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Huntington District

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Bluestone Dam DSA Anchor Challenges

Tri-Service Infrastructure Systems Conference

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Topics

- **Brief Overview of Bluestone Dam**
- **DSA efforts completed to date / ongoing and future efforts**
- **Lessons learned from the field anchor study**

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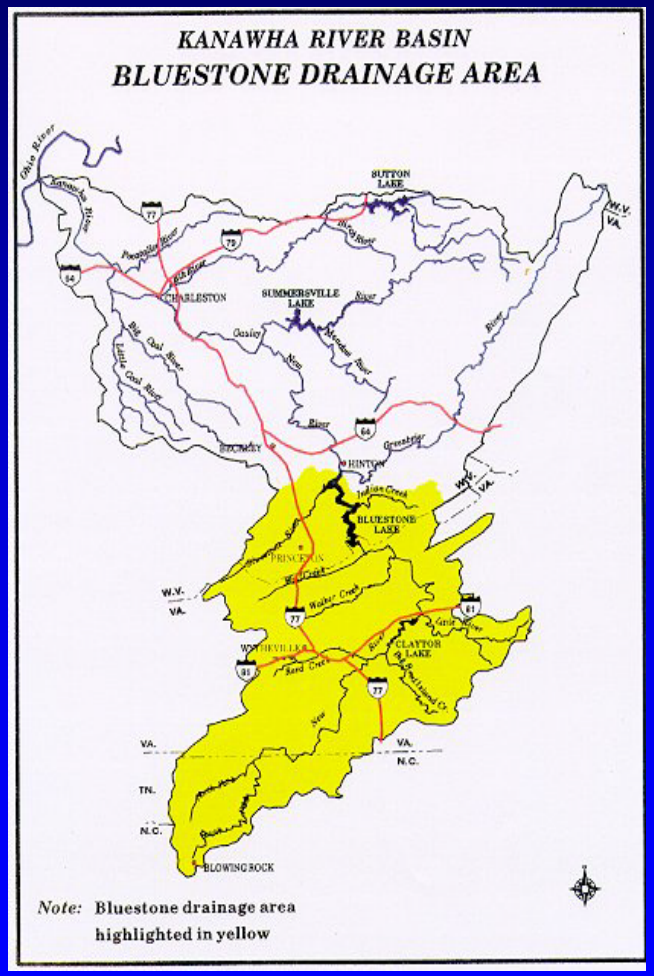
Location

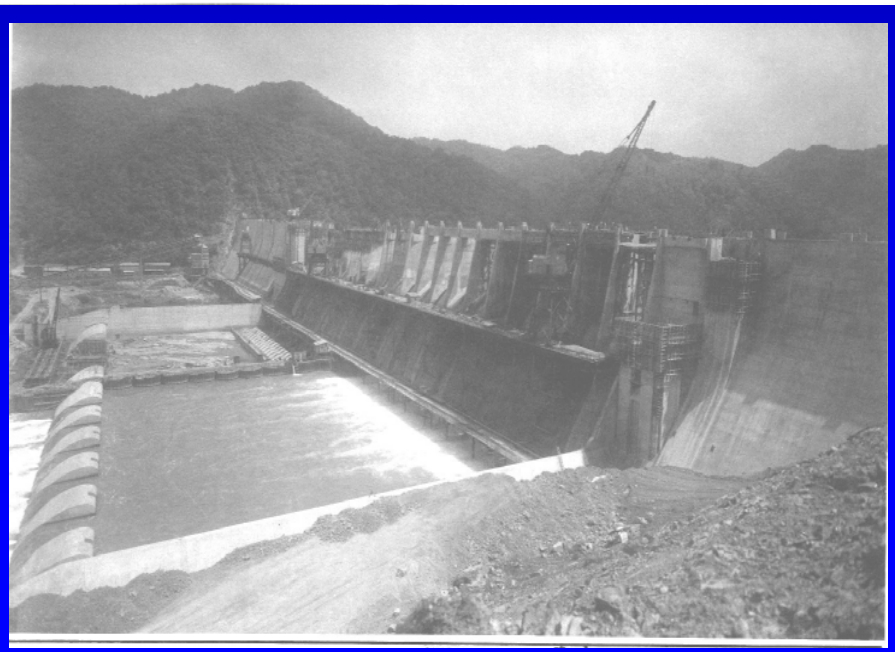


Features

- Concrete gravity dam
  - 165’ high
  - 2060’ long
- 4600 mi^2 drainage area
- Outlet works
  - 16 sluices
  - Gated spillway (21)
- 6 penstocks

Construction

- Started in 1942
- Suspended in 1944 (WWII)
- Resumed in 1946
- Completed in 1948
- Hydropower not implemented
  - Storage re-allocated for flood control
  - Pool elevation reduced from 1490 feet to 1410 feet

