Research Report
KTC-05-35/KH50-05-1F

KENTUCKY TRANSPORTATION CENTER

College of Engineering

CUMBERLAND GAP TUNNEL PAVEMENT PROBLEMS

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16. Abstract: Ground Penetrating Radar was used to verify voids beneath the concrete roadway located at the Cumberland Gap Tunnel, in Middelsboro, KY. Premilanary results indicate that several void areas reside beneath the north and southbound tunnel. The sizes and proximity of the voids are as follows.

Location	Direction	Void Number	Area (S.F.)	Approximate depth in some areas (inches)
CP3	Southbound	1	648	7
	Northbound	1	595	3
	Northbound	2	534	3
	Northbound	3	150	2
CP 5	Southbound	1	1035	9
	Northbound	1	623	3
	Northbound	2	80	3
CP 8 ½	Southbound	1	300	23
	Southbound	2	390	29
	Northbound	1	425	7

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The Kentucky Transportation Center was contacted by the Cumberland Gap Tunnel Authority in 2001 to conduct a Falling Weight Deflectormeter (FWD) test on the concrete pavement structure at two locations in the southbound tunnel that appeared to be settling. The FWD test showed at that time that the sub-grade strength was much less in the tested areas (CP 5 and CP 8 ½) than the surrounding pavement sub-grade. In 2002 the Cumberland Gap Tunnel Authority contracted with Uretek to place expansive foam material beneath the pavement at CP 5 and CP 8 ½ to raise the pavement structure. The foam was somewhat successful in raising the slabs back to normal elevation. After placement of the foam material both areas were tested again using the FWD. Results obtained from the FWD test indicated that no real gain in sub-grade strength was obtained by using the foam material. CP 5 and CP 8 ½ were tested again in 2003 and 2004 using the FWD. The FWD results from 2003 and 2004 also showed low sub-grade strengths in both areas.

In 2005 the Kentucky Transportation Center used ground penetrating radar (GPR) to identify void areas beneath the concrete pavement at CP 3, CP 5, and CP 8 ½ in both tunnel directions. The following results indicate the location and the approximate size/depth of the void areas at all three locations in both the north and sound bound tunnels.

Location	Direction	Void Number	Area (S.F.)	Approximate depth in some areas (inches)
CP3	Southbound	1	648	7
	Northbound	1	595	3
	Northbound	2	534	3
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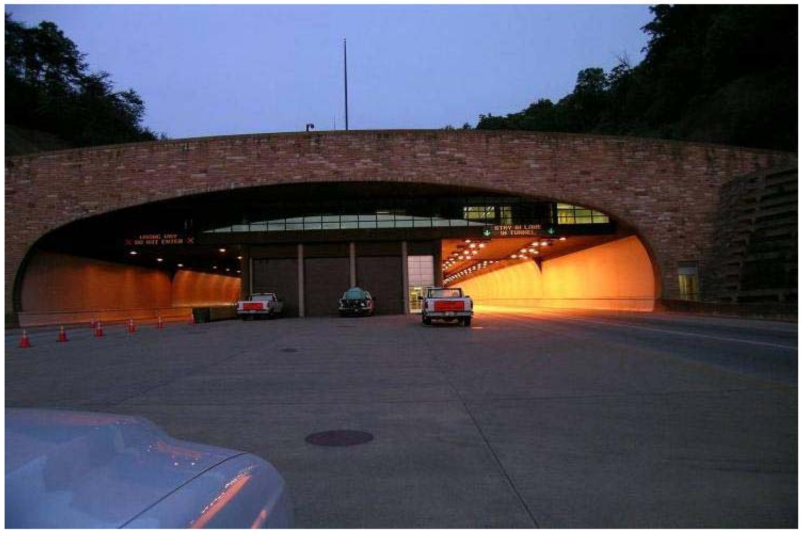
CP 5	Southbound	1	1035	9
	Northbound	1	623	3
	Northbound	2	80	3
CP 8 ½	Southbound	1	300	23
	Southbound	2	390	29
	Northbound	1	425	7

After compiling the test results shown above, two meetings have been held this past summer to notify concerned parties about the potential problems at the Cumberland Gap Tunnel. Those parties have consisted of Eastern Federal Lands, FHWA (KY division), and KYDOT (maintenance/operations). The attached Power-Point slides indicate the work performed by the Kentucky Transportation Center that was discussed at the two above mentioned meetings.

