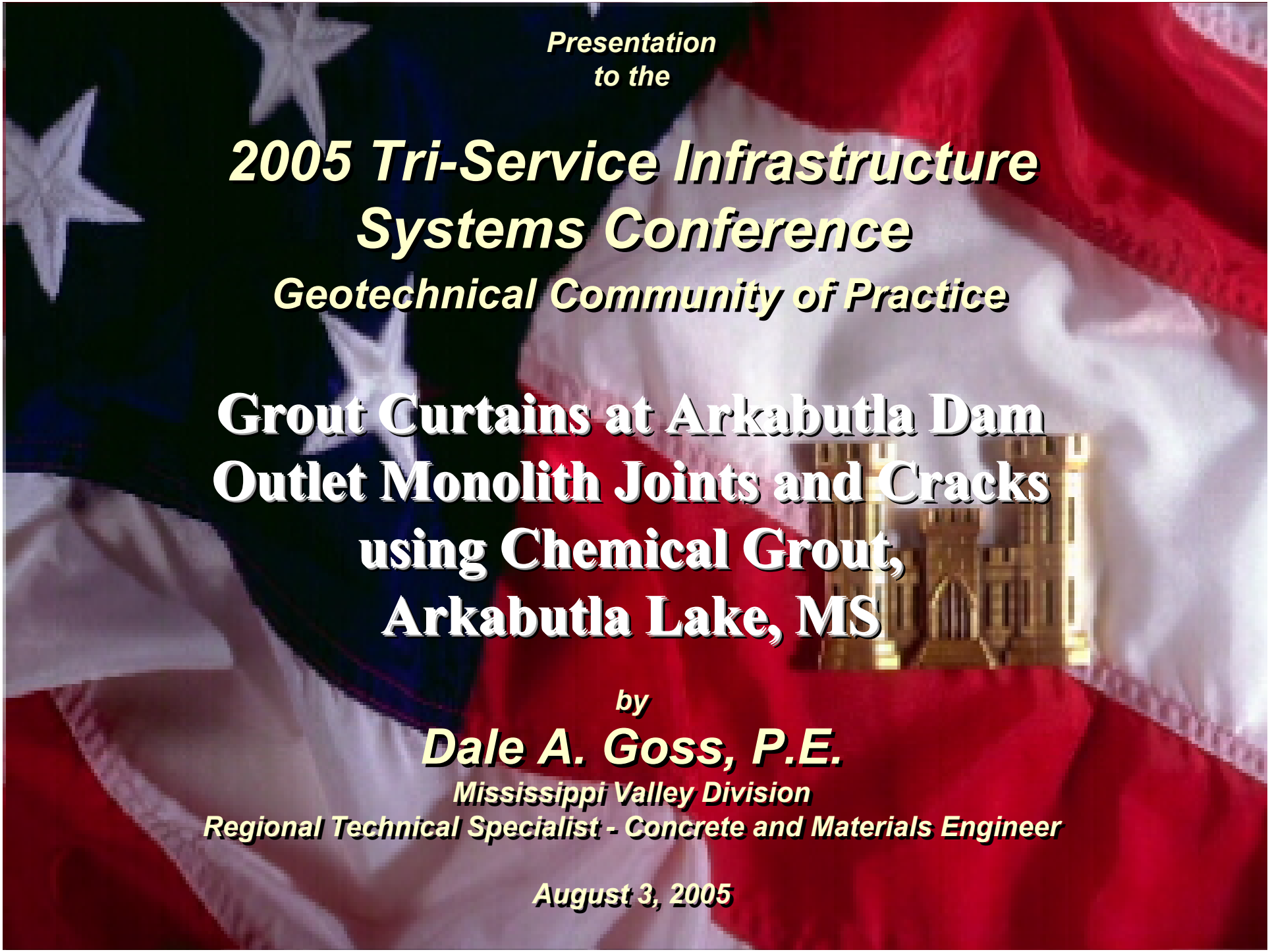

Presentation to the

2005 Tri-Service Infrastructure Systems Conference

Geotechnical Community of Practice

Grout Curtains at Arkabutla Dam Outlet Monolith Joints and Cracks using Chemical Grout, Arkabutla Lake, MS

by

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Mississippi Valley Division

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August 3, 2005

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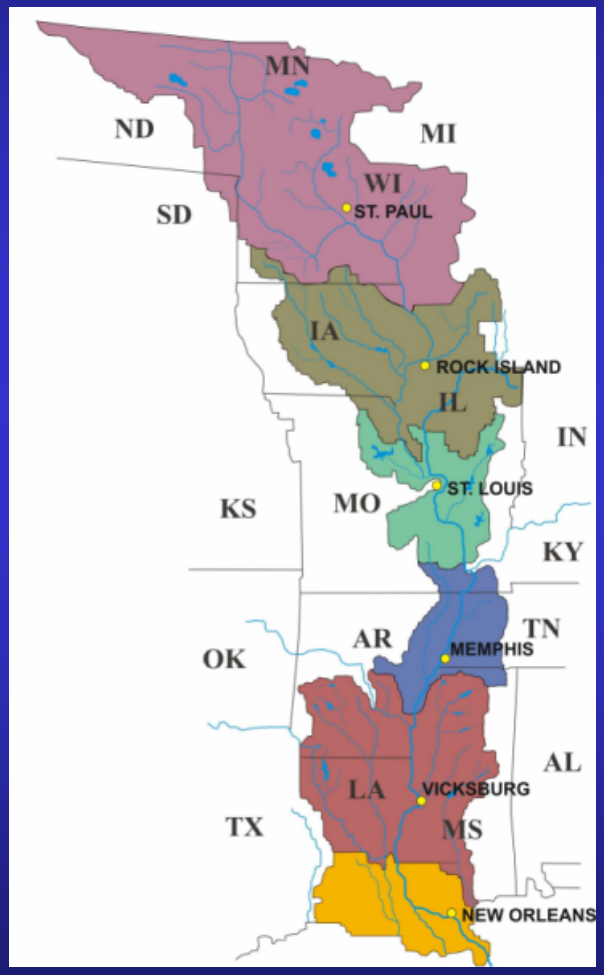
Mississippi Valley Division