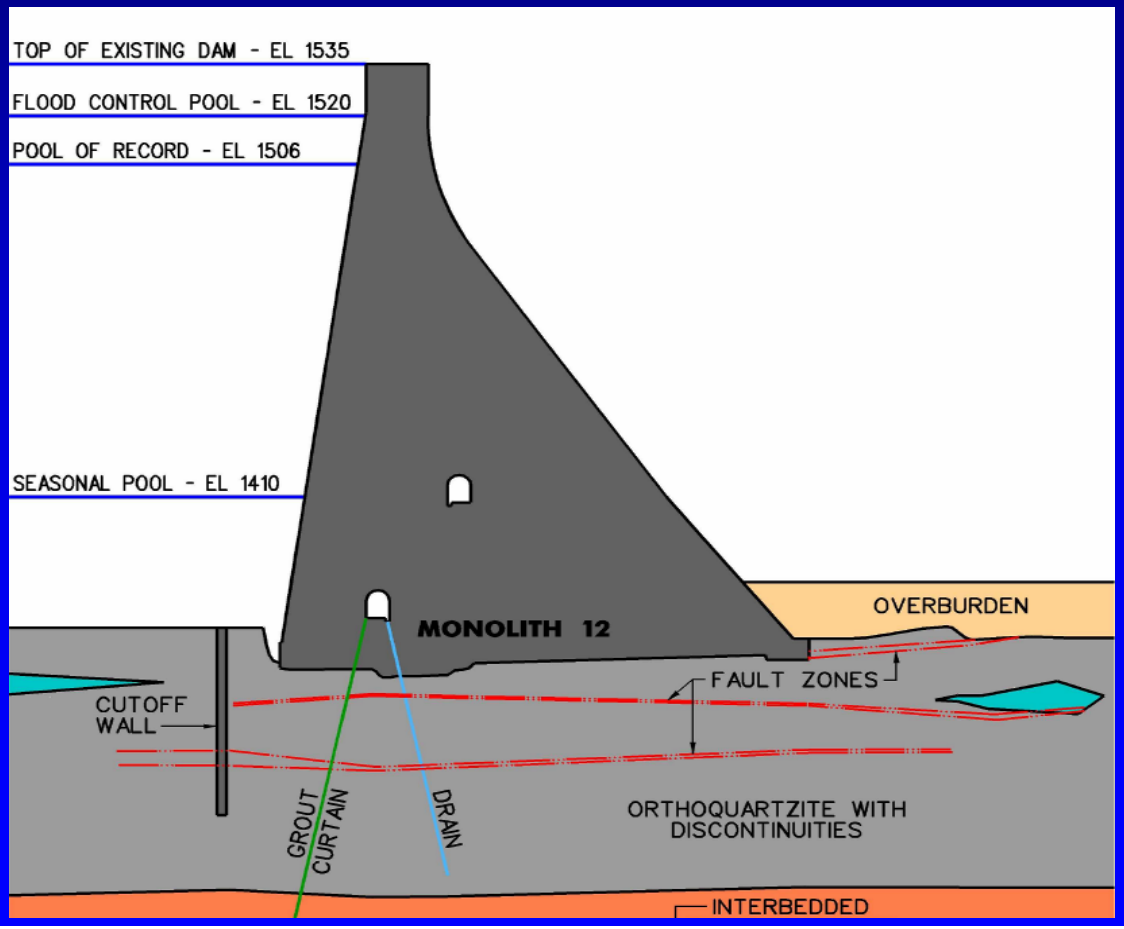


Bluestone Dam Overview

Spillway 790’ long

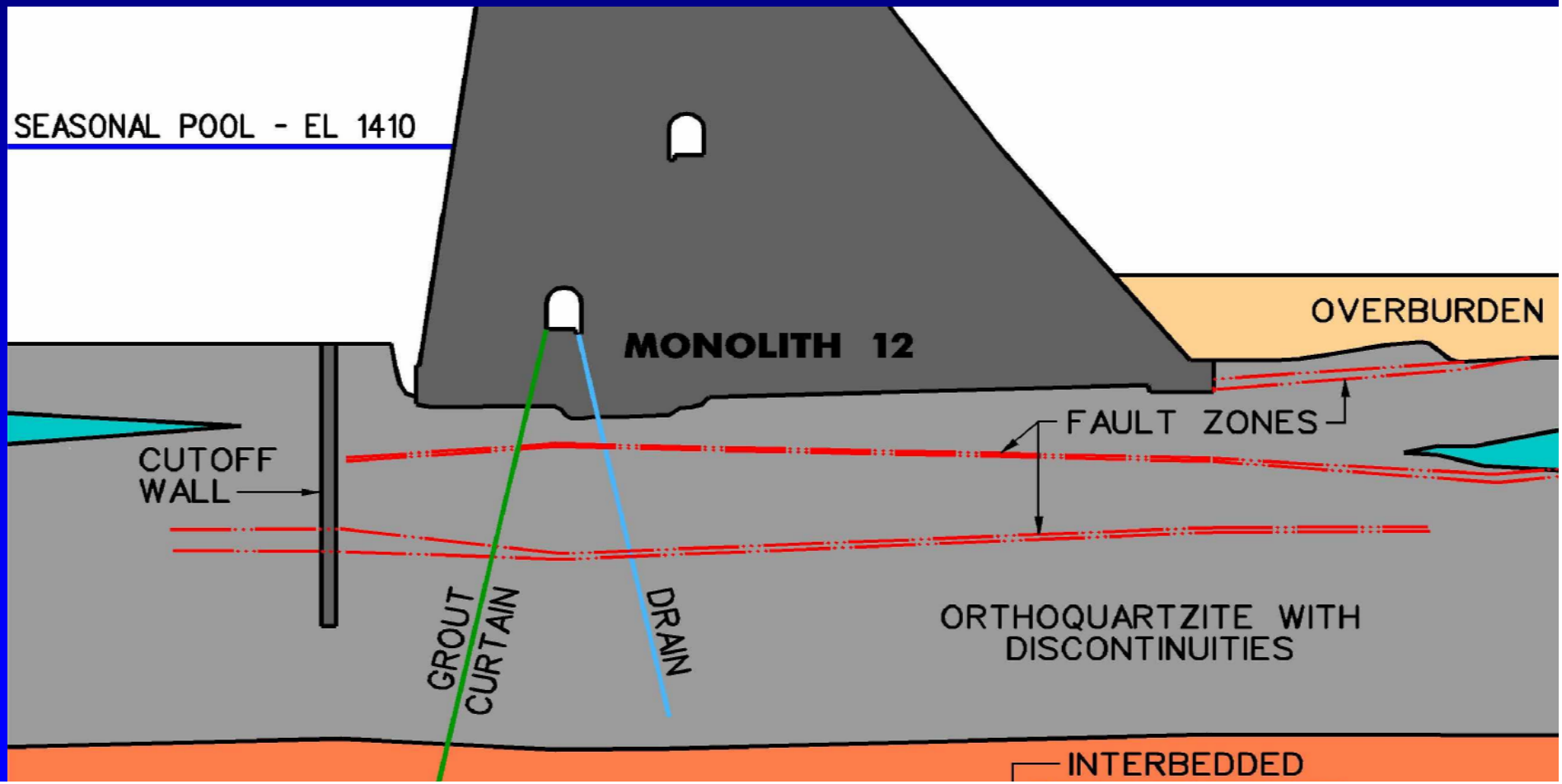
Bluestone Dam Overview

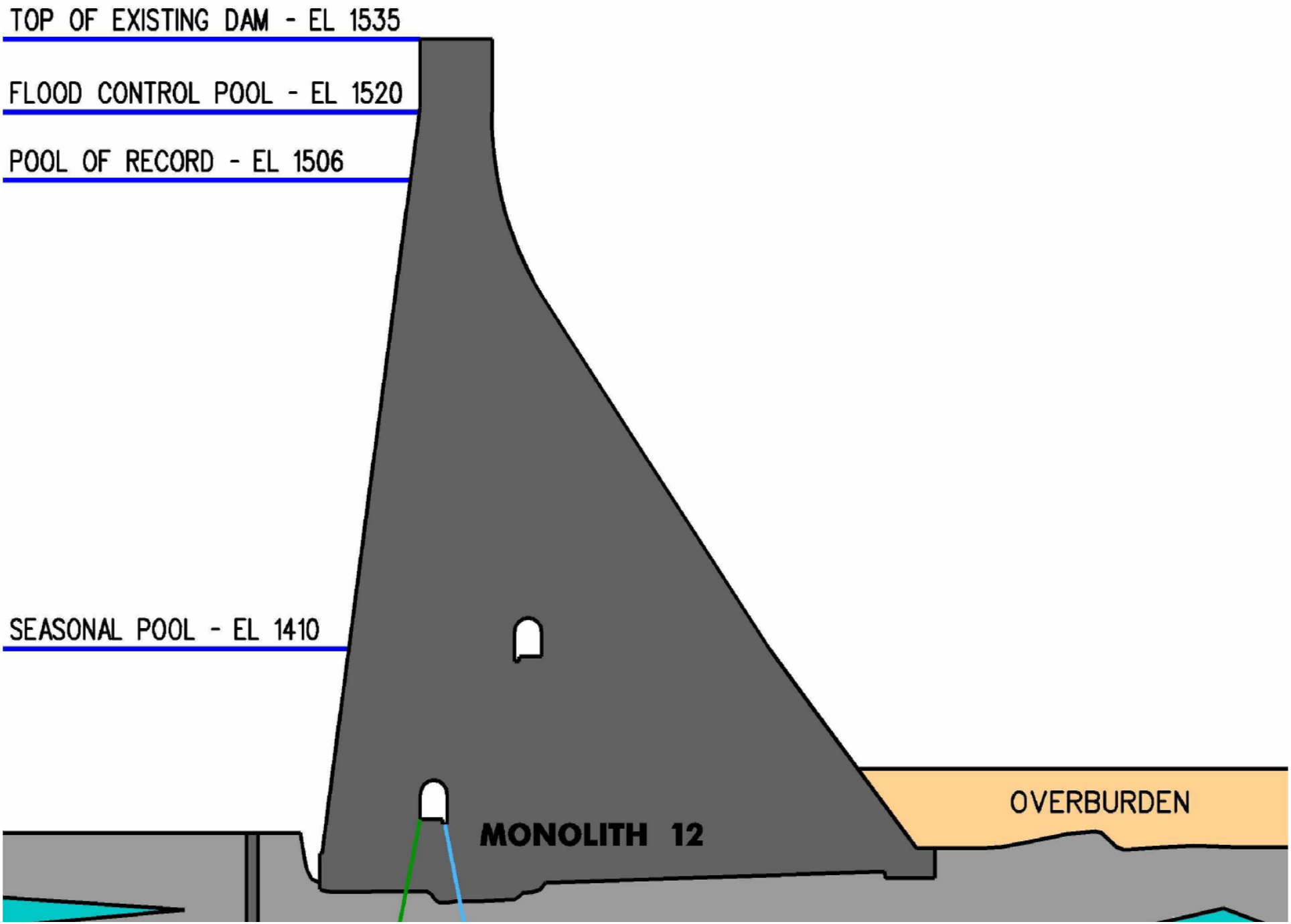
- **Project foundation:**
  - **Valley floor:**
    - **Founded on orthoquartzite or interbedded orthoquartzite and carbonaceous shale**
  - **Abutments:**
    - **Shales**
    - **Siltstone**
    - **Sandstone**