Cumberland Gap Tunnel
Inspection of concrete pavement settlement



Overview

- History of problems encountered to the pavement structure and inspections performed
- Ground penetrating radar inspection and results
- Areas of concern (CP 3, 5, 8 ½)
- 2 minute video of inspection
- Geology
- Discussion

History of problems encountered to the pavement structure and inspections performed

- 2001 (CGTA) requested a pavement inspection due to possible slab settlement
  - FWD testing CP 5 and 8 ½
  - Drainage inspection of tunnel drains

History of problems encountered to the pavement structure and inspections performed (cont.)

- 2002
  - (URETEK Foam was placed under the concrete pavement at CP 5 and 8 ½)
  - FWD testing preformed after URETEK placement
- 2003
  - FWD testing preformed throughout tunnel (50 ft. spacing) to develop trend line of pavement subgrade strength
- 2005
  - Surveyed tunnel using Ground Penetrating Radar (GPR)

Visual of pavement settlement at CP 3 (water ponding after tunnel washing)

southbound

Ground penetrating radar inspection and results

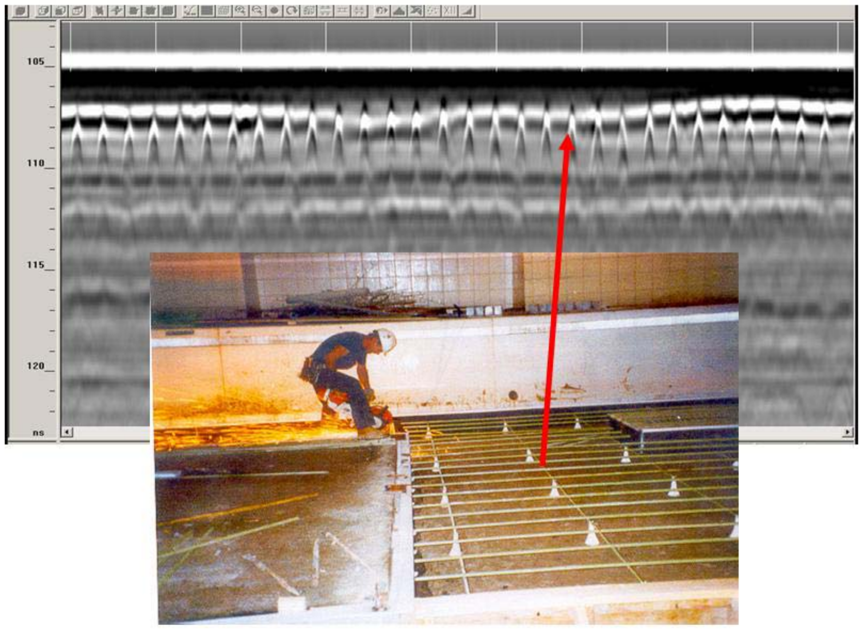
Equipment
900 MHz. antenna
Approx. depth 3 ft.

Data collection location
3 passes per lane
CWP, RWP
LWP

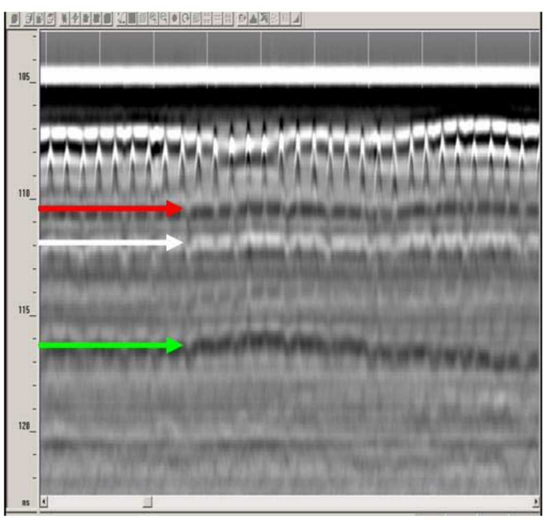
Data collection density
1 scan every inch

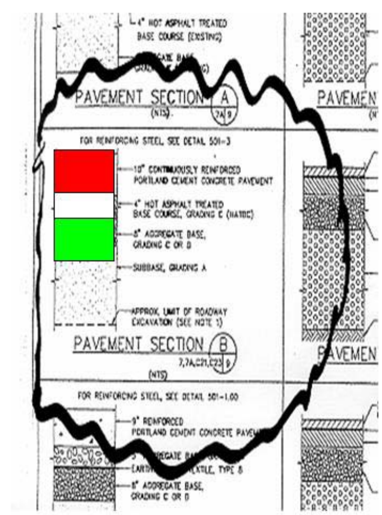
Data collection speed
5 m.p.h.

