City of Kennewick Reservoir Evaluation & Replacement

Presented by: Erik Peterson, PE & Ethan Alton, PE, SE

Peterson Structural Engineers

Presentation to: AWWA-PNWS Spring Conference May 5th, 2023

About Peterson Structural Engineers

- Founded in 1967
- 29 Employees
  - 19 Licensed Professional Engineers
  - 5 Licensed Structural Engineers
- Offices in Portland, Tacoma, Eugene and San Diego
- 50+ years providing structural consulting with significant municipal experience
- Specialize in water storage structures

Your Presenters Today

Erik Peterson, PE

In over 25 years with PSE, Erik has served as a Project Manager, Structural Engineer, and Consultant for a wide variety of public and private clients. Erik's diverse range of experience includes a variety of structures from commercial and residential buildings, recreational facilities, pump stations, water reservoirs and treatment facilities, to fisheries, ports and docks, cofferdams and retaining walls.

Ethan Alton, PE, SE

Ethan is a Senior Project Manager at PSE with 9 years of experience. In his time with PSE, Ethan has proven himself in a diverse range of project types – he is a lead engineer in prestressed concrete reservoirs, has overseen large scale seismic evaluations of dozens of industrial/commercial buildings and is our company champion of wood-framed residential design.

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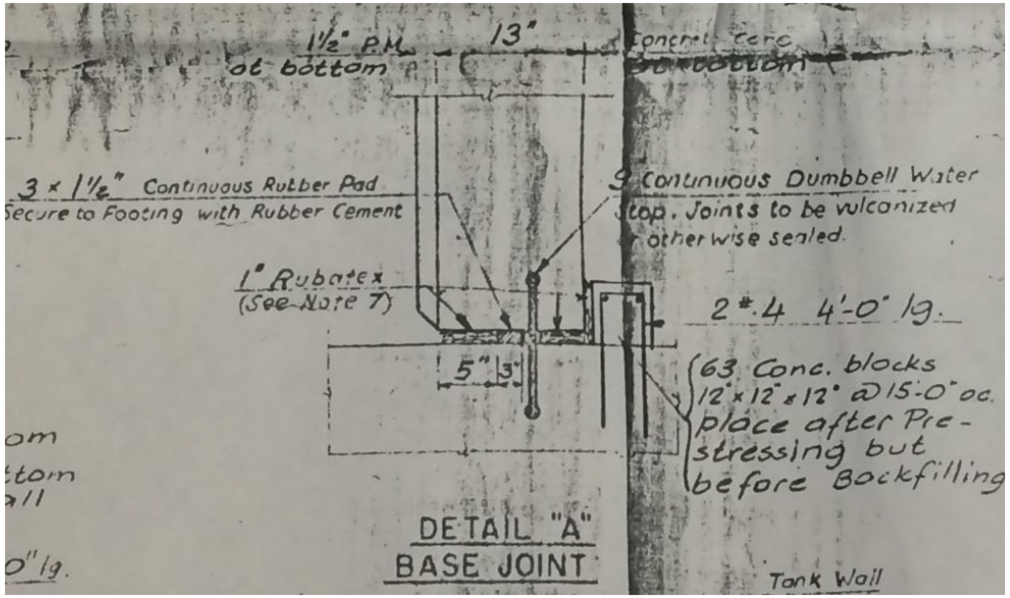
10.0MG Reservoir Evaluation

Structural Design & Construction History

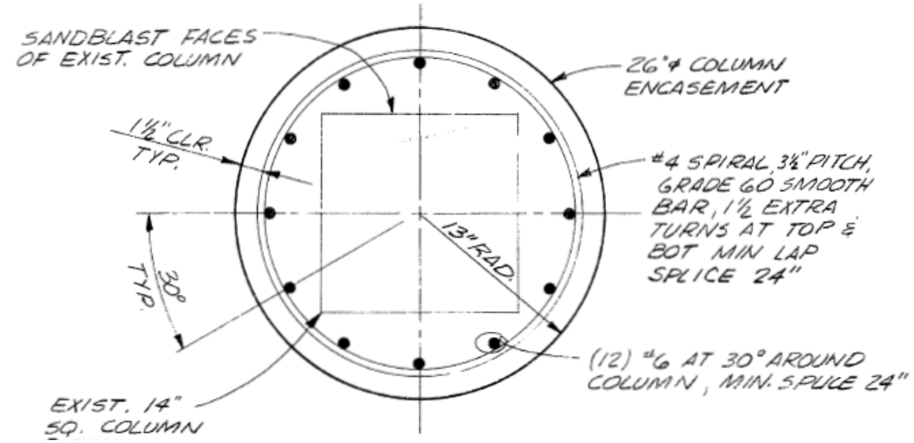


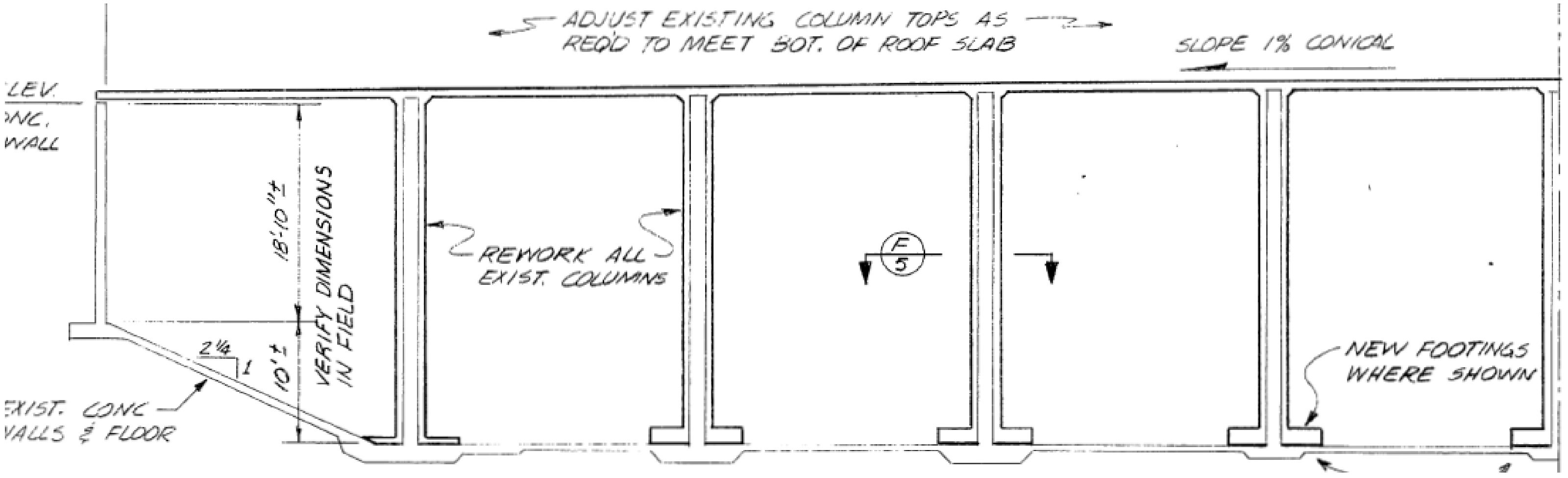
- Original Design and Construction circa 1959
- Partial "Hopper Bottom" Configuration, Concrete Slab
- Concrete Columns and Footings
- Base Isolated CIP Concrete Wall (no mechanical connection, shear blocks)
- Wire Wrapped Prestressing by PreLoad
- Original Roof was Wood Construction
  - Wood Beams, Joists and Decking
  - Wood Cripple Wall Atop Concrete Prestressed Wall

Structural Design & Construction History

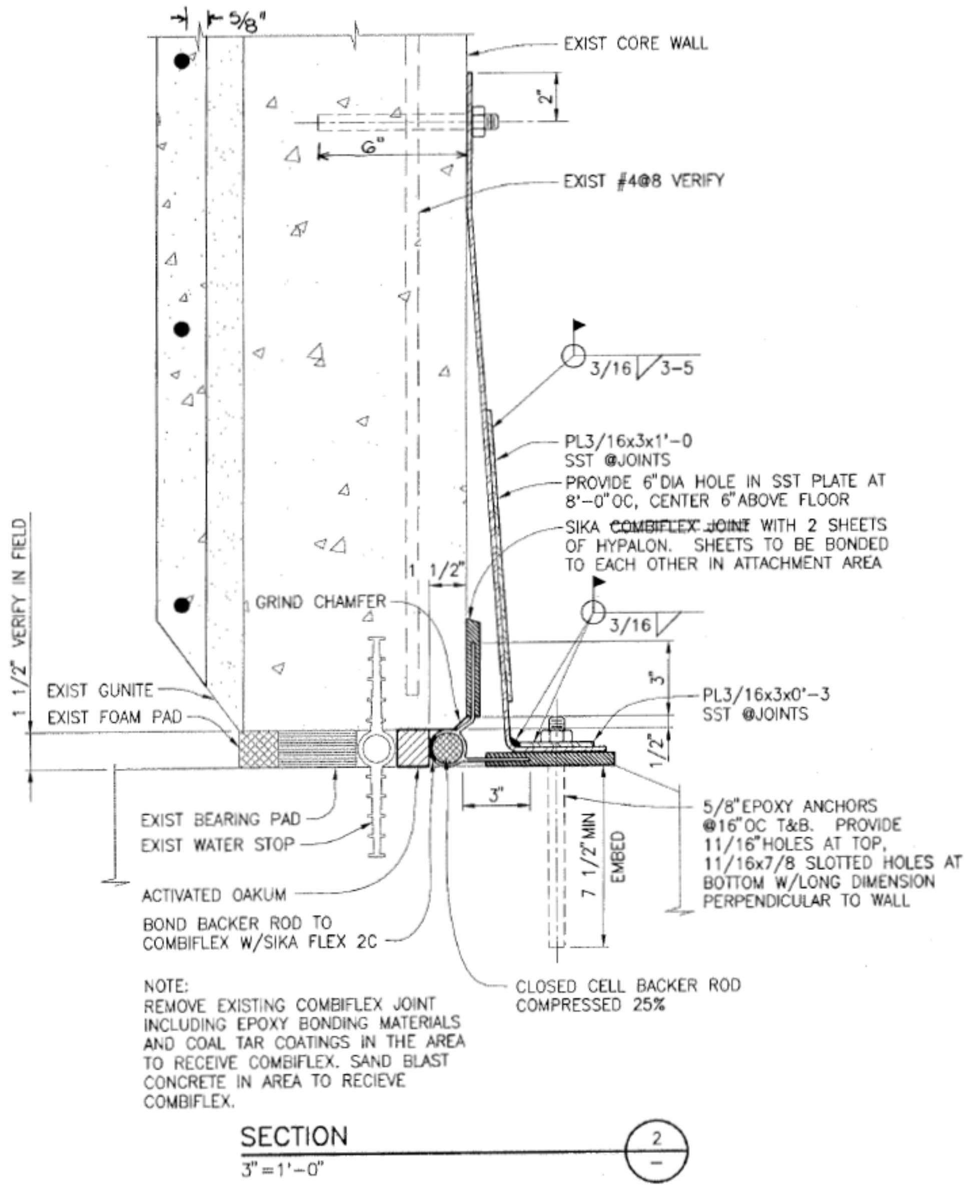
- In 1982 Wood Roof Removed
- New Concrete 2 -way Roof Slab Installed
- Concrete Columns Enlarged
- New Column Footings Added

