Little Rock District

Clearwater Dam
Major Rehab Project

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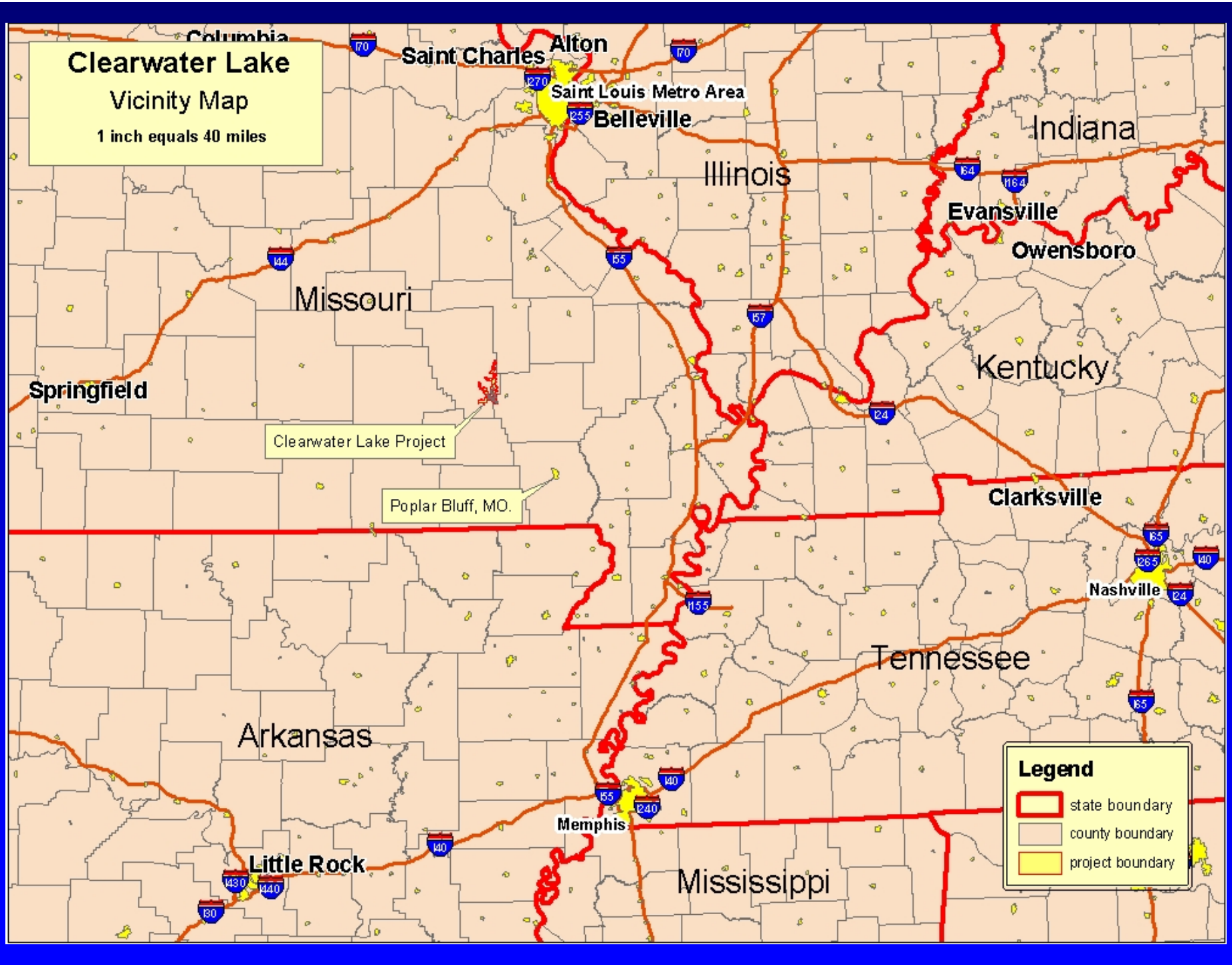
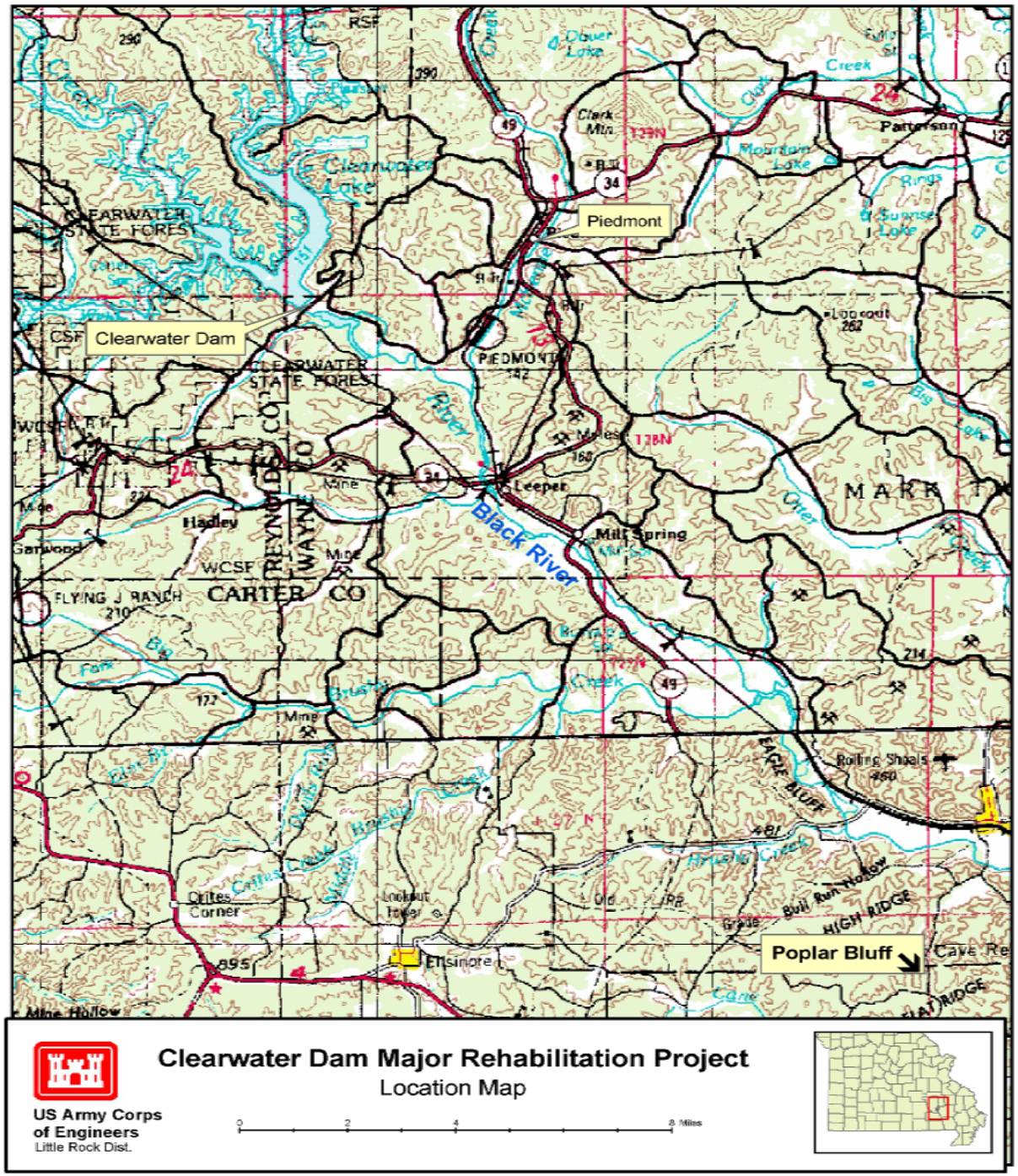

Clearwater Lake
Vicinity Map
1 inch equals 40 miles
Columbia
Saint Charles
Alton
Saint Louis Metro Area
Belleville
Indiana
Illinois
Evansville
Owensboro
Missouri
Springfield
Clearwater Lake Project
Poplar Bluff, MO.
Kentucky
Clarksville
Nashville
Tennessee
Arkansas
Memphis
Little Rock
Mississippi
Legend
state boundary
county boundary
project boundary



Clearwater Dam Major Rehabilitation Project

Location Map

US Army Corps of Engineers
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CLEARWATER LAKE - MISSOURI

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What's the problem(s)?