Good GPR data showing re-bar

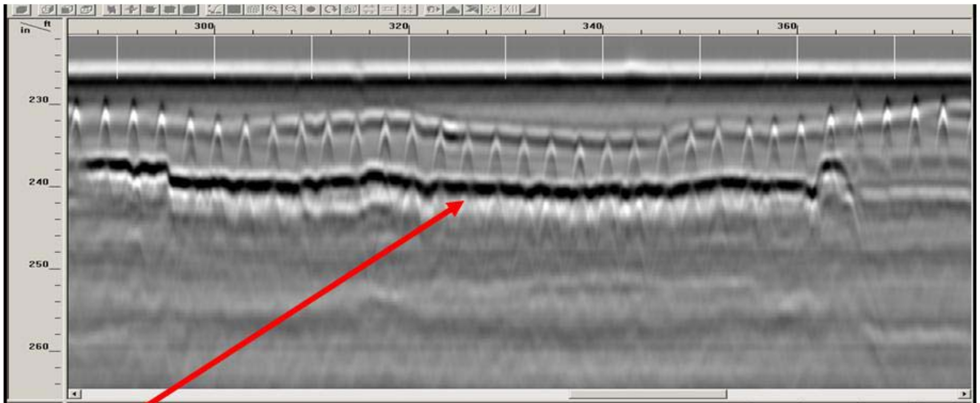


Good GPR data showing pavement layers



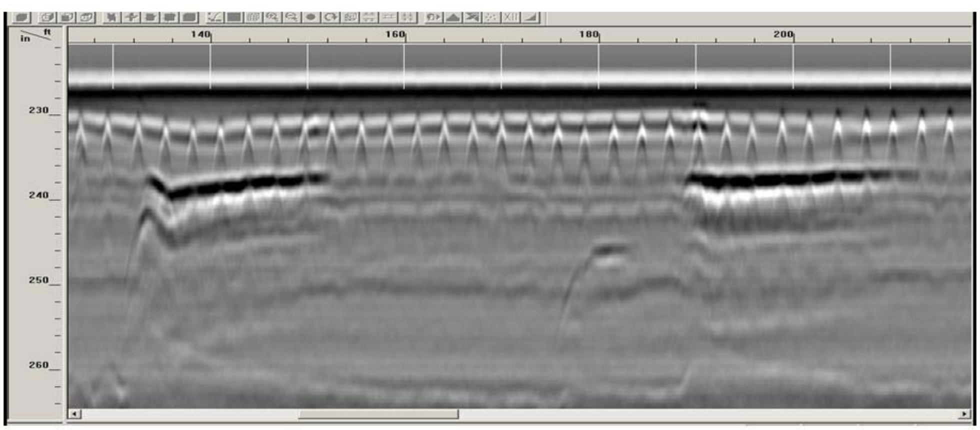


Void area beneath concrete pavement southbound tunnel



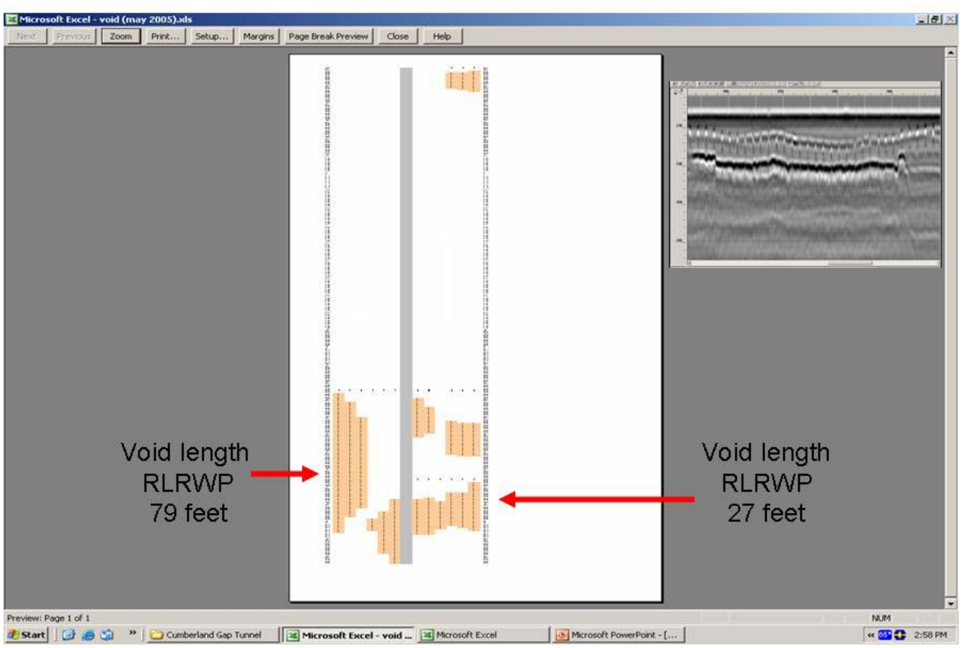
GPR signal has negative amplitude (noted as black space) because it doesn't have anything to bounce off of (namely air).

Multiple void areas beneath concrete pavement northbound tunnel



CP 3
tested area
119+50 to 124+50

Mapped void area CP 3



Southbound void length CP 3

location	lane	distance from left barrier wall	beg. Station #	end. Station #	Void Length (feet)
lwp	left	4.6	122.98	123.34	35
cwp	left	7	123.05	123.28	23
rwp	left	9	123.09	123.15	6
lwp	right	17.6	122.51	123.02	51
cwp	right	20	122.42	123.07	65
