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Kentucky Lock Addition Downstream Middle Wall Monolith Design

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Presentation Outline

- Project Overview
- Downstream Float-In Cofferdam
- Monolith Design
  - Seismic Criteria
  - Stability Analysis
  - Thermal Considerations
- Construction Issues

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Project Overview

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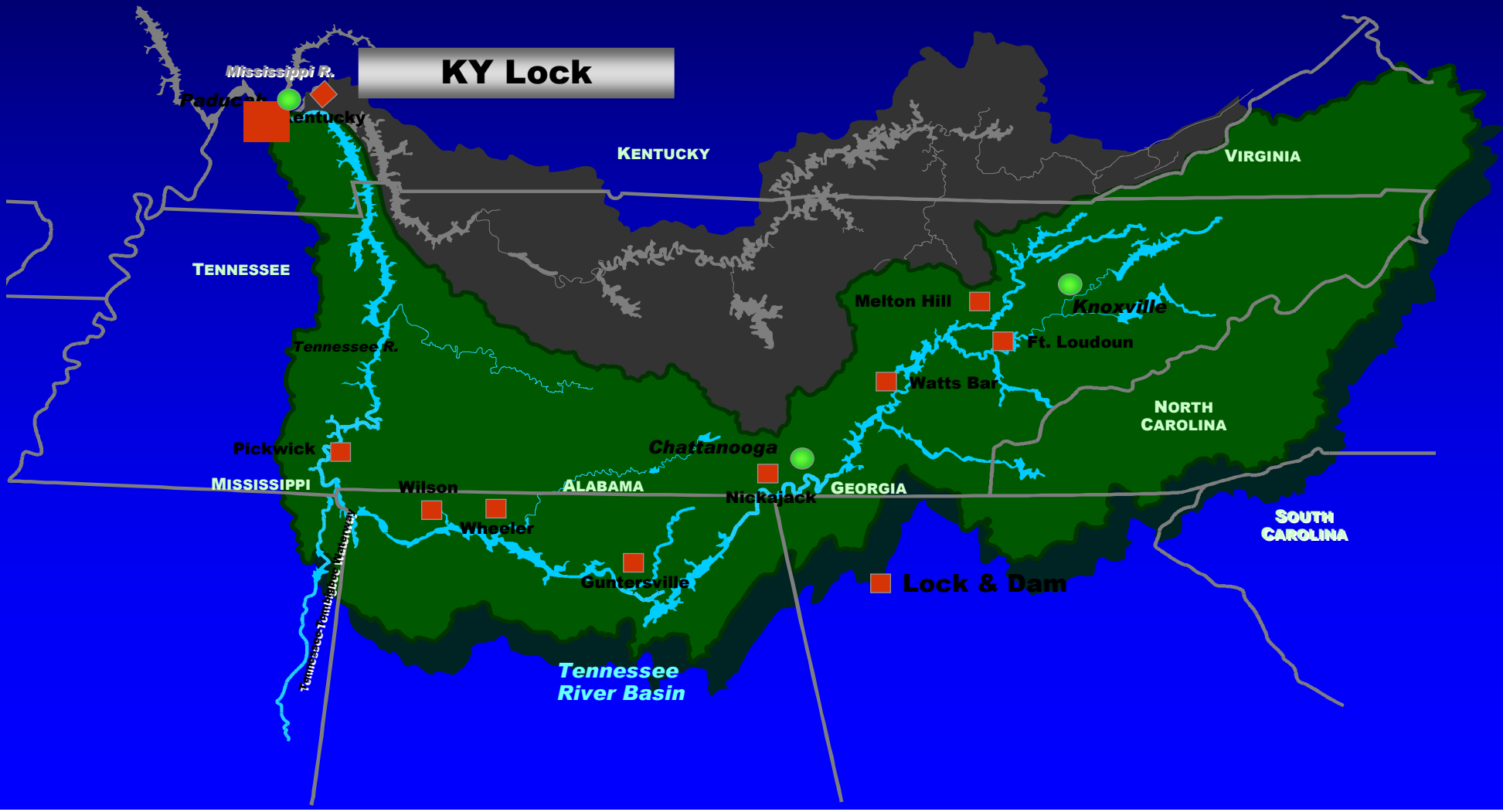
Kentucky Lock Location



Project Components

- **New 110’x1200’ Lock Landward of Existing 110’x600’ Lock**
- **Relocations of KY Hwy 62, P&L Railway, TVA Powerhouse Access, and TVA Transmission Towers**

Project Schedule & Cost

- Construction began FY98
- Lock and DS Cofferdam Construction from FY08 through FY18 or beyond based on current funding stream
- Total project costs are currently $639M

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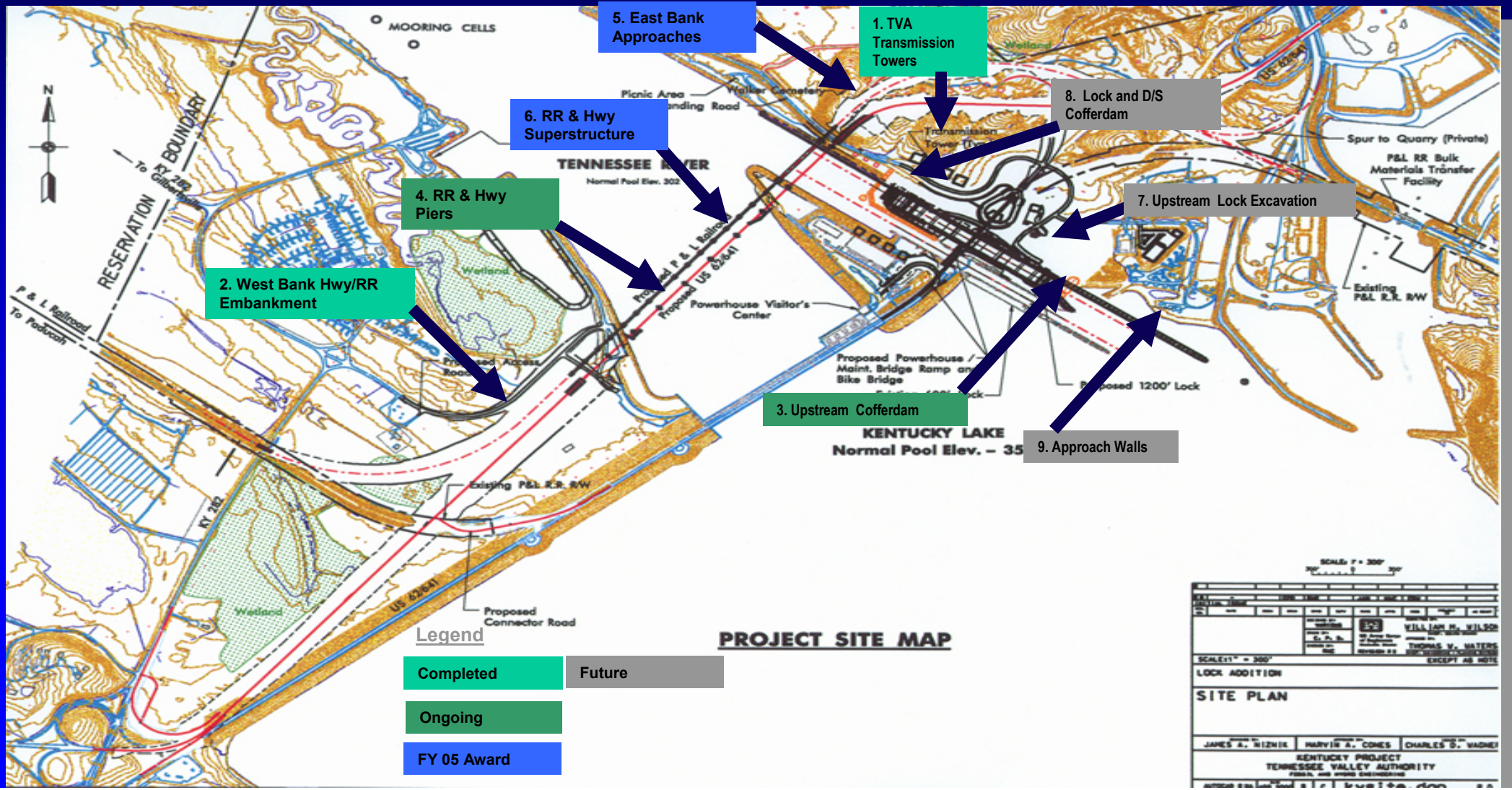
Construction Contracts