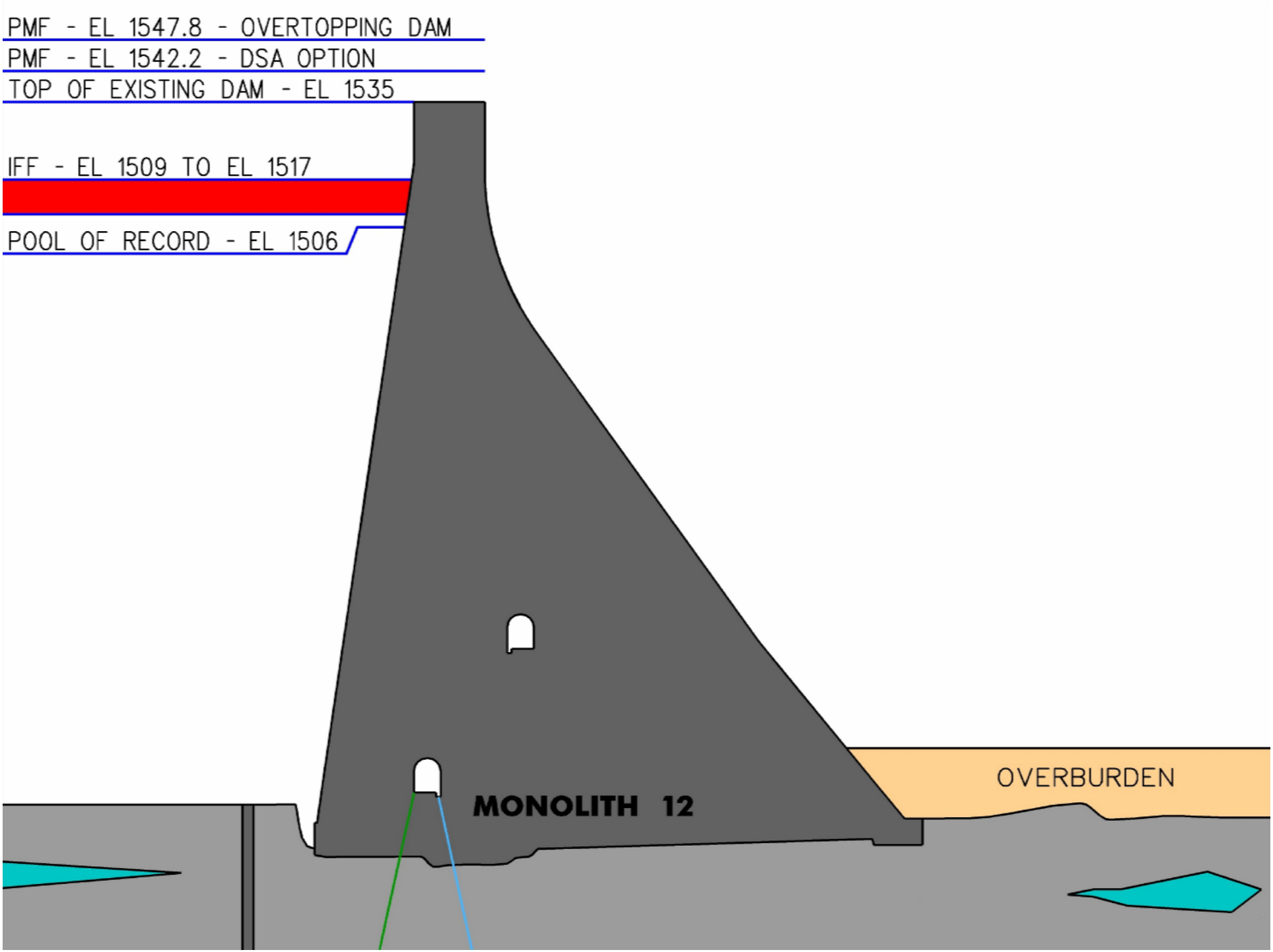


DSA Project History

Fault was not removed from monoliths 10 through 12

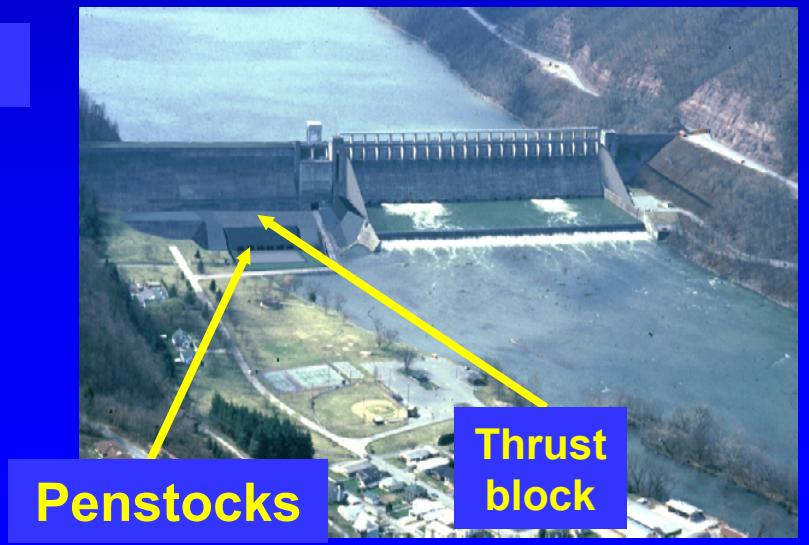



TOP OF EXISTING DAM - EL 1535
FLOOD CONTROL POOL - EL 1520
POOL OF RECORD - EL 1506
SEASONAL POOL - EL 1410
OVERBURDEN
MONOLITH 12