rwp	right	22.3	122.37	123.16	79

Northbound void length CP 3

location	lane	distance from left barrier wall	beg. Station #	end. Station #	Void Length (feet)
lwp	left	4.6	123.17	122.98	19
lwp	left	4.6	122.61	122.40	21
cwp	left	7	123.17	122.97	20
cwp	left	7	122.59	122.45	14
rwp	left	9	123.14	122.99	15
lwp	right	17.6	123.12	122.94	18
lwp	right	17.6	122.71	122.53	18
lwp	right	17.6	120.61	120.53	8
cwp	right	20	123.13	122.94	20
cwp	right	20	122.72	122.54	18
cwp	right	20	120.62	120.53	9
rwp	right	22.3	123.15	122.88	27
rwp	right	22.3	122.72	122.54	18
rwp	right	22.3	120.63	120.52	12

Void depth beneath 10 inch concrete pavement CP 3

Southbound

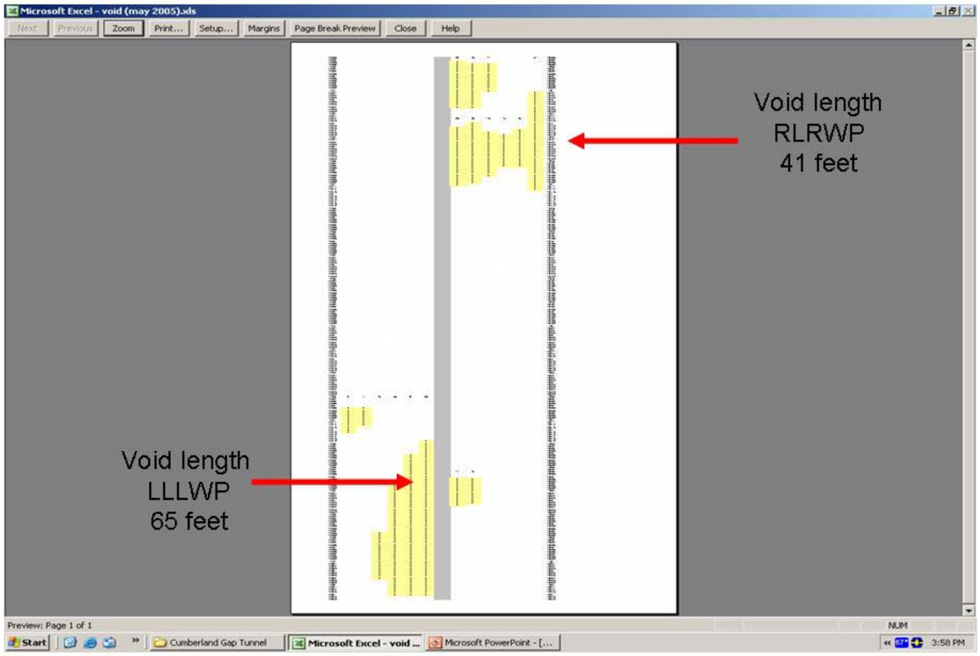
Sta. #	Lane	Void depth inch
122+77	R cwp	8
122+80	R cwp	7 5/8
123+00	L cwp	5 7/8