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Significant Deficiencies

- Long-Term Seepage
  - Seepage has been observed at and around the downstream left abutment since first filling.
  - Several remediation attempts have been accomplished over the past 60 years.
  - A sinkhole appeared on the upstream face of the embankment in 2003.
- Seismic
  - Clearwater is located in the New Madrid Seismic Zone.
  - Some of the alluvial soils beneath the structure may be susceptible to liquifaction under certain earthquake events.
- Spillway
  - There is currently material located within the spillway that should be removed to allow for the PMF event.

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What can happen?

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Consequences

- In the event of a dam breach caused by seepage or seismic
  - Total damages: $168,520,000
  - Total loss of life: 340

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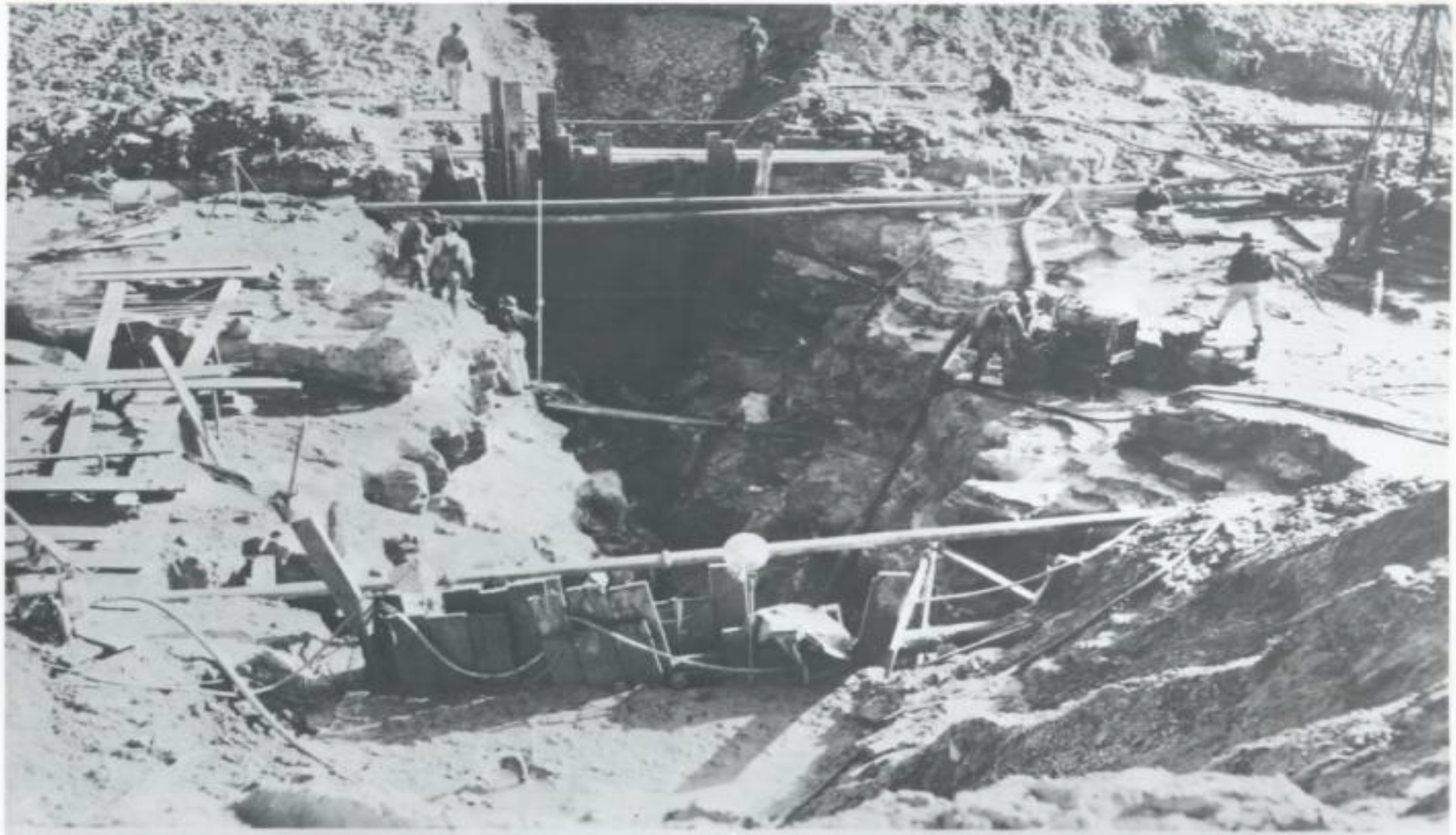
When were seepage problems first observed?

Original Construction – STA 41+68

Looking E from 150' U.S. of station 41 + 68. General view of cut-off trench operations.

Original Construction – STA 39+20

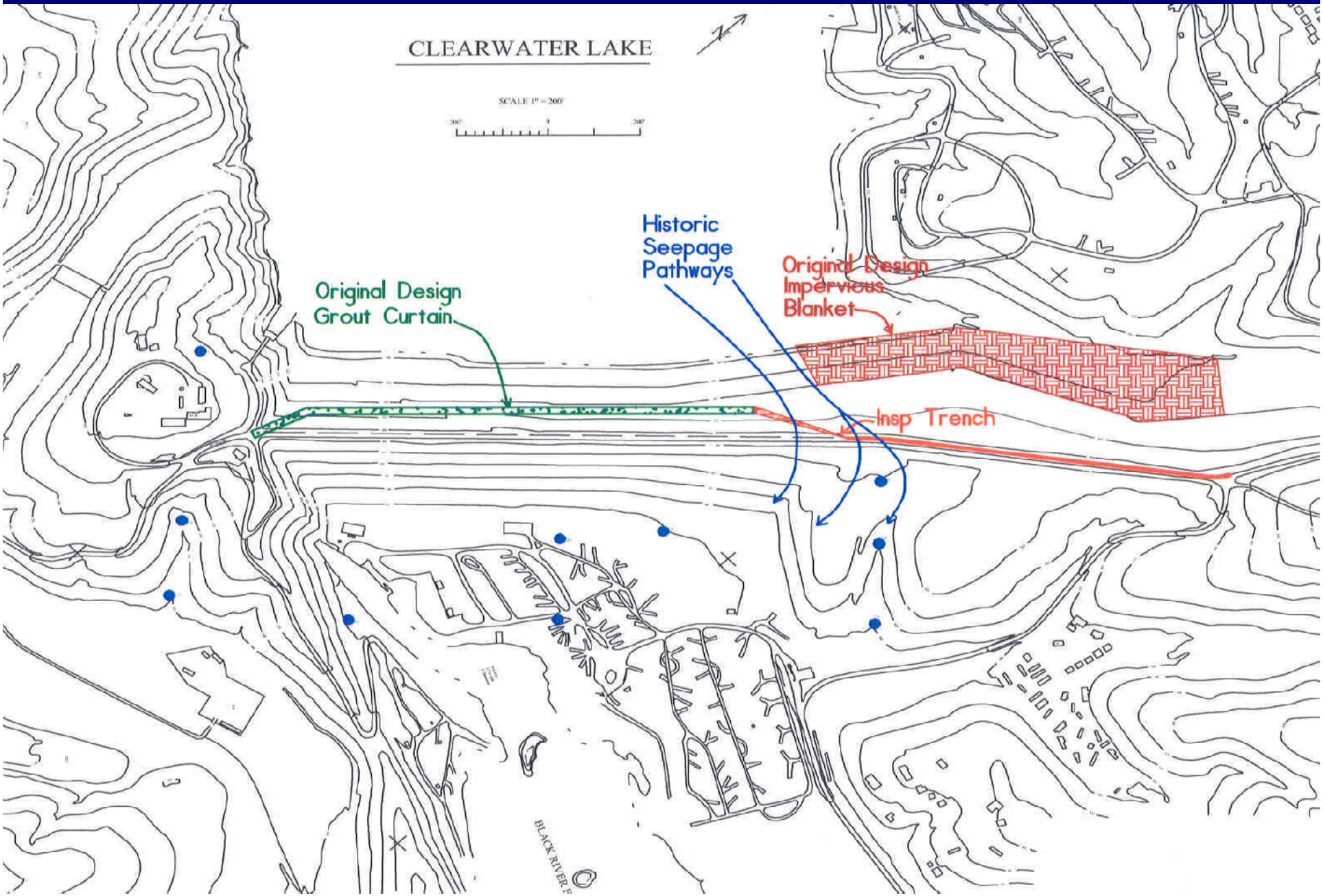


Looking S from 175' US of station 39 + 20: Open joint in cut-off trench foundation.