- REMOVE EXISTING ROOFING AND ROOF SUPPORT STRUCTURE. ADJUST EXISTING COLUMN TOPS AS REQUIRED TO MEET BOTTOM OF NEW ROOF SLAB (EXIST. ROOF SLOPES 3% NORTH/SOUTH) SEE SPECIFICATIONS





Structural Design & Construction History



- In 2000 More Upgrades Performed
- Issues With Original 1959 Wire Wrapping Identified
- Seismic Performance Improvement at Wall Base Connection
- Additional Galvanized Strand Wrapping added by DN Tanks

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Wood Roofs on Reservoirs Commentary

- Historically Wood Roof Systems on Water Reservoirs Perform Poorly
- Consistently Wet Environment, Dew Point Differential Leads to Rot and Damage in Wood
- Water Quality Concerns can Exist from Wood Preservatives Leaching
- Wood Systems Lack the Robustness of Concrete or Steel Used in Wall/Floor/Foundation Systems
- Quite Common to See Wood Roof Service Life Being Less Than Half the Service Life of the Rest of the Structure

Evaluation Process and Findings

- PSE Performed Internal and External Visual Inspections
- Hammer Strike Testing of Shotcrete
- Observing In -Situ Conditions
- Perform Static and Seismic Analysis of Existing System Using Current Code Loads
- Generation of Conditions and Analysis Report
- Make Recommendations for Repairs/Upgrades or Replacement
- Generate Cost Opinions for Proposed Alternatives

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Primary Structural Issues

- Roof Slab Conditions the Primary Issues
- Ponding Caused by Concrete Creep

Primary Structural Issues

- Roof Slab Conditions the Primary Issues
- Column Punching Shear Failure

Primary Structural Issues

- Wall Base Upgrade Analytically Insufficient
  - Plate System Sufficient
  - Anchors in Concrete Insufficient
  - Changes in Anchor Design Codes
- Roof Slab Analytically Insufficient
- Columns Analytically Insufficient for Seismic
- Lack of Wall Top Connections for Seismic
- Insufficient Seismic Slosh Freeboard/Resistance

Upgrade Options and Considerations

CONCRETE ROOF SLAB– REPAIRS

- Limited Options For Repair
- Carbon Fiber Only Partial Solution
- Adding Concrete Thickness Exacerbates Other Issues
- Creep is Permanent Deflection, Can be Arrested but Not Reversed

WALL BASE CONNECTION – UPGRADES

- Retrofit Added Anchors Not Viable for Current Plate System
- Alternative Interior Mechanical Connections Intrusive and Expensive
- Alternative Exterior Mechanical Connections Expensive and Require Excavation

CONCRETE ROOF SLAB – REPLACEMENT

- Remove & Replace Concrete 2-way Slab (new columns & footings)
- Aluminum Dome/ Concrete Dome
- Metal Roof System
- Floating Roof System

Upgrade Options and Considerations

- Original Construction Over 50 years Old
- Systems Such as Domes and Floating Roofs Not Viable
- Cost of Demolition and Replacement of Concrete Flat Roof Estimated to be 75% of the Cost of a New Reservoir
- Fully Code Compliant Repairs Would Not Appreciably Extend Ultimate Service Life

Reporting and Recommendations

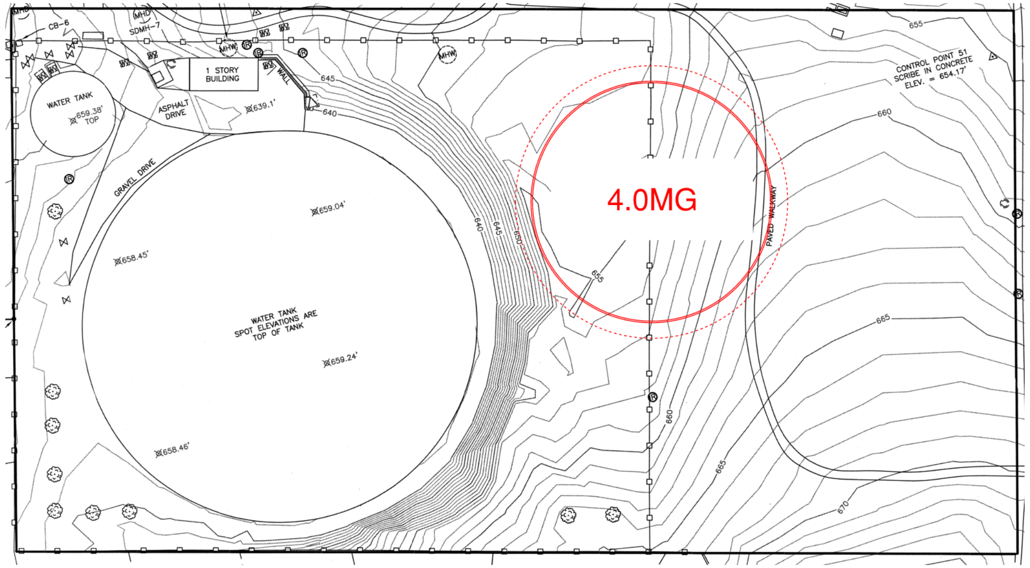
- Final Report Submitted to the City Outlining our Findings and Recommendations
- Our Primary Message was Continuing to Upgrade/Repair the Current Structure Wasn't Economically Viable
- Replacement with a Conventionally Designed Robust 100-Year Storage Reservoir was the Best Amortized use of Public Funds
- Based on PSE's Findings and Recommendations the City of Kennewick Elected to Replace the Existing Reservoir

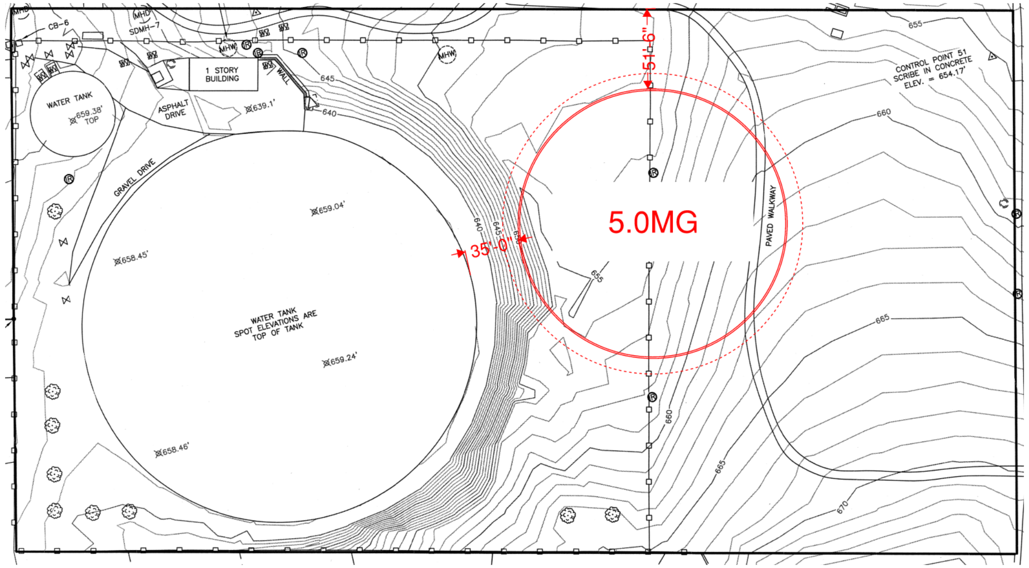
Reservoir Sizing, Siting & Construction Sequencing

