Rough River Lake Dam - Remedial Construction

24 March 2015

US Army Corps of Engineers
BUILDING STRONG®

Rough River Lake Dam:

Constructed: 1955-1958
Type: Compacted Earth Fill
Top Elevation: 556 msl
(559 msl - top of wall)
Drainage Area: 454 mi^2
Storage: 334,400 acre / ft.
Highest Water Level:
527.4 on May 11, 2011

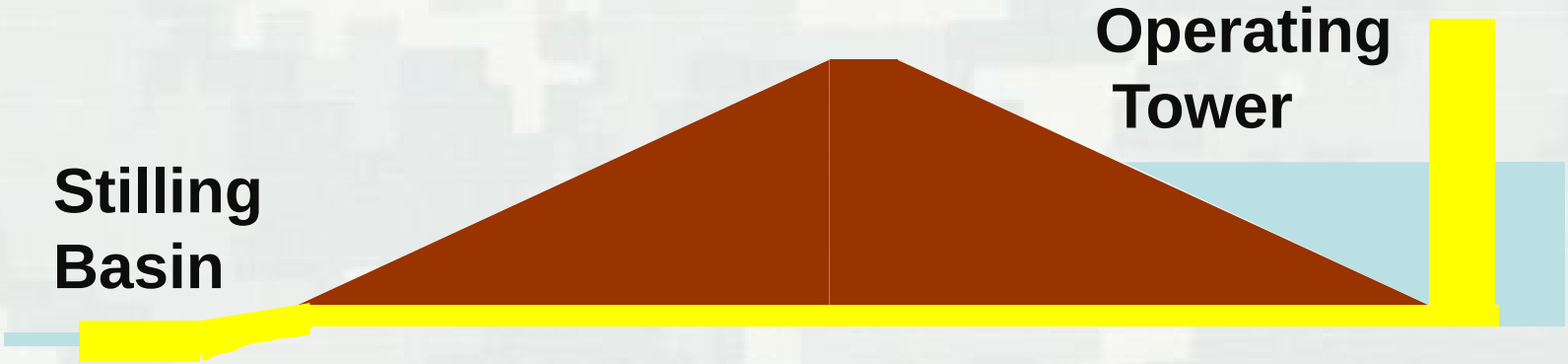
Flood Risk Management Benefits

Nolin River -	$115,731,000
Rough River -	$227,755,000
Green River -	$163,569,000
Barren River -	$183,966,000
Total -	$691,021,000

Lake Data:

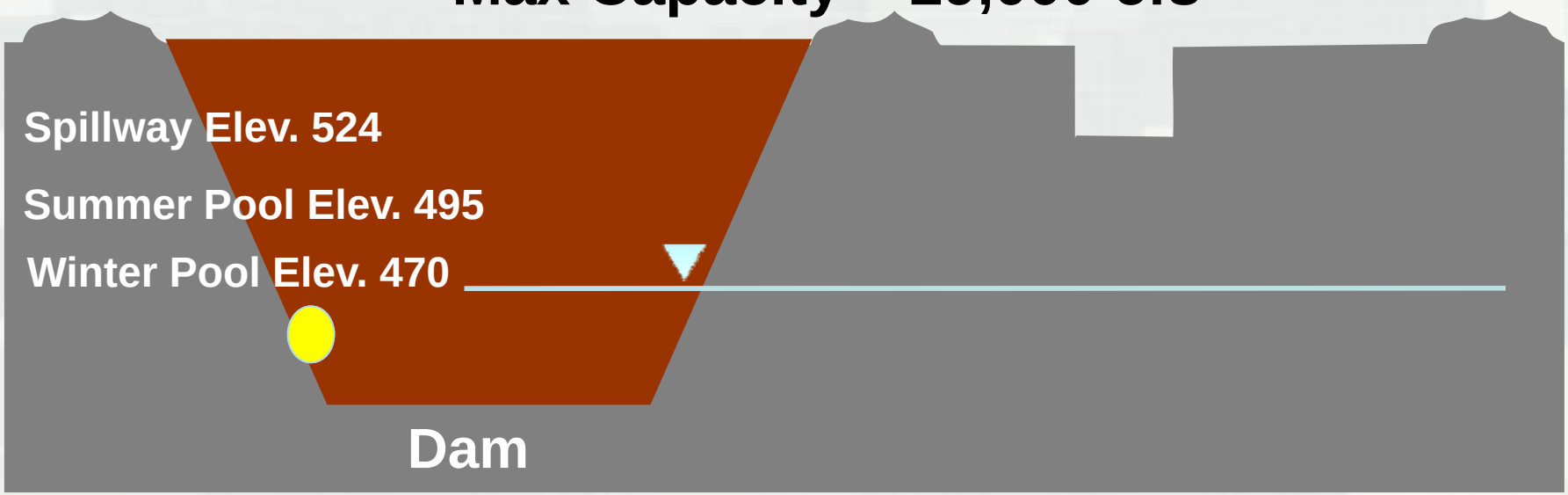
Seasonal Pool	Pool Elevation	Water Acres
Winter Pool	470 msl	2,180 acres
Summer Pool	495 msl	5,100 acres
Flood Pool	524 msl	10,260 acres
Probable Max Flood	553.9 msl	

Outlet Works (Controlled)



Conduit - Max Capacity – 5000 cfs

Emergency Spillway (Uncontrolled) – Max Capacity – 29,000 cfs



Louisville District Daily Lake Report

http://lrl-apps.lrl.usace.army.mil/wc/reports/lkreport.html

- Updates automatically ~ 8:00 a.m. (Central Time)
- Daily pool, precipitation, and storage information

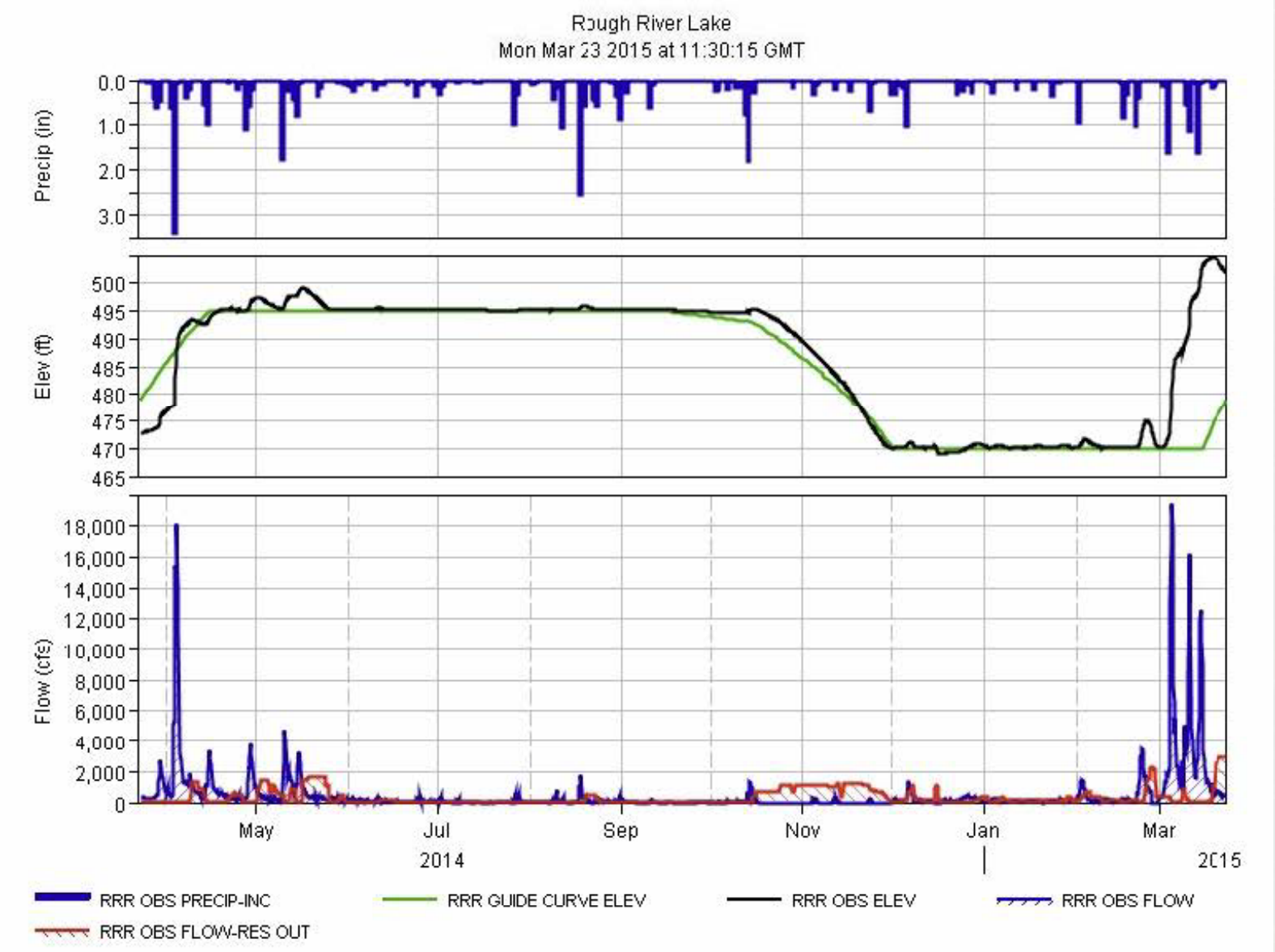
Louisville District Daily Lake Report
24 March 2015

Basin	Project	Lake Elevations: Winter Pool Feet	Summer Pool Feet	Flood Pool Feet	Todays Pool Feet	Dev. from Pool Feet	24 Hour Change Feet	24 Hour Precip Inches	Flood Storages: 6 A.M. Outflow CFS	Inches Avail	Percent Util
Little Miami	Caesar Creek	846.0	849.0	883.0	837.2	-8.8	-0.8	0.05	1022	13.52	-15.11
	W. H. Harsha	729.0	733.0	795.0	742.9	13.9	-1.9	0.00	2230	9.41	15.16
Mill Creek	West Fork	675.0	675.0	702.0	675.3	0.3	-0.1	0.00	9	6.18	0.59
Mad River	C. J. Brown	1009.0	1012.0	1023.0	1009.0	-0.6	0.0	0.06	64	7.52	-3.80
Whitewater	Brookville	740.0	748.0	775.0	741.9	0.3	0.0	0.00	484	10.18	0.59
Licking	Cave Run	724.0	730.0	765.0	746.2	20.9	-0.7	0.00	4571	5.40	44.62
Green River	Green River	668.0	675.0	713.0	677.8	8.3	-1.5	0.00	6783	12.50	12.74
	Nolin	490.0	515.0	560.0	520.6	21.4	-1.6	0.00	6834	10.78	21.47
	Barren River	525.0	552.0	590.0	554.2	18.8	-0.5	0.00	3868	10.70	22.70
	Rough River	470.0	495.0	524.0	501.0	21.4	-0.8	0.00	2892	7.48	34.95
Up. Wabash	J. E. Roush	737.0	749.0	798.0	737.8	0.8	-0.4	0.31	340	3.94	0.28
	Salamonie	730.0	755.0	793.0	730.5	0.5	0.1	0.37	207	8.32	0.16
	Mississinewa	712.0	737.0	779.0	713.8	1.8	0.0	0.18	402	7.94	0.70
Mid. Wabash	Cecil Harden	640.0	662.0	690.0	651.7	1.7	0.0	0.04	109	8.74	2.64
	Cagles Mill	636.0	639.5	704.0	648.2	12.2	-0.7	0.04	948	11.49	10.10
	Monroe	538.0	538.0	556.0	544.2	6.2	-0.1	0.00	627	7.89	28.32
	Patoka	532.0	536.0	548.0	538.3	6.3	-0.1	0.00	218	11.04	35.43

(ALWAYS WEAR YOUR LIFE JACKETS WHEN ON OR NEAR THE WATER)

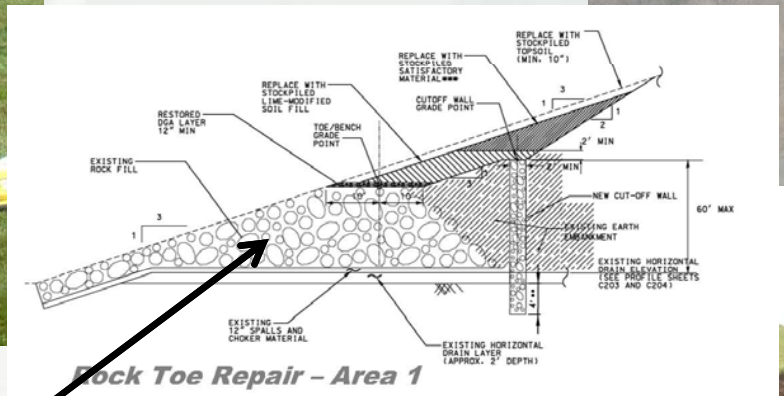
Comments:

Highest Pool Elevations of Record


Rough River Lake
Mon Mar 23 2015 at 11:30:15 GMT
Precip (in)
0.0
1.0
2.0
3.0
Elev (ft)
500
495
490
485
480
475
470
465
Flow (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
May
Jul
Sep
Nov
Jan
Mar
2014
2015
RRR OBS PRECIP-INC
RRR GUIDE CURVE ELEV
RRR OBS ELEV
RRR OBS FLOW
RRR OBS FLOW-RES OUT

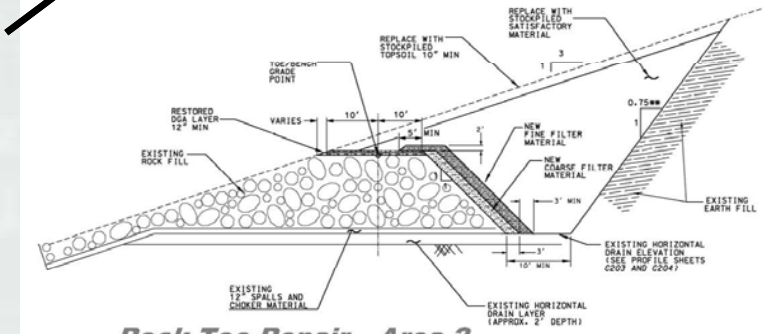
Didn't you just "fix" Rough River Dam? 2005-2007 Remedial Construction

