D - Tunnels

Plate No.	Drawing No.	Description
D-1	Q1A-64/2.3	General Plan
D-2	Q1A-64/6.2	Boring Plan
D-3	Q1A-64/30.2	Section A-A
D-4	Q1A-64/31.1	Section B-B
D-5	Q1A-64/71.1	Plan, Section, and Profile
D-6	Q1A-64/72.2	Support Details
D-7 thru D-27	----	Tunnel 1 Maps
D-28 thru D-47	---	Tunnel 2 Maps
D-48 thru D-67	---	Tunnel 3 Maps
D-67 thru D-85	---	Tunnel 4 Maps


5
4
3
D
C
B
A
N
CONSTRUCTION LIMITS
DOWNSTREAM PORTAL
UNDERGROUND EASEMENT
EDGE OF TUNNEL T1
T1 TUNNEL T1
T2 TUNNEL T2
BASELINE OF TUN
T3 TUNNEL T3
T4 TUNNEL T4
EDGE OF TUNNEL T
STA. 20+00
STA. 15+00
STA.10+00
STA.6+00
STA.4+00
STA.2+00
12' GATE
FLOW
CLOVER FORK
CONSTRUCTION LIMITS
PLAN
APPROX. GROUND LINE
DOWNSTREAM PORTAL
UPSTREAM PORTAL
I BRIDGE
I BRIDGE
OUTLINE OF TUNNELS
ELEVATION IN FEET
PROFILE



PLAN



NOTES:

1. ALL ELEVATIONS ARE IN FEET AND REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD).
2. FOR DETAILED PLANS OF THE PORTALS, SEE DRAWINGS OIA-64/51 AND 61.
3. FOR DETAILED PLANS OF THE DIVERSION STRUCTURE, SEE DRAWING OIA-64/73.
4. FOR DETAILED PLANS OF ROAD RELOCATIONS AND BRIDGES, SEE SEPARATE FOLIO.
5. LOCATION OF FENCING SHOWN IS APPROXIMATE. FINAL LOCATION OF FENCING SHALL BE AS APPROVED BY THE CONTRACTING OFFICER.

LEGEND

- - - - - - - UNDERGROUND EASEMENT
——·——·—— CONSTRUCTION LIMITS

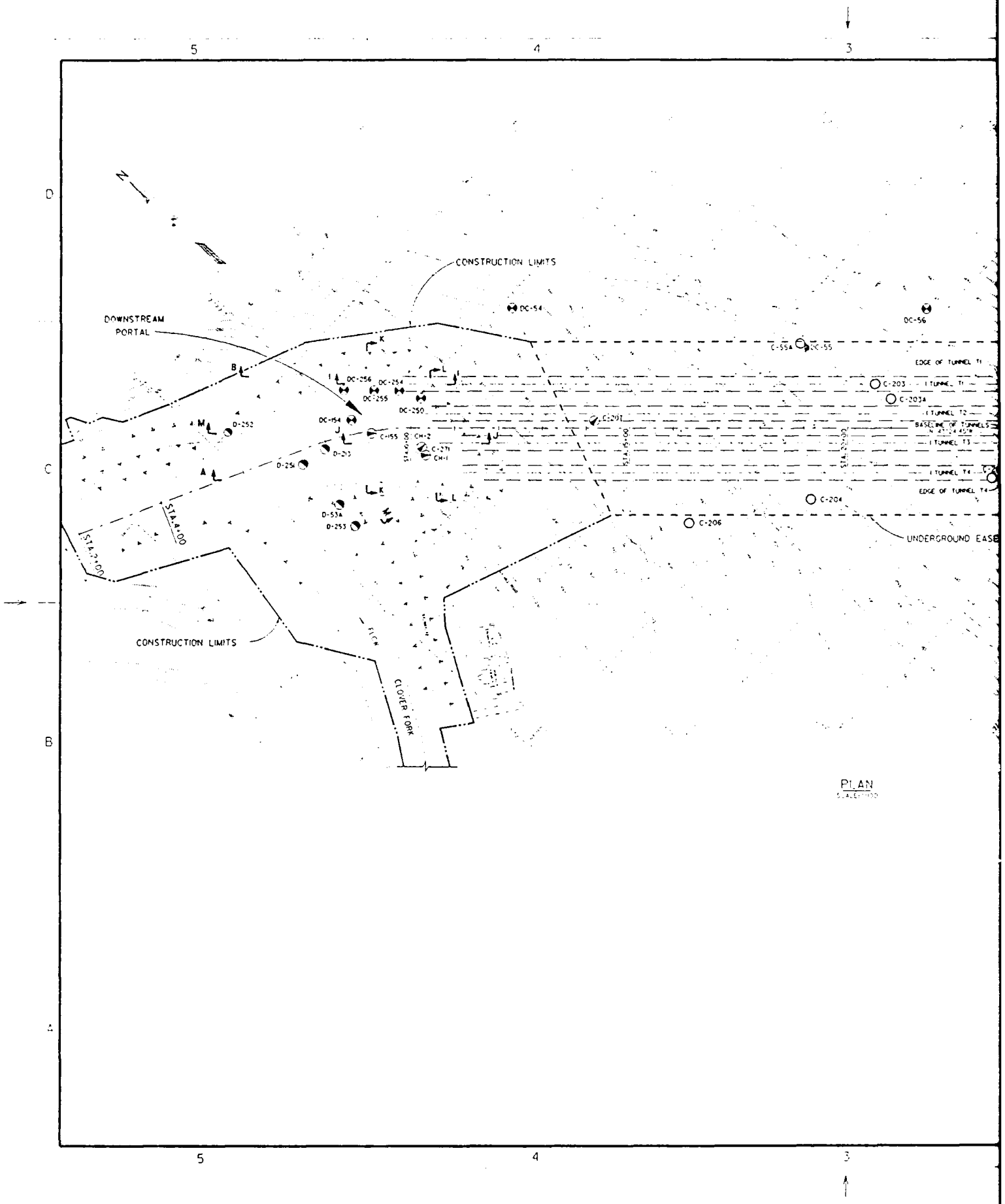
3	10-14-92	ADDED FENCES	S.B.D.
2	7-14-89	REVISED CONSTRUCTION LIMITS AND UPSTREAM PORTAL	A.G.
1	5-31-89	CONFORMING TO REVISED EASEMENTS	R.W.

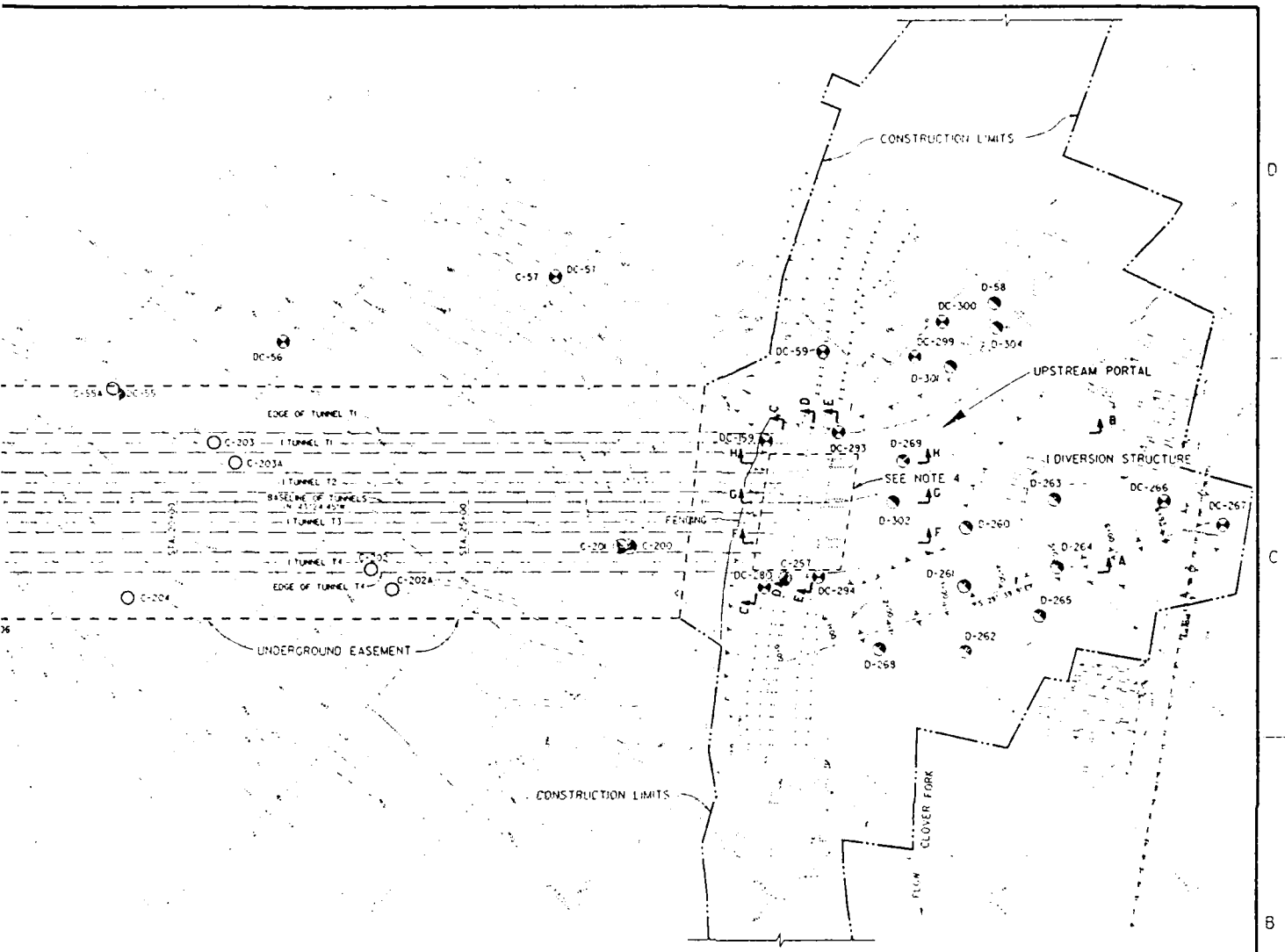
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DIVERSION TUNNELS
GENERAL PLAN

OIA-64/2.3

PLATE D-1


5
4
3
D
C
B
A
N
CONSTRUCTION LIMITS
DOWNSTREAM
PORTAL
DC-54
DC-56
C-55A
DC-55
EDGE OF TUNNEL T1
C-203
C-203A
TUNNEL T2
BASELINE OF TUNNELS
TUNNEL T3
TUNNEL T4
EDGE OF TUNNEL T4
C-204
C-206
UNDERGROUND EASE
DC-256
DC-254
DC-255
DC-250
DC-154
C-155
CH-2
CH-1
C-271
C-207
D-252
D-251
D-253
D-53A
STA 4+00
STA 2+00
STA 6+00
STA 8+00
CONSTRUCTION LIMITS
CLOVER FORK
PLAN



PLAN

NOTES

1. ALL ELEVATIONS ARE IN FEET AND REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD)
2. FOR DETAILED PLANS OF THE PORTALS, SEE DRAWINGS 01A-64/51 AND 61
3. FOR DETAILED PLANS OF THE DIVERSION STRUCTURE, SEE DRAWING 01A-64/73.
4. FOR BORING LOCATIONS IN UPSTREAM PORTAL AREA, SEE DRAWING 01A-64/32.
5. FOR DETAILED PLANS OF ROAD RELOCATIONS, SEE SEPERATE FOLIO.

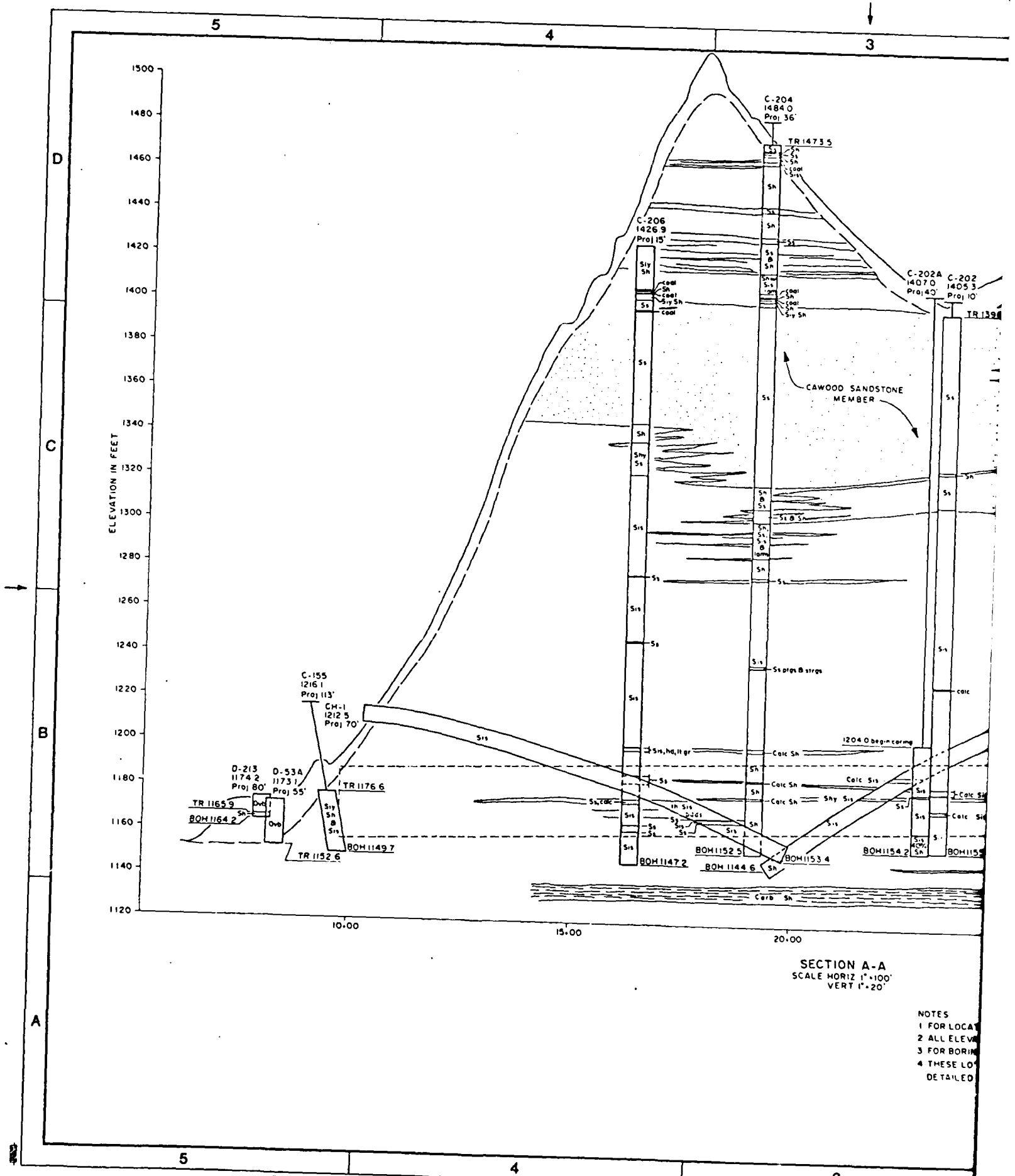
2	7-10-89	REVISED CONSTRUCTION LIMITS AND	C.A.G. J.L.S.
1	5-31-89	CONFORMING TO REVIEW COMMENTS	C.A.G. J.L.S.

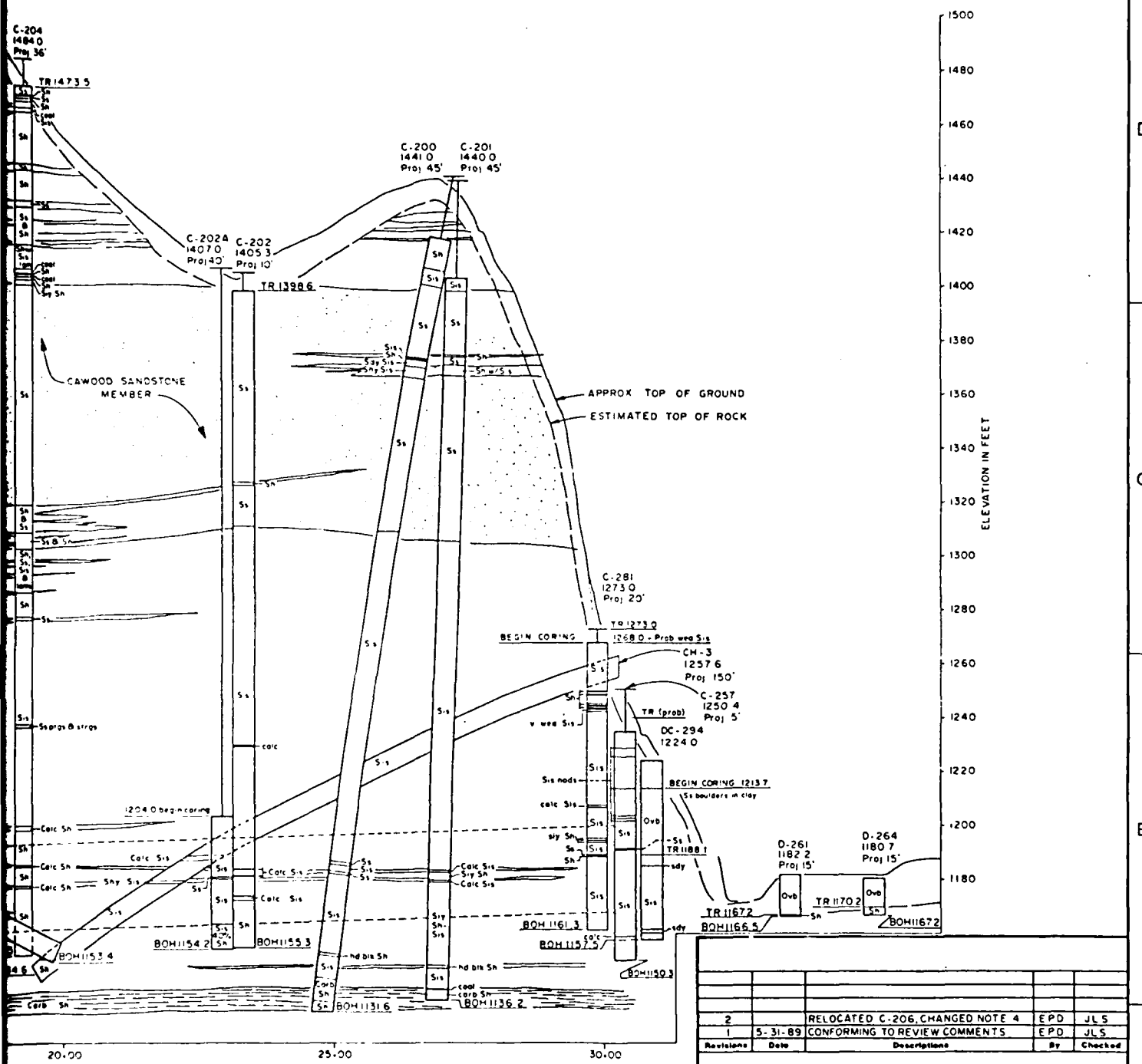
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DIVERSION TUNNELS
BORING PLAN

01A-64/6.2

PLATE D-2


5
4
3
D
C
B
A
ELEVATION IN FEET
1500
1480
1460
1440
1420
1400
1380
1360
1340
1320
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
10+00
15+00
20+00
C-204
1484 0
Proj 36'
TR 1473 5
C-206
1426 9
Proj 15'
C-202A
1407 0
Proj 40'
C-202
1405 3
Proj 10'
TR 1396
CAWOOD SANDSTONE MEMBER
C-155
1216 1
Proj 113'
CH-1
1212 5
Proj 70'
D-213
1174 2
Proj 80'
D-53A
1173 1
Proj 55'
TR 1176 6
TR 1165 9
BOH 1164 2
TR 1152 6
BOH 1149 7
BOH 1147 2
BOH 1152 5
BOH 1144 6
BOH 1153 4
BOH 1154 2
1204 0 begin coring
Carb Sh
SECTION A-A
SCALE HORIZ 1"=100'
VERT 1"=20'
NOTES
1 FOR LOCAT
2 ALL ELEV
3 FOR BORIN
4 THESE LO
DETAILED



SECTION A-A
SCALE HORIZ 1"=100'
VERT 1"=20'

NOTES
1 FOR LOCATION OF SECTION, SEE DRAWING 01A-64/6
2 ALL ELEVATIONS REFER TO MEAN SEA LEVEL
3 FOR BORING LEGEND AND NOTES, SEE DRAWING 01A-64/5
4 THESE LOGS PRIMARILY SHOW LITHOLOGIC DATA FOR DETAILED INFORMATION, SEE LOGS OF BORINGS

Revisions	Date	Descriptions	By	Checked
2		RELOCATED C-206, CHANGED NOTE 4	EPD	JLS
1	5-31-89	CONFORMING TO REVIEW COMMENTS	EPD	JLS

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

Designed by: JLS
Drawn by: EHL
Checked by: EP
Approved by: Marvin D. Simmons

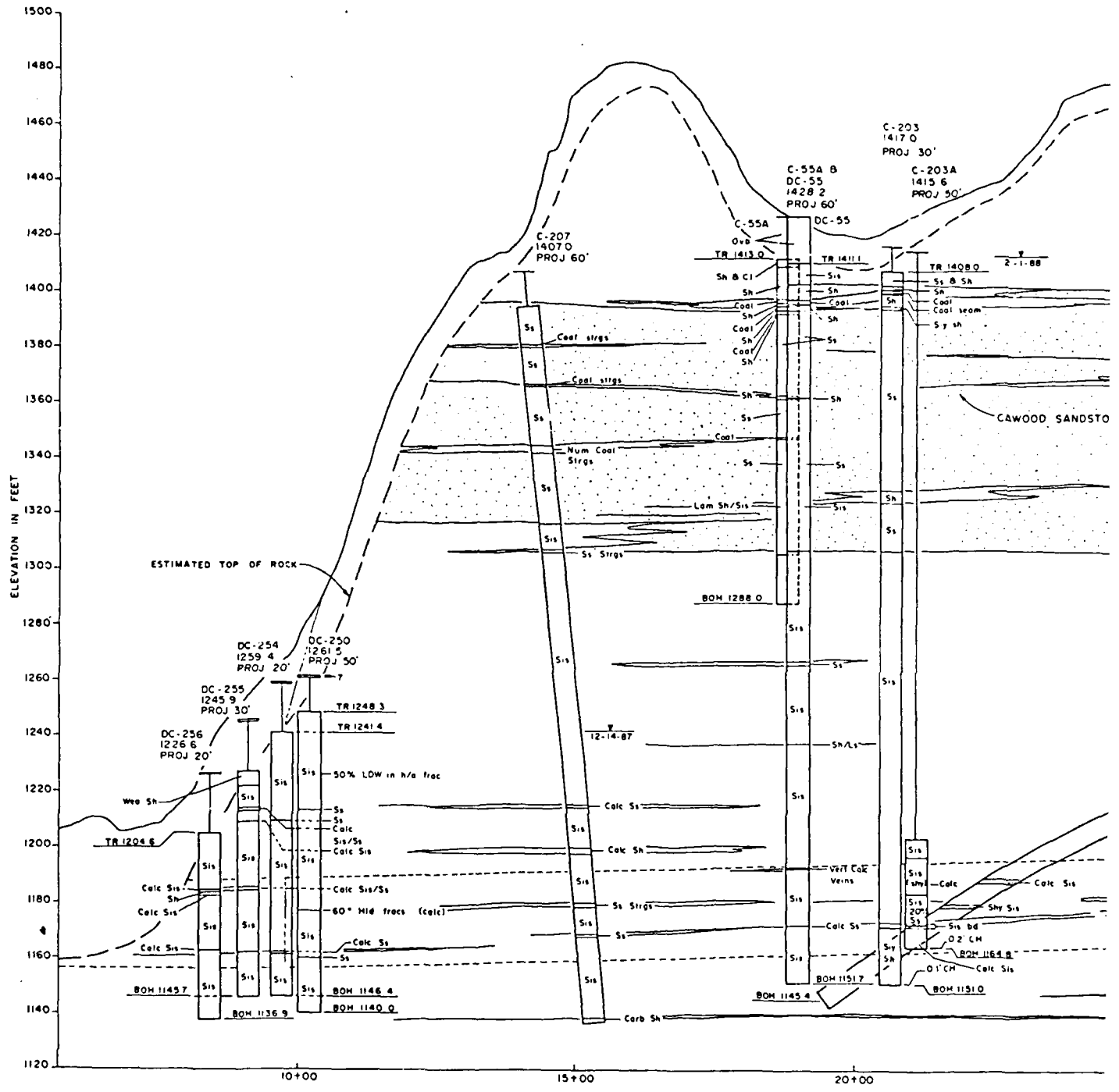
US Army Corps of Engineers Nashville District

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

SECTION A-A

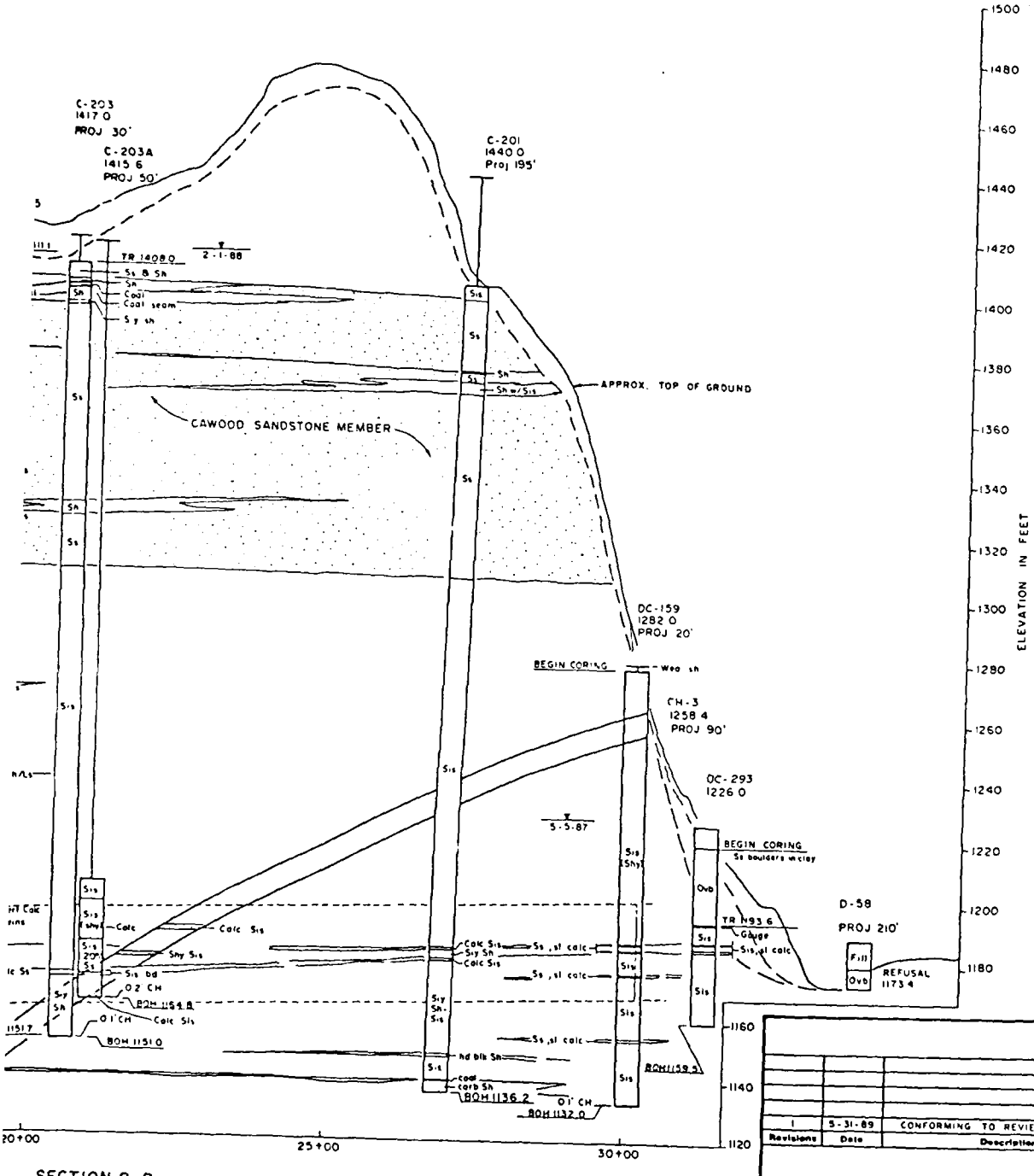
Date:
Scale:
Sheet _ _ of _ .
Drawing Number: 01A-64/30.2
Record Drawing as constructed dated

PLATE D-3



SECTION B-B
SCALE-HORIZ 1"=100'
VERT 1"=20'

NC
FC



SECTION B-B
SCALE HORIZ 1" = 100'
VERT 1" = 20'

NOTE:
FOR NOTES, SEE DRAWING 01A-64/30.

Revisions	Date	Descriptions	By	Checked
1	5-31-89	CONFORMING TO REVIEW COMMENTS	C A G	J L S

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

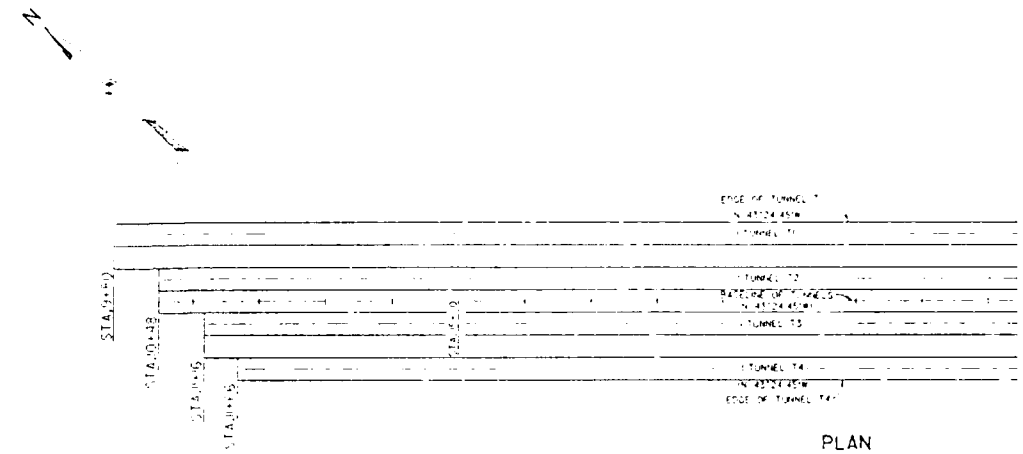
Designed by: John L. Hamm
Drawn by: CAG
Checked by: JLS
Approved by: M. E. S.

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

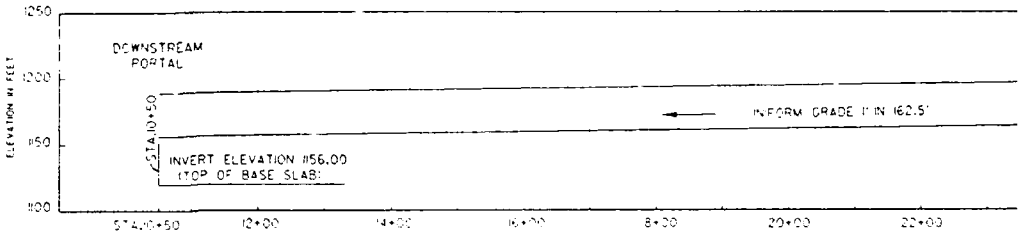
SECTION B-B

Date:
Sheet _ of _
Scale:
Drawing Number: 01A-64/31.1
Record Drawing as constructed dated

PLATE D-4

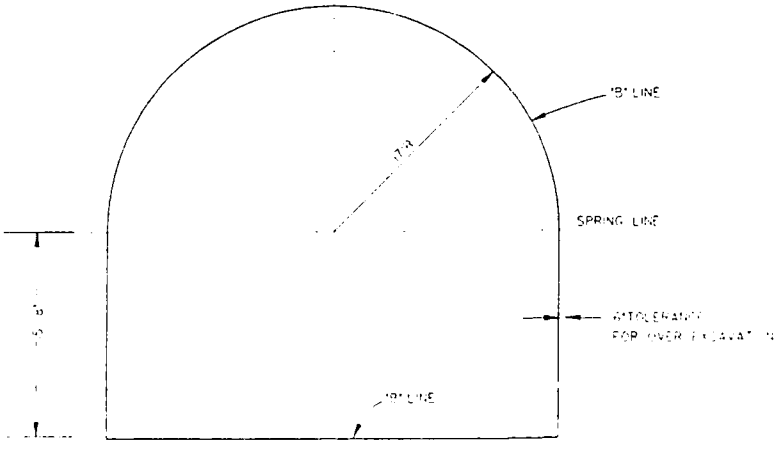


PLAN



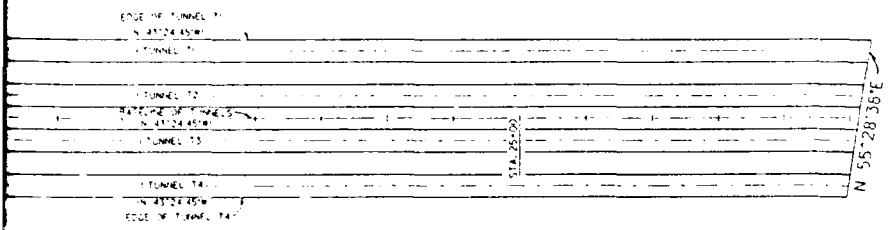
TYPICAL PROFILE

SCALE: 1"=50' VERT.
SCALE: 1"=100' HORIZ.



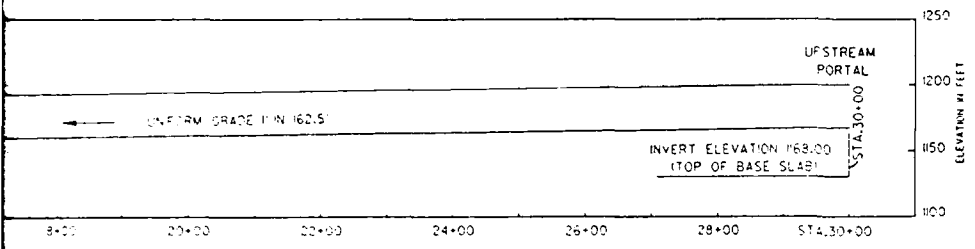
TUNNEL EXCAVATION
TYPICAL SECTION

SCALE: 1/4"



PLAN

SCALE: 1"=100'



TYPICAL PROFILE

SCALE: 1"=50' VERT.
SCALE: 1"=100' HORIZ.

NOTE

1. FOR GENERAL PLAN OF PROJECT, SEE DRAWING 01A-64/2.

1	5-31-89	CONFORMING TO REVIEW COMMENTS	C.A.G. J.L.S.

U.S. ARMY ENGINEER DISTRICT
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NASHVILLE, TENNESSEE

DIVERSION TUNNELS

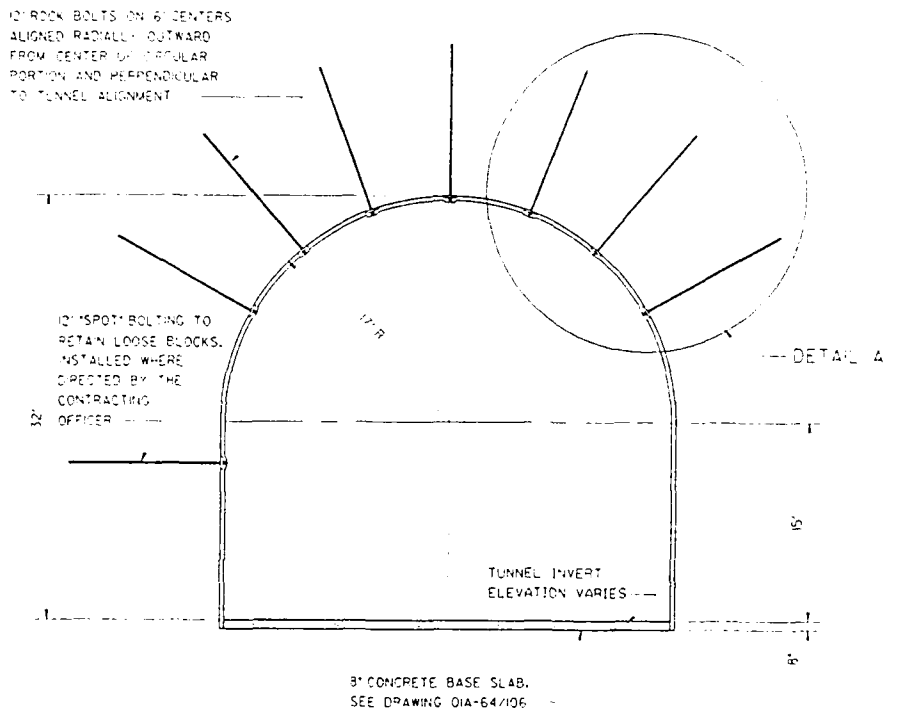
PLAN, SECTION, AND PROFILE

(GEOMETRY)

01A-64/71.1

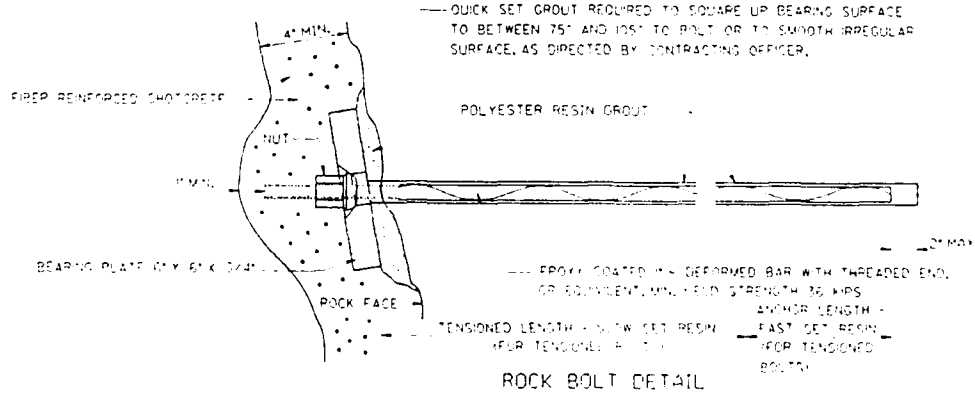
C A D D

PLATE D-5



SECTION

SCALE: 1" = 5'



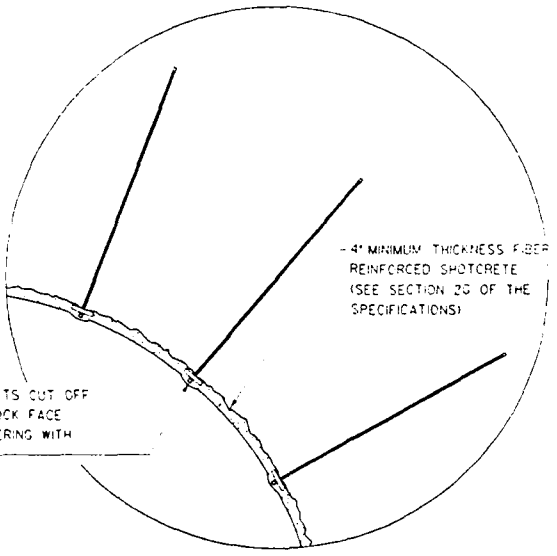
ROCK BOLT DETAIL

NOT TO SCALE

NOTE:

CONICAL NUT DETAILS, THEIR SYSTEM AS APPROVED MAY BE USED.

TENSIO
TO 4'
PRIOR
SHOTCR



DETAIL A
SCALE: 1" = 3'

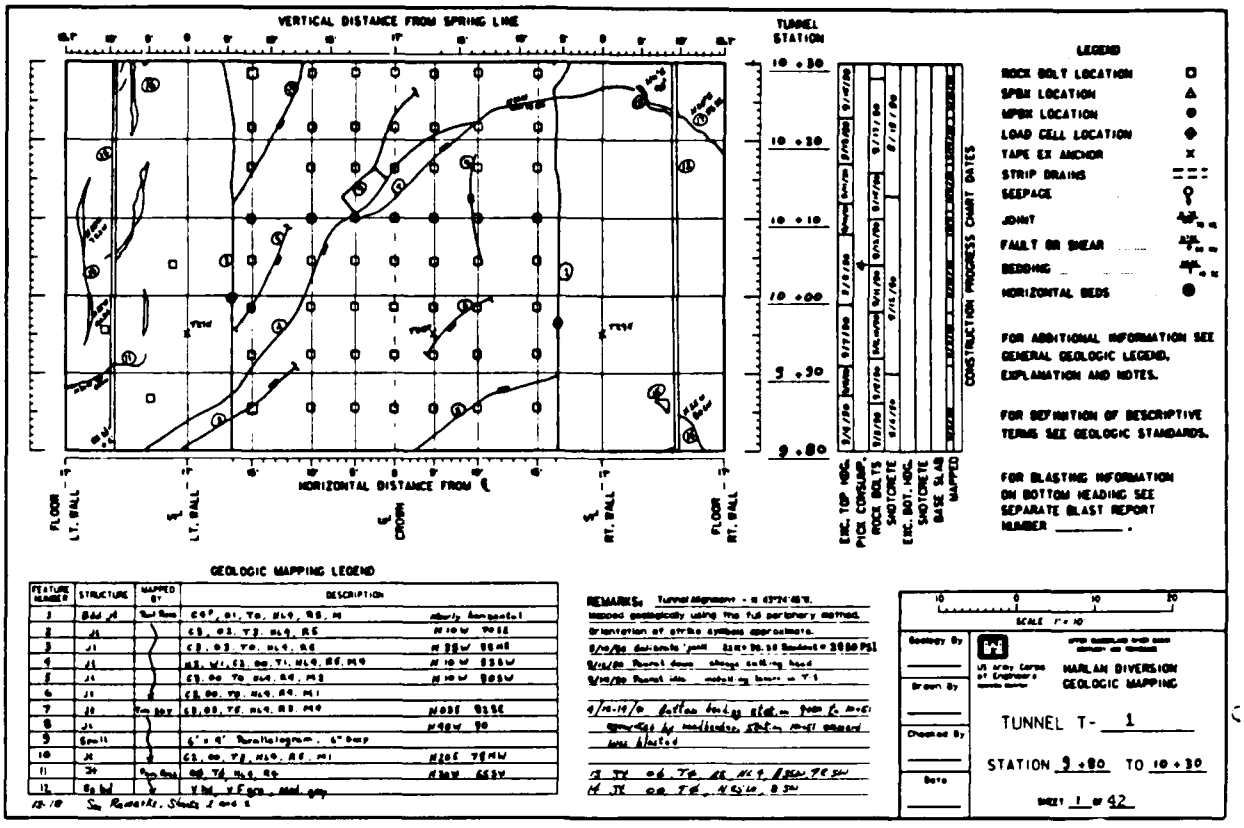
2	2-2-94	AS CONSTRUCTED	MAR
1	6-30-89	CONFORMING TO REVIEW COMMENTS	E.P.D. J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

SUPPORT DETAILS

DIA-64/72.2

PLATE D-6



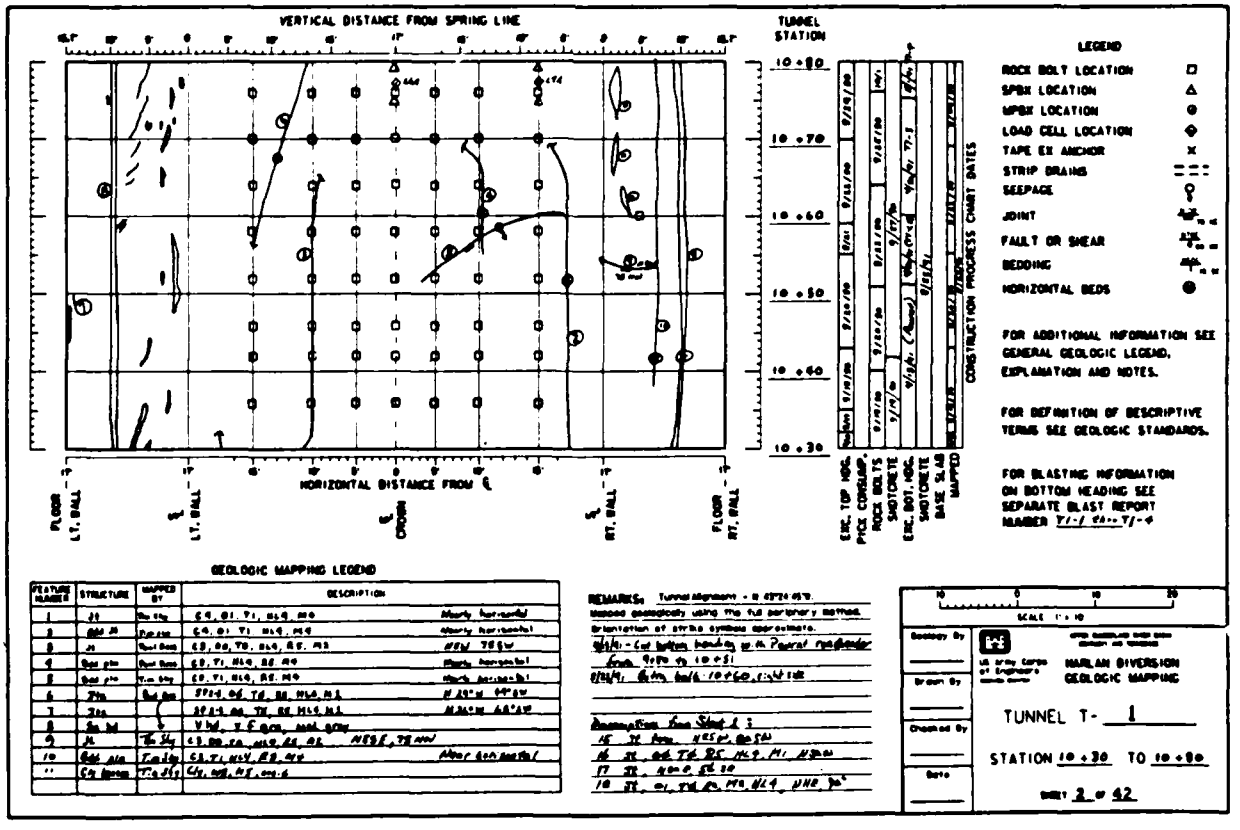
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd Jt	Tunnel Crew	CG?, O1, Y2, HL4, B5, M
2	Jt		CG, O3, Y2, HL4, B5
3	Jt		CG, O3, Y2, HL4, B5
4	Jt		MS, W1, CG, O2, Y1, HL4, B5, M4
5	Jt		CG, O2, Y2, HL4, B5, M3
6	Jt		CG, O2, Y2, HL4, B5, M1
7	Jt	Tunnel Crew	CG, O2, Y2, HL4, B3, M4
8	Jt		
9	Small		6" x 6" Parallelogram - 6" Deep
10	Jt		CG, O2, Y2, HL4, B5, M1
11	Jt	Tunnel Crew	O2, Y2, HL4, B5
12	Bdd		V Vbl, V F gcs, med gray

REMARKS: Tunnel Alignment - N 67°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
8/20/80 Encountered joint Size = 20.0 Gradient = 2000 PSI
9/15/80 Tunnel face changed heading
9/20/80 Tunnel face mapped as T-1
4/10-11/0 Portion having station from [illegible] Sprayed by [illegible], Station most exposed was blasted
15 JT 06 T6 88 HL4 B5SW 76 SW
14 JT 00 T6 N45°W 8 SW

SCALE 1" = 10

US Army Corps of Engineers — Sacramento District
HARLAN DIVERSION
GEOLOGIC MAPPING
Geology By
Drawn By
Checked By
Date
TUNNEL T- 1
STATION 9 + 80 TO 10 + 30
SHEET 1 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Jt	Tunnel Crew	CG, O1, Y1, HL4, M4
2	Bdd Jt	Tunnel Crew	CG, O1, Y1, HL4, M4
3	Jt	Tunnel Crew	CG, O2, Y2, HL4, B5, M3
4	Bdd Jt	Tunnel Crew	CG, Y1, HL4, B5, M4
5	Bdd Jt	Tunnel Crew	CG, Y1, HL4, B5, M4
6	Jts	Bdd Jts	SP&4, O6, T6, B5, HL4, M3
7	Jts		SP&4, O6, T6, B5, HL4, M3
8	Sm Bdd		V Vbl, V F gcs, med gray
9	Jt	Tunnel Crew	CG, O2, Y2, HL4, B5, M1
10	Bdd Jts	Tunnel Crew	CG, Y1, HL4, B5, M4
11	CG Lenses	Tunnel Crew	CG, O2, M1, med-c

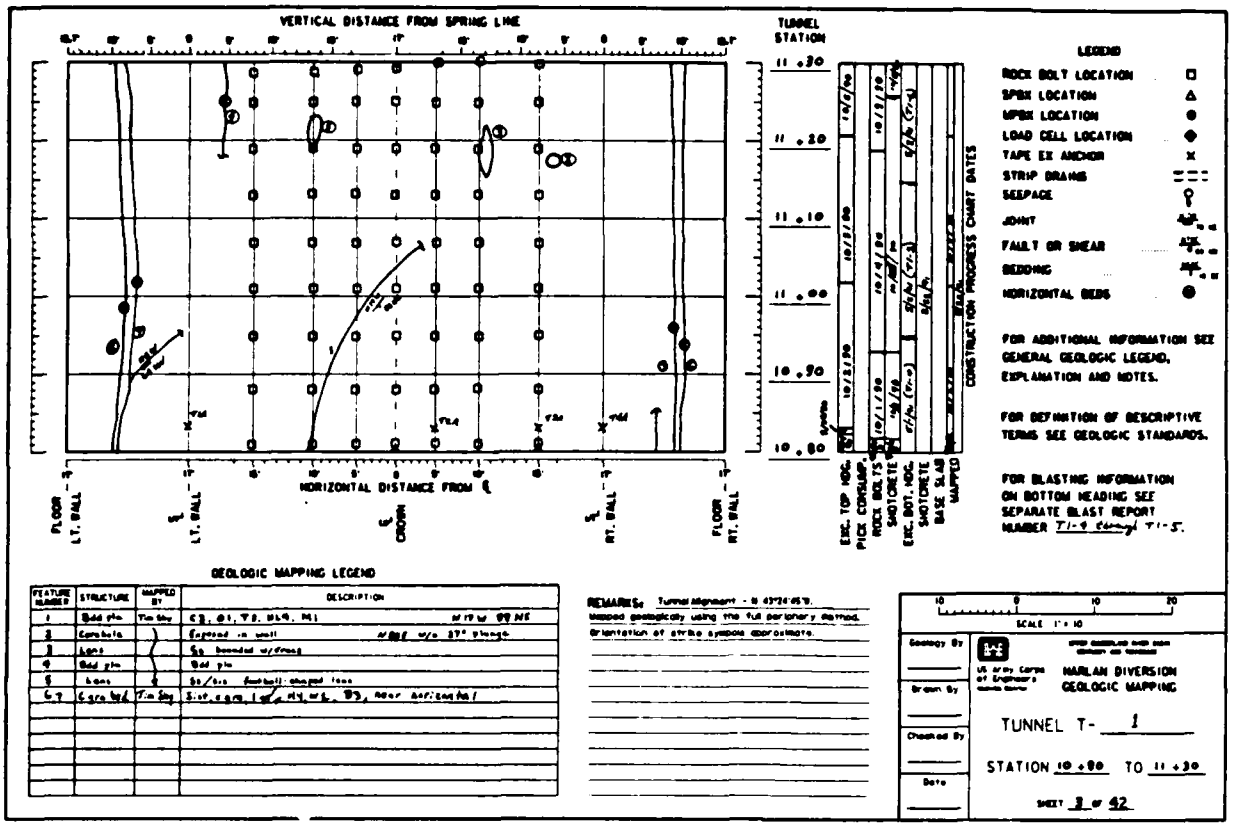
REMARKS: Tunnel Alignment - N 67°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
9/15/81 - Cut bottom heading on N Portal roadway from 9+70 to 10+51
9/16/81 Blast held 10+60 to 10+30

Encountered from Sheet 1 :
15 JT Joint N45°W, 85SW
16 JT 00 T6 SE HL4 M1 N45°W
17 JT Joint 85SW
18 JT 01 T6 B5 M3 HL4 Joint

SCALE 1" = 10

US Army Corps of Engineers — Sacramento District
HARLAN DIVERSION
GEOLOGIC MAPPING
Geology By
Drawn By
Checked By
Date
TUNNEL T- 1
STATION 10 + 30 TO 10 + 80
SHEET 2 OF 42

PLATE D-7



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tim Bay	CJ, 01, T2, HL4, M1 N19W 89 NE
2	Contact		Exposed in wall N88E w/o 37° plunge
3	Joint		Sg bounded w/Fract
4	Bdd pln		Bdd pln
5	Joint	S	Sl/Sc footwall stepped face
6,7	Comp Sed	Tim Bay	Silt, comp, [illegible] M1, w&c, B3, minor bedding/bdd

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

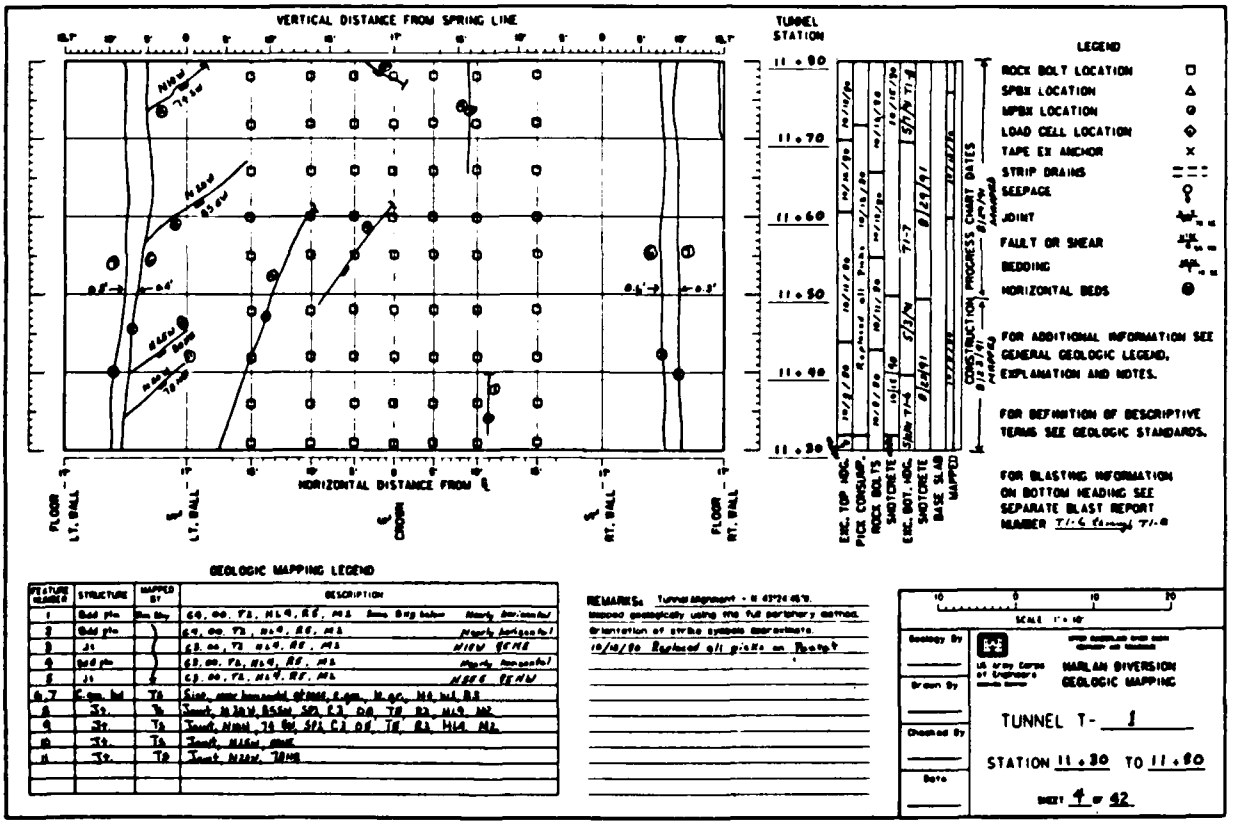
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 10 + 80 TO 11 + 30

SHEET 3 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tim Bay	CJ, 00, T2, HL4, E2, M2 Some Bdg below Nearly horizontal
2	Bdd pln		CJ, 00, T2, HL4, E2, M2 Nearly horizontal
3	Jt		CJ, 00, T2, HL4, E2, M2 N10W 90°NE
4	Bdd pln		CJ, 00, T2, HL4, E2, M2 Nearly horizontal
5	Jt	S	CJ, 00, T2, HL4, E2, M2 N10E 90°NW
6,7	Comp Sed	Tim	Silt, comp laminated, grnsh, comp, M, w&c, M4, bd, B3
8	Jt.	Tim	Joint, N 30 W, 85 SW, SPL CJ, O8, T2, B3, HL4, M2
9	Jt.	Tim	Joint, N 10 W, 75 SW, SPL CJ, O8, T2, B3, HL4, M2
10	Jt.	Tim	Joint, N 15 W, 90°NE
11	Jt.	Tim	Joint, N 15 W, 70°NE

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
10/10/80 Replaced all plots on Sheet 7

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

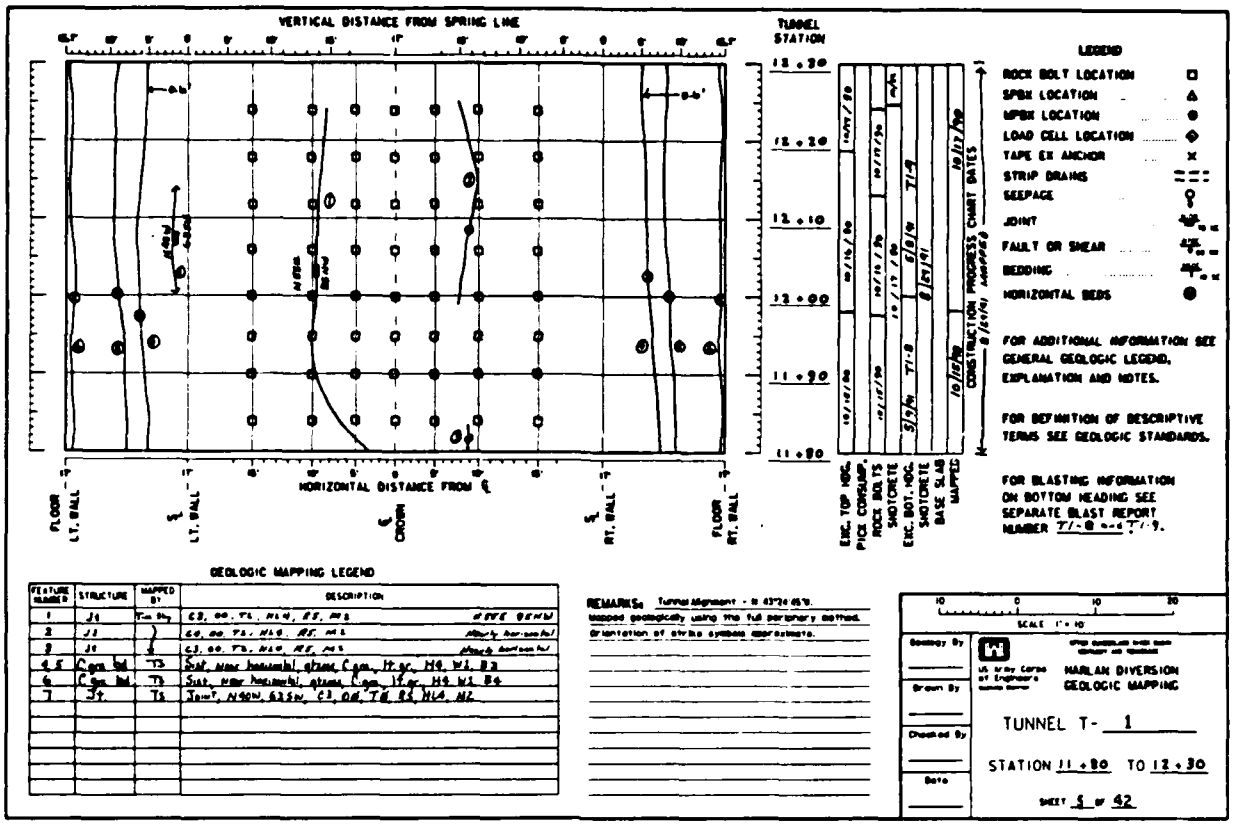
U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 11 + 30 TO 11 + 80

SHEET 4 OF 42

PLATE D-8



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Jt	Tm Ts	E3, 00, T5, H14, R5, M5 (FREE SEAM)
2	Jt		E4, 00, T5, H14, R5, M5
3	Jt		E3, 00, T5, H10, R5, M5
4,5	Cgn bd	T5	Sist, near hornenbl gtzose, Cgn, lt gr, H4, W1, B3
6	Cgn bd	T5	Sist, near hornenbl gtzose, Cgn, lt gr, H4 W1 B4
7	Jt	T5	Joint, N90W, 63SW, E3, 00, T5, R5, H14, M2

REMARKS: Tunnel alignment = N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10

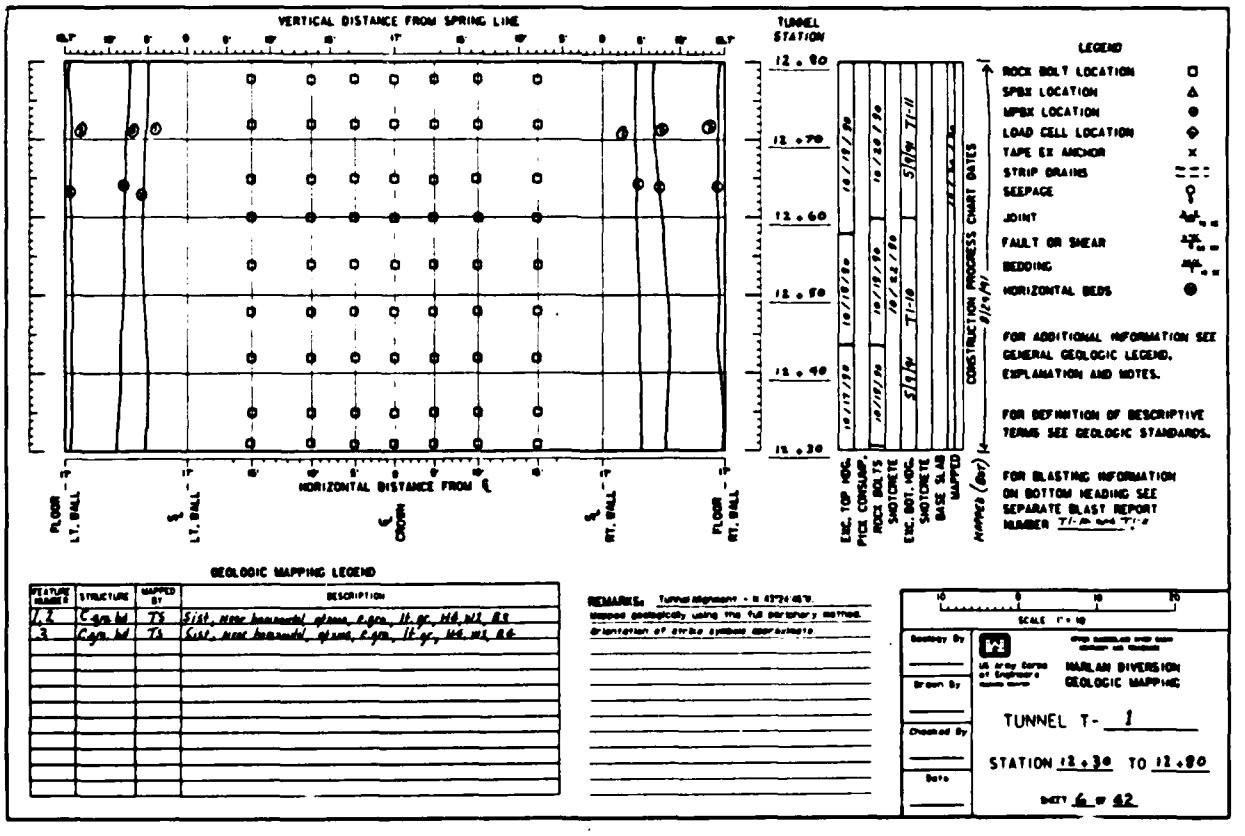
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 11+80 TO 12+30

SHEET 5 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Cgn bd	T5	Sist, near hornenbl gtzose, Cgn, lt gr, H4, W1, B3
3	Cgn bd	T5	Sist, near hornenbl gtzose, Cgn, lt gr, H4, W1, B4

REMARKS: Tunnel alignment = N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

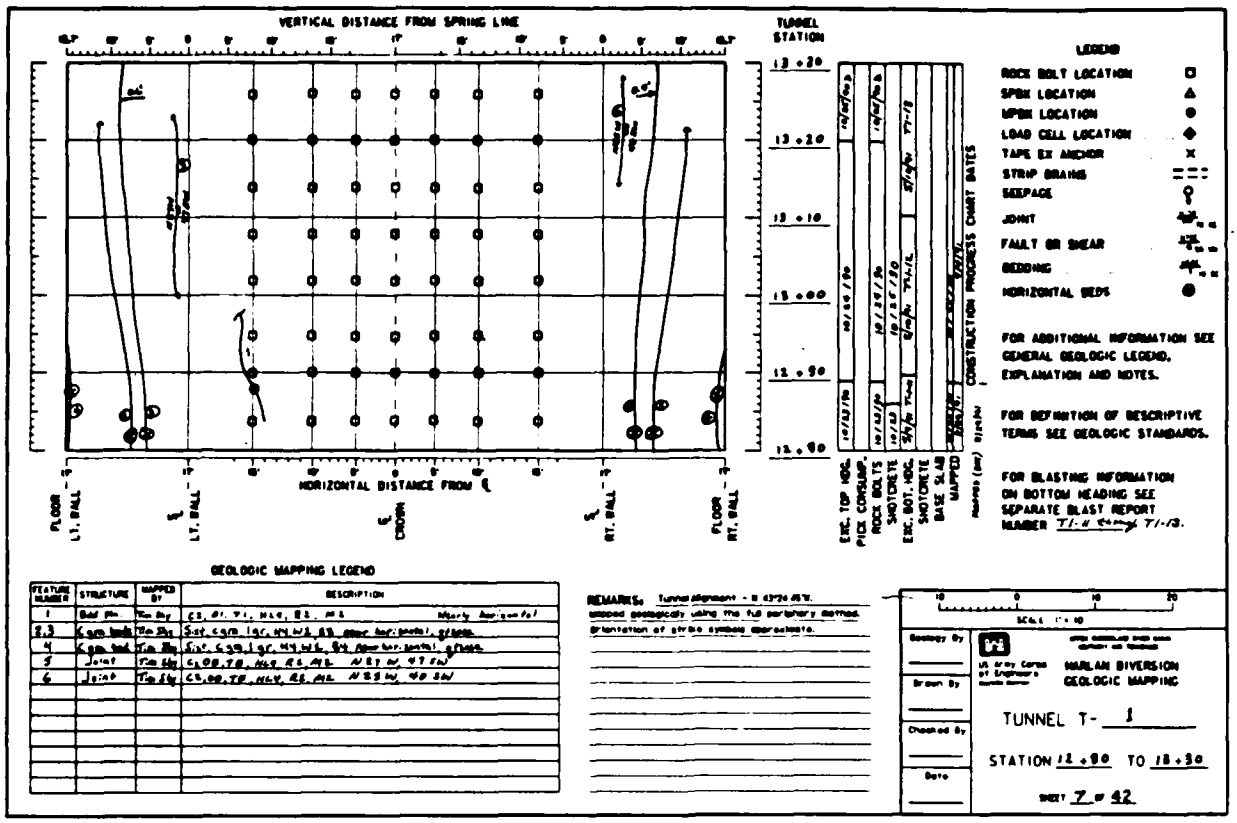
U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 12+30 TO 12+90

SHEET 6 OF 42

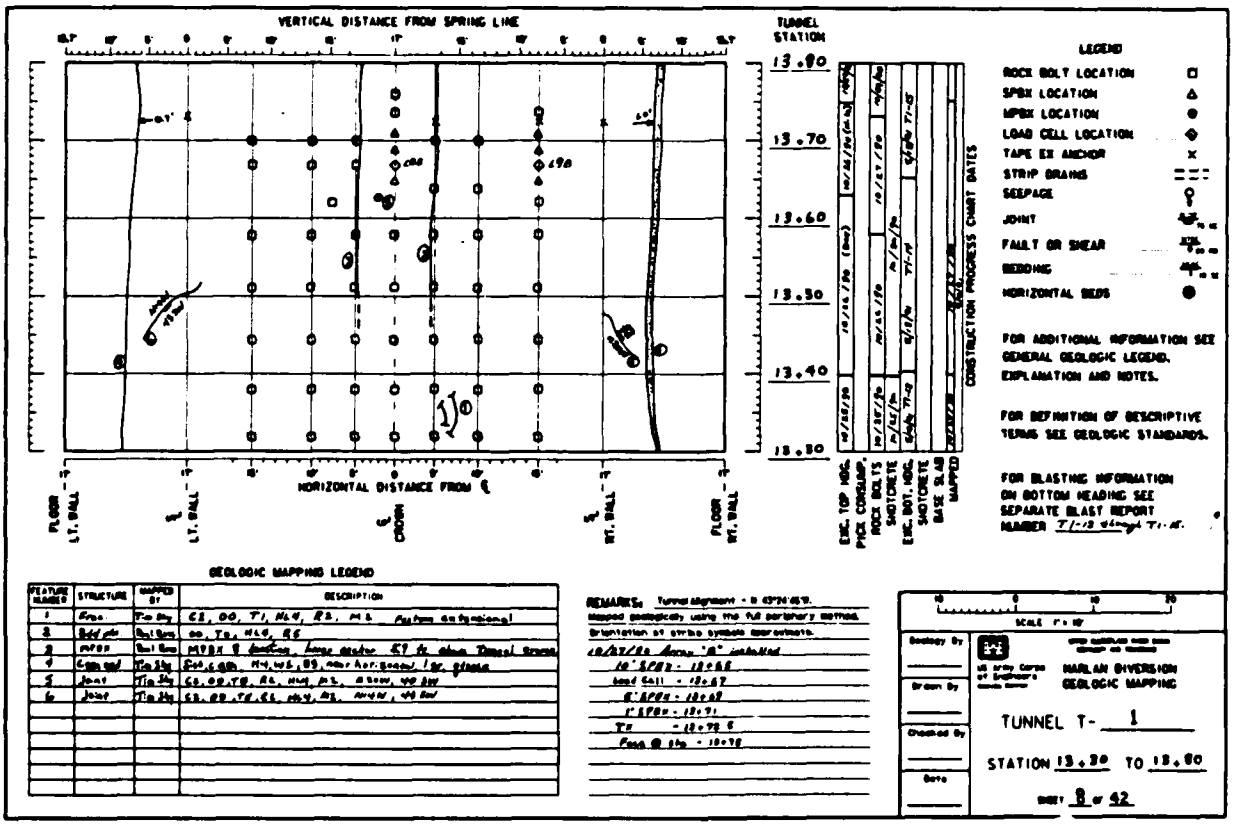
PLATE D-9



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed ding	Tim Day	CS, 01, T1, HL4, B3, M1 Mostly horizontal
2,3	Lamp beds	Tim Day	S-st, comp lgr, HY, W3, B3 some horizontal grains
4	Lamp bed	Tim Day	S-st, comp lgr, HY, W3, B4 Some horizontal grains
5	Joint	Tim Day	CS, 00, T8, H4, R5, M1 N 81 W, 47 SW
6	Joint	Tim Day	CS, 00, T8, H4, R5, M1 N 85 W, 40 SW

REMARKS: Tunnel alignment - N 43°24' 45"W.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

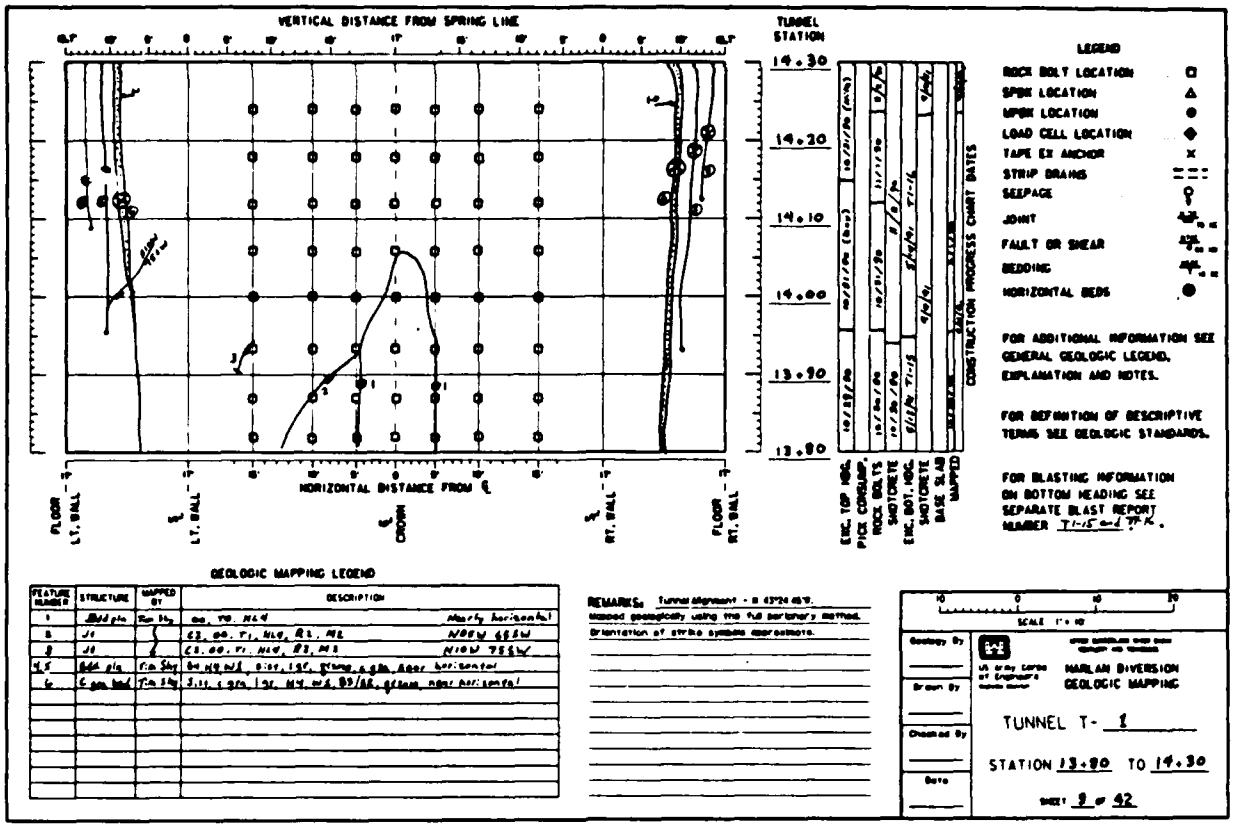


GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Fract	Tim Day	CS, 00, T1, HL4, B3, M1 Mostly horizontal
2	Bed ding	Tim Day	00, T2, HL4, B5
3	MPBX	Tim Day	MPBX 8 headings, long center 57 ft above Tunnel Grade
4	Lamp bed	Tim Day	Cst, comp lgr, HY, W3, B3, some horizontal lgr grains
5	Joint	Tim Day	CS, 00, T8, R5, HL4, M1, N 85 W, 40 SW
6	Joint	Tim Day	CS, 00, T8, R5, HL4, M1, N 90 W, 40 SW

REMARKS: Tunnel alignment - N 43°24' 45"W.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
10/27/82 Anchor "A" installed
10' SPBX - 13+85
Load Cell - 13+87
6' MPBX - 13+82
1' MPBX - 13+91
TS - 13+98 ℄
Face @ 24hr - 13+78

PLATE D-10



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	Tom Daly	00, Y10, N14 W	Nearly horizontal
2	J1		63, 00, Y1, N10, E2, N2	N80W 65SW
3	J2		28, 00, Y1, N10, E2, N2	N10W 75SW
4,5	Bdd plane	Tom Daly	Bd N9 W3	0:10, 15°, Strong, 4 Bdg, Appr. horizontal
6	C gen bnd	Tom Daly	3:11, 1 gen, 15°, N4 W4, B9/A8, stream, nearly horizontal

REMARKS: Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full perspective method.
Orientation of strike symbols approximate.

SCALE 1" = 10

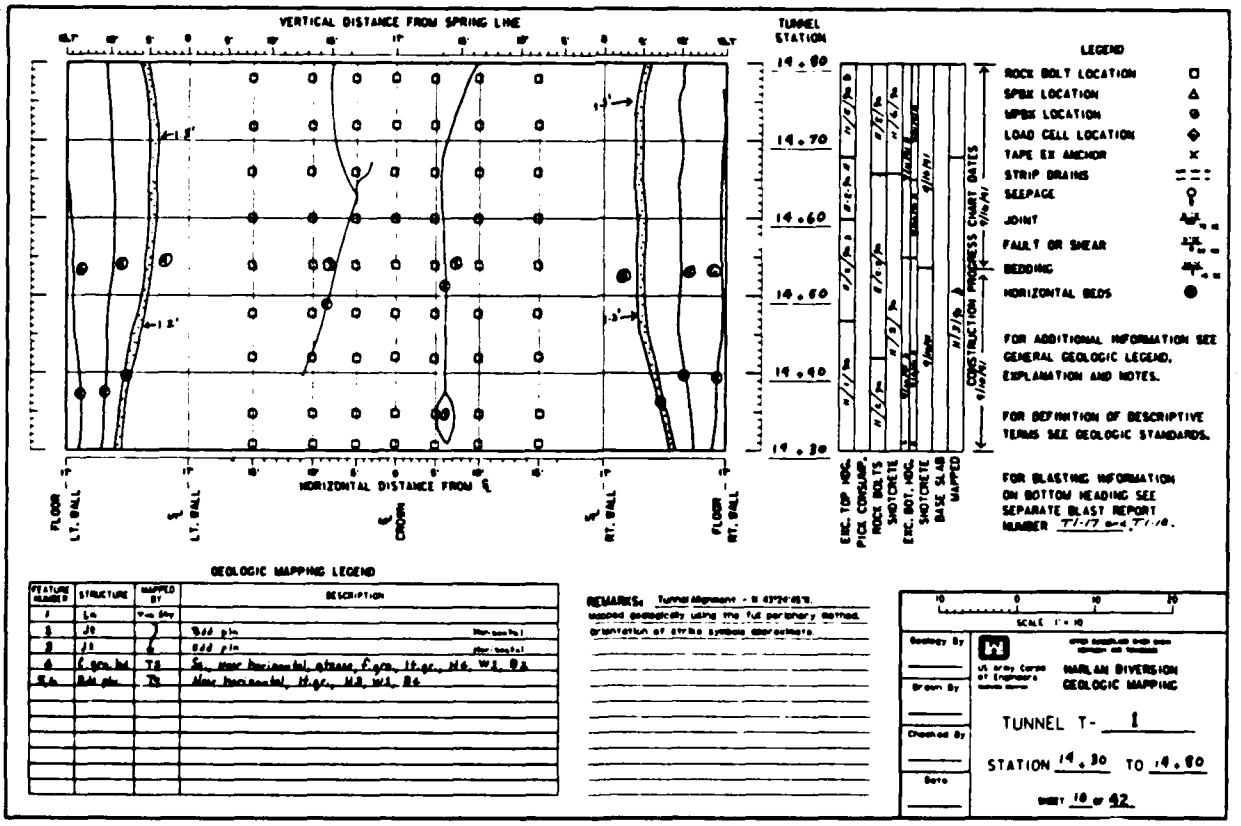
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 13+80 TO 14+30

SHEET 9 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Jn	Tom Daly	
2	J2		Bdd plane	Horizontal
3	J1		Bdd plane	Horizontal
4	C gen bnd	TD	Sh, near horizontal, stream, C gen, 11 gr, N6, W1, B2
5,6	Bdd plane	TD	Near horizontal, H gr, N3, W1, B6

REMARKS: Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full perspective method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

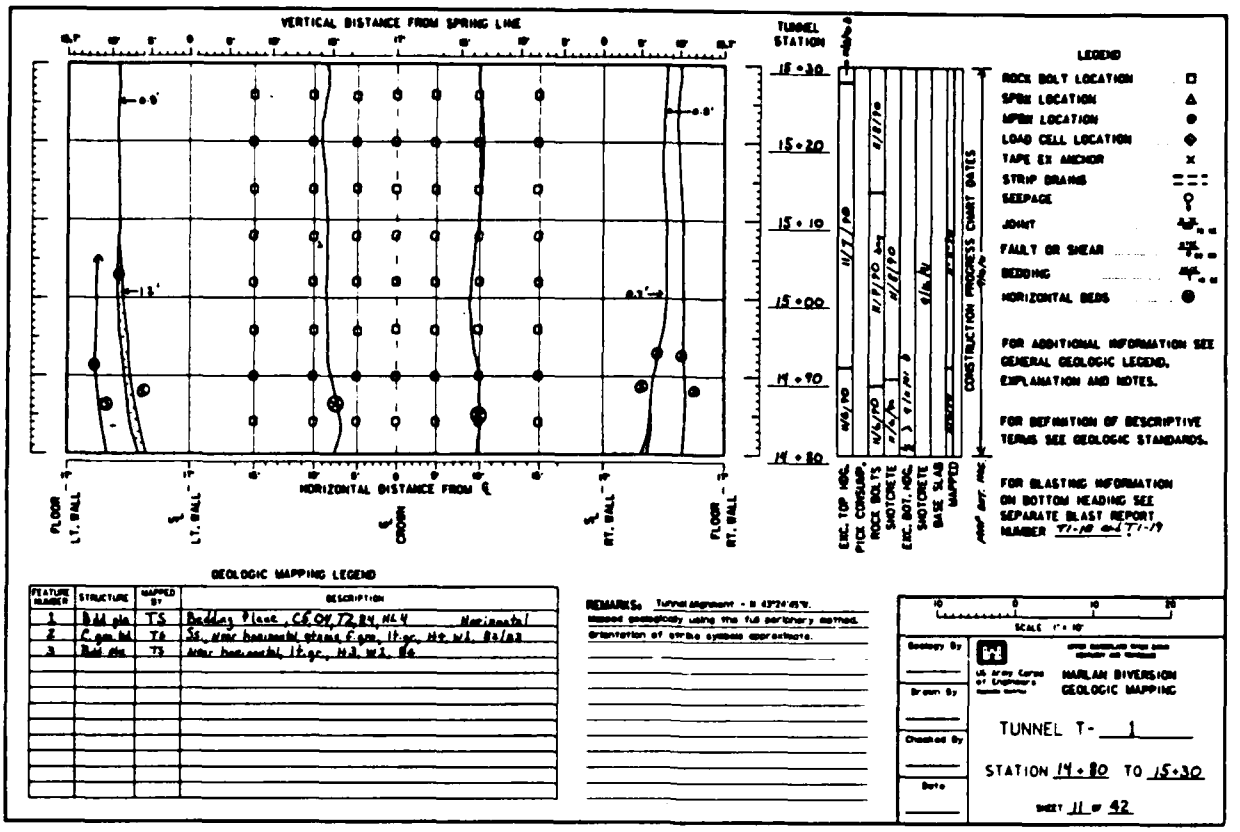
US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 14+30 TO 14+80

SHEET 10 OF 42

PLATE D-11



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plo	TS	Paddock Plane, CS 04, 72 84, HL 4 Horizontal
2	C gen bd	TS	SS, mbr horizontal grains C gen, lt gr, Hd wl, Bs/a3
3	Bdd plo	TS	Mbr horizontal, lt gr, H3 wl, B4

REMARKS: Tunnel alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

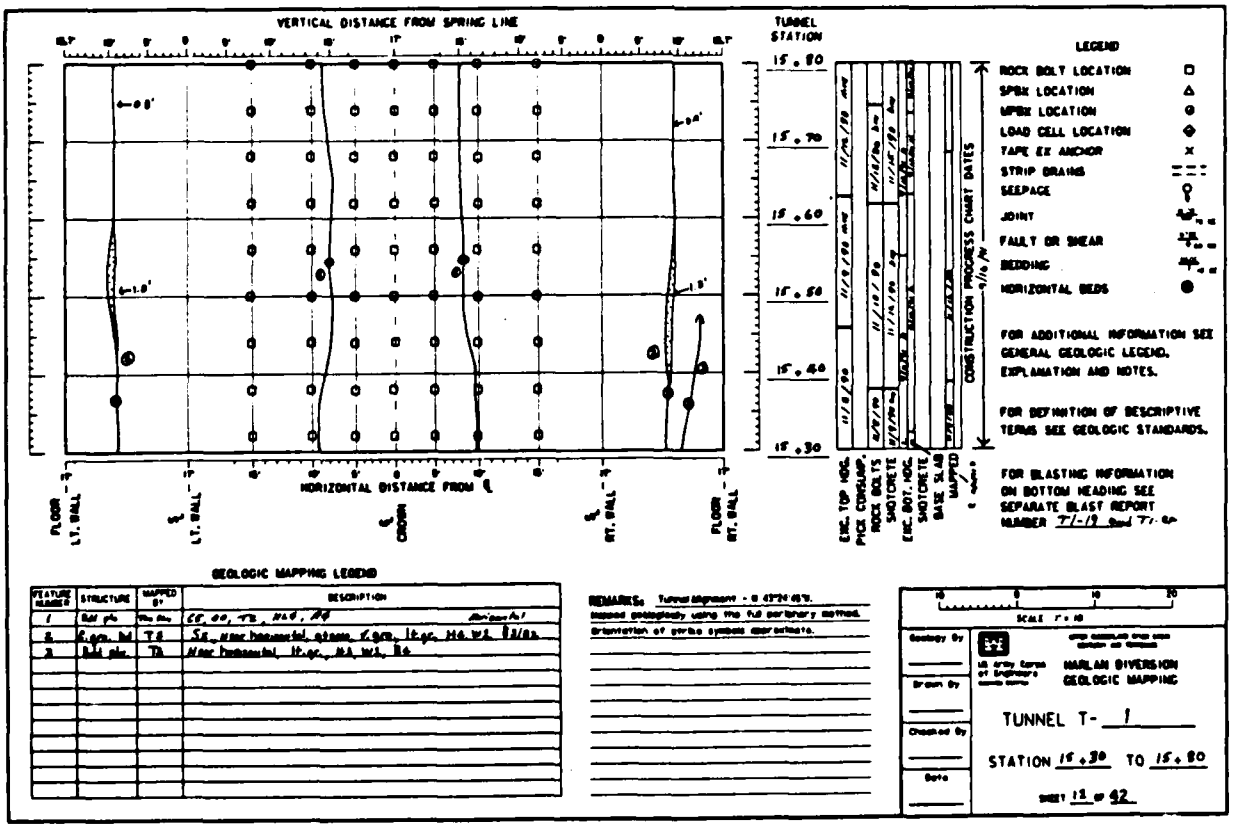
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 14+80 TO 15+30

SHEET 11 of 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plo	TS	CS 00, 72, 84, H4 Horizontal
2	C gen bd	TS	SS, mbr horizontal grains C gen, lt gr, Hd wl, Bs/a3
3	Bdd plo	TS	Mbr horizontal, lt gr, H3 wl, B4

REMARKS: Tunnel alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

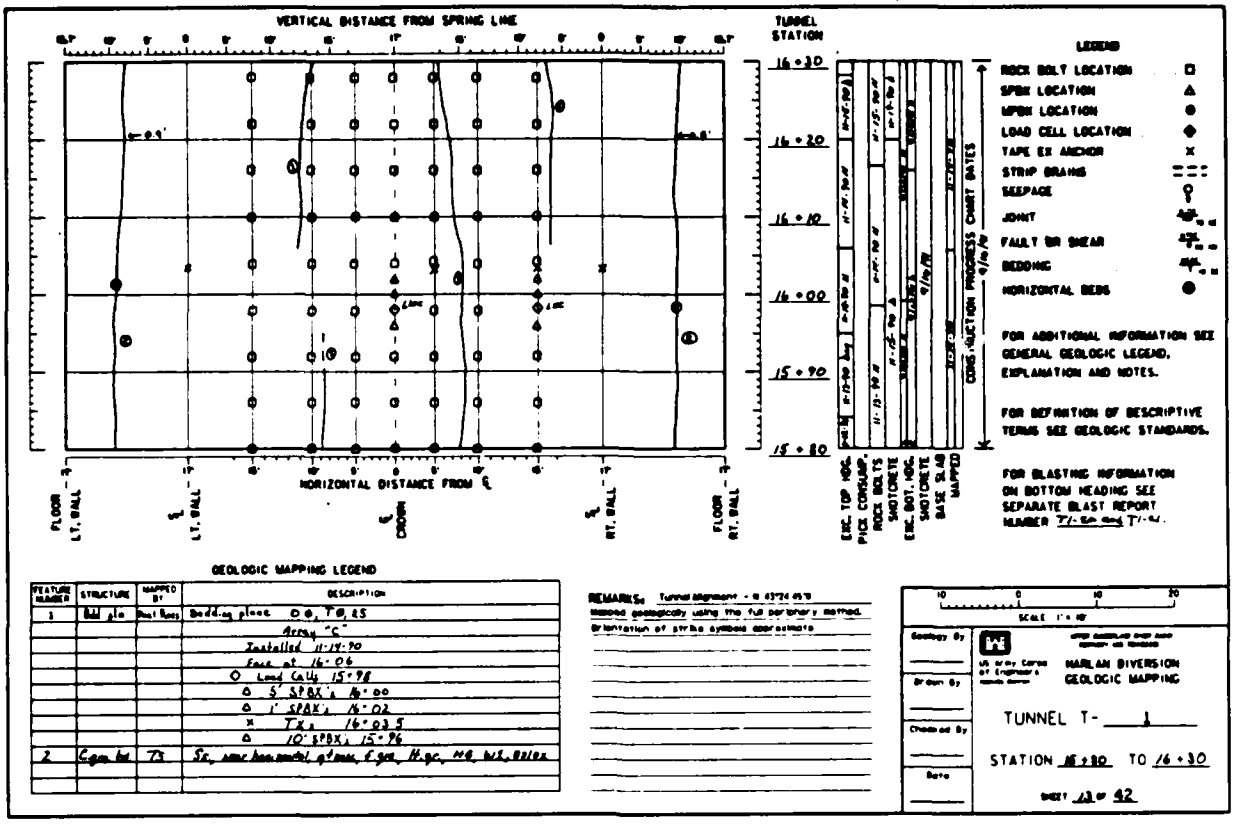
U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 15+30 TO 15+80

SHEET 12 of 42

PLATE D-12



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plo	Portlines	Bedding planes 08, T@, E5
			Array "C"
			Installed 11-19-90
			Face at 16+06
			○ Load Cells 15+98
			△ 5' SPBX's 16+00
			△ 1' SPBX's 16+02
			× TX's 16+03.5
			△ 10' SPBX's 15+96
2	F.gm. bd	TS	Sc, smc hor mod/ st mod, f.gm, H.gc, MB, bl, 8/16x

REMARKS: Tunnel Alignment = 0 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

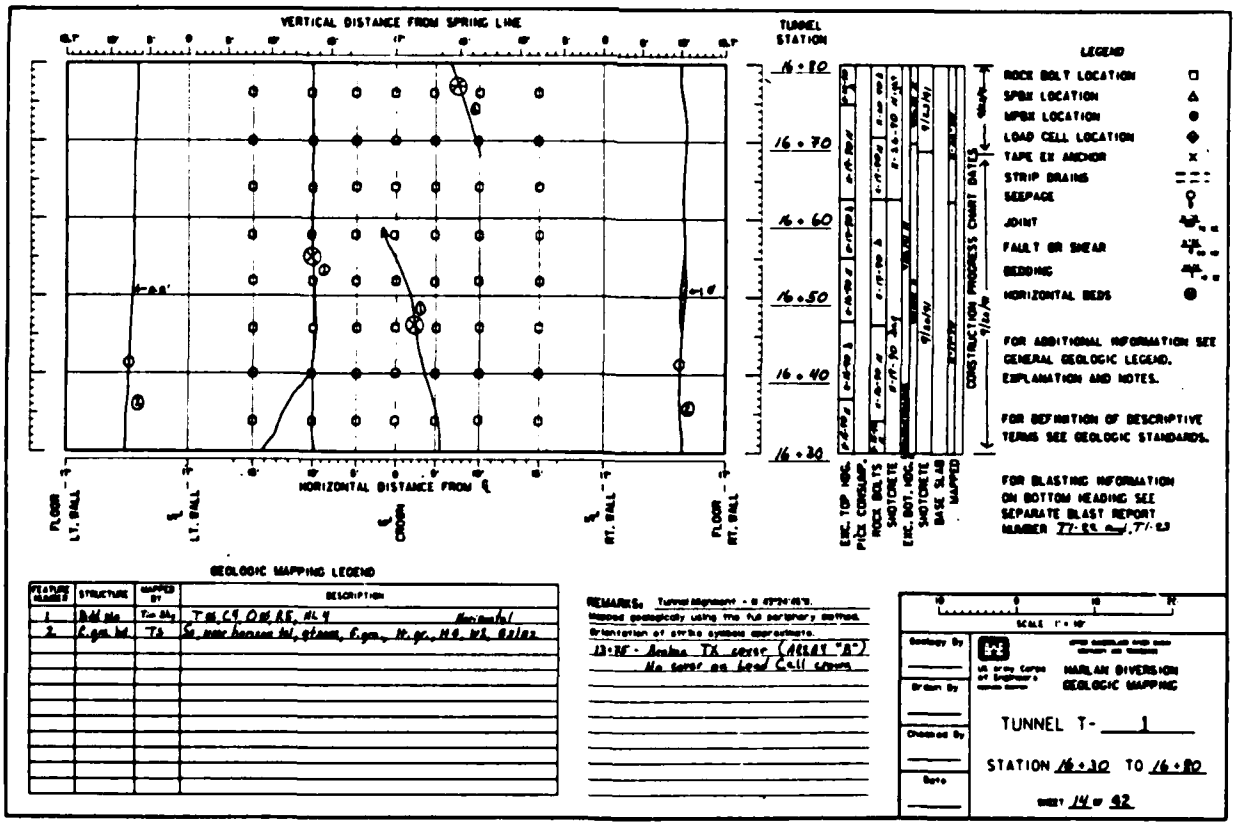
US Army Corps of Engineers

MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 15+90 TO 16+30

SHEET 13 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd Pln	Tm Bh	T at C9 0 at E5, HL 9 Horizontal
2	F.gm. bd	TS	Sc, smc hor mod bd, st mod, f.gm., H.gc., MB, WS, 8/16x
			13-RF - Arrow TX series (ARRAY "A")
			No series on Load Cell series

REMARKS: Tunnel Alignment = 0 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

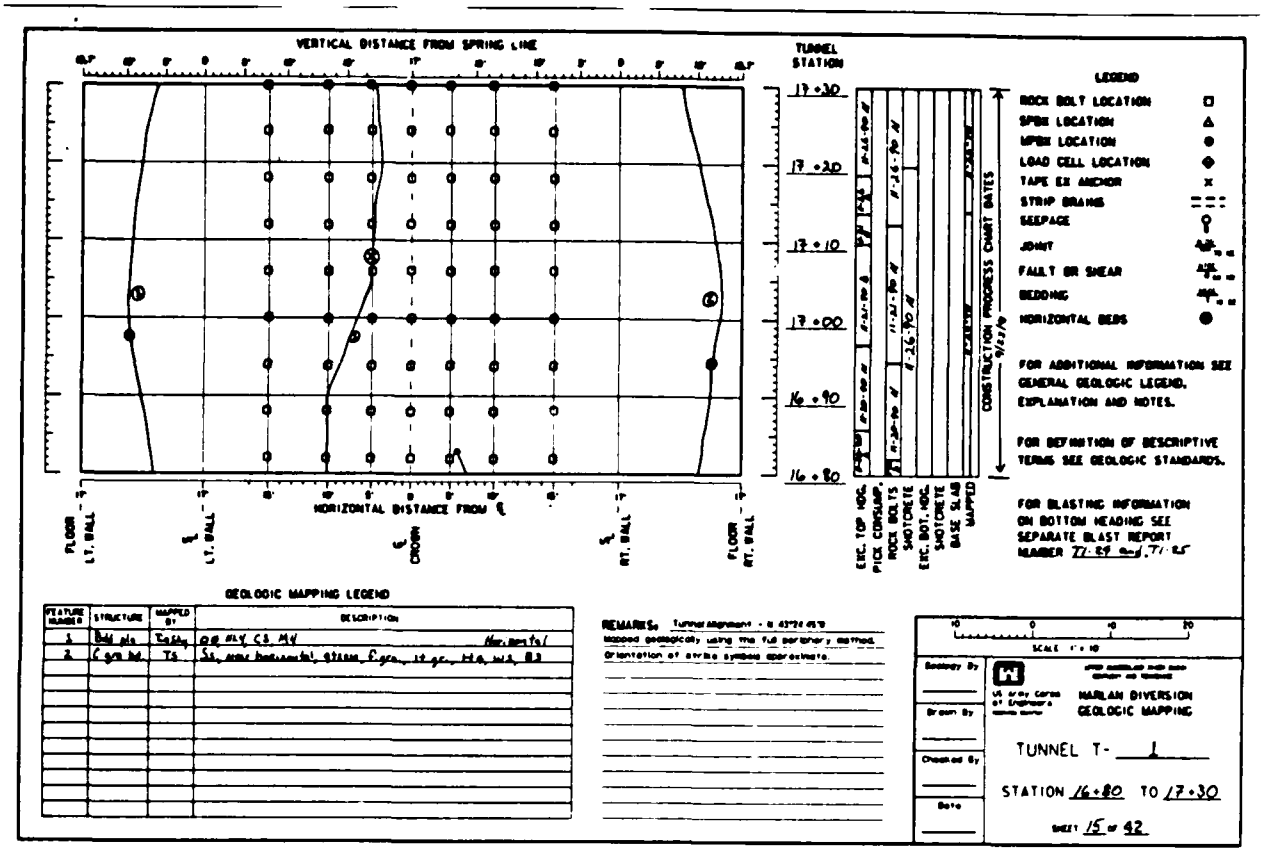
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 16+30 TO 16+80

SHEET 14 OF 42

PLATE D-13


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
17+30
17+20
17+10
17+00
16+90
16+80
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 77-89 and 77-85
CONSTRUCTION PROGRESS CHART DATES
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 Bdd plane TS/Hy Qtz MW, C3, MW Mar. bands/
2 Fault plane TS SS, some horizontal stress, F-gra., 10 gr., H4, W3, B3
REMARKS: Tunnel Alignment - S 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 16+80 TO 17+30
SHEET 15 OF 42

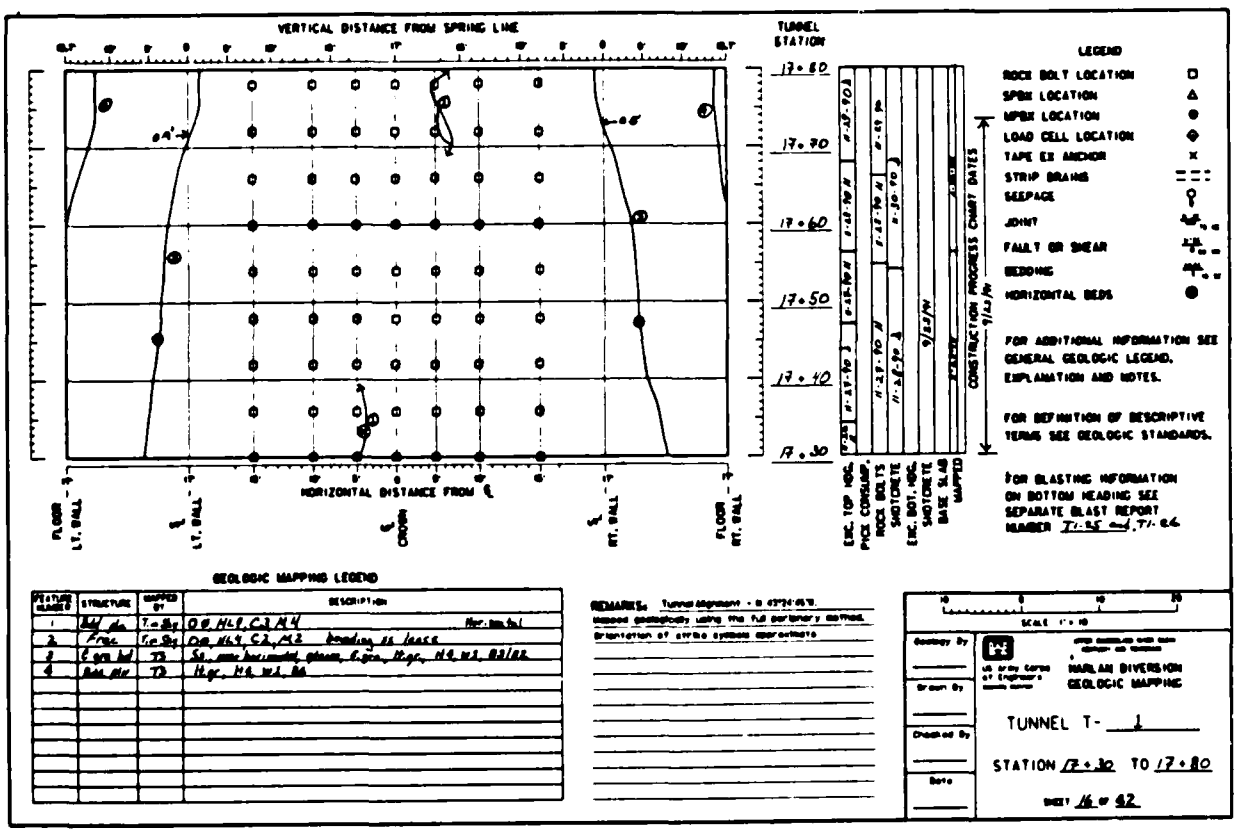
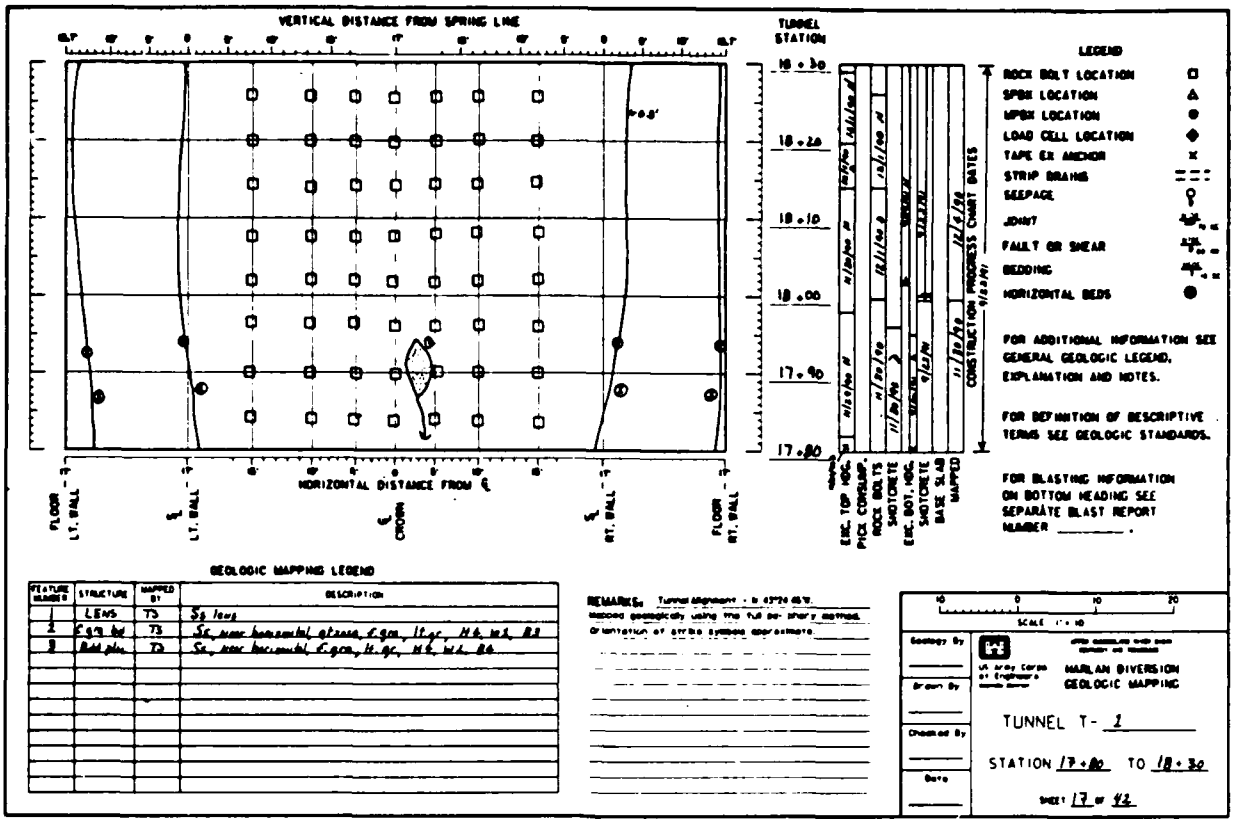

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
17+80
17+70
17+60
17+50
17+40
17+30
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 77-85 and 77-84
CONSTRUCTION PROGRESS CHART DATES
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
1 Bdd plane T-Hy Qtz MW, C3, MW Mar. bands/
2 Fract. Fr-Hy Qtz MW, C2, M2 bounding ss lense
3 Fault plane TS SS, some horizontal stress, F-gra., H-gr., H4, W3, B3/B2
4 Bdd plane TS H-gr., H4, W3, B2
REMARKS: Tunnel Alignment - S 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 17+30 TO 17+80
SHEET 16 OF 42

PLATE D-14



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	LENS	TS	Ss lens
2	Fgm bd	TS	Ss, mwr horizontal, strong, f-gm, lt-gr, HH, WJ, BB
3	Bdd plane	TS	Ss, mwr horizontal, strong, f-gm, H-gr, HH, WJ, BB

REMARKS: Tunnel alignment - is 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

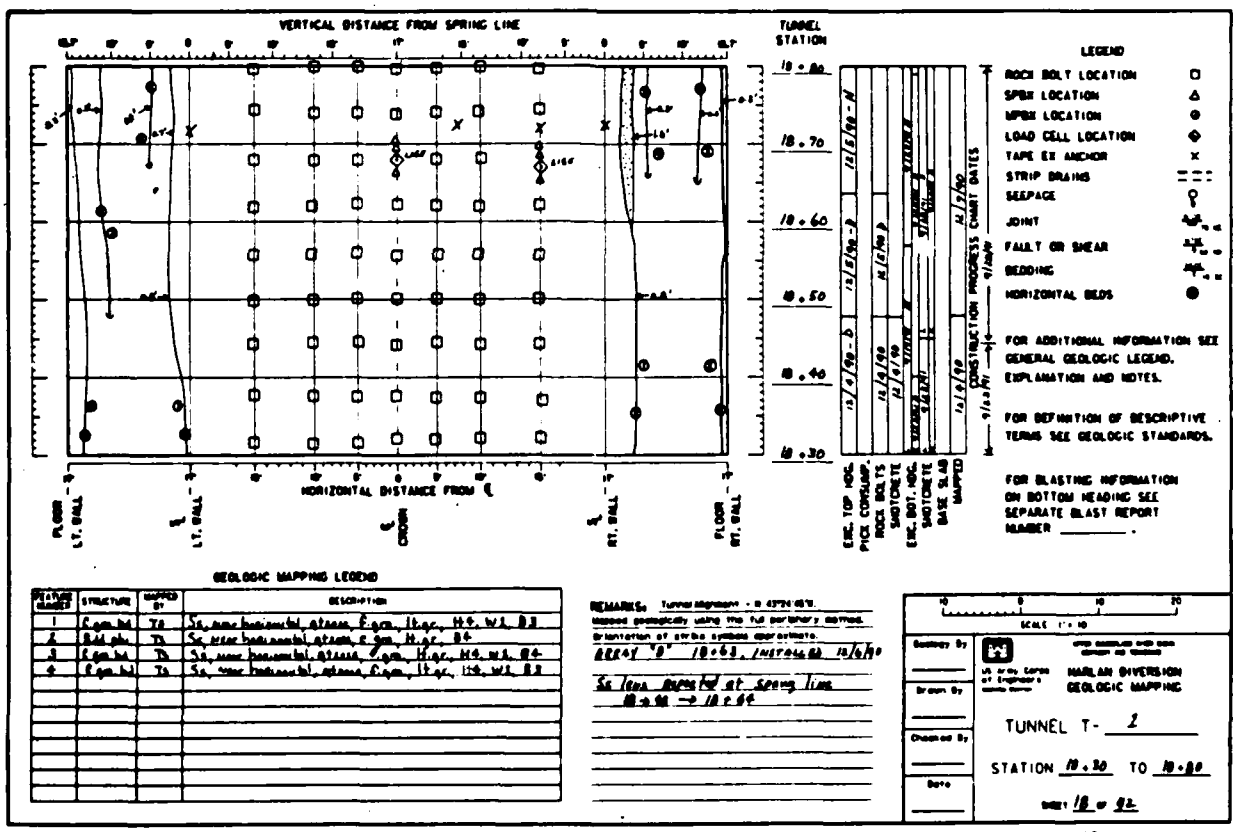
U.S. Army Corps of Engineers — Omaha District

MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 19 + 80 TO 18 + 30

SHEET 17 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Fgm bd	TS	Ss, mwr horizontal, strong, f-gm, lt-gr, HH, WJ, BB
2	Bdd plane	TS	Ss, mwr horizontal, strong, f-gm, H-gr, HH, WJ, BB
3	Fgm bd	TS	Ss, mwr horizontal, strong, f-gm, H-gr, HH, WJ, BB
4	Fgm bd	TS	Ss, mwr horizontal, strong, f-gm, lt-gr, HH, WJ, BB

REMARKS: Tunnel alignment - is 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
BREAK "B" 18+63, INSTALLED 10/6/90
Ss lens exposed at spring line 18+91 → 18+64

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Omaha District

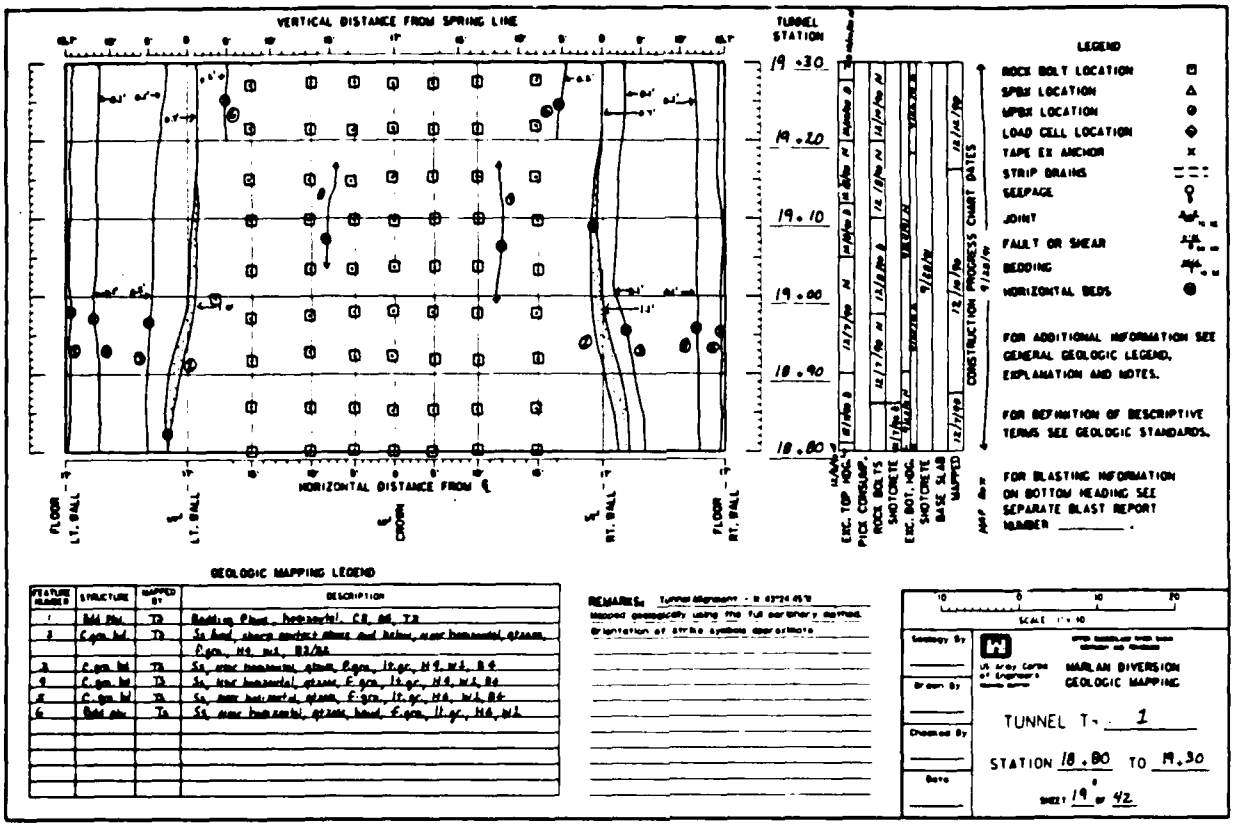
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 18 + 30 TO 18 + 80

SHEET 18 OF 42

PLATE D-15


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
19+30
19+20
19+10
19+00
18+90
18+80
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
ERC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 Bdd Mbr TB Bedding Plane, horizontal, CB, BB, TB
2 F.gm. bd TB Sh bed, closely jointed above and below, near horizontal, qtzsem, F.gm., H4, W1, B3/B4
3 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B4
4 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B4
5 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B4
6 Bdd Mbr TB Sh, near horizontal, qtzsm, bdd, F.gm., lt.gr., H4, W1
REMARKS: Tunnel Alignment - N 63°24'45"E
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARIAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 18+80 TO 19+30
SHEET 19 OF 42

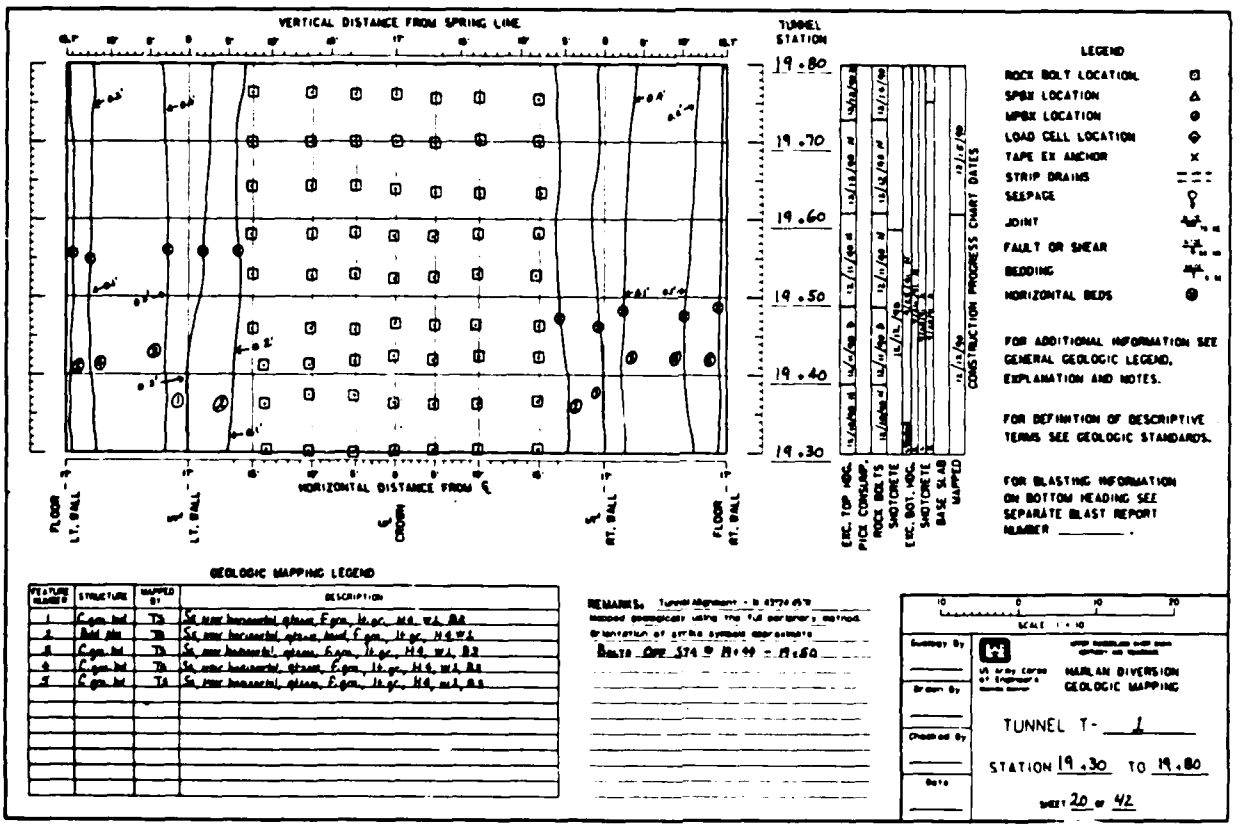
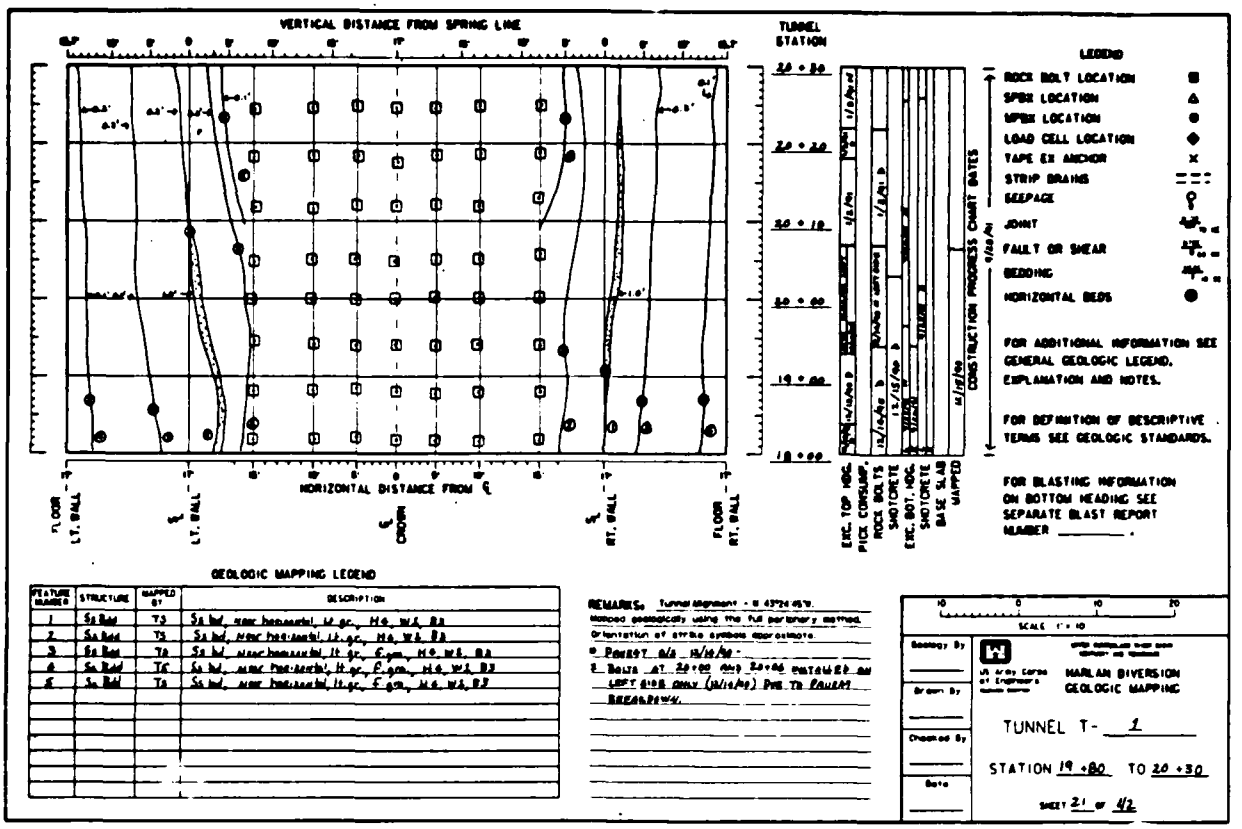

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
19+80
19+70
19+60
19+50
19+40
19+30
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
ERC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B2
2 Bdd Mbr TB Sh, near horizontal, qtzsm, bdd, F.gm., lt.gr., H4, W1
3 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B3
4 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B3
5 F.gm. bd TB Sh, near horizontal, qtzsm, F.gm., lt.gr., H4, W1, B3
REMARKS: Tunnel Alignment - N 63°24'45"E
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate
Basis Opr STA @ 19+49 = 19+60
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARIAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 19+30 TO 19+80
SHEET 20 OF 42

PLATE D-16



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bed	TS	Ss bd, mgr horizontal lt gr, f-g, MH, WJ, BA
2	Ss Bed	TS	Ss bd, mgr horizontal lt gr, f-g, MH, WJ, BA
3	Ss Bed	TS	Ss bd, mgr horizontal lt gr, f-gm, MH, WJ, BA
4	Ss Bed	TS	Ss bd, mgr horizontal, lt gr, f-gm, MH, WJ, BA
5	Ss Bed	TS	Ss bd, mgr horizontal lt gr, f-gm, MH, WJ, BA

REMARKS: Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
1. POWERT 0/0 10/10/80
2. BOLTS AT 20+00 thru 20+06 INSTALLED ON LEFT SIDE ONLY (10/10/80) DUE TO POWERT BREAKDOWN.

SCALE 1" = 10'

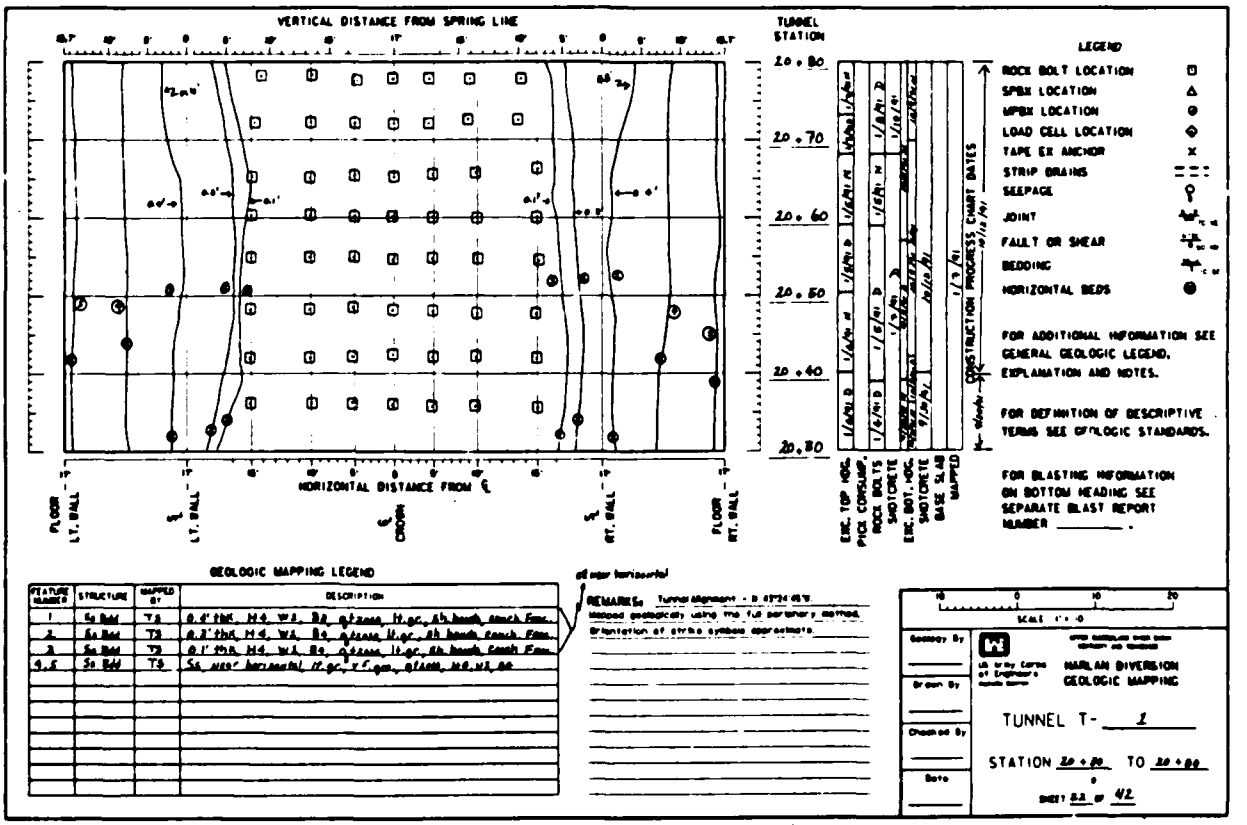
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 19 +80 TO 20 +30

SHEET 21 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bed	TS	0.4' thk, MH, WJ, Ba, g/seam, lt gr, fgr, sh bands, coarch Fms.
2	Ss Bed	TS	0.2' thk, MH, WJ, Ba, g/seam, lt gr, fgr, sh bands, coarch Fms.
3	Ss Bed	TS	0.1' thk, MH, WJ, Ba, g/seam, lt gr, fgr, sh bands, coarch Fms.
4,5	Ss Bed	TS	Ss, mgr horizontal, lt gr, f-gm, g/seam, MH, WJ, BA

of near horizontal

REMARKS: Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

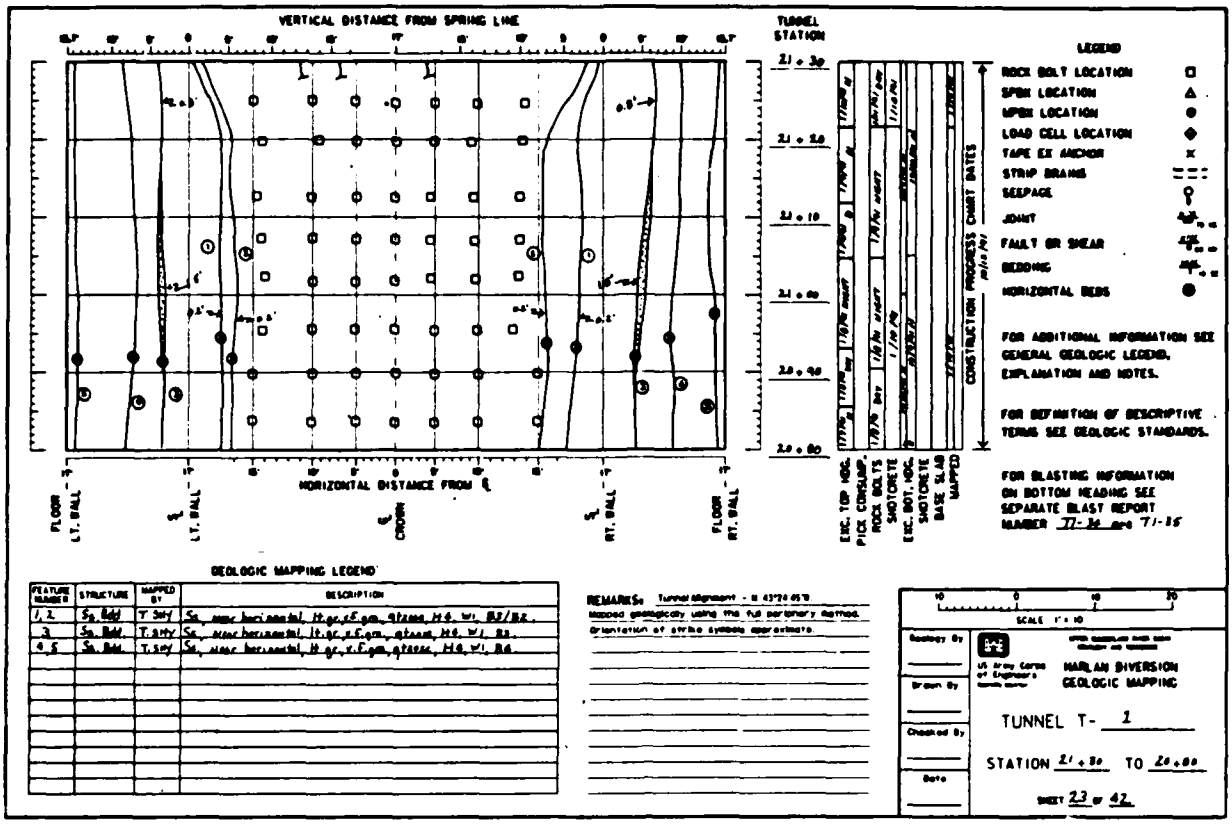
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 20 +30 TO 20 +80

SHEET 22 OF 42

PLATE D-17


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR - LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR - RT. WALL
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 77-34 and 77-35
CONSTRUCTION PROGRESS CHART DATES
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
REMARKS:
SCALE 1" = 10
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 21+30 TO 20+80
SHEET 23 of 42

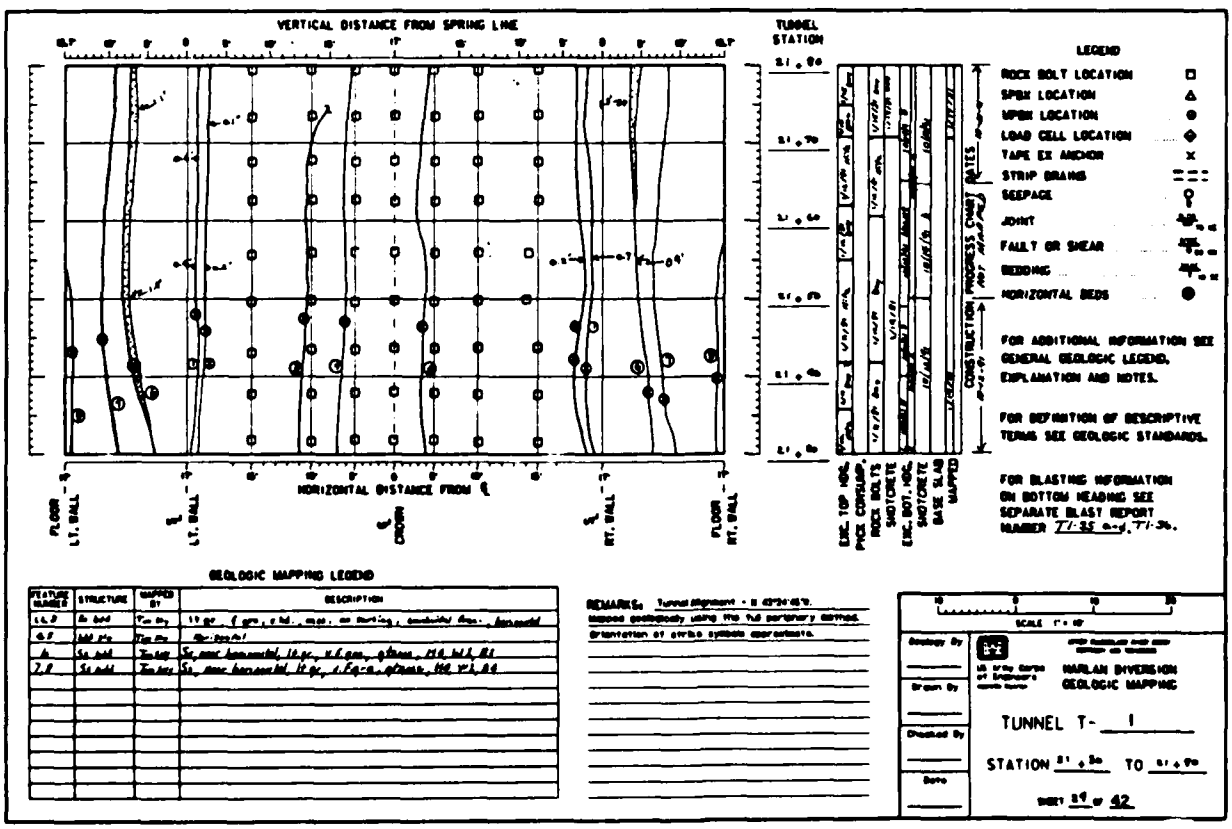
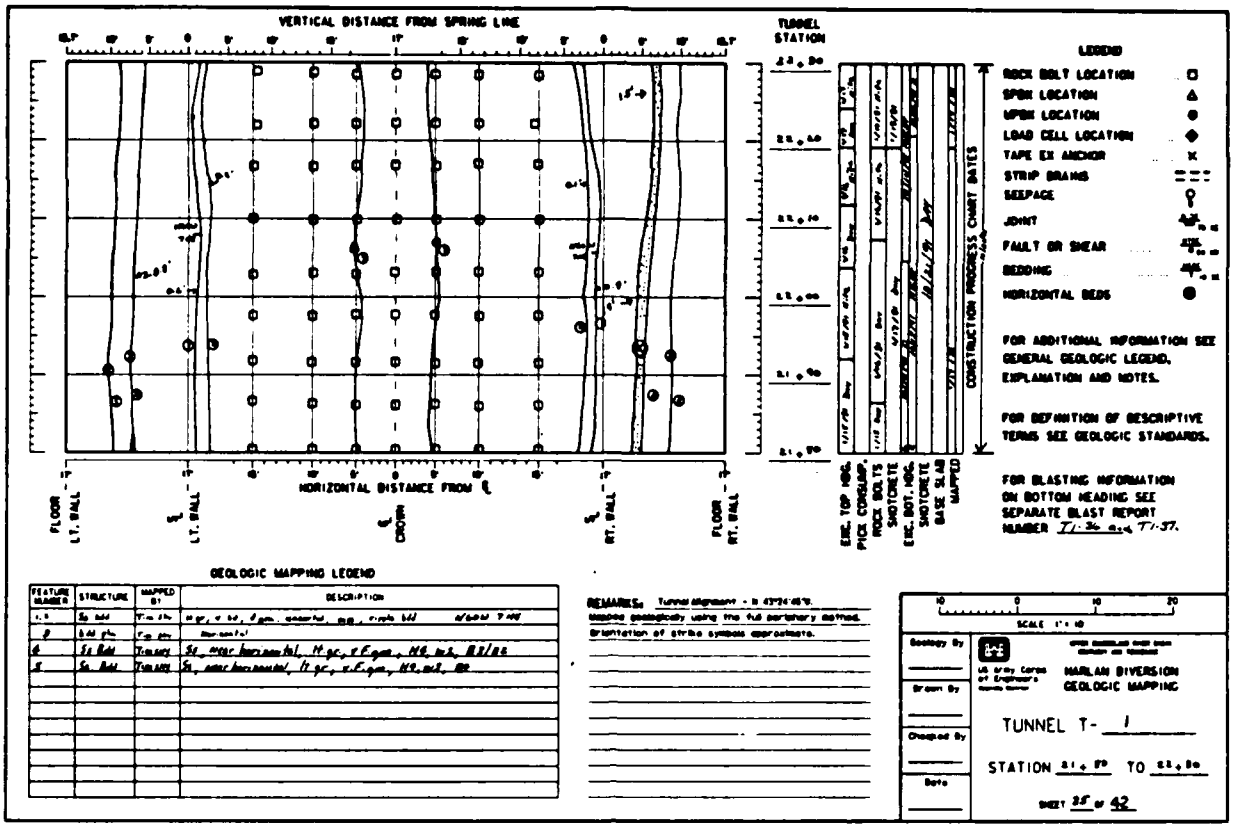

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR - LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR - RT. WALL
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 77-35 and 77-36.
CONSTRUCTION PROGRESS CHART DATES
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
REMARKS:
SCALE 1" = 10
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 21+30 TO 21+70
SHEET 24 of 42

PLATE D-18


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-36 to T/-37.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 21+90 TO 22+80
SHEET 25 OF 42

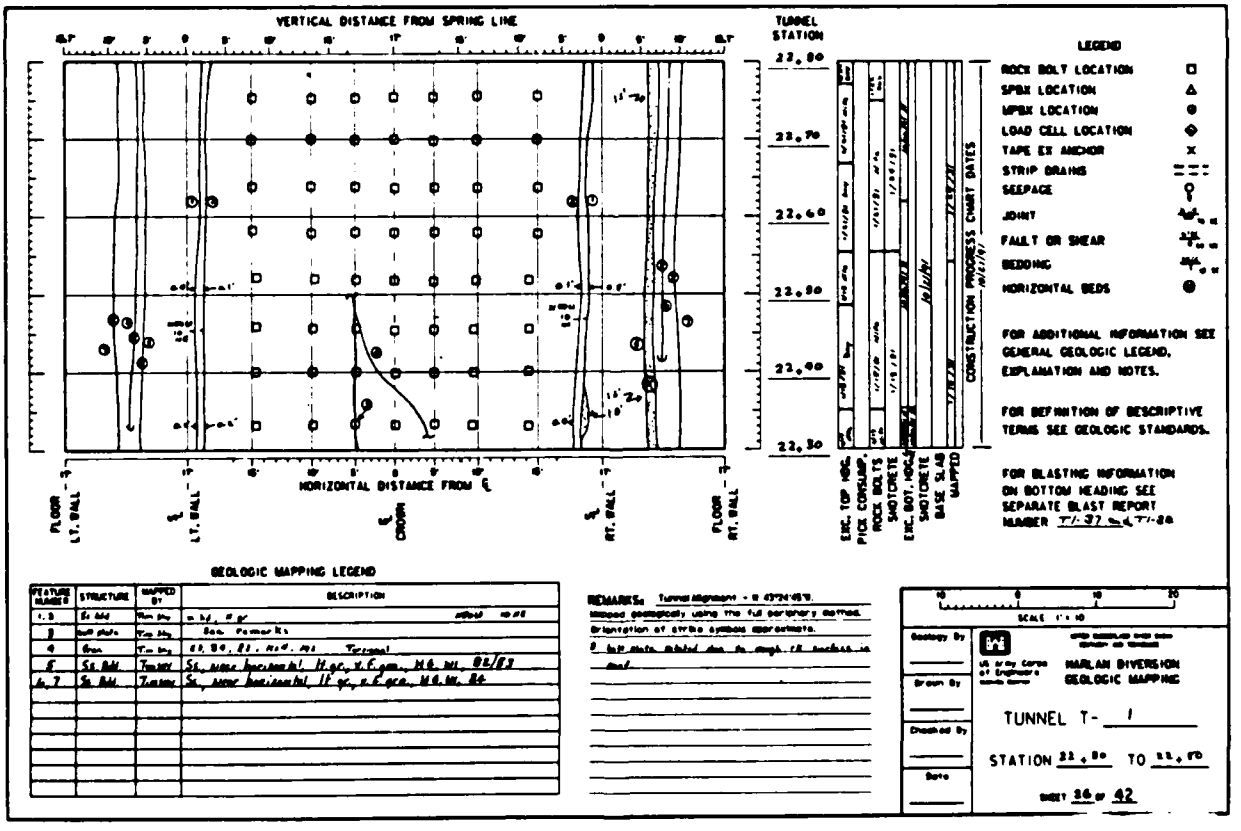
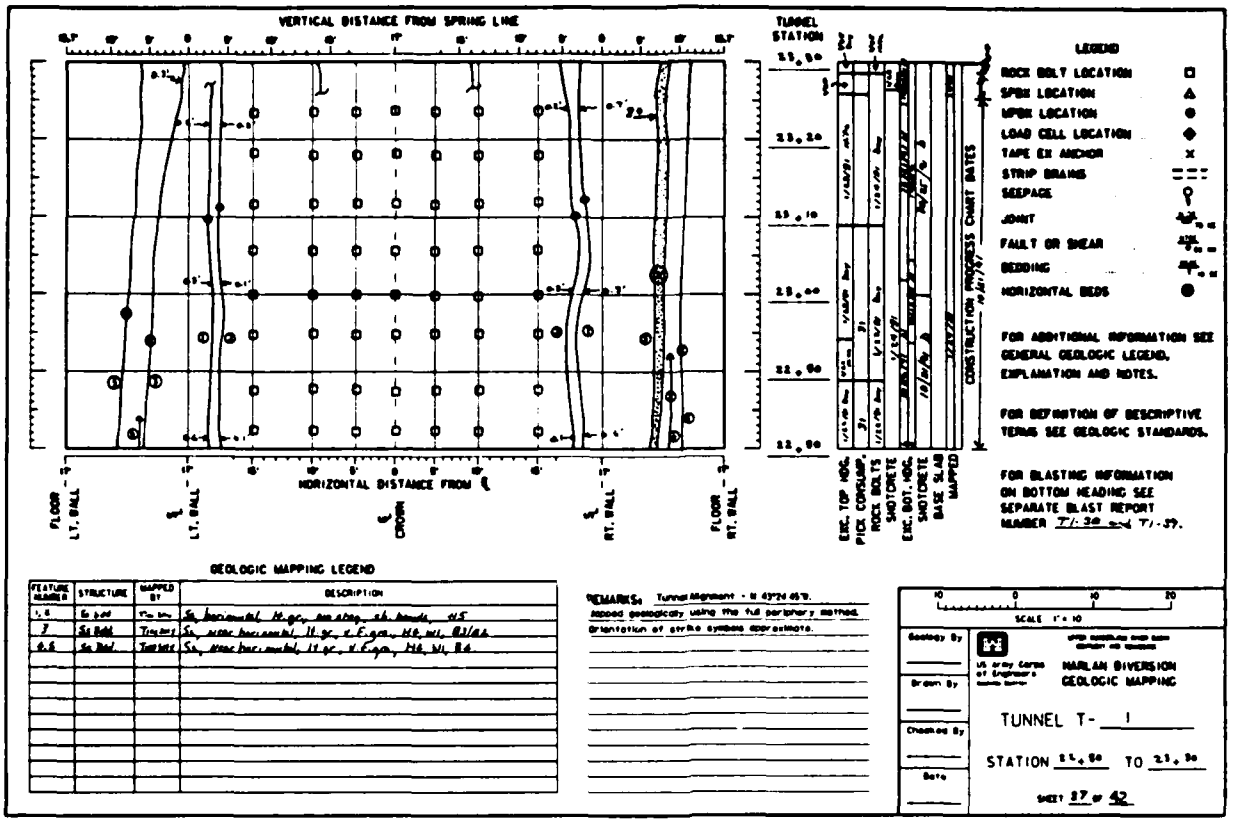

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-37 to T/-38
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 22+80 TO 23+70
SHEET 26 OF 42

PLATE D-19


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-30 and T/-39.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 23+90 TO 23+30
SHEET 37 OF 42

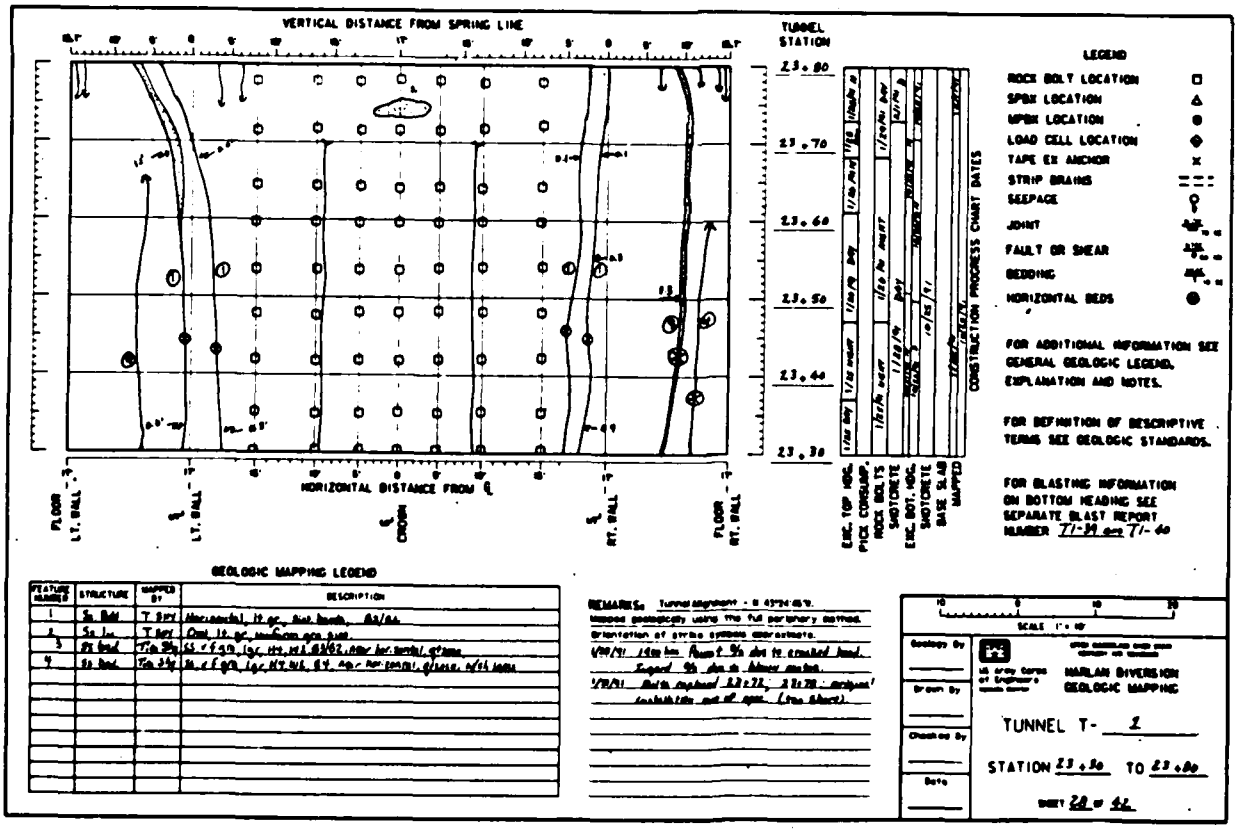
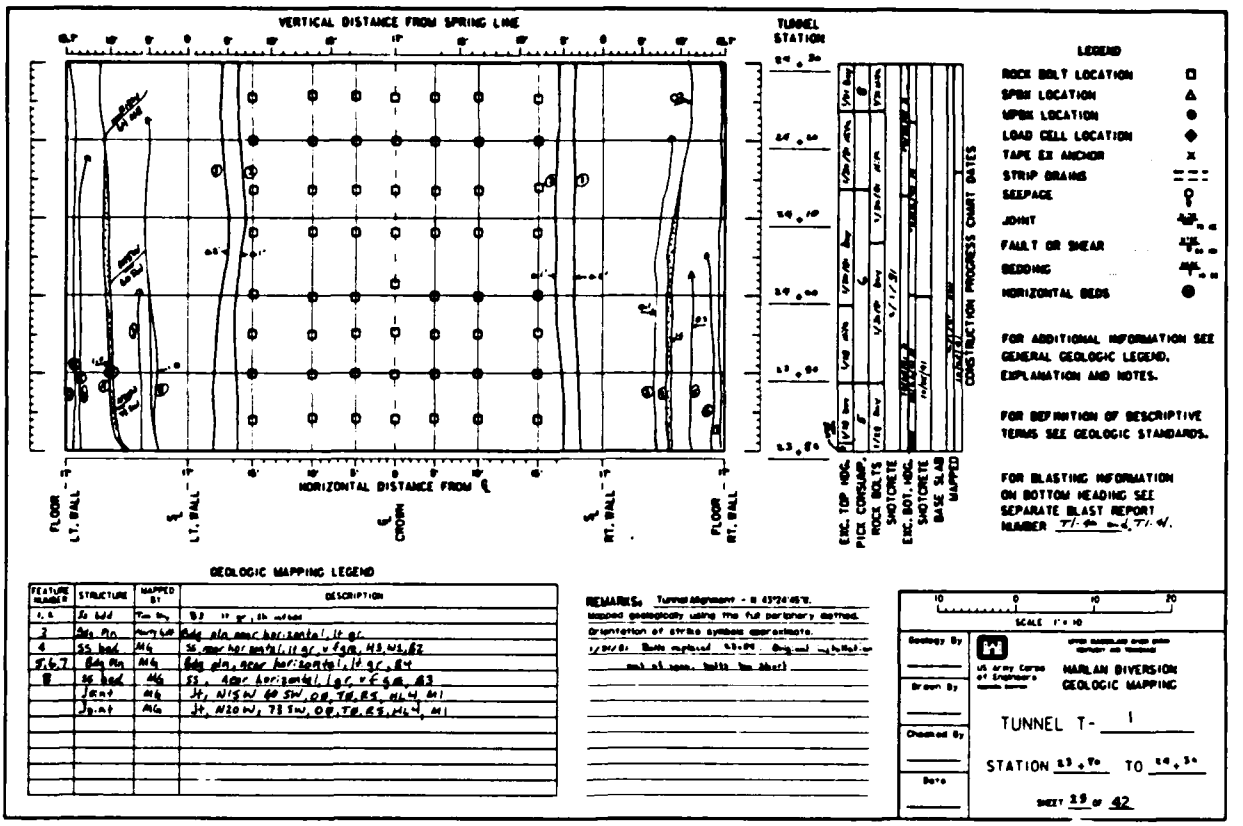

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-39 and T/-40
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 23+30 TO 23+80
SHEET 38 OF 42

PLATE D-20



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 6	Sh bdd		
2	Bdg pln		Bdg pln, near hor: semi-l, lt gr.
4	SS bed	MG	SS, near hor: semi-l, lt gr, v f gn, H5, W1, B2
5, 6, 7	Bdg pln	MG	Bdg pln, near hor: semi-l, lt gr, B4
8	SS bed	MG	SS, near hor: semi-l, l gr, v f gn, B3
	Joint	MG	Jt, N15W/60 SW, OR, TR, R5, H4, M1
	Joint	MG	Jt, N20W/73 SW, OR, TR, R5, H4, M1

REMARKS: Tunnel Alignment - N 63°26'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

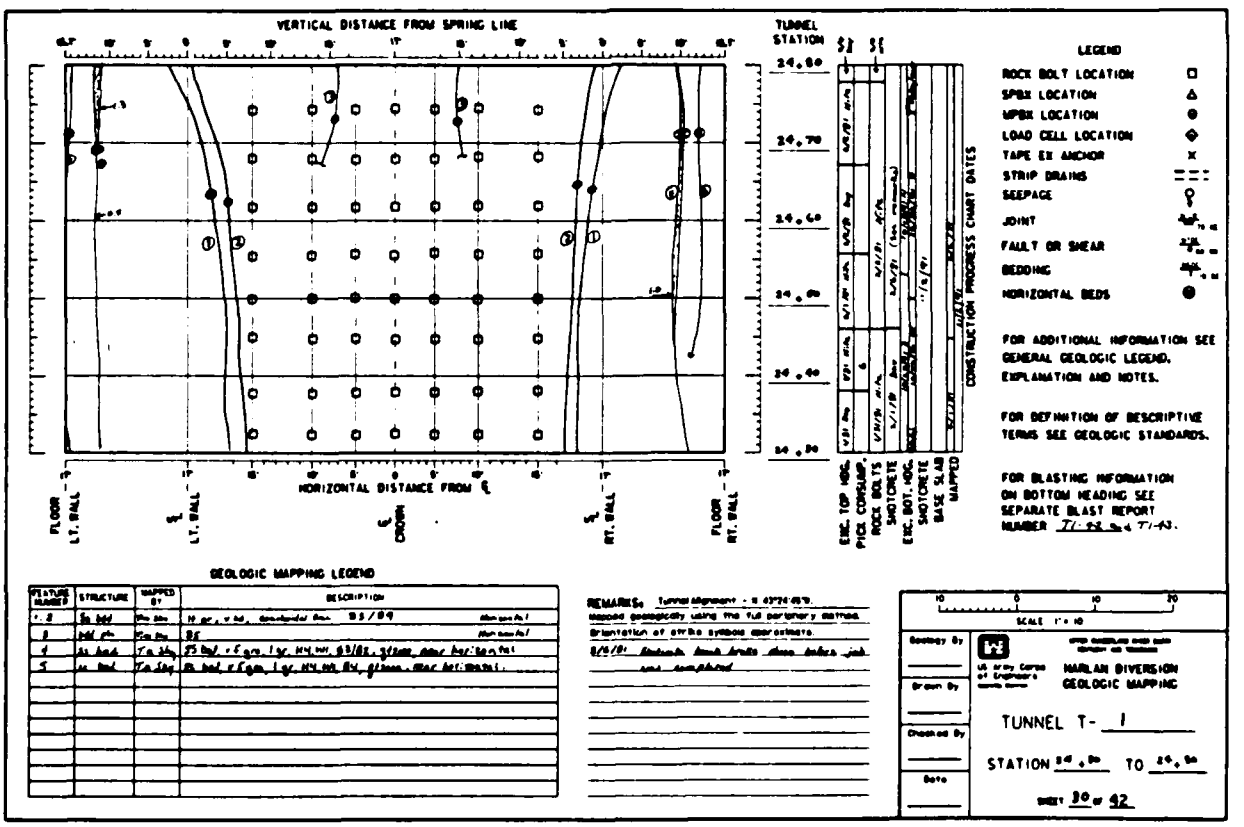
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 23+70 TO 24+30

SHEET 29 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 3	Sh bdd		H gr, v fd, occasional thin SS/SH
2	Bdd pln		SS
4	SS bed		SS bd, v f gn, l gr, H4, W1, B3/B2, strong near hor: semi-l
5	SS bed		SS bed, v f gn, l gr, H4, W1, B4, grown, near hor: semi-l.

