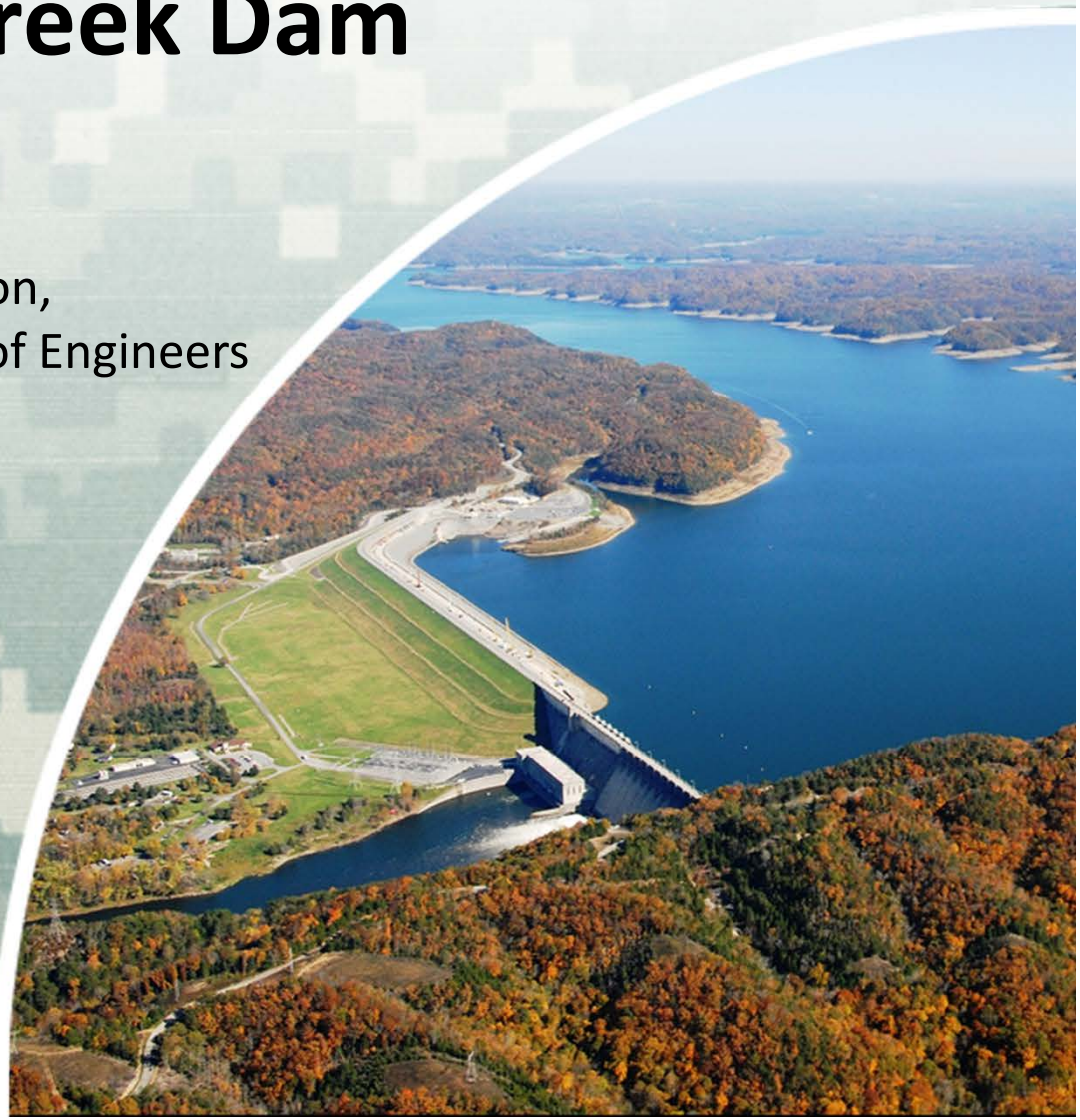
Successful Foundation Preparations in Karst Bedrock of the Masonry Section of Wolf Creek Dam

David M. Robison, P.G.
Geotechnical and Dam Safety Section,
Louisville District, U.S. Army Corps of Engineers



US Army Corps of Engineers
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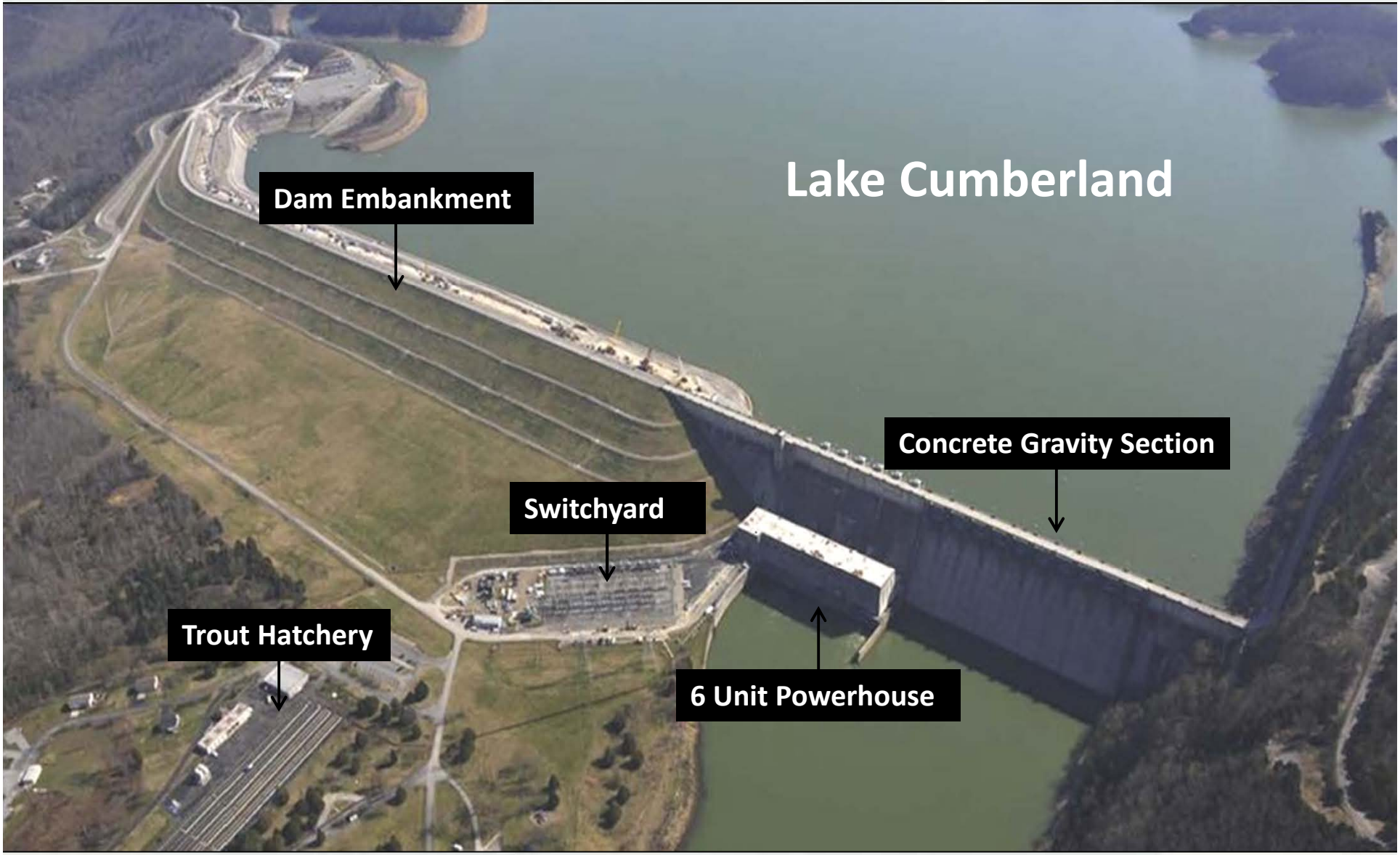
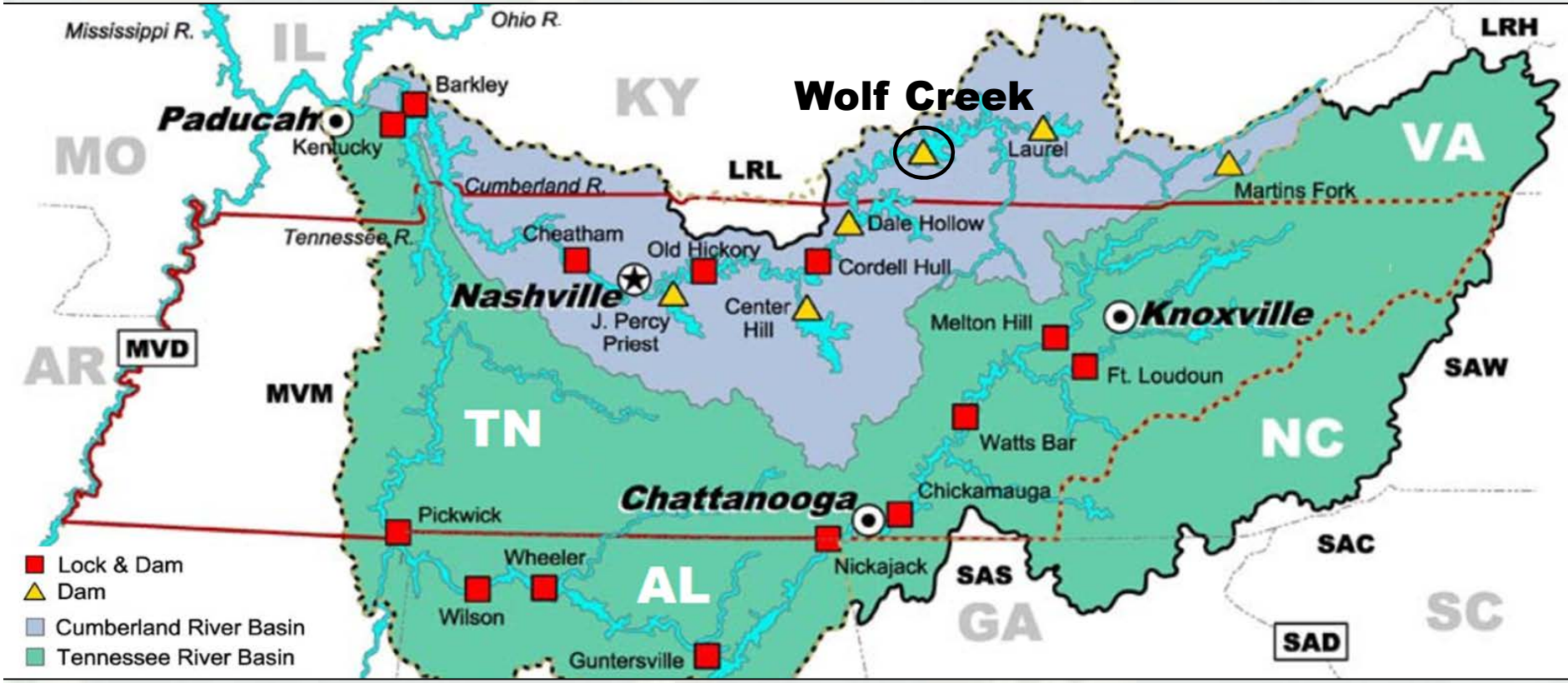
Wolf Creek Dam Project Features