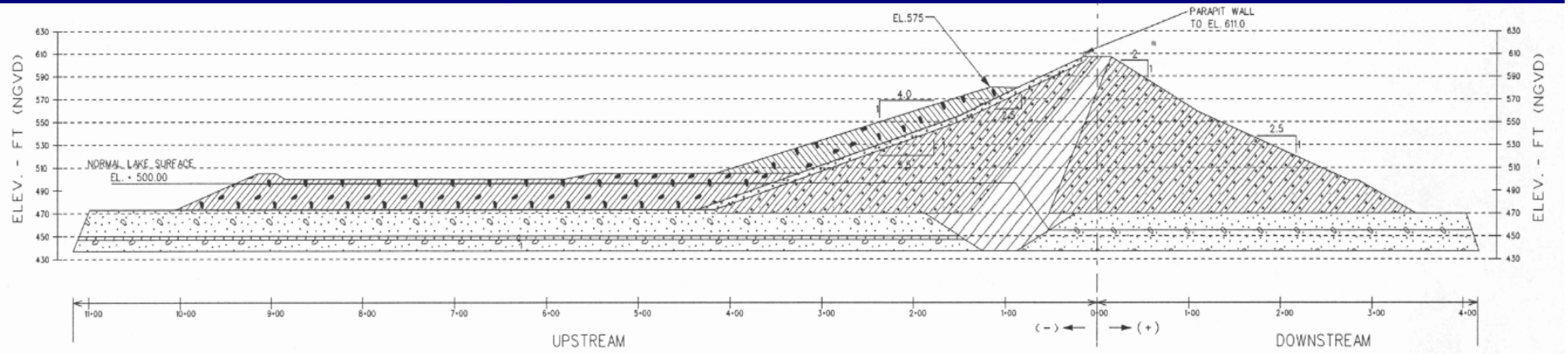
Original Construction – STA 40+15

Looking NW from 35' U.S. of station 40 + 15: Open joint in cut-off trench foundation.

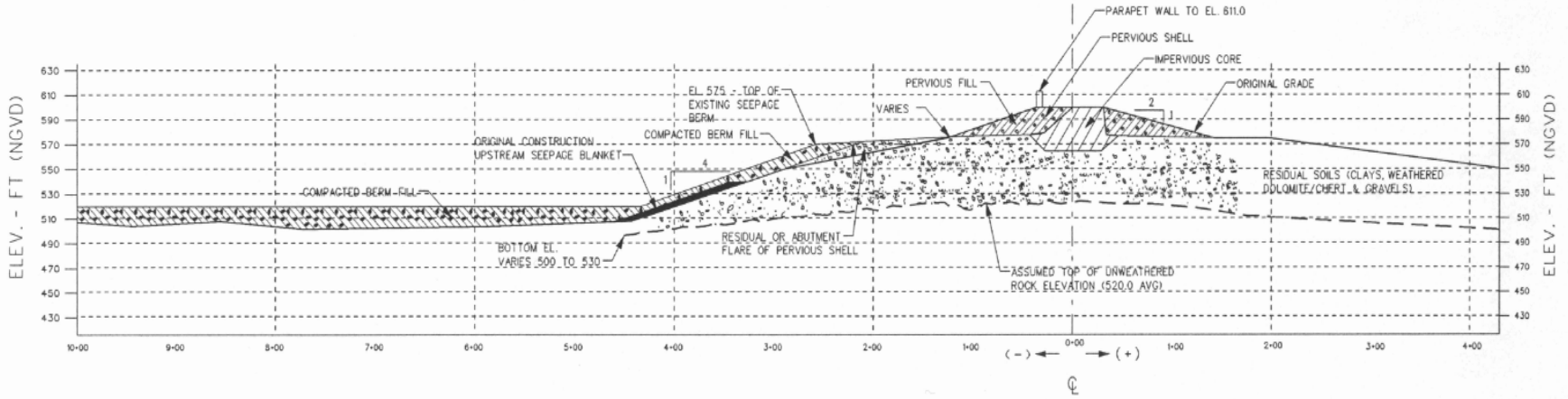
ORIGINAL DESIGN



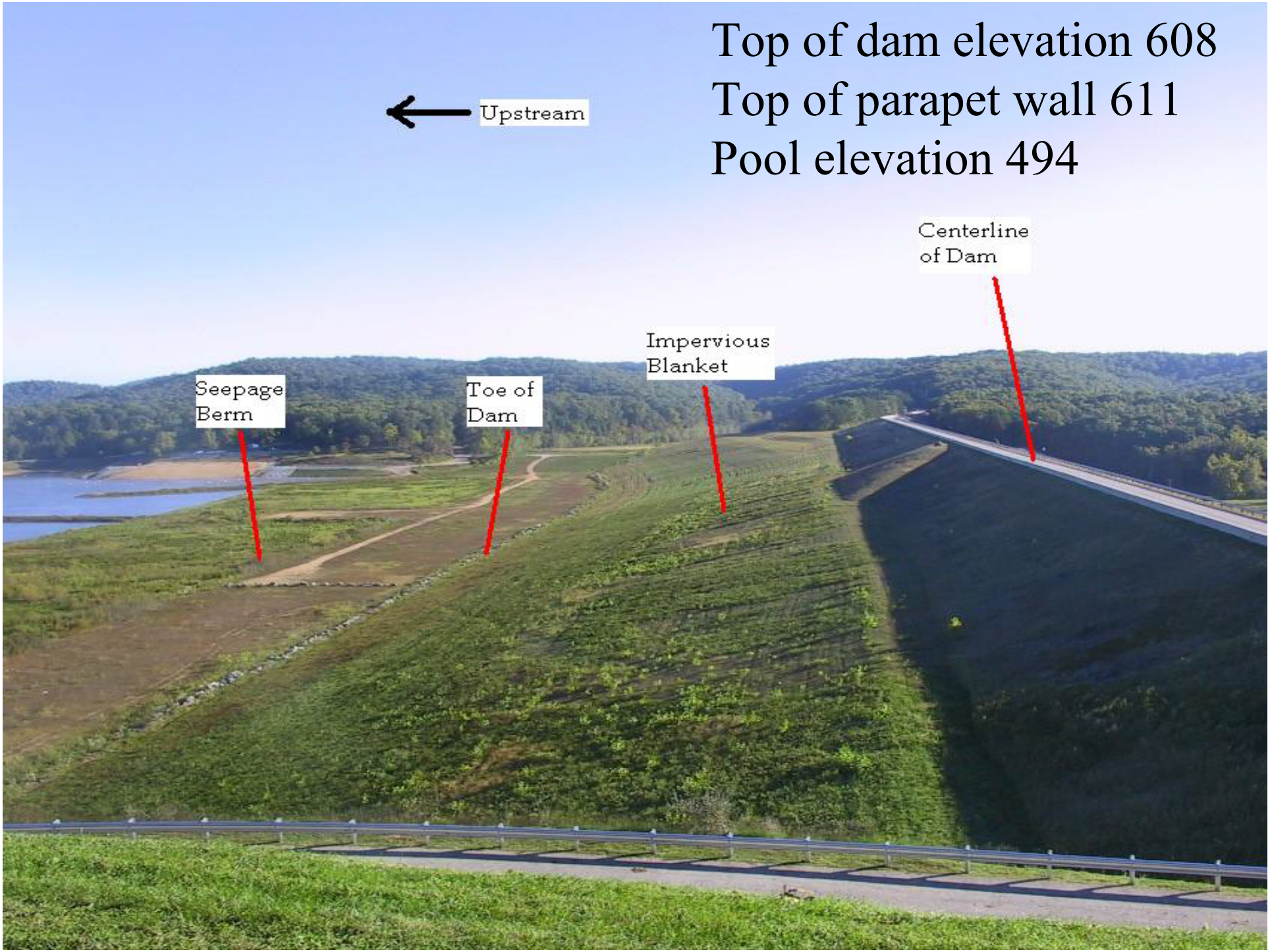
EXISTING STRUCTURE



SECTION A
TYPICAL EXISTING SECTION - NEAR CENTER OF DAM
(STATIONS 33 TO 55 +/-)
(SCALE: AS SHOWN)