Northbound

Sta. #	Lane	Void depth inch
122+72	L cwp	2 1/4

CP 5
tested area
126+00 to 130+00

Mapped void area CP 5



Southbound void length CP 5

location	lane	distance from left barrier wall	beg. Station #	end. Station #	Void Length (feet)
lwp	left	4.6	128.49	129.14	**65**
cwp	left	7	128.55	129.14	**59**
rwp	left	9	128.66	129.14	**48**
lwp	right	17.6	128.88	129.07	**18**
cwp	right	20	128.35	128.42	**7**
lrwp	right	22.3	128.35	128.45	**10**

Northbound void length CP 5

location	lane	distance from left barrier wall	beg. Station #	end. Station #	Void Length (feet)
lwp	left	4.6	128.76	128.65	11
lwp	left	4.6	127.40	127.16	25
lwp	left	4.6	127.07	126.88	20
cwp	left	7	128.75	128.65	10
cwp	left	7	127.39	127.14	24
cwp	left	7	127.07	126.89	18
rwp	left	9	127.36	127.18	18
rwp	left	9	127.00	126.89	11
lwp	right	17.6	127.32	127.19	14
cwp	right	20	127.32	127.17	16
rwp	right	22.3	127.42	127.01	41

Void depth beneath 10 inch concrete pavement CP 5

Southbound

Sta. #	Lane	Void depth inch
128+67	L cwp	4 3/4

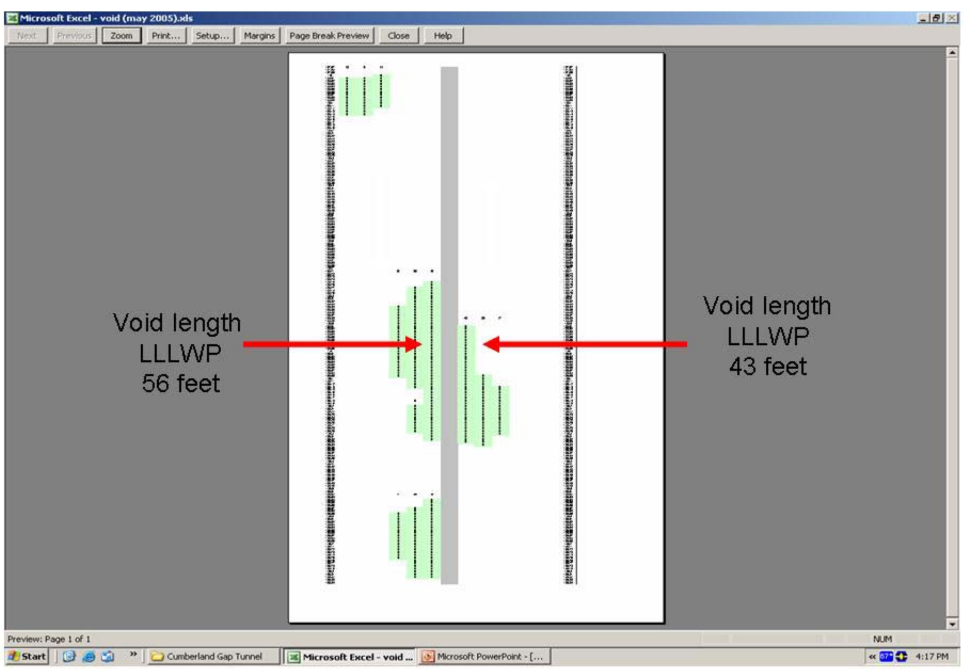
Void area under URETEK

Northbound

Sta. #	Lane	Void depth inch
127+35	L cwp	6 3/4

CP 8 1/2
tested area
137+00 to 140+50

Mapped void area CP 8 1/2



Southbound void length CP 8 1/2

location	lane	distance from left barrier wall	beg. Station #	end. Station #	Void Length (feet)
Lwp	left	4.6	138.75	139.32	56
Lwp	left	4.6	139.54	139.82	28
Cwp	left	7	138.77	139.13	36
Cwp	left	7	139.20	139.29	9
Cwp	left	7	139.57	139.82	26
Rwp	left	9	138.84	139.09	26
Rwp	left	9	139.59	139.75	17
Lwp	right	17.6	138.00	138.11	11
Cwp	right	20	138.01	138.14	14
Rwp	right	22.3	138.01	138.14	13