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Arkabutla Lake

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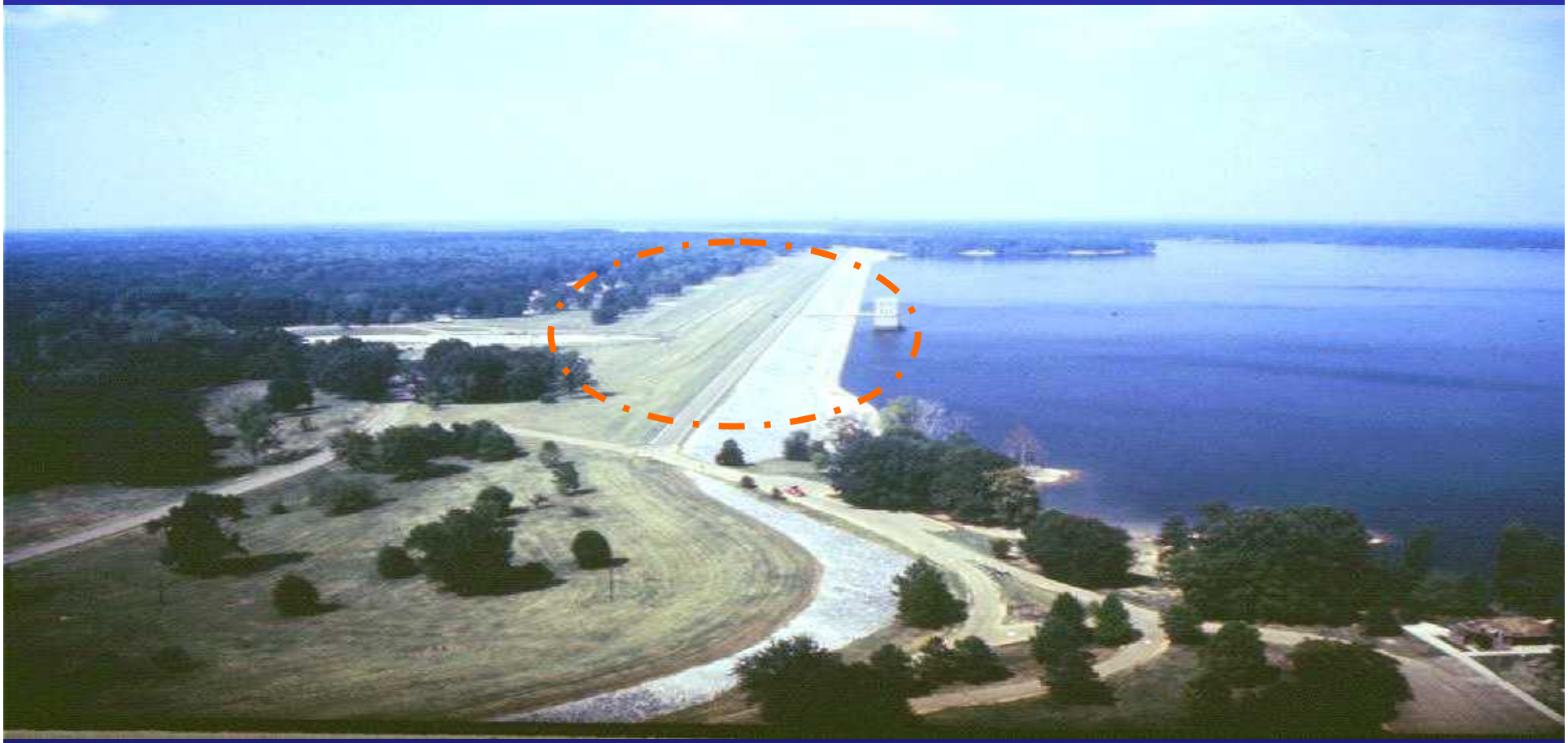
ARKABUTLA LAKE OUTLET WORKS



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BACKGROUND

- Condition of Conduit
- Previous Grouting
- Previous Joint Repair

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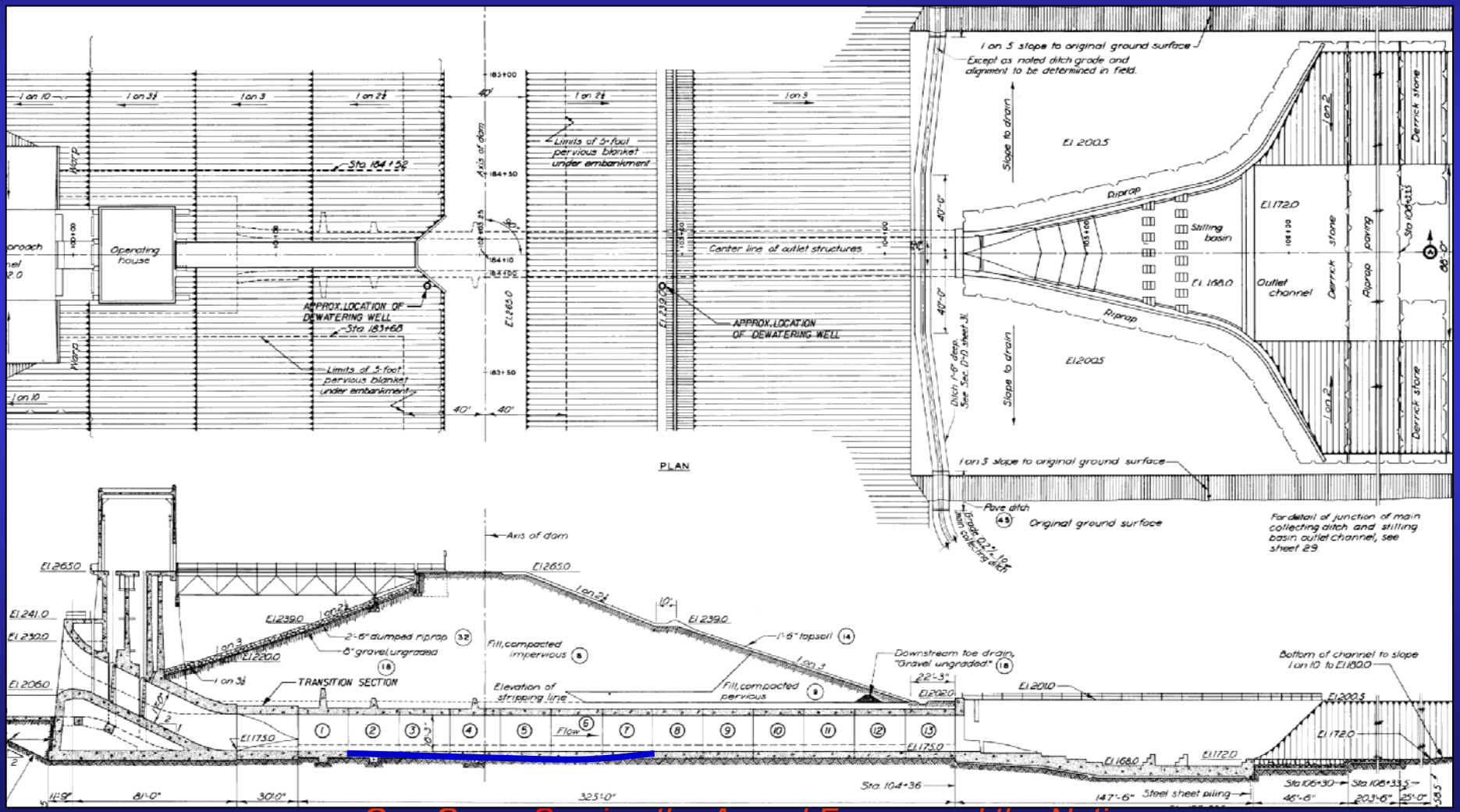
OUTLET WORKS

(Constructed in 1941)



Typical Monolith Joint with no waterstop in base of conduit

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Factors affecting monolith joints.