REMARKS: Tunnel Alignment - N 63°26'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

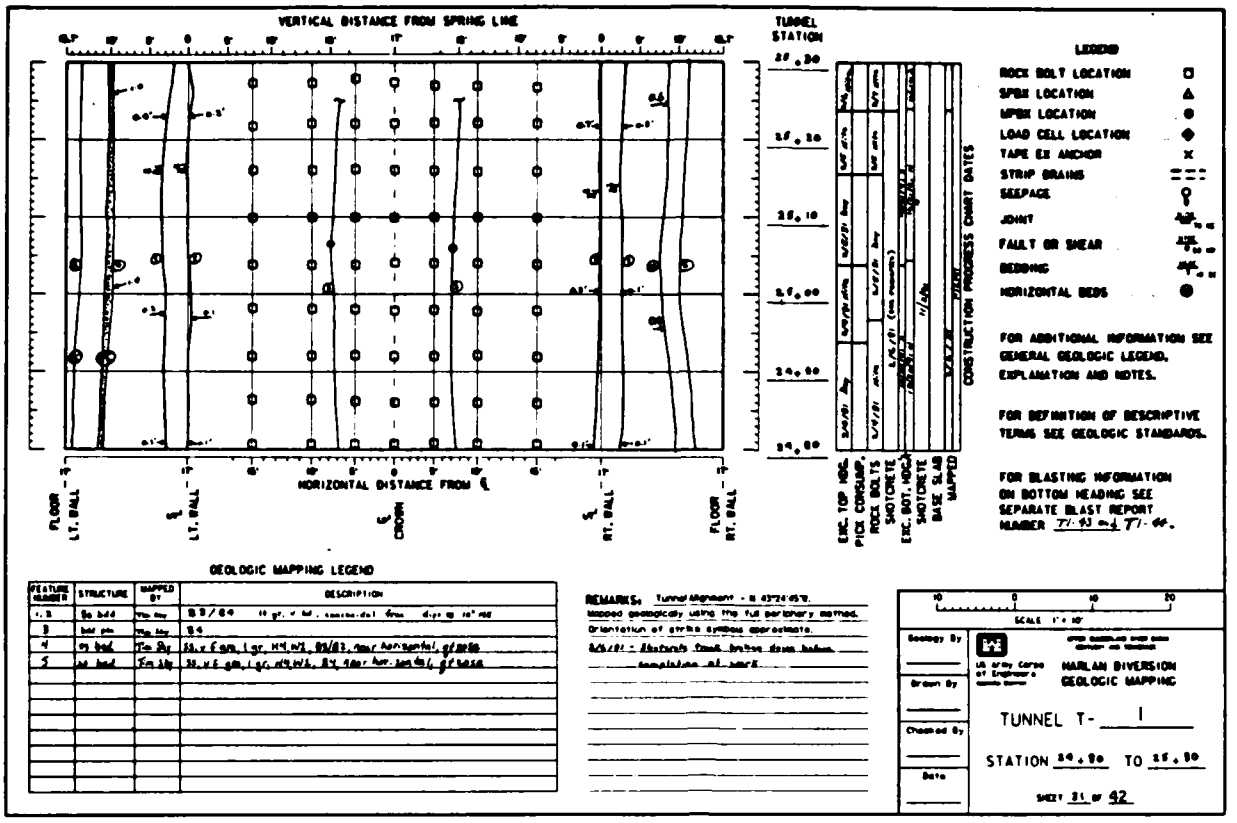
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 24+30 TO 24+90

SHEET 30 OF 42

PLATE D-21


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HOG, PICK CONSUMP., ROCK BOLTS
SHOTCRETE
EXC. BOT. HOG, SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-93 and T/-44.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full perimetry method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 24+90 TO 25+30
SHEET 31 OF 42

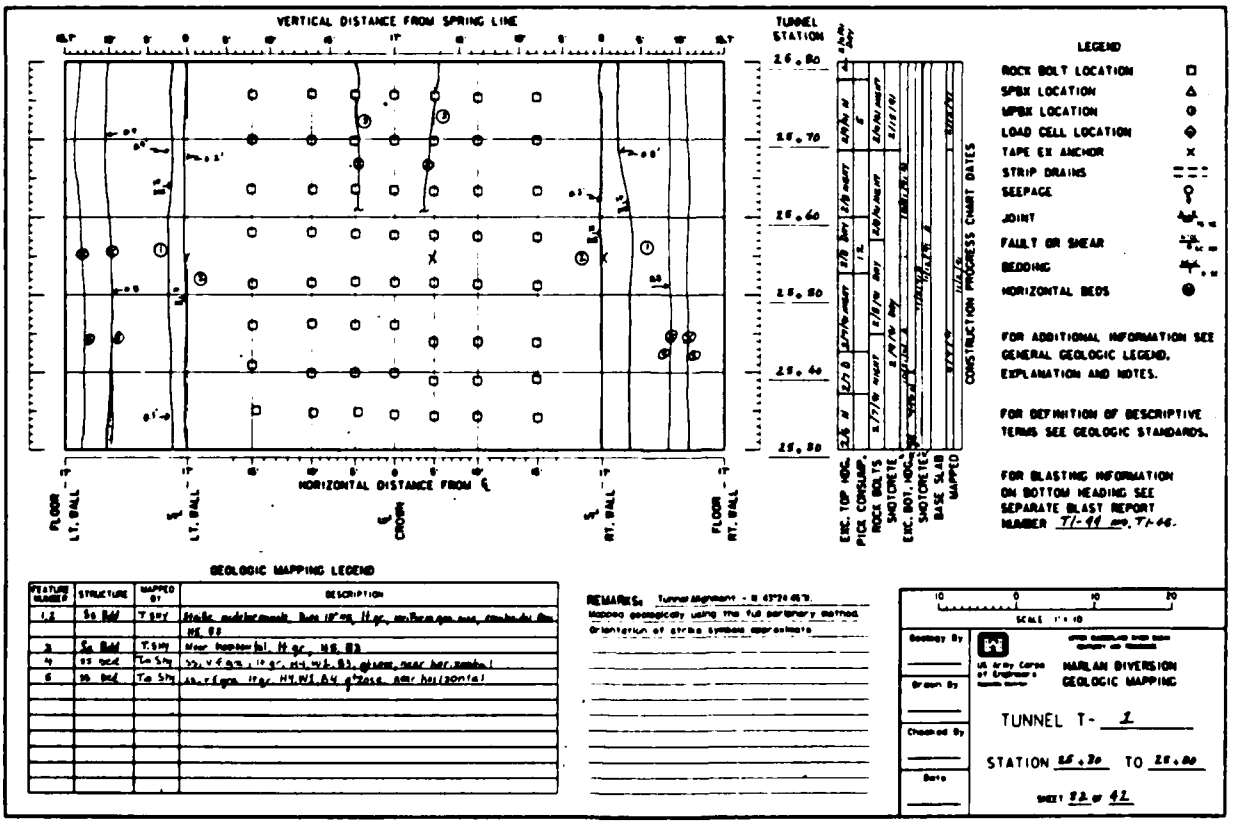
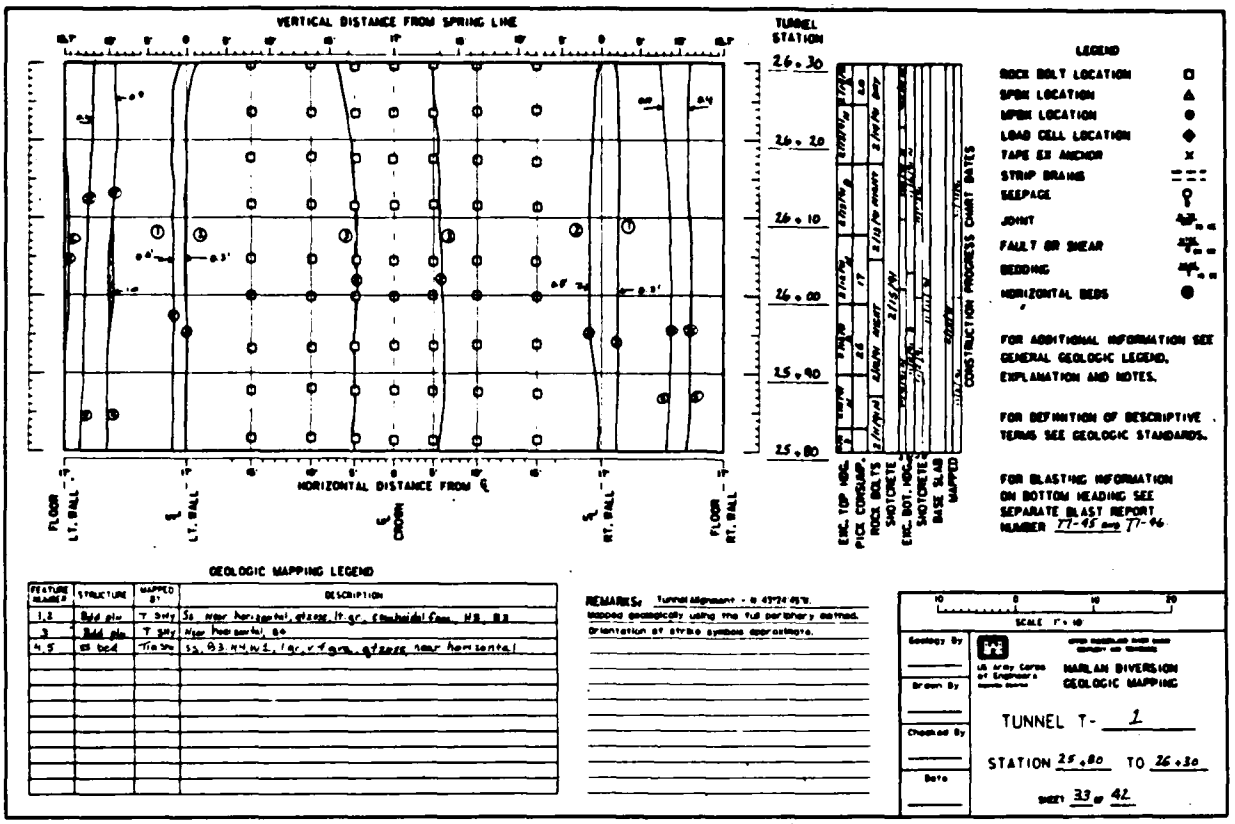

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HOG, PICK CONSUMP., ROCK BOLTS
SHOTCRETE
EXC. BOT. HOG, SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-44 and T/-46.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full perimetry method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 25+30 TO 25+80
SHEET 32 OF 42

PLATE D-22



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Bdd plu	T Shy	Ss, near horizontal, grease, lt gr, fine/med/f coa, MB, BB
3	Bdd plu	T Shy	Near horizontal, BA
4,5	ss bed	Tra Shy	Ss, BB, HH, W1, lgr, v f grn, grease, near horizontal

REMARKS: Tunnel Alignment - 0 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

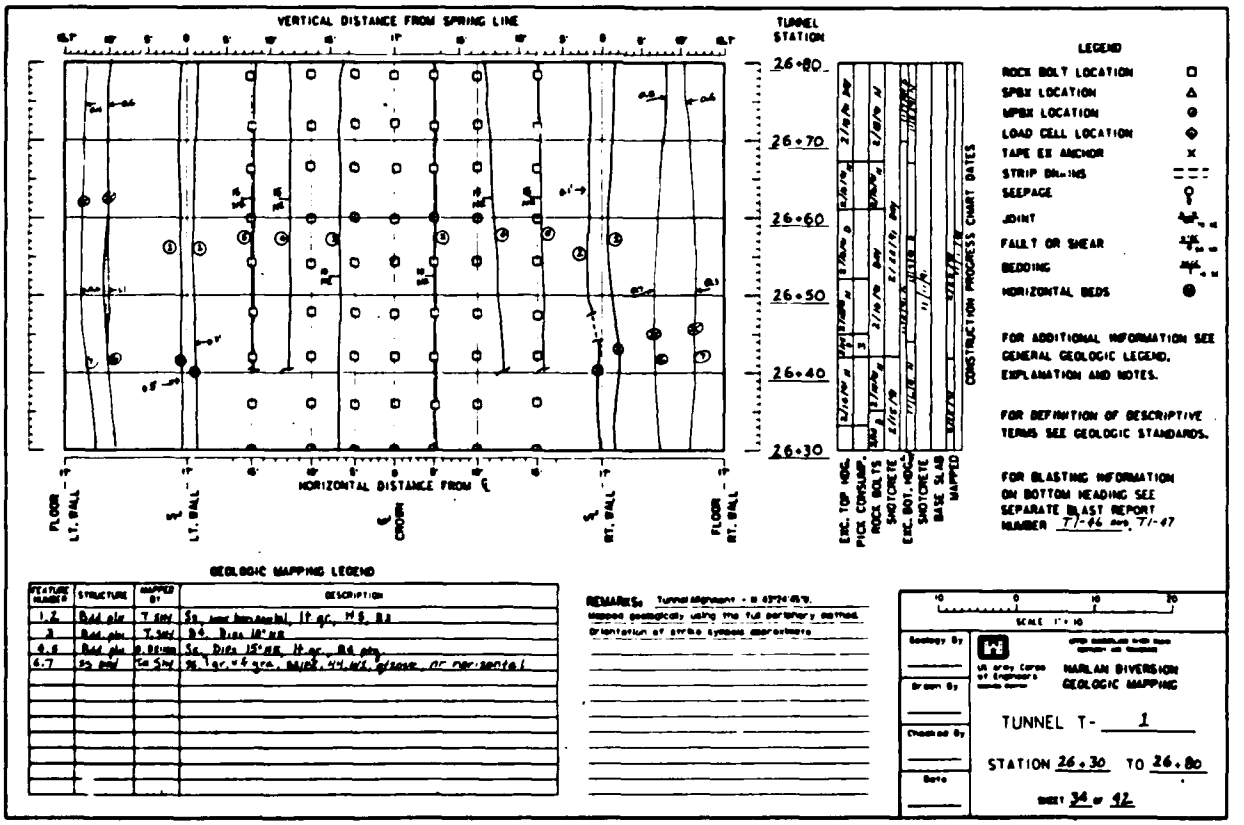
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HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 25+80 TO 26+30

SHEET 33 of 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Bdd plu	T Shy	Ss, near horizontal, lt gr, MB, BB
3	Bdd plu	T Shy	BA, Dips 10° NW
4,6	Bdd plu	B Robbins	Ss, Dips 15° NW, lt gr, BA grn
6,7	ss bed	Tra Shy	Ss, lgr, v f grn, bdd, HH, W1, grease, nr horizontal

REMARKS: Tunnel Alignment - 0 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Alaska District

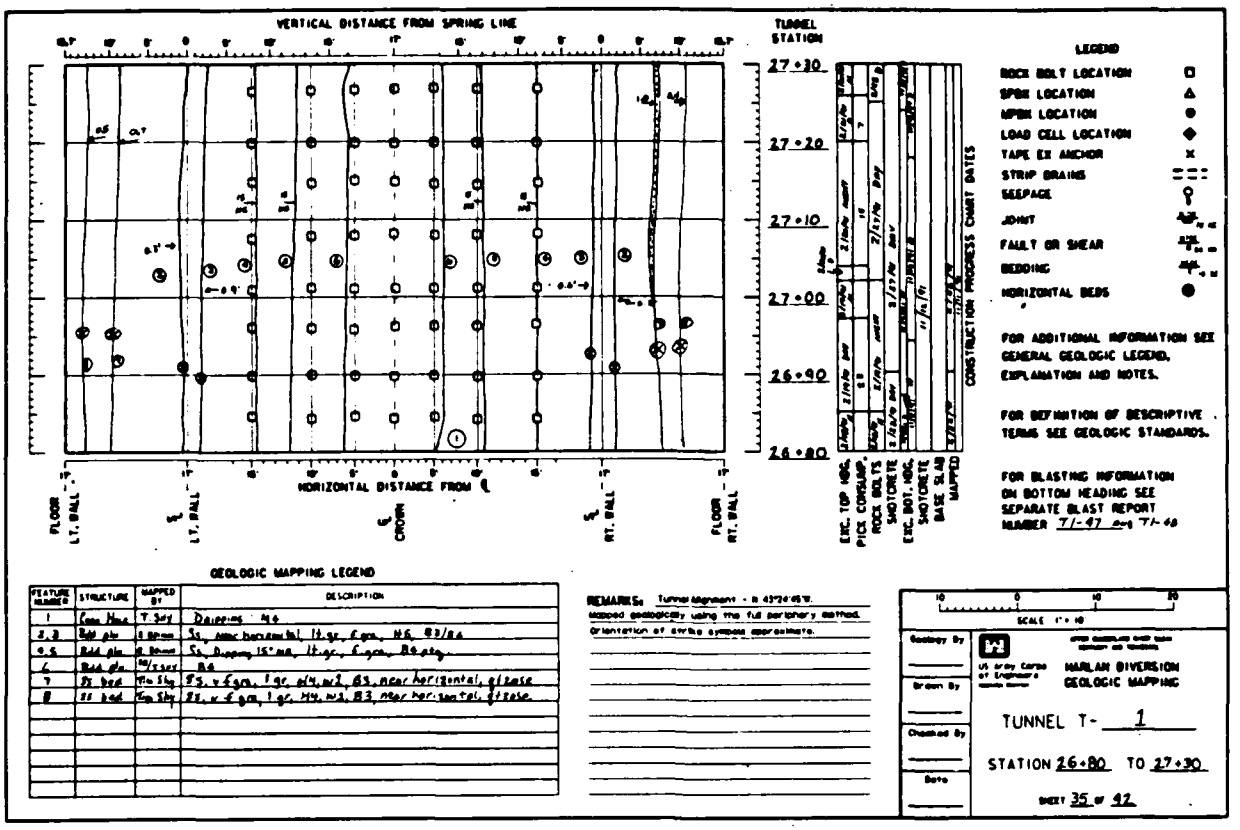
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 26+30 TO 26+80

SHEET 34 of 42

PLATE D-23



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Cont. Joint	T. Sky	Dacite-ms 40
2, 3	Bdd plane	8 Brown	Ss, mgr horizontal, lt gr, f-gra, MS, B3/B4
4, 5	Bdd plane	8 Brown	Ss, Dipping 15° ma, lt gr, f-gra, B4 qtz
6	Bdd plane	M/Sykes	B4
7	Ss bed	Tim Sky	Ss, v f-gra, 1 gr, H4, w1, B3, near horizontal, grease
8	Ss bed	Tim Sky	Ss, v f-gra, 1 gr, H4, w1, B3, near horizontal, grease.

REMARKS: Tunnel alignment - N 43°24'05"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

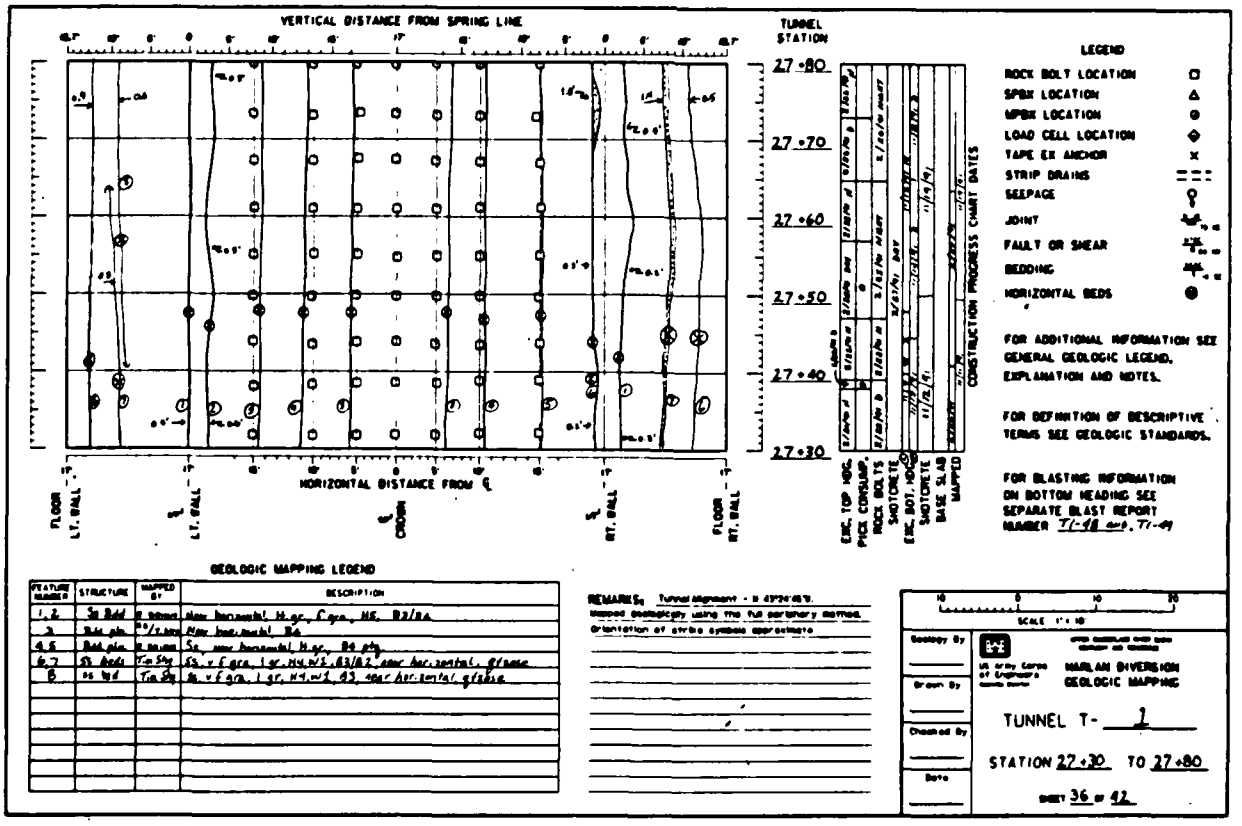
Geology By
Drawn By
Checked By
Date

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HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 26+80 TO 27+30

SHEET 35 of 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Ss Bdd	8 brown	Mgr horizontal, lt gr, f-gra, MS, B3/B4
3	Bdd plane	M/Sykes	Mgr horizontal, B4
4, 5	Bdd plane	8 brown	Ss, mgr horizontal, lt gr, B4 qtz
6, 7	Ss Beds	Tim Sky	Ss, v f-gra, 1 gr, H4, w1, B3/B2, near horizontal, grease
8	Ss bed	Tim Sky	Ss, v f-gra, 1 gr, H4, w1, B3, near horizontal, grease

REMARKS: Tunnel alignment - N 43°24'05"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

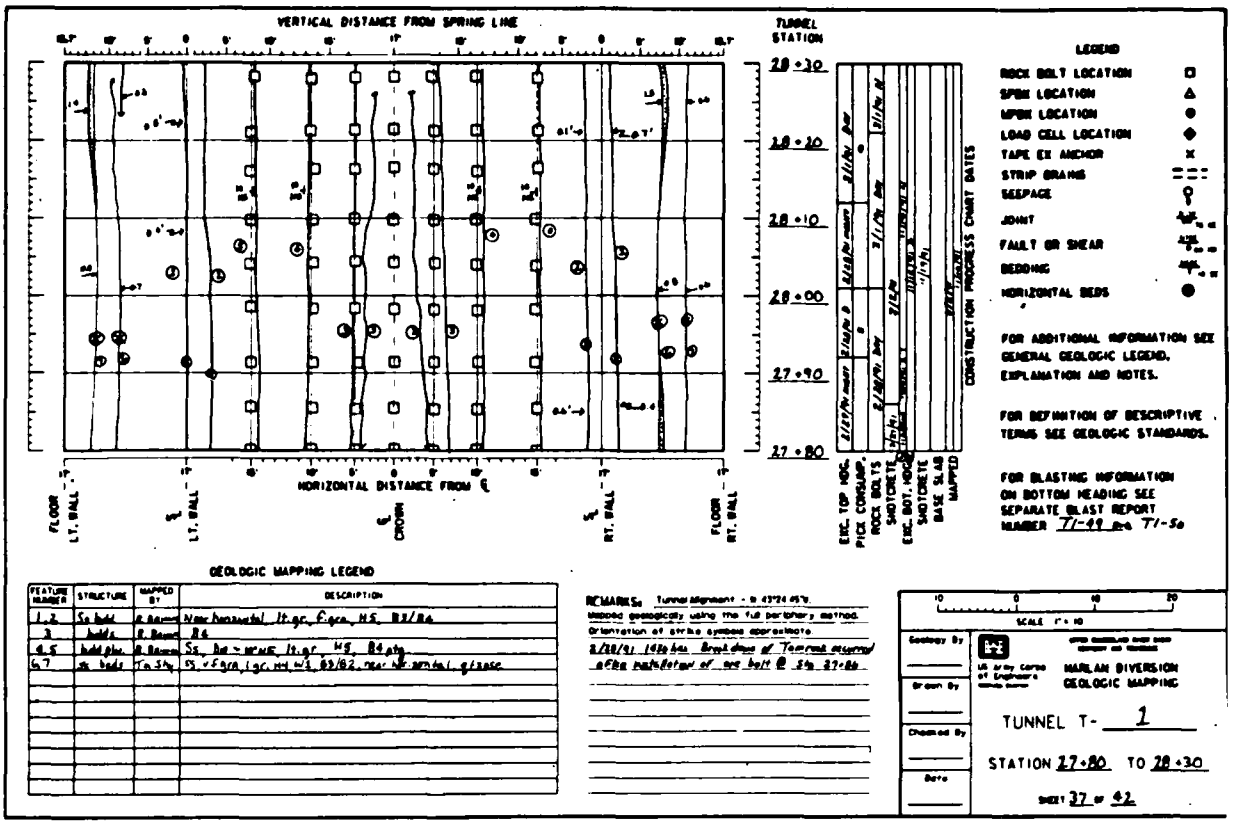
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GEOLOGIC MAPPING

TUNNEL T- 1

STATION 27+30 TO 27+80

SHEET 36 of 42

PLATE D-24



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Sz bdd	R Bauer	Near horizontal lt gr, f-gra, MS, B2/B4
3	bedds	R Bauer	B4
4,5	bdd plns	R Bauer	Ss, bd ~ N70E lt gr, MS, B4 sty
6,7	sh beds	Tm Shq	SS, v f-gra, lgr, MM w/ S, B2/B2, near horizontal, g/sase

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
2/28/91 16lb/cu. Breakdown of Tamrock steering arm malfunction of set bolt @ Sta 27+86

SCALE 1" = 10

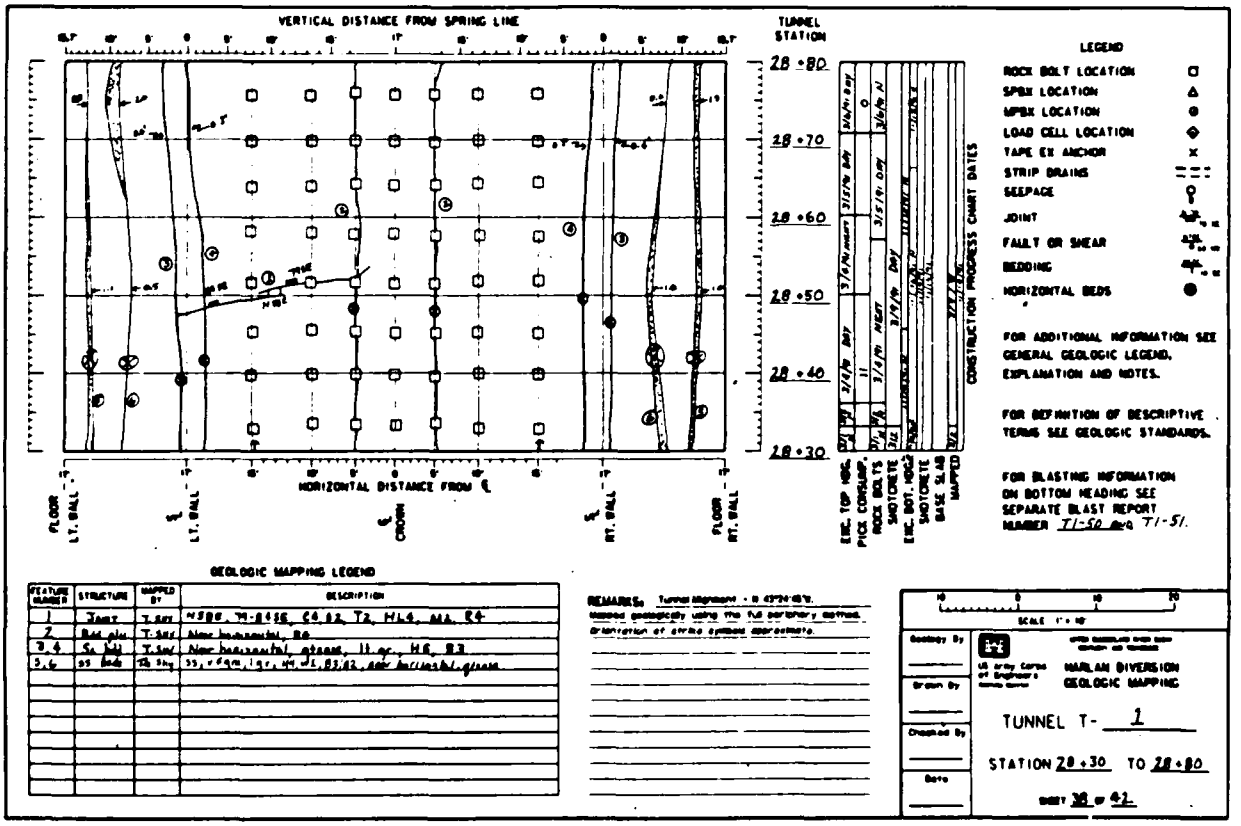
Geology By
Drawn By
Checked By
Date

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HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 27+80 TO 28+30

SHEET 37 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	T. Sitz	N58E, 79-84SE, C4 B2, T2, H14, MM, B4
2	Bdd plns	T. Sitz	Near horizontal, B4
3,4	Sz bdd	T. Sitz	Near horizontal, gtaase, lt gr, MS, B3
5,6	ss bdds	Tk Shq	SS, v f-gra, lgr, MM w/ S, B2/B2, near horizontal, g/sase

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

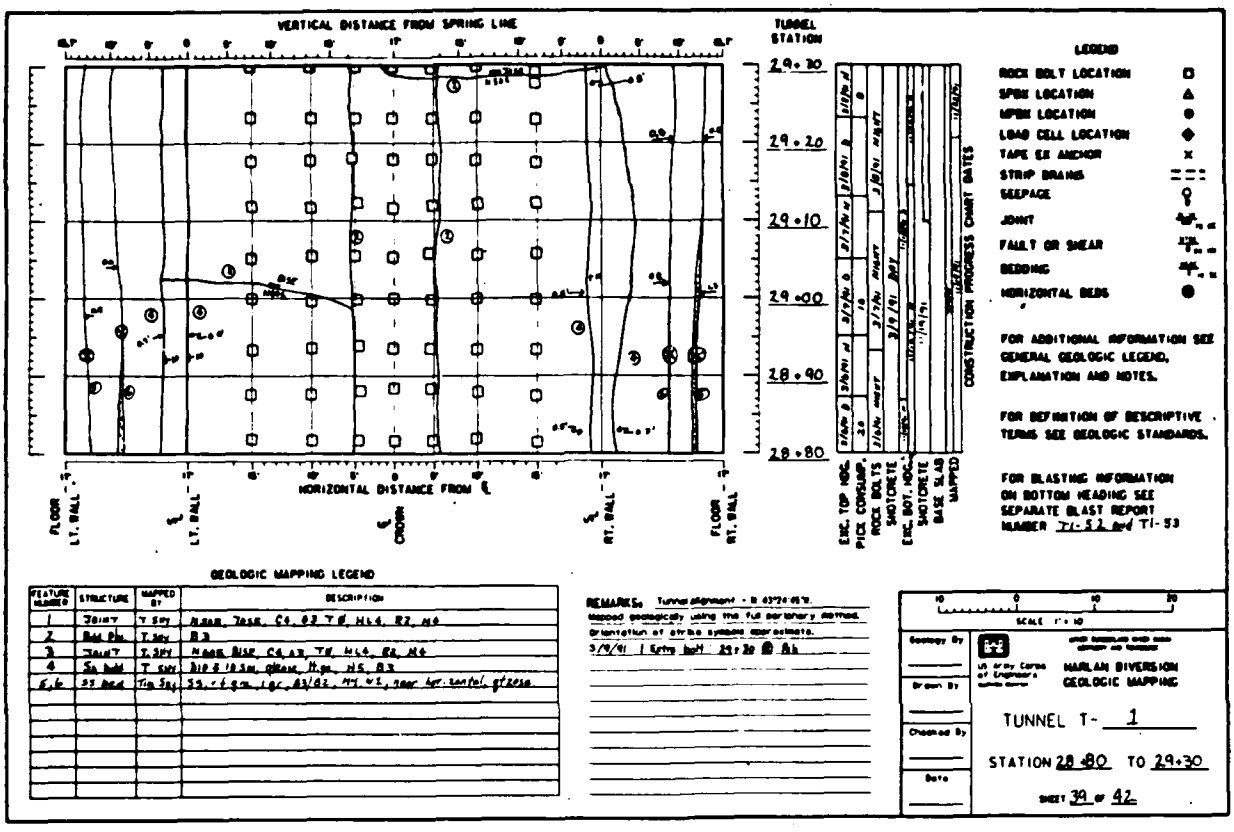
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GEOLOGIC MAPPING

TUNNEL T- 1

STATION 28+30 TO 28+80

SHEET 38 OF 42

PLATE D-25



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	T Spy	N.80E, 70SE, C4, 03, T4, HL4, R2, M4
2	Bed Pln.	T Spy	R3
3	Joint	T. Spy	N.80E, 85E, C4, 03, T4, HL4, R2, M4
4	Sh. bdd	T Spy	310 & 10 Sm. offset, N.90, N5, R3
5,6	R3 Bed	Tim Spy	55, r 6 gm, loc, R3/R2, M4, M5, near horizontal, grease

REMARKS: Tunnel alignment - N 63°24'45"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/9/91 | Spray bar M 29+30 @ R4

SCALE 1" = 10'

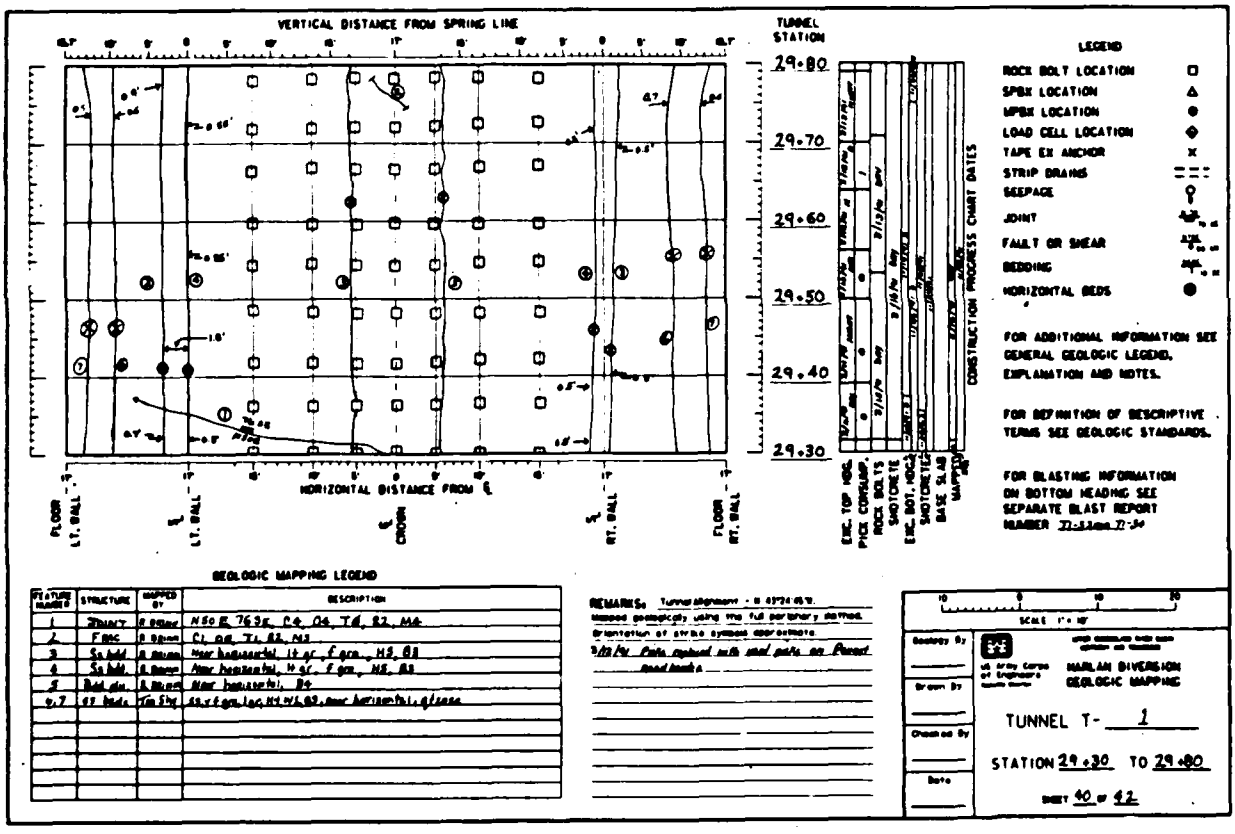
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 28+80 TO 29+30

SHEET 39 of 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	R Brown	N50E, 76SE, C4, 04, T4, R2, M4
2	Fault	R Brown	C1, 08, T1, R2, M3
3	Sh. bdd	R Brown	Near horizontal, 1 to 2' C gm, N5, R3
4	Sh. bdd	R Brown	Near horizontal, N of Fault, C gm, N5, R3
5	Bed pln.	R Brown	Near horizontal, R4
6,7	R3 Beds	Tim Spy	55, r 6 gm, loc, N1, N4, R3, near horizontal, grease

REMARKS: Tunnel alignment - N 63°24'45"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/12/91 Rock bolts marked with steel paint on Parker Road heading

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

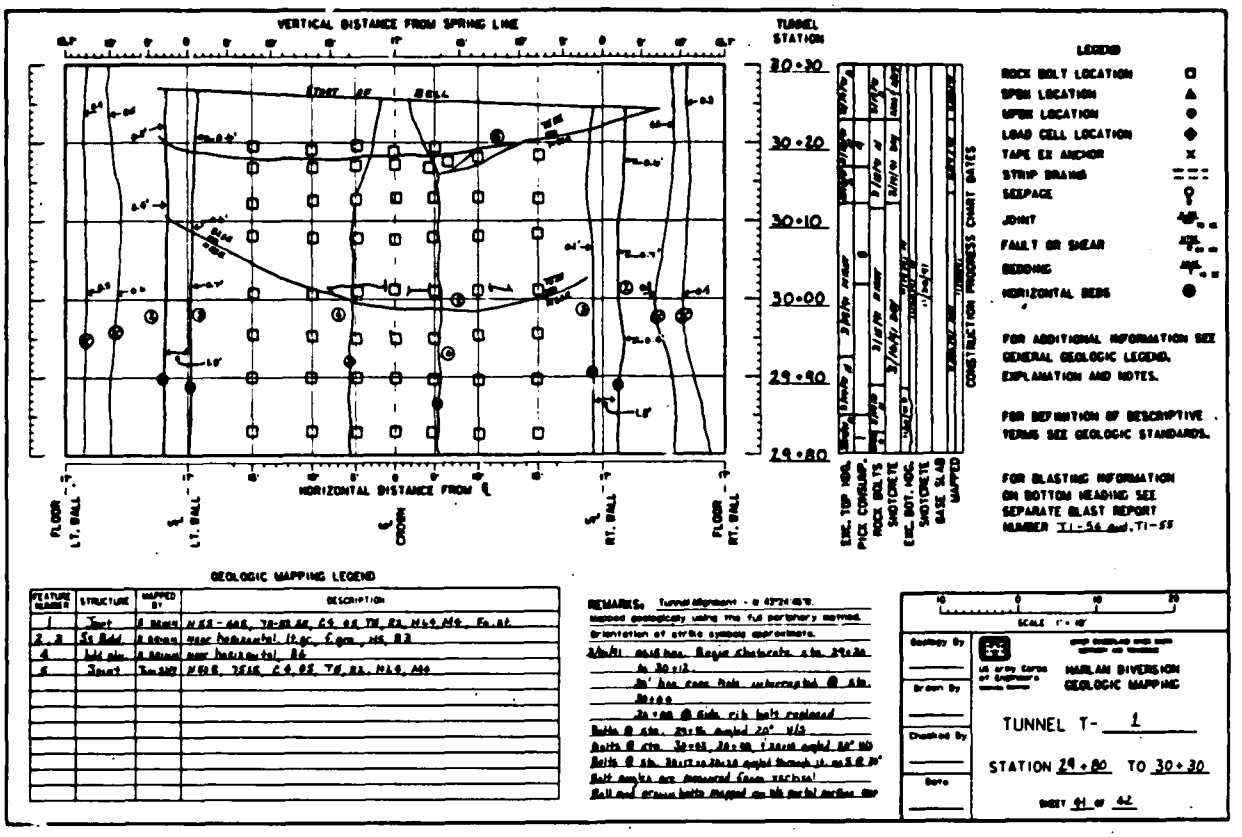
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 29+30 TO 29+80

SHEET 40 of 42

PLATE D-26



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	B Adams	N 65 - 68E, 78-85 SE, C4, 05 TH, R2, H40, A40, Fe, R5
2, 3	Sz Bdd	B Adams	near horizontal, It gr, f gm, MS, R3
4	Fault plane	B Adams	near horizontal, R4
5	Joint	Tom Smith	N 60 E, 75 SE, C4, 05, T4, R2, H40, A40

REMARKS: Tunnel alignment - 0 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
3/16/81 added hor. Shear Shotcrete also 29+80 to 30+12.
30' hor. cross fault intercepted @ sta. 30+00
30+00 @ side, rib bolt replaced
Bolts @ sta. 29+80, angled 20° W/S
Bolts @ sta. 30+05, 30+08, 1'bolt angled 30° W/S
Bolts @ sta. 30+12 to 30+18 angled through jt. as S @ 30°
Bolt angles are measured from vertical
Bolt and grouts bolts stopped on left partial section due

SCALE 1" = 10'

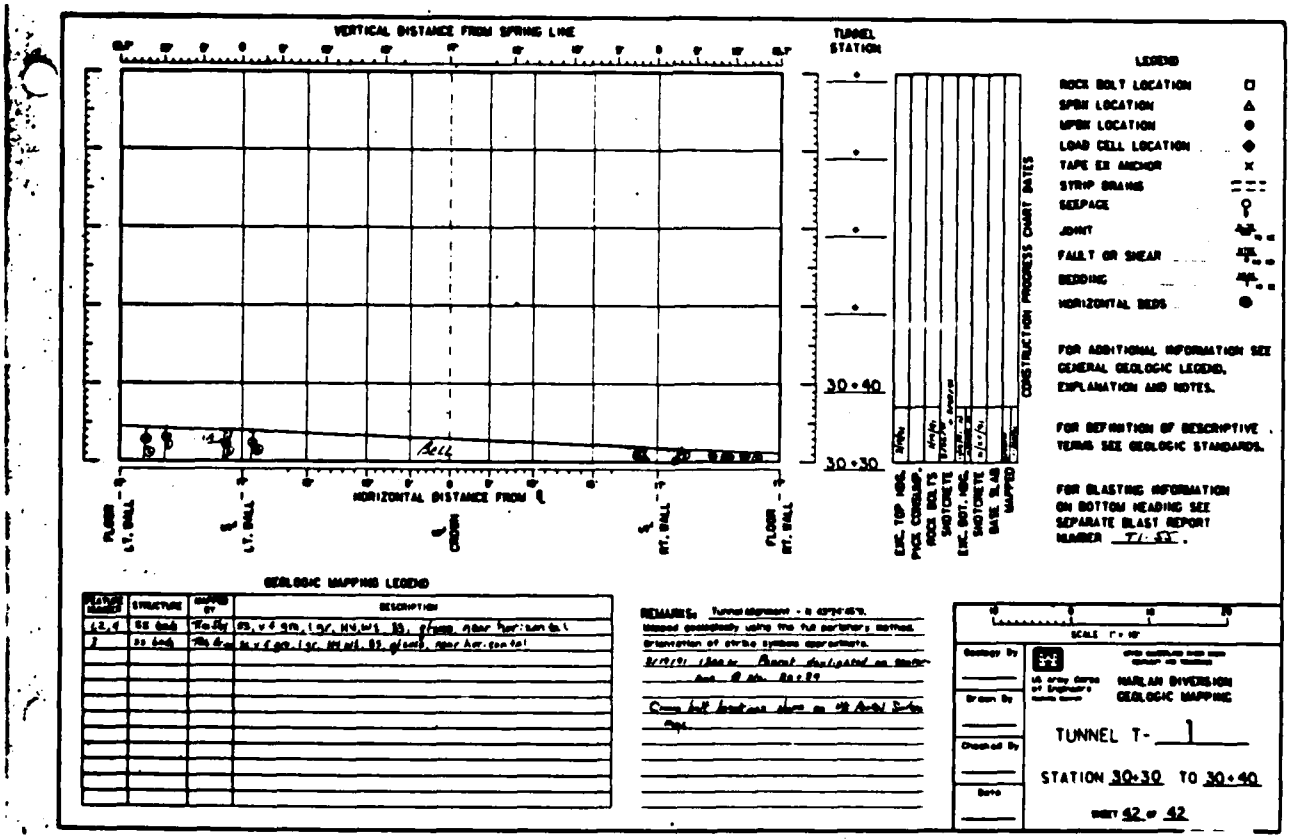
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HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 29+80 TO 30+30

SHEET 41 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,4	Sz Bdd	Tom Smith	075, v f gm, l gr, MW, MS, R5, grades near hor. contact
3	Sz Bdd	Tom Smith	N-S v f gm, l gr, MW, MS, R5, grades near hor. contact

REMARKS: Tunnel alignment - 0 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
3/19/81 18 ton Shear designated on Shotcrete @ sta. 30+29
Cross bolt locations shown on 42 Partial Section Map.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

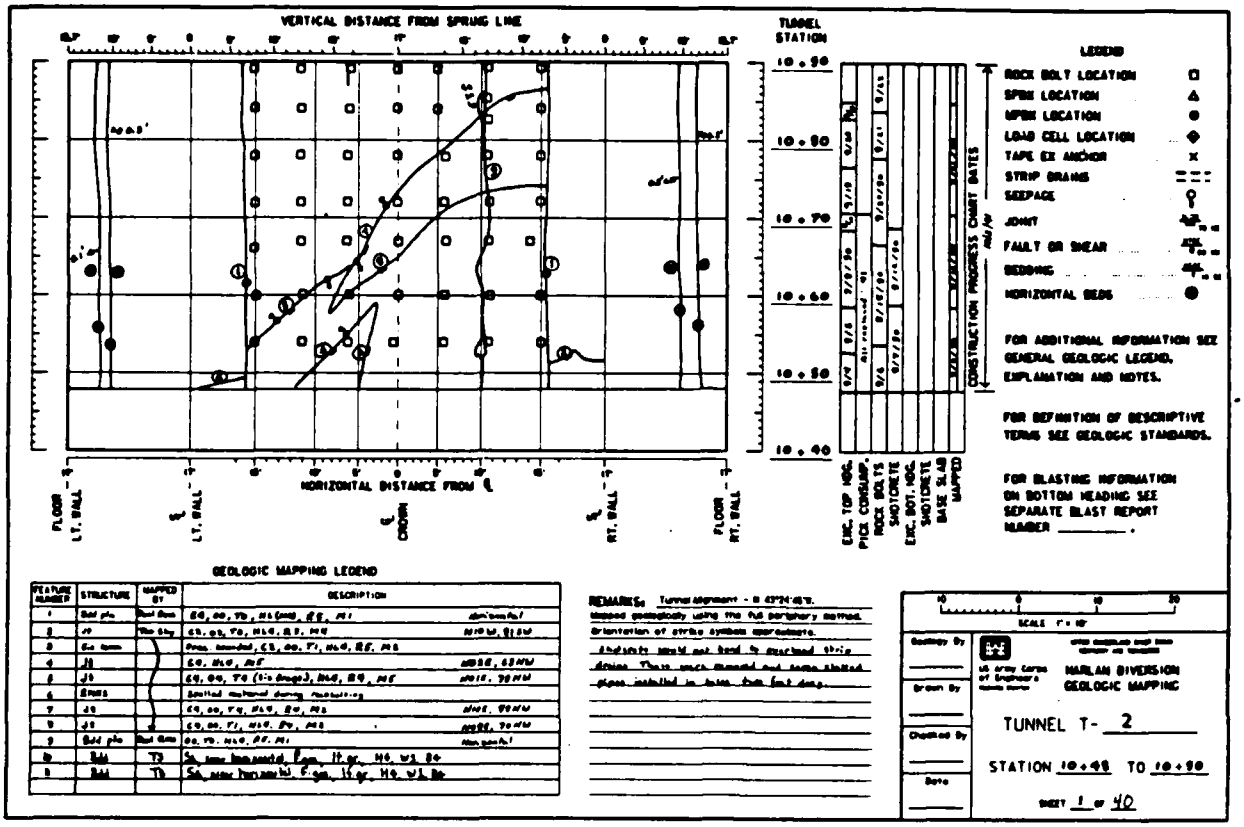
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HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 30+30 TO 30+40

SHEET 42 OF 42

PLATE D-27



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed plane	Thin Grey	SS, GD, TS, Mi (med), EE, Mi — dip/azimuth
2	Jt	Thin Grey	CS, GS, TS, Mi-G, EE, Mi — N10W, 81SW
3	Cs seam		Prob. bounded, CS, GD, TS, Mi-G, EE, Mi
4	Jt		CS, Mi-G, Mi — N85E, 63NW
5	Jt		CS, GD, TS (1:> Gouge), Mi-G, EE, Mi — N90E, 70NW
6	Strain		Limited movement during monitoring
7	Jt		CS, GD, TS, Mi-G, EE, Mi — N10E, 70NW
8	Jt		CS, GD, TS, Mi-G, EE, Mi — N85E, 70NW
9	Bed plane	Thin Grey	GD, TS, Mi-G, EE, Mi — dip/azimuth
A	Bdd	TS	Ss, occ laminated, F-gn, lt-gr, Mi, wl Bd
B	Bdd	TS	Ss, occ laminated, F-gn, lt-gr, Mi, wl Bd

REMARKS: Tunnel alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Joints would not tend to overload thick drains. Thick ones removed and some slotted pipes installed in holes that lost flow.

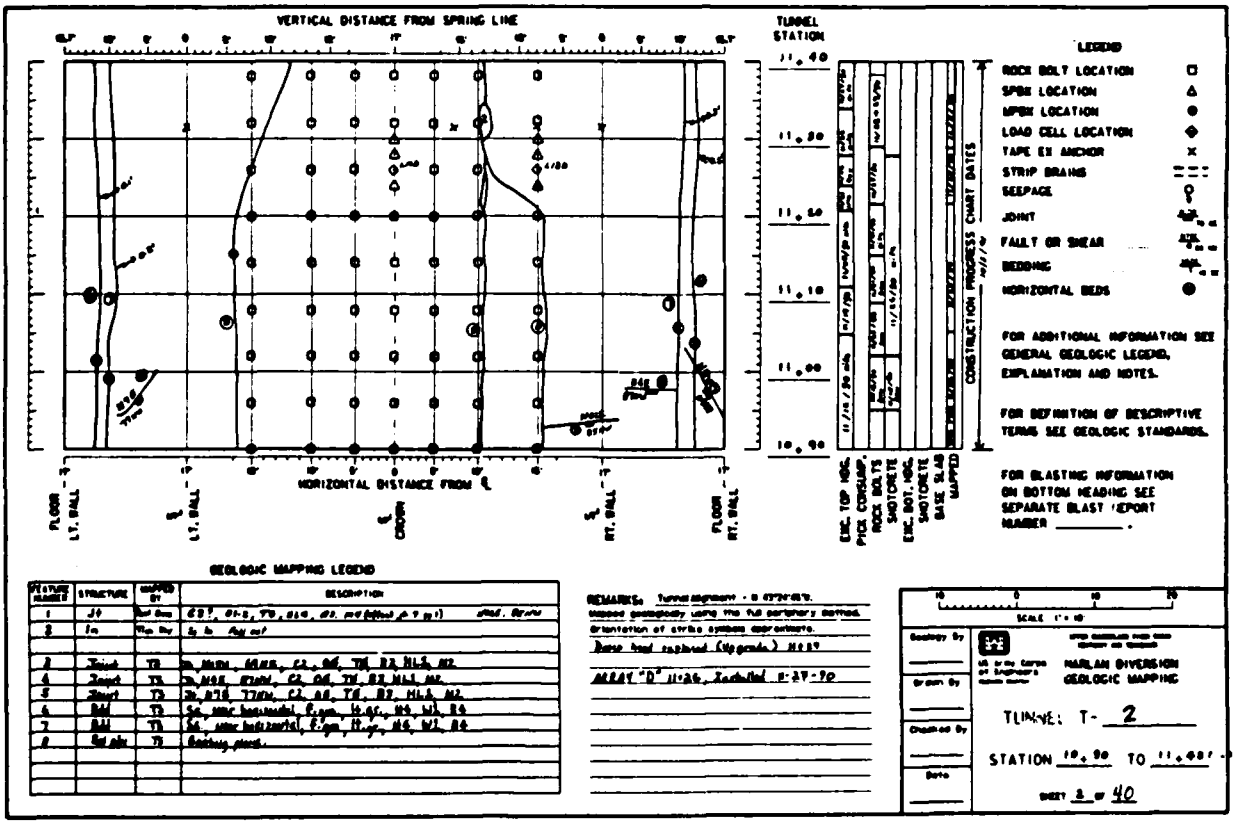
SCALE 1" = 10'

Geology By: [illegible] — US Army Corps of Engineers — MARIAN DIVERSION GEOLOGIC MAPPING
Drawn By:
Checked By:
Date:

TUNNEL T- 2

STATION 10+98 TO 10+90

SHEET 1 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Jt	Thin Grey	CS?, GS-S, TS, Mi-G, EE, Mi (offset @ 7 pt) — dip/azimuth
2	Jn	Thin Grey	Jt to Bdd Mi
3	Joint	TS	Jn, Mi-Gn, Mi-G, CS, GD, TS, EE, Mi-S, Mi
4	Joint	TS	Jn, Mi-G, Gn-Mi, CS, GD, TS, EE, Mi-S, Mi
5	Joint	TS	Jn, Mi-G, Tr-Gn, CS, GD, TS, EE, Mi-S, Mi
6	Bdd	TS	Ss, occ laminated, F-gn, lt-gr, Mi, wl, Bd
7	Bdd	TS	Ss, occ laminated, F-gn, lt-gr, Mi, wl, Bd
8	Bed plane	TS	Bedding plane.

REMARKS: Tunnel alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Dense head replaced (Upgrade) Mi-G
AREA "D" 11+26, Excavated 8-27-90

SCALE 1" = 10'

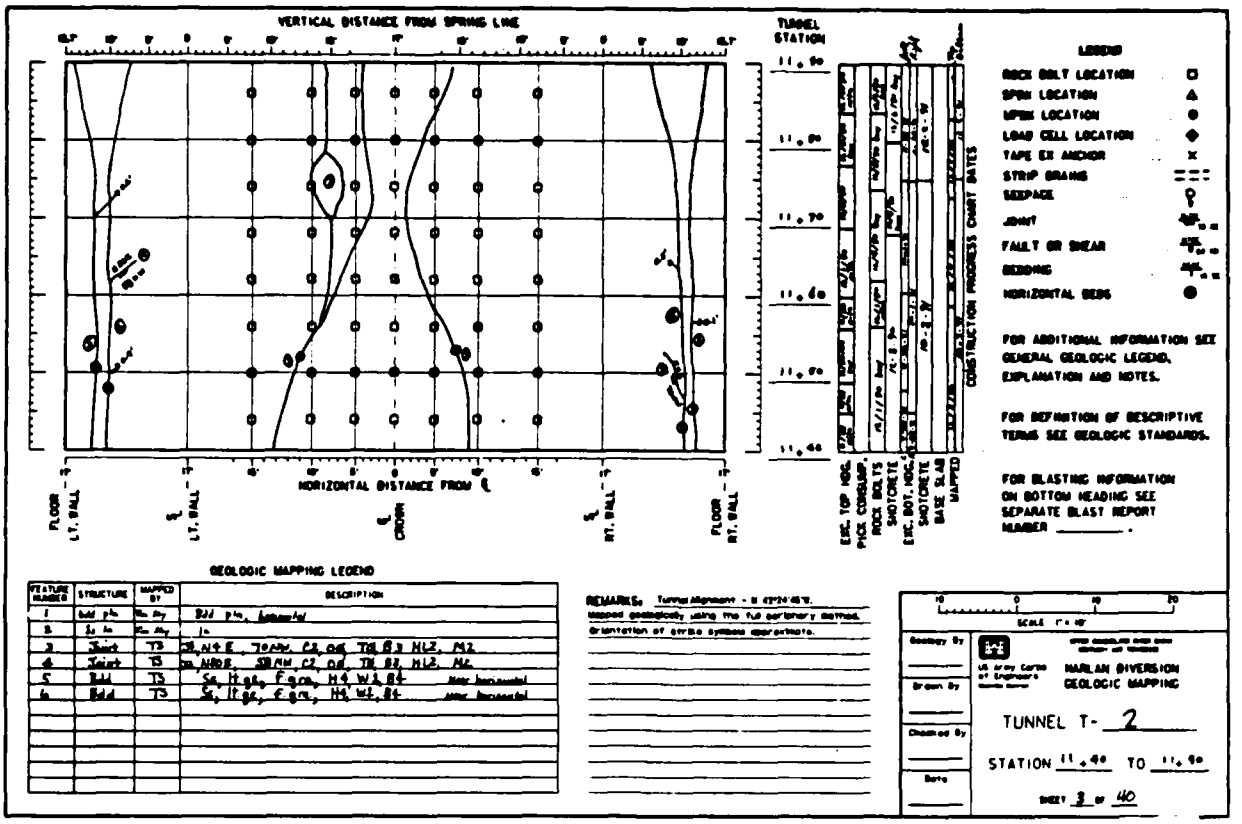
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Drawn By:
Checked By:
Date:

TUNNEL T- 2

STATION 10+90 TO 11+40

SHEET 2 OF 40

PLATE D-28



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	Bdd pln, [illegible]
2	Jn	[illegible]	Jn
3	Joint	TS	38, N4E, 70NW, C2, OR, TR 83, HL2, M2
4	Joint	TS	28, N88E, 58NW, C2, OR, TR 82, HL2, M2
5	Bdd	TS	Ss, ltgy, fgrn, H4, W1, B4 Near horizontal
6	Bdd	TS	Ss, ltgy, fgrn, H4, W1, B4 Near horizontal

REMARKS: Tunnel Alignment - S 47°24'45"E. Mapped geologically using the full perimeter method. Orientation of strike symbols approximate.

SCALE 1" = 10'

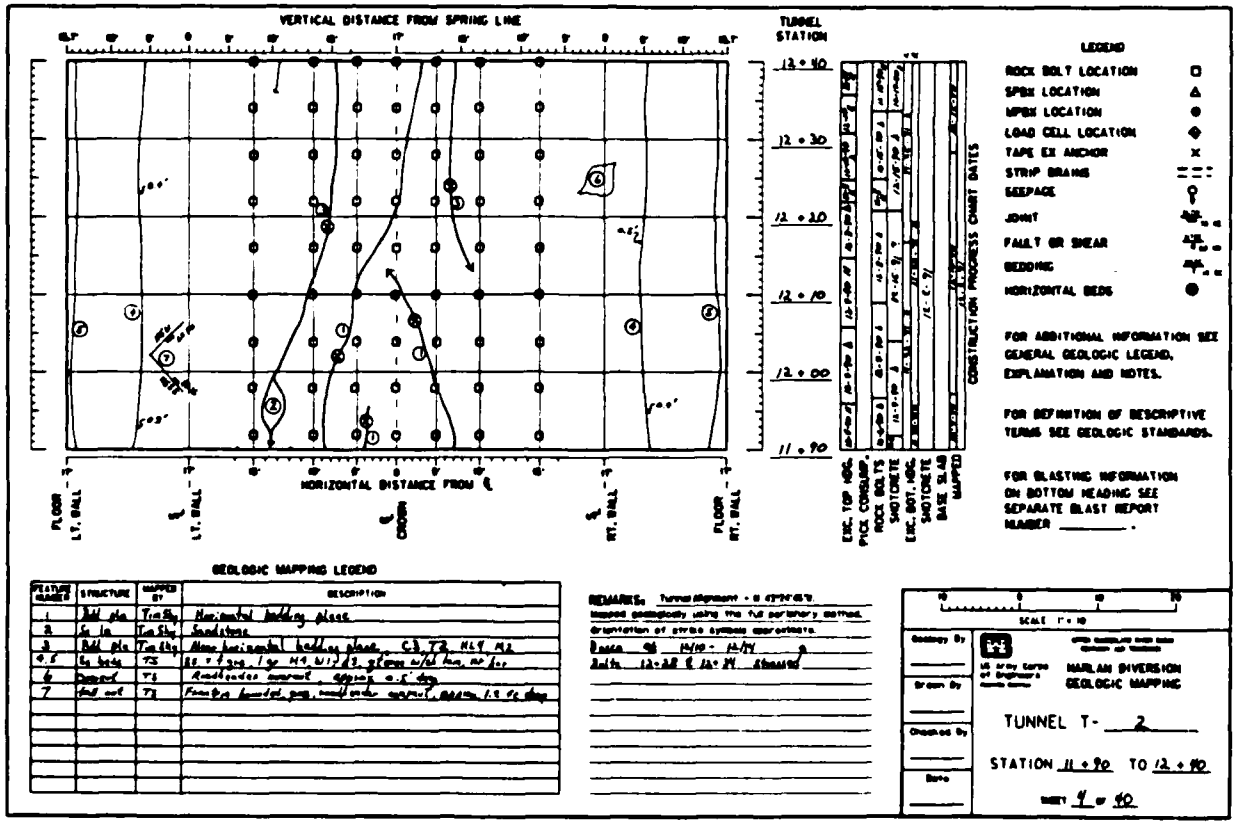
Geology By
Drawn By
Checked By
Date

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TUNNEL T- 2

STATION 11+40 TO 11+90

SHEET 3 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tim Sky	Horizontal bedding plane
2	Sc In	Tim Sky	Sandstone
3	Bdd pln	Tim Sky	Near horizontal bedding plane, C3, T3, HL4, M2
4,5	Sy beds	TS	Ss + fgrn / Sc H4, W1-2, B3 grades w/in bed, no fol.
6	Dyke	TS	Rhyolite dike
7	Bdd out	TS	Fine to [illegible] grn, rhyolite dike, 080°W, 1.5' ft dip

REMARKS: Tunnel Alignment - S 47°24'45"E. Mapped geologically using the full perimeter method. Orientation of strike symbols approximate.

Date 9/6 10/10 - 11/17

Date 12-28 & 12-29 Shawn

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

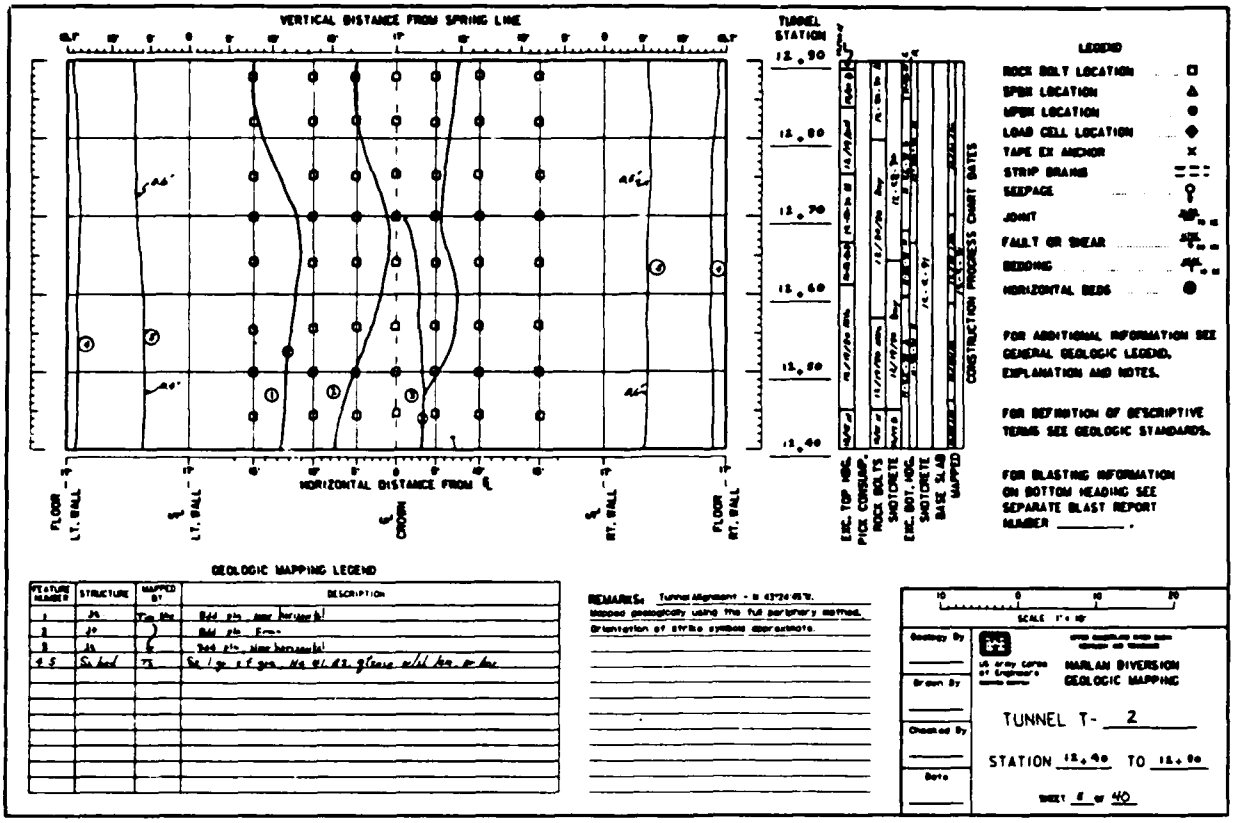
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TUNNEL T- 2

STATION 11+90 TO 12+40

SHEET 4 OF 40

PLATE D-29



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Jn	Tm Rm	Bdd plane near horizontal
2	Jn		Bdd plane Erratic
3	Jn		Bdd plane, near horizontal
4 5	Sh bnd	TC	Sh 1 gp 1 set gns. HS 0/1 A2 g'mass m/il bng. w dec

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

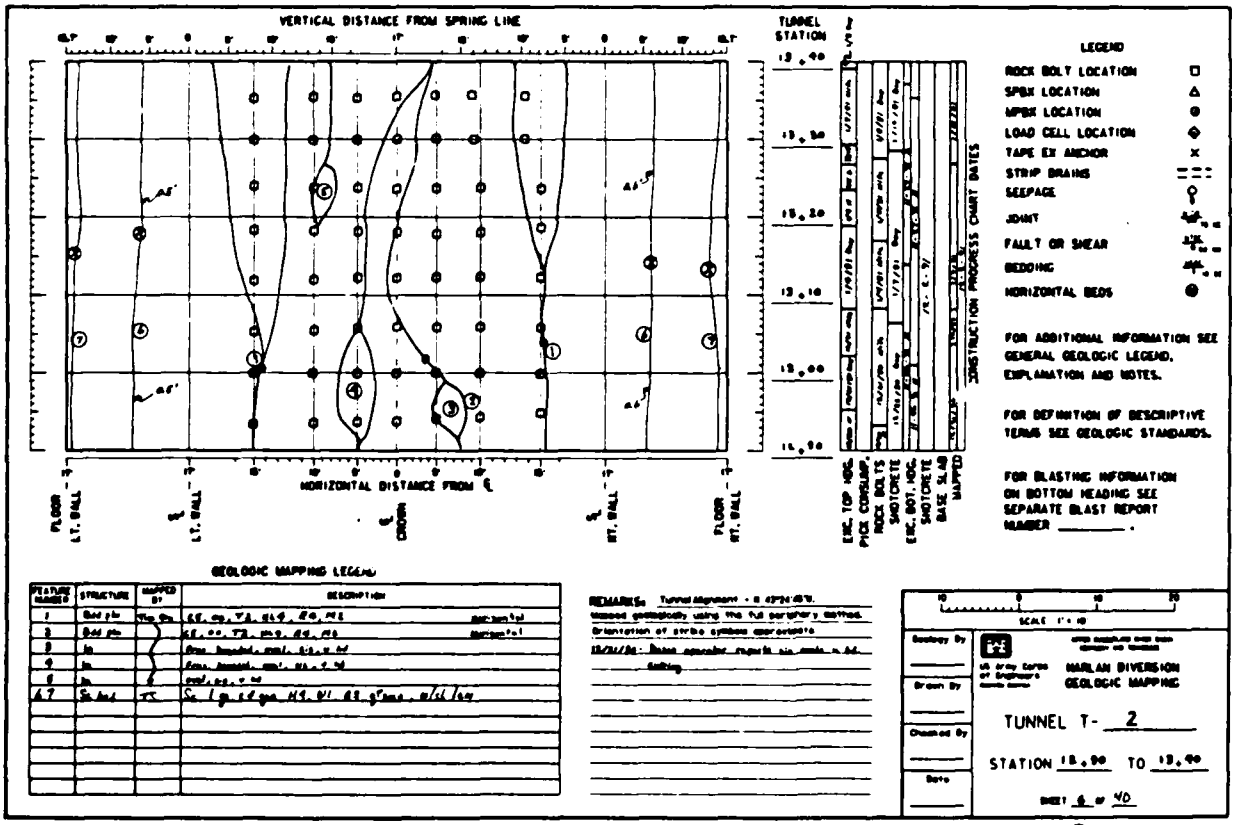
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 13+40 TO 13+90

SHEET 4 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	Tm Rm	EE. dip, 72, dip, 80, NE
2	Bdd plane		EE. dip, 72, dip, 80, NE
3	Jn		Rmn. bedded, mod. to v. w hd
4	Jn		Rmn. bedded, mod. to v. w hd
5	Jn		mod. to v. w hd
6 7	Sh bnd	TC	Sh 1 gp 1 set gns. HS 0/1 A2 g'mass. m/il bng

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
10/31/86: Rmn. opposite reports six weeks w hd. caving.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

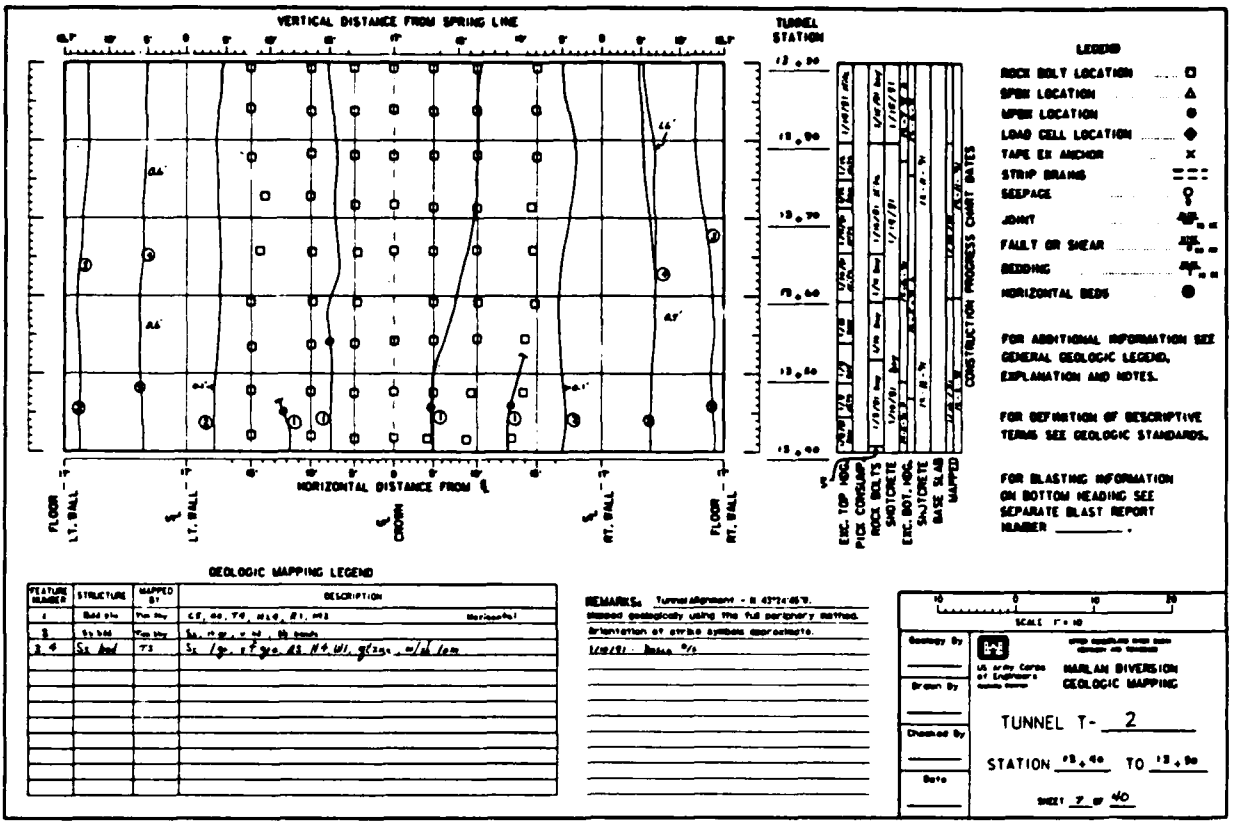
TUNNEL T- 2

STATION 13+90 TO 13+40

SHEET 6 OF 40

P.C.4

PLATE D-30


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 13+40 TO 13+90
SHEET 7 OF 40

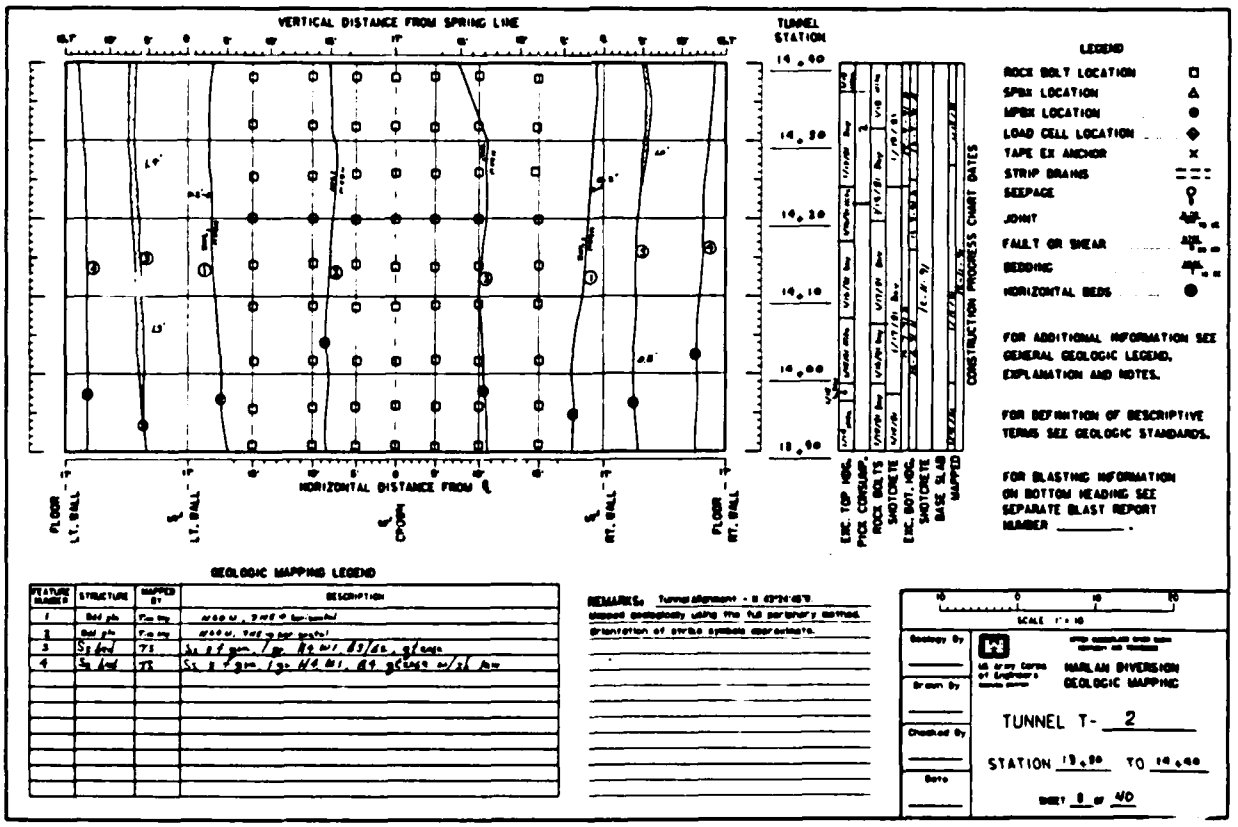
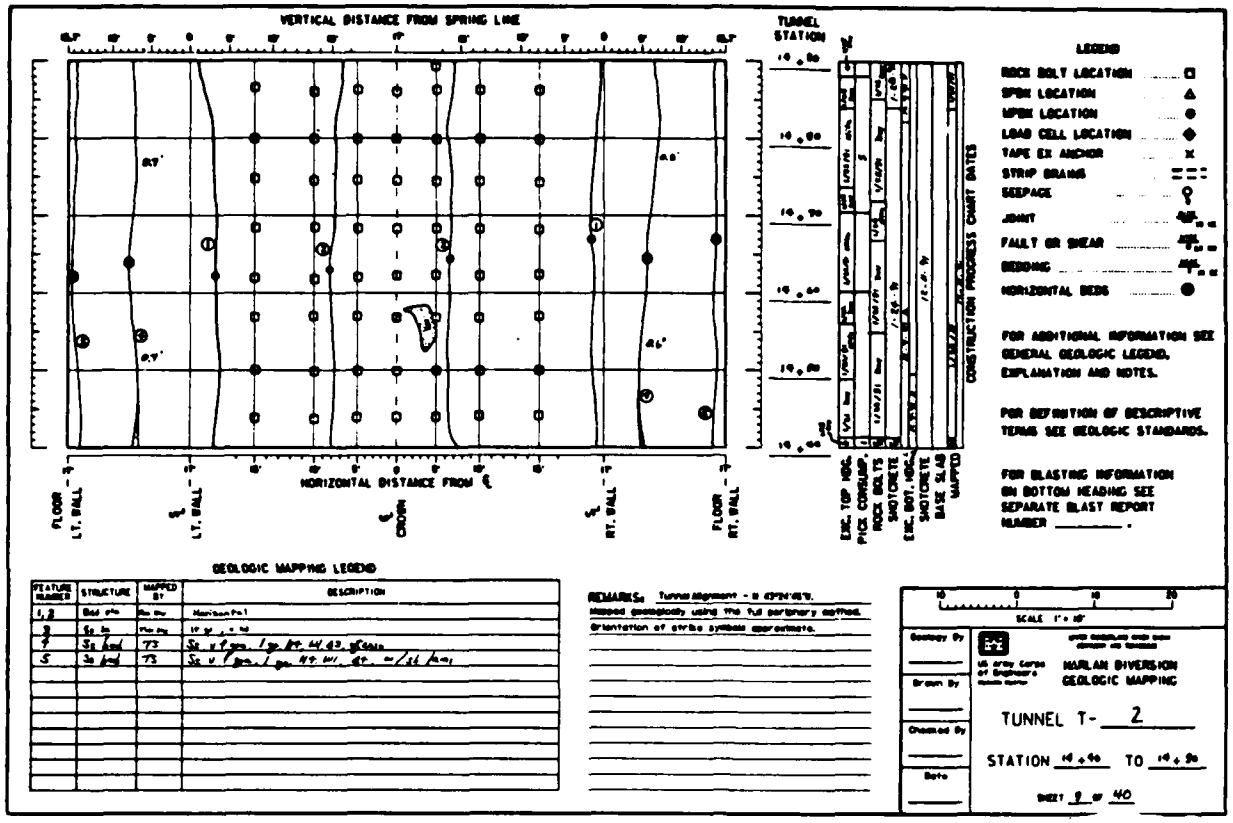

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 13+90 TO 14+40
SHEET 8 OF 40

PLATE D-31



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Bdd plane	Mc Coy	Horizontal
3	Sh Jt	Mc Coy	17° W, + 10
4	Sh Joint	TG	Sh v f gm, l gr RY 4/4 63. gSmith
5	Sh Joint	TG	Sh v f gm, l gr RY 4/4 61. ~/21 Jones

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

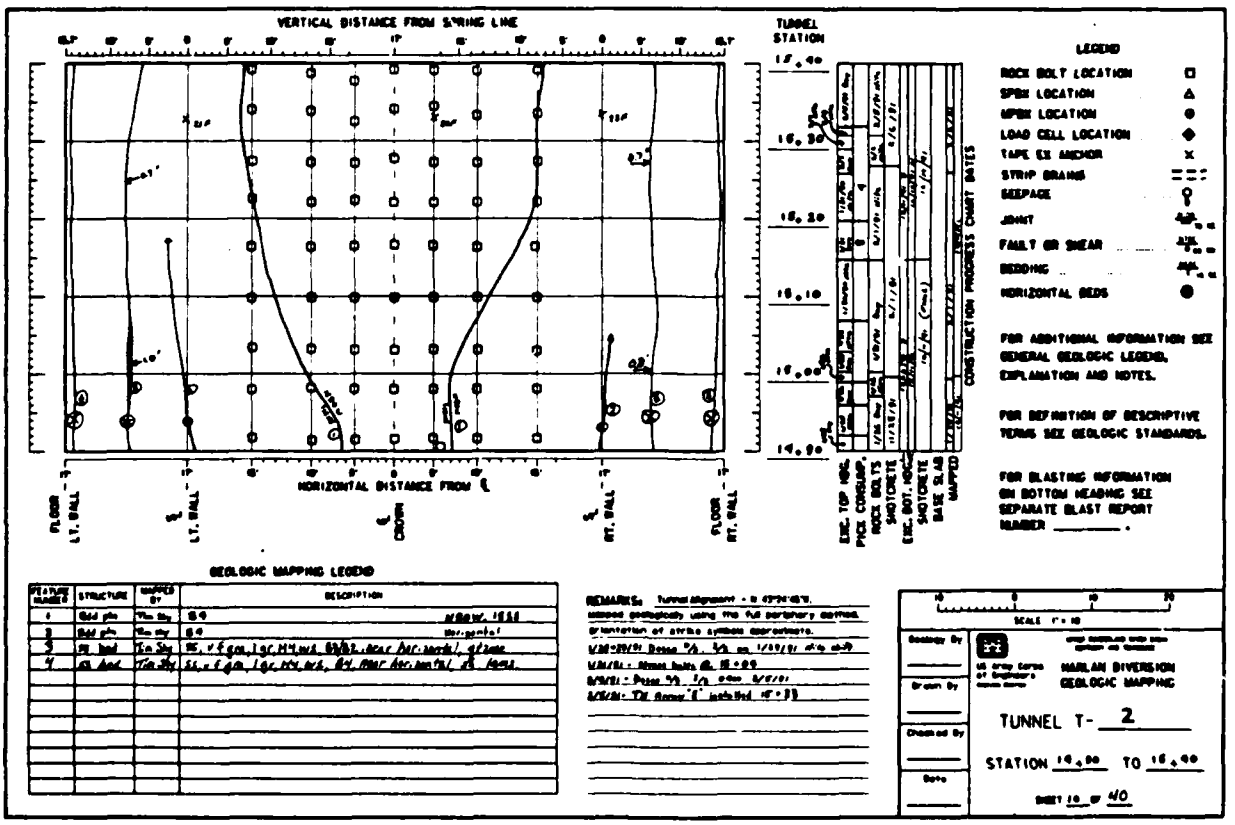
U.S. Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 19+90 TO 19+30

SHEET 9 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	Mc Coy	BG
2	Bdd plane	Mc Coy	BG
3	Sh Joint	Mc Coy	NS, v f gm, lgr, MH, wk, SMBS, clay bet. sands, gSmith
4	Sh Joint	Mc Coy	EW, v f gm, lgr, MH, wk, BG, clay bet. sands, JS Jones

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
1/28-29/91: Drove 7'6 in 1/2 on 1/30/91 at 6:45 AM
1/31/91: Mined holes @ 18+89
2/1/91: Drove 5'6 in 1/2 on 2/2/91
2/5/91: TBM Runner 'E' installed at 19+93

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers

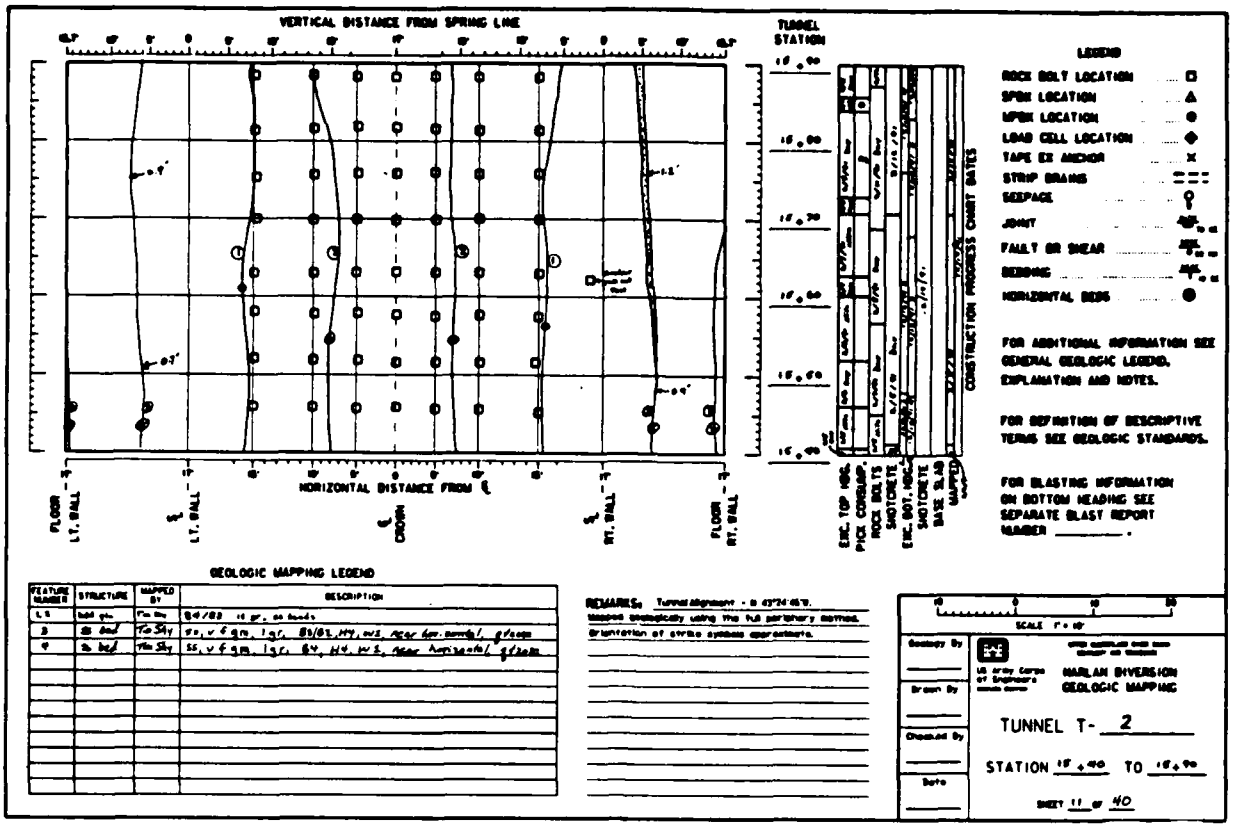
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 19+90 TO 18+40

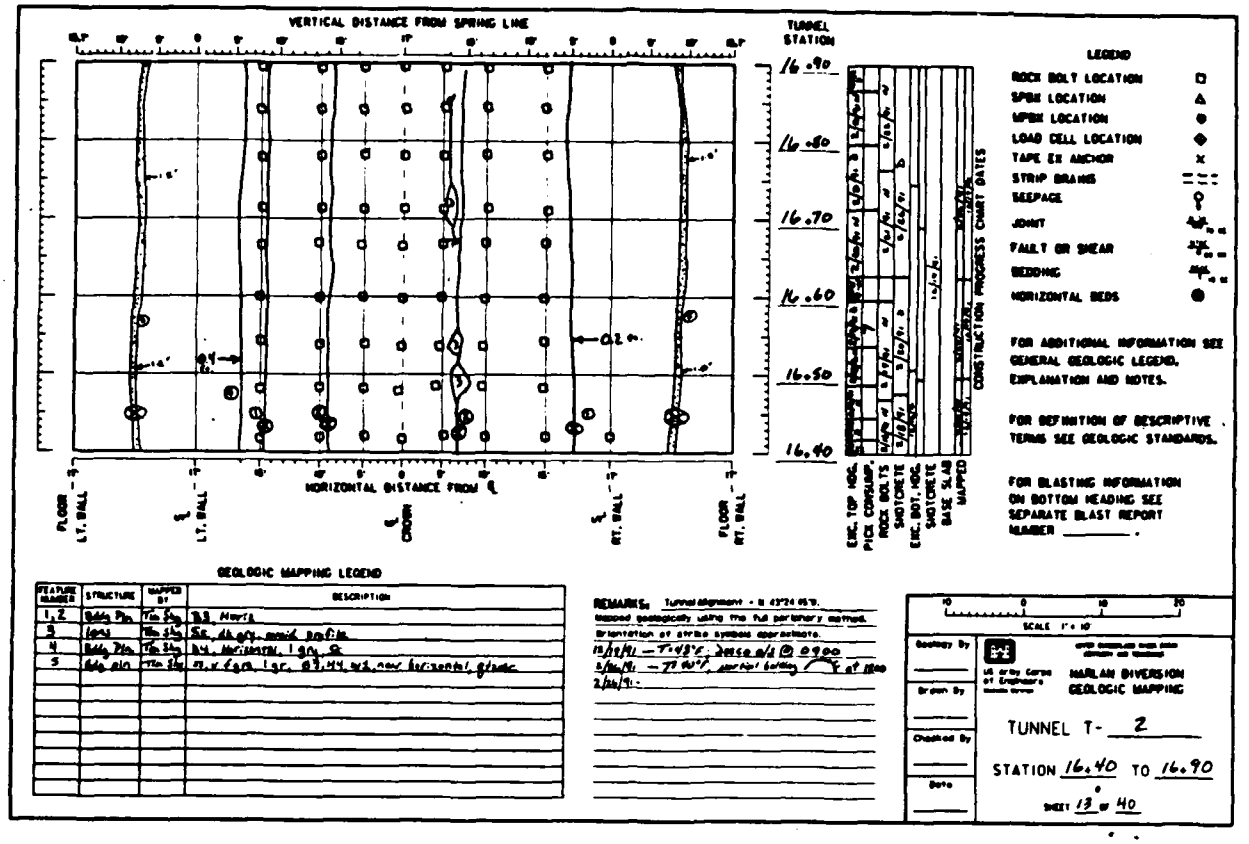
SHEET 10 OF 40

PLATE D-32


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
16+40
16+30
16+20
16+10
16+00
15+90
HORIZONTAL DISTANCE FROM ℄
FLOOR – LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR – RT. WALL
ENC. TOP HDG. PICK CORRUGP.
ROCK BOLTS
SHOTCRETE
ENC. BOT. HDG. SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPRING LOCATION
WEEP LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel alignment = S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 15+90 TO 16+40
SHEET 12 OF 40

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
16+40
16+30
16+20
16+10
16+00
15+90
HORIZONTAL DISTANCE FROM ℄
FLOOR – LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR – RT. WALL
ENC. TOP HDG. PICK CORRUGP.
ROCK BOLTS
SHOTCRETE
ENC. BOT. HDG. SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPRING LOCATION
WEEP LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel alignment = S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 15+90 TO 16+40
SHEET 12 OF 40

PLATE D-33



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Bdy, Pln	TM, SM	B3, Horiz
3	Joint	TM, SM	Sil, dk gry, smooth, planar
4	Bdy, Pln	TM, SM	B4, Horizontal, 1 gry, Sil
5	Bdy, pln	TM, SM	B3, v f gra, 1 gr, B3, W3, near horizontal, glassy

REMARKS: Tunnel alignment = N 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
10/29/91 – T-45°E, Dasco a/i @ 0900
2/26/91 – T-70-80°E, portal building @ 1100
2/26/91: -

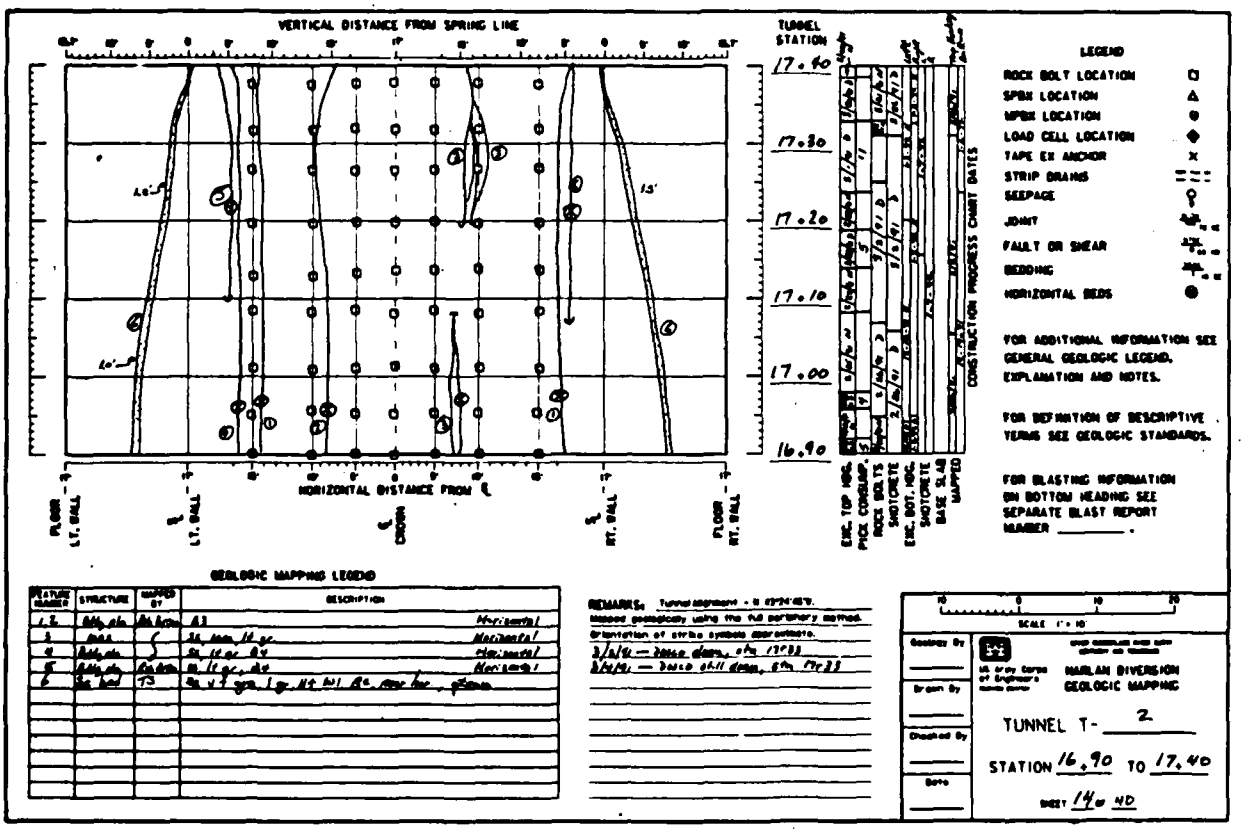
SCALE 1" = 10'

Geology By _____
Drawn By _____
Checked By _____
Date _____

US Army Corps of Engineers
Alaska District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 16+40 TO 16+90
SHEET 13 of 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Bdy, pln	RA, SM	B3	Horizontal
3	Joint	[illegible]	Sil, dark, 10 gr	Horizontal
4	Bdy, pln	RA, SM	Sil, 10 gr, B4	Horizontal
5	Bdy, pln	RA, SM	Sil, 10 gr, B4	Horizontal
6	Bdy, pln	TM	Sil, v f gra, 1 gr, B3, W1, Ro, near hor, glassy

REMARKS: Tunnel alignment = N 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
2/6/91 – Dasco diam, 6th 1703
2/6/91 – Dasco drill diam, 6th 1733

SCALE 1" = 10'

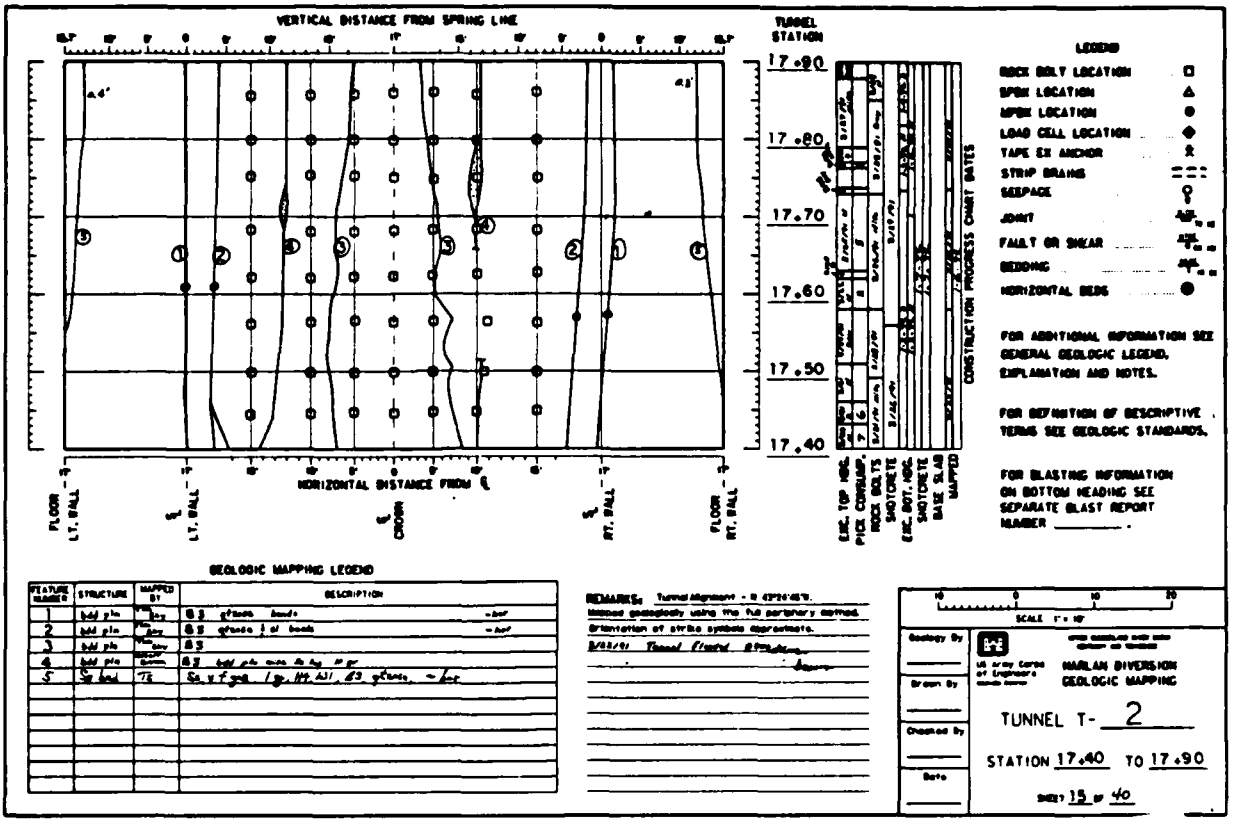
Geology By _____
Drawn By _____
Checked By _____
Date _____

US Army Corps of Engineers
Alaska District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 16+90 TO 17+40
SHEET 14 of 40

PLATE D-34


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
17+90
17+80
17+70
17+60
17+50
17+40
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
ERC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 17+40 TO 17+90
SHEET 15 OF 40

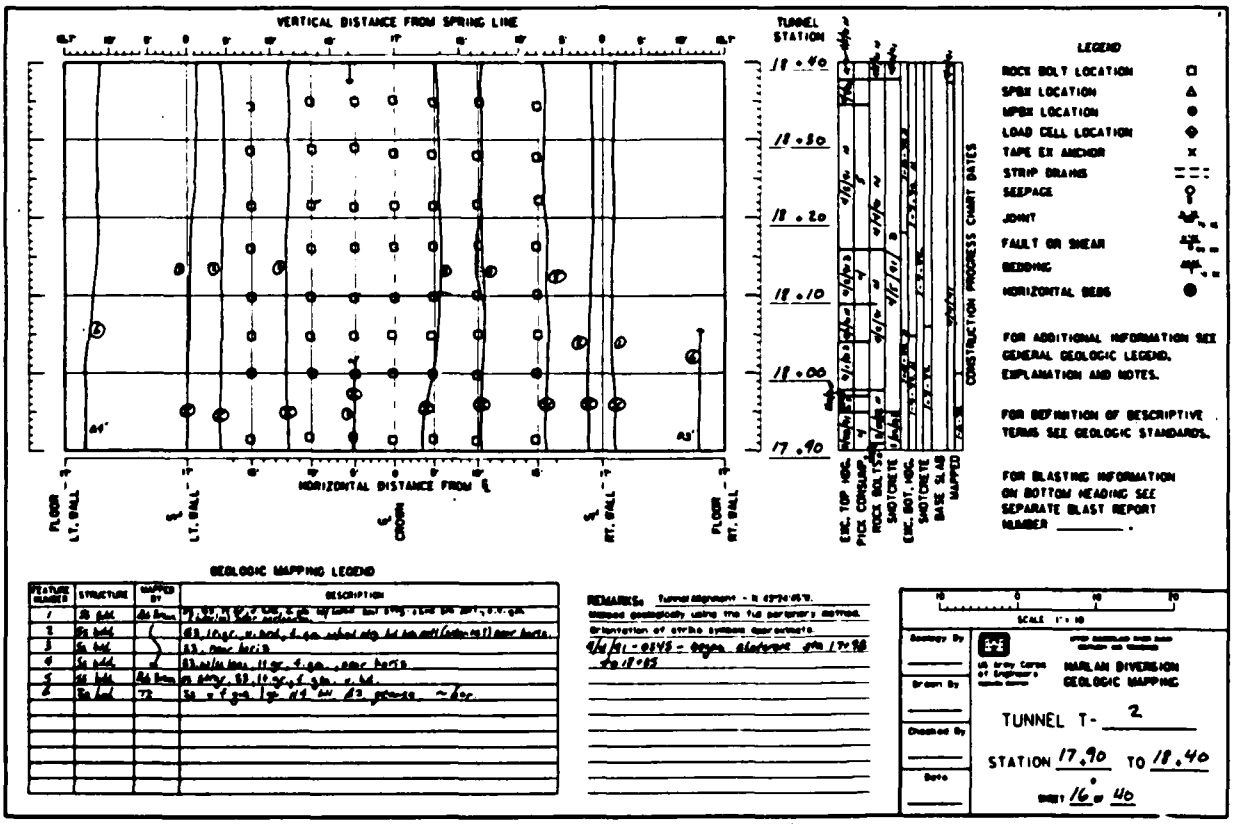
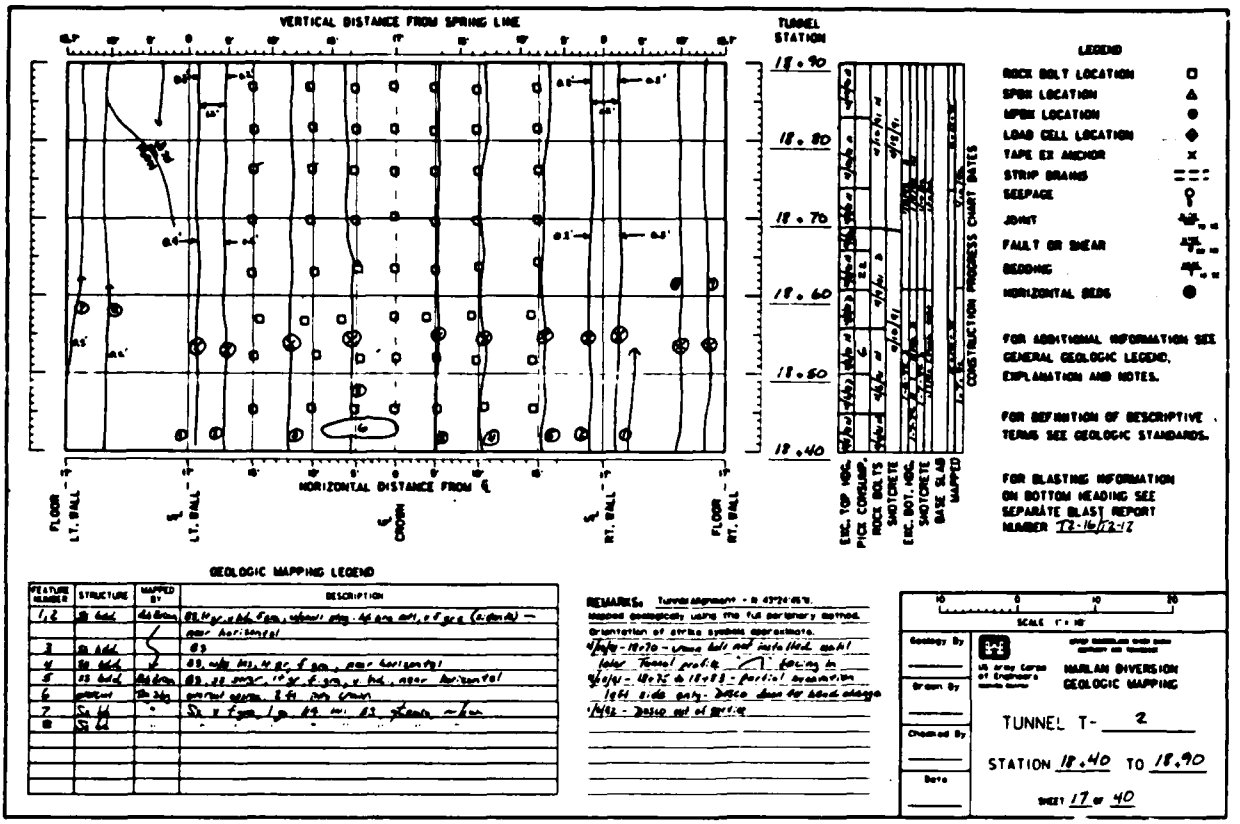

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
18+40
18+30
18+20
18+10
18+00
17+90
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
ERC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 17+90 TO 18+40
SHEET 16 OF 40

PLATE D-35



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2			
3			
4			
5			
6			
7			
8			

REMARKS: Tunnel alignment - 0 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
4/26/91 - 18+70 - crown bolt not installed, mesh later. Face mapped/ profile ___ facing in
4/29/91 - 18+35 to 18+88 - partial excavation
5/1/91 - 18+40 only - Detail done for blast design
5/4/91 - Detail out of service

SCALE 1" = 10'

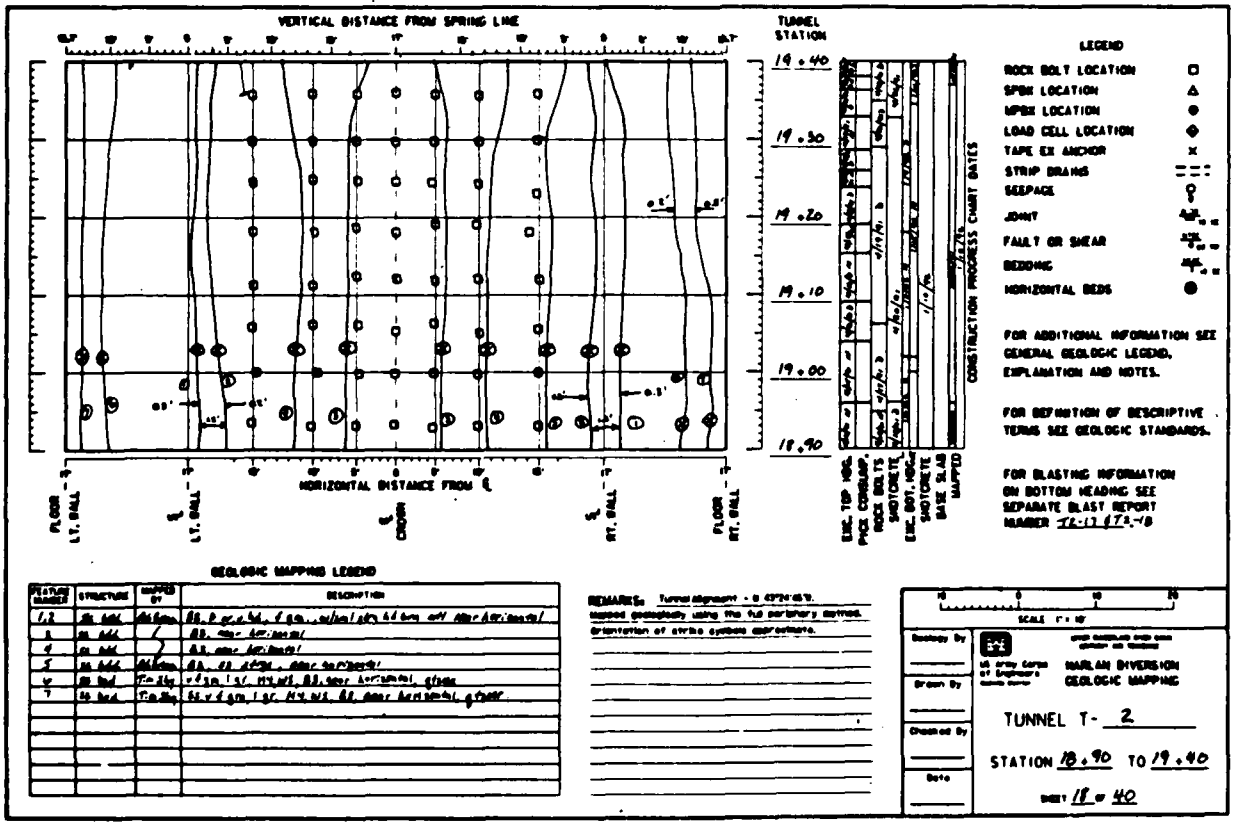
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 18+40 TO 18+90

SHEET 17 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2			
3			
4			
5			
6			
7			
8			

REMARKS: Tunnel alignment - 0 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

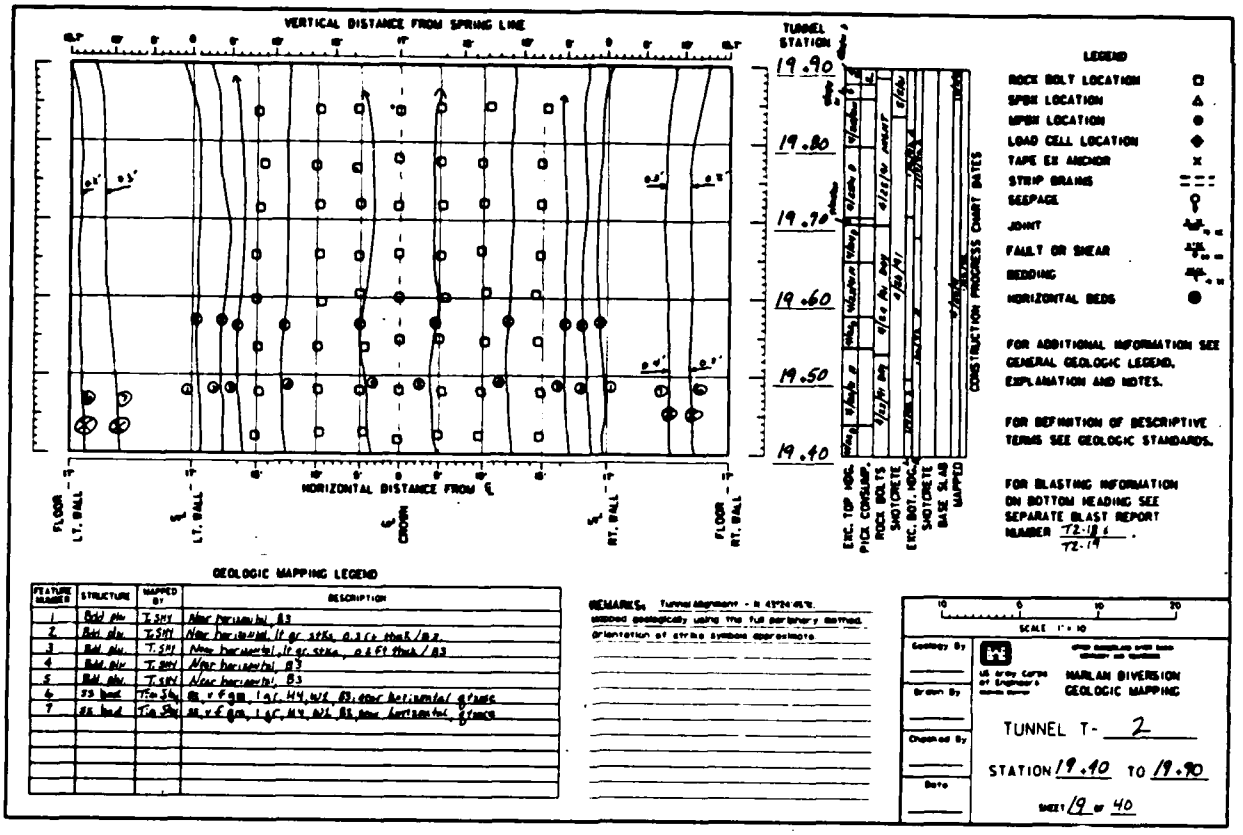
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 18+90 TO 19+40

SHEET 18 OF 40

PLATE D-36



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plu	T. SHY	Near horizontal, B3
2	Bdd plu	T. SHY	Near horizontal, lt gr strks, 0.3 ft thick / B2
3	Bdd plu	T. SHY	Near horizontal, lt gr strks, 0.5 ft thick / B3
4	Bdd plu	T. SHY	Near horizontal B3
5	Bdd plu	T. SHY	Near horizontal B3
6	SS bed	Tm Shy	SS, v f gm, lgy, MW, W1, B3, near horizontal, grades
7	SS bed	Tm Shy	SS, v f gm, lgy, MW, W1, B3, near horizontal, grades

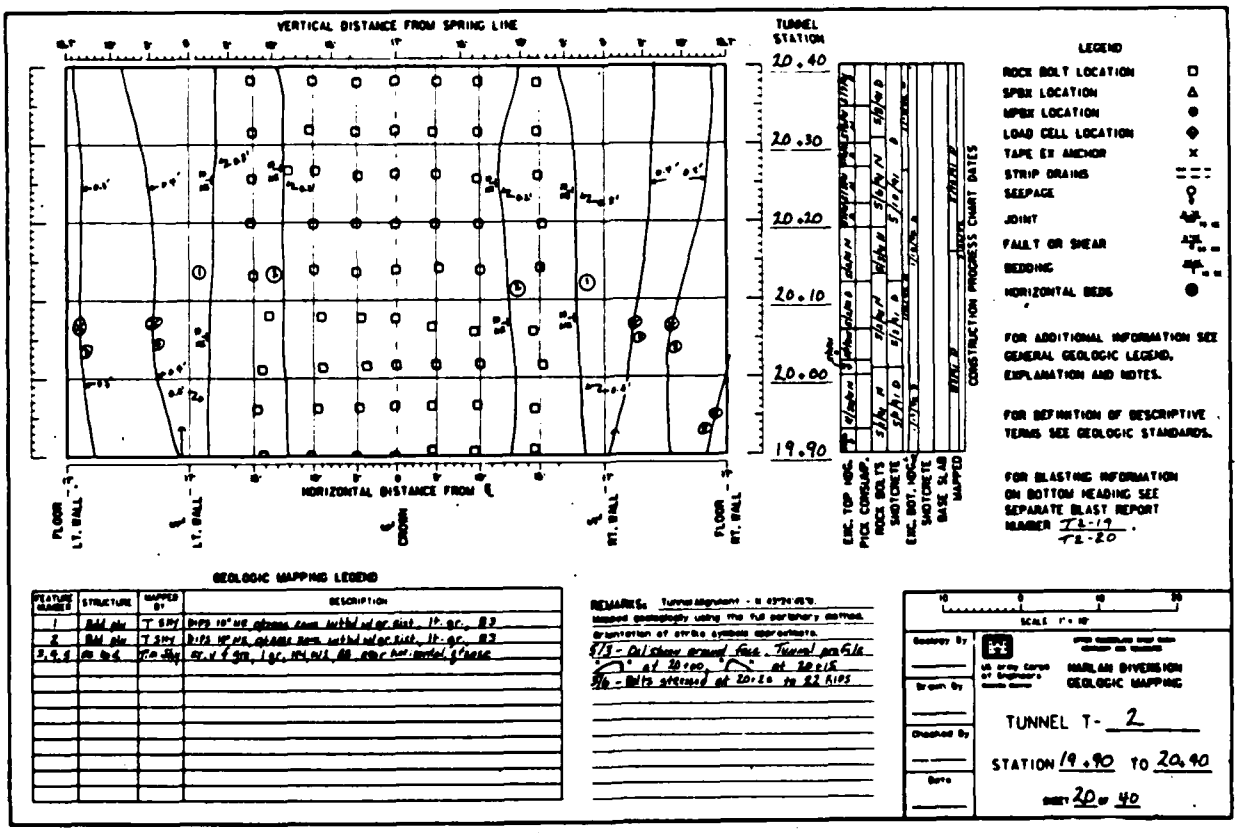
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Alaska District
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 19+90 TO 19+90
SHEET 19 of 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plu	T. SHY	Dips 10° NE, gtranite zone, vertical w/ gr strk, lt. gr., B3
2	Bdd plu	T. SHY	Dips 10° NE, gtranite zone, vertical w/ gr strk, lt. gr., B3
3, 4, 5	SS bed	Tm Shy	gr, v f gm, lgy, MW, W1, B3, near horizontal, grades

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
5/3 - Oil sheen around face. Tunnel profile at 20+00, 5° at 20+15
5/6 - Bolts stressed at 20+20 to 82 KIPS

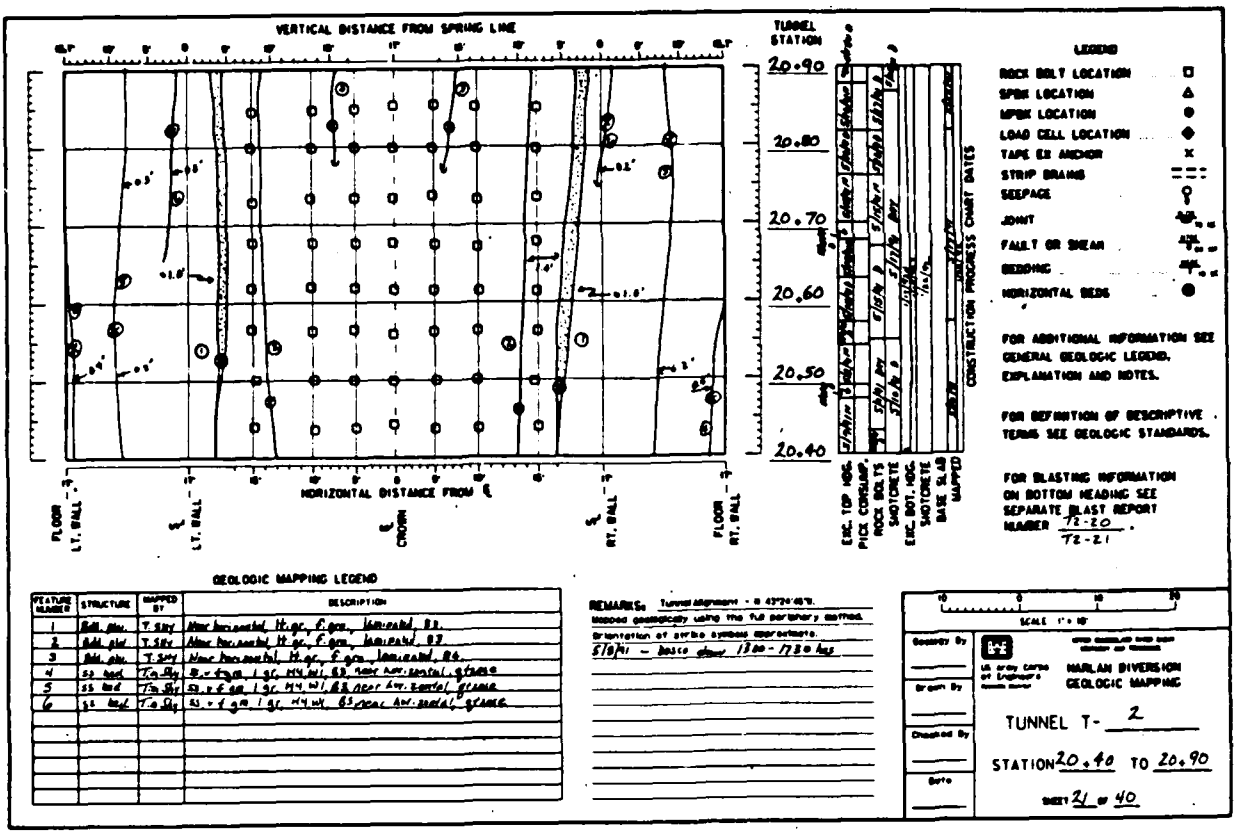
SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Alaska District
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 19+90 TO 20+40
SHEET 20 of 40

PLATE D-37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. plu.	T. Sitz	Mine horizontal, lt. gr., f. grn., laminated, 83.
2	Bdd. plu.	T. Sitz	Mine horizontal, lt. gr., f. grn., laminated, 83.
3	Bdd. plu.	T. Sitz	Mine horizontal, lt. gr., f. grn., laminated, 84.
4	ss bed	Tim Sitz	SS, v f grn, lgr, HW, MI, 83, near hor. bedd, grains
5	ss bed	Tim Sitz	SS, v f grn, lgr, HW, MI, 83, near hor. bedd, grains
6	ss bed	Tim Sitz	SS, v f grn, lgr, HW, MI, 83, near hor. bedd, grains

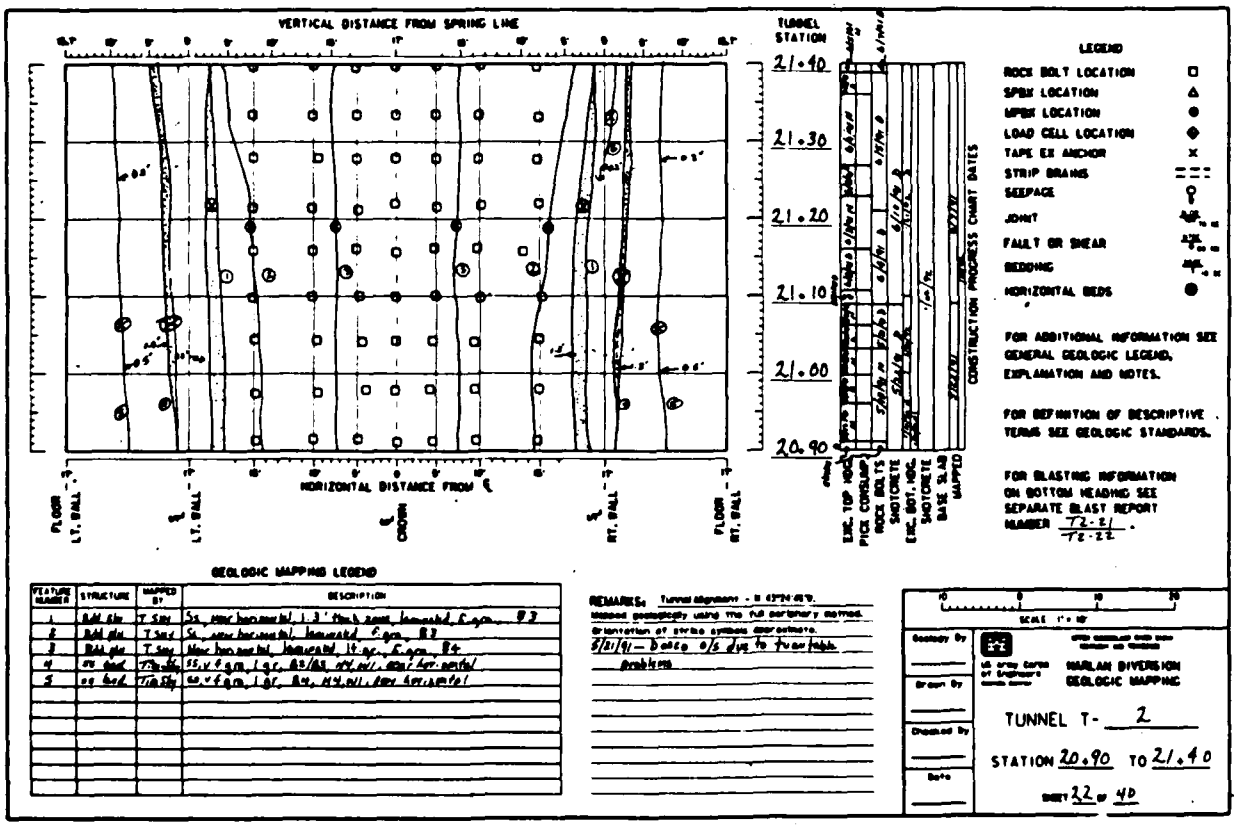
REMARKS: Tunnel alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
5/8/91 - Basic above 1180 - 1130 hrs