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Existing Project Site

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Pool, Lock and Cofferdam Elevations

Pool Levels

• Headwater:	Minimum Normal	Elev. 354
	Maximum	Elev. 375
• Tailwater:	Minimum	Elev. 300
	Maximum Design	Elev. 344

Lock Elevations

• Chamber:	Top of Wall	Elev. 382
	Lock Sills	Upper Elev. 335
		Lower Elev. 285
• Approach Walls:	Upper	Elev. Varies (Floating)
	Lower	Elev. 345

Cofferdams

• Upper Cofferdam:	Top of Protection	Elev. 375 (Top of Spillway Gates)
• Lower Cofferdam:	Top of Protection	Elev. 343.5 (25 Year Frequency)

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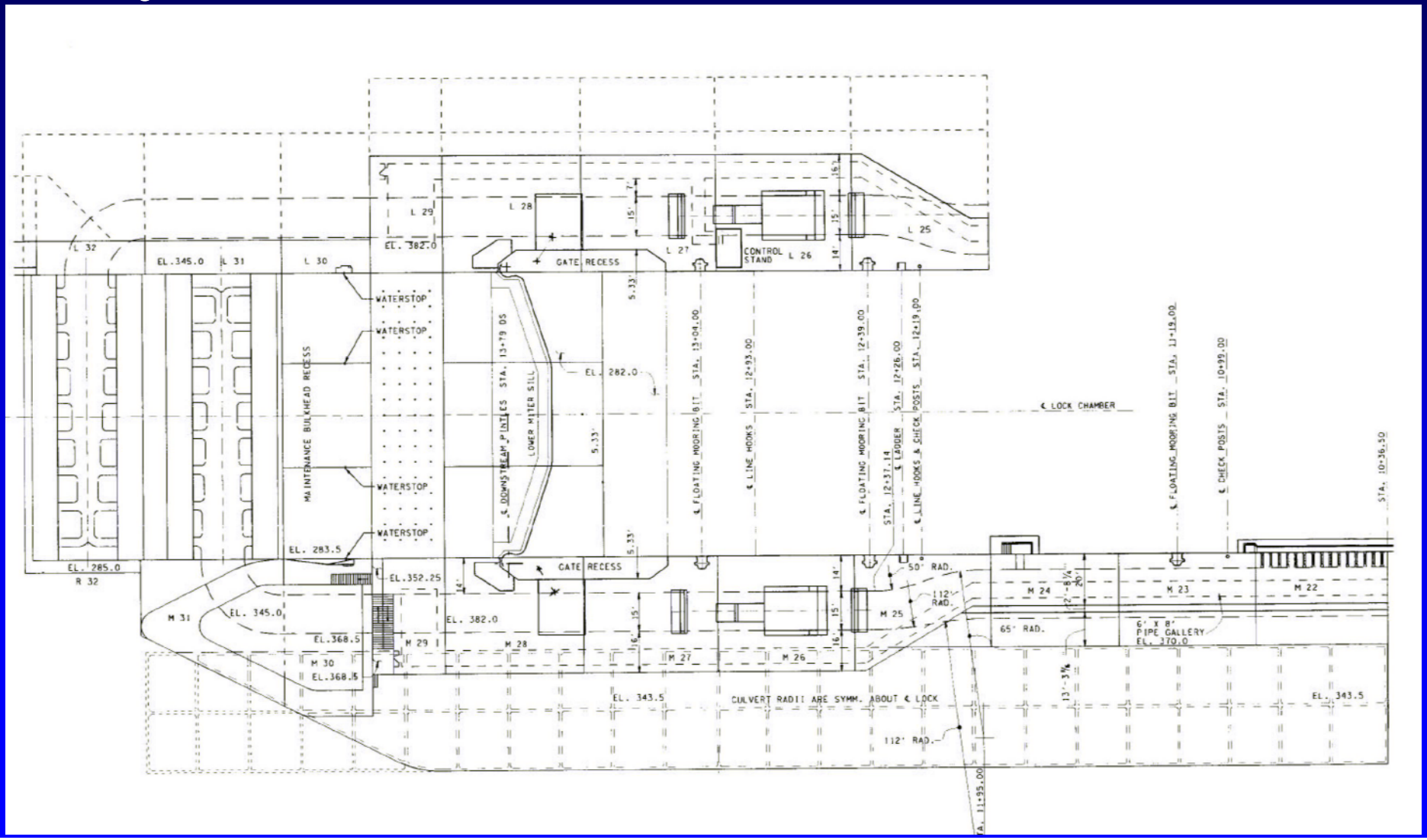
Downstream Monoliths



PDT Members

- TVA – Owner
- Nashville District – Lock O&M and Project Management
- Bergmann Associates, et. al. – Downstream Cofferdam Design
- Huntington District – Design of DS Monoliths and Sills
- Many others involved in the overall design of the project