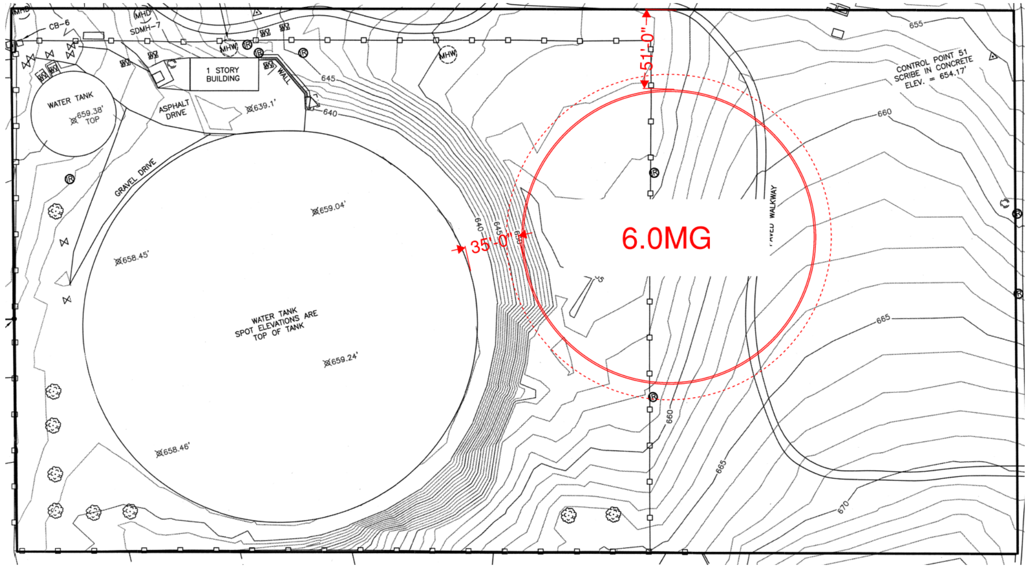
- A new AWWA D-110 Type 1 Prestressed Concrete Reservoir Selected
- Sizing and Siting Considerations
  - Final capacity needed to match existing 10MG capacity.
  - Storage Requirements for the pressure zone allowed for a short-term reduction in capacity.
  - The existing reservoir had to stay online until a new reservoir was completed and online.
  - Piping and pumping improvements needed for the new and future reservoirs.
  - Most cost-effective option

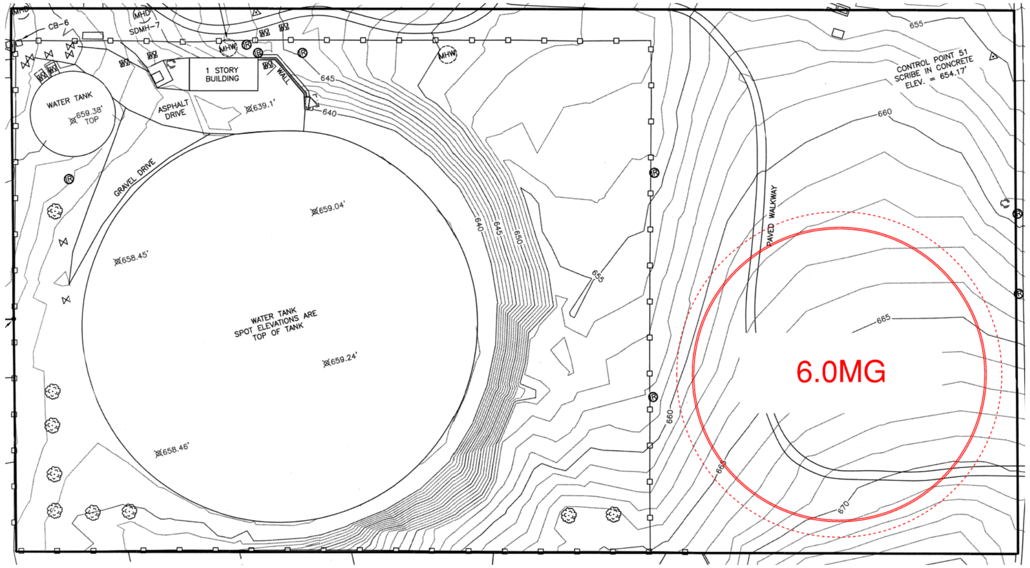
6.0MG Reservoir
Planning & Design

New Reservoir *Sizing and Siting*









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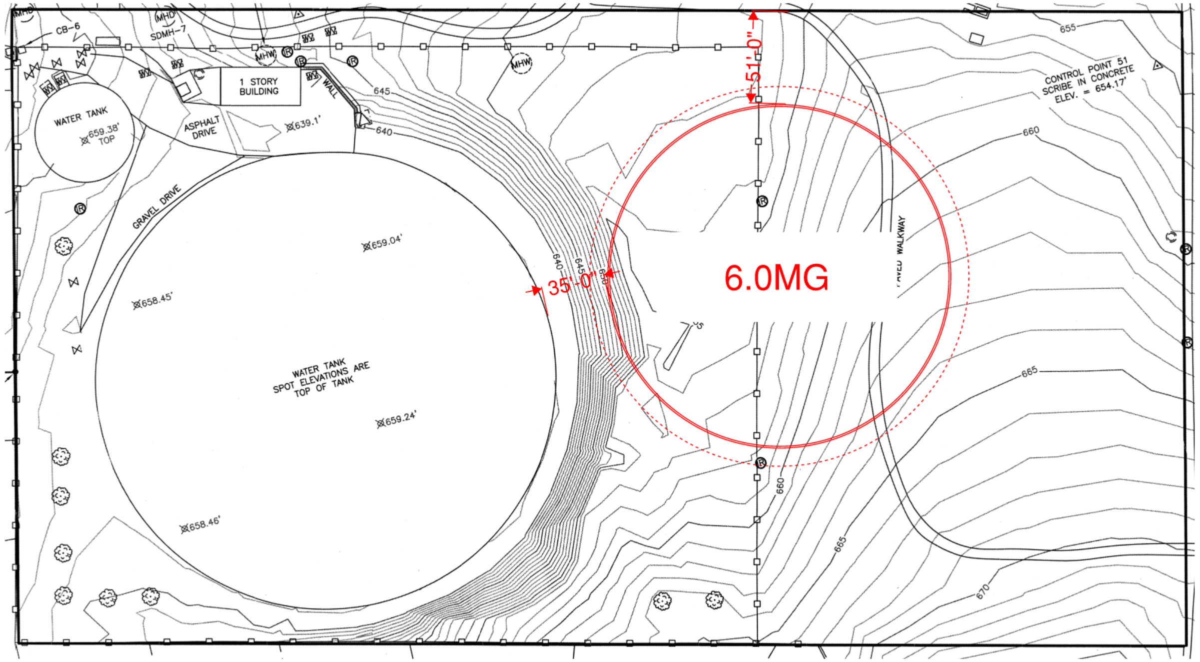