PMF - EL 1547.8 - OVERTOPPING DAM
PMF - EL 1542.2 - DSA OPTION
TOP OF EXISTING DAM - EL 1535
IFF - EL 1509 TO EL 1517
POOL OF RECORD - EL 1506
OVERBURDEN
MONOLITH 12

Bluestone DSA Phase 1

- **Phase I Contract**
  - Awarded Sept. 2000
  - Completed 2004
- **Project Features**
  - 2 Lane Bridge
  - Thrust Blocks
  - Extending Penstocks
  - Sacrificial Bulkheads



Bluestone DSA – Phase 2A

Crest gate guide extensions

Route 20 gate closure

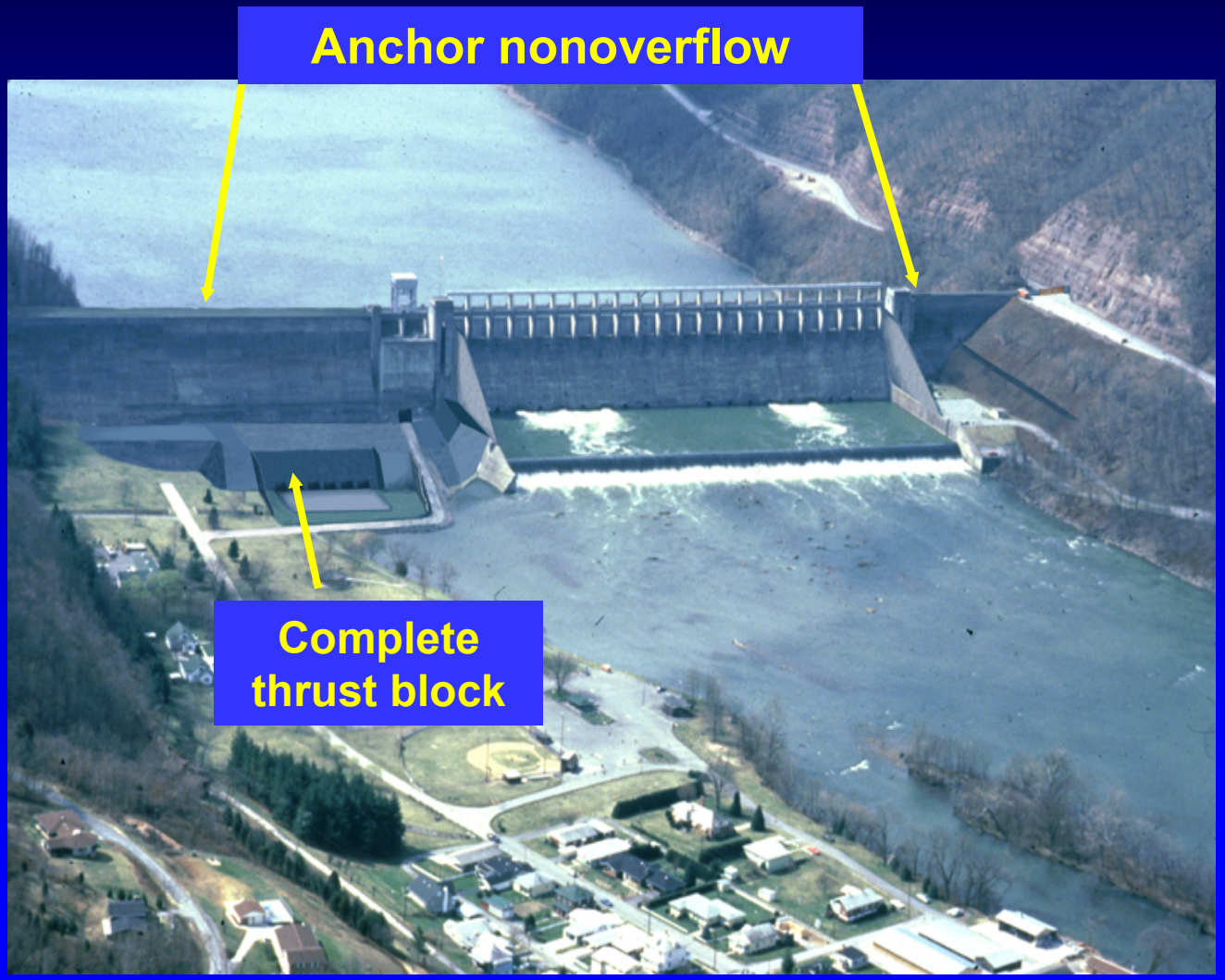
monolith (not shown)