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Downstream Cofferdam

Design

- Design of the Downstream Cofferdam was contracted to a joint venture of Bergmann Associates and Ben C. Gerwick with D'Appolonia Engineering
- Design completed in FY03
- Combination of precast concrete float-in with tremie and cast-in-place in-fill, conventional sheet pile cellular, and tied Z-pile structures

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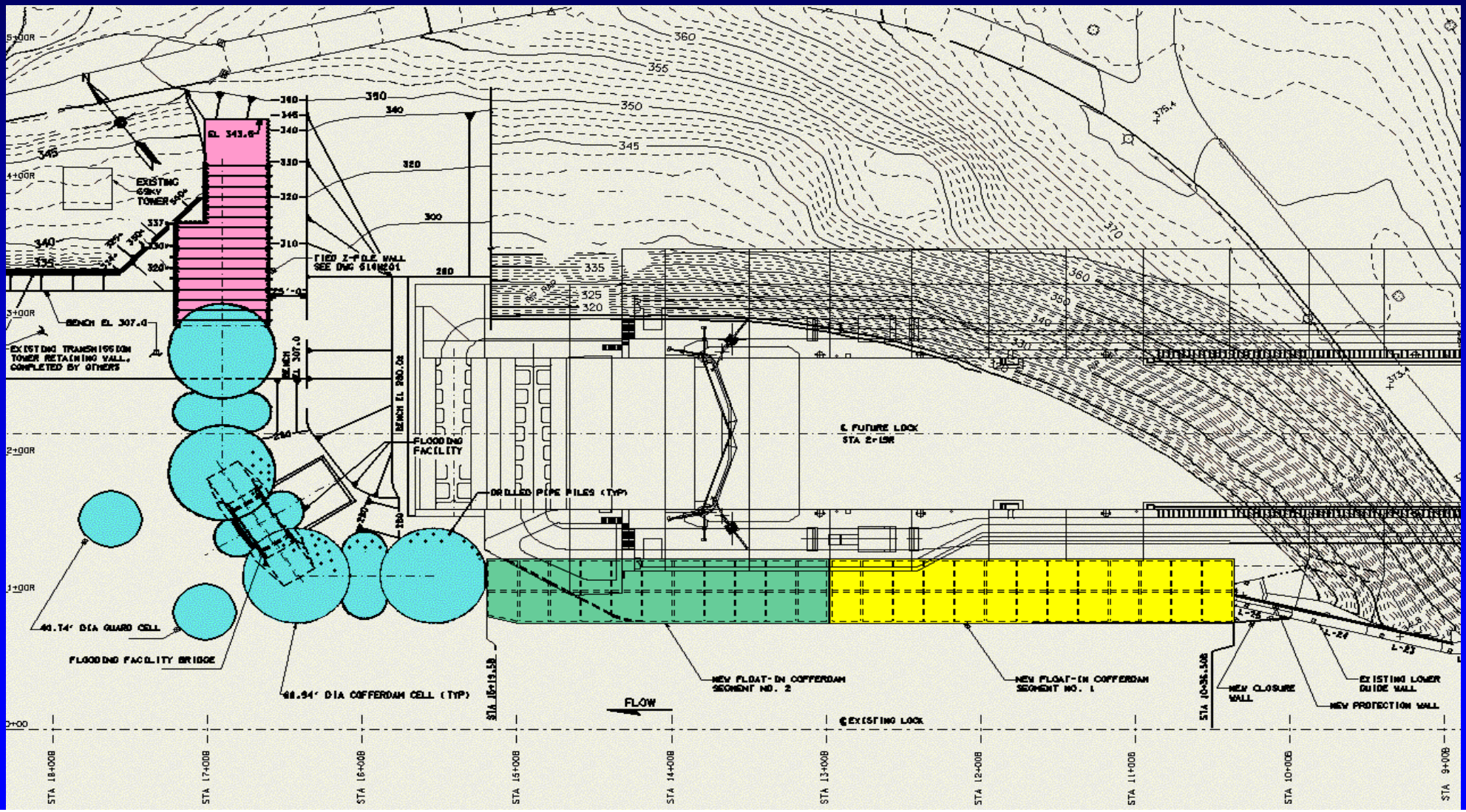
DS Cofferdam Plan



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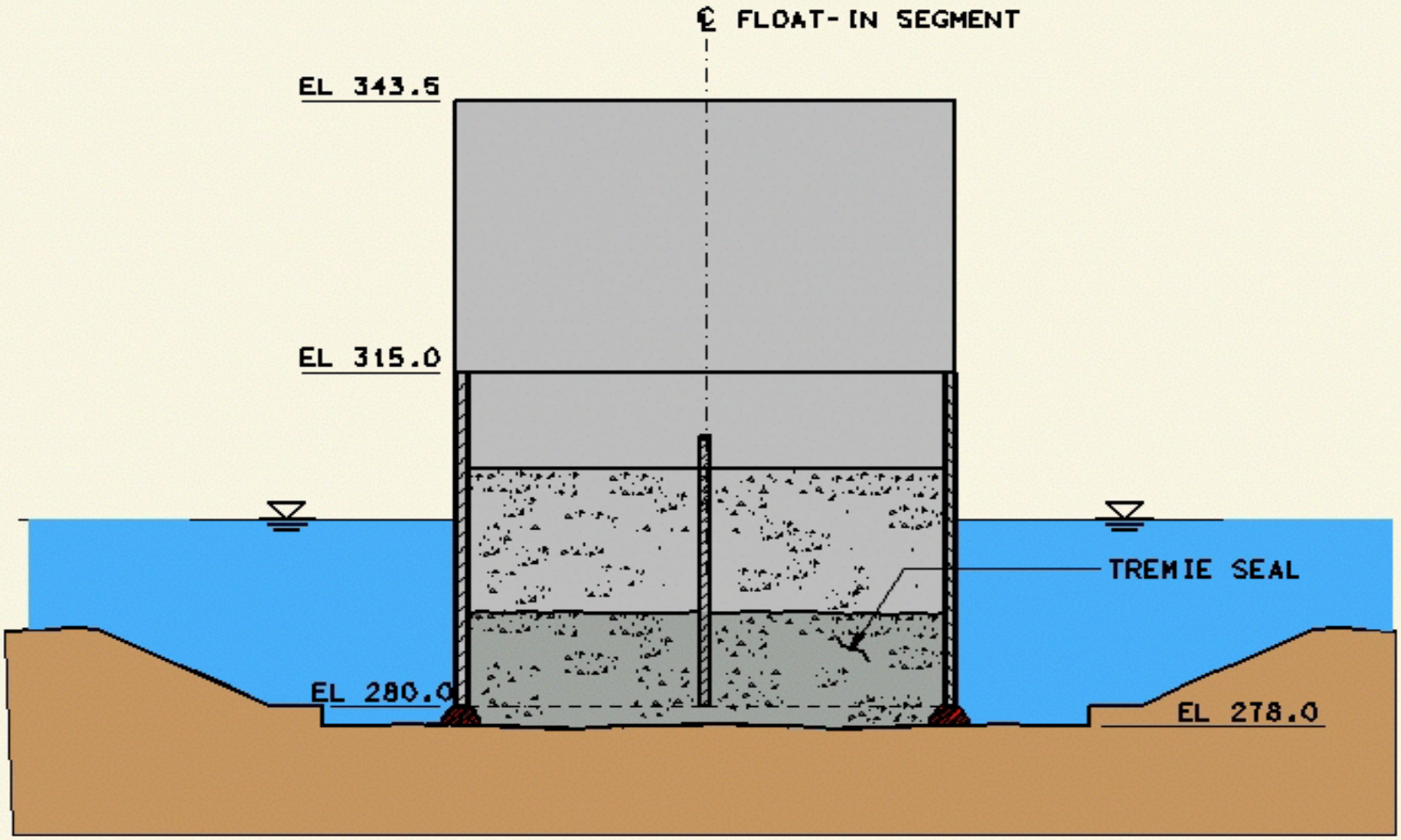
Typical Cofferdam Section