2003 sinkhole near downstream rock toe



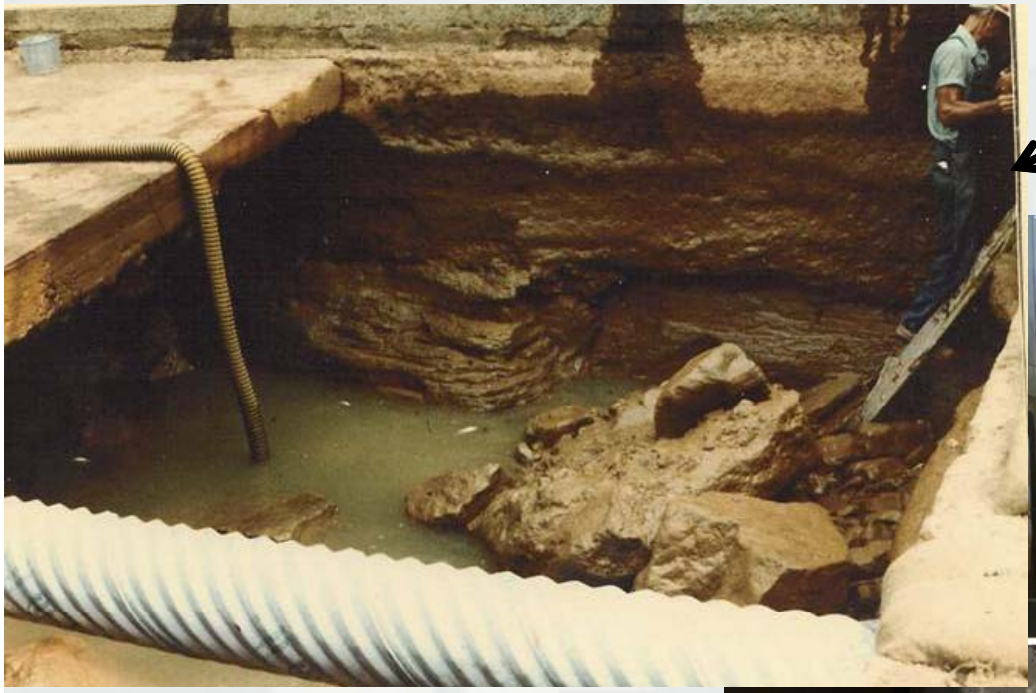
Rock Toe Repair – Area 1

Migration of embankment into rock toe

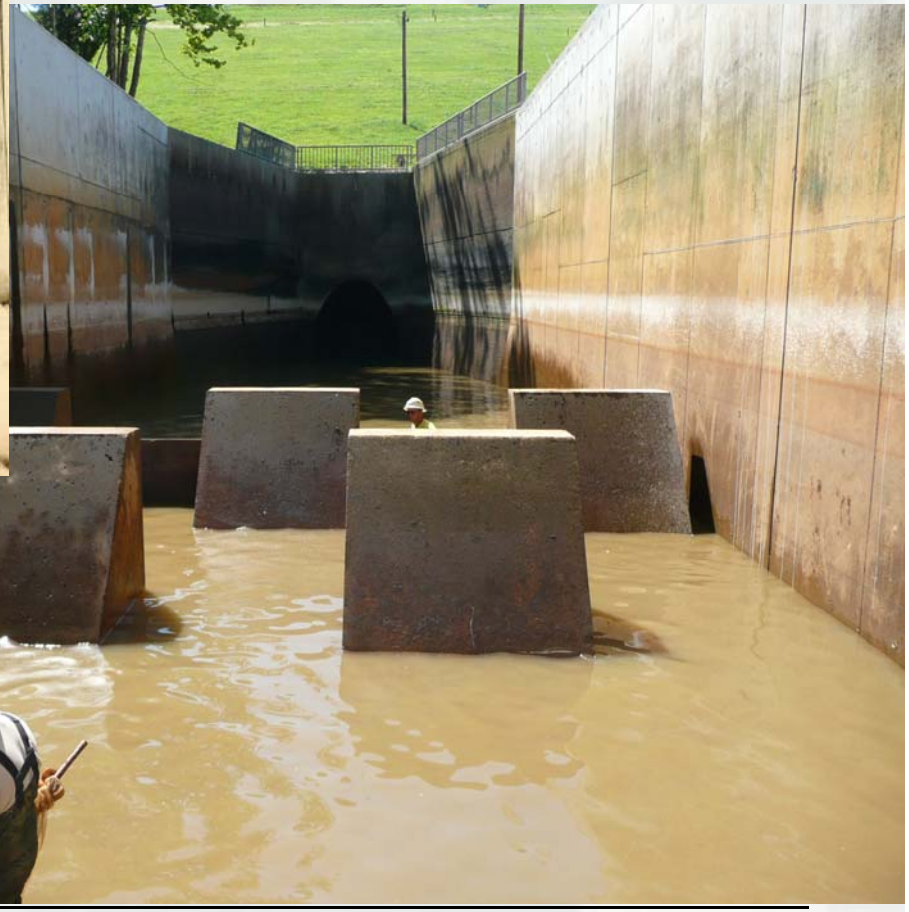


Rock Toe Repair – Area 2

Didn't you just "fix" Rough River Dam?
2005-2007 Remedial Construction



Heavy erosion at stilling basin



Extended the stilling basin and added baffle blocks

Didn't you just "fix" Rough River Dam? 2005-2007 Remedial Construction

Raised the dam 5 ft. to contain Probable Maximum Flood

Raised the road 2 ft. and added "parapet" wall for 3 additional ft.

Rough River – Timeline for Risk Informed Process

- Risk: "A measure of the probability and severity of undesirable consequences or outcome"
  (ER 1110-2-1156 Safety of Dams, Policy and Procedures)

- 2005 – USACE Began Portfolio Screening Process (SPRA)
  - Ranked the entire Corps portfolio of structures
  - One – day screening per structure
  - Conducted by a multi-disciplined SPRA Cadre

Rough River – Timeline for Risk Informed Process

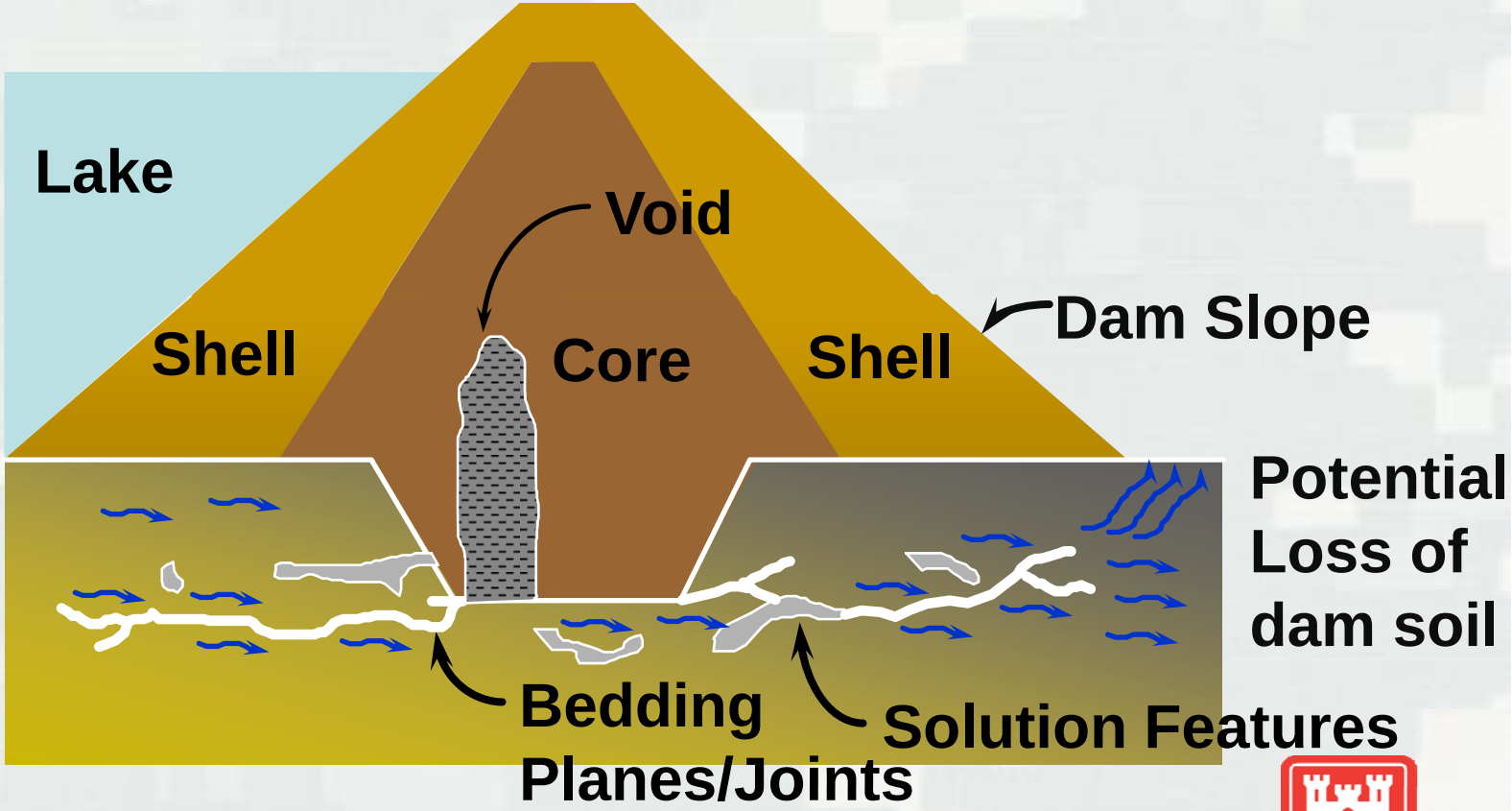
- Rough River SPRA conducted in 2005
  - Established Dam Safety Action Classification (DSAC)
  - Rough River classified as DSAC 2
    - Failure Initiation Foreseen or,
    - Very High Incremental Risk
- 2008 – Established Interim Risk Reduction Measures
  - Enhanced surveillance and monitoring
  - Additional exploration and instrumentation
  - Automation of instruments
  - Supplemental Dam Safety Training for project staff
  - Recommended Emergency Action Plan Exercises
    - Engage partners and stakeholders
    - Improve communications and emergency planning

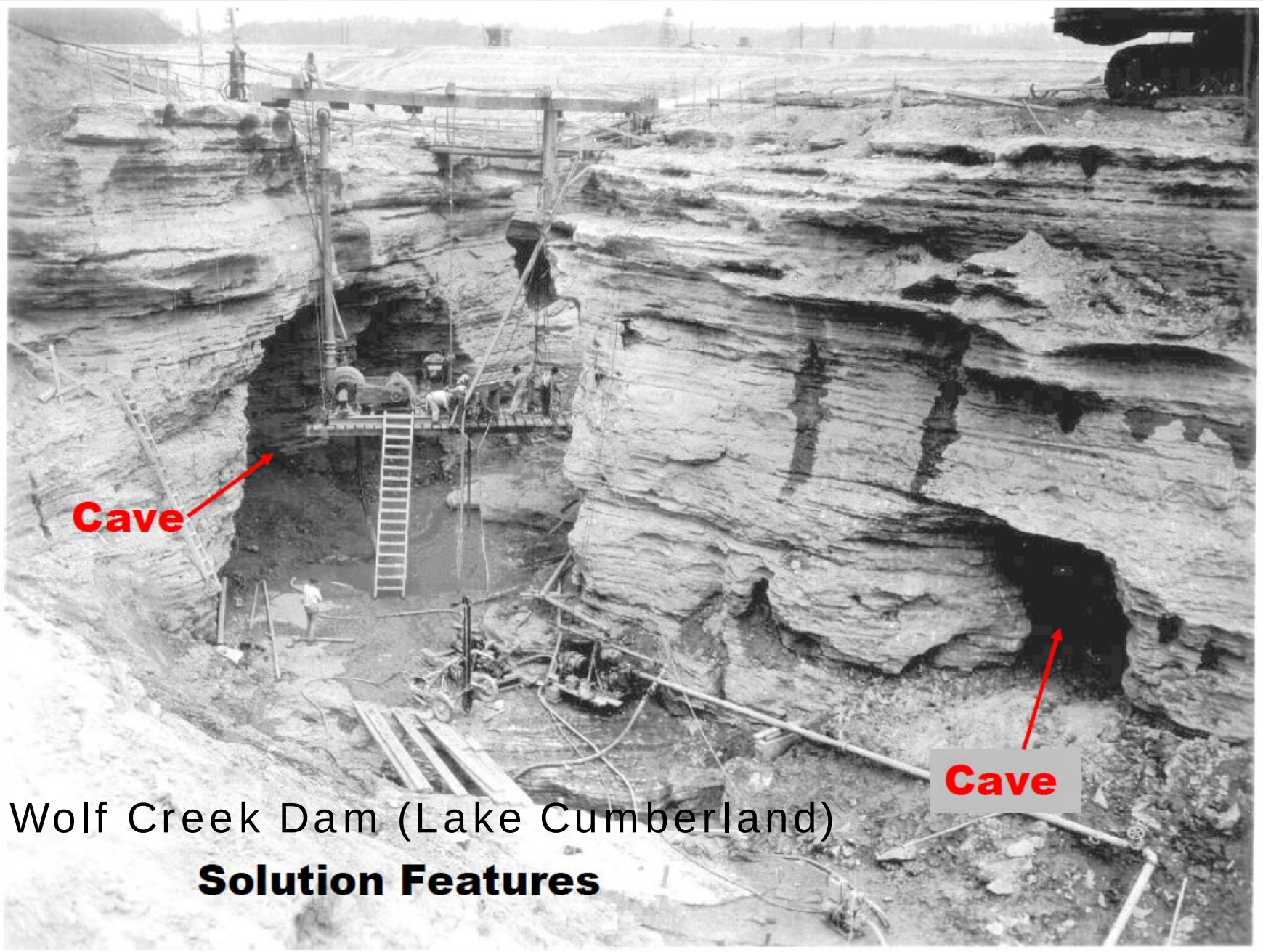
Rough River – Timeline for Risk Informed Process

- 2008 – 2012 - Dam Safety Modification Study
  - Establish baseline risk
  - Determine need for remediation
  - Make the case that remedial construction is prudent

- 2012 – Present - Design and Implement permanent Risk Reduction Measures

Karst Foundations
Internal erosion of dam embankment soil by groundwater flow through joints / solution features





Wolf Creek Dam (Lake Cumberland)

Solution Features

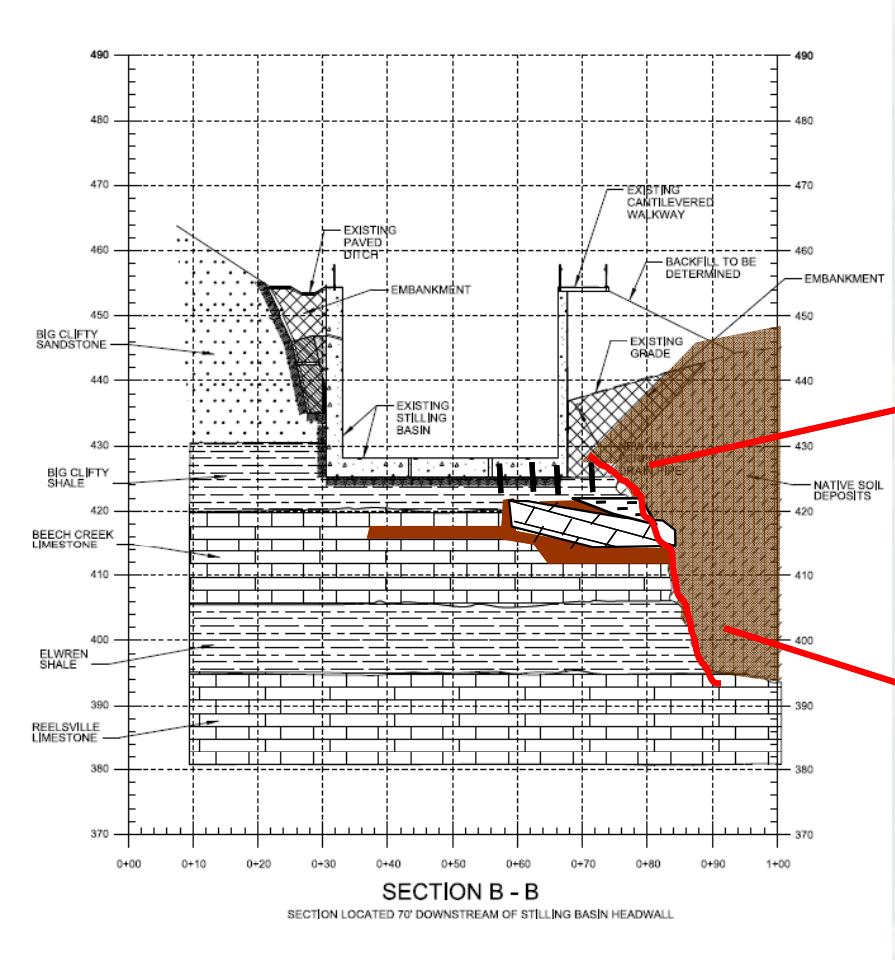
1950-1960 Vintage Life

Surgery

Dentistry

Technology

1950-1960 Vintage Dam Engineering


490
480
470
460
450
440
430
420
410
400
390
380
370
0+00
0+10
0+20
0+30
0+40
0+50
0+60
0+70
0+80
0+90
1+00
EXISTING PAVED DITCH
EMBANKMENT
EXISTING CANTILEVERED WALKWAY
BACKFILL TO BE DETERMINED
EMBANKMENT
EXISTING GRADE
EXISTING STILLING BASIN
NATIVE SOIL DEPOSITS
BIG CLIFTY SANDSTONE
BIG CLIFTY SHALE
BEECH CREEK LIMESTONE
ELWREN SHALE
REELSVILLE LIMESTONE
SECTION B - B
SECTION LOCATED 70' DOWNSTREAM OF STILLING BASIN HEADWALL