SECTION B
TYPICAL EXISTING SECTION NEAR LEFT ABUTMENT
(STATIONS 15 TO 33 +/-)
(SCALE: AS SHOWN)


Top of dam elevation 608
Top of parapet wall 611
Pool elevation 494
Upstream
Centerline of Dam
Impervious Blanket
Seepage Berm
Toe of Dam

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CLEARWATER DAM
POOL OF RECORD – MAY 2002
ELEVATION 566.7

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POOL OF RECORD – MAY 2002
LOOKING TOWARDS LEFT ABUTMENT

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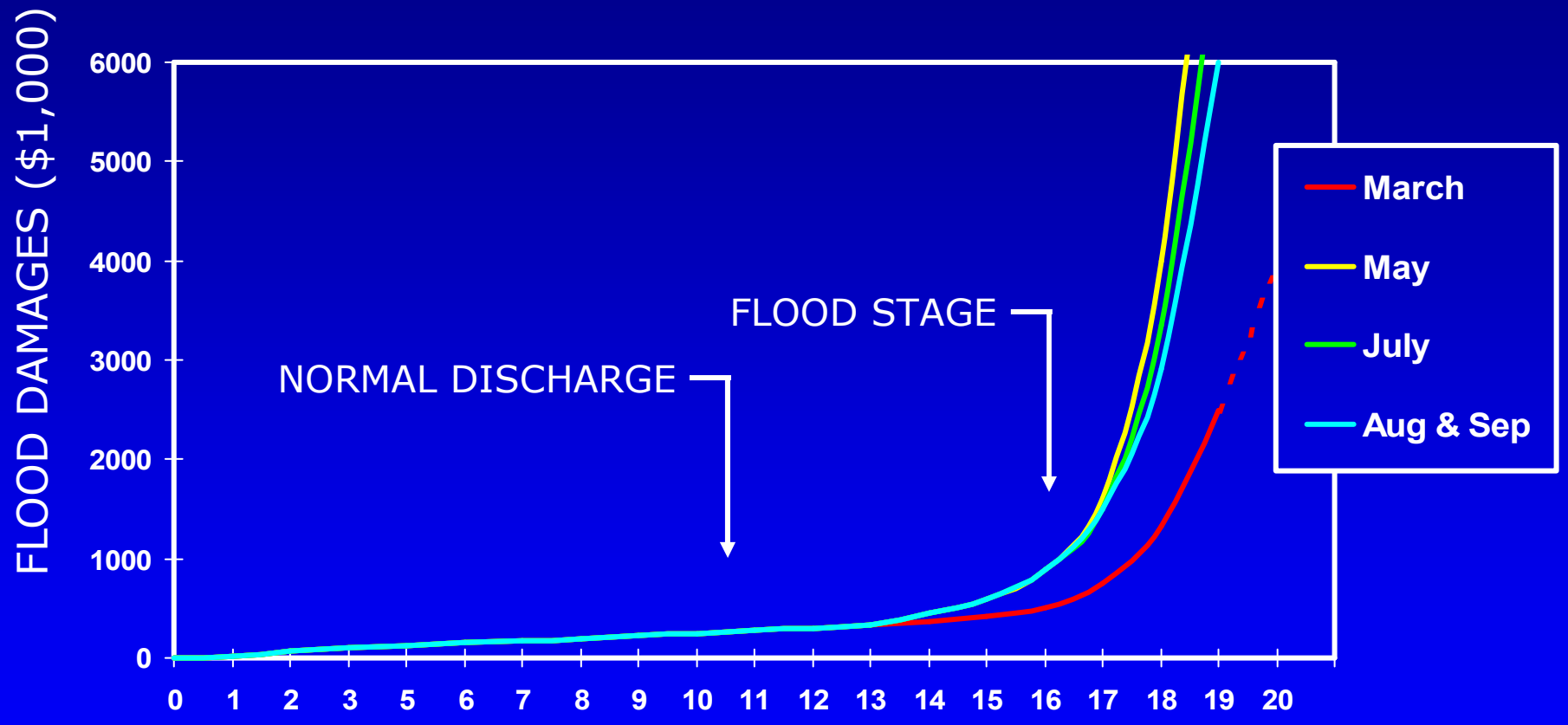
POOL OF RECORD – MAY 2002
EMERGENCY SPILLWAY
LOOKING TOWARDS NORTHEAST

CLEARWATER DAM DISCHARGE IMPACTS



Black River Stage @ Popular Bluff, MO (ft.)

Clearwater Dam – Sinkhole Investigation
15 January 2003


Legend
sinkhole

Clearwater Dam – Sinkhole Investigation
16 January 2003

Clearwater Dam – Sinkhole Investigation
16 January 2003

Final excavation at 25 feet deep

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Geophysical and Subsurface Investigations