- Structure constructed in old stream channel (sands) to minimize differential settlement.
- Missing Waterstops
- Misplaced Reinforcement

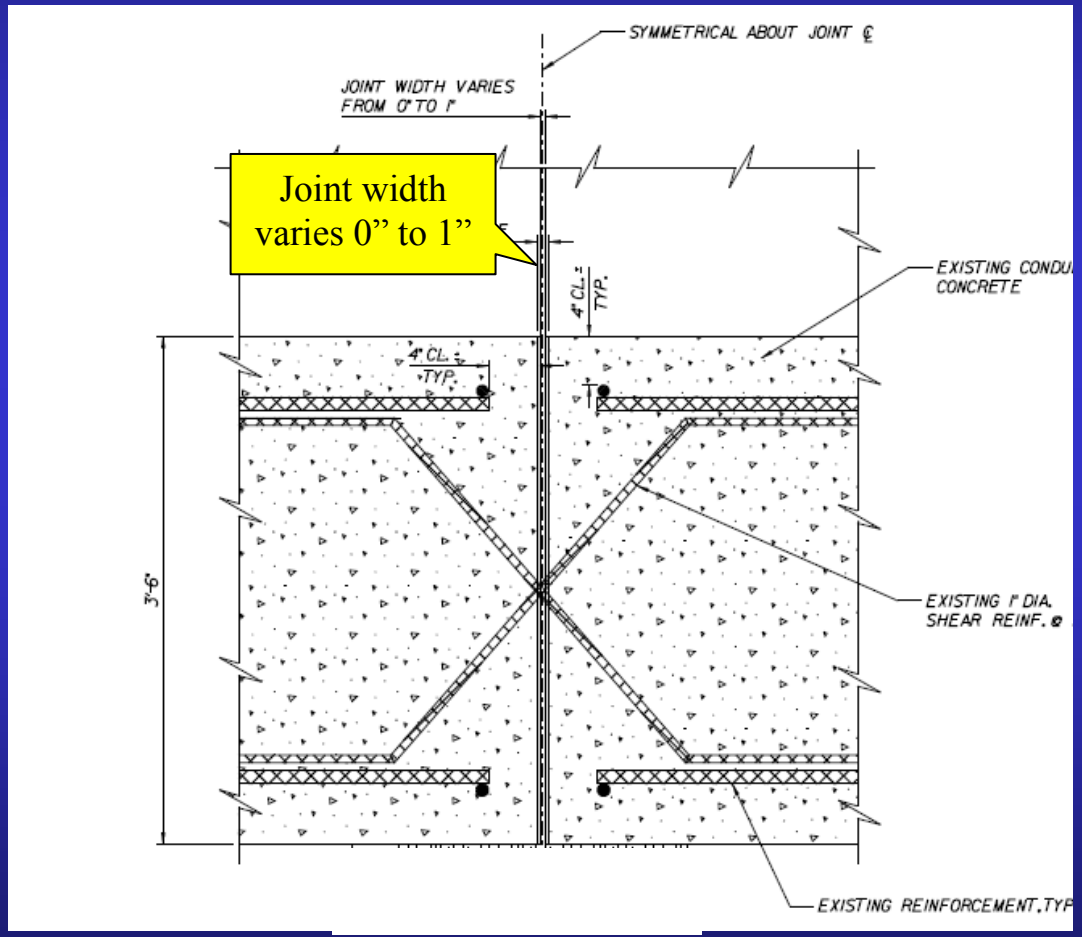

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Table 1

Previous Grouting at Outlet Works Performed during 1950 and 2003								
Joint No.	Cement Grout, Cu. Ft.			Chemical Grout, gal.				Cement Grout, Cu. Ft.
	1950	1971	1977	1988	1998	2000	2003	2003
Transiiton/1								
1/2		0.5	0.4	3.5	2.5		15	11.4
2/3	1.0	0.6		15.0		5.0		10.0
3/4	9.5	410	0.5	2.0				
4/5	12.5	4.6						
5/6	47	33.1	6.9	9.0				
6/7	98	67.6	7.6	10.0				13.4
7/8	7	0.8						
8/9		0.6	1.0					
9/10		1.0						
10/11		0.6						
11/12		0.4						
12/13								
Subtotal	175	519.8	16.4	39.5[1]	2.5[2]	5.0[2]	15[2]	34.8
	711.2			62 gal. ≈ 285.8cu. ft				
Total	1031.8 cu. ft. (38.2 cu. yd.)							

Note: 1. The chemical grouting was performed using Hydro Active Cut (1 gal ≈ 6.67 cu. ft. of stabilized soil)
2. The chemical grouting was performed using Hydro Active Flex LV (1 gal ≈ 1 cu. ft. of grout)
3. Settlement of monoliths 1 through 8 of approximately 11 inches account for the loss of 78 cu. yd. of material.

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Sand Bags, Three foot high, to Control Sand Boil at Monolith Joint 5/6, Aug. 2003

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3/4 Cubic Yards of Foundation Sand piped through Monolith Joint 5/6, Aug. 2003

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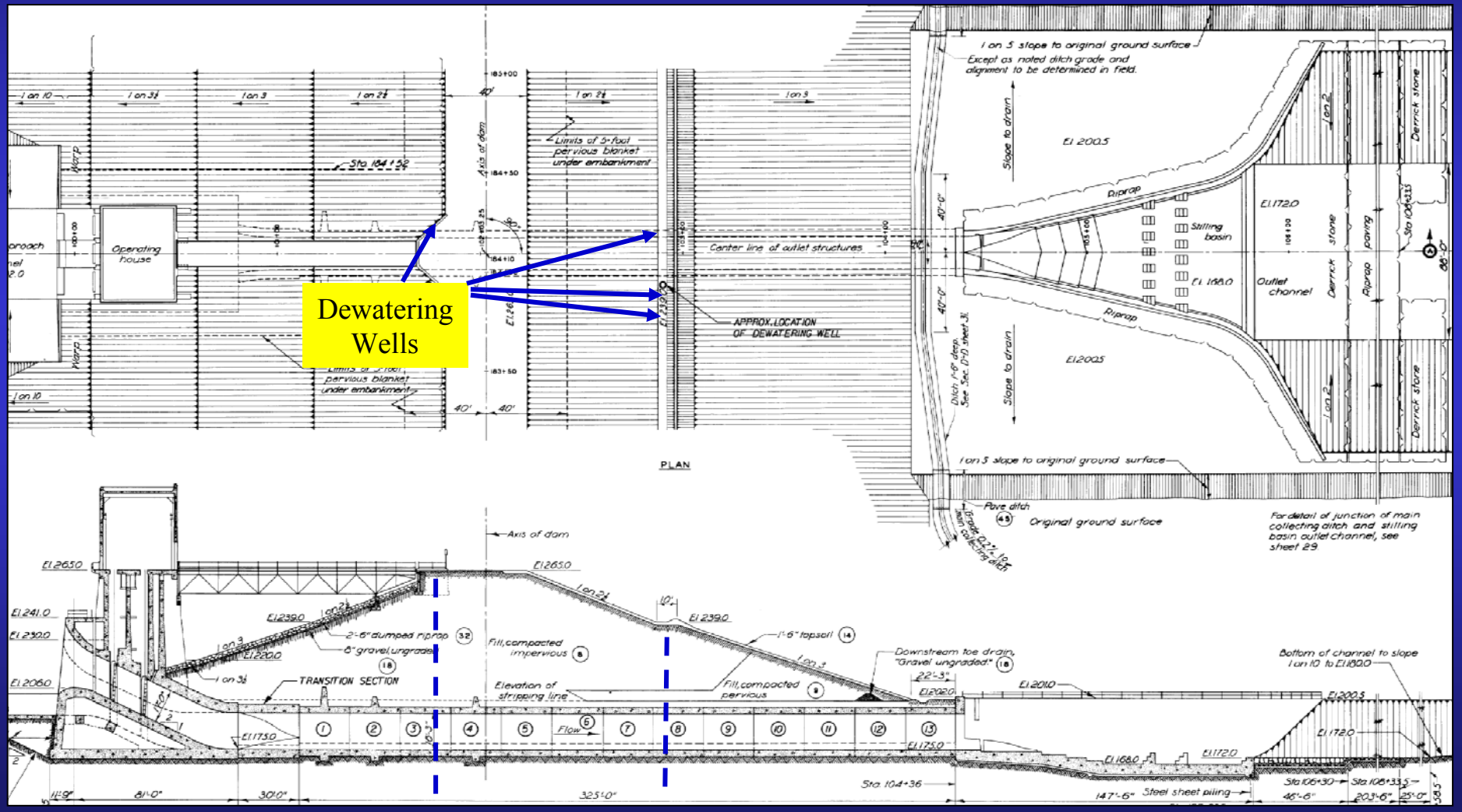
OUTLET WORKS