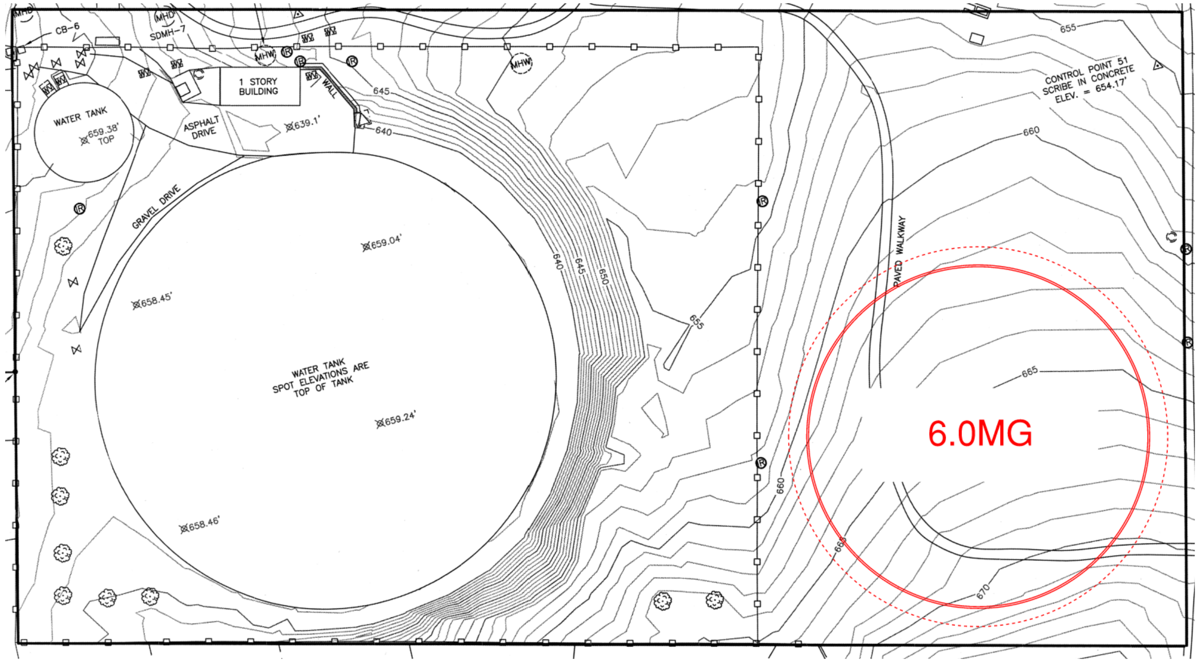

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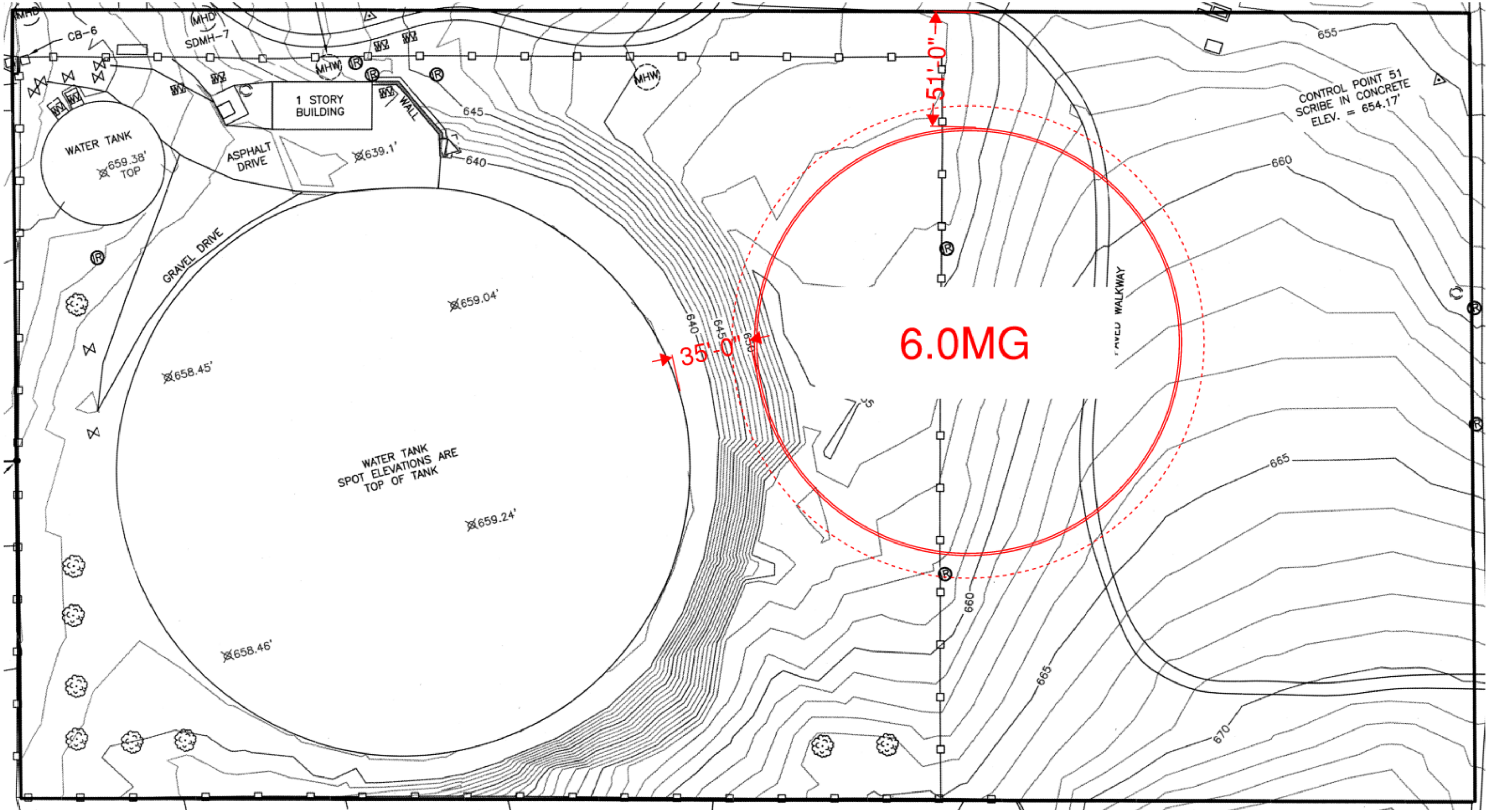

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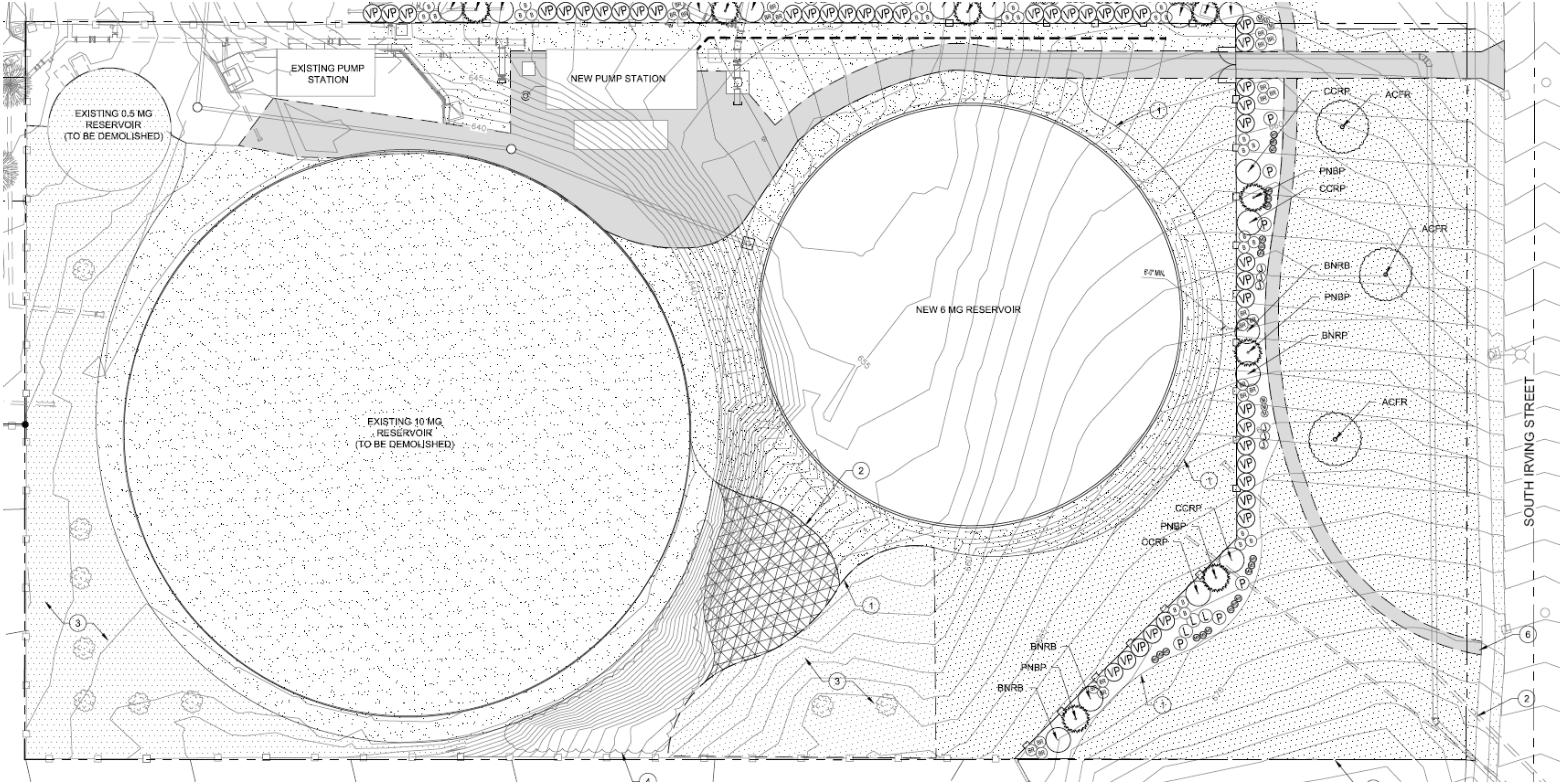
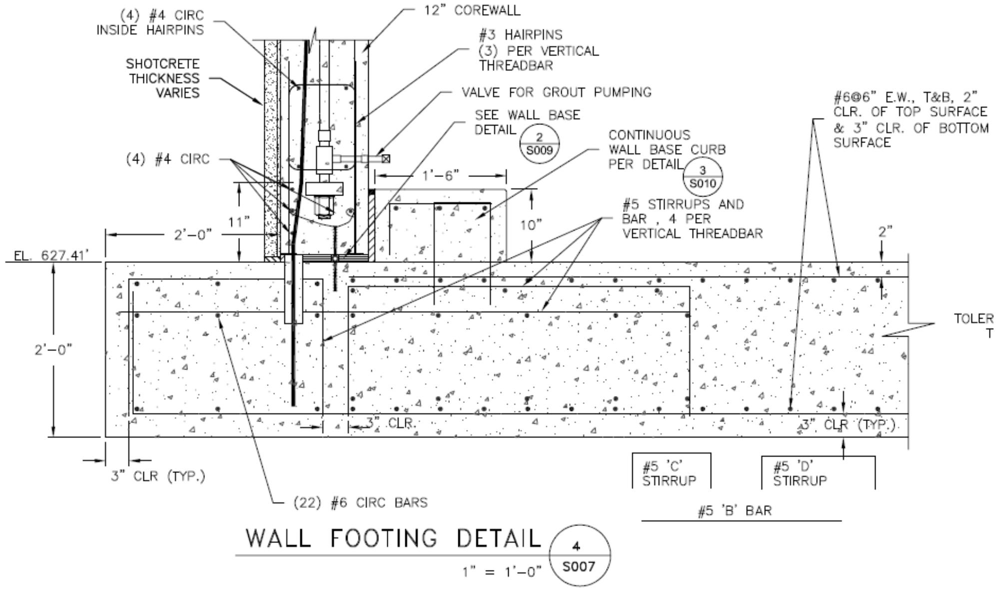
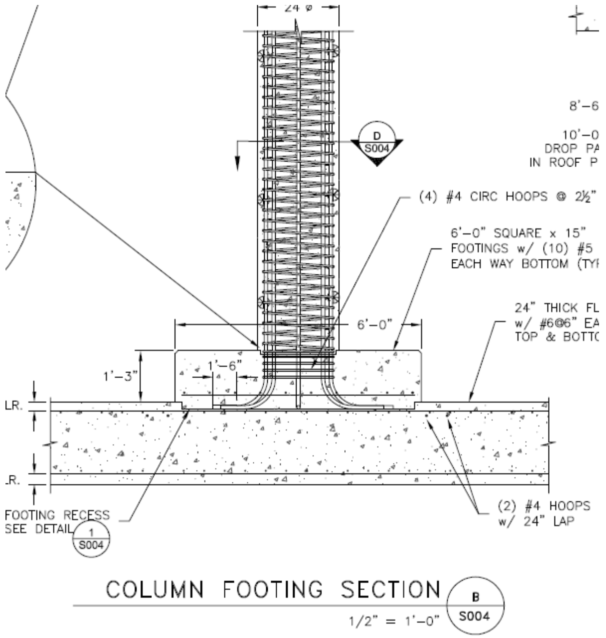


Geotechnical Considerations & Foundation Selection

- Geotechnical Study Critical To Reservoir Design
- Membrane Slab
  - 6” slab with minimal reinforcing
  - Much less expensive
  - Limited to ¼” differential deflection over 50ft.
- Mat Slab
  - Thicker, rigid foundation
  - Redistributes structural loads into relatively even bearing pressures, which allows the structure to “float” on softer soils.
- Mat Slab was selected due to settlement criteria