Northbound void length CP 8 1/2

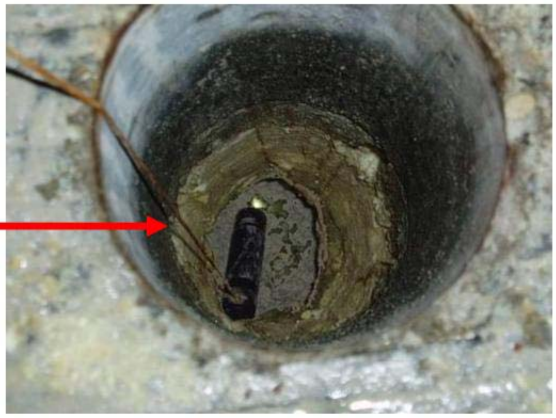
location	lane	distance from left barrier wall	beg. Station #	end. Station #	Void Length (feet)
lwp	left	4.6	139.33	138.91	43
cwp	left	7	139.34	139.09	25
rwp	left	9	139.30	139.13	17
lwp	right	17.6	0.00	0.00	0
cwp	right	20	0.00	0.00	0
rwp	right	22.3	0.00	0.00	0

Void depth beneath 10 inch concrete pavement CP 8 1/2

Southbound

Sta. #	Lane	Void depth inch
138+98	L cwp	21 7/8
139+02	L cwp	29 3/8

URETEK material



Northbound

Sta. #	Lane	Void depth inch
139+14	L cwp	7 1/8

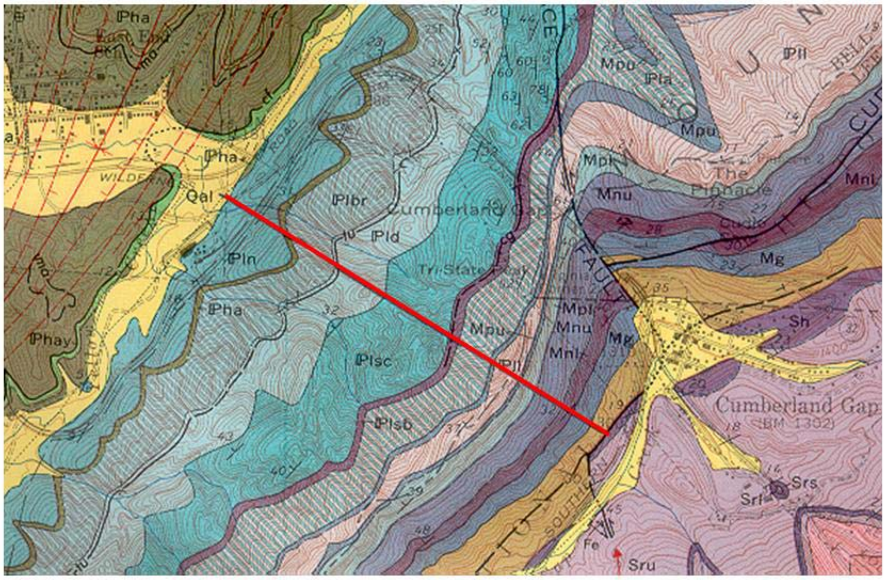
GPR scanning of Walls in concerned areas (July 2005)