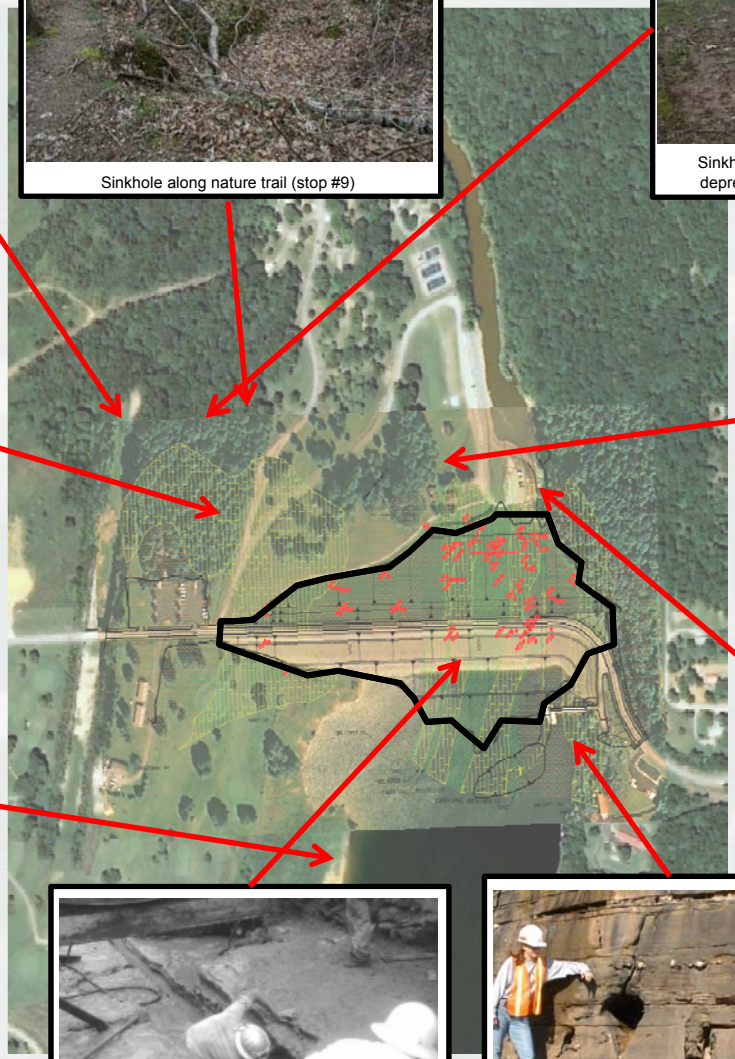
Stilling Basin Training Wall Repair November 2012

Karstic Haney Limestone in spillway

Sinkhole along nature trail (stop #9)

Sinkholes along access road, exhibiting active depressions (note resulting road realignment)

Sinkhole behind Project Office



Spring location in ravine (dam in background)

Spring location US of dam

Karst encountered in stilling basin excavation

Karst in Beech Creek Lst in Conduit Excavation

Karst in Haney Lst in right abutment

ROUGH RIVER DAM PUBLIC MEETING – March 24, 2015

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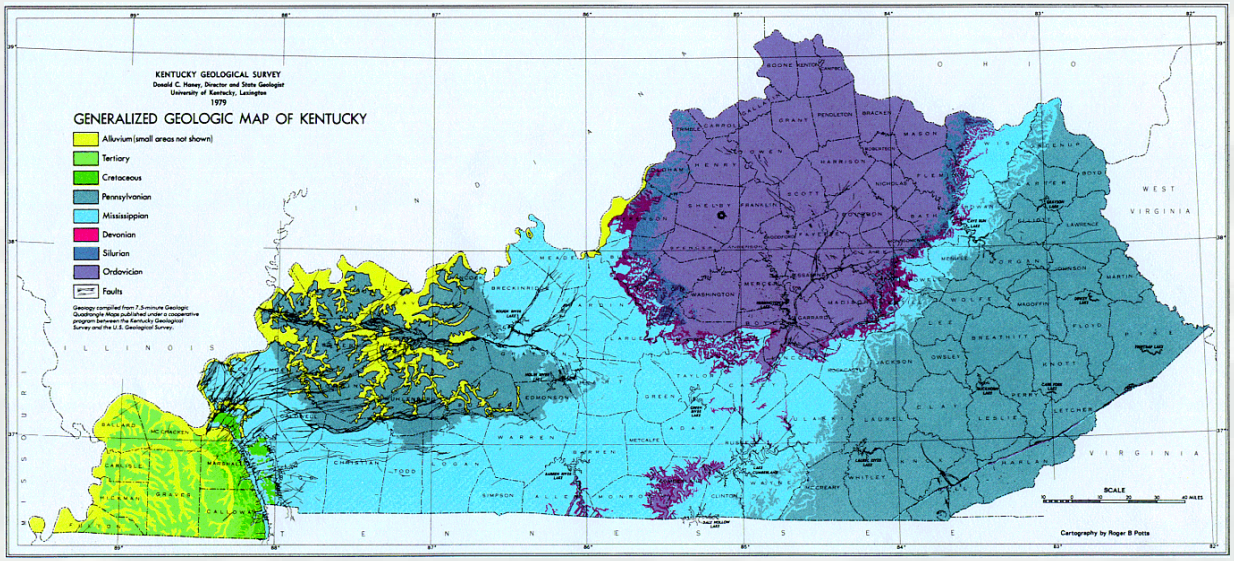
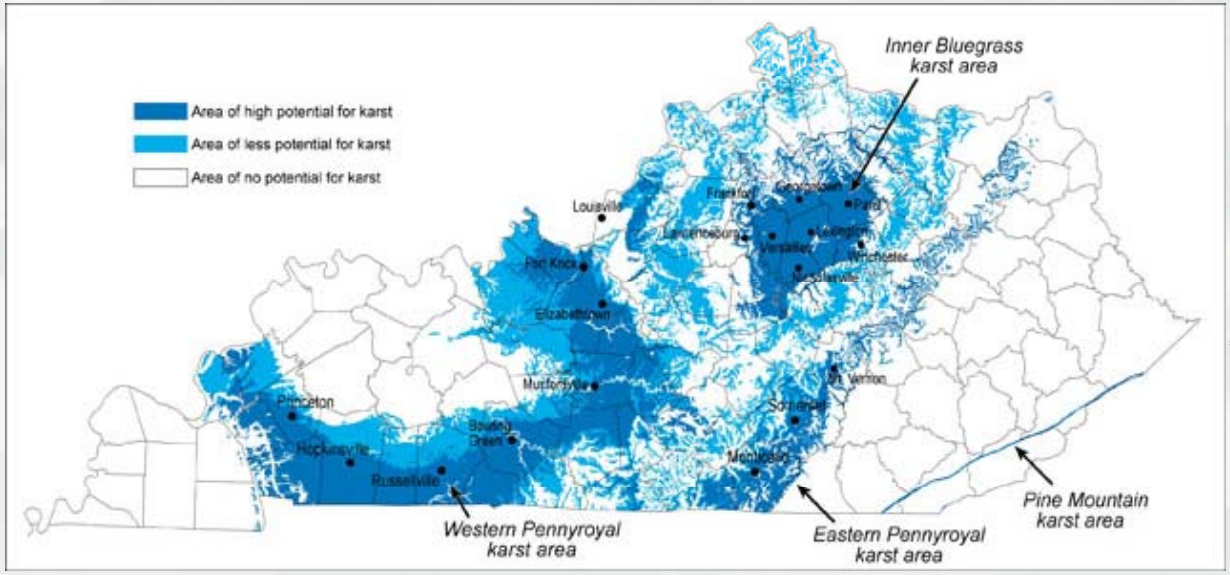
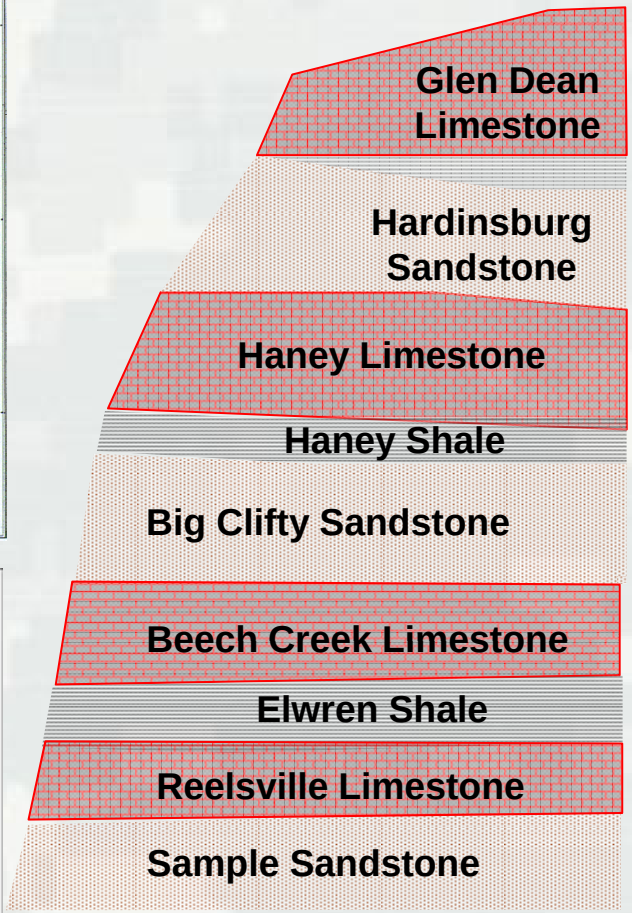
Rough River Geology

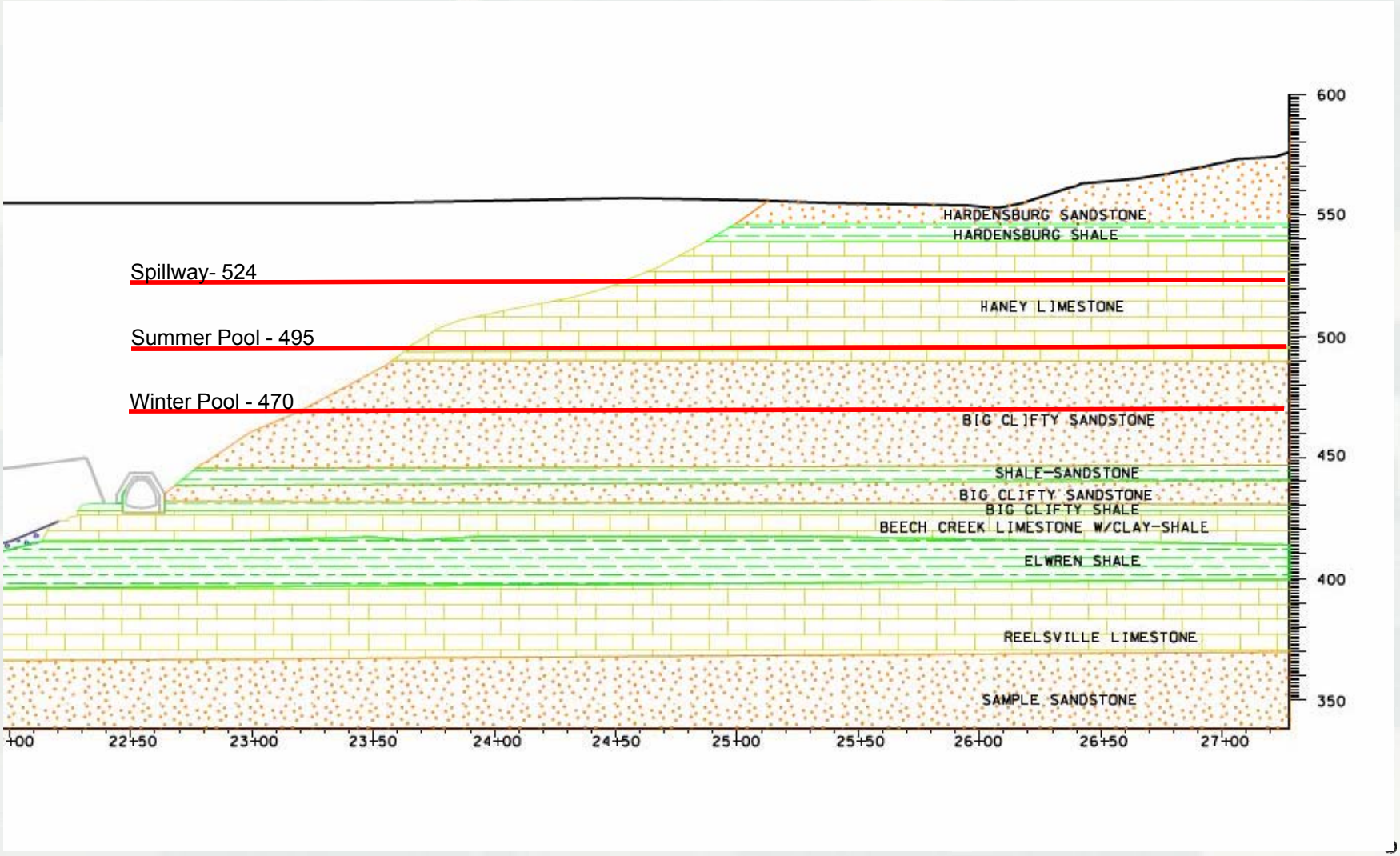




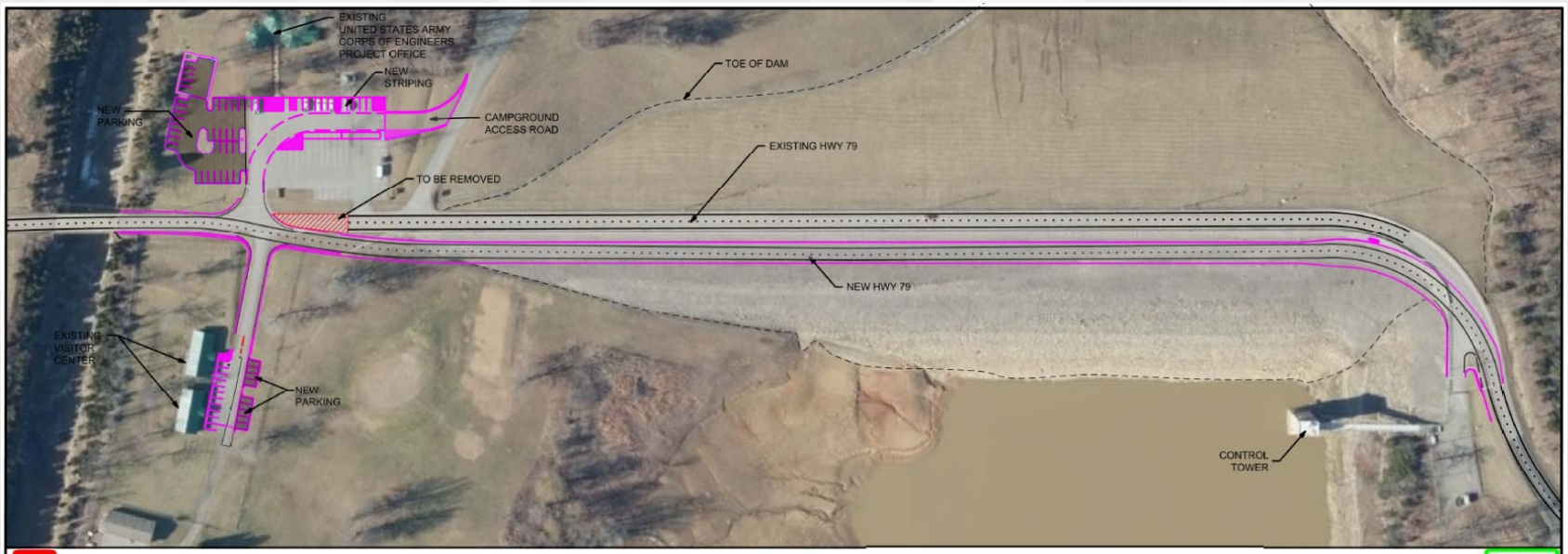


Rough River Dam, KY

Rough River Stratigraphy

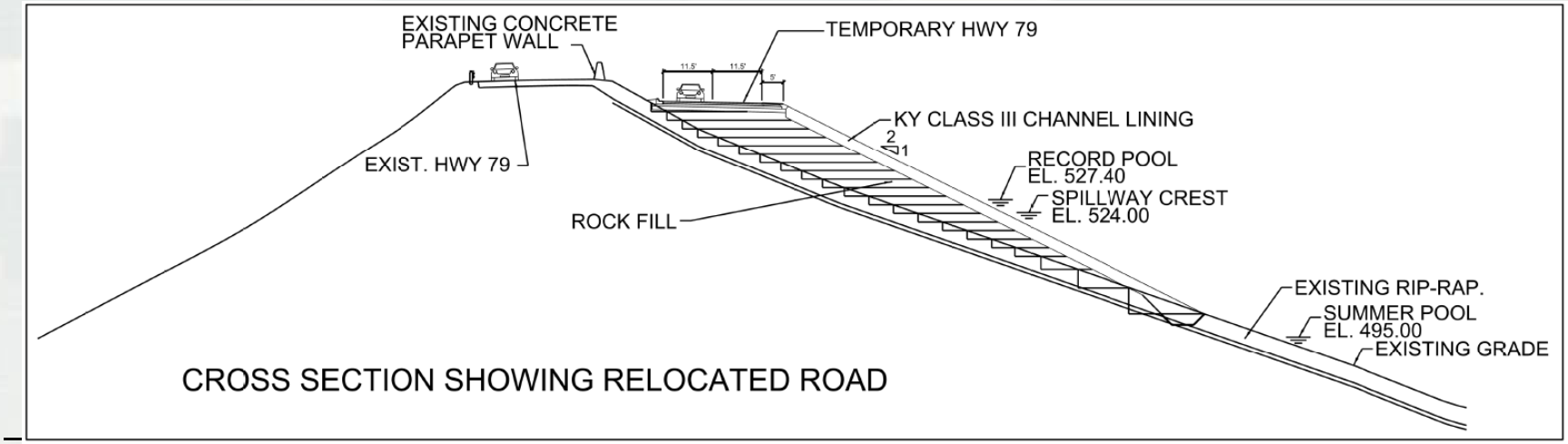


Phase 1A - Temporary Road Relocation for use of Existing Roadway Alignment as Work Platform