Constructed in 1941



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Installation of Stainless Steel Plates at Two Monolith Joints as Test Section

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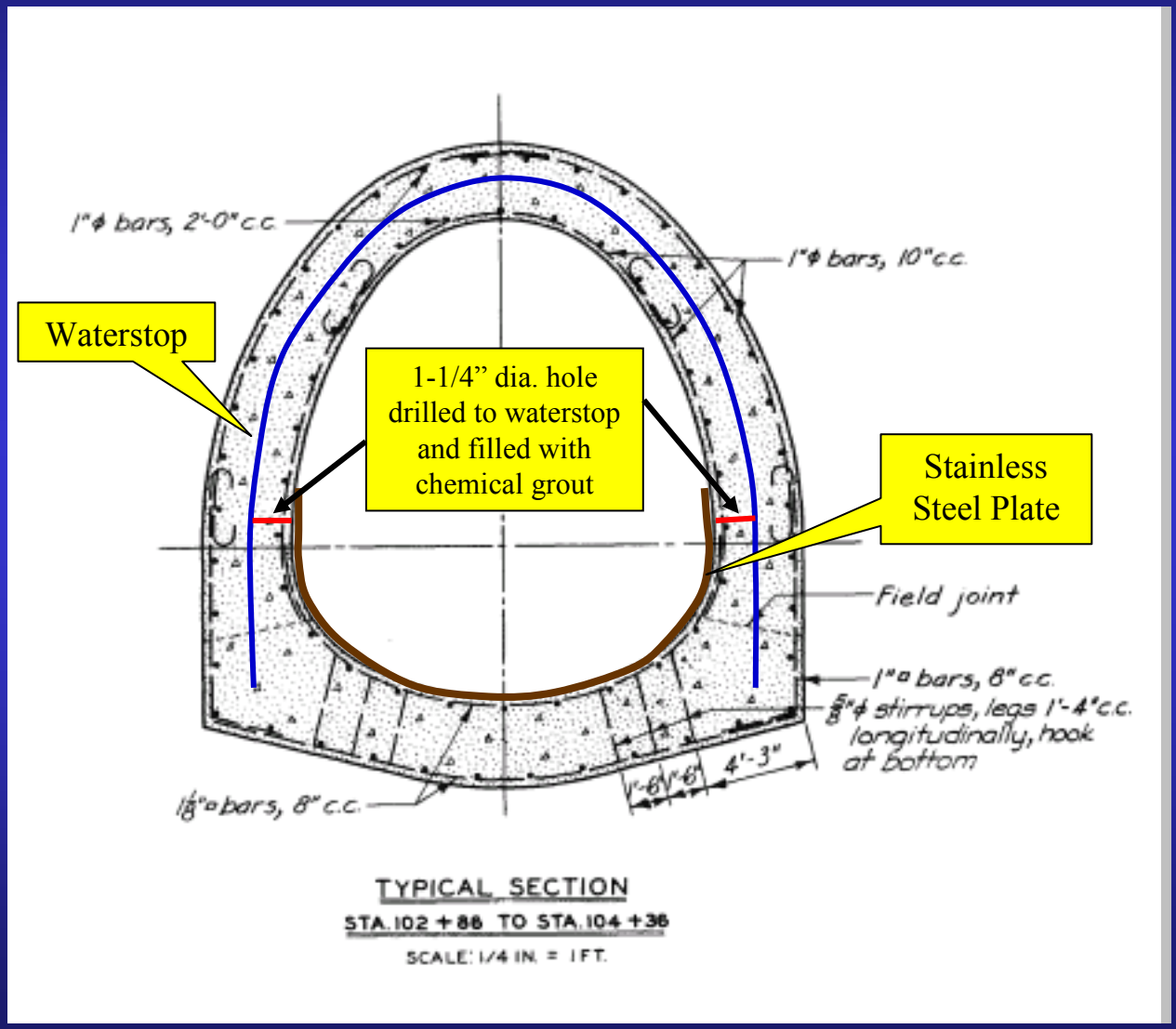
Detail for Installation of Stainless Steel Plates at Monolith Joints 5/6 and 6/7, Aug 2004



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Forming Plug at Concrete Surface of Conduit for Injection of Chemical Grout between Waterstop and Plate.

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Geotextile and Rubber Strips placed between Concrete Surface and Plate to trap any Material that could pipe through joint.

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Completed Plate Installation at one of the Monolith Joints, 17 Aug. 2004

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Failure of Plate at Monolith Joint 5/6 a Few Weeks after Installation, 2 Sep. 2004

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Close up View of Stainless Steel Plate Showing Tearing and Bending of Plate, 2 Sep 2004

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Example of 1/4-inch diameter jets of water observed on 26 Jan 05 from one location Joint 2/3 and from 3 locations Joint 3/4