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 20.40 TO 20.90
SHEET 21 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. plu.	T. Sitz	SS, mine horizontal, 3' thick, near laminated, f. grn. 83
2	Bdd. plu.	T. Sitz	SS, mine horizontal, laminated, f. grn. 83
3	Bdd. plu.	T. Sitz	Mine horizontal, laminated, lt. gr., f. grn. 84
4	ss bed	Tim Sitz	SS, v f grn, lgr, 83/84, HW, MI, near hor. bedd
5	ss bed	Tim Sitz	SS, v f grn, lgr, 84, HW, MI, near hor. bedd

REMARKS: Tunnel alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
5/21/91 - Basic o/s due to fracturing problems

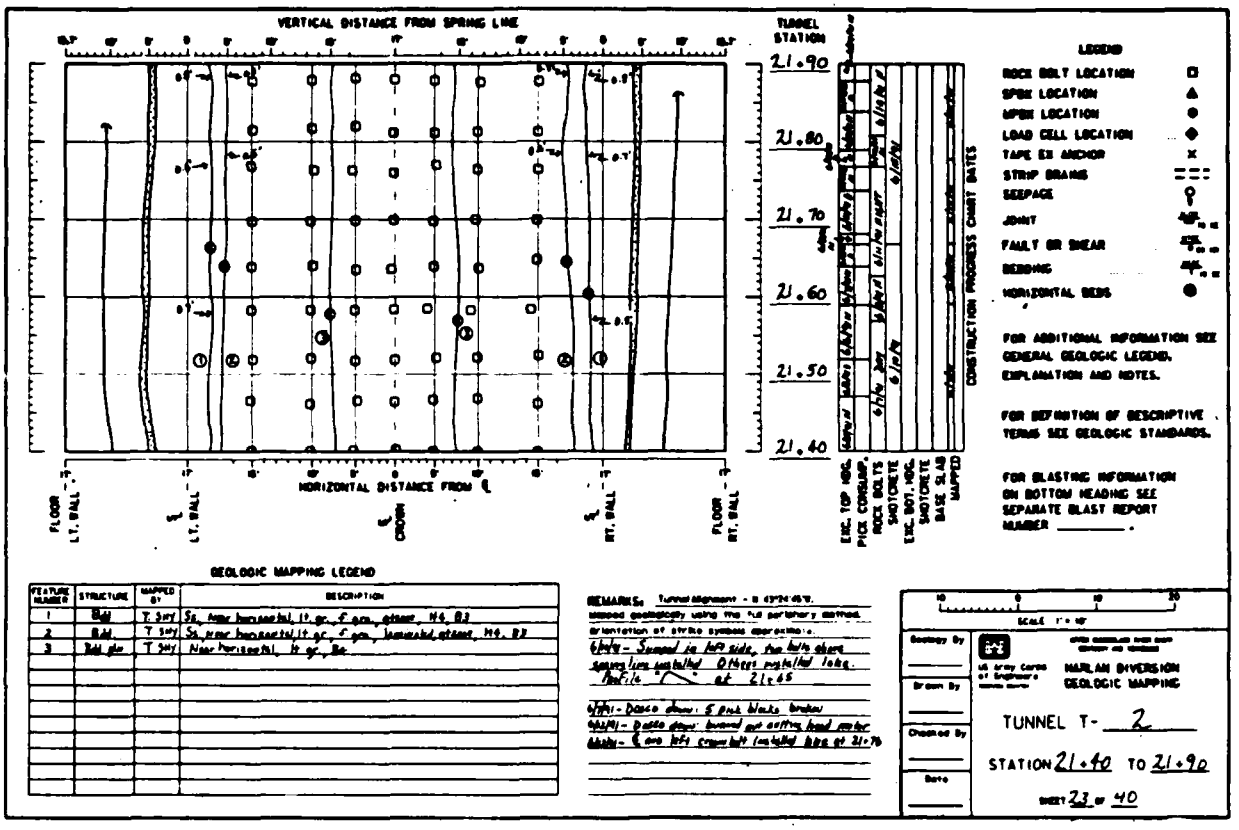
SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 20.90 TO 21.40
SHEET 22 OF 40

PLATE D-38


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
21.90
21.80
21.70
21.60
21.50
21.40
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
REMARKS:
Geology By
Drawn By
Checked By
Date
US army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 21+40 TO 21+90
SHEET 23 OF 40

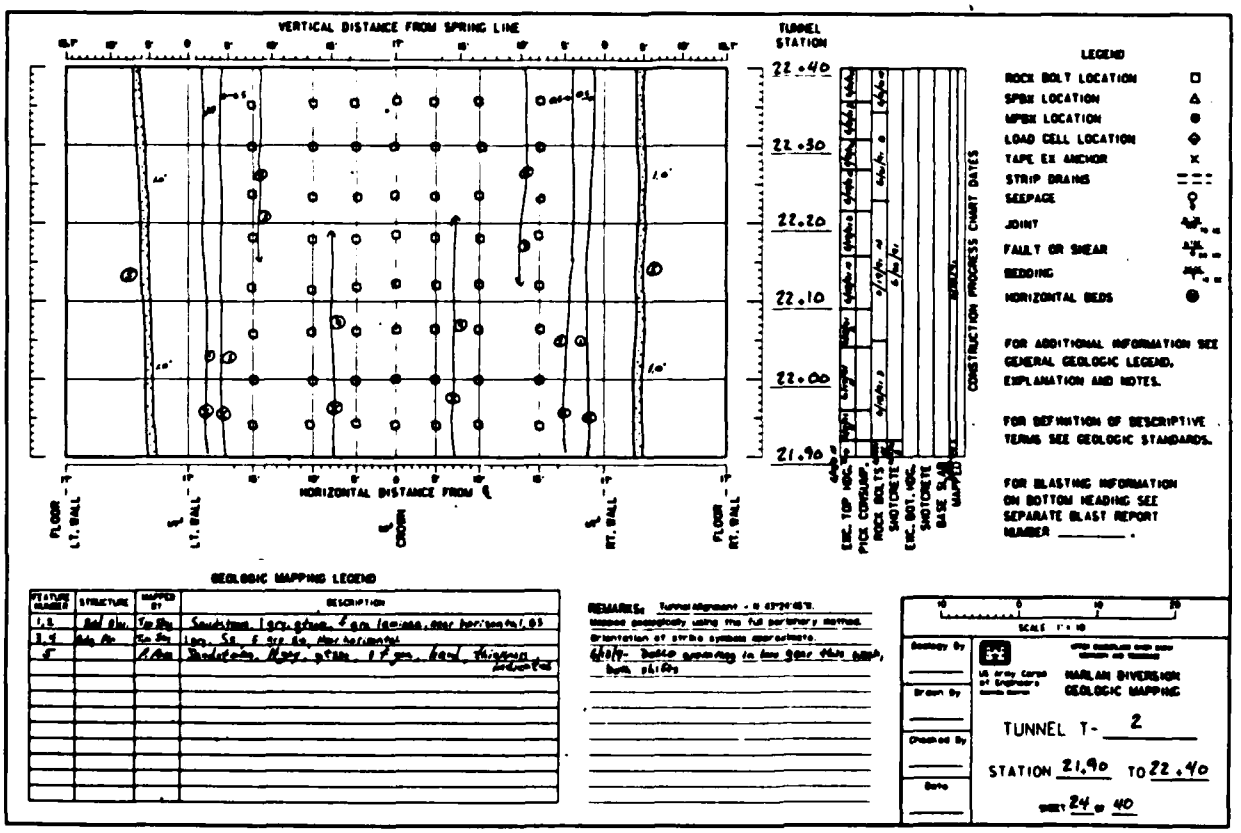
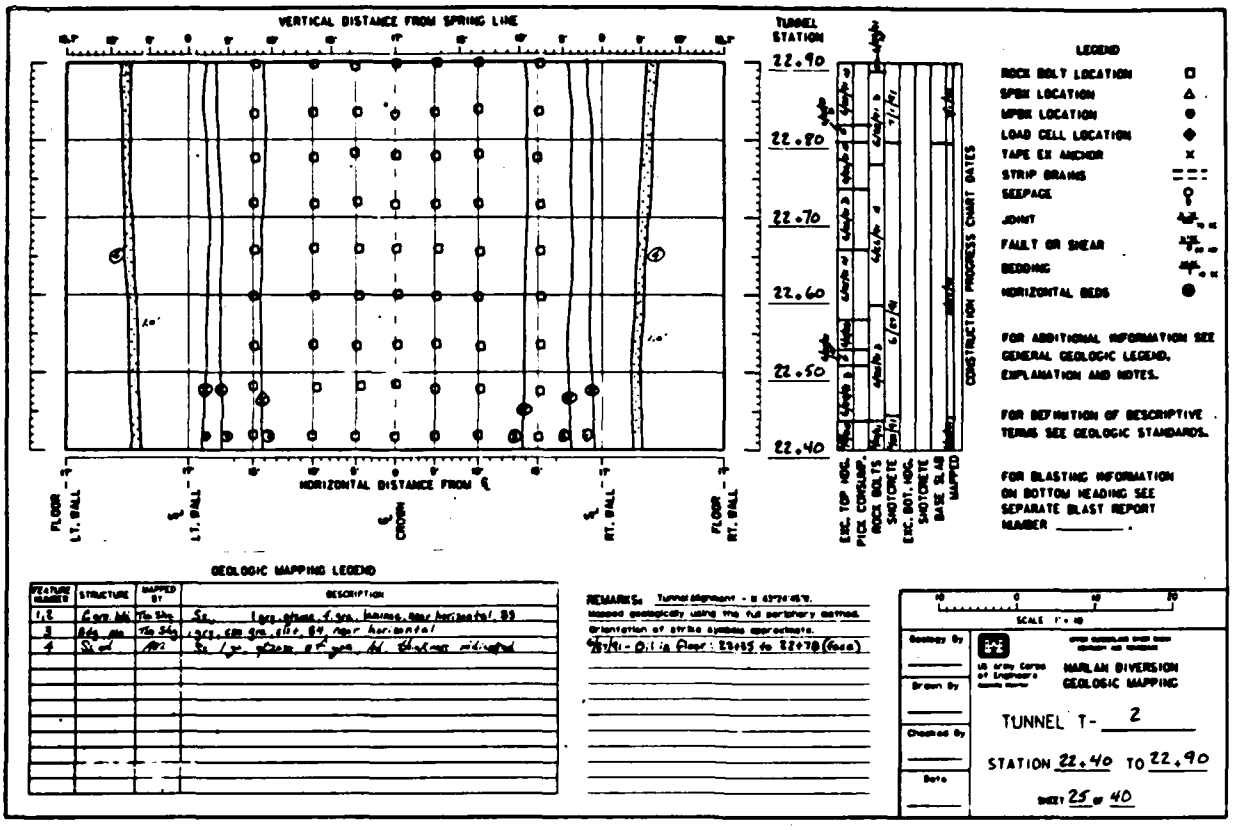

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
22.40
22.30
22.20
22.10
22.00
21.90
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
REMARKS:
Geology By
Drawn By
Checked By
Date
US army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 21.90 TO 22.40
SHEET 24 OF 40

PLATE D-39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Com blk	Tm Shq	Sc, 1 grs, stone, 1 gm, bedding, near horizontal, 85
3	Bdg Pln	Tm Shq	1 grs, stn gm, silt, 84 near horizontal
4	Shear	MPX	Sc 1 gr stone, 8" gm, fol thickness mineralized

REMARKS: Tunnel alignment - S 63°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
9/9/81 - Ditch Floor: 22+85 to 22+78 (face)

SCALE 1" = 10

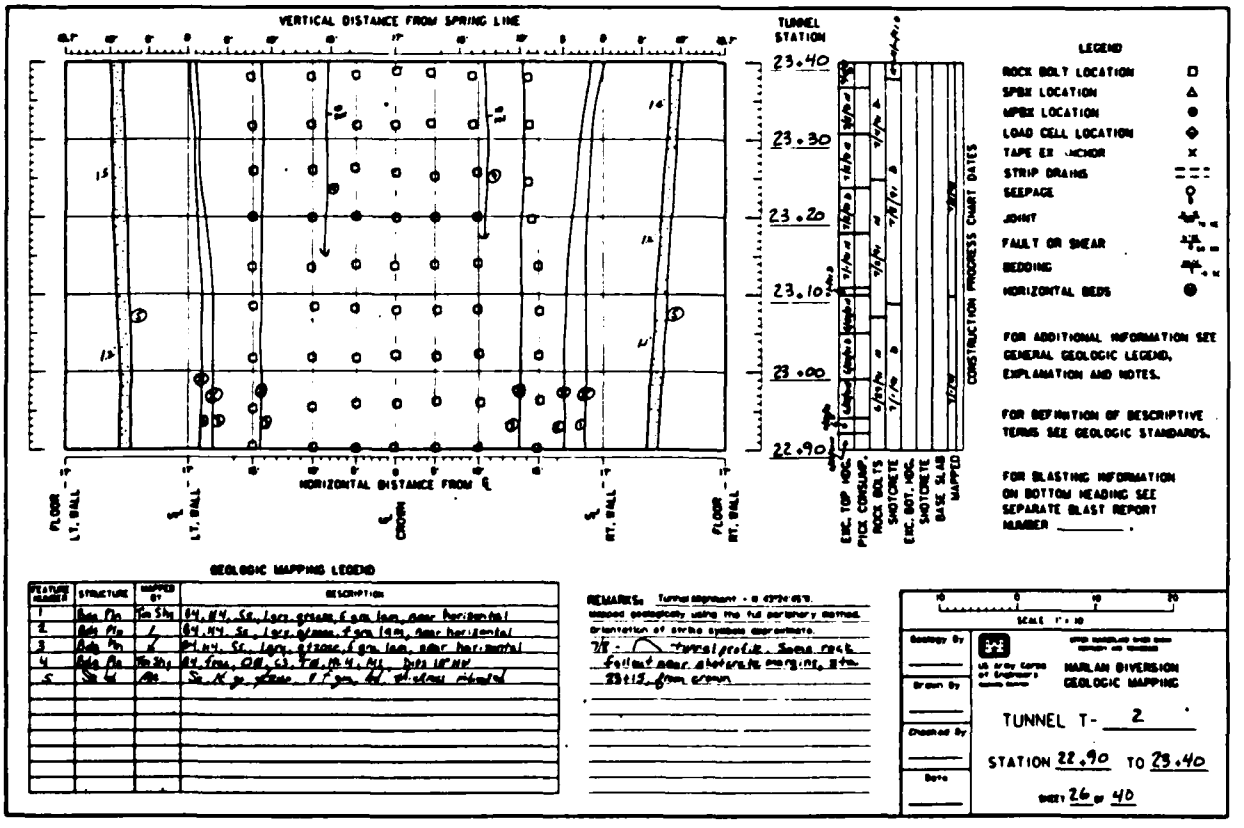
Geology By
Drawn By
Checked By
Date

USA Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 22.40 TO 22.90

SHEET 25 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	Tm Shq	84, NW, Sc, 1 grs, grease, 6 gm, lam, near horizontal
2	Bdg Pln	〃	84, NW, Sc, 1 grs, grease, 4 gm, lam, near horizontal
3	Bdg Pln	〃	84, NW, Sc, 1 grs, grease, 6 gm, lam, near horizontal
4	Bdg Pln	Tm Shq	84, fms, CSB, 63, FM, NW, NE, dips 18° NW
5	Shear	MPX	Sc, 1" gr stone, 1" gm, fol thickness mineralized

REMARKS: Tunnel alignment - S 63°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
9/8 - Transition: Sand rock, fault near alternate marking, 23+13 from crown

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

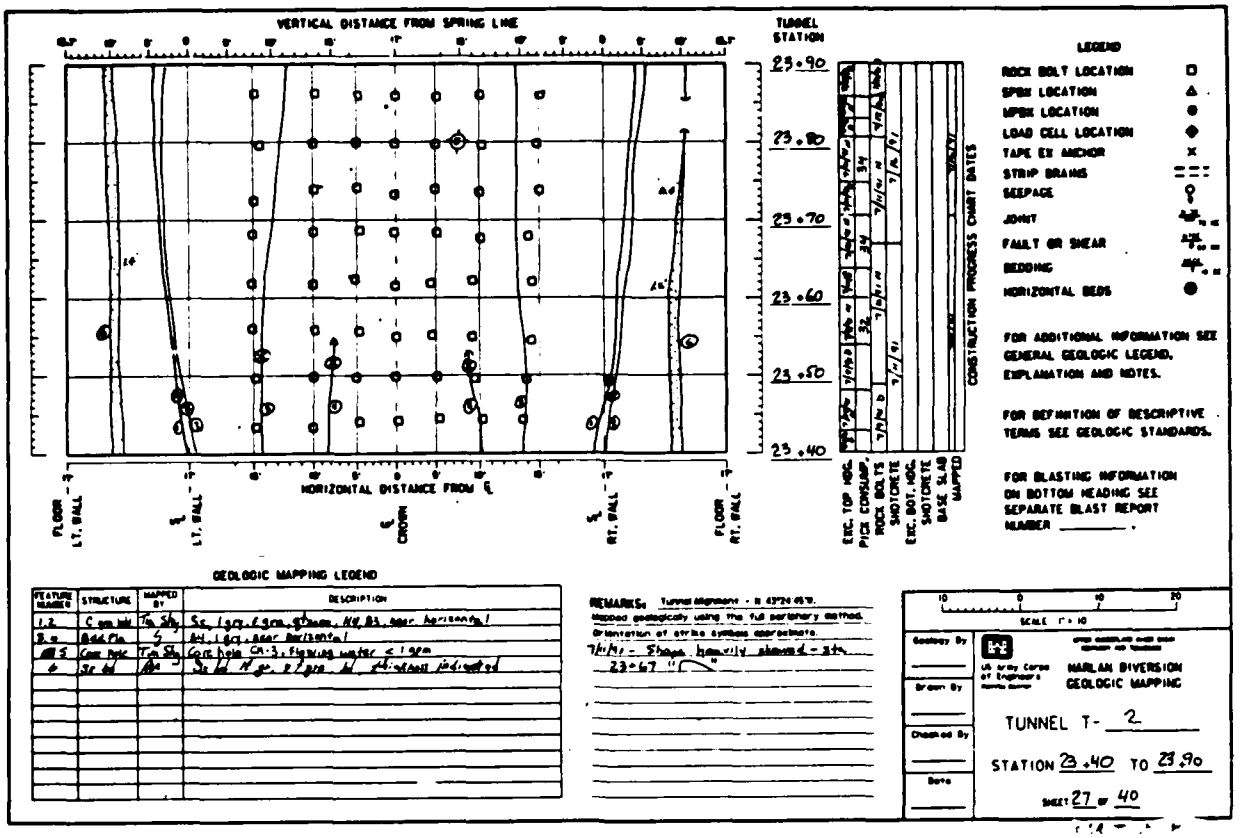
USA Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 22.90 TO 23.40

SHEET 26 OF 40

PLATE D-40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	C gm Intr	Tim Sky	Ss, lgr, f-gm, gthum, Hd, BS, occ horizontal
3	Bdd Pln	〃	Int. lgr, occ horizontal
4 & 5	Com Joint	Tim Sky	Core from CH-3, flowing water < 1 gpm
6	Sr Bd	Abt	Ss Int N gr, v f gm, Hd, thickness indicated

REMARKS: Tunnel alignment - S 43°24 45" E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/6/91 - Shows heavily sheared - 24+
23+67 "

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

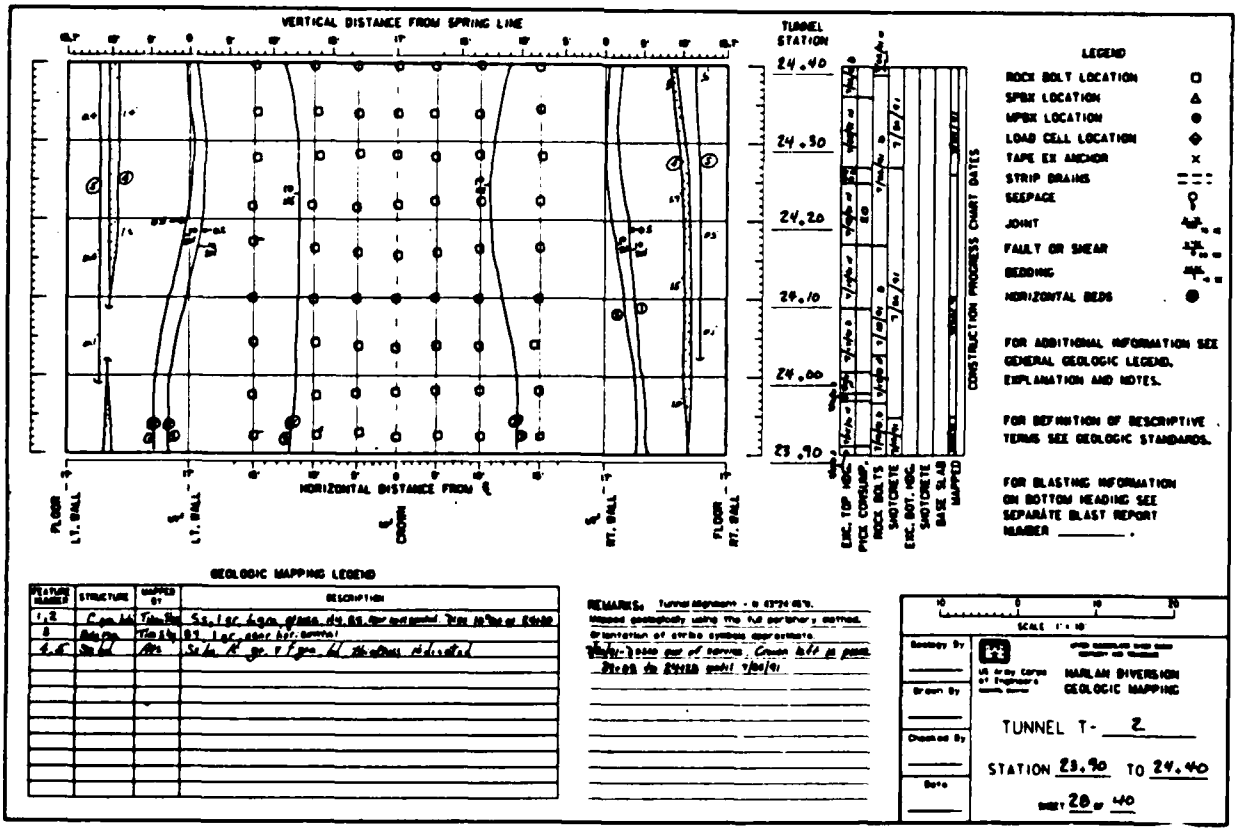
U.S. Army Corps of Engineers — Huntington District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 23+40 TO 23+90

SHEET 27 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	C gm Intr	Tim Sky	Ss, lgr, f-gm, gthum, Hd, BS, occ horizontal, Trim 18"Ss at 23+80
3	Bdd Pln	Tim Sky	BS, lgr, occ hor. bedding
4, 5	Sm Bd	Abt	Ss Int, M gr, v f gm, Hd, thickness indicated

REMARKS: Tunnel alignment - S 43°24 45" E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/6/91 - Shows one set of joints. Crown left in place.
Break in joints noted 7/26/91

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Huntington District

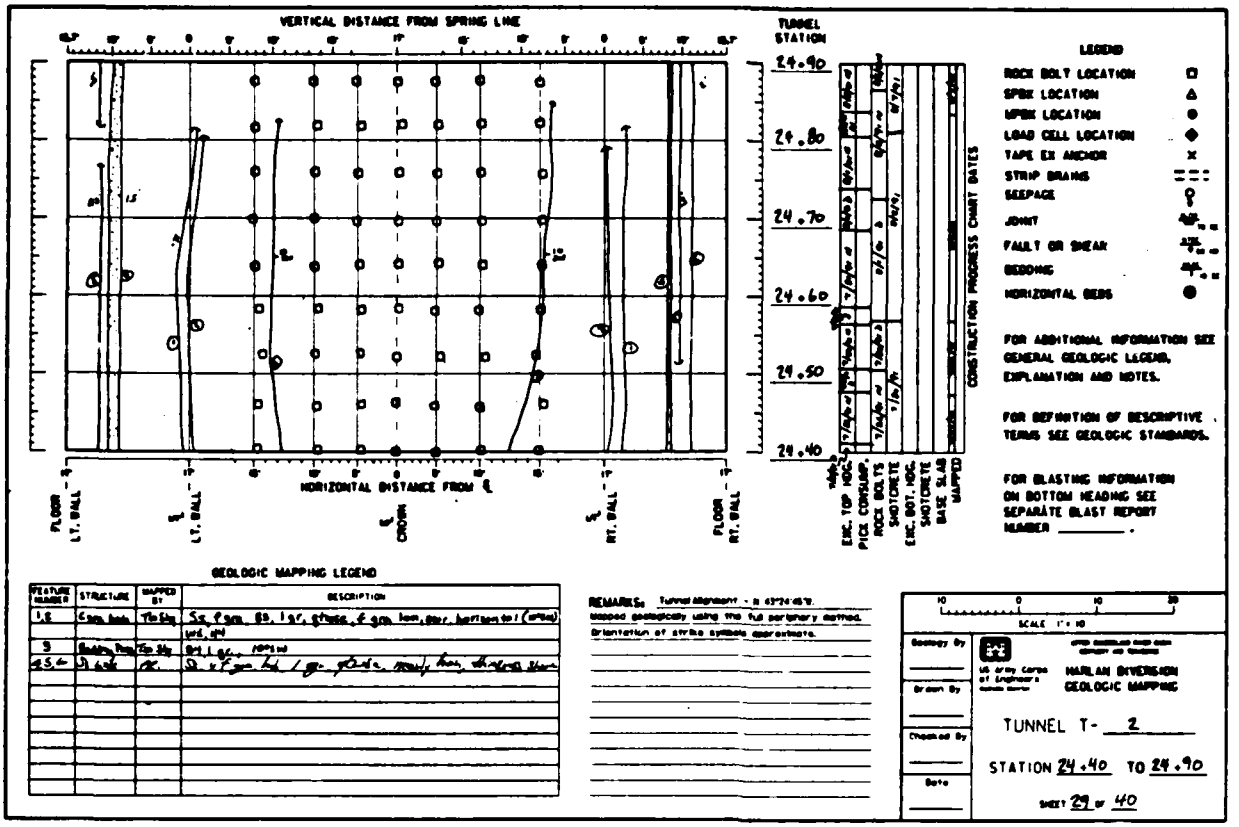
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 23+90 TO 24+40

SHEET 28 OF 40

PLATE D-41



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Contact	Tim Eby	Ss, f-gm, Bd, 1 or, gtnite, f-gm lam, iltr, bottom to top (arbitrary) unit, qtz
3	Bedding Plane	Tim Eby	Bd 1 or, approx
4,5,6	Shear Zone	JK	Ss w/ f-gm Ld / gr. gtnite, mostly lam, thinly bedded

REMARKS: Tunnel Alignment - 0 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

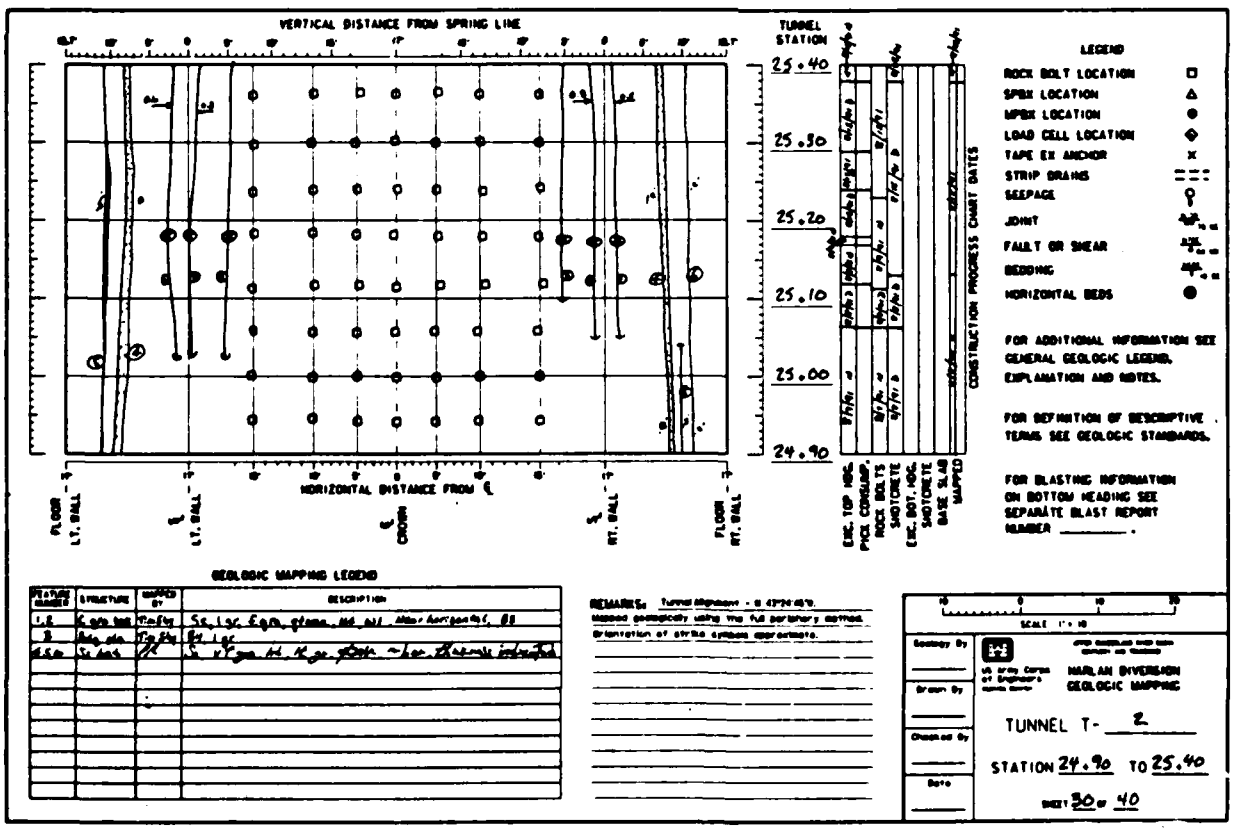
US Army Corps of Engineers — Omaha District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 24+40 TO 24+90

SHEET 29 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Contact	Tim Eby	Ss, 1 or, f-gm, gtnite, Bd, Alt. Alter. bottom to top, Bd
3	Bedding Plane	Tim Eby	Bd 1 or
4,5,6	Shear Zone	JK	Ss w/ f-gm Ld, K-gr. gtnite ~1 or. Thinly bedded

REMARKS: Tunnel Alignment - 0 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — Omaha District

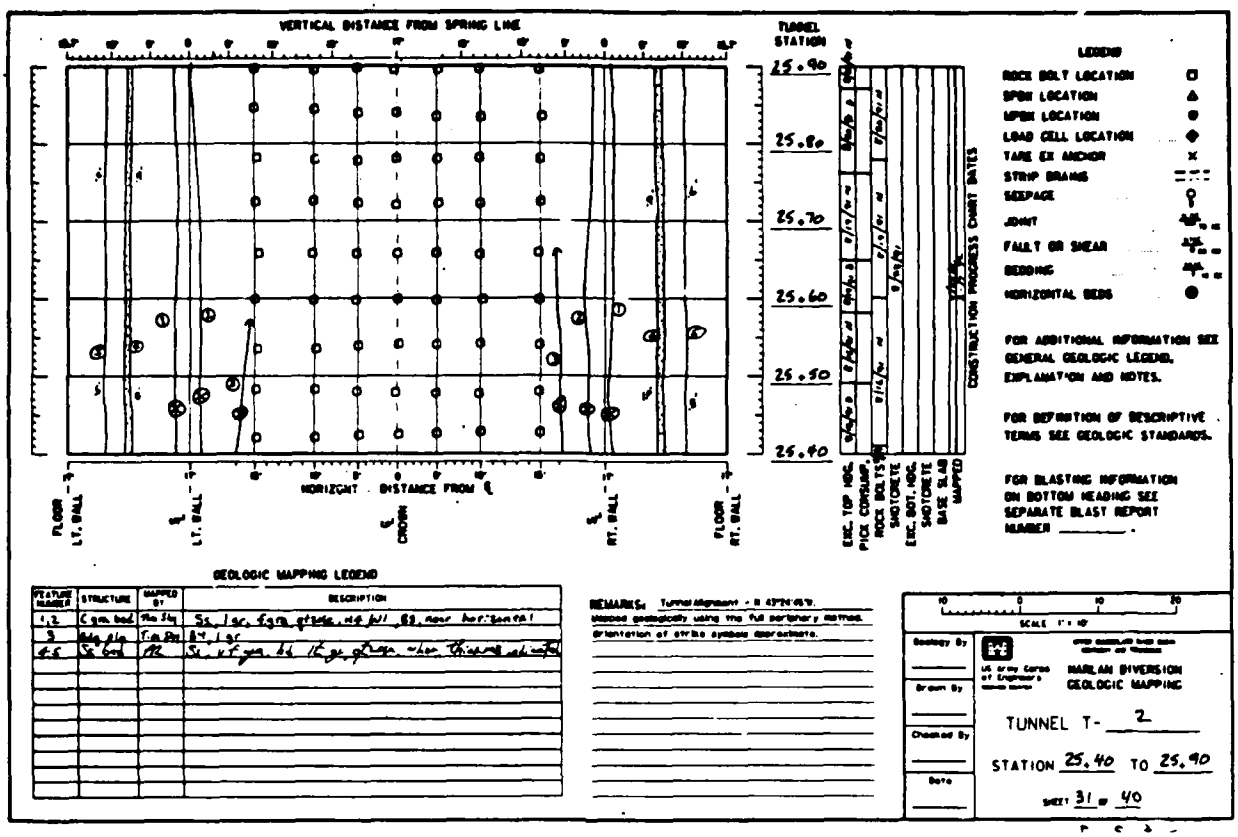
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 24+90 TO 25+40

SHEET 30 OF 40

PLATE D-42


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
25.90
25.80
25.70
25.60
25.50
25.40
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONTOUR
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1,2
Cgm bed
Tm Ha
Ss, lgr, fgm, grbls, rnd fill, 63, near horizontal
3
Bdg Ha
Tm Ha
Sh, lgr
4,5
Sh bed
AR
Ss, vfgm, bl, lgy, grbls, chert nodules
REMARKS: Tunnel alignment - S 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 25.40 TO 25.90
SHEET 31 OF 40

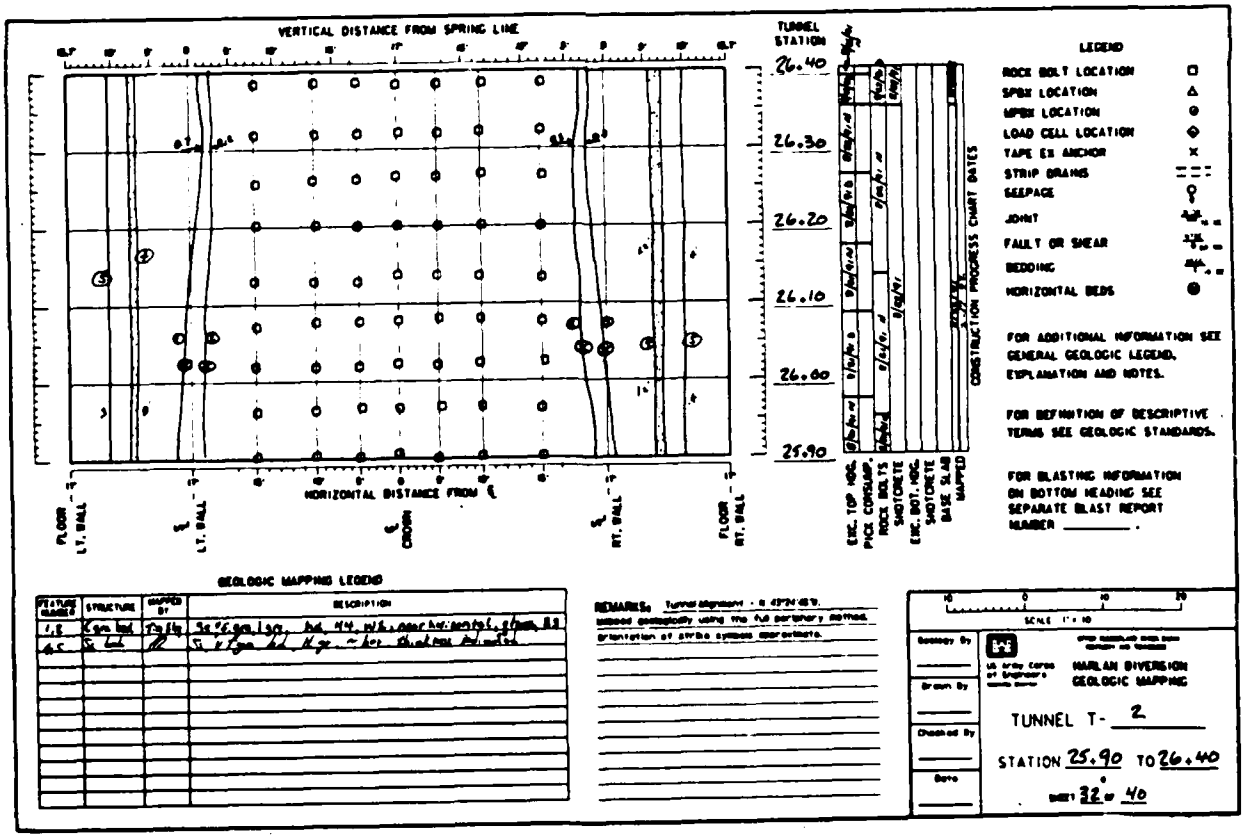
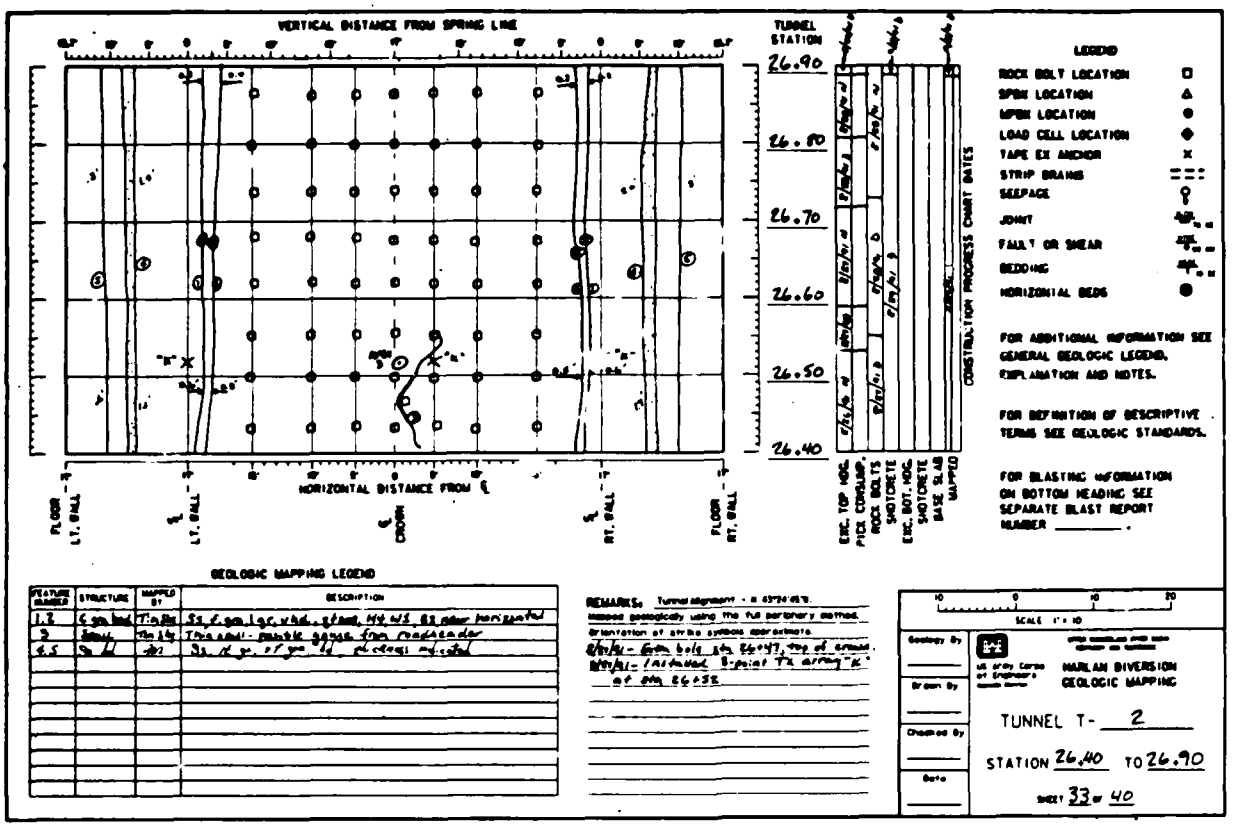

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
26.40
26.30
26.20
26.10
26.00
25.90
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONTOUR
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1,2
Cgm bed
Tm Ha
Ss, fgm, lgy, bed, 44, w/5, near horizontal, grbls, 83
4,5
Sh bed
AR
Ss, vfgm, bl, lgy, ~ hor. chert nodules
REMARKS: Tunnel alignment - S 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 2
STATION 25.90 TO 26.40
SHEET 32 OF 40

PLATE D-43



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Com bed	TM/EM	Ss, f-gm, lgr, vhd., gl'ized, Hk w/S, 83 aber horizontal
3	Joint	TM/EM	Thin addl - possible gouge from roadheader
4,5	Sh Fl	do	Ss, lt gy, vf-gm, lg pl colluvial material

REMARKS: Tunnel alignment - 0 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate
26+90 - 27+00 bolts 4th 26+97, top of crown
26+90 - 27+00 Fairhead, 8-point TX drilling "A" at 4th 26+32

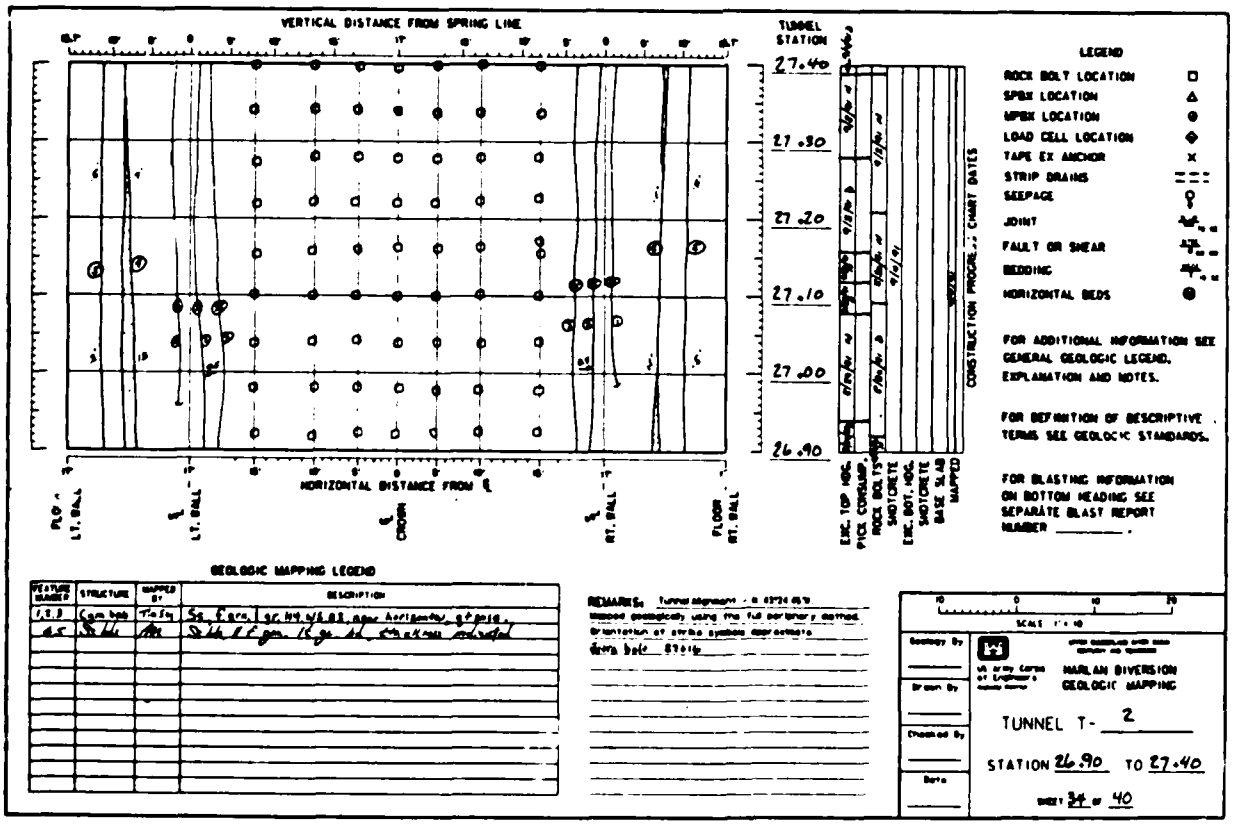
SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 26.40 TO 26.90
SHEET 33 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Com bed	TM/EM	Ss, f-gm, gr, HK w/S, 83 aber horizontal, gl'ized,
4,5	Sh Fl	do	Sh, lt gy, f-gm, lg pl, colluvial material

REMARKS: Tunnel alignment - 0 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate
Same bolt 27+16

SCALE 1" = 10

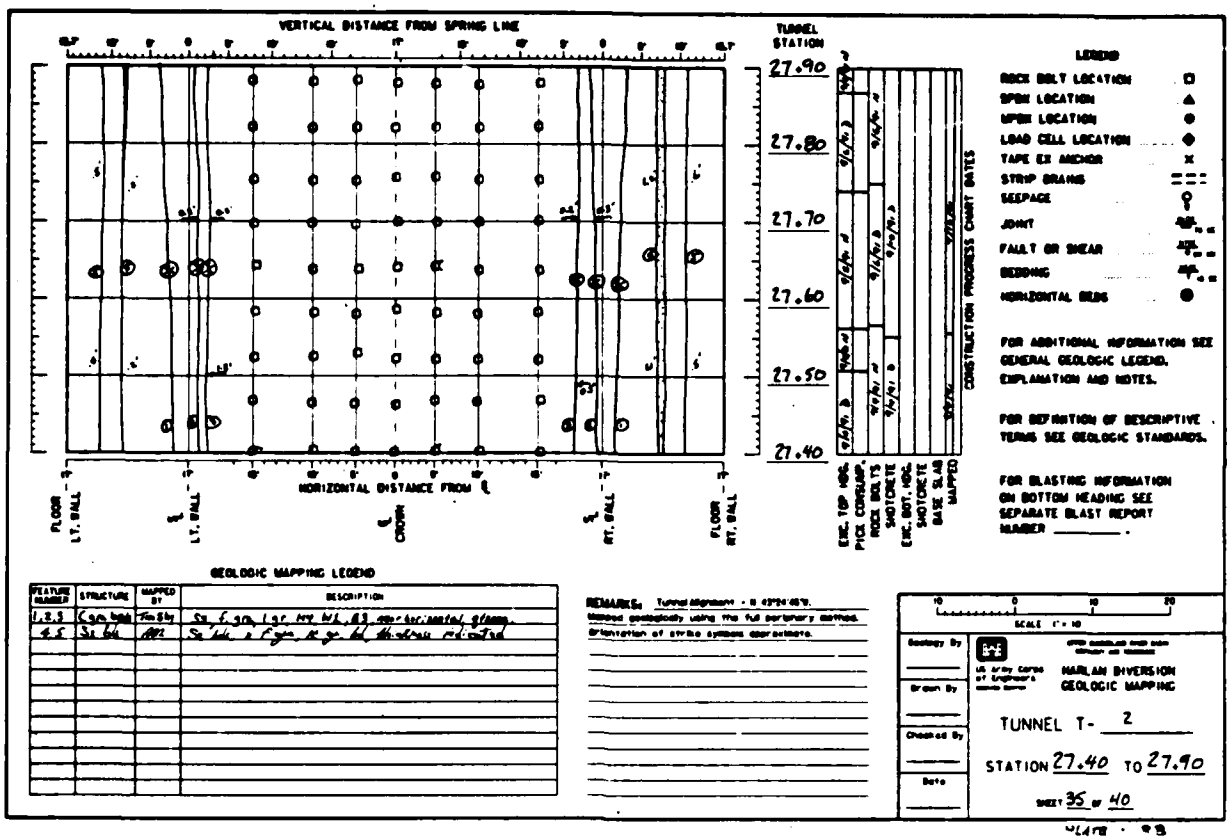
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2
STATION 26.90 TO 27.40
SHEET 34 OF 40

PLATE D-44



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Coal Bed	Tm Sh	Ss, f grn, l gr, HW w/ l. BS carbonaceous/coaly/ shaly.
4,5	Ss Bed	Ant	Ss bd, a f grn, lt gy bd thickness mid-bedd

REMARKS: Tunnel Alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Huntington District

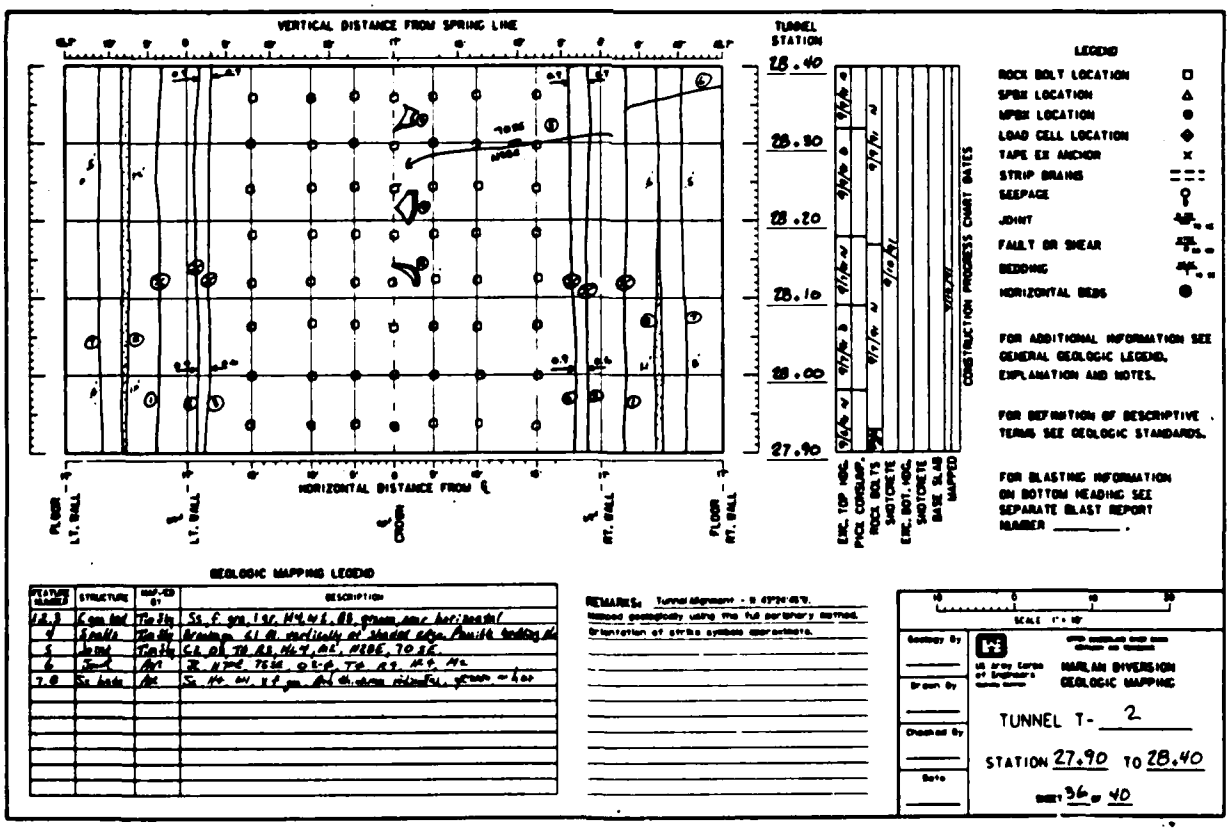
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 27.40 TO 27.90

SHEET 35 OF 40

PLATE D-45



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Coal Bed	Tm Sh	Ss, f grn, l gr, HW w/ l. BS grnish gray carbonaceous/
4	Fossils	Tm Sh	Brachiopods (Lingula) abundantly at shallow depth in shale bedding pl
5	Joint	Tm Sh	Cs, DP 70 E, BS, HW, AC, MEDE, TO SE.
6	Joint	Ant	JT, N 20° E, 85 E, TO E, BS, MW, MC
7,8	Ss beds	Ant	Ss, MG GN, f-m grn, thick-thin bedded, grnish gray

REMARKS: Tunnel Alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Huntington District

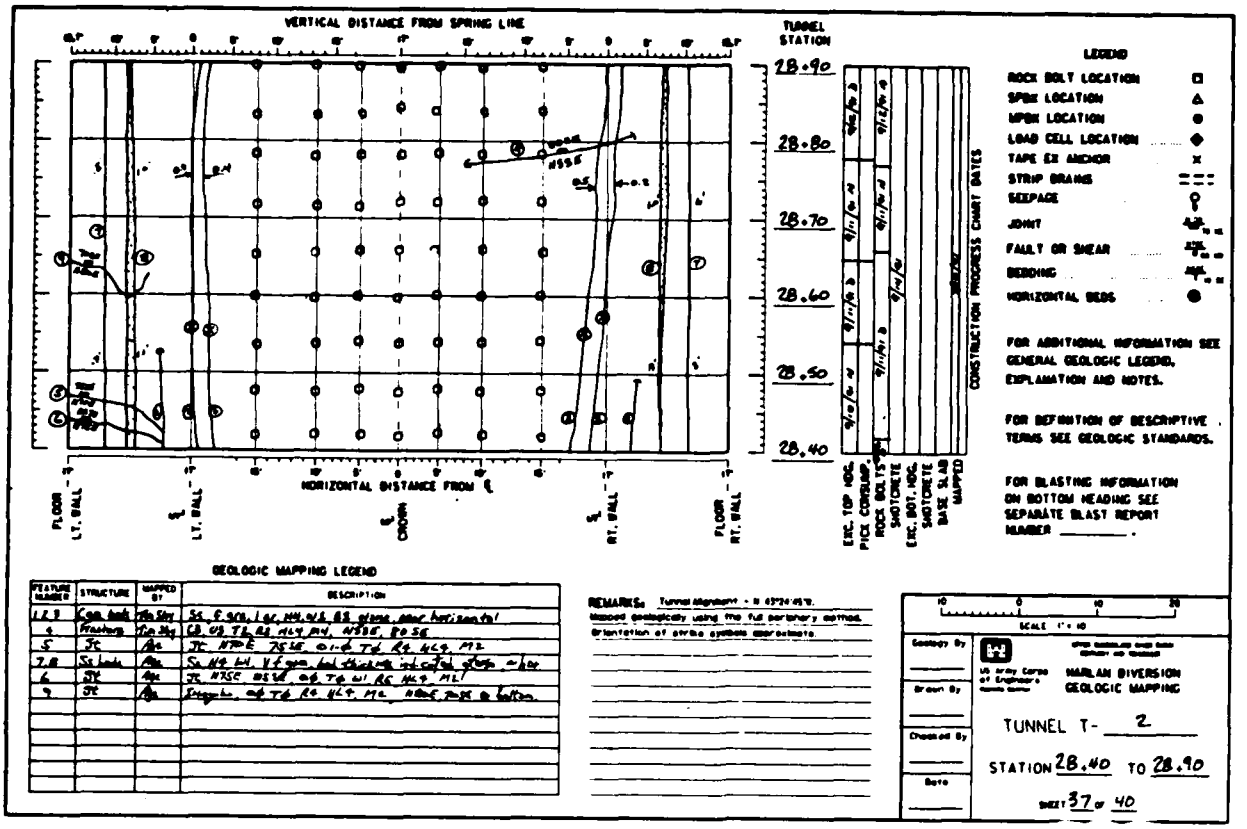
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 27.90 TO 28.40

SHEET 36 OF 40

PLATE D-45



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Cgn. bnd.	Tm Sky	Ss, f-grn, l gy, MM, w-l, BB, planar, other horizontal
4	Fracture	Tm Sky	CB, 08, TR, BB, MM, MM, N55E, 80SE
5	Jt.	Abt	Jt. N70E, 75SE, 01-6 TR, RR, MM, MR
7,8	Ss Lens	Abt	Ss, MM, LM, VF-grn, local thinning and conical shape ~1.5m
6	Jt.	Abt	Jt. N75E, 85SE, 06 TR, 01, RR, MM, MR
9	Jt.	Abt	Irregular, 06 TR, RR, MM, MR, N80E, 70SE & bottom

REMARKS: Tunnel Alignment = N 67°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

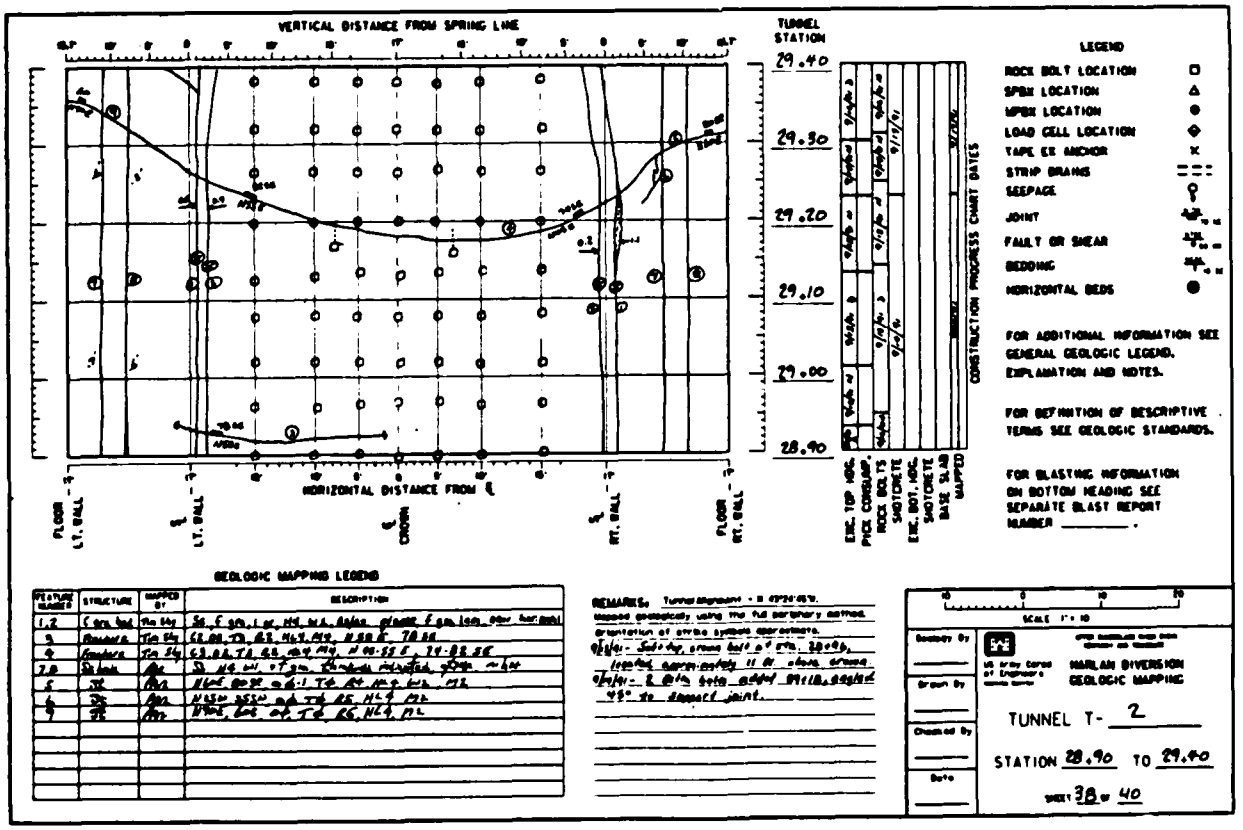
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 28.40 TO 28.90

SHEET 37 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Cgn. bnd.	Tm Sky	Ss, f-grn, l gy, MM, w-l, BB, planar, f-grn lens, other horizontal
3	Fracture	Tm Sky	CB, 08, TR, BB, MM, MM, N55E, 70SE
4	Fracture	Tm Sky	CB, 08, TR, BB, MM, MM, N 60-65 E, 70-80 SE
7,8	Ss Lens	Abt	Ss, MM, LM, VF-grn, [illegible] ~1.5m
5	Jt.	Abt	N60E, 80SE to 01-1 TR, RR, MM, MR, MR
6	Jt.	Abt	N45E, 85SE, 06 TR, RR, MM, MR
9	Jt.	Abt	N70E, 60E, 06 TR, RR, MM, MR

REMARKS: Tunnel Alignment = N 67°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
06/16/81 - Soil-like seams 1cm to 2cm, 20cm to 30cm spacing, [illegible] 11 ft. above crown.
06/16/81 - 2 @ 1cm to 2cm apart 90°/18, 295/NE 45° to dominant joint.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

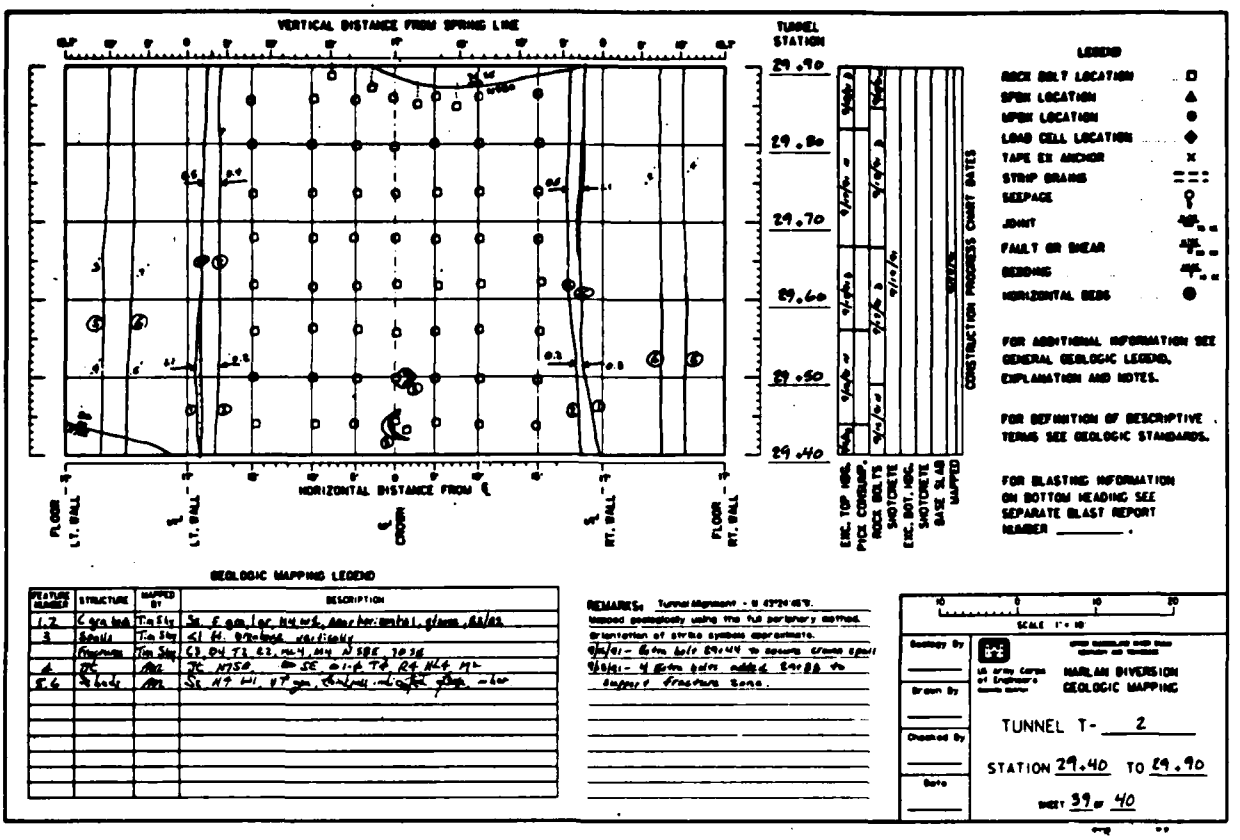
US Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 28.90 TO 29.40

SHEET 38 OF 40

PLATE D-46



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Contact	Tim Eby	Jn. E gen. lor. N4 W5, dense horizontal gloom, 88/83
3	Seam	Tim Eby	<1 H. Orange vertically
	Fracture	Tim Eby	C3, D4, T3, B2, M4, M4, N SBE, 10 ft
4	JTC	MM	JTC N150 E 35E 0.1-1.0 T2 R4 HL4 M1
5,6	Shear	MM	Sh. N9 W1, VT gn. Calcite - Clay Gouge - Low

REMARKS: Tunnel Alignment - N 47°24'48"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
9/26/91 - 6 cm hole 89+44 to assess crown spall
9/26/91 - 4 cm hole 64+88 added 64+88 to 89+44 fracture zone.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

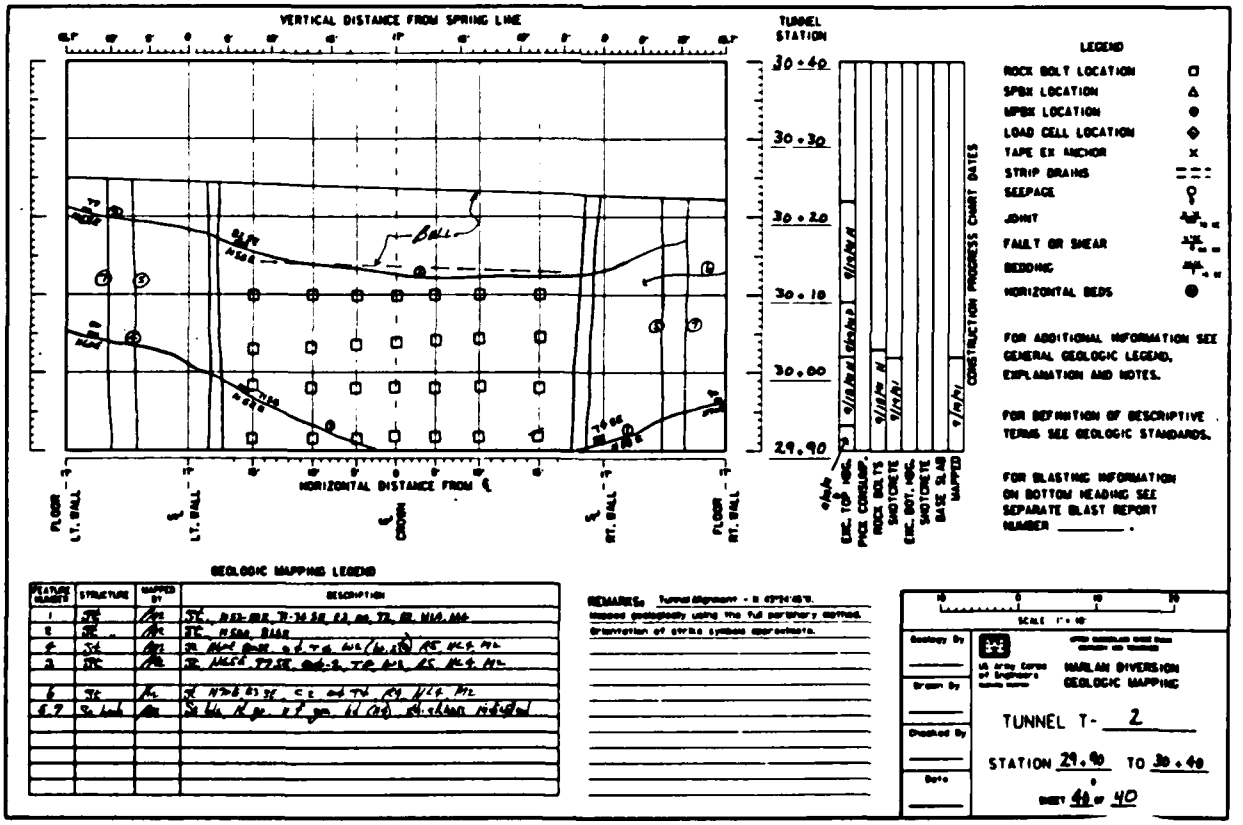
US Army Corps of Engineers — Sacramento District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 29+40 TO 29+90

SHEET 39 OF 40



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	JTC	MM	JTC, N35 W5, 70-90 SE, E3, B4, T2, B3, M4A, M4
2	JTC	MM	JTC N60W, Blind
3	Sh	MM	Sh. Black gouge, 0.5 to 0.6 in (1.3-1.5) RS, HL4, M2
4	JTC	MM	JTC, N45 E 77 SE, Rough, T2, B4, E5, HL4, M2
5			
6	JTC	MM	JTC N75 E 85 SE, C2, R4, T4, HL4, M2
6,7	Sh Lock	MM	Sh Lock N 90 E 7 gm, 1/2 (1.3) R4, Calcite Healed

REMARKS: Tunnel Alignment - N 47°24'48"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — Sacramento District

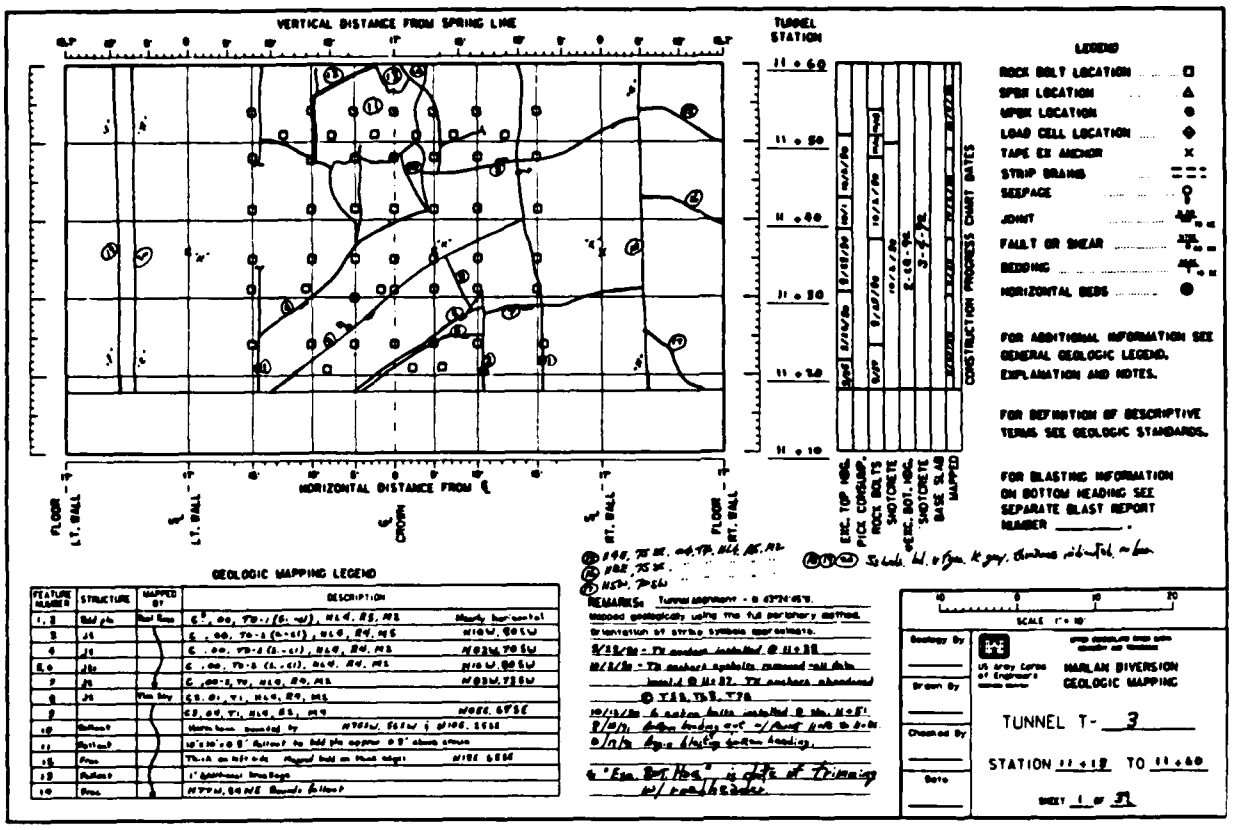
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 29+40 TO 30+40

SHEET 40 OF 40

PLATE D-47


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
11 + 60
11 + 50
11 + 40
11 + 30
11 + 20
11 + 10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ____.
CONSTRUCTION PROGRESS CHART DATES
ERC. TOP HDG. PICK CORDUMP
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
Geology By
Drawn By
Checked By
Date
TUNNEL T- 3
STATION 11 + 60 TO 11 + 20
SHEET 1 OF 31

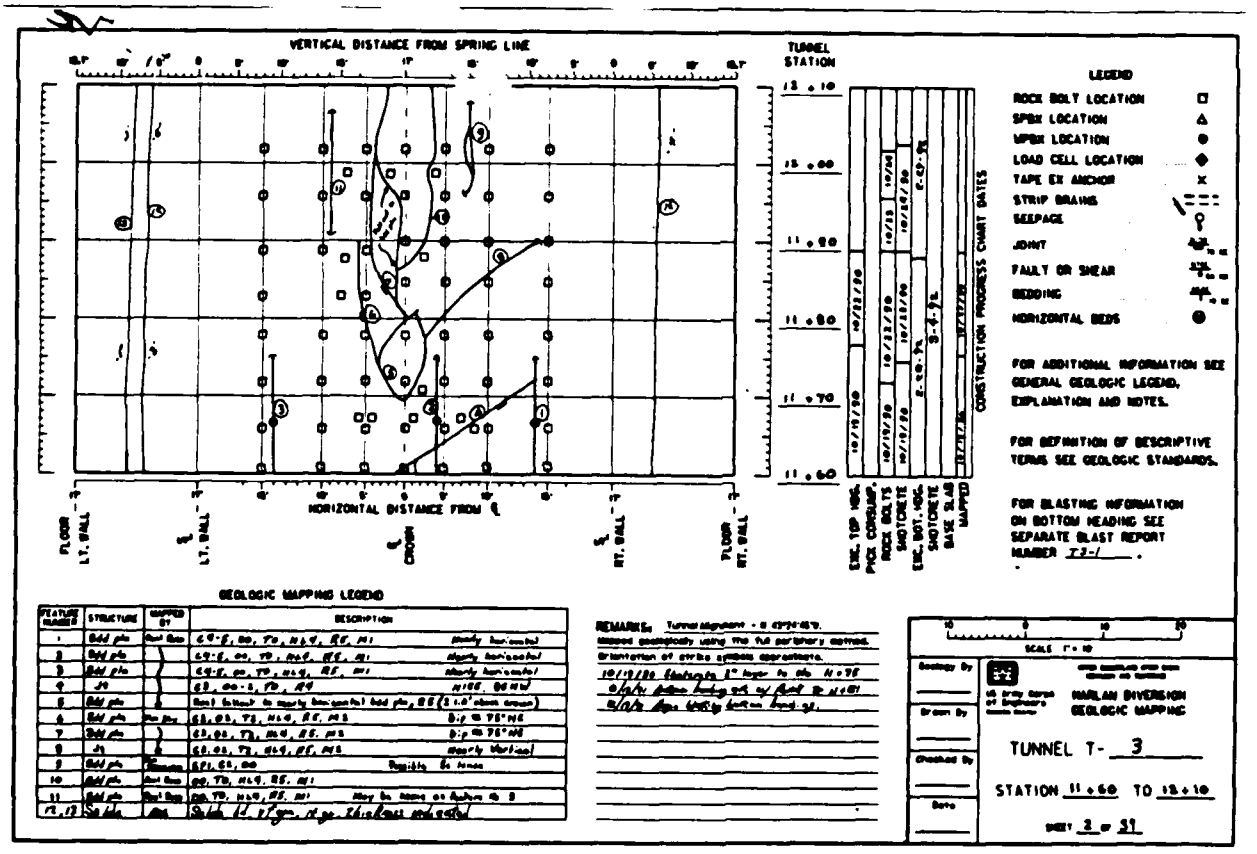
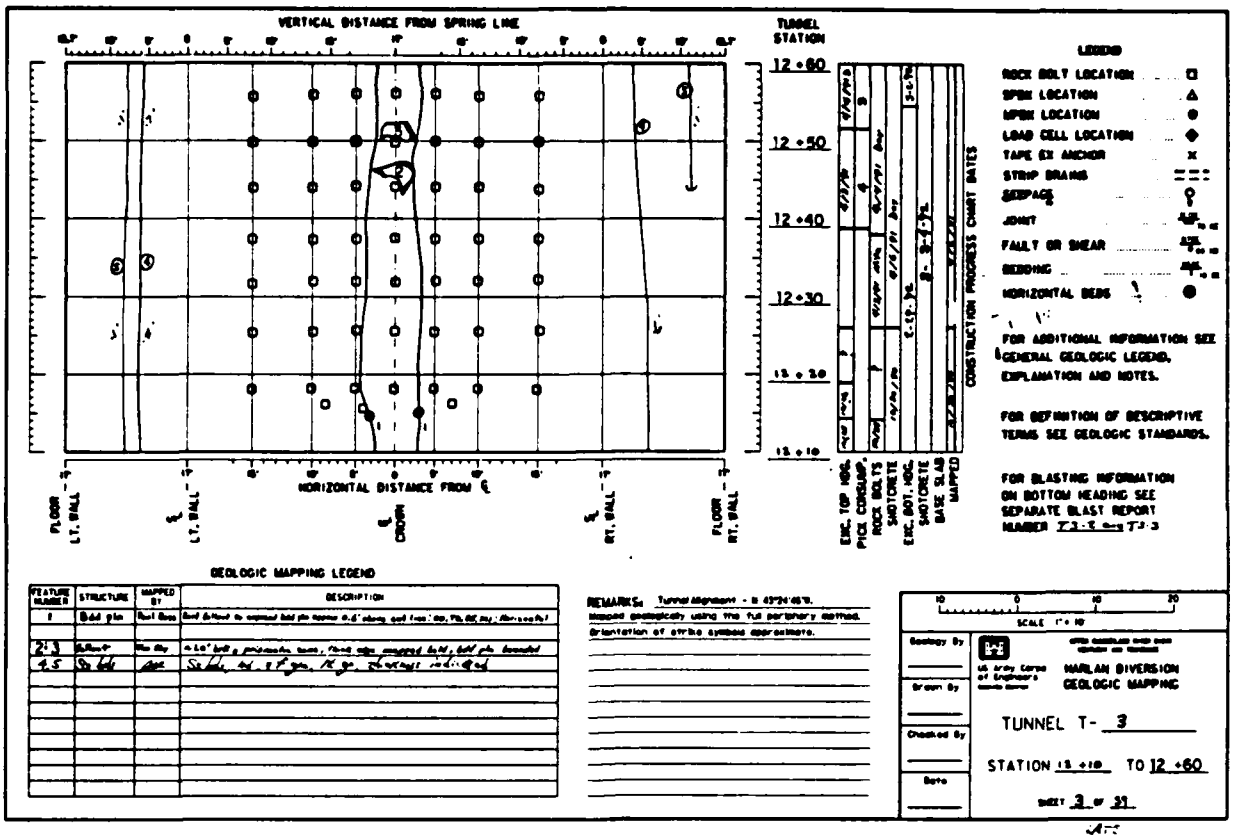

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
13 + 10
13 + 00
11 + 90
11 + 80
11 + 70
11 + 60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-1.
CONSTRUCTION PROGRESS CHART DATES
ERC. TOP HDG. PICK CORDUMP
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
Geology By
Drawn By
Checked By
Date
TUNNEL T- 3
STATION 11 + 60 TO 13 + 10
SHEET 2 OF 31

PLATE D-48


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
12+60
12+50
12+40
12+30
12+20
12+10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPRM LOCATION
MPRM LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-1 thru T3-3
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 67°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 13+10 TO 12+60
SHEET 3 OF 31

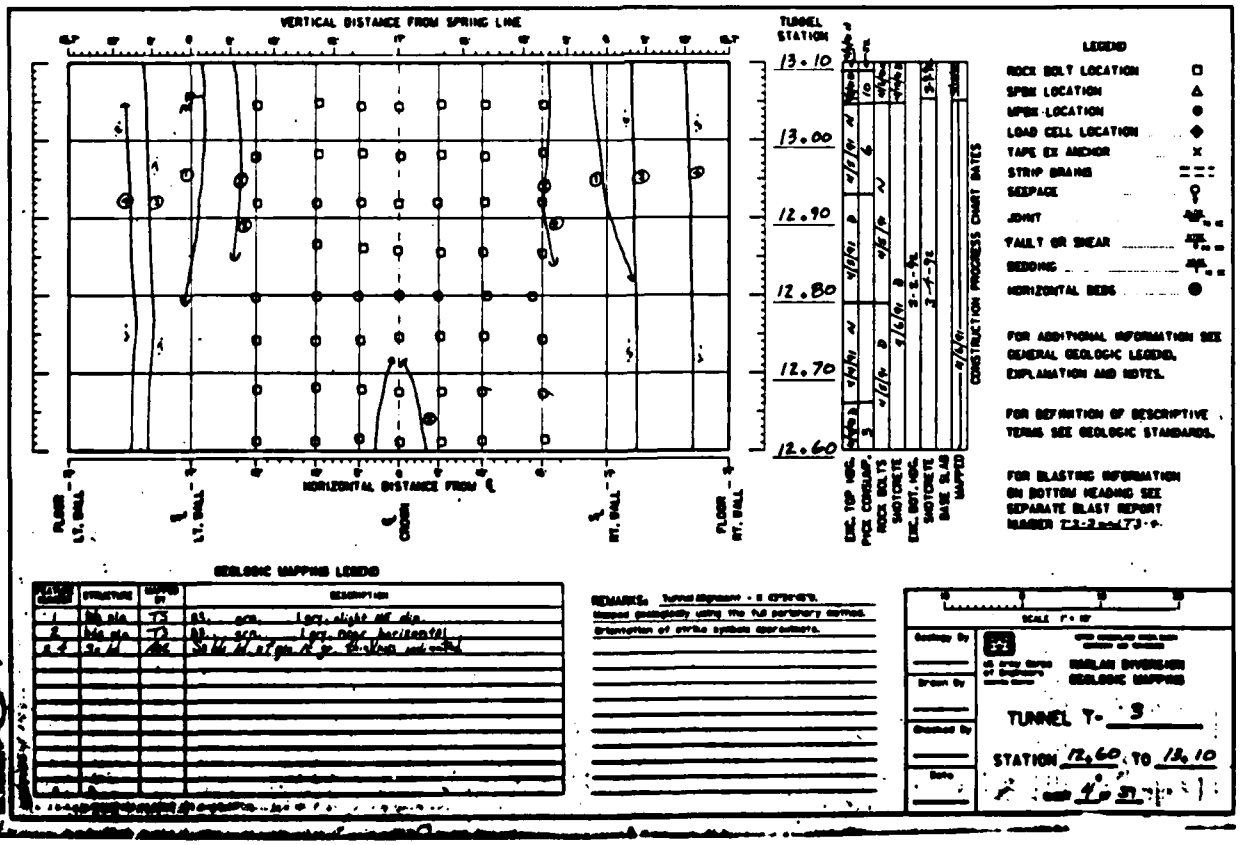
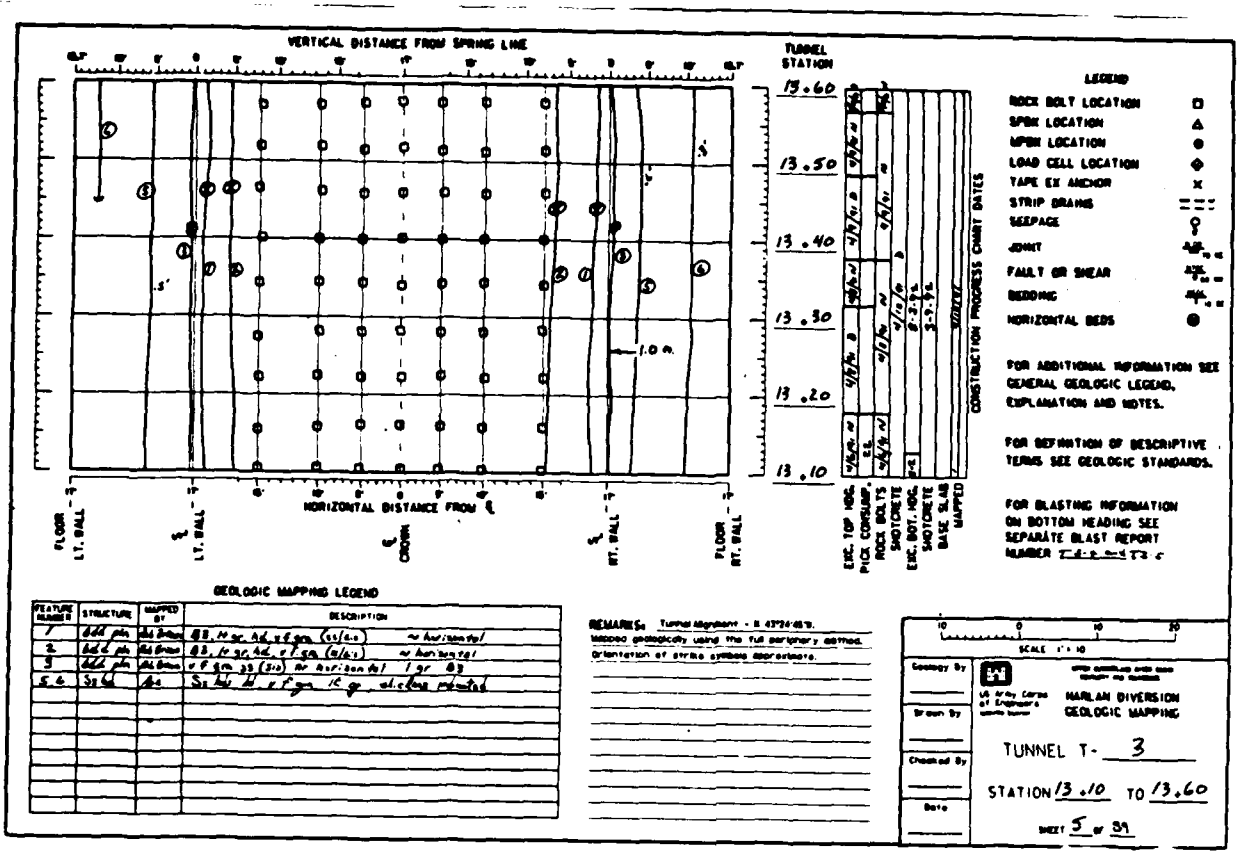

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
13+10
13+00
12+90
12+80
12+70
12+60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPRM LOCATION
MPRM LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-2 thru T3-4
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 67°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 12+60 TO 13+10
SHEET 4 OF 31

PLATE D-49



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	Abbott	03, 10 gr, bd, v f gm (si/clay) — w hor/sandy/
2	Bdd plane	Abbott	03, 10 gr, bd, v f gm (si/cl) — w hor/sandy/
3	Bdd plane	Abbott	v f gm ss (3in) w horizontal / gr 03
5, 6	Si bd	Abbott	Si bd, bl v f gm, 1C gr, w/ calcite mineral

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10

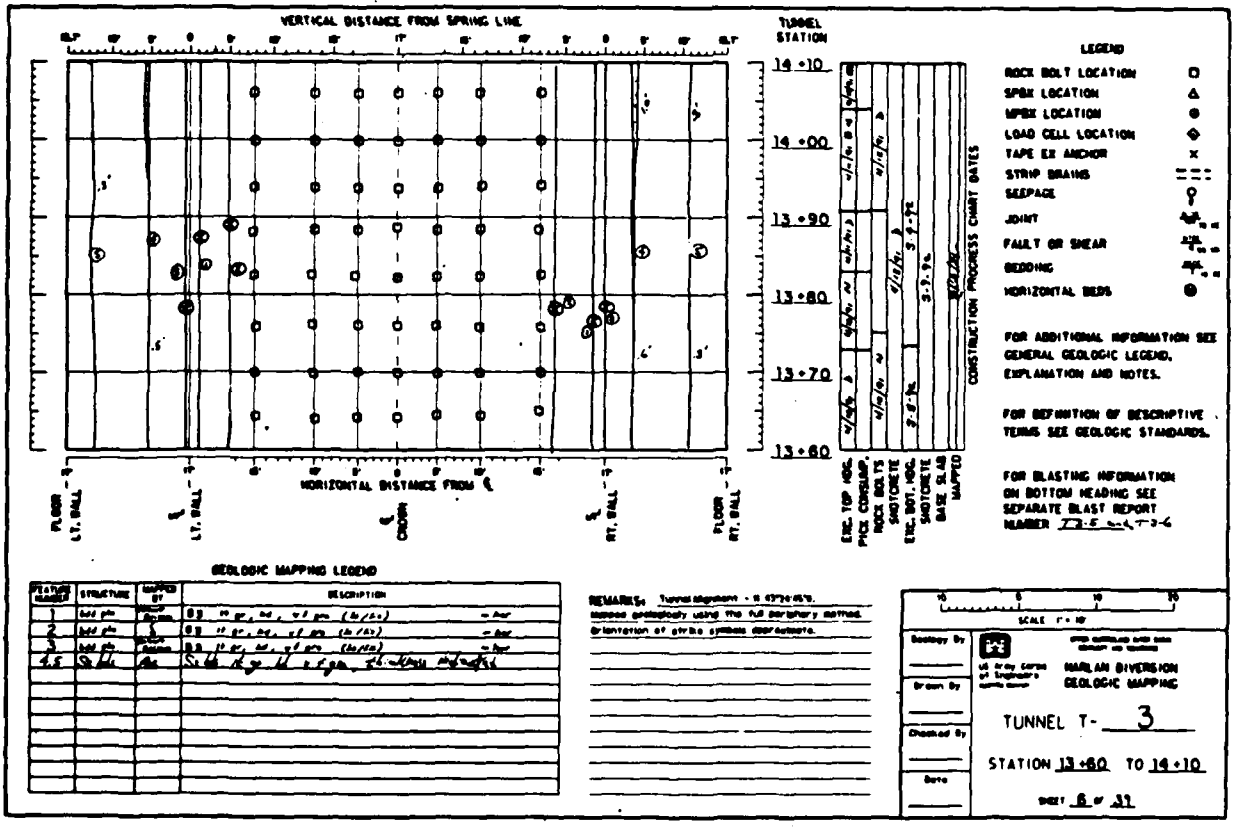
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 13+10 TO 13+60

SHEET 5 OF 31



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	Abbott	03, 10 gr, bd, v f gm (si/cl) — hor
2	Bdd plane	Abbott	03, 10 gr, bd, v f gm (si/cl) — hor
3	Bdd plane	Abbott	03, 10 gr, bd, v f gm (si/cl) — hor
4, 5	Si bd	Abbott	Si bd, dk gy, bl, v f gm, 1C calcite mineral

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

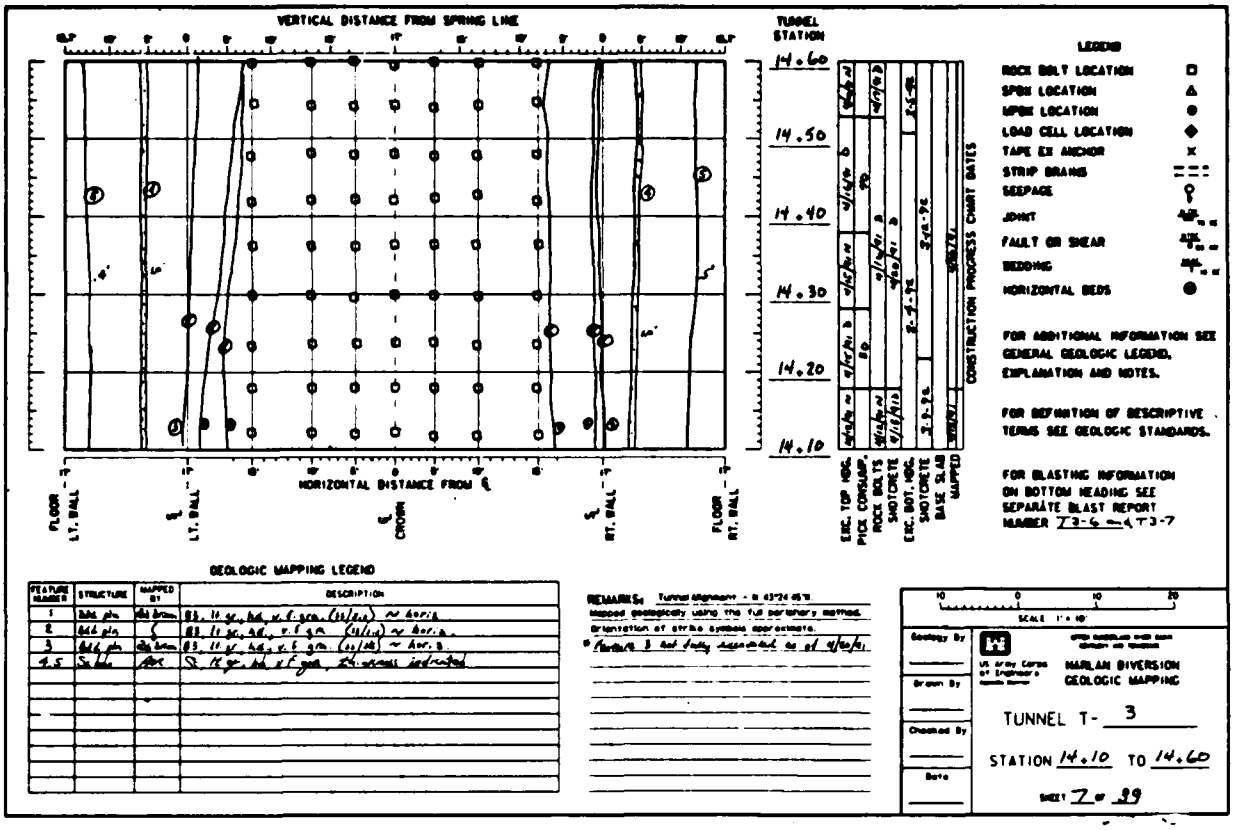
U.S. Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 13+60 TO 14+10

SHEET 6 OF 31

PLATE D-50


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
14.60
14.50
14.40
14.30
14.20
14.10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-6 thru T3-7
GEOLOGIC MAPPING LEGEND
REMARKS:
SCALE 1" = 10'
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
Geology By
Drawn By
Checked By
Date
TUNNEL T- 3
STATION 14.10 TO 14.60
SHEET 7 OF 39

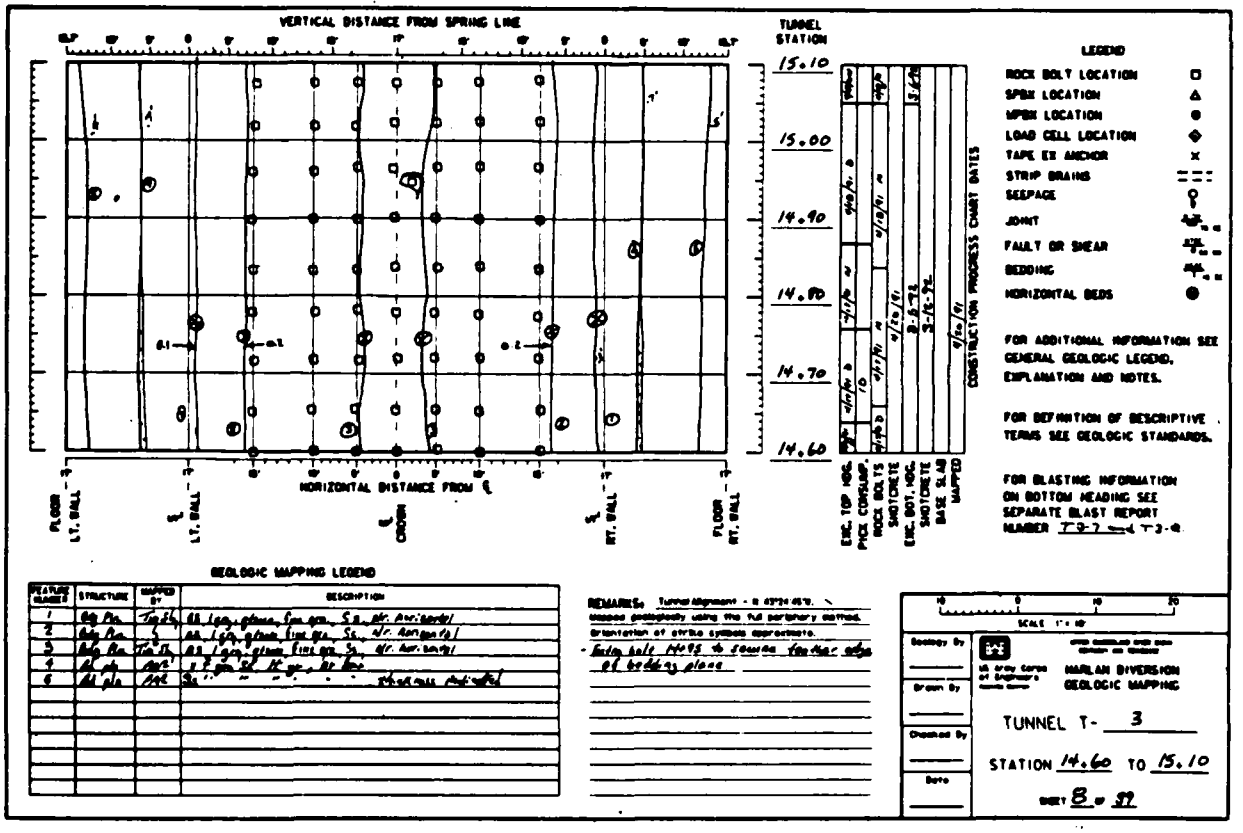
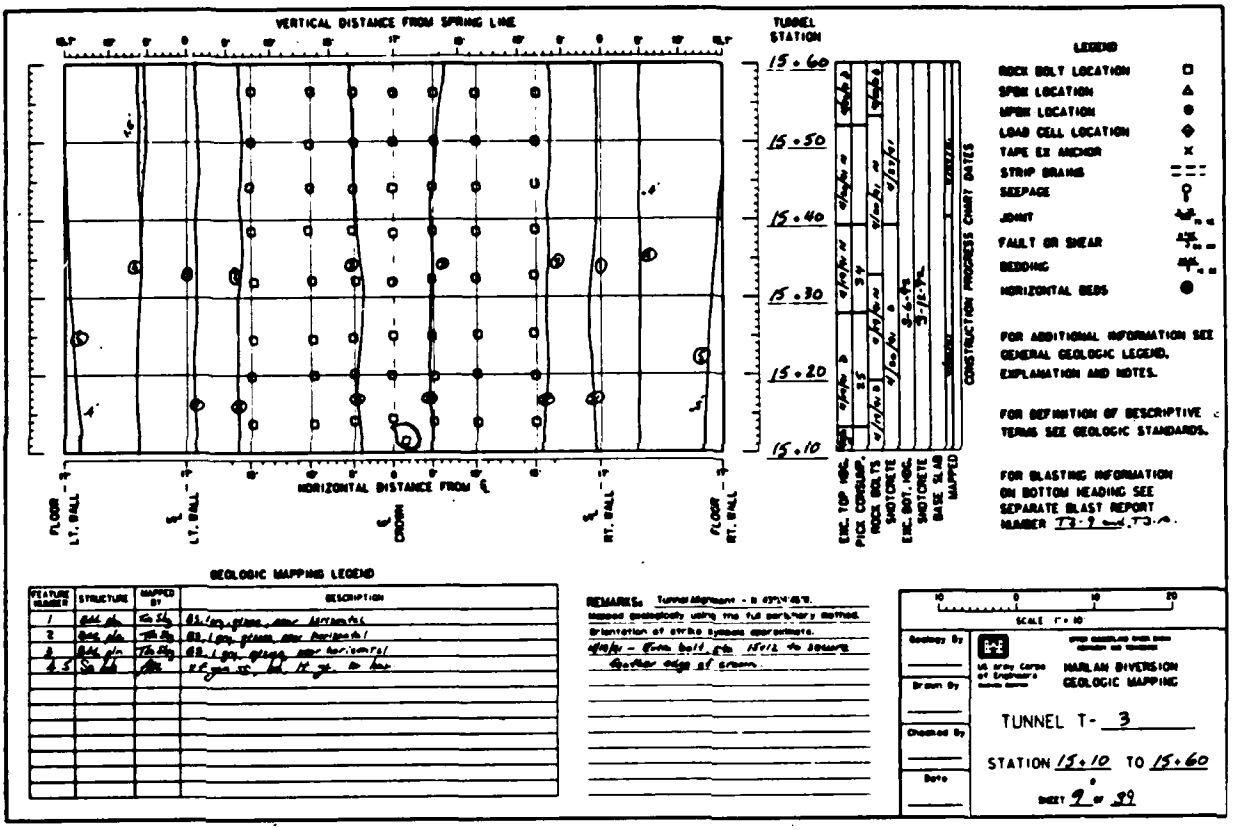

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
15.10
15.00
14.90
14.80
14.70
14.60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-7 thru T3-8
GEOLOGIC MAPPING LEGEND
REMARKS:
SCALE 1" = 10'
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
Geology By
Drawn By
Checked By
Date
TUNNEL T- 3
STATION 14.60 TO 15.10
SHEET 8 OF 39

PLATE D-51


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
15+60
15+50
15+40
15+30
15+20
15+10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
ERC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-9 and T3-A.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 67°W/N 67°E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Geology By
Drawn By
Checked By
Date
SCALE 1" = 10
U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 15+10 TO 15+60
SHEET 9 OF 39

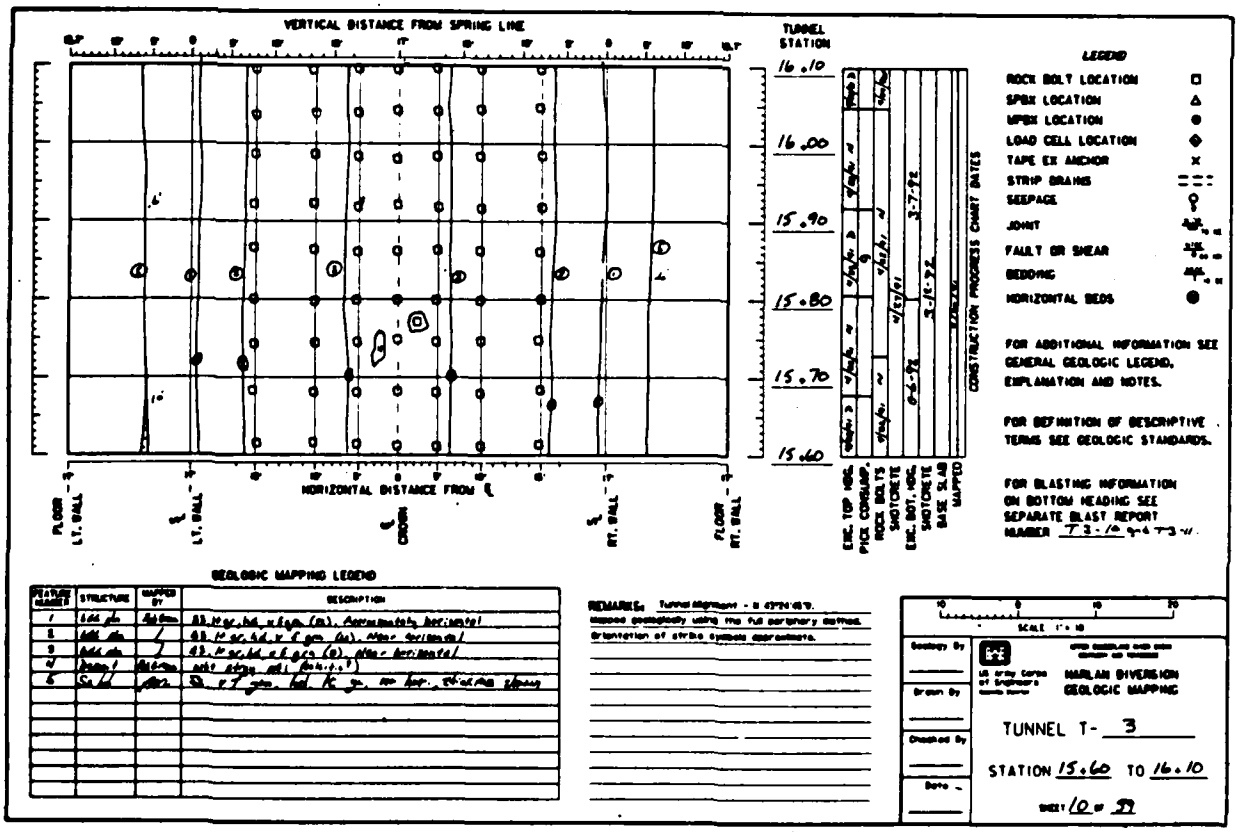
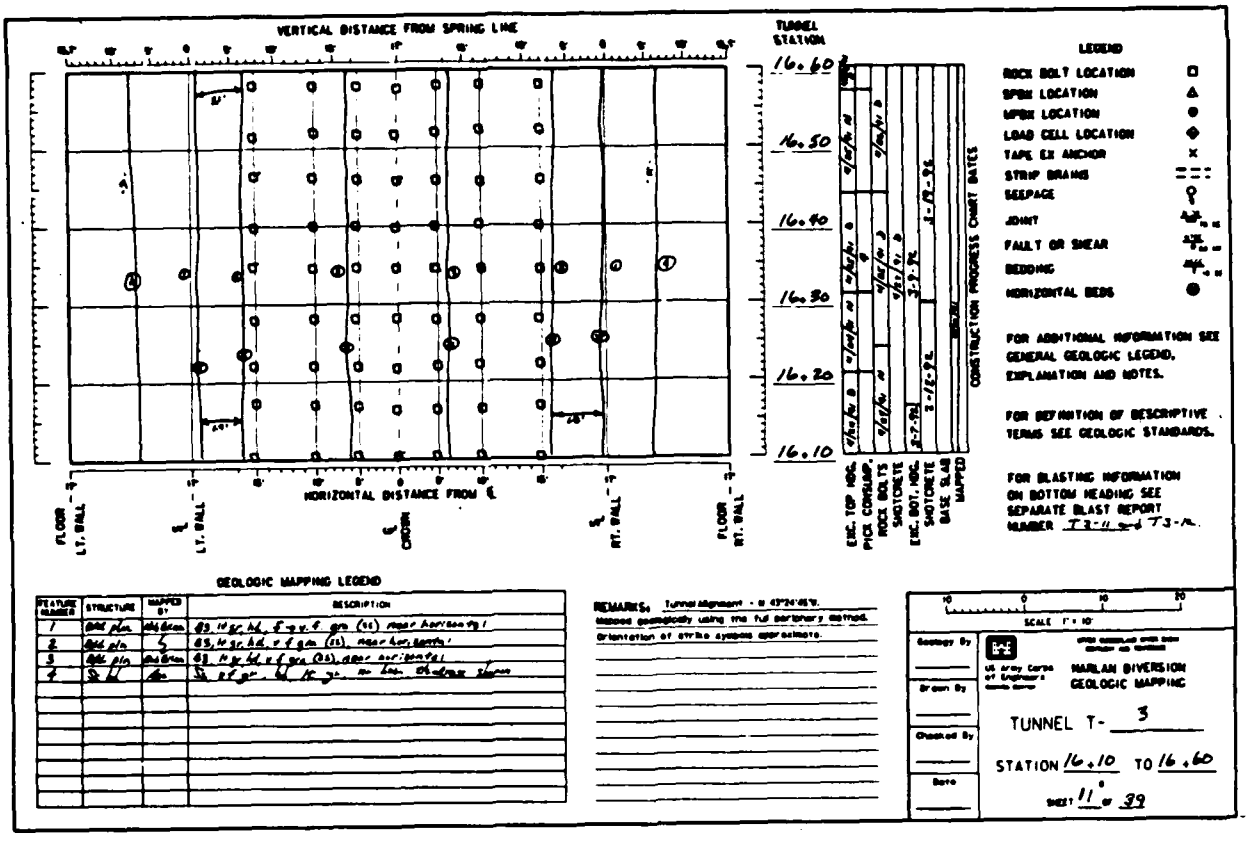

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
16+10
16+00
15+90
15+80
15+70
15+60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
ERC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-10 and T3-W.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 67°W/N 67°E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Geology By
Drawn By
Checked By
Date
SCALE 1" = 10
U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 15+60 TO 16+10
SHEET 10 OF 39

PLATE D-52



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	dbb & rm	65, 10 gr, bd, f-g v. f gm (SS) near horizontal
2	Bdd plane	S	65, 10 gr, bd, v f gm (SS), near horizontal
3	Bdd plane	dbb & rm	65, 10 gr, bd, v f gm (SS), near horizontal
4	Sh bd	dbb	Sh, ef gr, bd, 15 yr, m bm, thickness shown

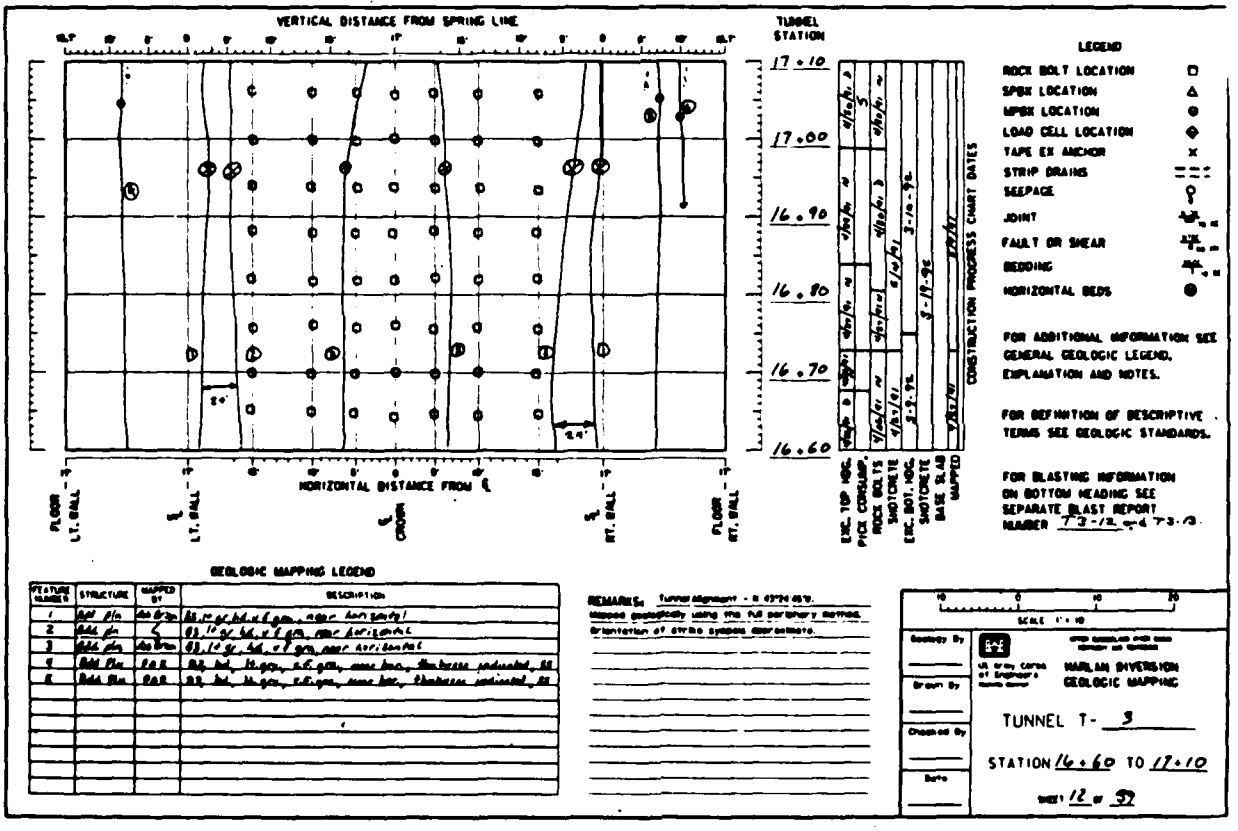
REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 16+10 TO 16+60
SHEET 11 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plane	dbb & rm	65, 10 gr, bd, v f gm, near horizontal
2	Bdd plane	S	65, 10 gr, bd, v f gm, near horizontal
3	Bdd plane	dbb & rm	65, 10 gr, bd, v f gm, near horizontal
4	Bdd Plane	DAR	65, bd, 10 gm, v.f. gm, near hor, thickness indicated, SS
5	Bdd Plane	DAR	65, bd, 10 gm, v.f. gm, near hor, thickness indicated, SS

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

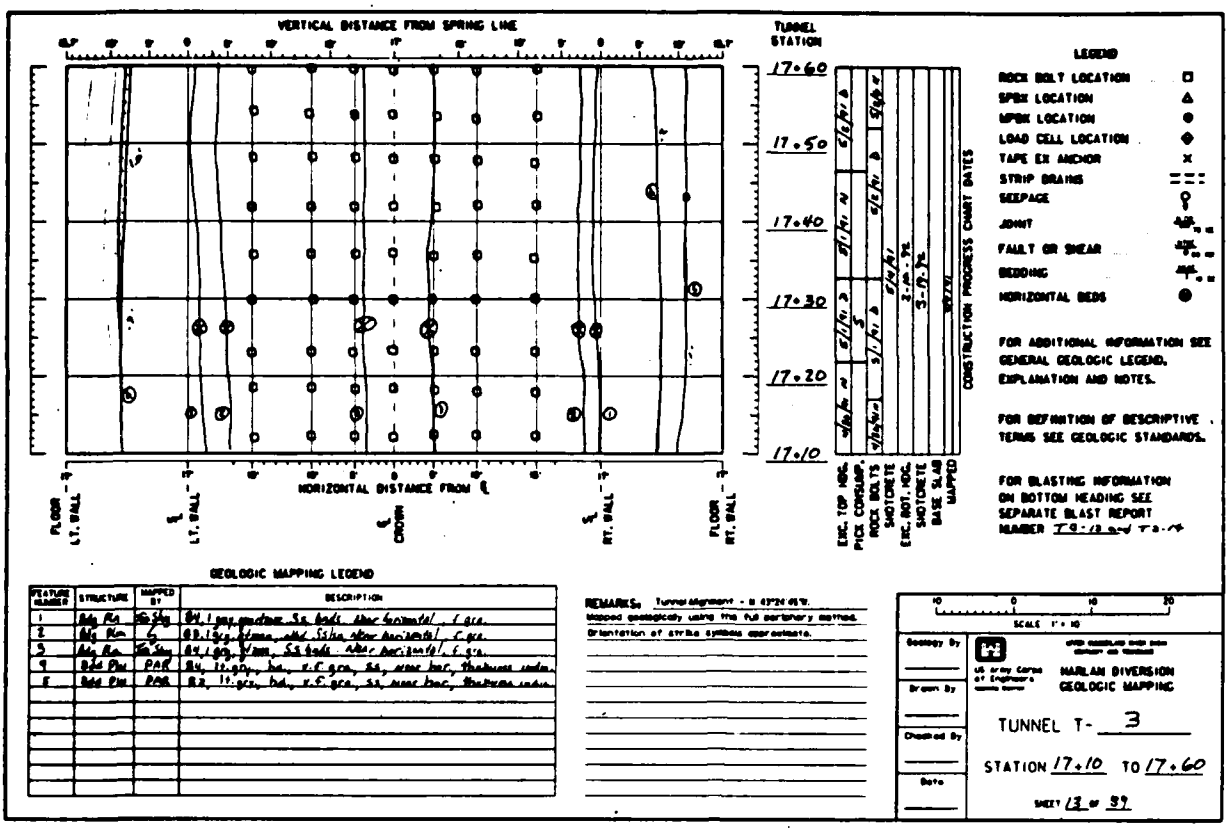
SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 16+60 TO 17+10
SHEET 12 OF 39

PLATE D-53



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	Tim Sby	Bd, 1 grn, medium Ss beds, clear horizontal, 1 grn.
2	Bdg Pln	"	Bd, 1 grn, 4-6mm, silt Ss beds, clear horizontal, 1 grn.
3	Bdg Pln	Tim Sby	Bd, 1 grn, 4-6mm, Ss beds, clear horizontal, 1 grn.
4	Bdd Pln	PAR	Bd, 11 grn, bd, v.f. grn, Ss, some bur, thickness varies
5	Bdd Pln	PAR	Bd, 11 grn, bd, v.f. grn, Ss, some bur, thickness varies

REMARKS: Tunnel Alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

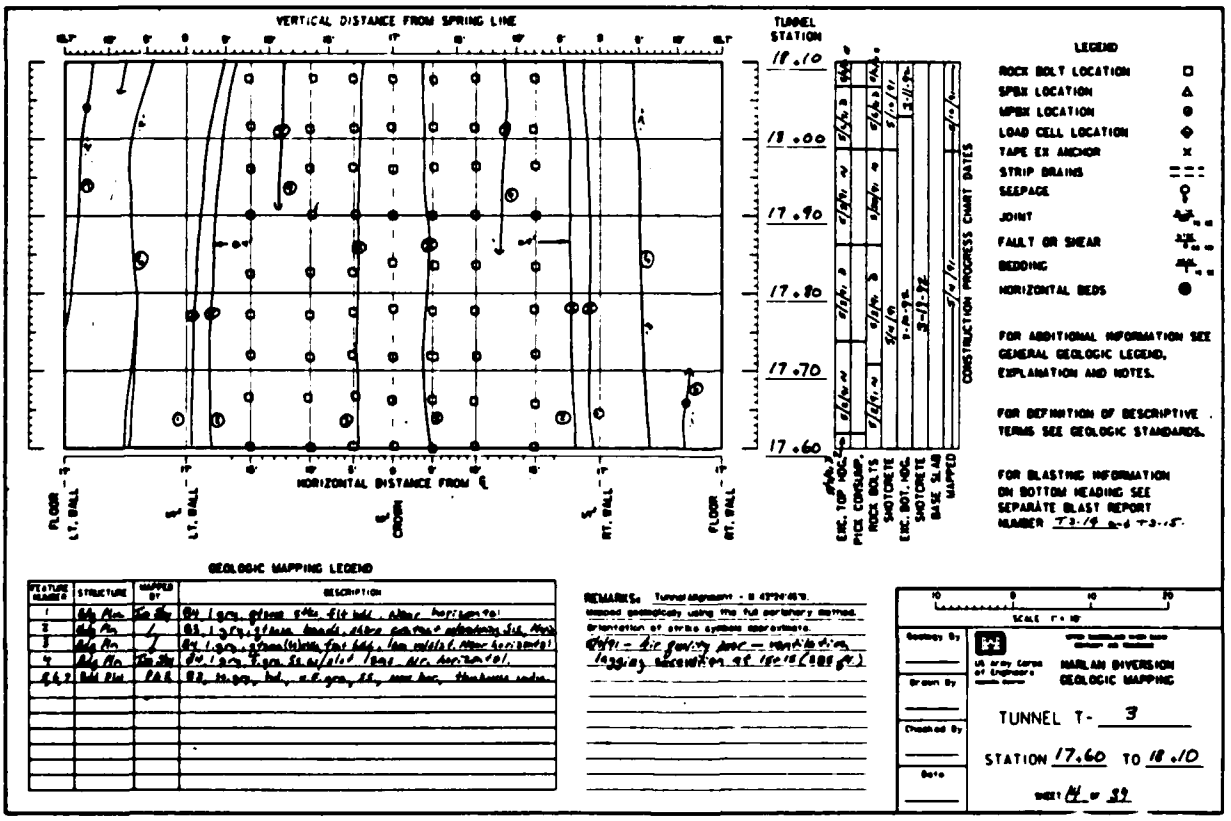
U.S. Army Corps of Engineers — Sacramento District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 17+10 TO 17+60

SHEET 13 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	Tim Sby	Bd, 1 grn, 6mm silt Ss bed, clear horizontal
2	Bdg Pln	"	Bd, 1 grn, 4-6mm, beds, clear contact undulating Silt, Mud
3	Bdg Pln	"	Bd, 1 grn, 4-6mm(+) silt, fine bdg, thin mbdd, clear horizontal
4	Bdg Pln	Tim Sby	Bd, 1 grn, 8 grn Ss w/ silt bed, clear horizontal
5 & 7	Bdd Pln	PAR	Bd, 11 grn, bd, v.f. grn, Ss, some bur, thickness varies

REMARKS: Tunnel Alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Qal = Air gravity deposits — Mantle deposits, lagging excavation at 18+10 (988 ft.)

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Sacramento District

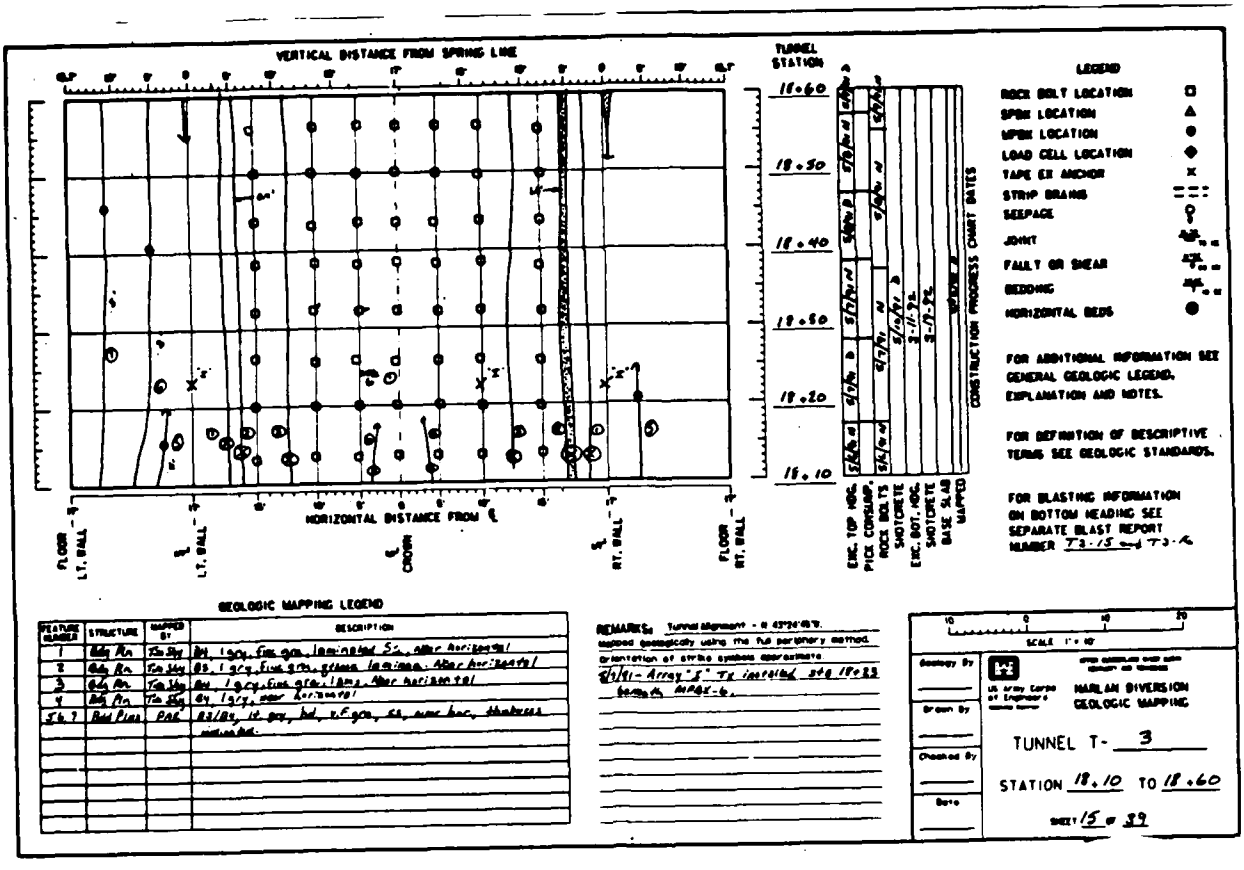
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 17+60 TO 18+10

SHEET 14 OF 39

PLATE D-54



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	Tim Say	Bd, l gry, fine grn, laminated S/s, alter horizontal
2	Bdg Pln	Tim Say	Bd, l gry, fine grn, grnish laminae, alter horizontal
3	Bdg Pln	Tim Say	Bd, l gry, fine grn, l brn, alter horizontal
4	Bdg Pln	Tim Say	Bd, l gry, near horizontal
5 & 7	Bed Plan	PAR	B3/B4, lt gy, bd, v.f.grn, ss, near hor, thickness undivided

REMARKS: Tunnel alignment - ℄ 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate. 6/3/81 - Array "S" TX inserted at 18+33 looking N. NMAS-6.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

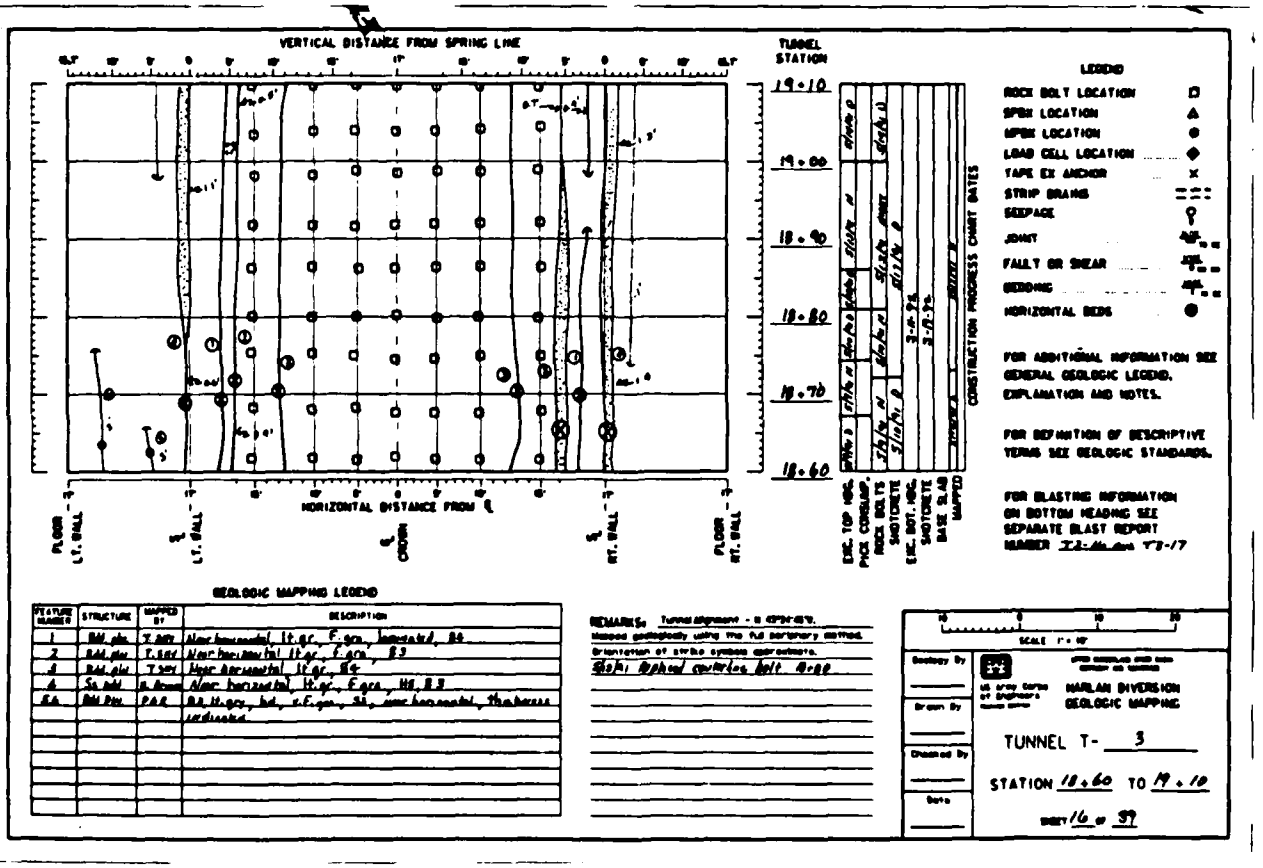
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 18+10 TO 18+60

SHEET 15 of 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd plns	T. Say	Alter horizontal, lt gr, F grn, laminated, B4
2	Bdd plns	T. Say	Alter horizontal lt gr, F grn, B3
3	Bdd plns	T Say	Alter horizontal, lt gr, B4
4	Ss bdd	B. Brown	Alter horizontal, lt gr, F grn, B3, B3
5A	Bdd Pln	PAR	B3, lt gry, bd, v.f.grn, ss, near horizontal, thickness undivided

REMARKS: Tunnel alignment - ℄ 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate. 6/3/81 Optical centerline built 4+00

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

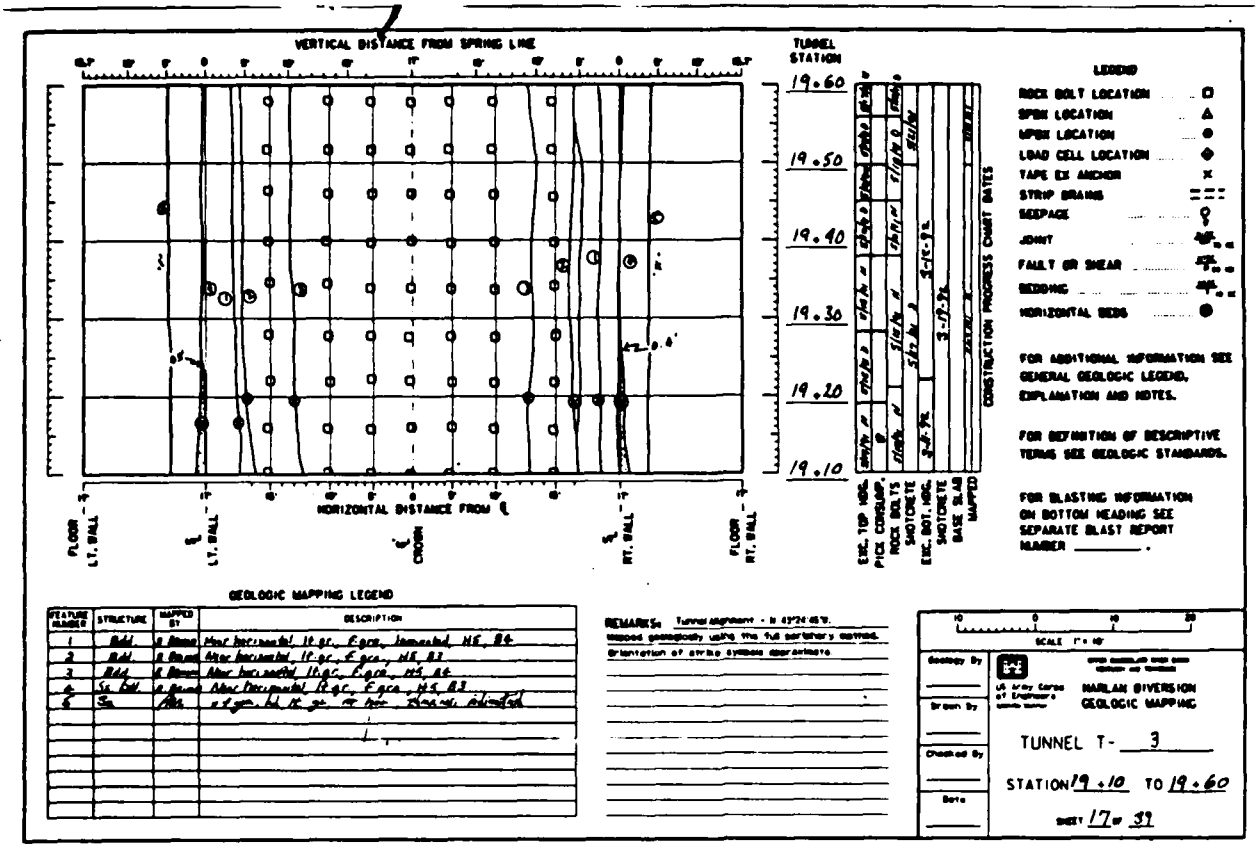
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 18+60 TO 19+10

SHEET 16 of 39

PLATE D-55


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
19.60
19.50
19.40
19.30
19.20
19.10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel alignment
mapped geologically using the full perimeter method.
Orientation of strike symbols approximate
SCALE
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 19+10 TO 19+60
SHEET 17 OF 39

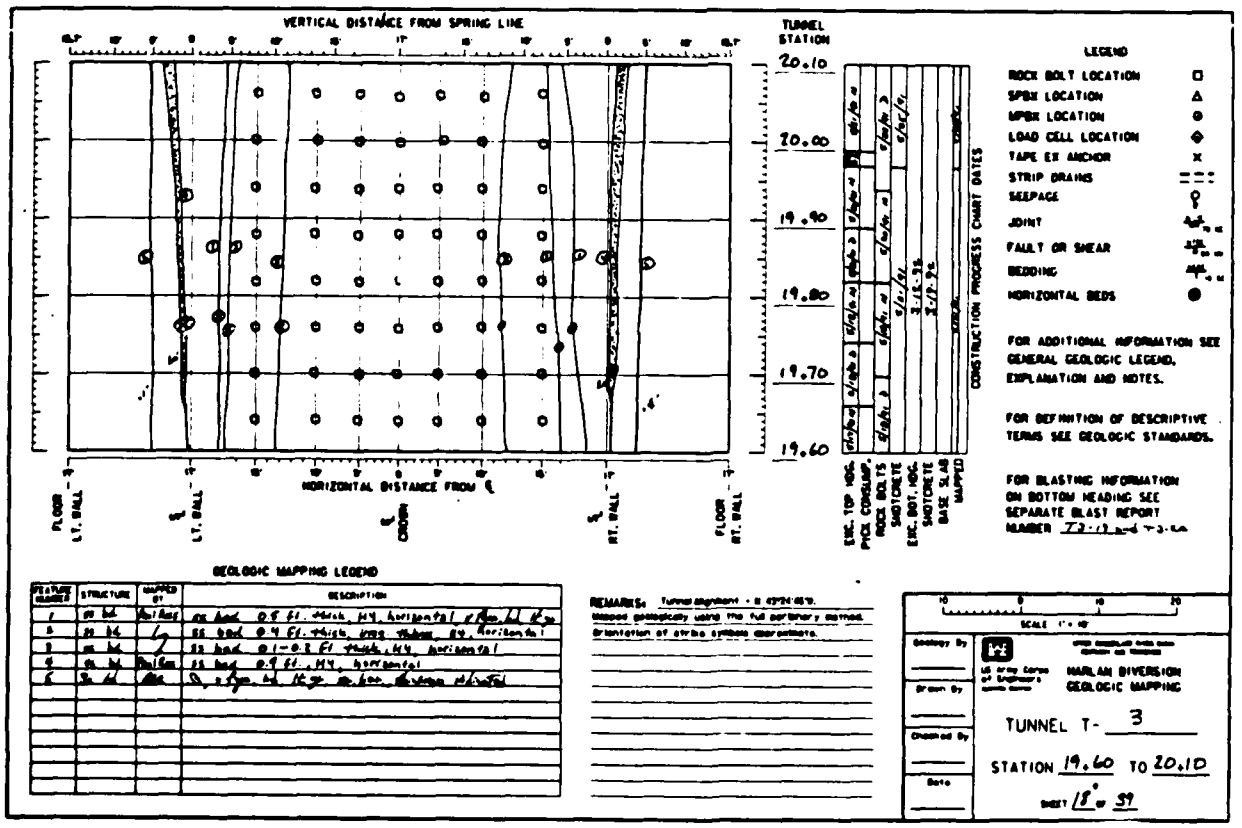
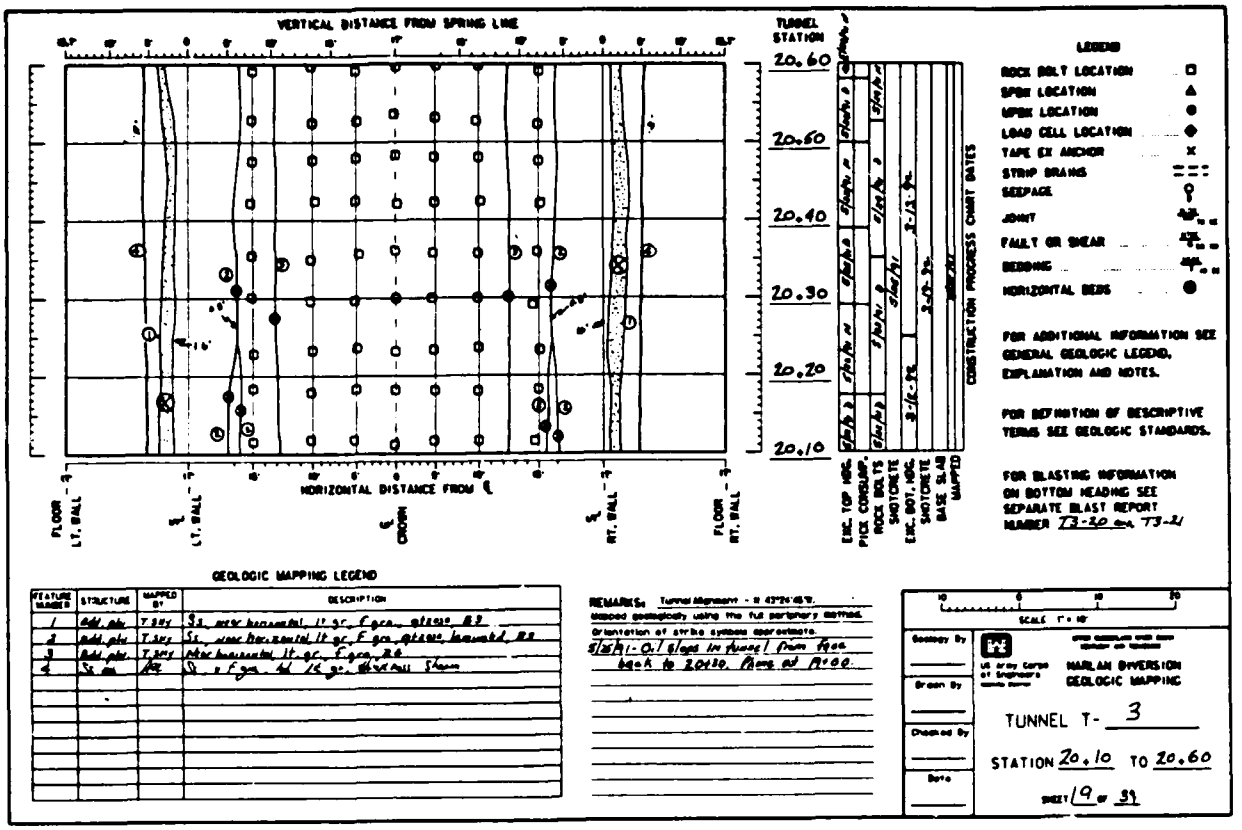

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
20.10
20.00
19.90
19.80
19.70
19.60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 73-19 and 73-14
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel alignment
mapped geologically using the full perimeter method.
Orientation of strike symbols approximate
SCALE
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 19.60 TO 20.10
SHEET 18 OF 39

PLATE D-56



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. plane	T.SAY	Ss, near horizontal, lt gr, f grn, qtzose, B2
2	Bdd. plane	T.SAY	Ss, near horizontal, lt gr, f grn, qtzose, laminated, B2
3	Bdd. plane	T.SAY	Ss, near horizontal, lt gr, f grn, B4
4	Ss dike	SAY	Ss, f grn, lt/dk gr, thin wall Storm

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/28/73 - 0.1 slope in invert from face back to 20+30. Floor at 4.00

SCALE 1" = 10

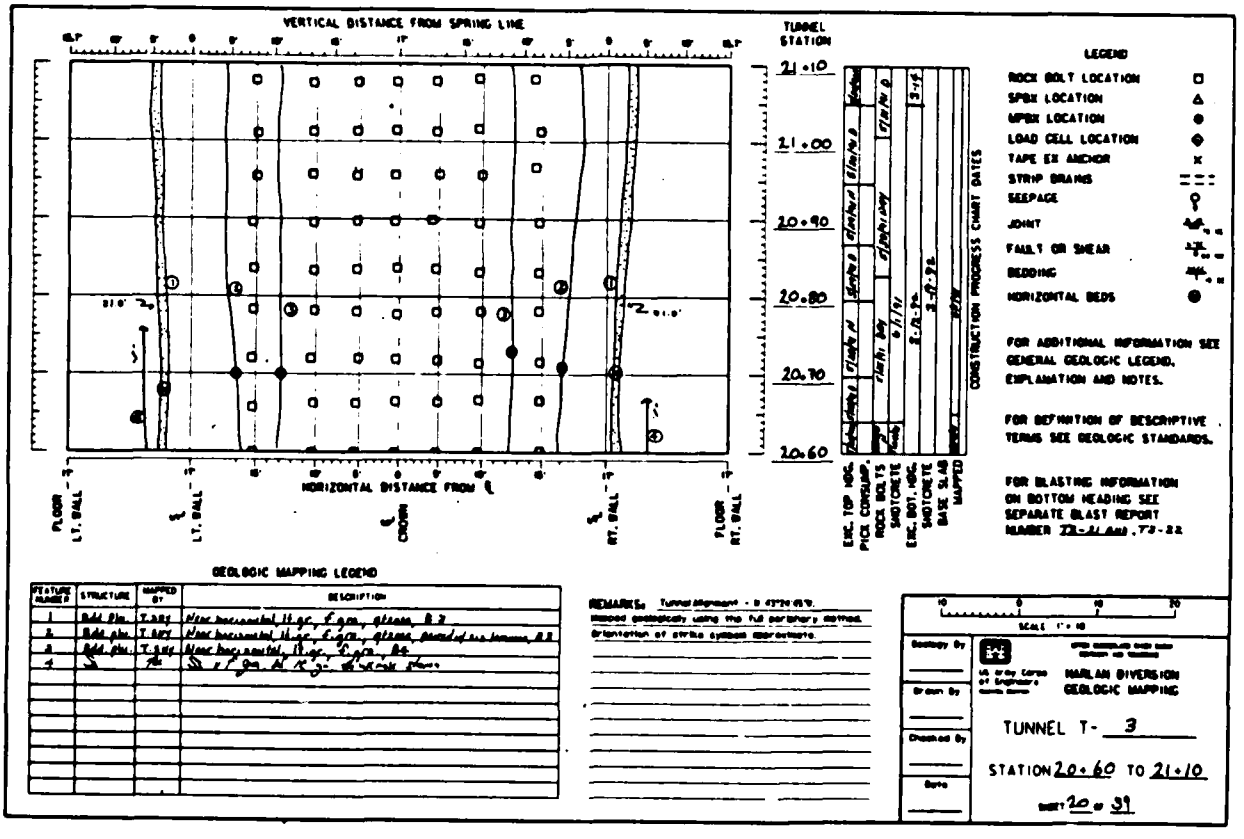
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — NARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 20.10 TO 20.60

SHEET 19 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. Plane	T.SAY	Mear horizontal, lt gr, f grn, qtzose, B2
2	Bdd. plane	T.SAY	Mear horizontal, lt gr, f grn, qtzose, laminated, B2
3	Bdd. plane	T.SAY	Mear horizontal, lt gr, f grn, B4
4	Ss	SAY	Ss, f grn, lt/dk gr, thin wall Storm

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

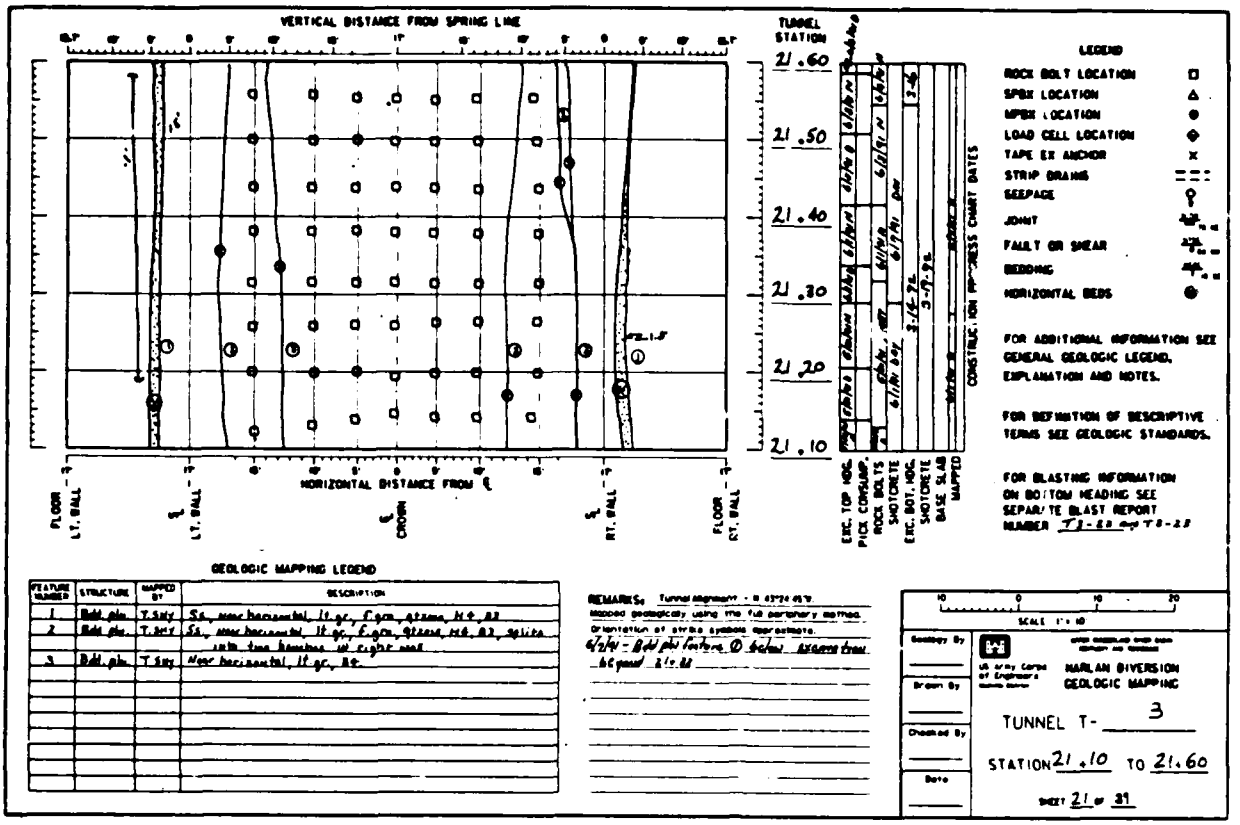
U.S. Army Corps of Engineers — NARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 20.60 TO 21.10

SHEET 20 OF 39

PLATE D-57



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. plane	T.Sitz	Ss, mwr horizontal, lt gr, f-gcm, qtzose, Mt. B3
2	Bdd. plane	T.Sitz	Ss, mwr horizontal, lt gr, f-gcm, qtzose, Mt. B3, splits with two benches at right wall
3	Bdd. plane	T.Sitz	Mwr horizontal, lt gr, Ss.