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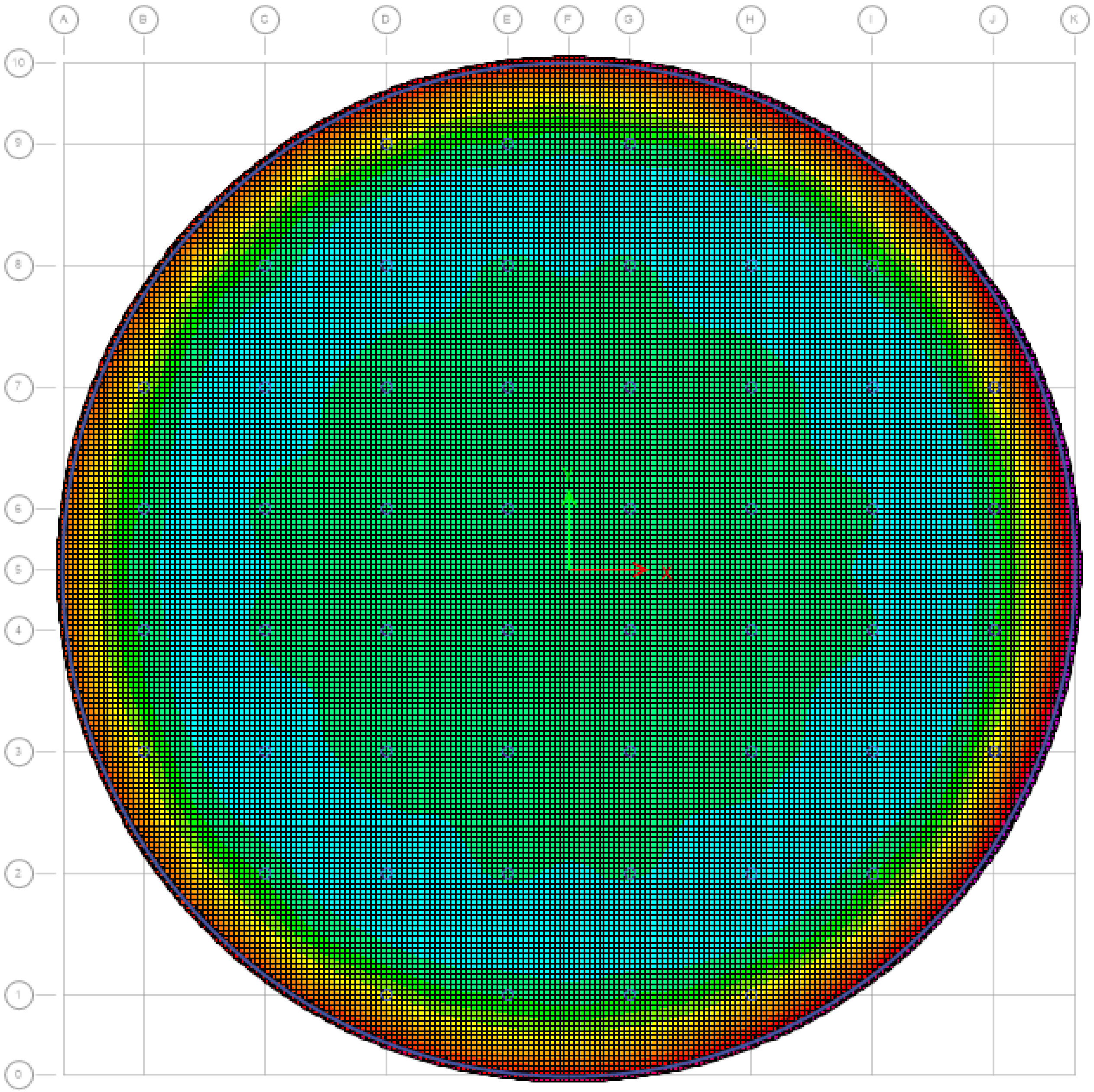
Mat Slab Design

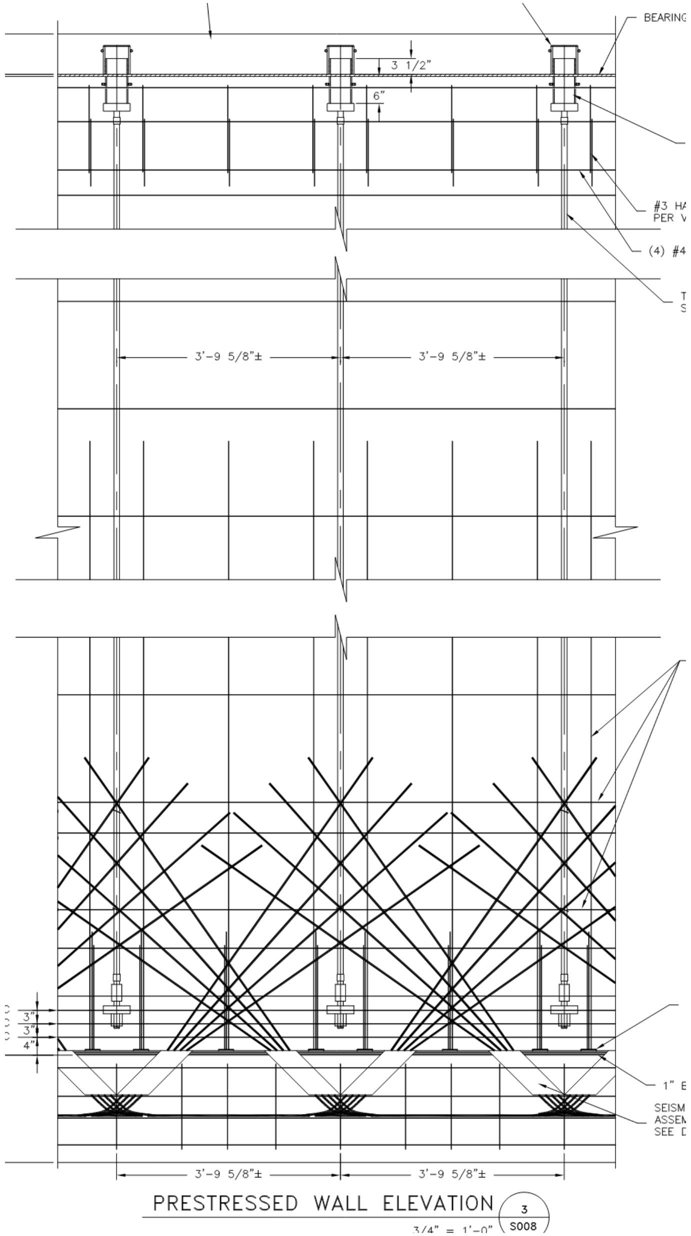
- Modulus of Subgrade Reaction
- Initial value from Shannon and Wilson was lower than expected
  - Large area of influence leads to deeper stress bulb in soil
  - This site had deep silts
- Design team coordination and additional 24” mat of crushed rock below slab yielded a higher modulus
- CSI SAFE used to create a finite element model of the mat slab
- Final design was a 24” slab with #6 bars at 6” spacing at the top and bottom in both directions.

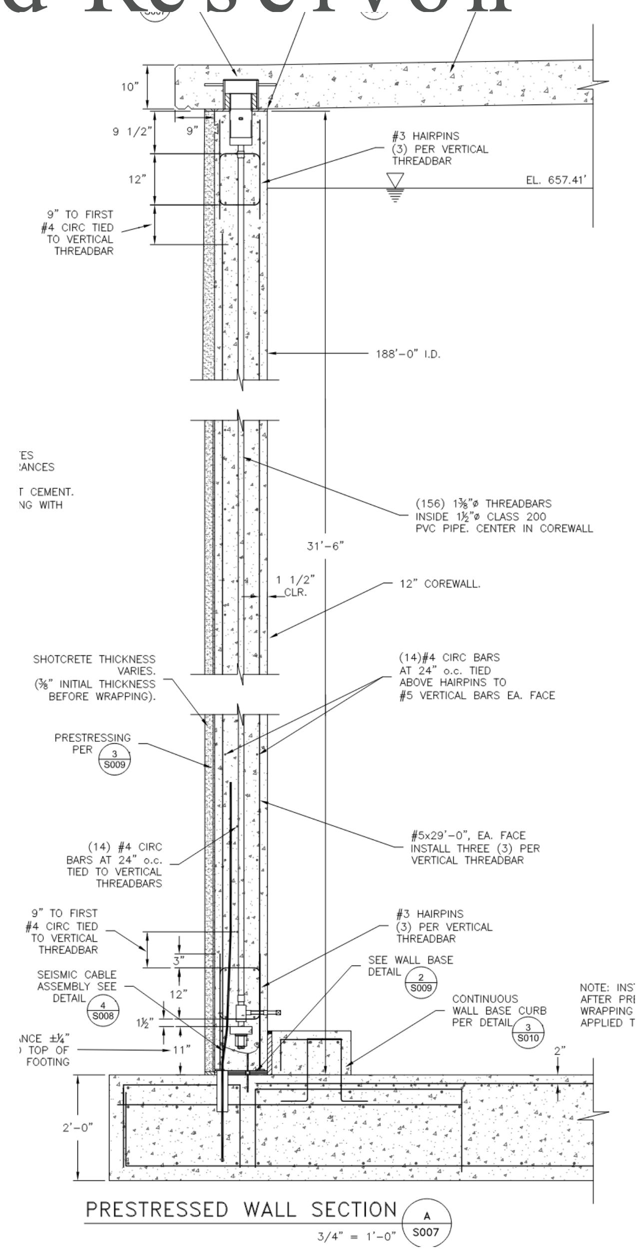


AWWA D110 Type 1 Prestressed Reservoir

- All D110 tanks are wrapped with prestressed wire or cables strands

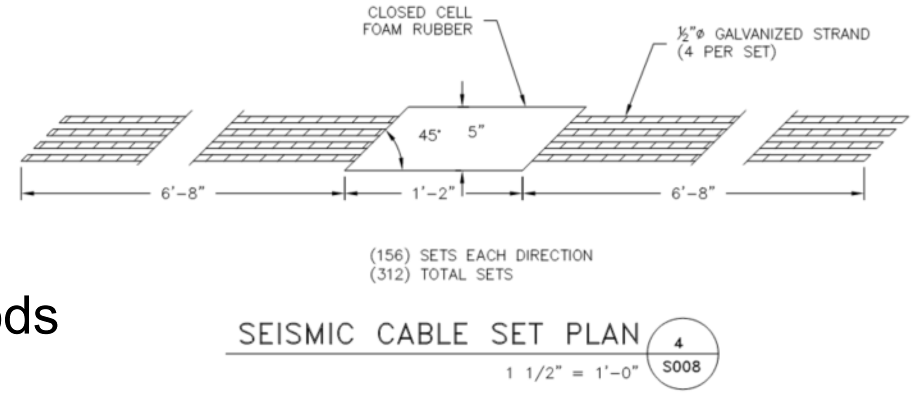
- Type 1 wall indicates a cast in place wall with vertical prestressing
  - Waterstops cast into the wall give superior waterproofing at joints
  - Cast in place allows for an anchored flexible base
  - Vertical prestressing enhances watertightness of the concrete