TEMPORARY RELOCATION OF HWY 79 DURING CONSTRUCTION - ROUGH RIVER LAKE DAM

US ARMY CORPS OF ENGINEERS LOUISVILLE DISTRICT



CROSS SECTION SHOWING RELOCATED ROAD

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

Phase 1A Construction

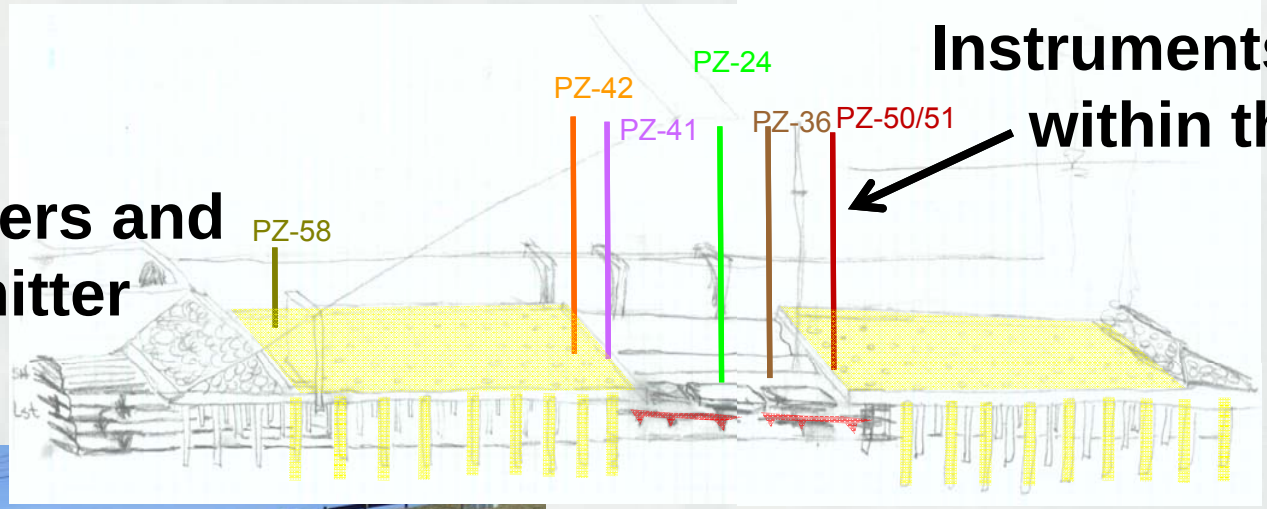
Phase 1A – What's Left?

- Complete installation of upstream piezometers
- Re-locate utilities to under new road
- Switch traffic from crest road to new road
- Minor demolition and site restoration

Pre-Phase 1B Instrumentation

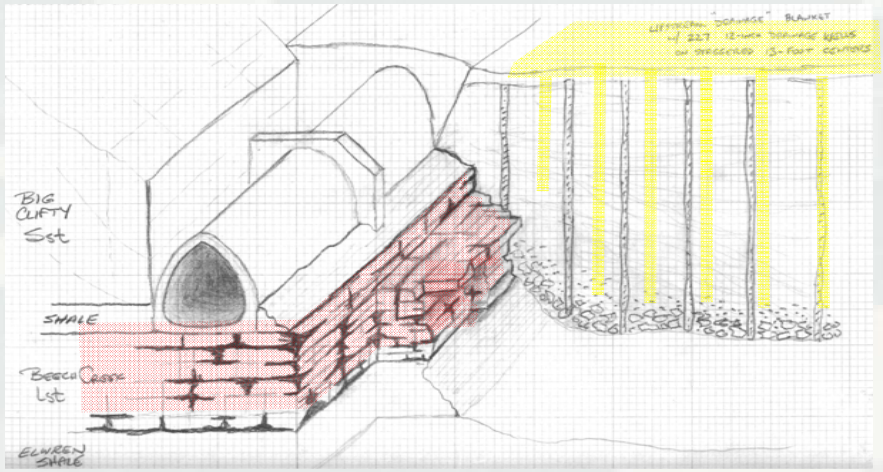
- Install 58 new piezometers (in 22 holes)
- 29 Piezometers upstream (in 11 holes)
- 29 Piezometers downstream (in 11 holes)
- All fully automated “vibrating wire” instruments

Enhanced Real Time Instrumentation Monitoring



Instruments installed within the dam

Data Loggers and Transmitter



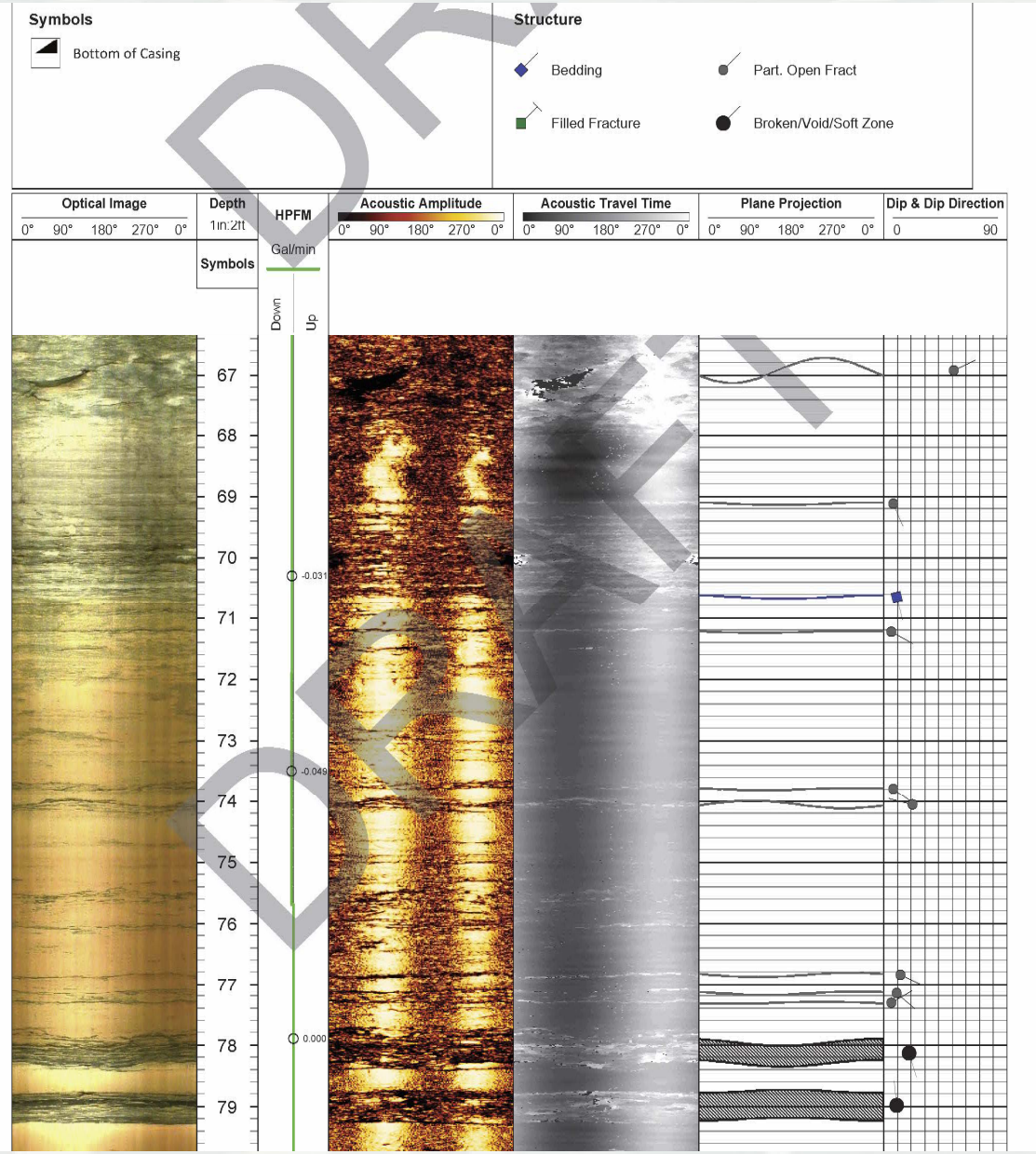
Instrumentation Installation

Trench excavation in preparation for Piezometer installation

Pre-Phase 1B Instrumentation

Pre-Phase 1B Instrumentation

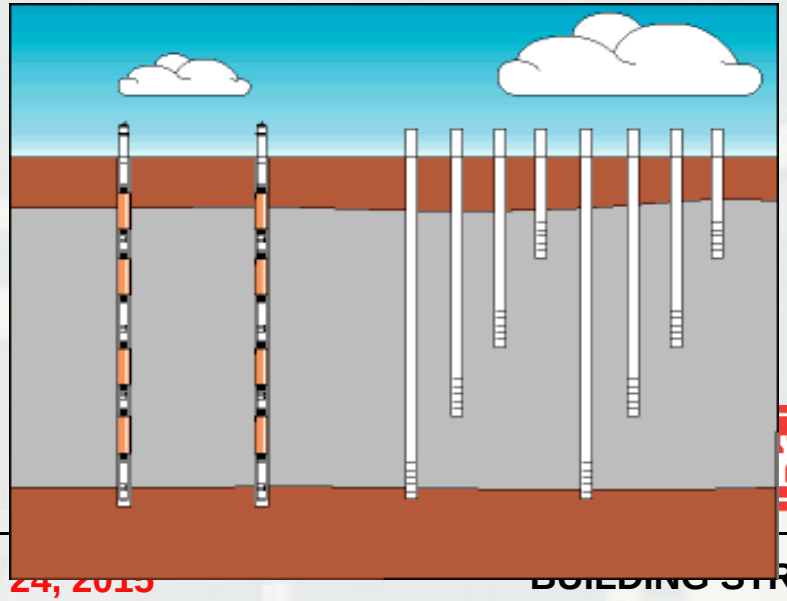
Pre-Phase 1B Instrumentation



DRAFT

Pre-Phase 1B Instrumentation

Pre-Phase 1B Instrumentation



Rough River – Construction Timeline

- 2012 to Present – Develop Plans and Specifications (Phase 1A complete, Phase 1B and Phase 2 ongoing)
- 2014 - 2015 – Phase 1A contract to relocate KY State Hwy 79 to the upstream slope (awarded)
- 2015 - 2016 – Initiate Grouting Phase and determine additional (final) remediation if needed

What's Next? – Phase 1B
Exploratory Drilling and Grouting

- Why are you doing this new work?
- How do you "Drill" the dam?
- What is Grouting?
- What is the purpose of Grouting?

What's Next? – Phase 1B Exploratory Drilling and Grouting

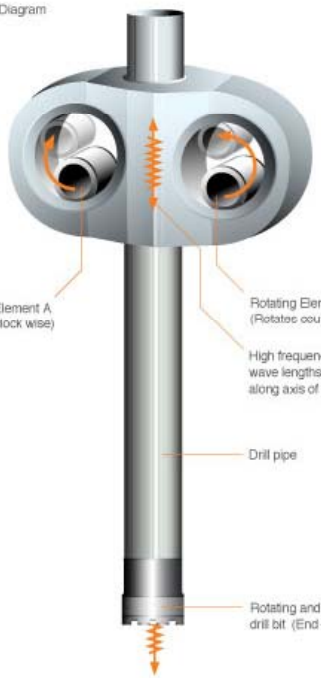
- Why are you doing this new work?
  - Further define foundation characteristics
  - Establish the need for future remedial action

What's Next? – Phase 1B
Exploratory Drilling and Grouting

- How do you "drill" the soil?

Oscillator Detail

Oscillator Diagram



- Achieve and Maintain Resonance of the Drill String
- Eliminate / Minimize Friction Between Borehole and Pipe
  - Penetration in any Material
  - High Quality Sample
  - Minimal Disturbance of Borehole Wall

What's Next? – Phase 1B
Exploratory Drilling and Grouting

- How do you "drill" the rock?