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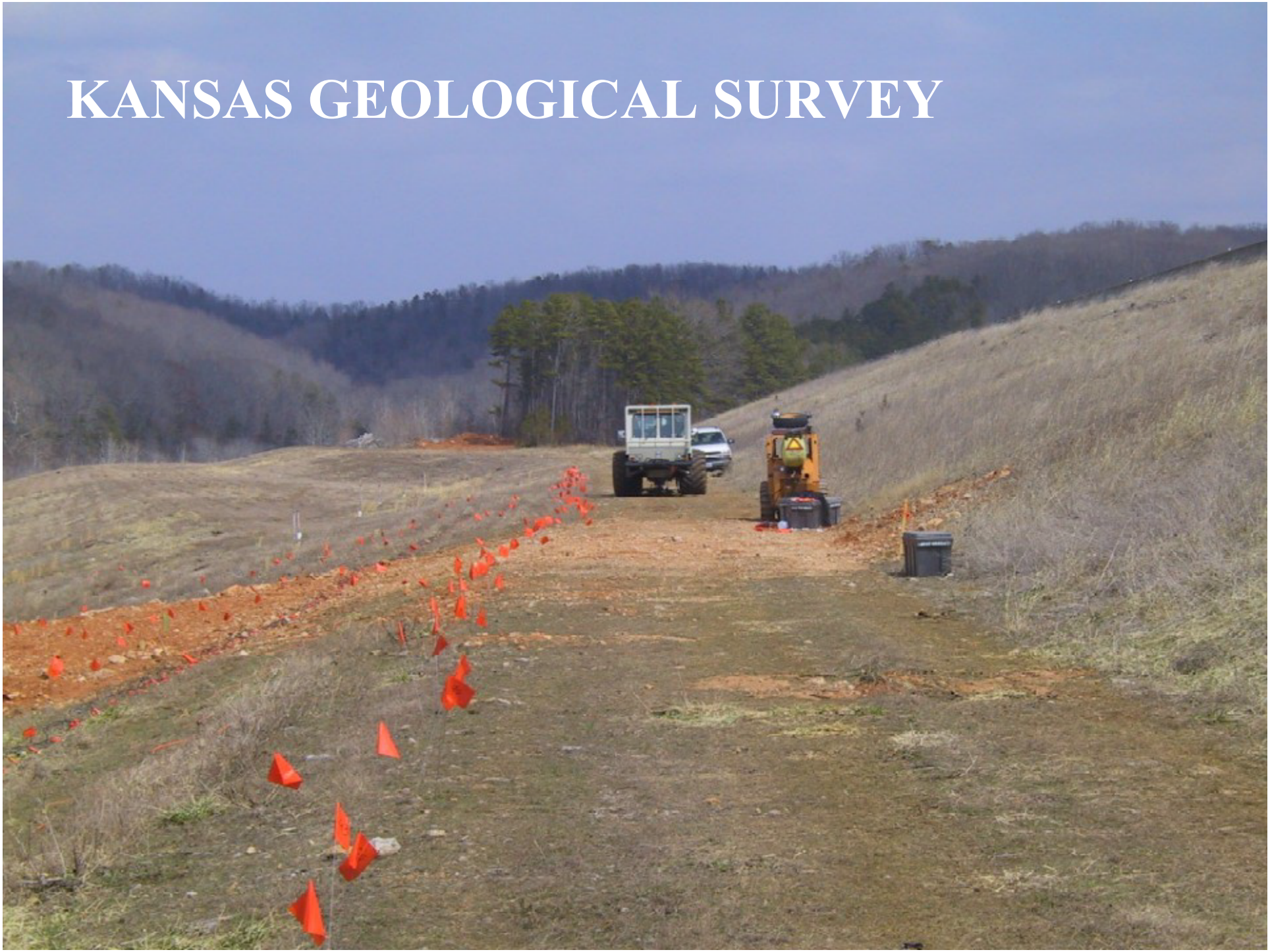
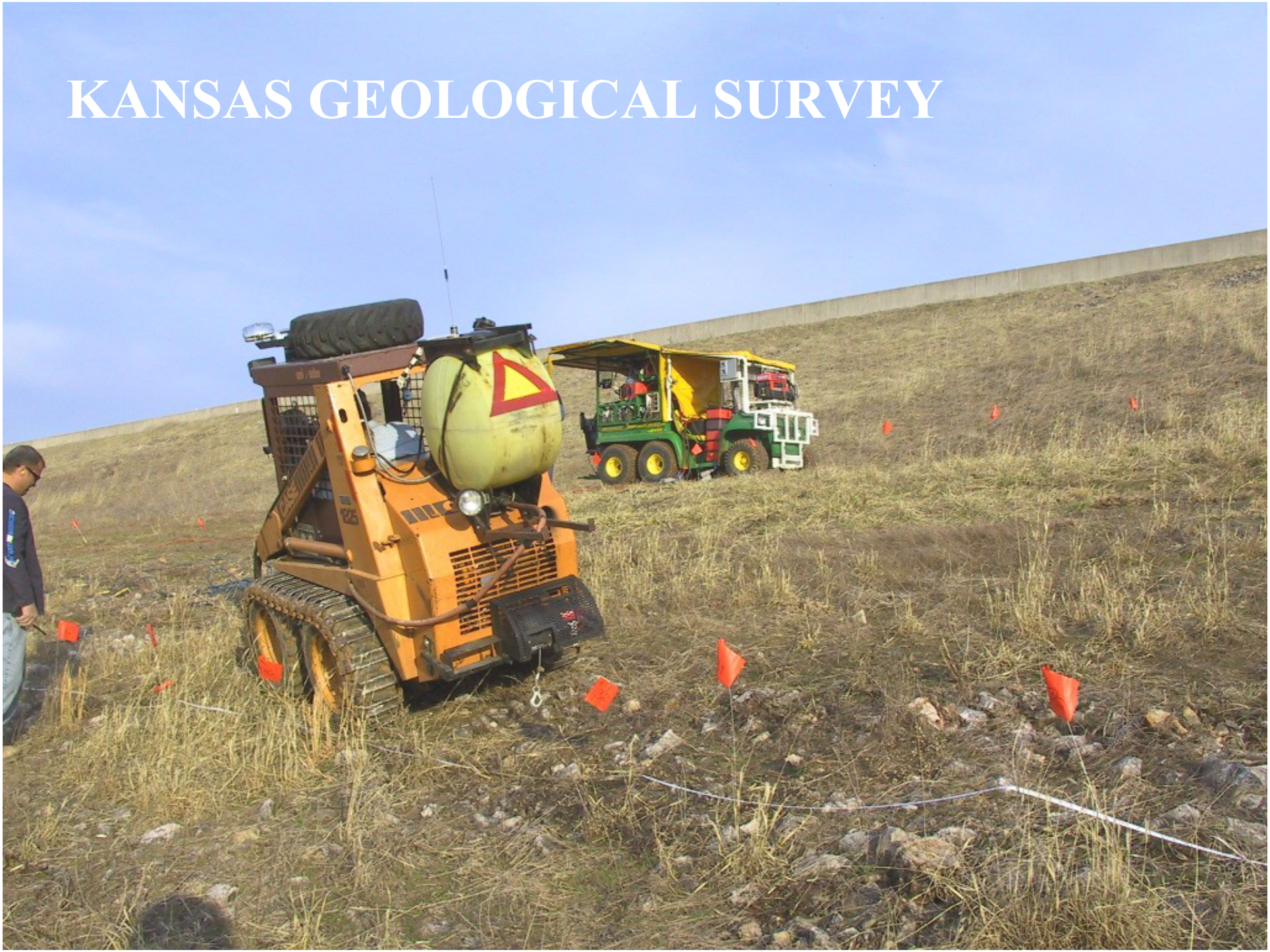
- Kansas Geological Survey – surface wave, reflection
- Sonic Drilling – 6 borings, 50’ into rock
- Bureau of Reclamation – crosshole tomography
- ERDC – SP, EM conductivity, ER

KANSAS GEOLOGICAL SURVEY



KANSAS GEOLOGICAL SURVEY



Sonic drilling – Clearwater Dam – 8 April 2003


1' of concrete below impervious core
Sinkhole boring SH-1A
9 April 2003

Bureau of Reclamation – June 2003

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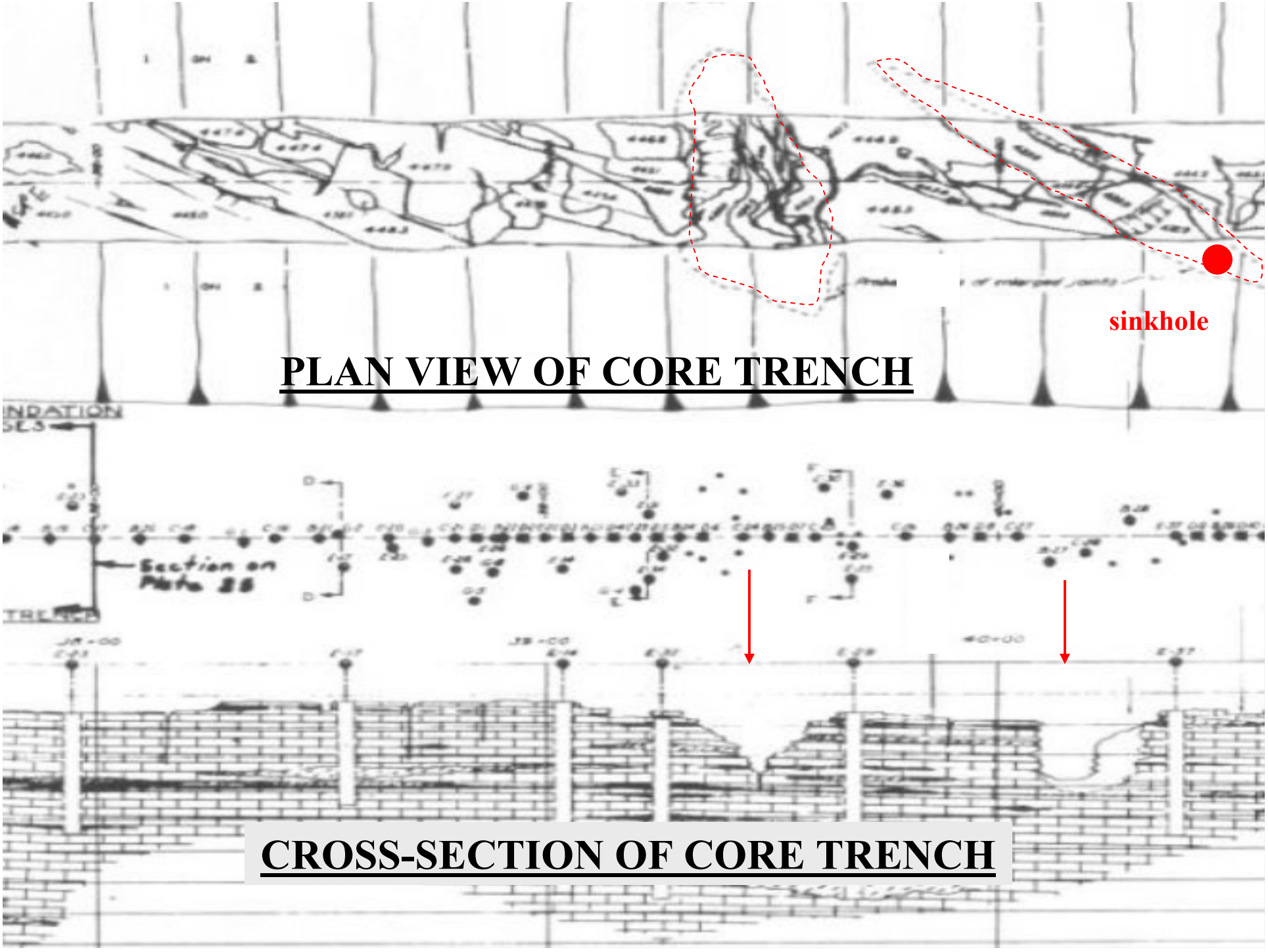
What information was gained from these investigations?


sinkhole
PLAN VIEW OF CORE TRENCH
Section on
CROSS-SECTION OF CORE TRENCH

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MAJOR REHAB PROJECT SUMMARY

- PDT arrived at two primary structural alternatives (out of 10 measures evaluated) that address the Clearwater seepage problems.
- Report submitted June 04.
- Approved by SWD 6 August 04.
- Receive CG Wedge Funds from HQ 13 Aug 04.