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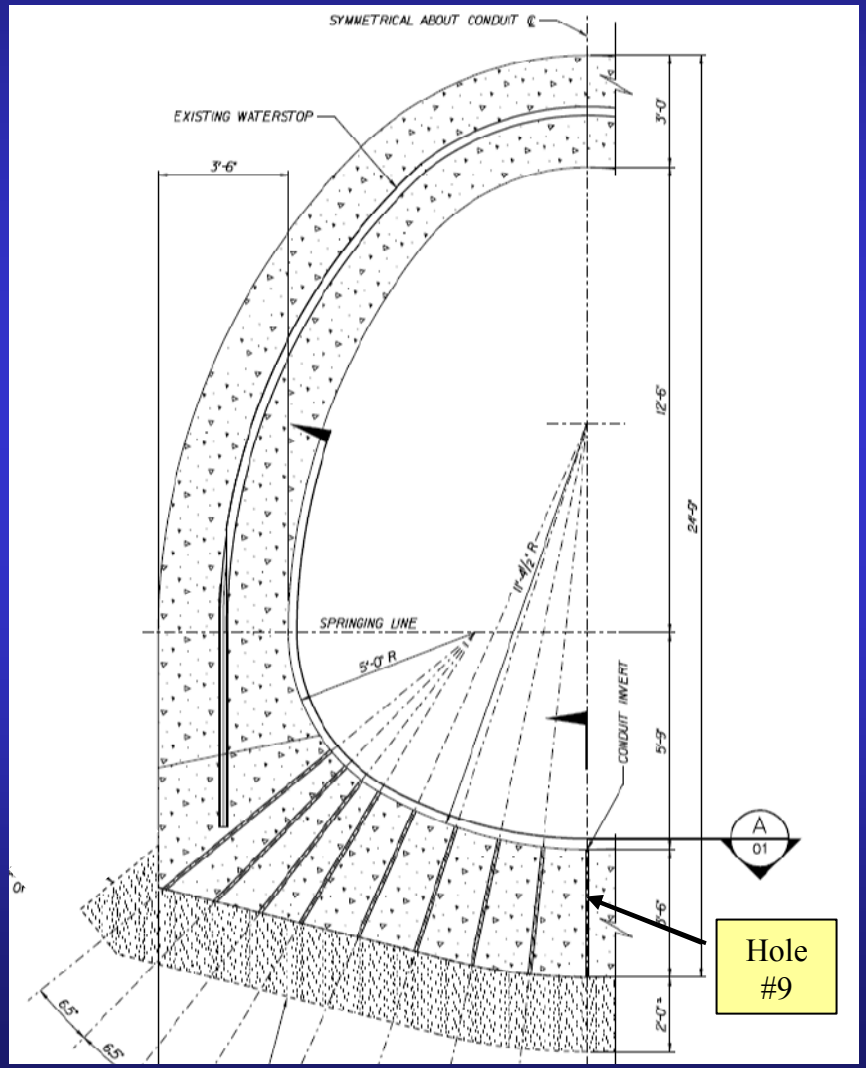
Location of grout holes

Approximate location of the 9 holes using odd numbers, 9 through 17 or 1 through 9 depending on either looking upstream or downstream, respectively. Even number holes were used to verify soil stabilization between primary injection holes.



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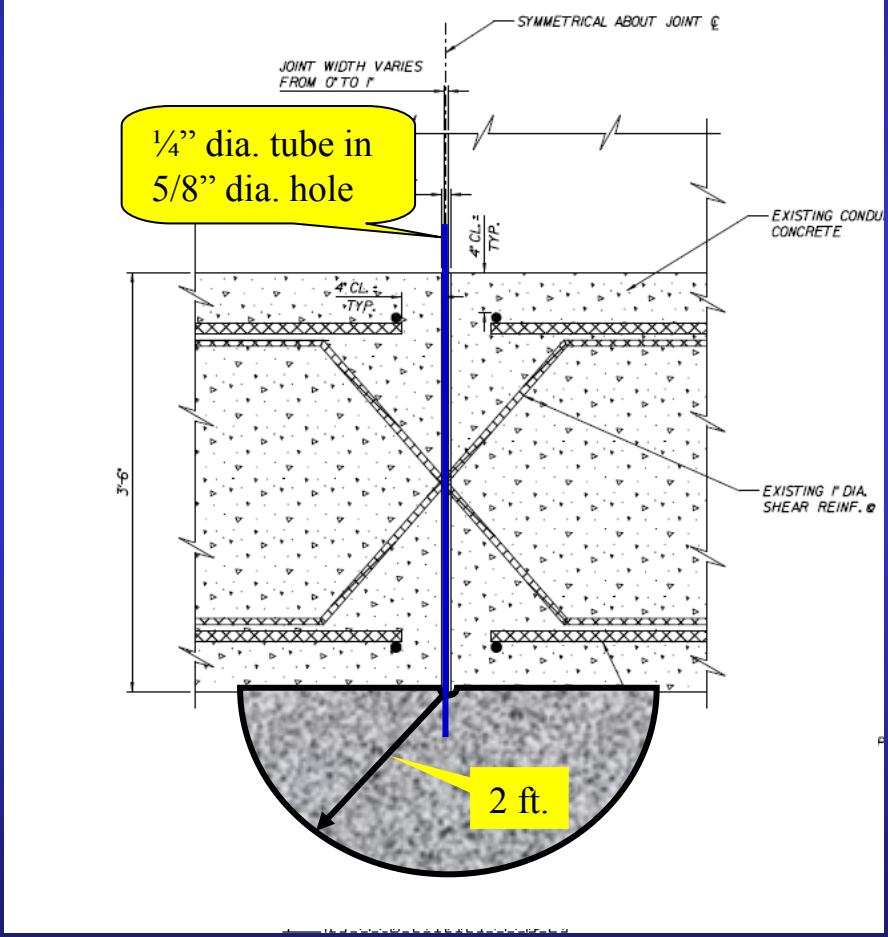
Theoretical Cross Section of Stabilized Soil (Grout Curtain)



Assuming that grout is injected at the bottom of the conduit and expands radially from the injection point. For example if 2.7 gallons were injected at a hole, the radius of the hemisphere created would be 24.5inches.

Assuming 0.15 cu. ft. voids/ cu. ft. of soil, and 1gal of liquid chemical grout ≈ 1 cu. ft. of urethane foam. Therefore, volume of sand stabilized = 1/0.15 = 6.67 cu. ft

Chemical grout being injected as a hemisphere, radius = $\sqrt[3]{(3V/2\pi)}$;
V= 2.7 gal (6.67 cu. ft./ gal)

$\sqrt[3]{[(3)(18.0)/2\pi]}$= 2.05 ft = **24.5 inches**

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Table 2

Hole No.	Monolith Joints or Cracks, 14-23 February 2005																Remedial Effort	
	T/1	1/2	2/3	A(3)	3/4	4/5	5/6	B(6)	6/7	7/8	8/9	9/10	10/11	11/12	12/13	13/C	A(3)	C(5)
	Chemical Grout Take per hole (gallons)																	
1	0.7	6.5	8.0	4.0	2.7	0.5	1.8	1.5	0.9	3.5	3.5	0.7	0.5	0.5	0.7	18”		3
2		0.5				G	G		G			0.5		G	G			
3	0.5	G	8.5	4.0	9.0	1.5	3.6	4.5	0.5	0.5	3.5	3.6	2.5	1.5	0.5	18”		0.5
4	G	6.3				6.7	0.9		3.5									
5	0.5	2.7	5.5	4.0	3.6	0.9	8.5	4.5	1.5	3.5	3.0	3.0	3.5	5.4	4.5	steel		5
6		4.5				8.5											5.0	
7	5.8	0.5	4.5	4.0	1.5	0.9	0.5	3.5	8.5	4.5	3.5	2.6	4.5	1.5	4.5	steel		1.5
8			1.0			G	9.0										5.0	
9	8.0	8.0	2.5	4.0	4.5	4.0	1.9	3.0	0.5	3.0	3.5	3.0	0.5	4.5	5.4	13.5		3.0
10					G								2.5				5.0	
11	1.0	4.5	9.0	4.0	4.0	6.7	0.5	0.9	6.0	4.5	3.5	2.6	0.5	2.5	4.5	steel		5.0
12	0.5						7.0						2.5					
13	0.5	4.3	2.5	4.0	0.5	9.0	2.5	3.5	2.5	3.0	3.5	2.6	4.0	0.5	4.9	steel		3.0
14	G				9.0						0.5		0.5					
15	0.5	4.5	13.0	4.0	1.5	0.5	1.9	0.5	2.5	3.5	0.5	0.5	0.5	0.5	4.5	18”		5.0
16	G	2.5			G	0.2		G	G		G	0.5	0.5	G	G			0.00
17	0.5	1.4	1.0	4.0	0.5	1.5	4.0	0.5	0.9	3.5	0.9	1.4	0.9	0.5	0.5	18”		0..25
18						3.6												
Total	18.5	46.2	55.5	36.0	36.8	44.5	42.1	22.4	27.3	29.5	25.9	21.0	23.4	17.4	30.0	13.5	15.0	26.25
	490.0 gallons ≈ 3267 cu. ft of stabilized sands																41.25 ≈ 275	

Notes: T – Transition Monolith; C- Chute Monolith; A(3) is crack in monolith 3; B(6) is crack in monolith 6; C(5) is crack in monolith 5;
G – drilled hole at this location and chemical grout was found and no additional chemical grout could be injected.