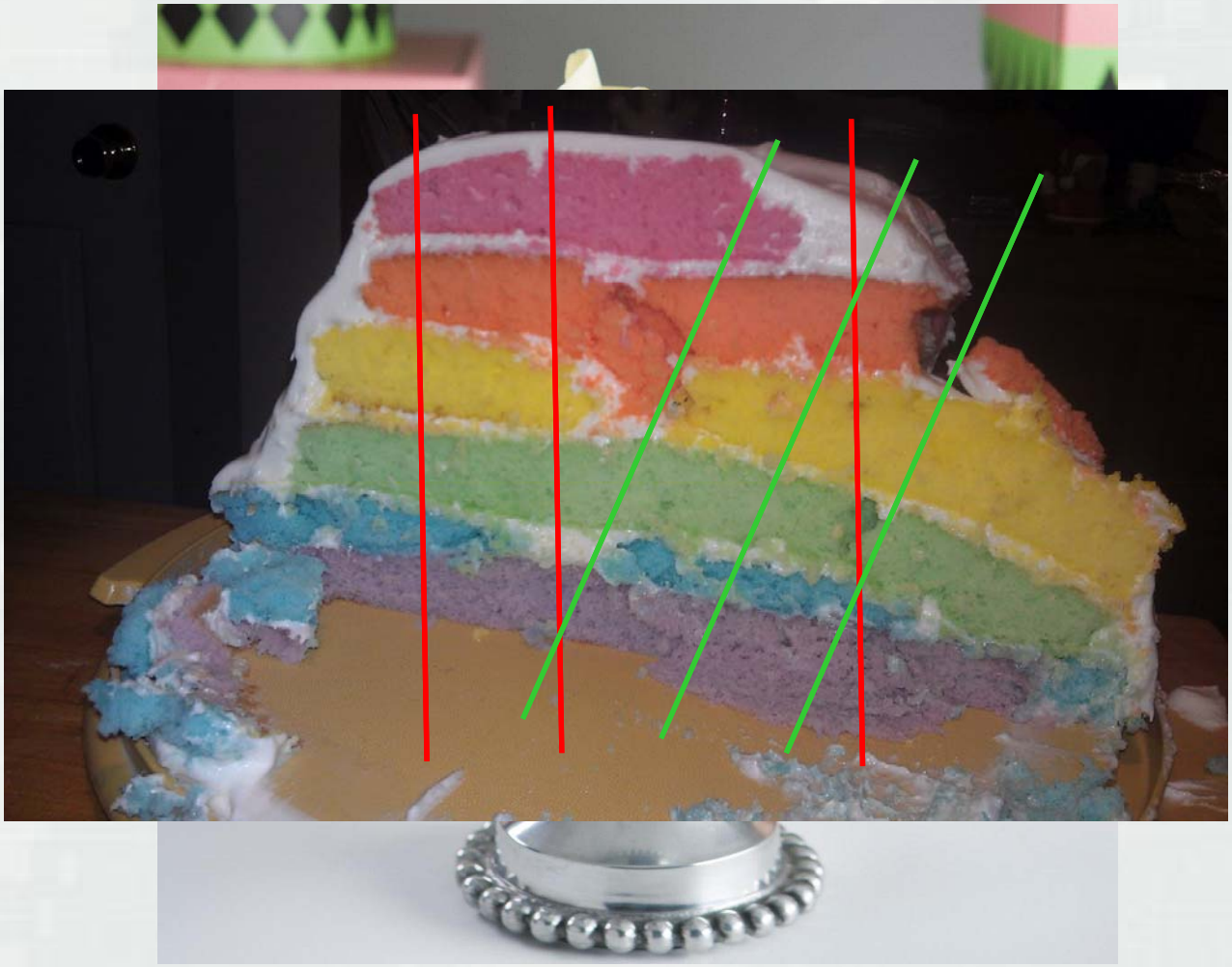
Rock Drilling Bits

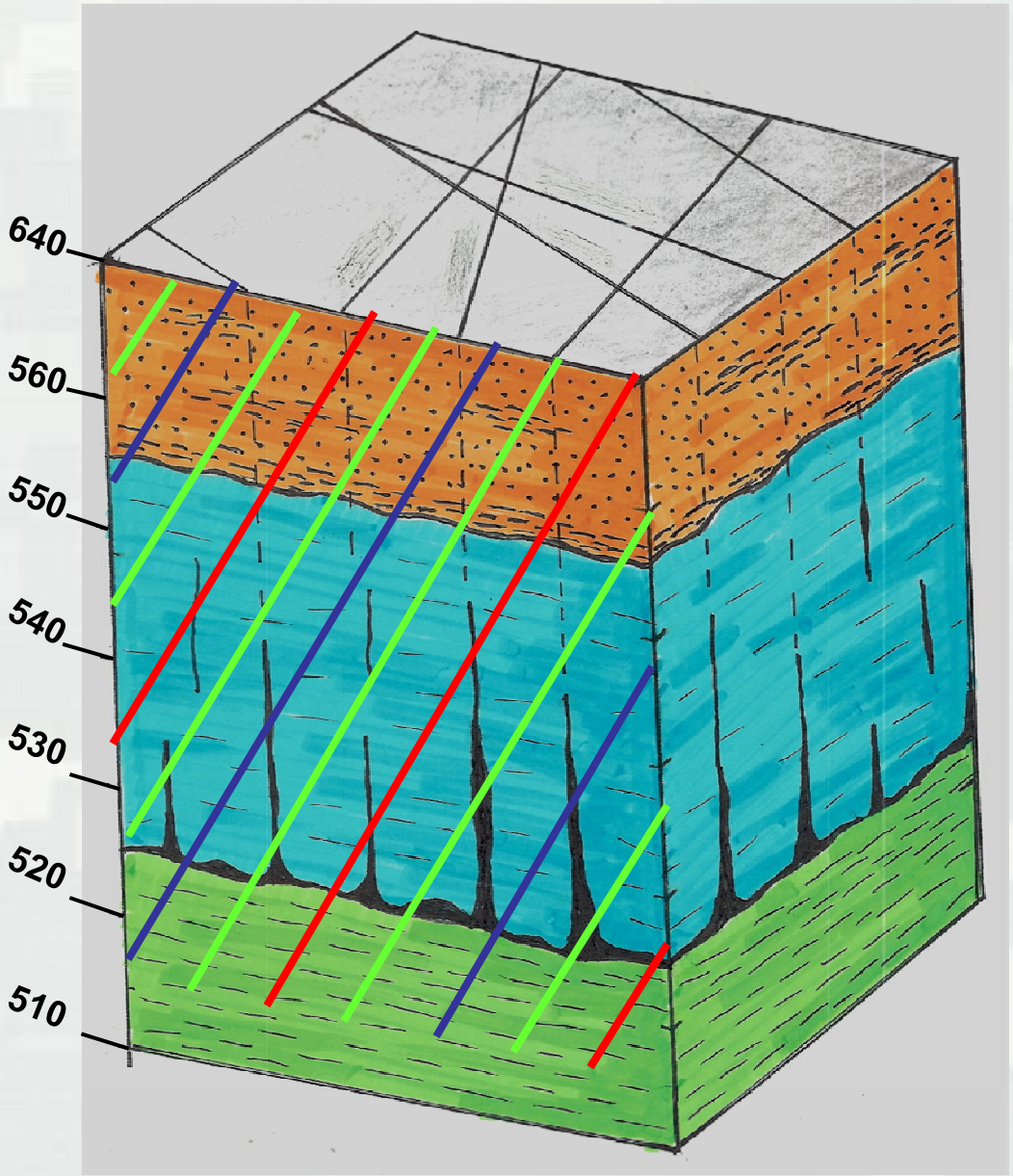
Rock Core Sample

Rock Coring Bit

What's Next? – Phase 1B Exploratory Drilling and Grouting

- How do you "Drill" the dam?

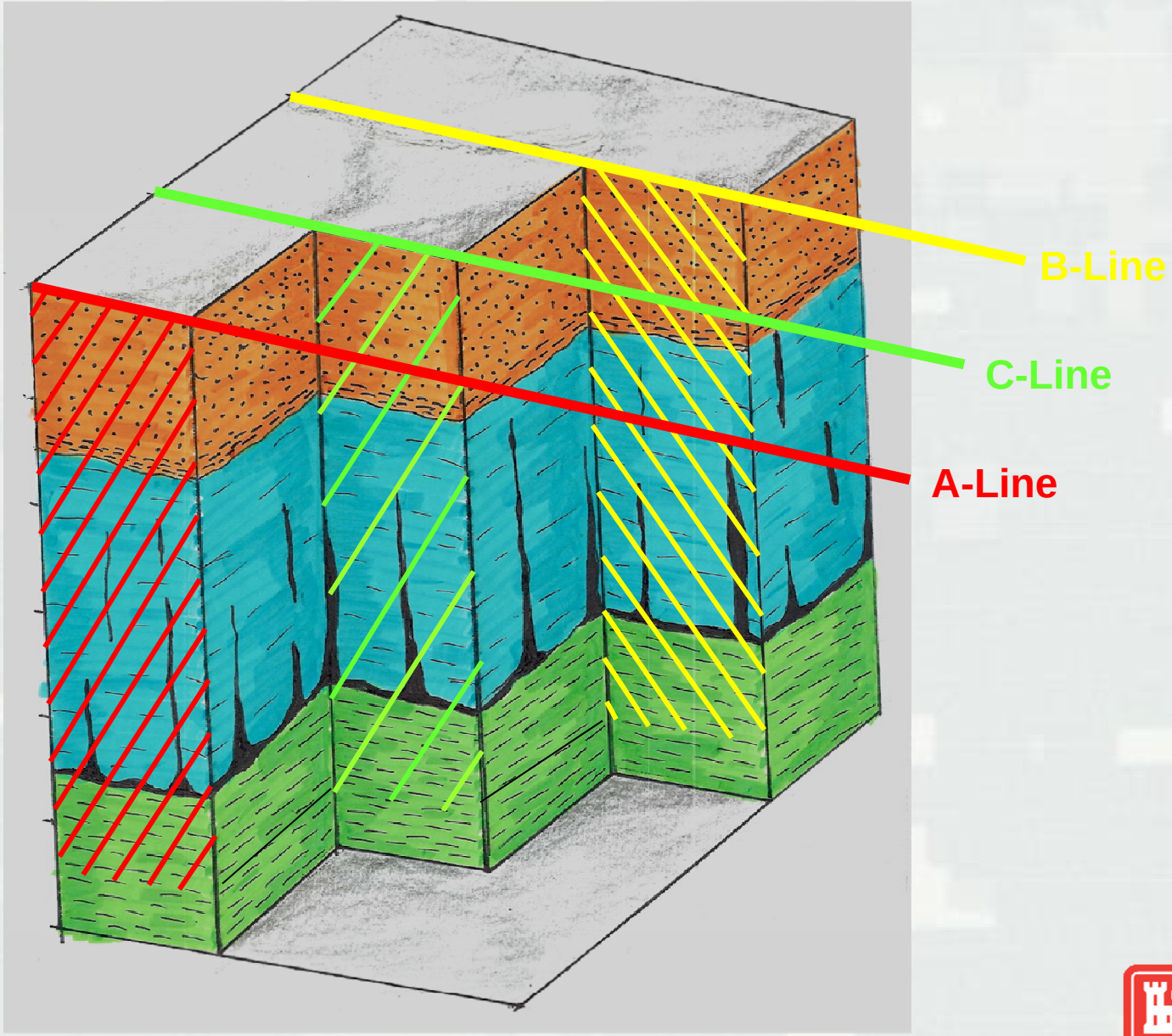




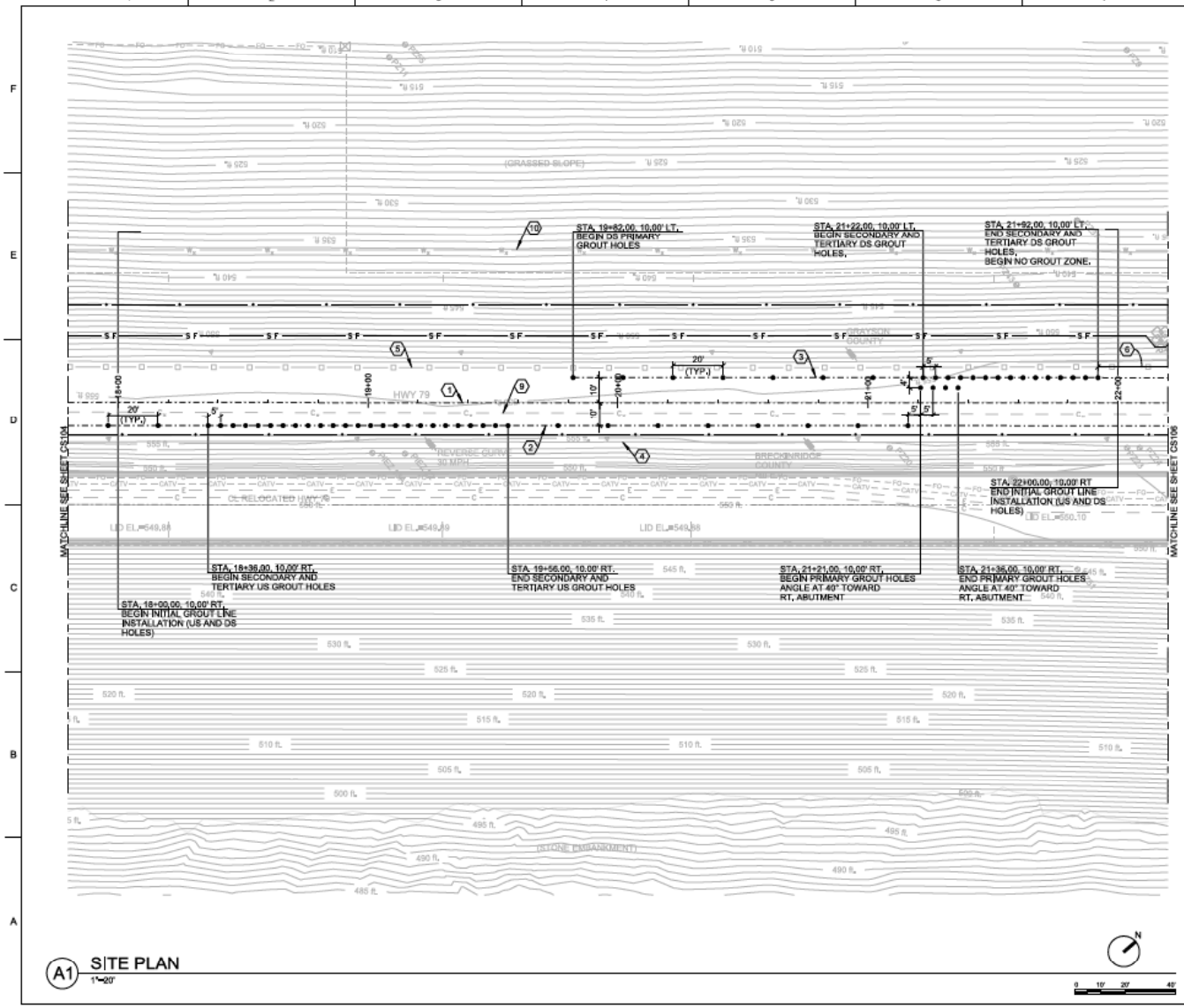
PRIMARIES
20' Centers

SECONDARIES
10' Centers

TERTIARIES
5' Centers


B-Line
C-Line
A-Line

*** SAFETY PAYS ***



A1 SITE PLAN
1"=20'

GENERAL SHEET NOTES

1. SEE SHEETS CG201-CG202 FOR DETAILED PLAN AND PROFILE OF UPSTREAM GROUT LINE AND GEOLOGIC PROFILE.
2. SEE SHEETS CG203-CG204 FOR DETAILED PLAN AND PROFILE OF DOWNSTREAM GROUT LINE AND GEOLOGIC PROFILE.
3. SEE SHEETS CG205-CG206 FOR DETAILED PLAN AND PROFILE OF COMBINED US AND DS GROUT LINE.
4. SEE SHEETS CS501-CS502 FOR EROSION CONTROL DETAILS.
5. GROUT HOLES WILL BE DRILLED THROUGH EXISTING ROAD PAVEMENT.

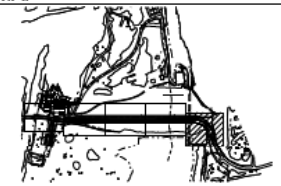
SHEET KEYNOTES

1. CONTRACT BASELINE FOR GROUTING.
2. UPSTREAM (US) GROUT LINE.
3. DOWNSTREAM (DS) GROUT LINE.
4. EXISTING PARAPET WALL. DO NOT DISTURB.
5. EXISTING GUARDRAIL. DO NOT DISTURB EXCEPT AS NOTED ON DEMOLITION PLANS.
6. NO GROUT ZONE TO AVOID IMPACT TO EXISTING CONDUIT.
7. EXISTING OUTLET CONDUIT.
8. VERTICAL US AND DS PRIMARY GROUT HOLES TO STRADDLE EXISTING CONDUIT AT STA. 21+42.00 AND STA. 22+67.00. SEE SHEETS CG204 AND CG206.
9. ABANDONED UNDERGROUND FIBER OPTIC LINE.
10. ABANDONED WATER LINE.

LEGEND

- CONTRACTOR WORK LIMITS
- GROUT HOLE LOCATION
- S F — SILT FENCE. SEE SHEET CS501, DETAIL A1.
- CD — STONE SILT CHECK. SEE SHEET CS502, DETAIL A7.
- CE — TEMPORARY GRAVEL CONSTRUCTION ENTRANCE/EXIT. SEE SHEET CS502, DETAIL D7.
- SIP — STONE INLET PROTECTION. SEE SHEET CS502, DETAIL E1.