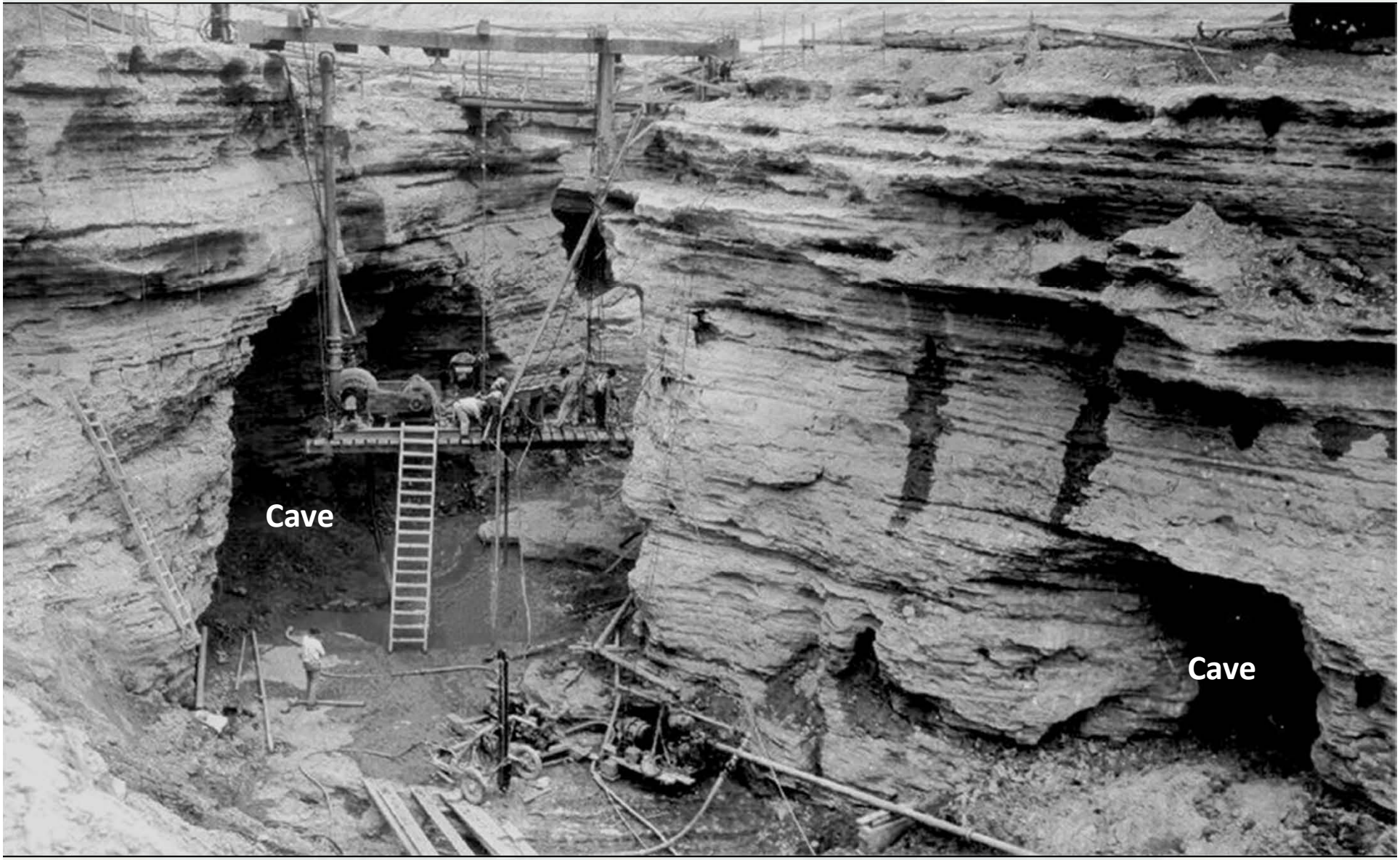


Wolf Creek Dam Location and Purpose



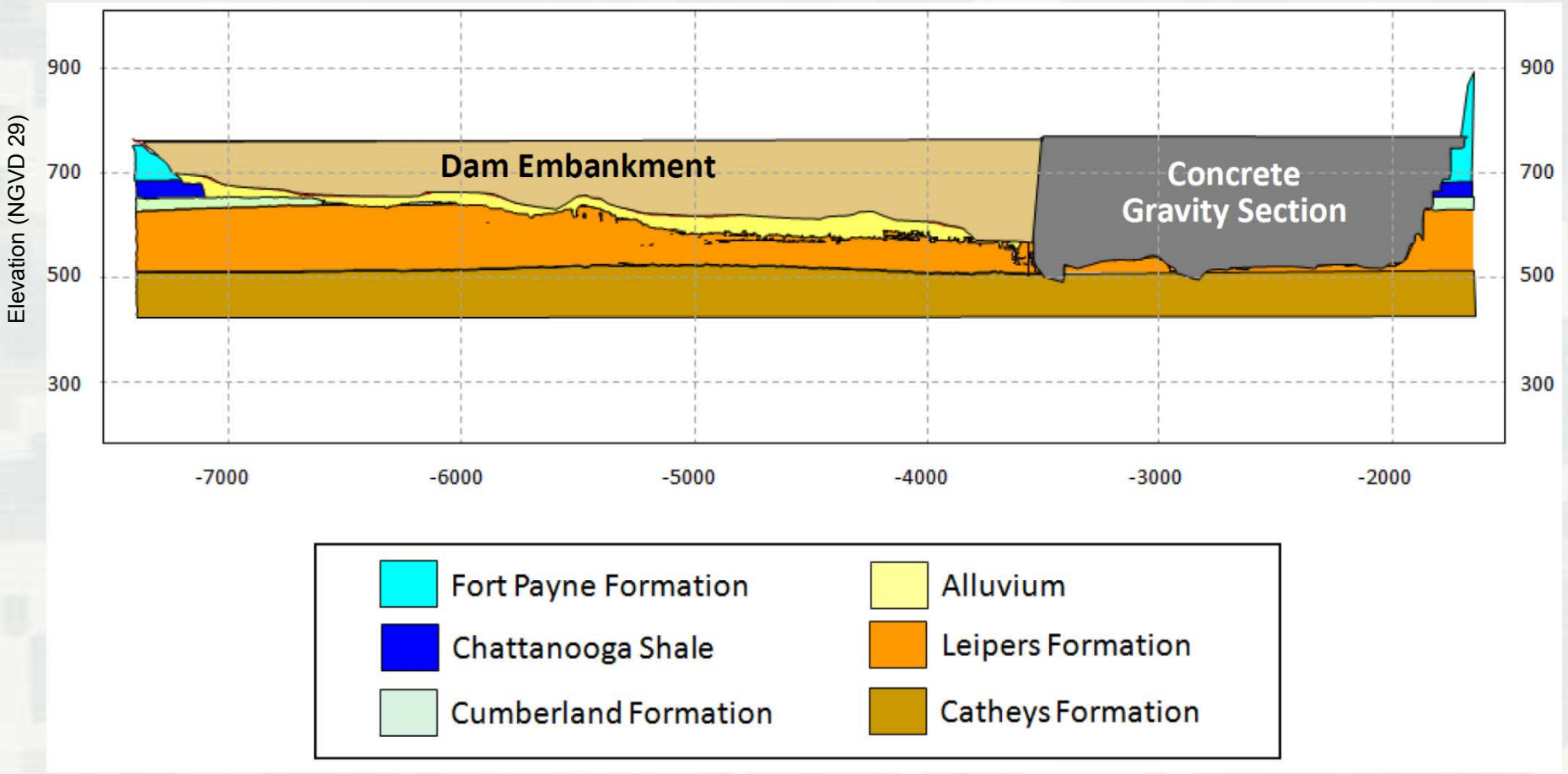
- Location: Cumberland River in Russell County, Kentucky
- Authorized Purposes: Flood Control and Hydropower
- Additional Benefits: Navigation, Recreation, Water Supply, and Water Quality
- Reservoir first impounded in December 1950

Karstic Foundation



Karstic Foundation

Dam and Foundation Profile

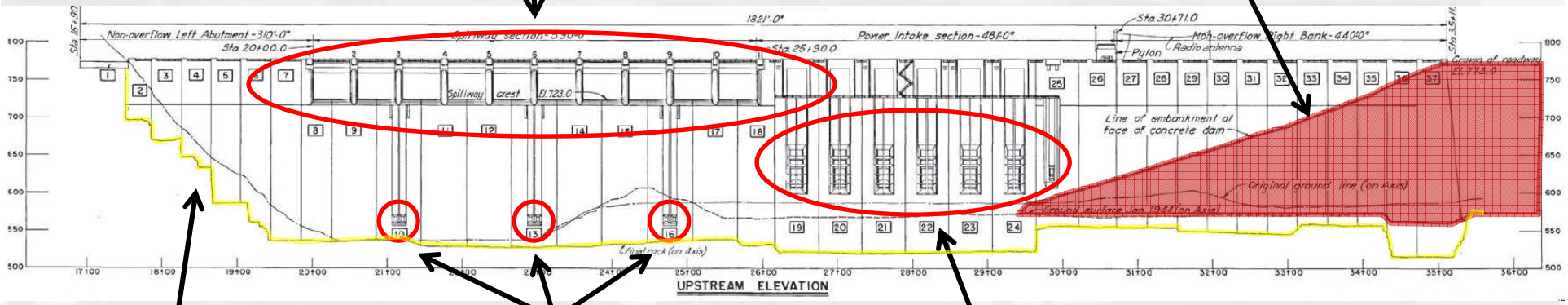


Masonry/Concrete Dam Upstream Profile

37 Monoliths

10 Tainter gates
37’ x 50’ each

Embankment
wrap-around



Stair-step
foundation

6 sluice gates
4’ x 6’ each

6 power intakes
to turbines

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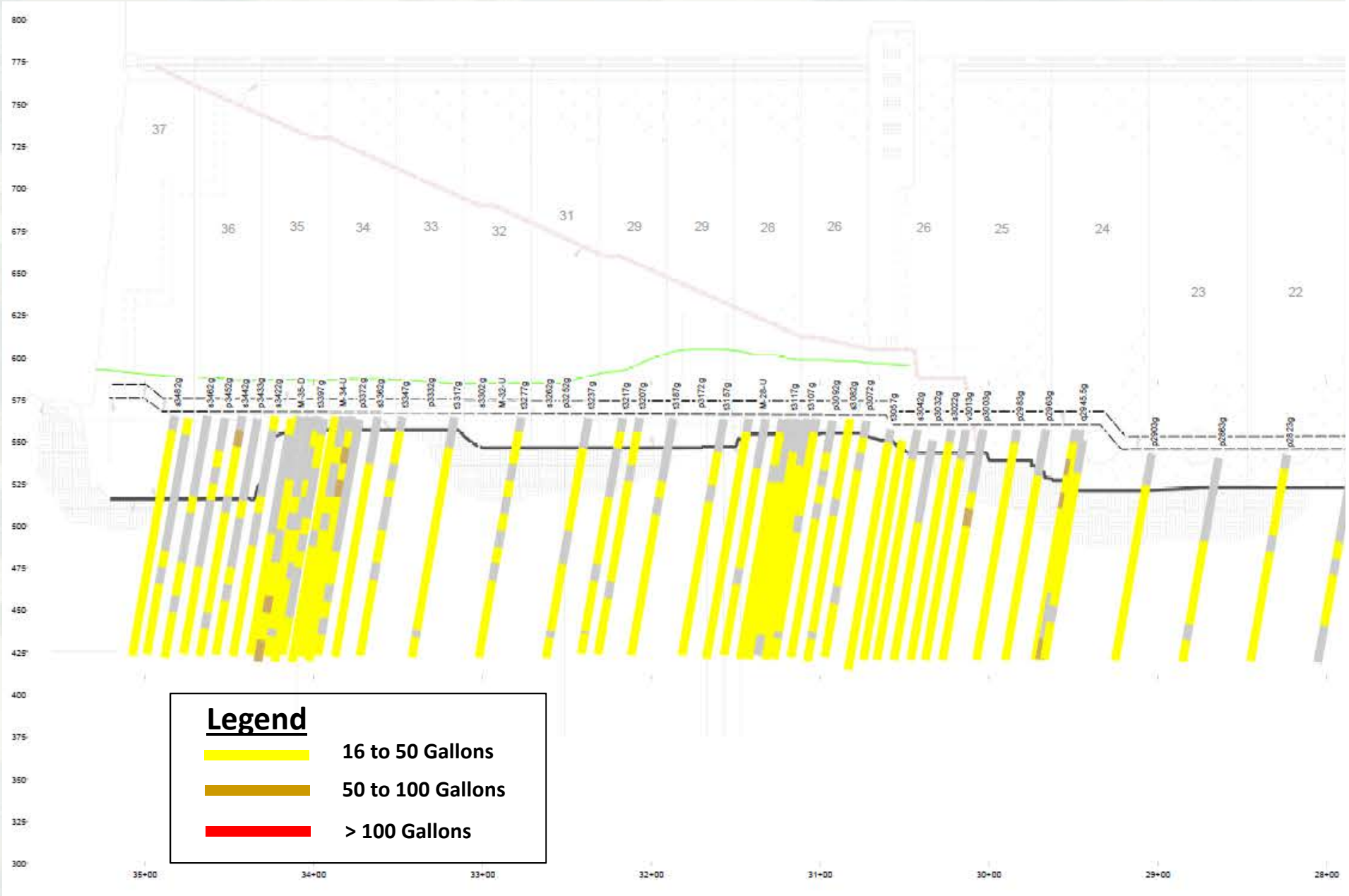
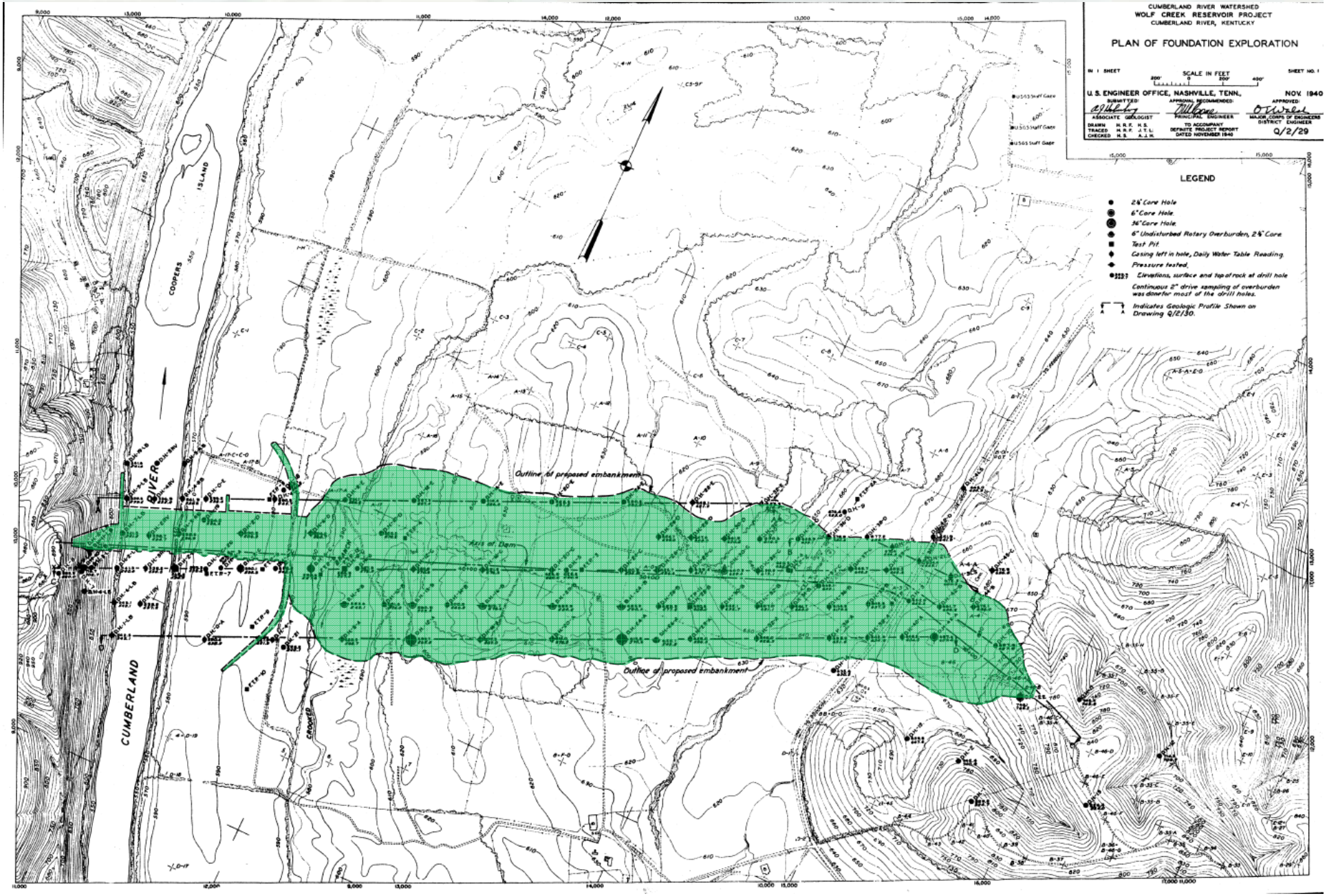
Exploratory Grouting (2011-2012)



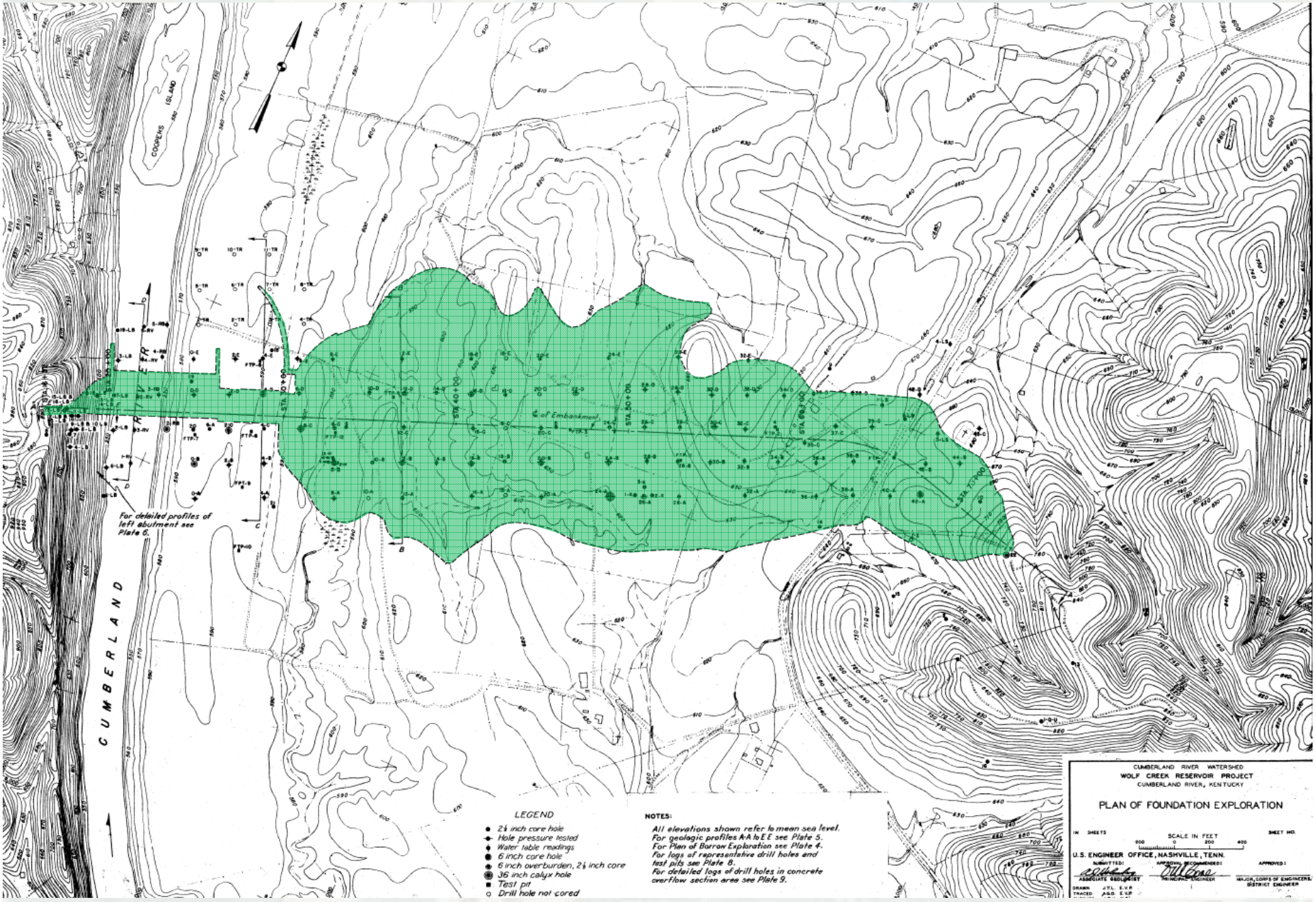
Dam Site Before Construction

OLF CREEK DAM.--View of dam site from left bank, downstream from axis of dam. 18 June 1941. 22,256