GPR Wall scanning

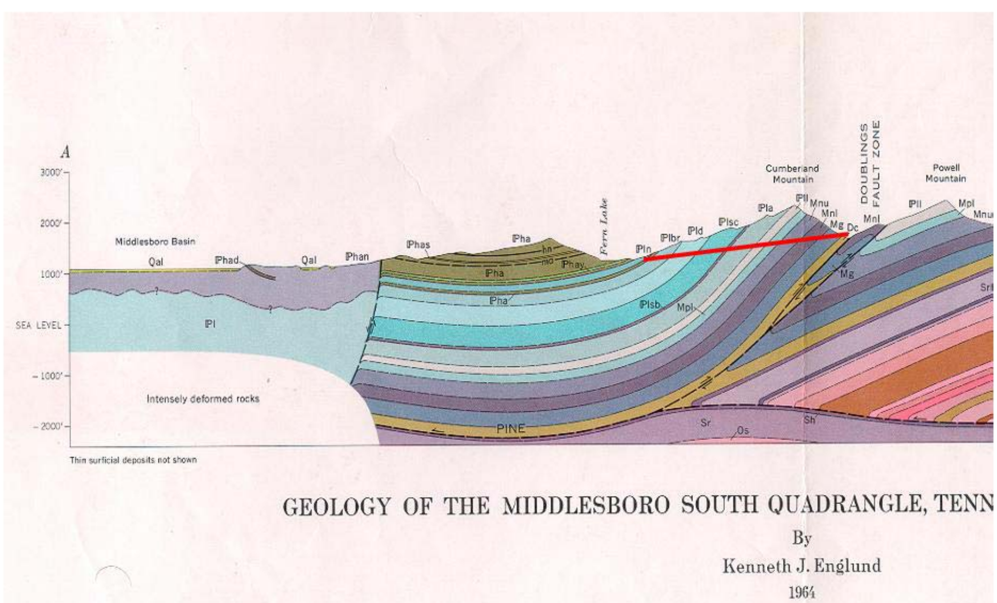
- No large void areas were discovered
- Small/medium size voids were less than 12 inches from face of wall
- Believed that these void areas reside inside of the waterproof membrane

CP	survey area (beg. sta #)	survey area (end sta #)	Direction (north or south)	location of radar scan	Tunnel wall (inside or outside)	beg. possible void (ft)	end possible void (ft)	beg. possible void (sta. #)	end possible void (sta. #)	depth of possible void from tile (inches)	severity (small, medium, large)
3	124.50	119.50	north	high	inside	490	522	119.60	119.28	12	m
3	124.50	119.50	north	low	outside	473	503	119.77	119.47	13	s
3	124.50	119.50	north	high	outside	470	498	119.80	119.52	12	s
5	130.00	126.00	north	high	inside	48	52	129.52	129.48	13	s
5	130.00	126.00	north	high	outside	43	47	129.57	129.53	13	s
8 1/2	140.50	137.00	north	high	inside	39	60	140.11	139.90	11	s
8 1/2	140.50	137.00	north	low	outside	47	56	140.03	139.94	13	s
8 1/2	140.50	137.00	north	high	outside	38	53	140.12	139.97	13	s
8 1/2	140.50	137.00	north	high	outside	275	282	137.75	137.68	12	s
8 1/2	137.00	140.50	south	high	inside	100	120	138.00	138.20	9	m
8 1/2	137.00	140.50	south	high	outside	80	124	137.80	138.24	10	s
8 1/2	137.00	140.50	south	high	outside	300	309	140.00	140.09	13	s

Geology (plan view)



Geology (elevation view)



Geology CP 3
Middlesboro formation (sandstone)

- Heavy water in-flow 10-50 g.p.m. (NB tunnel)
- Numerous thin silt/sand seems (both tunnels)
- Weathered face material (both tunnels)
- Water in-flow 10-20 g.p.m. (SB tunnel)
- Clay seems, thin silt seems (SB tunnel)
- Support category IV (both tunnels)

Geology CP 5
Contact between Middlesboro and Dark Ridge

- Water in-flow 3-4 g.p.m. (SB tunnel)
- Mud/sand/water west wall 127+44 (NB tunnel)
- Water in-flow 15-20 g.p.m. (NB tunnel)
- Support category IV (both tunnels)

Geology CP 8 1/2
Pennington formation (sandstone)

- Close to contact between Pennington sandstone and Newman Limestone
- 14 water-seeps, in-flow 1-5 g.p.m. (SB tunnel)
- Poorly cemented sandstone with silt stone (SB tunnel)
- Soft wet mud in areas (SB tunnel)
- 13 water-seeps, in-flow 1-5 g.p.m. (NB tunnel)
- Station 138+73, 2 inch seem of wet sandy mud (NB Tunnel)

Discussion