Upgrade access road to stilling basin

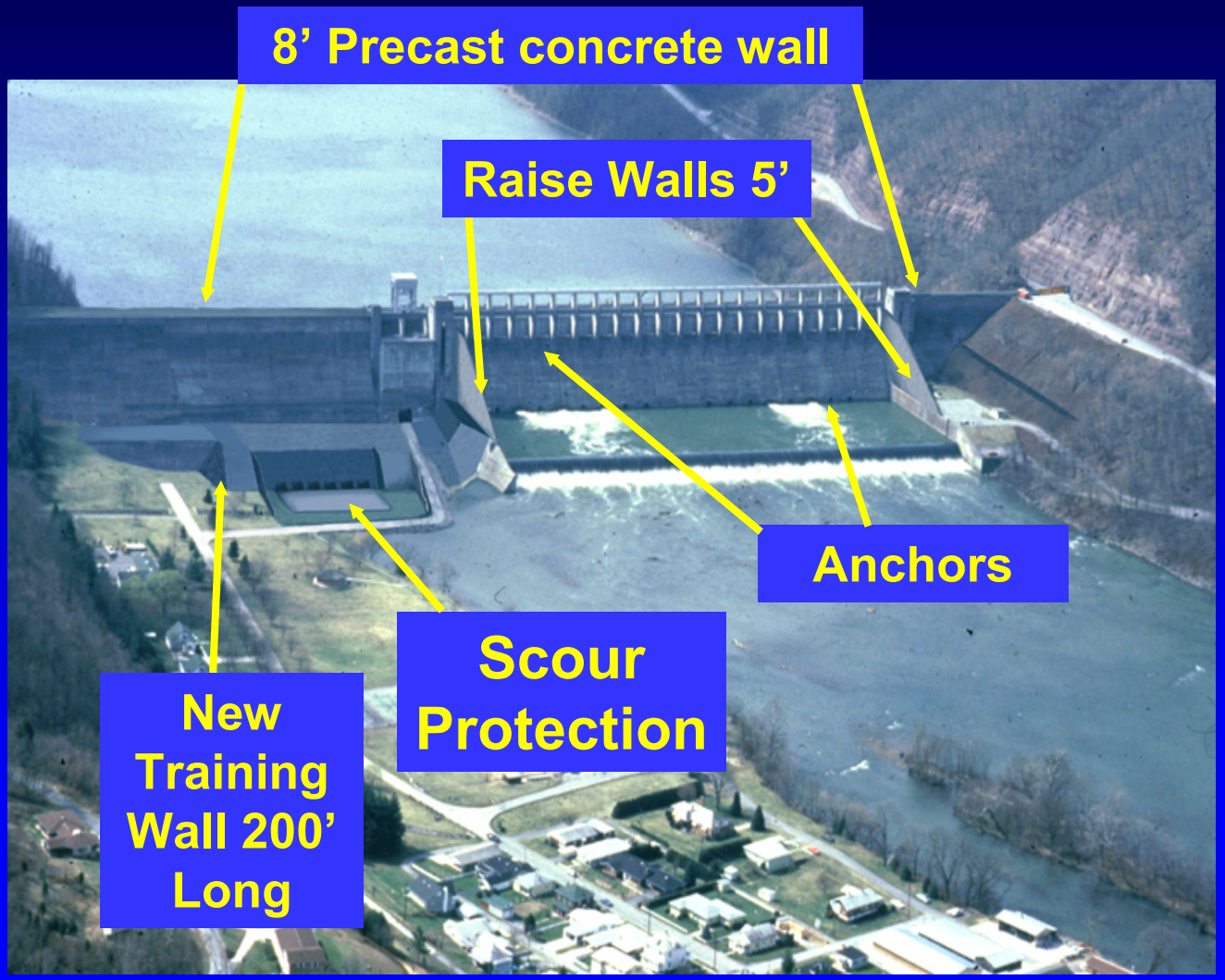
Bluestone DSA – Phase 2B

- **Awarded 31 May 2005**
- **Brayman Construction Corporation**
- **$30,000,000**

Bluestone DSA – Phase 2B



Bluestone DSA – Phase 2C



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Lessons Learned from the Field Anchor Study

- **Corrosion Protection**
- **Drill Hole Alignment**

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2002 Field Anchor Study

- **Install Four 61 Strand Production Anchors**
  - **Two from top of dam and instrumented (8°)**
  - **Two from face of dam (45°)**
  - **Corrosion protection is 10" corrugated polyethylene pipe 70-mil.**
  - **Bond zones forty feet.**
  - **Stressed lengths 130 to 200 feet.**

Field Anchor Study (cont.)

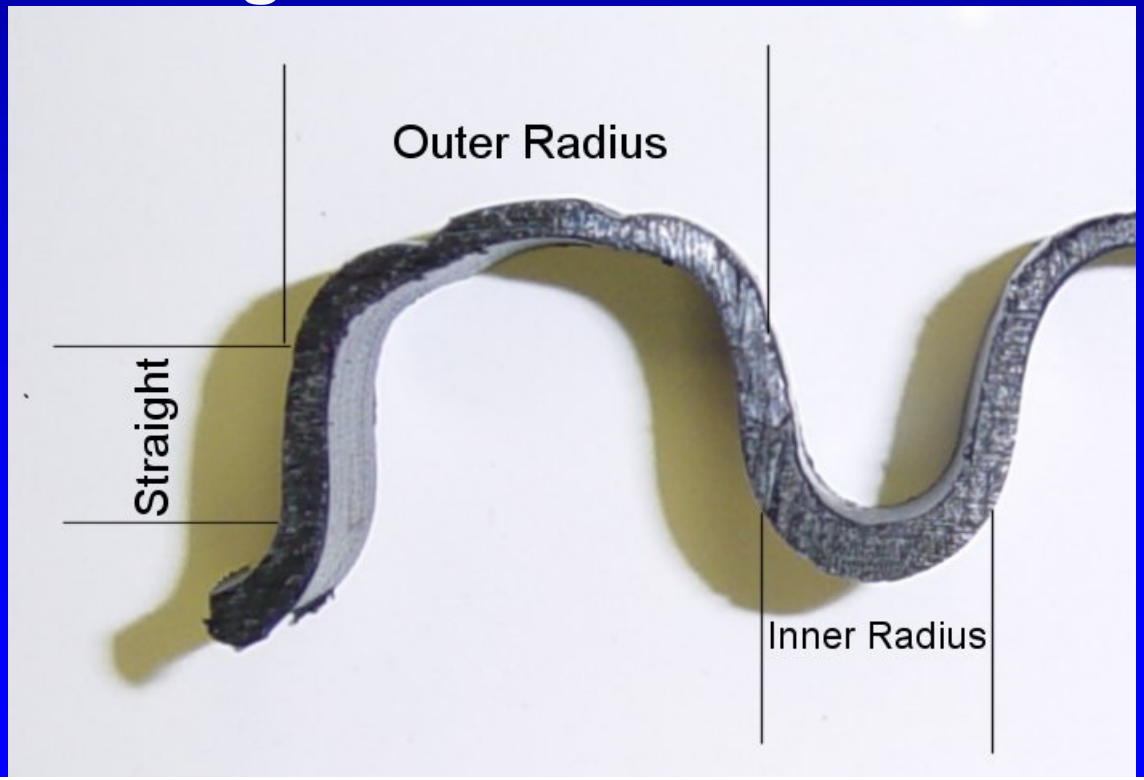
- **Install Eight Bond Stress Test Anchors**
  - **18 strand anchors in 5" holes**
  - **Bond zones 10'**
  - **Load to, or near, bond failure**
  - **4 lithologies tested**
  - **Parallel lab pull-out tests for comparison**

Lessons Learned from the Field Anchor Study

- **Corrosion Protection**
  - **Corrugated**
    - **Thickness**
    - **Handling**
  - **Sheathing**
    - **Polyethylene VS Polypropylene**
    - **Handling**

Corrosion Protection

- **Corrugated (Prinsco, Goldline)**
  - **70-mil (measured at the crown)**
    - **84-mil max**
    - **56-mil minimum**
  - **550 ft lengths**



Corrosion Protection

Corrugated collapses

- First lift 9 ft
- Second lift 30 ft
  - Collapses at 9 ft and travels up 8 ft
- All lifts reduced to 20 ft

Smooth Walled HDPE ½" Thick

HDPE Welded

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Corrosion Protection

Corrosion Protection

- **Corrugated** (Prinsco, Goldline)
  - 4-mm (157-mil)
    - Manufactured in maximum 60 ft sections
- **Smooth Wall** (CPChem, Driscoplex 4100
  - 0.5 inch

Corrosion Protection

- **Smooth Wall Collapse**
  - **First lift 10 ft**
  - **Second lift 41ft**
  - **Third lift 119 ft (to the surface)**
    - **Collapse at 51.5 ft**

Corrosion Protection

- **Critical buckling pressure for 10” diameter, 70-mil corrugated: 19 PSI**
- **Critical buckling pressure for 10” diameter, 157-mil corrugated: 59 PSI**
- **Critical buckling pressure for 10” diameter, 0.50-inch smooth: 19 PSI**

Corrosion Protection

Specifications call for a 100-mil corrugated

- **Critical buckling pressure for 10” diameter, 100-mil corrugated: 39 PSI**

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Installation of Corrugated

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Installation of Corrugated

Specifications call for a simple falling head test on the installed, but ungrouted corrugated.

Loss of less than 2.75 gallons in 10 minutes at 5 psi head shall constitute a watertight encapsulation.

Corrosion Protection

Field Fix of Polyethylene


NICHOLSON
Safety First
NICHOLSON
9. 24. 20

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Tendon Installation

Corrosion Protection

Specifications call for a polypropylene hot-melt extruded coating. Polypropylene is much tougher than polyethylene sheathing but does cost more.