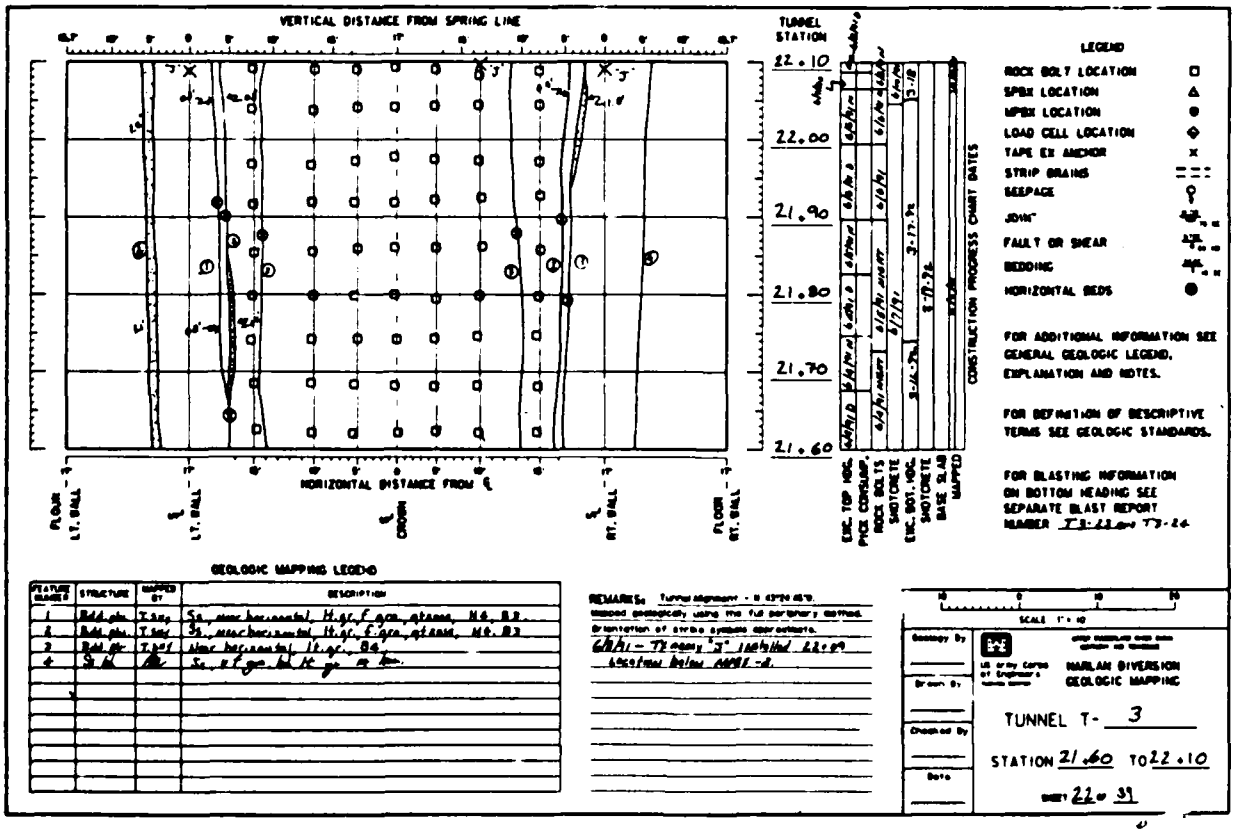
REMARKS: Tunnel alignment - 0 43°24 45"E
mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/2/81 - Bdd. plane (#3) 6±/ow 45±cm from ACground 21±ft

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 21.10 TO 21.60
SHEET 21 OF 31



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. plane	T.Sitz	Ss, mwr horizontal, lt gr, f-gcm, qtzose, Mt. B3
2	Bdd. plane	T.Sitz	Ss, mwr horizontal, lt gr, f-gcm, qtzose, Mt. B3
3	Bdd. plane	T.Sitz	Mwr horizontal, lt gr, Ss
4	Shear		Ss, f-gcm, lt gr to tan.

REMARKS: Tunnel alignment - 0 43°24 45"E
mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/8/81 - Tr away "3" 160±/dd 22±cm
45±cm/row below AMPL-d.

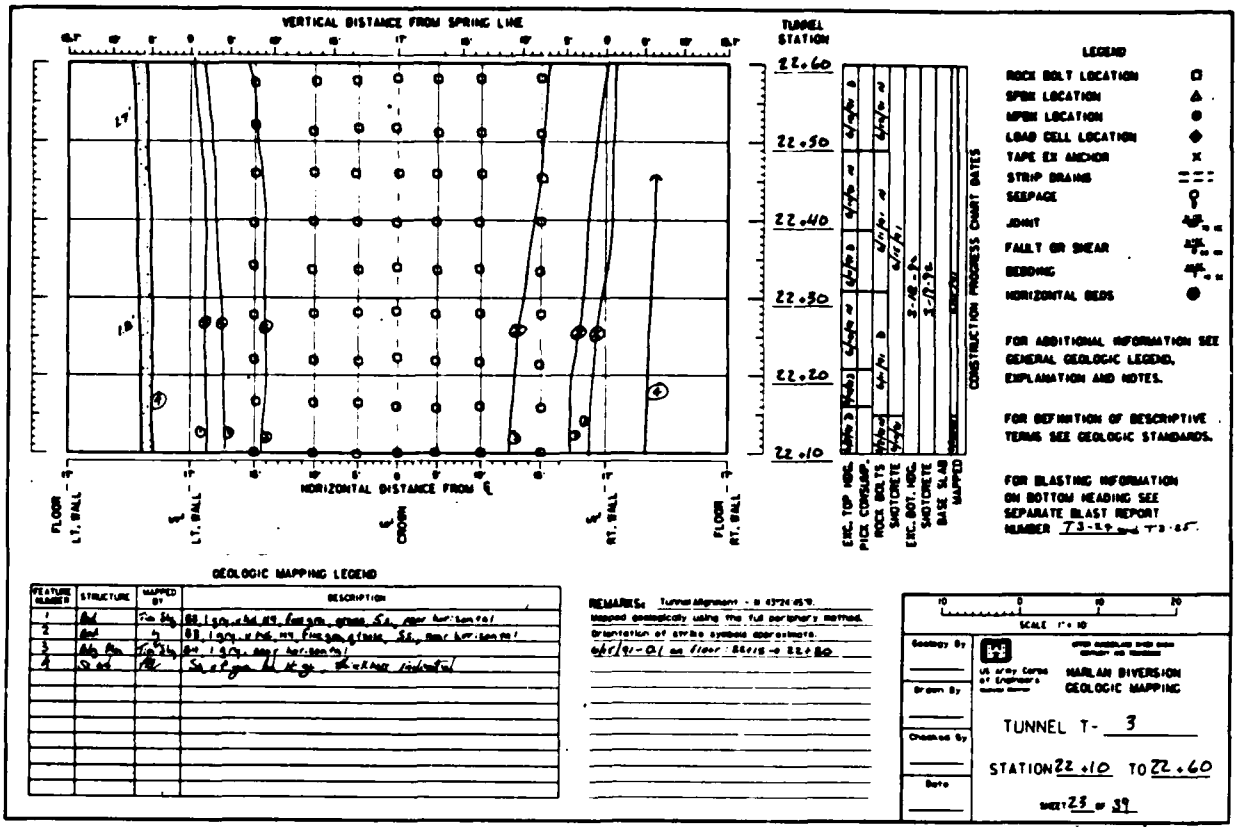
SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 21.60 TO 22.10
SHEET 22 OF 31

PLATE D-58


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
22.60
22.50
22.40
22.30
22.20
22.10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
ENC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ENC. BOT. HDG. SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 73-49 and 73-65.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - 0.0724 05°E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
4/4/91-0.1 on floor 22+15 to 22+60
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 22+10 TO 22+60
SHEET 23 OF 39

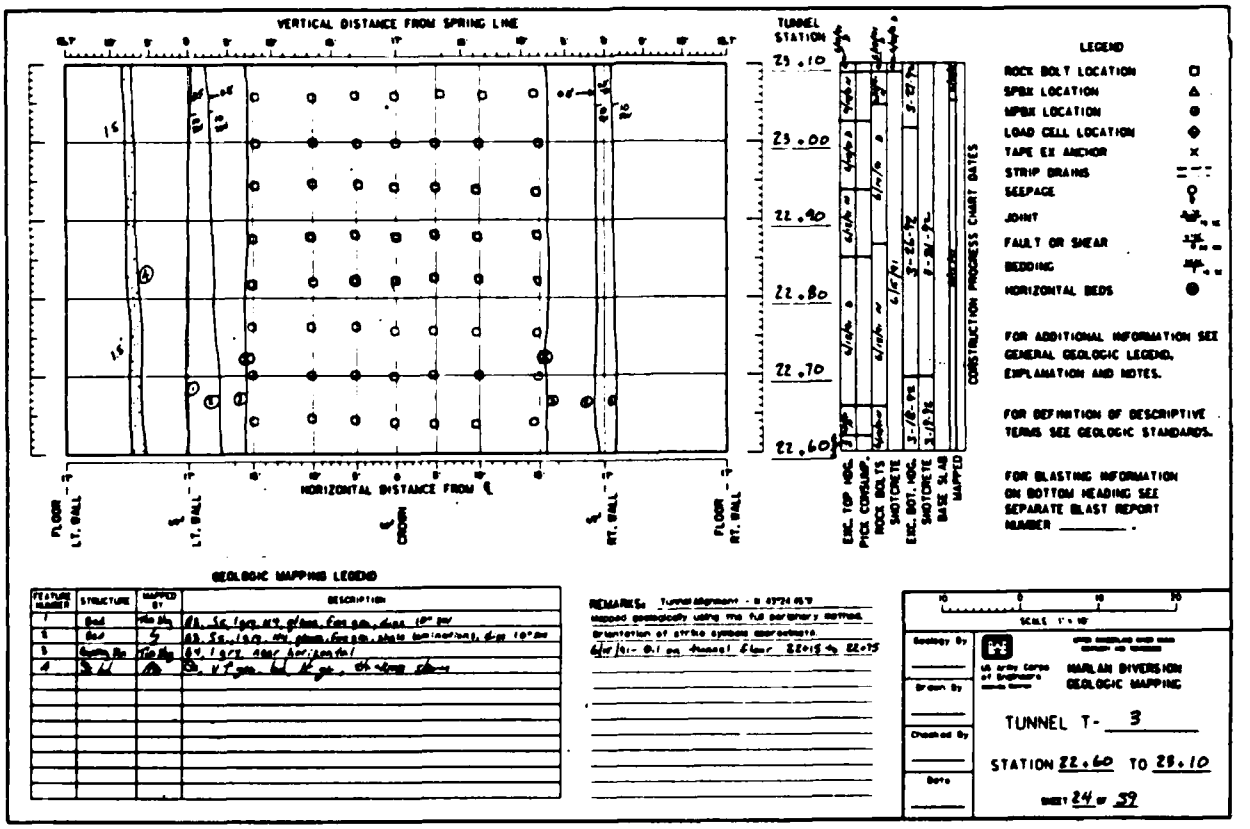
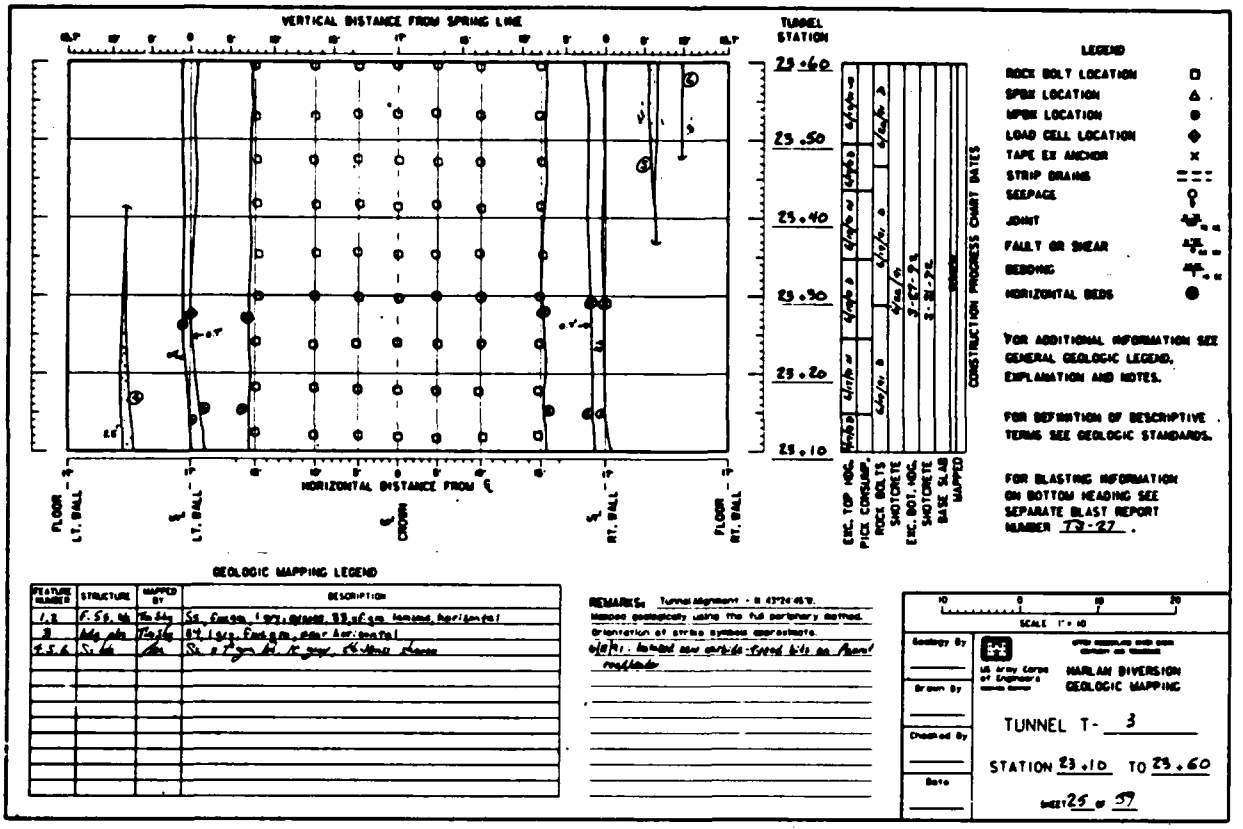

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
23.10
23.00
22.90
22.80
22.70
22.60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
ENC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ENC. BOT. HDG. SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - 0.0724 05°E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
4/4/91- 0.1 on Tunnel Floor 22+15 to 22+25
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 22+60 TO 23+10
SHEET 24 OF 39

PLATE D-59


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
23+60
23+50
23+40
23+30
23+20
23+10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HOG
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HOG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-27.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 47°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 23+10 TO 23+60
SHEET 25 OF 39

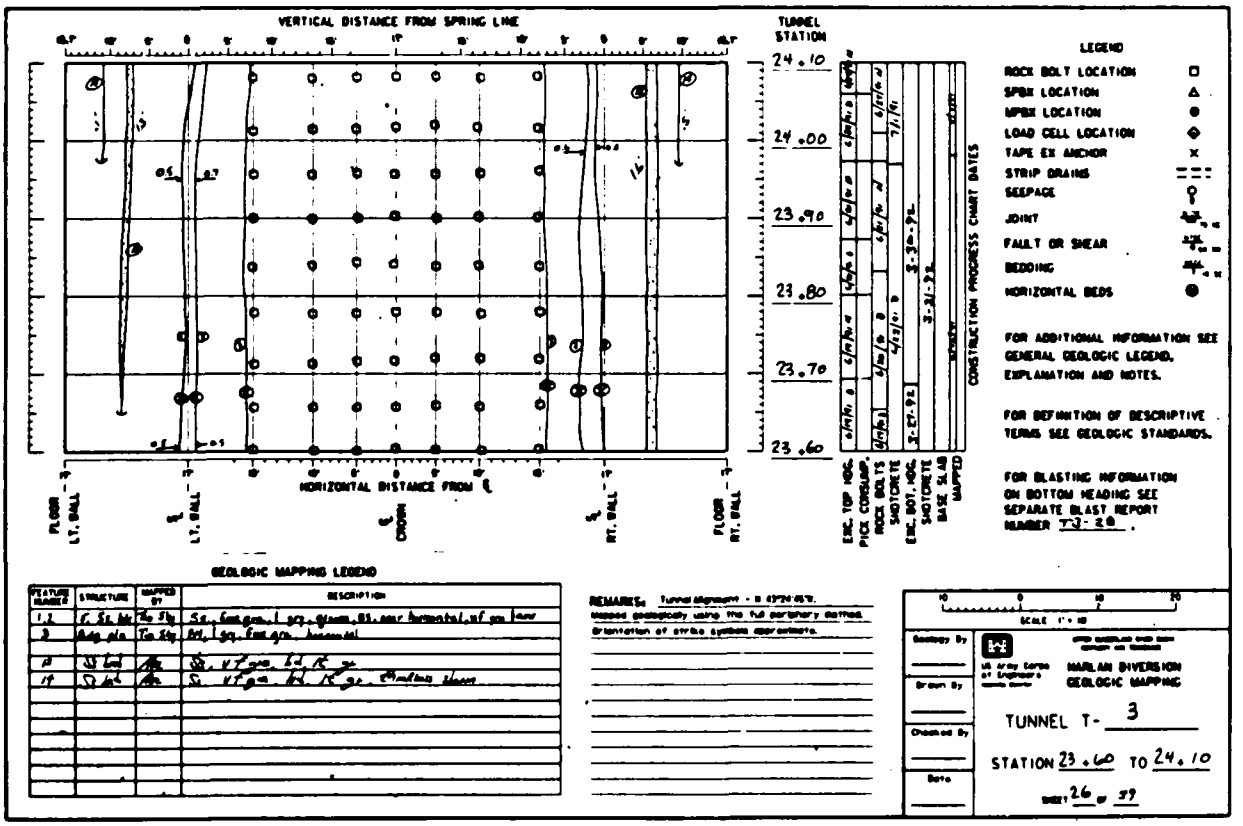
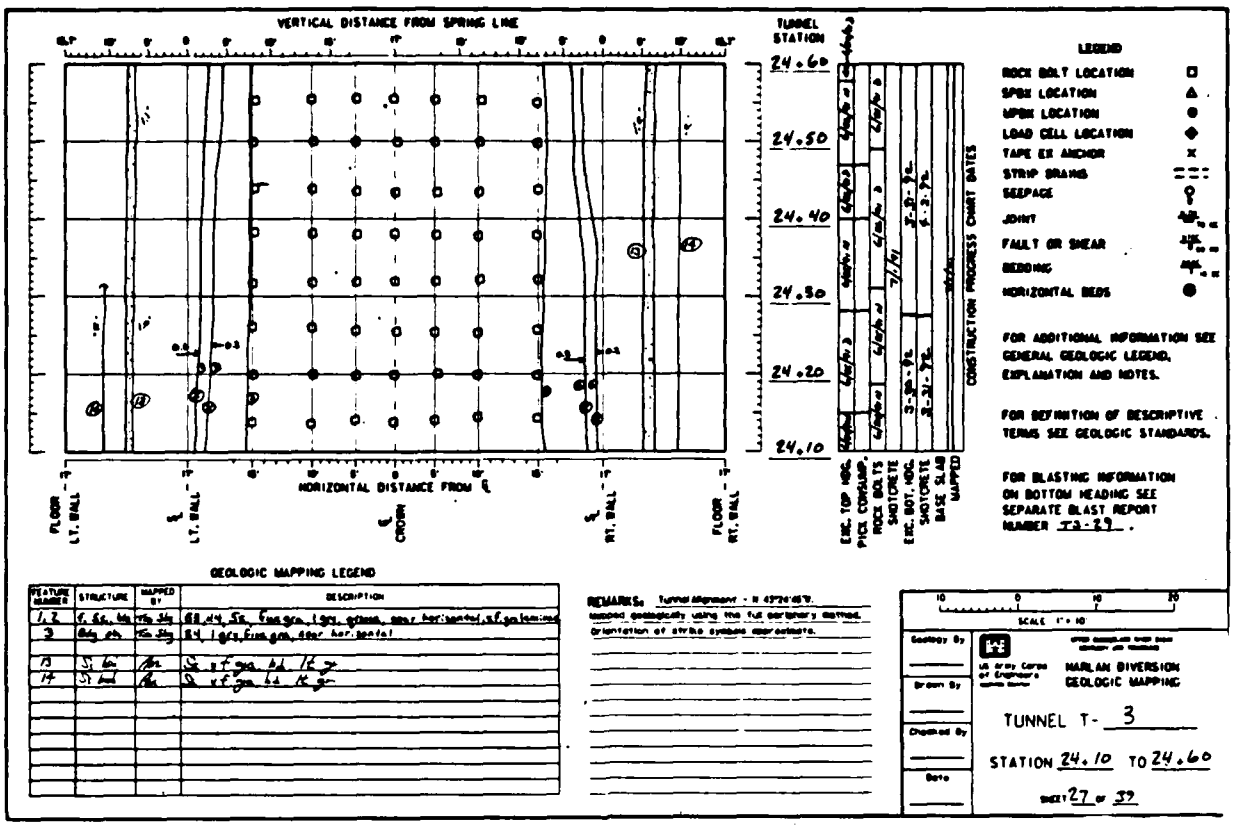

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
24+10
24+00
23+90
23+80
23+70
23+60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HOG
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HOG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-28.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 47°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 3
STATION 23+60 TO 24+10
SHEET 26 OF 39

PLATE D-60



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	F. Ss, Ms	Tm Sty	SS, m-f gm, l grn, grnsh, occ hor laminae/cl gn laminae
3	Bdg str	Tm Sty	SH, l grn, f-m gm, occ hor bedd
13	St Ls	Jbn	Ss, m f gm, bd, lt gy
14	St Ls	Jbn	Ss, vf gm, bd, lt gy

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

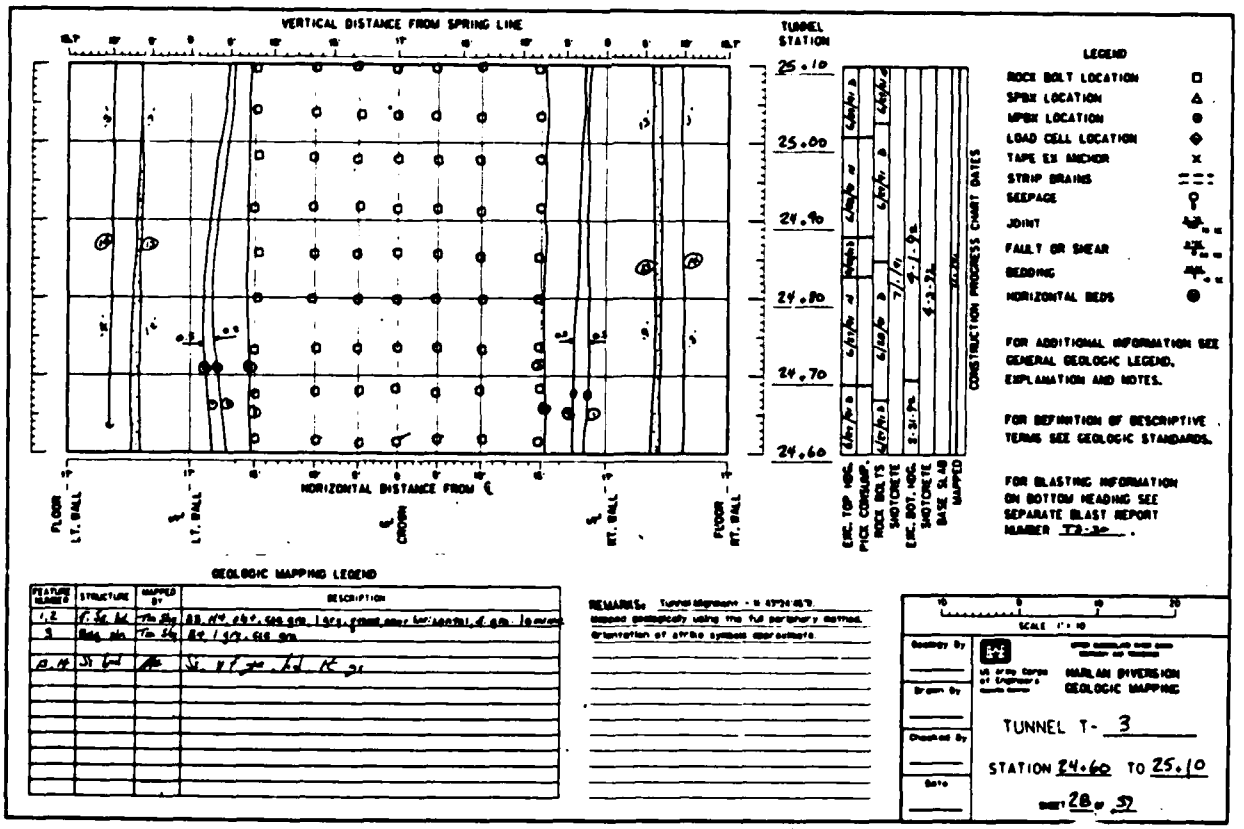
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 24.10 TO 24.60

SHEET 27 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	F. Ss, Ms	Tm Sty	SS, m-f gm, l grn, grnsh, occ hor laminae/cl gn laminae
3	Bdg str	Tm Sty	SH, l grn, f-m gm
13, 14	St Ls	Jbn	Ss, vf gm, bd, lt gy

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

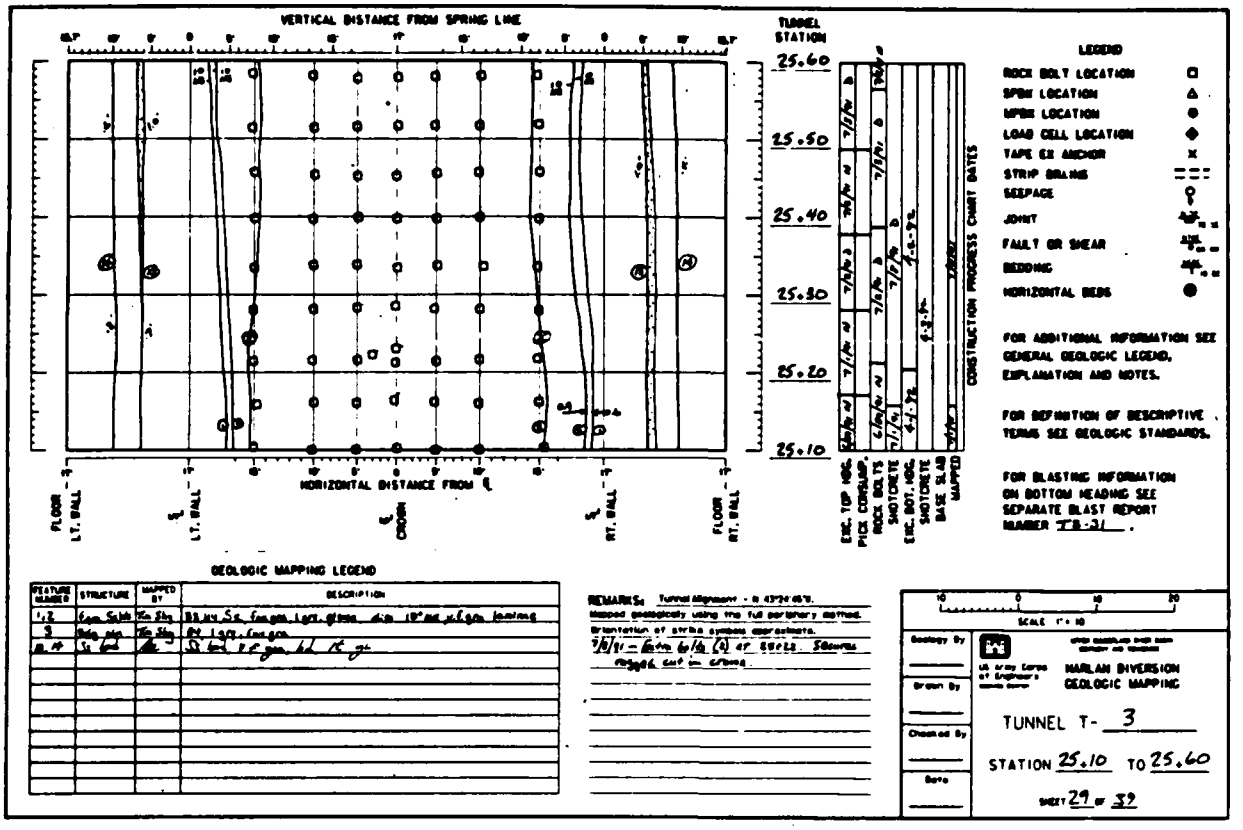
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 24.60 TO 25.10

SHEET 28 OF 39

PLATE D-61



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Fgm Schist	Tim Kay	85 alt Sc f-gm lgrt-gtnss dkn 10° ast w/ fgm laminae
3	Bdg. zone	Tim Kay	Bdg lgrt-fmgtnss
4, 5	Sc fault	Mac	Sc fault w/ fgm bd Kfgm

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/8/71 - Blasted 6:15 (2) at 60 ft. 58 rounds
Mapped Sept in crown.

SCALE 1" = 10

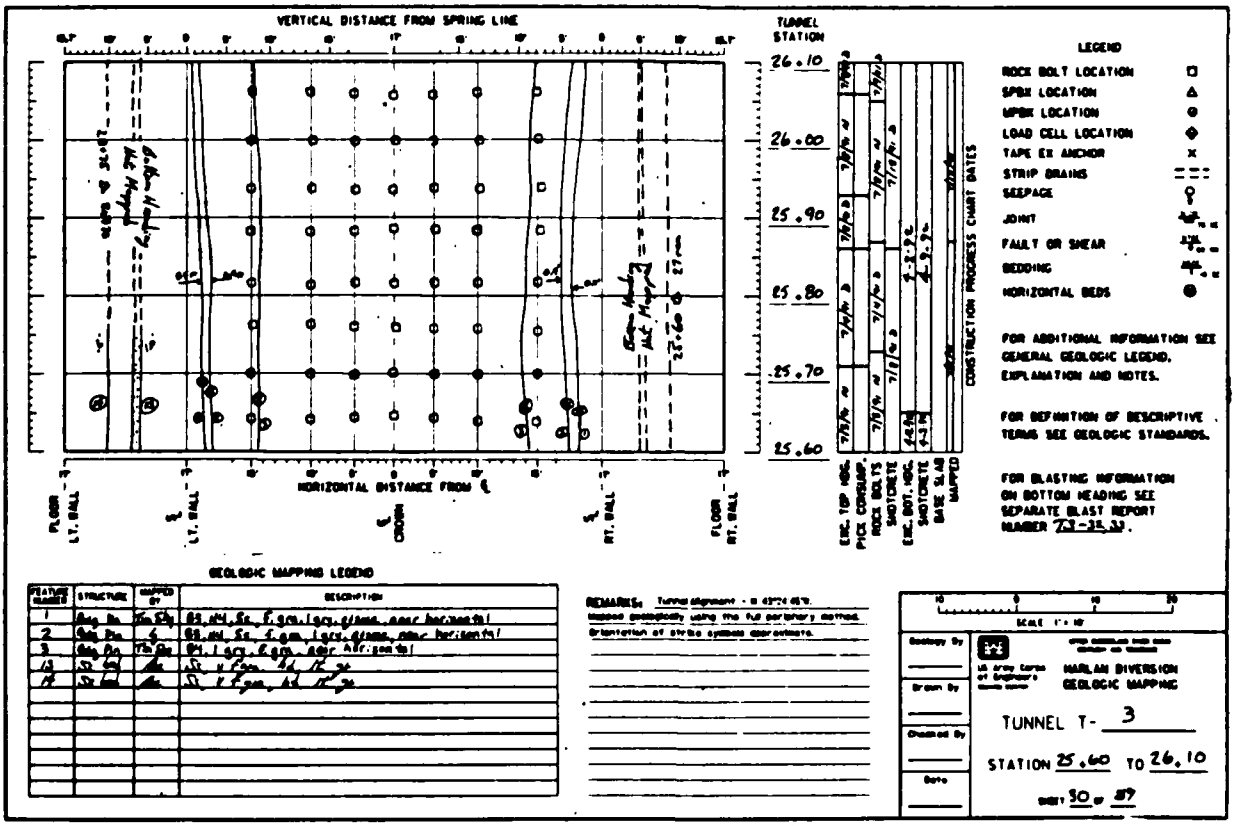
Geology By
Drawn By
Checked By
Date

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 25.10 TO 25.60

SHEET 29 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg. Zn	Tim Kay	85 alt Sc f-gm lgrt-gtnss, occ horizontal
2	Bdg. Zn	↓	85 alt Sc f-gm lgrt-gtnss, occ horizontal
3	Bdg. Zn	Tim Kay	Bdg lgrt-fmgtnss occ hor. seams
4,5	Sc fault	Mac	Sc w/ fgm bd Kfgm
6	Sc fault	Mac	Sc w/ fgm bd Kfgm

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

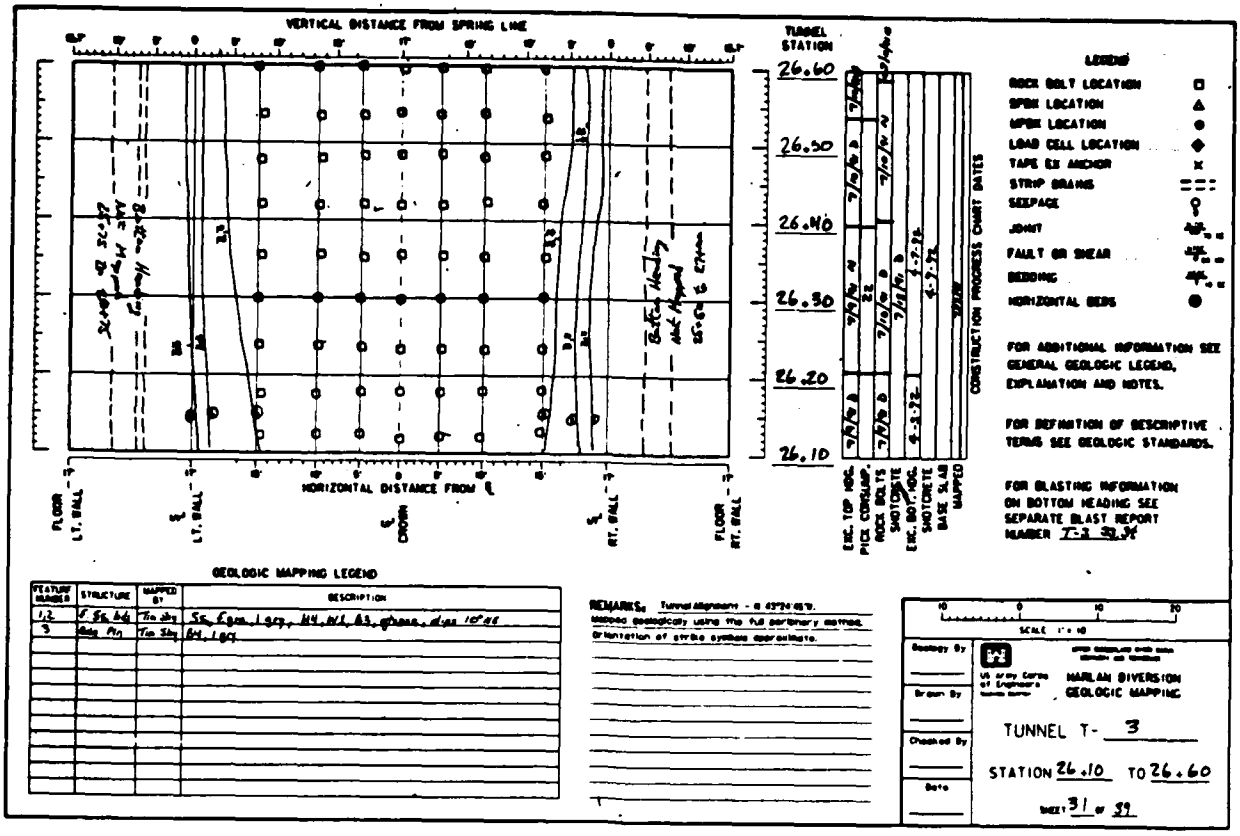
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 25.60 TO 26.10

SHEET 30 OF 39

PLATE D-62



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F. Sh. bdg	Tim Sby	Ss, f.gra, l.gray, Mt, Wt, Bl, ghase, dips 10°NE
3	Bdg Pln	Tim Sby	Ss, l.gray

REMARKS: Tunnel Alignment - ℄ 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

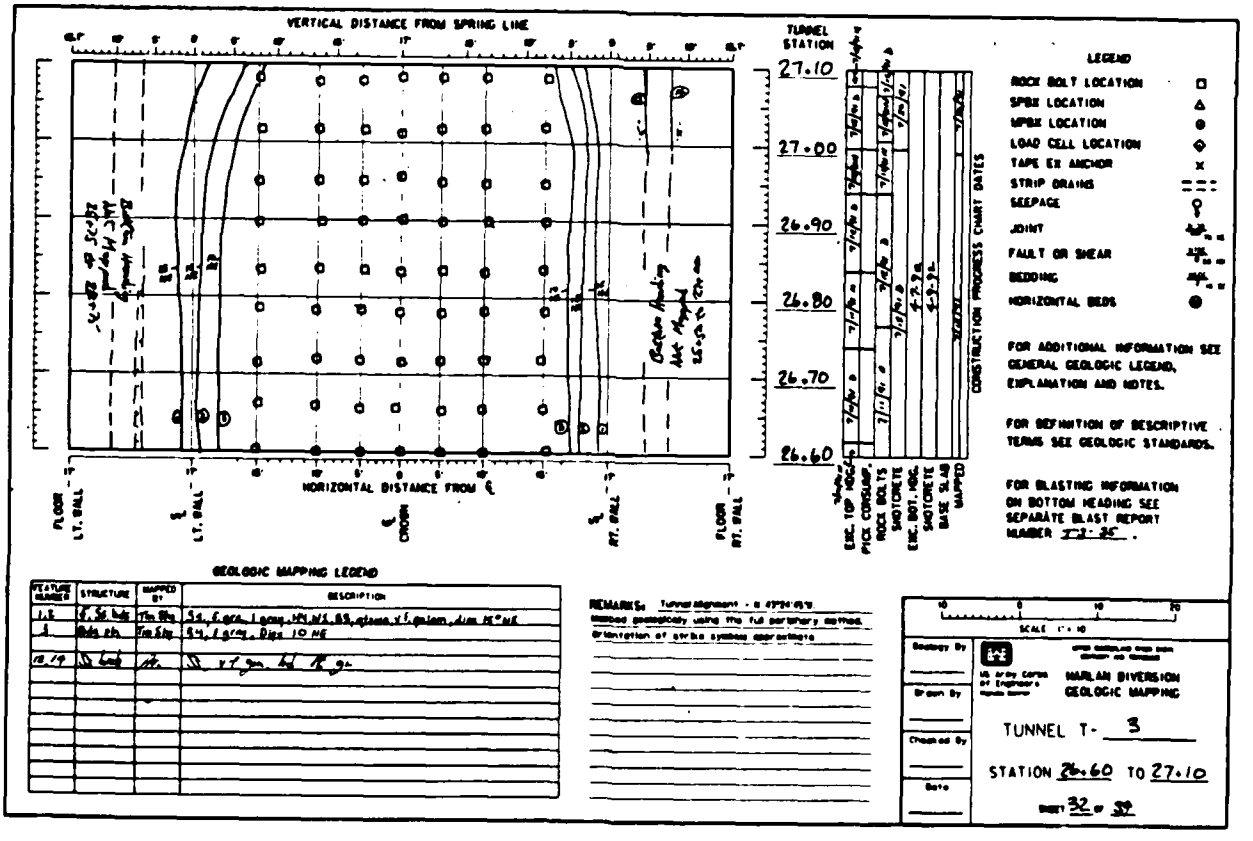
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 26.10 TO 26.60

SHEET 31 of 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F. Sh. bdg	Tim Sby	Ss, f.gra, l.gray, Mt, Wt, Bl, ghase, v f.gslam, dips 10°NE
3	Bdg Pln	Tim Sby	Ss, l.gray, Dips 10 NE
18, 19	Sh Lmtn		Ss, v f.gra, bd, Mt, gy

REMARKS: Tunnel Alignment - ℄ 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

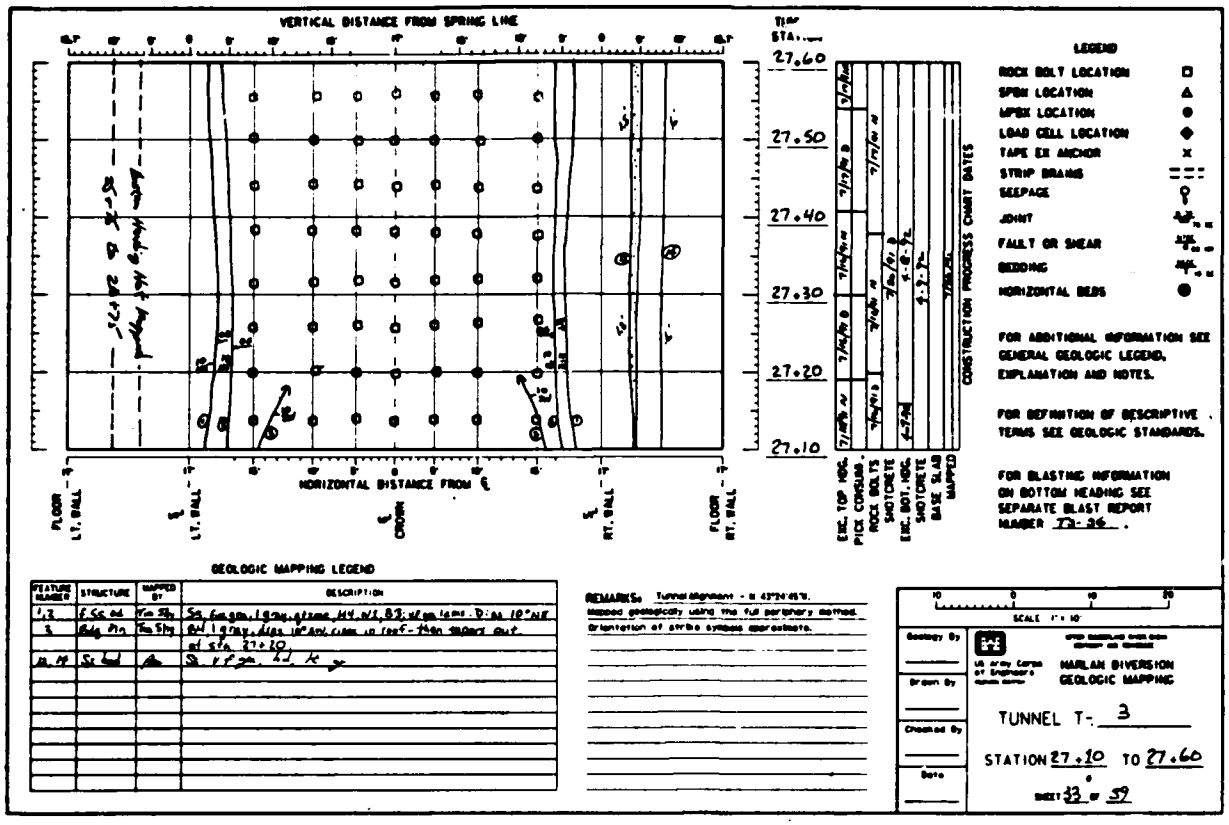
U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 26.60 TO 27.10

SHEET 32 of 39

PLATE D-63



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F Sc ad	Tm Sh	Sc fm gm, l gry, grnsh, MH, wl, BS: nf on lam, D: At 10°/NE
3	Bdg Pln	Tm Sh	Pl l gry, dips 10° AM, com in top F-thin SHOTCRETE out at Sta 27+10
8, 14	Sc Lnd		Sc f gm, Ld, Jc

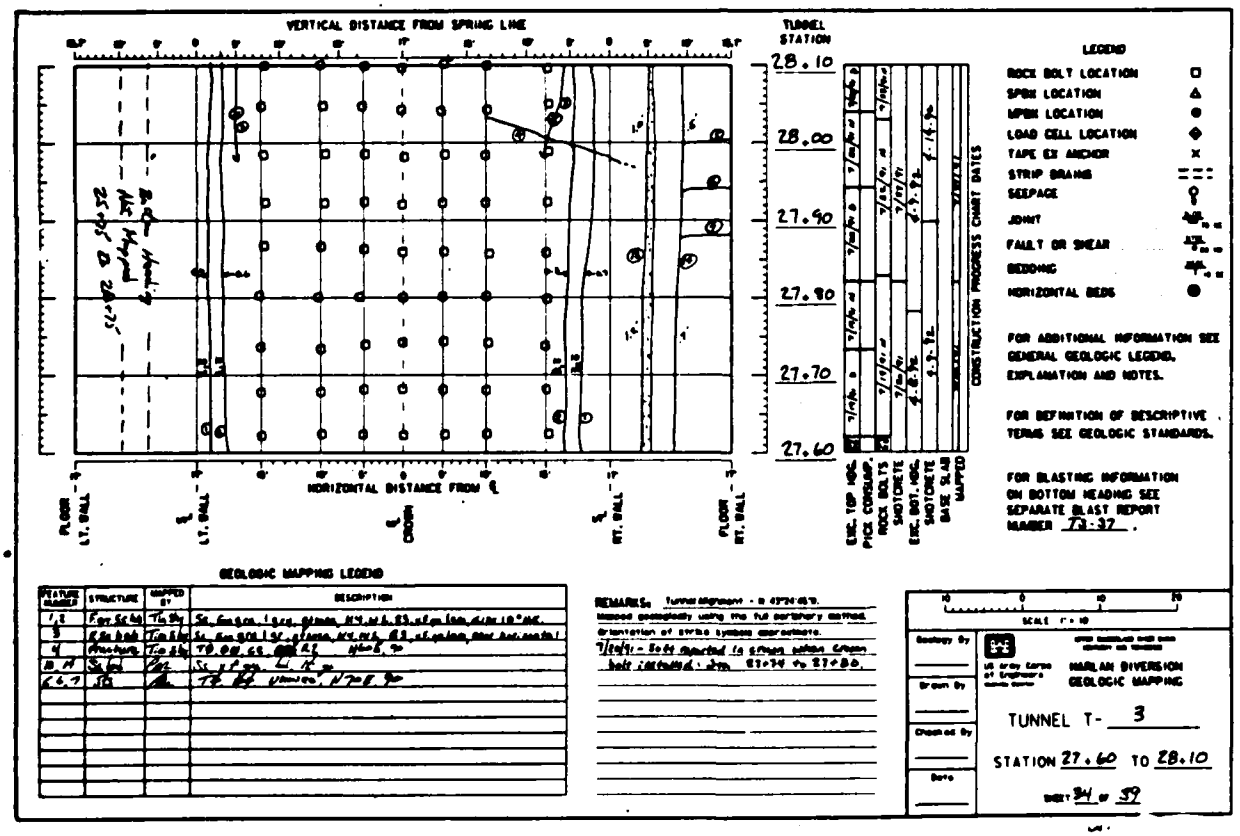
REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 27+10 TO 27+60
SHEET 33 OF 59



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Fgr Sc Ad	Tm Sh	Sc fm gm, l grn, grnsh, MH, wl, BS: nf on lam, dips 10° NE
3	Bdg Pln	Tm Sh	Sc, fm gm, l Sc, grnsh, MH, wl, BS: nf on lam, dips 10° NE
4	Fracture	Tm Sh	T@ 28+00, 65° NE
8, 14	Sc Lnd		Sc f gm, L Jc
5, 6, 7	Jts		T@ 60° Vertical, N70°E Sp

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Tr Jt #1 - Soft material in crown within Crown bolt pattern @ Sta 27+94 to 27+80.

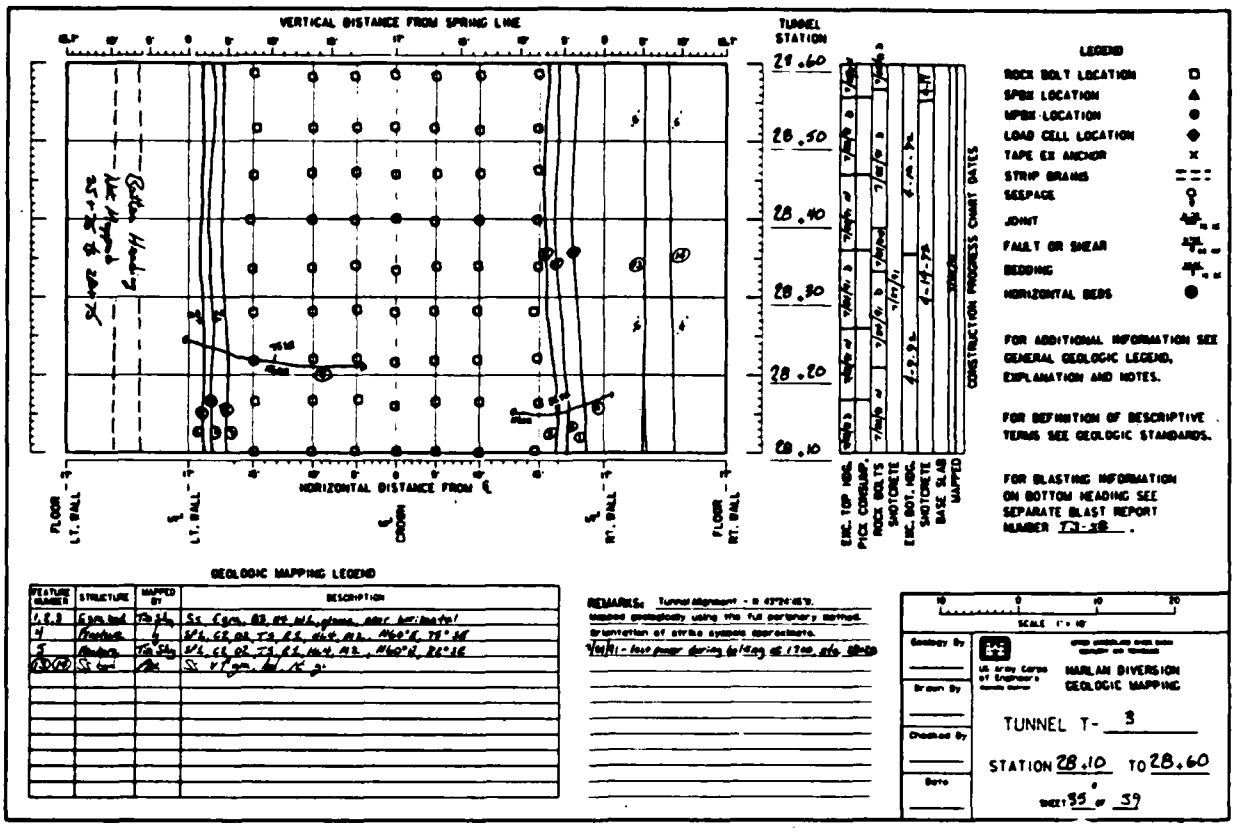
SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 27+60 TO 28+10
SHEET 34 OF 59

PLATE D-64



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Cgm. bed	Tb Sltg	Ss. Cgm. 60, ms wk, glauc, calc cem/matrix!
4	Fracture	4	54°E, 62 SE; T3, 65, dk-t, sh. N60°E, 75° SE
5	Fracture	Tb Sltg	54°E, 62 SE; T3, 65, dk-t, sh. N60°E, 75° SE
6 7 8	Ss bed	Tb	Ss. v f gm, thd, ltr gy.

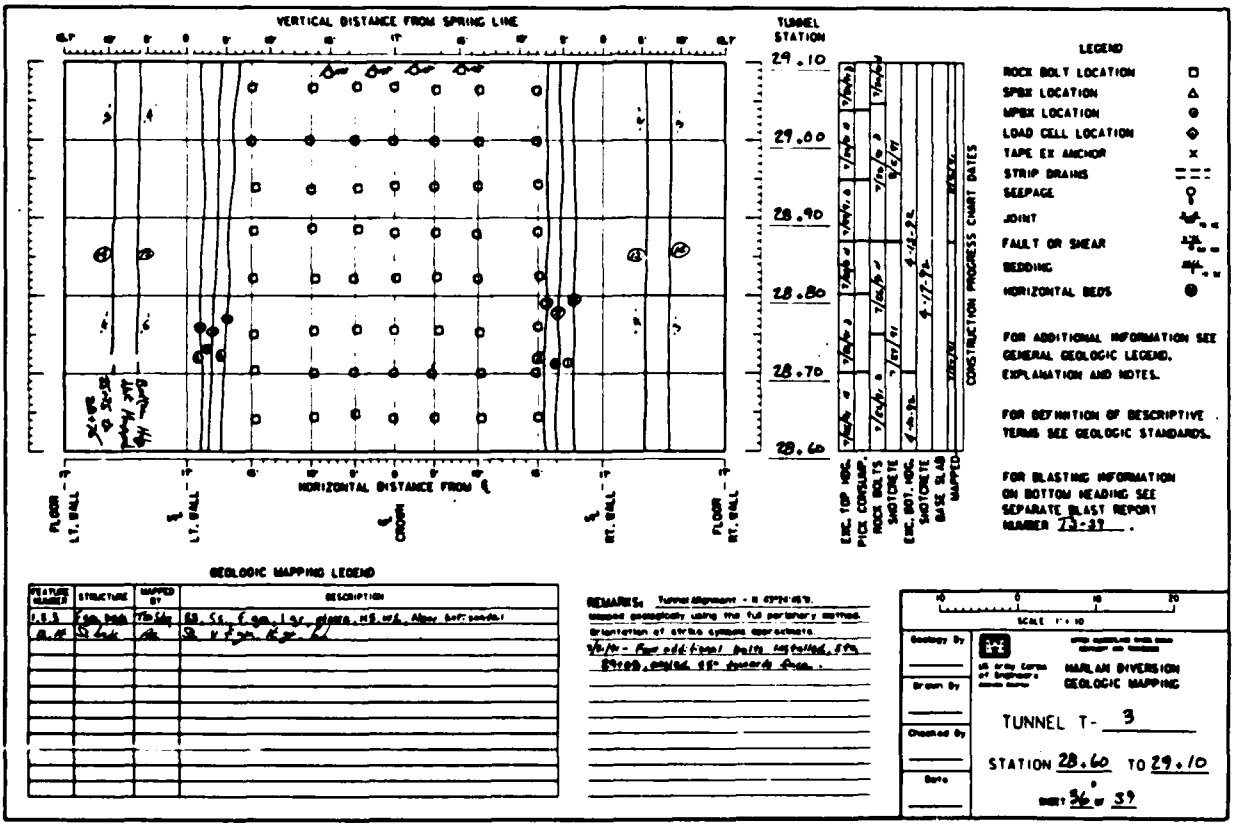
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/6/81 - Rain most of morning, light to heavy at times.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 28.10 TO 28.60
SHEET 35 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Cgm. beds	Tb Sltg	SS. Ss, f gm, l gr, glauc, MS wk, Abov bnt sandst
6, 7, 8	Ss bed	Tb	Ss. v f gm, thd, gy.

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/6/81 - Rain most of morning, light to heavy at times.
Strike, average 65° downhill from.

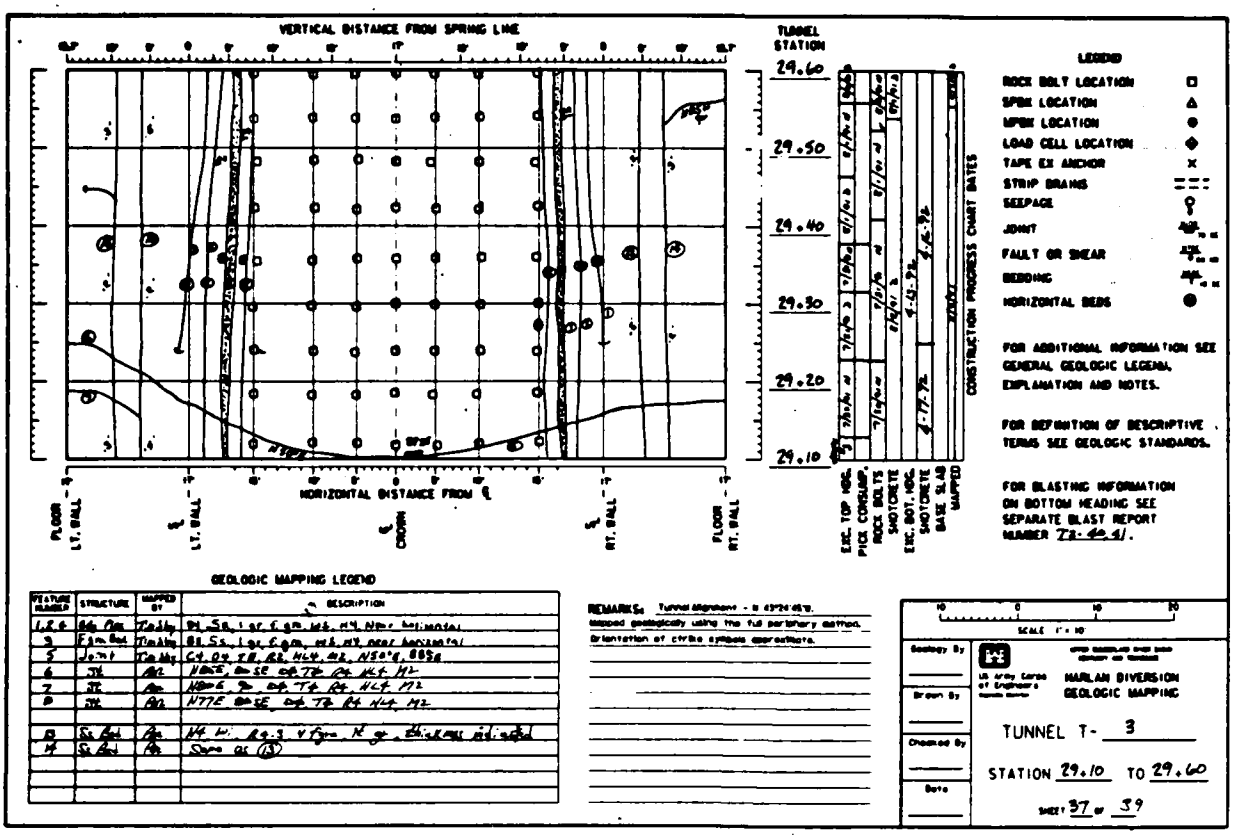
SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3
STATION 28.60 TO 29.10
SHEET 36 OF 39

PLATE D-65



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,4	Bdg Plane	Tm Mg	BS, SS, 1 or 2 sets, MS, HR, NNW-SSE, horizontal
3	Exp. Bed	Tm Mg	BS SS, 1 or 2 sets, MS, HR, near horizontal
5	Joint	Tm Mg	C4, 04 FR, RS, HLR, MS, N50°E, 88°S
6	JTS	RH	NNW, 8° SE of TR, RR, HLR, M2
7	JTS	RH	NNW 8° SW of TR, RR, HLR, M2
8	JTS	RH	N77E 8° SE of TR, RR, HLR, M2
10	Sh Bed	RH	HR, W, RQ-3, V Fgrn, N of Bk-Gray MS w/Sh
11	Sh Bed	RH	Same as (10)

REMARKS: Tunnel Alignment - N 4774.48'E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

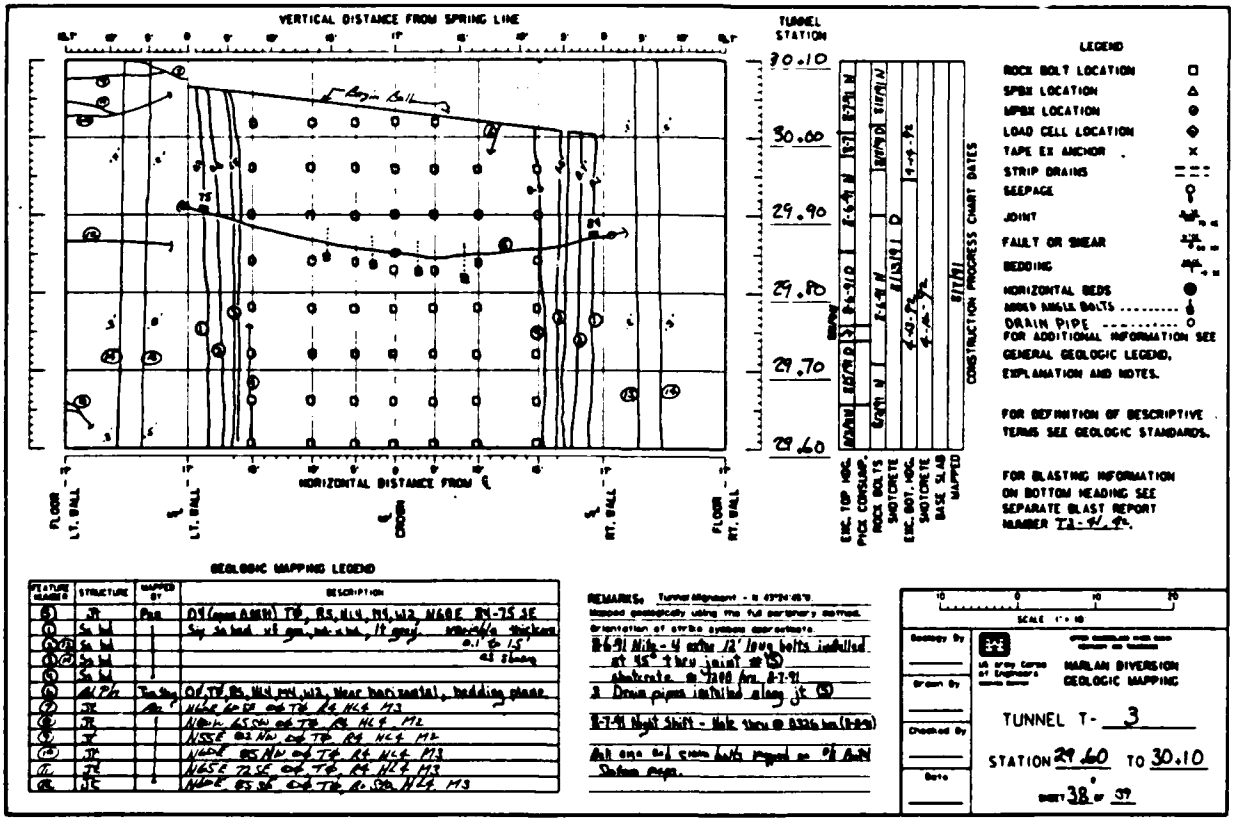
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 29.10 TO 29.60

SHEET 37 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
9	JTS	Pm	DS (open ABOVE) TR, RS, HLR, MS, W2, N68E 84-75 SE
	Sh Bed		Slip on bed w/ gyp, blk w/ bed, lt gray, interbeds thickness 0.1' to 1.5' at floor
	Sh Bed		
	Sh Bed		
	Sh Bed		
	Bdg Pln	Tm Mg	OF TR, RS, HLR, MS, W2, Near horizontal, bedding plane
	JTS	RH	NNW 8° SE of TR, RR, HLR, M2
	JTS		NNW 85 SW of TR, RR, HLR, M2
	JTS		N55E 85 NW of TR, RR, HLR, M2
	JTS		N40E 85 NW of TR, RR, HLR, M2
	JTS		N65E 75 SE of TR, RR, HLR, M2
	JTS		N10E 85 SE of TR, RR, HLR, M2

REMARKS: Tunnel Alignment - N 4774.48'E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
8-6-91 Hole-4 rebar 12' long bolts installed at 55° to new joint at (9) thickness @ 7200 hrs. 8-7-91
2 Drain pipes installed along jt (9)
8-7-91 Night Shift - Hole thru @ 8326 hrs (1400)
All rock bolt system holes drilled at 90° to Joint System mapped.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

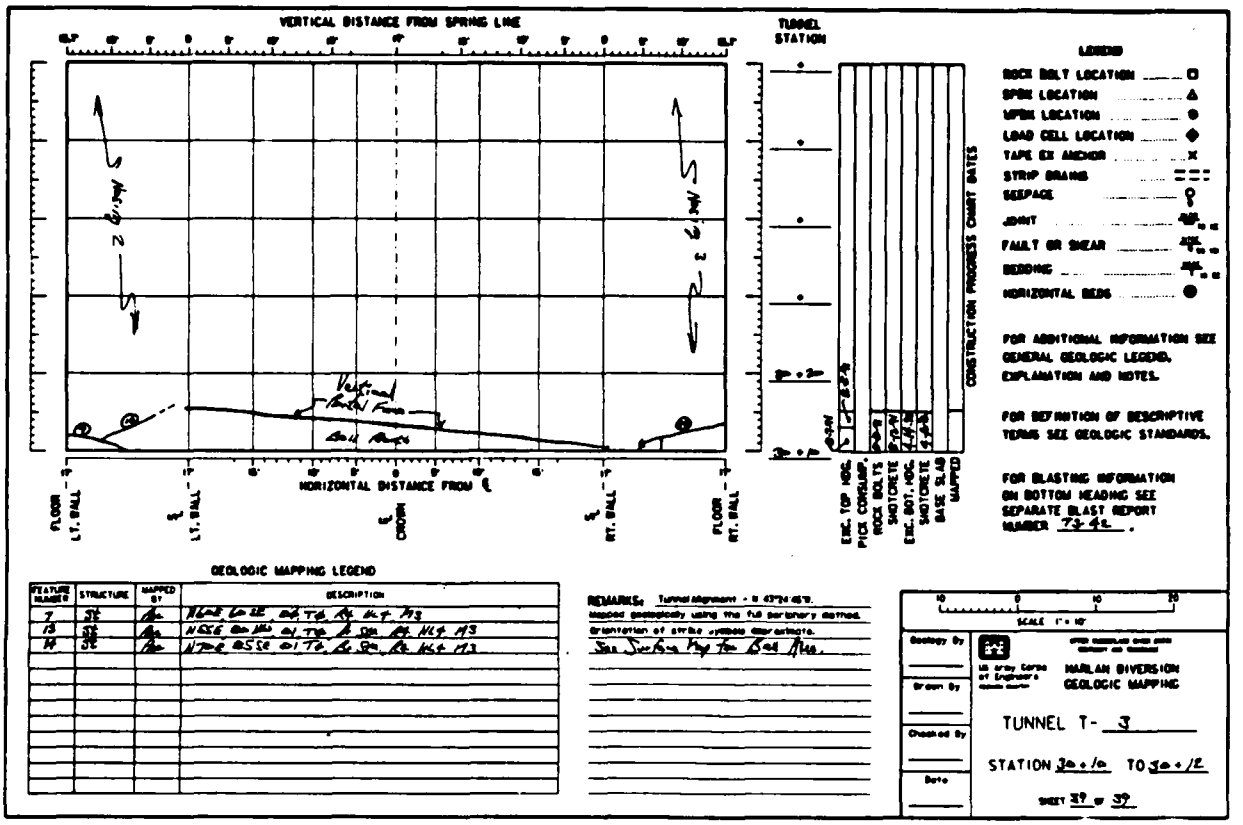
US Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 29.60 TO 30.10

SHEET 38 OF 39

PLATE D-66



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
7	JT	[illegible]	[illegible]
13	JT	[illegible]	[illegible]
14	JT	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24 45°E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
See Surface Map for Bed Attd.

SCALE 1" = 10'

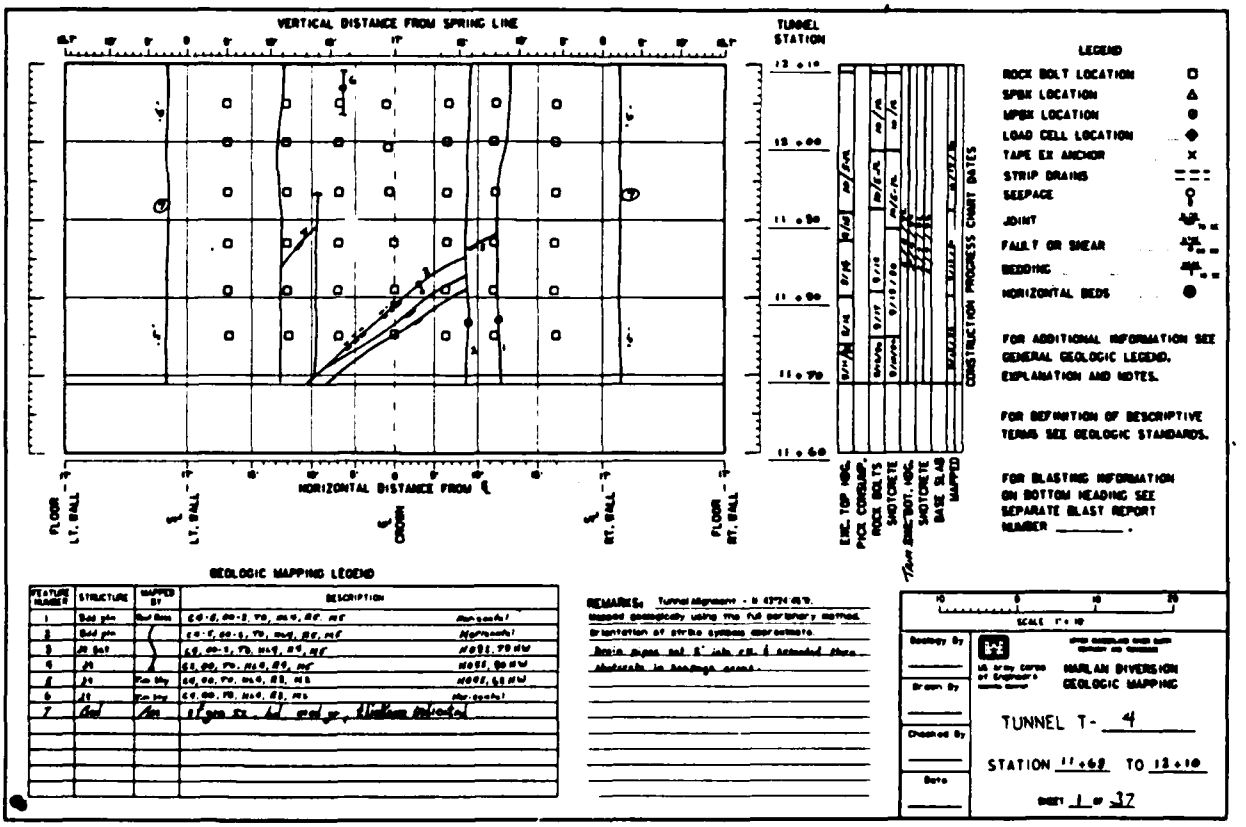
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 30+10 TO 30+12

SHEET 39 OF 39



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed plane	[illegible]	[illegible]
2	Bed plane	[illegible]	[illegible]
3	JT Set	[illegible]	[illegible]
4	JT	[illegible]	[illegible]
5	JT	[illegible]	[illegible]
6	JT	[illegible]	[illegible]
7	Bed	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24 45°E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Basin ripped out 5' into rib & extended there-
after to headings cease.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

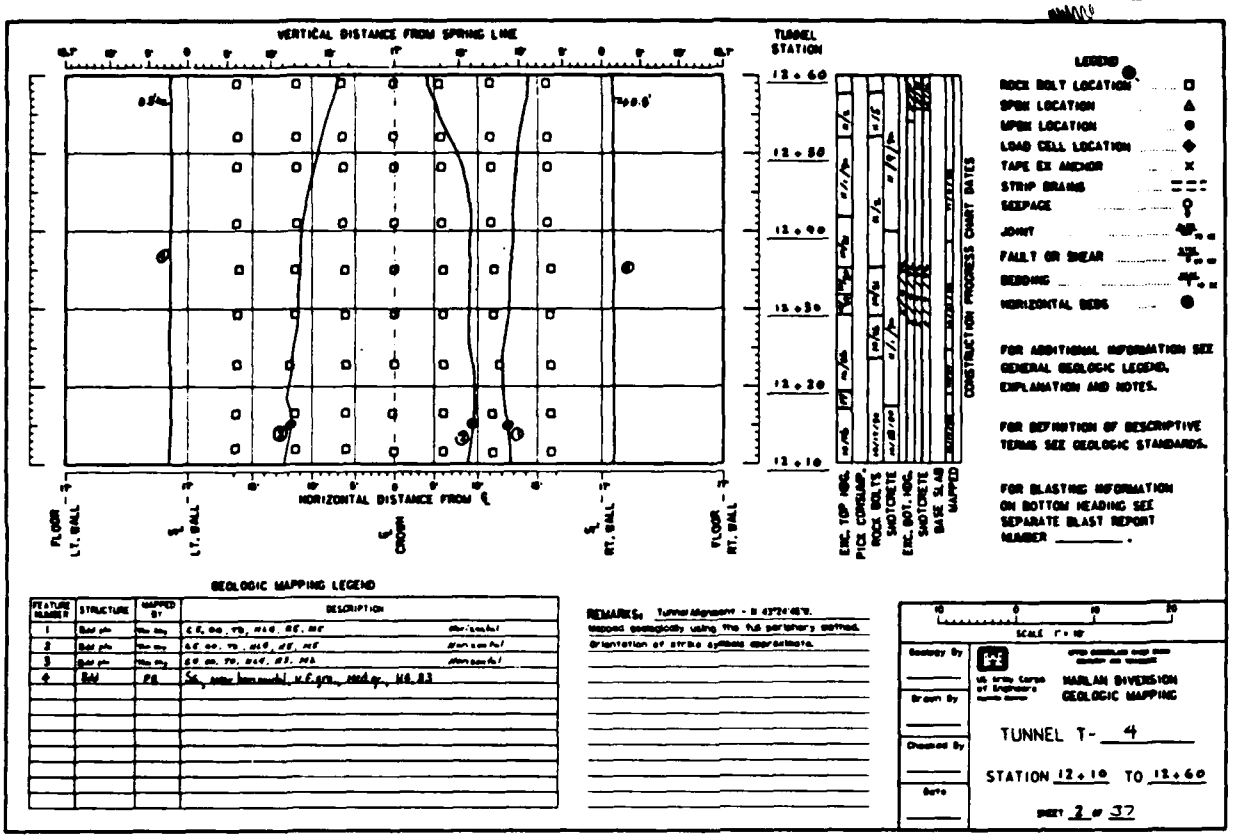
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 11+69 TO 12+10

SHEET 1 OF 37

PLATE D-67


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
12+60
12+50
12+40
12+30
12+20
12+10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
ERC. TOP HDG.
PICK CORRUG.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 Bdd ph FB Sh, mwr horizontal, v.f.grn, med.gr, H4.B3
REMARKS: Tunnel Alignment - S 43°24'45"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 12+10 TO 12+60
SHEET 2 OF 37

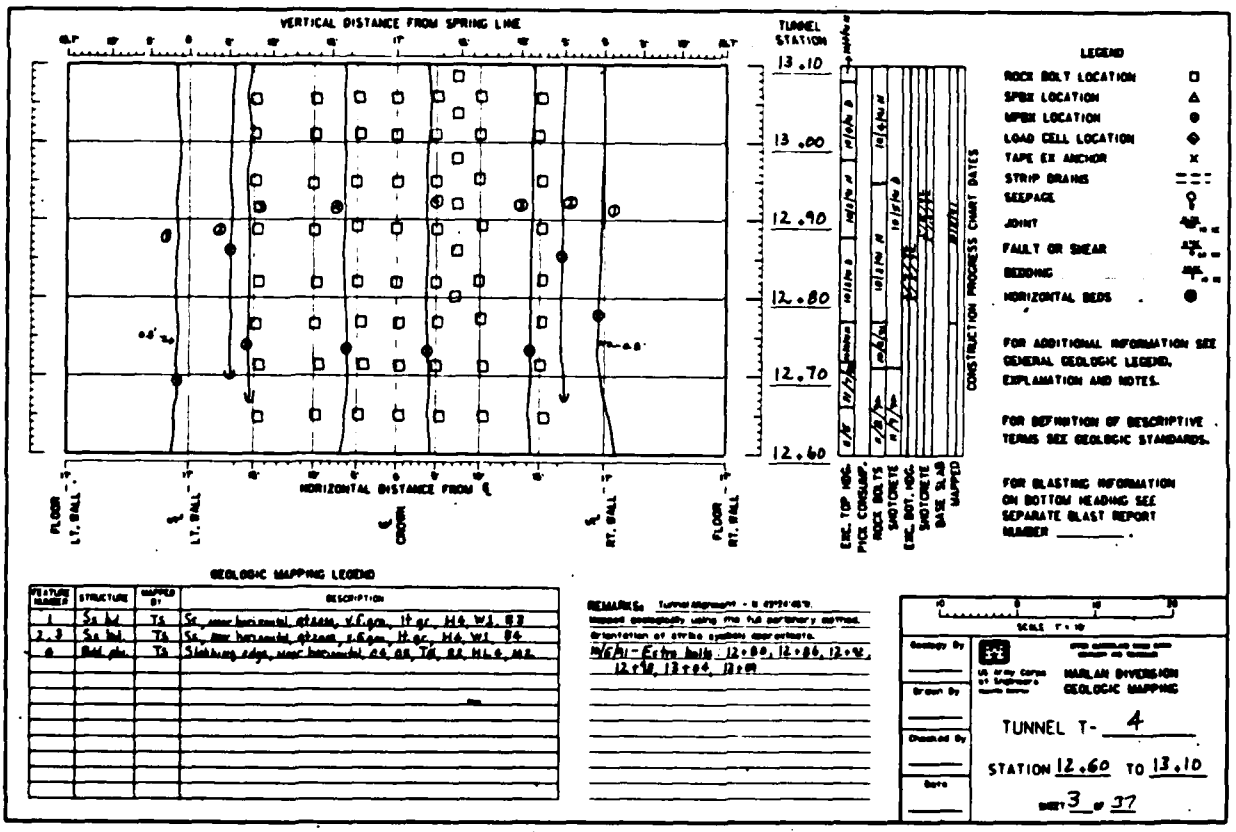
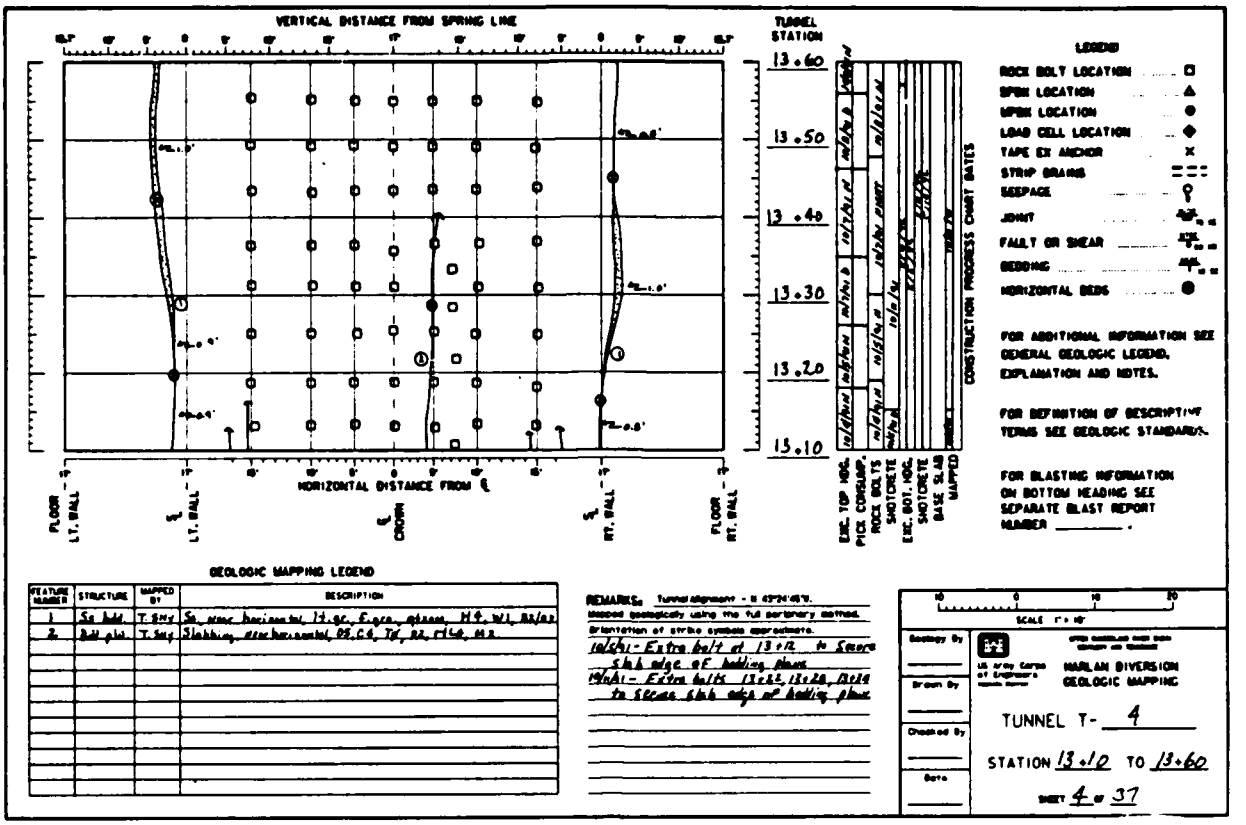

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
13+10
13+00
12+90
12+80
12+70
12+60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
ERC. TOP HDG.
PICK CORRUG.
ROCK BOLTS
SHOTCRETE
ERC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 Ss bd TS Ss, mwr horizontal, stream, v.f.grn, lt gr, H4, W1, B3
2, 3 Ss bd TS Ss, mwr horizontal, stream, v.f.grn, lt gr, H4, W1, B4
4 Bdd ph TS Sidehill ridge, mwr horizontal, B4, B5, TS, B2, H1.5, M3.
REMARKS: Tunnel Alignment - S 43°24'45"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
N/C/H1 - Extra bolts 12+80, 12+86, 12+92, 12+98, 13+04, 13+09
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
U.S. Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 12+60 TO 13+10
SHEET 3 OF 37

PLATE D-68



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sz Bdd	T. Sny	Sz zone horizontal, 11 gc, 6 gcs, gtsand, MG, W1, B2/B3
2	Bdd plane	T. Sny	Slickens, zone horizontal, 09 C6, TR, B2, R1 W1, B2

REMARKS: Tunnel alignment - N 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
10/5/81 - Extra bolt at 13+12 to secure slab edge of bedding plane
10/6/81 - Extra bolts 13+22, 13+28, 13+38 to secure slab edge of bedding plane

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

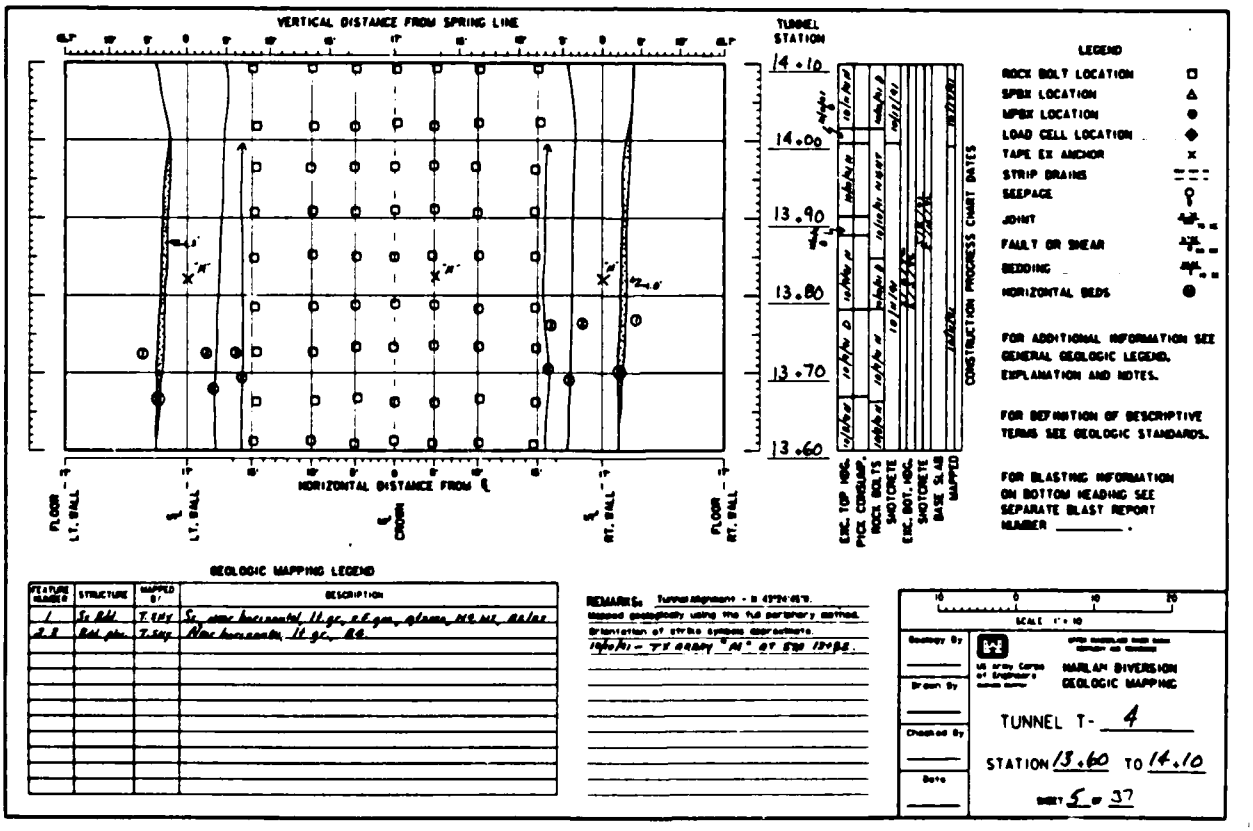
US Army Corps of Engineers — Omaha District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 13+10 TO 13+60

SHEET 4 of 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sz Bdd	T. Sny	Sz zone horizontal, 11 gc, 6 gcs, gtsand, MG, W2, B2/B3
2,3	Bdd plane	T. Sny	Slickens, zone horizontal, 11 gc, R6.

REMARKS: Tunnel alignment - N 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
10/6/81 - FT GREEN "A" AT STA 13+62.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — Omaha District

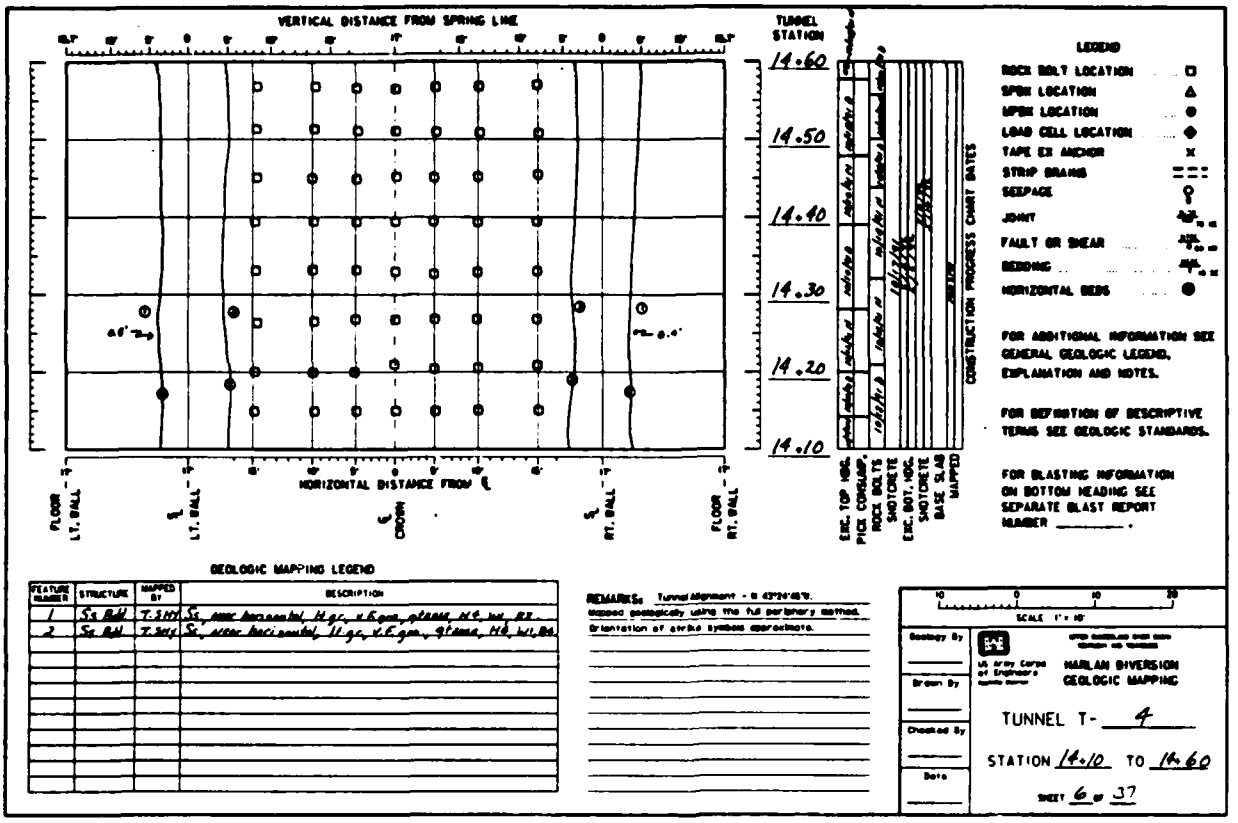
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 13+60 TO 14+10

SHEET 5 of 37

PLATE D-69



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sz Bdd	T.SHY	Sz, near horizontal, H gr, v f gm, gleaux, H6, wi, dx
2	Sz Bdd	T.SHY	Sz, near horizontal, H gr, v f gm, gleaux, H6, wi, Bb

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

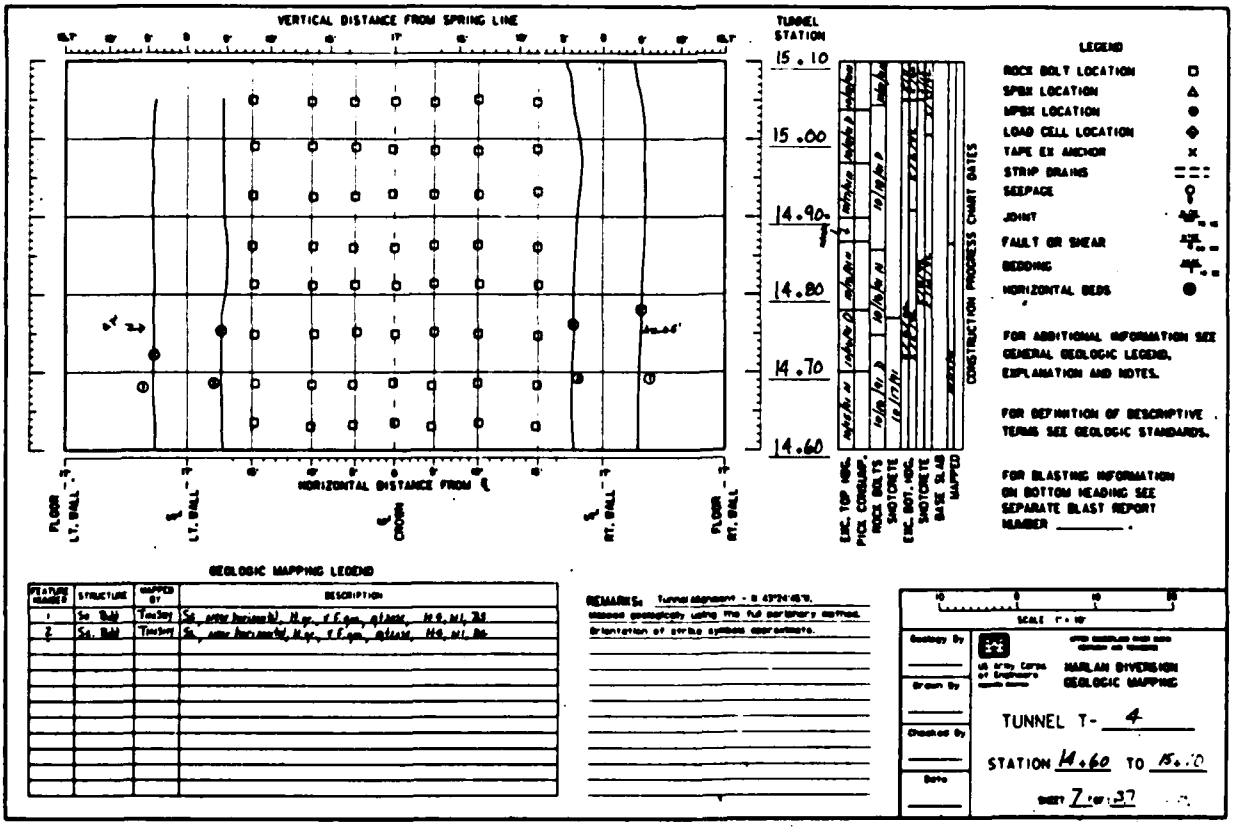
US Army Corps of Engineers — Sacramento District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 14+10 TO 14+60

SHEET 6 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sz Bdd	Tawney	Sz, near horizontal, H gr, v f gm, gleaux, H6, wi, Bb
2	Sz Bdd	Tawney	Sz, near horizontal, H gr, v f gm, gleaux, H6, wi, Bb

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers — Sacramento District

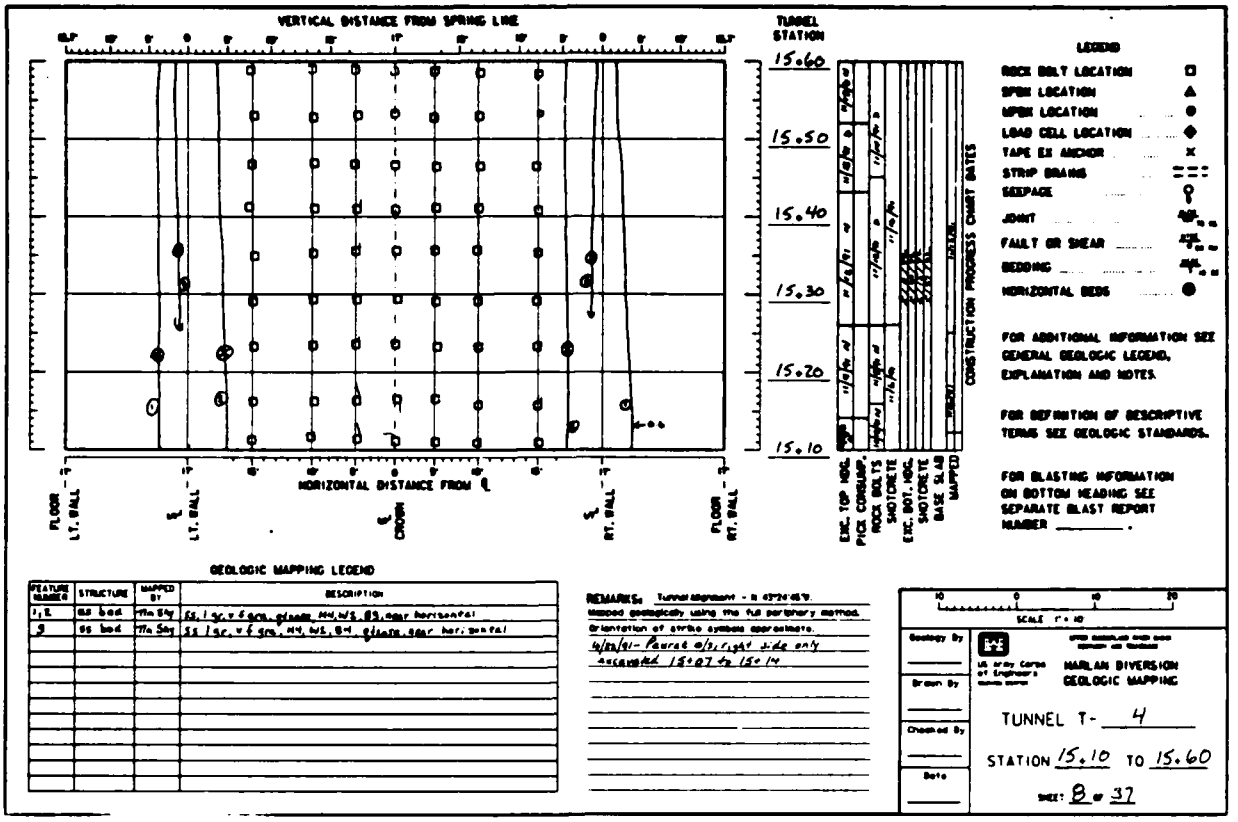
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 14+60 TO 15+10

SHEET 7 OF 37

PLATE D-70



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	BS bed	Tha Sky	SS, lt gy, v f gm, glauc, HH, WS, BS, near horizontal
3	BS bed	Tha Sky	SS lt gy, v f gm, HH, WS, BH, glauc, near horizontal

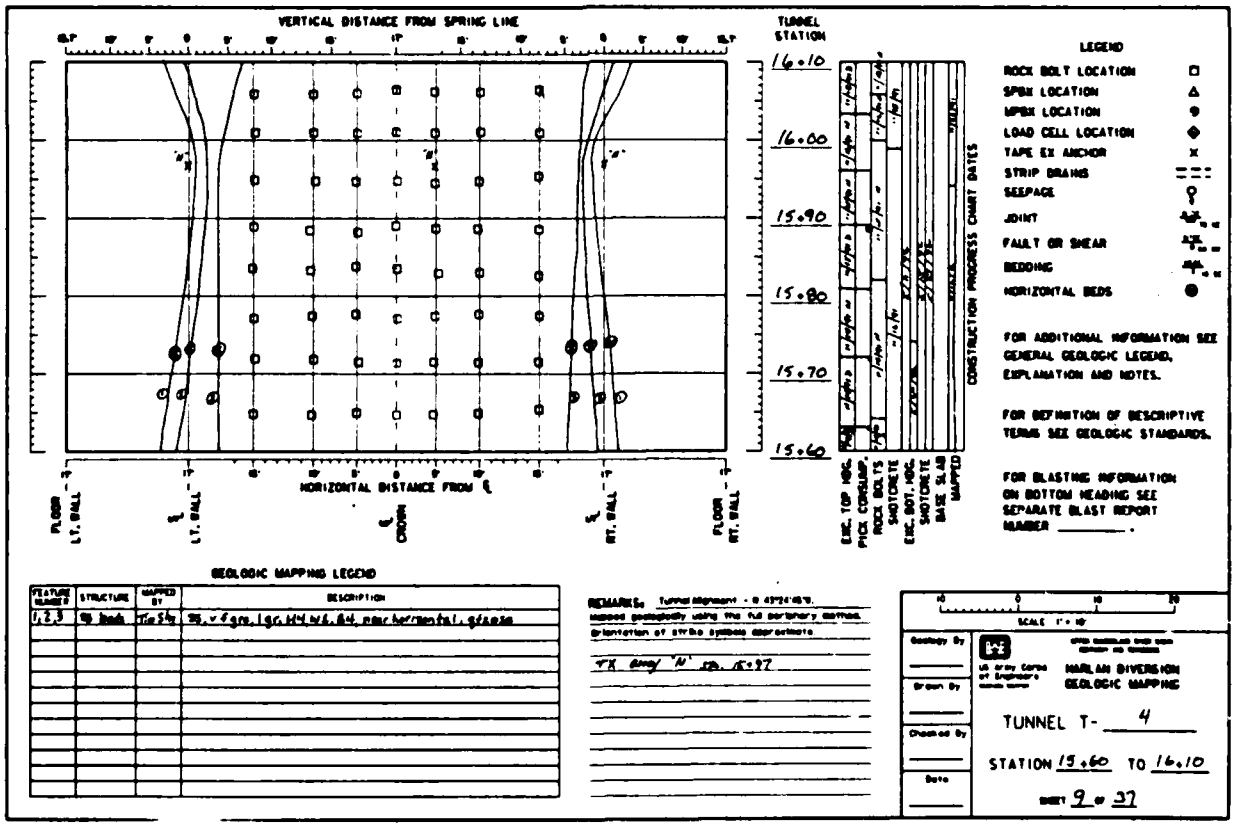
REMARKS: Tunnel alignment - N 45°24'45"W.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
4/28/81 - Faced o/b, right side only excavated 15+07 to 15+14

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4
STATION 15.10 TO 15.60
SHEET 8 of 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2, 3	BS bed	Tha Sky	SS, v f gm, lgr, HH, WS, BH, near horizontal, glauc

REMARKS: Tunnel alignment - N 45°24'45"W.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
TK Body "N" sta. 15+97

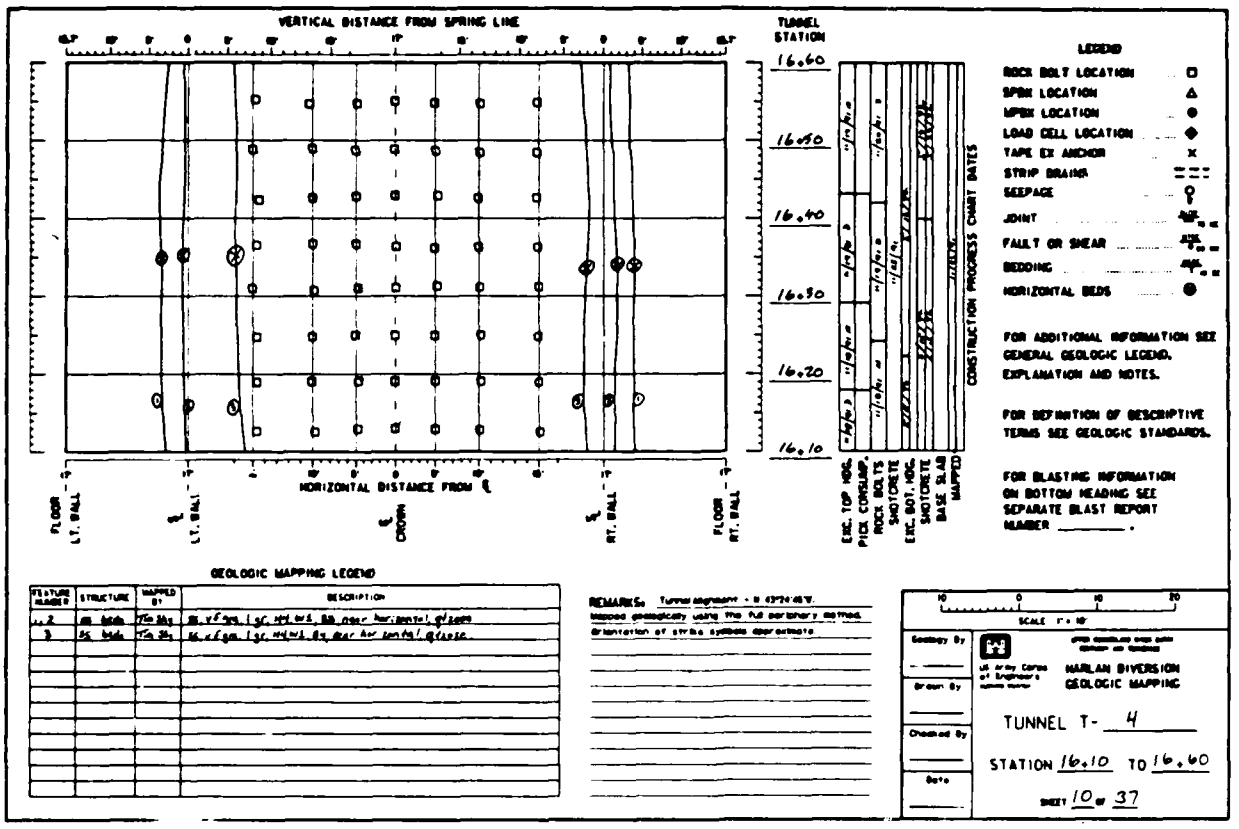
SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4
STATION 15.60 TO 16.10
SHEET 9 of 37

PLATE D-71


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
16.60
16.50
16.40
16.30
16.20
16.10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HOG.
PICK CORRUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HOG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Geology By
Drawn By
Checked By
Date
SCALE 1" = 10'
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 16.10 TO 16.60
SHEET 10 OF 37

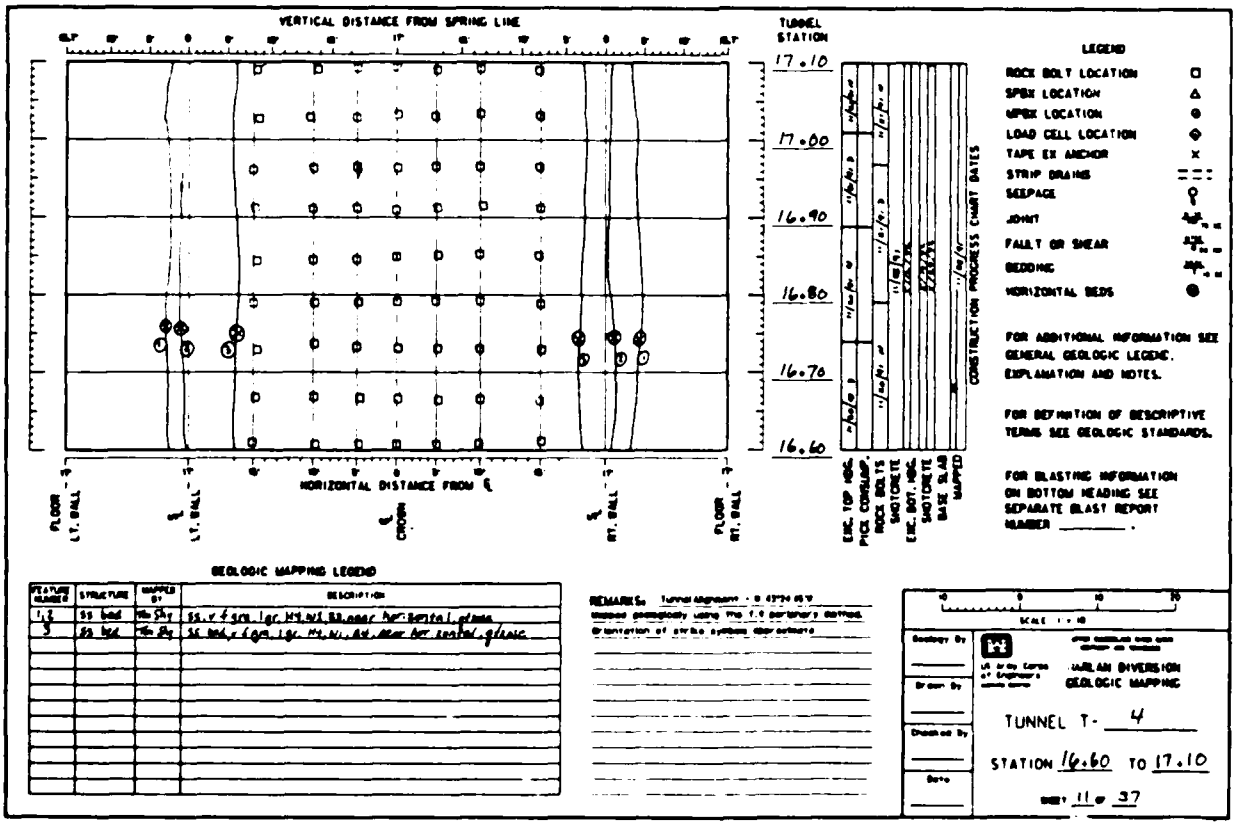
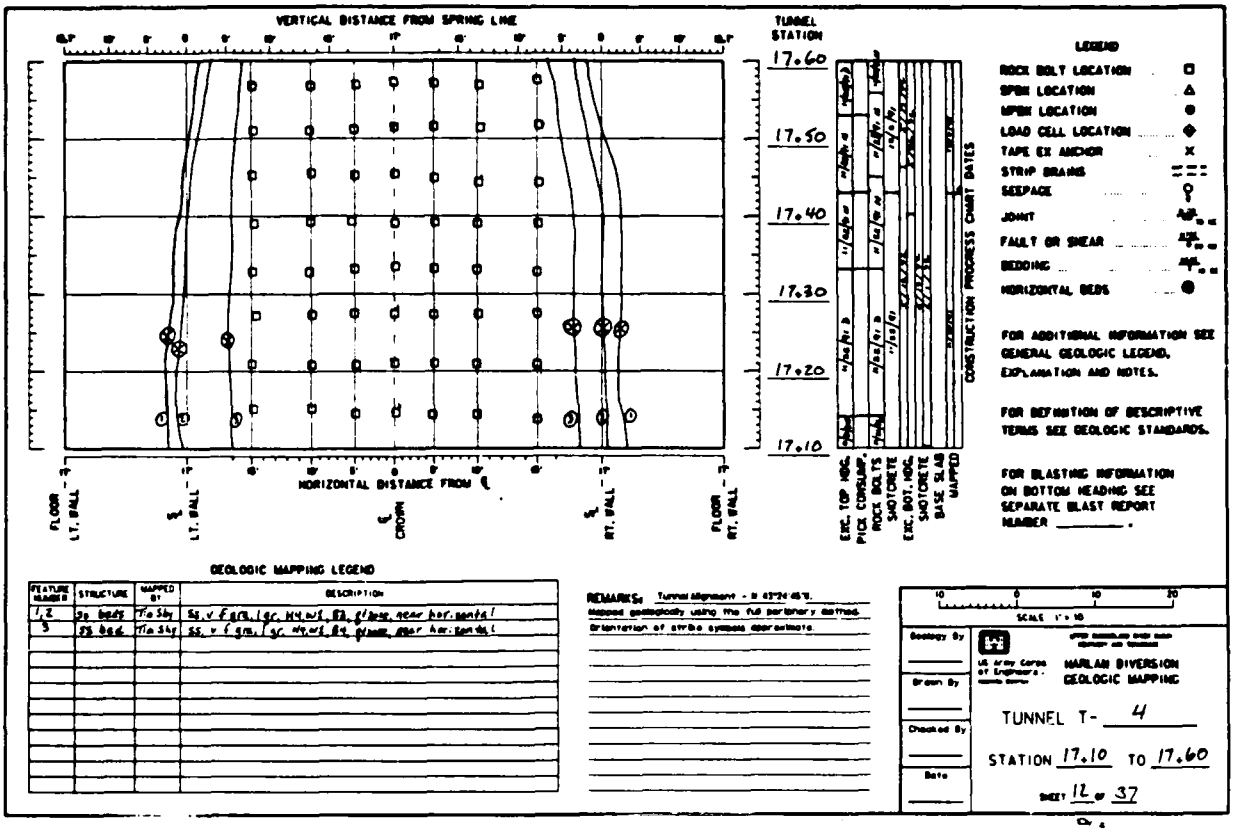

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
17.10
17.00
16.90
16.80
16.70
16.60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HOG.
PICK CORRUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HOG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Geology By
Drawn By
Checked By
Date
SCALE 1" = 10'
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 16.60 TO 17.10
SHEET 11 OF 37

PLATE D-72



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Jts bedg	Tim Sky	SS, v f grn, lgr, HY w/ BR, glauc, near hor. bed'g
3	FS bedd.	Tim Sky	SS, v f gm, lgr, HY w/ BR, glauc, near hor. bed'g

REMARKS: Tunnel Alignment - S 63°24' 45" E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.

SCALE 1" = 10

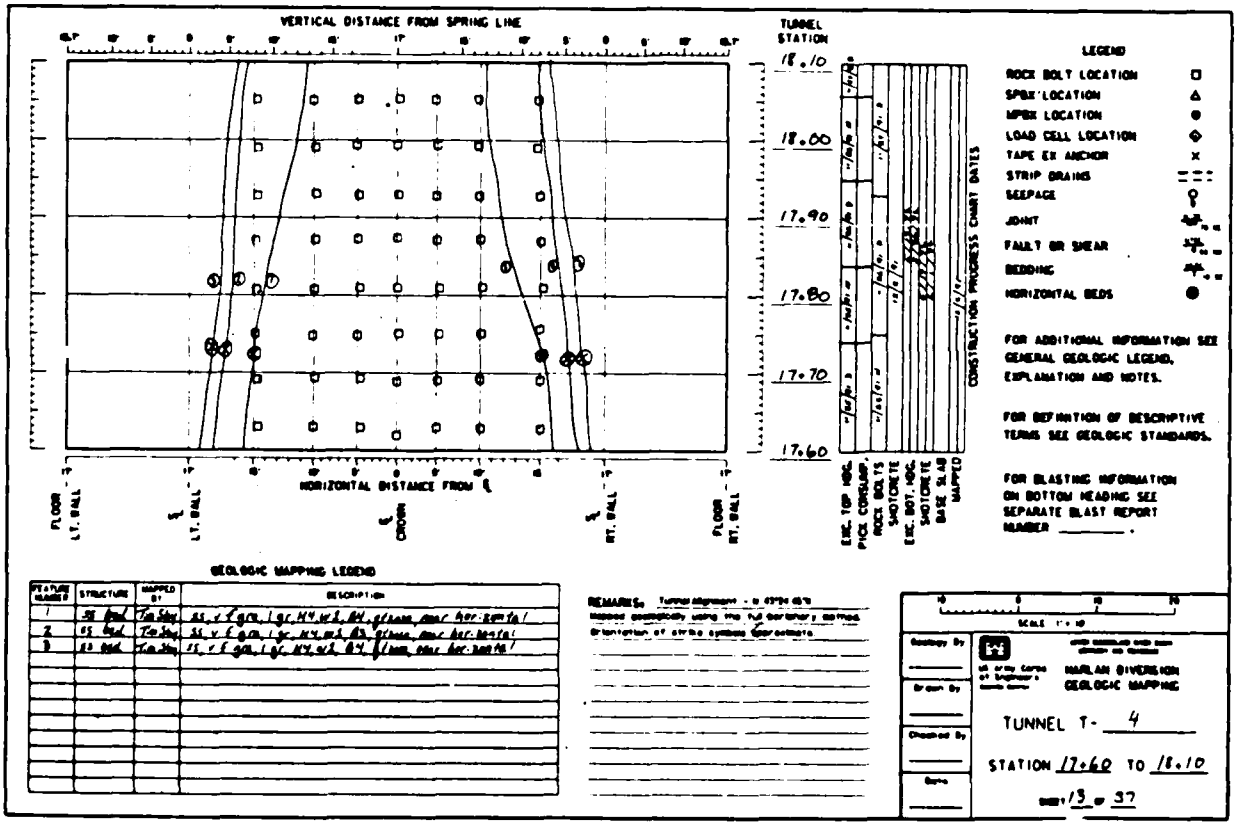
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 17.10 TO 17.60

SHEET 12 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	FS Bedd	Tim Sky	SS, v f grn, lgr, HY w/ BR, glauc, near hor. bed'g
2	FS Bedd	Tim Sky	SS, v f gm, lgr, HY w/ BR, glauc, near hor. bed'g
3	FS Bedd	Tim Sky	SS, v f grn, lgr, HY w/ BR, glauc, near hor. bed'g

REMARKS: Tunnel Alignment - S 63°24' 45" E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

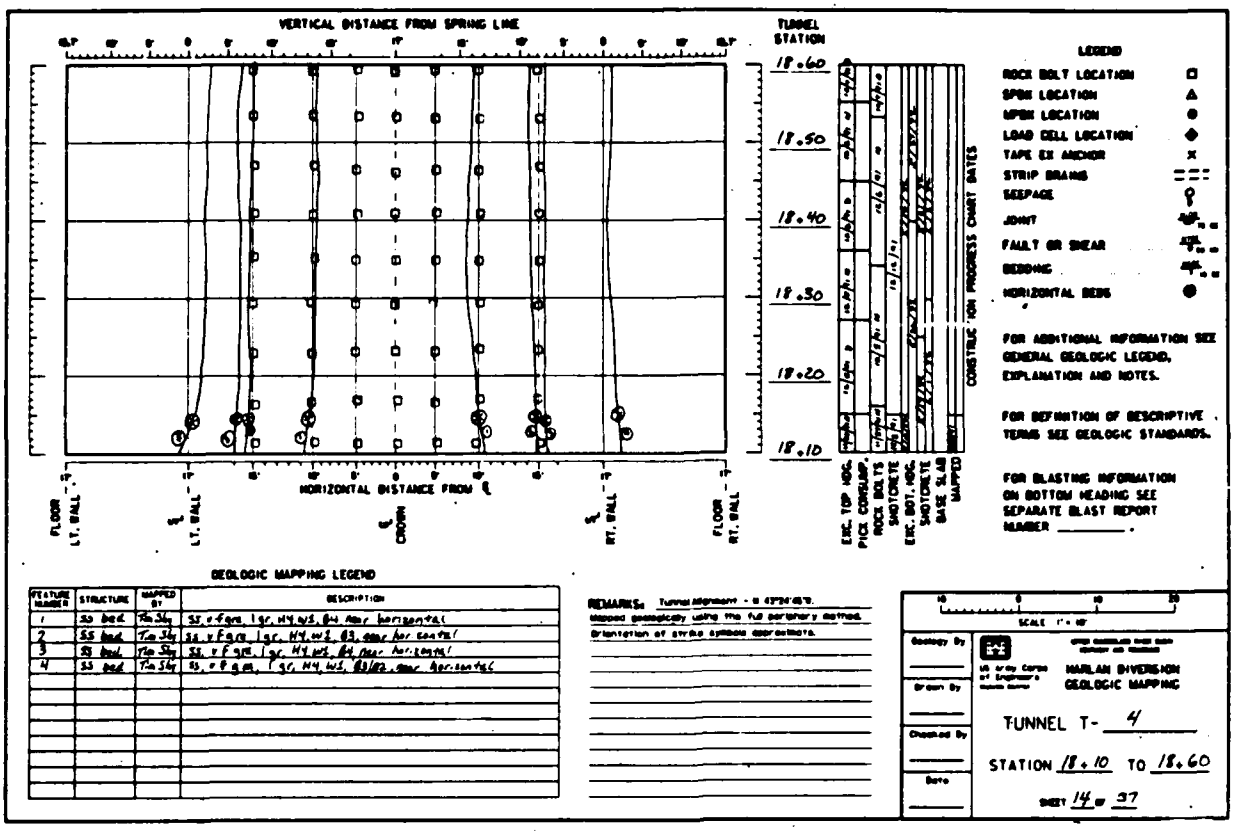
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 17.60 TO 18.10

SHEET 13 OF 37

PLATE D-73



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tim Sly	SS, v f gm, lgr, HW, w/s, 84 deg/ horizontal
2	SS bed	Tim Sly	SS, v F gm, lgr, HW, w2, 83 deg/ hor contact
3	SS bed	Tim Sly	SS, v F gm, lgr, HW, w2, 84 deg/ hor contact
4	SS bed	Tim Sly	SS, v f gm, lgr, HW, w2, 83/82, deg/ horizontal

REMARKS: Tunnel alignment - 0 47'24"E/S.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

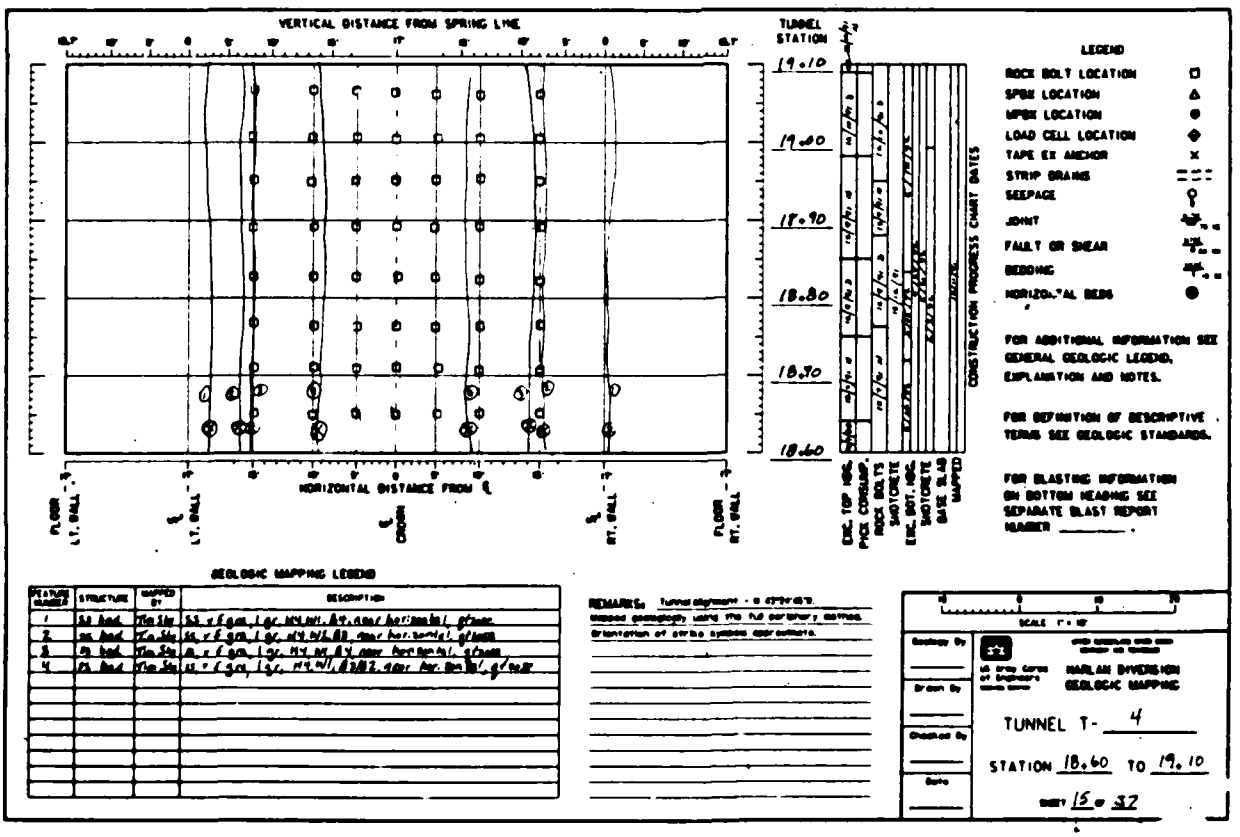
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 18+10 TO 18+60

SHEET 14 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tim Sly	SS, v f gm, lgr, HW, w1, 84 deg/ horizontal, groove
2	SS bed	Tim Sly	SS, v f gm, lgr, HW, w1/w2, 83 deg/ horizontal, groove
3	SS bed	Tim Sly	SS, v f gm, lgr, HW, w1, 84 deg/ horizontal, groove
4	SS bed	Tim Sly	SS, v f gm, lgr, HW, w1/w2, 83/82, deg/ hor. horizontal, groove

REMARKS: Tunnel alignment - 0 47'24"E/S.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

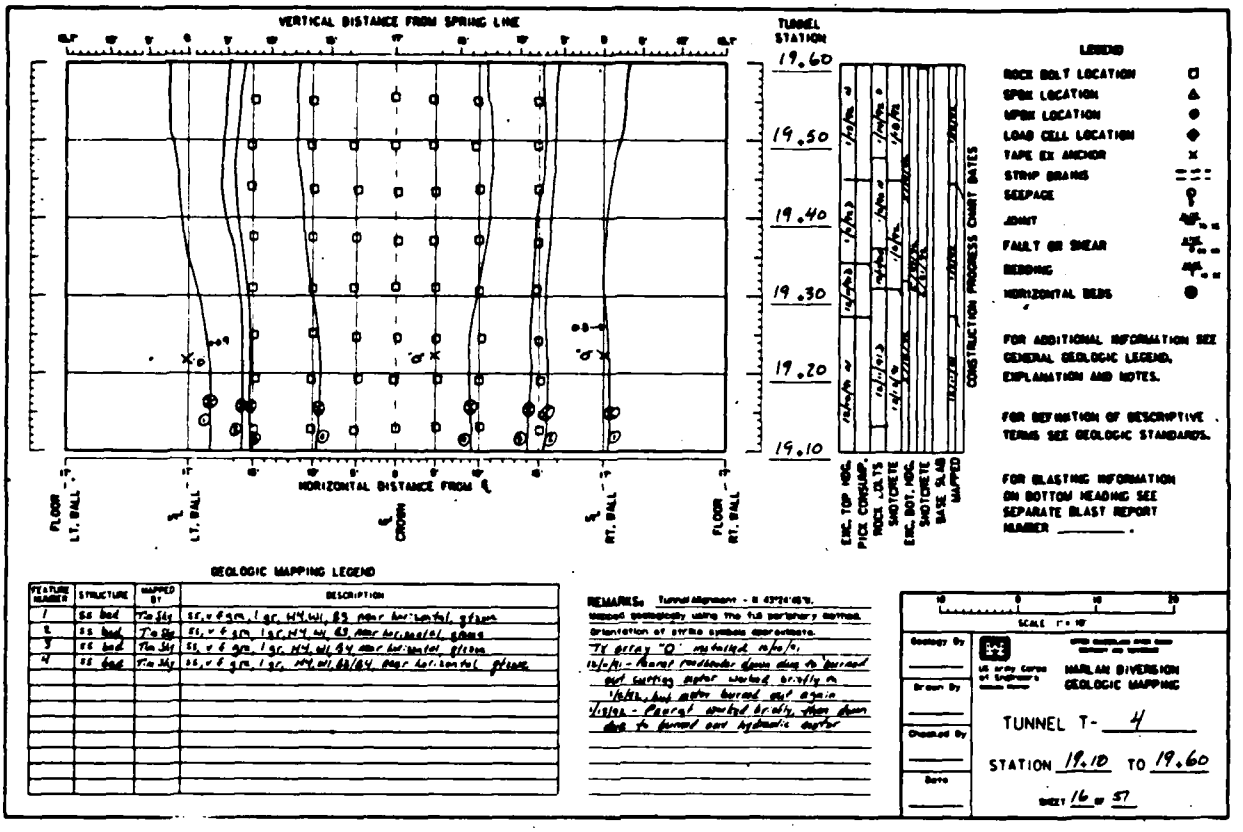
U.S. Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 18+60 TO 19+10

SHEET 15 OF 37

PLATE D-74



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 85 meas hor'izontal, gleam
2	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 83 meas hor'izontal, gleam
3	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 84 meas hor'izontal gleam
4	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 82/84 meas hor'izontal gleam

REMARKS: Tunnel Alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
"T" series "D" mylonized zone.
10/6/81 - Heavy rainstorm shuts down due to burned out cutting water washed brush in 1/26/82, but water burned out again
4/29/82 - Heavy washed brush, shuts down due to burned out hydraulic water

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

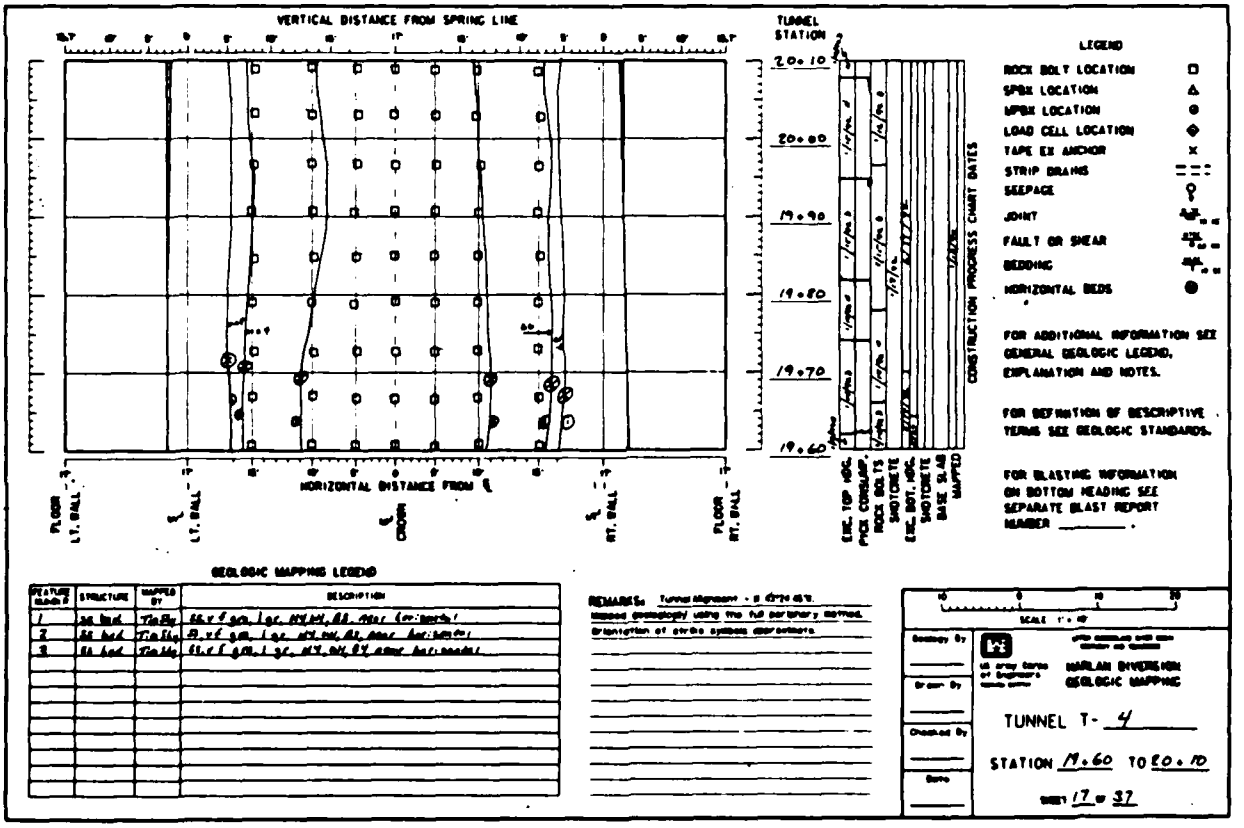
U.S. Army Corps of Engineers

MARIAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 19.10 TO 19.60

SHEET 16 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 82 meas hor'izontal
2	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 84 meas hor'izontal
3	BB bed	Tia Sky	BB, v f gm, l gr, HY, wl, 84 meas hor'izontal

REMARKS: Tunnel Alignment - 0 47°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers

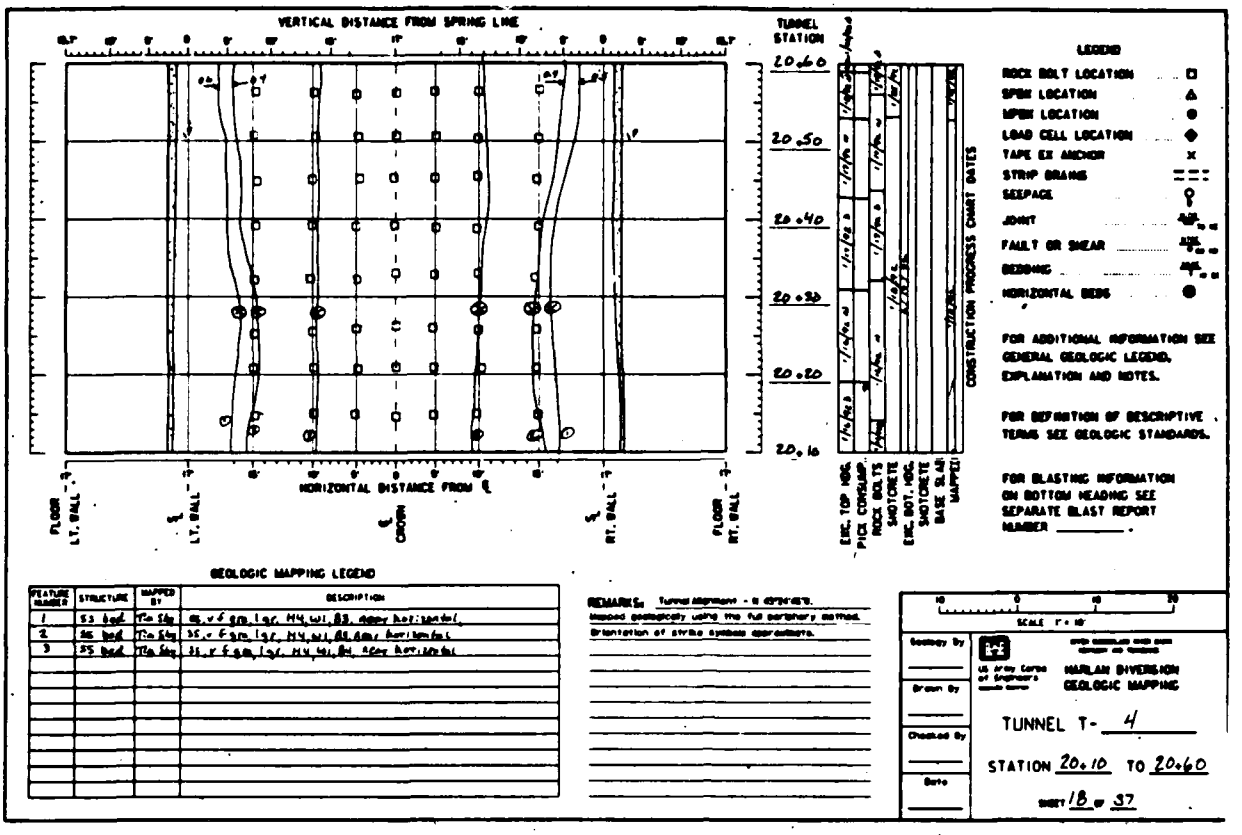
MARIAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 19.60 TO 20.10

SHEET 17 OF 37

PLATE D-75



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tim Say	ss, v f gm, lgr, HW, wi, 83, upper hor: ripples
2	SS bed	Tim Say	ss, v f gm, lgr, HW, wi, 81, 68m, hor: ripples
3	SS bed	Tim Say	ss, v f gm, lgr, HW, wi, 84, 45m, hor: ripples

REMARKS: Tunnel alignment - S 67°W/15°.
Mapped geologically using the full centerline method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

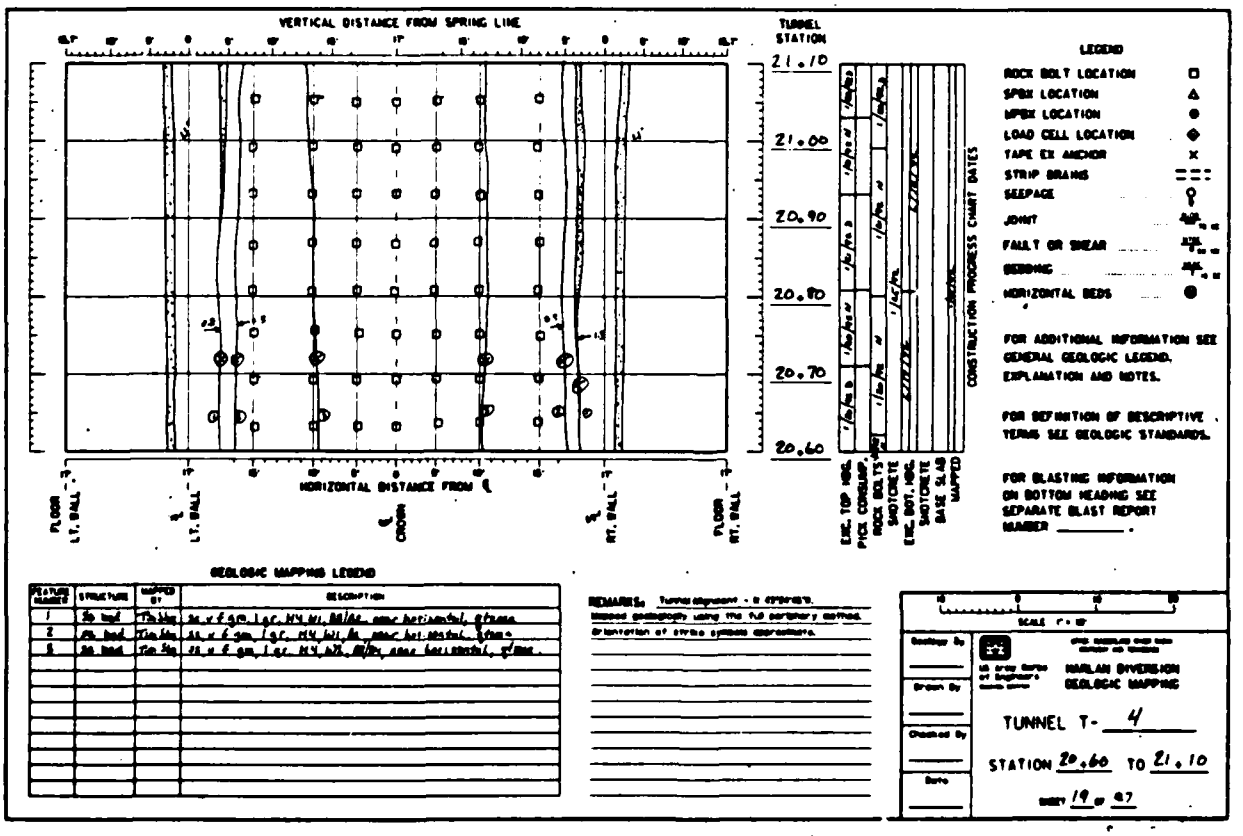
Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 20+10 TO 20+60

SHEET 18 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tim Say	ss, v f gm, lgr, HW, wi, 88/66, upper hor: ripples, 6"max
2	SS bed	Tim Say	ss, v f gm, lgr, HW, wi, 86, upper hor: ripples, 6"max
3	SS bed	Tim Say	ss, v f gm, lgr, HW, wi, 88/66, upper hor: ripples, 6"max

REMARKS: Tunnel alignment - S 67°W/15°.
Mapped geologically using the full centerline method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

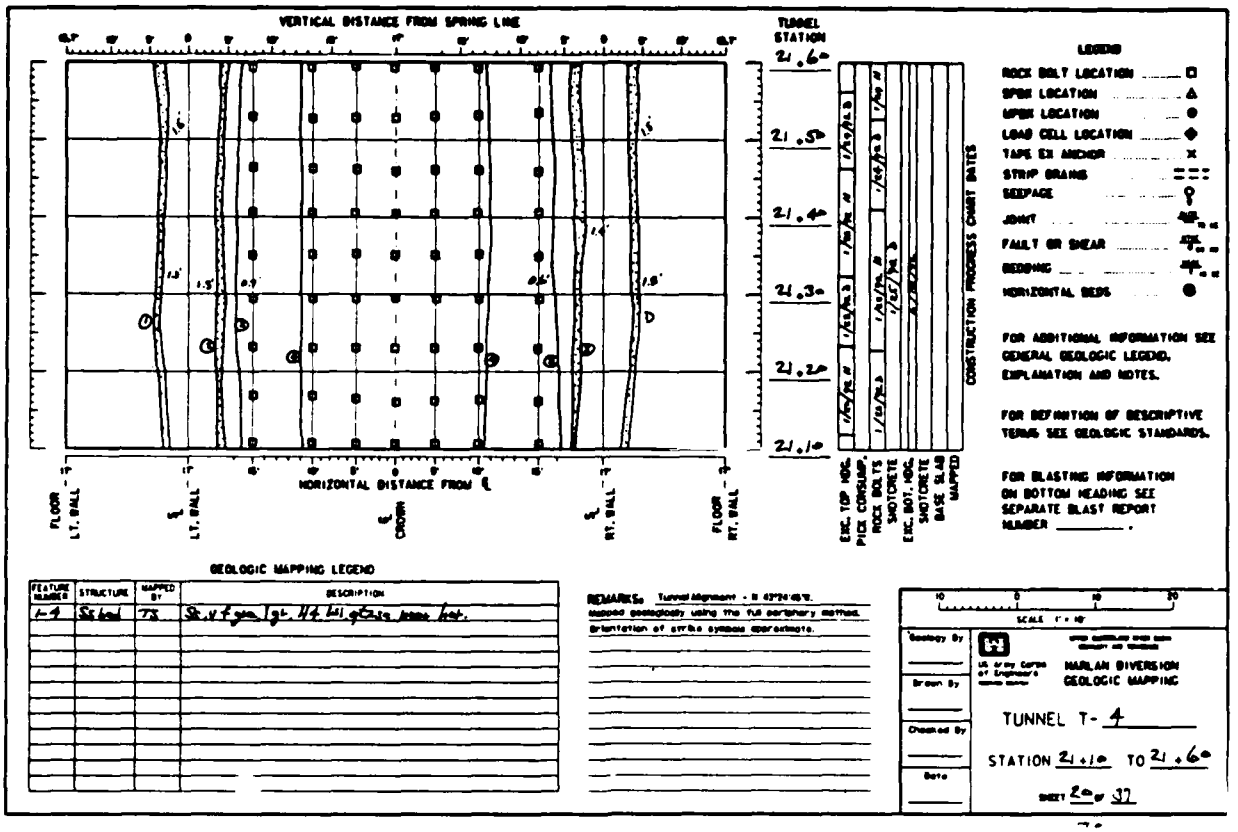
U.S. Army Corps of Engineers — MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 20+60 TO 21+10

SHEET 19 OF 37

PLATE D-76



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1-4	Sh bed	TS	Sh w f gsn, lgt. Hd, bd, gCbls, brown bed.