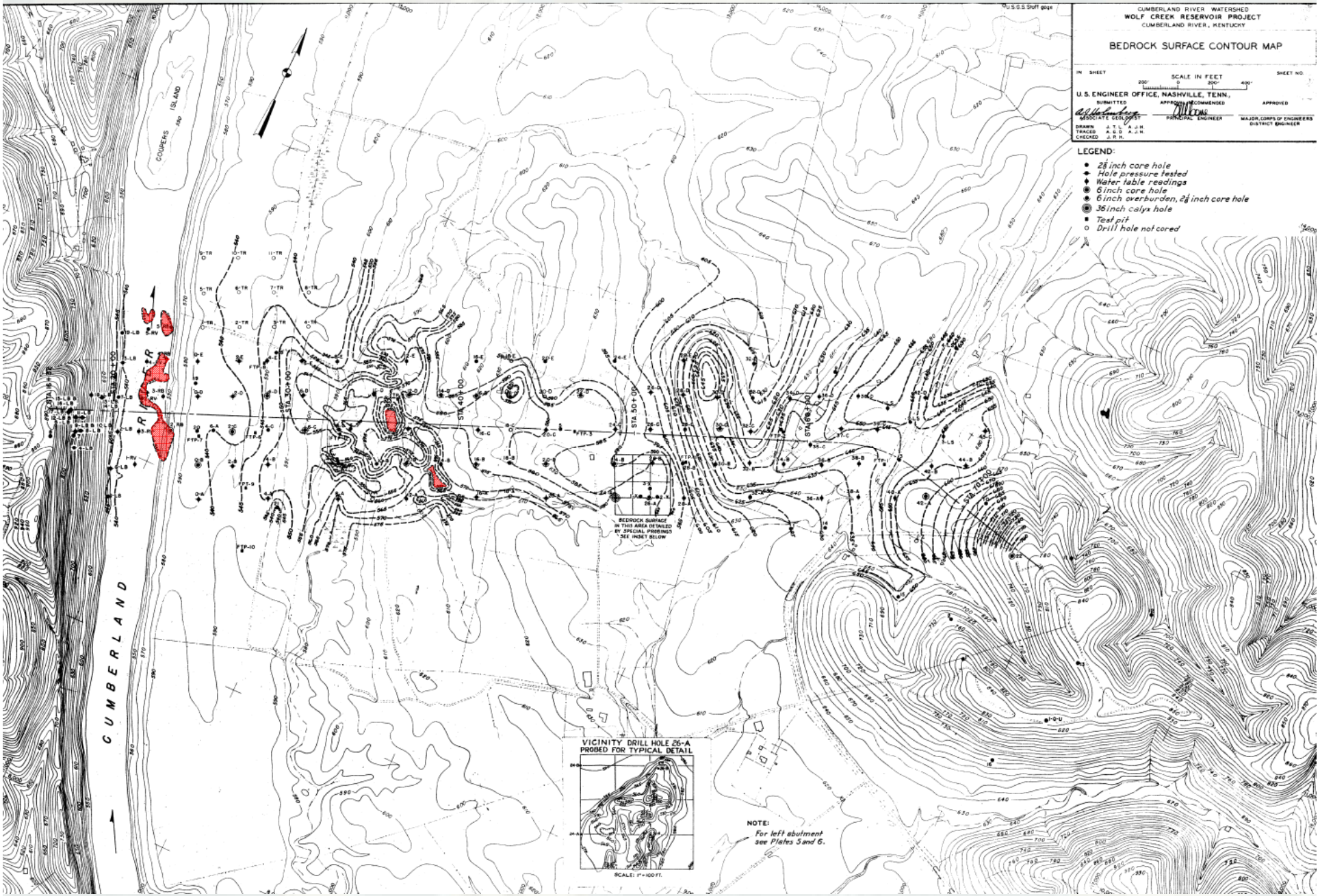
Preliminary Borehole Exploration (1930's) – 200 ft. centers



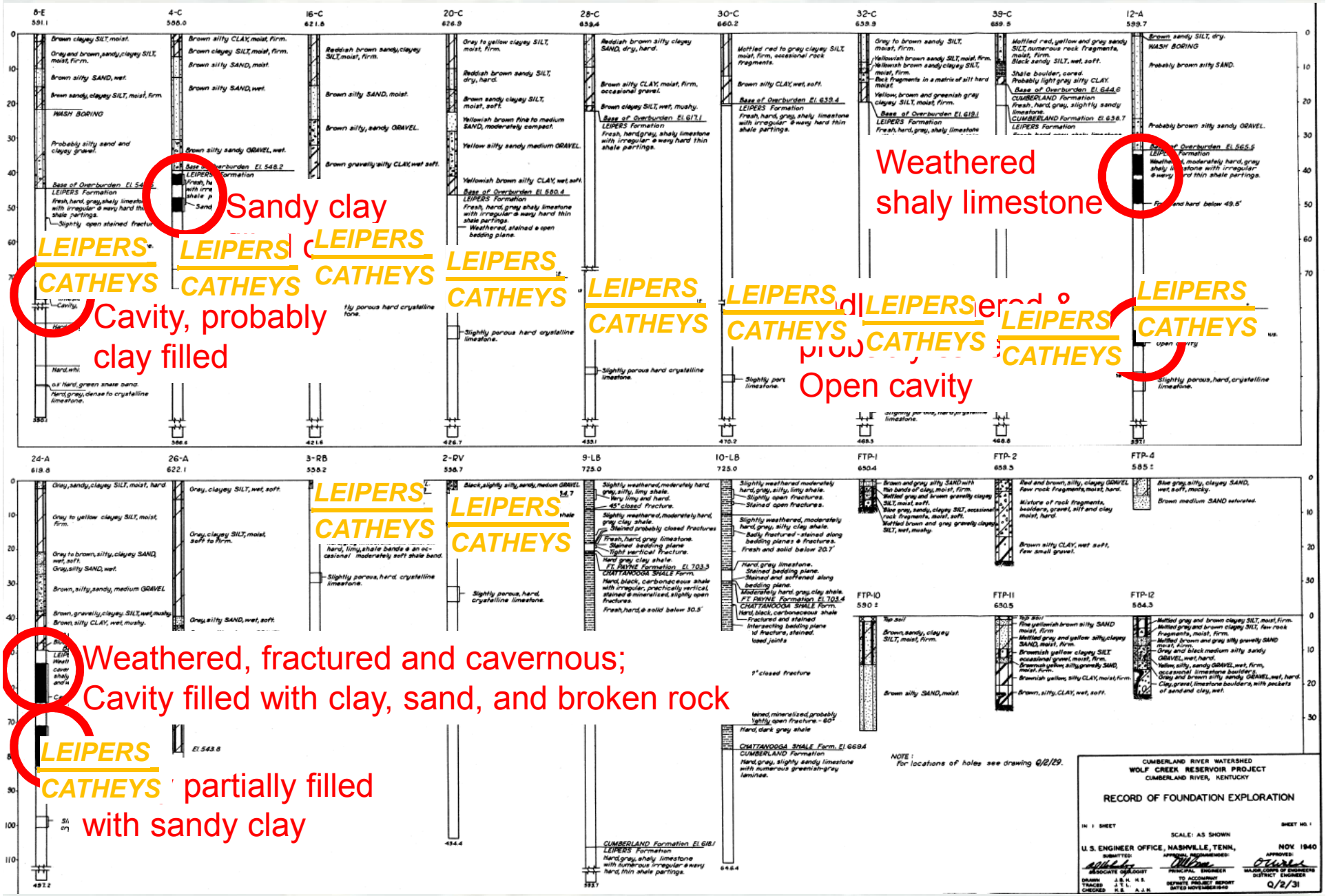
Additional Early Borehole Exploration



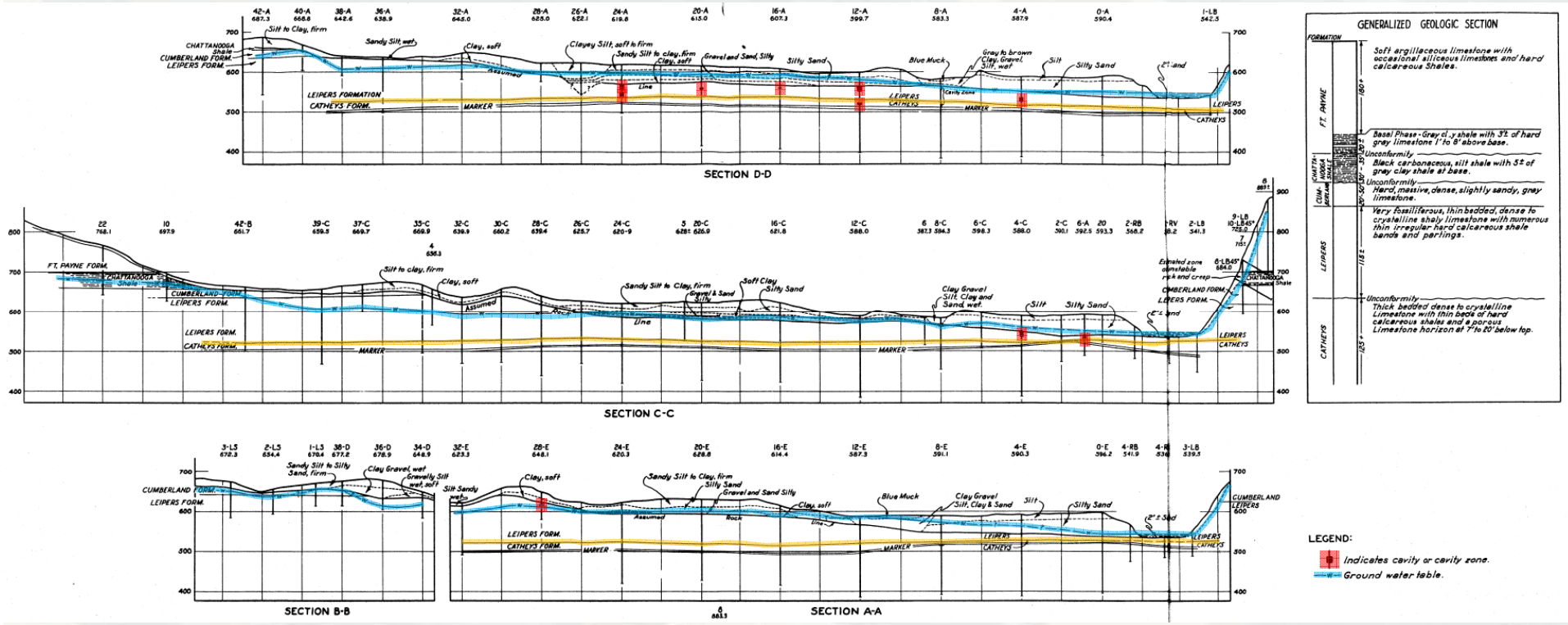
Bedrock Surface Contours



Preliminary Borehole Exploration (1940)



Early Borehole Exploration



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Overburden Removal

Mon. No. 20 Removal of Overburden by Dredge
Photo No. 114

Mon. No. 20 Removal of Overburden by Dredge
Photo No. 137

Mon. No. 20 Final Removal of Overburden by Shoval
Photo No. 159 after Dredging Operation

02-61/139 Masonry Monolith 37-32 1+00 B

Overburden Removal

Additional Drilling Post-Overburden Removal

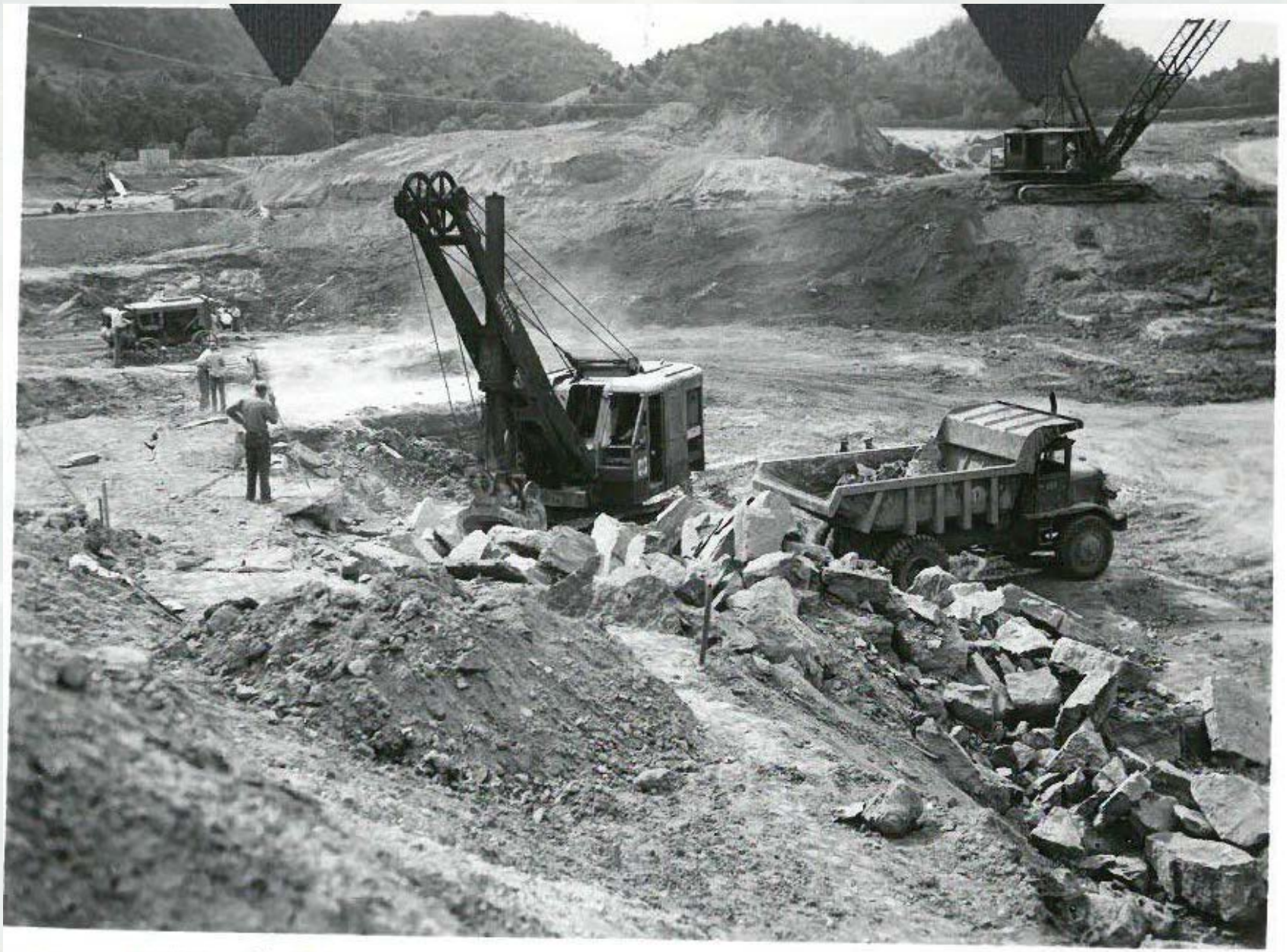
Before rock removal was begun in an area, a study was made of all geological information pertinent to that area. This geological information consisted of the logs of the holes drilled during the preliminary investigations of the site as well as the various informative reports prepared by the Geological Section. From this information, it was usually possible to determine within reasonable accuracy the quantity and depth of rock to be removed in a given area to provide structurally sound foundations.