KEY MAP



US ARMY CORPS OF ENGINEERS
LOUISVILLE DISTRICT

SYMBOL	DESCRIPTION	DATE	APPR.
REVISIONS			

DESIGNED BY: B. DORSCH, T. WILLBANKS
DATE: JANUARY 2015
DRAWN BY: B. SAYLOR
SCALE: 1"=20'
CHECKED BY: K. DORSCH
DRAWING CODE: R18B-12J01
PROJECT ENGINEER/ARCHITECT: W. ALSTOCK
DATE: JANUARY 2015

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

ROUGH RIVER DAM SAFETY
EXPLORATORY DRILLING AND GROUTING
FALLS OF ROUGH, KENTUCKY

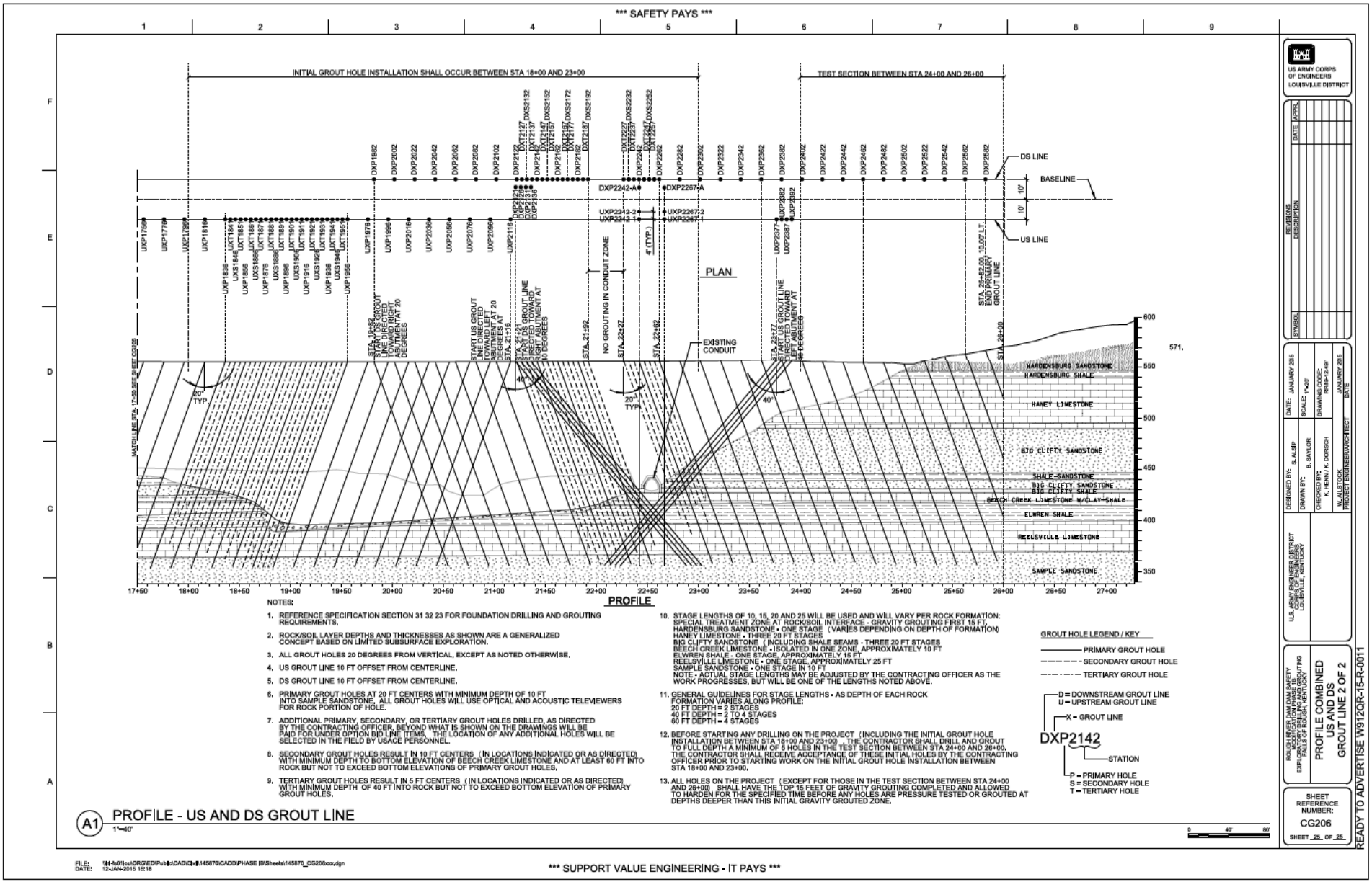
SITE PLAN
4 OF 5

SHEET REFERENCE NUMBER:
CS105
SHEET 16 OF 25

READY TO ADVERTISE W912QR-15-R-0011

FILE: \\[illegible]\DRGED\Pub\CADD\[illegible]\145870\CADD\PHASE II\Sheets\145870_CS105xxx.dgn
DATE: 12-JAN-2015 15:17

*** SUPPORT VALUE ENGINEERING - IT PAYS ***



NOTES:

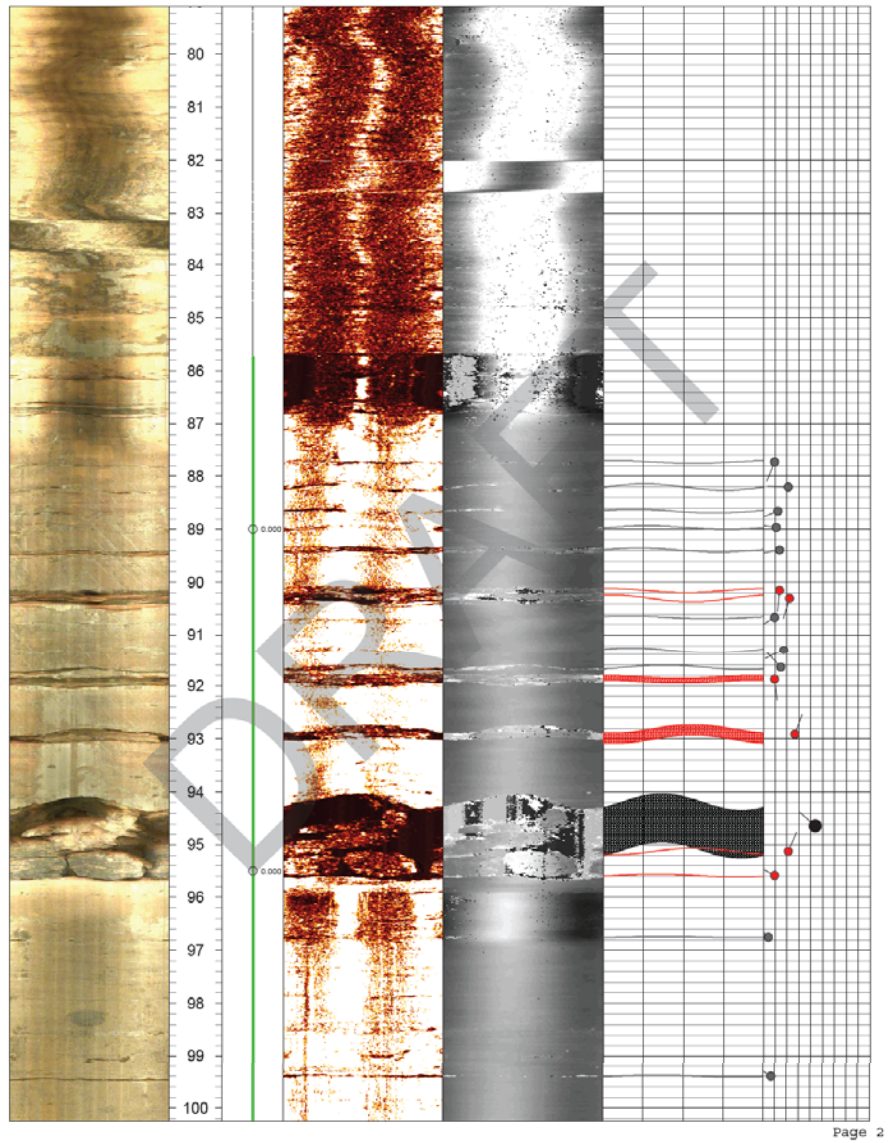
1. REFERENCE SPECIFICATION SECTION 31 32 23 FOR FOUNDATION DRILLING AND GROUTING REQUIREMENTS.
2. ROCK/SOIL LAYER DEPTHS AND THICKNESSES AS SHOWN ARE A GENERALIZED CONCEPT BASED ON LIMITED SUBSURFACE EXPLORATION.
3. ALL GROUT HOLES 20 DEGREES FROM VERTICAL, EXCEPT AS NOTED OTHERWISE.
4. US GROUT LINE 10 FT OFFSET FROM CENTERLINE.
5. DS GROUT LINE 10 FT OFFSET FROM CENTERLINE.
6. PRIMARY GROUT HOLES AT 20 FT CENTERS WITH MINIMUM DEPTH OF 10 FT INTO SAMPLE SANDSTONE. ALL GROUT HOLES WILL USE OPTICAL AND ACOUSTIC TELEVIEWERS FOR ROCK PORTION OF HOLE.
7. ADDITIONAL PRIMARY, SECONDARY, OR TERTIARY GROUT HOLES DRILLED, AS DIRECTED BY THE CONTRACTING OFFICER, BEYOND WHAT IS SHOWN ON THE DRAWINGS WILL BE PAID FOR UNDER OPTION BID LINE ITEMS. THE LOCATION OF ANY ADDITIONAL HOLES WILL BE SELECTED IN THE FIELD BY USACE PERSONNEL.
8. SECONDARY GROUT HOLES RESULT IN 10 FT CENTERS (IN LOCATIONS INDICATED OR AS DIRECTED) WITH MINIMUM DEPTH TO BOTTOM ELEVATION OF BEECH CREEK LIMESTONE AND AT LEAST 60 FT INTO ROCK BUT NOT TO EXCEED BOTTOM ELEVATIONS OF PRIMARY GROUT HOLES.
9. TERTIARY GROUT HOLES RESULT IN 5 FT CENTERS (IN LOCATIONS INDICATED OR AS DIRECTED) WITH MINIMUM DEPTH OF 40 FT INTO ROCK BUT NOT TO EXCEED BOTTOM ELEVATION OF PRIMARY GROUT HOLES.
10. STAGE LENGTHS OF 10, 15, 20 AND 25 WILL BE USED AND WILL VARY PER ROCK FORMATION: SPECIAL TREATMENT ZONE AT ROCK/SOIL INTERFACE - GRAVITY GROUTING FIRST 15 FT. HARDENSBURG SANDSTONE - ONE STAGE (VARIES DEPENDING ON DEPTH OF FORMATION) HANEY LIMESTONE - THREE 20 FT STAGES BIG CLIFTY SANDSTONE (INCLUDING SHALE SEAMS - THREE 20 FT STAGES BEECH CREEK LIMESTONE - ISOLATED IN ONE ZONE, APPROXIMATELY 10 FT ELWREN SHALE - ONE STAGE, APPROXIMATELY 15 FT REELSVILLE LIMESTONE - ONE STAGE, APPROXIMATELY 25 FT SAMPLE SANDSTONE - ONE STAGE IN 10 FT NOTE - ACTUAL STAGE LENGTHS MAY BE ADJUSTED BY THE CONTRACTING OFFICER AS THE WORK PROGRESSES, BUT WILL BE ONE OF THE LENGTHS NOTED ABOVE.
11. GENERAL GUIDELINES FOR STAGE LENGTHS - AS DEPTH OF EACH ROCK FORMATION VARIES ALONG PROFILE: 20 FT DEPTH = 2 STAGES 40 FT DEPTH = 2 TO 4 STAGES 60 FT DEPTH = 4 STAGES
12. BEFORE STARTING ANY DRILLING ON THE PROJECT (INCLUDING THE INITIAL GROUT HOLE INSTALLATION BETWEEN STA 18+00 AND 23+00) THE CONTRACTOR SHALL DRILL AND GROUT TO FULL DEPTH A MINIMUM OF 5 HOLES IN THE TEST SECTION BETWEEN STA 24+00 AND 26+00. THE CONTRACTOR SHALL RECEIVE ACCEPTANCE OF THESE INITIAL HOLES BY THE CONTRACTING OFFICER PRIOR TO STARTING WORK ON THE INITIAL GROUT HOLE INSTALLATION BETWEEN STA 18+00 AND 23+00.
13. ALL HOLES ON THE PROJECT (EXCEPT FOR THOSE IN THE TEST SECTION BETWEEN STA 24+00 AND 26+00) SHALL HAVE THE TOP 15 FEET OF GRAVITY GROUTING COMPLETED AND ALLOWED TO HARDEN FOR THE SPECIFIED TIME BEFORE ANY HOLES ARE PRESSURE TESTED OR GROUTED AT DEPTHS DEEPER THAN THIS INITIAL GRAVITY GROUTED ZONE.

GROUT HOLE LEGEND / KEY

- PRIMARY GROUT HOLE
- SECONDARY GROUT HOLE
- TERTIARY GROUT HOLE

D = DOWNSTREAM GROUT LINE
U = UPSTREAM GROUT LINE
X = GROUT LINE
DXP2142 — STATION
P = PRIMARY HOLE
S = SECONDARY HOLE
T = TERTIARY HOLE

What does it all Mean?



-How do we interpret the data?

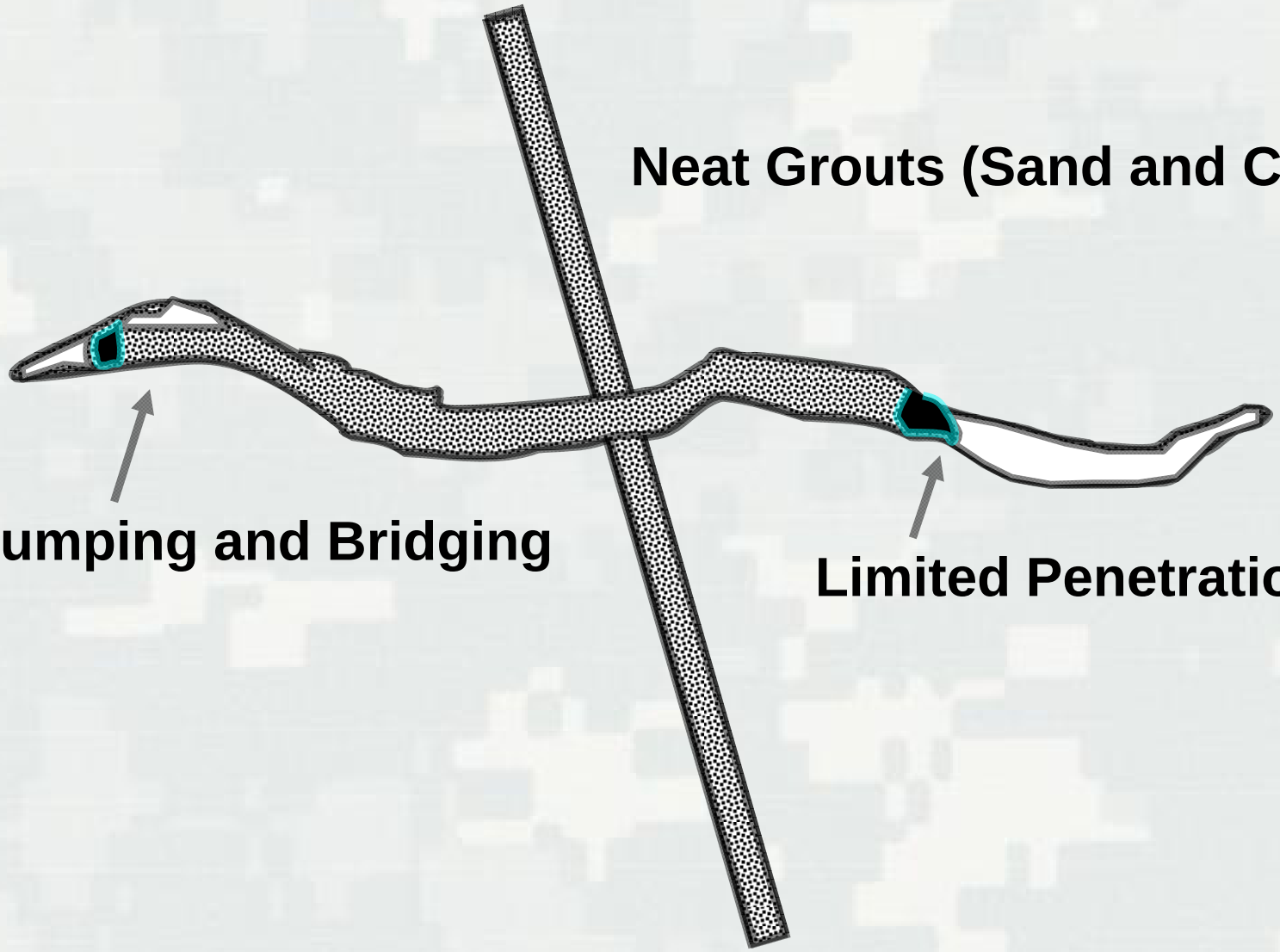
- -Optical and Accoustical Televiewer
- -Hand written logs
- -Monitoring other instruments

What's Next? – Phase 1B
Exploratory Drilling and Grouting

What is Grouting?