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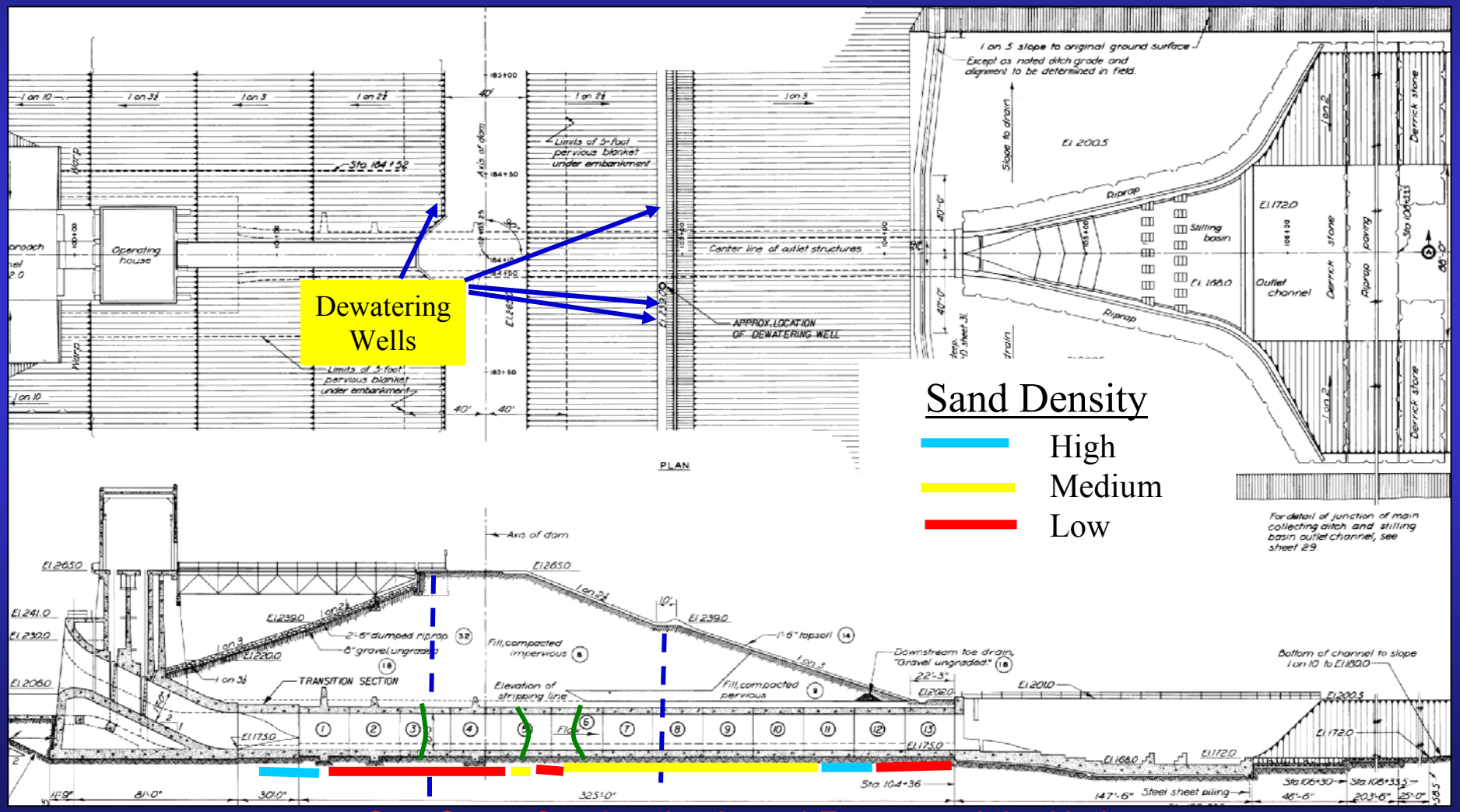
OUTLET WORKS

Constructed in 1941



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Drilling of Holes during Feb 2005. Water used to remove cuttings from holes otherwise bit would become locked in hole.

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Washing injection tubing into drilled hole. TopCor Services, Baton Rouge, LA, personnel performed the chemical grouting.

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Placing oakum saturated with chemical grouting in annular space around tubing using a screw driver to pack the oakum

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Line for injection of chemical grout beneath conduit is attached and grout is being injected. Notice light brown color of material above tubing is water and unset liquid grout.

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Chemical grouting has setup after sealing off any voids in a joint or crack large enough to allow water seepage (0.02 in width).

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Foundation sand being pumped at monolith joint T/1 by gases being released from chemical grout injected at monolith joint 2/3, 50 feet away, prior to grouting joint T/1.

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Chemical grout has been measured in gallon bucket and catalyst was added and mixed by hand. Pouring grout into bucket so that it can be injected.

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Pails of Hydro Active Grout used for sealing joints and cracks and to bind foundation sands together beneath the conduit

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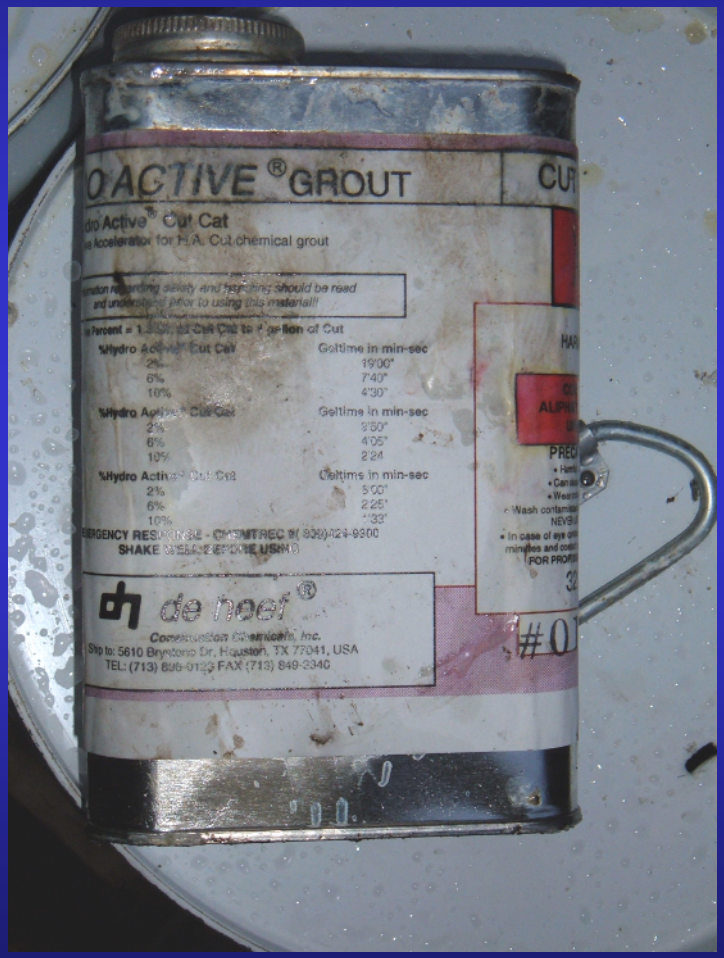
Can of Hydro Active Cut Catalyst used to vary setting time of chemical grout.