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

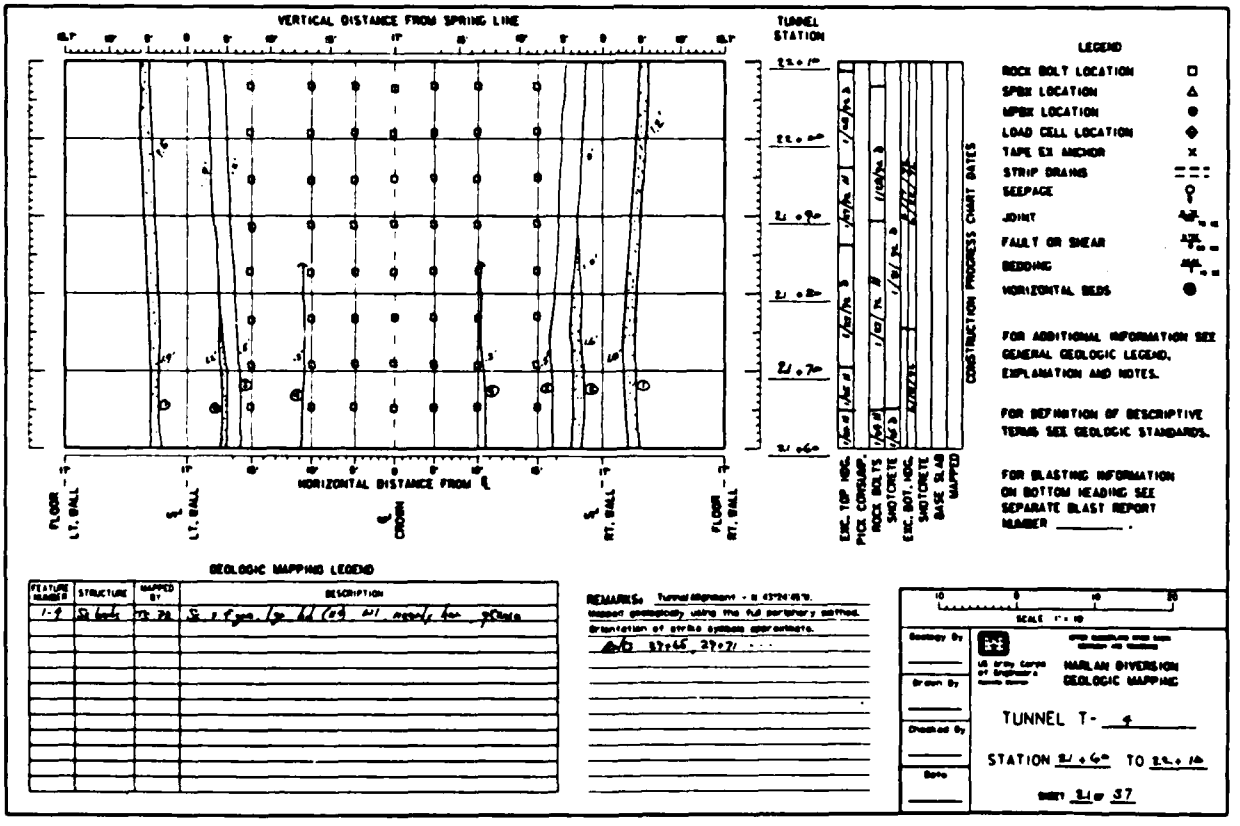
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 21+10 TO 21+60

SHEET 20 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1-9	Sh beds	TS PB	Sh w f gsn, lgt bd Cbls, occas bou gCbls

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

22+65, 22+71

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

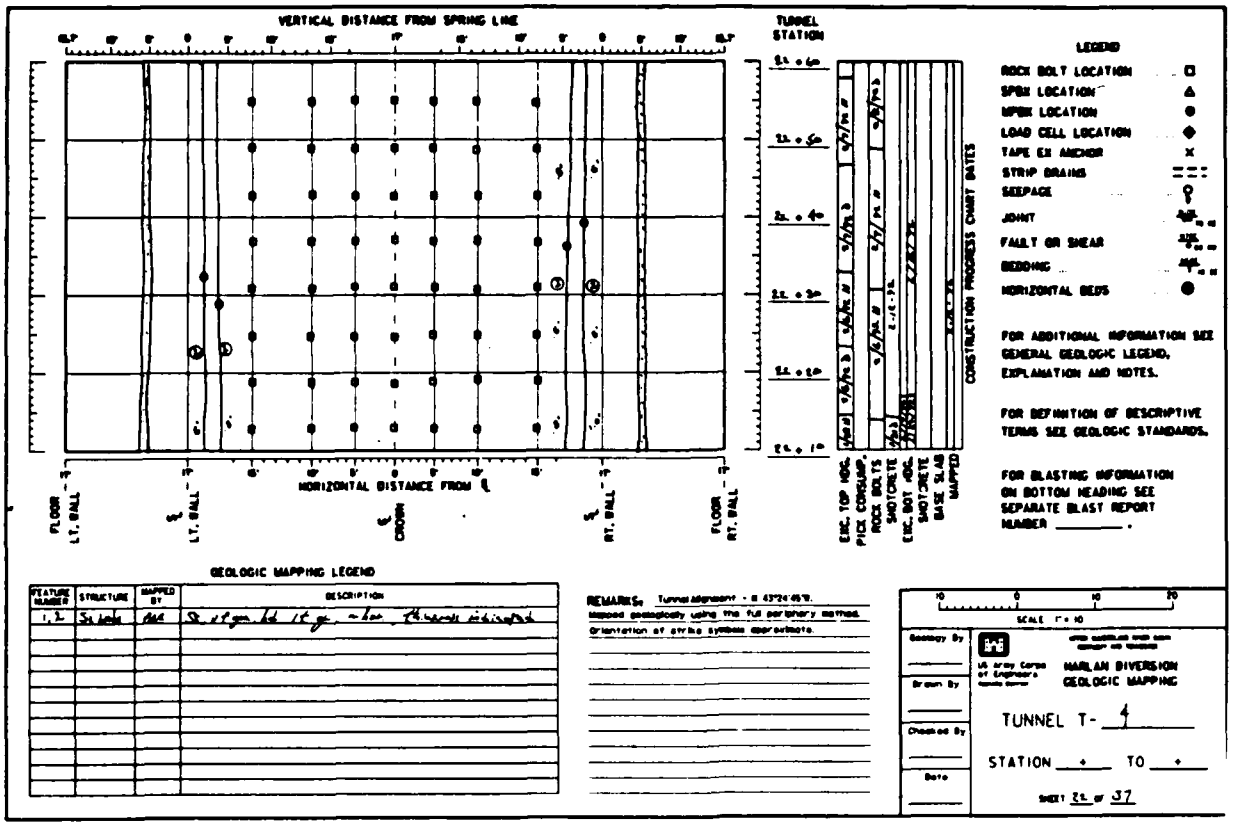
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 21+60 TO 22+10

SHEET 21 OF 37

PLATE D-77


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
℄ CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION ____ + ____ TO ____ + ____
SHEET 24 OF 37

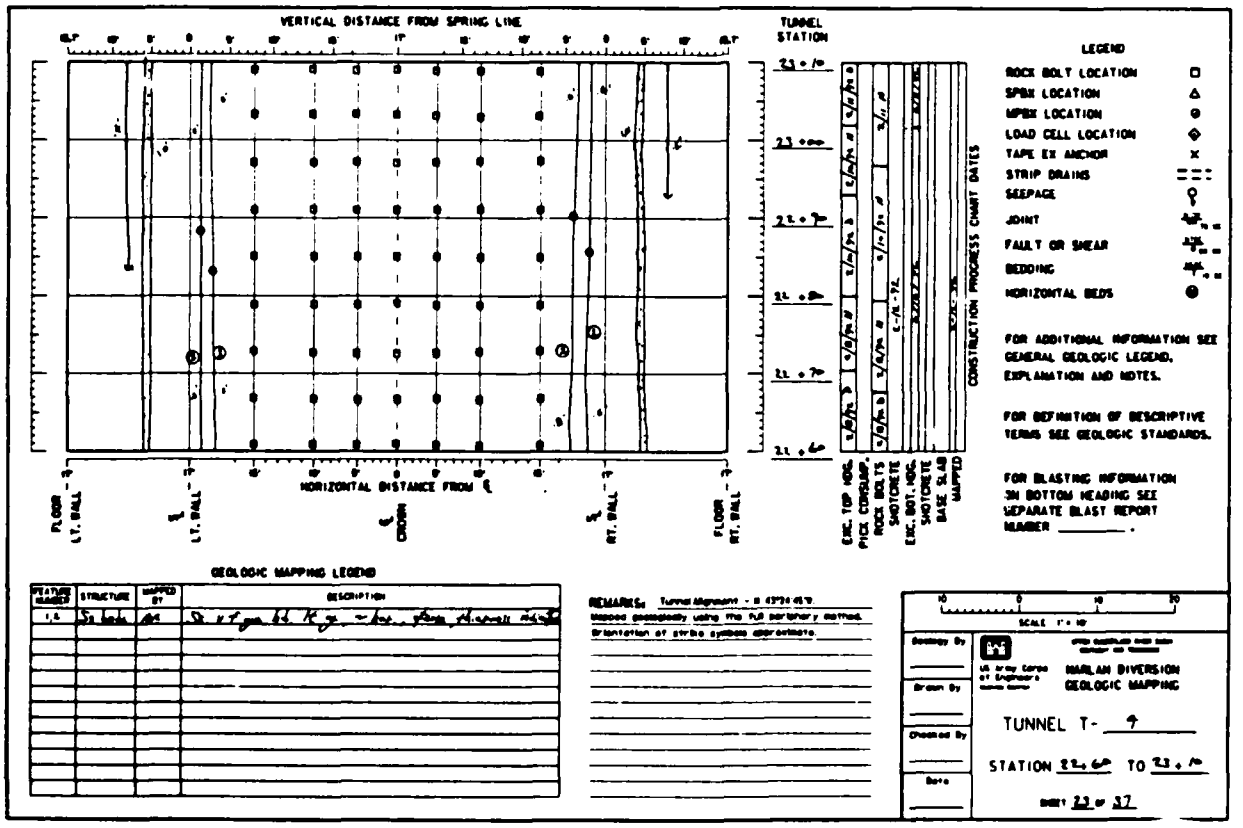
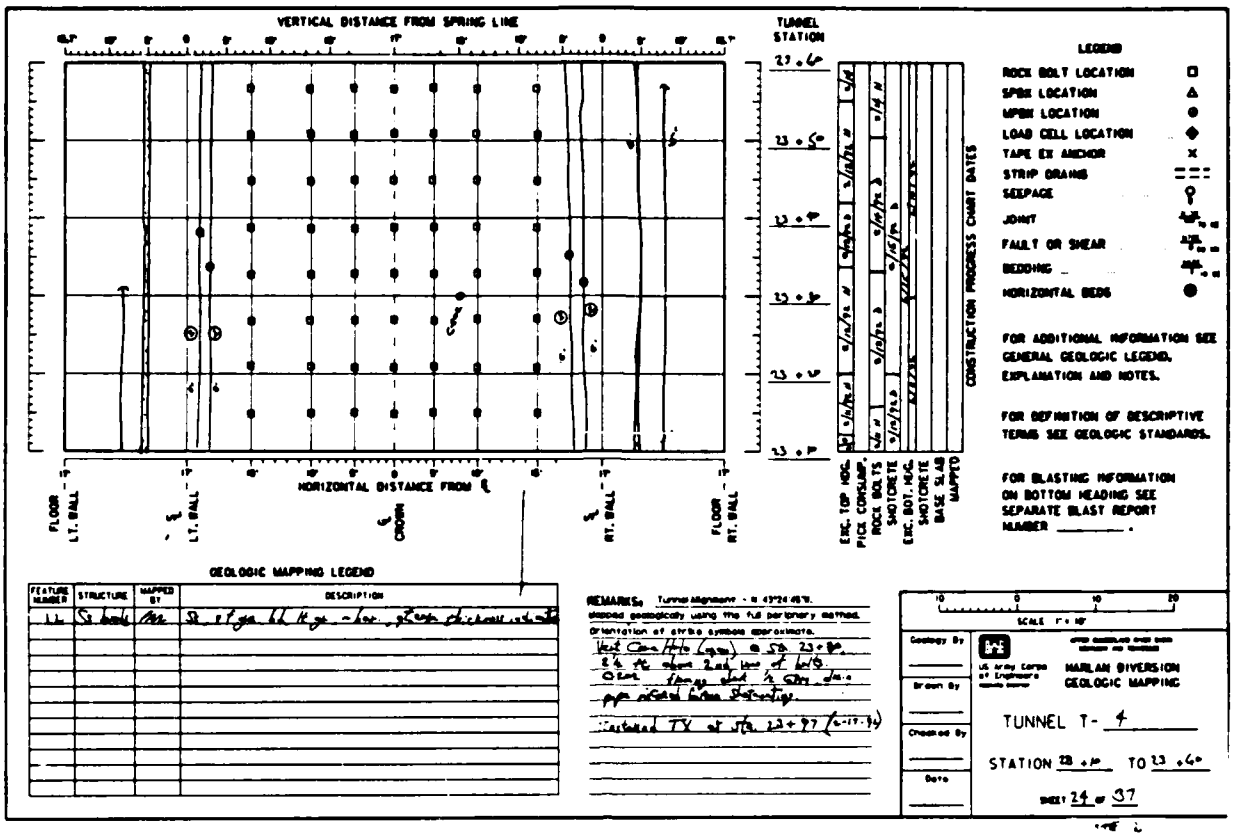

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
℄ CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 22+60 TO 23+00
SHEET 23 OF 37

PLATE D-78



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sh bedg	Abr	Sh + Fgm ll, Mgr ~ Lor, gl brn ch clast w/ sh bed

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
West Chm Hills (typ) @ Sta 23+80
Brk Mx about 2nd lift of bnd
Occ flowage along bnd Sta 23+
appr related to bedding.
Estimated TX at Sta. 23+97 (6-17-94)

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

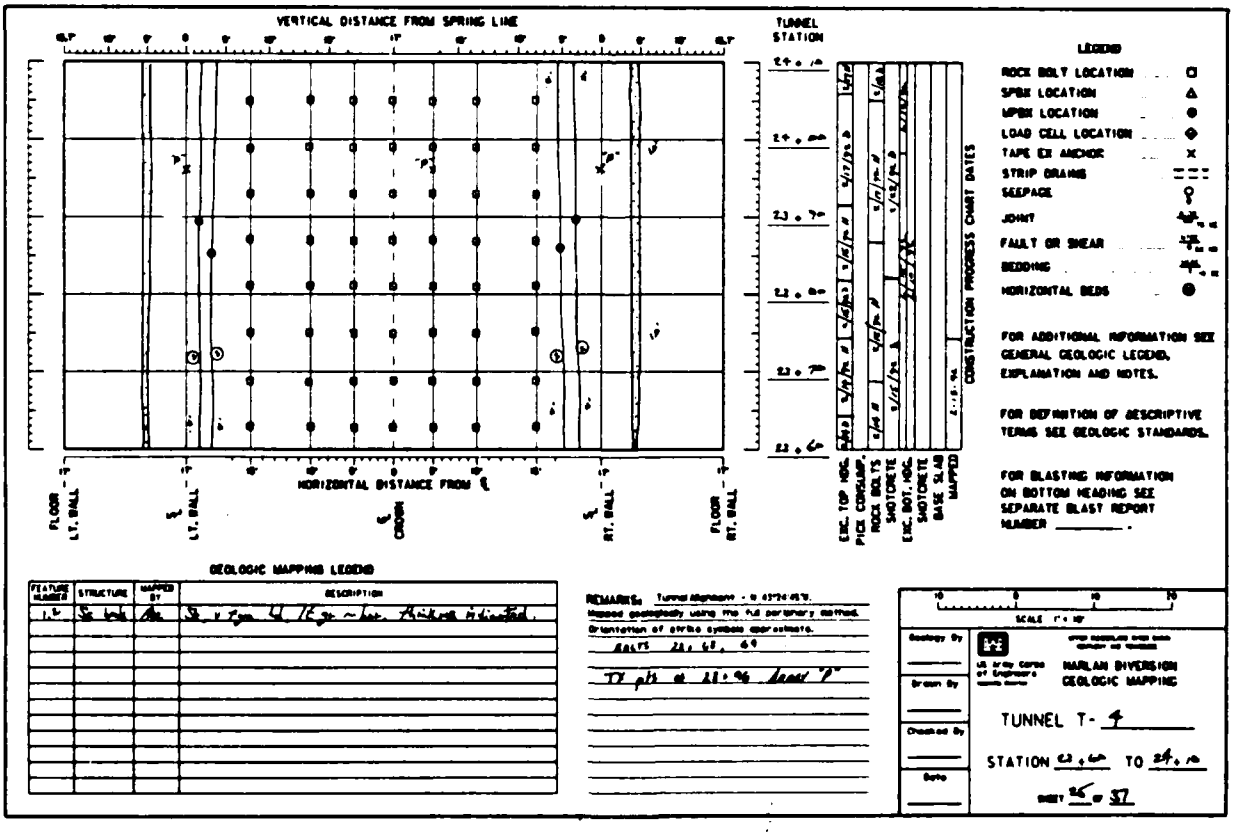
U.S. Army Corps of Engineers — Albuquerque District

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 23+40 TO 23+60

SHEET 24 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sh bedg	Abr	Sh + Fgm ll, Mgr ~ Lor, Rubbly Fractured

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
Adits 22+68, 69
TX pk at 23+96 (est 7")

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

U.S. Army Corps of Engineers — Albuquerque District

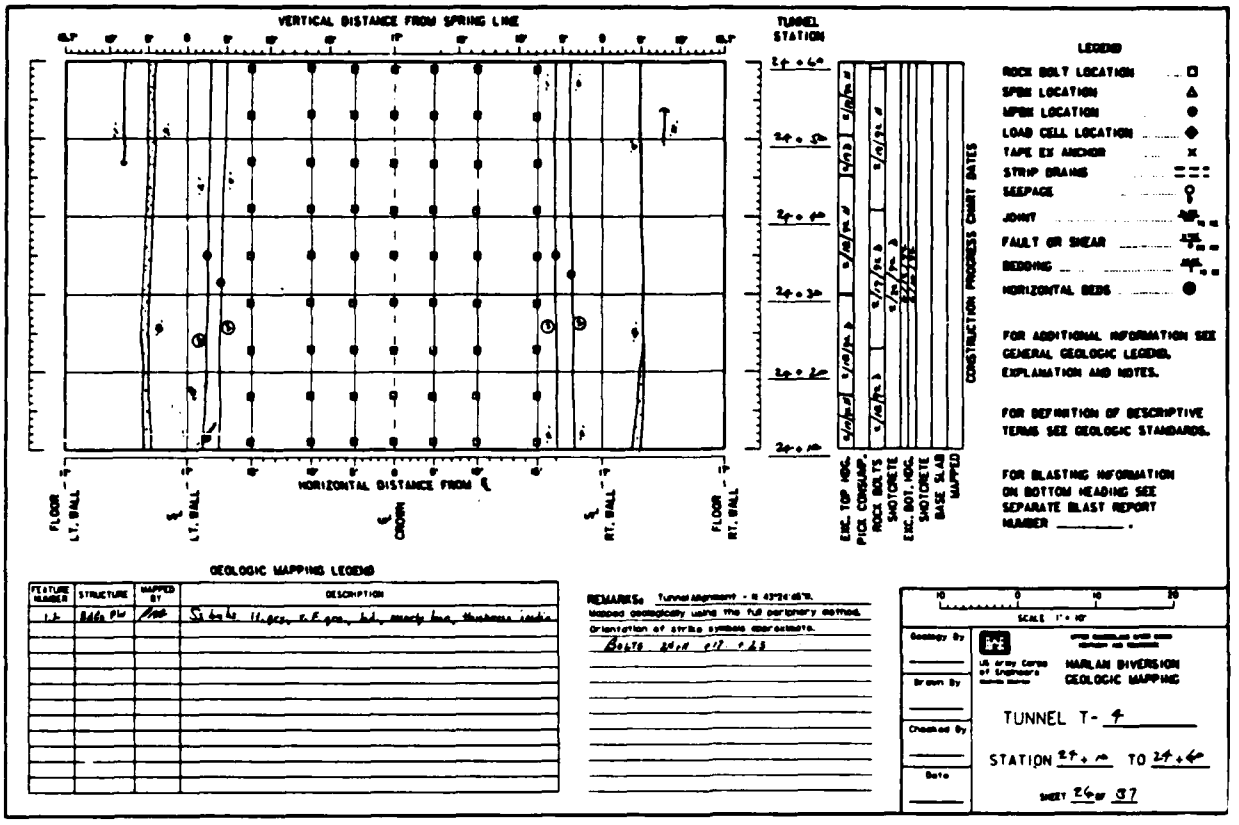
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 23+60 TO 24+20

SHEET 25 OF 37

PLATE D-79



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1.1	Bdds Plu	[illegible]	Sltstn & ll.gcy, v.f.gm, lbd, mnrly lam, thickness indic

REMARKS: Tunnel Alignment - N 43°24'48"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

Bdds 22+11 @ 17 ± 43

SCALE 1" = 10'

Geology By

Drawn By

Checked By

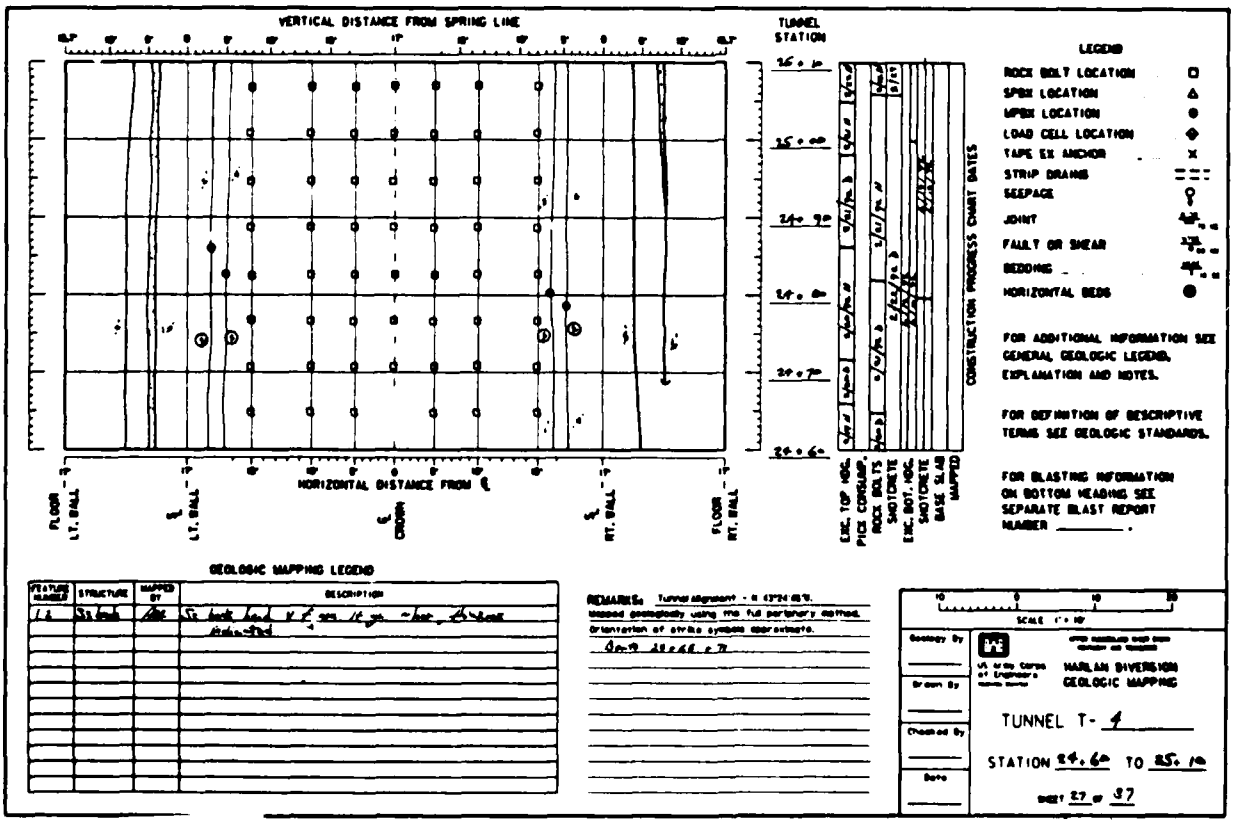
Date

US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 24+10 TO 24+60

SHEET 26 OF 37



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1.1	Sltstn	[illegible]	Sltstn lbd, v.f.gm, lt.gn, ~bdd, thickness indic

REMARKS: Tunnel Alignment - N 43°24'48"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

Bdds 25+68 ± 7°

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

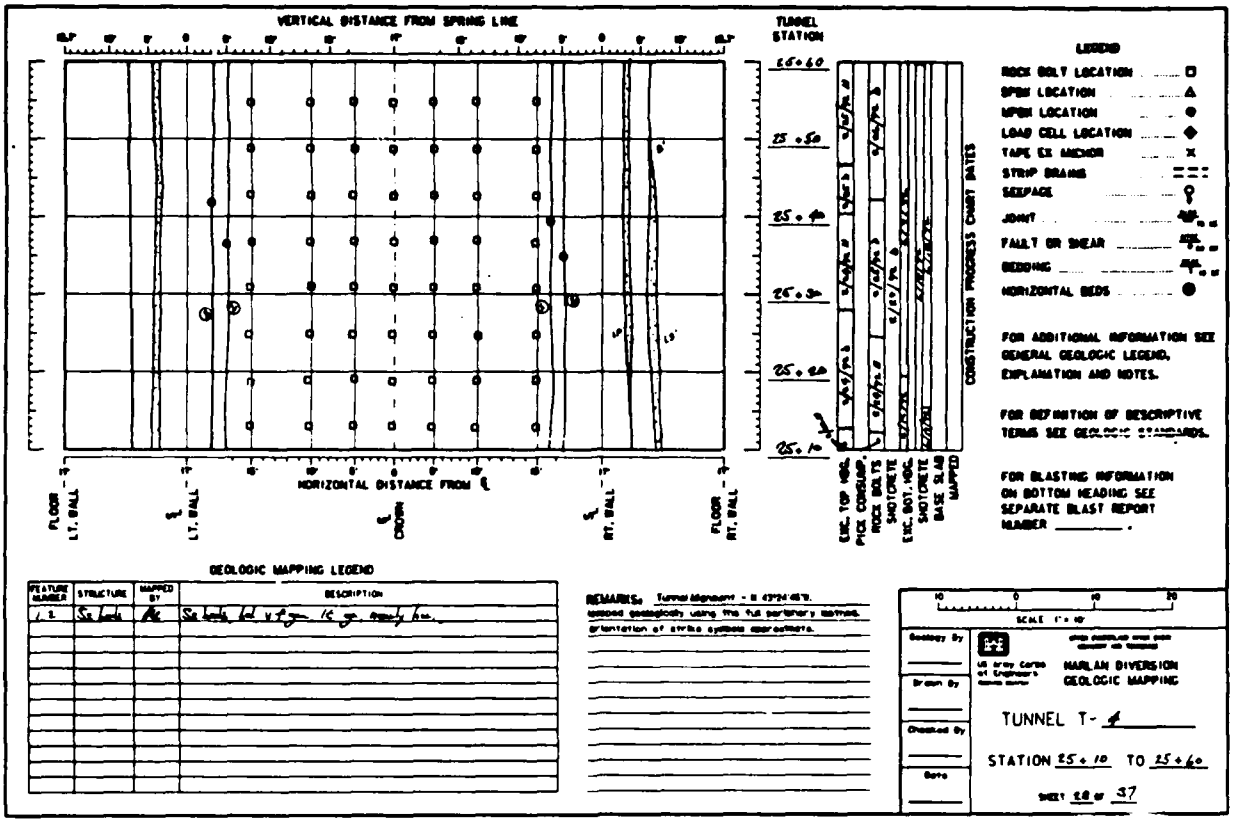
US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 24+60 TO 25+10

SHEET 27 OF 37

PLATE D-80


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 25+10 TO 25+60
SHEET 28 OF 37

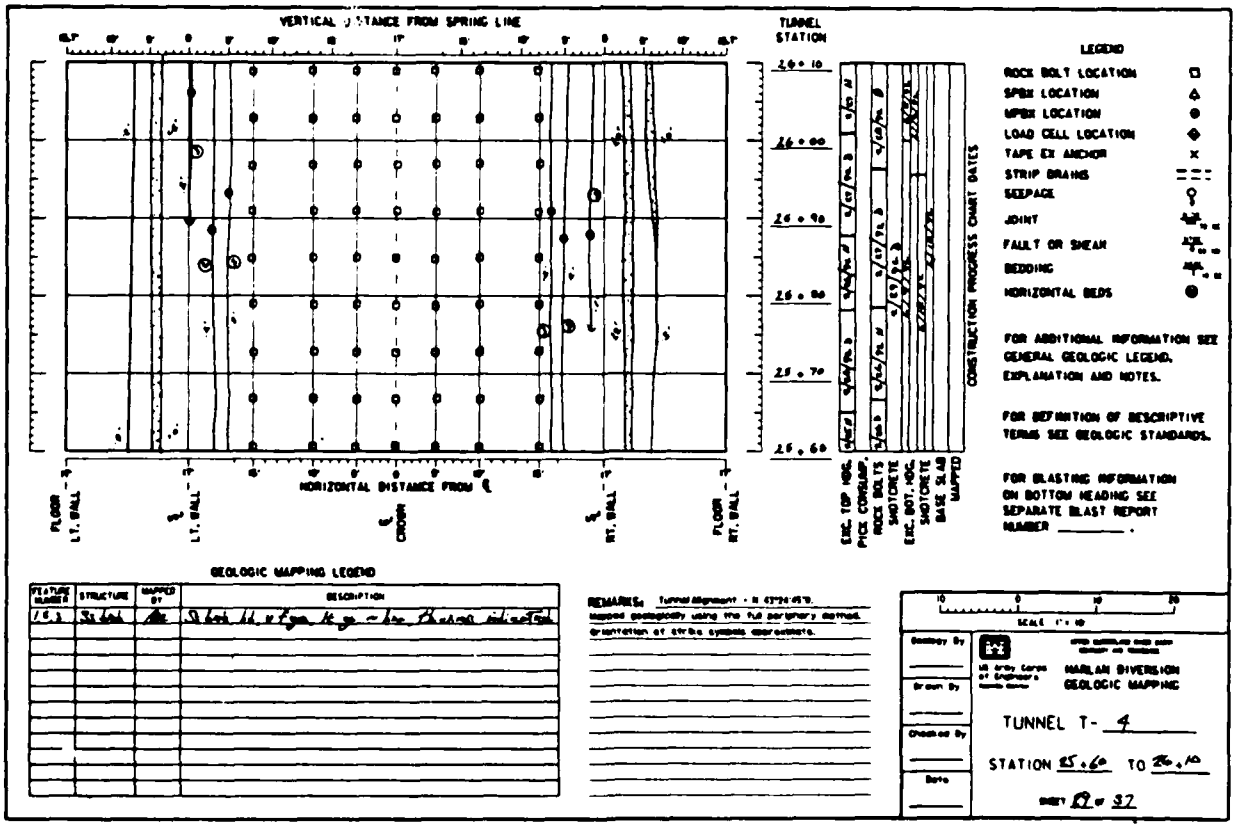
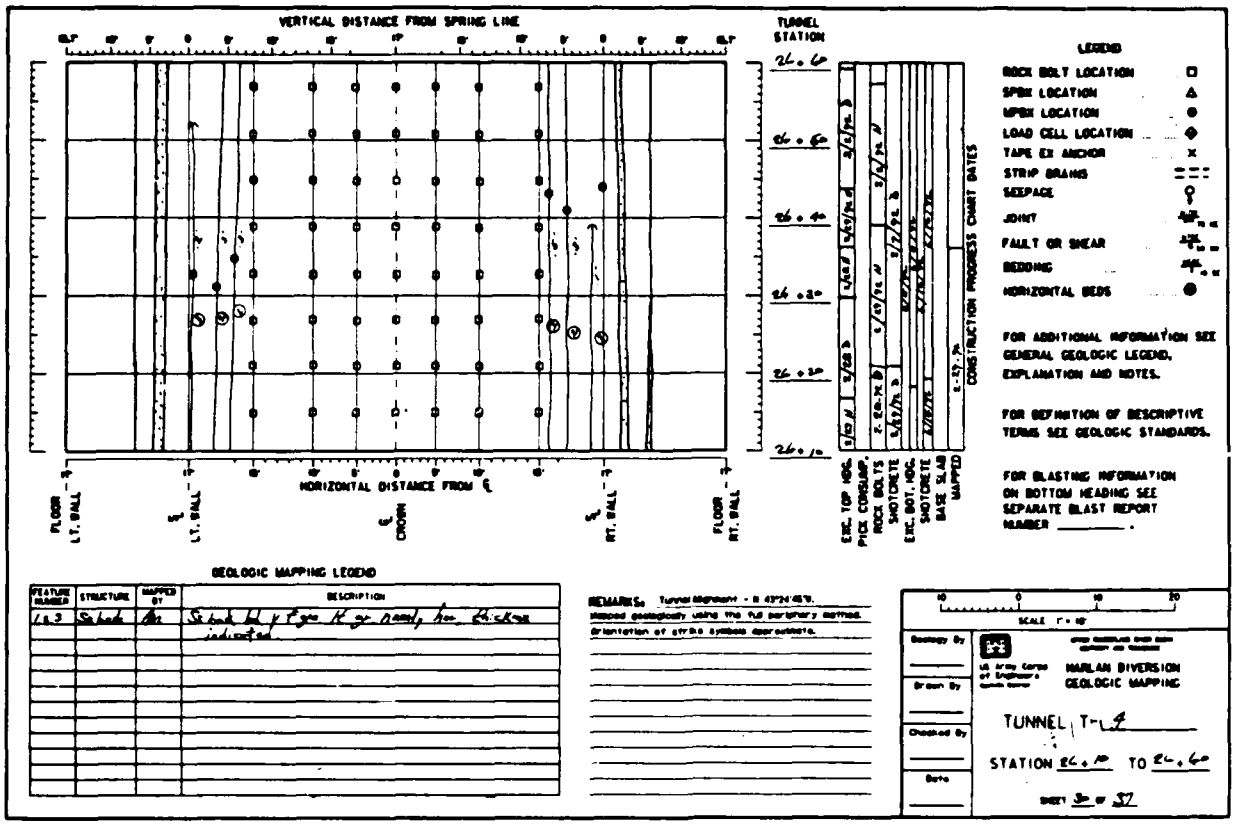

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 25+60 TO 26+10
SHEET 29 OF 37

PLATE D-81


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
CONSTRUCTION PROGRESS CHART DATES
ENC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ENC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T-4
STATION 24+40 TO 24+60
SHEET 30 OF 37

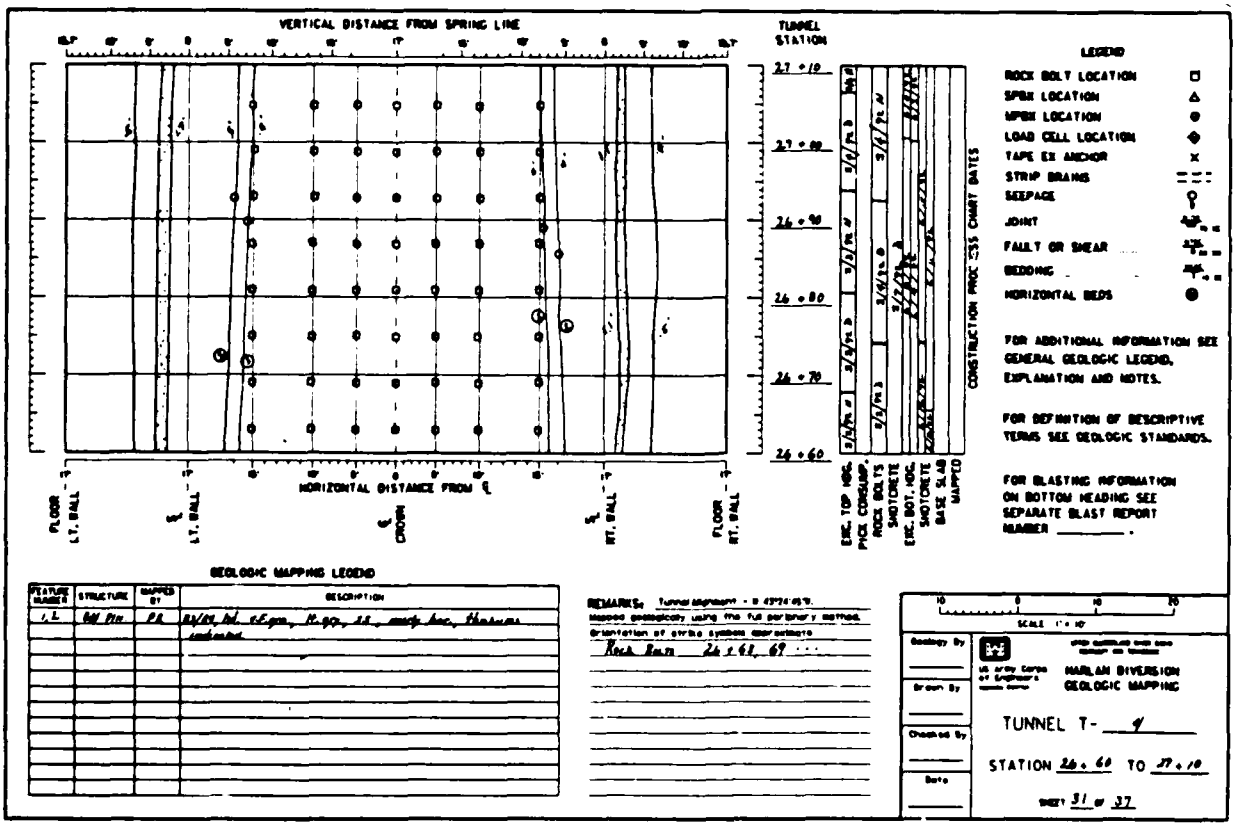
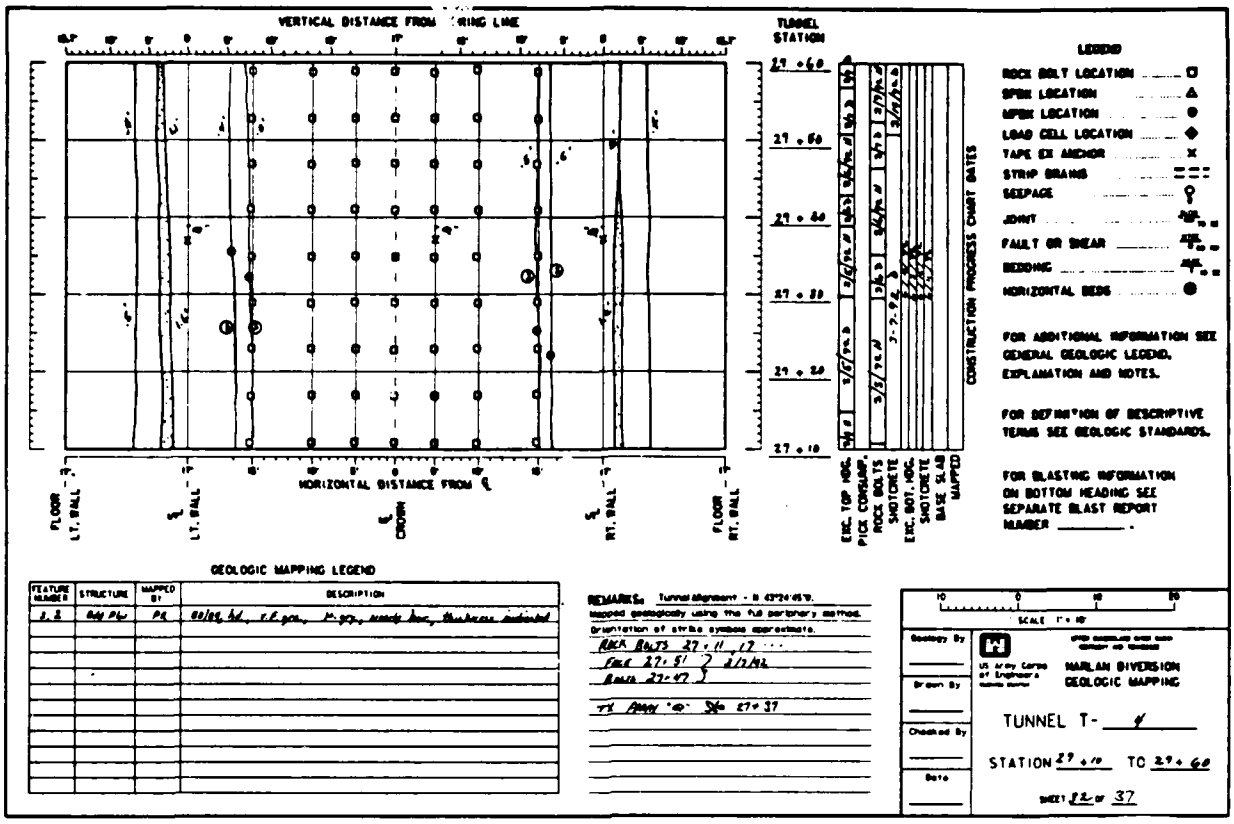

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
CONSTRUCTION PROGRESS CHART DATES
ENC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
ENC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Rock Bolts 26+61, 69
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T-4
STATION 26+60 TO 27+10
SHEET 31 OF 37

PLATE D-82


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
29 + 60
29 + 50
29 + 40
29 + 30
29 + 20
29 + 10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
℄ CROWN
RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
EXC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1, 2
Bdg Pln
PR
60/65 hd, r-f grn, f-gr, sandy loc, thickness indicated
REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
ROCK BOLTS 27+11, 17 ...
FAULT 27+51
BASE 27+47
TH Penny "40" Sta 27+37
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
U.S. Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 29 + 10 TO 29 + 60
SHEET 32 OF 37

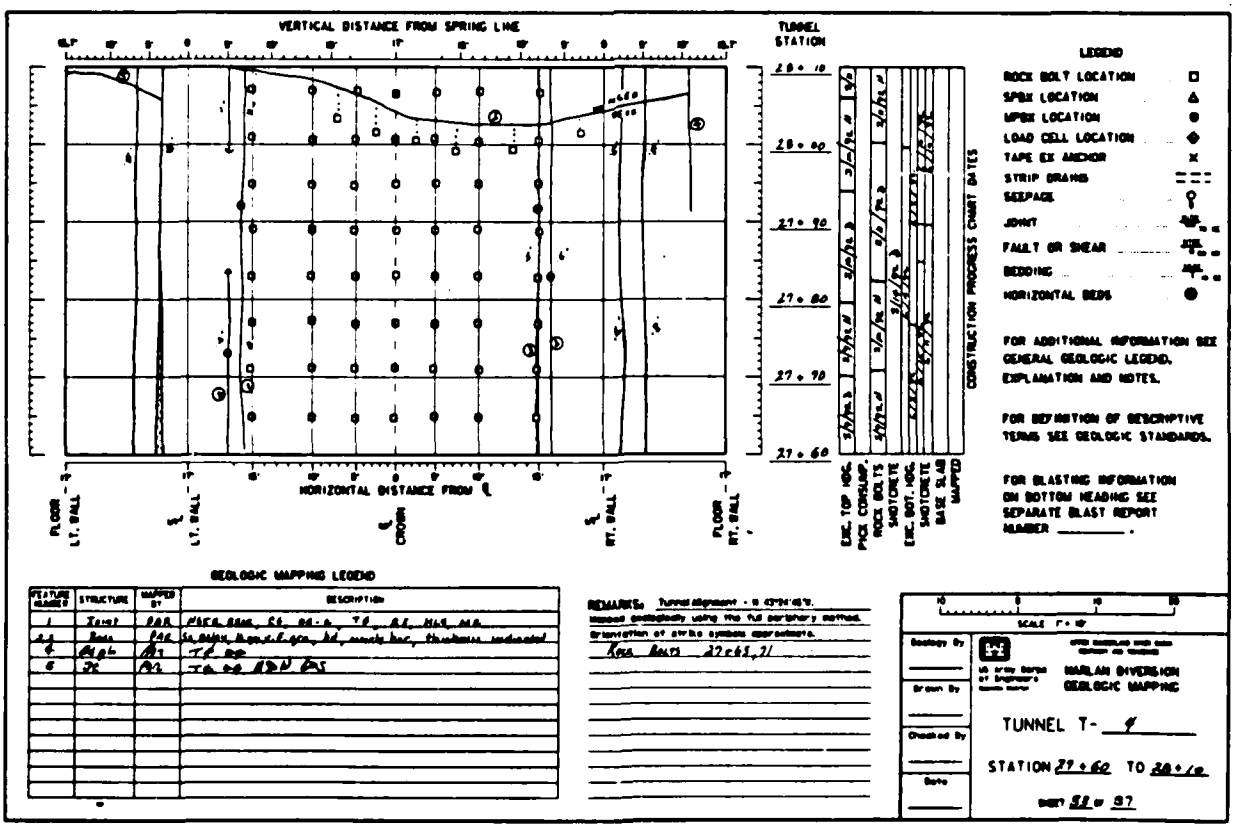
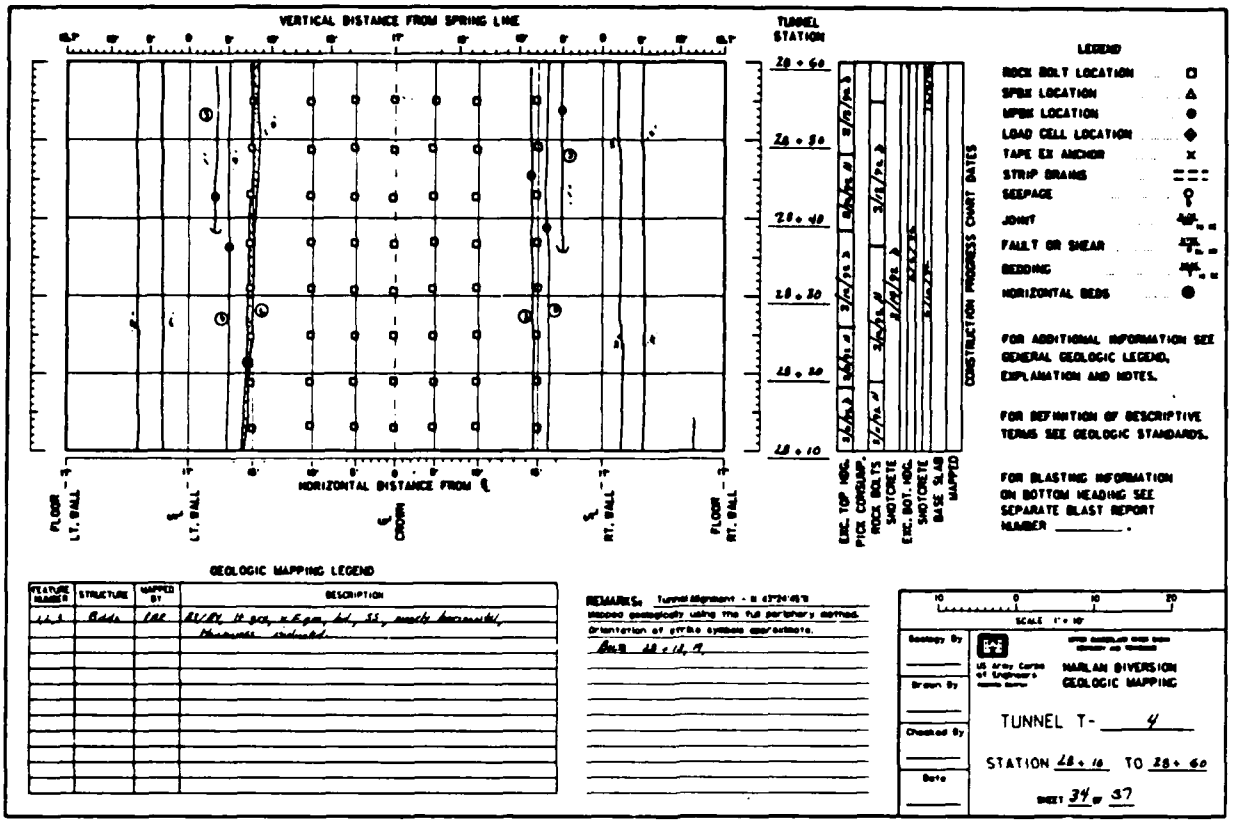

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
29 + 10
29 + 00
27 + 90
27 + 80
27 + 70
27 + 60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
℄ CROWN
RT. WALL
FLOOR RT. WALL
CONSTRUCTION PROGRESS CHART DATES
EXC. TOP HDG. PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB MAPPED
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1
Joint
BAR
N54°E, 88°S, TH, BS, HAS, MB
2, 3
Bdg
PAR
Sh Brn, R-gr, F-gr, hd, sandy loc, thickness indicated
4
Bdg Pln
PR
TH
5
Jt
PR
TH, BS, RBD Brn
REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Rock Bolts 27+63, 71
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
U.S. Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 29 + 60 TO 29 + 10
SHEET 33 OF 37

PLATE D-83


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
28+60
28+50
28+40
28+30
28+20
28+10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONCRETE
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 67°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 28+10 TO 28+60
SHEET 34 OF 37

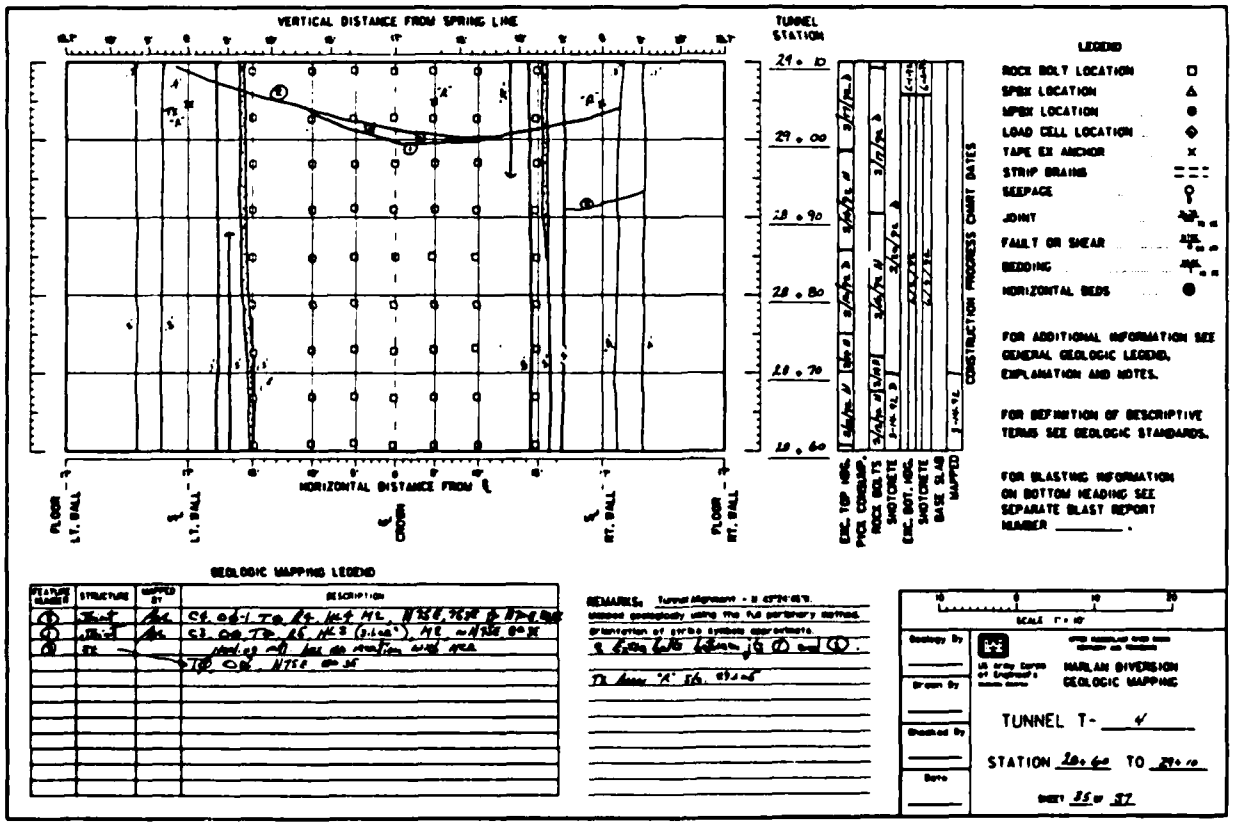
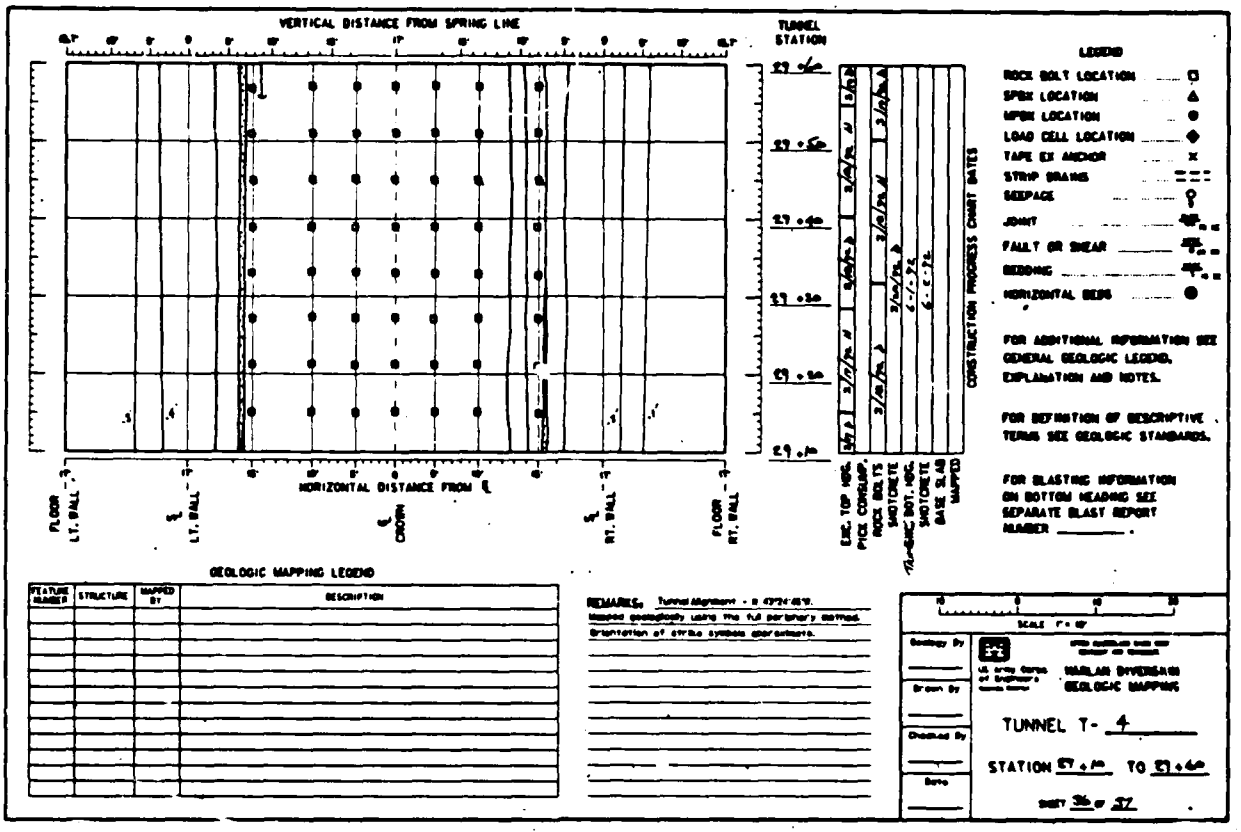

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
29+10
29+00
28+90
28+80
28+70
28+60
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONCRETE
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Tunnel Alignment - S 67°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 28+60 TO 29+10
SHEET 35 OF 37

PLATE D-84


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR – LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR – RT. WALL
EXC. TOP HOR.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HOR.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 29+60 TO 30+00
SHEET 36 OF 37

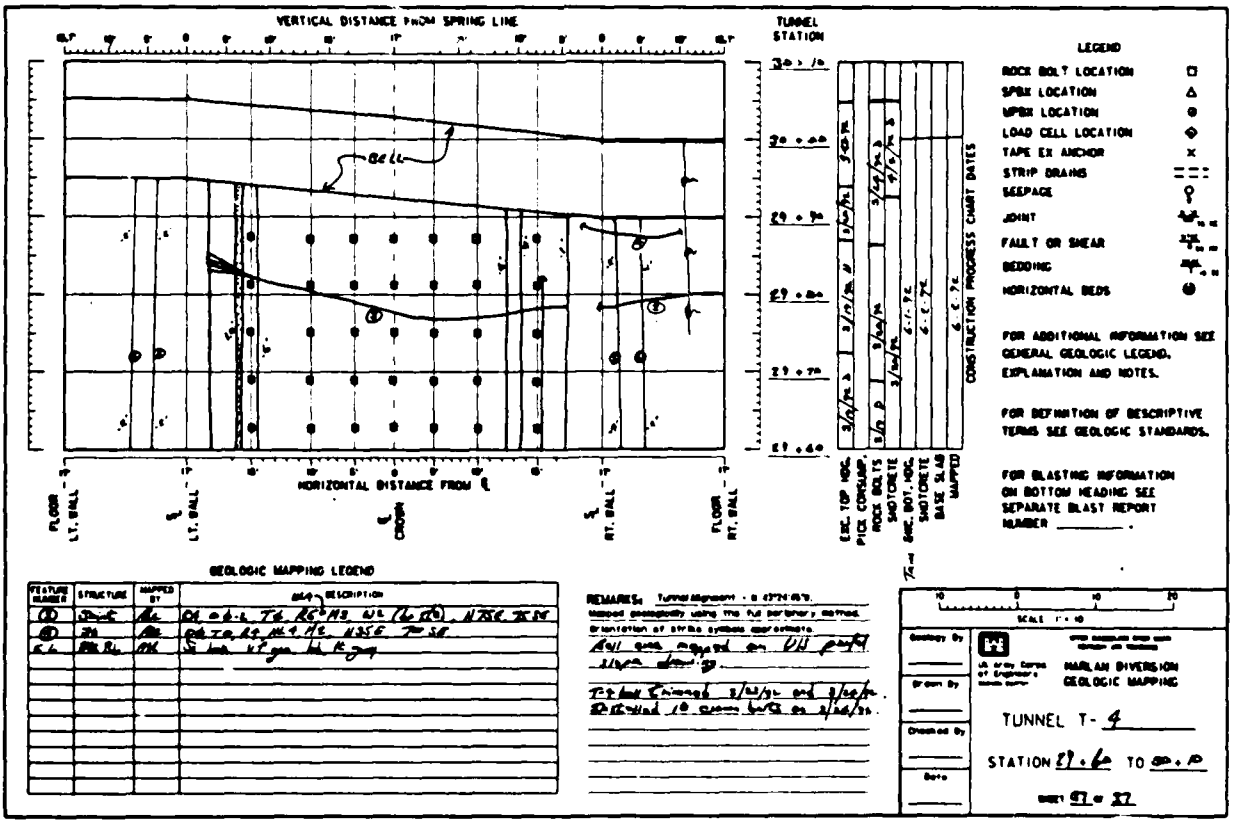
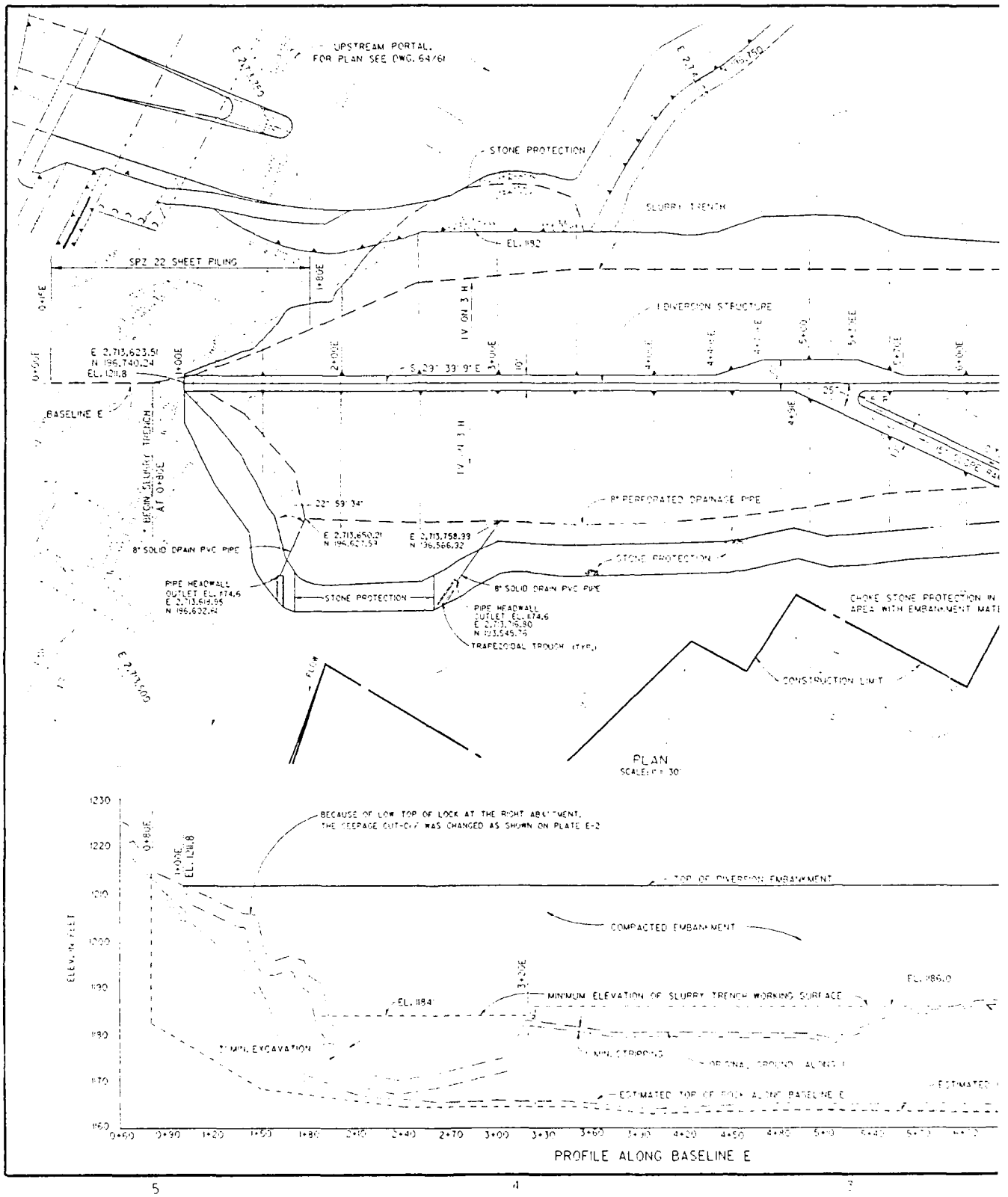
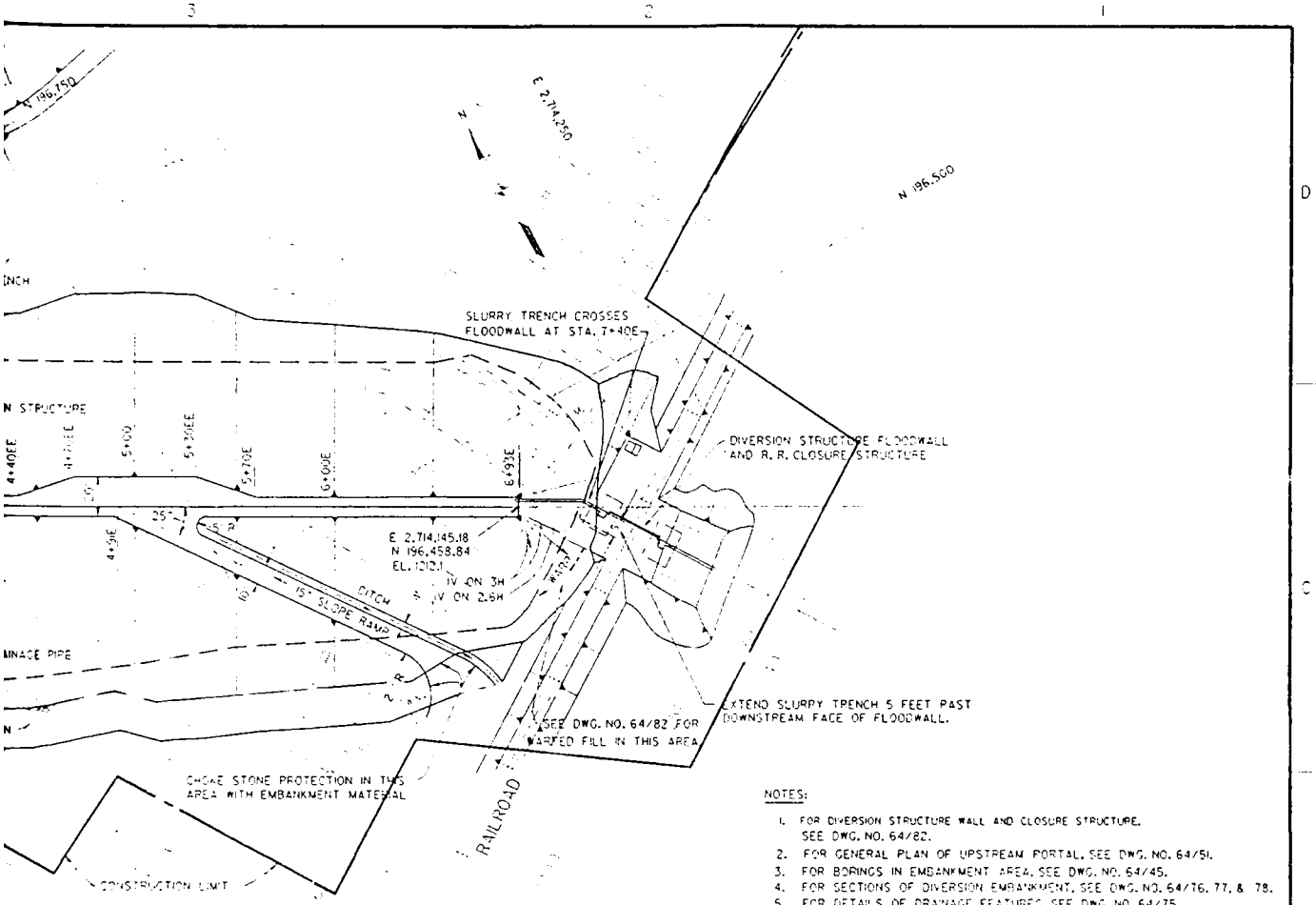

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
Belt
HORIZONTAL DISTANCE FROM ℄
FLOOR – LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR – RT. WALL
EXC. TOP HOR.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HOR.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER _____.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 29+60 TO 30+00
SHEET 37 OF 37

PLATE D-85

Appendix E - Diversion Embankment and Slurry Trench

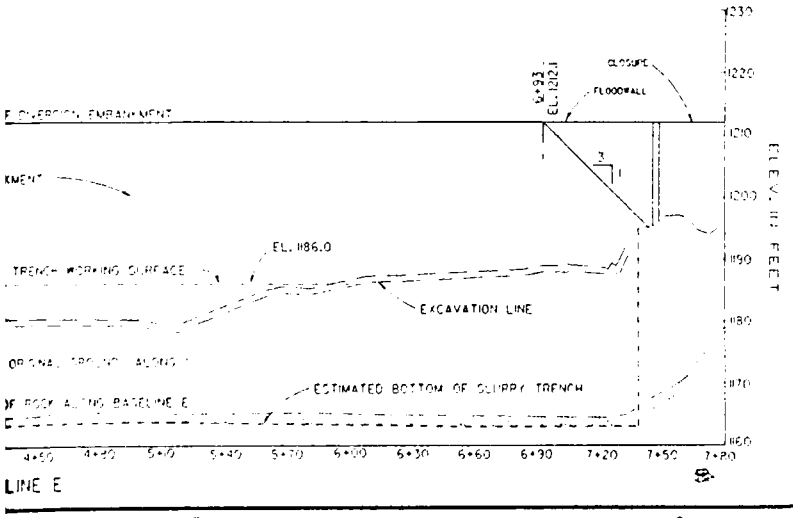
Plate No.	Drawing No.	Description
E-1	Q1A-64/73.3	Plan
E-2	Q1A-4/397	Seepage Cutoff Section
E-3	------	Piling Records
E-4	Q1A-64/74.3	Embankment Details
E-5	Q1A-64/45.1	Boring Plan
E-6	Q1A-64/46.1	Embankment Sections
E-7	Q1A-4/401	Boring Logs
E-8	------	Slurry Trench Backfill Borrow Site
E-9	------	Slurry Trench Backfill Gradations
E-10	------	Slurry Trench Backfill Gradations
E-11	------	Embankment Fill Compaction Tests
E-12	------	Water Line Relocation


UPSTREAM PORTAL
FOR PLAN SEE DWG. 64761
STONE PROTECTION
SLURRY TRENCH
EL. 1192
SPZ 22 SHEET PILING
DIVERSION STRUCTURE
E 2,713,623.51
N 196,740.24
EL. 1211.8
BASELINE E
BEGIN SLURRY TRENCH AT 0+80E
8" PERFORATED DRAINAGE PIPE
8" SOLID DRAIN PVC PIPE
PIPE HEADWALL
OUTLET EL. 1174.6
E 2,713,614.95
N 196,632.42
STONE PROTECTION
E 2,713,650.21
N 196,627.59
E 2,713,758.39
N 196,566.32
PIPE HEADWALL
OUTLET EL. 1174.6
E 2,713,796.80
N 193,545.79
TRAPEZOIDAL TROUGH (TYP.)
CHOKE STONE PROTECTION IN AREA WITH EMBANKMENT MATL
CONSTRUCTION LIMIT
FLOW
PLAN
SCALE: 1" = 30'
BECAUSE OF LOW TOP OF LOCK AT THE RIGHT ABUTMENT, THE SEEPAGE CUT-OFF WAS CHANGED AS SHOWN ON PLATE E-2
TOP OF DIVERSION EMBANKMENT
COMPACTED EMBANKMENT
EL. 1184
MINIMUM ELEVATION OF SLURRY TRENCH WORKING SURFACE
EL. 1186.0
SLURRY EXCAVATION
ESTIMATED TOP OF ROCK ALONG BASELINE E
ELEV. IN FEET
1230
1220
1210
1200
1190
1180
1170
1160
0+60
0+90
1+20
1+50
1+80
2+10
2+40
2+70
3+00
3+30
3+60
4+20
4+50
PROFILE ALONG BASELINE E



NOTES:

1. FOR DIVERSION STRUCTURE WALL AND CLOSURE STRUCTURE, SEE DWG. NO. 64/82.
2. FOR GENERAL PLAN OF UPSTREAM PORTAL, SEE DWG. NO. 64/51.
3. FOR BORINGS IN EMBANKMENT AREA, SEE DWG. NO. 64/45.
4. FOR SECTIONS OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/76, 77, & 78.
5. FOR DETAILS OF DRAINAGE FEATURES, SEE DWG. NO. 64/75.
6. FOR TYPICAL SECTIONS OF EMBANKMENT AND OTHER DETAILS, SEE DWG. NO. 64/74.
7. SOIL BENTONITE BACKFILL USED THROUGHTOUT.
8. SLURRY TRENCH ENDED AT STATION 1+70 AND A SHEET PILE CUTOFF WAS INSTALLED FROM STATION 1+80 TO 0+15, SEE PLATE E-2.



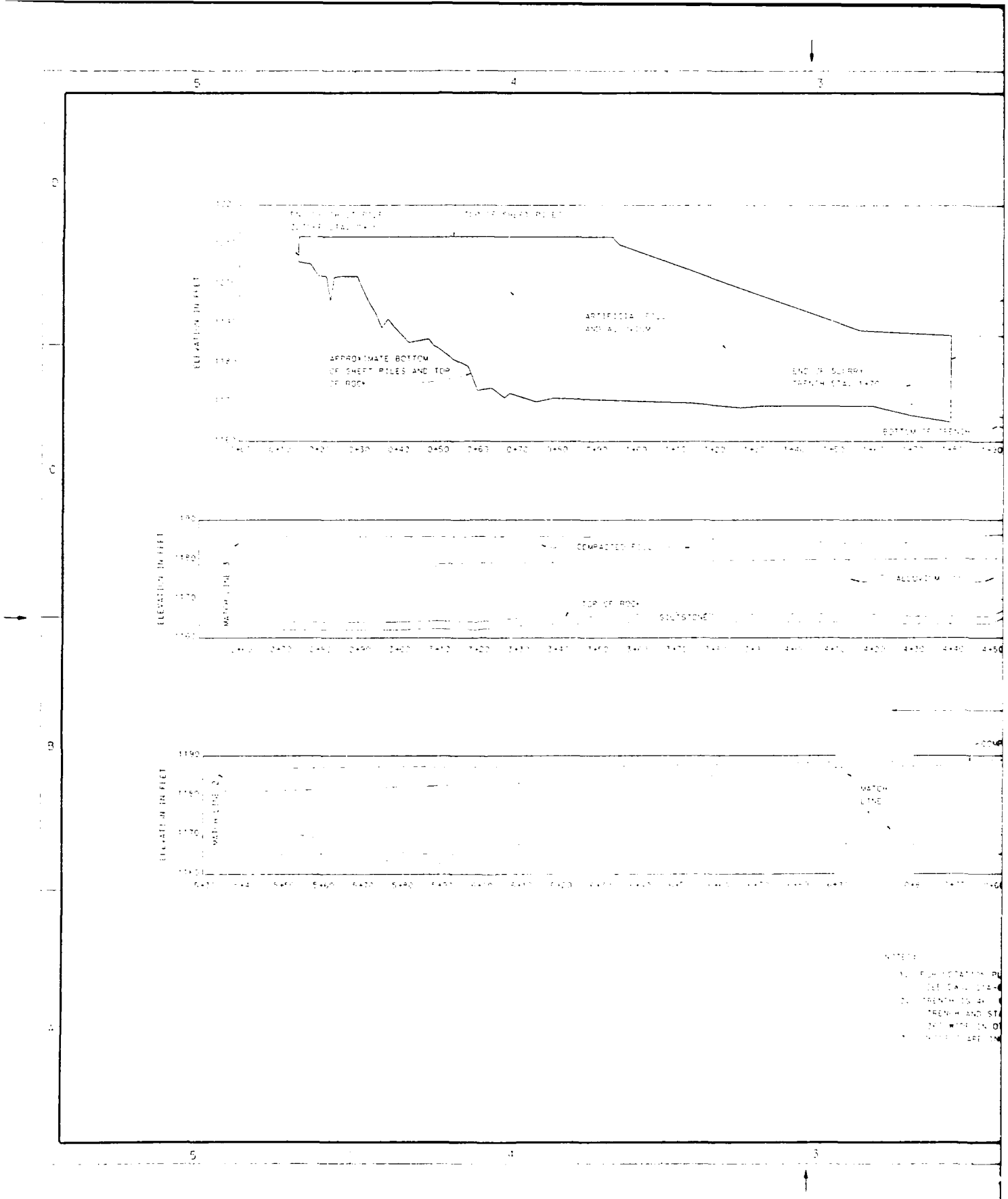
3	1-4-94	REVISED AS CONSTRUCTED	S.B.D.	
2	6-30-89		B.F.	D.J.
1	5-31-89	CONFORMING TO REVIEW COMMENTS	W.J.	D.J.

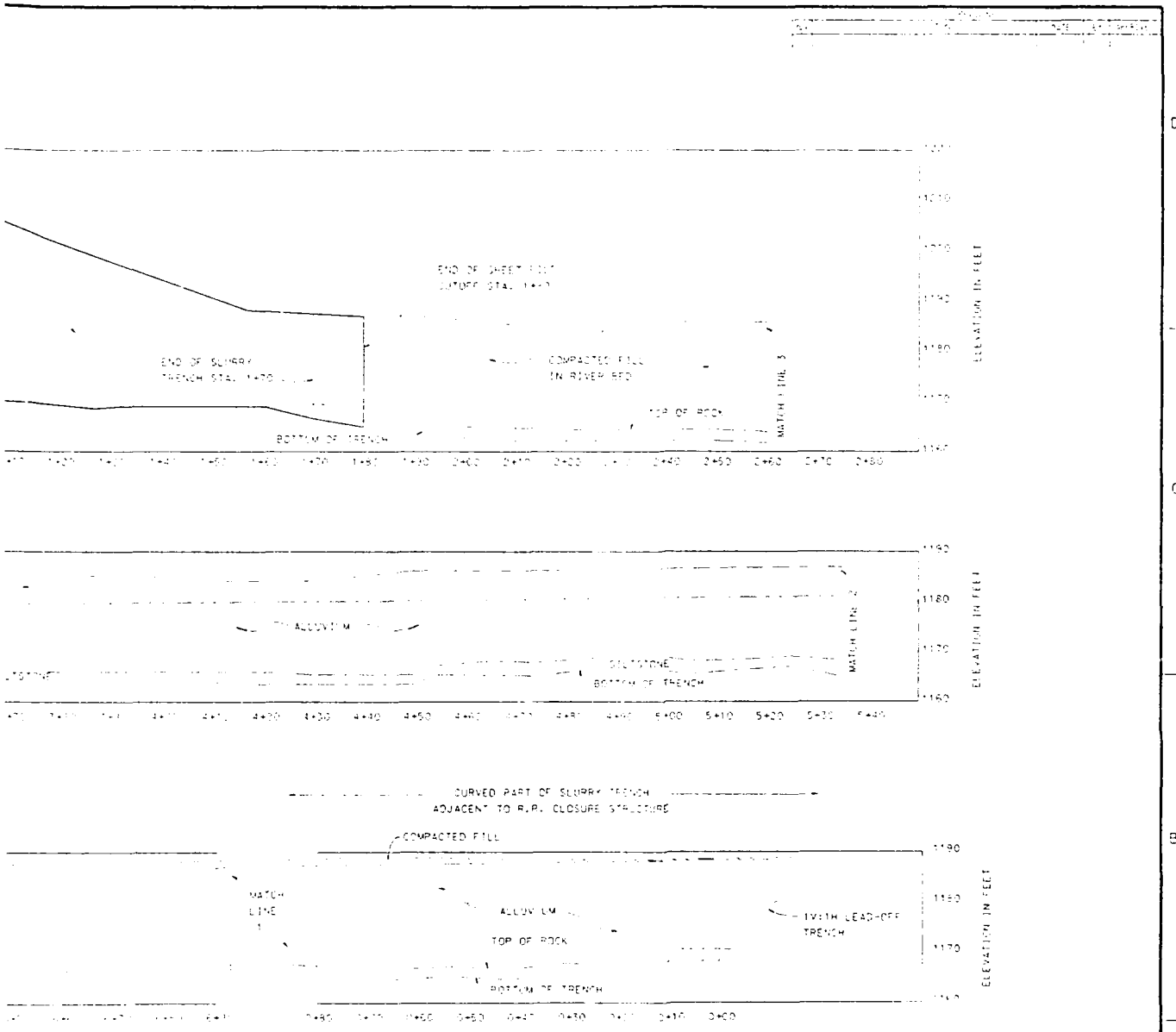
DIVERSION TUNNELS

DIVERSION EMBANKMENT
PLAN

DIA-64/73.3

PLATE E-1


5
4
3
D
C
B
A
ELEVATION IN FEET
ARTIFICIAL FILL
AND ALLUVIUM
APPROXIMATE BOTTOM
OF SHEET PILES AND TOP
OF ROCK
BOTTOM OF TRENCH
COMPACTED FILL
ALLUVIUM
TOP OF ROCK
SILTSTONE
WATER
LINE



NOTES:

1. FOR LOCATION PLAN OF SLURRY TRENCH SEE DWG. SPA-KM 71.1-PLATE 1.
2. TRENCH IS 30' WIDE FROM LEAD-OFF TRENCH AND STA. 0+00 TO STA. 0+72. 50' WIDE IN OTHER AREAS.
3. DETAILS ARE INCLUDED IN APPENDIX E.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

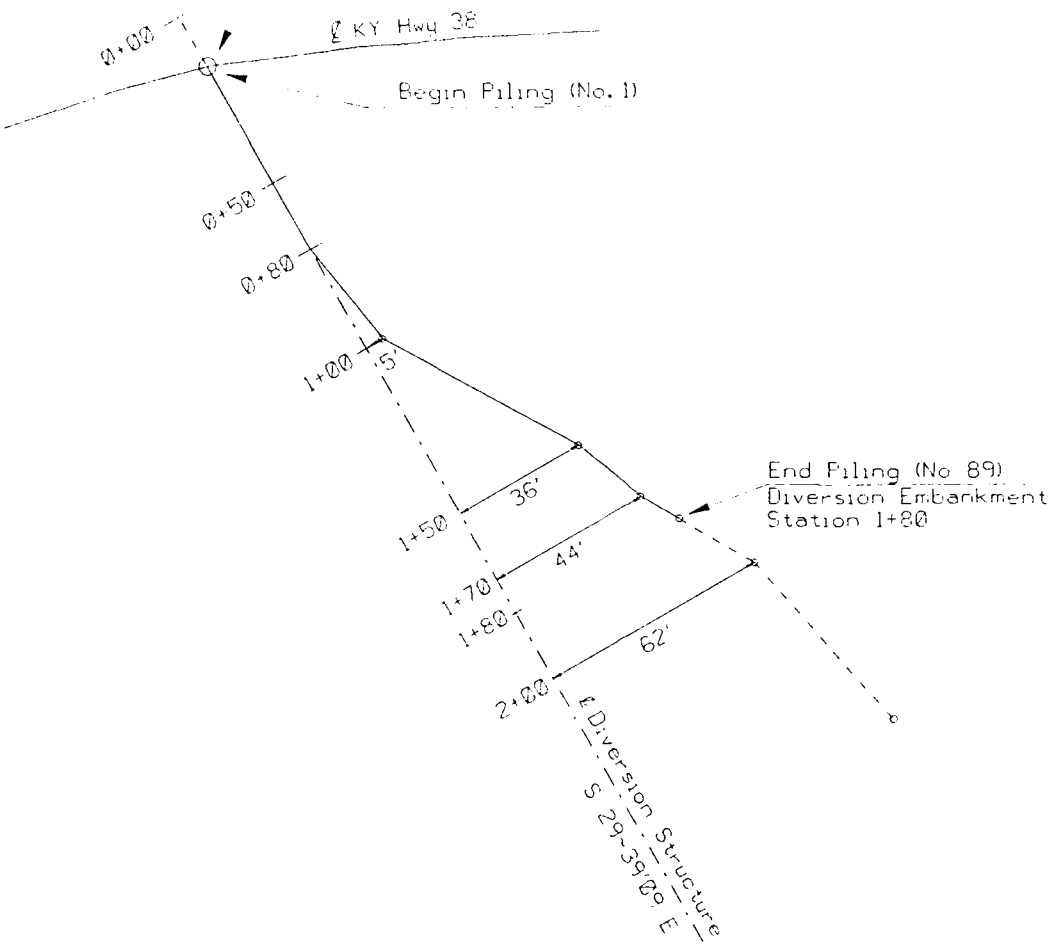
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
CROSS SECTION ALONG ℄ OF SLURRY TRENCH

Q1A-4397

Chief, Survey & Design Section

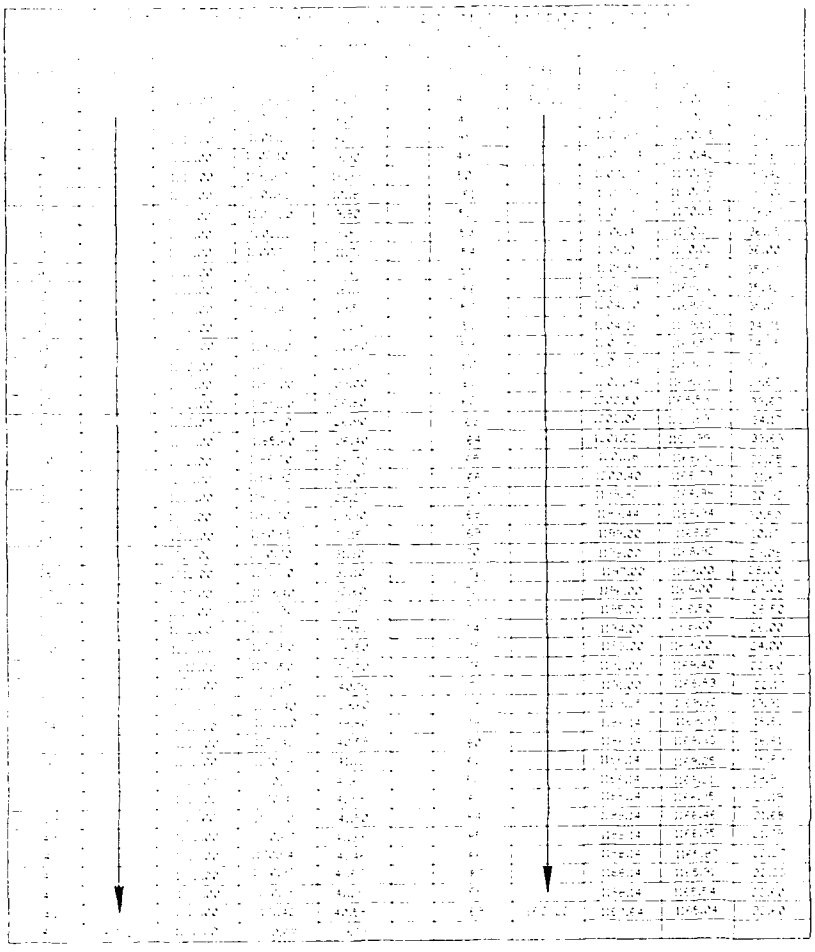
PLATE E-2

KY Hwy 38 Station 59+58
= Diversion Embankment Station 0+15



PLAN VIEW

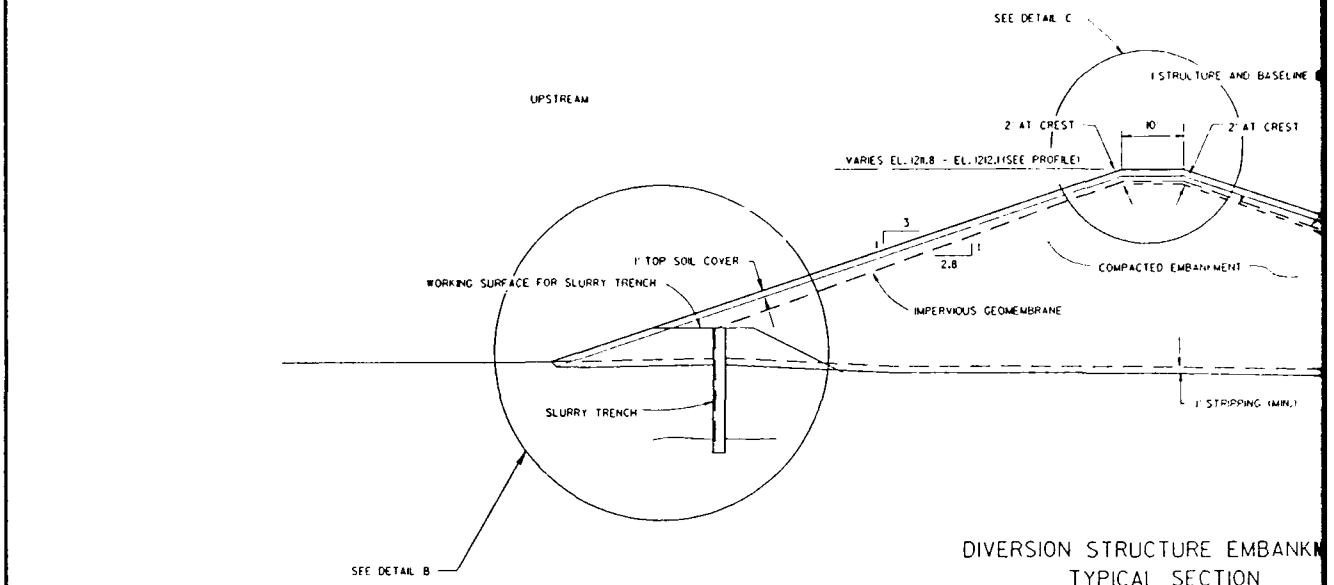
1"=20'-0"



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

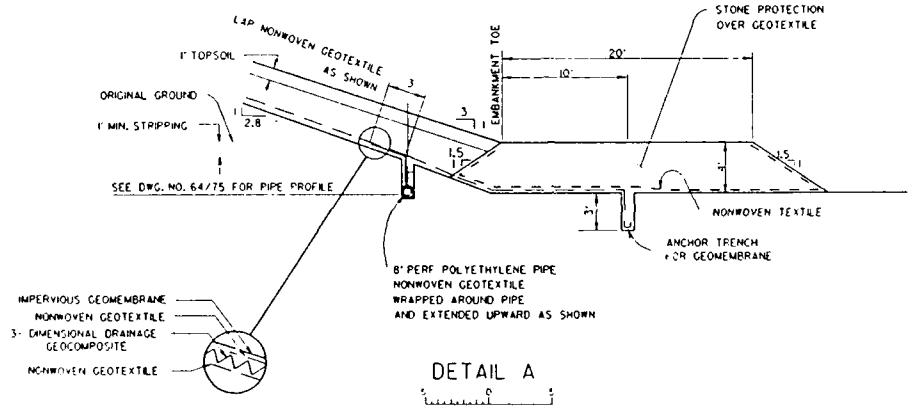
Drawn By: SAEB	HARLAN DIVERSION PROJECT
Checked By:	AS CONSTRUCTED
ENGINEER	DIVERSION EMBANKMENT
Approved By: CHIEF, BRANCH	SHEET PILING MODIFICATION
CHIEF, ENGINEERING DIVISION	PILING LOCATION and RECORDS
	Date: JAN. 1994
	Record Drawing as constructed dated

PLATE E-3



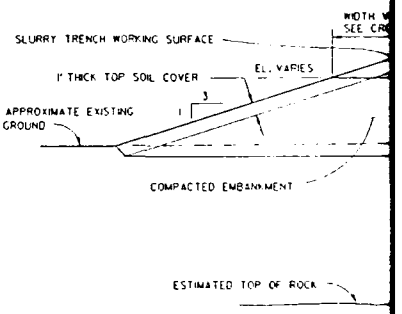
DIVERSION STRUCTURE EMBANKM
TYPICAL SECTION

SCALE: 1"=10'



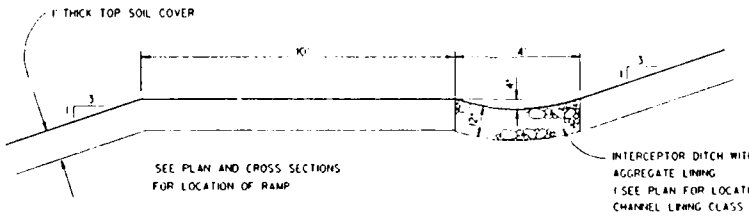
DETAIL A

SCALE: 1"=5'



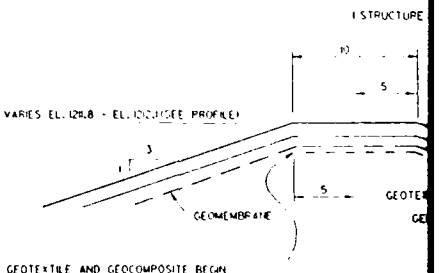
DETA

SCALE



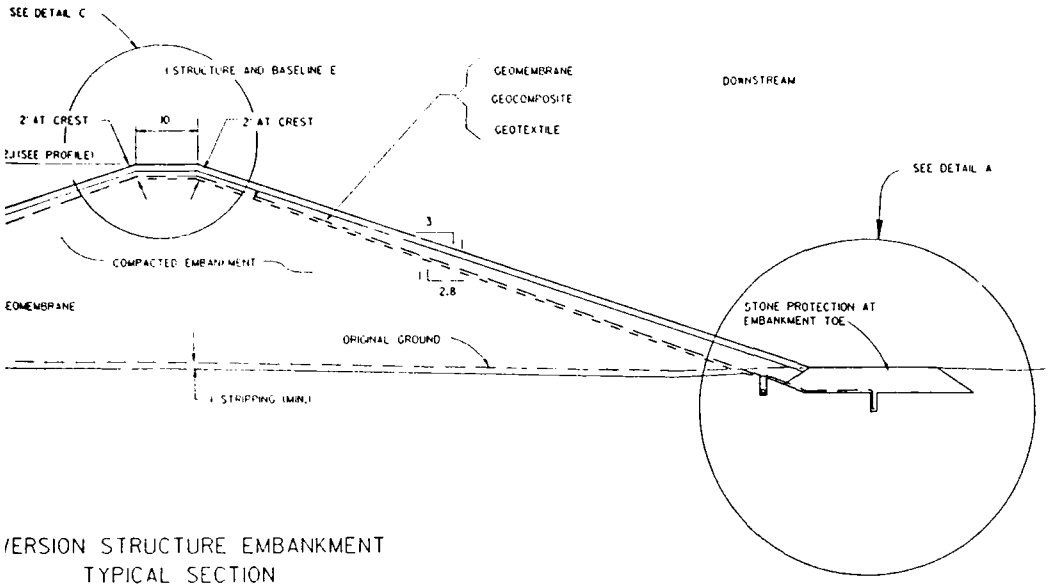
TYPICAL RAMP SECTION

SCALE: 1"=2'

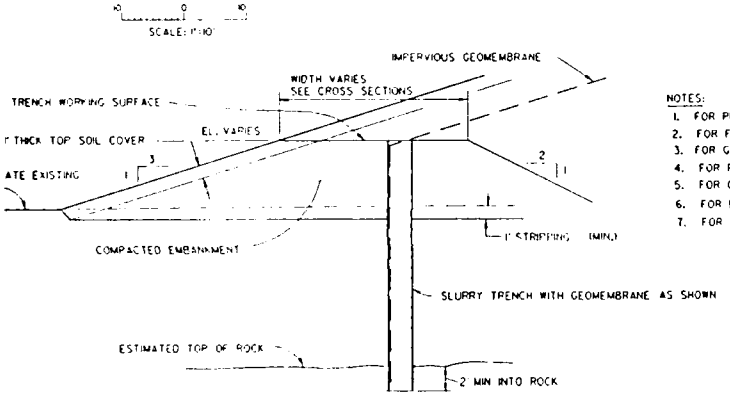


DETAIL C

SCALE: 1"=5'

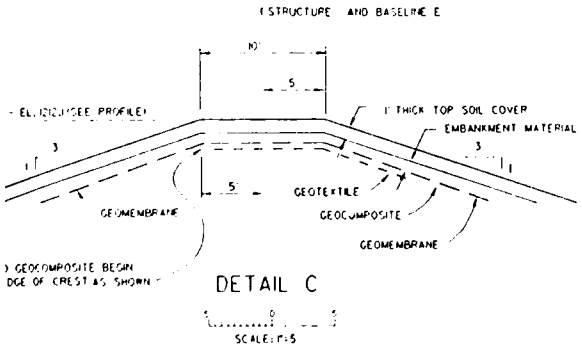


/ERSION STRUCTURE EMBANKMENT
TYPICAL SECTION



DETAIL B

NOTES:
1. FOR PLAN OF UPSTREAM PORTAL AREA, SEE DWG. NO. 64/51.
2. FOR FLOODWALL AND CLOSURE STRUCTURE, SEE DWG. NO. 64/82.
3. FOR GENERAL PLAN OF PROJECT, SEE DWG. NO. 64/2.
4. FOR PLAN - PROFILE OF DIVERSION STRUCTURE, SEE DWG. NO. 64/73.
5. FOR CROSS SECTIONS ALONG BASELINE E, SEE DWG. NOS. 64/76, 77, & 78.
6. FOR DETAILS OF EMBANKMENT DRAIN, SEE DWG. NO. 64/75.
7. FOR ELEVATIONS OF SLURRY TRENCH WORKING SURFACE, SEE DWG. NO. 64/73.



DETAIL C

.3	11-29-93	REVISED AS CONSTRUCTED	S.B.D.	
.2	6-29-89	REVISED GEOMEMBRANE	B.F.	D.J.
.1	5-31-89	CONFORMING TO REVIEW COMMENTS	W.L.	P.E.B.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

PAUL E. PETTH

DON FEDRICK

P. E. B.

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

DIVERSION TUNNELS

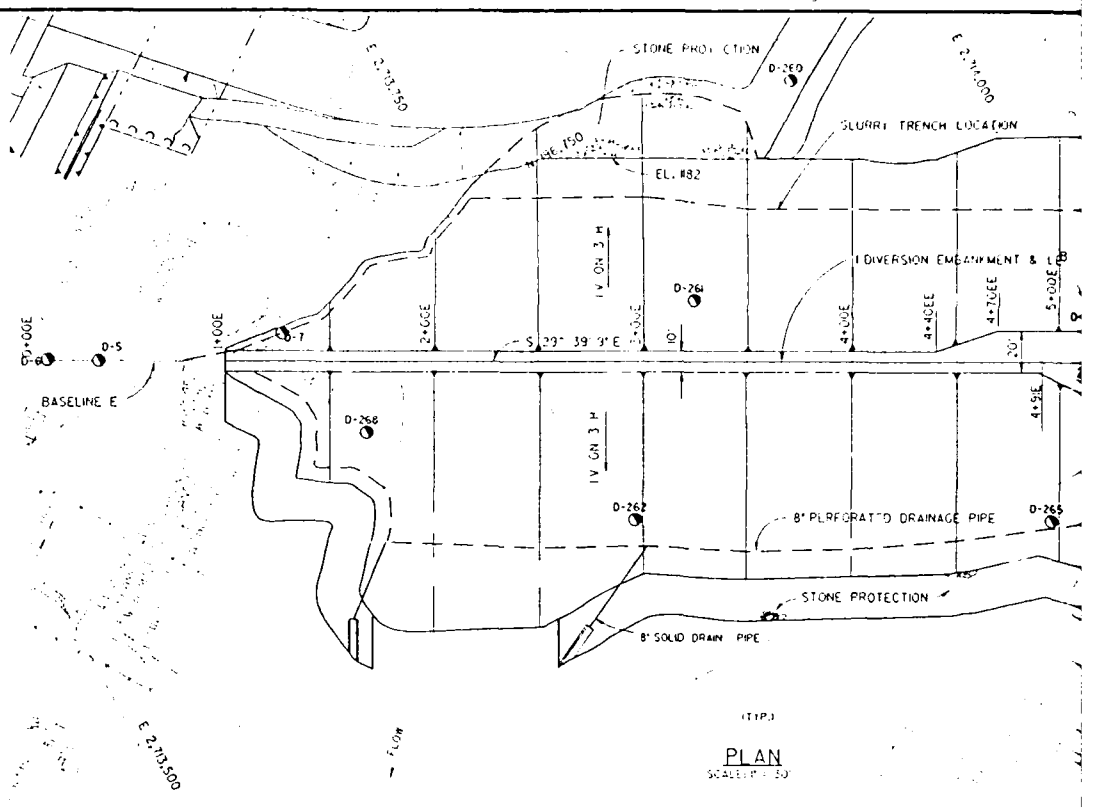
DIVERSION EMBANKMENT
TYPICAL SECTION AND DETAILS

MAR. 1983

AS SHOWN

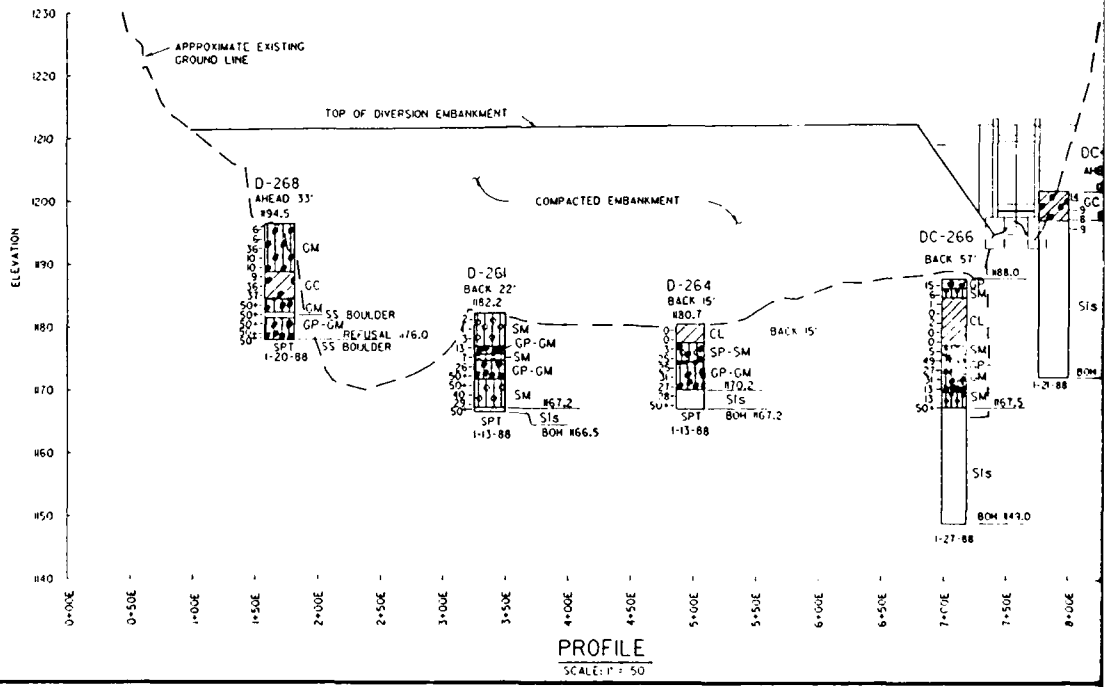
OIA-64/74 .3

PLATE E-4



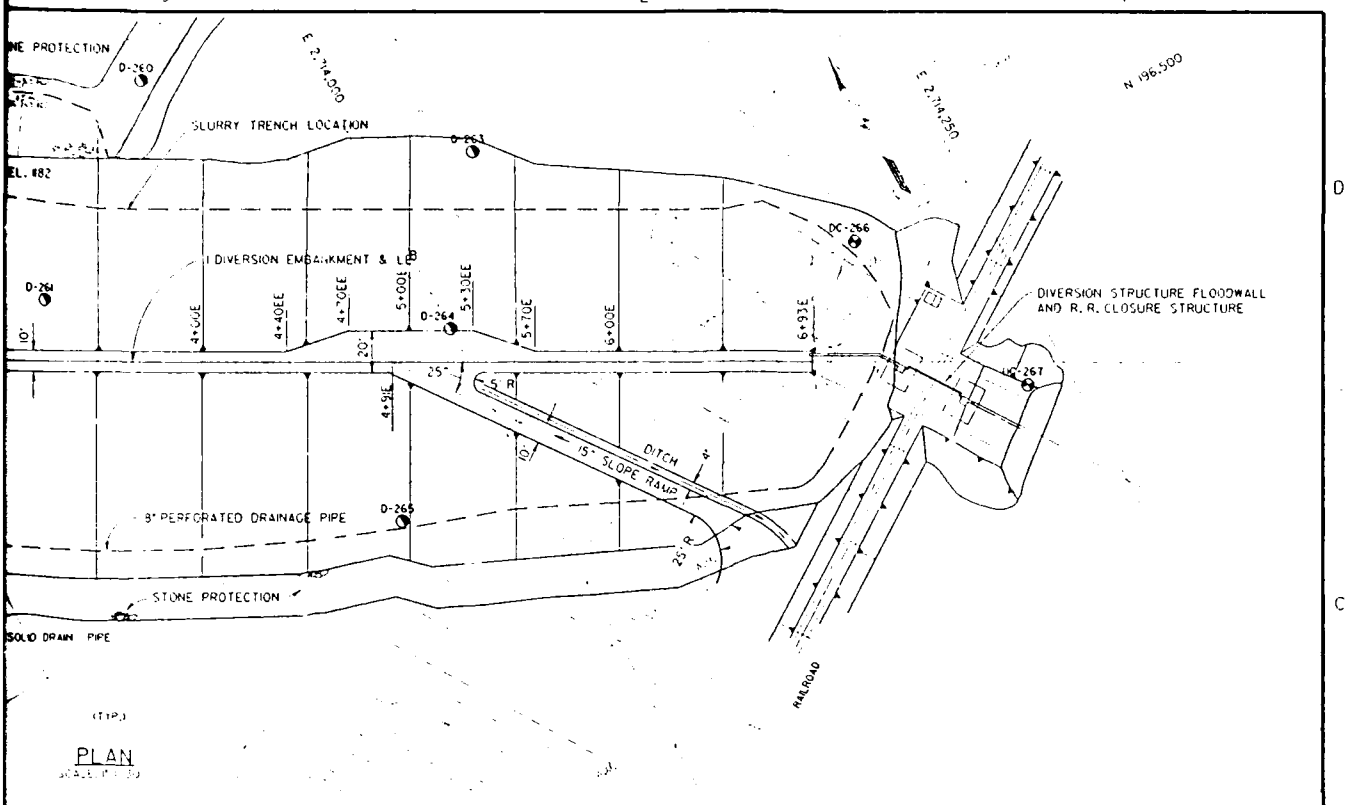
PLAN

SCALE: 1" = 50'

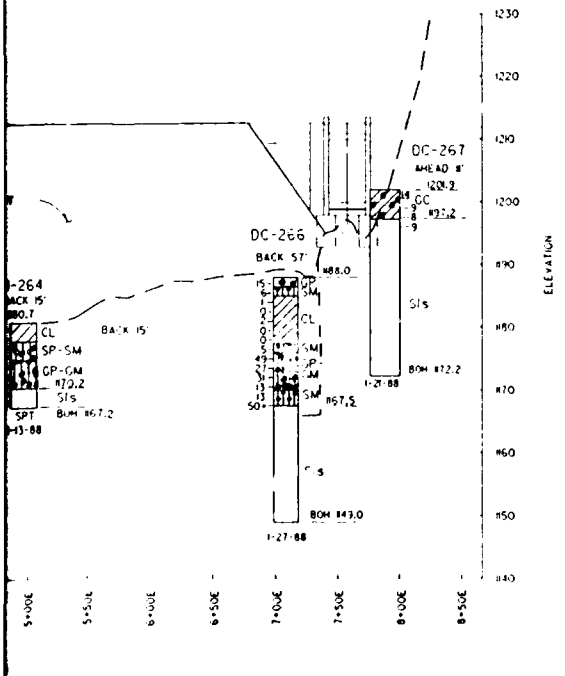


PROFILE

SCALE: 1" = 50'



PLAN



NOTES:
1. FOR GENERAL PLAN OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/73.
2. FOR BORING LEGEND, SEE DWG. NO. 64/5.
3. FOR OVERALL BORING PLAN, SEE DWG. NO. 64/4.
4. FOR ADDITIONAL EXPLORATION IN UPSTREAM PORTAL, SEE DWG. NO. 64/32.
5. FOR SUBSURFACE SECTIONS THROUGH EMBANKMENT, SEE DWG. NO. 64/46.
6. GRAPHIC LOGS SHOWN ARE GENERALIZED AND SHOULD BE USED IN CONJUNCTION WITH DETAILED TESTING INFORMATION PRESENTED IN APPENDIX A OF THE SPECIFICATIONS.
7. SLURRY TRENCH CONSTRUCTED AS SHOWN ON PLATES E-1 AND E-2.

No. Revisions	Date	Description	By	Checked
1	2-2-94	AS CONSTRUCTED	MEP	

50' 0 50 HORIZONTAL SCALE
10' 0 10 VERTICAL SCALE

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

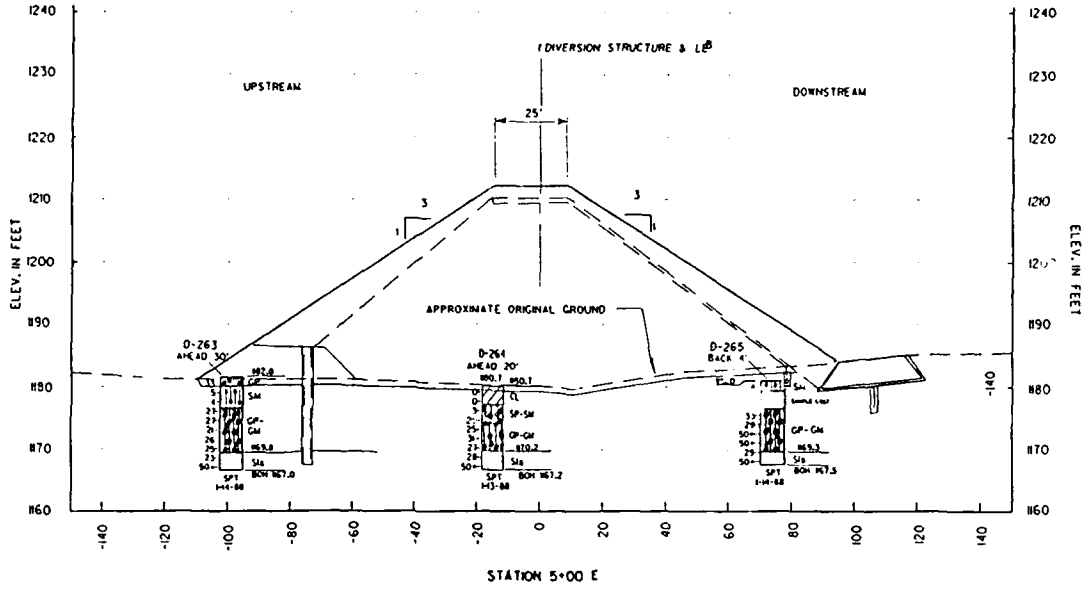
Designed By: P.E.B.
Drawn By: T. COLLINS
Checked By: P.E.B.
Approved By: CHIEF, GEOTECHNICAL BRANCH
FILE: SP

LOWER CUMBERLAND RIVER
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNEL

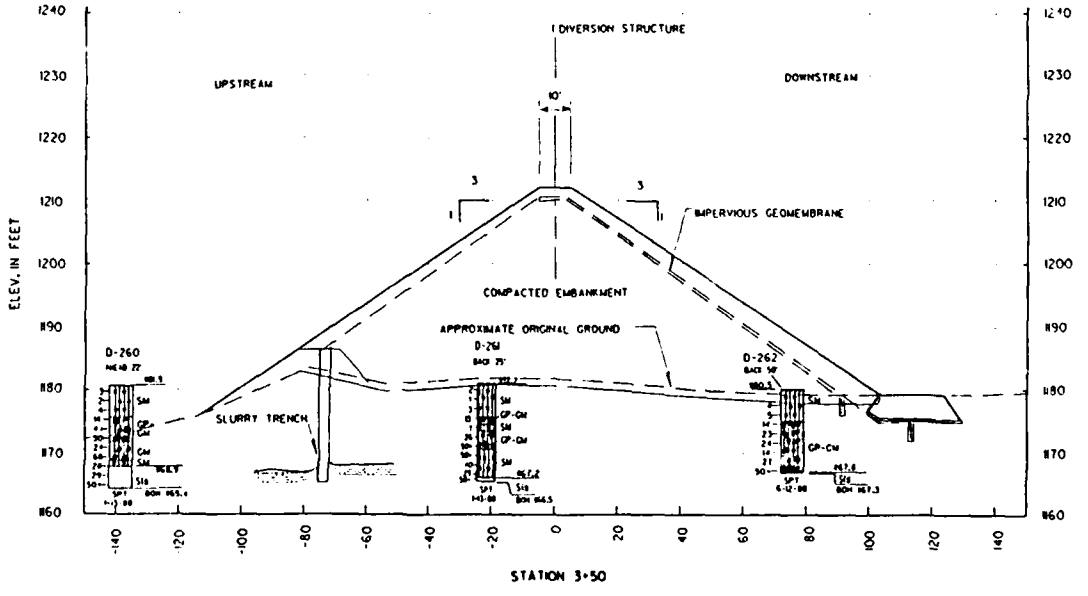
DIVERSION EMBANKMENT
BORING PLAN AND SUBSURFACE PROFILE

Date: FEB 1980
Scale: AS SHOWN
Sheet 1 of 2
Drawing Number: 01A-64/45.1
Record Drawing as constructed dated

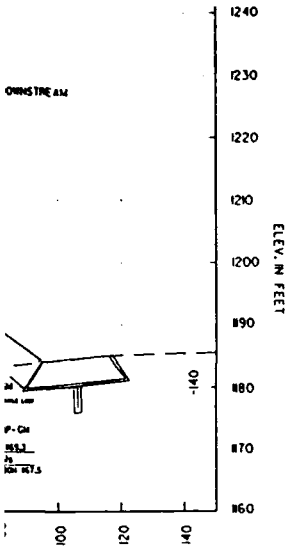
PLATE E-5

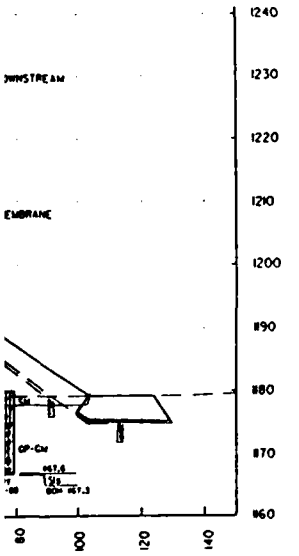


STATION 5+00 E



STATION 3+50





NOTES:
1. FOR BORING PLAN OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/45.
2. FOR BORING LEGEND, SEE DWG. NO. 64/5.
3. FOR OVERALL BORING PLAN, SEE DWG. NO. 64/4.
4. FOR GENERAL PLAN OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/73.

Revisions	Date	Description	By	Checked
J	1-94	REVISED AS-CONSTRUCTED	MAR	

H SCALE: 1" = 20'
V SCALE: 1" = 10'
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Designed By: Paul C. Smith
Drawn By: T. COLLINS
Checked By: P.E.B.
Approved By: CHIEF, GEOTECHNICAL BRANCH
FILE:

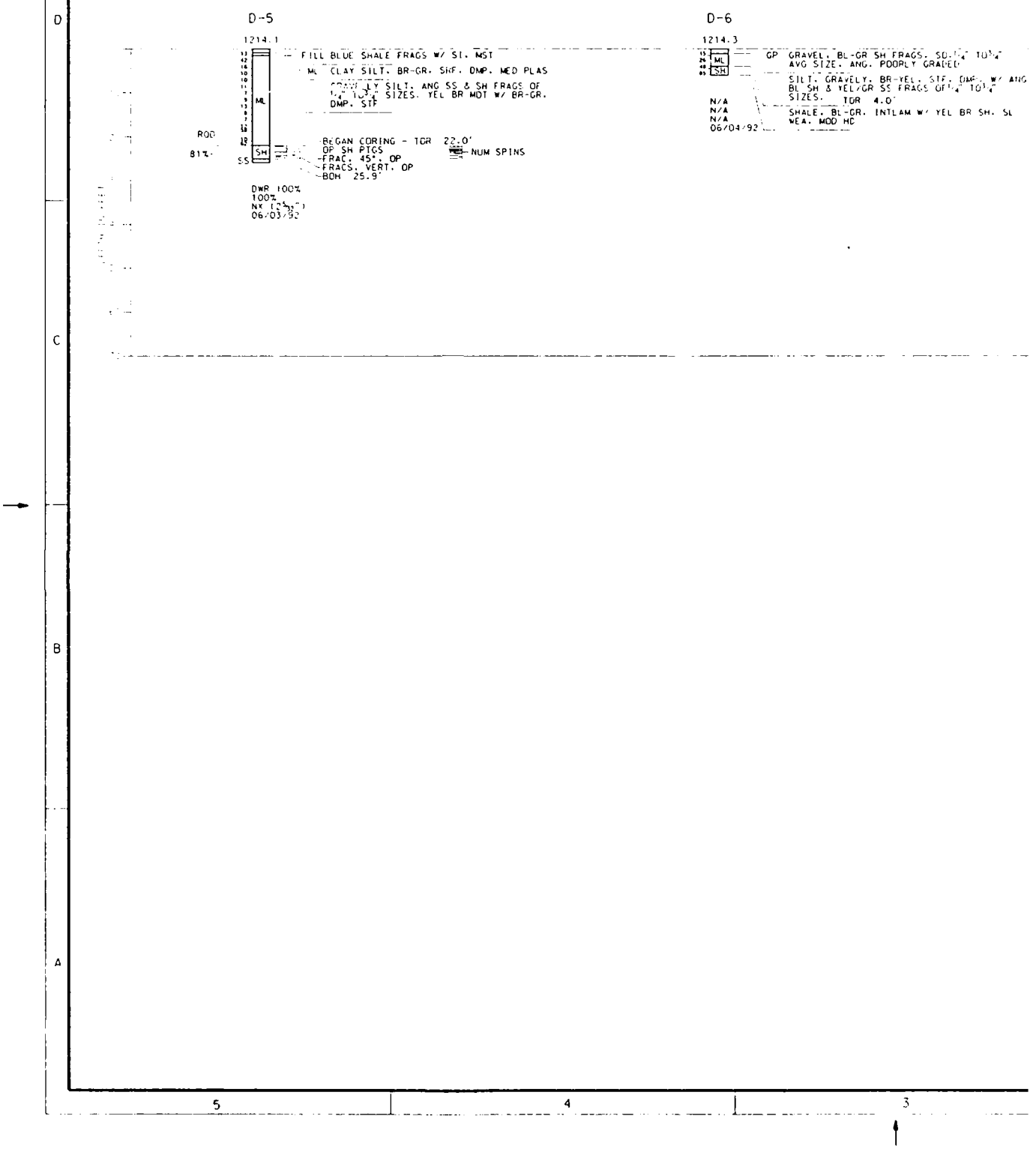
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

DIVERSION EMBANKMENT
SUBSURFACE SECTIONS

Date: FEB 1989
Scale: 1" = 20' H 1"=10' V
SHEET 2 OF 2
Drawing Number: DIA-64/46J
Record Drawing as constructed dated

Computer Soils Aided Design & Drafting

PLATE E-6


5
4
3
D
C
B
A
D-5
1214.1
FILL BLUE SHALE FRAGS W/ SI. MST
ML CLAY SILT. BR-GR. SKF. DMP. MED PLAS
ML
SH
SS
ROD
81%
BEGAN CORING - TOR 22.0'
OP SH PCS
FRAC. 45°, OP
FRACS. VERT. OP
BOH 25.9'
NUM SPINS
DWR 100%
100%
NX
06/03/92
D-6
1214.3
GP GRAVEL. BL-GR SH FRAGS. SD.
AVG SIZE. ANG. POORLY GRADED
ML
SH
SILT. GRAVELLY. BR-YEL. STF. DMP. W/ ANG
BL SH & YEL/GR SS FRAGS OF
SIZES. TOR 4.0'
N/A
N/A
N/A
06/04/92
SHALE. BL-GR. INTLAM W/ YEL BR SH. SL
WEA. MOD HC

D-7

GP GRAVEL, BL-GR SH FRAGS, SD, 1/4" TO 3/4" AVG SIZE, ANG, POORLY GRADED

SILT, GRAVELLY, BR-YEL, STF, DMP, W/ ANG BL SH & YEL/GR SS FRAGS OF 1/4" TO 3/4" SIZES. TOR 4.0'

SHALE, BL-GR, INTLAM W/ YEL BR SH, SL WEA, MOD HD

1220.6

GM SILTY GRAVEL, BR-YEL, SL DMP, W/ GVL, CBL & BLD SIZED ANG SS, SH, & SLS FRAGS

SANDSTONE FRAGS, COBBLE TO BOULDER SIZED

GM SILTY GRAVEL, AS ABOVE

SAND, BR, V LS, POORLY GRADED, MST

GM SANDY GRAVEL, MED, W/ 1/2" - 3/4" SIZED ANG SS FRAGS, POORLY GRADED

GP SILTY GRAVEL, AS ABOVE

GM SANDY GRAVEL, AS ABOVE

GP SANDSTONE COBBLES & BOULDERS

GP SANDY GRAVEL, AS ABOVE

ROD

54% SH TOR 40.2'
BEGAN CORING 40.4'
-SPIN
-SPIN, FRAGS
-OP FRAC ALONG SH PTG
-SPIN
-BOH 45.9'

DWR 100%
100%
NX (2 3/8")
06/11/92

NOTES:

1. SEE PLATE A-2 FOR ABBREVIATIONS.
2. SEE PLATES A-3 THRU A-5 FOR DEFINATIONS AND DESCRIPTIVE TERMS.
3. SEE PLATE H-2 FOR BORING LOCATION PLAN.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: R.U.
Checked By: P.R.
P.R. GEOLOGIST
Approved By: CHIEF, GEOTECHNICAL BRANCH / CHIEF, ENGINEERING DIVISION

UPPER CUMBERLAND RIVER BASIN
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

LOGS OF BORINGS
DIVERSION DAM RIGHT ABUTMENT

Date: DECEMBER 1992
Scale: AS SHOWN
Revised Drawing as constructed dated
Drawing Number: Q1A-4/401

Computer Aided Design & Drafting / Geology Section

PLATE E-7

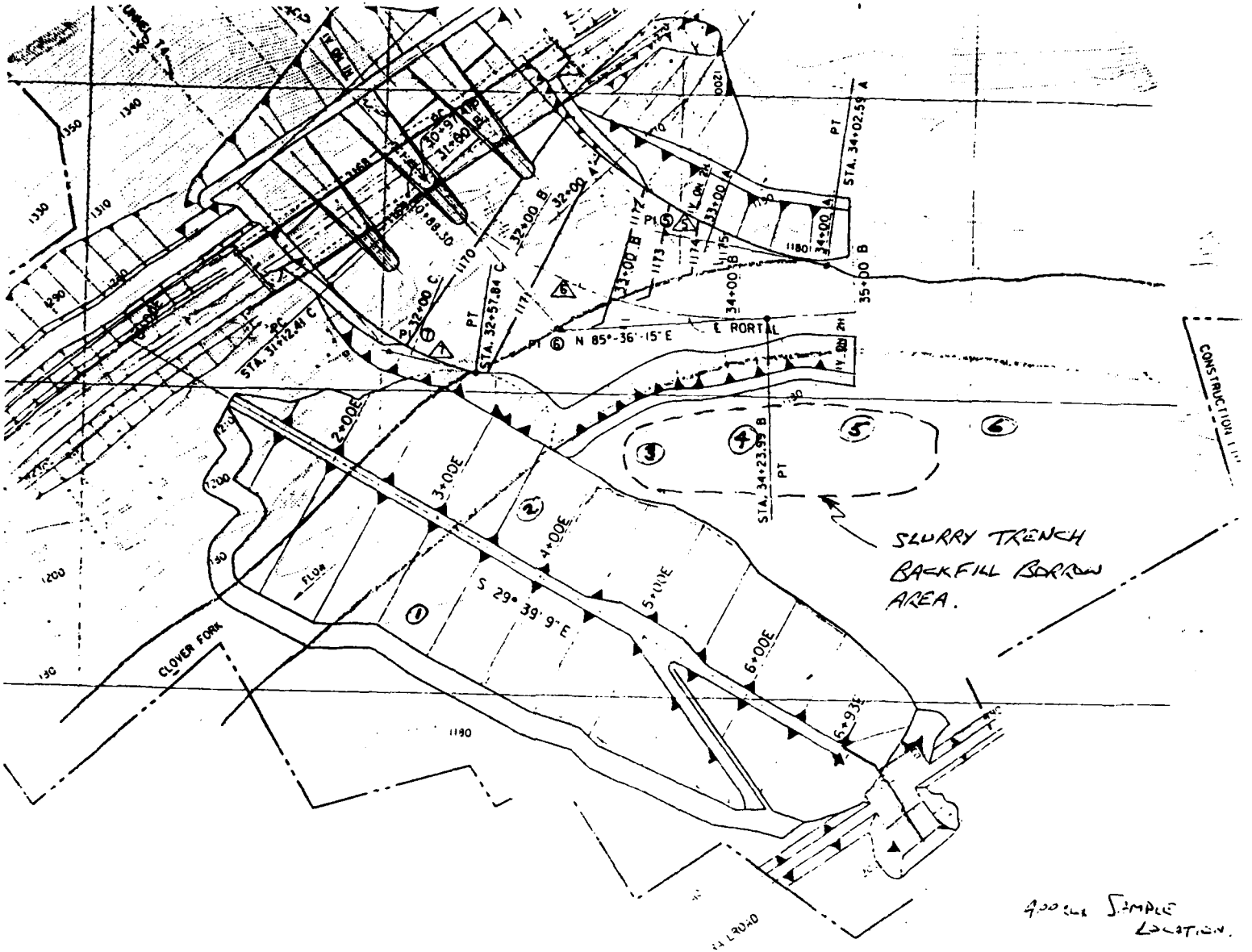

CLOVER FORK
FLOW
E PORTAL
PT
PT ⑥ N 85°-36'-15" E
STA. 32+57.84 C
STA. 31+12.41 C
STA. 34+02.59 A
STA. 34+23.95 B
2+00E
3+00E
4+00E
5+00E
6+00E
6+93E
S 29° 39' 9" E
SLURRY TRENCH
BACKFILL BORROW
AREA.
CONSTRUCTION
1180
1190
1200
1210
1220
1230
1240
1250
1260
1270
1280
1290
1300
1310
1320
1330
1340
1350
1360

PLATE E-8

PLATE E-9

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion

Approved: /

Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)
					F.M.
					SOFTS
					DELETERIOUS
					COLOR
					SILT
					WT./CU.FT.
6"	0.0	0.0	0.0	100.0	SP.GR. 100
3"	0.0	0.0	0.0	100.0	VOIDS 95-100
#4	38.1	15.0	15.0	85.0	50-100
#40	45.6	18.0	33.0	67.0	30-80
#200	115.0	45.5	78.5	21.5	15-25
PAN	54.3	21.5	100.0		
TOTAL	253.0	100.0			

REMARKS:

#3

DISPOSITION: Mat for Soil Bentonite

SAMPLE NO. 3 of 6

SAMPLED: C.C. ANALYSIS: Boswell

LOCATION: See Attachment

DATE: 3-Sept. 91

SOUNDNESS: WEIGHT: 253.0

ORH Form 266 Constr. Div. CEORH-CD

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion

Approved: /

Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)
					F.M.
					SOFTS
					DELETERIOUS
					COLOR
					SILT
					WT./CU.FT.
6"	0.0	0.0	0.0	100.0	SP.GR. 100
3"	0.0	0.0	0.0	100.0	VOIDS 95-100
#4	32.7	10.2	10.2	89.8	50-100
#10	46.6	14.5	24.7	75.3	30-80
#200	169.5	52.6	77.3	22.7	15-25
PAN	73.3	22.7	100.0		
TOTAL	322.1	100.0			

REMARKS:

#4

DISPOSITION: Mat of Soil Bentonite

SAMPLE NO. 4 of 6

SAMPLED: C.C. ANALYSIS: Boswell

LOCATION: See Attachment

DATE: 3-Sept. 1991

SOUNDNESS: WEIGHT: 322.1

ORH Form 266 Constr. Div. CEORH-CD

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion
Approved: ✓
Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)
					F.M.
					SOFTS
					DELETERIOUS
					COLOR
					SILT
					WT./CU.FT.
6"	0.0	0.0	0.0	100.0	SP.GR. 100
3"	0.0	0.0	0.0	100.0	VOIDS 95-100
# 4	135.3	38.4	38.4	61.6	50-100
# 40	43.6	12.3	50.7	49.3	30-80
# 200	108.1	30.6	81.3	18.7	15-25
PAN	65.5	18.7	100.0		
TOTAL	352.3	100.0			

REMARKS:
5

DISPOSITION: Mat. for soil Bentonite
LOCATION: See Attachment
SAMPLE NO. 5 of 6
DATE: 3-Sept 91
SAMPLED: G.C
ANALYSIS: Boswell
SOUNDNESS:
WEIGHT: 352.3

266 Constr. Div. CEORH-CD

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion
Approved: ✓
Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)
					F.M.
					SOFTS
					DELETERIOUS
					COLOR
					SILT
					WT./CU.FT.
6"	0.0	0.0	0.0	100.0	SP.GR. 100
3"	0.0	0.0	0.0	100.0	VOIDS ~~100~~ 95-100
# 4	91.1	26.6	26.6	73.4	~~95-100~~ 50-100
# 40	38.5	11.3	37.9	62.1	~~50-100~~ 30-80
# 200	146.2	42.8	80.7	19.3	30-80 15-25
PAN	65.6	19.3	100.0		
TOTAL	341.4	100.0			

REMARKS:
6

DISPOSITION: Mat. for soil Bentonite
LOCATION: See Attachment
SAMPLE NO. 6 of 6
DATE: 3-Sept 91
SAMPLED: G.C
ANALYSIS: Boswell
SOUNDNESS:
WEIGHT: 341.4

ORH Form 266 Constr. Div. CEORH-CD

PLATE E-10

U.S. ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

NUCLEAR COMPACTION
TEST DATA

PROJECT: H. W. Hayes
JOB NO.:
DATE: 16 Jan 1992
TAKEN BY: Boswell

TEST NUMBER	1	2	3	4	5	6
STATION	5+80	5+50	5+00			
OFFSET	Rt. 10' of & Levee	20' Lt & of Levee	Lt. 15' of Levee &			
ELEVATION	7' Above Slurry T.	7' Above Slurry T.	17' Above Slurry T.			
SOURCE	Levee Fill	Levee Fill	Levee Fill			
MODE & DEPTH	8"	8"	8"			
DENS. COUNT	1028	1017	0865			
MSTRE. COUNT						
WET DENSITY	143.8	146.1	141.7			
MOISTURE	6.0	8.0	9.1			
DRY DENSITY	137.8	136.1	150.2			
% MOISTURE	4.3	5.7	6.5			
STANDARD DENS.	167.0	167.0	167.0			
OPT. MSTRE.						
% COMPACTION	82.5	81.5	84.2			
MSTRE. CORR.						
	6-passes	8-passes	8-passes			

REMARKS:

Test No. 1. Fill looked good but possibly on the dry side for best compaction.

Test No. 2 Fill was creeping and pumping due to moisture (high) under the surface.

Test No. 3 Fill area had more fine material than first two. Area was soft and pumping.