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MAJOR REHAB PROJECT SUMMARY

- Design/Const schedule developed Oct 04
- New survey initiated in Oct 04, complete Feb 05
- Seepage consultants on board Feb 05
  - Bruce, Silva, Poulos
- Cutoff wall through the centerline of the dam was approved. Wall location has been moved to centerline of clay core by SWL and Consultants with approval by SWD and HQ.

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What immediate remediation efforts need to be performed?

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Foundation Drilling and Grouting – Sinkhole Repair Project

Location of Sinkhole and Grouting Project

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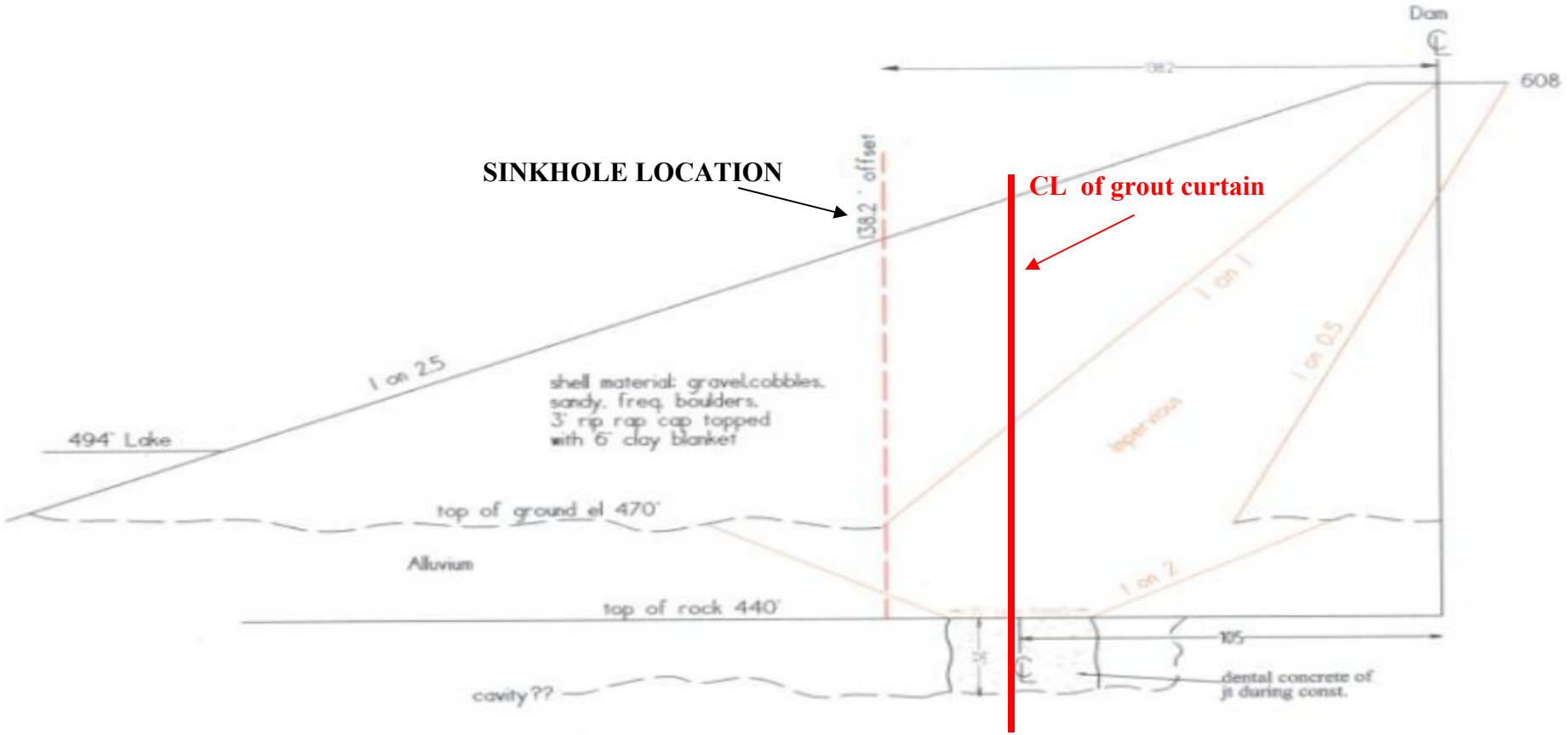
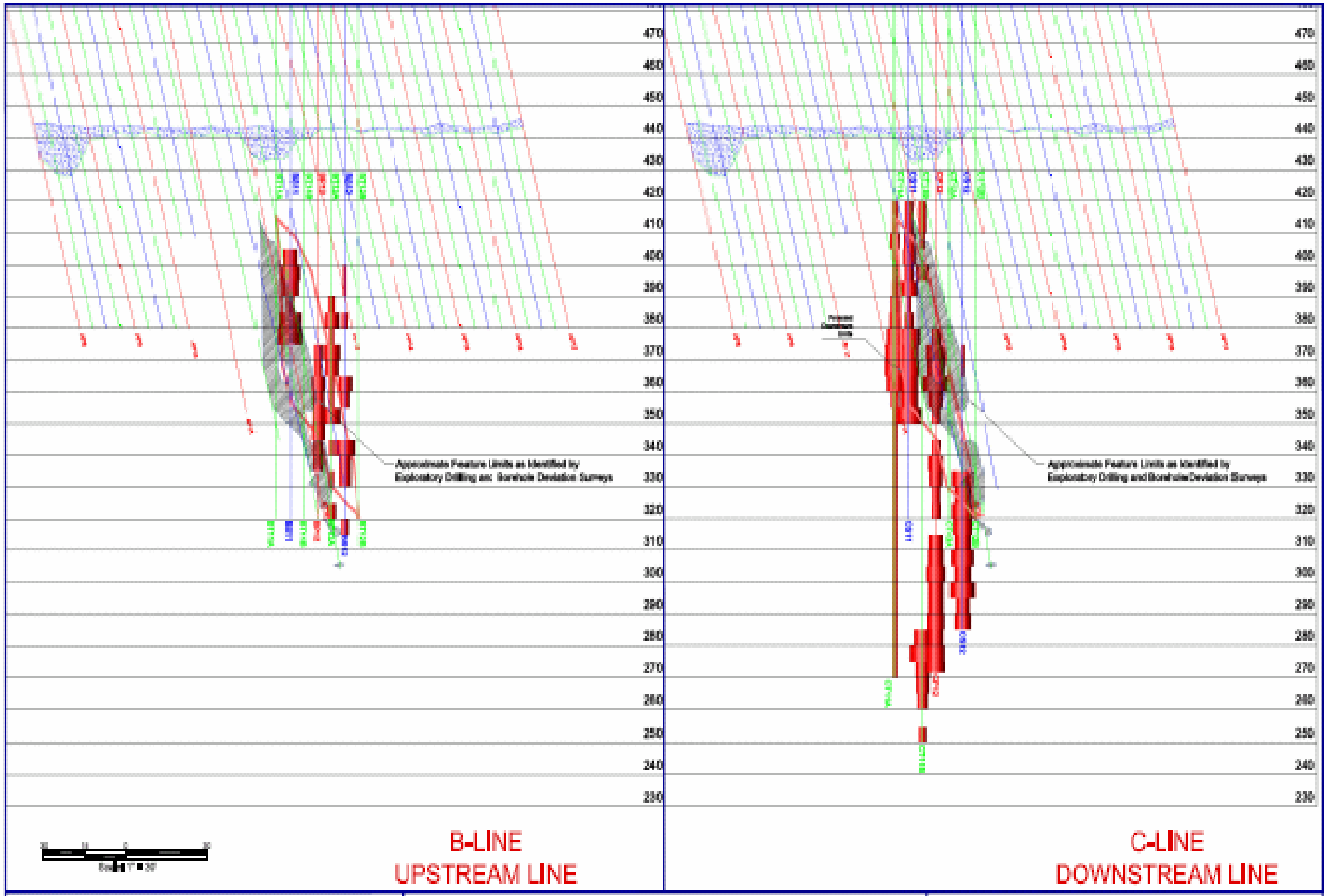
Clearwater Dam