- *Injecting grout under pressure into voids below the ground surface.*

Grout Injection



What's Next? – Phase 1B
Exploratory Drilling and Grouting

What is the general purpose of Grouting?

- *Typically the purpose is to fill voids sufficiently to reduce the potential seepage through the Foundation.*

What is the purpose of our Grouting?

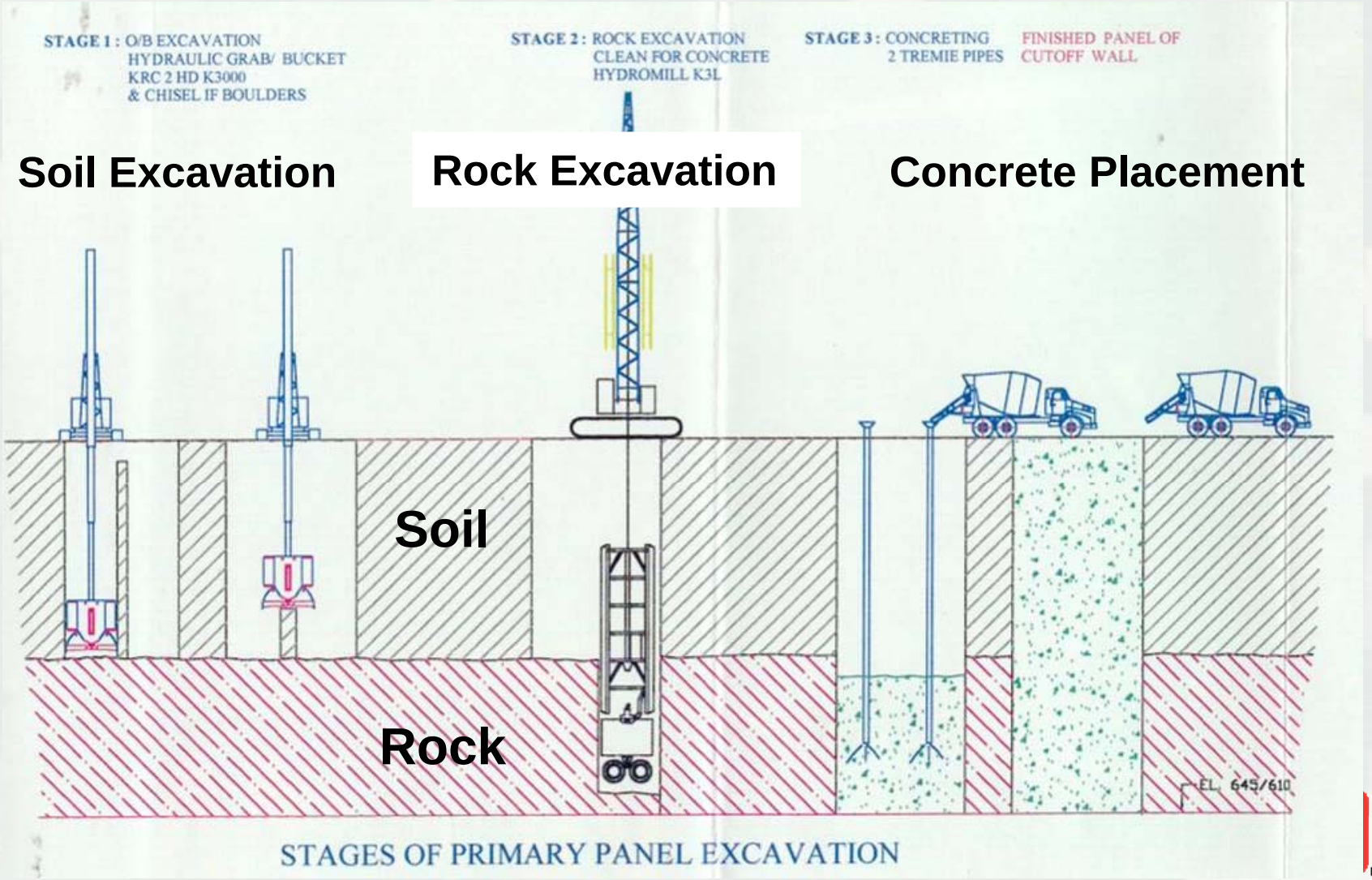
- *"Exploratory Drilling and Grouting"*
- *Define extent of future repair*
- *Provide interim risk reduction to the project*

Phase 2 – Future Remediation

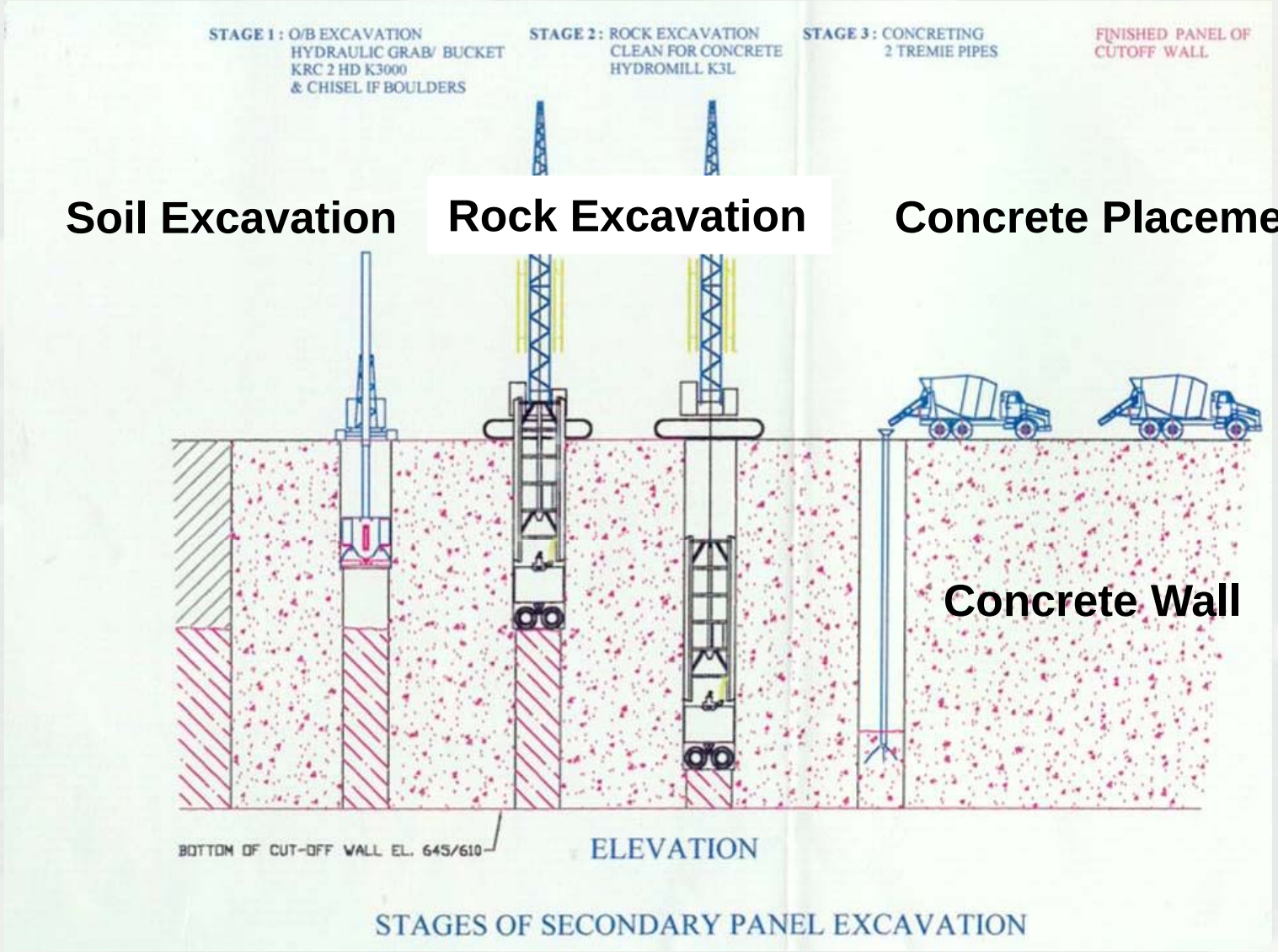
•Phase 1B - justify the need for further remediation (additional grouting or cutoff wall)

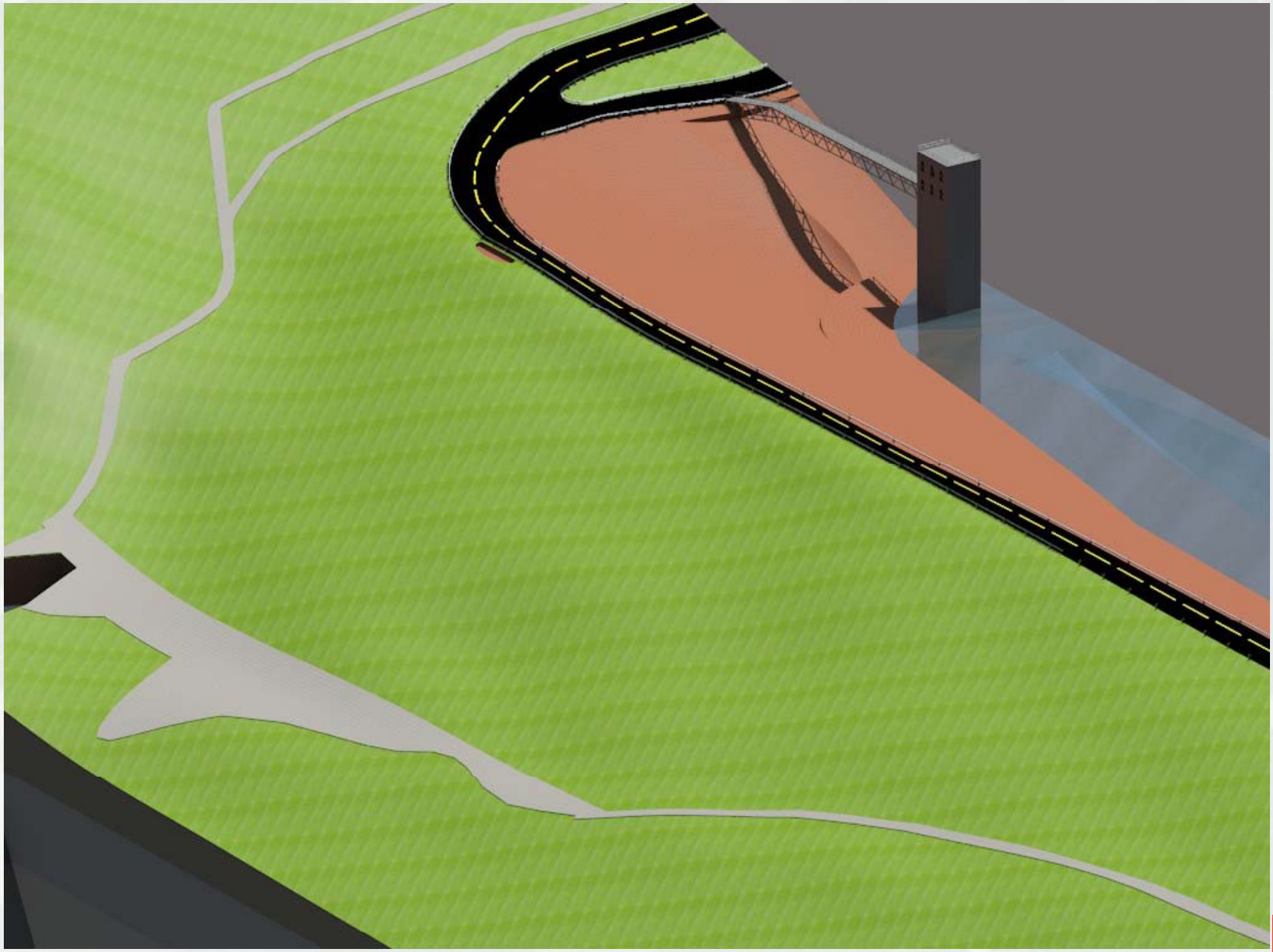
•Cutoff wall - the most reliable method of cutting off potential seepage paths and, therefore, potential failure modes.