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Drilling holes at cracks in monoliths 3 & 5 during June 2005. Holes drilled at an angle of 45 to 60 degrees to surface to intercept cracks.

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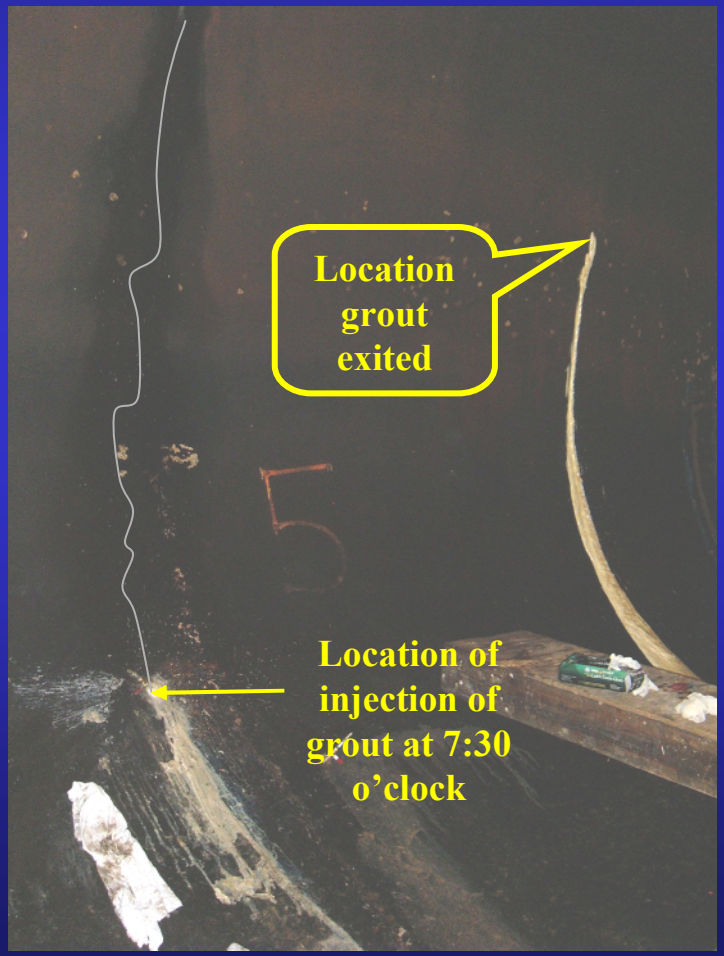
Crack in monolith 5, the grout migrated up the crack to approx. 9 o'clock and then traveled through a zone of honeycombed concrete. Exited 7 feet downstream of crack



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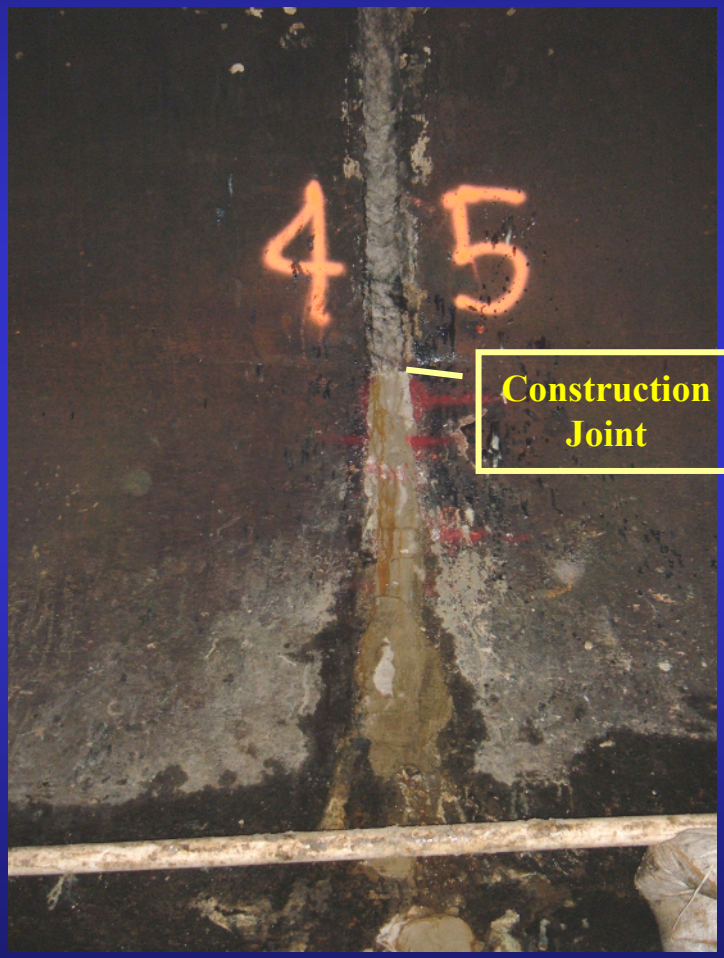
Monolith joint 4/5 showing weeping from construction joint on left side of conduit when looking downstream, 24 Feb 05



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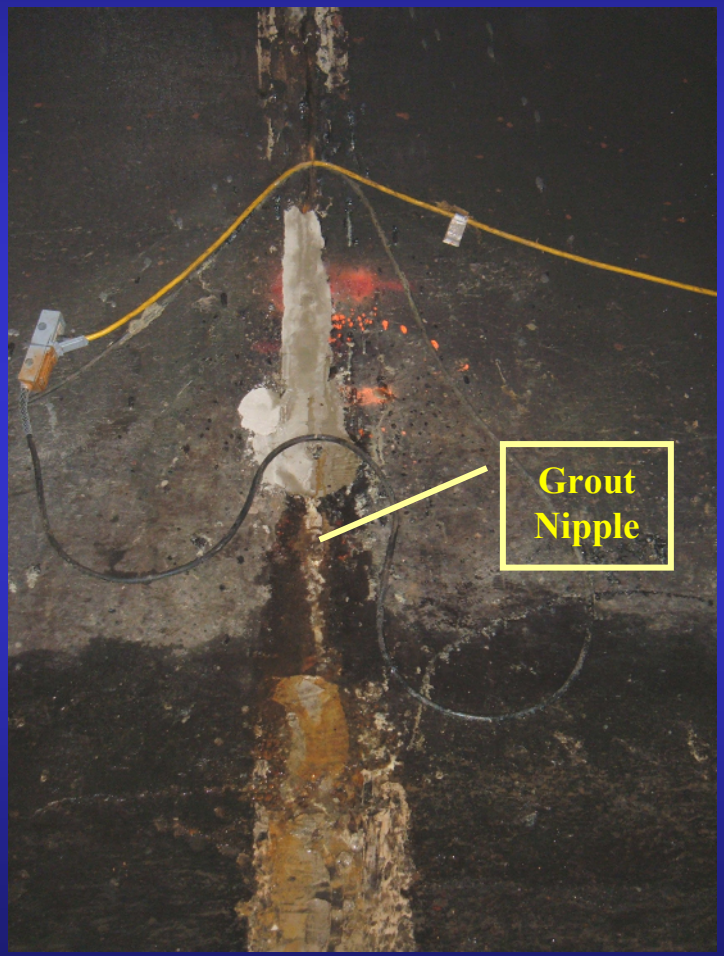
Monolith joint 4/5 showing weeping from around grout nipple on right side of conduit when looking downstream, 24 Feb 05