Embankment Cross Section



Clearwater Dam – Sonic Drilling

Clearwater Dam – Grout Line



B-LINE
UPSTREAM LINE

C-LINE
DOWNSTREAM LINE

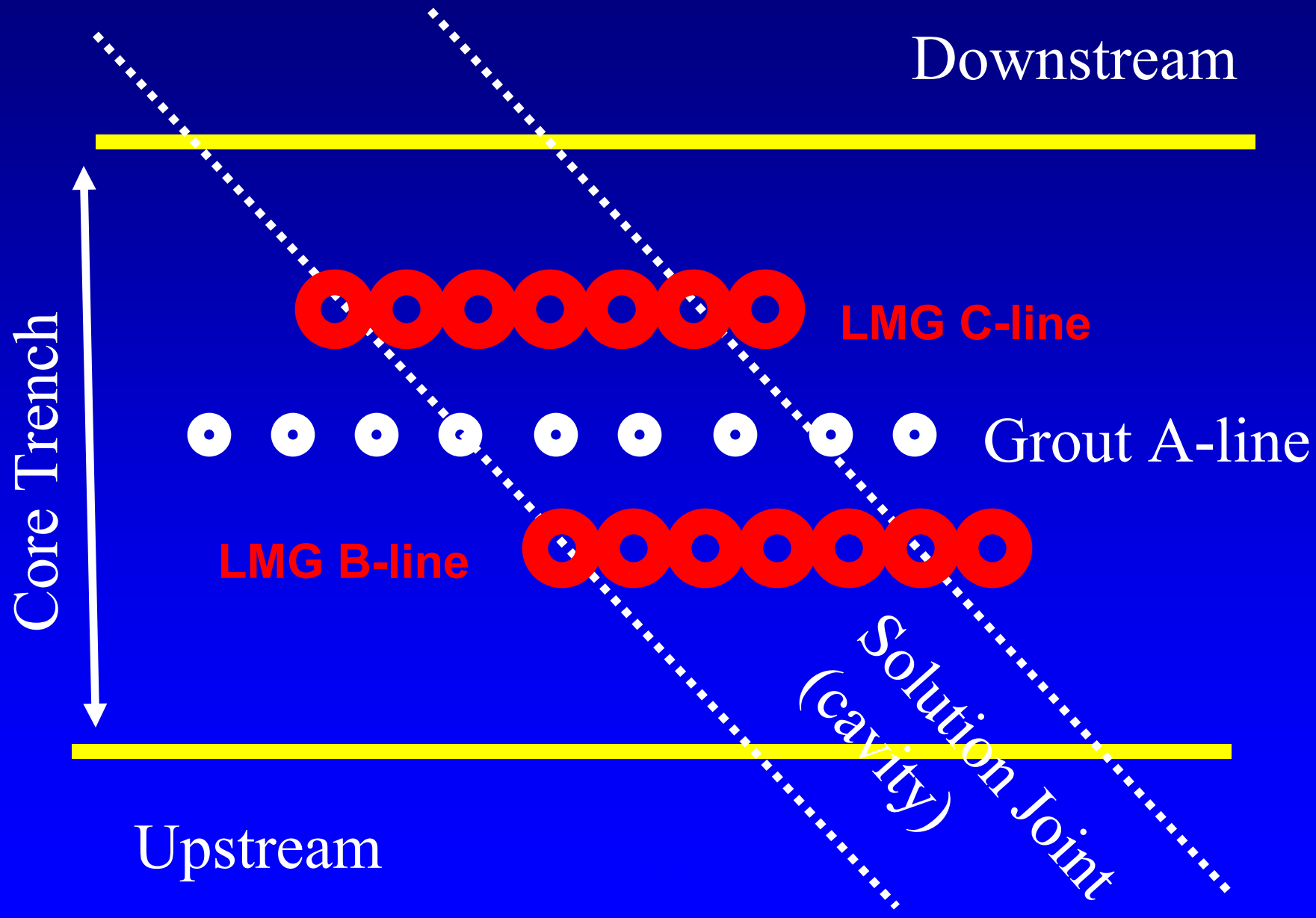
IntelliGrout™
The Science of Grouting

CLEARWATER DAM SINKHOLE REPAIR
PIEDMONT, MISSOURI
FOUNDATION DRILLING AND GROUTING
CONTRACT NO.: W9127S-04-C-0003

US Army Corps of Engineers

FIGURE 3
PROFILE VIEW OF LMG HOLES
Updated as of 3-15-05

LOW MOBILITY GROUT HOLES – PLAN VIEW



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FY 04-05 Grouting Contract Summary

- November 2003 – ACT/Gannett-Fleming
- December 2003 – NTP
- April 2004 – grouting began in rock
- August 2004 – grouting 75% complete; discovery of unknown cavity
- November 2004 – modify contract for low mobility grout (LMG)
- April 2005 – complete LMG
- May 2005 – contractor demob

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Will seismic issues affect seepage remediation?

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SEISMIC STUDY EFFORTS

- Hired FMSM to perform parametric seismic analysis.
- Obtained services of seismic consultants – Seed, Castro, Lorig, Hempen.
- Performed additional SPT for limited seismic investigation requested by consultants to verify historical drilling data.

Drilling and Sampling Photos

Instrumented Drill Rod to Measure Hammer Energy

Drilling and Sampling Photos

SPT Analyzer Readout Terminal

Drilling and Sampling Photos

Disturbed Tube Sample

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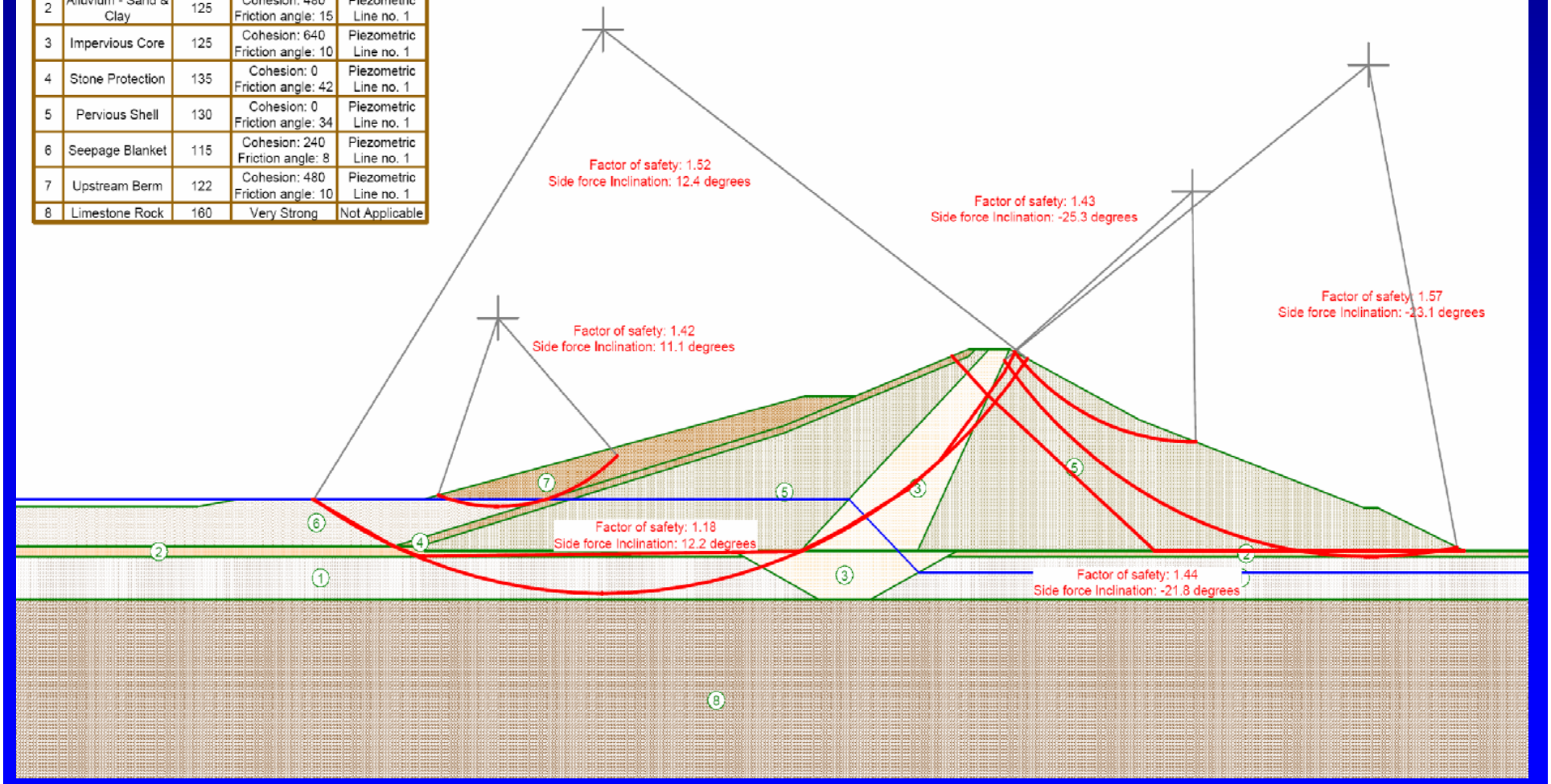
Pseudostatic Analyses with UTEXAS4

NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	Alluvium - Sand & Gravel	132	Cohesion: 0 Friction angle: 27	Piezometric Line no. 1
2	Alluvium - Sand & Clay	125	Cohesion: 480 Friction angle: 15	Piezometric Line no. 1
3	Impervious Core	125	Cohesion: 640 Friction angle: 10	Piezometric Line no. 1
4	Stone Protection	135	Cohesion: 0 Friction angle: 42	Piezometric Line no. 1
5	Pervious Shell	130	Cohesion: 0 Friction angle: 34	Piezometric Line no. 1
6	Seepage Blanket	115	Cohesion: 240 Friction angle: 8	Piezometric Line no. 1
7	Upstream Berm	122	Cohesion: 480 Friction angle: 10	Piezometric Line no. 1
8	Limestone Rock	160	Very Strong	Not Applicable



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SEISMIC STUDY SUMMARY

- Slope stability and FLAC analyses indicate no slope failure under current OBE assigned by ERDC.
- SPT samples were relatively consistent with historical data.
- The cutoff wall should incorporate a plastic concrete to match the strengths of the embankment materials.
- FMSM to finalize data and report in July.
- Continue seismic analysis through DSAP (FY06-FY08).

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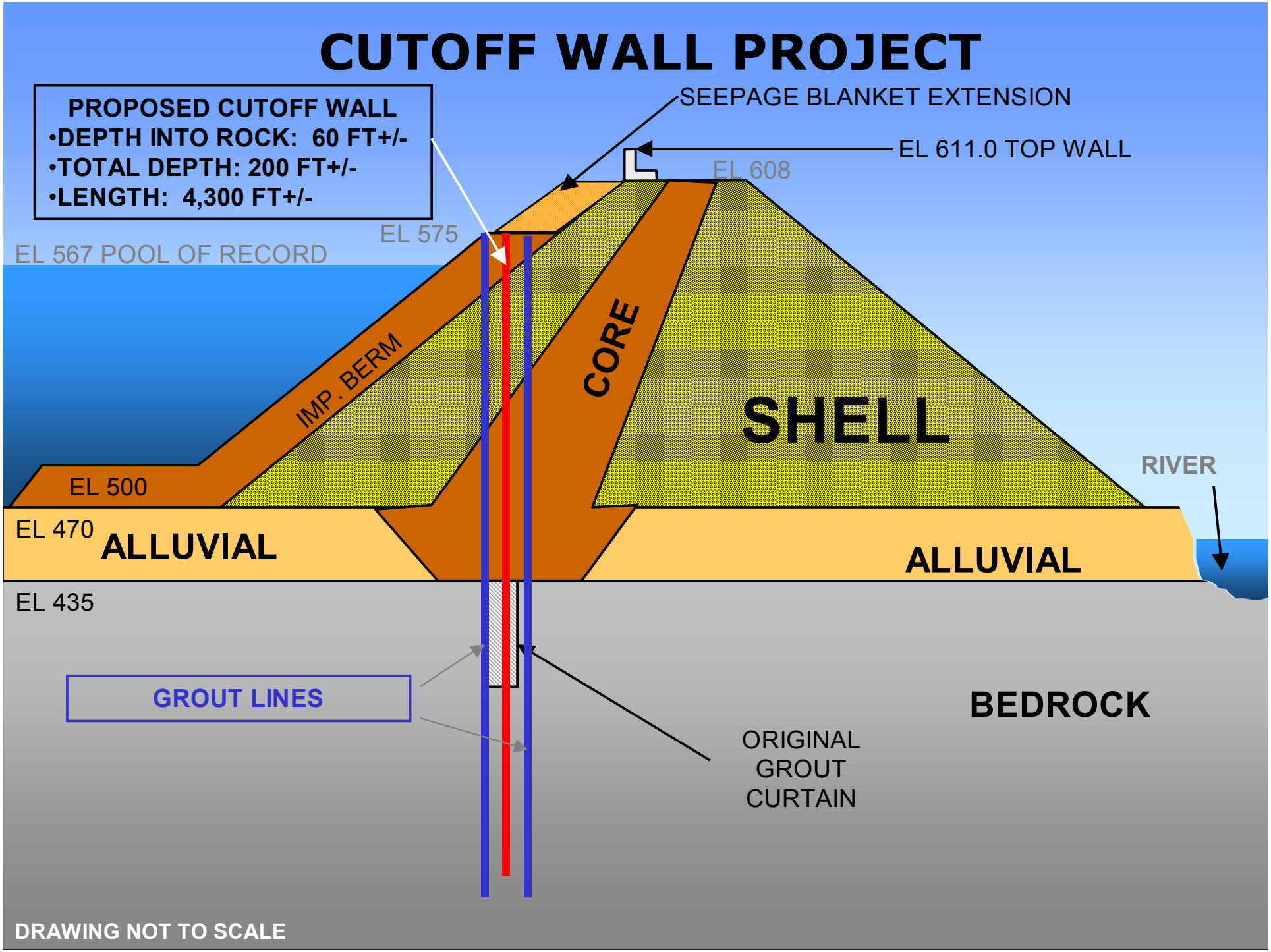
MAJOR REHAB PROJECT STATUS

- Phase I –exploratory drilling/grouting along full length of dam. (early FY06)
- Phase II – construction of work platform, Cutoff wall construction and seepage blanket extension. (late FY06)


CUTOFF WALL PROJECT
PROPOSED CUTOFF WALL
•DEPTH INTO ROCK: 60 FT+/-
•TOTAL DEPTH: 200 FT+/-
•LENGTH: 4,300 FT+/-
SEEPAGE BLANKET EXTENSION
EL 611.0 TOP WALL
EL 608
EL 575
EL 567 POOL OF RECORD
IMP. BERM
CORE
SHELL
RIVER
EL 500
EL 470
ALLUVIAL
ALLUVIAL
EL 435
GROUT LINES
BEDROCK
ORIGINAL
GROUT
CURTAIN
DRAWING NOT TO SCALE

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CRITICAL INFORMATION NEEDED FOR CUTOFF WALL DESIGN

- Depth of rock embedment.
- Permeability of existing soils and rock.
- Method of construction:
  - Rock mill or Secant pile
- The presence of any other large cavities/features.

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MAJOR REHAB AND DAM SAFETY PROJECT FUNDING

- FY05
  - **$1.05M CG**– detailed design for MRP
  - Per direction from HQ/SWD, utilized $350k for limited seismic deformation and stability analysis
- FY06
  - **$22M CG** – Phase I construction (exploratory drilling/grouting)
  - Complete design and initiate Phase II construction (work platform, cutoff wall)
  - **$245k** O&M – Seismic Intensity for MCE, Borings and Testing
- FY07
  - **$23M** CG – Phase II construction (work platform, cutoff wall)
  - **$260k** O&M – Seismic Analysis Phase I and II

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MAJOR REHAB AND DAM SAFETY PROJECT FUNDING

- FY08
  - **$23M** CG – Phase II construction (cutoff wall)
  - **$300k** O&M – Seismic Evaluation Report
- FY09
  - **$21.1M** CG – Phase II construction (cutoff wall)
- FY10
  - **$23M** CG – Phase II construction (work platform, cutoff wall)

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