Alignment Tolerance Field Anchor Study

The scope specified a minimum drill tolerance of 1 in 150. Each drilled hole was surveyed for positional accuracy by the Baker-Hughes INTEQ using the Seeker™ Surveying System.

Survey accuracy

1 in 700 8-degree holes

1 in 300 45-degree holes

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Starter Guide

Sub-Bearing Plate and Trumpet

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Installation and Alignment

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Installation and Alignment

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Installation and Alignment

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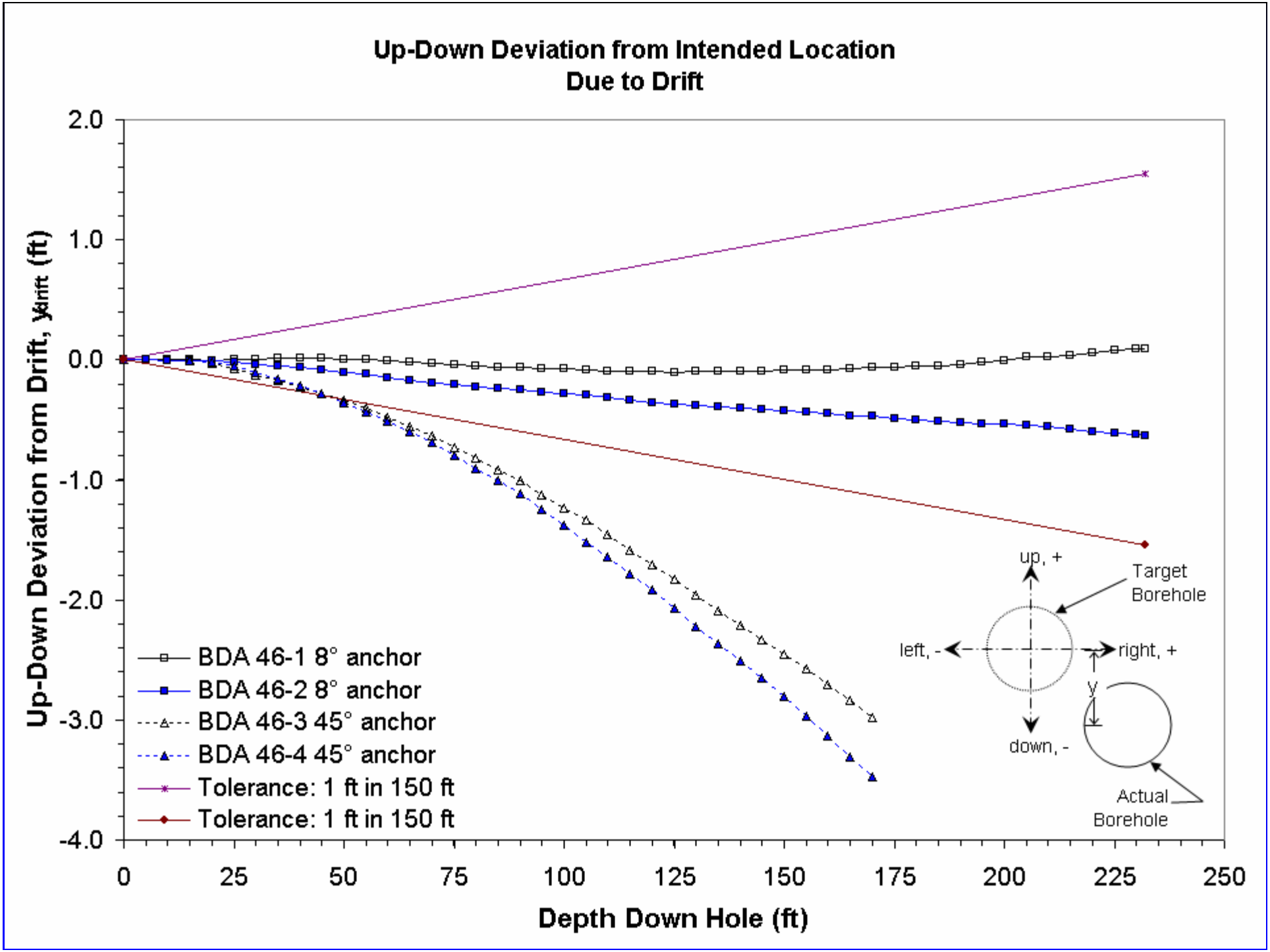
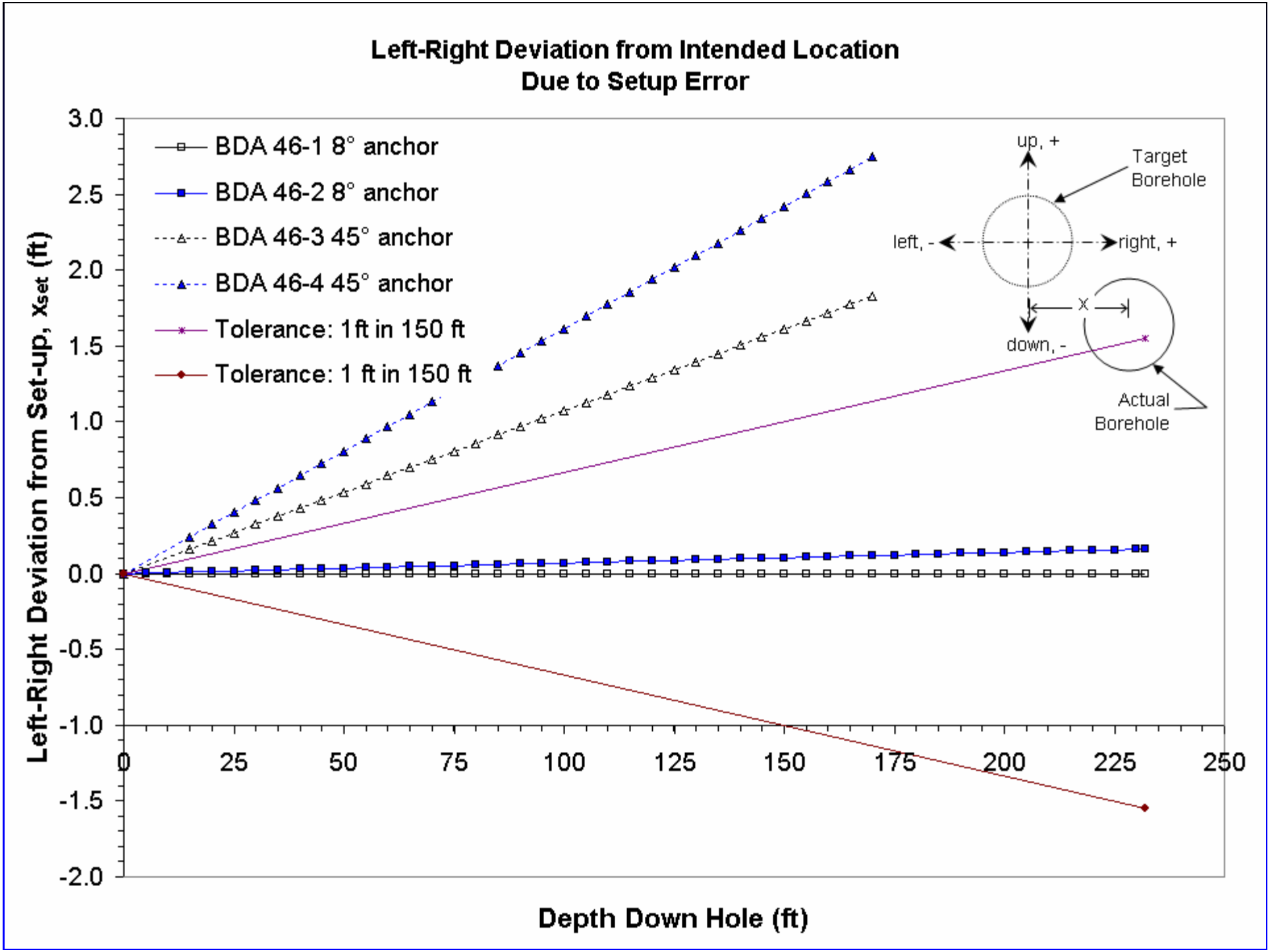
15” Hammer