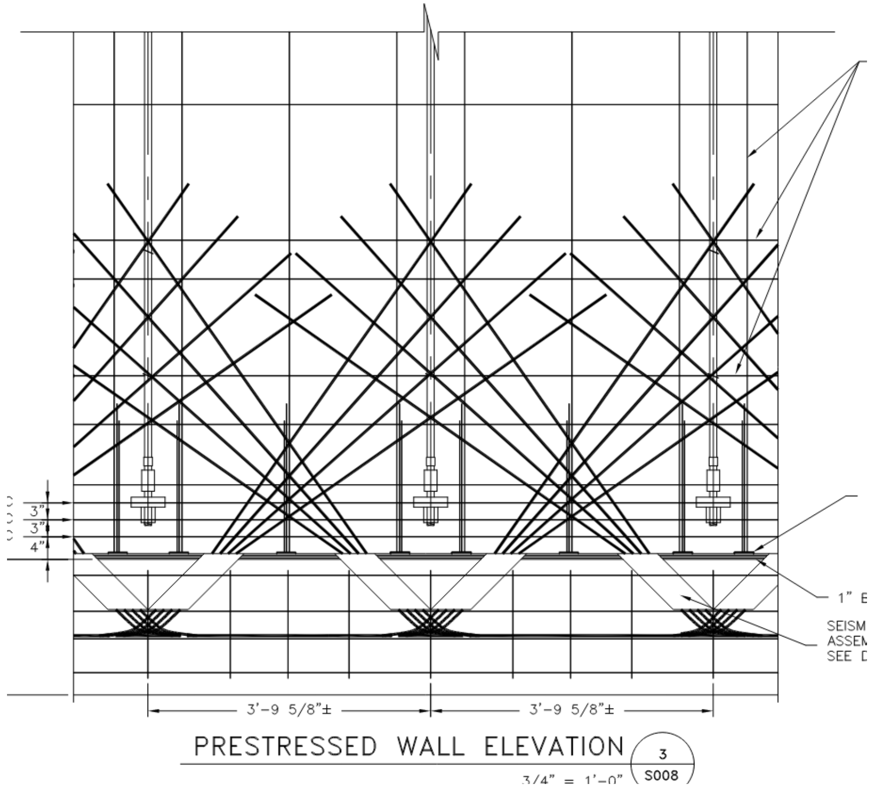




Anchored Flexible Wall Base

- Flexible base allows for higher ductility
- Wall, Roof, and Floor Slab with different fundamental periods
- Cables parallel to direction of seismic loads engage in tension





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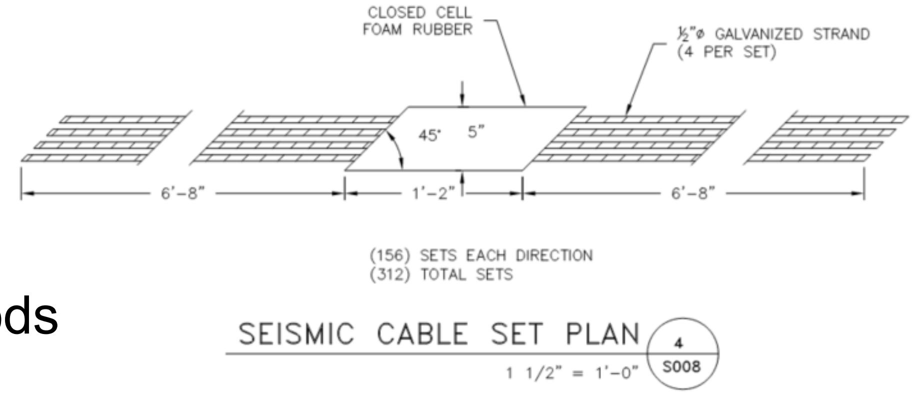
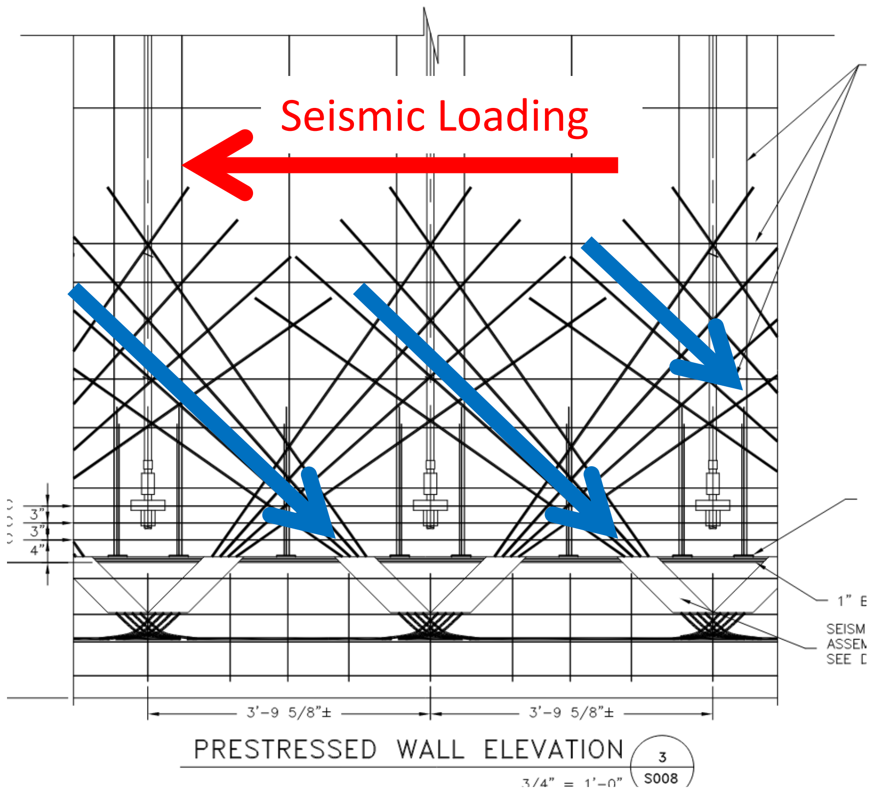
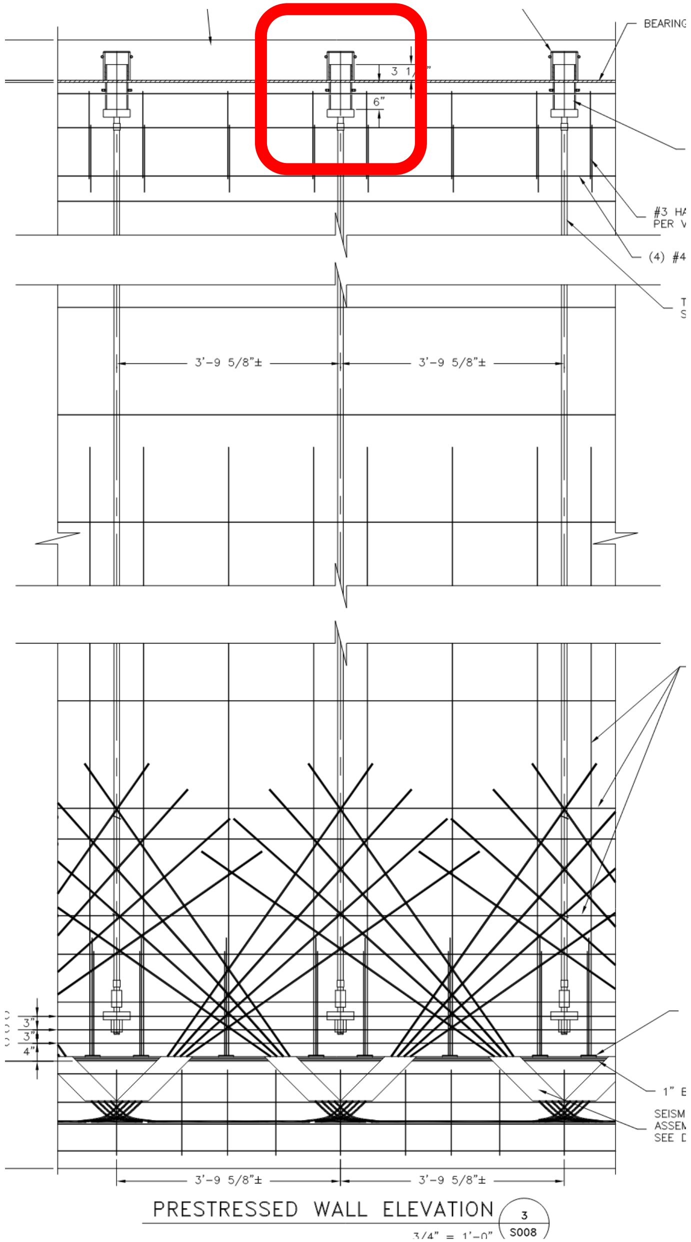
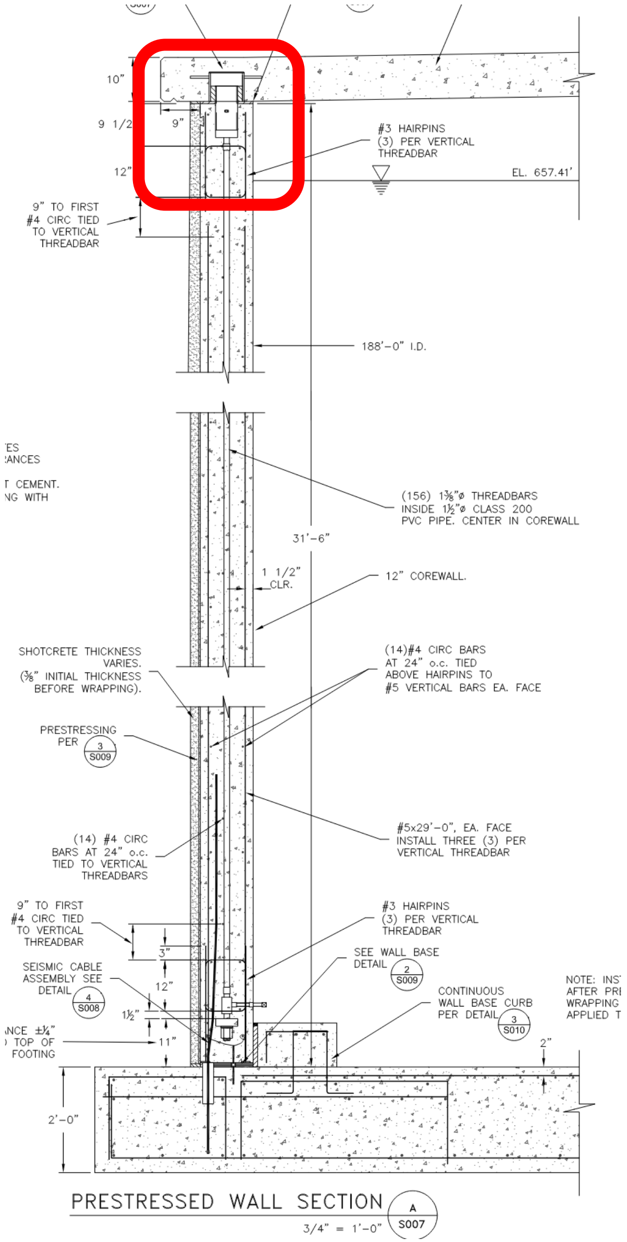