As the preliminary investigation drillings were made on one hundred (100) foot centers, it was decided that if a closer on-center pattern of drilling was made, a better knowledge of rock conditions would be afforded and rock removal would be confined to a minimum.

Additional Drilling Post-Overburden Removal

Beginning at the axis, two (2) inch percussion drilled holes were drilled on twenty (20) foot centers normal to and paralleling the axis until the entire area of the monolith or other structure had been drilled. These holes were drilled vertically, and were sixteen (16) feet deep. The drilling was carefully observed in order to locate possible subsurface solution channels, soft bedding of appreciable thickness, or other defects. A log was prepared of the results of the test drilling, and compared with the original geological findings. Upon completion of this review, the removal of the necessary rock was ordered.

Blasting

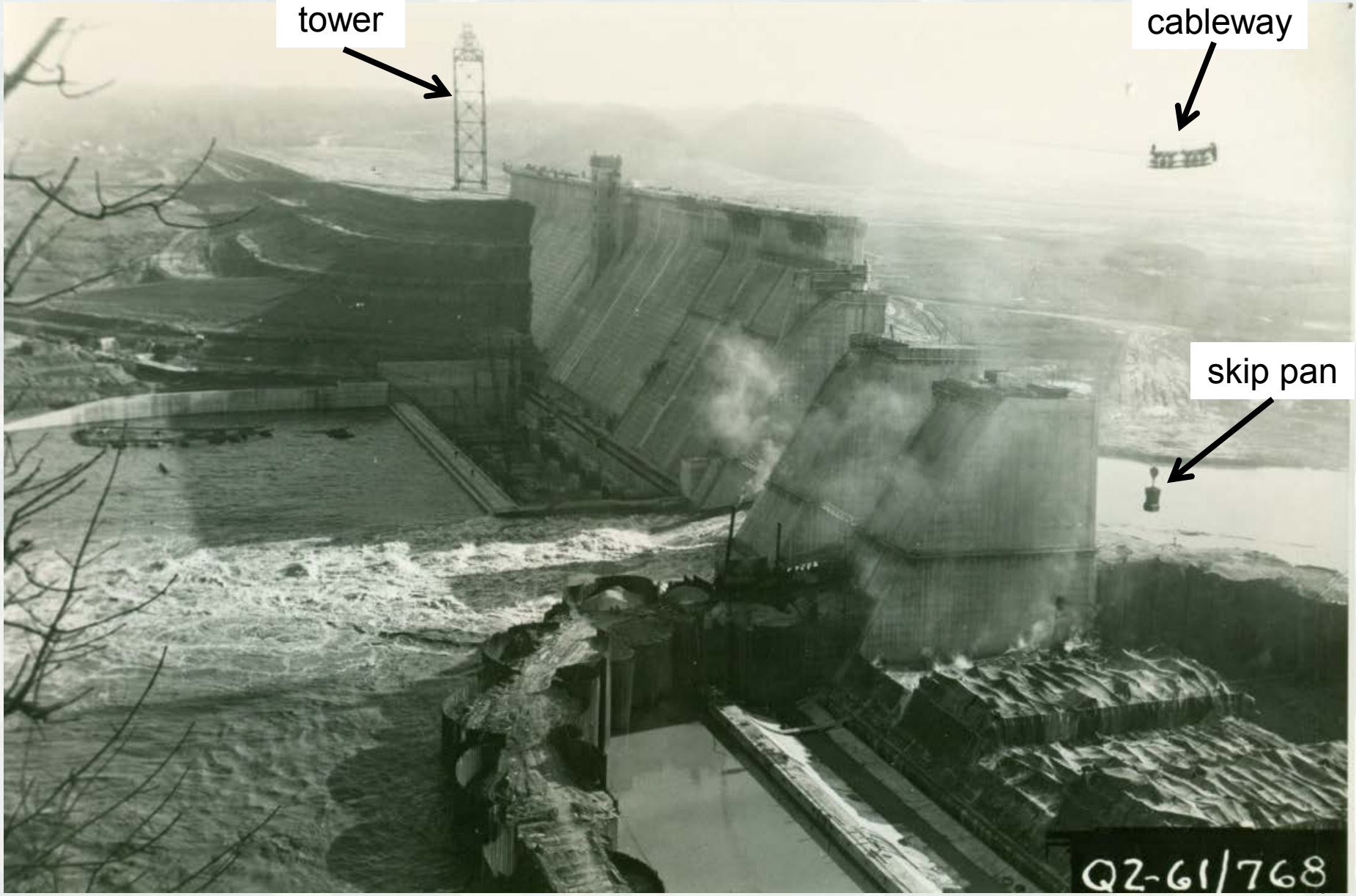


Monolith # 30 Rock Removal by Shovel Elev. 662

PHOTO Nº 52

Manual Removal of all Rock not "Firmly Bedded"

Rock Removal



Bedrock Excavation Monoliths 37-30

Bedrock Excavation Monoliths 37-30

Mon.No.32
Cleaning Out Solution Channel

Photo No.89

Bedrock Excavation Monoliths 37-30

Mon.No.32 Photo No. 139
Widening & Exploring Solution Channel

Large Solution Channel Excavated

Second Channel with First

Solution Channel Cleaning

Solution Channel Cleaning

Bedrock Excavation Monoliths 29-25

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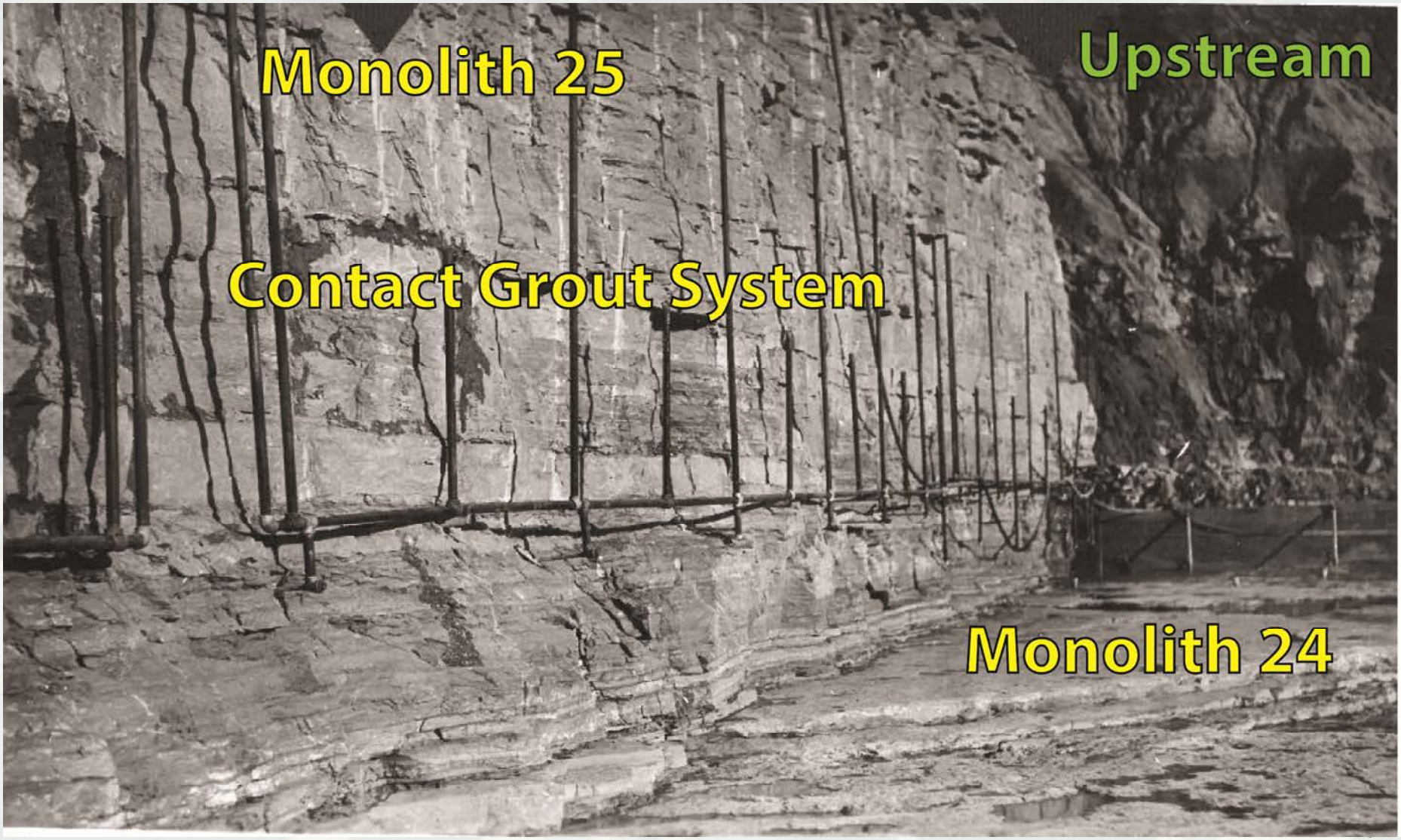
Contact Grouting

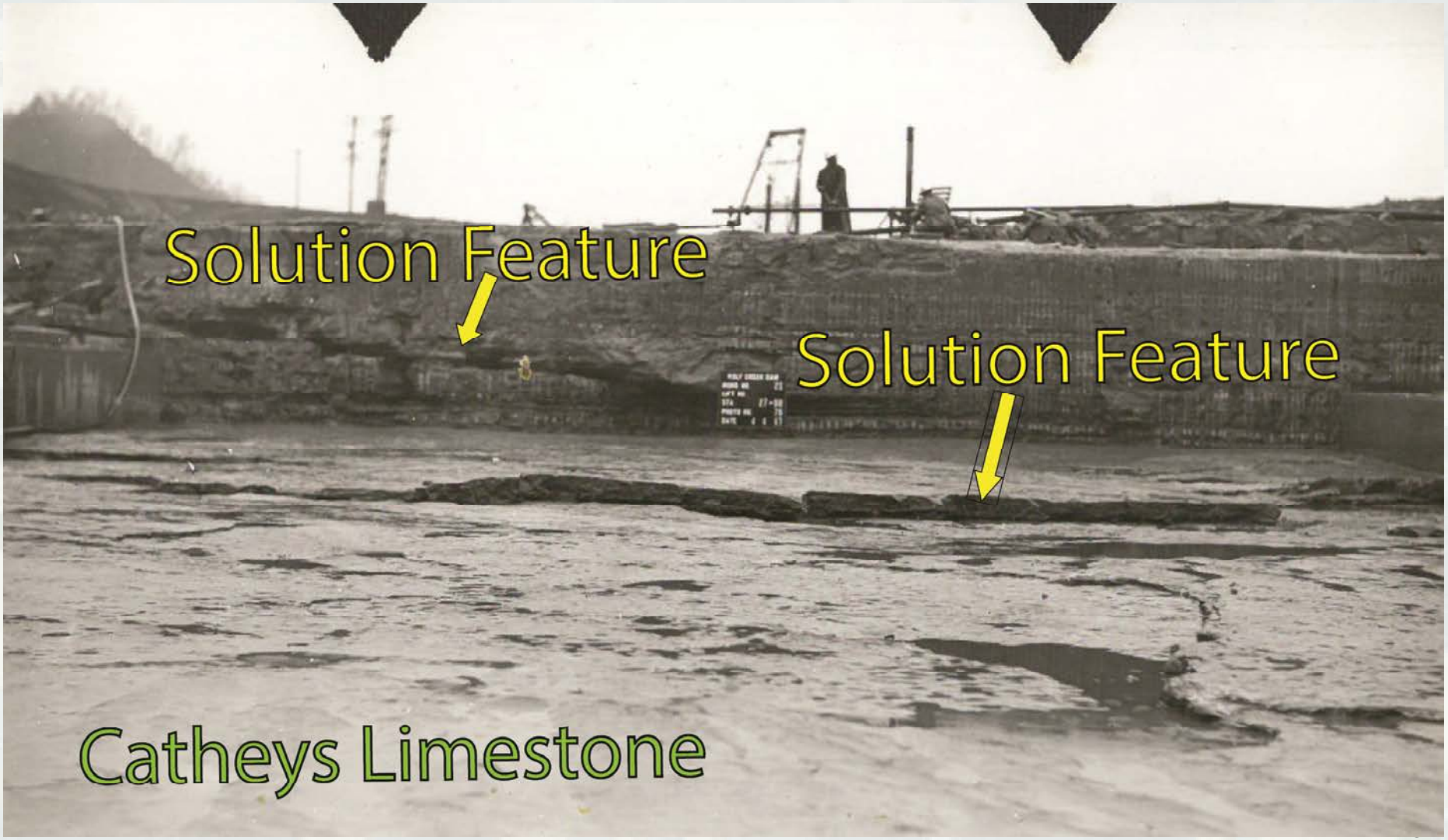


Bedrock Excavation Monoliths 24-19

(Power Intake Section)