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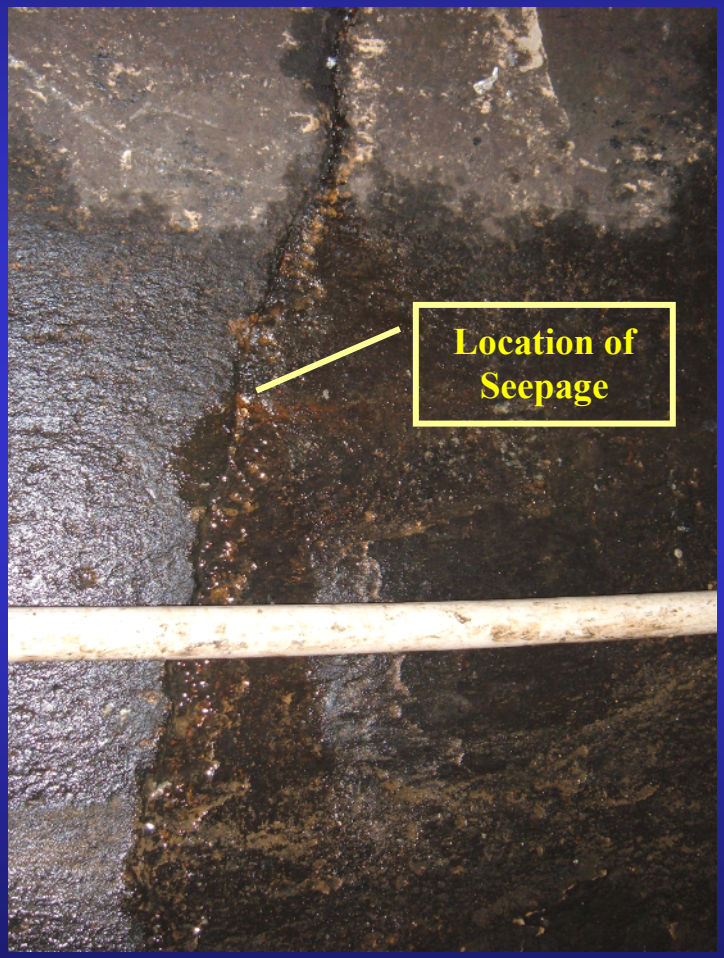
Crack in monolith 5 which was not grouted. Seepage at 2 feet left of centerline when looking downstream, 24 Feb 05



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Monolith joint 13/C showing a good seal due to the chemical grouting

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Table 3

Monolith Joints or Cracks	Remarks
Visual Evaluation of Chemical Grouting on 24 February 2005, Day after Completing the Initial Grouting	
T-1	Minor weeping at construction joint, right side
1/2	Minor weeping at construction joint and at grout nipple right side
2/3	Minor weeping at grout nipple, left side and construction joint right side
A(3)	Seepage 1 foot left and 2 foot right of center. Also, bubbles escaping indicting chemical grout still active.
3/4	Minor weeping at grout nipple right side
4/5	Minor weeping at grout nipple, right side, and at construction joint, left side
Crack Monolith 5	Not grouted, Seepage 2 feet left of centerline and 2 feet right of centerline. Flow increased to 1 gallon per minute from the invert on 21 Mar 05.
5/6	Seepage 3 feet left of centerline
B(6)	Seepage 2 feet left of centerline
6/7	Minor weeping at construction joint right side
7/8	Good
8/9	Minor weeping 4 feet right of centerline
9/10	Minor weeping 2 feet left of centerline
10/11	Minor weeping 2 feet above grout nipple on right side
11/12	Good, damp but not weeping
12/13	Good, damp but not weeping
13/C	Good

NOTES:
Damp – Concrete surface is darker than surrounding area but when area is touched, fingers remain dry.
Weeping – Concrete Surface is dark and reflective and when touched, fingers will be damp.
Seepage – Visually can see water movement on concrete surface.

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Table 4

Monolith Joints or Cracks	Remarks
Visual Evaluation of Chemical Grouting on 9 June 05, Day after Completing Remedial Grouting.	
T-1	Damp at construction joint, right side
1/2	Damp at construction joint and at grout nipple right side
2/3	Damp at grout nipple, left side and construction joint right side
A(3)	Good, bubbles escaping indicting chemical grout still active.
3/4	Damp at grout nipple right side
4/5	Damp at grout nipple, right side, and at construction joint, left side
C(5)	Good, bubbles escaping indicting chemical grout still active.
5/6	Damp 3 feet left of centerline
B(6)	Minor weeping form crack at 2 o'clock and 10 o'clock
6/7	Damp at construction joint right side
7/8	Good
8/9	Good
9/10	Good
10/11	Good
11/12	Good
12/13	Good
13/C	Good

NOTES:
Damp – Concrete surface is darker than surrounding area but when area is touched, fingers remain dry.
Weeping – Concrete Surface is dark and reflective and when touched, fingers will be damp.
Seepage – Visually can see water movement on concrete surface.

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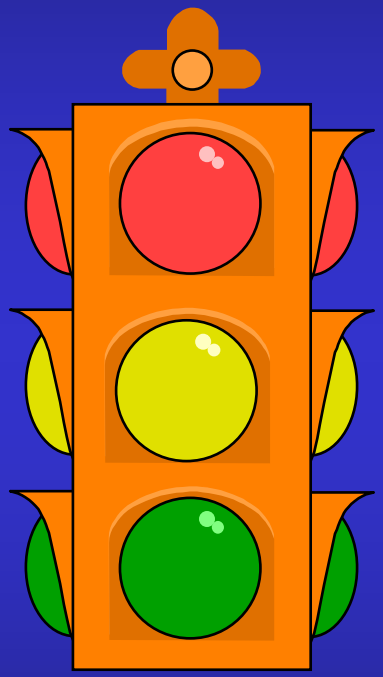
QUESTIONS?



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- MVK HQ – ED-D, ED-G, ED-O, ED-P, ED, C & Project Delivery Team
- Greenwood Area Office
- Inspectors – Noah Vroman, Jay Sims, & Al Hitchcock