Top of Wall Connection

- Shear cans with bearing pads
- Allows for radial movement of the slab, but not for global translation
- Prevents out of plane loads on the wall
- Also acts as bearing plate for vertical tensioning





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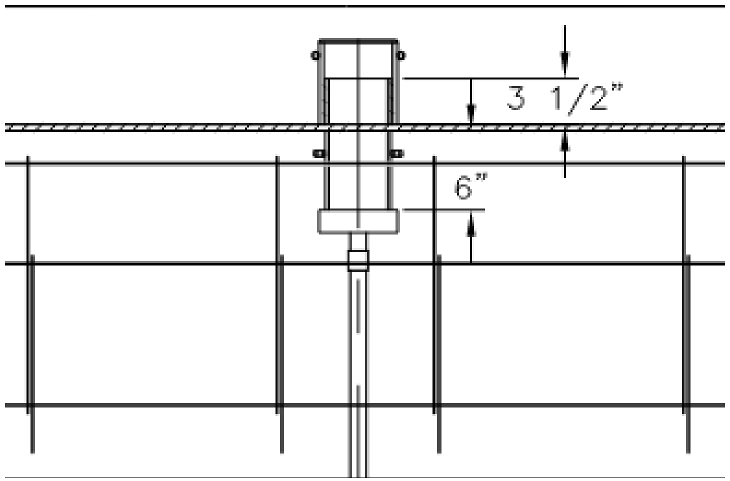
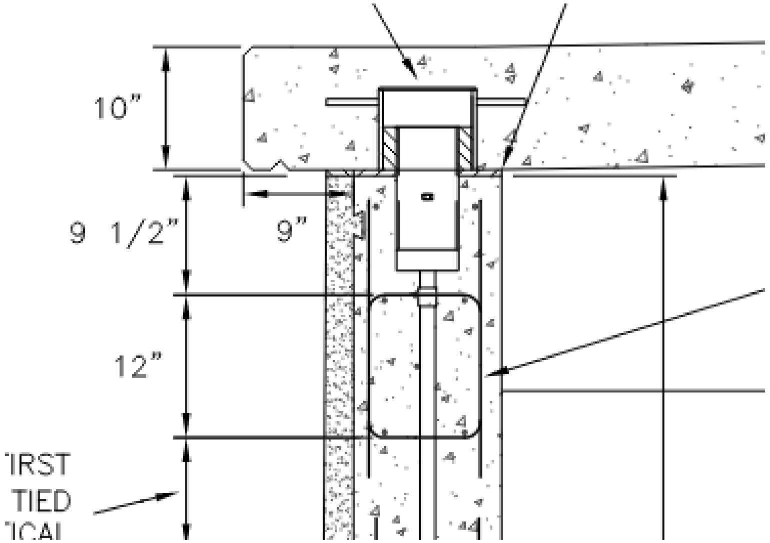
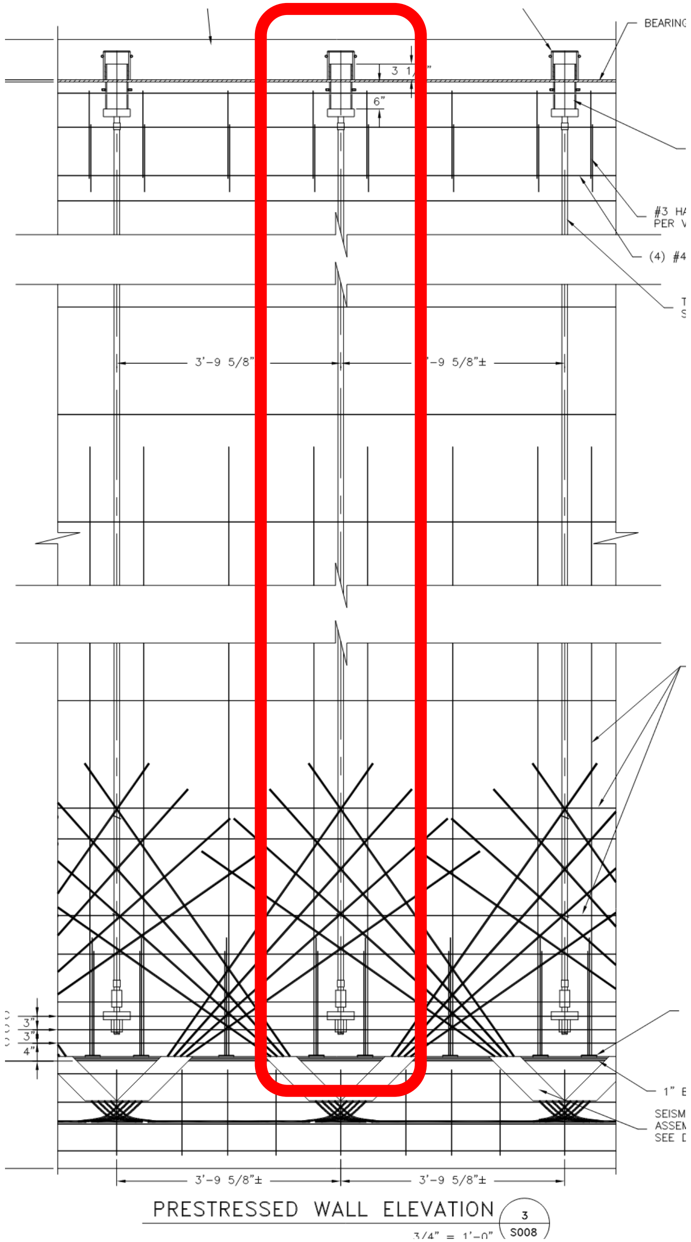
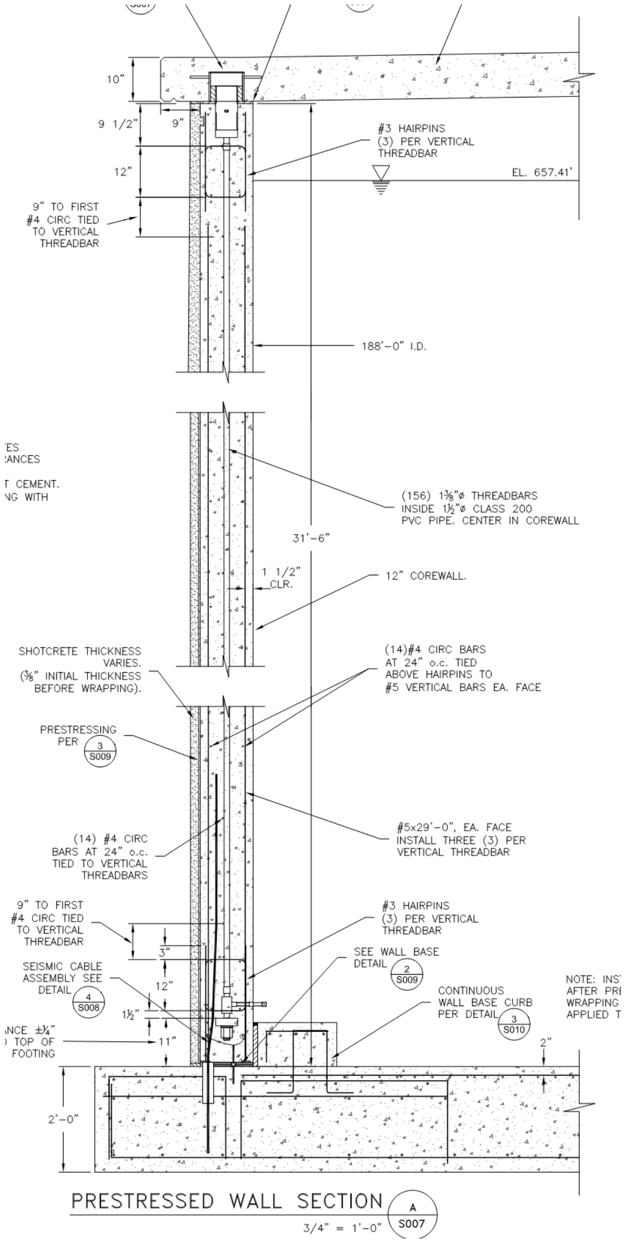