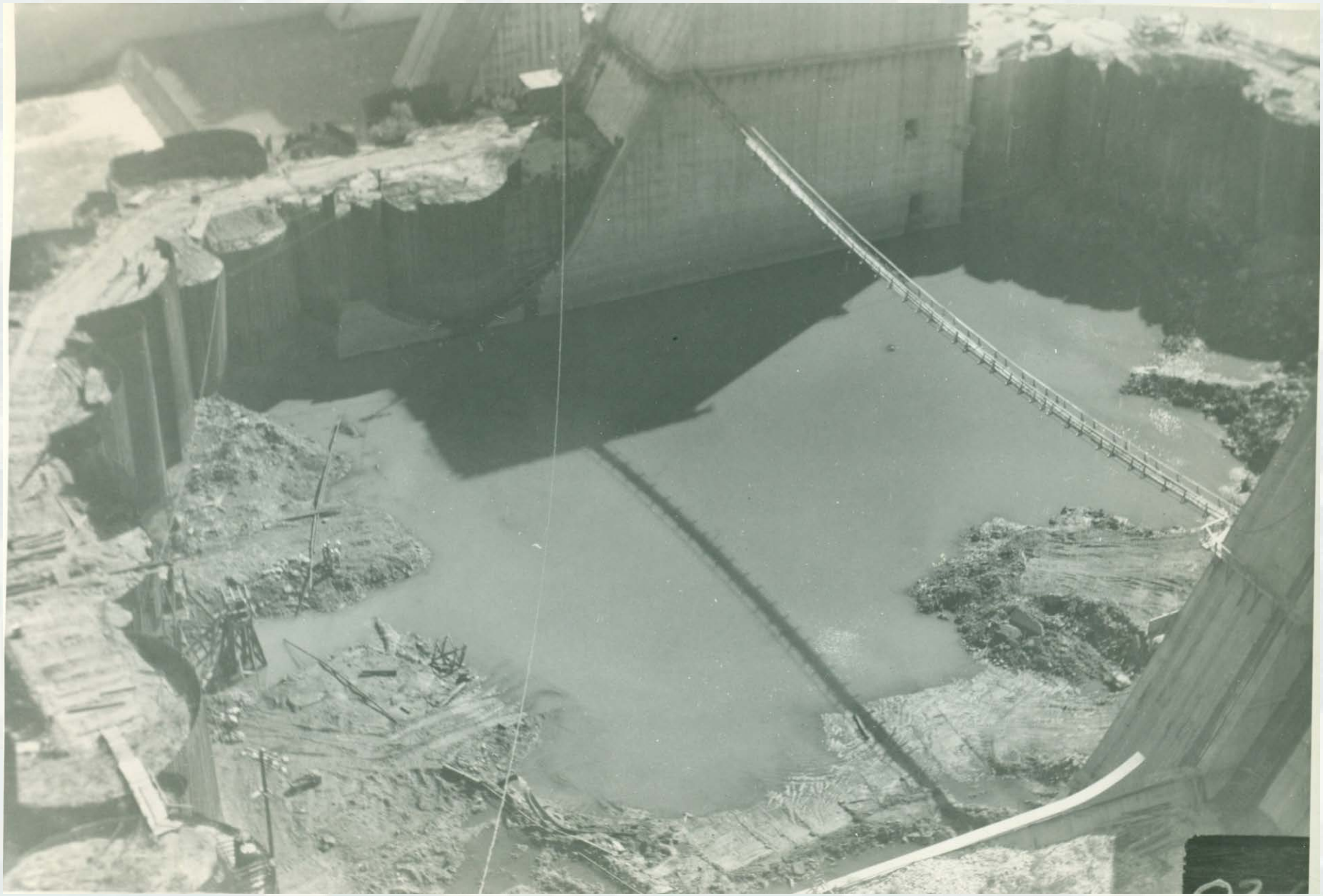
Bedrock Excavation Monoliths 29-19

(Power Intake Section)



Monolith 20 –Grouting without Pressure

Bedrock Excavation Monoliths 18-14



Bucket Excavation Monoliths 18-14

(Spillway Section)

PRELIMINARY EXPLORATION:

During the rock removal a solution channel was uncovered that exte along the entire downstream toe of the bucket. It was excavated to its full depth, and after its removal, percussion drilled holes on 10-foot centers were drilled 6 to 10 feet deep, into the area it occupied, and revealed the rock to be sound.

Bucket Excavation Monoliths 18-14

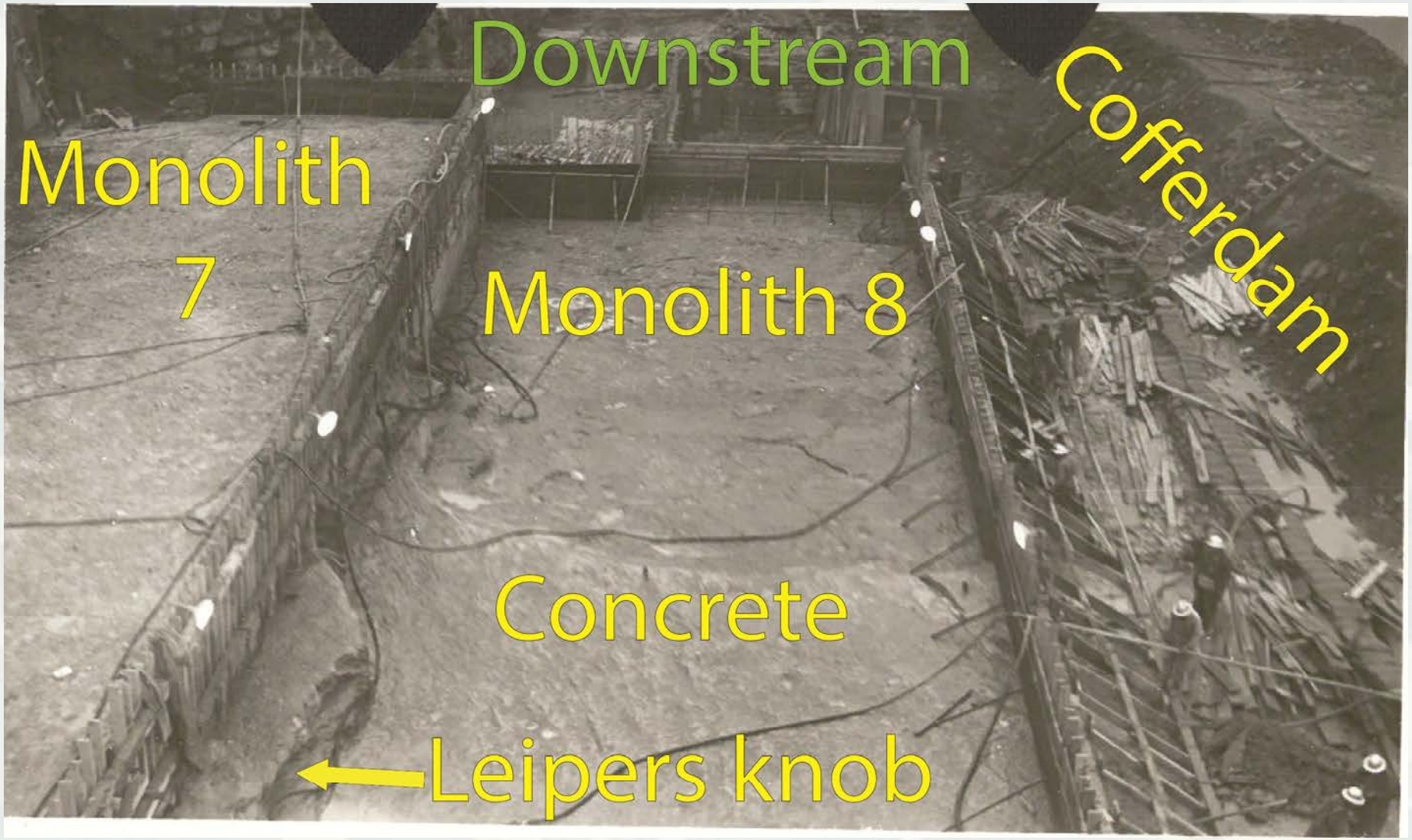
(Spillway Section)

Bedrock Excavation Monoliths 13-9

(Spillway Section – River Channel)

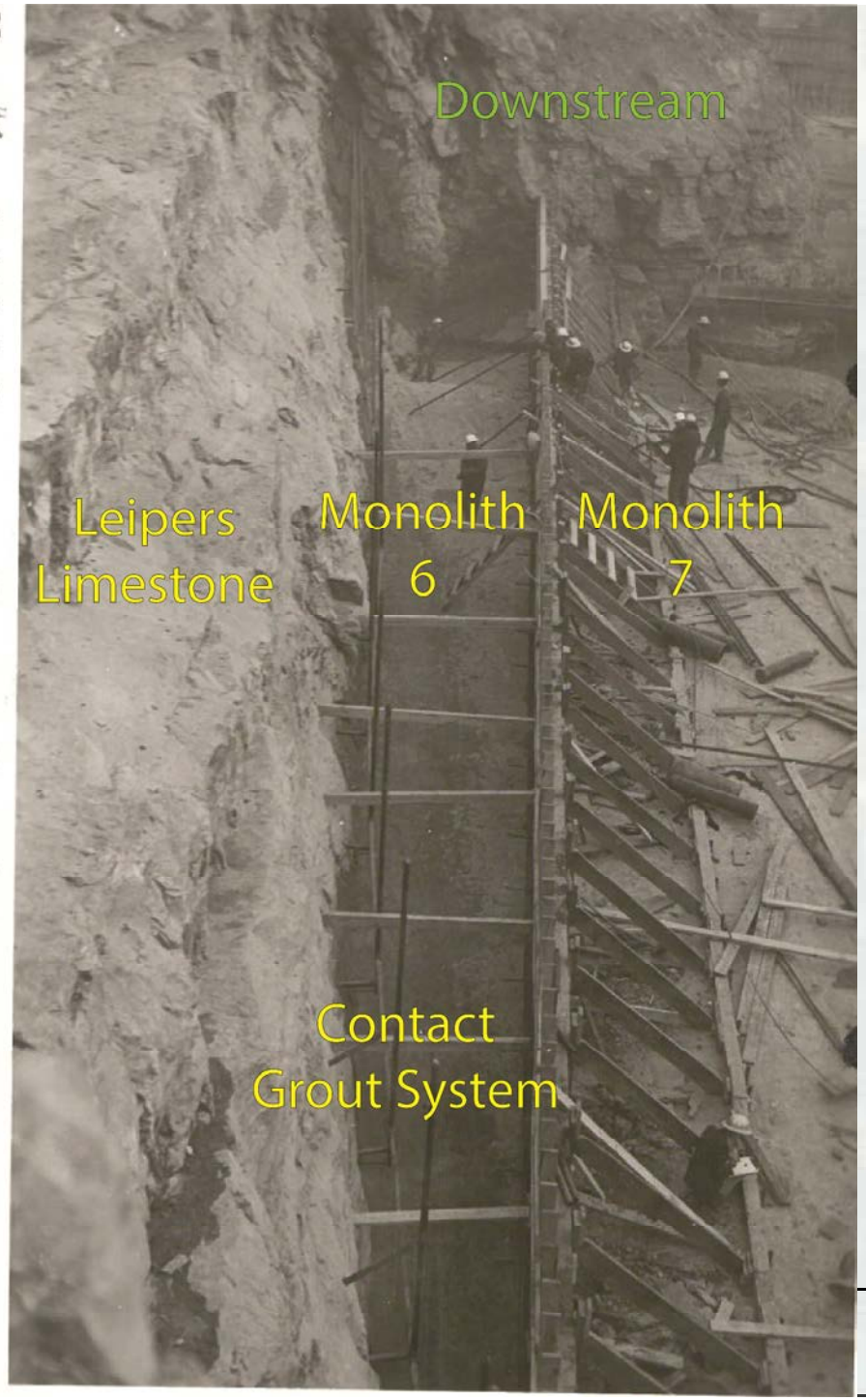
Bedrock Excavation Monoliths 8-1

(Left Abutment)



Bedrock Excavation Monoliths 8-1

(Left Abutment)



Bedrock Excavation Monoliths 8-1

(Left Abutment)

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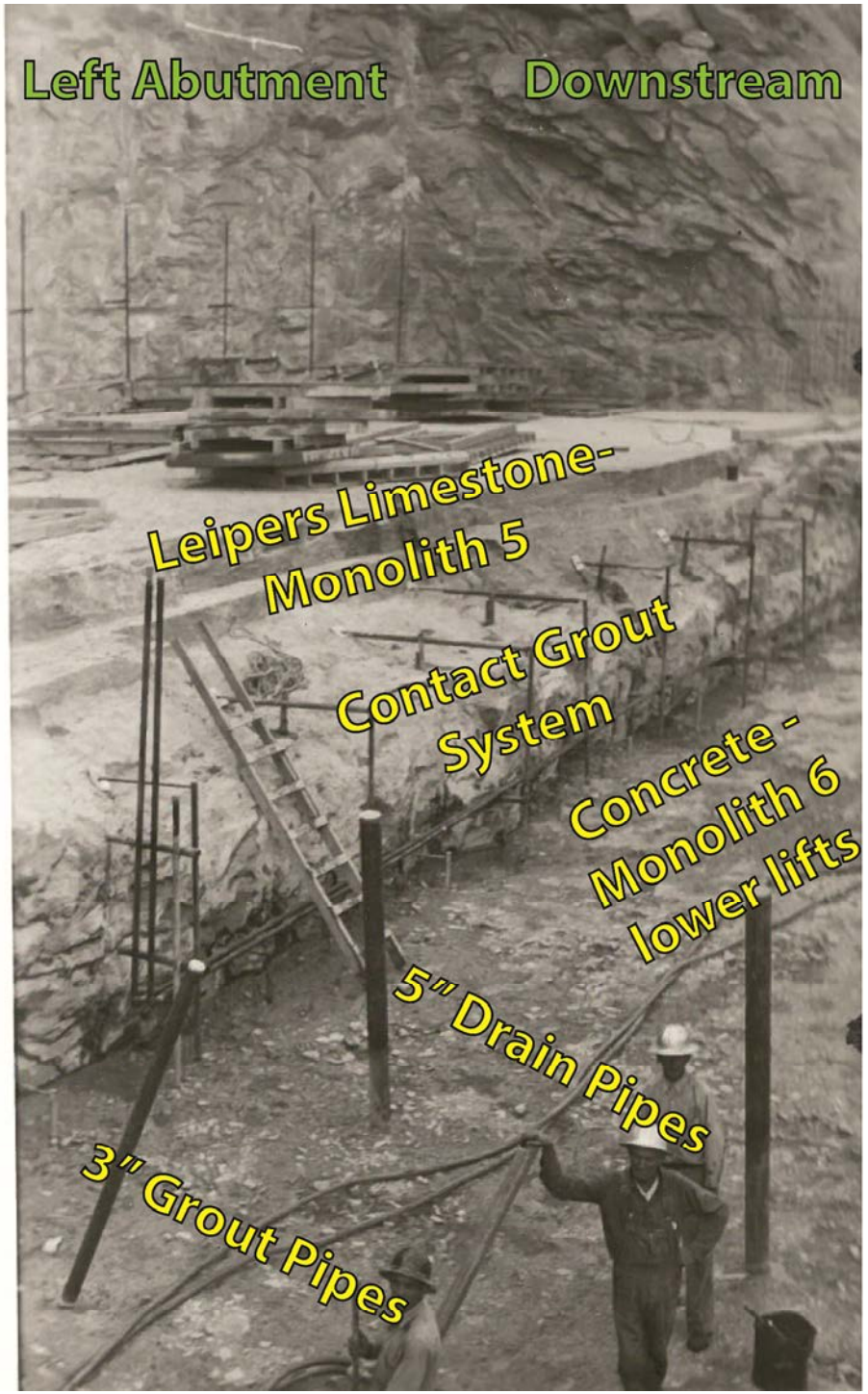