ORN FORM 548
DEC 1984

ORNCD

PLATE E-11

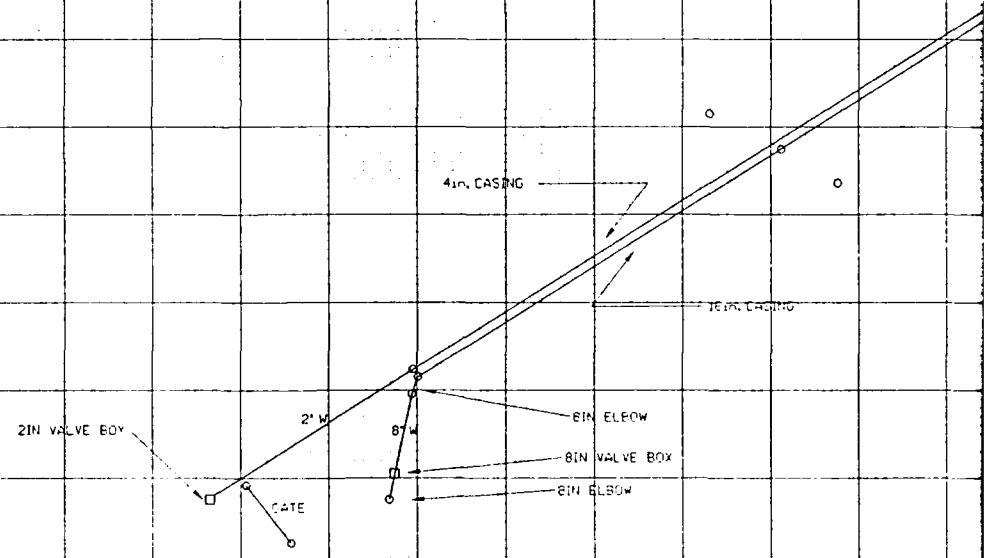
NORTH	EAST	ELEVATION	REMARKS
196,503.56	2,714,039.15	1184.73	TOP OF 16" CASTING EAST END
196,400.67	2,714,073.91	1185.32	TOP OF 16" CASTING WEST END
196,505.56	2,714,038.24	1183.78	TOP OF 4" CASTING-EAST END
196,402.84	2,714,076.37	1184.48	TOP OF 4" CASTING-WEST END
196,454.[illegible]	2,714,[illegible].29	1184.90	PIPE CROSSING [illegible]
196,[illegible]	2,714,[illegible]	1184.26	ELBOW EAST END 8"
196,[illegible]	2,714,[illegible].62	1184.44	ELBOW EAST END 6"
196,399.58	2,714,078.83	1184.86	ELBOW WEST END 6"
196,374.50	2,714,073.09	1185.23	ELBOW WEST END-8"
196,374.08	2,714,033.08	1189.11	8" VALVE-WEST END
196,377.80	2,714,041.30		GATE POST-NORTH EDGE ROAD
196,365.70	2,714,051.44		GATE POST-SOUTH EDGE ROAD
196,380.72	2,714,073.98	1189.98	2" VALVE-WEST END
196,500.93	2,714,260.33	1187.91	8" VALVE-EAST END
196,544.94	2,714,296.20	1188.42	2" VALVE- EAST END

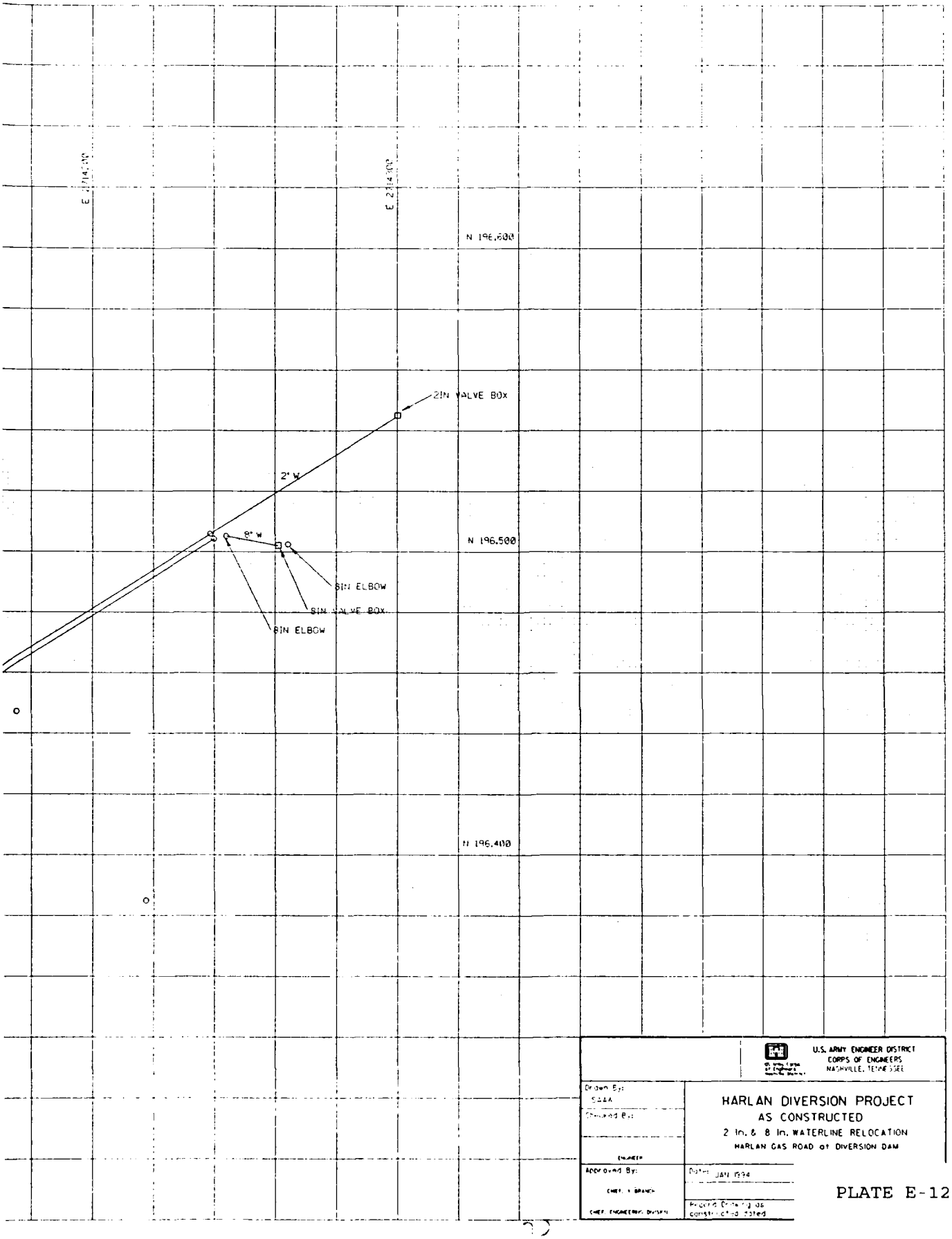
E 2714,000

E 2714,[illegible]

N 196,500

N 196,400





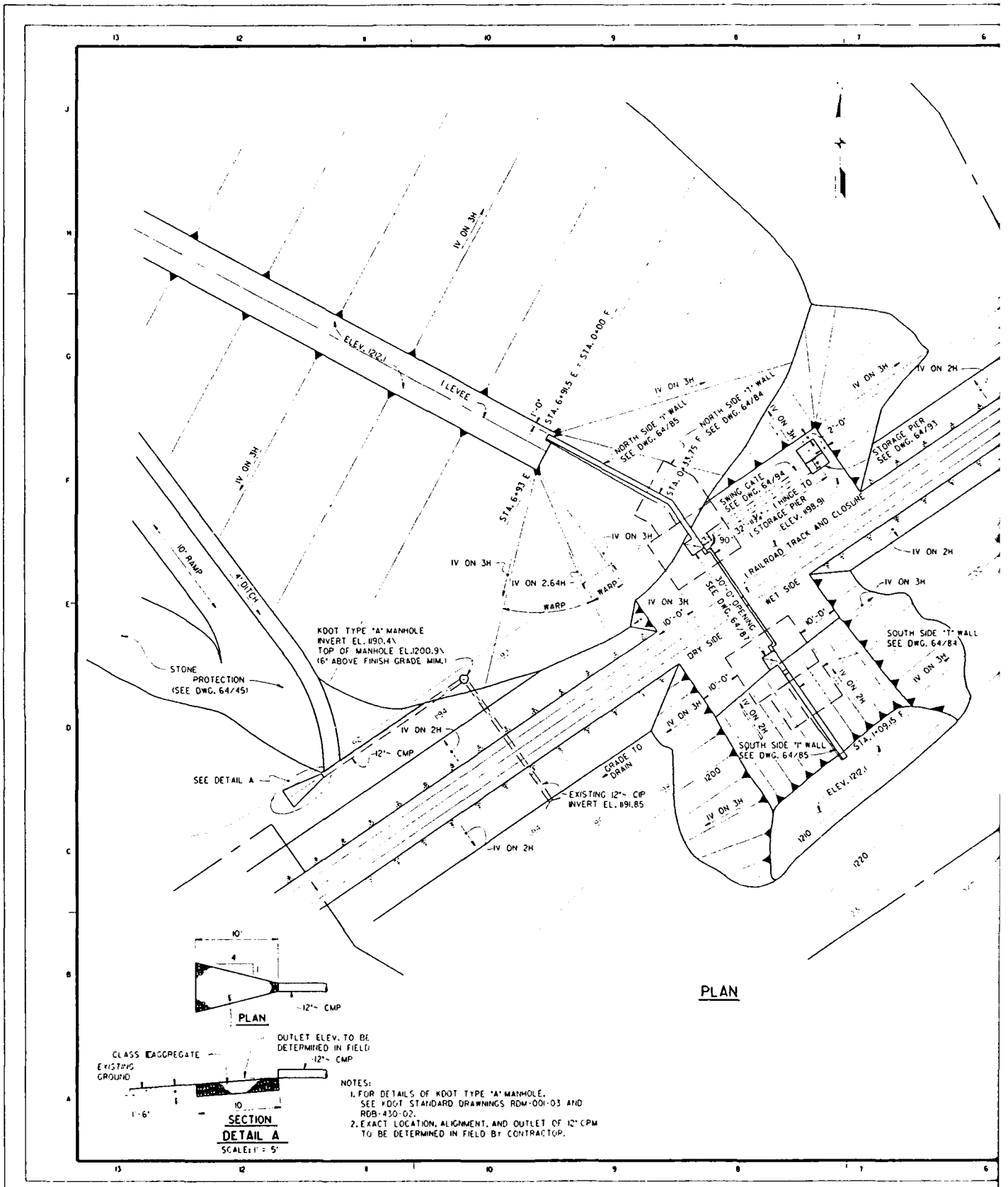
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

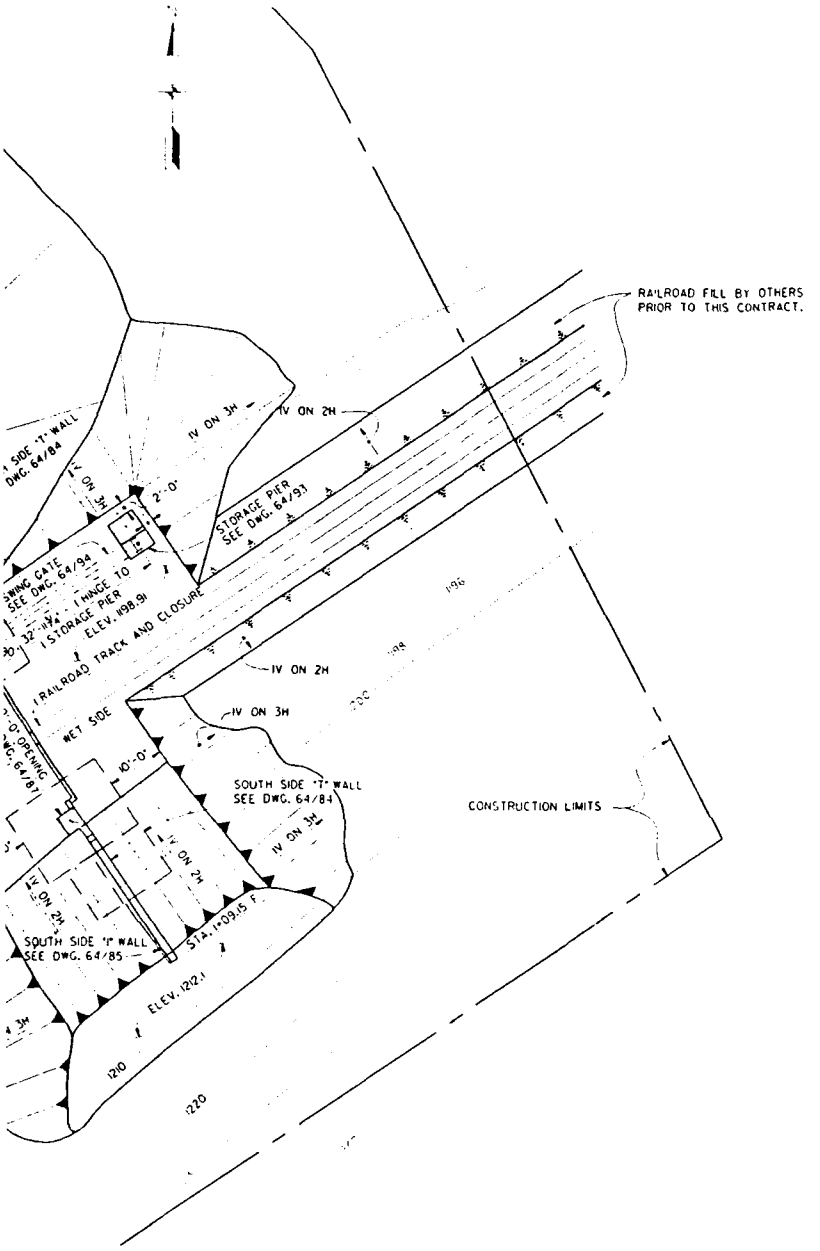
Drawn By: SAA	HARLAN DIVERSION PROJECT AS CONSTRUCTED 2 In. & 8 In. WATERLINE RELOCATION HARLAN GAS ROAD at DIVERSION DAM
Checked By:	
ENGINEER	
Approved By:	Date: JAN 1994
CHIEF, ENGINEERING BRANCH	
CHIEF, ENGINEERING DIVISION	Project Completed and constructed stated

PLATE E-12

Appendix F - Floodwall and Closure Structure

Plate No.	Drawing No.	Description
F-1	Q1A-64/82	General Plan
F-2	Q1A-64/83.3	Plan and Elevation
F-3	------	Piling Records
F-4	Q1A-64/84.1	T-Wall Details
F-5	Q1A-64/91.1	Pile Layout
F-6	------	Pile Records


ELEV. 1212.1
LEVEE
STA. 6+91.5 E = STA. 0+00 F
STA. 6+93 E
STA. 0+33.75 F
NORTH SIDE "T" WALL SEE DWG. 64/85
NORTH SIDE "T" WALL SEE DWG. 64/84
SWING GATE SEE DWG. 64/94
HINGE TO STORAGE PIER ELEV. 1198.91
STORAGE PIER SEE DWG. 64/93
RAILROAD TRACK AND CLOSURE
WET SIDE
DRY SIDE
30'-0" OPENING SEE DWG. 64/87
SOUTH SIDE "T" WALL SEE DWG. 64/84
SOUTH SIDE "T" WALL SEE DWG. 64/85
STA. 1+09.5 F
ELEV. 1212.1
1IV ON 3H
1IV ON 2H
IV ON 2.64H
WARP
10' RAMP
4' DITCH
KDOT TYPE "A" MANHOLE
INVERT EL. 1190.41
TOP OF MANHOLE EL. 1200.91
(6" ABOVE FINISH GRADE MIN.)
STONE PROTECTION (SEE DWG. 64/45)
12"~ CMP
SEE DETAIL A
GRADE TO DRAIN
EXISTING 12"~ CMP
INVERT EL. 1191.85
10'-0"
1200
1210
1220
PLAN
10'
4
1
12"~ CMP
PLAN
CLASS E AGGREGATE
EXISTING GROUND
OUTLET ELEV. TO BE DETERMINED IN FIELD
12"~ CMP
1'-6"
10
SECTION
DETAIL A
SCALE: 1" = 5'
NOTES:
1. FOR DETAILS OF KDOT TYPE "A" MANHOLE, SEE KDOT STANDARD DRAWNINGS RDM-001-03 AND RDB-430-02.
2. EXACT LOCATION, ALIGNMENT, AND OUTLET OF 12" CPM TO BE DETERMINED IN FIELD BY CONTRACTOR.



STRUCTURAL NOTES:

1. ALL CORNERS SHALL BE CHAMFERED 1" UNLESS NOTED OTHERWISE.
2. ALL STRUCTURAL SHAPES, PLATES AND BARS SHALL BE ASTM-36, UNLESS NOTED OTHERWISE.
3. ALL WELDING SHALL BE IN ACCORDANCE WITH APPLICABLE PORTION OF THE AMERICAN WELDING SOCIETY'S STRUCTURAL WELDING CODE D1.1 AND AND D1.4.
4. ALL WELDS THAT ARE TO BE GROUND SHALL HAVE A FINISHED SURFACE EQUAL TO OR SMOOTHER THAN THE MILL FINISH OF THE MATERIAL BEING WELDED UNLESS NOTED OTHERWISE.
5. ALL STEEL DENOTED CRES SHALL BE CORROSION RESISTING STEEL, SEE SPECIFICATIONS.
6. ALL WELDS ON CORROSION-RESISTING STEEL SHALL BE MADE WITH CRES ELECTRODE.
7. ALL REINFORCEMENT SHALL HAVE A MINIMUM COVER OF 4"
8. REINFORCING BAR SIZES ARE INDICATED ON THE DRAWINGS BY NUMBERS 3 THRU 11 IN CONFORMANCE WITH ASTM SPECIFICATION-615, GRADE 60, UNLESS OTHERWISE SHOWN OR DIRECTED. BAR BENDING DETAILS SHALL CONFORM TO THE REQUIREMENTS OF THE CONCRETE REINFORCING STEEL INSTITUTE.
9. BAR SPLICES SHALL BE AT LOCATIONS SHOWN ON THE DRAWING OR AS OTHERWISE APPROVED BY THE CONTRACTING OFFICER.
10. WHERE RE-BAR ARE SHOWN PASSING THROUGH SHEET PILING A HOLE SHALL BE BURNED IN THE SHEET PILING. THE HOLE SIZE SHALL NOT EXCEED ½" CLEAR DISTANCE AROUND THE BAR OR BARS.
11. ALL REINFORCEMENT IN THE TOP SURFACE OF THE CLOSURE STRUCTURE BETWEEN FACE TO FACE OF PIERS SHALL BE EPOXY COATED.
12. SPLICES AND ANCHORAGE FOR REINFORCEMENT BARS SHALL BE IN ACCORDANCE WITH "BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318-83)". MINIMUM SPLICES AND EMBEDMENT LENGTHS ARE SHOWN IN THE TABLE ON DWG. 64/87, EXCEPT AS SHOWN OR NOTED ON THE DRAWINGS.
13. ALL CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH (f'c) OF 3000 P.S.I. AT 28 DAYS UNLESS NOTED OTHERWISE.
14. FOR GENERAL NOTES, SEE DRAWING 64/2.
15. ALL EXPOSED CONCRETE SURFACES SHALL RECEIVE A SACK-RUBBED FINISH.

REVISION	DATE	DESCRIPTION	BY	CHKD

GRAPHIC SCALE

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DRAWN D. J.
CHECKED D. J. & M. W.
TRACED
COMPARED
W. M. WILSON ENGINEER

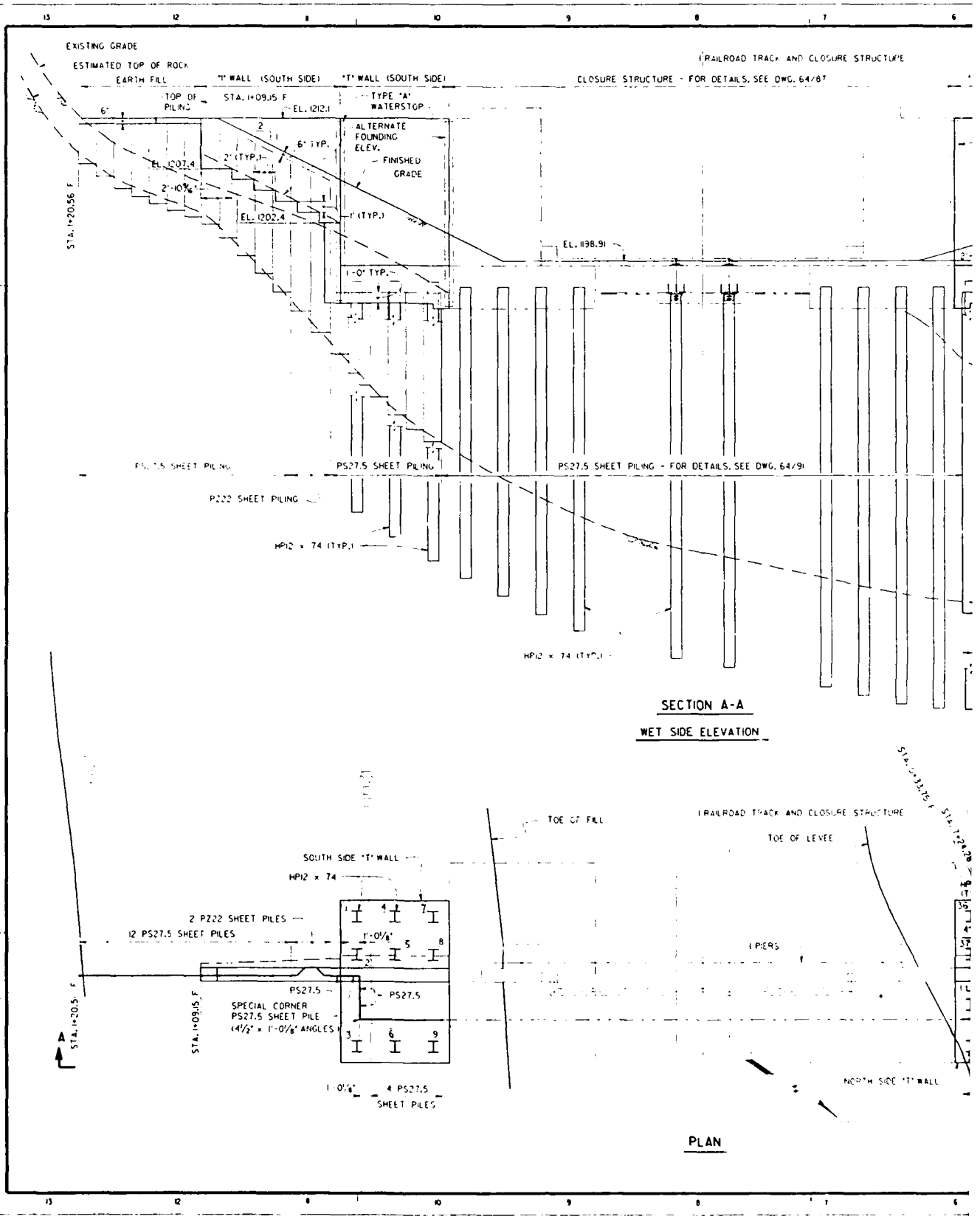
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

FLOODWALL & CLOSURE STRUCTURE
GENERAL PLAN

SUBMITTED: CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED: CHIEF, ENGINEERING DIVISION
APPROVED: COLONEL, C.E. DISTRICT ENGINEER
DATE: MARCH 1989
SCALE AS NOTED
SPEC. NO.
DRAWING NUMBER
SHEET OF
OIA-64/82
RECORD DRAWING AS CONSTRUCTED DATED

COMPUTER AIDED DESIGN & DRAFTING

PLATE F-1


EXISTING GRADE
ESTIMATED TOP OF ROCK
EARTH FILL
"T" WALL (SOUTH SIDE)
"T" WALL (SOUTH SIDE)
RAILROAD TRACK AND CLOSURE STRUCTURE
CLOSURE STRUCTURE - FOR DETAILS, SEE DWG. 64/87
TOP OF PILING
STA. 1+09.15 F
EL. 1212.1
TYPE "A" WATERSTOP
ALTERNATE FOUNDING ELEV.
FINISHED GRADE
6" TYP.
2' (TYP.)
EL. 1207.4
2'-10⅜"
EL. 1202.4
1' (TYP.)
STA. 1+20.56 F
EL. 1198.91
1'-0" TYP.
PS27.5 SHEET PILING
PS27.5 SHEET PILING - FOR DETAILS, SEE DWG. 64/91
PZ22 SHEET PILING
HP12 x 74 (TYP.)
HP12 x 74 (TYP.)
SECTION A-A
WET SIDE ELEVATION
SOUTH SIDE "T" WALL
HP12 x 74
2 PZ22 SHEET PILES
12 PS27.5 SHEET PILES
1'-0⅛"
PS27.5
PS27.5
SPECIAL CORNER PS27.5 SHEET PILE (4½" x 1'-0⅛" ANGLES)
STA. 1+20.5 F
STA. 1+09.15 F
A
1'-0⅛"
4 PS27.5 SHEET PILES
TOE OF FILL
RAILROAD TRACK AND CLOSURE STRUCTURE
TOE OF LEVEE
PIERS
NORTH SIDE "T" WALL
PLAN

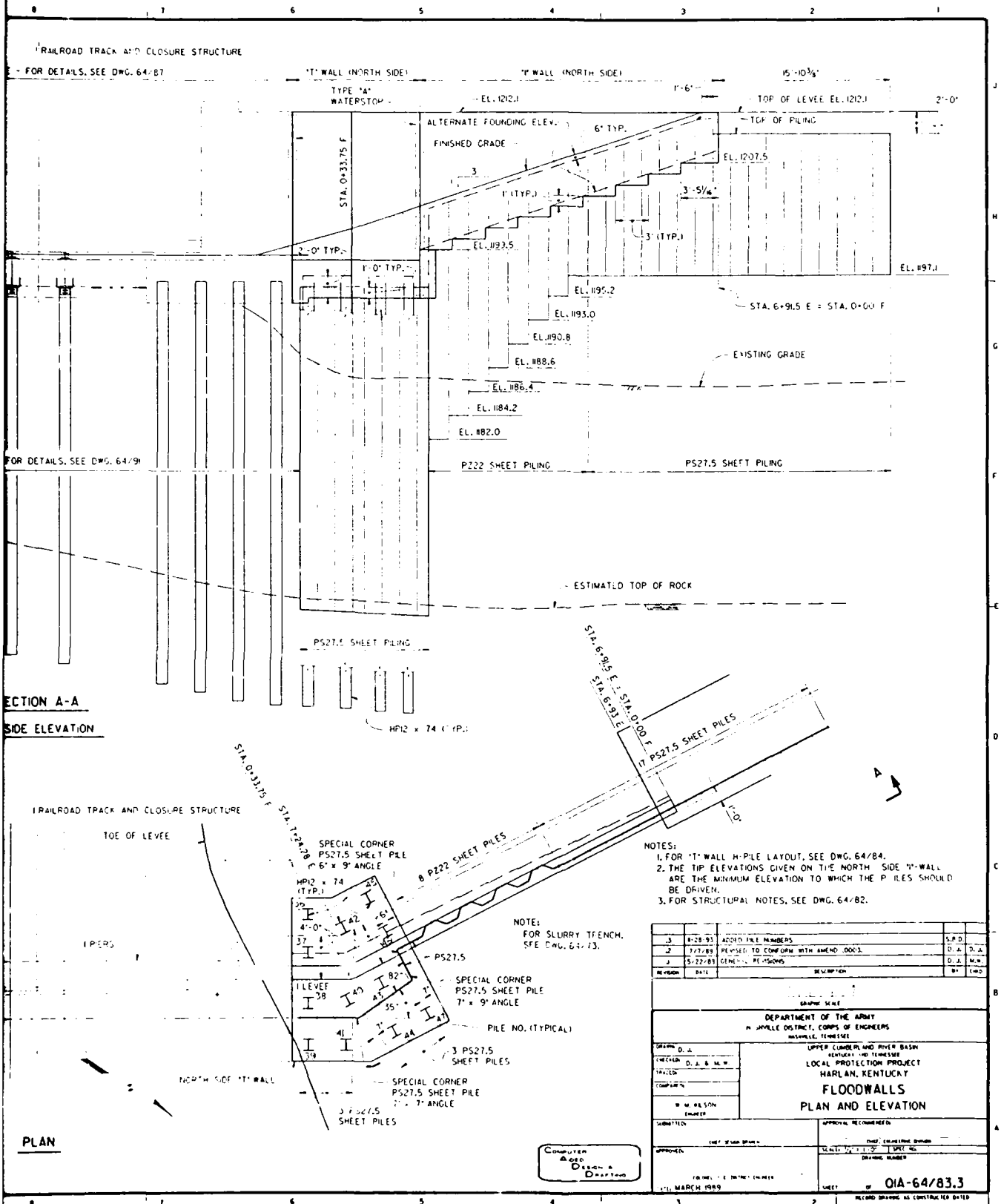
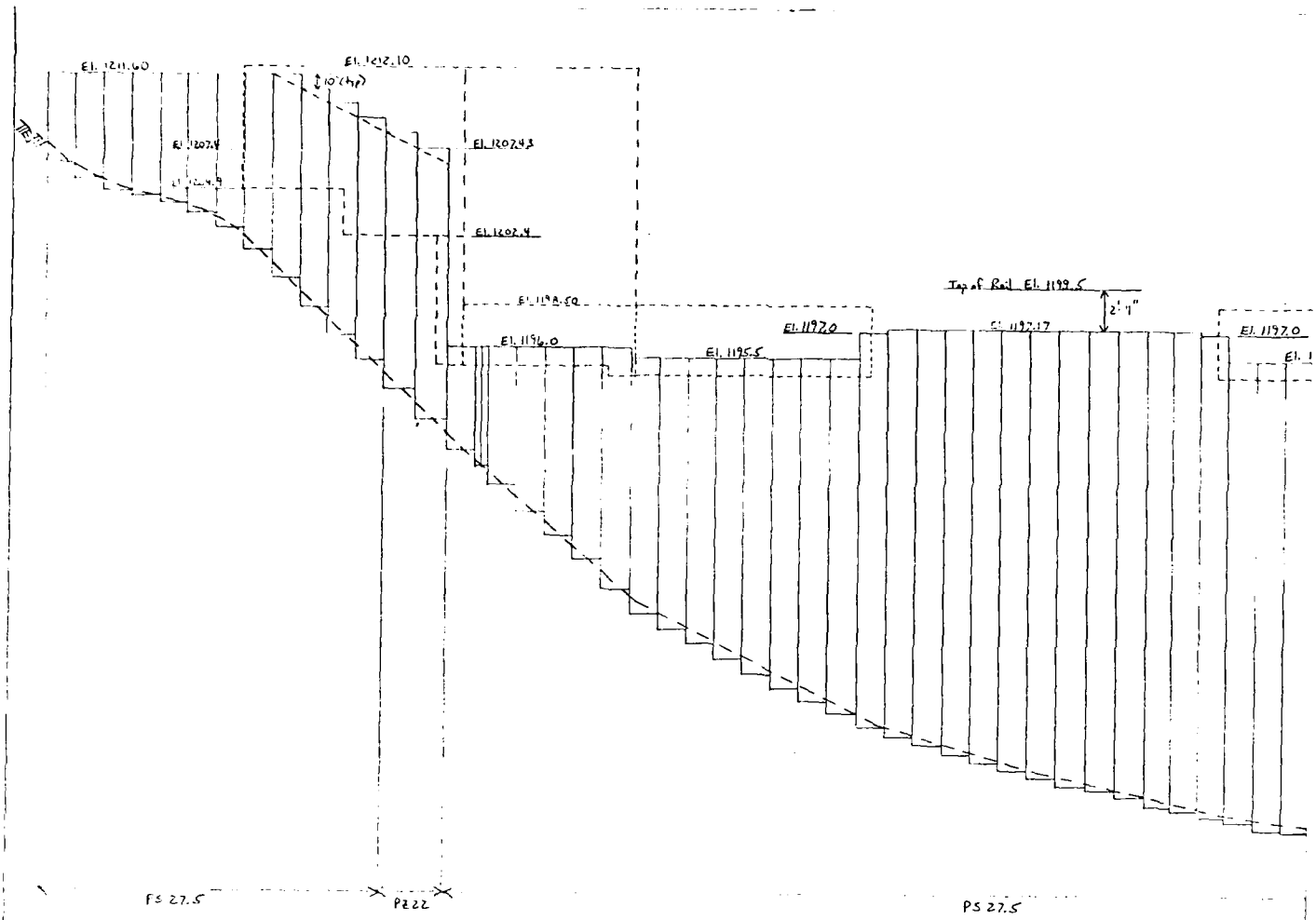
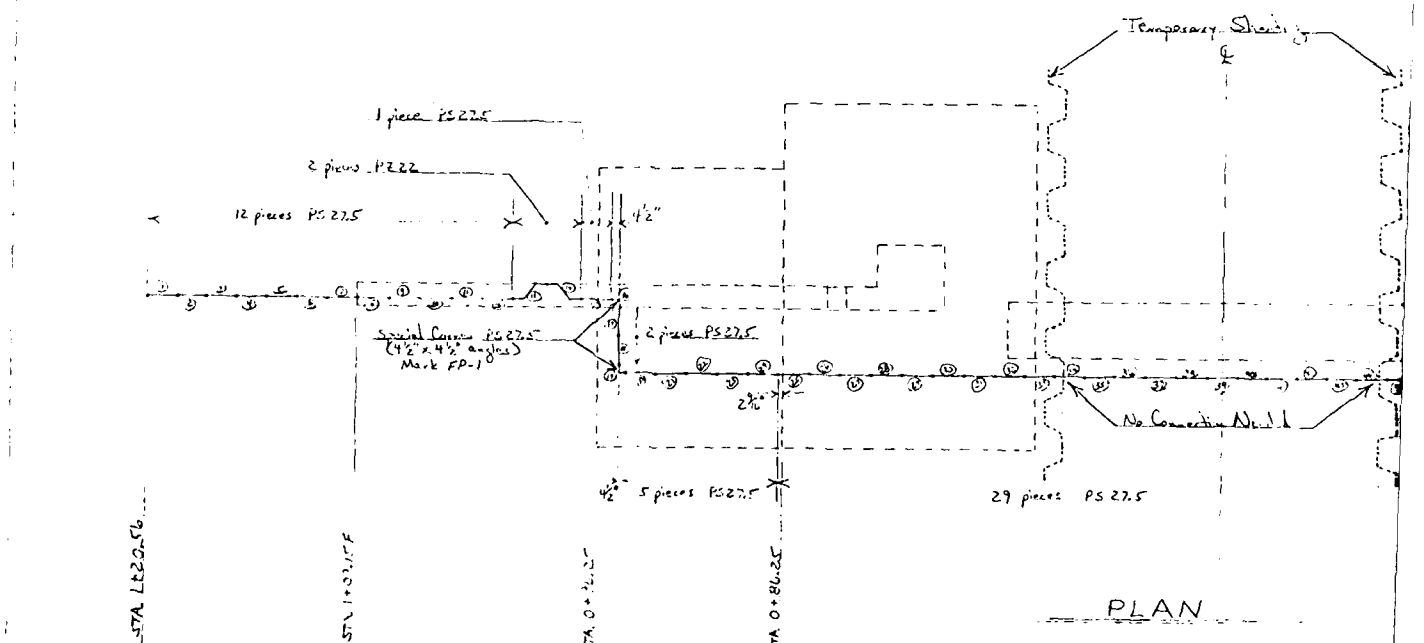

RAILROAD TRACK AND CLOSURE STRUCTURE
- FOR DETAILS, SEE DWG. 64/87
"T" WALL (NORTH SIDE)
"T" WALL (NORTH SIDE)
TYPE "A" WATERSTOP
EL. 1212.1
TOP OF LEVEE EL. 1212.1
ALTERNATE FOUNDING ELEV.
FINISHED GRADE
6" TYP.
TOP OF PILING
EL. 1207.5
STA. 0+33.75 F
1'-0" TYP.
EL. 1193.5
EL. 1195.2
EL. 1193.0
EL. 1190.8
EL. 1188.6
EL. 1186.4
EL. 1184.2
EL. 1182.0
EL. 1197.1
STA. 6+91.5 E = STA. 0+00 F
EXISTING GRADE
FOR DETAILS, SEE DWG. 64/91
PZ22 SHEET PILING
PS27.5 SHEET PILING
ESTIMATED TOP OF ROCK
PS27.5 SHEET PILING
HP12 x 74 (TYP.)
SECTION A-A
SIDE ELEVATION
STA. 6+91.5 E = STA. 0+00 F
STA. 6+93.1 E
17 PS27.5 SHEET PILES
STA. 0+33.75 F
STA. 7+24.28 E
RAILROAD TRACK AND CLOSURE STRUCTURE
TOE OF LEVEE
SPECIAL CORNER PS27.5 SHEET PILE 6" x 9" ANGLE
8 PZ22 SHEET PILES
HP12 x 74 (TYP.)
PS27.5
SPECIAL CORNER PS27.5 SHEET PILE 7" x 9" ANGLE
PILE NO. (TYPICAL)
3 PS27.5 SHEET PILES
NORTH SIDE "T" WALL
SPECIAL CORNER PS27.5 SHEET PILE 7" x 7" ANGLE
3 PS27.5 SHEET PILES
PLAN
NOTE: FOR SLURRY TRENCH, SEE DWG. 64/73.
NOTES:
1. FOR "T" WALL H-PILE LAYOUT, SEE DWG. 64/84.
2. THE TIP ELEVATIONS GIVEN ON THE NORTH SIDE "T"-WALL ARE THE MINIMUM ELEVATION TO WHICH THE PILES SHOULD BE DRIVEN.
3. FOR STRUCTURAL NOTES, SEE DWG. 64/82.
.3 8-28-93 ADDED PILE NUMBERS S.P.D.
.2 7-27-89 REVISED TO CONFORM WITH AMEND. 0003. D.A. D.A.
.1 5-22-89 GENERAL REVISIONS D.A. M.W.
REVISION DATE DESCRIPTION BY CHKD
GRAPHIC SCALE
DEPARTMENT OF THE ARMY
N. JAVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
DRAWN D.A.
CHECKED D.A. & M.W.
TRACED
COMPARED
W. M. WILSON ENGINEER
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
FLOODWALLS
PLAN AND ELEVATION
SUBMITTED
CHIEF, DESIGN BRANCH
APPROVED
CHIEF, ENGINEERING DIVISION
SCALE 1" = 1'-0" SPEC. NO.
DRAWING NUMBER
FOR COL. J. E. PUTNEY, CE
DIST. ENGINEER
DATE: MARCH 1989
SHEET OF 01A-64/83.3
RECORD DRAWING AS CONSTRUCTED DATED
COMPUTER AIDED DESIGN & DRAFTING

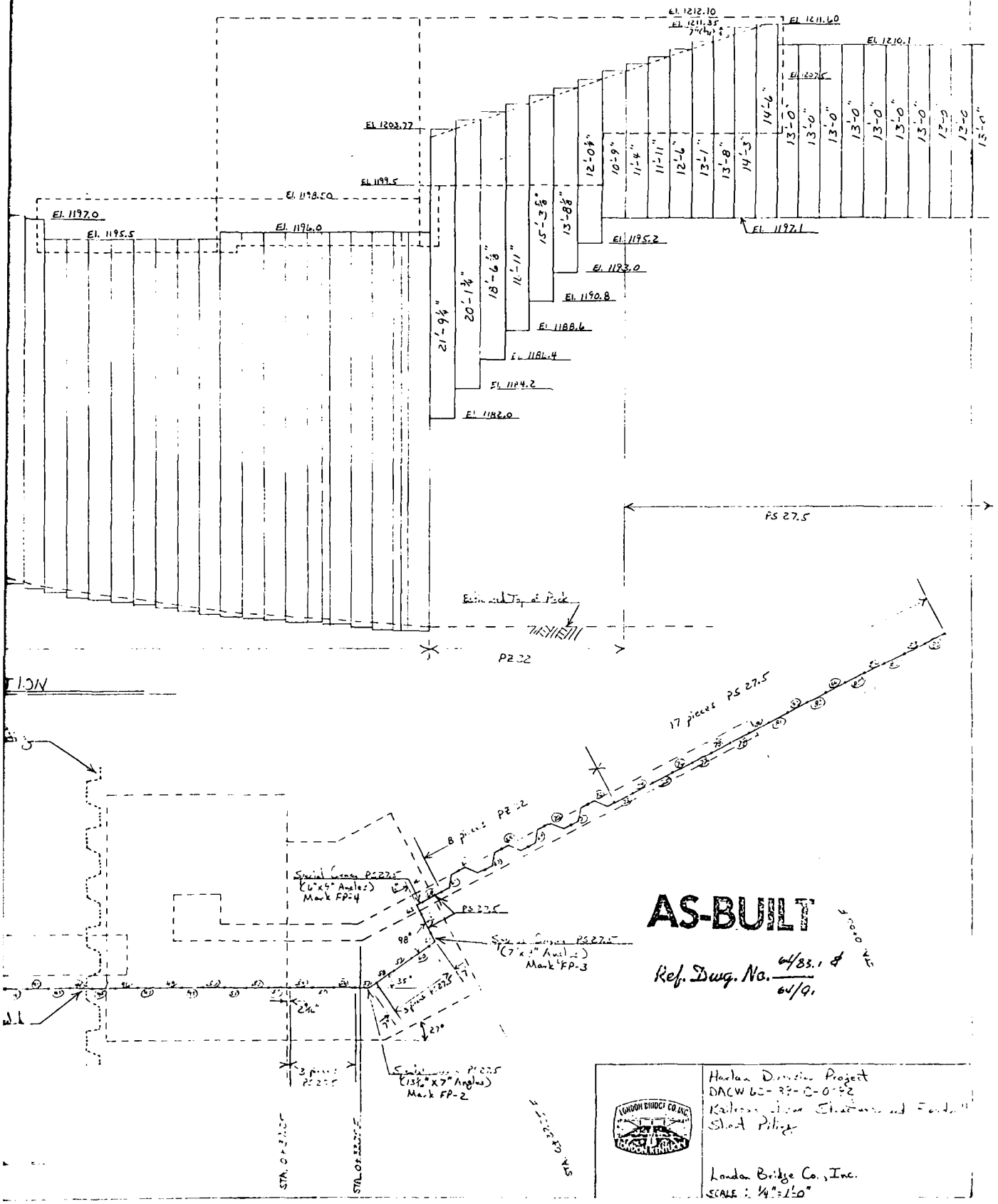
PLATE F-2



WET SIDE ELEVATION



PLAN



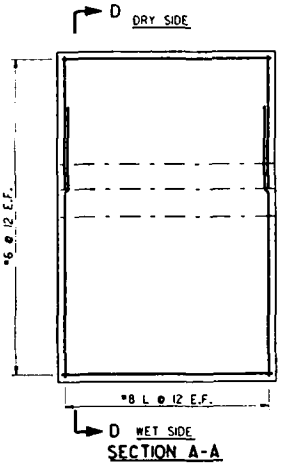
AS-BUILT

Ref. Dwg. No. 64/83.1 & 64/9.

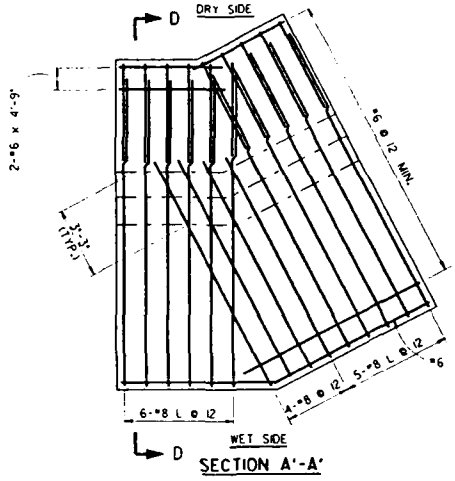
Harlan Division Project
DACW 62-83-C-0052
Railroad Sheet Pile Cofferdam and Foundation
Steel Piling

London Bridge Co., Inc.
SCALE : 1/4"=1'-0"

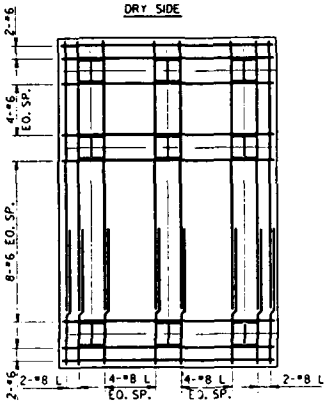
PLATE F-3



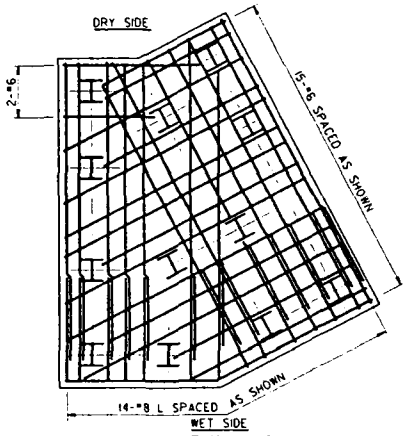
SECTION A-A



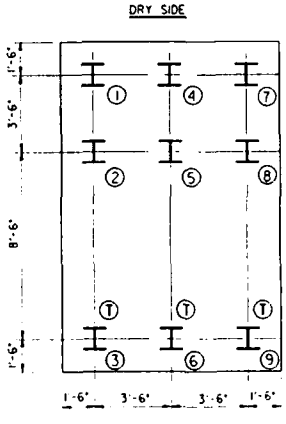
SECTION A'-A'



SECTION B-B



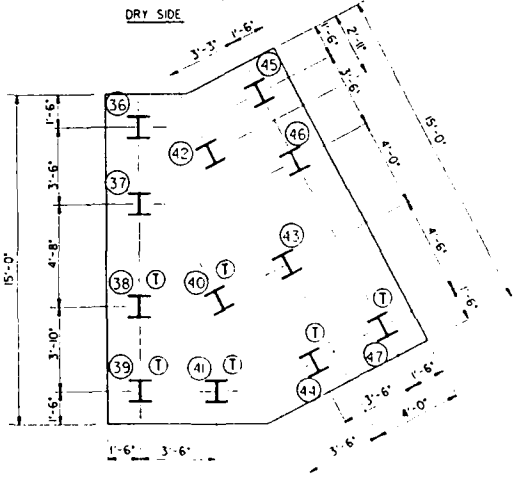
SECTION B'-B'



SECTION C-C

SOUTH SIDE "T" WALL

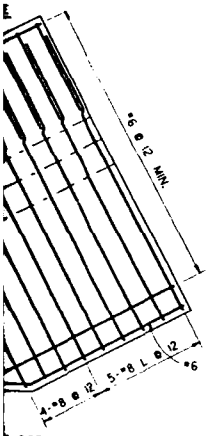
NOTE: "H" PILES LABELED (T) ARE TENSION PILES



SECTION C'-C'

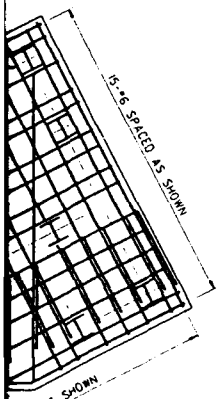
NORTH SIDE "T" WALL

"T" WALL PILING & REINFORCEMENT



SIDE

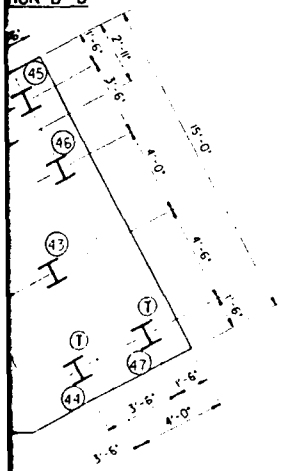
ON A'-A'

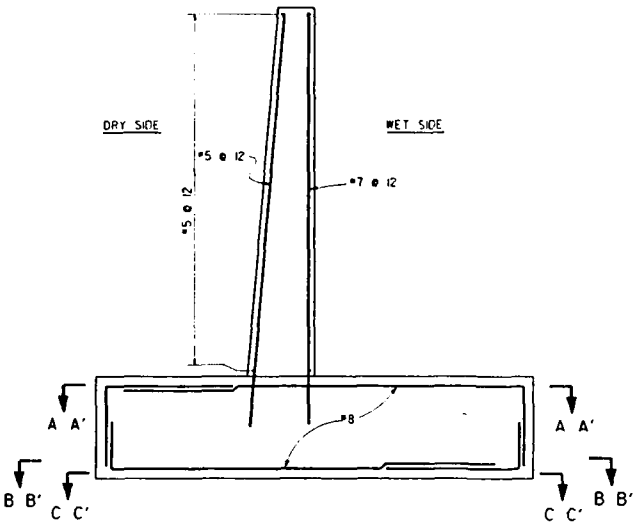


CED AS SHOWN

ET SIDE

TION B'-B'





SECTION D-D

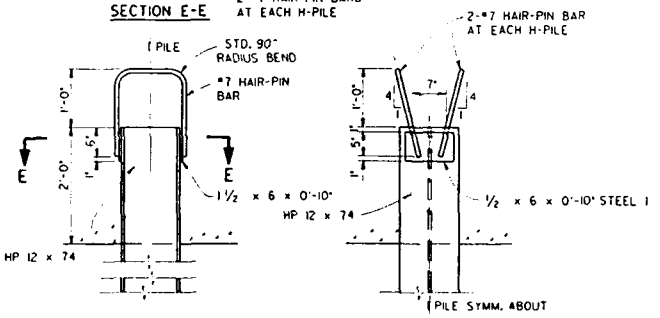
SCALE: ½"=1'-0"



SECTION E-E

CONNECTION NOTES:

1. ALL WELDING OF REINFORCING SHALL BE IN ACCORDANCE TO AWS D1.4.
2. ALL WELDING SHALL BE PERFORMED USING E70xx ELECTRODES.



WEB ELEVATION

FLANGE ELEVATION

TENSION PILE FOOTING CONNECTION

SCALE: 1"=1'-0"

NOTES:

1. FOR STRUCTURAL NOTES, SEE DWG. 64/82.

REVISION	DATE	DESCRIPTION	BY	CHKD.
2	2-3-84	Φ PILES RENUMBERED	S.B.D.	

GRAPHIC SCALE

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DRAWN B.L.Z.
CHECKED D. J. & W. H.
TRACED
COMPARED
R. M. WILSON ENGINEER

SUBMITTED: CHIEF, DESIGN BRANCH
APPROVED: COL. C. E. HERNEY GRAVES
DATE: MARCH 1969

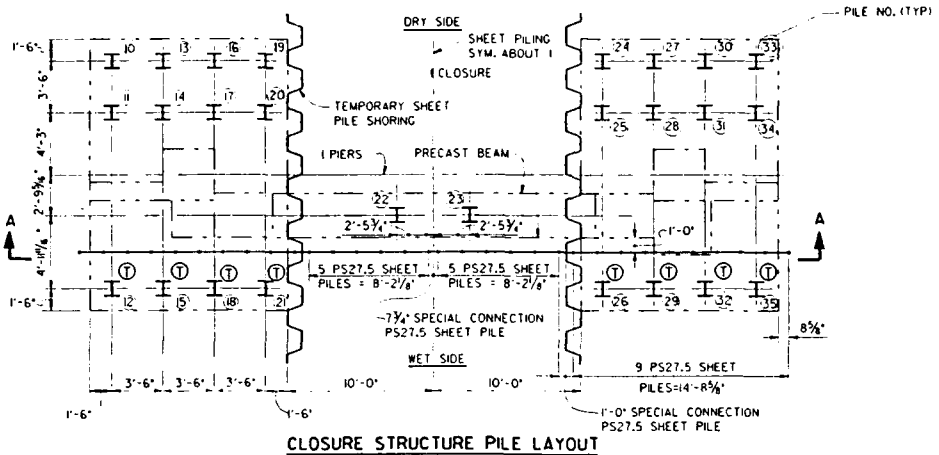
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

FLOODWALLS
"T" WALL DETAILS

APPROVAL RECOMMENDED: CHIEF, ENGINEERING DIVISION
SCALE: ½"=1'-0" SPEC. NO.
DRAWING NUMBER
SHEET OF 01A-64/84.1
RECORD DRAWING AS CONSTRUCTED DATED

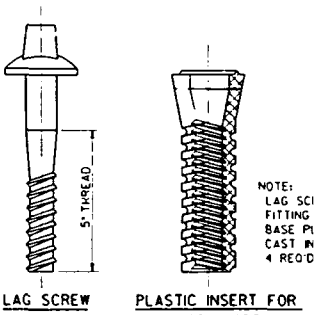
COMPUTER AIDED DESIGN & DRAFTING

PLATE F-4



CLOSURE STRUCTURE PILE LAYOUT

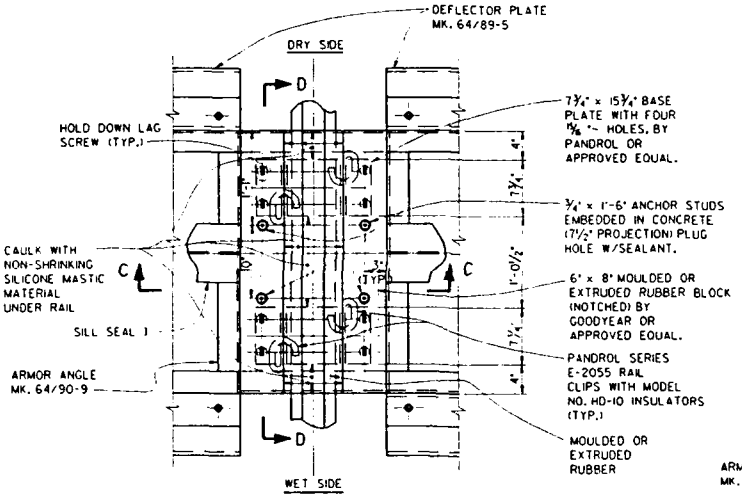
Ⓣ - TENSION PILES. SEE DETAILS. DWG. 64/84.



LAG SCREW — PLASTIC INSERT FOR LAG SCREW (GREASED)

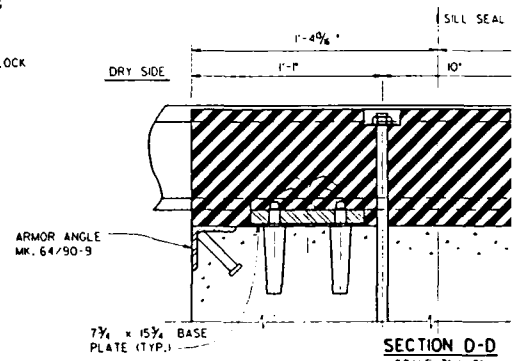
HOLD DOWN LAG SCREW BY FERROSTAAL CORP. OR APPROVED EQUA

N. T. S.



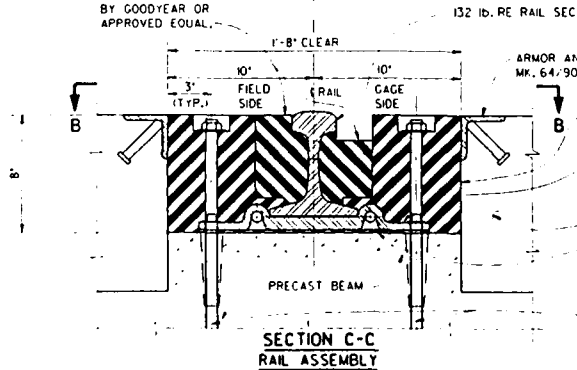
PLAN B-B

SCALE: 1/2"=1'-0"



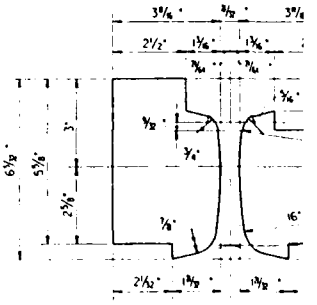
SECTION D-D

SCALE: 3"=1'-0"



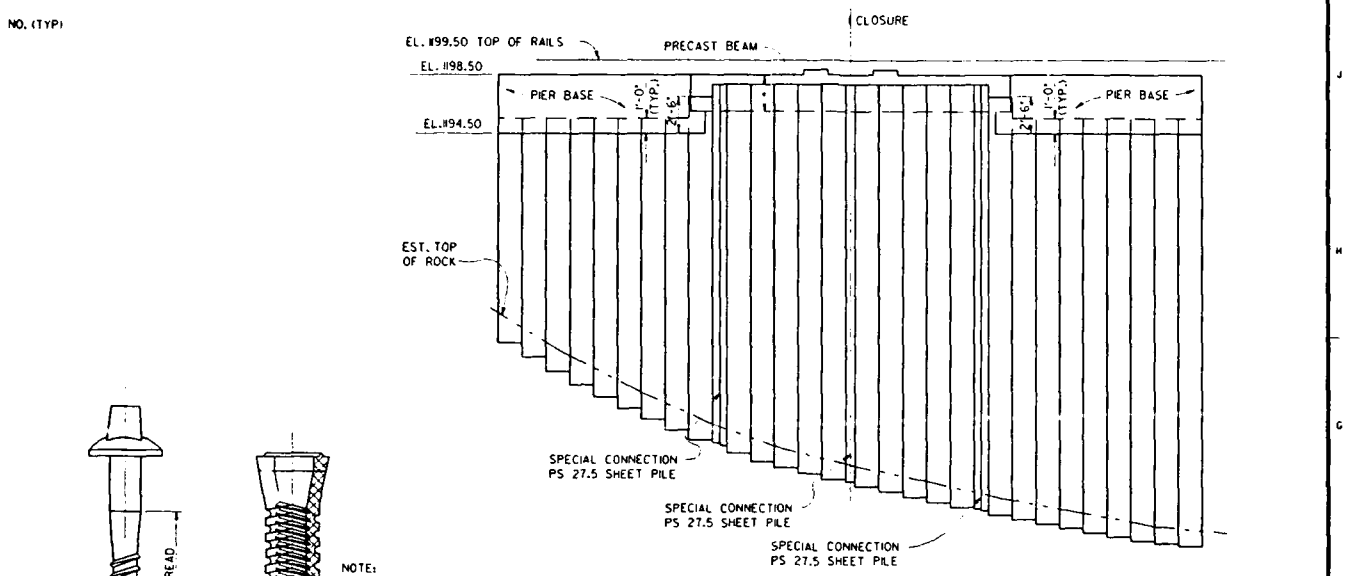
SECTION C-C RAIL ASSEMBLY

SCALE: 3"=1'-0"



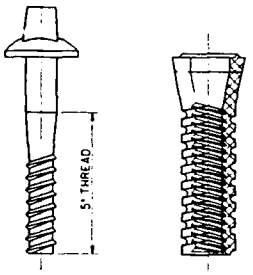
FILLER BLOCKS FOR 132

SCALE: 6"=1'-0"



SECTION A-A

DEVELOPED ALONG SHEET PILING ALIGNMENT



NOTE:
LAG SCREW SCREWS INTO FITTING TO HOLD DOWN BASE PLATE. INSERTS ARE CAST INTO PRECAST BEAM, 4 REQ'D. EACH BASE PLATE.

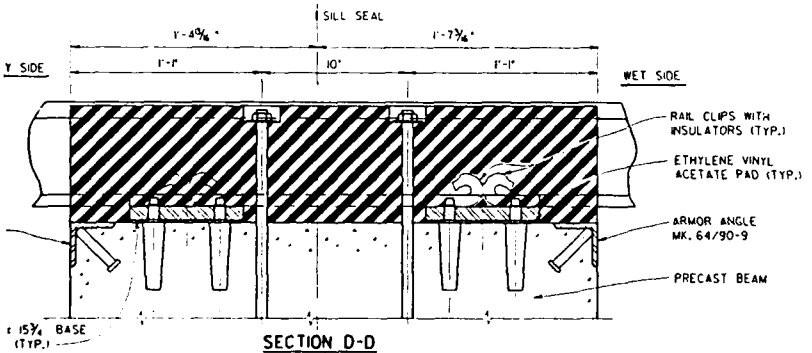
LAG SCREW

PLASTIC INSERT FOR LAG SCREW (GREASED)

HOLD DOWN LAG SCREW

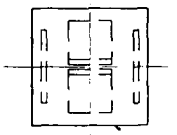
BY FERROSTAAL CORP. OR APPROVED EQUAL

N. T. S.



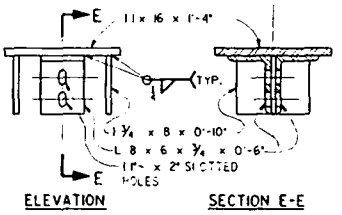
SECTION D-D

SCALE: 3"=1'-0"



PLAN

11 x 16 x 1'-4"



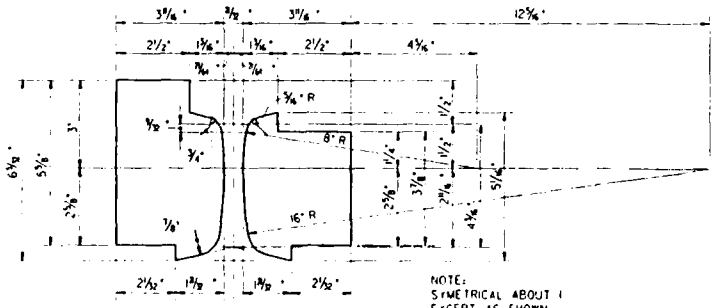
ELEVATION SECTION E-E

PILE CAP MK. 64/91-1

MAKE 2

SCALE: 1 1/2"=1'-0"

NOTES:
1. FOR STRUCTURAL NOTES, SEE DWG. 64/82.



NOTE:
SYMETRICAL ABOUT ℄ EXCEPT AS SHOWN

FILLER BLOCKS FOR 132 LB. RAIL

SCALE: 6"=1'-0"

LBS.

REVISION	DATE	DESCRIPTION	BY	CHKD
1	9-29-93	ADDED PILE NUMBERS	S.B.D.	

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DRAWN B.L.E.
CHECKED D. J. & M. W.
TRACED
COMPARED
R. M. WILSON ENGINEER

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

CLOSURE STRUCTURE
PILE LAYOUT & MISC. DETAILS

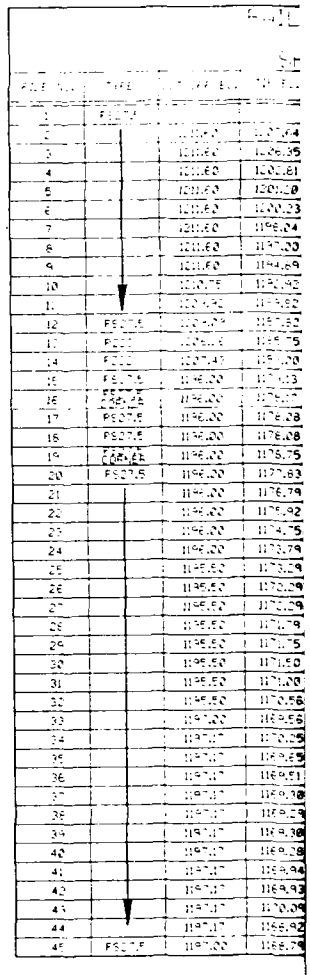
SUBMITTED — CHIEF, DESIGN BRANCH
APPROVED — COL., C.E., DISTRICT ENGINEER
DATE: MARCH 1989
APPROVAL RECOMMENDED — CHIEF, ENGINEERING DIVISION
SCALE 1/4"=1'-0" SPEC. NO.
DRAWING NUMBER
SHEET 1 OF
DIA-64/91.1
RECORD DRAWING AS CONSTRUCTED DATED

COMPUTER AIDED DESIGN & DRAFTING

PLATE F-5

ABUTMENT CLOSURE STRUCTURE
PILE SCHEDULE
PILE FOOTING BENT

PILE NO.	TYPE	TOP OF PILE ELEV.	TIP ELEV.	LENGTH
1	HP12 x 74	1196.50	1176.43	20.07
2		1196.50	1176.47	20.03
3		1196.50	1177.40	19.10
4		1196.50	1175.19	21.31
5		1196.50	1175.11	21.39
6		1196.50	1175.16	21.34
7		1196.50	1172.00	24.50
8		1196.50	1172.46	24.04
9		1196.50	1173.11	23.39
10		1196.50	1171.67	24.83
11		1196.50	1172.08	24.42
12		1196.50	1171.71	24.79
13		1196.19	1171.90	24.29
14		1196.24	1170.99	25.25
15		1196.25	1171.06	25.19
16		1196.50	1170.04	26.46
17		1196.50	1169.96	26.54
18		1196.50	1170.67	25.83
19		1196.50	1169.08	27.42
20		1196.50	1169.16	27.34
21		1196.50	1169.65	26.85
22		1196.00	1168.38	27.62
23		1196.00	1168.25	27.75
24		1196.50	1168.15	28.35
25		1196.50	1167.87	28.63
26		1196.50	1167.88	28.62
27		1196.50	1167.16	28.34
28		1196.50	1168.19	28.31
29		1196.50	1168.16	28.34
30		1196.50	1167.42	29.08
31		1196.50	1167.92	28.58
32		1196.50	1167.75	28.75
33		1196.50	1167.00	29.50
34		1196.50	1166.58	29.92
35		1196.50	1167.56	28.94
36		1196.50	1166.23	30.27
37		1196.50	1166.23	30.27
38		1196.50	1166.31	30.19
39		1196.50	1166.93	29.57
40		1196.50	1166.04	30.46
41		1196.50	1165.68	30.82
42		1196.50	1166.51	29.99
43		1196.50	1166.92	29.58
44		1196.50	1166.50	30.00
45		1196.50	1167.83	28.67
46		1196.50	1167.71	28.79
47	HP12 x 74	1196.50	1167.31	29.19



RAILROAD CLOSURE STRUCTURE
AND FLOODWALLS
SHEET PILE RECORD

PILE NO.	TYPE	CUTOFF EL.	TIP EL.	LENGTH	PILE NO.	TYPE	CUTOFF EL.	TIP EL.	LENGTH
1	PS27.5	1210.60	1206.64	3.96	47	PS27.5	1196.60	1170.75	25.85
2		1210.60	1206.74	3.86	48		1196.60	1170.75	25.85
3		1210.60	1205.35	5.25	49		1196.60	1169.65	26.95
4		1210.60	1201.81	8.79	50		1196.60	1169.60	27.00
5		1210.60	1200.20	10.40	51		1196.60	1169.62	26.98
6		1210.60	1199.23	11.37	52		1196.60	1169.68	26.92
7		1210.60	1196.24	13.56	53		1196.60	1169.60	27.00
8		1210.60	1197.00	14.60	54		1196.60	1168.42	27.08
9		1210.60	1194.89	16.71	55		1196.00	1168.83	27.17
10		1210.76	1192.92	17.83	56		1196.00	1167.83	28.17
11		1209.92	1189.82	20.10	57	PS27.5	1196.00	1167.00	29.00
12	PS27.5	1209.24	1187.82	21.42	58	PS27.5 FISHTAIL CORNER	1196.00	1167.08	28.92
13	PZ22	1208.68	1186.78	21.90	59	PS27.5	1196.00	1167.33	28.67
14	PZ22	1207.43	1183.00	24.43	60	PS27.5	1196.00	1167.50	28.50
15	PS27.5	1196.00	1179.13	16.87	61	PS27.5 FISHTAIL CORNER	1196.00	1167.75	28.25
16	PS27.5 FISHTAIL CORNER	1196.00	1178.07	17.93	62	PS27.5	1196.00	1168.00	28.00
17	PS27.5	1196.00	1178.08	17.92	63	PS27.5 FISHTAIL CORNER	1196.00	1168.25	27.75
18	PS27.5	1196.00	1178.08	17.92	64	PS27.5	1196.00	1168.35	27.65
19	PS27.5 FISHTAIL CORNER	1196.00	1178.75	17.25	65	PZ22	1196.00	1168.29	27.71
20	PS27.5	1196.00	1177.83	18.17	66		1203.77	1182.00	21.77
21		1196.00	1176.79	19.21	67		1204.05	1184.00	20.05
22		1196.00	1175.92	20.08	68		1204.95	1186.40	18.55
23		1196.00	1174.75	21.25	69		1205.50	1188.60	16.90
24		1196.00	1173.79	22.21	70		1206.10	1190.60	15.50
25		1195.60	1173.39	22.21	71		1206.66	1193.00	13.66
26		1195.60	1172.09	23.21	72		1207.06	1195.00	12.06
27		1195.60	1172.09	23.33	73	PZ22	1207.85	1197.10	10.75
28		1195.60	1171.79	23.71	74	PS27.5	1208.43	1197.10	10.33
29		1195.60	1171.75	23.75	75		1209.02	1197.10	11.92
30		1195.60	1171.60	24.00	76		1209.60	1197.10	12.50
31		1195.60	1171.00	24.60	77		1210.16	1197.10	13.06
32		1195.60	1170.66	24.94	78		1210.77	1197.10	13.67
33		1197.00	1169.54	27.46	79		1211.35	1197.10	14.25
34		1197.17	1170.25	26.92	80		1211.60	1197.10	14.50
35		1197.17	1169.65	27.52	81		1210.10	1197.10	13.00
36		1197.17	1169.51	27.66	82		1210.10	1197.10	13.00
37		1197.17	1169.30	27.87	83		1210.10	1197.10	13.00
38		1197.17	1169.29	27.88	84		1210.10	1197.10	13.00
39		1197.17	1169.30	27.87	85		1210.10	1197.10	13.00
40		1197.17	1169.28	27.89	86		1210.10	1197.10	13.00
41		1197.17	1169.94	27.23	87		1210.10	1197.10	13.00
42		1197.17	1169.93	27.24	88		1210.10	1197.10	13.00
43		1197.17	1170.09	27.08	89	PS27.5	1210.10	1197.10	13.00
44		1197.17	1168.92	28.25					
45	PS27.5	1197.00	1168.79	28.21					

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: JTM
Checked By:
ENGINEER
Approved By:
CHIEF, ENGINEERING DIVISION

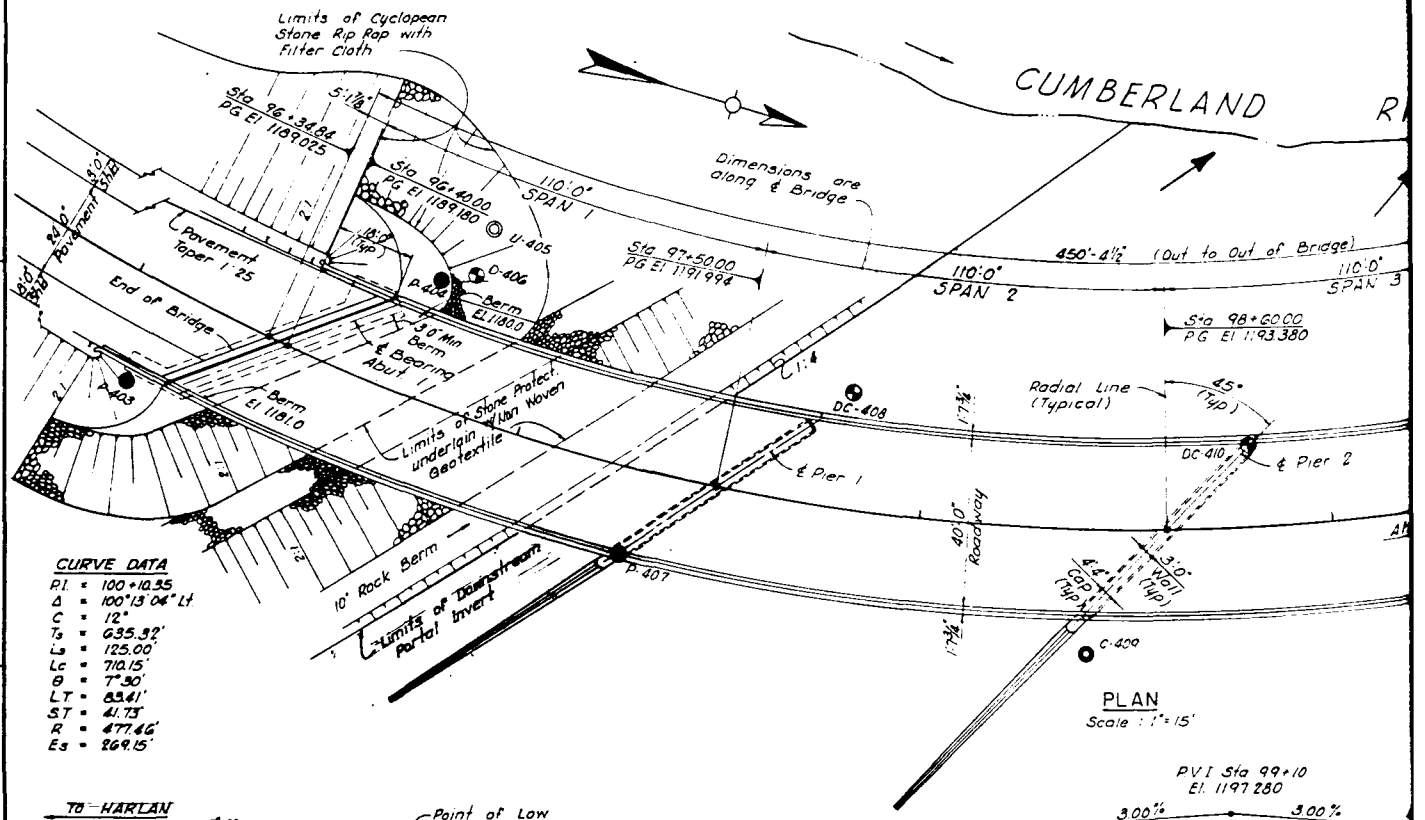
HARLAN DIVERSION PROJECT
AS CONSTRUCTED
RAILROAD CLOSURE STRUCTURE and FLOODWALLS
H-PILE and SHEET PILE RECORDS

Date: JAN 1994
Record Drawing as constructed dated

PLATE F-6

Appendix G - Highway 72 Bridge

Plate No.	Drawing No.	Description
G-1	Q1A-81/75.1	Bridge Layout
G-2	Q1A-81/76.2	Pile Layout & Record
G-3	Q1A-81/79.1	Pier Details
G-4	Q1A-4/398	Pier Foundation Maps


Limits of Cyclopean Stone Rip Rap with Filter Cloth
CUMBERLAND
Dimensions are along ℄ Bridge
Sta 96+34.84 PG El 1189.025
Sta 96+40.00 PG El 1189.180
Sta 97+50.00 PG El 1191.994
Sta 98+60.00 PG El 1193.380
110'-0" SPAN 1
110'-0" SPAN 2
110'-0" SPAN 3
450'-4½" (Out to Out of Bridge)
24'-0" Pavement
30'-0" Shld
Pavement Taper 1:25
End of Bridge
Berm El 1180.0
3.0' Min Berm & Bearing Abut. 1
Limits of Stone Protect. w/Non Woven Geotextile
10' Rock Berm
Limits of Downstream Portal Invert
Radial Line (Typical)
45° (Typ.)
℄ Pier 1
℄ Pier 2
40'-0" Roadway
3'-0" Wall (Typ.)
4'-4" Cap (Typ.)
A-403
P-404
P-407
D-406
U-405
DC-408
DC-410
C-400
CURVE DATA
P.I. = 100+10.35
Δ = 100°13'04" Lt
C = 12°
Ts = 635.32'
Ls = 125.00'
Lc = 710.15'
θ = 7°30'
LT = 839.41'
S.T = 411.73'
R = 477.46'
Es = 269.15'
PLAN
Scale : 1"=15'
PVI Sta 99+10
El. 1197.280
3.00%
3.00%
500' VC
TO HARLAN
℄ Neoprene Expansion Jt
Point of Low Superstructure El 1181.76
Exp
Fix
Earth Core
Low Br Seat El 1181.442
Low Br Seat El 1184.097
Low Br Seat El 1185.455
Existing Ground
HP 14 x 73
Bot of Ftg El 1175.462
Approx Rock Line (Avg.)
Approx Pile Tip El 1157.0 (Avg.)
Pile Points Typ. each Abut.
"Stone Protection underlain w/Non woven Geotextile (Incl in Tunnel Summary)
Downstream Portal Invert El 1152.5
Cyclopean Stone Rip Rap 2' Thick with Filter Cloth (Typ) (Included in Bridge Summary)
Bot of Ftg El 1148.583
Bot of Ftg El 1146.382
ABUTMENT 1
PIER 1
PIER 2
1200
1190
1180
1170
1160
1150
1140
ELEVATION
Scale : 1"=15'
1:7¾%
40'-0" Roadway
10¼"
2'-6"
7"
20'-0"
20'-0"
℄ Survey & ℄ Roadway
.06"/Ft
Profile Grade
8½" Slab
8"
72"
Drop Haunch at Drain
8"ϕ Air Porthole (Typ)
7'-6" Min.
5'-6" Max.
5 Precast Conc. Modified Type IV (72-8) Beams @ equal Spaces
5'-9" Max.
2'-6" Min.
Intermediate Diaphragm. Steel Sway Bracing in Concrete Diaph. (Typ.)
TYPICAL SECTION THRU DECK (Looking Ahead) Scale : ½"=1'-0"
CONCRETE
110'-110'-110'-110 Prestressed
Continuous for Live Lo
40'-0" Roadway , 1:7¾% Bar
48' Shoulders at Brid
REVISION
DATE
6.26.89

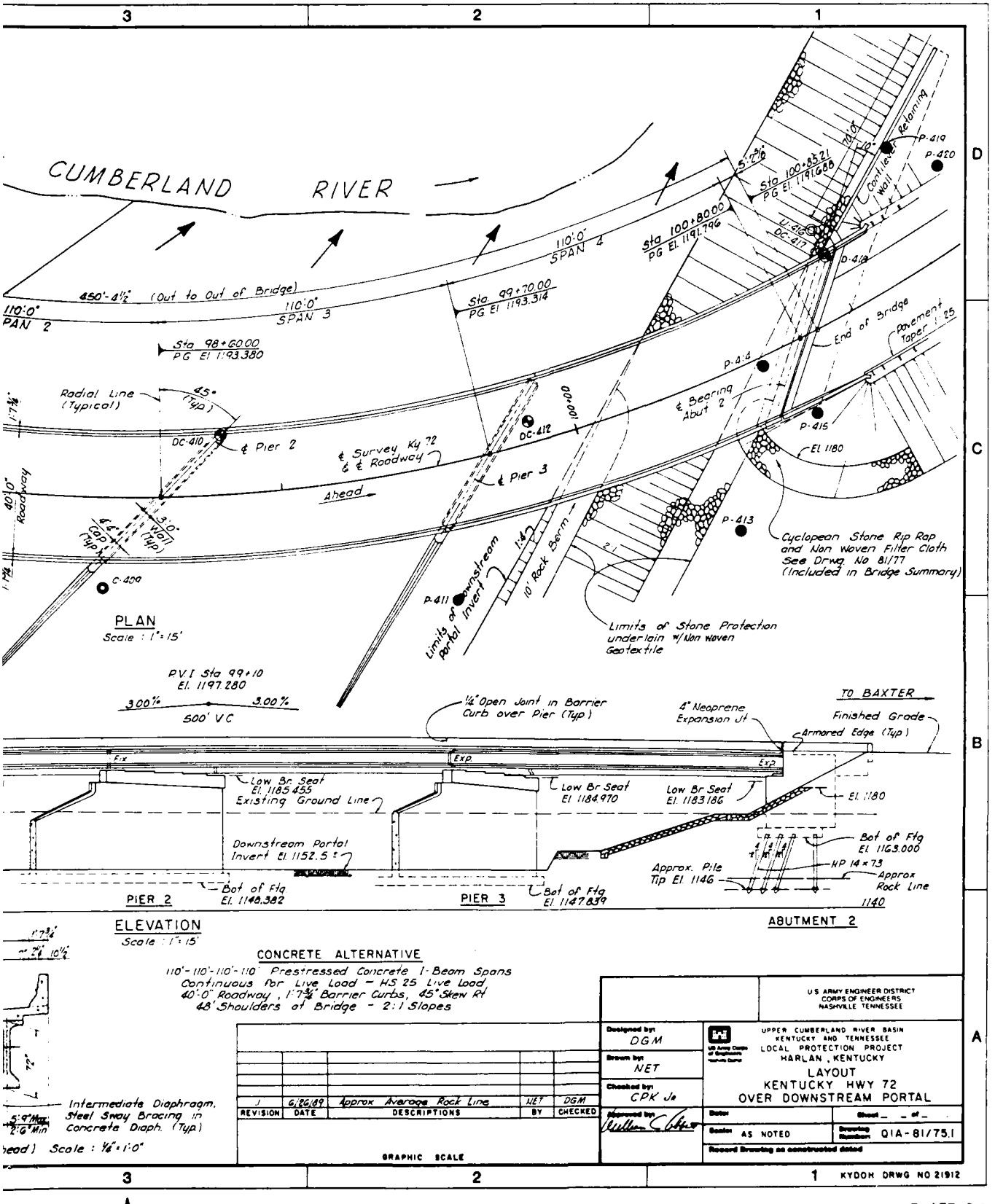
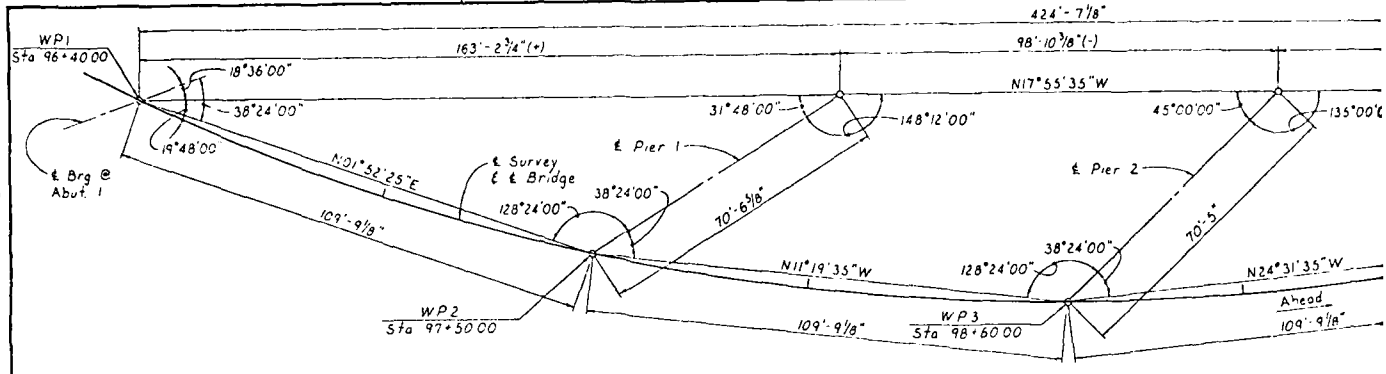
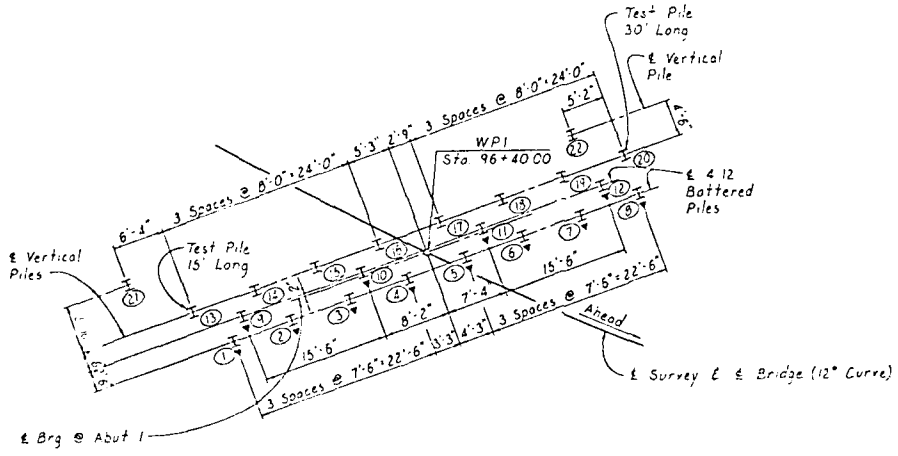

CUMBERLAND RIVER
110'-0" SPAN 2
450'-4½" (Out to Out of Bridge)
110'-0" SPAN 3
110'-0" SPAN 4
Sta 98+60.00 PG El 1193.380
Sta 99+70.00 PG El 1193.314
Sta 100+80.00 PG El 1191.796
Sta 100+83.21 PG El 1191.686
Radial Line (Typical)
45° (Typ)
DC-410
℄ Pier 2
℄ Survey Ky 72 & ℄ Roadway
DC-412
℄ Pier 3
Ahead
Roadway
Cap (Typ)
Wall (Typ)
C-409
P-411
Limits of Downstream Portal Invert
10' Rock Berm
Limits of Stone Protection underlain w/Non Woven Geotextile
P-413
P-414
℄ Bearing Abut 2
End of Bridge
Pavement Taper
P-415
El 1180
P-416
DC-417
P-418
P-419
P-420
Cantilever Retaining Wall
Cyclopean Stone Rip Rap and Non Woven Filter Cloth See Drwg No 81/77 (Included in Bridge Summary)
PLAN
Scale : 1"=15'
PVI Sta 99+10
El. 1197.280
3.00%
3.00%
500' VC
TO BAXTER
½" Open Joint in Barrier Curb over Pier (Typ)
4" Neoprene Expansion Jt
Finished Grade
Armored Edge (Typ)
Exp
Low Br Seat El. 1185.455
Existing Ground Line
Low Br Seat El 1184.970
Low Br Seat El. 1183.186
El. 1180
Downstream Portal Invert El 1152.5 ±
Bot of Ftg El 1163.000
HP 14 x 73
Approx Pile Tip El 1146
Approx Rock Line
1140
Bot of Ftg El. 1148.382
PIER 2
PIER 3
Bot of Ftg El 1147.839
ABUTMENT 2
ELEVATION
Scale : 1"=15'
CONCRETE ALTERNATIVE
110'-110'-110'-110' Prestressed Concrete I-Beam Spans
Continuous for Live Load - HS 25 Live Load
40'-0" Roadway, 1'-7¾" Barrier Curbs, 45° Skew Rt
48' Shoulders of Bridge - 2:1 Slopes
Intermediate Diaphragm, Steel Sway Bracing in Concrete Diaph. (Typ)
Scale : ⅛"=1'-0"
1 6/26/89 Approx Average Rock Line NET DGM
REVISION DATE DESCRIPTIONS BY CHECKED
GRAPHIC SCALE
US ARMY ENGINEER DISTRICT CORPS OF ENGINEERS NASHVILLE TENNESSEE
Designed by DGM
Drawn by NET
Checked by CPK Jo
Approved by
UPPER CUMBERLAND RIVER BASIN KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
LAYOUT
KENTUCKY HWY 72
OVER DOWNSTREAM PORTAL
Date
Sheet _ of _
Scale AS NOTED
Drawing Number Q1A-81/75.1
Record Drawing as constructed dated
KYDOH DRWG NO 21912

PLATE G-1



SUBSTRUCTURE LAYOUT

Scale 1"=15'-0"



PILE LAYOUT – ABUTMENT 1

Scale ⅛"=1'-0"

PILE RECORD – ABUTMENT 1

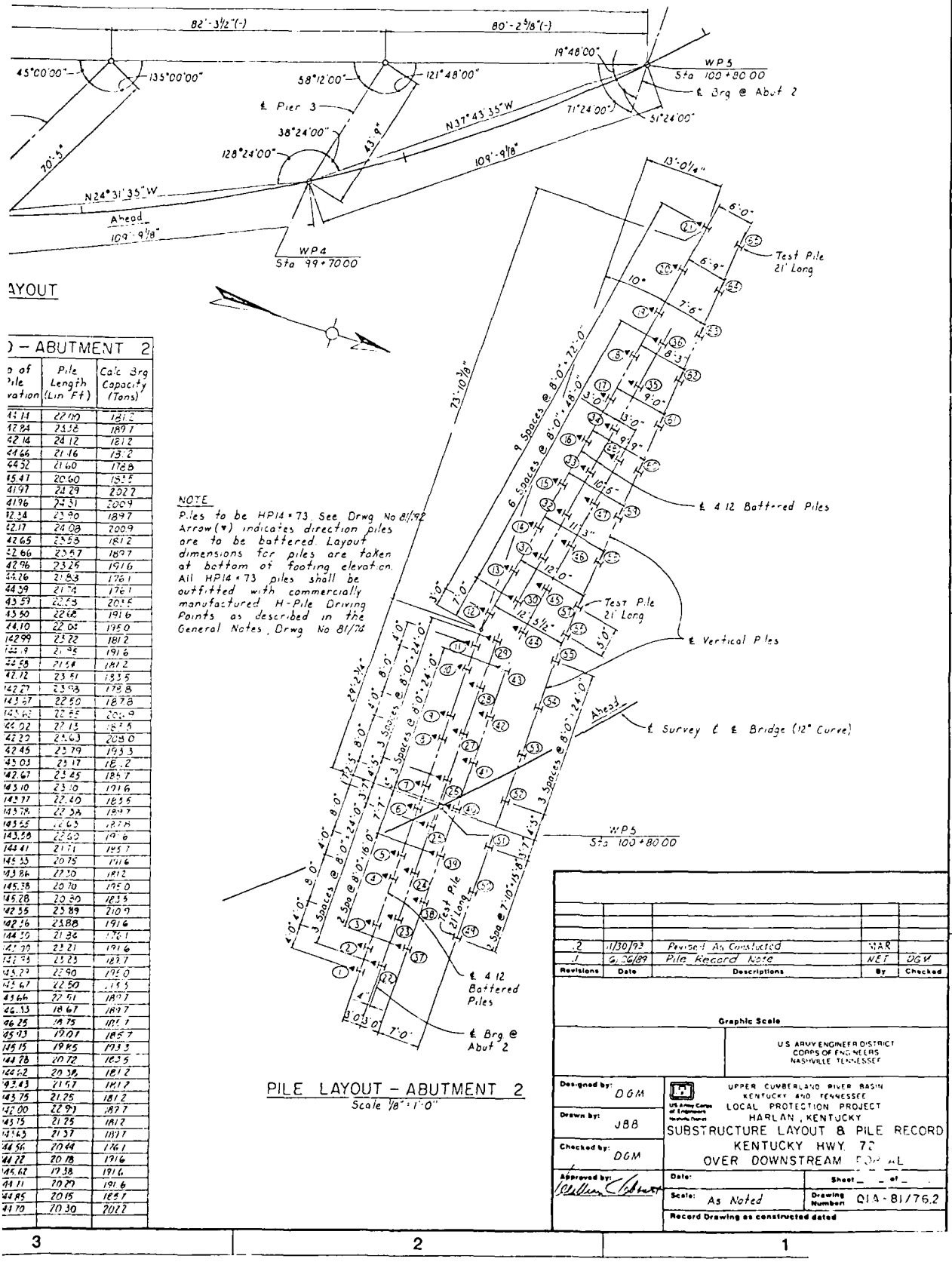
Pile No	Pile Cut-off Elevation	Tip of Pile Elevation	Pile Length (Lin Ft)	Calc Brg Capacity (Tons)
1	1176.460	1160.18	17.21	212.7
2	"	1160.57	16.75	193.5
3	"	1158.83	18.55	199.5
4	"	1157.87	19.61	216.7
5	"	1157.87	19.61	213.6
6	"	1156.34	21.23	205.8
7	"	1154.07	23.62	222.8
8	"	1151.86	25.95	178.8
9	"	1163.87	16.45	198.1
10	"	1155.31	19.15	200.2
11	"	1156.95	20.58	222.8
12	"	1151.61	26.21	185.7
13	"	1159.42	16.98	173.3
14	"	1158.53	17.93	173.3
15	"	1158.36	18.10	173.3
16	"	1157.17	19.29	178.8
17	"	1153.05	23.41	189.7
18	"	1151.00	25.38	193.1
19	"	1147.79	28.67	210.0
20	"	1147.59	28.87	176.1
21	"	1159.85	17.61	195.0
22	"	1147.03	29.39	193.3

PILE RECORD – ABUTMENT 2

Pile No	Pile Cut-off Elevation	Tip of Pile Elevation	Pile Length (Lin Ft)	Calc Brg Capacity (Tons)
1	1165.00	1143.11	22.09	181.2
2	"	1147.84	23.36	189.7
3	"	1142.14	24.12	181.2
4	"	1144.66	21.46	131.2
5	"	1144.52	21.60	178.8
6	"	1145.47	20.60	185.5
7	"	1141.97	23.29	202.2
8	"	1141.96	24.31	200.9
9	"	1142.34	23.90	189.7
10	"	1142.17	24.08	200.9
11	"	1142.65	23.58	181.2
12	"	1142.66	23.57	189.7
13	"	1142.96	23.25	191.6
14	"	1141.26	21.83	176.1
15	"	1144.39	21.74	176.1
16	"	1145.59	20.58	203.5
17	"	1145.50	22.06	191.6
18	"	1144.10	22.04	195.0
19	"	1142.99	23.22	181.2
20	"	1165.19	21.95	191.6
21	"	1144.58	21.54	181.2
22	"	1147.72	23.51	193.5
23	"	1142.27	23.98	178.8
24	"	1143.27	22.50	187.8
25	"	1143.62	22.65	200.9
26	"	1145.92	22.13	185.5
27	"	1142.20	23.63	209.0
28	"	1142.45	23.79	193.3
29	"	1143.03	23.17	181.2
30	"	1142.67	23.45	185.7
31	"	1143.10	23.10	191.6
32	"	1143.37	22.40	183.5
33	"	1143.78	22.38	189.7
34	"	1143.55	22.63	183.5
35	"	1143.58	22.60	191.6
36	"	1144.41	21.71	185.7
37	"	1145.35	20.75	191.6
38	"	1143.86	22.30	181.2
39	"	1145.38	20.70	195.0
40	"	1145.28	20.80	183.5
41	"	1142.35	23.89	210.9
42	"	1142.36	23.88	191.6
43	"	1144.30	21.84	176.1
44	"	1145.20	23.21	191.6
45	"	1142.79	23.25	183.7
46	"	1143.23	22.90	195.0
47	"	1143.67	22.50	193.3
48	"	1143.66	22.51	189.7
49	"	1146.33	18.67	189.7
50	"	1146.25	19.75	185.7
51	"	1145.93	19.07	185.7
52	"	1145.15	19.85	193.3
53	"	1144.28	20.72	183.5
54	"	1144.62	20.38	181.2
55	"	1143.43	21.67	181.2
56	"	1143.75	21.25	181.2
57	"	1142.00	22.93	189.7
58	"	1143.75	21.25	181.2
59	"	1143.63	21.37	189.7
60	"	1144.56	20.44	176.1
61	"	1144.22	20.78	191.6
62	"	1145.62	19.38	191.6
63	"	1144.71	20.29	191.6
64	"	1144.85	20.15	185.7
65	"	1144.70	20.30	202.2

NOTE

After piles have been driven, the Contractor shall record for each pile, the tip of pile elevation as driven, the length of pile in place and the calculated bearing capacity and shall return one blueprint copy of this sheet with this data to the Contracting Officer so that the data may be recorded on the original plans Length of piles in place shown hereon are the actual lengths of piles in the finished structure below cut-off elevation and are not necessarily pay items This pile record does not replace other records of piles required to be kept and submitted by the Contractor. This data is to be verified by the Resident Engineer.



AYOUT

NOTE

Piles to be HP14 x 73. See Drwg No 81/92. Arrow (▼) indicates direction piles are to be battered. Layout dimensions for piles are taken at bottom of footing elevation. All HP14 x 73 piles shall be outfitted with commercially manufactured H-Pile Driving Points as described in the General Notes, Drwg No 81/74.

) – ABUTMENT 2

o of ile vation	Pile Length (Lin Ft)	Calc Brg Capacity (Tons)
43.11	22.09	1812
42.84	23.38	1897
42.14	24.12	1812
41.66	21.16	1712
44.32	21.60	1768
45.47	20.60	1855
41.97	24.29	2027
41.96	24.31	2009
42.34	23.90	1897
42.17	24.08	2009
42.65	23.58	1812
42.66	23.57	1897
42.96	23.26	1916
44.26	21.83	1761
44.39	21.74	1761
43.59	22.53	2035
43.60	22.68	1916
44.10	22.05	1950
42.99	23.22	1812
42.9	23.25	1916
42.58	21.58	1812
42.12	23.51	1835
42.27	23.98	1778
42.67	22.50	1878
42.62	22.55	2009
42.02	22.13	1675
42.22	23.63	2090
42.45	23.79	1933
43.03	23.17	1812
42.67	23.45	1897
43.10	23.10	1916
43.77	22.40	1855
43.78	22.38	1897
43.65	22.63	1878
43.59	22.62	1916
44.41	21.71	1957
45.53	20.75	1916
43.86	22.30	1812
45.38	20.70	1950
45.28	20.80	1835
42.55	23.89	2109
42.56	23.88	1916
44.30	21.86	1761
42.70	23.21	1916
42.73	23.23	1897
43.27	22.90	1950
43.67	22.50	1855
43.66	22.51	1897
46.33	18.67	1897
46.25	18.75	1881.7
45.93	19.07	1855.7
45.15	19.85	1933.3
44.28	20.72	1835.5
44.62	20.38	1812.2
43.83	21.17	1812.2
43.75	21.25	1812.2
42.00	22.93	1897.7
43.15	21.75	1812.2
43.63	21.37	1897.7
44.56	20.44	1761.1
44.22	20.78	1916.6
45.62	19.38	1916.6
44.11	20.29	1916.6
44.85	20.15	1855.7
44.70	20.30	2022.2

PILE LAYOUT – ABUTMENT 2
Scale 1/8" = 1'-0"

Revisions	Date	Descriptions	By	Checked
2	11/30/93	Revised As Constructed	MAR	
1	6/26/89	Pile Record Note	NET	DGM

Graphic Scale

US ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

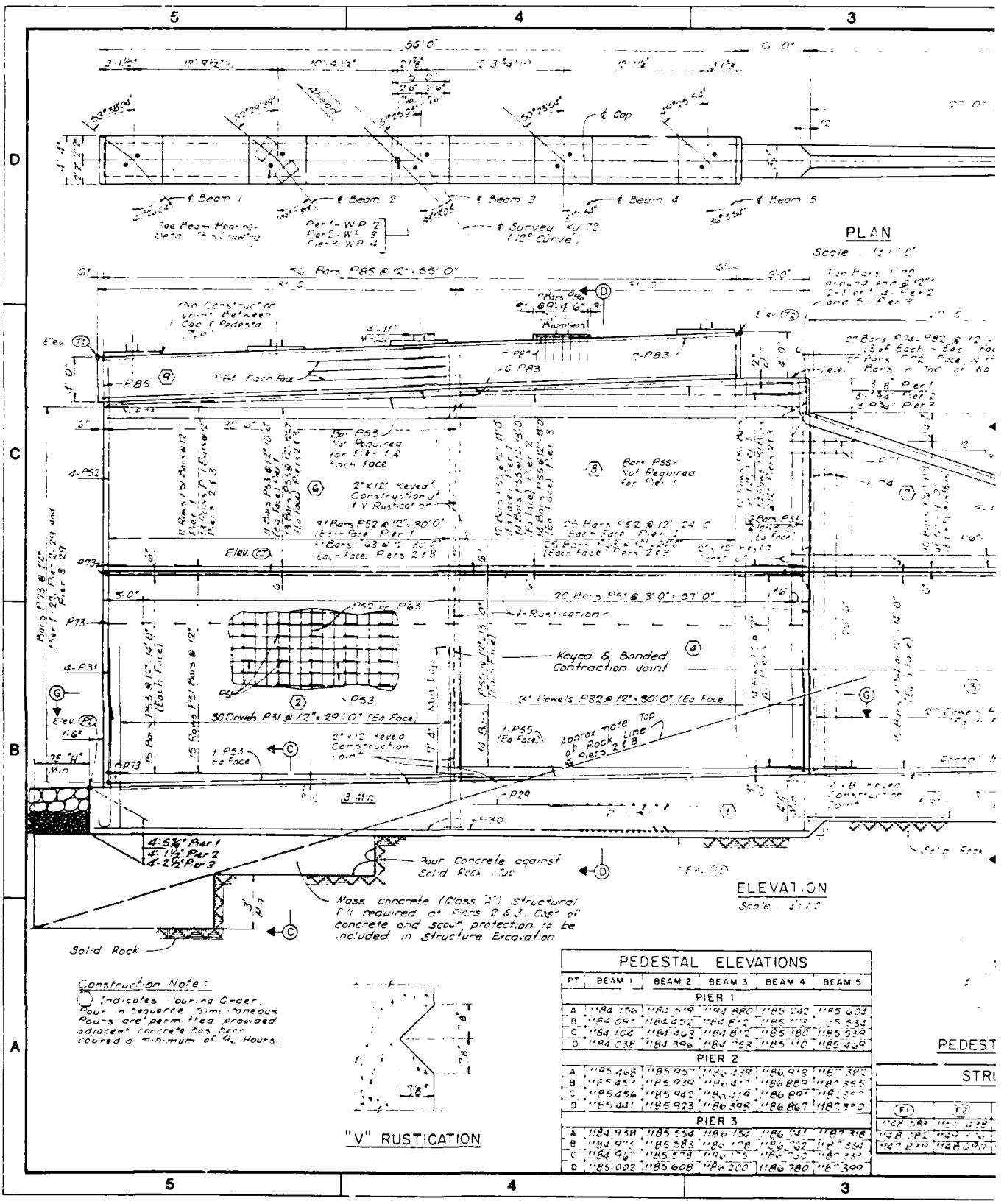
Designed by: DGM
Drawn by: JBB
Checked by: DGM
Approved by:

US Army Corps of Engineers

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
SUBSTRUCTURE LAYOUT & PILE RECORD
KENTUCKY HWY. 72
OVER DOWNSTREAM [illegible]

Date:
Sheet _ of _
Scale: As Noted
Drawing Number: QIA-81/76.2
Record Drawing as constructed dated

PLATE G-2



PEDESTAL ELEVATIONS

PT	BEAM 1	BEAM 2	BEAM 3	BEAM 4	BEAM 5
PIER 1					
A	1184.156	1183.510	1184.880	1185.242	1185.603
B	1184.041	1184.452	1184.814	1185.178	1185.534
C	1184.104	1184.463	1184.812	1185.180	1185.539
D	1184.238	1184.396	1184.753	1185.110	1185.469
PIER 2					
A	1185.466	1185.95	1186.320	1186.913	1187.382
B	1185.453	1185.930	1186.411	1186.880	1187.355
C	1185.436	1185.942	1186.319	1186.807	1187.290
D	1185.441	1185.923	1186.398	1186.867	1187.350
PIER 3					
A	1184.938	1185.554	1186.154	1186.941	1187.318
B	1184.915	1185.583	1186.178	1186.962	1187.334
C	1184.896	1185.538	1186.175	1186.950	1187.333
D	1185.002	1185.608	1186.200	1186.780	1187.300

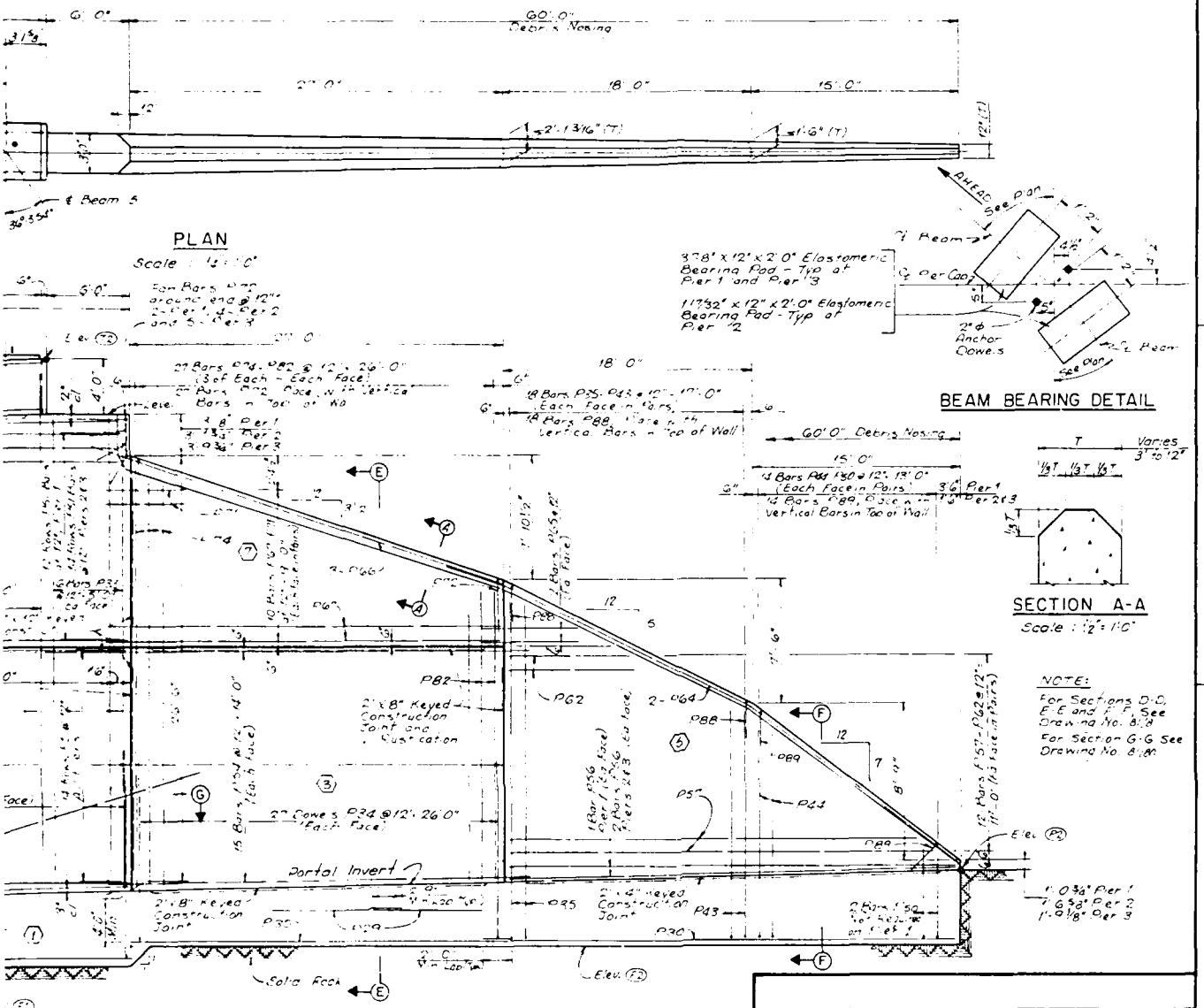
Construction Note:

⬡ Indicates Pouring Order. Pour in Sequence. Simultaneous Pours are permitted provided adjacent concrete has been cured a minimum of 24 Hours.

"V" RUSTICATION

PEDEST

STR



ELEVATIONS

BEAM 3	BEAM 4	BEAM 5
PIER 1		
1184.880	1185.242	1185.608
1184.811	1185.172	1185.534
1184.812	1185.180	1185.539
1184.753	1185.110	1185.469
PIER 2		
1186.439	1186.913	1187.382
1186.411	1186.889	1187.355
1186.419	1186.897	1187.375
1186.398	1186.867	1187.330
PIER 3		
1186.154	1186.741	1187.318
1186.128	1186.662	1187.314
1186.175	1186.720	1187.351
1186.200	1186.780	1187.390

STRUCTURE CONTROL POINTS ELEVATIONS

F1	F2	P1	P2	CJ	T1	T2	LOCATION
1148.589	1150.438	1153.060	1154.750	1169.063	1184.583	1185.208	PIER 1
1148.382	1149.976	1152.510	1153.200	1168.002	1184.882	1187.023	PIER 2
1147.850	1148.690	1152.045	1153.300	1167.310	1184.339	1187.000	PIER 3

Revisions	Date	Description	By	Checked
1	31 AUG 89	ADDED KYDOH DWG NO.	PNB	WGG

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

Designed by: CPK Jr
Drawn by: NET/BSB
Checked by: DGM
Approved by:

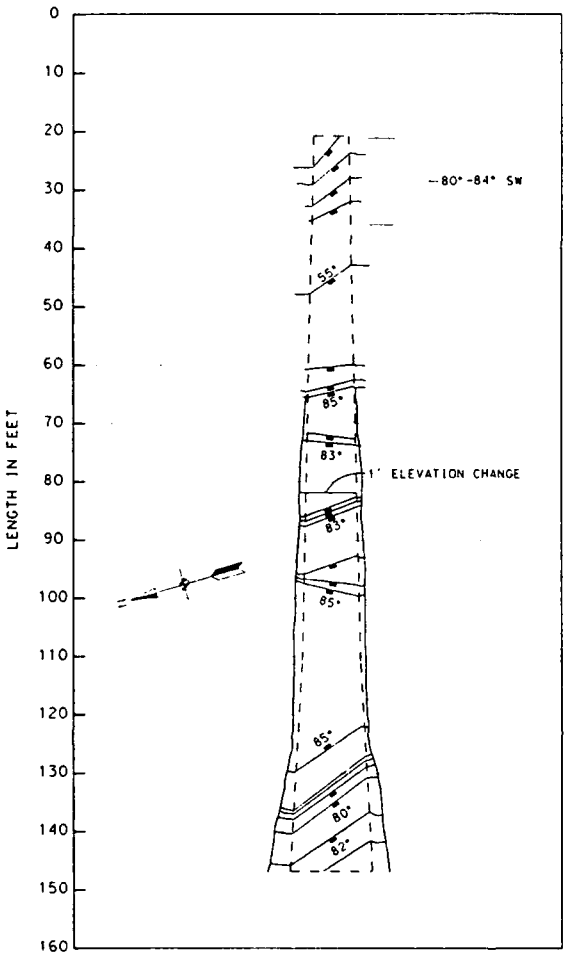
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
PIER 1, PIER 2 AND PIER 3
KENTUCKY HWY 72
OVER DOWNSTREAM PORTAL

Date:
Sheet _ of _
Scale: AS NOTED
Drawing Number: Q1A-81/791

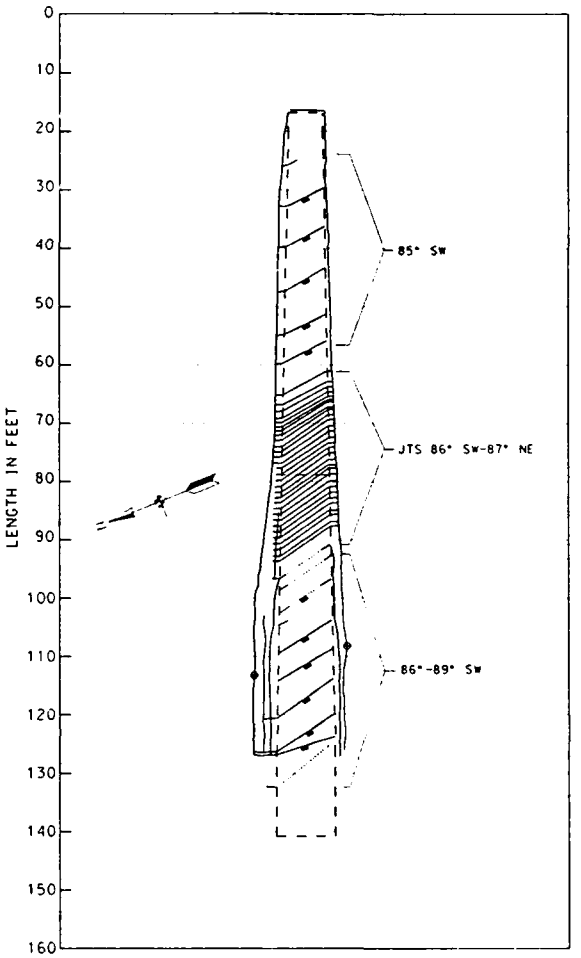
Record Drawing as constructed dated

KYDOH DRWG NO 21912

PLATE G-3



PIER 3



PIER 2

LEGEND

- HORIZONTAL BEDDING PLANE

65 JOINT WITH DIP INDICATED. NOT ALL JOINT SYMBOLS AND DIPS ARE SHOWN DUE TO SPACE LIMITATIONS. VERY CLOSELY SPACED JOINT ZONES ARE BRACKETED WITH DIPS NOTED.

NOTES:

1. SILTSTONE BEDROCK FOUNDATION IS MOD TO SLIGHTLY WEATHERED, MASSIVE TO
2. JOINTS ARE TYPICALLY HIGH ANGLE(AS MODERATELY SPACED, TIGHT, CLEAN OR SOFT SILTY CLAY, AND NOT HEALED.
3. BEDDING PLANES ARE TIGHT TO SLIGHTI SLIGHTLY ROUGH, AND HORIZONTAL.
4. DASHED LINES REPRESENT PERIMETER A' EXCAVATION. ADJACENT AREAS OUTSIDE VERTICAL SIDES OF THE EXCAVATION AS PLANAR SURFACES.
5. SEE PLATE A-2 FOR GENERAL NOTES.
6. SEE PLATES A-3 THRU A-5 FOR EXPLAN

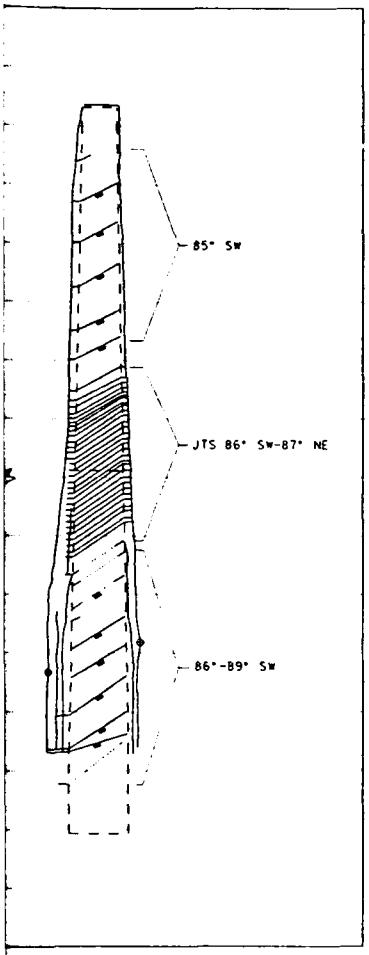
DRILLING LOG

HARLAN DIVERSION PROJECT

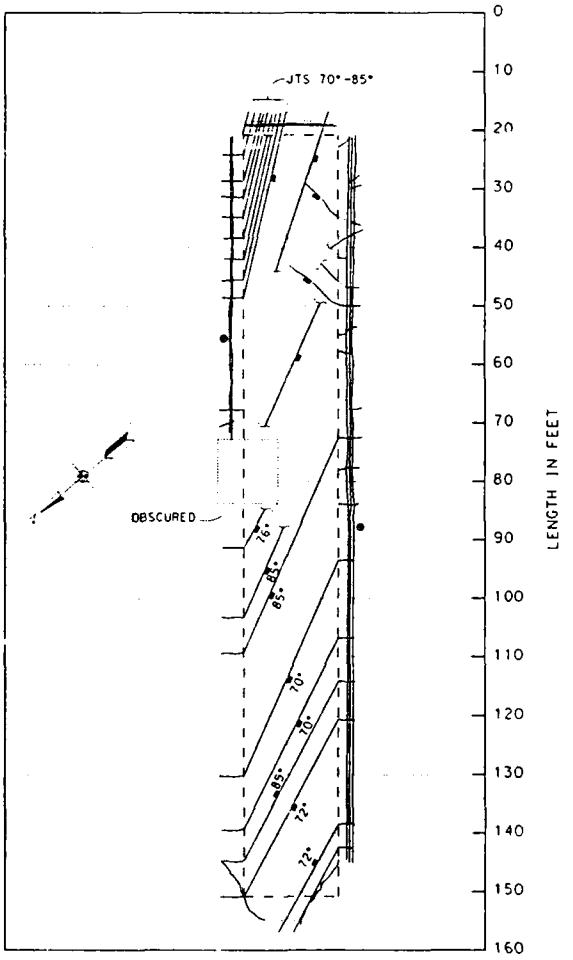
Highway 18 Bridge Abutment No. 1

48 in Auger Rotary Tool

REVISIONS				
REV.	DESCRIPTION	DATE	BY	APPROVED



PIER 2



PIER 1

NOTES:

1. SILTSTONE BEDROCK FOUNDATION IS MODERATELY HARD, UNWEATHERED TO SLIGHTLY WEATHERED, MASSIVE TO MEDIUM BEDDED, DARK GRAY.
2. JOINTS ARE TYPICALLY HIGH ANGLE (AS SHOWN) VERY WIDELY TO MODERATELY SPACED, TIGHT, CLEAN OR FILLED WITH UP TO 0.3' SOFT SILTY CLAY, AND NOT HEALED.
3. BEDDING PLANES ARE TIGHT TO SLIGHTLY OPEN, CLEAN, SMOOTH TO SLIGHTLY ROUGH, AND HORIZONTAL.
4. DASHED LINES REPRESENT PERIMETER AT BOTTOM OF FOOTING EXCAVATION. ADJACENT AREAS OUTSIDE DASHED LINES REPRESENT VERTICAL SIDES OF THE EXCAVATION FOLDED BACK AND MAPPED AS PLANAR SURFACES.
5. SEE PLATE A-2 FOR GENERAL NOTES.
6. SEE PLATES A-3 THRU A-5 FOR EXPLANATION OF DESCRIPTIVE TERMS.

10' 5 0 10 20FT
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: C.A.G.
Checked By: P.R.
P.R. (REGISTERED)

UPPER CUMBERLAND RIVER BASIN
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
HIGHWAY 72 BRIDGE
PIER FOUNDATIONS

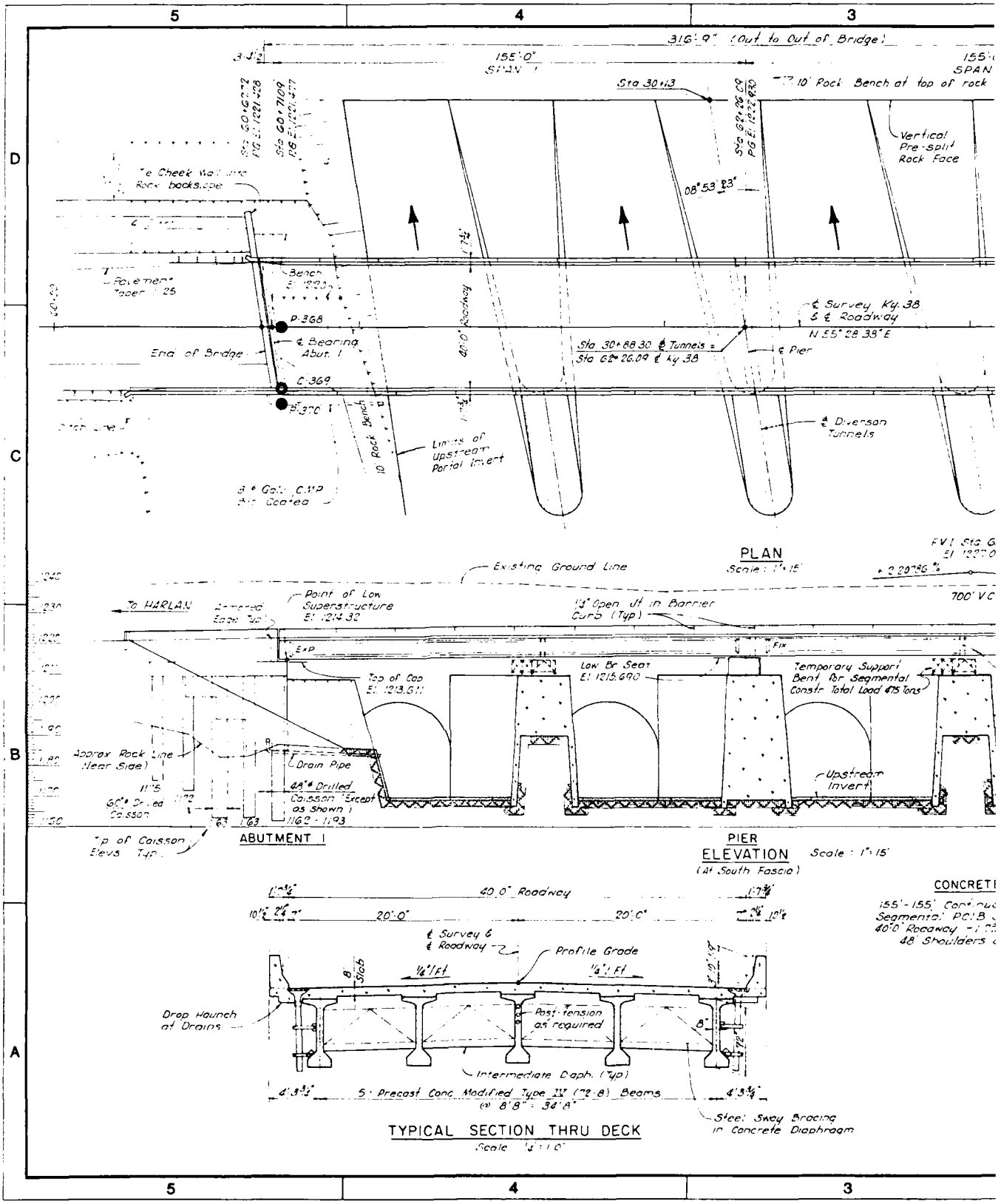
Approved By:
Date: FEB 1994
Scale: 1"=10'
Record Drawing as constructed dated
Drawing Number: **Q1A-4398**

COMPUTER AIDED DESIGN & DRAFTING — SOILS SECTION

PLATE G-4

Appendix H - Highway 38 and Bridge

Plate No.	Drawing No.	Description
H-1	Q1A-81/3.2	Bridge Layout
H-2	Q1A-81/4.3	Caisson Details
H-3	Q1A-4/399	Boring Logs
H-4	Q1A-4/400	Boring Logs
H-5 thru 19	----	Caisson Hole Maps



DRILLING LOG	Division ORD	INSTALLATION NED	Hole No. CA 1-8
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT 48 in ROCK AUGER	
3. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	

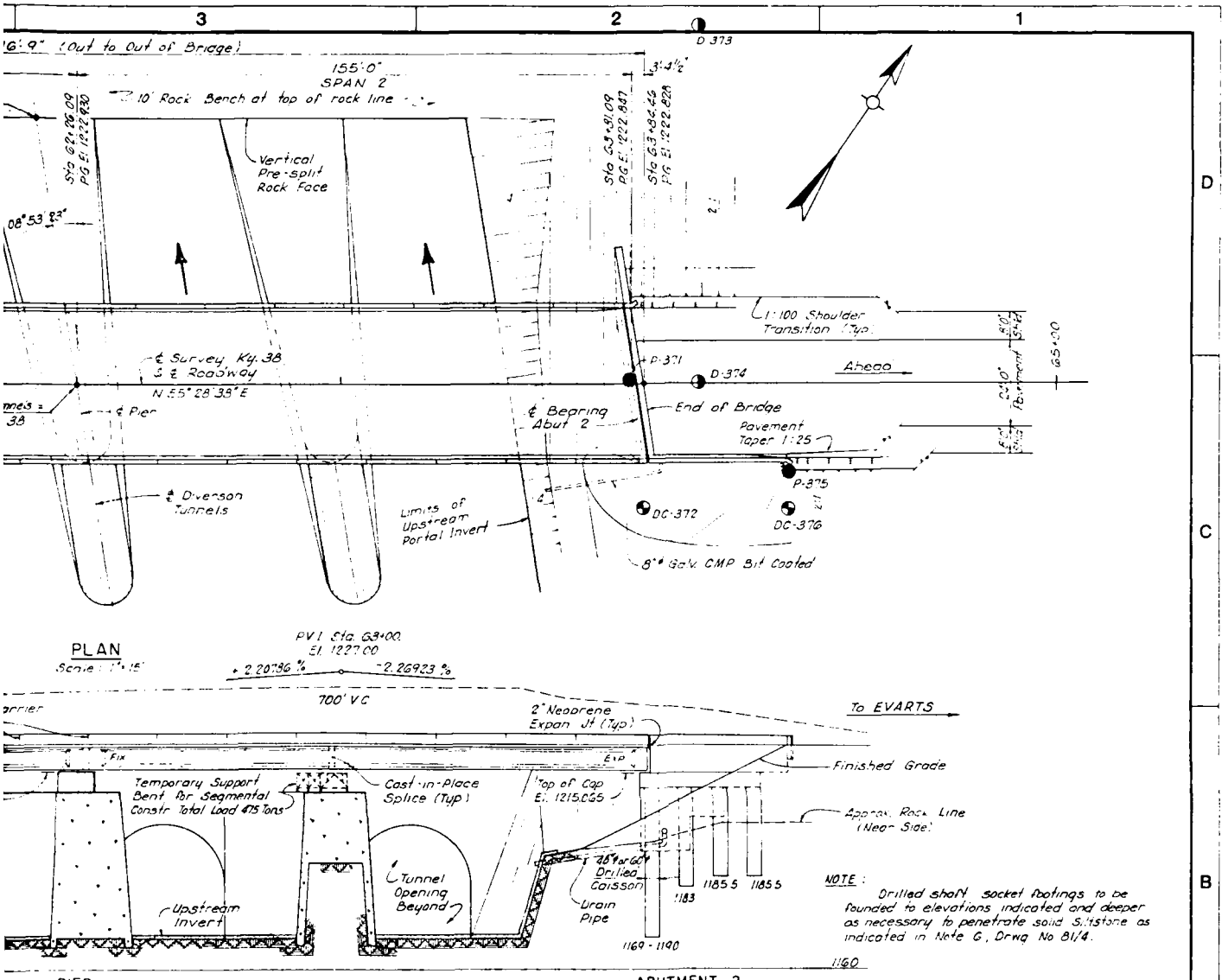
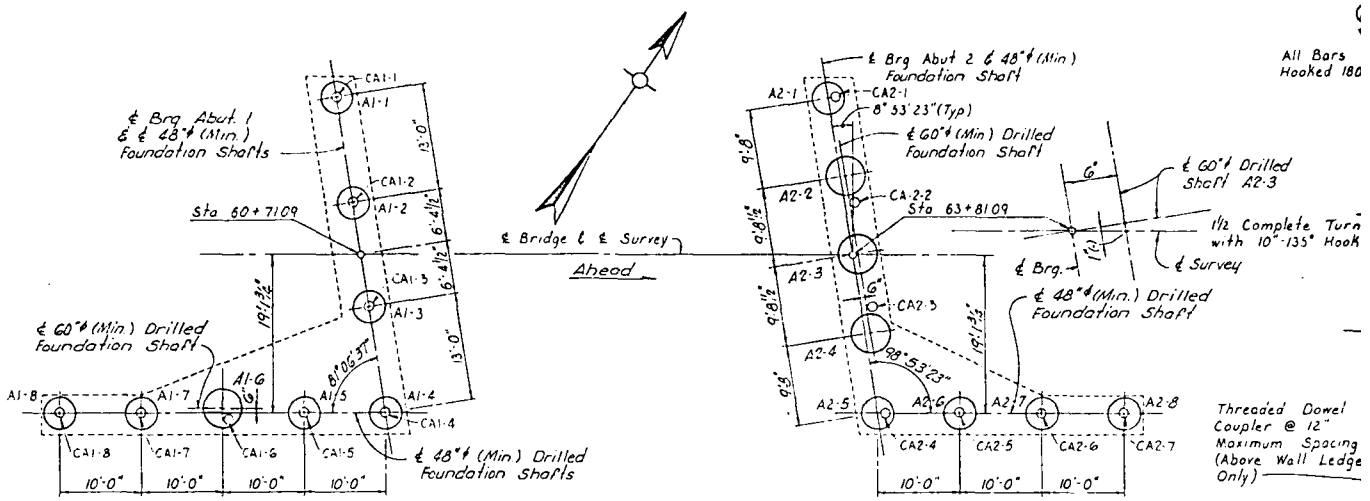

3
2
1
D
C
B
A
'6"9" (Out to Out of Bridge)
155'0"
SPAN 2
10' Rock Bench at top of rock line
Vertical Pre-split Rock Face
08°53'83"
℄ Survey Ky. 38
S ℄ Roadway
N 55° 28' 39" E
℄ Pier
38
℄ Bearing
Abut 2
End of Bridge
Pavement
Taper 1:25
Ahead
1:100 Shoulder Transition (Typ.)
P-371
D-374
P-375
DC-372
DC-376
℄ Diversion Tunnels
Limits of Upstream portal Invert
8" ϕ Galv. CMP Bit Coated
D 373
PLAN
Scale : 1" = 15'
PVI Sta. 63+00
El. 1227.00
+ 2.20786 %
- 2.26923 %
700' VC
To EVARTS
2" Neoprene Expan Jt (Typ)
Finished Grade
Approx. Rock Line (Near Side)
Temporary Support Bent for Segmental Constr Total Load 475 Tons
Cast-in-Place Splice (Typ)
Top of Cap El. 1215.055
Tunnel Opening Beyond
Upstream Invert
Drain Pipe
1183
1185.5
1185.5
1169 - 1190
NOTE :
Drilled shaft socket footings to be founded to elevations indicated and deeper as necessary to penetrate solid Siltstone as indicated in Note 6, Drwg No 81/4.
1:60
ABUTMENT 2
PIER ELEVATION
(At South Fascia)
Scale : 1" = 15'
Steel Sway Bracing in Concrete Diaphragm
CONCRETE ALTERNATIVE
155' - 155' Continuous Spans, Post-Tensioned Segmental PCIB Sections - HS 25 Live Load
40'0" Roadway - 1'7¾" Barrier Curbs - 8°53 23 Skew LH
48' Shoulders at Bridge - 2:1 Slopes
2 4-8-91 Caisson Elev / Notes Abutments 1 & 2 NET DGM
1 6-26-89 Added Joints in Barrier Wall KEP DGM
Revisions Date Descriptions By Checked
Graphic Scale
US ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE
Designed by: DGM
Drawn by: NET
Checked by: CPK Jr
Approved by:
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
LAYOUT
KENTUCKY HWY 38
OVER UPSTREAM PORTAL
Date:
Sheet _ of _
Scale: AS NOTED
Drawing Number Q1A-81/3.2
Record Drawing as constructed dated
KYDOH DRWG NO 21911

PLATE H-1



All Bars Hooked 180

Threaded Dowel Coupler @ 12" Maximum Spacing (Above Wall Ledge Only)

DRILLED SHAFT LAYOUT
AND PROOF-TEST CORE HOLE LOCATIONS

Vertical Reinforcement

DRILLED SHAFT FOUNDATION SCHEDULE

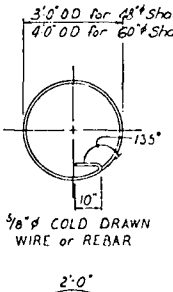
Drilled Shaft Mark	Shaft Dia (Min)	Vertical Reinforcement: No	Size	Cutoff Elevation	Top of Drilled Shaft Elev Ⓐ	Bottom of Wall Ledge Elev Ⓑ	Top of Rock Elevation Ⓒ: Design	Actual	Bottom of Drilled Shaft-Elevation Ⓓ: Design	Actual	Design-Drilled Shaft Length: Over-burden(Ft)	Rock (Ft)	Payment Lengths: Over-burden(Ft)	Rock (Ft)	FOR INFO ONLY Design Quantities: Drilled Shaft Concrete (Cu Yds)	Drilled Shaft Stl Reinf (Lbs)
A1-1	48"	12	#11	1212.67	1209.67	1206.67	1208.3	1209.7	1193.0	1193.2	—	16.7	0.0	16.5	7.7	1708
A1-2	48"	12	#11	1212.67	1209.67	1199.67	1209.7	1209.7	1187.0	1188.7	—	22.7	0.0	21.0	10.3	2177
A1-3	48"	12	#11	1212.67	1209.67	1184.67	1201.6	1202.7	1172.0	1174.2	8.1	27.6	7.0	28.5	15.8	3195
A1-4	48"	12	#11	1212.67	1209.67	1184.67	1188.0	1191.7	1162.0	1162.4	21.7	26.0	18.0	29.3	21.4	4135
A1-5	48"	12	#11	1212.67	1209.67	1184.67	1183.0	1187.2	1163.0	1162.9	26.7	20.0	23.0	24.2	20.9	4050
A1-6	60"	27	#11	1212.67	1209.67	1195.67	1182.6	1185.7	1163.0	1163.2	27.1	19.6	25.0	22.5	33.5	8410
A1-7	48"	12	#11	1212.67	1209.67	1202.67	1190.0	1191.4	1172.0	1172.5	19.7	18.0	18.2	18.9	17.3	3355
A1-8	48"	12	#11	1212.67	1209.67	N A	1190.0	1189.2	1175.0	1174.2	19.7	15.0	20.5	15.0	16.1	3120
A2-1	48"	12	#11	1214.07	1211.07	1206.065	1206.7	1211.8	1190.0	1189.2	4.3	16.7	0.0	21.8	9.5	4235
A2-2	60"	27	#11	1214.07	1211.07	1191.065	1200.0	1207.2	1178.0	1177.6	11.0	22.0	4.6	29.2	23.4	6190
A2-3	60"	27	#11	1214.07	1211.07	1190.065	1194.5	1202.2	1172.0	1171.1	16.5	22.5	9.0	30.2	27.6	7165
A2-4	60"	27	#11	1214.07	1211.07	1190.065	1191.5	1193.7	1169.0	1168.7	19.5	22.5	17.1	24.7	29.8	7655
A2-5	48"	12	#11	1214.07	1211.07	1193.065	1191.065	1195.5	1193.0	1179.0	1175.1	15.5	16.5	18.0	17.9	13.6	2915
A2-6	48"	12	#11	1214.07	1211.07	1193.065	1198.3	1196.3	1183.0	1181.3	12.7	15.3	14.8	15.0	12.5	2600
A2-7	48"	12	#11	1214.07	1211.07	1203.065	12008	1205.4	1185.5	11856	10.2	15.3	7.7	17.8	11.6	2400
A2-8	48"	12	#11	1214.07	1211.07	NA	12008	1201.0	1185.5	1185.0	10.2	15.3	11.5	15.5	11.9	2400

Ⓐ Based on Nominal Diameter Shafts

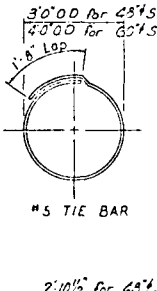
⅝"ϕ Spiral @ 8" Pitch, Full Length

DRILLED SHAFT NOTES

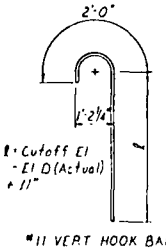
1. Foundation Shafts shall be Cast-in-Place Concrete, f'_c = 4000 psi
2. Construction Joints not shown on Project Plans will require the approval of the Engineer prior to construction.
3. Spiral Reinforcement shall be ⅝"ϕ Cold Drawn Wire. The Ends of the Spiral shall be anchored with a 135° Hook around one of the Vertical Bars. Laps in Spiral Ties to be minimum distance of 2 turns with Spiral Tie anchored with 135° Hook.
4. For Reinforcement Cutoff Elevation, etc., see Schedule, this sheet
5. Fabrication of Reinforcing Steel Cage shall include Spacing Blocks so as to maintain proper Spiral Pitch and Vertical Steel Spacing.
6. Drilled Shafts to be founded to elevations indicated and deeper as necessary to penetrate into solid rock a minimum of 15 feet for 48"ϕ shaft and 20 feet for 60"ϕ shaft. Solid rock is defined in Note 7 & shown on Typical Drilled Shaft Elevation.
7. For Drilling/Payment purposes, solid rock is defined as any material which cannot be drilled with a Conventional Earth Auger, and requires the use of Special Rock Augers, Core Barrels, Air Tools, Blasting and/or other methods of hand excavation.
8. After shafts are drilled, the Contractor in the presence of the Resident Engineer shall record for each shaft, the Top of Rock Elevation, Bottom of Shaft Elevations and Payment Lengths and shall return one blueprint copy of this completed sheet to the Engineer so the data may be recorded on the original plans. This Foundation Record does not replace other records of Drilled Shafts required to be kept and submitted by the Contractor.