Alignment Tolerances

- **Crest Anchors**
  - **1 in 110 feet**
- **Anchors on downstream slope**
  - **1 in 20 feet**


Up-Down Deviation from Intended Location
Due to Drift
Up-Down Deviation from Drift, y_{drift} (ft)
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0
25
50
75
100
125
150
175
200
225
250
Depth Down Hole (ft)
BDA 46-1 8° anchor
BDA 46-2 8° anchor
BDA 46-3 45° anchor
BDA 46-4 45° anchor
Tolerance: 1 ft in 150 ft
Tolerance: 1 ft in 150 ft
up, +
down, -
left, -
right, +
Target Borehole
Actual Borehole
y


Left-Right Deviation from Intended Location
Due to Setup Error
BDA 46-1 8° anchor
BDA 46-2 8° anchor
BDA 46-3 45° anchor
BDA 46-4 45° anchor
Tolerance: 1ft in 150 ft
Tolerance: 1 ft in 150 ft
up, +
Target Borehole
left, -
right, +
X
down, -
Actual Borehole
Left-Right Deviation from Set-up, xset (ft)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0
25
50
75
100
125
150
175
200
225
250
Depth Down Hole (ft)

Alignment Tolerances

Each bidder was given a video documenting the lessons learned from the 2002 field anchor study and a copy of a report on directional drilling and bore hole alignment measurement technology.

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Alignment Tolerances

Specifications call for each anchor hole to be surveyed using a rate gyrocompass, or equal equipment. If the hole alignment is not within these tolerances, the hole shall be backfilled and redrilled at the contractor's expense.

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Questions?

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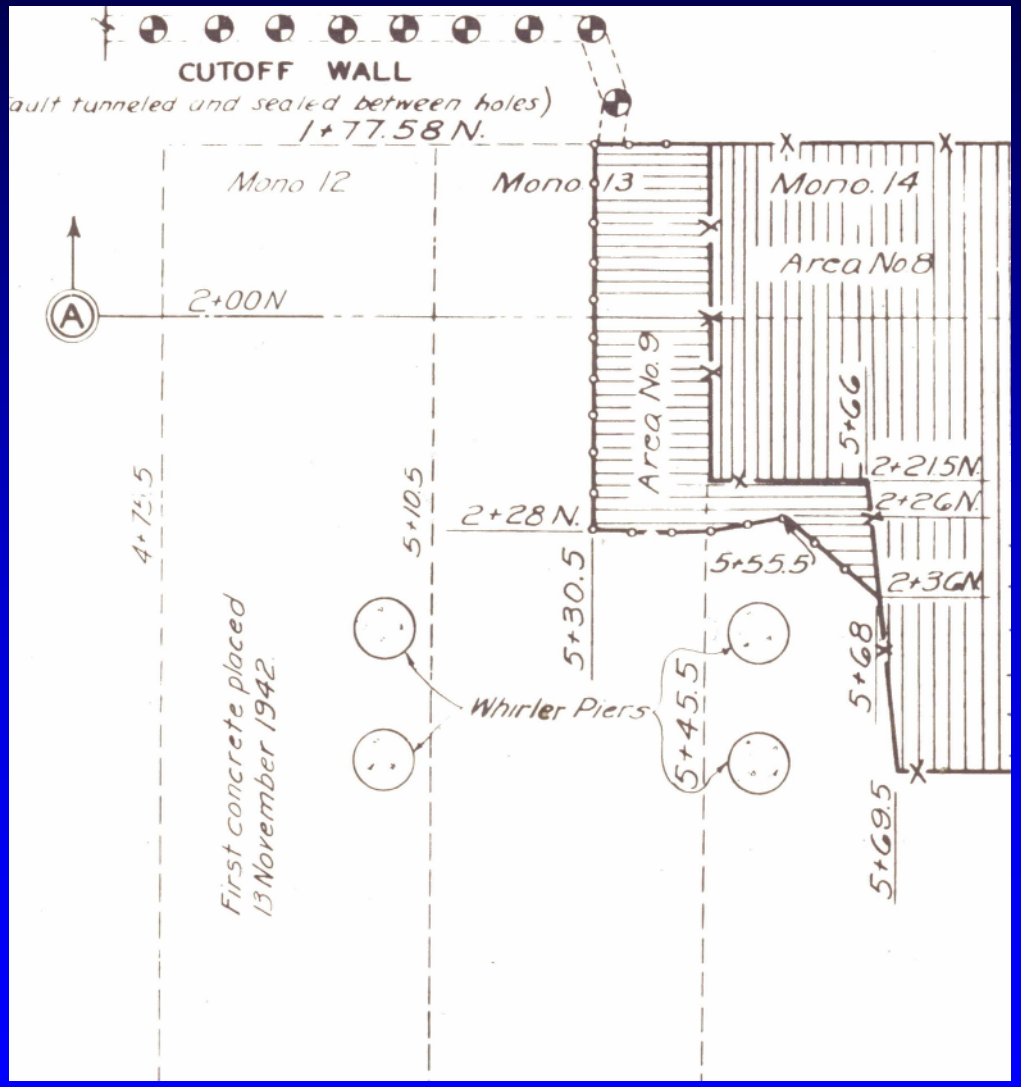
Foundation Conditions

- **Construction Events**
  - **Fault was only partially removed from monoliths 13 and 14**
  - * **Fault was not removed from monoliths 10 through 12**