Grout Holes and Drains

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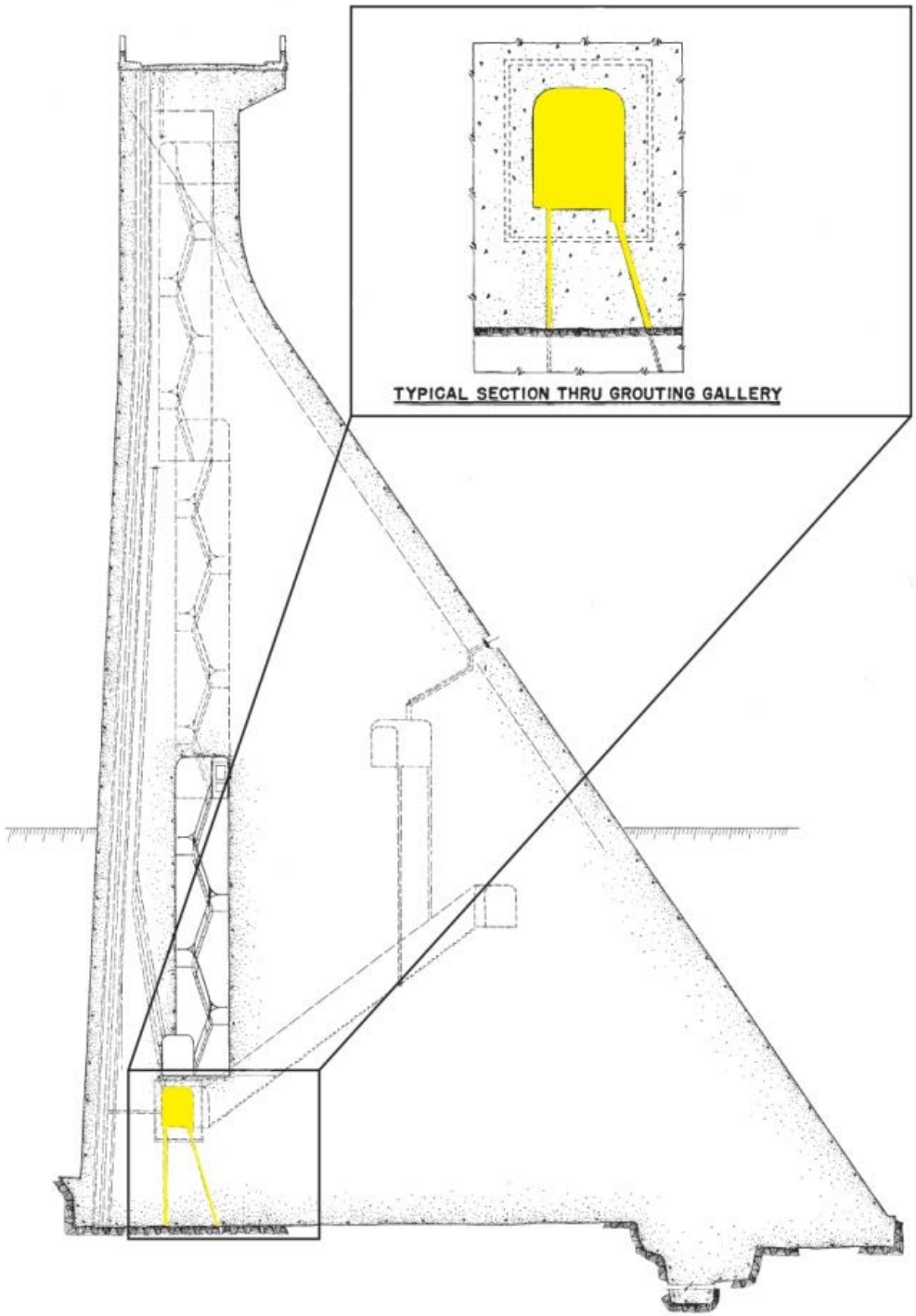

Grout Holes and Drains

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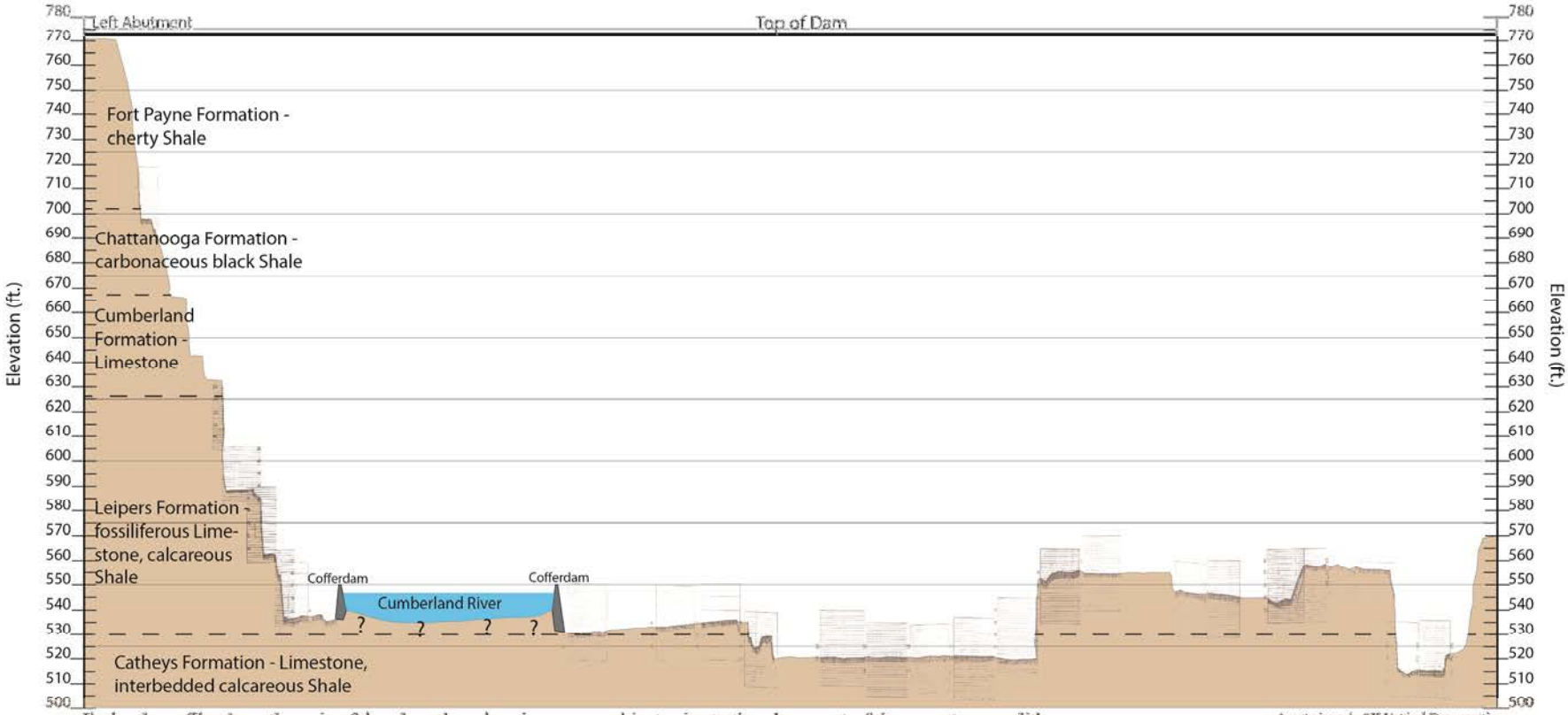
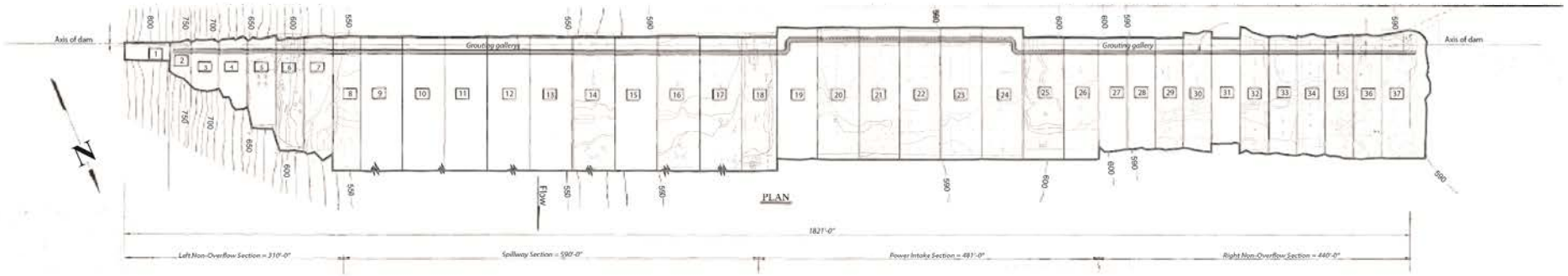
Masonry/Concrete Dam Foundation Profile





Original Dam Construction Cost

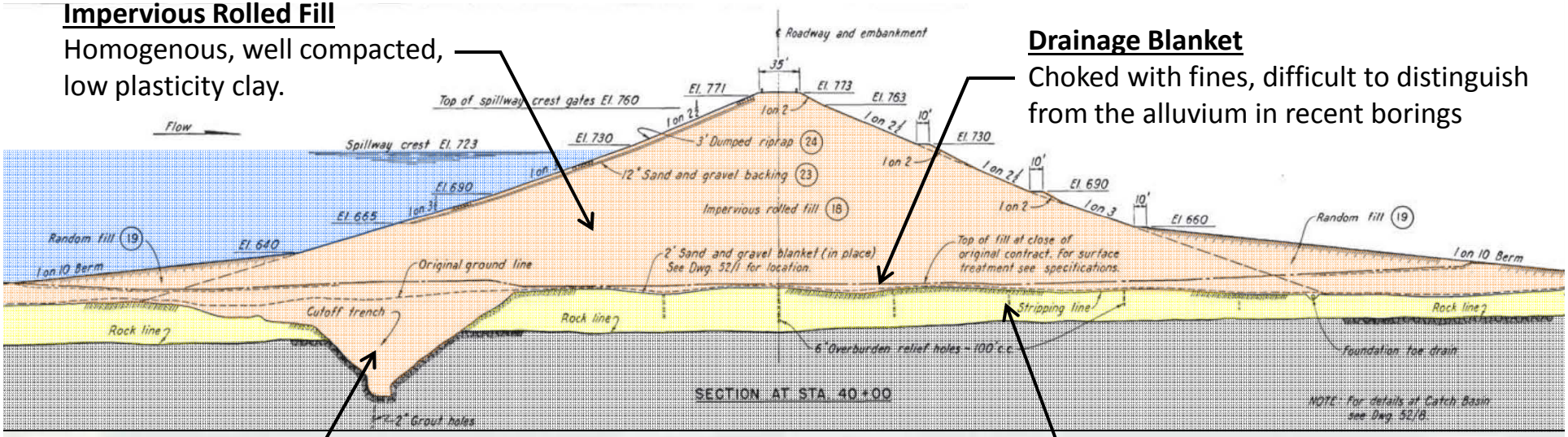
TOTAL CONTRACT COST		$ 19,648,450.36
DEDUCTIONS:		
The amount due the Government for Utilities and for credit assumed from S. A. Healy, Inc., the original contractor. In accordance with paragraph (f) of Article 29 of Contract No. W-40-058-eng-249	- $	952,351.26
The amount equals to the number of yards of concrete placed multiplied by $0.40 for a given length of time. In accordance with paragraph (d) of Article 29 of Contract No. W-40-058-eng-249.	-	447,889.51
Payment for Government furnished cement used by contractor in erecting construction plants and facilities. In accordance with paragraph 1-C-10(b)(3) of the Specifications.	-	102,187.82
Deduction in accordance with Modification Number 6 dated 9 December 1946.	-	18,452.38
Deduction in accordance with Modification Number 15 dated 8 September 1947.	-	5,361.67
NET PAID CONTRACTOR		$ 18,122,207.72

Original construction cost about **$240 million** in 2015 dollars

Recent remediations of embankment cost about **$600 million**

Embankment Cross Section

Impervious Rolled Fill
Homogenous, well compacted, low plasticity clay.



Drainage Blanket
Choked with fines, difficult to distinguish from the alluvium in recent borings

Cutoff Trench
Compaction was likely variable. Placement and compaction, often by hand, occurred against rough vertical walls and under rock overhangs.

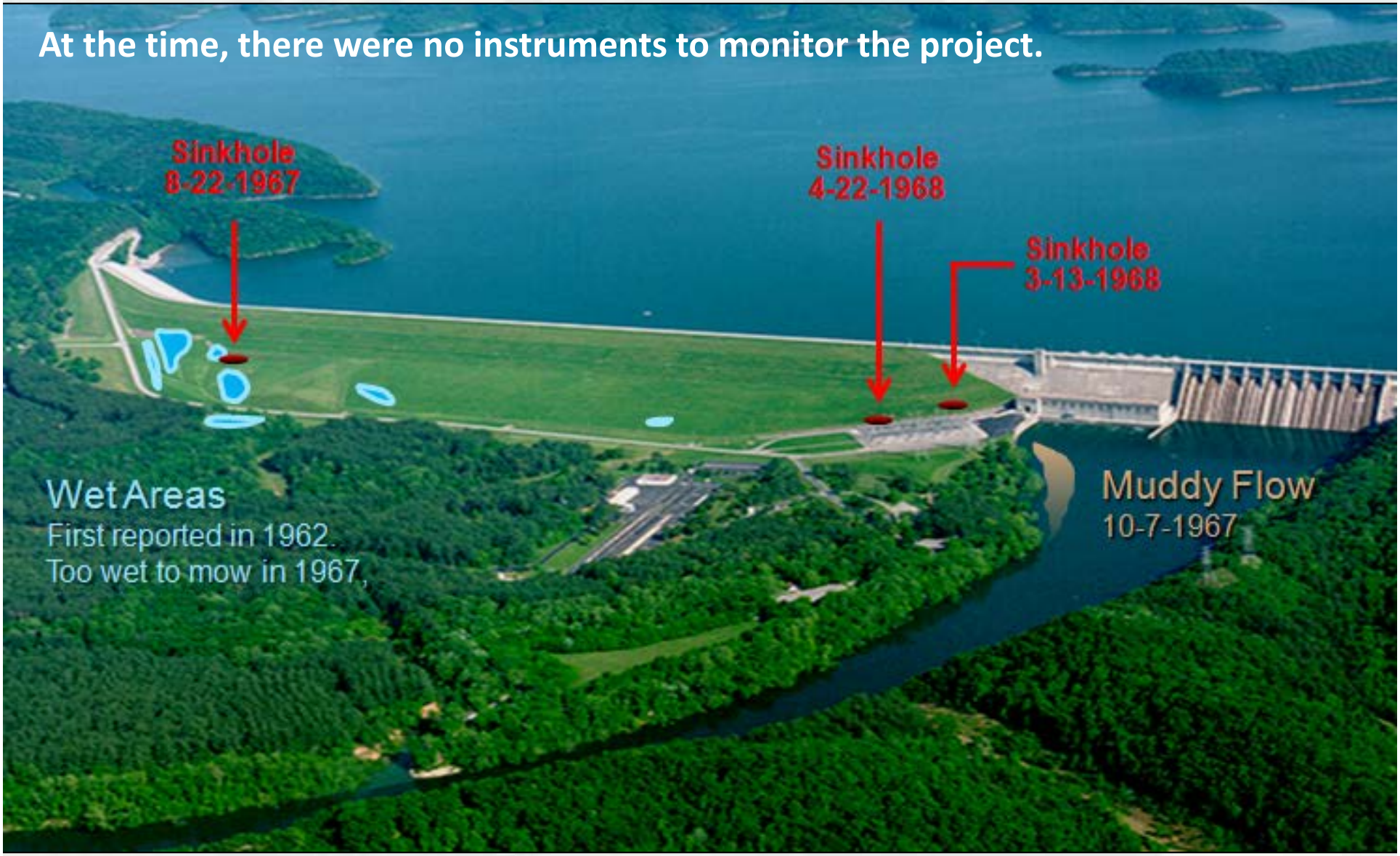
Alluvium
Predominately fine grained but with sand and gravel lenses

Cutoff Trench Design Philosophy (Core Trench Foundation Report, 1943):

"Overhangs and loose rock will be removed only where they cross the lines of the trench, since the earthfill in the sides of the trench will have the function only of stability and not of an absolutely uniform tight contact with the trench walls."