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Monolith Design

- **Seismic Criteria**
- Stability Analysis
- Thermal Considerations

Seismic Criteria

- **Two sets of criteria for design**
  - TVA – “Federal Guidelines for Earthquake Analyses and Design of Dams” and USCOLD
  - USACE – Earthquake Design and Evaluation for Civil Works Projects, ER 1110-2-1806

Seismic Criteria

- **TVA Criteria**
  - Probabilistic Approach for MCE – 10,000 year event
  - MDE = MCE
  - OBE = ½ MDE
  - Only Reservoir Retaining Structures to be designed to the MDE

Seismic Criteria

- **USACE Criteria**
  - Deterministic Approach for MCE
  - MDE/OBE based on Hazard Potential Classification – High, Significant, or Low
  - High Hazard – MDE = MCE
  - Significant & Low – MDE < MCE

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Seismic Criteria

Peak Horizontal Accelerations			
Agency	Hazard	MDE	OBE
TVA	Reservoir Ret.	0.25g	0.12g
USACE	High	0.25g	0.12g
	Significant	0.13g	0.05g
	Low	0.10g	0.05g

Seismic Criteria

- **Downstream Monolith Hazard**
  - TVA – Non-Reservoir Retaining Structure
    - Below Upstream Gates
    - Below Axis of Dam
  - USACE – Significant Hazard Classification
    - Little or no potential for direct loss of life
    - Loss of a major public facility

Seismic Criteria

- **Load Cases to Consider**
  - OBE
    - **TVA – 0.12g**
    - USACE – 0.05g
  - MDE
    - TVA – N/A
    - **USACE – 0.13g**
  - Since MDE ≈ OBE, only OBE was analyzed

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Monolith Design

- Seismic Criteria
- **Stability Analysis**
- Thermal Considerations

Stability Analysis

- 8 Load Cases Analyzed
- 3D Analysis on Miter Gate Monoliths
- 2D Analysis on Remaining Monoliths
- Monolith and Cofferdam treated as one structure
- Miter Gate Monolith and Monolith Immediately D/S analyzed as one Structure

Stability Analysis

- **Monolith/Cofferdam Combined Analysis**
  - Required for some load cases
  - Tied together with #7 bars at 18” spacing vertically and horizontally
  - Ties checked against seismic load case

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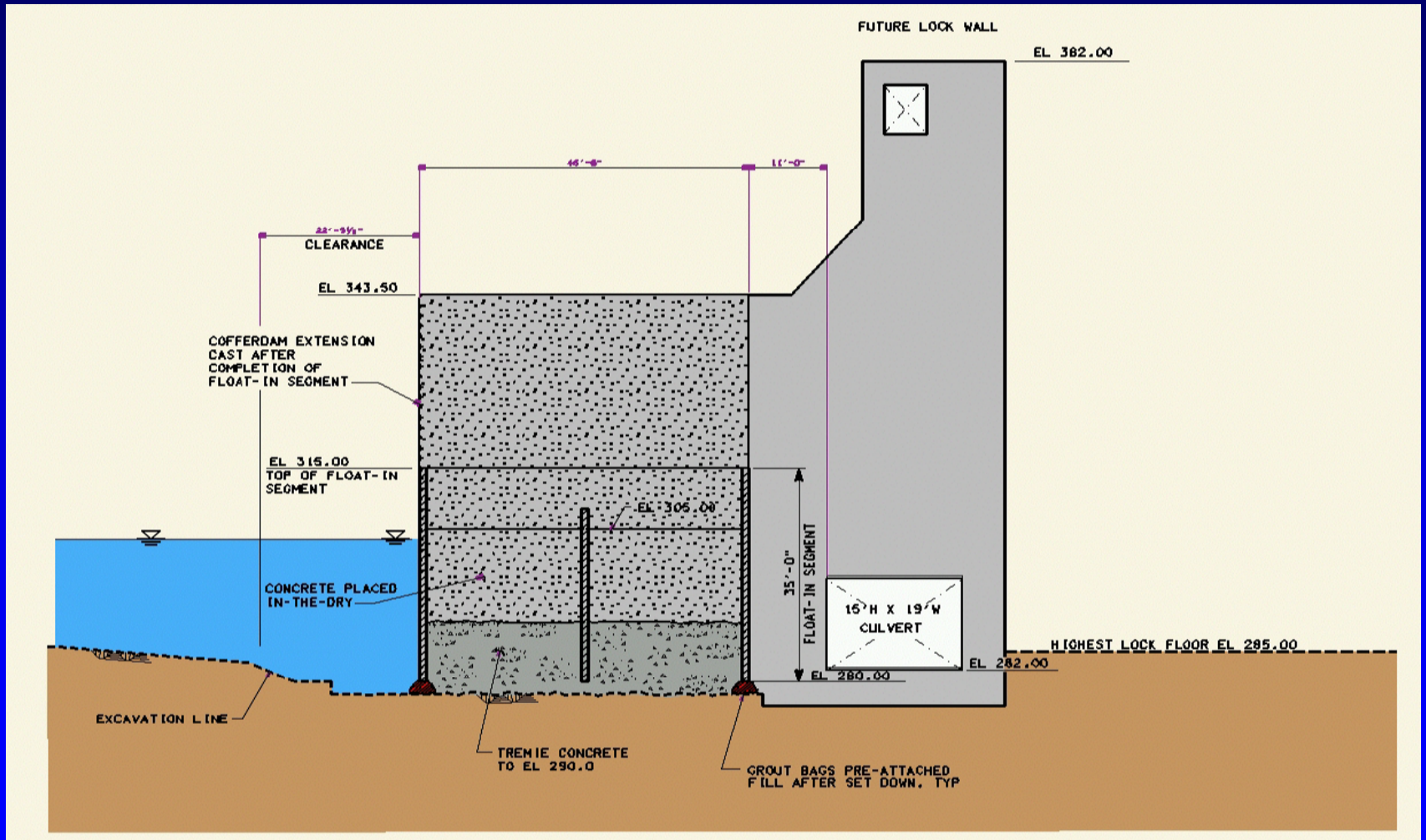
Stability Analysis