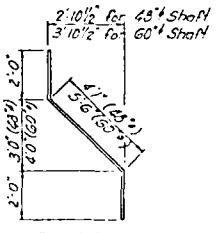
⅝"ϕ COLD DRAWN WIRE or REBAR



#5 TIE BAR



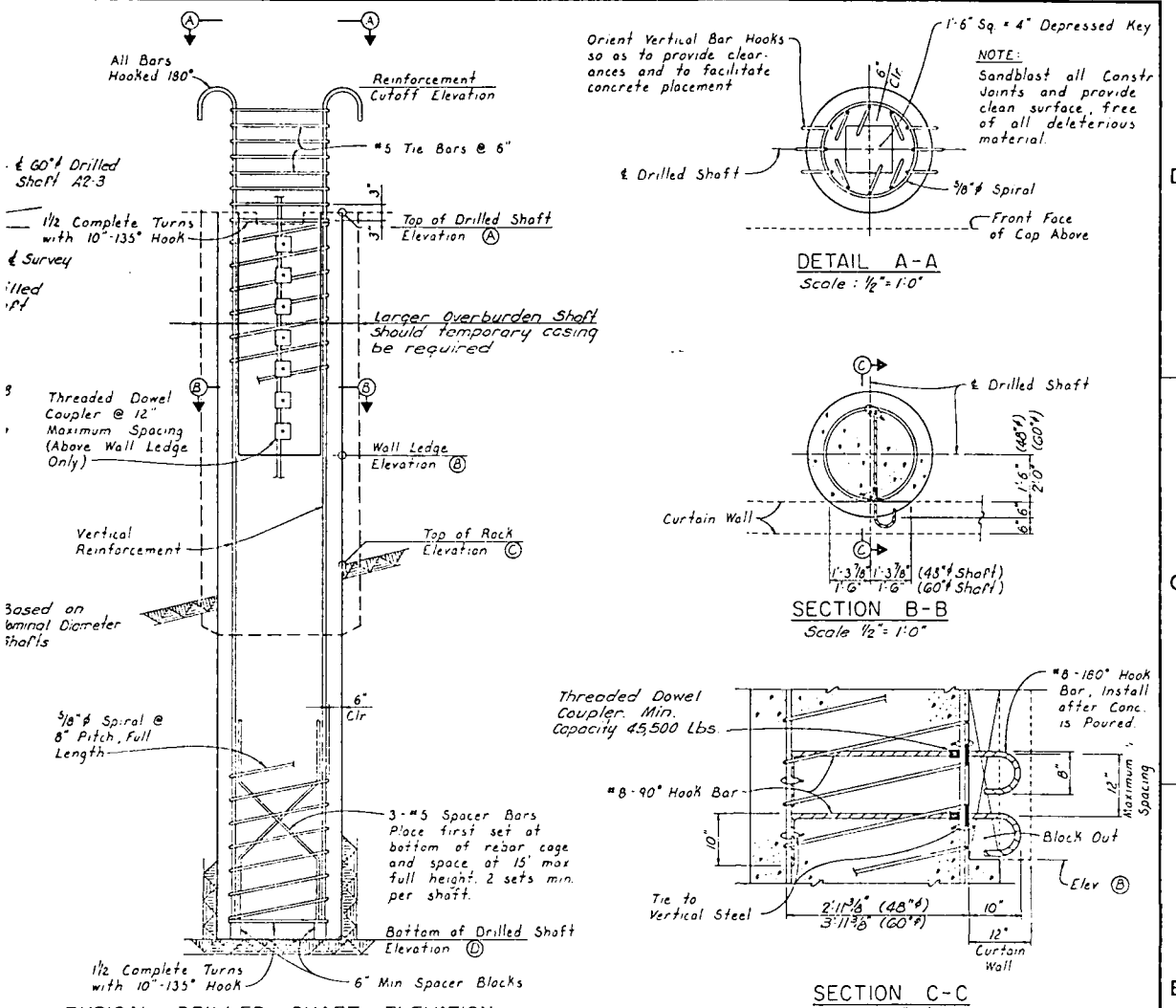
#11 VERT HOOK BAR



#5 - Z BAR

1½ Complete with 10"-135

TYPICAL



Revisions	Date	Descriptions	By	Checked
3	11/24/93	Revised as Constructed	MAR	
2	4/9/91	Revise Caisson Sizes, Spacings & Control Elev.	NET	DGM
1	6/26/89	Revise Notes 6, 7 & 8	NET	DGM

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

Designed by: DGM
Drawn by: JBB
Checked by: CPK JR.
Approved by:

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DRILLED FOUNDATION DETAILS
KENTUCKY HWY. 38
OVER UPSTREAM PORTAL

Date:
Sheet _ of _
Scale: AS NOTED
Drawing Number: QIA-81/4.3
Record Drawing as constructed dated

KYDOH DRWG NO 21911

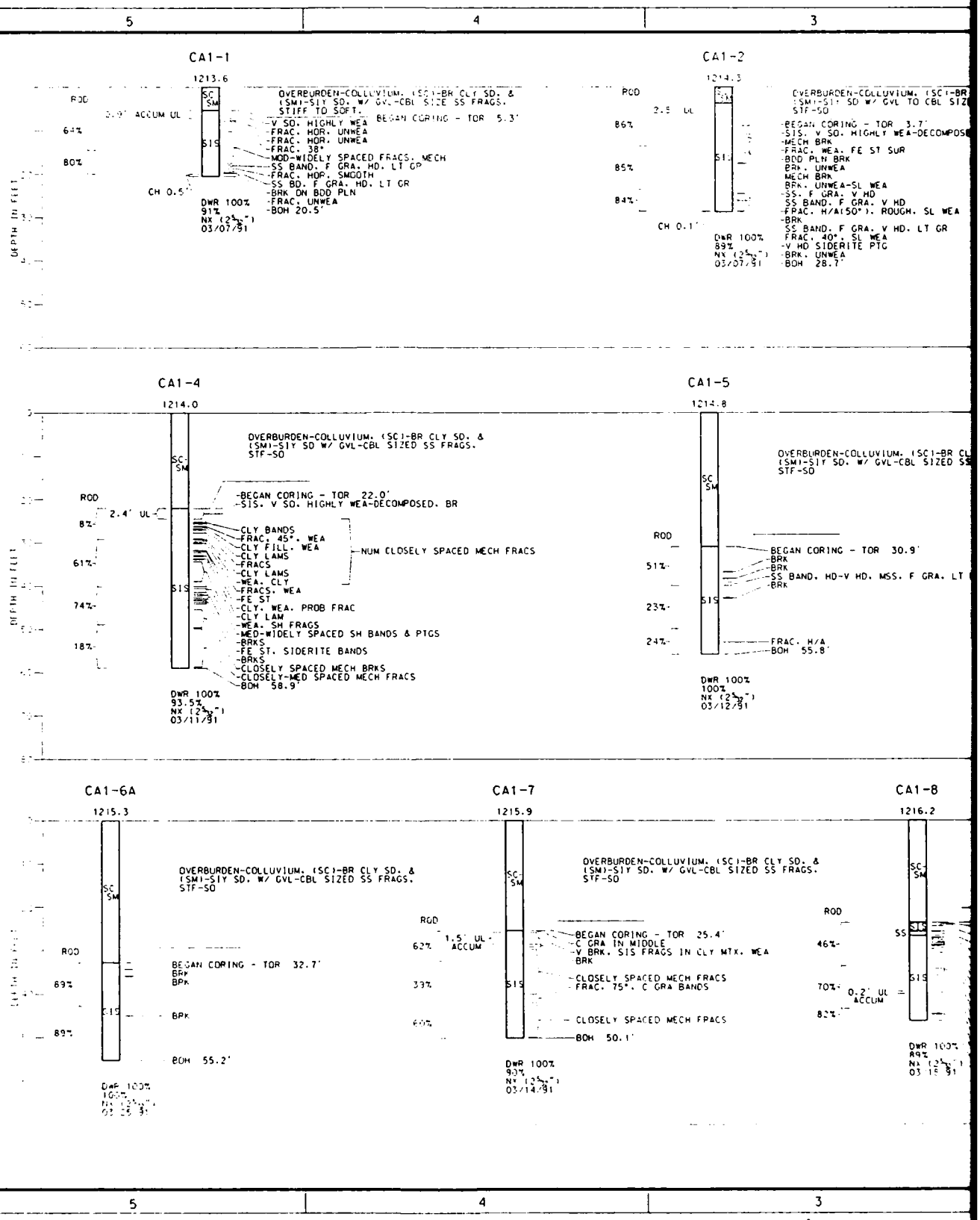
PLATE H-2

DRILLING LOG

PROJECT
HARLAN DIVERSION PROJECT

NED

2-3



DRILLING UNIT

PROJECT

HARLAN DIVERSION PROJECT

LOCATION

A2-4

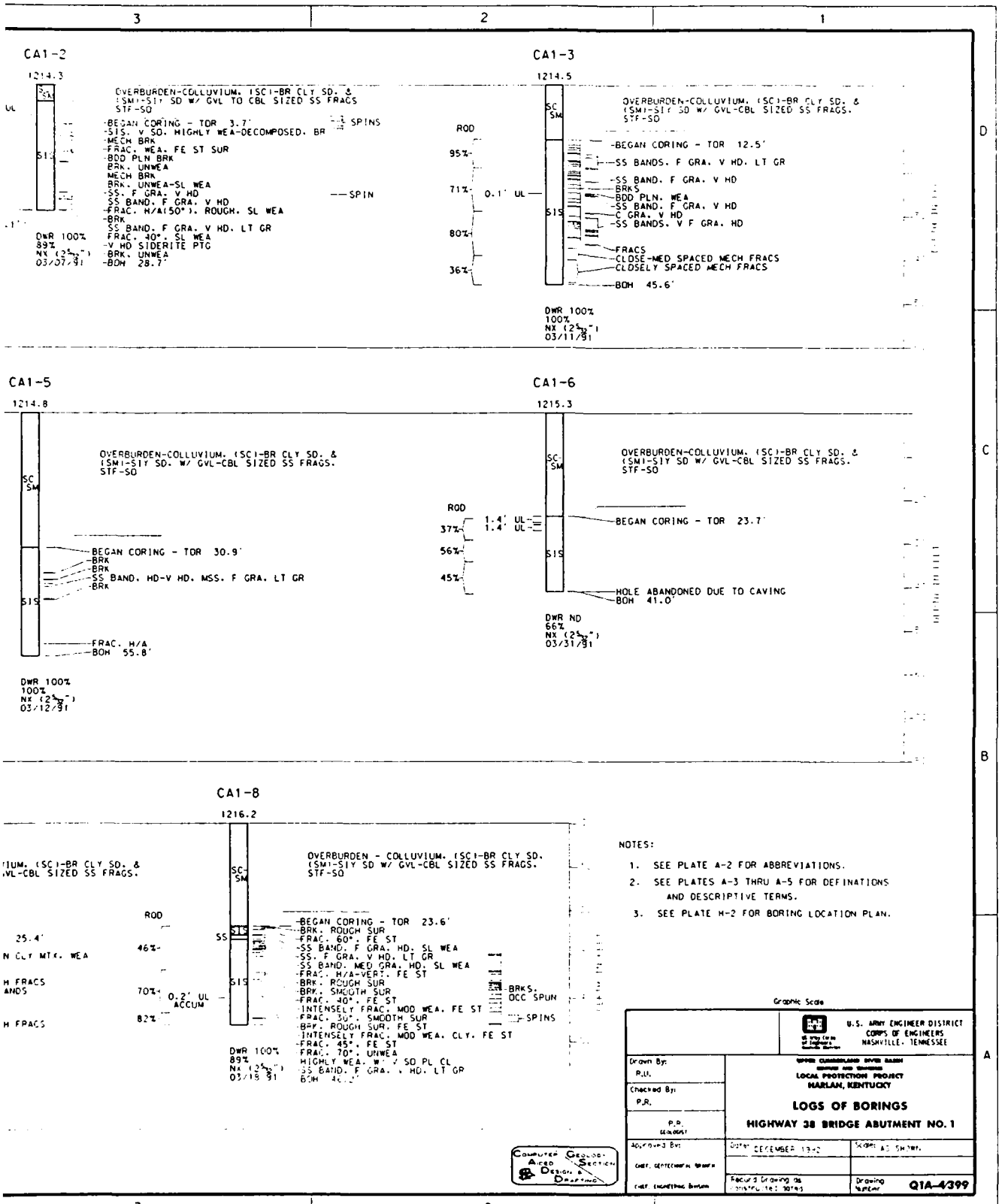
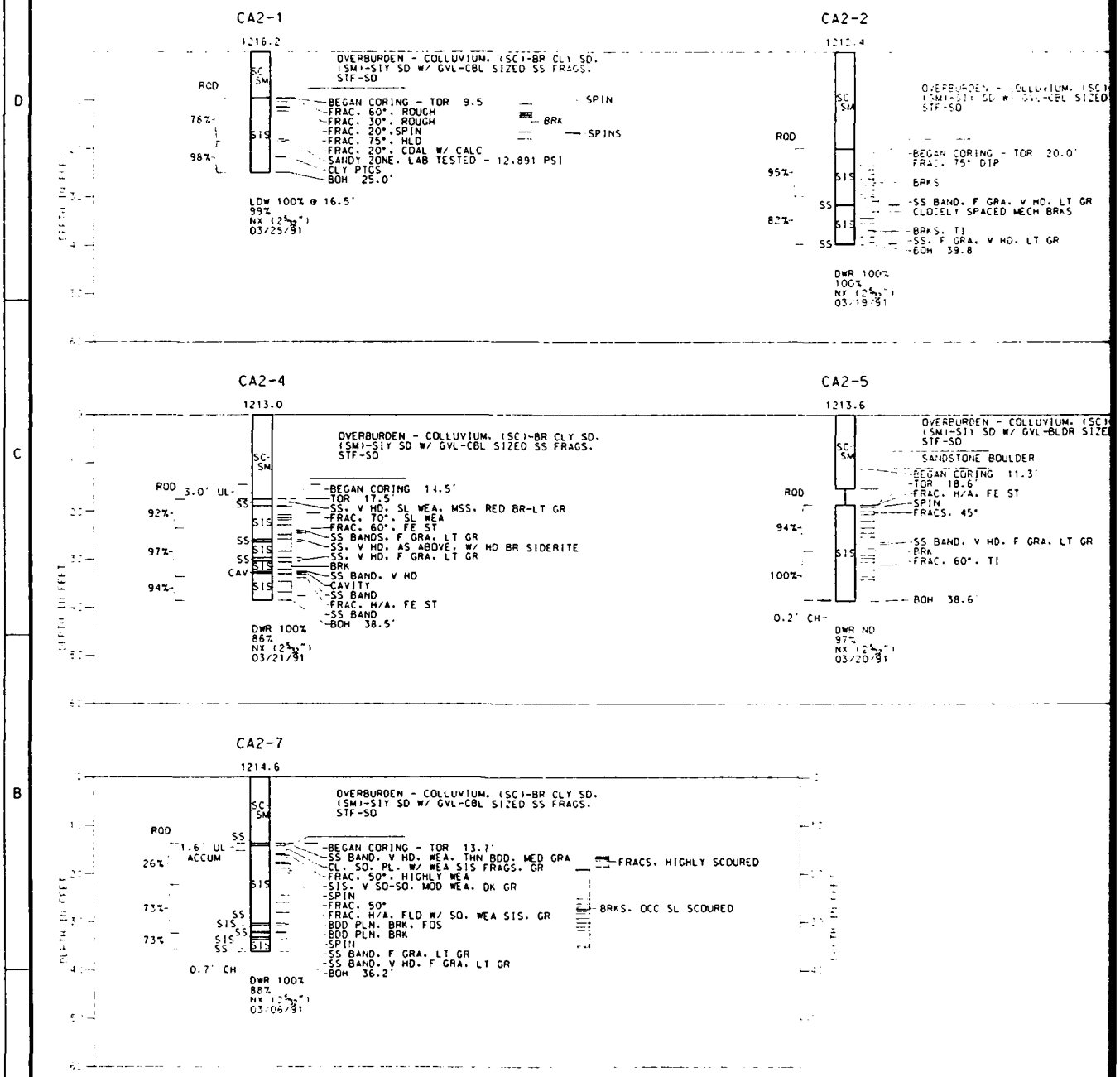


PLATE H-3

Hole No. CA 2-5

DRILLING LOG	Division ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	



DRILLING LOG | Division ORD | INSTALLATION NED | SHEET 1 OF 1 SHEETS

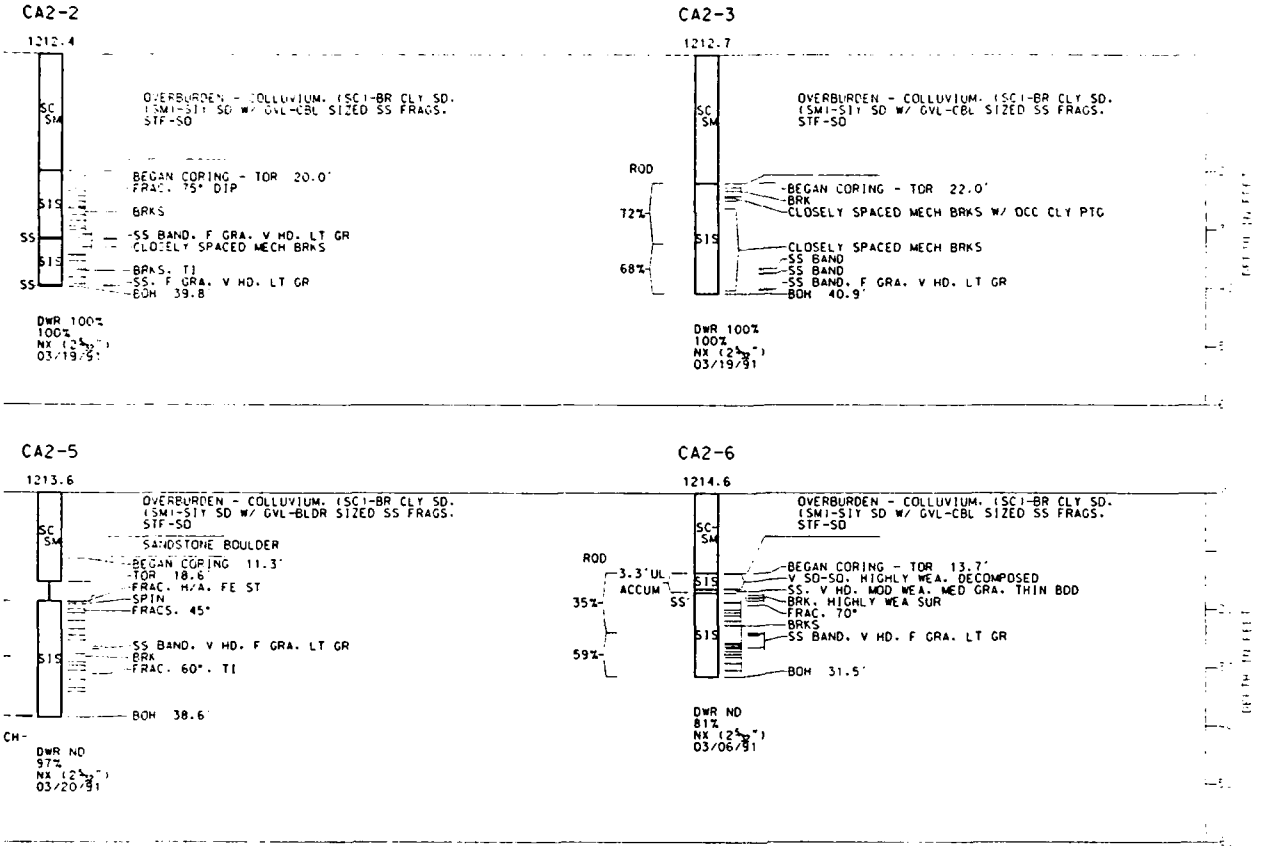
1. PROJECT HARLAN DIVERSION PROJECT

2. LOCATION (Coordinates or Station)

10. SIZE AND TYPE OF BIT 4Ø " Rock Auger

11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL

A2-4



NOTES:

1. SEE PLATE A-2 FOR ABBREVIATIONS.
2. SEE PLATES A-3 THRU A-5 FOR DEFINATIONS AND DESCRIPTIVE TERMS.
3. SEE PLATE H-2 FOR BORING LOCATION PLAN.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: R.U.
Checked By: P.R.

LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

LOGS OF BORINGS

HIGHWAY 38 BRIDGE ABUTMENT NO. 2

Recommended By:
CHIEF, GEOTECHNICAL BRANCH
CHIEF, ENGINEERING DIVISION

Date: DECEMBER 1990

Record Drawing as constructed dated:

Drawing No. **Q1A-4400**

COMPUTER AIDED DESIGN & DRAFTING SECTION

PLATE H-4

Hole No. A 1-1

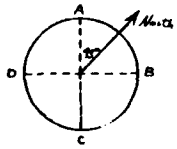
DRILLING LOG	Division ORD	Installation NED	Sheet 1 of 1 Sheets
1. Project: HARLAN DIVERSION PROJECT		10. Size and Type of Bit: 4B (in. Rock Bit)	
2. Location (Coordinates or Station): Highway 38 Bridge Abutment No. 1		11. Datum for Elevation Shown (MSL or Assumed): MSL	
3. Drilling Agency: Hayes		12. Manufacturer's Designation of Drill: Hayes CBH 70	
4. Hole No. (As shown on drawing title and file number): A 1-1		13. Total No. of Overburden Samples Taken: Undisturbed —; Disturbed —	
5. Name of Driller:		14. Total Number Core Boxes: —	
6. Direction of Hole: ☒ Vertical ☐ Inclined ____ deg. from vert.		15. Elevation Ground Water: None	
7. Thickness of Overburden: 0.0		16. Date Hole: Started 6-24-91; Finished 6-24-91	
8. Depth Drilled into Rock: 16.5		17. Elevation Top of Hole: 1209.7	
9. Total Depth of Hole: 16.5 (1193.2)		18. Total Core Recovery for Boring: —	
		19. Signature of Inspector: [signature]	

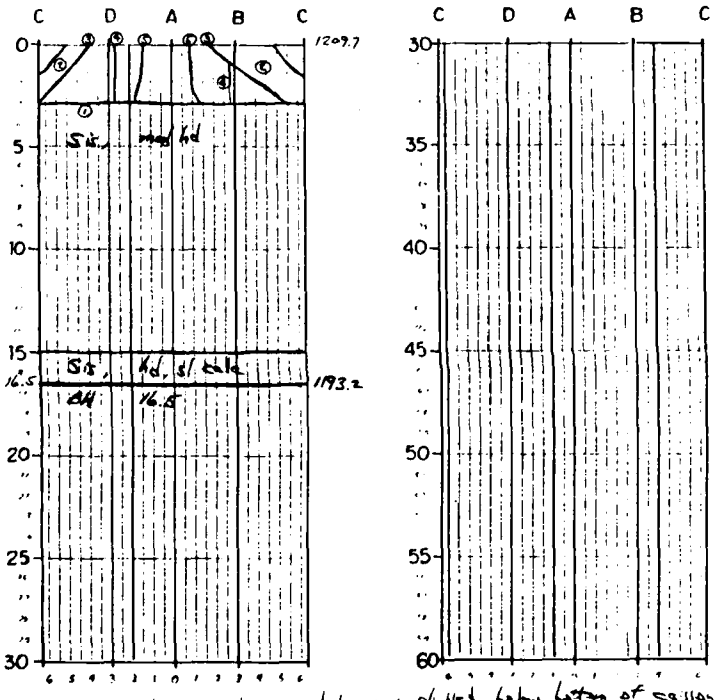
Caisson No.: CA1-1

Surface El: 1209.7

El TOR: 1209.7

BH 1193.2





A 5 ft deep jackhammer hole was drilled below bottom of caisson level, from 16.5 to 21.5 ft. depth. No fractures or voids detected.

FEATURE NO.	DESCRIPTION
①	Bed plane, hor, t.
②	Jt filling, Sa sl w/ sls fgsd, 0.5-2.0' th
③	Jt, N25E, 42SE, filled (See Note 2 above)
④	Jt, N55E, 77SE, filled w/ ½ in Sa sy cl
⑤	Jt, N40E, 88SE, filled w/ ½ in Sa sy cl

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: None
0' - 15' 3 hrs
Drill Time: 15 - 16.5 2½ hrs

Concrete Placed: 6-25-91

Plate H-5

DRILLING LOG | Division ORD | Installation NED
1. Project: HARLAN DIVERSION PROJECT

Hole No. CA 1-2

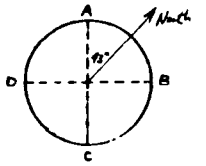
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT: 48" Core Auger	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No.		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: Hughes CDM 70	
4. HOLE NO. (As shown on drawing title and file number): A 1-2		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES: —	
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER: None	
7. THICKNESS OF OVERBURDEN: 0.0		16. DATE HOLE: STARTED — COMPLETED 7-9-91	
8. DEPTH DRILLED INTO ROCK: 21.0		17. ELEVATION TOP OF HOLE: 1209.7	
9. TOTAL DEPTH OF HOLE: 21.0		18. TOTAL CORE RECOVERY FOR BORING: —	
		19. SIGNATURE OF INSPECTOR: [signature]	

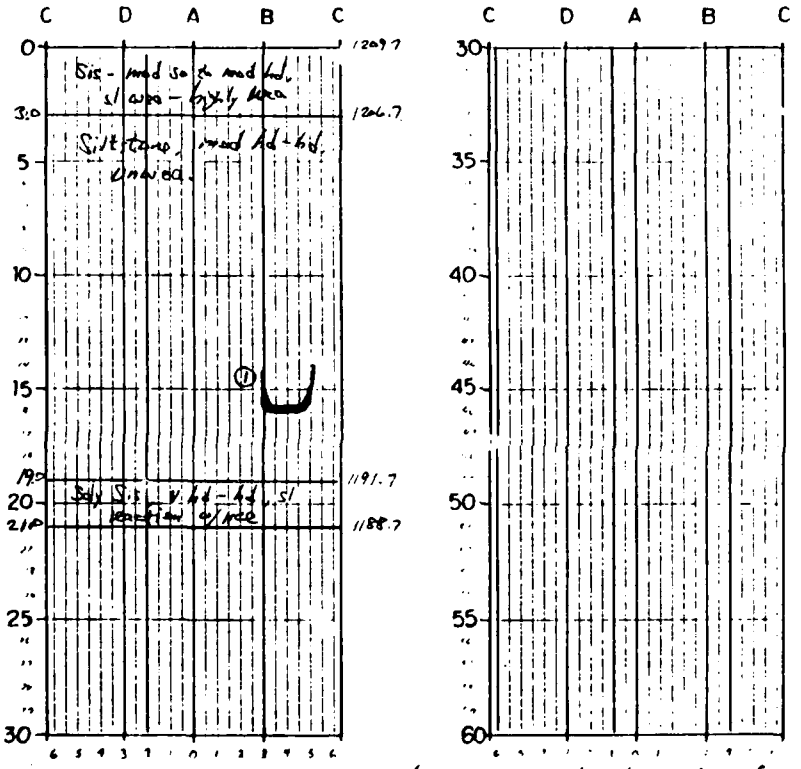
Caisson No.: CA 1-2

Surface El: 1209.7

El TOR: 1209.7

BH 1188.7





A 5-ft deep jackhammer pilot test hole was drilled below bottom of caisson from 21.0 to 26.0 ft. w/ hand unwatered core for full depth. At 21 ft the cutting rate was 1"/5 hrs w/ approx 100 carbide picks worn out.

FEATURE NO.	DESCRIPTION
①	Jt, Ti, clean, rnd rough, irreg dip Nearly ⊥ vert.

REMARKS: Hole was terminated at 21.0

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: None

Drill Time: ____

Concrete Placed: 7-9-91

Plate H-6

Plate No. CA 1-3

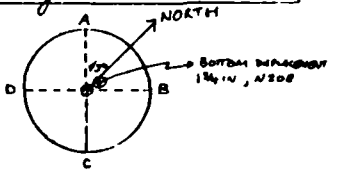
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT: 48 in Rock Auger / CORING TOOL	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. ____		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH 70	
4. HOLE NO. (As shown on drawing title and file number): A 1-3		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — / UNDISTURBED —	
5. NAME OF DRILLER:		14. TOTAL NUMBER CORE BOXES: —	
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER: NONE	
7. THICKNESS OF OVERBURDEN: 7.0 FT		16. DATE HOLE: STARTED 6/27/91 COMPLETED 7/1/91	
8. DEPTH DRILLED INTO ROCK: 28.5 FT		17. ELEVATION TOP OF HOLE: 1209.7	
9. TOTAL DEPTH OF HOLE: 35.5 FT		18. TOTAL CORE RECOVERY FOR BORING: —	
		19. SIGNATURE OF INSPECTOR: Tim Shy	

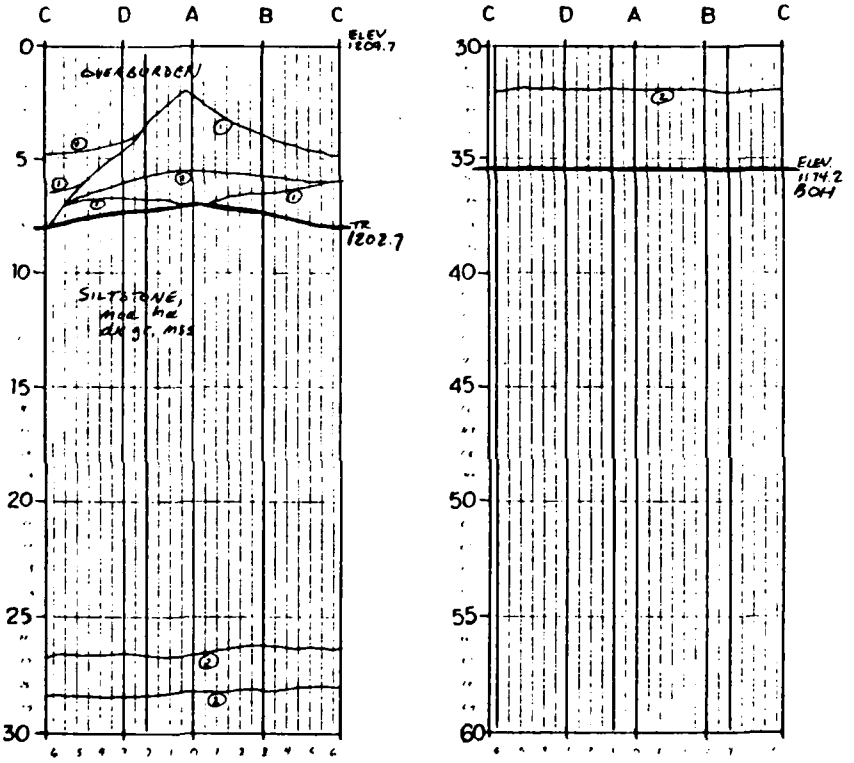
Caisson No.: CA1-3

Surface El: 1209.7

El TOR: 1202.7

BH 1174.2





FEATURE NO.	DESCRIPTION
①	Slip surface in overburden
②	Bedding plane, Bd, NH, sis, c gra, l sy, near horizontal

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: NONE

Drill Time: ____

Concrete Placed: 7-1-91

Plate H-7

1-4

DRILLING LOG

HARLAN DIVERSION PROJECT

Highway 38 Bridge Abutment No. 1

Hayes

A 1-4

NAME OF DRILLER: JERRY HAYES

DIRECTION OF HOLE: VERTICAL

THICKNESS OF OVERBURDEN: 18.0 FT

DEPTH DRILLED INTO ROCK: 29.3 FT

TOTAL DEPTH OF HOLE: 47.3 FT

SIZE AND TYPE OF BIT: 4 3/4 AUGER/CORING TOOL

MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70

TOTAL CORE RECOVERY FOR ROUND: —

ELEVATION GROUND WATER: 1167.0

DATE HOLE STARTED: 7/15/91

ELEVATION TOP OF HOLE: 1209.7

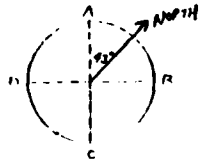
SIGNATURE OF INSPECTOR: Tim Shy

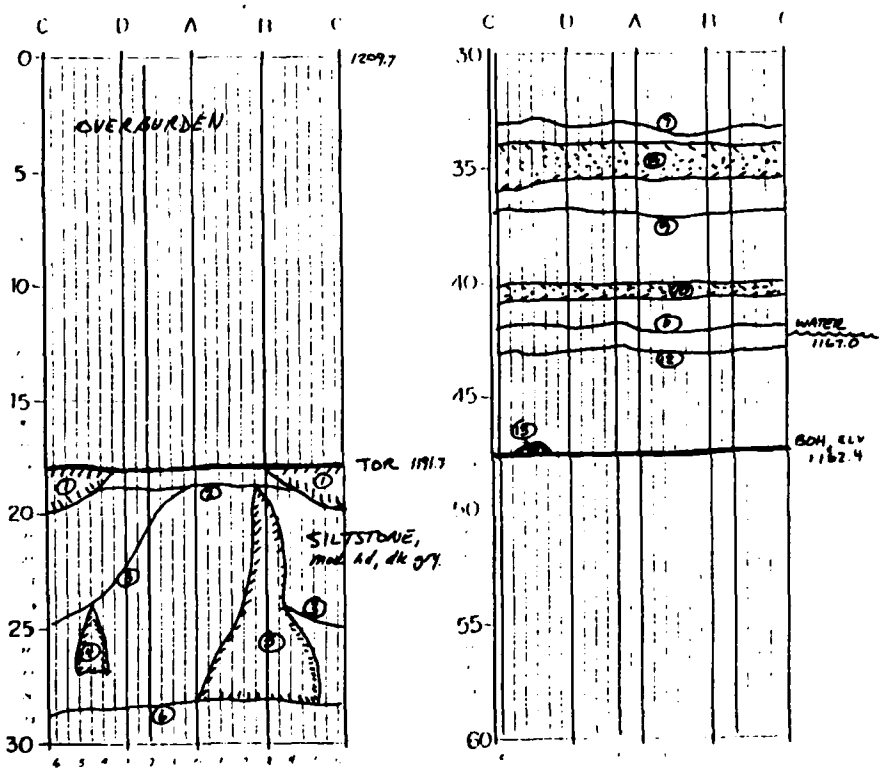
Caisson No.: CA 1-4

Surface El: 1209.7

El TOR: 1191.7

BH 1162.4





FEATURE NO.	DESCRIPTION
①	Cly lens, N2, W4
②③⑦⑨⑪⑫	Bdg phs, OB, T2, M2
⑤	Jt, N80E, 75 SE, CB, OB, T5, R2, MW, M4
④⑧	Joint Filling, cly, N1, W5
⑩⑬	sht, c gm, N4, W1
⑥	cly lens, N2, W4, flowing water (1 gpm).

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N 45° W

Groundwater: Flowing at 1162.5
Standing at 1167.0

Drill Time:

Concrete Placed: 7/18/91

Plate E-8

DRILLING LOG

PROJECT
HARLAN DIVERSION PROJECT

LOCATION (Coordinates or Station)
Highway 38 Bridge Abutment No. 1

DRILLING AGENCY
Hayes

HOLE NO. (As shown on drawing title and file number)
A 1-5

NAME OF DRILLER
Jerry Hayes

DIRECTION OF HOLE
Vertical

THICKNESS OF OVERBURDEN 22.5
DEPTH DRILLED INTO ROCK 24.3
TOTAL DEPTH OF HOLE 46.8

INSTALLATION
HDD

SIZE AND TYPE OF BIT 4" AUGER/CASING TOOL

DATUM FOR ELEVATION SHOWN (TBM, MSL, etc.)
MSL

MANUFACTURER'S DESIGNATION OF DRILL
HUGHES LDH-70

TOTAL NO. OF OVERBURDEN SAMPLES TAKEN —

TOTAL NUMBER CORE BOXES —

ELEVATION GROUND WATER ND

DATE HOLE 7/29/91

ELEVATION TOP OF HOLE 1210.2

TOTAL CORE RECOVERY FOR BORING —

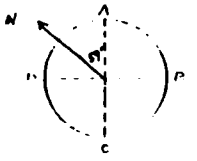
SIGNATURE OF INSPECTOR
Tim Shy

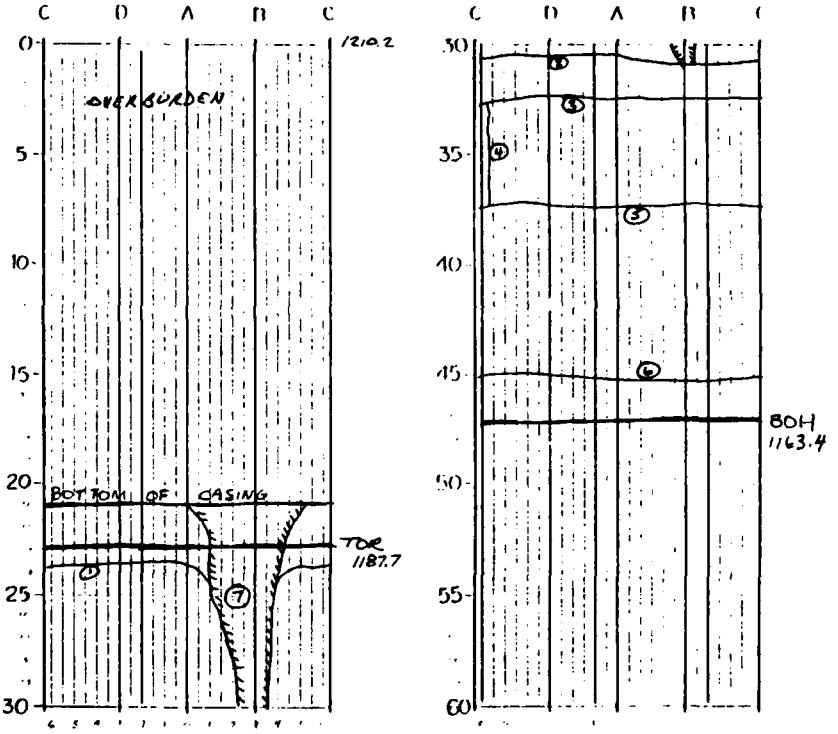
Caisson No.: A1-5

Surface El: 1210.2

TOR: 1187.7

BH 1163.4





FEATURE NO.	DESCRIPTION
1,2,3,5,6	Bedding Planes, B4, S1sf, cgm, lg10, W2, NH, Horizontal
4	Fracture, C2, O3, T3, R4, MEDE, vertical
7	Fracture, C3, O3, T5, R2, HL4, MH, cly filling HI, WS. N75W, 70 NE

REMARKS:

Line A-C is along caisson row alignment
Bearing: N59°E

Groundwater: ND

Drill Time:

Concrete Placed: 7-30-91

Plate H-9

DRILLING LOG	
PROJECT	HARLAN DIVERSION PROJECT
LOCATION	Highway 38 Bridge Abutment No.
DRILLING AGENCY	Hayes
HOLE NO.	A 1-7
NAME OF DRILLER	JERRY HAYES
DIRECTION OF HOLE	
THICKNESS OF OVERBURDEN	18.2
DEPTH DRILLED INTO ROCK	18.9
TOTAL DEPTH OF HOLE	37.1

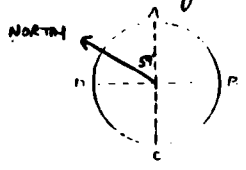
SIZE AND TYPE OF BIT	48 in Rock Auger
DIP	HUGHES LDH-70
TOTAL NO. OF CORE BOXES	-
ELEVATION GROUND WATER	ND
DATE HOLE	7/16/91 — 7/17/91
ELEVATION TOP OF HOLE	1209.6
TOTAL CORE RECOVERY FOR ROCK	-

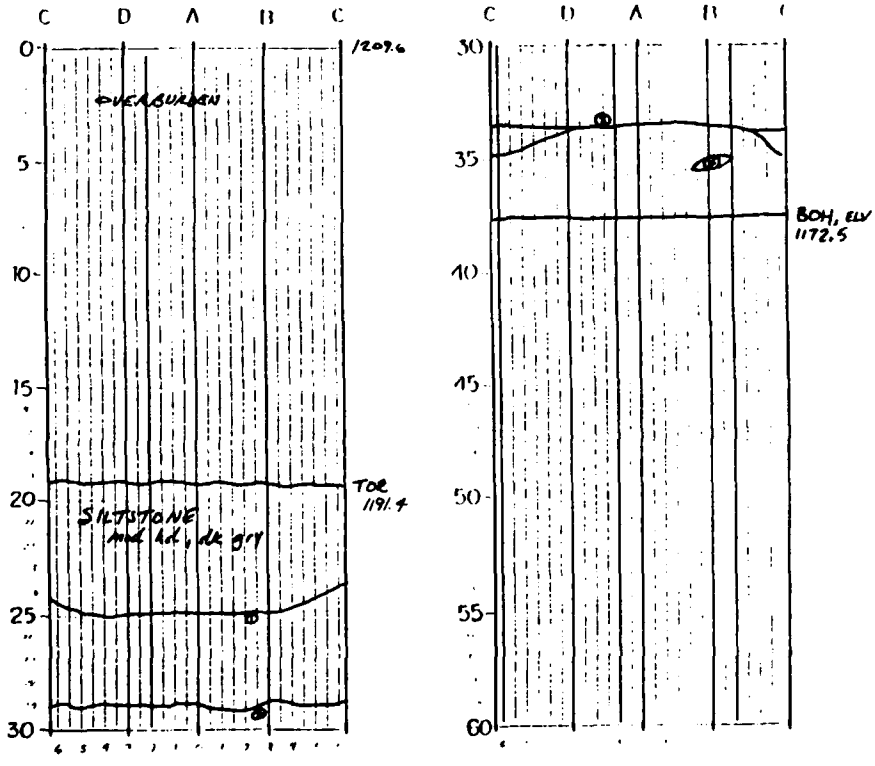
Caisson No.: CA1-7

Surface El: 1209.6

TOR: 1191.4

BH 1172.5





FEATURE NO.	DESCRIPTION
1,2,3	Bedding planes, OB, TS, MZ
4	Cly seas, MZ, MW

REMARKS:

Line A-C is along caisson row alignment. Bearing: N 59° E

Groundwater: 0.5m STANDING

Drill Time:

Concrete Placed: 7/18/91

Plate H-10

Hole No. CA 1-8

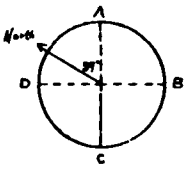
DRILLING LOG	Division: ORD	Installation: NED	Sheet 1 of 1 sheets
1. Project: HARLAN DIVERSION PROJECT		10. Size and type of bit: 48 in Rock Auger	
2. Location (Coordinates or Station): Highway 38 Bridge Abutment No. 1		11. Datum for elevation shown (ft. msl): MSL	
3. Drilling agency: Hayes		12. Manufacturer's designation of drill: Hughes LDH-70	
4. Hole no. (As shown on drawing title and file number): A 1-8		13. Total no. of overburden samples taken: Undisturbed – / Disturbed –	
5. Name of driller: Jerry Hayes		14. Total number core boxes: —	
6. Direction of hole: ☒ Vertical ☐ Inclined ____ deg from vert.		15. Elevation ground water: NONE	
7. Thickness of overburden: 20.5		16. Date hole: Started 7/01/91 Completed 7/03/91	
8. Depth drilled into rock: 15.0		17. Elevation top of hole: 1209.7	
9. Total depth of hole: 35.5		18. Total core recovery for boring: —	
		19. Signature of inspector: Tim Sky	

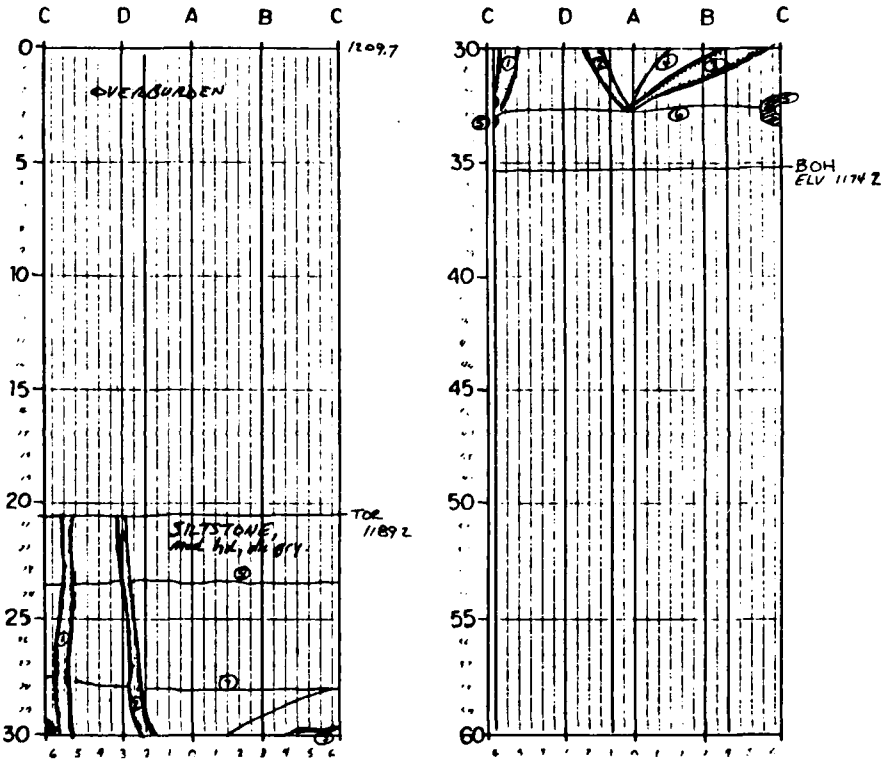
Caisson No.: CA-1-8

Surface El: 1209.7

El TOR: 1189.2

BH 1174.2





FEATURE NO.	DESCRIPTION
1, 2	JOINT, CS, OB, TS, RS, HL4, MH, [N 20°W vertical
3	Cly lens, HZ, W4
4	FRAC, CL, OB, TH, R4, ML4, MZ, [N 20°E 45° NW
5	Cly lens, HZ, W4
6, 7, 8	Bedding planes, OB, TZ, MZ

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N 59° E

Groundwater: NONE

Drill Time: _____

Concrete Placed: 7-3-91

Plate H-11

2-1

DRILLING LOG | DIVISION ORD

PROJECT: HARLAN DIVERSION PROJECT

LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. 2

DRILLING AGENCY: Hayes

HOLE NO. (As shown on drawing title and file number): A 2-1

NAME OF DRILLER: JERRY HAYES

DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED — DEG. FROM VERTICAL

THICKNESS OF OVERBURDEN: 0.0

DEPTH DRILLED INTO ROCK: 22.6

TOTAL DEPTH OF HOLE: 22.6

INSTALLATION: NED — SHEET 1 OF 1 SHEETS

SIZE AND TYPE OF BIT: 4" ø AUGER/CORING TOOL

DATUM FOR ELEVATION SHOWN (MSL): MSL

MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70

TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: — UNDISTURBED: —

TOTAL NUMBER CORE BOXES: —

ELEVATION GROUND WATER: ND

DATE HOLE: STARTED 7/25/91

ELEVATION TOP OF HOLE: 1211.8

TOTAL CORE RECOVERY FOR BORING: —

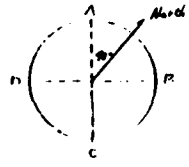
SIGNATURE OF INSPECTOR: Tim Sley

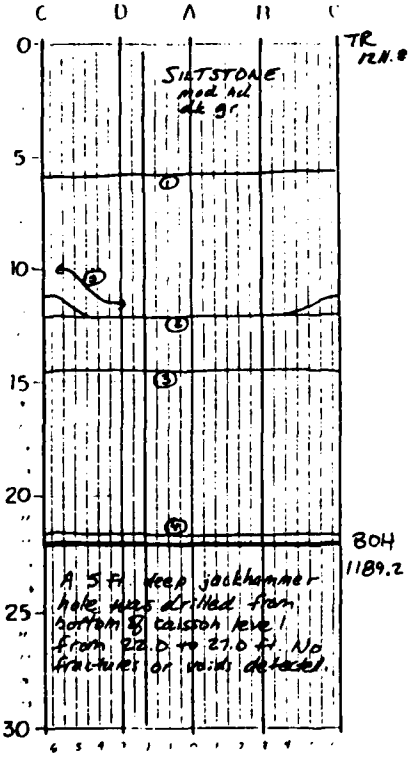
Caisson No.: CA2-1

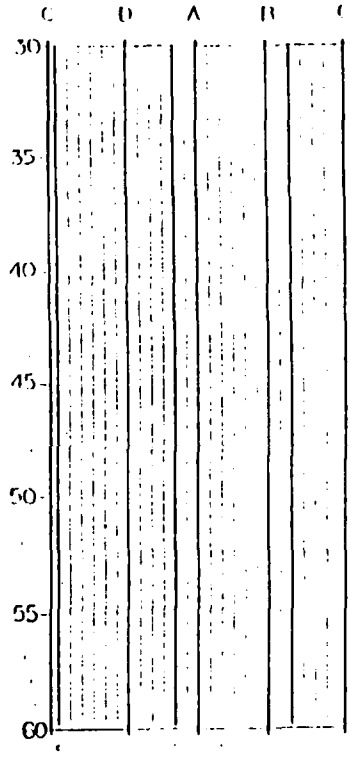
Surface El: 1211.8

TI TOP: 1211.8

BH 1189.2







FEATURE NO.	DESCRIPTION
1, 2, 3	Bedding plane, SI sd, BS, c gm, lgr, mw sndst W1, H4
5	Fracture, C1, OB, T1, R4, HL4, A2

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: NONE

Drill Time:

Concrete Placed: 7-31-91

Plate E-12

2-2

DRILLING LOG

PROJECT: HARLAN DIVERSION PROJECT

LOCATION: Highway 38 Bridge Abutment No. 2

DRILLING AGENCY: Hayes

HOLE NO.: A 2-2

NAME OF DRILLER: SHERMAN

DIRECTION OF HOLE: Vertical

THICKNESS OF OVERBURDEN: 4.6

DEPTH DRILLED INTO ROCK: 29.6

TOTAL DEPTH OF HOLE: 34.2

SIZE AND TYPE OF BIT: 60 in. Rock Auger

MANUFACTURER'S DESIGNATION OF DRILL: Hughes LDH-70

ELEVATION GROUND WATER: 1178.6 STANDING

ELEVATION TOP OF HOLE: 1211.8

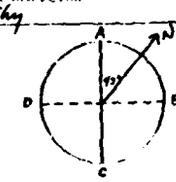
SIGNATURE OF INSPECTOR: Tim Sky

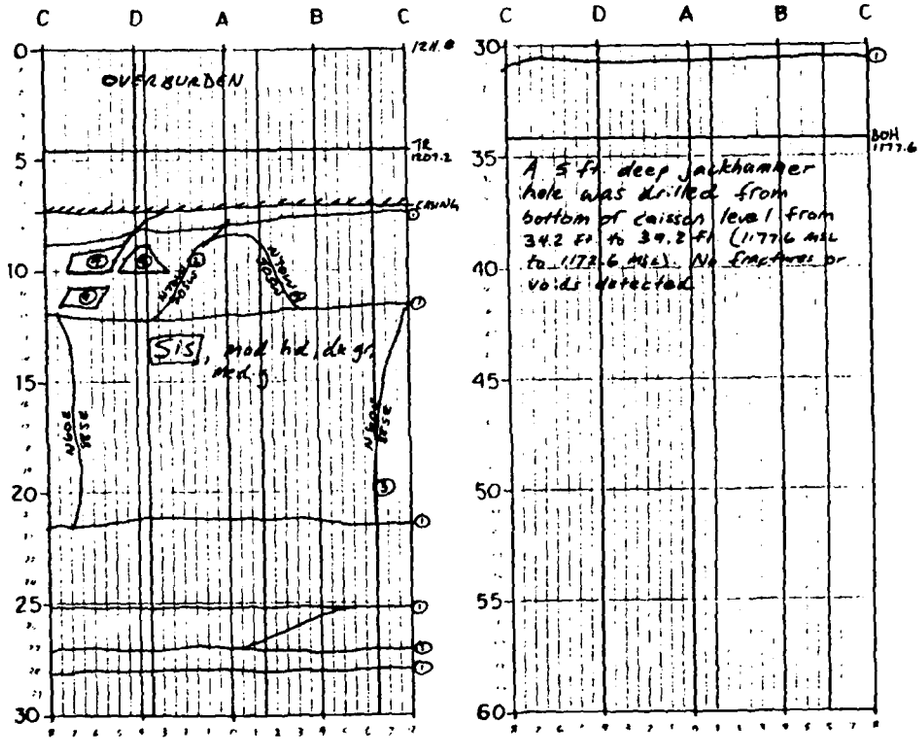
Caisson No.: CA2-2

Surface El: 1211.8

El TOR: 1207.2

BH: 1177.6





FEATURE NO.	DESCRIPTION
1	Bedding plane, fgr, B4, H4, W1, near horizontal
2	Fracture, C2, O1, T4, R2, HL4, M4, N70W, 50SW
3	Fracture, C2, O1, T4, R2, HL4, M4, N45E, 85SE
4	Splits to N45E, vertical face

REMARKS:

Line A-C is along caisson row alignment. Bearing: N 43° W

Groundwater: 1178.6 STANDING NO FLOW:

Drill Time:

Concrete Placed:

Plate H-13

2

DRILLING LOG	DIVISION ORD
1 PROJECT: HARLAN DIVERSION PROJECT	
2 LOCATION: Highway 38 Bridge Abutment No. 2	
3 DRILLING AGENCY: Hayes	
4 HOLE NO. (As shown on drawing) and file number: A 2-3	
5 NAME OF DRILLER	
6 DIRECTION OF HOLE: (X) VERTICAL ( ) INCLINED	DEG. FROM VERT.
7 THICKNESS OF OVERBURDEN: 9.0	
8 DEPTH DRILLED INTO ROCK: 31.1	
9 TOTAL DEPTH OF HOLE: 40.1	

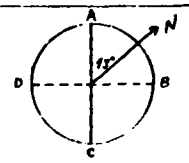
INSTALLATION: NED	SHEET 1 OF 1 SHEETS
10 SIZE AND TYPE OF BIT	
11 DATUM FOR ELEVATION SHOWN (MSL)	
12 MANUFACTURER'S DESIGNATION OF DRILL	
13 TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	UNDISTURBED: — DISTURBED: —
14 TOTAL NUMBER CORE BOXES	—
15 ELEVATION GROUND WATER	1184.7 FLOWING
16 DATE HOLE: STARTED	7/24/91
17 ELEVATION TOP OF HOLE	1211.2
18 TOTAL CORE RECOVERY FOR BORING	
19 SIGNATURE OF INSPECTOR	

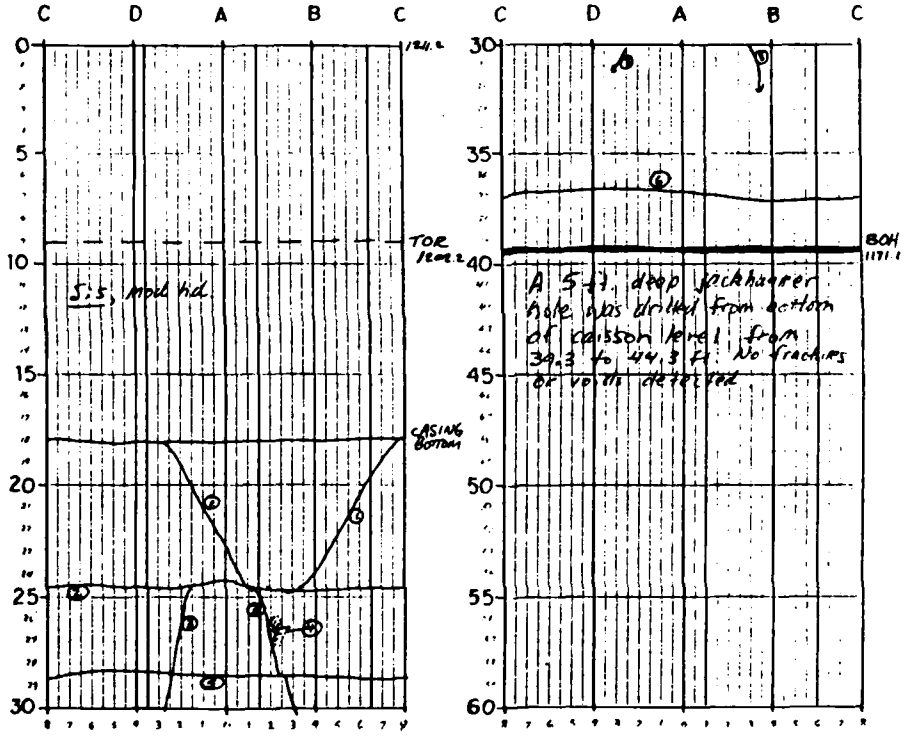
Caisson No.: CA2-3

Surface El: 1211.2

El TOR: 1202.2

BH 1171.1





FEATURE NO.	DESCRIPTION
①	JOINT, N40W 70°NE, c2, o3, T4, R1, NLN. MS
②⑤⑥	BEDDING PLANE, MORE HORIZONTAL, B4 s.sh, l gry, c grn, g'ness above plane
③	JOINT, N50E, 85°NW, c2, o3, T4, R1, NLV MG (see ⑤ below)
④	WATER FLOW POINT - 12 gal/min.

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: 1184.7 FLOWING

Drill Time: _____

Concrete Placed: 7-30-91

Plate H-14

A2-4

DRILLING LOG

PROJECT: HARLAN DIVERSION PROJECT

LOCATION: Highway 38 Bridge Abutment No. ...

DRILLING AGENCY: Hayes

HOLE NO. (As shown on drawing title and file number): A2-4

NAME OF DRILLER:

DIRECTION OF HOLE: Vertical (Inclined) ... DEG. FROM VERT.

THICKNESS OF OVERBURDEN: 17.1

DEPTH DRILLED INTO ROCK: 25.0

TOTAL DEPTH OF HOLE: 42.1

DIP OF ROCK SURFACE: 60° Rock Augr

ELEVATION GROUND WATER: 1170.7

DATE HOLE: ... ELEVATION TOP OF HOLE: 1210.8

TOTAL CORE RECOVERY FOR BORING: —

SIGNATURE OF INSPECTOR: Abel A. Ross

MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70

TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: —

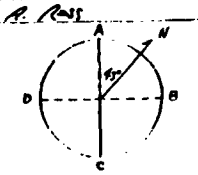
TOTAL NUMBER CORE BOXES: —

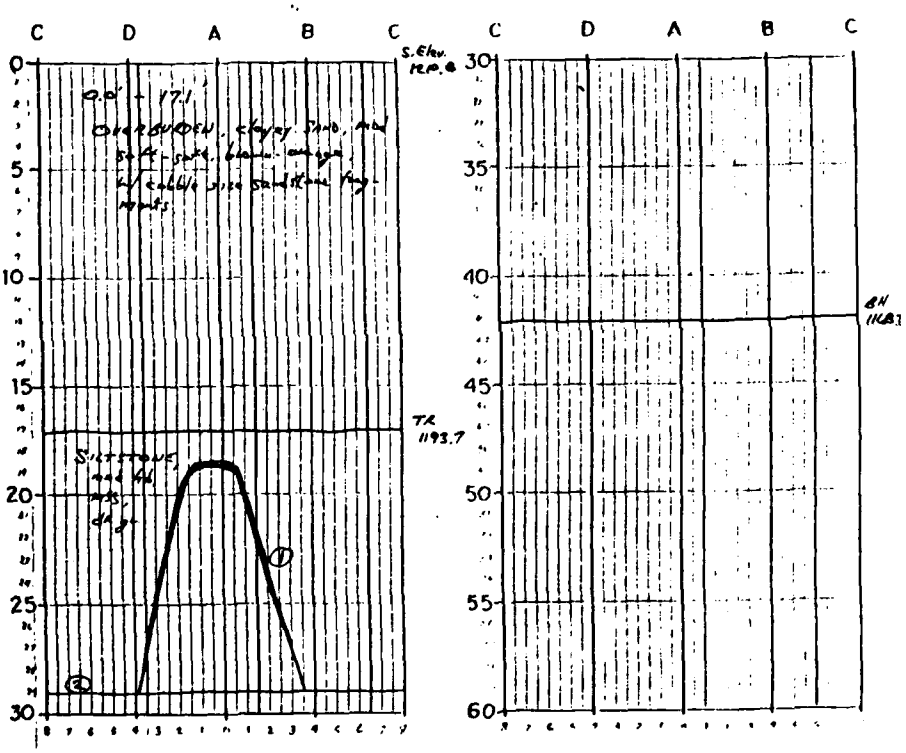
Caisson No.: A2-4

Surface El: 1210.8

El TOR: 1193.7

BH 1168.7





FEATURE NO.	DESCRIPTION
①	Joint N60E, 65 SE, Oxid, T 2-5 (up to 0.6 ft. 20 cly, silt frags), RS, HL4, MS
②	Bdd plane, Oxid, T4, RS, HL4, MS, ~ horiz

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: 1170.7

Drill Time: ...

Concrete Placed: ...

Plate H-15

Hole No. CA 2-5

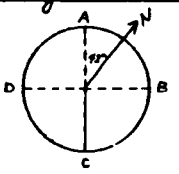
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. ____		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70	
4. HOLE NO. (As shown on drawing title and file number): A 2-5		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED – UNDISTURBED –	
5. NAME OF DRILLER: SHERMAN		14. TOTAL NUMBER CORE BOXES: –	
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER: NONE	
7. THICKNESS OF OVERBURDEN: 18.0		16. DATE HOLE: STARTED ____ COMPLETED ____	
8. DEPTH DRILLED INTO ROCK: 17.9		17. ELEVATION TOP OF HOLE: 1211.0	
9. TOTAL DEPTH OF HOLE: 35.9		18. TOTAL CORE RECOVERY FOR BORING: – %	
		19. SIGNATURE OF INSPECTOR: Ian Shy	

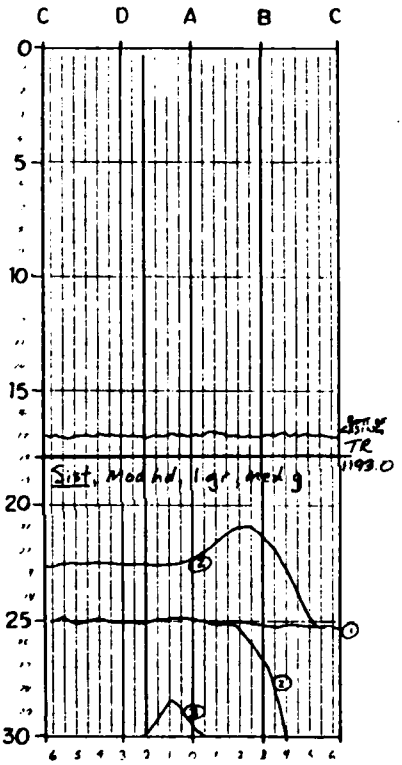
Caisson No.: CA2-5

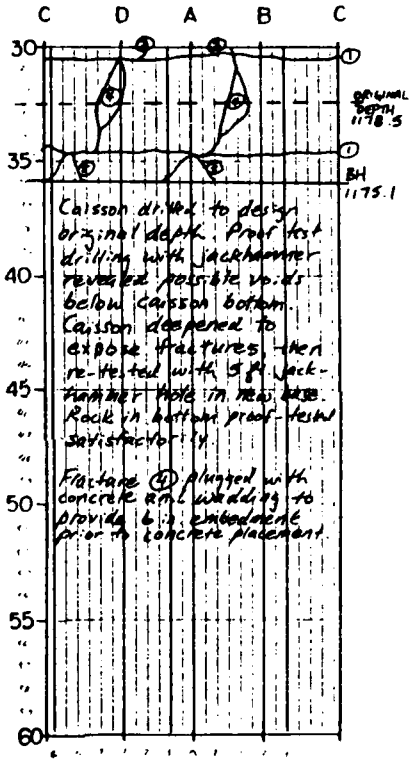
Surface El: 1211.0

El TOR: 1193.0

BH 1175.1







FEATURE NO.	DESCRIPTION
1	Bedding planes, B4, lgr
2	Fractures, C2, OB, T3, R4, HL4, M2, N60W, 75SW
3	Joint face, N10W, 72 SW.
4	Fracture, C2, OS(1.6 ft), HL4, TB, R2, M2 N20E, 80 NW.
5	Fracture, C2, OB, T5, R4, HL4, M4, N25E, 75 NW.

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43°W

Groundwater: NONE

Drill Time: _____

Concrete Placed: _____

Plate H-16

A2-6

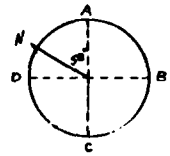
DRILLING LOG	Division: ORD	Installation: NED	Sheet 1 of 1 Sheets
1. Project: HARLAN DIVERSION PROJECT		10. Size and Type of Bit: 48" Rock Auger	
2. Location (Coordinates or Station): Highway 38 Bridge Abutment No. 2		11. Datum for Elevation Shown (TBM or MSL): MSL	
3. Drilling Agency: Hayes		12. Manufacturer's Designation of Drill: HUGHES LDH-70	
4. Hole No. (As shown on drawing title and file number): GA A2-6		13. Total No. of Overburden Samples Taken: Disturbed — Undisturbed —	
5. Name of Driller:		14. Total Number Core Boxes: —	
6. Direction of Hole: ☒ Vertical ☐ Inclined ____ deg. from vert.		15. Elevation Ground Water: —	
7. Thickness of Overburden: 14.8		16. Date Hole: Started — Completed 9-11-91	
8. Depth Drilled into Rock: 15.5		17. Elevation Top of Hole: 1211.07	
9. Total Depth of Hole: 30.5		18. Total Core Recovery for Boring: —	
		19. Signature of Inspector: Paul A. Ross	

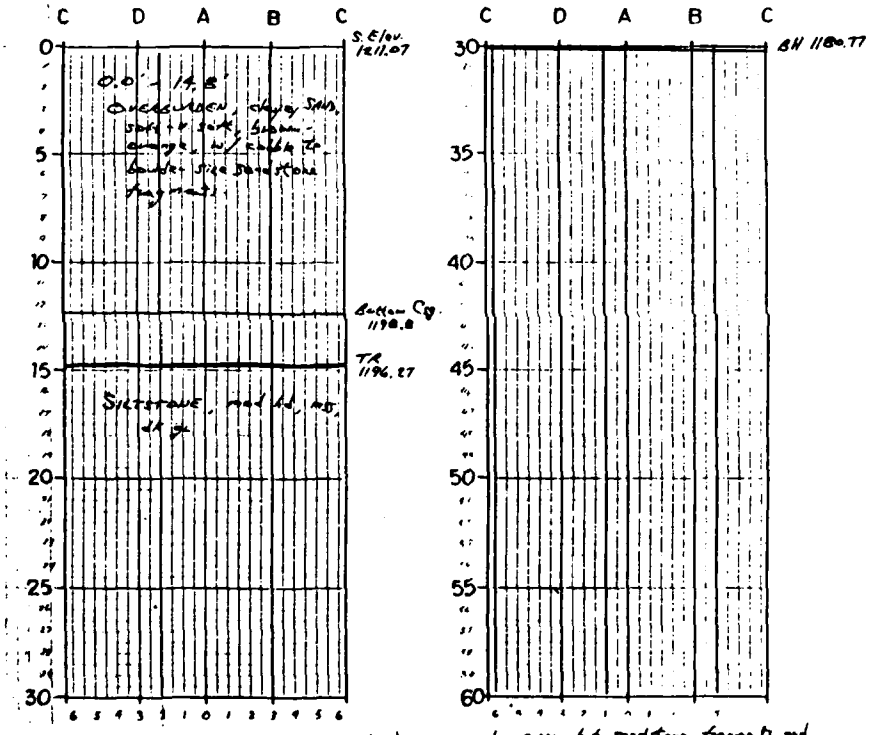
Caisson No.: A2-6

Surface El: 1211.07

El TOR: 1196.27

BH 1180.77





Note: Top of rock was erroneously called at 1199.55 when auger hit sandstone fragments, and drilling was stopped at elev 1181.27. Downhole inspection revealed TR to be 4 hours thru. called hole was deepened to provide minimum 15 ft rock embedment.

FEATURE NO.	DESCRIPTION

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N58E

Groundwater: _____

Drill Time: _____

Concrete Placed: _____

Plate H-17

(2)

DRILLING LOG	DIVISION: ORD
1. PROJECT: HARLAN DIVERSION PROJECT	
2. LOCATION: Highway 38 Bridge Abutment No. 2	
3. DRILLING AGENCY: Hayes	
4. HOLE NO.: A 2-7	
5. NAME OF DRILLER: SHERMAN	
6. DIRECTION OF HOLE: (X) VERTICAL ( ) INCLINED ____ DEG FROM VERT.	
7. THICKNESS OF OVERBURDEN: 7.7	
8. DEPTH DRILLED INTO ROCK: 17.8	
9. TOTAL DEPTH OF HOLE: 25.5	

INSTALLATION: ORD — SHEET 1 OF 1 SHEETS

11. RATING FOR ELEVATION GIVEN: MSL
13. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70
14. TOTAL NO. OF OVERBURDEN AND ROCK SAMPLES TAKEN: — — —
15. TOTAL NUMBER CORE BOXES: —
16. ELEVATION GROUND WATER: NONE
17. ELEVATION TOP OF HOLE: 1211.1
18. TOTAL CORE RECOVERY FOR BORING: —
19. SIGNATURE OF INSPECTOR: Tom Sky

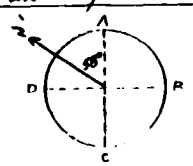
A2-1

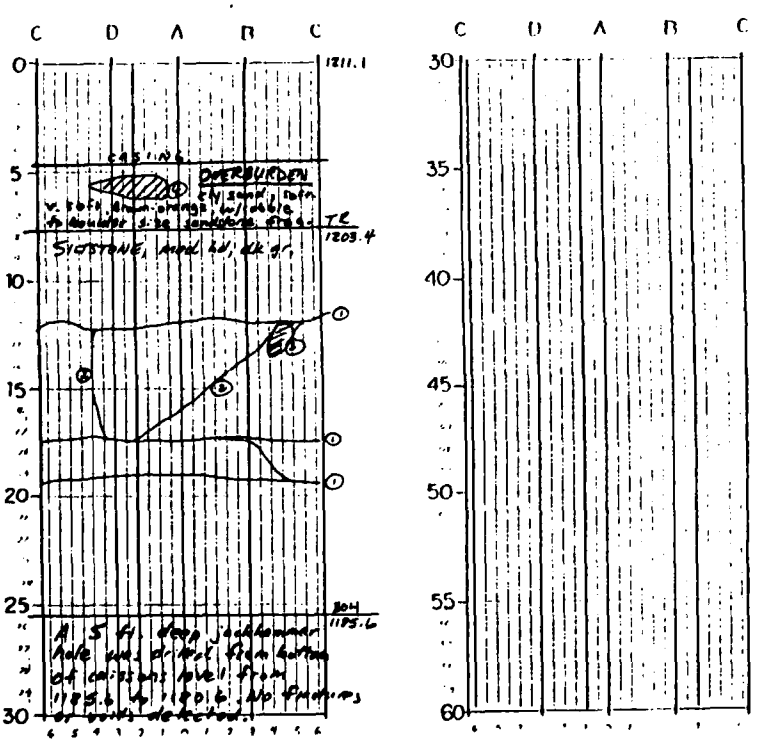
Caisson No.: A2-7

Surface El: 1211.1

El TOR: 1203.4

BoH 1185.6





FEATURE NO.	DESCRIPTION
1	Bedding, planes, BA, lgr.
2	Fracture, CB, OB, TS, R4, HL4, A8, NOSW, SOME
3	Earth fill, wet, dry
4	SS boulder in overburden.

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N5B E

Groundwater: NONE

Drill Time: ____

Concrete Placed: ____

Plate H-18

A2-8

DRILLING LOG	DIVISION: ORD
1. PROJECT: HARLAN DIVERSION PROJECT	
2. LOCATION: Highway 38 Bridge Abutment No.	
3. DRILLING AGENCY: Hayes	
4. HOLE NO.: BA 2-8	
5. NAME OF DRILLER: SHERMAN	
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED	
7. THICKNESS OF OVERBURDEN: 11.5	
8. DEPTH DRILLED INTO ROCK: 16.0	
9. TOTAL DEPTH OF HOLE: 27.5	

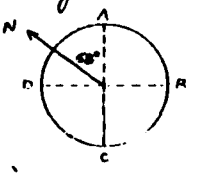
INSTALLATION: ORD	SHEET 1 OF 1 SHEETS
10. SIZE AND TYPE OF BIT:	
11. DATUM FOR ELEVATION SHOWN: MSL	
12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH 70	
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN:	
14. TOTAL NUMBER CORE BOXES:	
15. ELEVATION GROUND WATER: NONE	
16. DATE HOLE: STARTED / COMPLETED	
17. ELEVATION TOP OF HOLE: 1212.5	
18. TOTAL CORE RECOVERY FOR BORING:	
19. SIGNATURE OF INSPECTOR: Tom Shy	

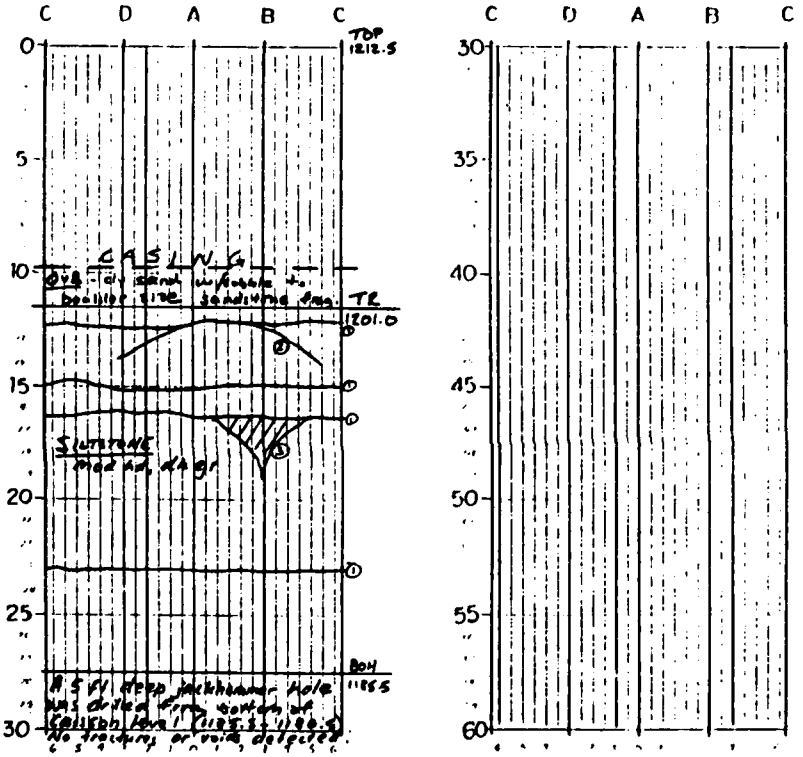
Caisson No.: A2-8

Surface El: 1212.5

El Top: 1201.0

BOH 1185.5





FEATURE NO.	DESCRIPTION
1	Bedding planes, BH, 1gr, Abar horizontal
2	Fracture, N5W, 80SW, C2, OB, T3, R4, NLH, IN2.
3	Ch fms, OB, WY, NLH

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N58E

Groundwater: NONE

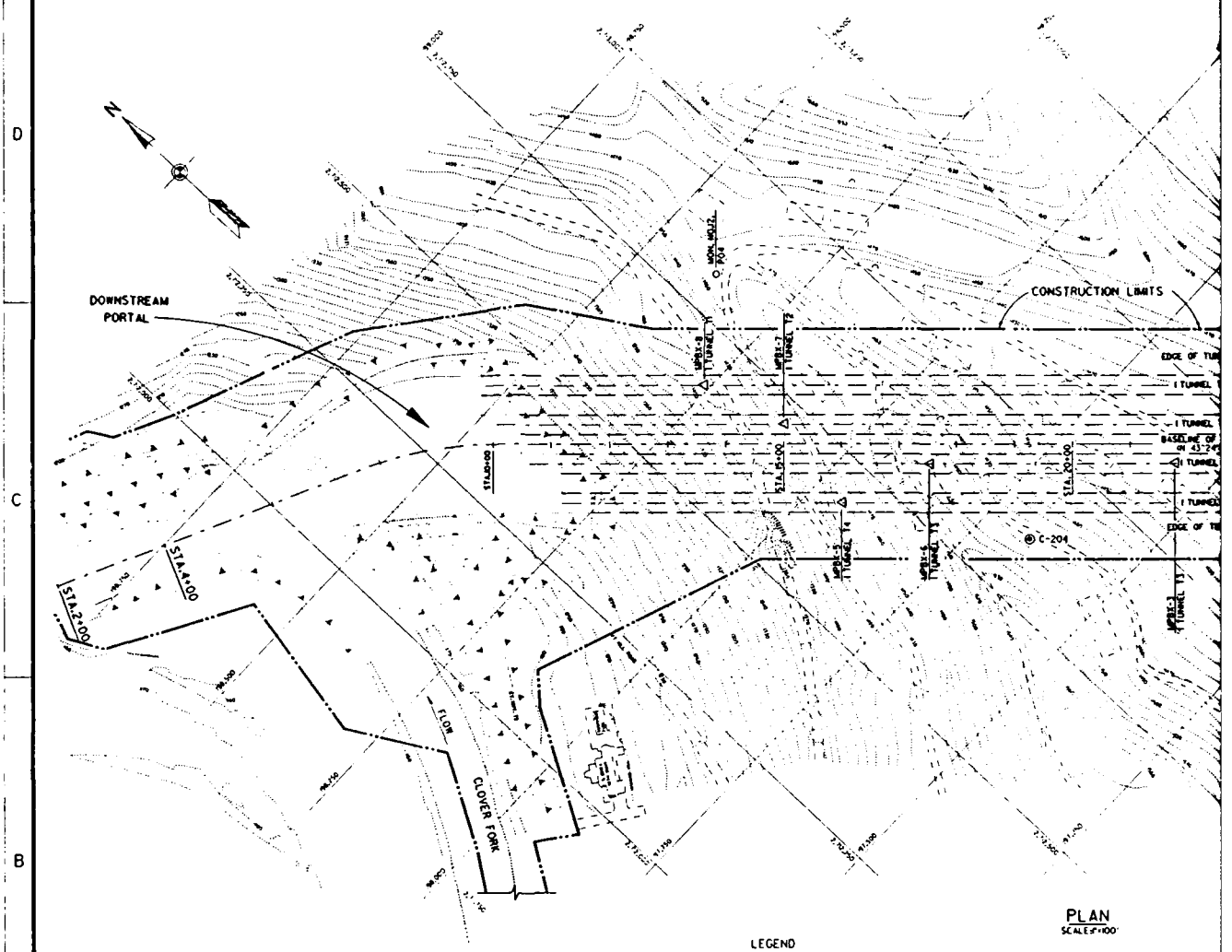
Drill Time: _____

Concrete Placed: _____

Plate H-19

Appendix I - Instrumentation

Plate No.	Drawing No.	Description
I-1	Q1A-64/79.1	Plan
I-2	Q1A-64/80.3	Section and Details
I-3 thru 11	-----	Locations
I-12 thru 23	----	MPBX's
I-23	---------	Observation Well
I 24 thru 31	----	Load Cells
I 32 thru 40	----	Tape Extensometers
I 41 thru 48	----	SPBX's



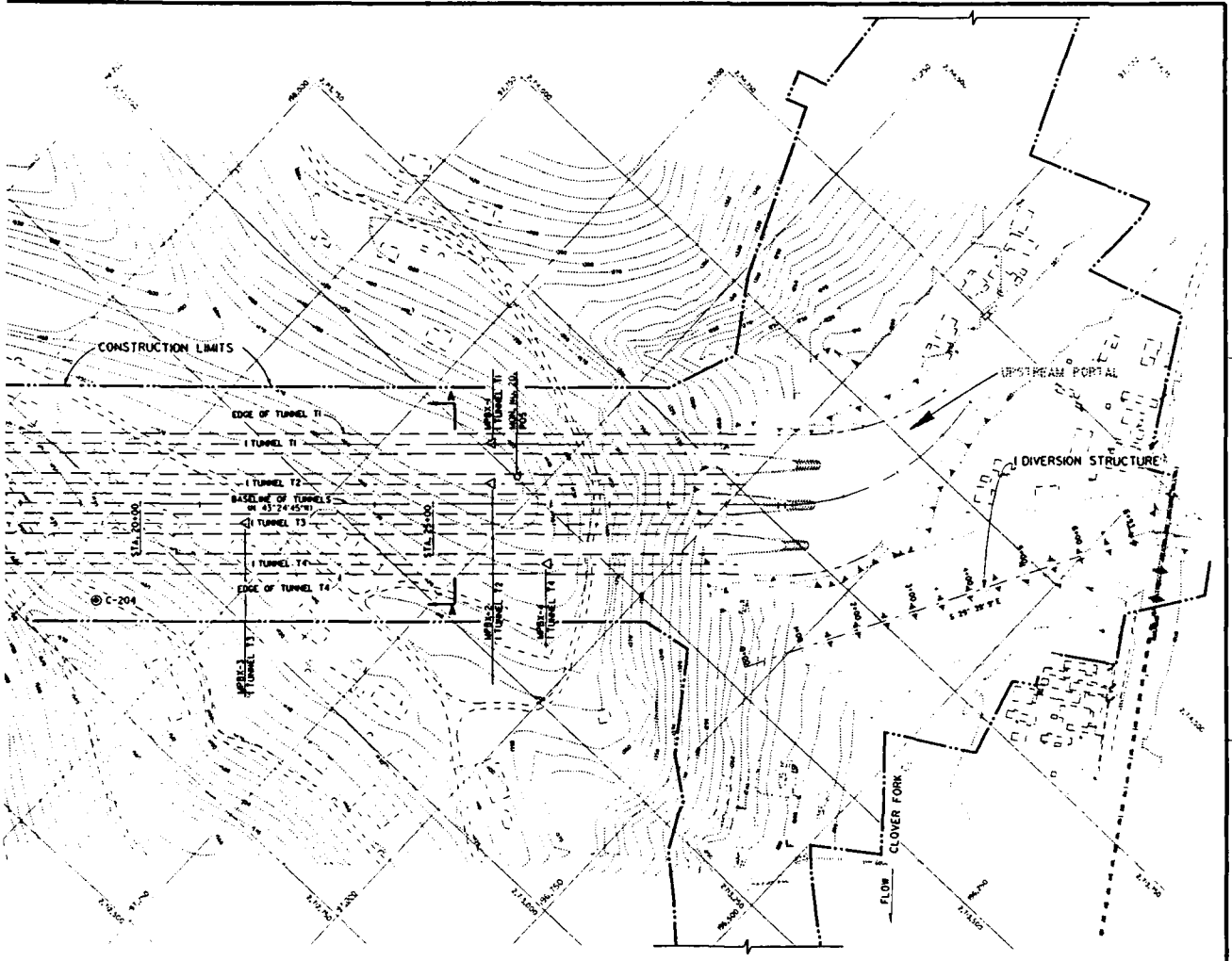
PLAN
SCALE: 1"=100'

LEGEND

- ◉ - EXISTING OBSERVATION WELL (C-204) HAVE A 3-INCH DIAMETER PVC PLASTIC RISER PIPE.
- ▽ - EXISTING (MPBX) EXTENSOMETERS (MPBX - 1 THRU MPBX-8).
- — - TAPE EXTENSOMETER (LOCATIONS NOT SHOWN).
- ○ - EXISTING MONUMENTS (MON. NO. 12, P04 & MON. NO. 20, P05).

NOTES:

1. ALL INSTRUMENTS SHALL BE INSTALLED BY THE CONTRACTOR, EXCEPT FOR THE OBSERVATION WELL AND THE (MPBX) EXTENSOMETER WHICH WERE INSTALLED BY THE GOVERNMENT.
2. ALL INSTRUMENTATION SHALL BE PROTECTED AND READ BY THE CONT THROUGHOUT THE DURATION OF THE CONTRACT. A PROTECTIVE HOUS SHALL BE PROVIDED FOR EACH INSTRUMENT.
3. SEE DWG. NO. 01A-64/80 FOR INSTRUMENTATION SECTION AND DETAILS OF INSTRUMENTS.
4. THE (MPBX) EXTENSOMETERS LOCATIONS ARE APPROXIMATE.
5. LOCATIONS OF THE (SPBX) EXTENSOMETERS, ROCK BOLT LOAD CELLS AND (Tx) TAPE EXTENSOMETERS ARE NOT SHOWN. SEE DWG. NO. 01A-64/80.
6. FINAL LOCATIONS OF INSTRUMENTS MAY BE CHANGED FROM THOSE SHOWN DUE TO GEOLOGIC CONDITIONS.



PLAN
SCALE: 1"=100'

WELL (C-204) HAVE A 3-INCH
RISER PIPE.
OMETERS (MPBX - 1 THRU MPBX-8) .
OCATIONS NOT SHOWN).
ION. NO. 12, P04 & MON. NO. 20, P05) .

BE INSTALLED BY THE CONTRACTOR.
ATION WELL AND THE (MPBX) EXTENSOMETERS.
Y THE GOVERNMENT.

ALL BE PROTECTED AND READ BY THE CONTRACTOR
ON OF THE CONTRACT. A PROTECTIVE HOUSING
EACH INSTRUMENT.

FOR INSTRUMENTATION SECTION AND

RS LOCATIONS ARE APPROXIMATE.

) EXTENSOMETERS, ROCK BOLT
PE EXTENSOMETERS ARE NOT SHOWN.

TRUMENTS MAY BE CHANGED
TO GEOLOGIC CONDITIONS.

Revisions	Date	Description	By	Checked
J	5-31-89	CONFORMING TO REVIEW COMMENTS	W.L.	C.E.D.

100' 0 100
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Designed By: C.E.D.A.V.
Drawn By: LYLA LEAS
Traced By:
Checked By:

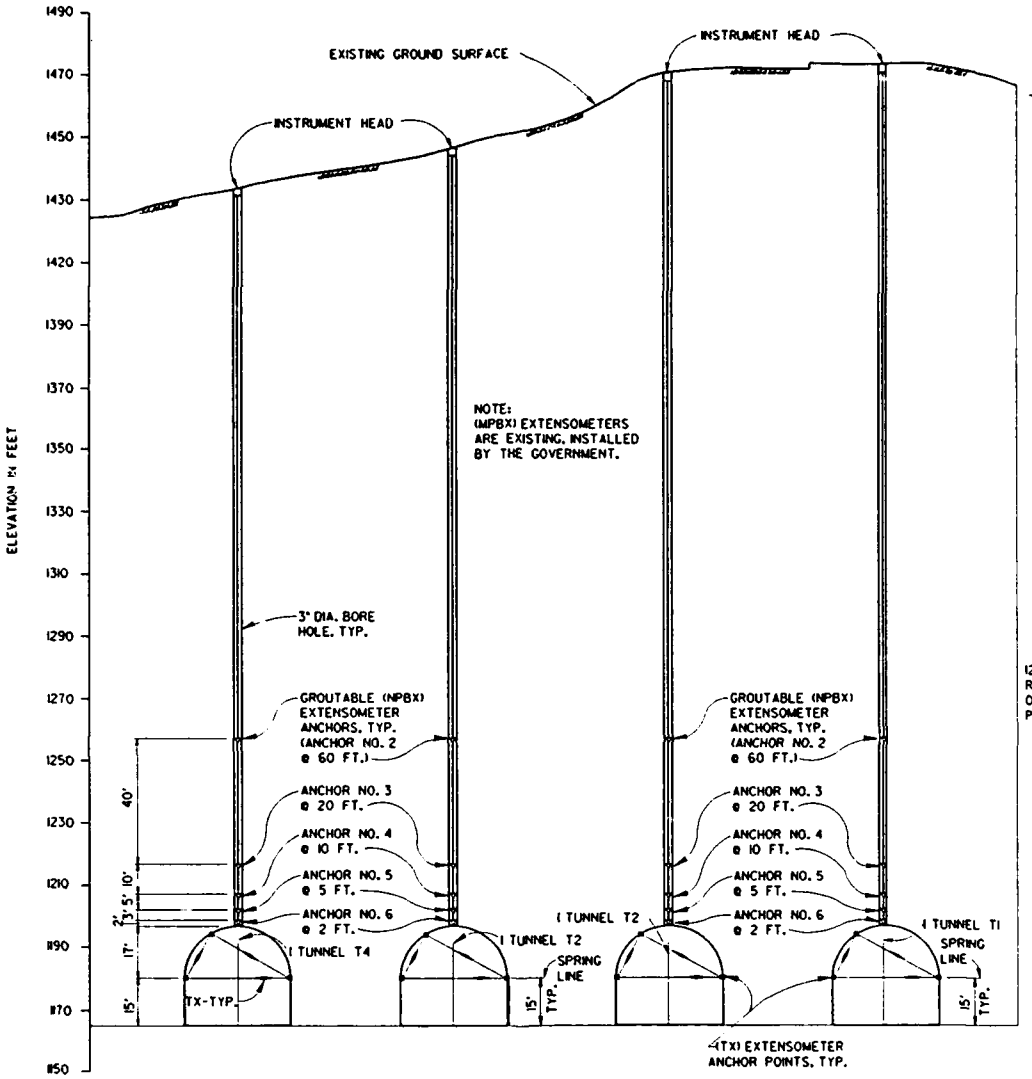
CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
WOLF CREEK DAM
MARTINSVILLE
DIVERSION TUNNELS

INSTRUMENTATION PLAN

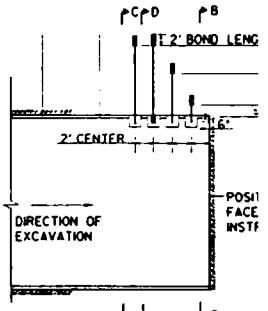
Sheet
Drawing Number: 01A-64/79 J

COMPUTER AIDED DESIGN & DRAFTING

PLATE I-1

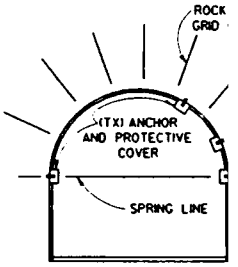


SECTION A - A



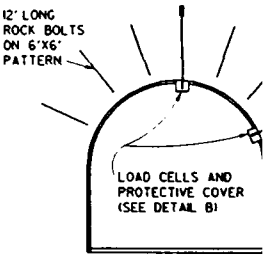
TUNNEL I PROFI

(NOT TO SCALE)



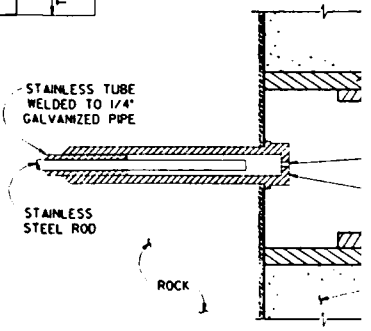
SECTION B-B TYPIC
TAPE EXTENSOMET
ANCHOR LAYOUT

(NOT TO SCALE)



SECTION D-D TYPICAL
BOLT LOAD CELL L

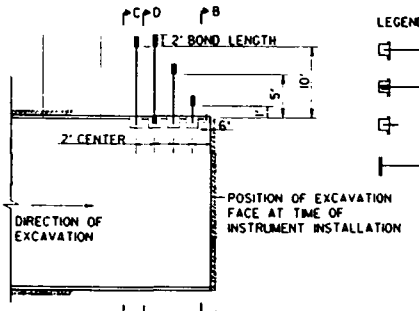
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DETAIL

(SPBX) EXTEN

(NOT TO SC

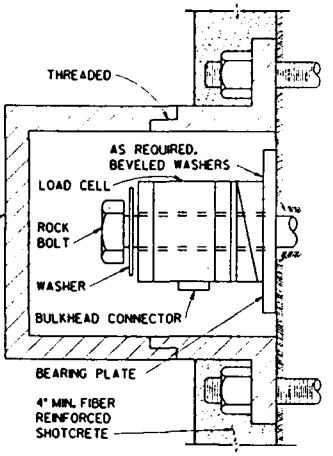


TUNNEL I PROFILE

(NOT TO SCALE)

LEGEND

- SINGLE POINT BOREHOLE EXTENSOMETER (SPBX) WITH PROTECTIVE COVER
- INSTRUMENTED ROCK BOLT WITH LOAD CELL AND PROTECTIVE COVER
- (TX) TAPE EXTENSOMETER ANCHOR WITH PROTECTIVE COVER
- FULLY GROUTED PRODUCTION ROCK BOLT

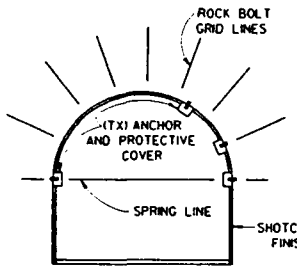


DETAIL B

ROCK BOLT LOAD CELL

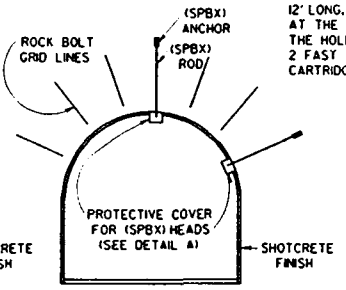
(NOT TO SCALE)

NOTE:
ROCK BOLT SHALL BE 12' LONG, ANCHORED AT THE BOTTOM OF THE HOLE, WITH 2 FAST SET RESIN CARTRIDGES.



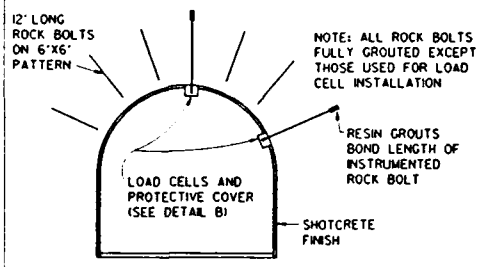
SECTION B-B TYPICAL TAPE EXTENSOMETER ANCHOR LAYOUT

(NOT TO SCALE)



SECTION C-C TYPICAL (SPBX) LAYOUT

(NOT TO SCALE)

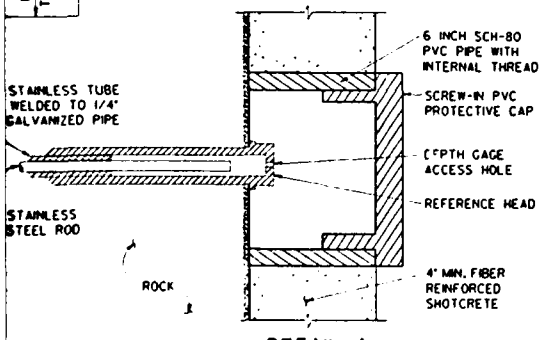


SECTION D-D TYPICAL ROCK BOLT LOAD CELL LAYOUT

(NOT TO SCALE)

NOTES:

1. THE CONTRACTOR SHALL PROTECT THE (SPBX) EXTENSOMETERS REFERENCE HEADS, ROCK BOLT LOAD CELLS, AND (TX) TAPE EXTENSOMETER ANCHOR POINTS FROM BLAST, MECHANICAL, OR OTHER DAMAGE AS A RESULT OF CONSTRUCTION ACTIVITY, AND FROM BEING COVERED WITH SHOTCRETE.
2. INSTRUMENTS AND PROTECTIVE COVERS SHALL BE INSTALLED BEFORE SHOTCRETE IS APPLIED BY THE CONTRACTOR.
3. THE CONTRACTOR SHALL TAKE THE PRECAUTION, WHEN PLACING SHOTCRETE, TO PREVENT THE (SPBX) PROTECTIVE CAPS FOR THE (SPBX) EXTENSOMETERS, THE (TX) TAPE EXTENSOMETER ANCHOR POINTS, AND THE LOAD CELLS FROM BEING COVERED WITH SHOTCRETE.
4. ALL PROTECTIVE CAPS SHALL BE KEPT ON WHEN THE INSTRUMENTS ARE NOT BEING READ.
5. THE LOCATION OF INSTRUMENTS IS GIVEN ON DWG. NO. 01A-64/79 AND IN THE SPECIFICATIONS.
6. FIVE ARRAYS, AS SHOWN IN THE TUNNEL I PROFILE, SECTIONS B-B, C-C AND D-D, CONSISTING OF 6 (SPBX) EXTENSOMETERS, 4 (TX) TAPE EXTENSOMETER ANCHOR POINTS, AND 2 ROCK BOLT LOAD CELLS TO BE WITHIN THE FIRST 1000 FEET OF TUNNELING AT LOCATIONS DIRECTED BY CONTRACTING OFFICER. ONE OF THESE ARRAYS TO BE LOCATED AT THE SAME STATION AS THE (MPBX) EXTENSOMETER, SEE DWG. NO. 01A-64/79.
7. 16 LOAD CELLS SHALL BE INSTALLED ON ROCK BOLTS DESIGNATED BY THE CONTRACTING OFFICER.



DETAIL A

(SPBX) EXTENSOMETER

(NOT TO SCALE)

NOTE:
THE PROTECTIVE PVC CAP AS SHOWN FOR THE (SPBX) EXTENSOMETERS SHALL BE THE SAME PROTECTIVE PVC CAP FOR THE (TX) TAPE EXTENSOMETERS, A 6-INCH SCH-80 PVC PIPE WITH A SCREW-IN PVC PROTECTIVE CAP. SEE DETAIL A.

Revisions	Date	Description	By	Checked
.3	2-3-94	AS CONSTRUCTED	S.B.D.	
.2	29 JUN 89	DELETED NOTE 6 & RENAME NOTES 7 & 8.	B.F.	CED
.1	31 MAY 89	CONFORMING TO REVIEW COMMENTS	LEWIS	CED

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

INSTRUMENTATION SECTION & DETAILS

Designed By: C. E. DAVIS	Date: MAY 1989
Drawn By: LYLA LEWIS	Scale:
Checked By: Charles E. Davis	Sheet of
Approved By: CHIEF, GEOTECHNICAL BRANCH	Drawing Number: 01A-64/80.3
FILE: 01A64B80.DGN	Record Drawing as constructed dated

COMPUTER AIDED DESIGN & DRAFTING — SOILS SECTION

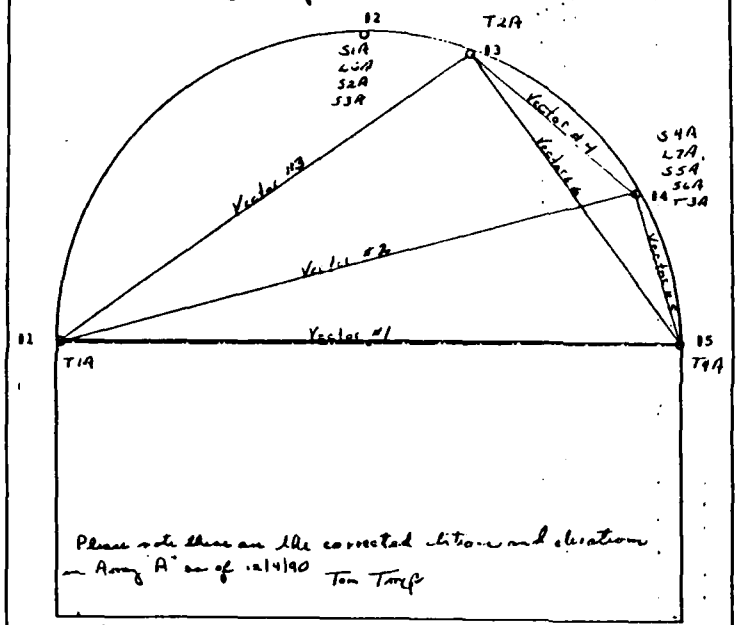
PLATE I-2

01 DEC 90

INSTRUMENTATION ARRAY LOCATION

Date Installed: 9/24/90 Project: Harlan Diversion

Person Installed: Bill Jumbawy Contractor: Grassetto-Incisa



Please note these are the corrected station and elevation on Array "A" as of 12/4/90 Tom Trapp

TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	10+83	1176.2
3	10+83	1187.7
4	10+83	1179.2
5	10+83	1171.2
LOAD CELL POSITIONS		
Location	Station	Elevation
2	10+77	1188.17
4	10+77	1179.17

TUNNEL# 1
STATION 10+77
ARRAY A

SPRX POSITIONS		
Location	Station	Elevation
2	10+75	1188.15
3	10+79	1188.19
2	10+81	1188.21
4	10+75	1179.15
4	10+79	1179.19
4	10+81	1179.21

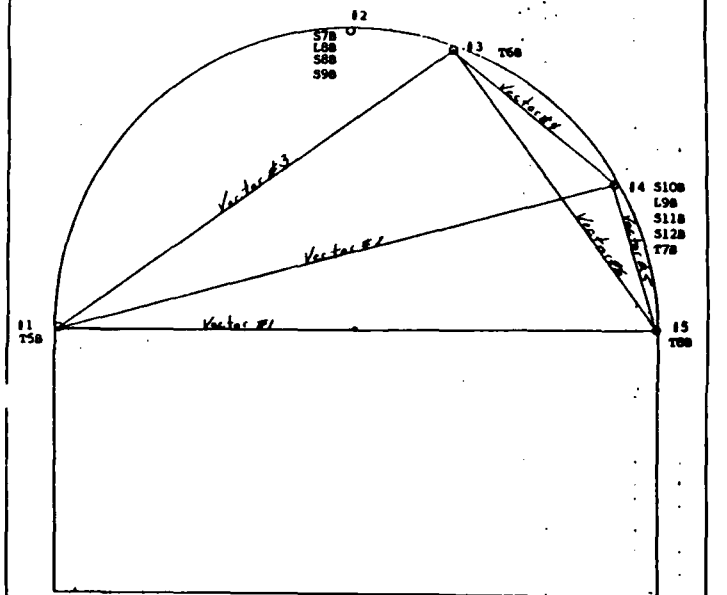
PLATE I-3

01 NOV 90

INSTRUMENTATION ARRAY LOCATION

Date Installed: 10/27/90 Project: Harlan Diversion

Person Installed: Tom Trapp Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	13+72.5	1171.99
3	13+72.5	1188.69
4	13+72.5	1180.99
5	13+72.5	1172.99
LOAD CELL POSITIONS		
Location	Station	Elevation
2	13+67	1189.95
4	13+67	1180.99

TUNNEL# 1
STATION 13+67
ARRAY B

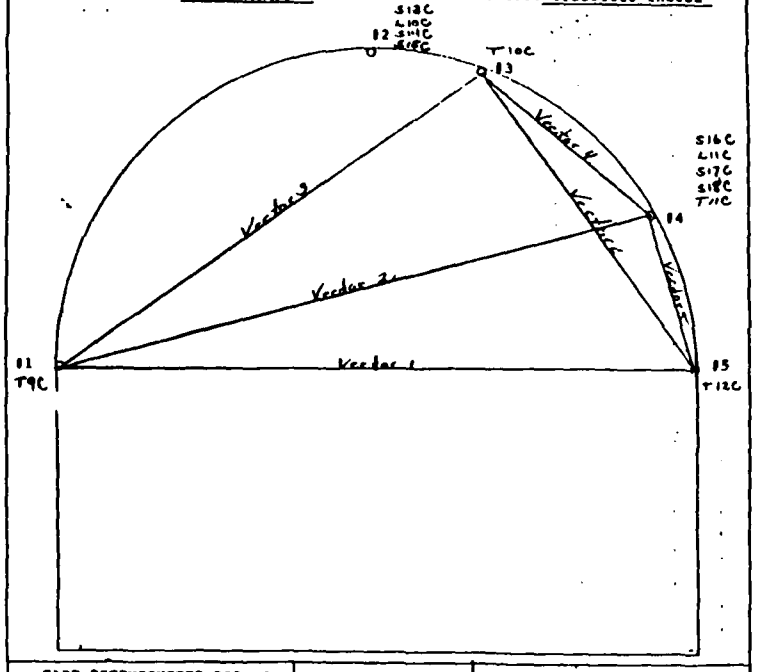
SPRX POSITIONS		
Location	Station	Elevation
2	13+65	1189.94
2	13+69	1189.96
2	13+71	1189.98
4	13+65	1180.94
4	13+69	1180.96
4	13+71	1180.98

PLATE I-4

INSTRUMENTATION ARRAY LOCATION

Date Installed: 11/4/90 Project: Marian Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Indisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	16+03.5	1176.41
3	"	1180.11
4	"	1182.41
5	"	1176.41
LOAD CELL POSITIONS		
Location	Station	Elevation
2	15+98	1191.37
4	15+98	1182.37

TUNNEL 1
STATION 15+98
ARRAY C

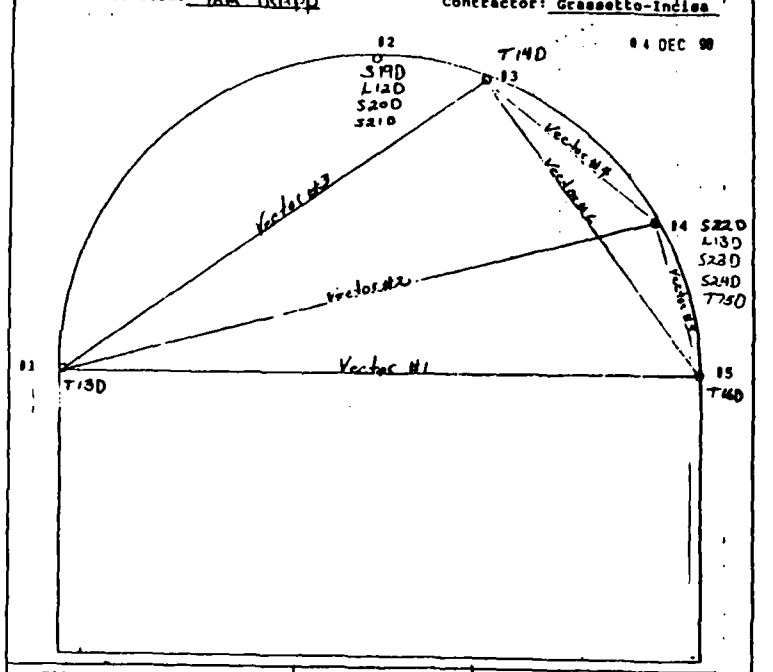
SPBX POSITIONS		
Location	Station	Elevation
2	15+96	1191.36
2	16+00	1192.38
2	16+02	1191.41
4	15+96	1182.36
4	16+00	1182.38
4	16+02	1182.41

INSTRUMENTATION ARRAY LOCATION

Date Installed: 11/27/90 Project: Marian Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Indisa

04 DEC 90



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	114.31.5	1171.51
3	"	1178.41
4	"	1174.50
5	"	1171.51
LOAD CELL POSITIONS		
Location	Station	Elevation
2	11+26	1188.47
4	11+26	1179.47

TUNNEL 2
STATION 11+26
ARRAY D

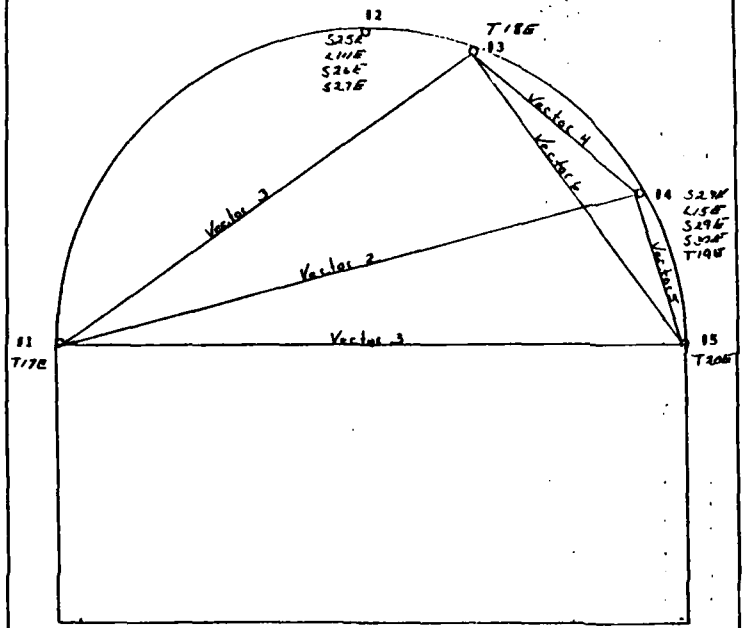
SPBX POSITIONS		
Location	Station	Elevation
2	11+24	1188.46
2	11+28	1188.47
2	11+30	1188.48
4	11+24	1179.46
4	11+28	1179.47
4	11+30	1179.48

18 DEC 90

INSTRUMENTATION ARRAY LOCATION

Date Installed: 12/6/90 Project: Harlan Diversion

Person Installed: Tom Trapp Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	18+78E	1176.07
3	18+78E	1192.77
4	18+73E	1184.07
5	18+73E	1176.07

LOAD CELL POSITIONS		
Location	Station	Elevation
2	18+68	1193.03
4	18+68	1184.03

TUNNEL# 1

STATION 18+68

ARRAY E

SPAN POSITIONS		
Location	Station	Elevation
2	18+66	1193.02
2	18+70	1193.04
2	18+72	1193.05
4	18+66	1184.02
4	18+70	1184.04
4	18+72	1184.05

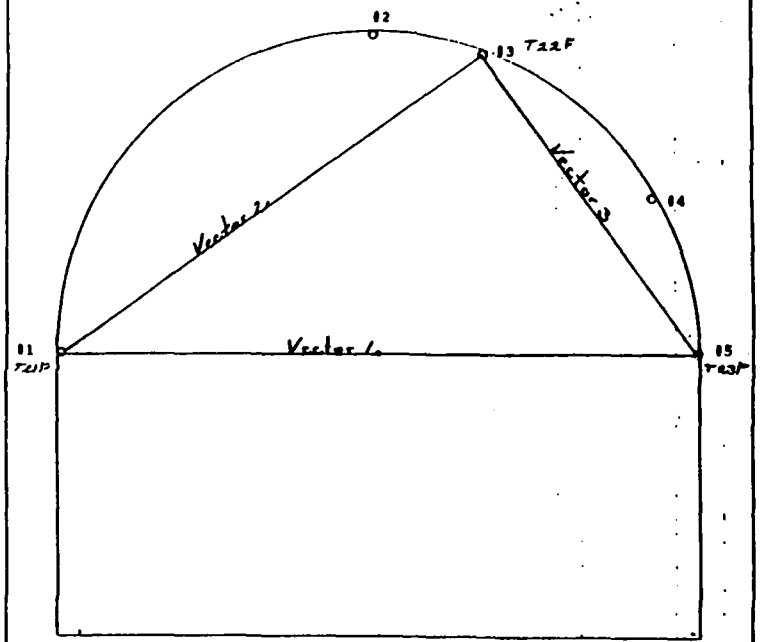
PLATE I-5

7 FEB 9

INSTRUMENTATION ARRAY LOCATION

Date Installed: 2/5/91 Project: Harlan Diversion

Person Installed: Tom Trapp Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	15+33	1173.98
3	15+33	1189.68
5	15+33	1173.98

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 2

STATION 15+33

ARRAY E

SPAN POSITIONS		
Location	Station	Elevation

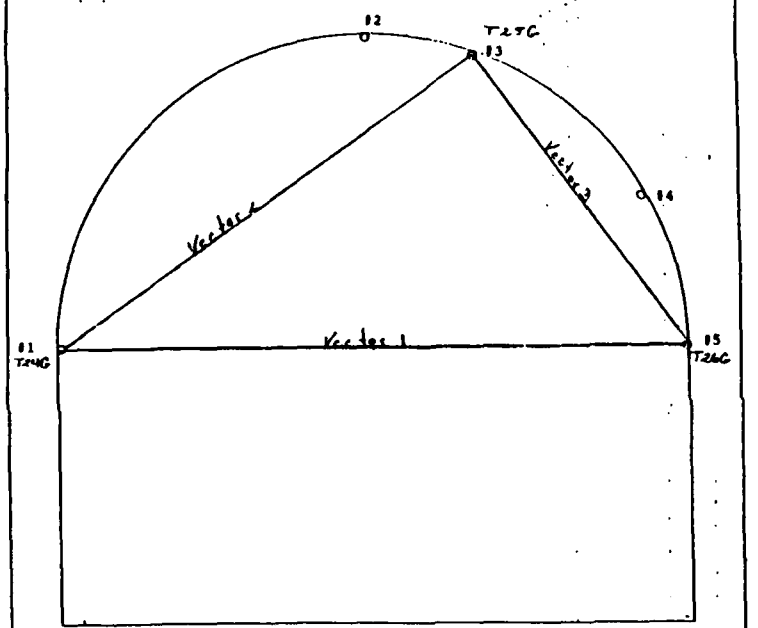
PLATE I-6

11 FEB 91

INSTRUMENTATION ARRAY LOCATION

Date Installed: 2/8/91 Project: Harlan Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	25+55	1180.3
3	25+55	1176.3
5	25+55	1180.3

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 1

STATION 25+55

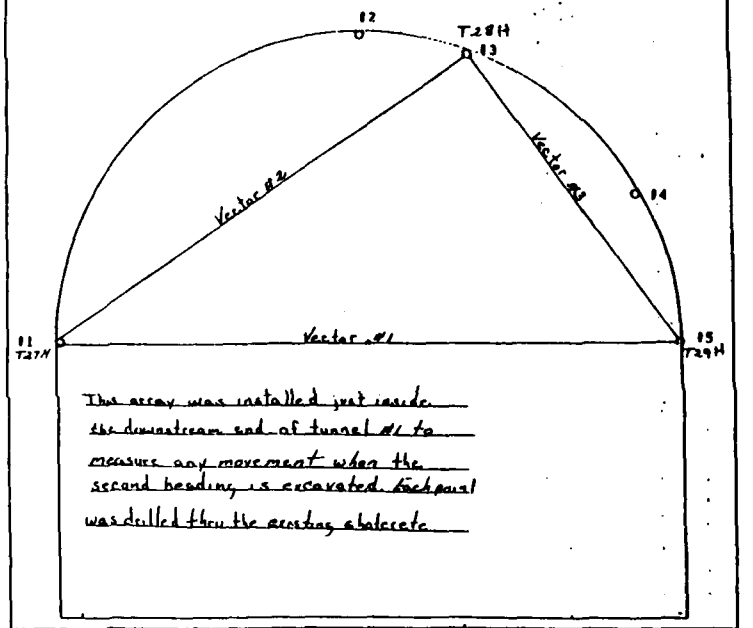
ARRAY G

SPRX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 2/13/91 Project: Harlan Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Incisa



This array was installed just inside the downstream end of tunnel #1 to measure any movement when the second heading is excavated. Each point was drilled thru the existing shotcrete.

TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	9+95	1170.6
3	9+95	1176.6
5	9+95	1170.6

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 1

STATION 9+95

ARRAY H

SPRX POSITIONS		
Location	Station	Elevation

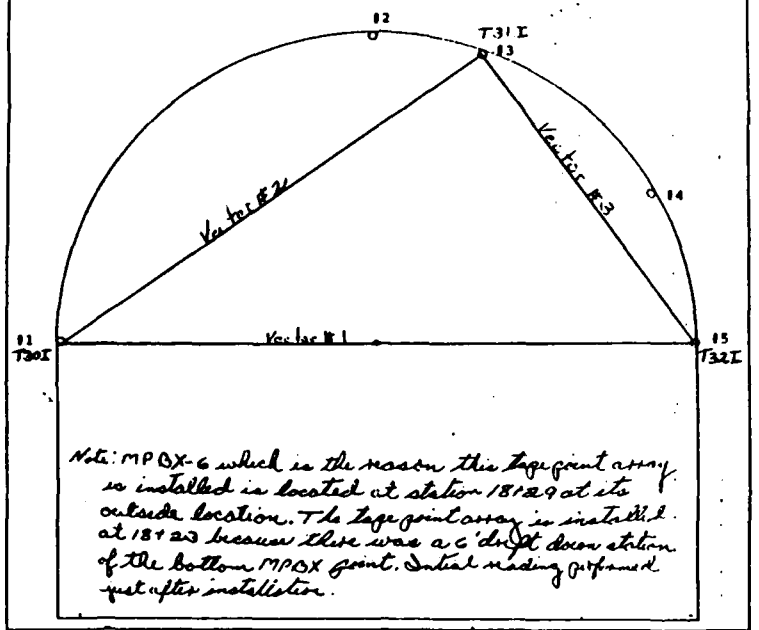
GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

INSTRUMENTATION ARRAY LOCATION 9 MAY 91

Date Installed: 5/7/90 Project: Marlan Diversion

Person Installed: T. Trapp/R. Fuqua/e Contractor: Grassetto-Incisa



Note: MPBX-6 which is the reason this tape point array is installed is located at station 18+29 at its outside location. The tape point array is installed at 18+23 because there was a conduit down station of the bottom MPBX point. Initial reading performed just after installation.

TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	18+23	1175.25
3	18+23	1174.65
5	18+23	1175.25

LOAD CELL POSITIONS		
Location	Station	Elevation
—	—	—
—	—	—

TUNNEL# 3

STATION 18+23

ARRAY I

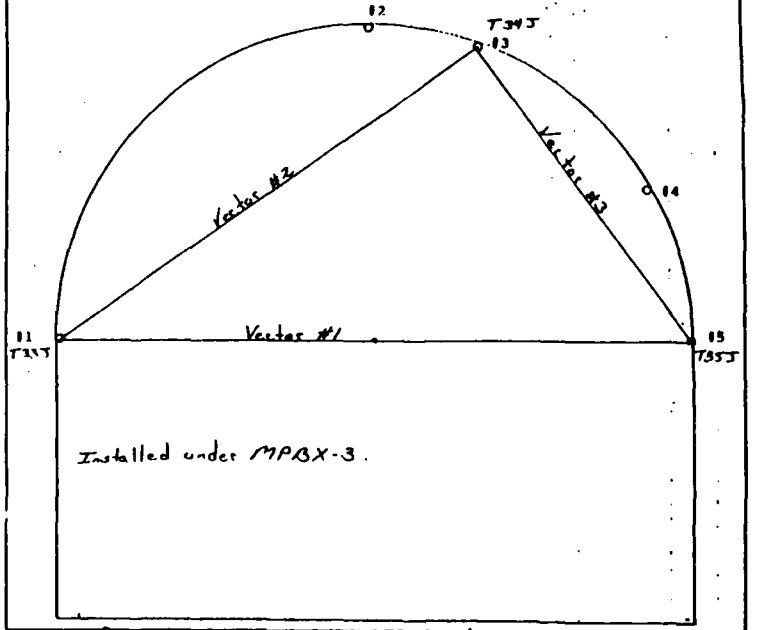
SPRX POSITIONS		
Location	Station	Elevation
—	—	—
—	—	—
—	—	—
—	—	—
—	—	—
—	—	—

3 JUL 91

INSTRUMENTATION ARRAY LOCATION

Date Installed: 6/8/91 Project: Marlan Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Incisa



Installed under MPBX-3.

TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	22+11	1178.05
3	22+11	1178.15
5	22+11	1178.15

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 3

STATION 22+10

ARRAY J

SPRX POSITIONS		
Location	Station	Elevation

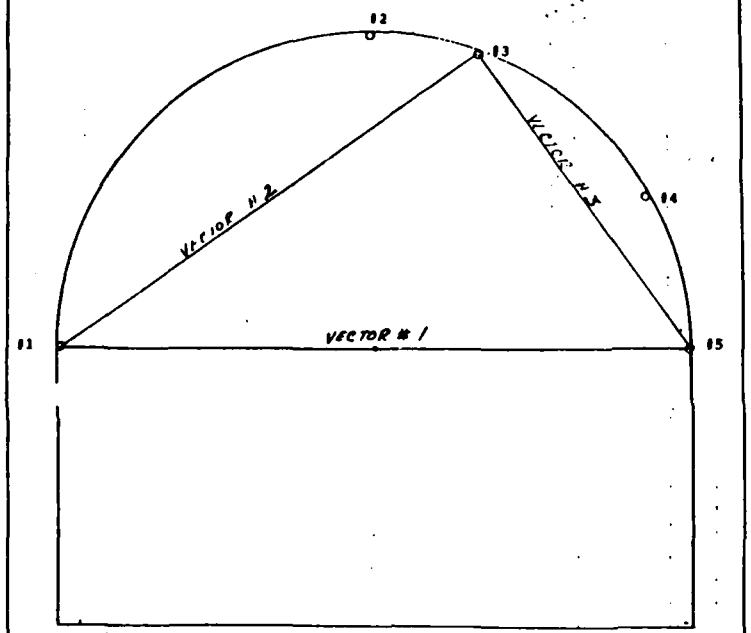
PLATE I-7

PLATE I-8

INSTRUMENTATION ARRAY LOCATION

Date Installed: 8-11-91 Project: Marian Diversion

Installed: Jim Osborne Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	11+36	1171.33
3	11+36	1187.43
5	11+36	1187.43

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL # 3

STATION 11+36

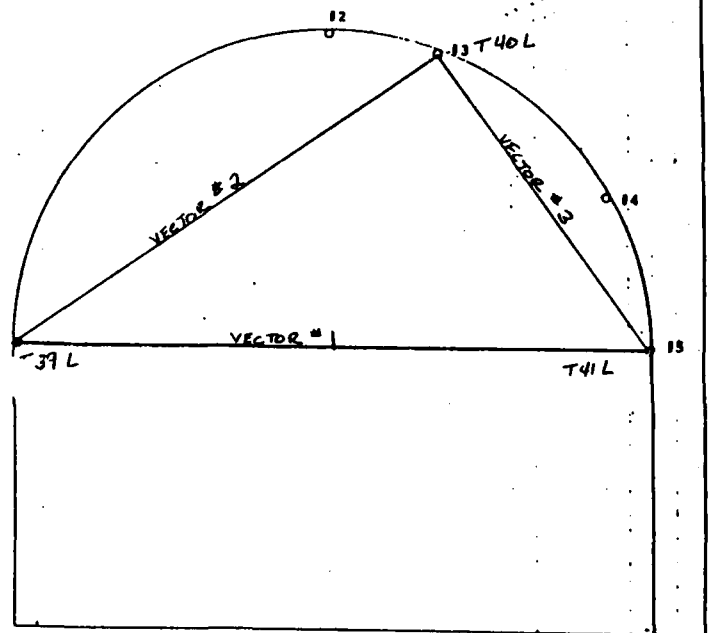
ARRAY K

SPRX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 8/27/91 Project: Marian Diversion

Installed: TRAPP/COLLINS Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	26+52	1180.87
3	26+52	1196.97
5	26+52	1180.87

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL # 2

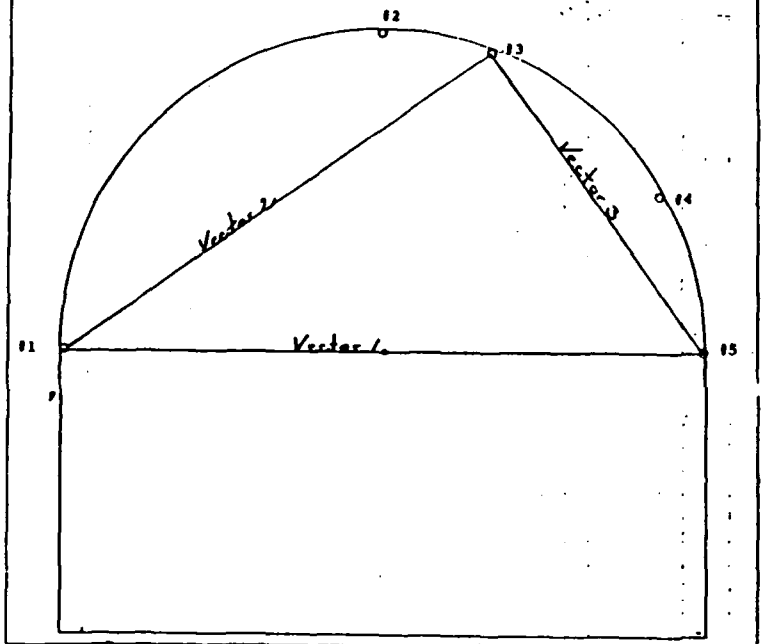
STATION 26+52

ARRAY L

SPRX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 10/9/91
Project: Harlan Diversion
Installed: _____
Contractor: Grassetto-Indian



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	13+82	
3	13+82	
5	13+82	

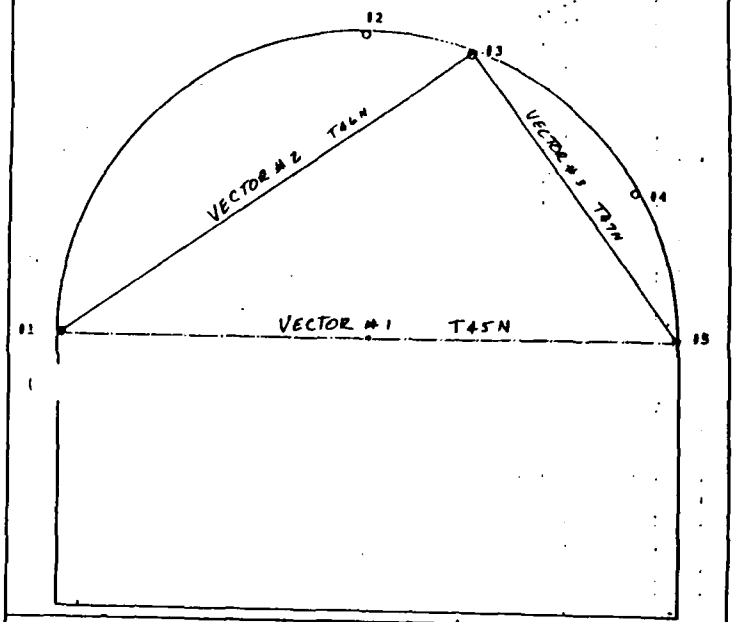
LOAD CELL POSITIONS		
Location	Station	Elevation
1		

TUNNEL: 4
STATION: 13+82
ARRAY: M

SPRX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 17 Dec 91
Project: Harlan Diversion
Installed: June Osborne
Contractor: Grassetto-Indian



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	15+97	
3	15+97	
5	15+97	

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: T4
STATION: 15+97
ARRAY: N

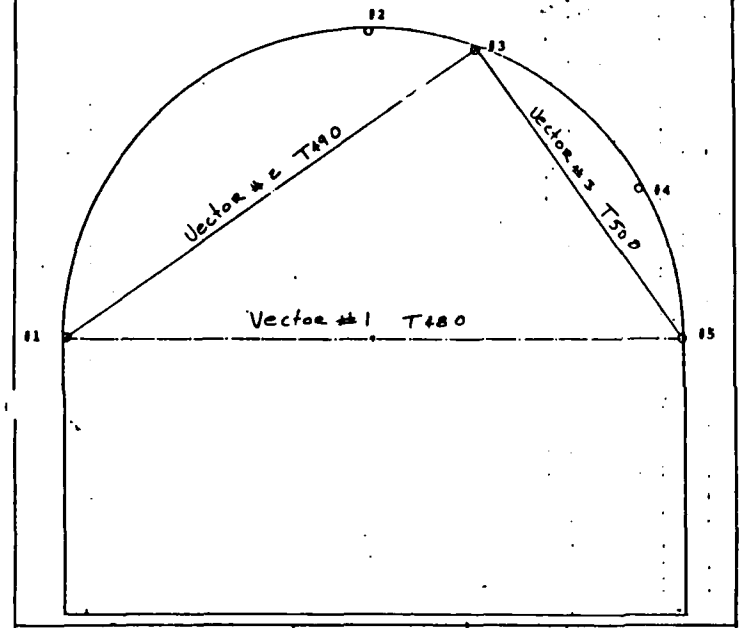
SPRX POSITIONS		
Location	Station	Elevation

PLATE I-9

PLATE I-10

INSTRUMENTATION ARRAY LOCATION

Date Installed: 11 Dec 91
Project: Narlan Diversion
Person Installed: Tom Tapp
Contractor: Grassetto-Indisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	17+83	
4	19+83	
5	19+83	

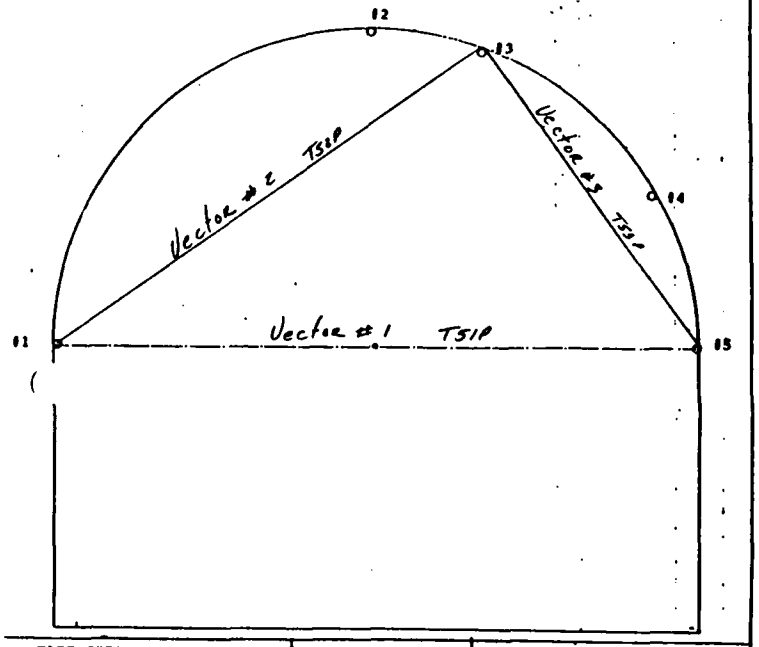
LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: T4
STATION: 19+83
ARRAY: O

SPRX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 17 Feb 92
Project: Narlan Diversion
Person Installed: J. Osborne
Contractor: Grassetto-Indisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	23+96	
4	23+96	
5	23+96	

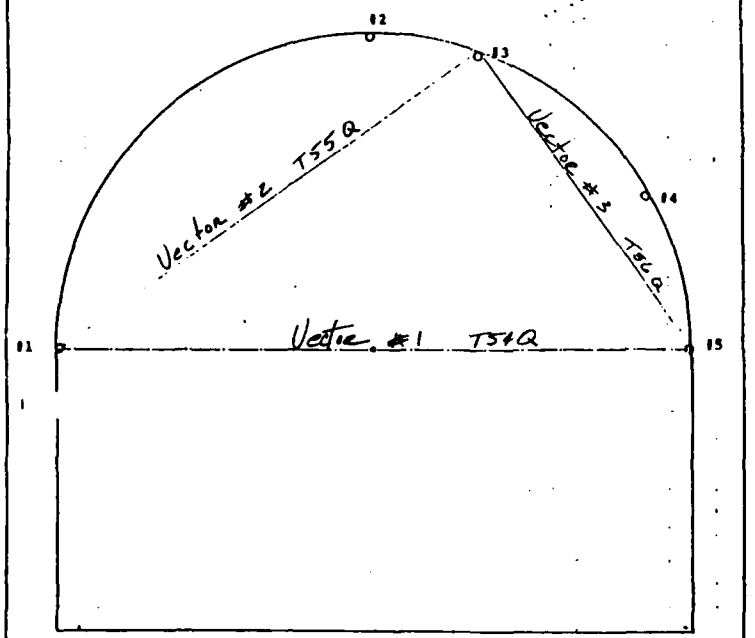
LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: T4
STATION: 23+96
ARRAY: P

SPRX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 06 Mar 92
Project: Marlan Diversion
Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	27+39	
3	27+39	
5	27+39	

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: T4
STATION: 27+39
ARRAY: Q

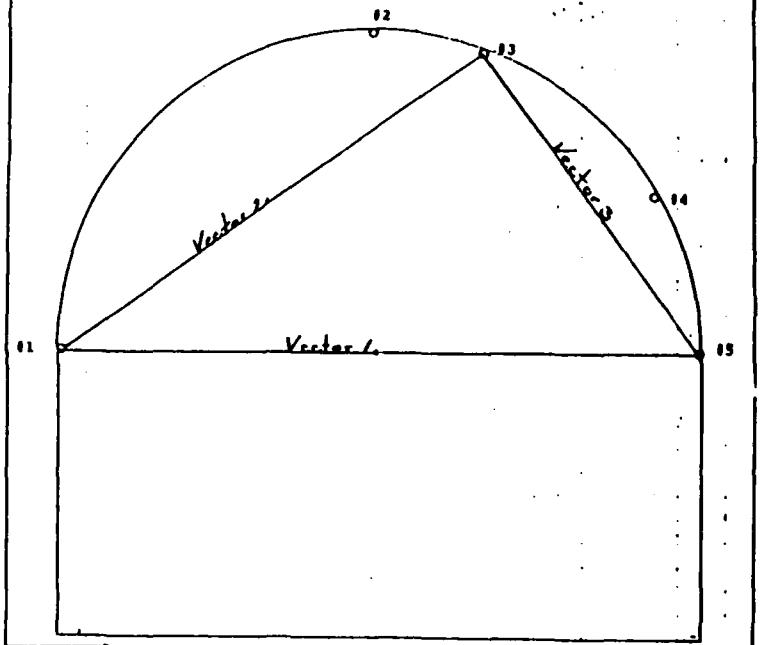
SPRX POSITIONS		
Location	Station	Elevation

PLATE I-11

INSTRUMENTATION ARRAY LOCATION

7 FEB 92

Date Installed: 5/17/92
Project: Marlan Diversion
Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	29+05	
3	29+05	
5	29+05	

LOAD CELL POSITIONS		
Location	Station	Elevation
1		

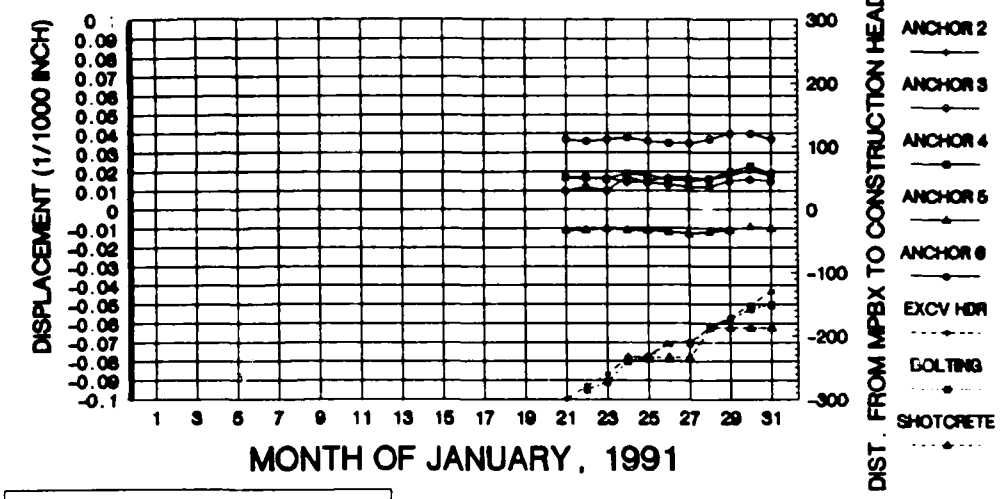
TUNNEL: 4
STATION: 29+05
ARRAY: R

SPRX POSITIONS		
Location	Station	Elevation

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-1



MONTH OF JANUARY, 1991

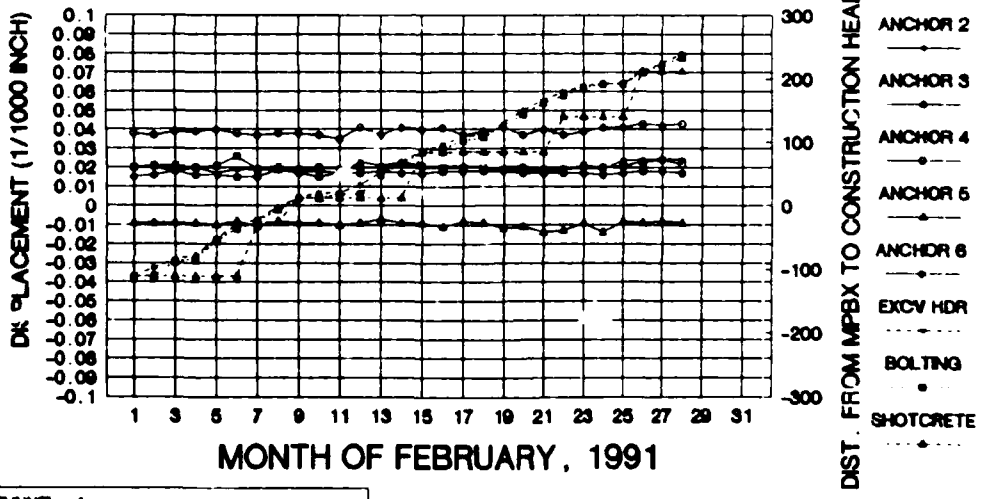
TUNNEL #1
STATION 25+55
ELEVATION OF REFERENCE HEAD = 1475.92

ZERO IS INITIAL READING.
AS OF 1/28 THE PLOTS HAVE BEEN CORRECTED.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-1



MONTH OF FEBRUARY, 1991

TUNNEL #1
STATION 25+55
ELEVATION OF REFERENCE HEAD = 1475.92

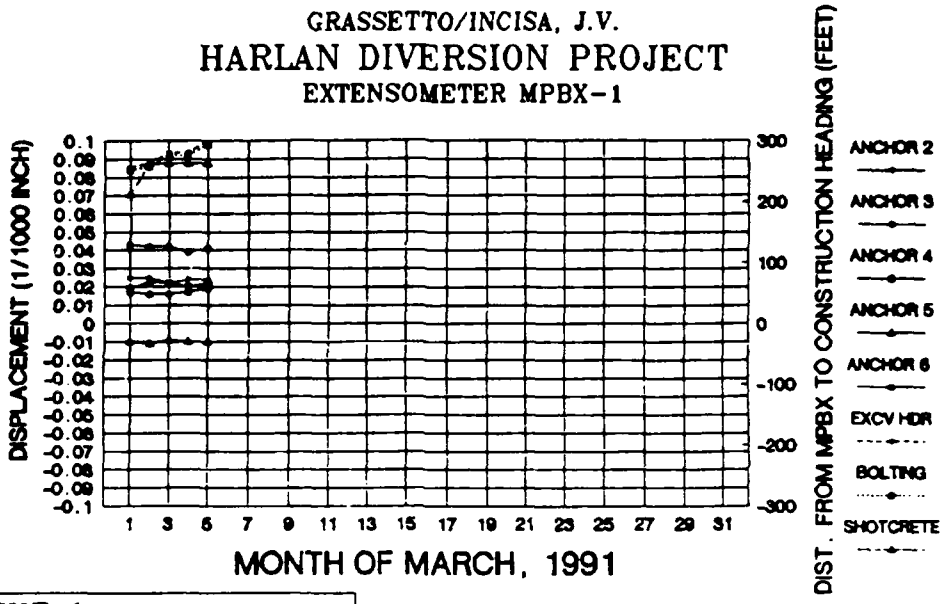
ZERO IS INITIAL READING.

PLATE I-12

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-1



MONTH OF MARCH, 1991

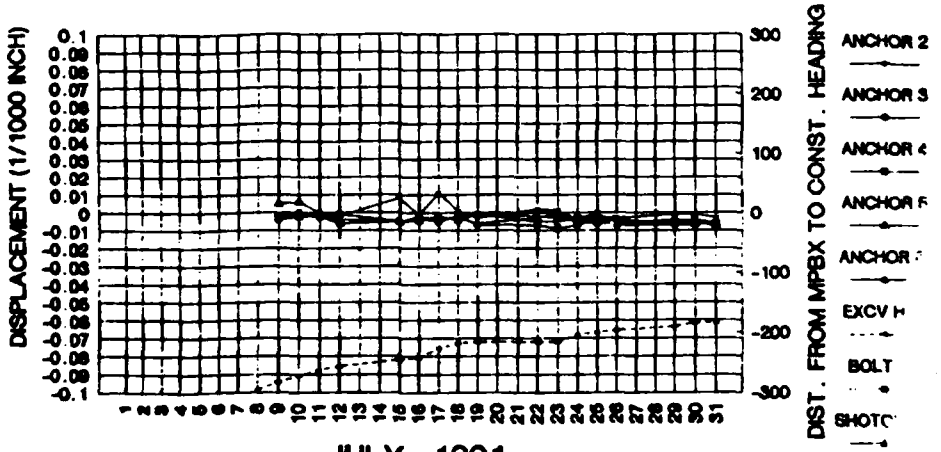
TUNNEL #1
STATION 25+55
ELEVATION OF REFERENCE HEAD = 1475.92

ZERO IS INITIAL READING.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-2



JULY, 1991

NOTED ERRATIC READINGS ON 6/24.
ZERO IS INITIAL READING FOR ALL POINTS.
TUNNEL #2 / STATION 26+43

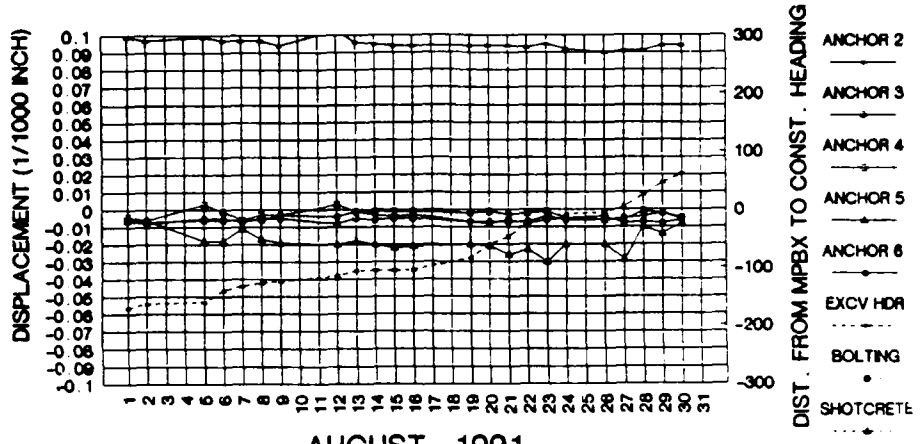
INSTRUMENT WAS REPAIRED AND REINITIALIZED 7/
PAUL ROSS REPAIRED INSTRUMENT ON 7/6.
STARTING ON 7/9 IS NEW SET OF NUMBERS

PLATE I-13

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-2



AUGUST, 1991

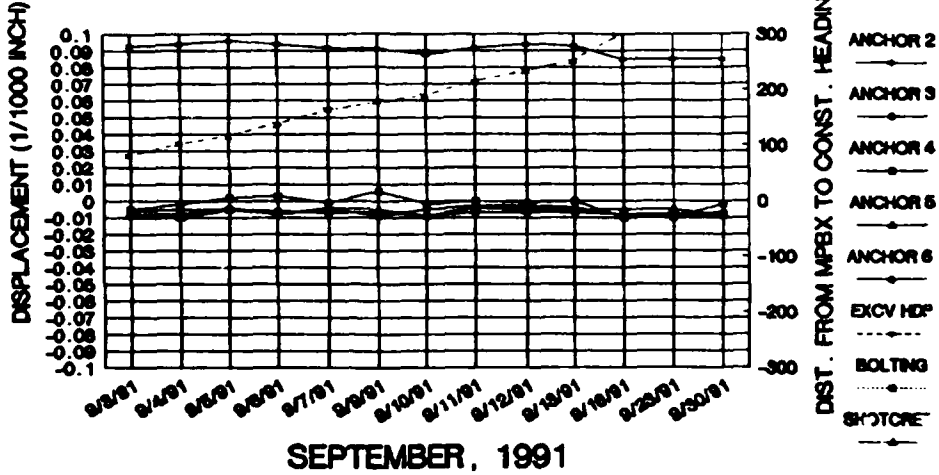
NOTED ERRATIC READINGS ON 8/24.
ZERO IS INITIAL READING FOR ALL POINTS.
TUNNEL #2 / STATION 26+43

INSTRUMENT WAS REPAIRED AND REINITIALIZED 7/8
PAUL ROSS REPAIRED INSTRUMENT ON 7/8.
STARTING ON 7/9 IS NEW SET OF NUMBERS.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-2



SEPTEMBER, 1991

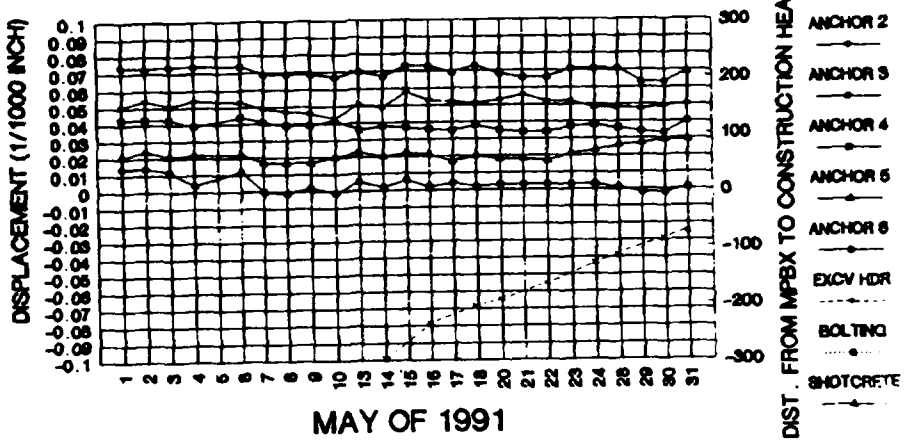
NOTED ERRATIC READINGS ON 8/24.
ZERO IS INITIAL READING FOR ALL POINTS.
TUNNEL #2 / STATION 26+43

INSTRUMENT WAS REPAIRED AND REINITIALIZED
PAUL ROSS REPAIRED INSTRUMENT ON 7/8.
STARTING ON 7/9 IS NEW SET OF NUMBERS.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-3



MAY OF 1991

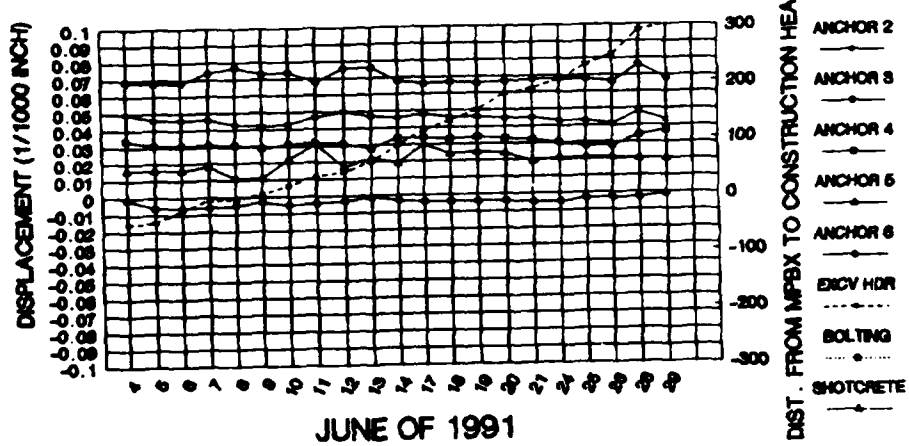
TUNNEL #3
STATION 22+10.6
ELEVATION OF REFERENCE HEAD = 1410.55

ZERO IS INITIAL REA[illegible]

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-3



JUNE OF 1991

TUNNEL #3
STATION 22+10.6
ELEVATION OF REFERENCE HEAD = 1410.55

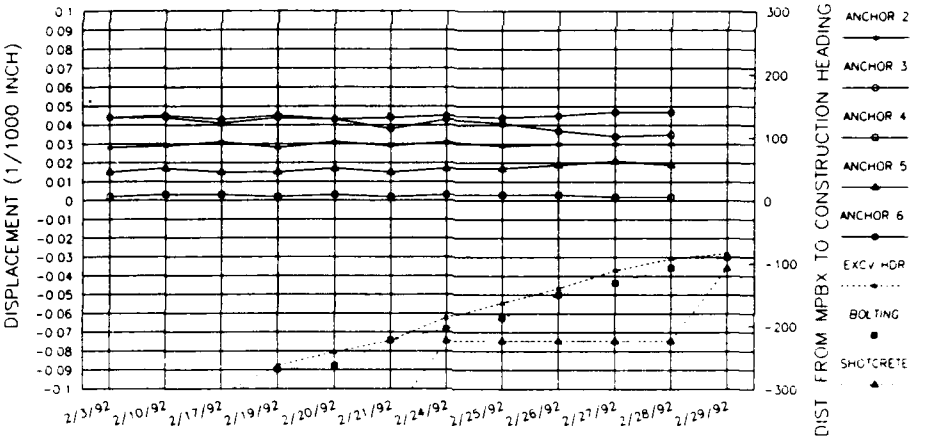
ZERO IS INITIAL READING.