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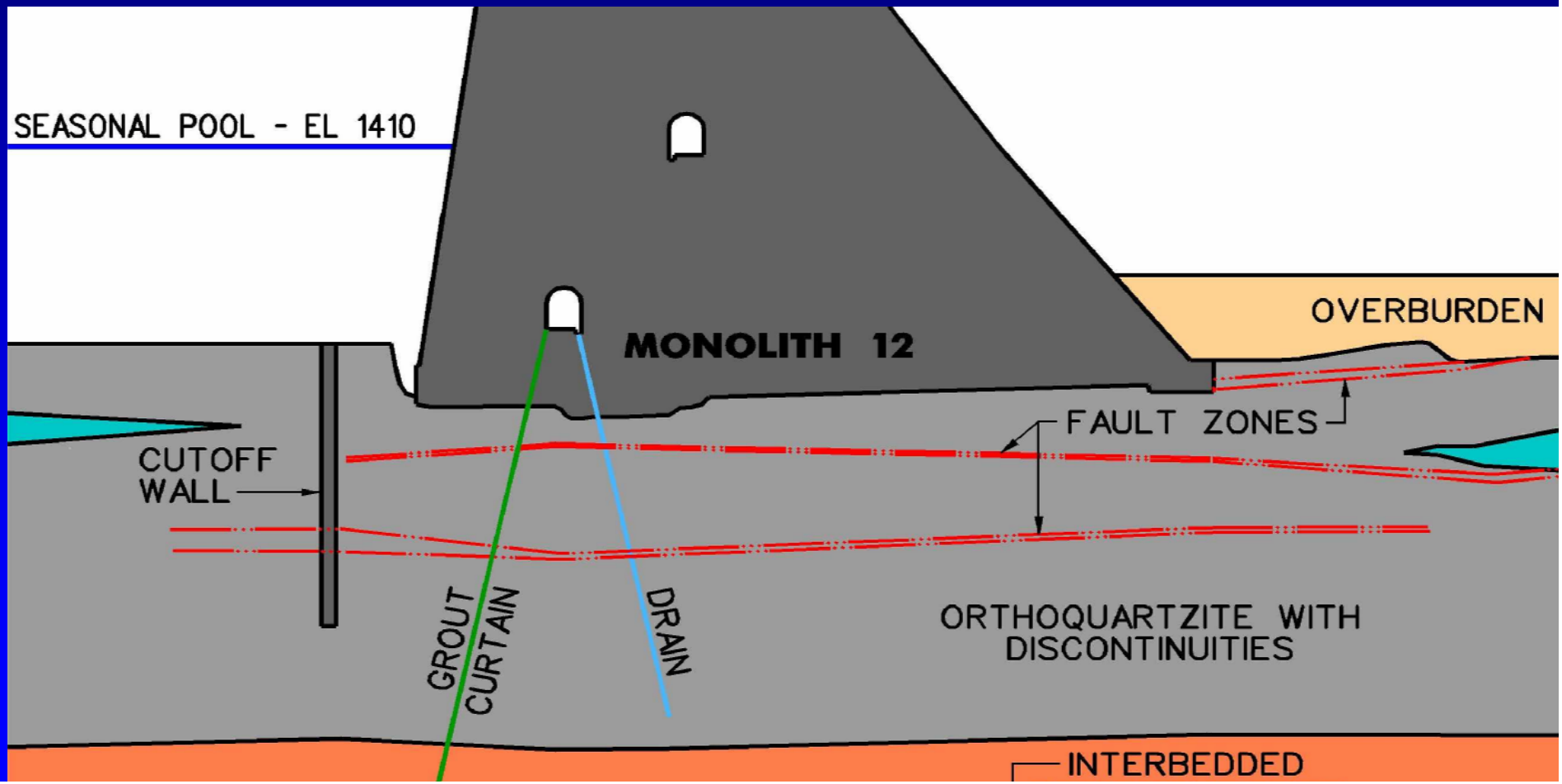

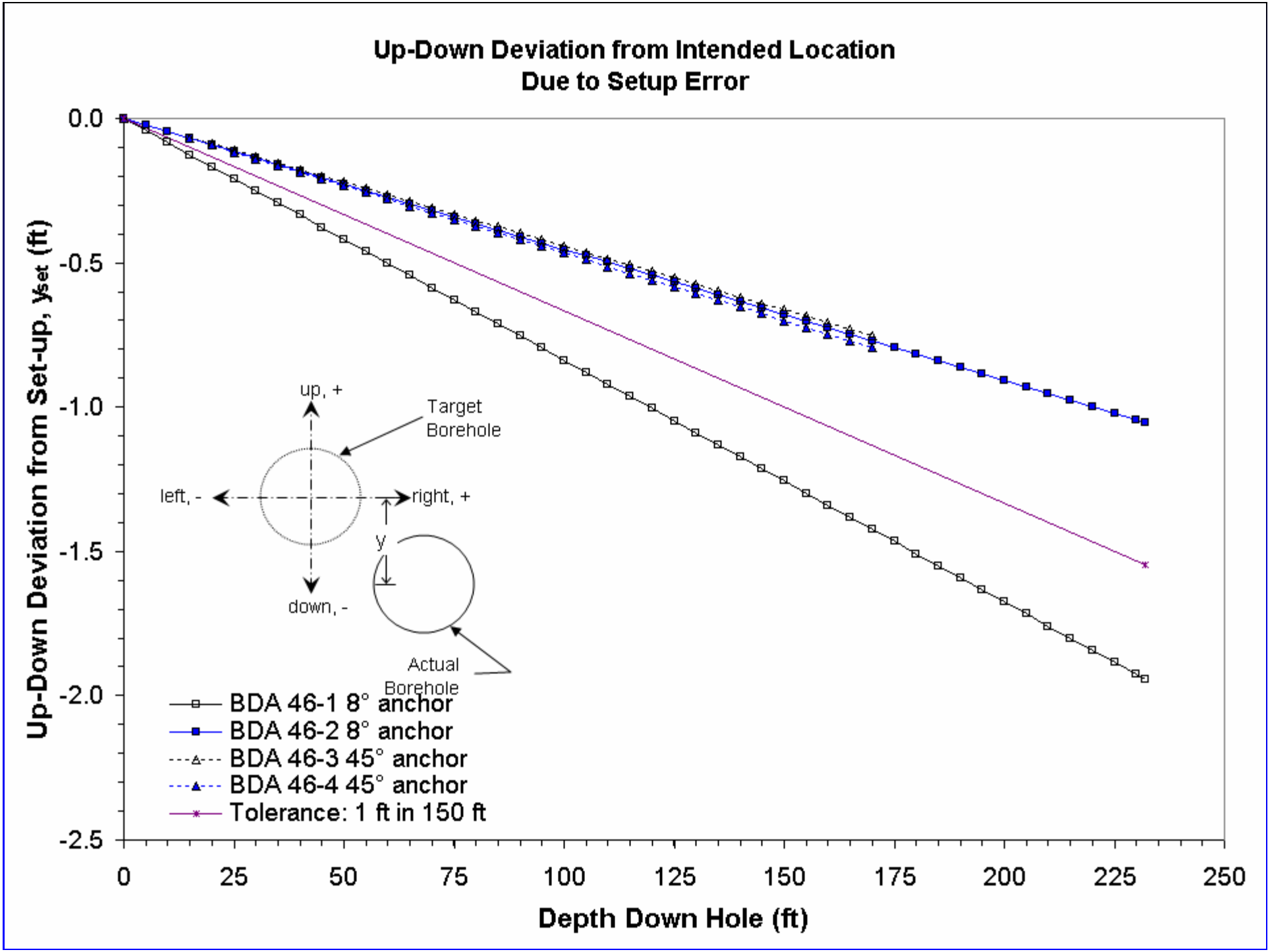
Up-Down Deviation from Intended Location
Due to Setup Error
Up-Down Deviation from Set-up, yset (ft)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0
25
50
75
100
125
150
175
200
225
250
Depth Down Hole (ft)
up, +
Target
Borehole
left, -
right, +
y
down, -
Actual
Borehole
BDA 46-1 8° anchor
BDA 46-2 8° anchor
BDA 46-3 45° anchor
BDA 46-4 45° anchor
Tolerance: 1 ft in 150 ft