Placement and Compaction of Cutoff Trench Fill

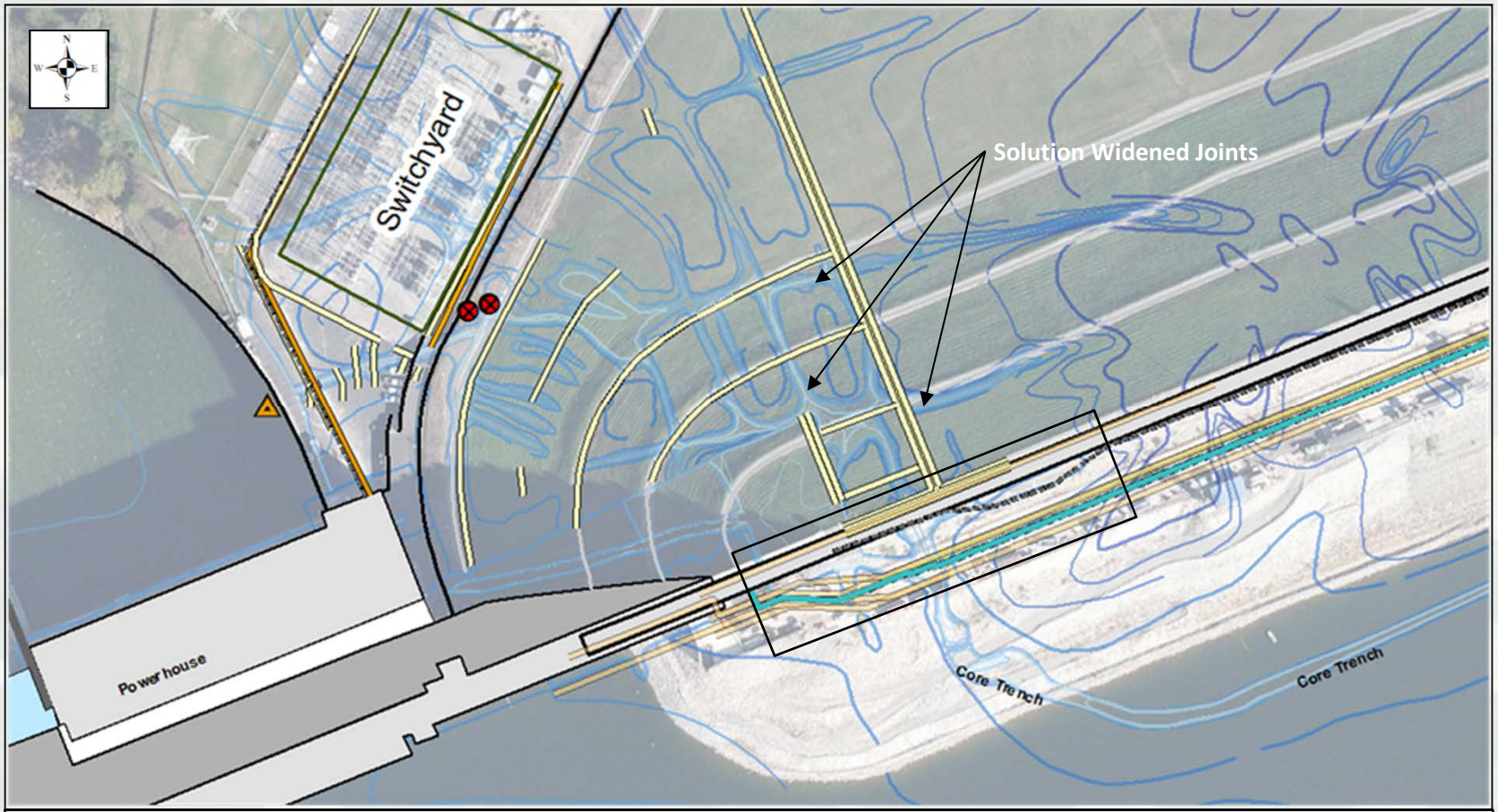
Distress Indicators Observed in the 1960's



Turbid Discharge into the Tailrace in 1967

Sinkhole Observed near Switchyard in 1968

Sinkhole Observed near Switchyard in 1968



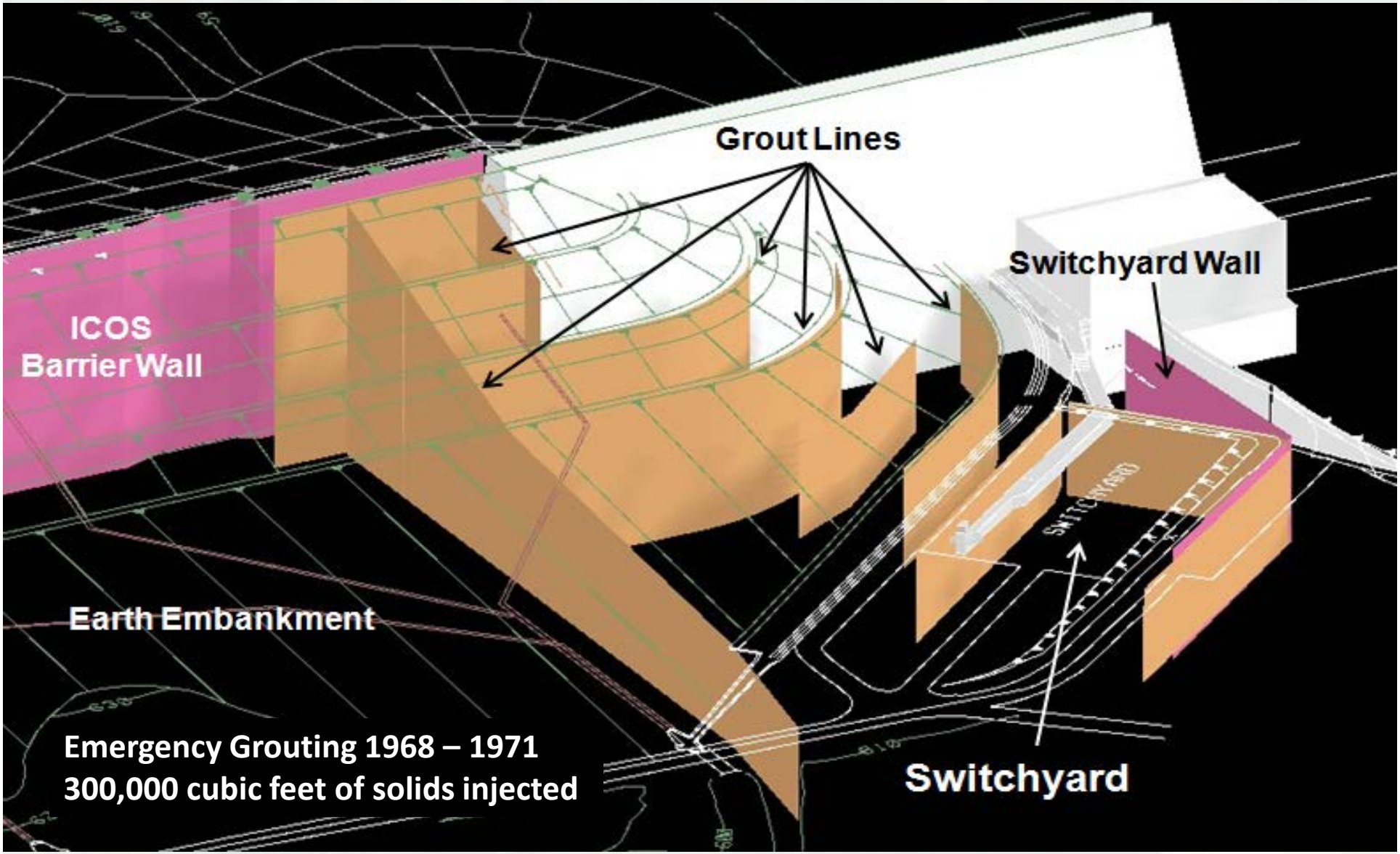
Plan Legend

- Roadway
- ICOS Walls
- Barrier Wall
- 1960s Grout Lines
- 1967 Muddy Flow
- 1968 Sinkholes
- New Grout Lines
- 2011-12 Switchyard Grout Lines

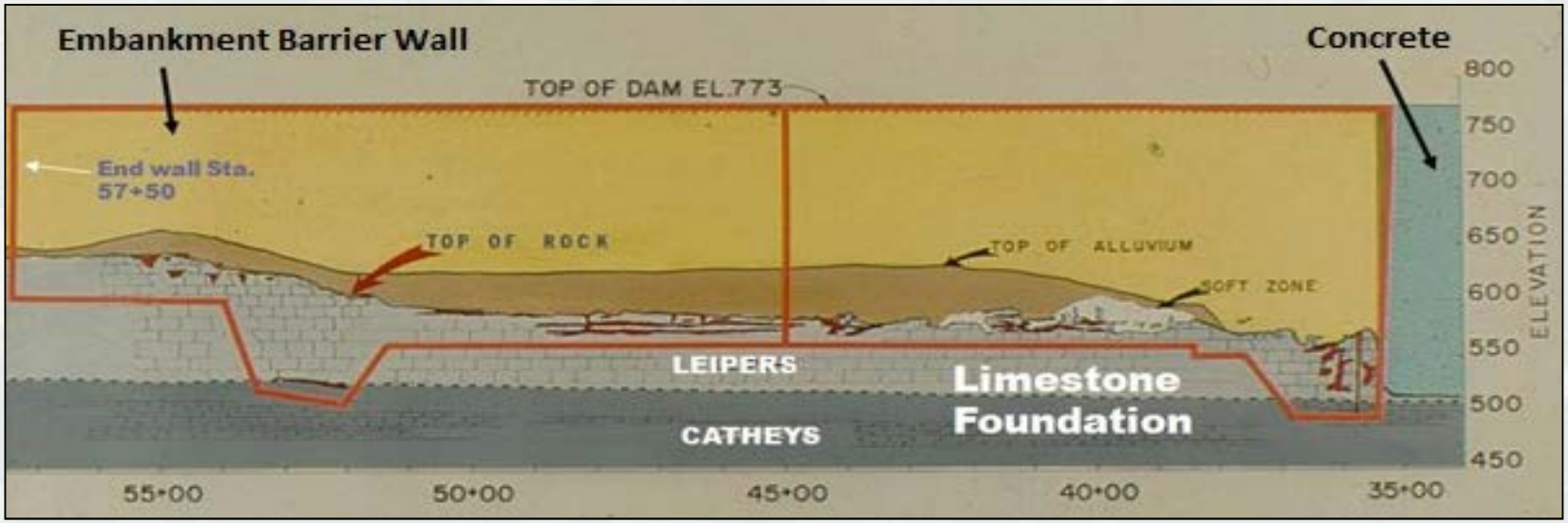
Top of Rock Contours - Elevation (ft)

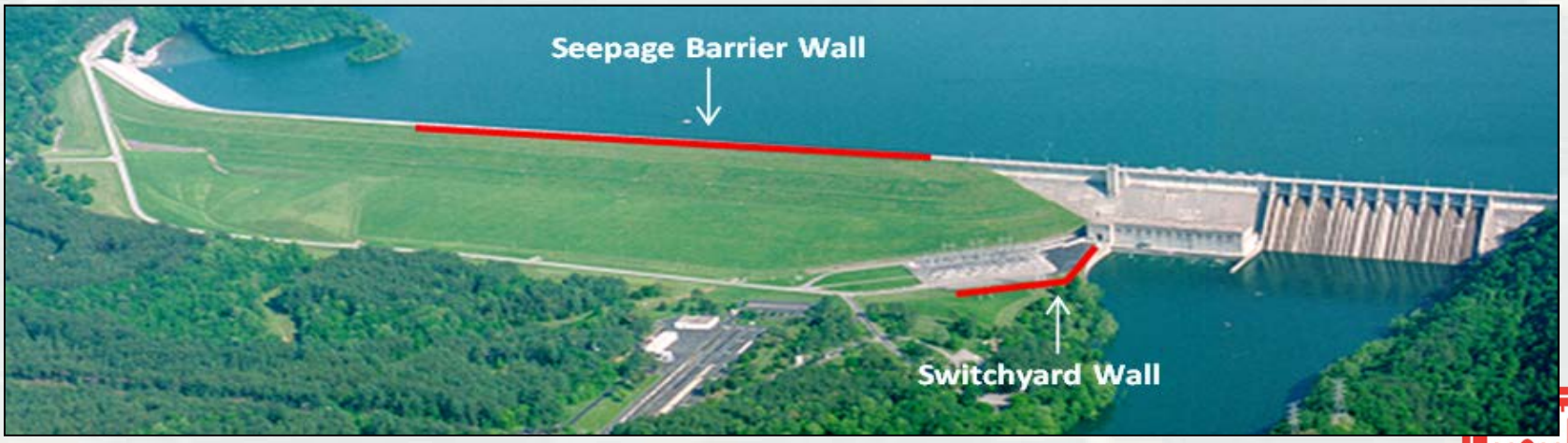
<520	540-550	570-580
520-530	550-560	580-590
530-540	560-570	590-600
		600-800