Vertical Prestressing

- Compresses wall vertically
- 1 3/8” diameter threadbars
- Approximately 4ft spacing
- 173,900lb tension
- Elongates 1.379”
- PVC tube with threadbar is filled with epoxy after tensioning





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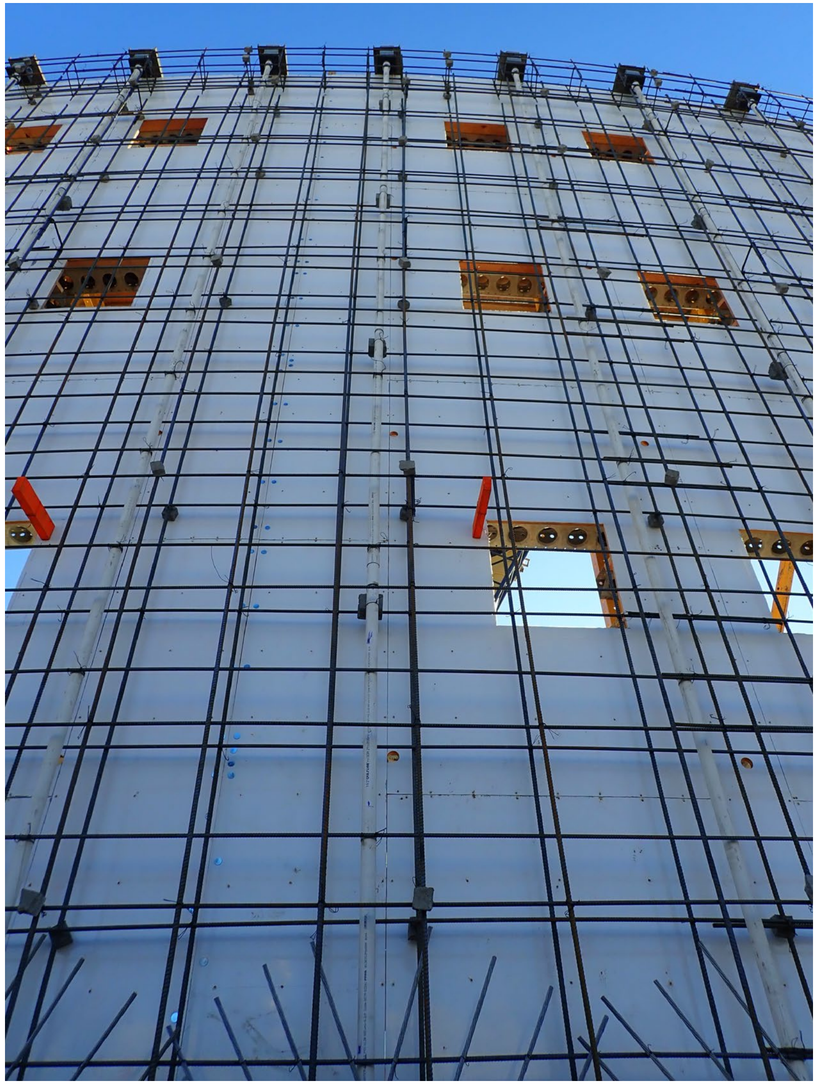


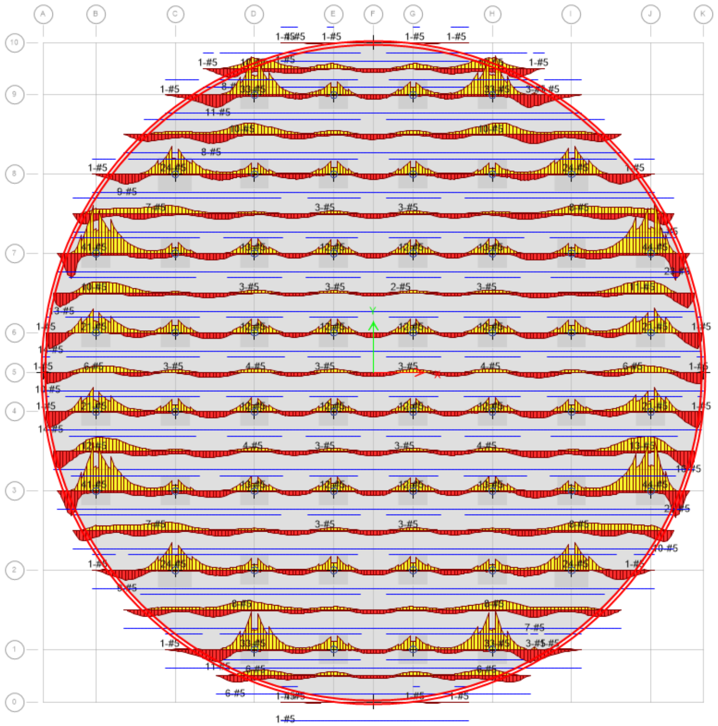
Horizontal Prestressing/Wrapping

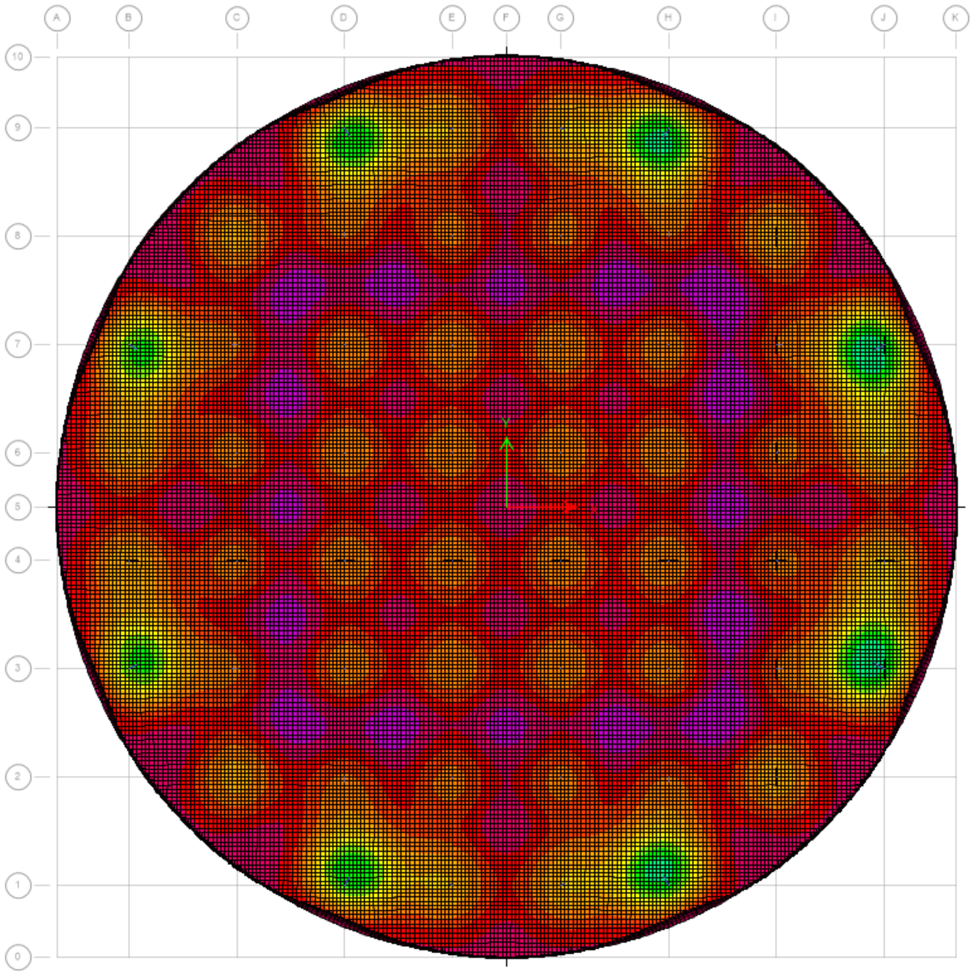
- 3/8” diameter cables
- Tensioned to 14,950lb
- Spacing varies. Tightest spacing near the bottom, and increased spacing near top
- Shotcrete between each layer of wrapping
- Applied by DN Tank’s specialized machine

Horizontal Prestressing/Wrapping

Roof Slab Design

- 2 way flat slab spanning between a square grid of columns and the core wall
- Designed using CSI SAFE Software
- Iterative design with floor slab
- 10” slab with #5 spaced at 8” over column strips and 12” at middle strips





Construction

- Rotschy with Ward Henshaw as the Reservoir Subcontractor
- Prestressing performed by DN Tanks

CHALLENGES:

- Local residential area, limited working hours
- Tight site with excavation requirements
- 2020 Construction: Still figuring out the best way to perform the early site visits with Covid

Construction

PSE PERFORMED 7 OBSERVATIONS

- Floor slab reinforcing
- Wall reinforcing
- Column reinforcing
- Vertical stressing
- Roof slab reinforcing
- Wall wrapping
- Final observation