Stability Analysis

- **Seismic Analysis of Ties**
  - 1st Attempt – Non-Linear Time History Analysis using GTSTRUDL
  - Ties Modeled as Non-Linear Springs
  - Non-Linear Gap Elements at Concrete-Rock Interface
  - 1st Runs Took 15+ Days and Produced Useless Results
  - Next Attempt Exceeded the Computer's Addressable Memory Space

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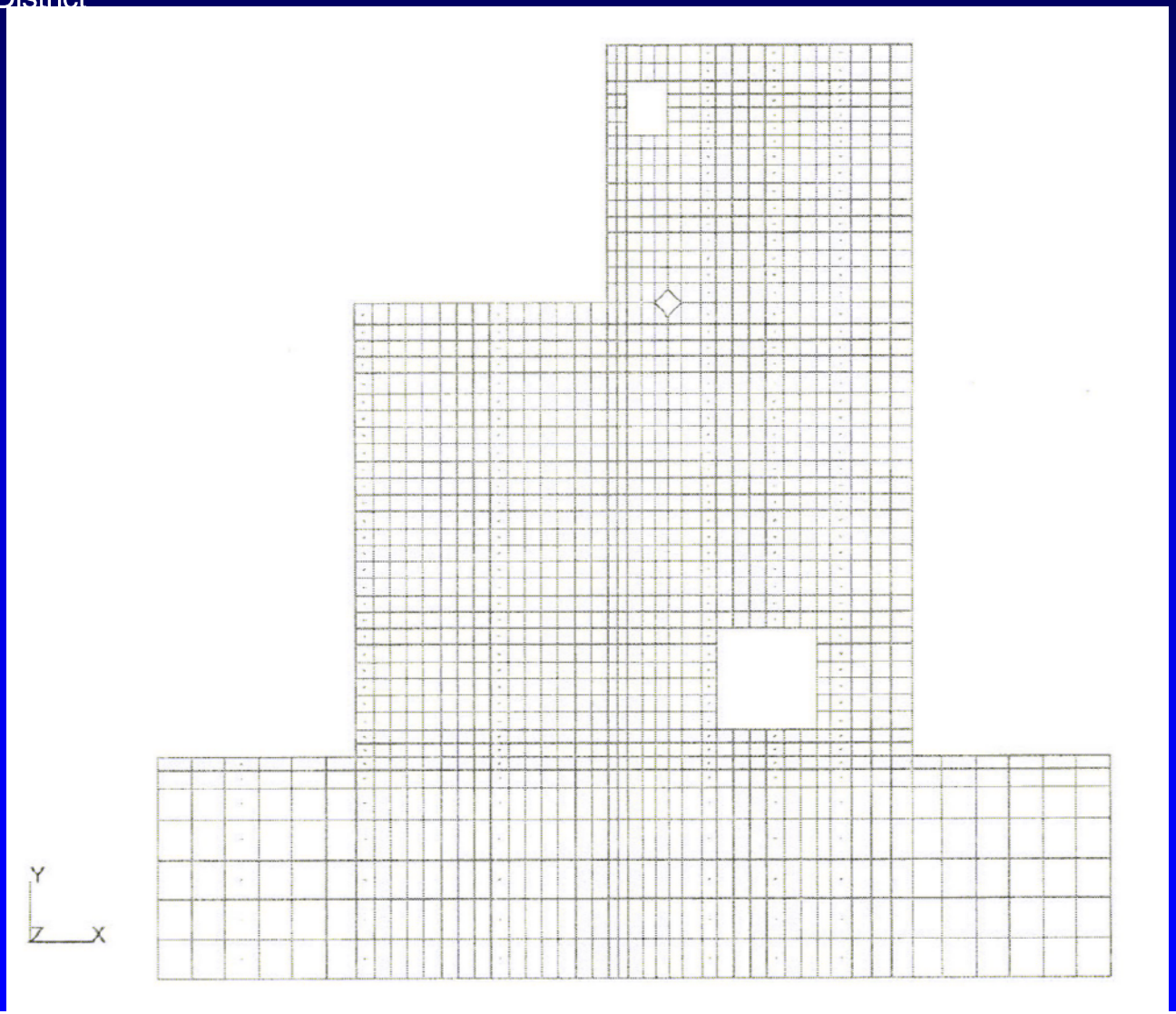
Stability Analysis



Stability Analysis

- **Seismic Analysis of Ties** (Cont'd)
  - Abandoned the Non-Linear Analysis
  - Response Spectrum Analysis of Individual Structures (Cofferdam and Monolith)
  - Modal Analysis using GTSTRUDL
  - Assumed Worst Case of Peak Response of Each Structure Occurring at Same Time and Completely Out of Phase
  - Results Gave a FS of About 3