Emergency Grouting

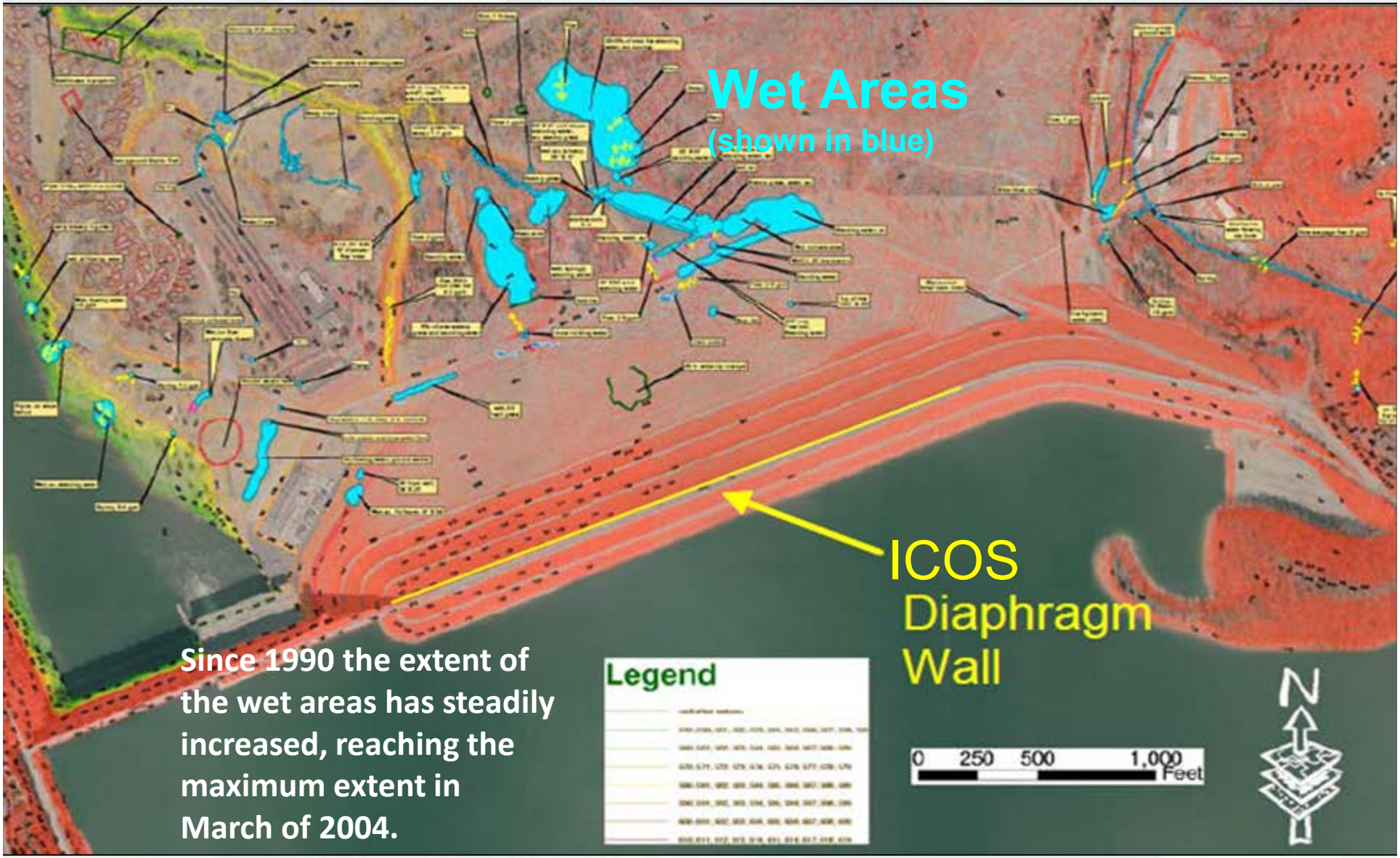


1975 ICOS Combination Wall



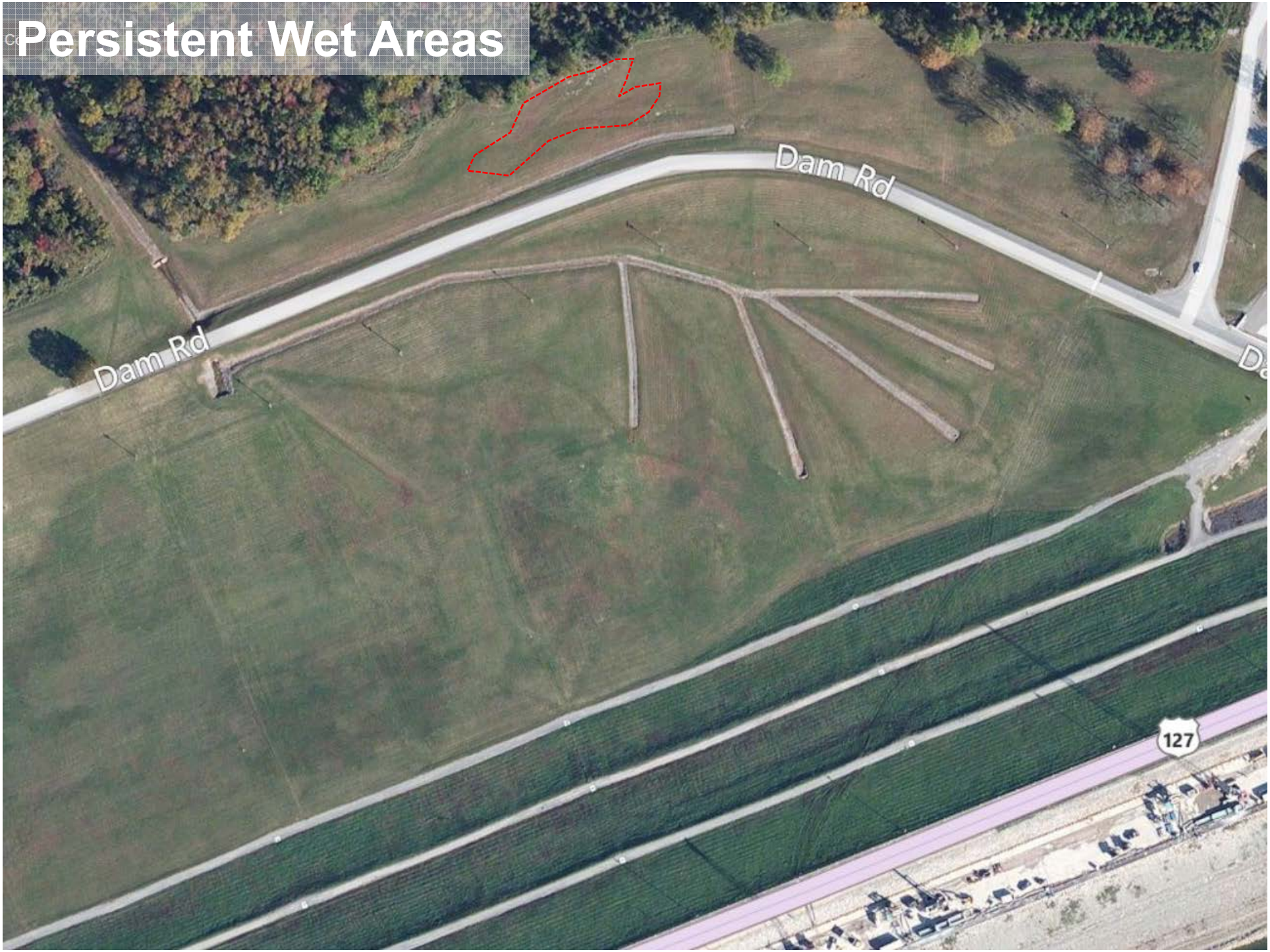


Downstream Wet Areas



March 09, 2010

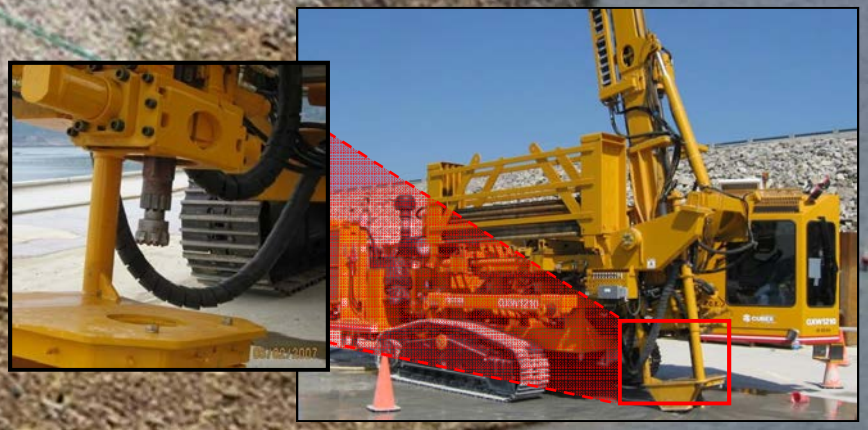
Persistent Wet Areas



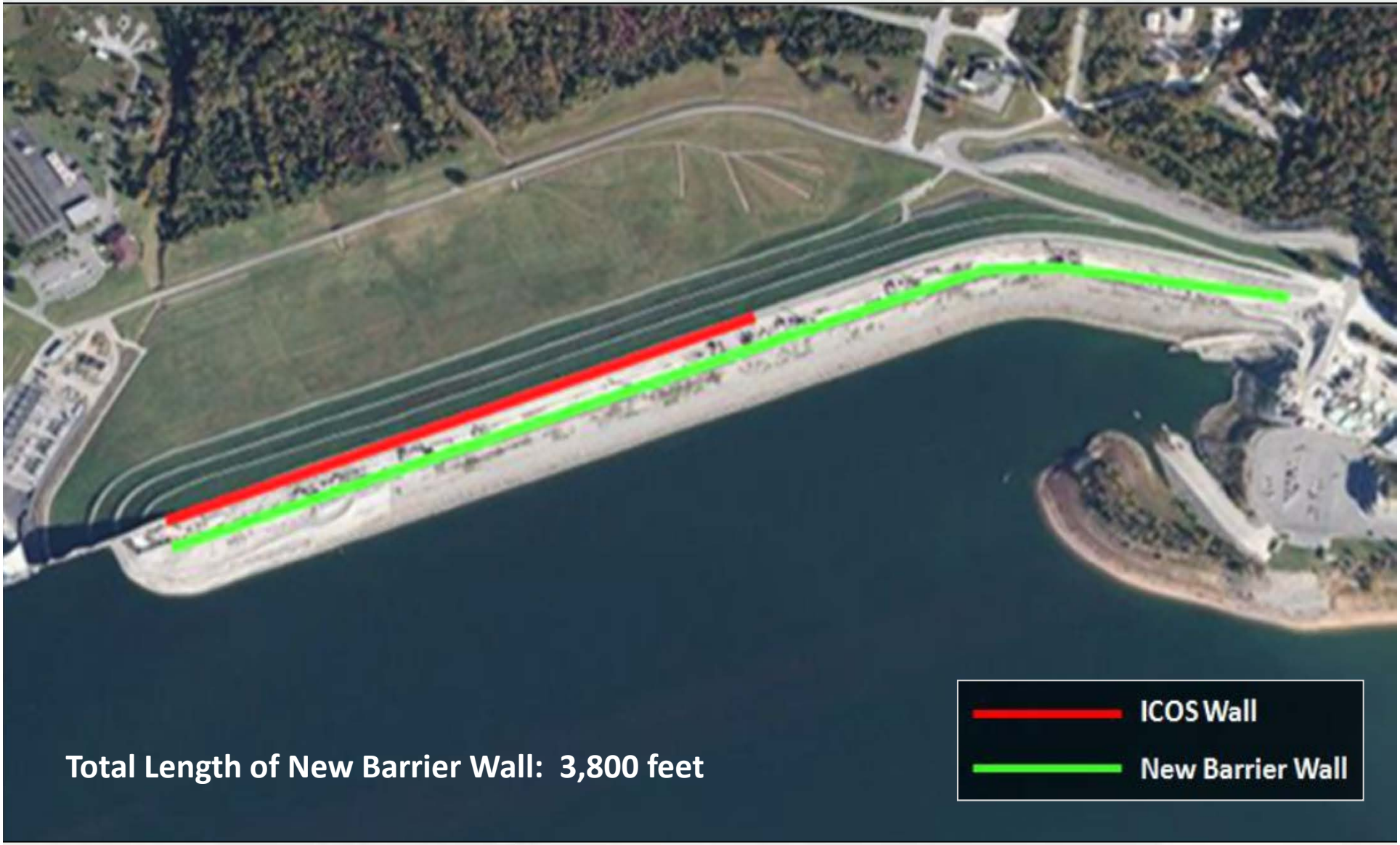
ACT Grouting (2007-2008)

1300 holes
900,000 gallons of grout
$70 million
Completed September 2008

Double Line Grout Curtain

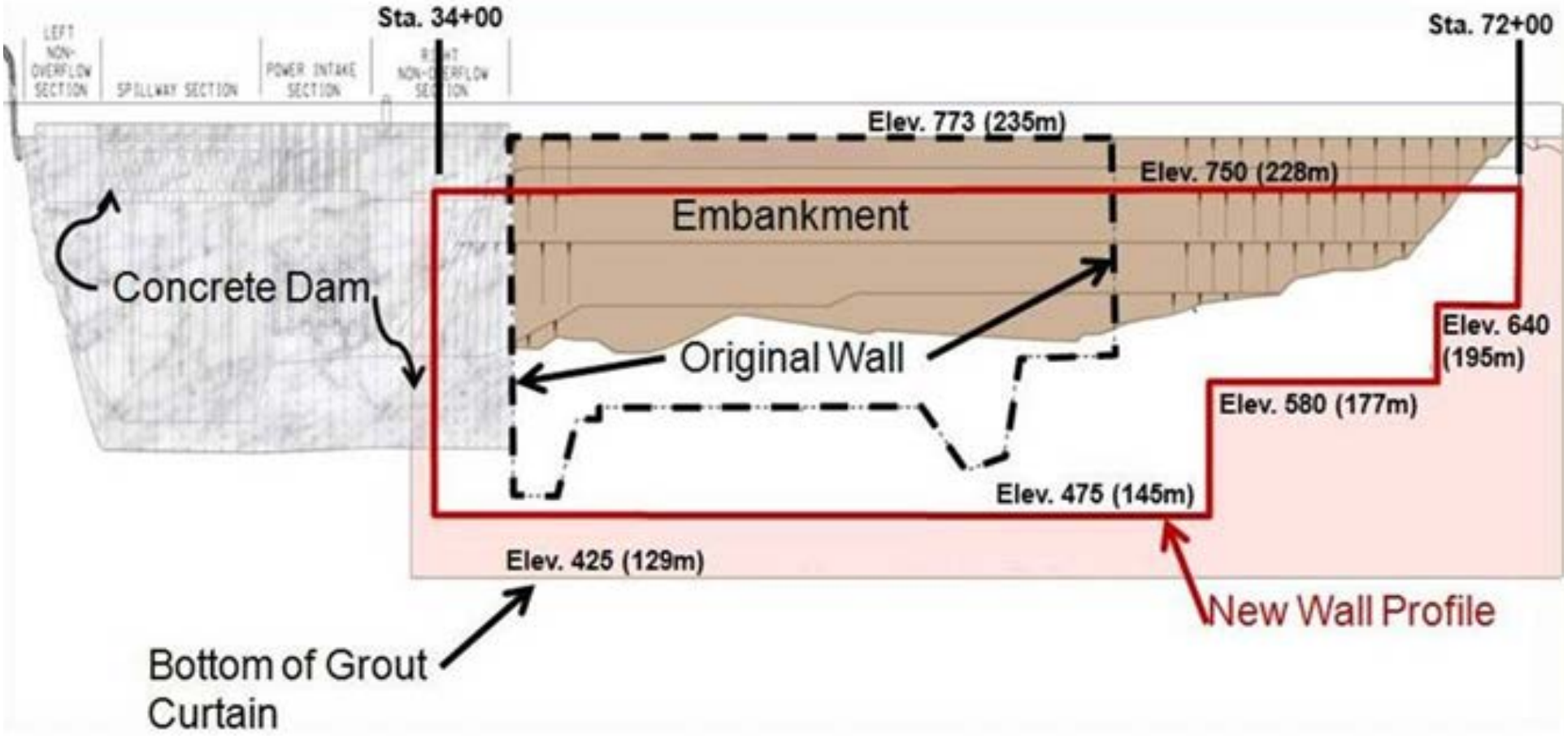


Barrier Wall Construction (2009-2013)



Total Length of New Barrier Wall: 3,800 feet

Barrier Wall Construction (2009-2013)



Questions?