PLATE I-15

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-4



FEBRUARY, 1992

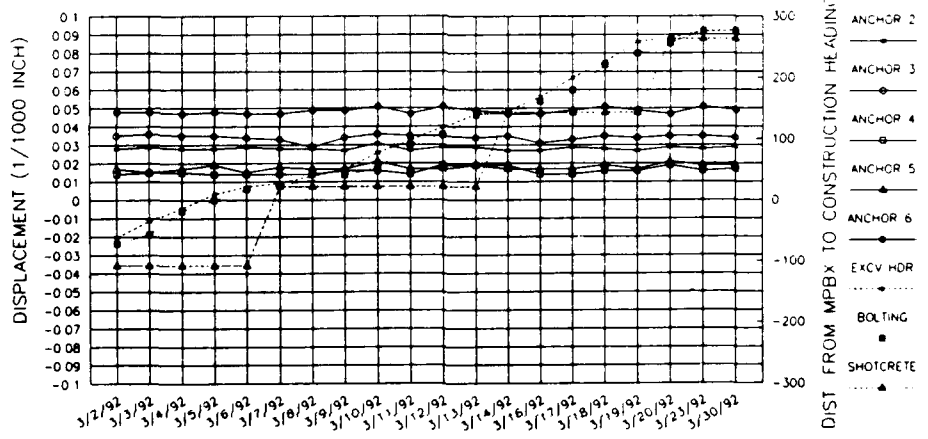
TUNNEL #4
STATION 27+24.7
ELEVATION OF REFERENCE HEAD = 1443.02

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-4



MARCH, 1992

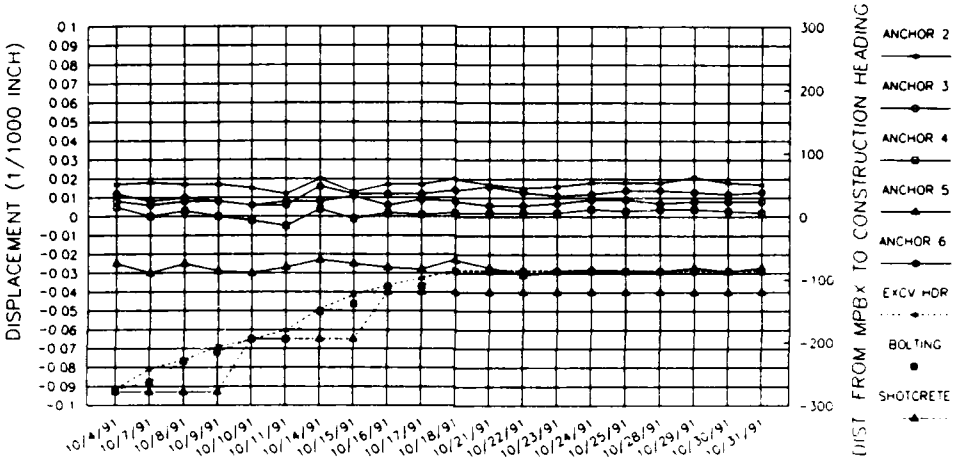
TUNNEL #4
STATION 27+24.7
ELEVATION OF REFERENCE HEAD = 1443.02

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-5



OCTOBER OF 1991

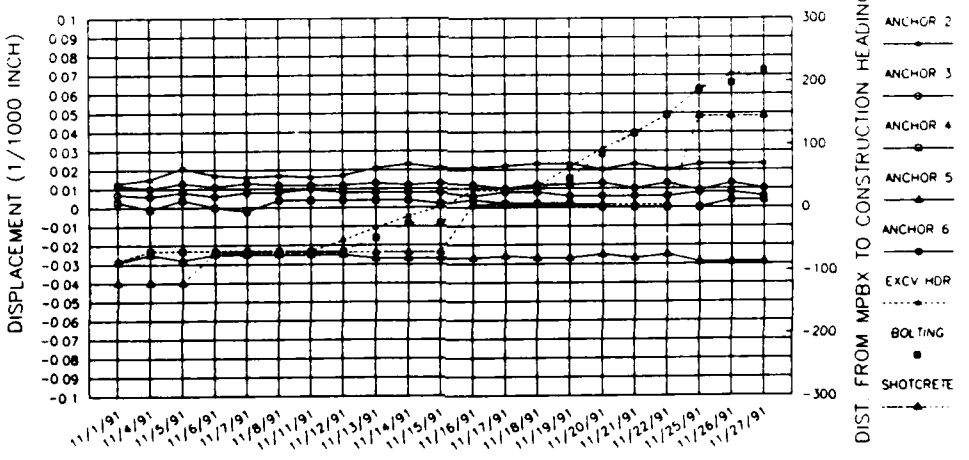
TUNNEL #4
STATION 15+93.4
ELEVATION OF REFERENCE HEAD = 1438.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-5



NOVEMBER, 1991

TUNNEL #4
STATION 15+93.4
ELEVATION OF REFERENCE HEAD = 1438.67

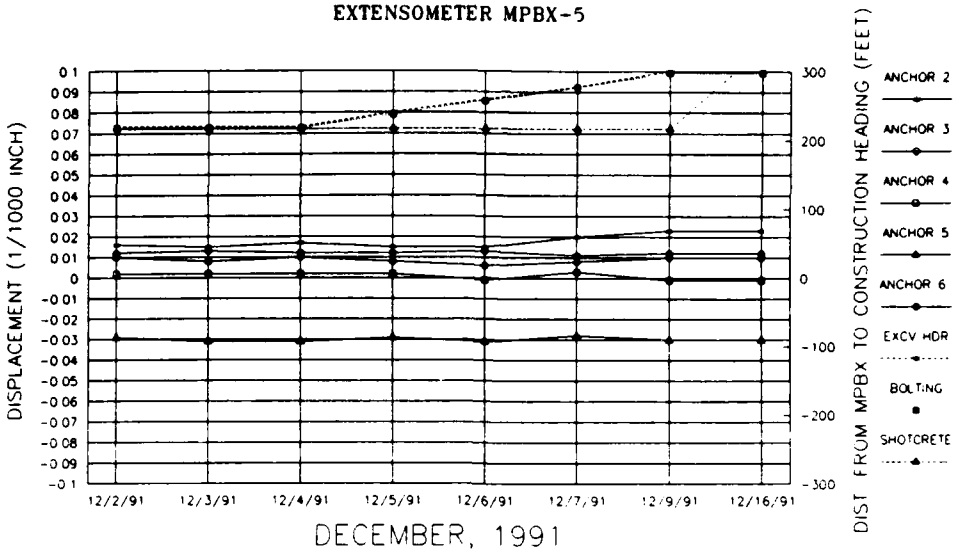
ZERO IS INITIAL READING

PLATE I-17

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-5



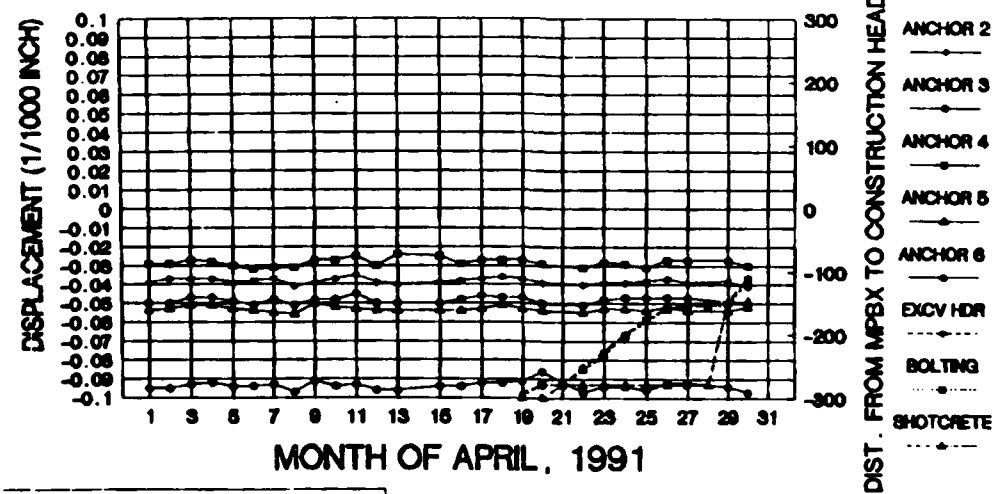
TUNNEL #4
STATION 15+93.4
ELEVATION OF REFERENCE HEAD = 1438.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-6



TUNNEL #3
STATION 18+29
ELEVATION OF REFERENCE HEAD = 1467.67

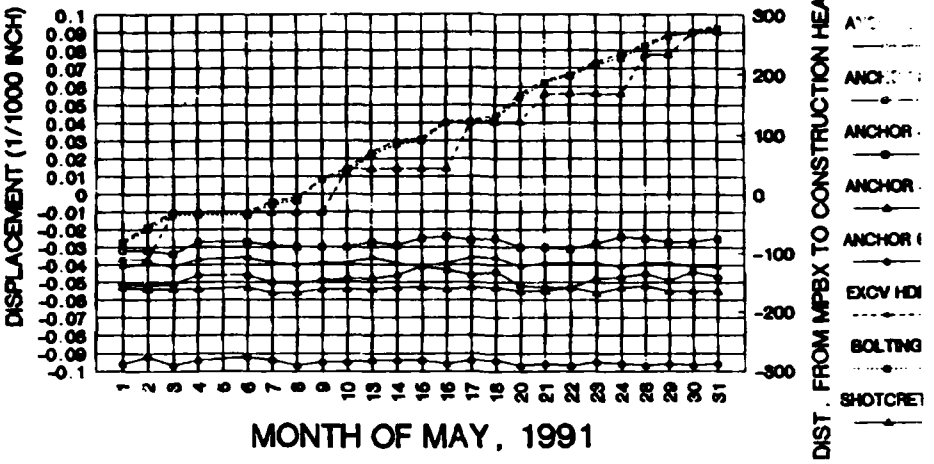
ZERO IS INITIAL READING.

PLATE I-18

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-6



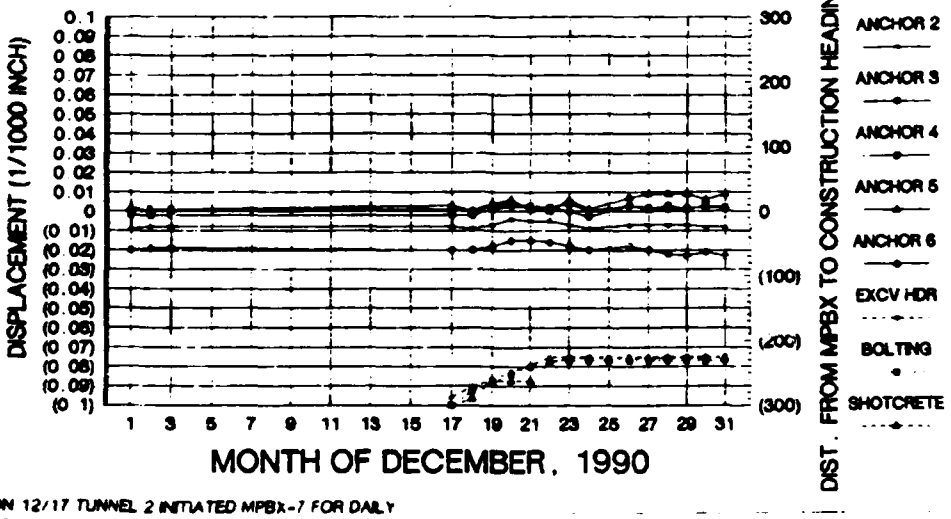
TUNNEL #3
STATION 18+29
ELEVATION OF REFERENCE HEAD = 1487.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



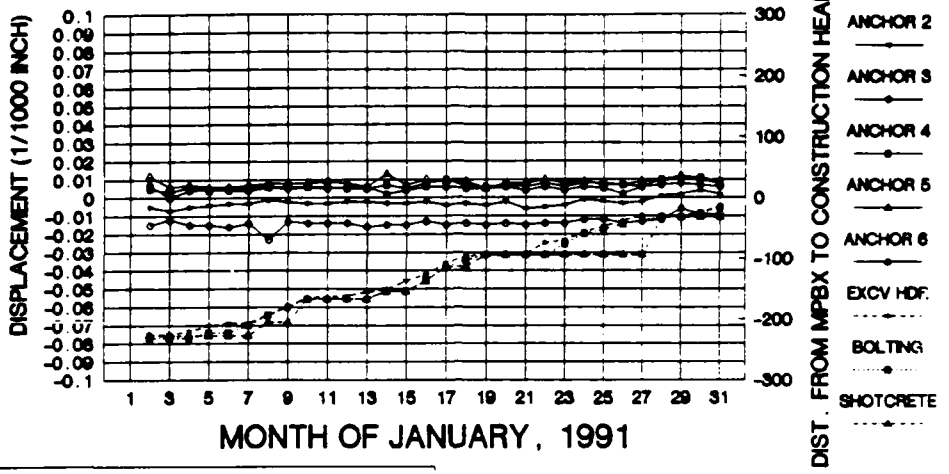
ON 12/17 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS

ON 12/22/90 PROJECT WAS SHUT DOWN UNTIL 1/2/91

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



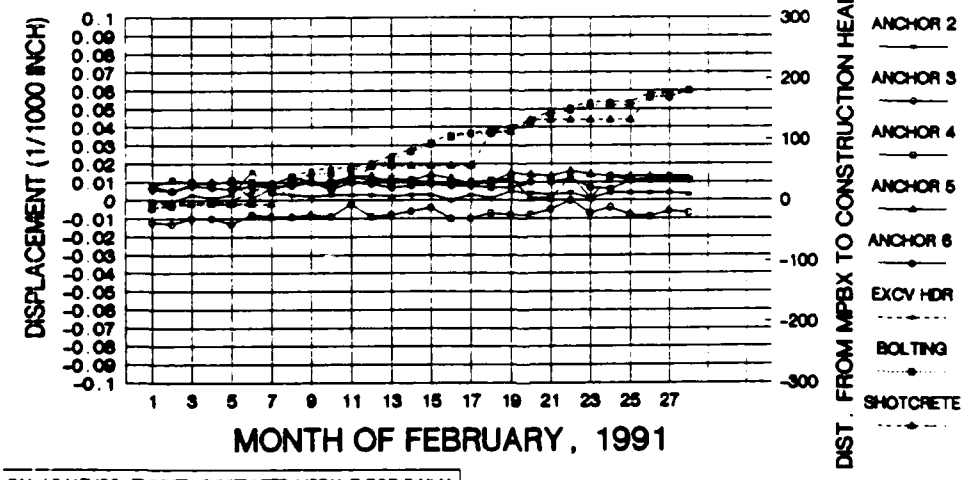
ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS.
TUNNEL #2 / STATION 15+33

NO READING WAS TAKEN ON 1/1/91.
ZERO IS INITIAL READING FOR ALL POINTS.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS.
TUNNEL #2 / STATION 15+33

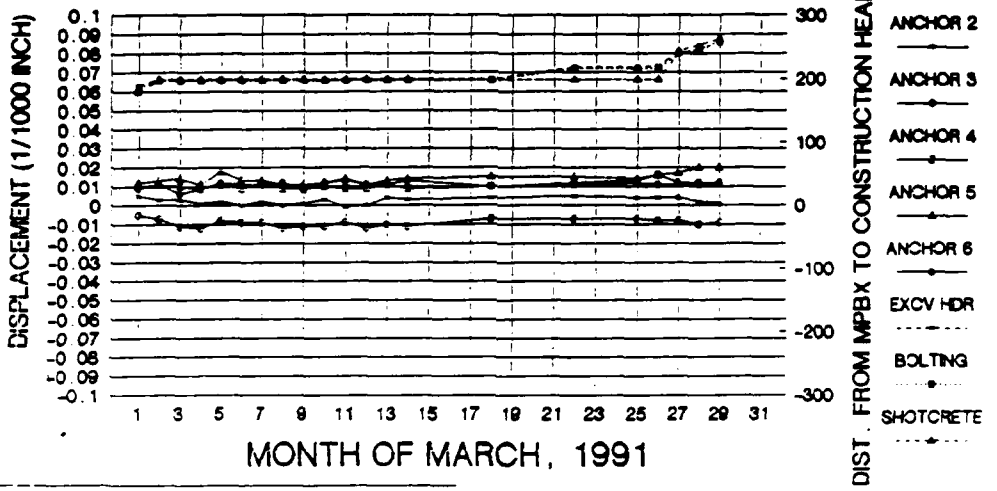
ZERO IS INITIAL READING FOR ALL POINTS.

PLATE I-20

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



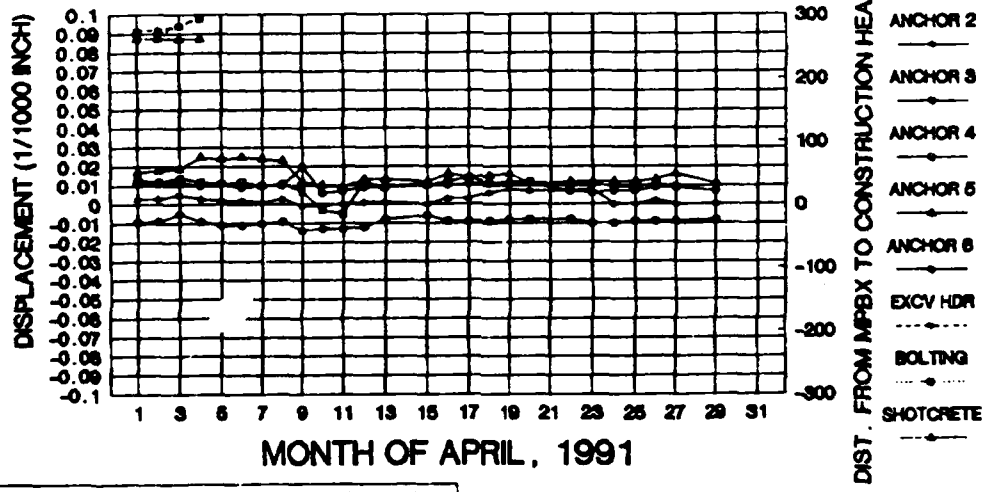
ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS
TUNNEL #2 / STATION 15+33

ZERO IS INITIAL READING FOR ALL POINTS

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS.
TUNNEL #2 / STATION 15+33

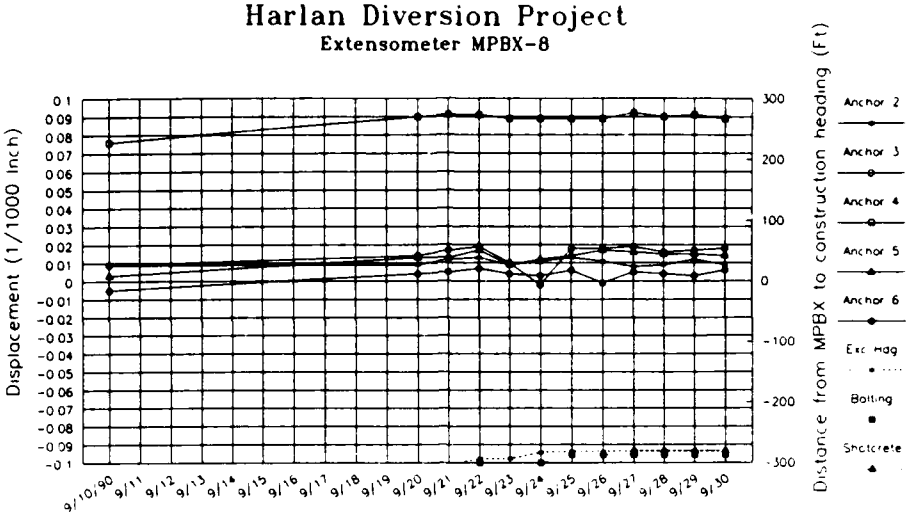
ZERO IS INITIAL READING FOR ALL POINTS.

PLATE I-21

Grassetto/Incisa, J.V.

Harlan Diversion Project

Extensometer MPBX-8



September 1990

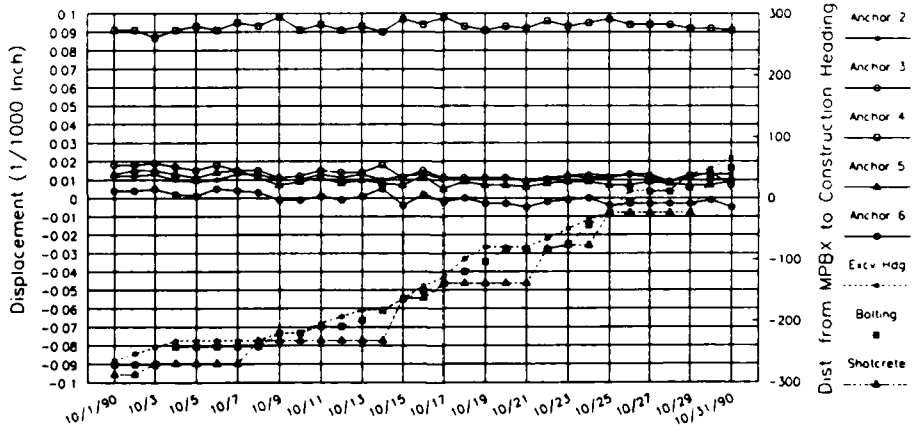
Tunnel #1
Station 13+65
Elevation Reference Head = 1415.43

Zero is initial reading

Grassetto/Incisa, J.V.

Harlan Diversion Project

Extensometer MPBX-8



October 1990

Tunnel #1
Station 13+65
Reference Head Elevation 1415.43

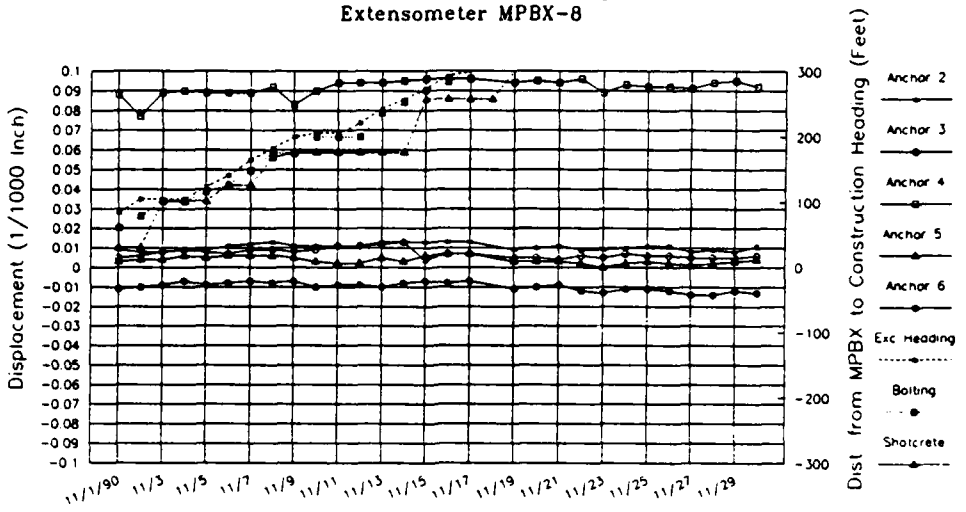
Zero is initial reading

PLATE I-22

Grassetto/Incisa, J.V.

Harlan Diversion Project

Extensometer MPBX-8



November 1990

Tunnel #1
Station 13+65
Reference Head Elevation 1415.43

Zero is initial reading

HARLAN DIVERSION PROJECT

OBSERVATION WELL(C-204)

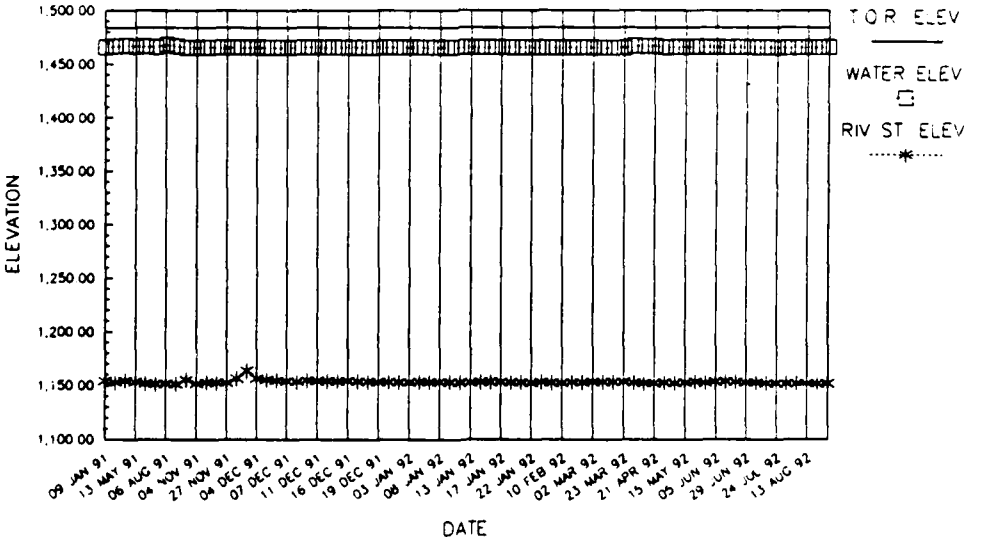
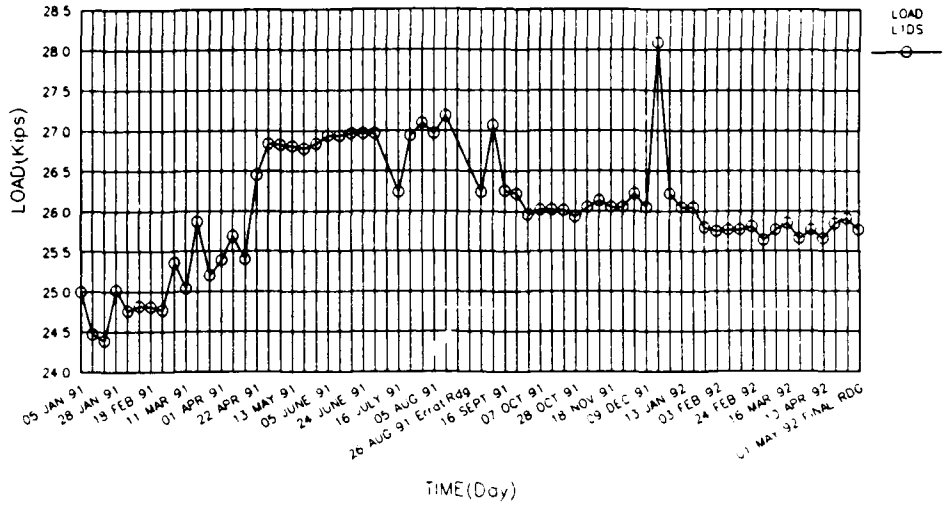


PLATE I-23

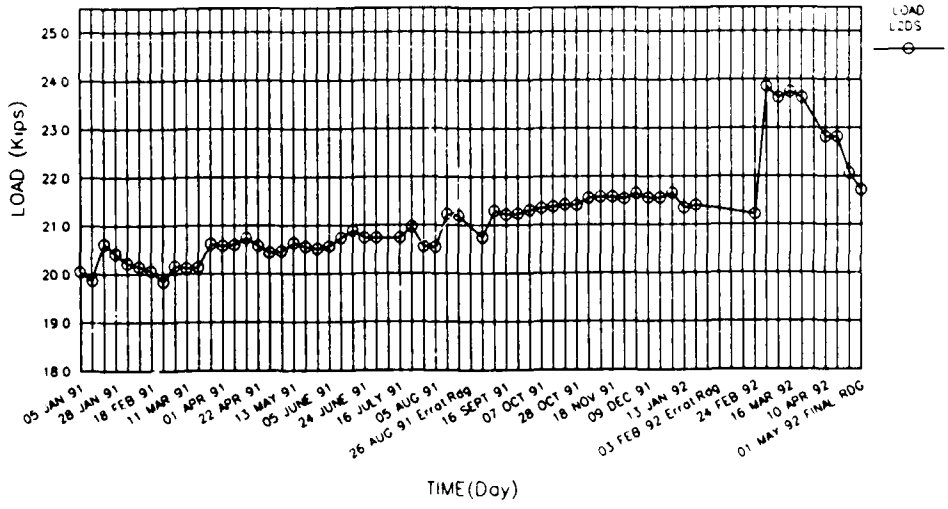
HARLA' DIVERSION PROJECT
LOAD CELL (L1DS) READOUT GRAPH



Load Cell L1DS Installed 7/12/90
Location Sta 10+36.1 / Offset 51.1' Rt (-B')
Elevation 1189.06'

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L2DS) READOUT GRAPH

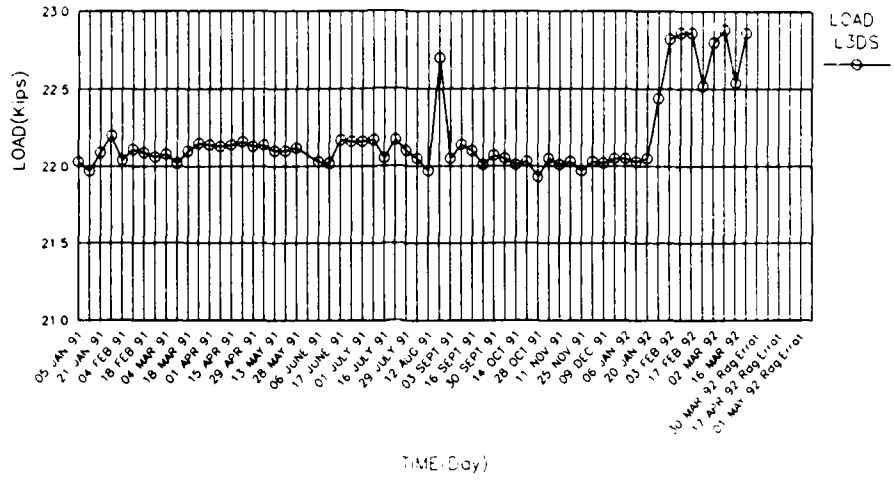


Load Cell L2DS Installed 7/12/90
Location Sta 10+92.6 / Offset 17.3' Rt (-B')
Elevation 1189.42

01 MAY 92 NO FURTHER MONITORING

PLATE I-24

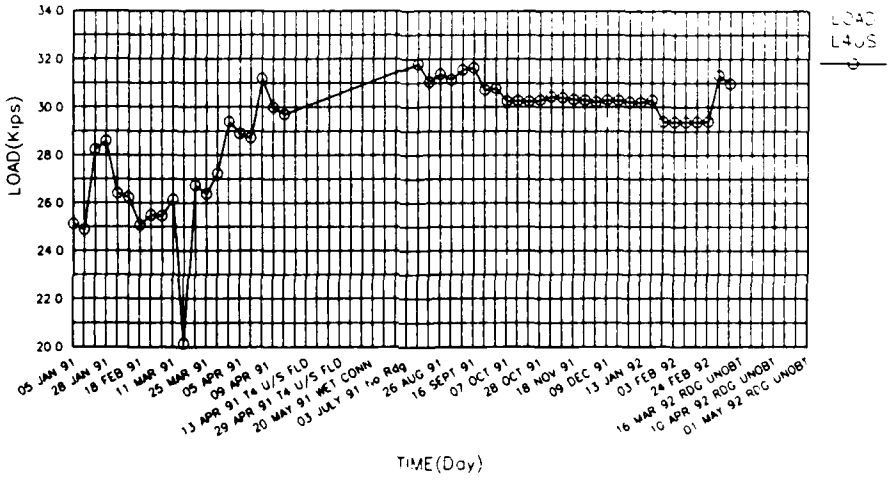
HARLAN DIVERSION PROJECT
LOAD CELL (L3DS) READOUT GRAPH



Load Cell L3DS Installed 8/24/90
Location Sta 10+89.3 / Offset 16.8'Rt BL("B")
Elevation 1169.56

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L4US) READOUT GRAPH

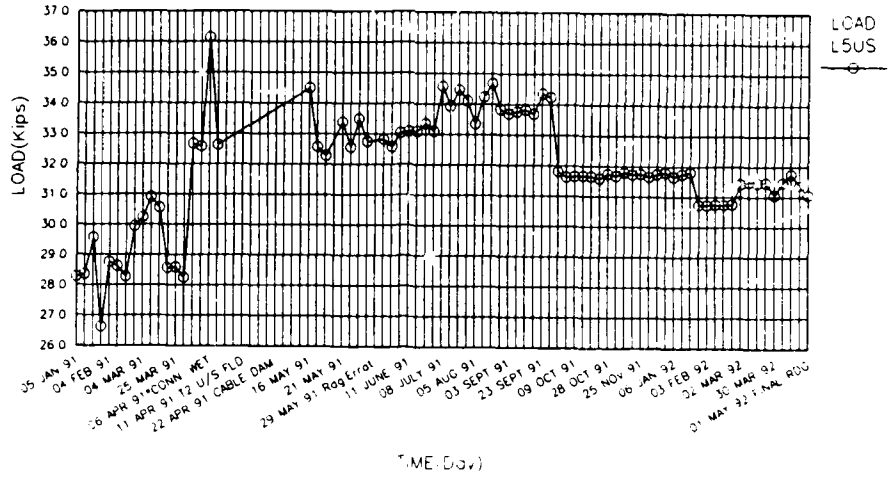


Load Cell L4US Installed 8/27/90
Location BL"B" 30+13 /Offset 78.8'Rt of BL("B")
Elevation 1234.0

01 MAY 92 NO FURTHER MONITORING

PLATE I-12

HARLAN DIVERSION PROJECT
LOAD CELL (L5US) READOUT GRAPH

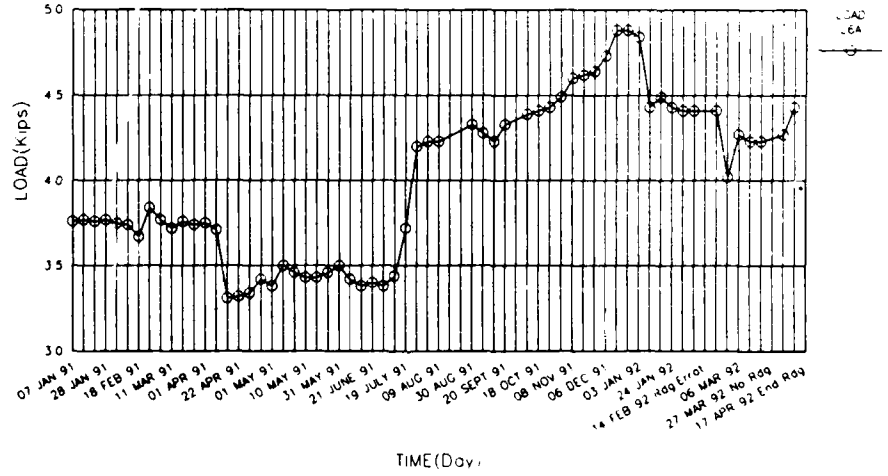


Load cell L5US
Location 2+31.7
Elevation 1,318.6

Installed 9/19/90
Offset Left BL "B"

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L6A) READOUT GRAPH



Load cell L6A
Location Crown
Elevation 1188.2

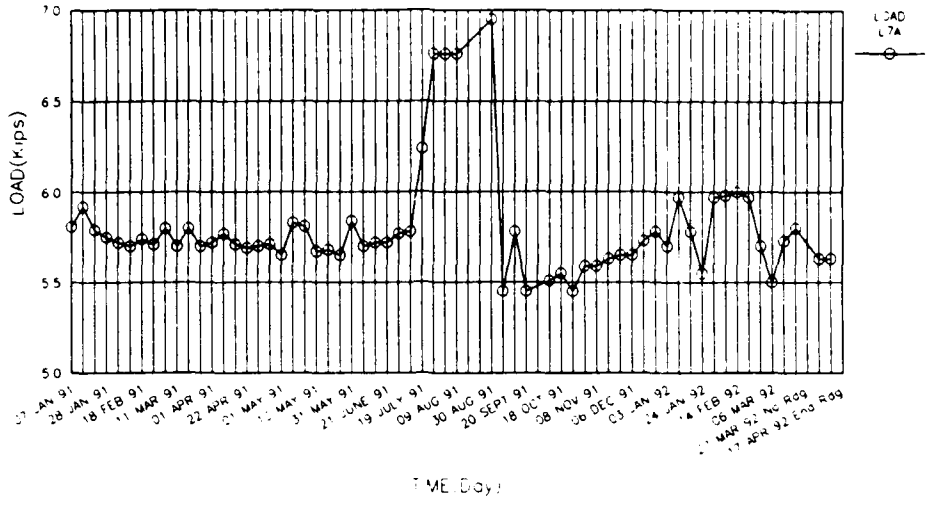
Installed 9/26/90
Station 10+75

Array A

01 MAY 92 NO FURTHER MONITORING

PLATE I-26

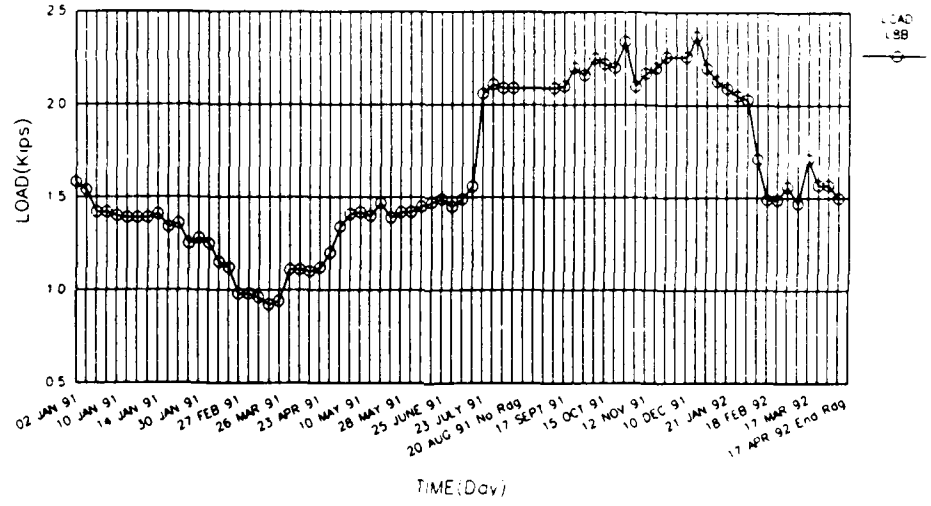
HARLAN DIVERSION PROJECT
LOAD CELL (L7A) READOUT GRAPH



Load cell L7A — Installed 9/26/90
Location Right Bauxite — Station 10+76.5
Elevation [illegible]

Tunnel T-1 Array A
[illegible] FEATHER MOUNTAIN, INC.

HARLAN DIVERSION PROJECT
LOAD CELL (8B) READOUT GRAPH

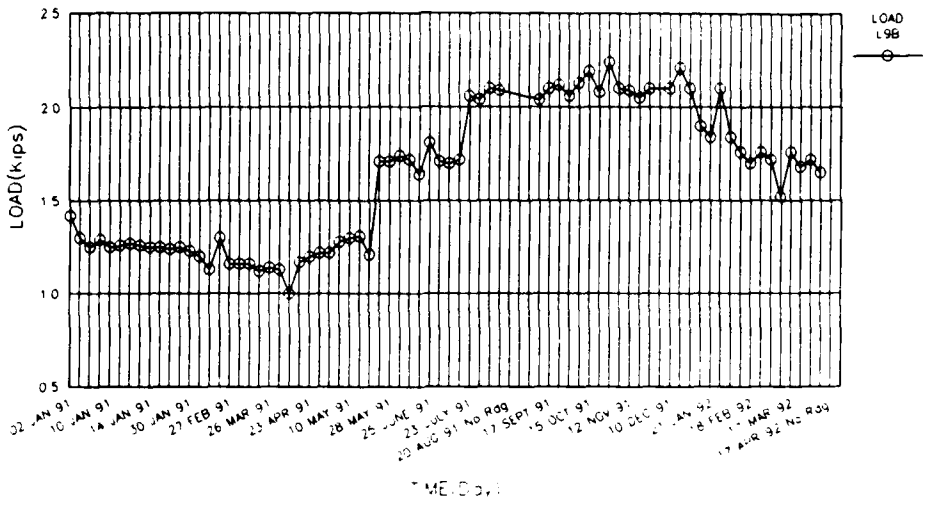


Load cell L8B — Installed 10/27/90
Location Crown Array B — Station 13+65-67
Elevation 1189.95

Tunnel T-1 Array B
[illegible] FEATHER MOUNTAIN, INC.

PLATE I-27

HARLAN DIVERSION PROJECT
LOAD CELL (L9B) READOUT GRAPH

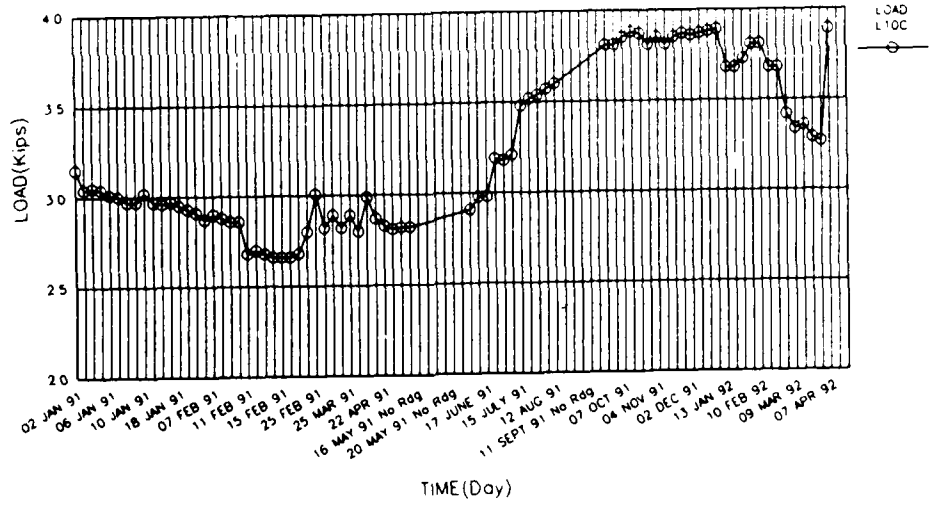


Load cell L9B
Location Right Bounch
Elevation 1130.95

Installed 10/27/90
Station 13+67

Tunnel T-1 Area
01 MAY 92 NO FURTHER MONITOR

HARLAN DIVERSION PROJECT
LOAD CELL (L10C) READOUT GRAPH



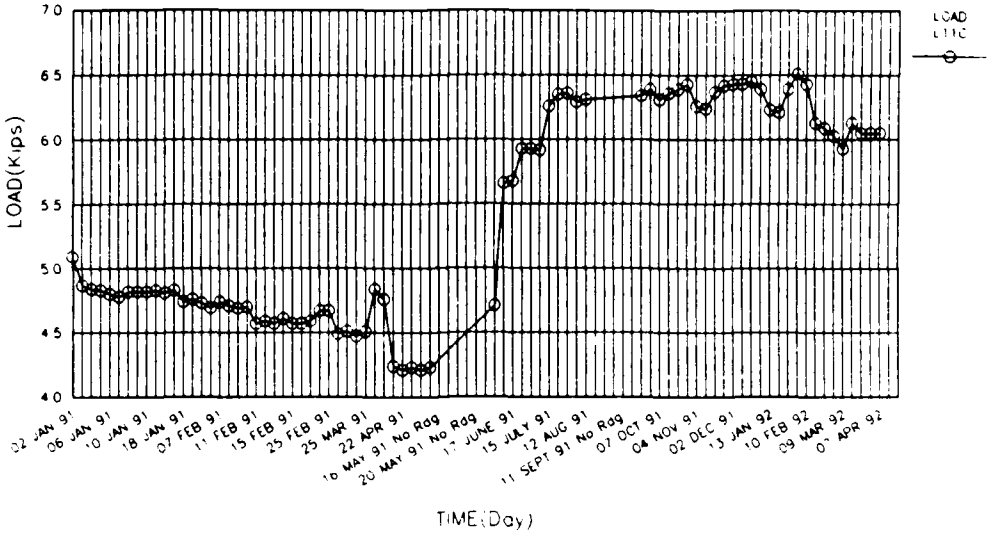
Load Cell L10C
Location Crown C
Elevation 1191.37

Installed 11/14/90
Station 15+98

Tunnel T-1 Area
01 MAY 92 NO FURTHER MONITOR

PLATE I-28

HARLAN DIVERSION PROJECT
LOAD CELL (L11C) READOUT GRAPH

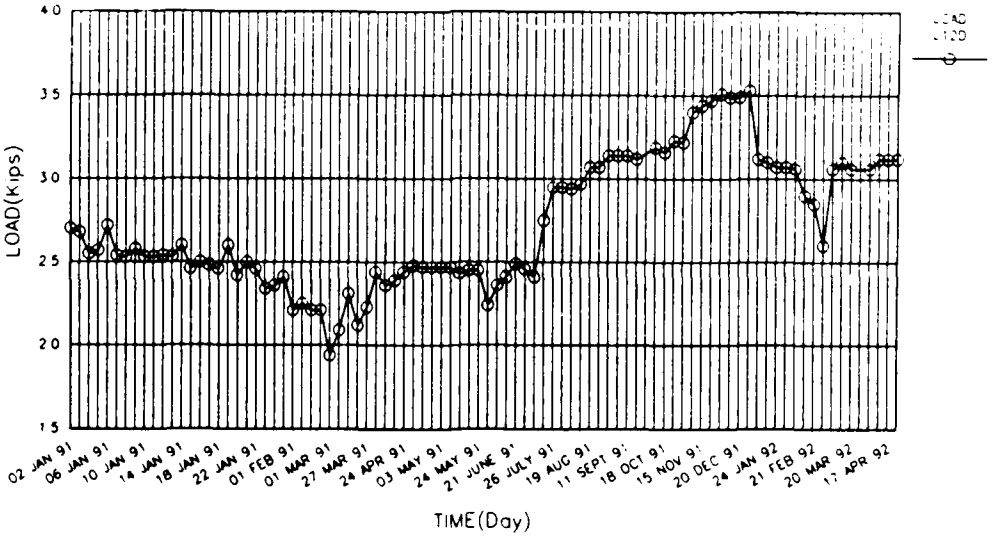


Load Cell L11C
Location Rt Haunch
Elevation 1182.37

Installed 11/14/90
Station 15+98

Tunnel T-2 Area
07 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L12D) READOUT GRAPH



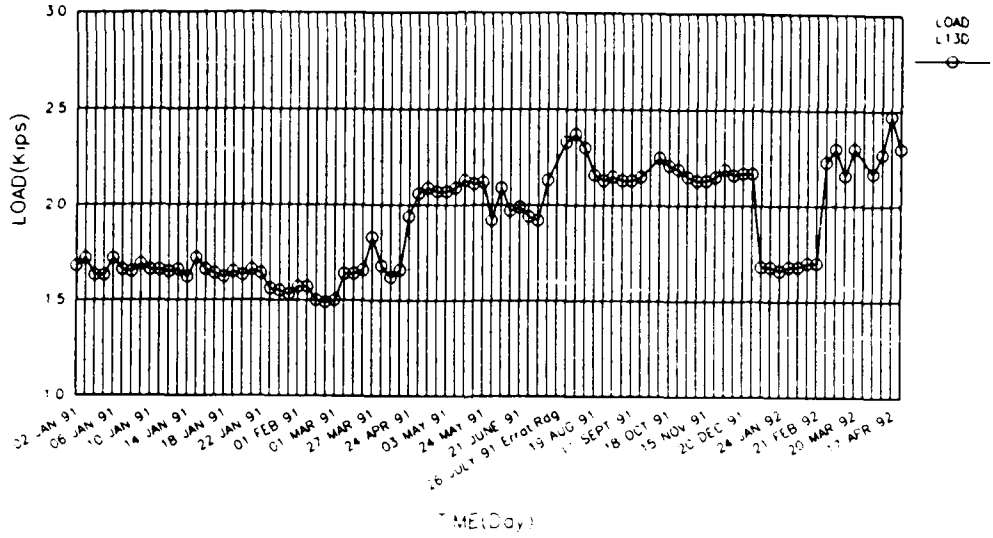
Load cell L12D
Location Crown
Elevation 1188.47

Installed 11/27/90
Station 11+26

Tunnel T-2 Area
07 MAY 92 NO FURTHER MONITORING

PLATE I-29

HARLAN DIVERSION PROJECT
LOAD CELL (L13D) READOUT GRAPH

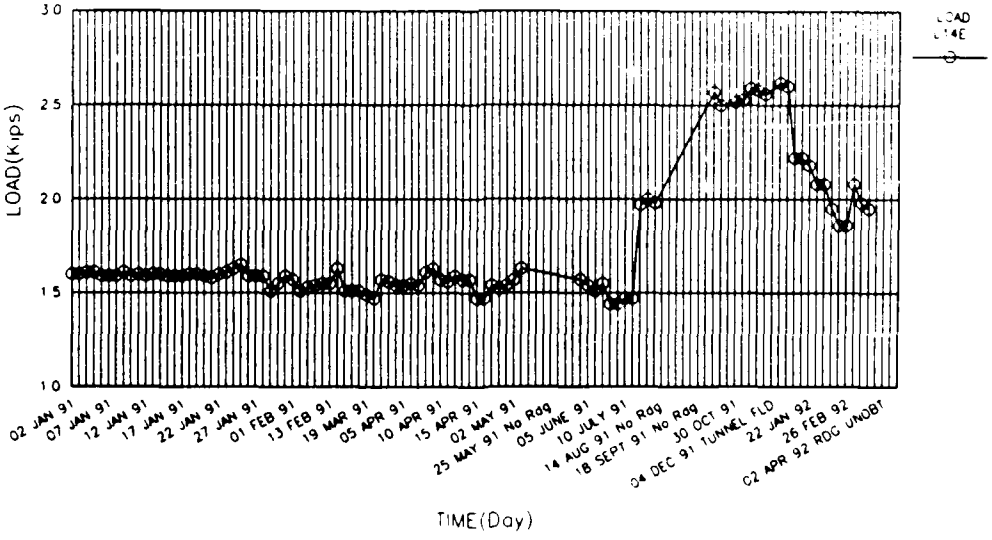


Load Cell L13D
Location Rt. Haunch
Elevation 119347

Installed 11/27/90
Station 11+26

Tunnel T-2 Array C
01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L14E) READOUT GRAPH



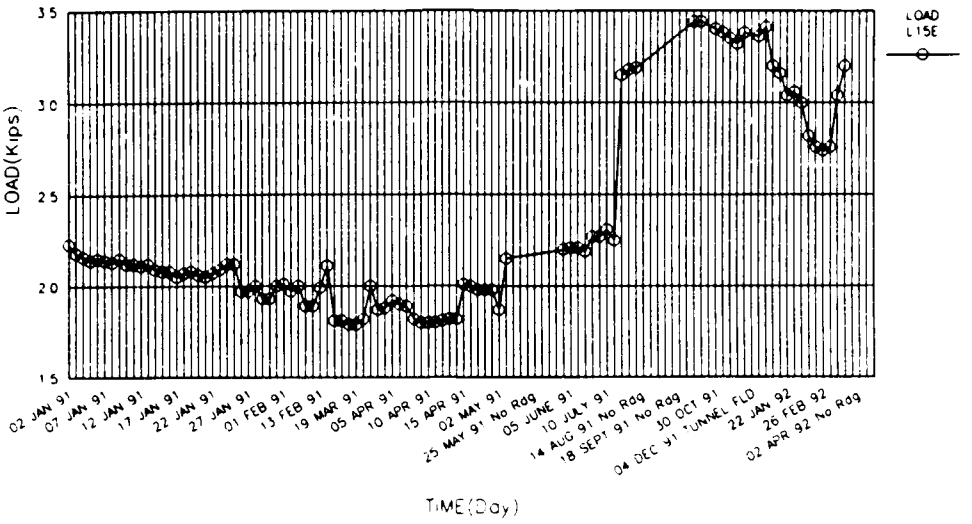
Load Cell L14E
Location Crown
Elevation 119303

Installed 12/06/90
Station 18+68

Tunnel T-1 Array E
01 MAY 92 NO FURTHER MONITORING

PLATE I-30

HARLAN DIVERSION PROJECT
LOAD CELL (L15E) READOUT GRAPH

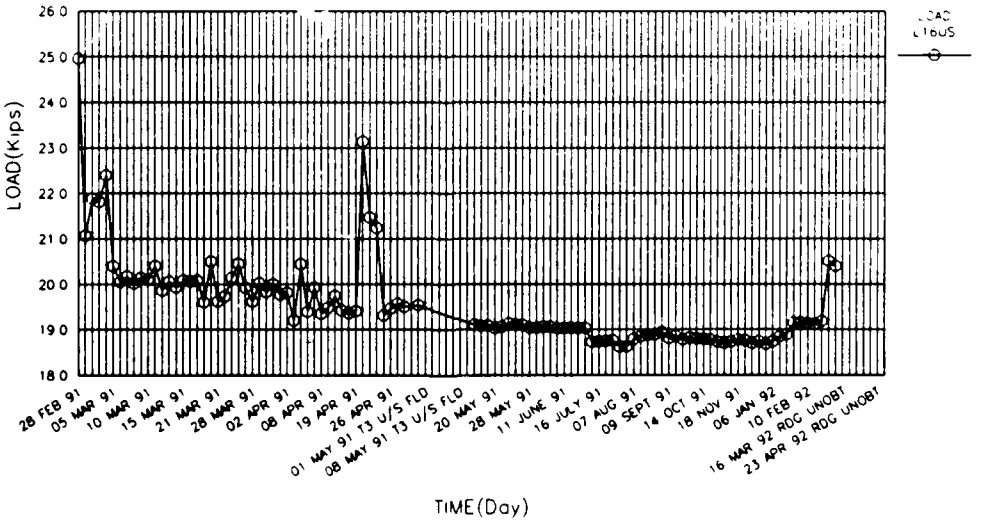


Load Cell L15E
Location Rt. Haunch
Elevation 1184.03

Installed 12 DEC 90
Station 18+68

Force Test Array E
01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L16US) READOUT GRAPH

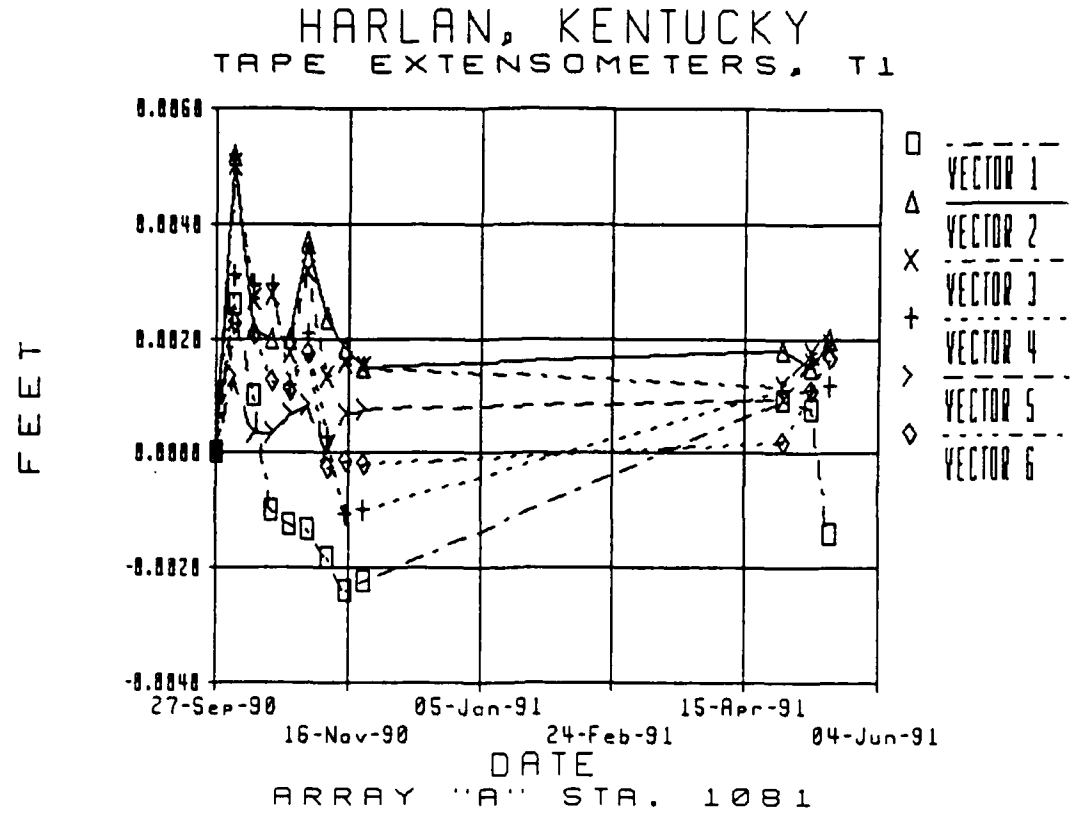


Load Cell L16US
Location Sta. 30+20, 10' Lt. of rt. Wall of T-3
Elevation 1210.10

Installed 28 FEB 91

01 MAY 92 NO FURTHER MONITORING

PLATE I-31


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
FEET
0.0060
0.0040
0.0020
0.0000
-0.0020
-0.0040
27-Sep-90
16-Nov-90
05-Jan-91
24-Feb-91
15-Apr-91
04-Jun-91
DATE
VECTOR 1
VECTOR 2
VECTOR 3
VECTOR 4
VECTOR 5
VECTOR 6
ARRAY "A" STA. 1081

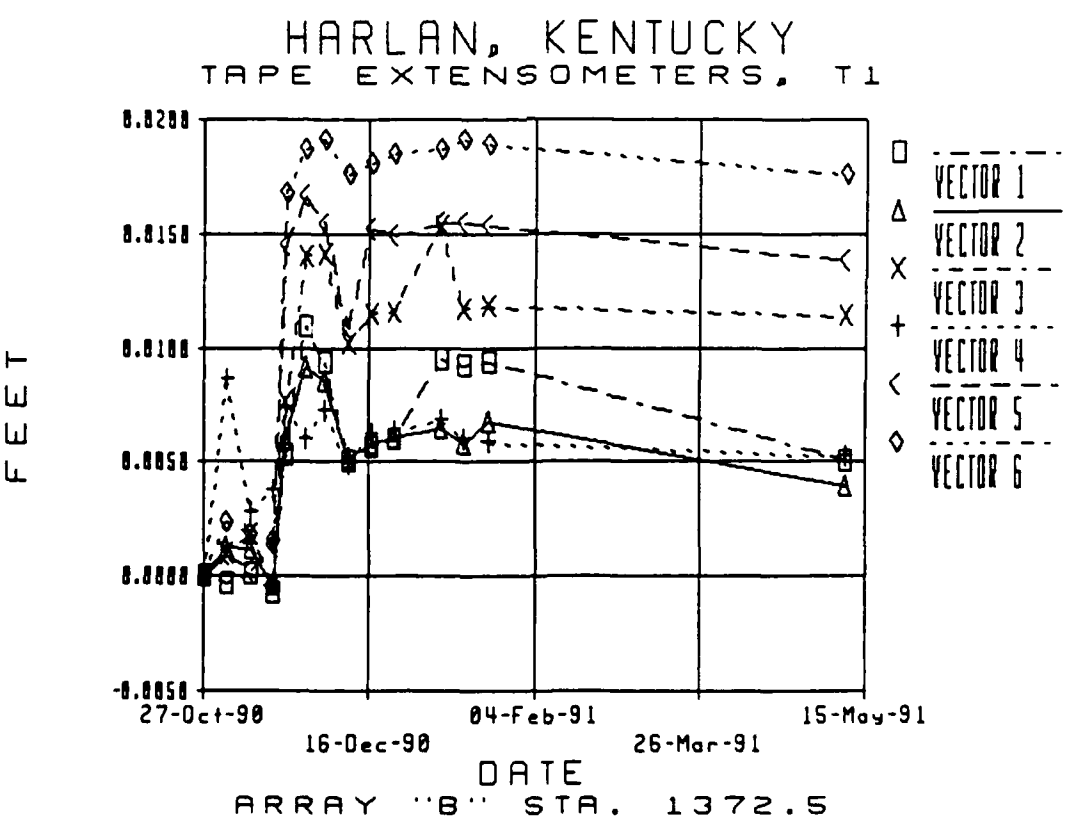
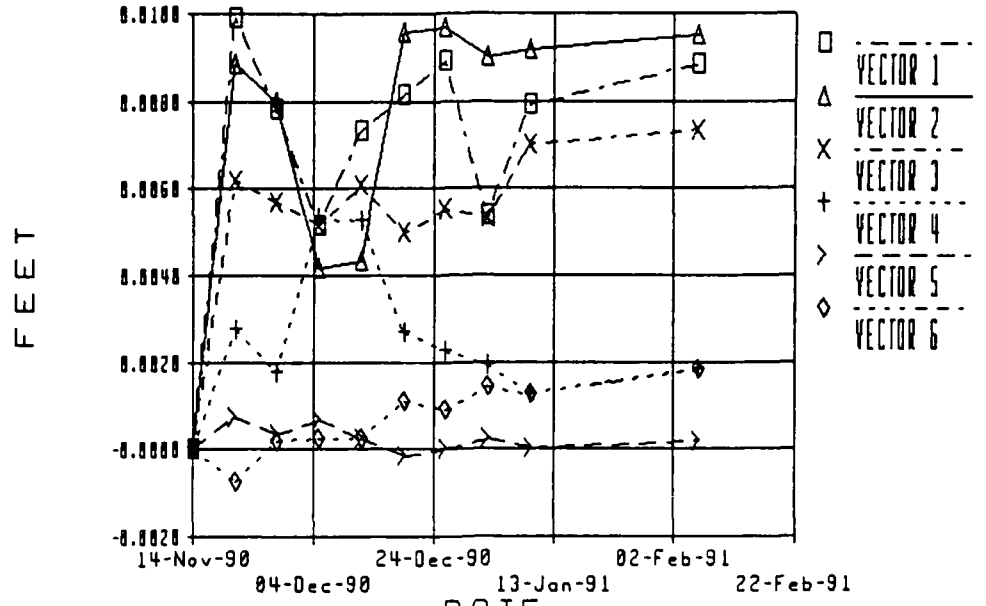

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
FEET
0.0200
0.0150
0.0100
0.0050
0.0000
-0.0050
27-Oct-90
16-Dec-90
04-Feb-91
26-Mar-91
15-May-91
DATE
VECTOR 1
VECTOR 2
VECTOR 3
VECTOR 4
VECTOR 5
VECTOR 6
ARRAY "B" STA. 1372.5

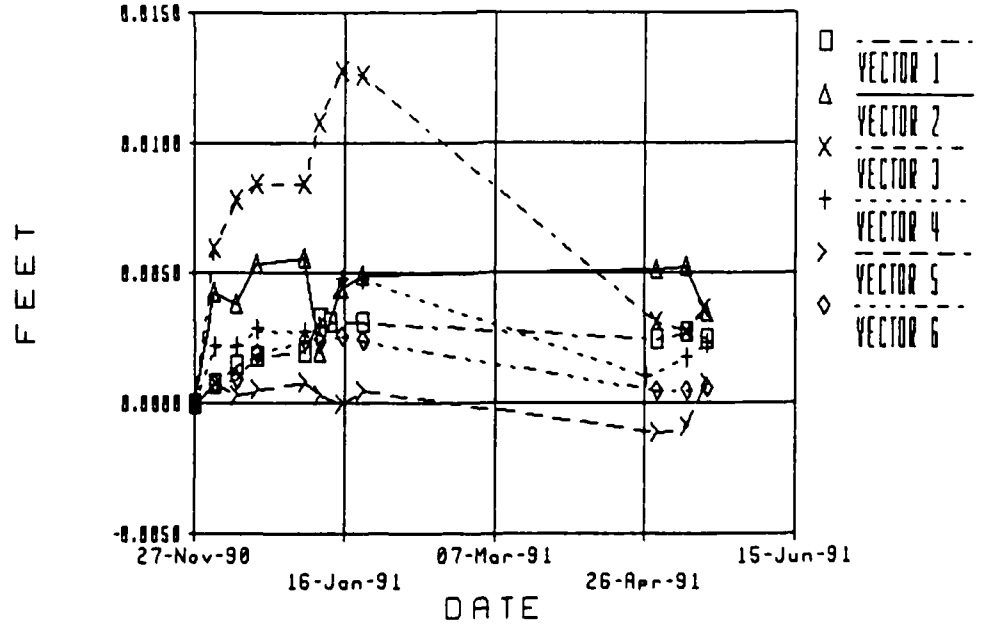
PLATE I-32

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1



ARRAY "C" STA. 1603.5

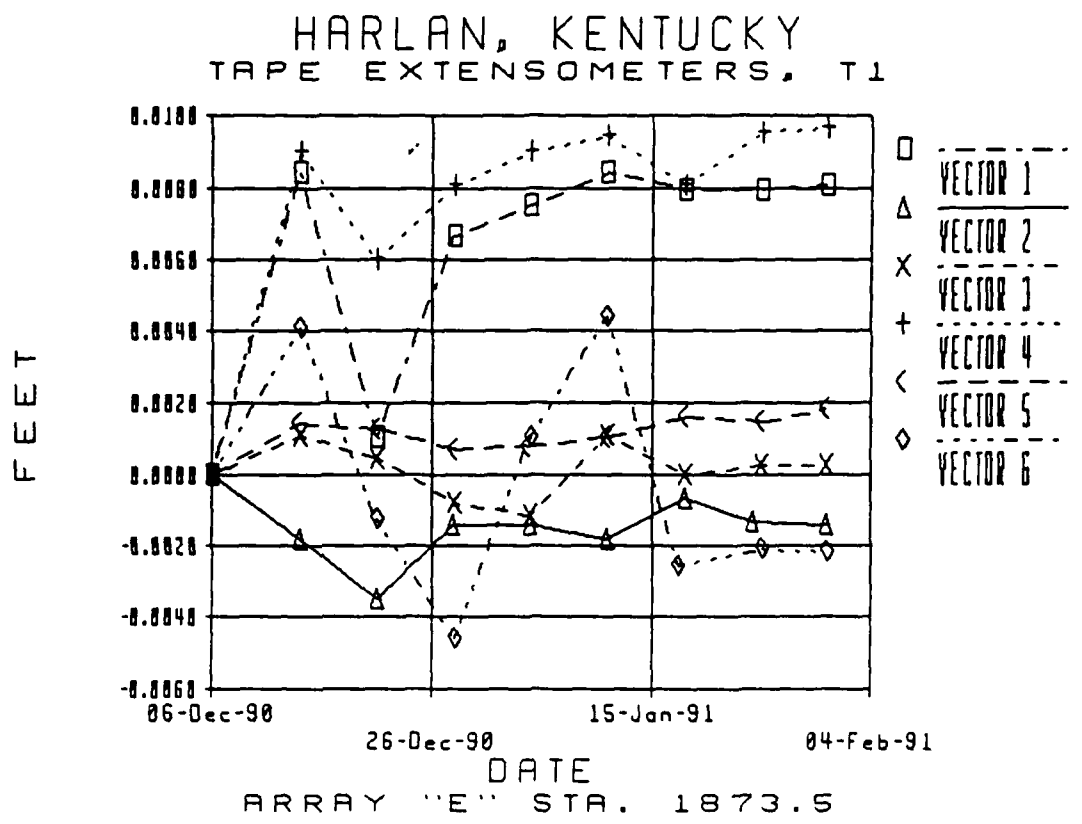
HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T2



ARRAY "D" STA. 1132

PLATE I-33

HARLAN, KENTUCKY


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
FEET
VECTOR 1
VECTOR 2
VECTOR 3
VECTOR 4
VECTOR 5
VECTOR 6
06-Dec-90
26-Dec-90
15-Jan-91
04-Feb-91
DATE
ARRAY "E" STA. 1873.5

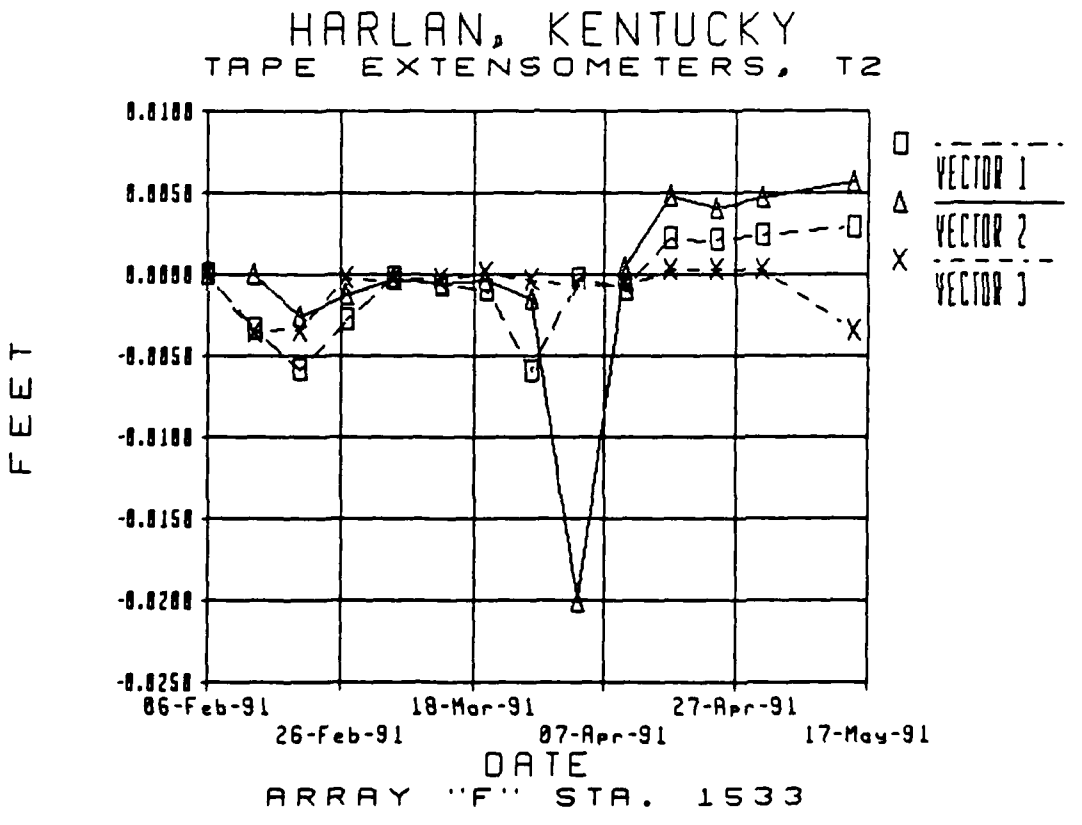
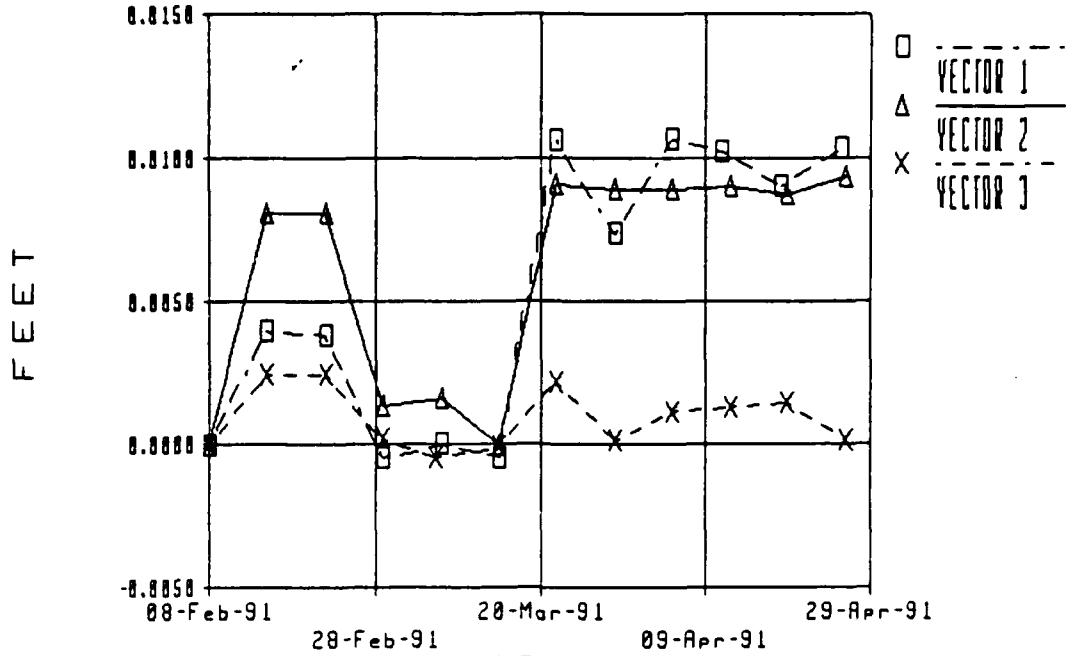

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T2
FEET
VECTOR 1
VECTOR 2
VECTOR 3
06-Feb-91
26-Feb-91
18-Mar-91
07-Apr-91
27-Apr-91
17-May-91
DATE
ARRAY "F" STA. 1533

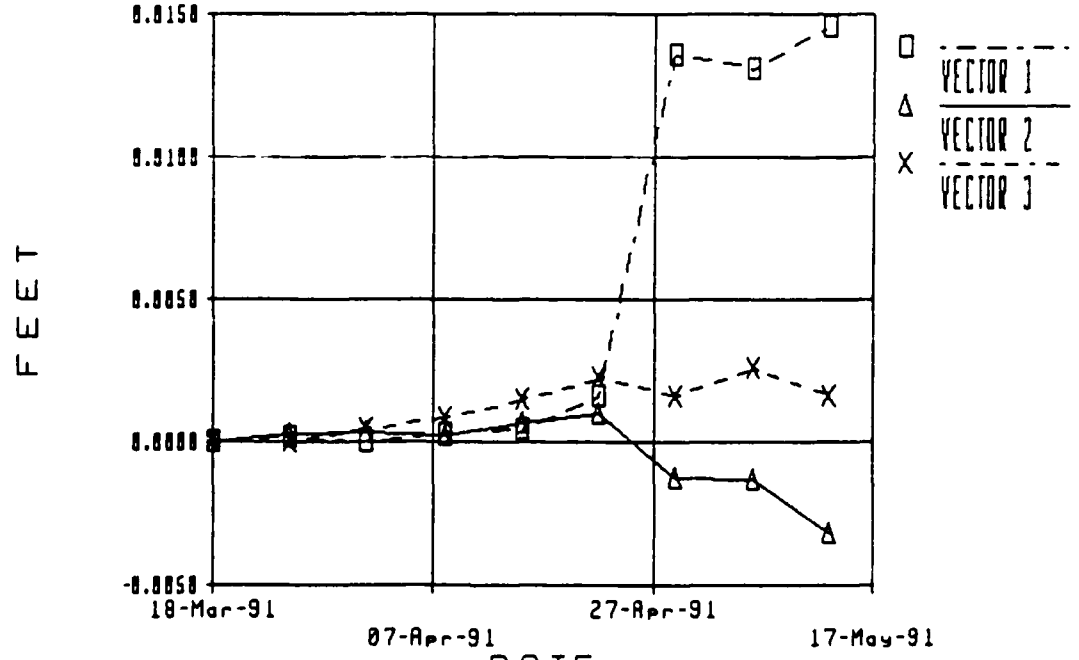
PLATE I-34

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1



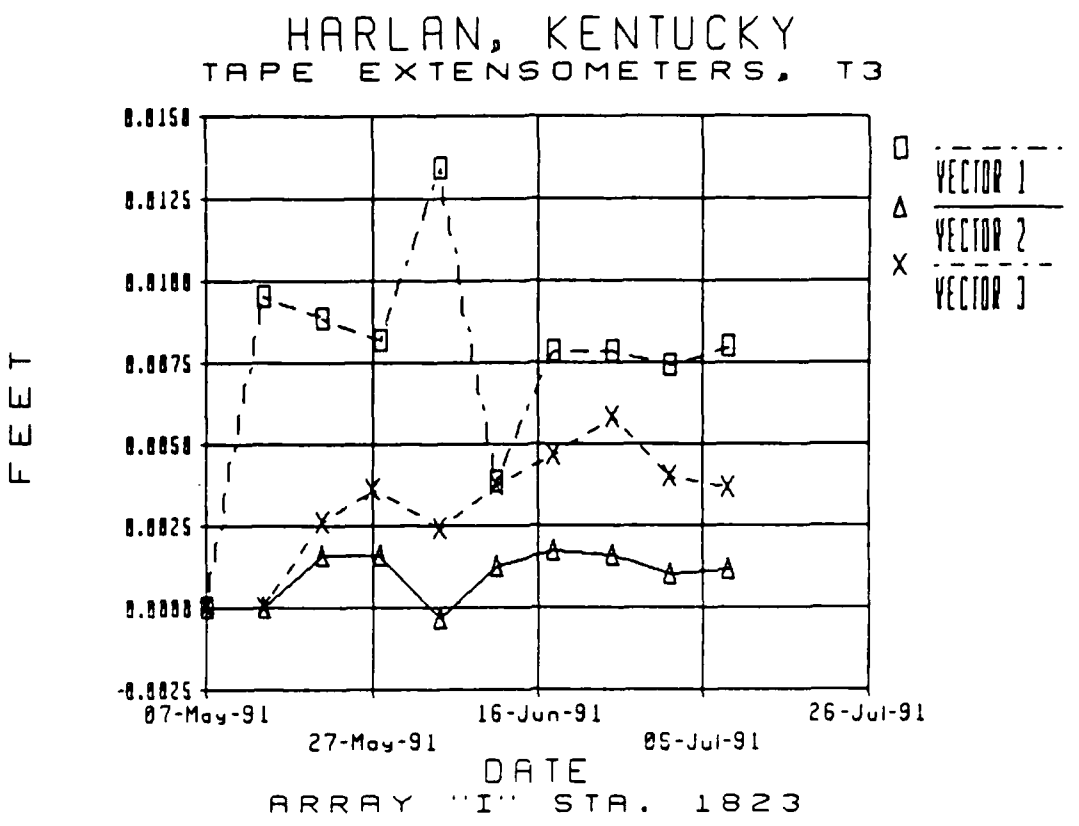
ARRAY "C" STA. 2555

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1



ARRAY "H" STA. 995

PLATE I-35


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T3
FEET
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
-0.0025
07-May-91
27-May-91
16-Jun-91
05-Jul-91
26-Jul-91
DATE
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "I" STA. 1823

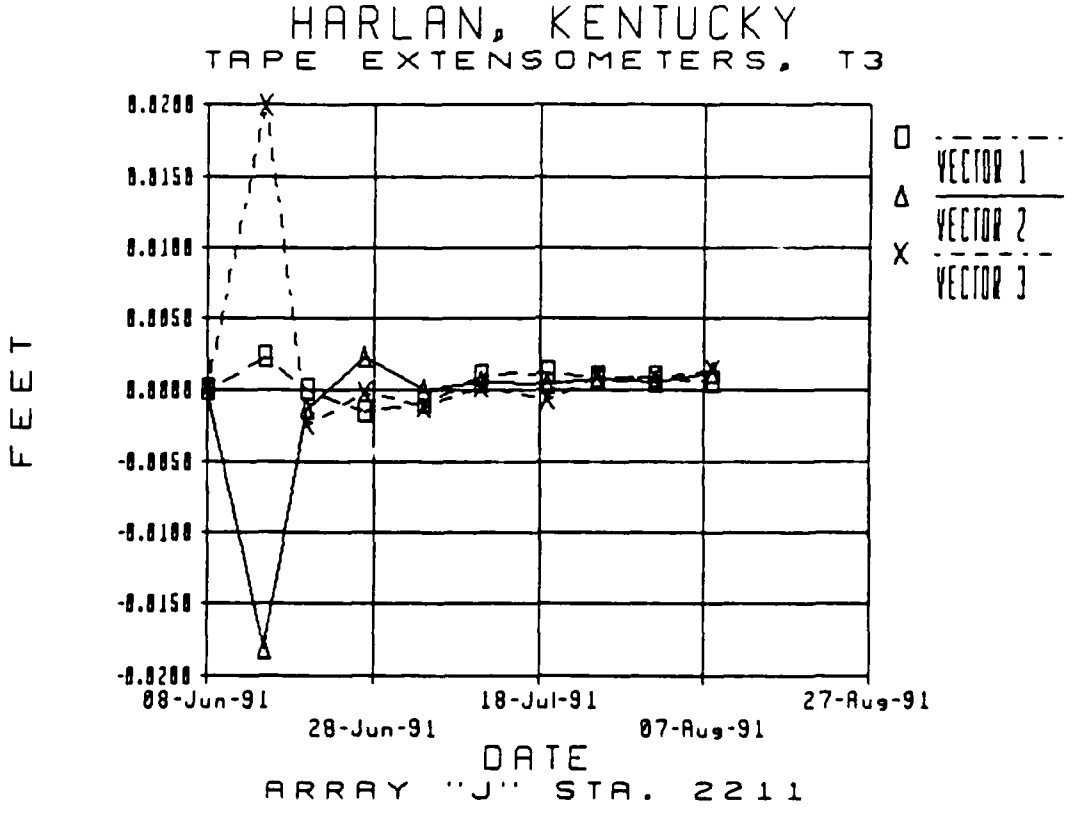
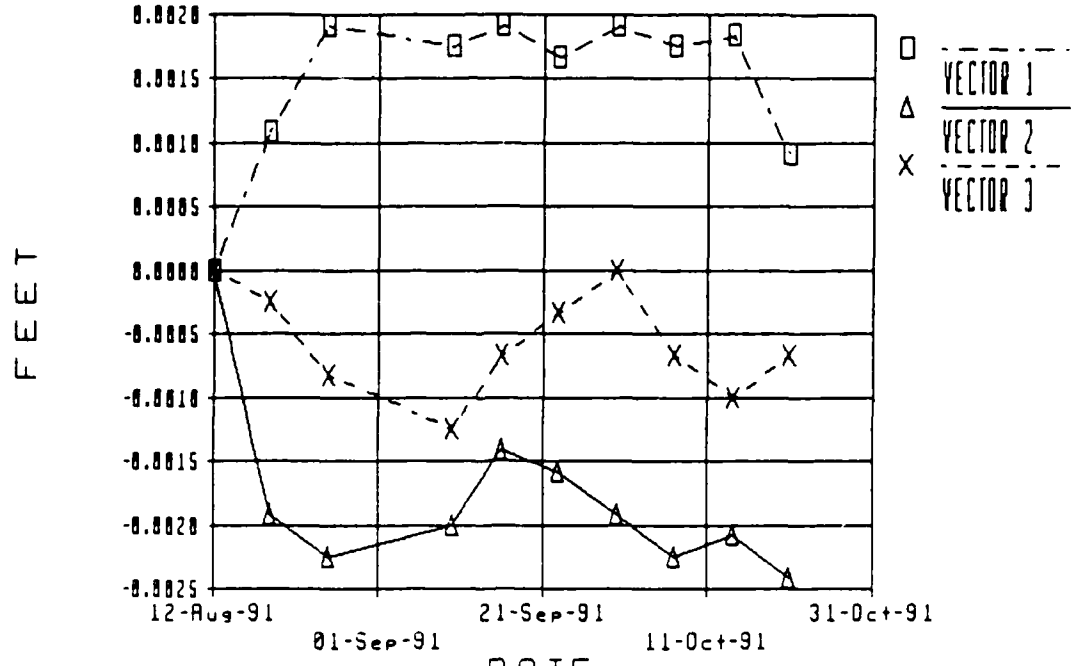

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T3
FEET
0.0200
0.0150
0.0100
0.0050
0.0000
-0.0050
-0.0100
-0.0150
-0.0200
08-Jun-91
28-Jun-91
18-Jul-91
07-Aug-91
27-Aug-91
DATE
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "J" STA. 2211

PLATE I-36

HARLAN, KENTUCKY

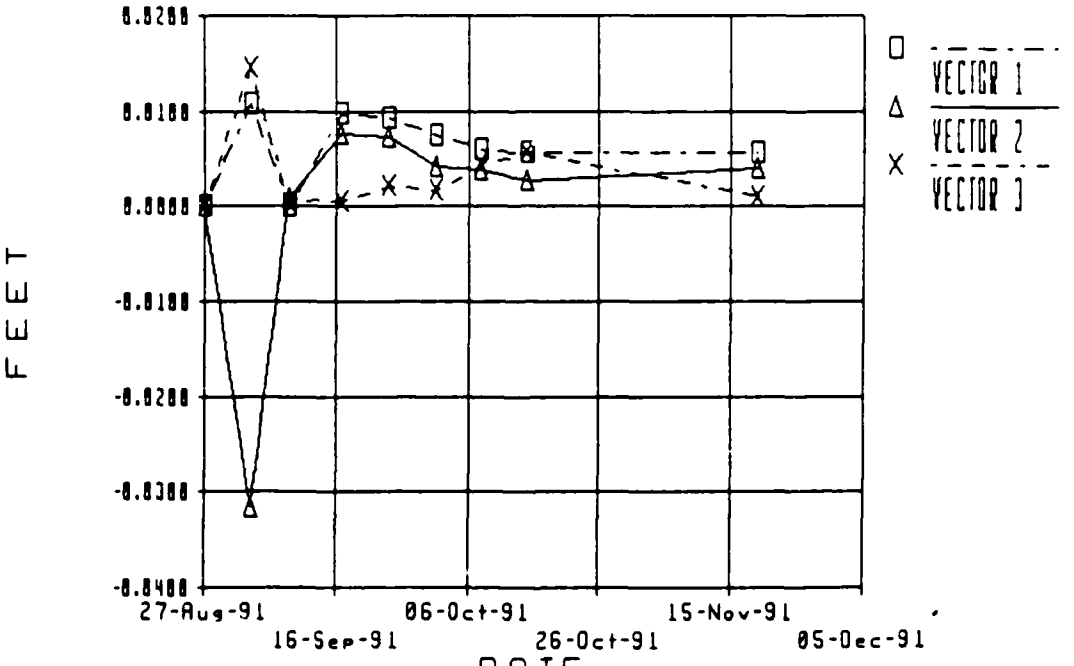
TAPE EXTENSOMETERS, T3



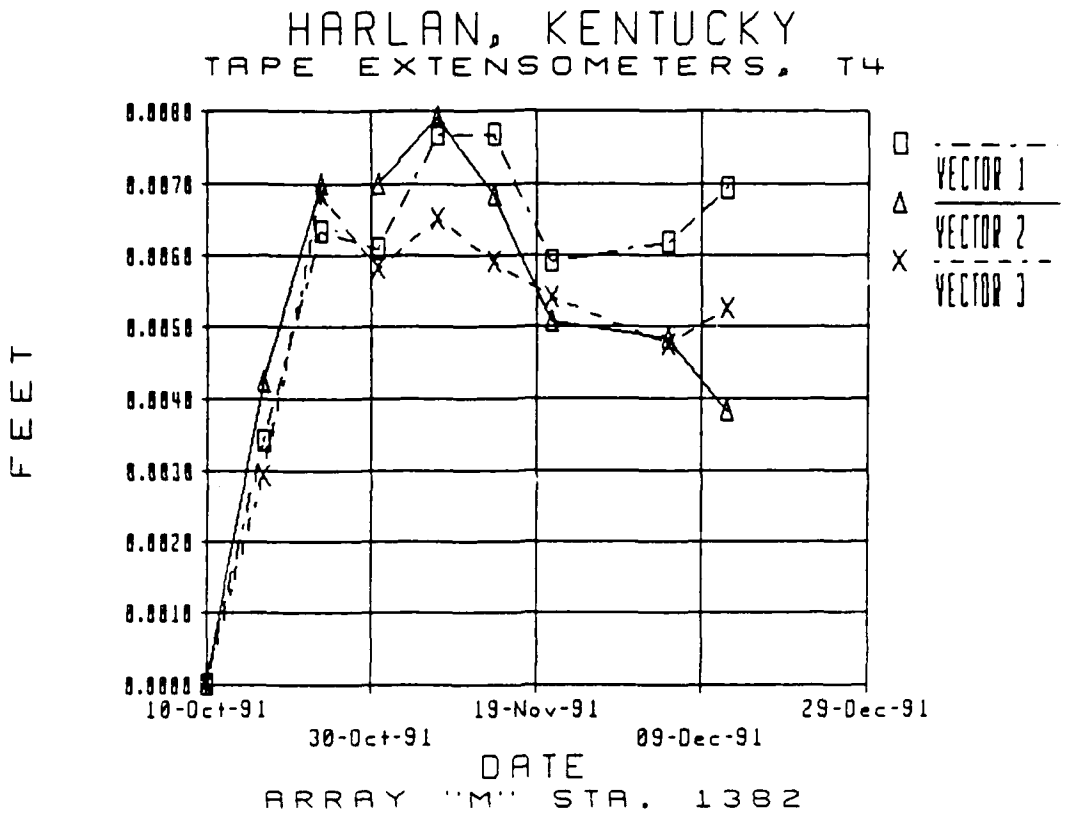
ARRAY "K" STA. 1136

HARLAN, KENTUCKY

TAPE EXTENSOMETERS, T2



ARRAY "L" STA. 2652


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4
FEET
0.0888
0.0878
0.0868
0.0858
0.0848
0.0838
0.0828
0.0818
0.0808
10-Oct-91
19-Nov-91
29-Dec-91
30-Oct-91
09-Dec-91
DATE
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "M" STA. 1382

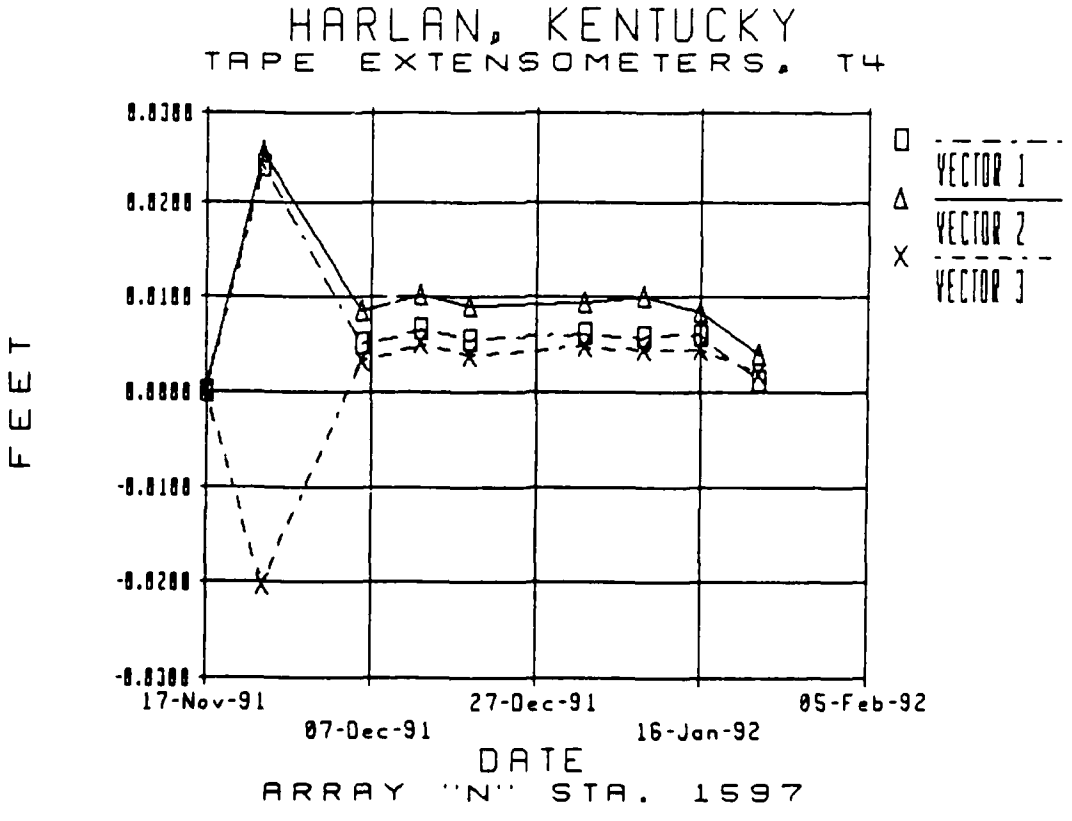
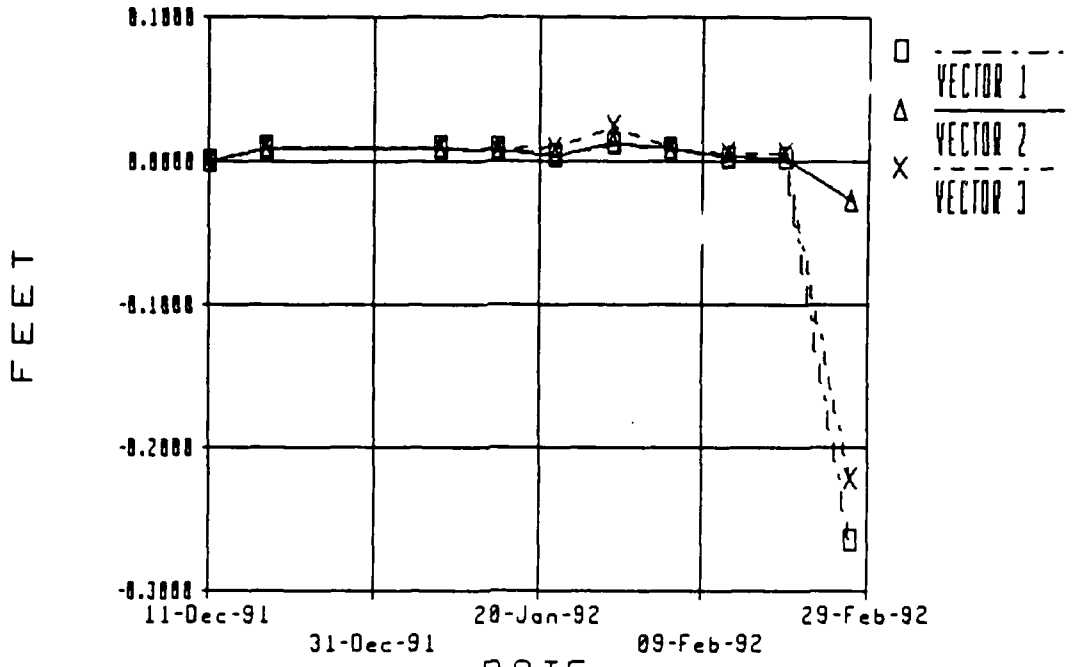

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4
FEET
0.0388
0.0288
0.0188
0.0088
-0.0188
-0.0288
-0.0388
17-Nov-91
27-Dec-91
05-Feb-92
07-Dec-91
16-Jan-92
DATE
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "N" STA. 1597

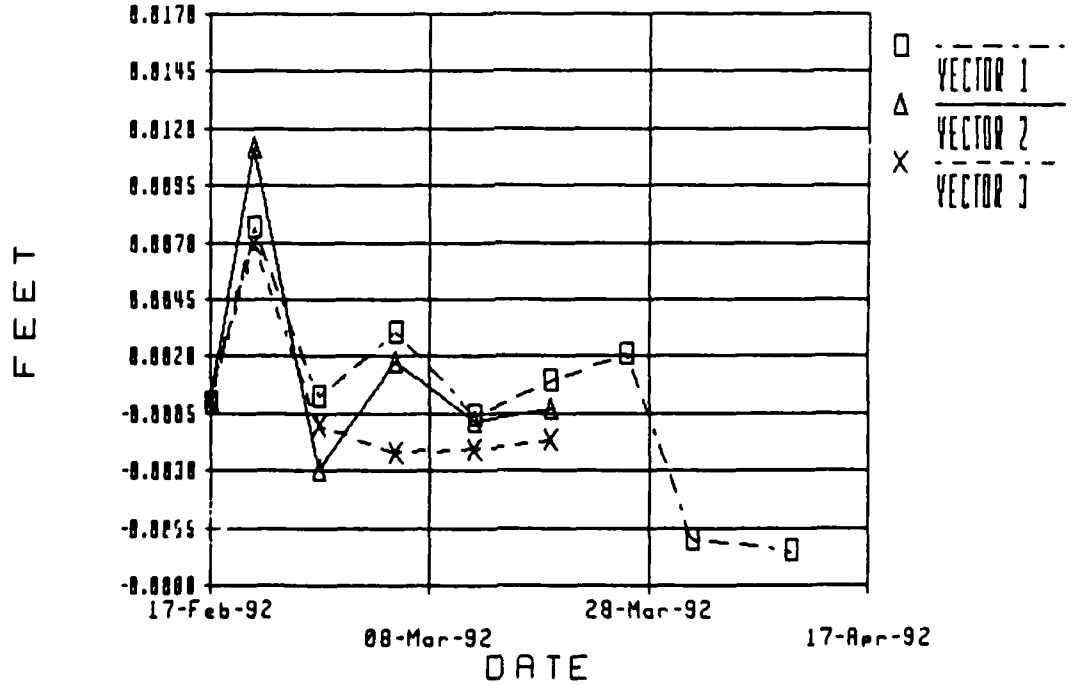
PLATE I-38

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4

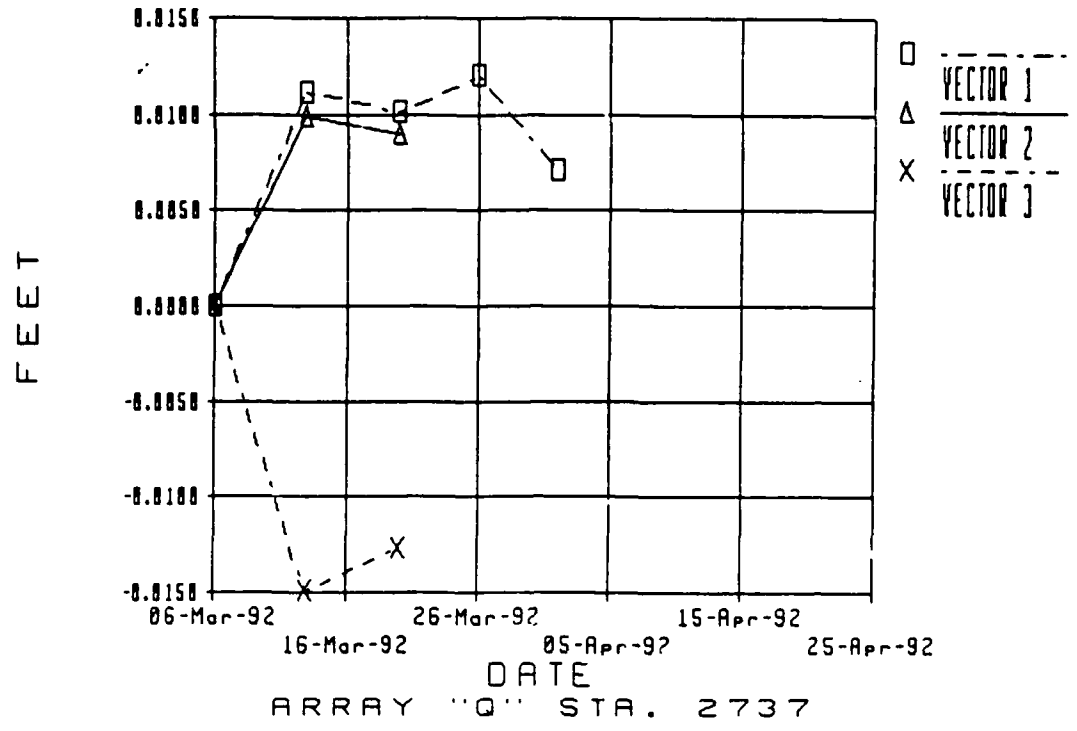


ARRAY "O" STA. 1923

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "P" STA. 2396


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4
0.0150
0.0100
0.0050
0.0000
-0.0050
-0.0100
-0.0150
FEET
06-Mar-92
16-Mar-92
26-Mar-92
05-Apr-92
15-Apr-92
25-Apr-92
DATE
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "Q" STA. 2737

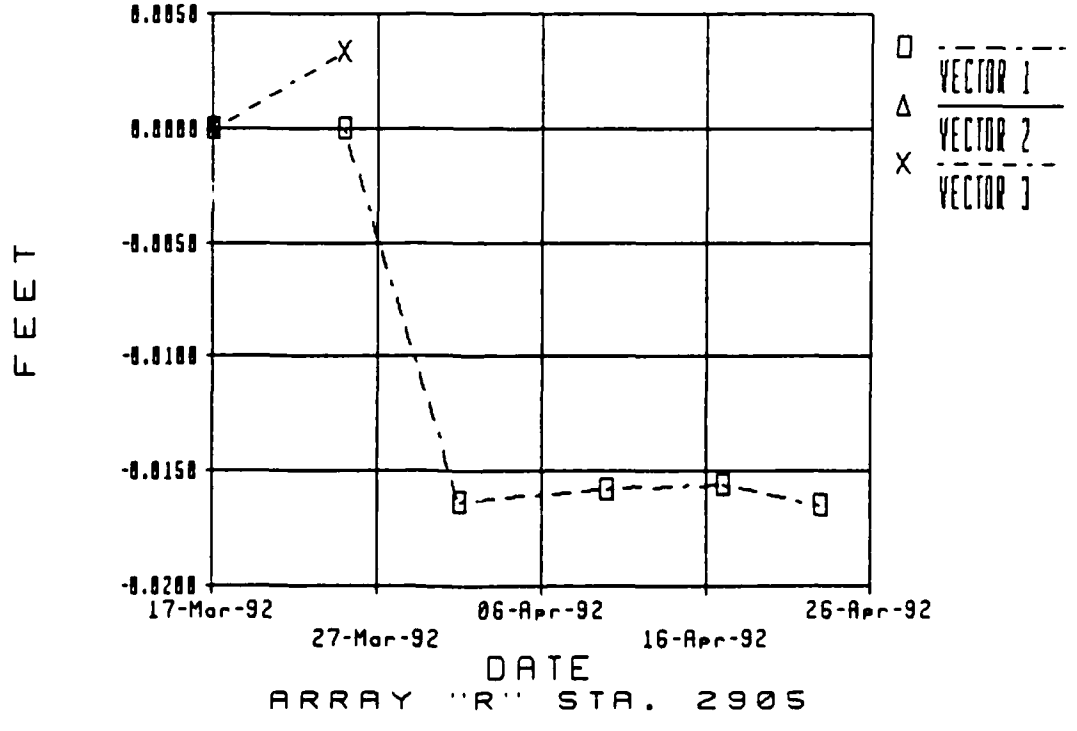
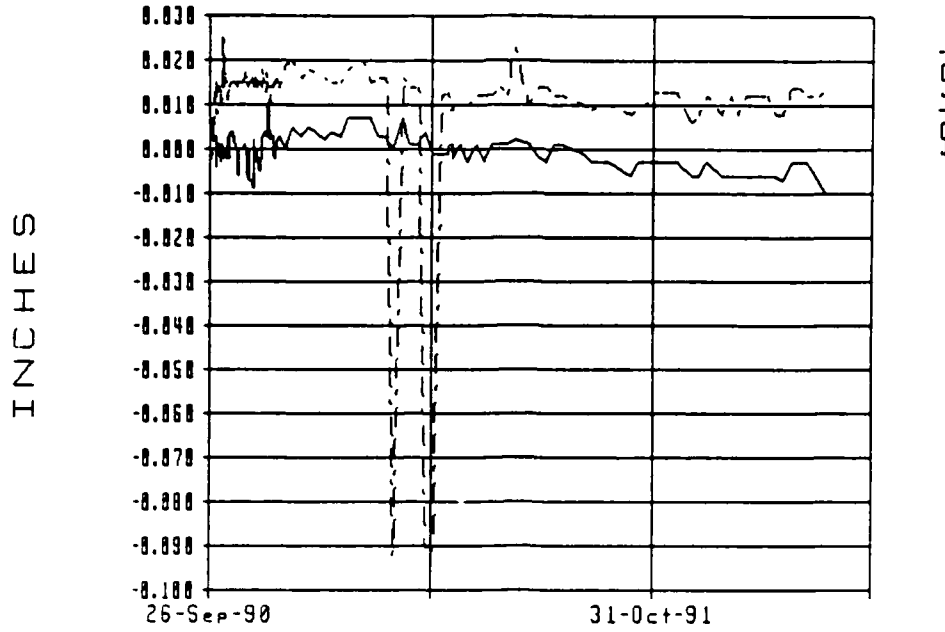

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4
0.0050
0.0000
-0.0050
-0.0100
-0.0150
-0.0200
FEET
17-Mar-92
27-Mar-92
06-Apr-92
16-Apr-92
26-Apr-92
DATE
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "R" STA. 2905

PLATE I-40

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



INCHES

DATE

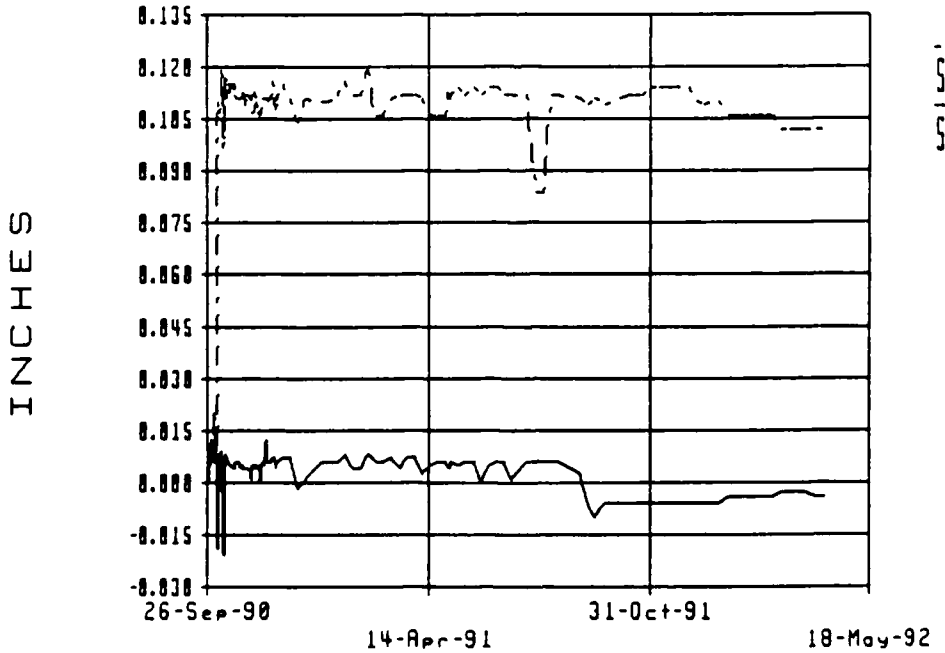
S1A(1073)

S2A(1077)

Anchor Depth:
S1A 10 ft.
S2A 5 ft.

ARRAY "A" STA. 1077

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



INCHES

DATE

S3A(1079)

S4A(1074)

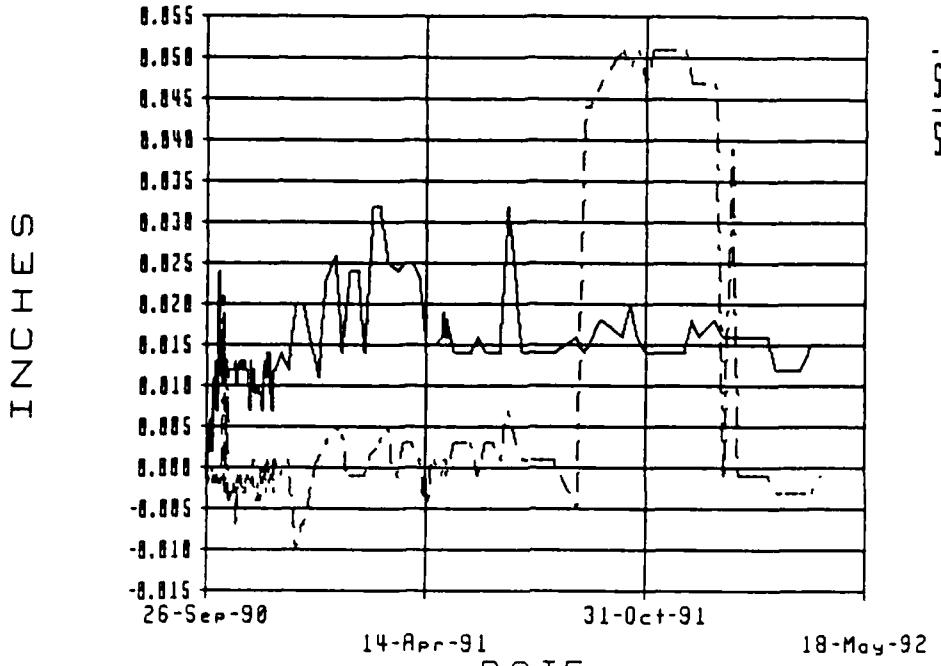
Anchor Depth:
S3A 1 ft.
S4A 10 ft.

ARRAY "A" STA. 1077

PLATE I-41

HARLAN, KENTUCKY

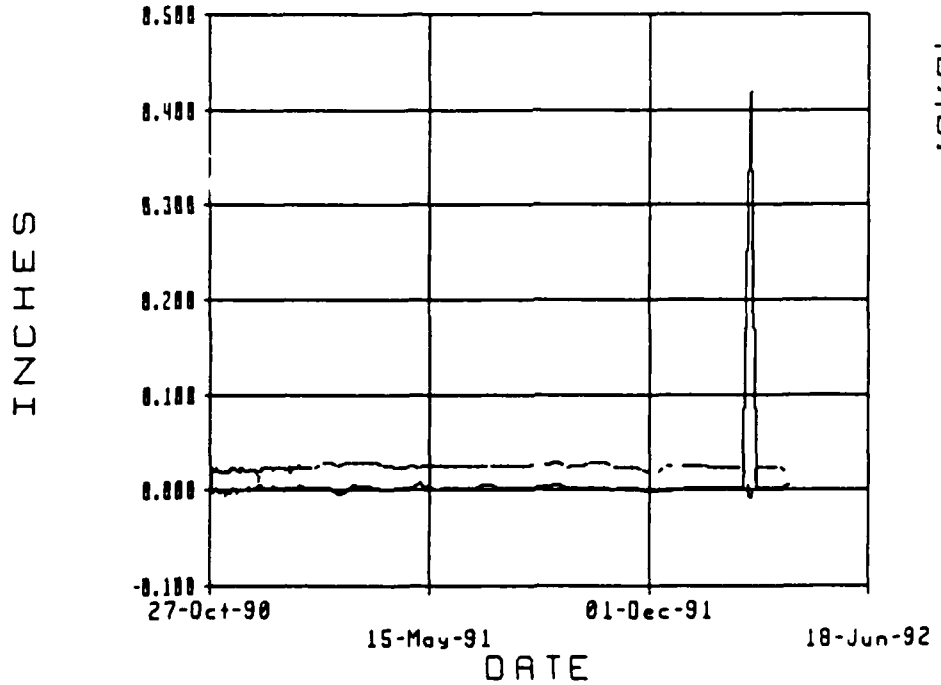
SPB EXTENSOMETERS, T1



ARRAY "A" STA. 1077

HARLAN, KENTUCKY

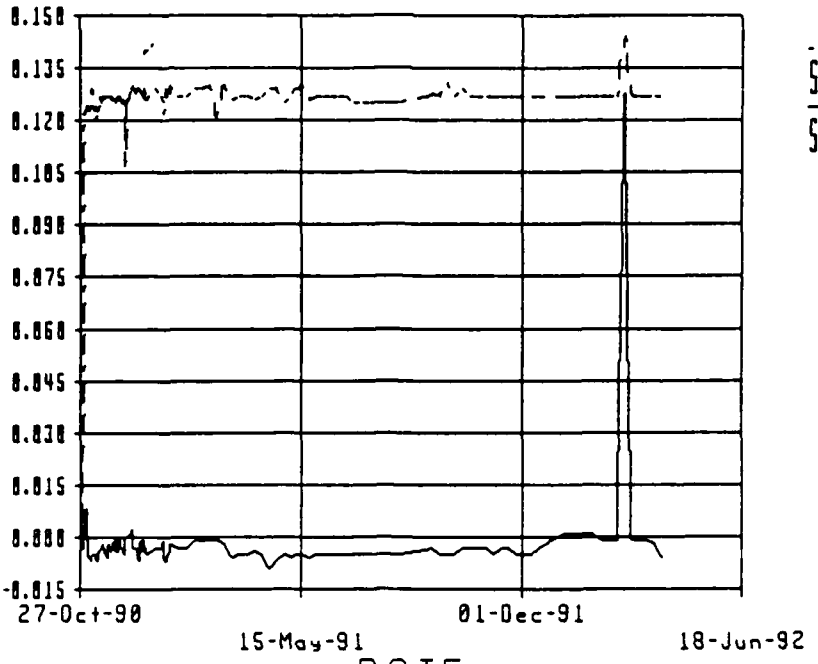
SPB EXTENSOMETERS, T1



ARRAY "B" STA. 1367

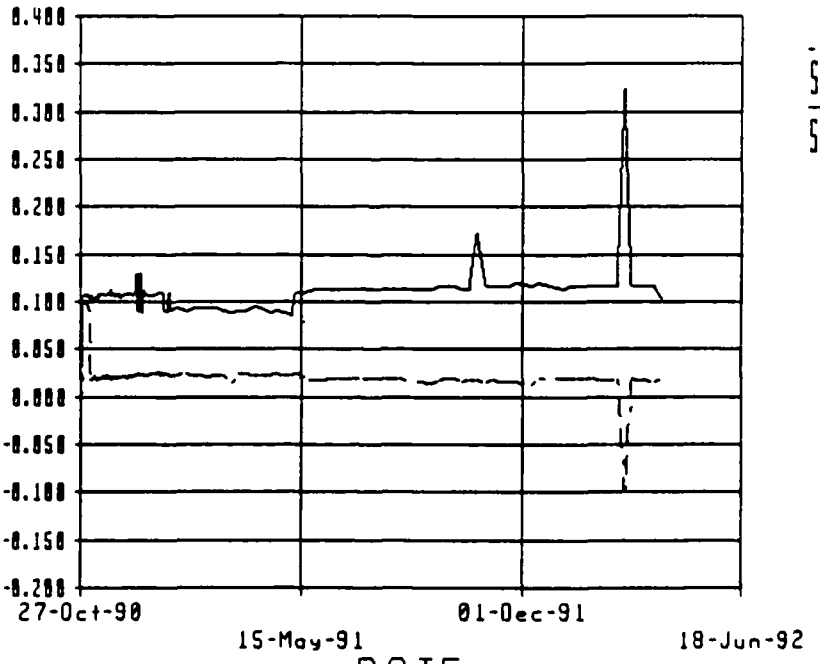
PLATE I-42

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



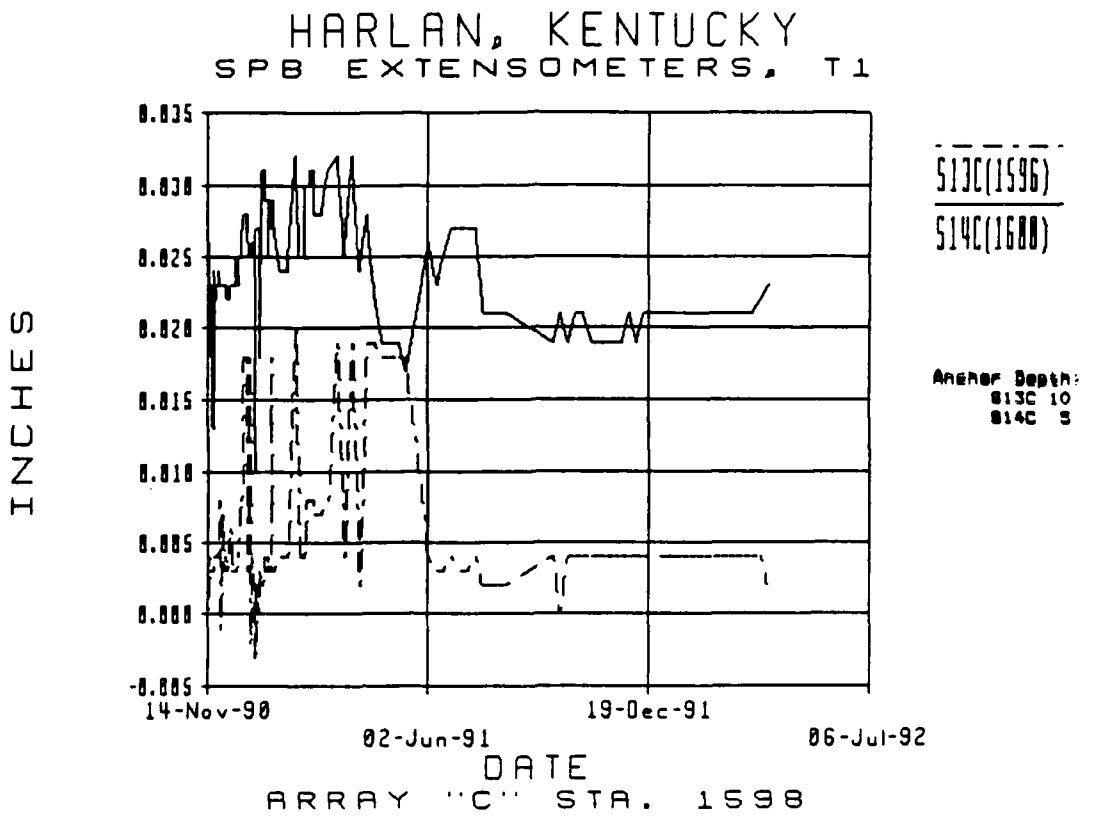
ARRAY "B" STA. 1367

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "B" STA. 1367

PLATE I-43


HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1
INCHES
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
14-Nov-90
02-Jun-91
19-Dec-91
06-Jul-92
DATE
ARRAY "C" STA. 1598
S13C(1596)
S14C(1600)
Anchor Depth:
S13C 10
S14C 5

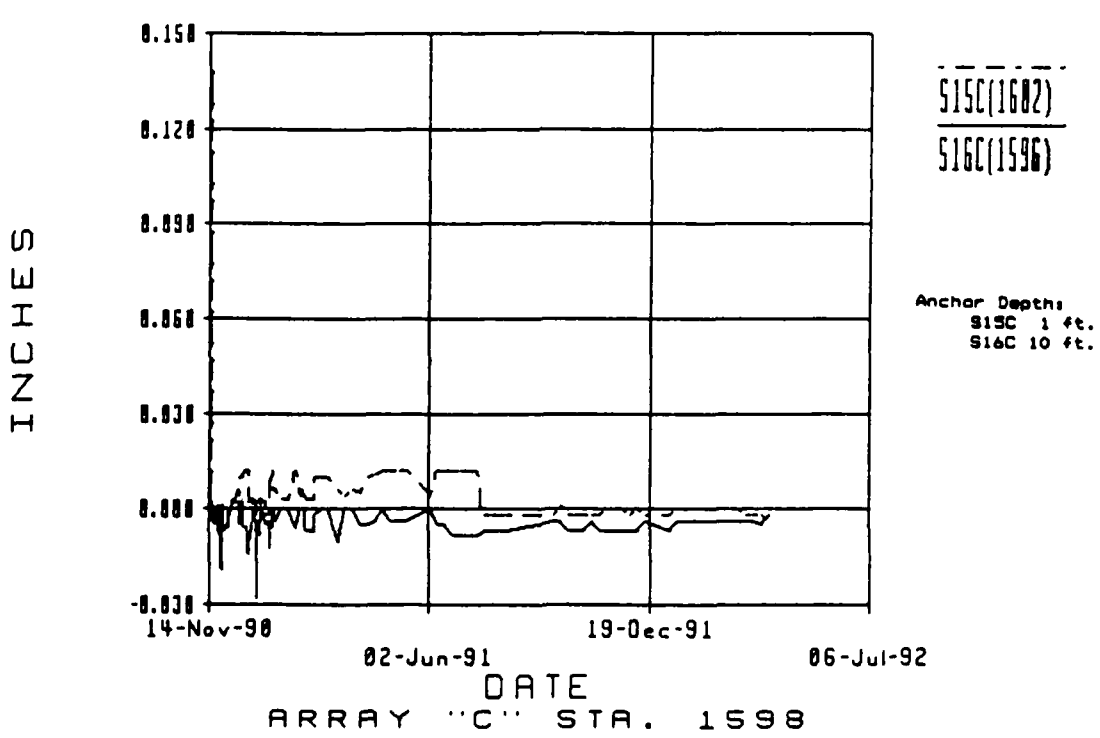
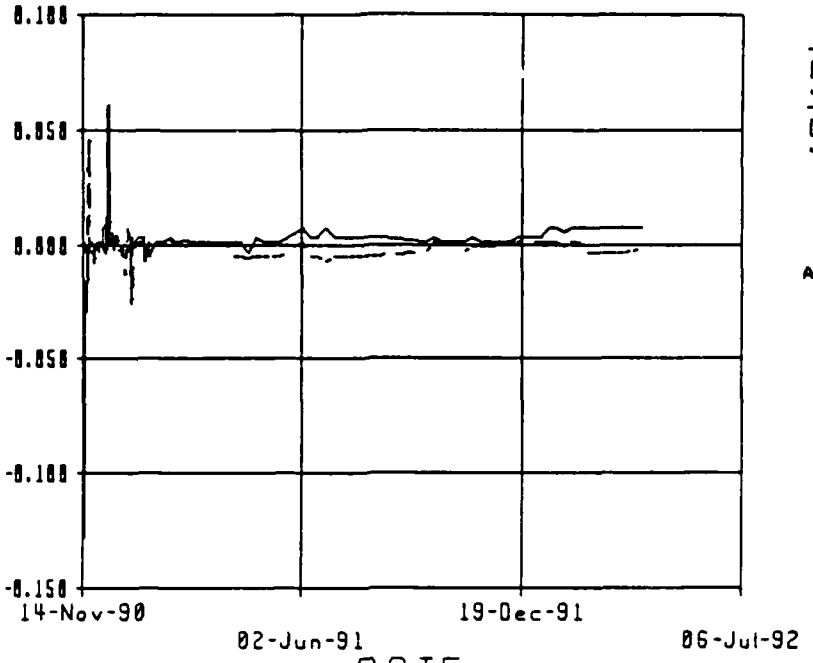

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1
INCHES
0.150
0.120
0.090
0.060
0.030
0.000
-0.030
14-Nov-90
02-Jun-91
19-Dec-91
06-Jul-92
DATE
ARRAY "C" STA. 1598
S15C(1602)
S16C(1596)
Anchor Depth:
S15C 1 ft.
S16C 10 ft.

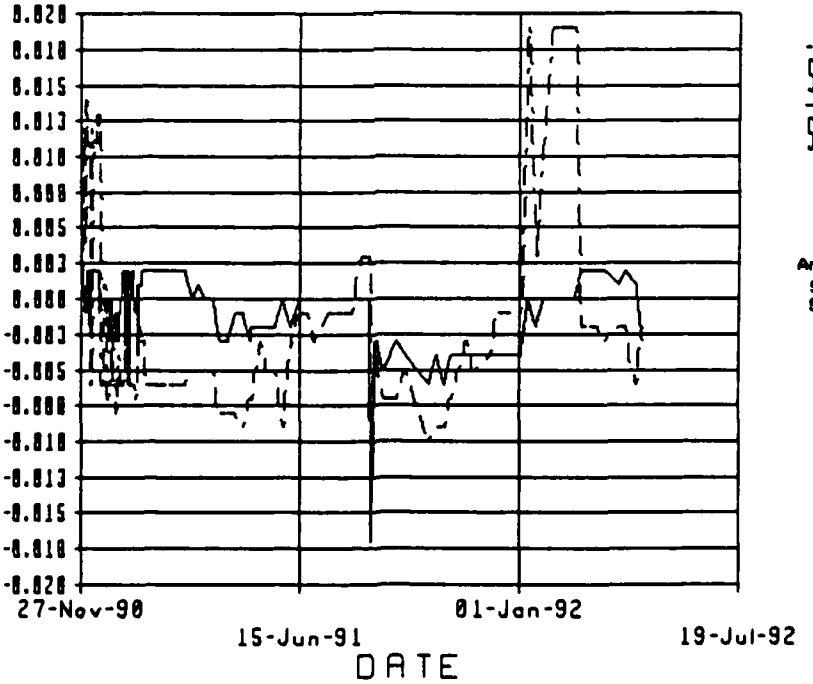
PLATE I-44

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



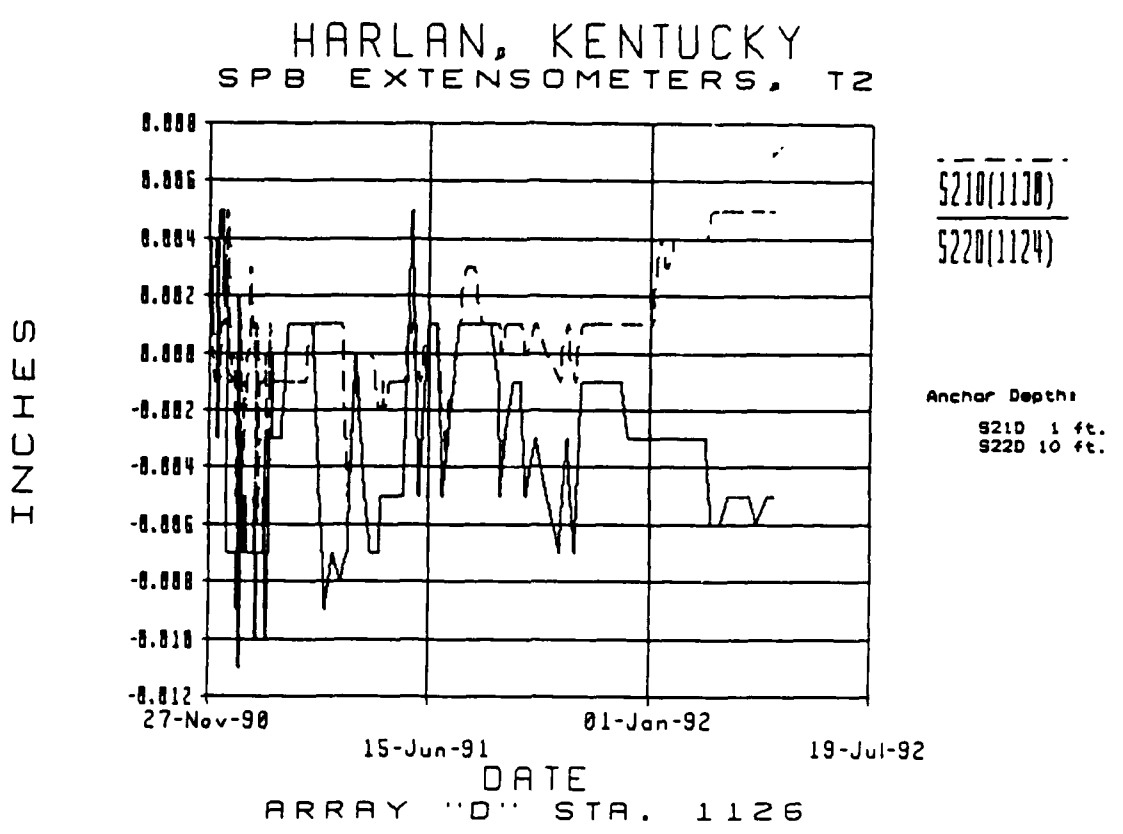
ARRAY "C" STA. 1598

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T2



ARRAY "D" STA. 1126

PLATE I-45


HARLAN, KENTUCKY
SPB EXTENSOMETERS, T2
INCHES
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
27-Nov-90
15-Jun-91
01-Jan-92
19-Jul-92
DATE
ARRAY "D" STA. 1126
S210(1130)
S220(1124)
Anchor Depth:
S21D 1 ft.
S22D 10 ft.

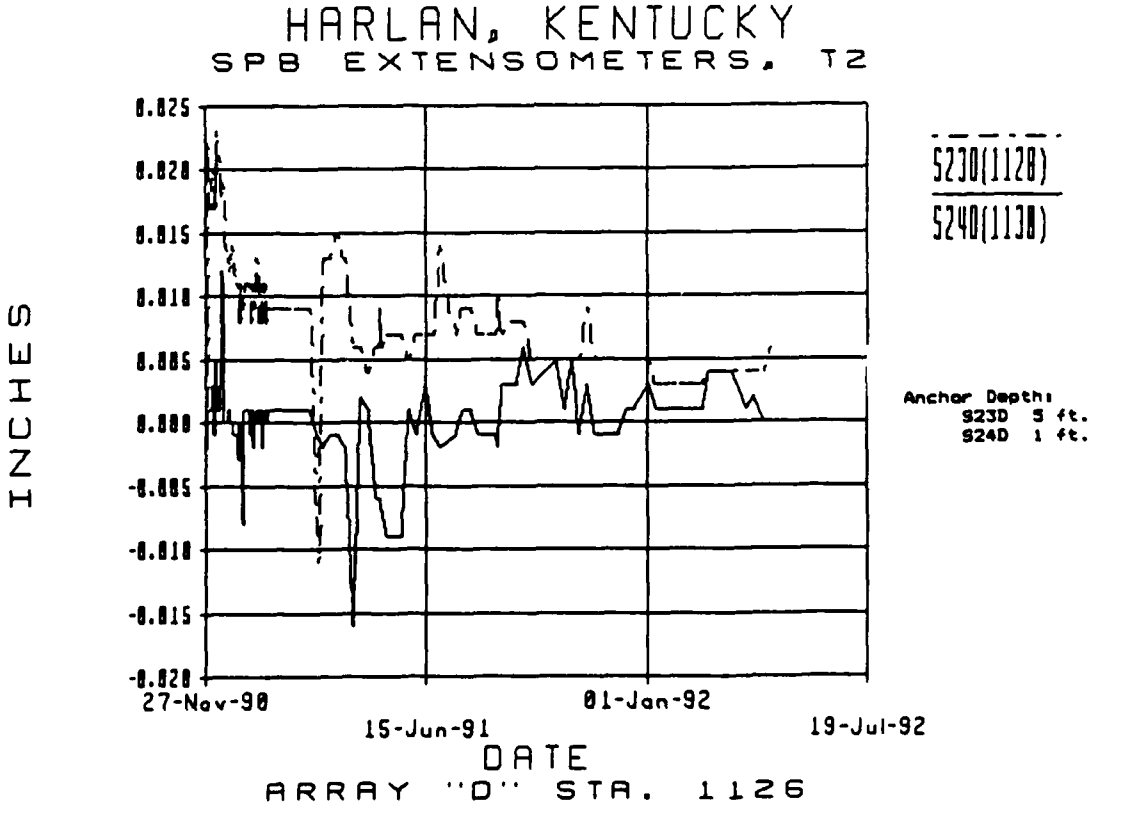
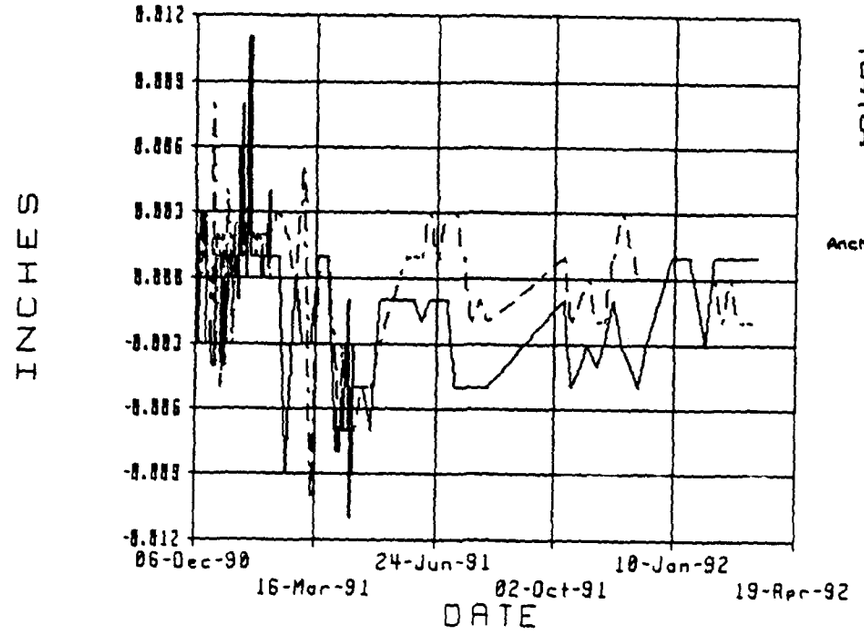

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T2
INCHES
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
27-Nov-90
15-Jun-91
01-Jan-92
19-Jul-92
DATE
ARRAY "D" STA. 1126
S230(1120)
S240(1130)
Anchor Depth:
S23D 5 ft.
S24D 1 ft.

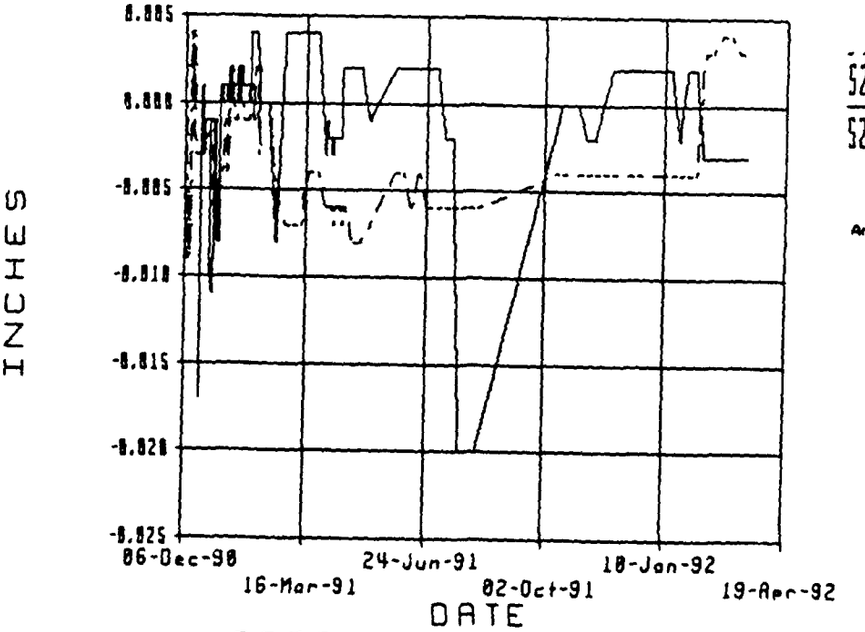
PLATE I-46

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "E" STA. 1868

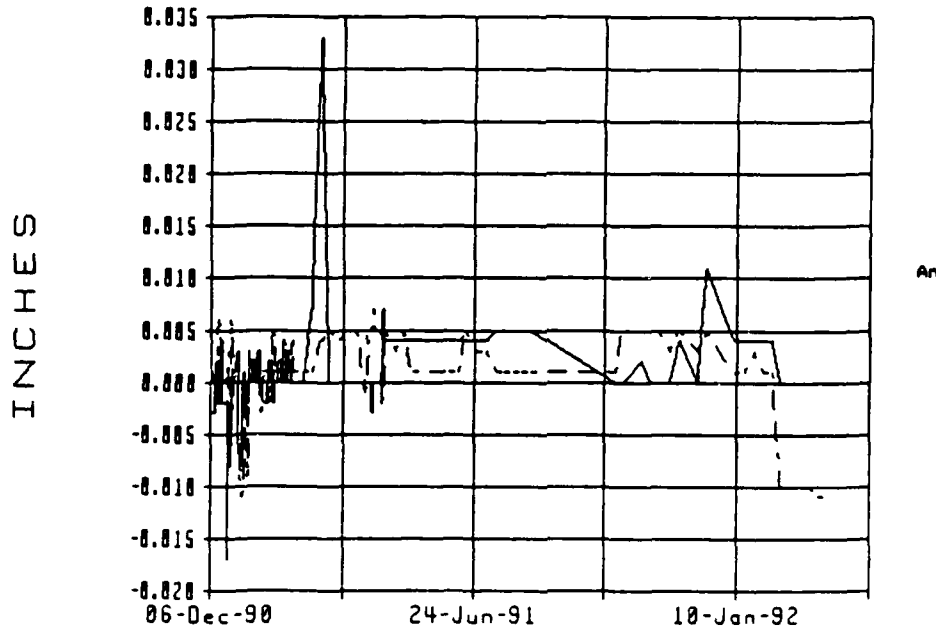
HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "E" STA. 1868

PLATE I-47

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "E" STA. 1866

PLATE I-48