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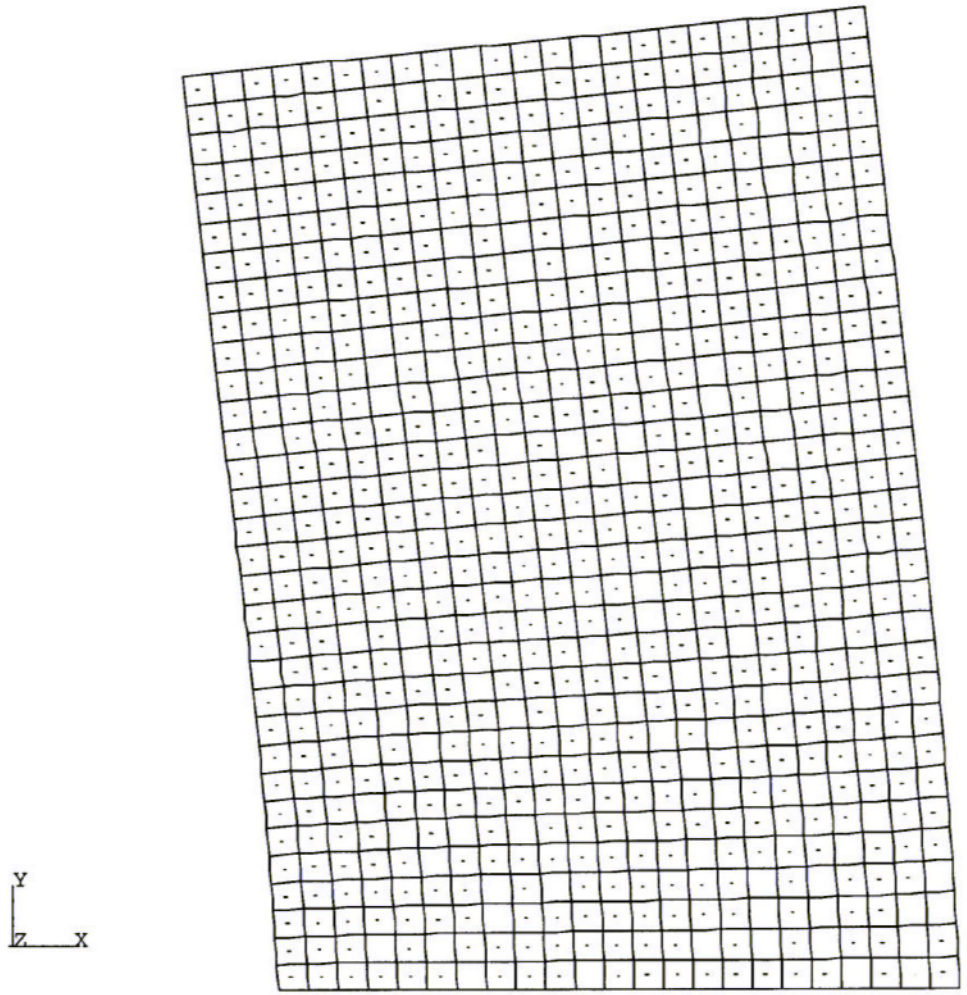
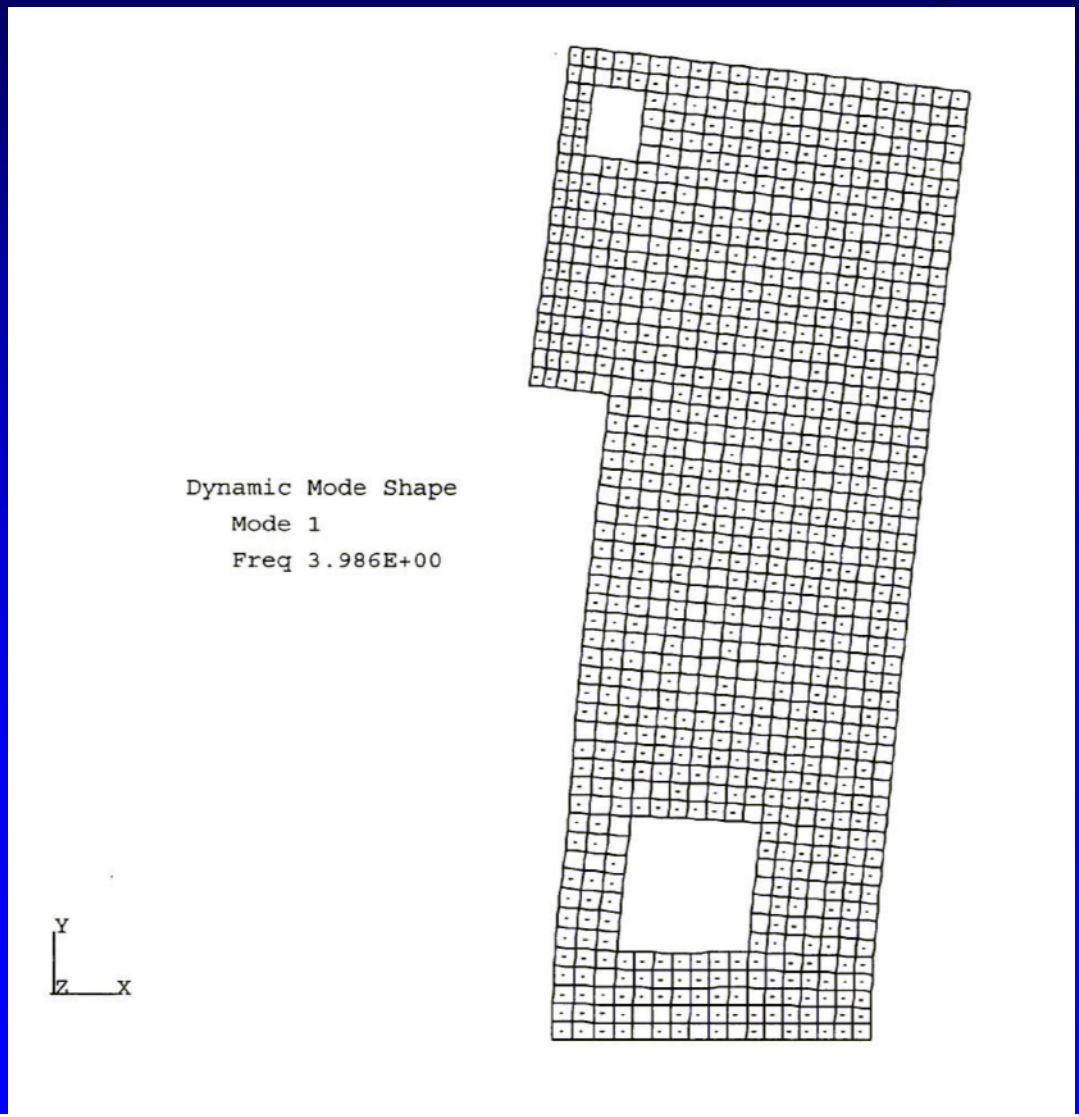
Stability Analysis



Stability Analysis



Stability Analysis

- **Miter Gate Monolith Design**
  - Does Not Meet Criteria for Some Load Cases When Analyzed Alone
  - Determined What Additional Force Required at D/S Joint to Meet Criteria
  - Designed a Shear Key to Carry this Force
  - Monolith Joint To Also Be Grouted