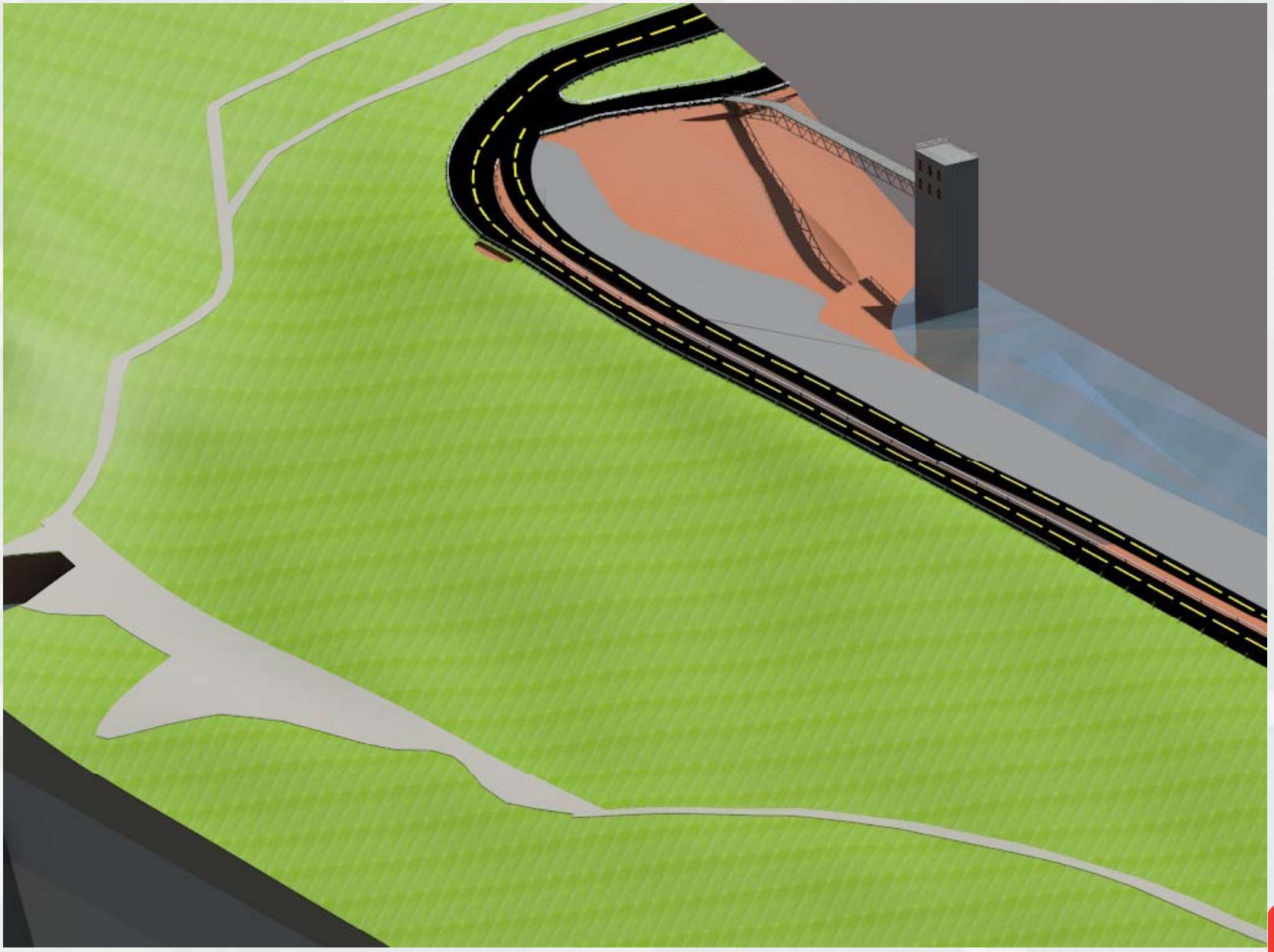
Cut-off Wall - Primary Panel Placement

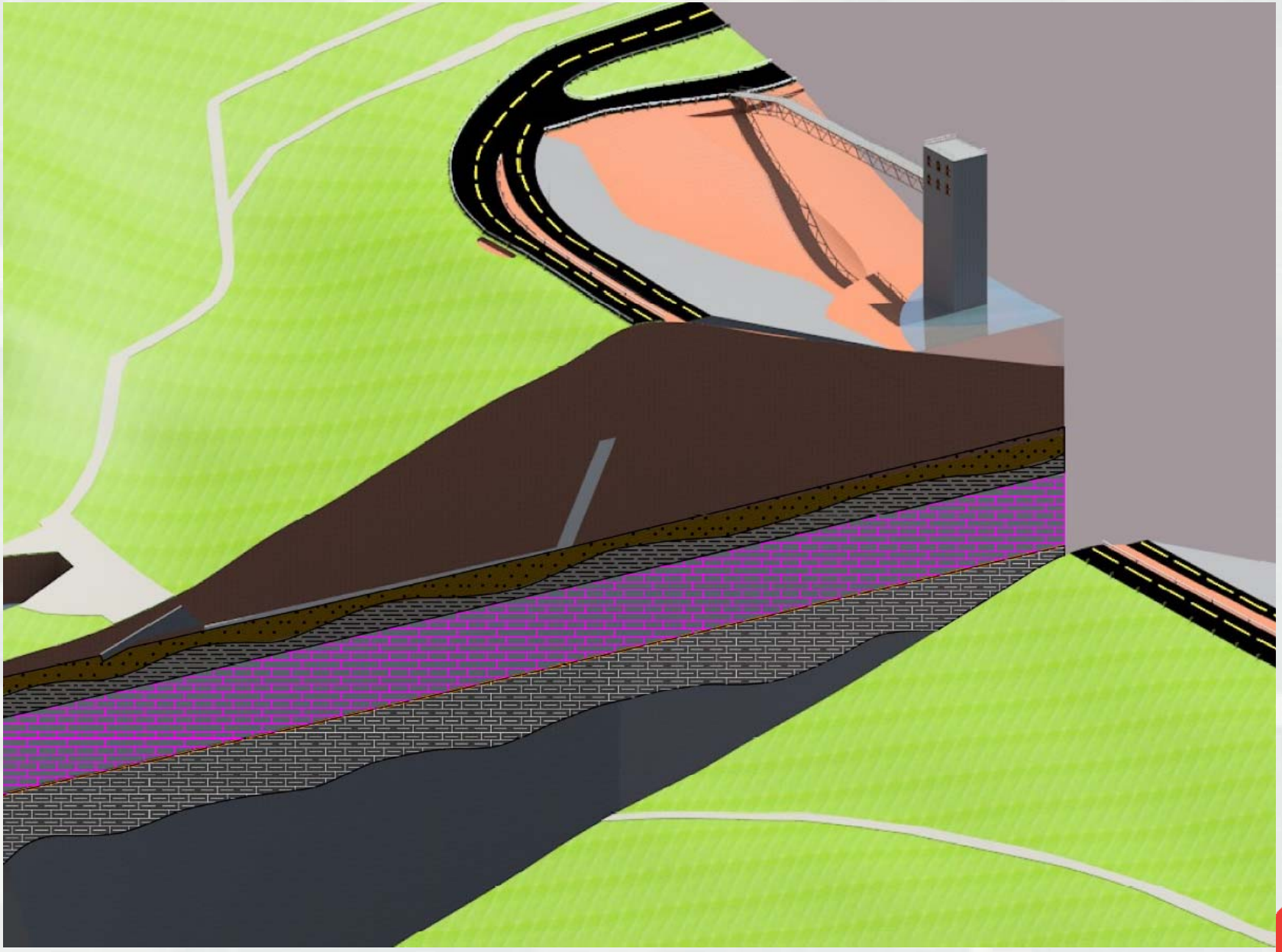


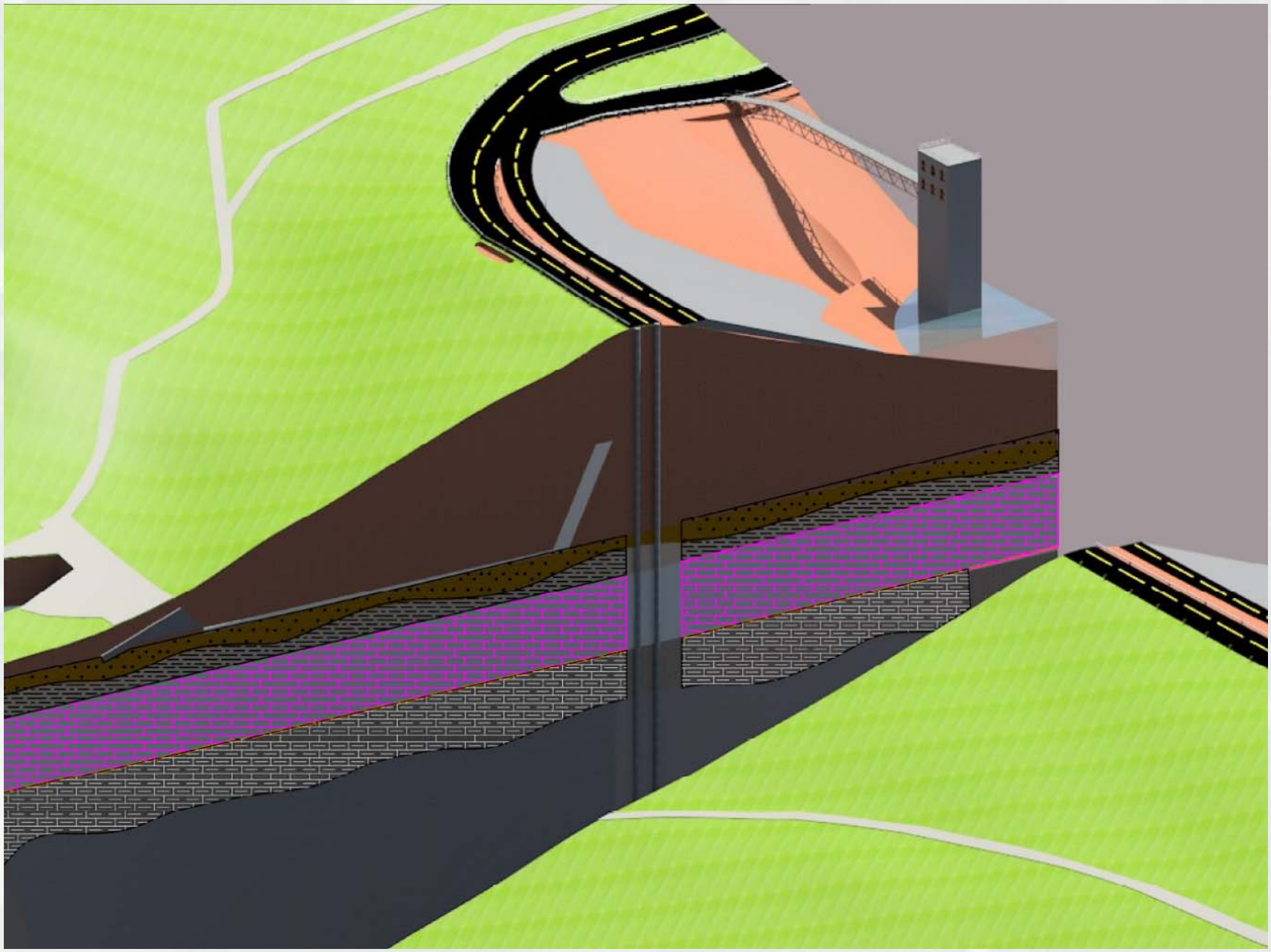
Cut-off Wall - Closure Panel Placement

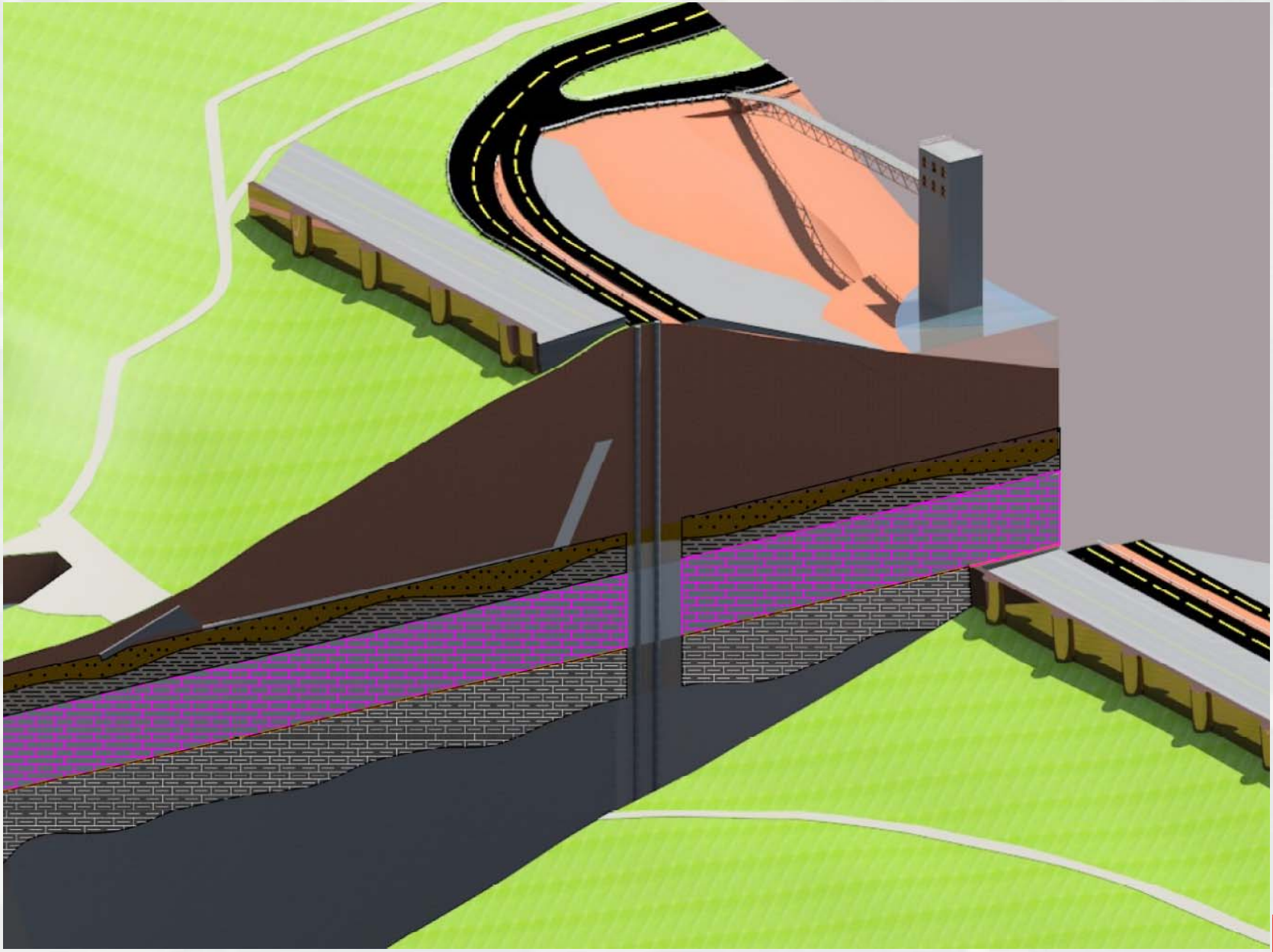


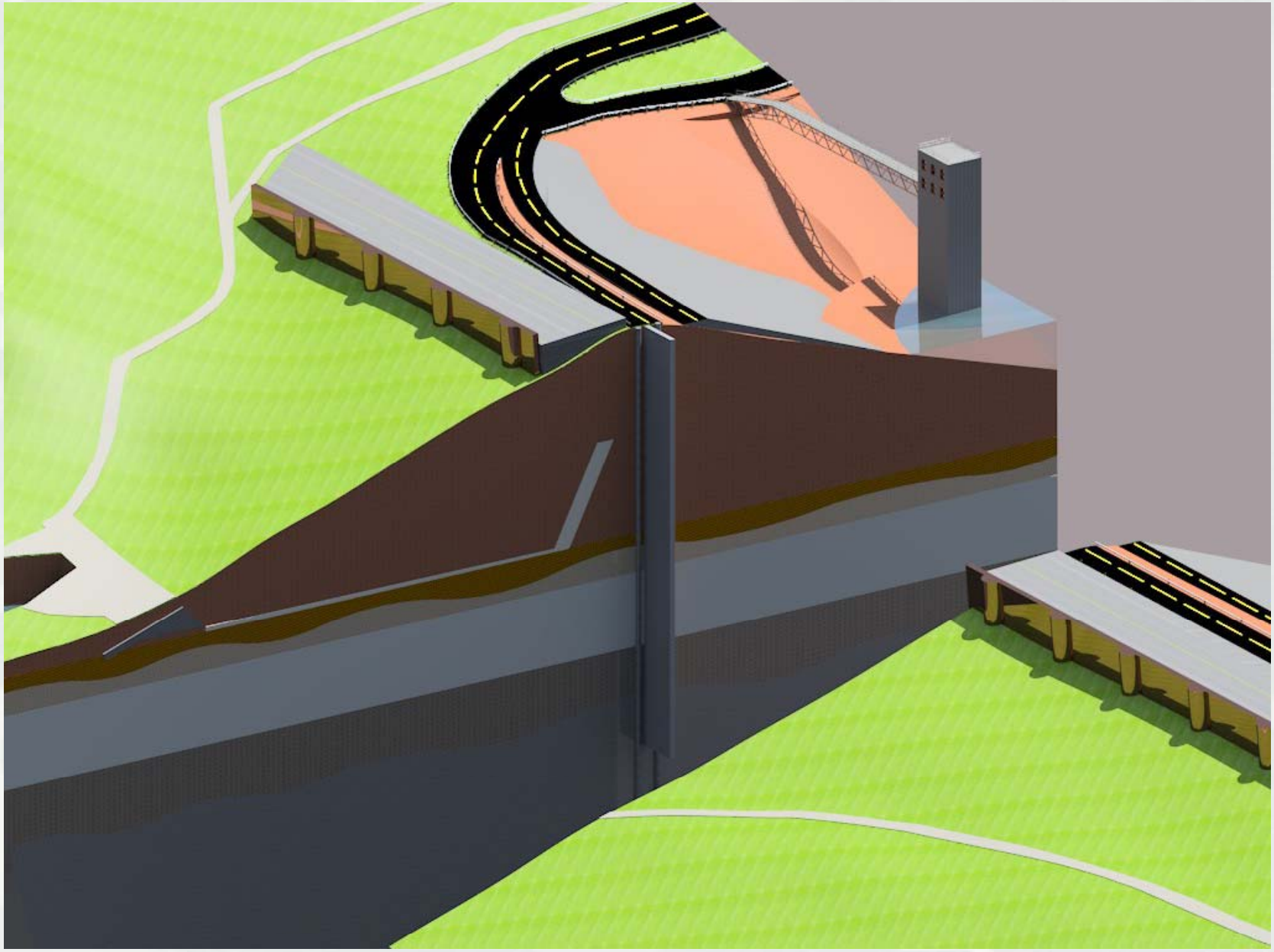












Cutoff Wall Construction (Mississinewa)

Cutoff Wall Construction (Wolf Creek)

Questions?