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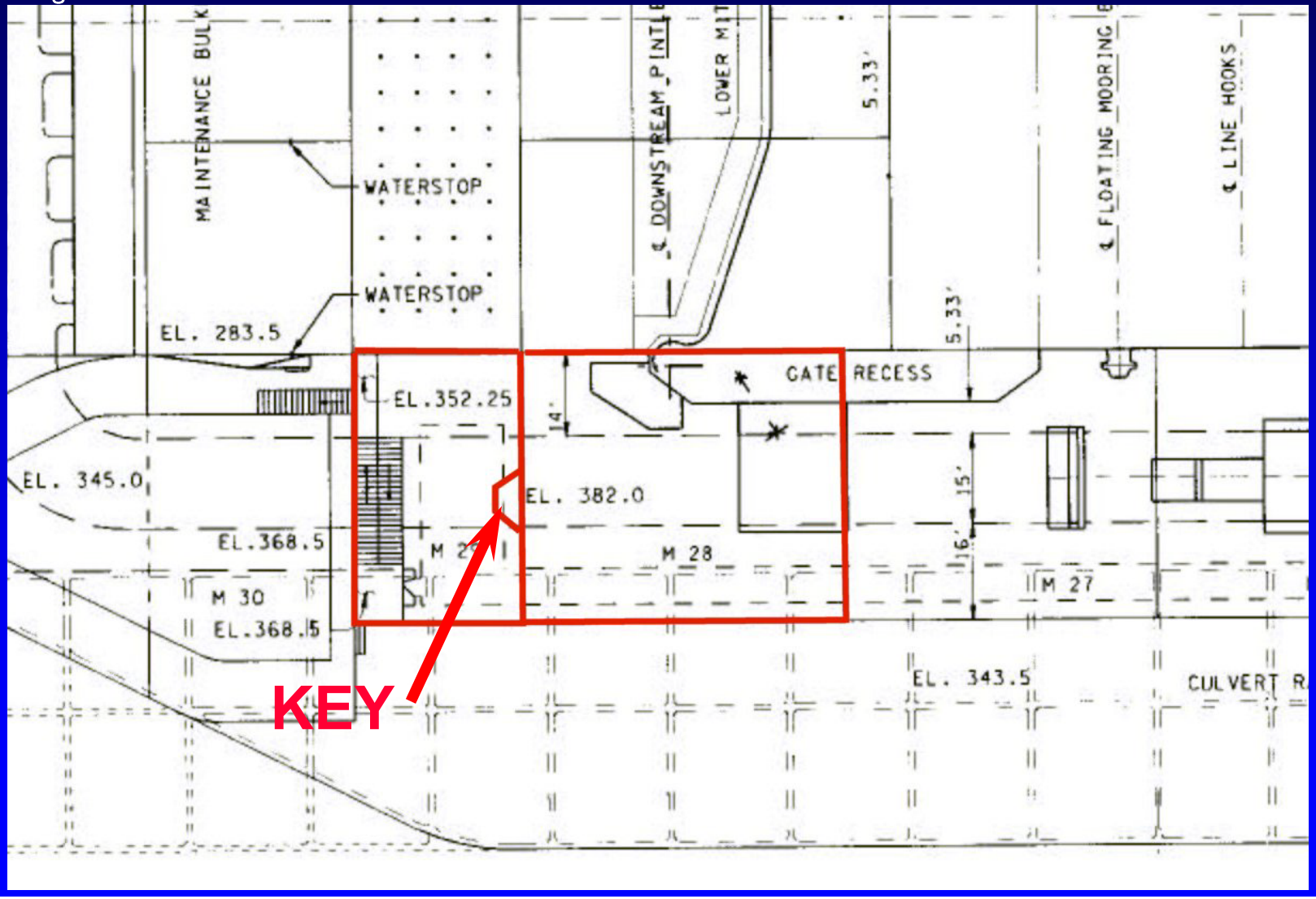
Stability Analysis



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Monolith Design

- Seismic Criteria
- Stability Analysis
- **Thermal Considerations**

Thermal Considerations

- **Two Options to Deal with Thermal Loads**
  - Separate the Structures with Bond Breaker and/or Insulation and Model Just the Lock Concrete
  - Model the Combined Structure Accounting for the Heat Transfer and Restraint Provided by the Cofferdam
- Second Option Required Based on Stability
- Thermal Analysis Performed by Black & Veatch

Thermal Considerations

- **Parametric Studies to Determine Lift Heights and Placement Restrictions**
- **Thermal Cracking Analysis**
  - First Step Was to Model the Construction Sequence of the Cofferdam
    - 10’ Tremie Placement
    - 5’ Lifts Every 7 Days
  - Lock Construction Then Began on Day 365
    - Approximately 5’ Lifts Every 5 Days

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Thermal Considerations

Thermal Considerations

- **Thermal Analysis Results**
  - Temperature and Shrinkage Steel Required
    - Around Culvert and Gallery
    - All Exposed Faces
    - Around the Chamfer at Top of Cofferdam
  - Didn't Account for Longitudinal Restraint from Cofferdam
    - Provide T&S Steel at This Face, or
    - Create Joints in Cofferdam

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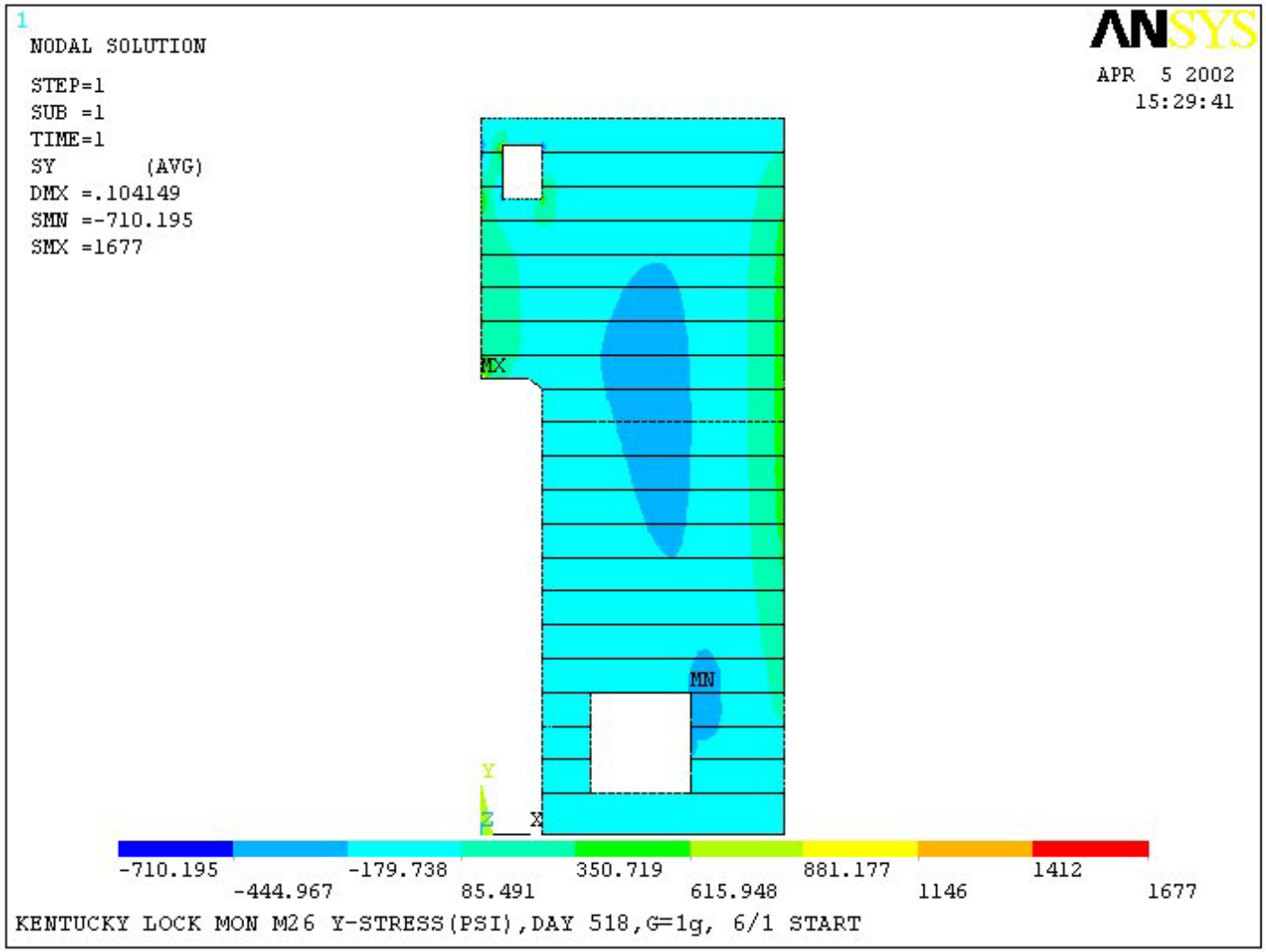
Thermal Considerations



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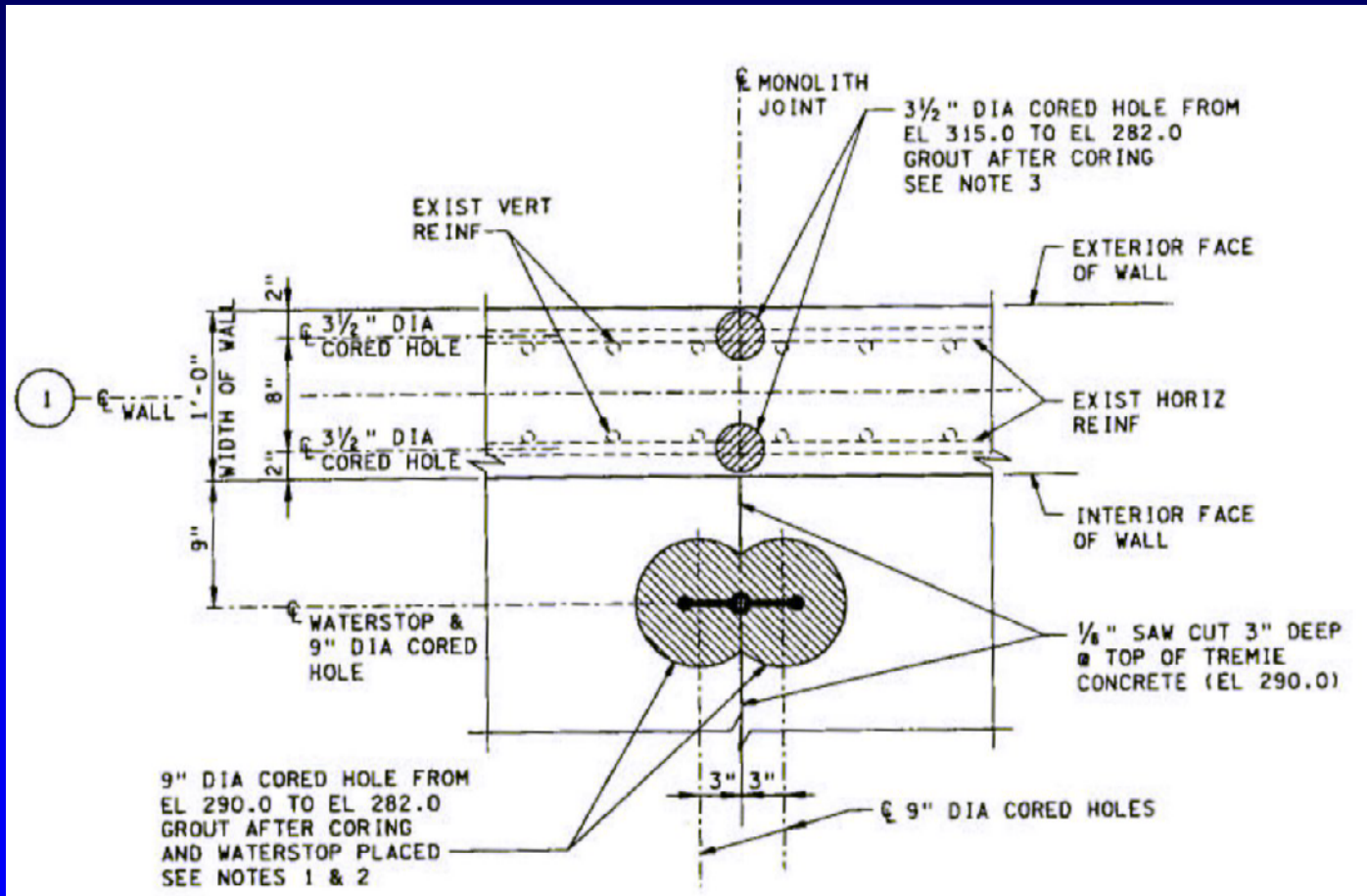
Thermal Considerations



FROM EL 282.0 TO EL 315.0

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Construction Issues

Construction Issues

- **Primarily Related to Foundation**
  - Excavation Adjacent to Cofferdam – Founding Elevation of Lock 2’ to 17’ Below Cofferdam Foundation
  - Presence of Solution Channels – One Known Channel That May Extend to Below Upstream Corner of First Monolith

Construction Issues

Construction Issues

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KY Lock Addition – D/S Middle Wall Monolith Design

Questions?

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