

# Reservoir Seismic Upgrades and Improvements

## City of Corvallis' North Hills 1<sup>st</sup> Level East Reservoir Improvements Project



Murray, Smith & Associates, Inc.

AMERICAN WATERWORKS ASSOCIATION  
**PACIFIC NORTHWEST SECTION**  
IDAHO OREGON WASHINGTON



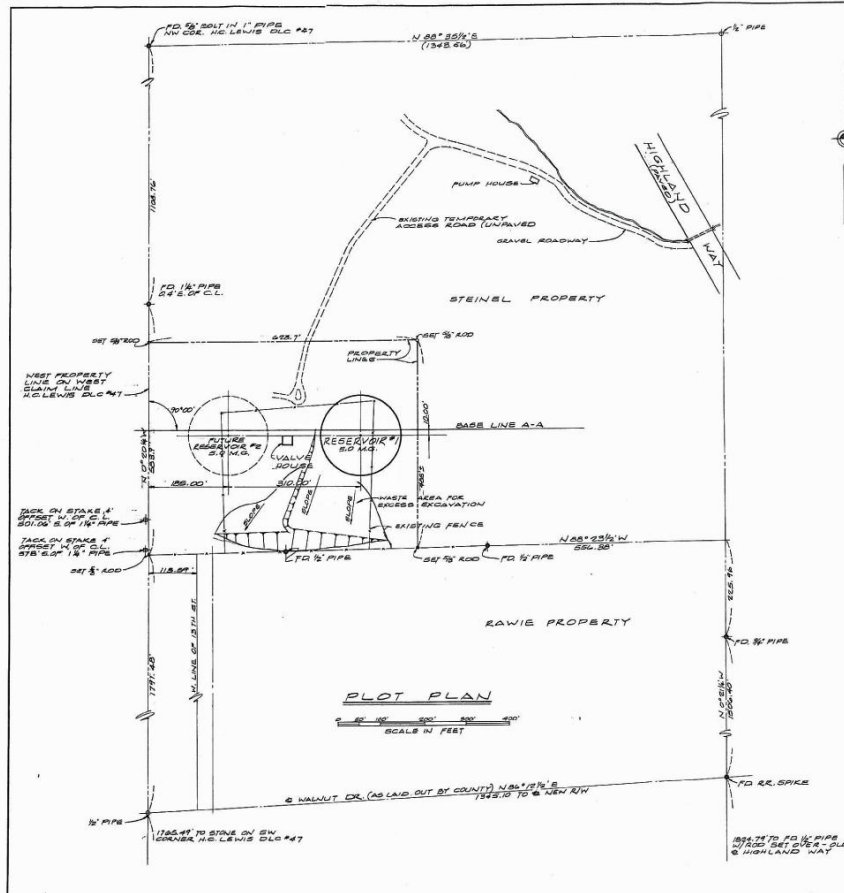
# A Case Study of Concrete Reservoir Seismic Upgrades and Improvements

## Jeff Jones, P.E., Presenter

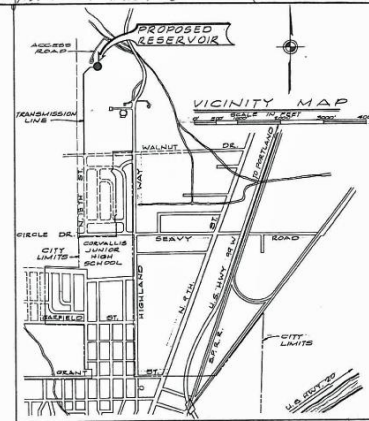
### Presentation Outline:

- Introduction to City of Corvallis' North Hills 1<sup>st</sup> Level East Reservoir;
- An overview of circular wire-wrapped prestressed reservoir design and construction;
- A background of the North Hills 1<sup>st</sup> Level East Reservoir Improvements Project;
- Conducting concrete reservoir structural analysis and condition assessment;
- Results of the condition and structural assessment of the North Hills 1<sup>st</sup> Level East Reservoir; and
- Construction of North Hills 1<sup>st</sup> Level East Reservoir's structural upgrade, repairs and improvements.

# North Hills East Reservoir



Original construction 1959



**INDEX TO DRAWINGS**

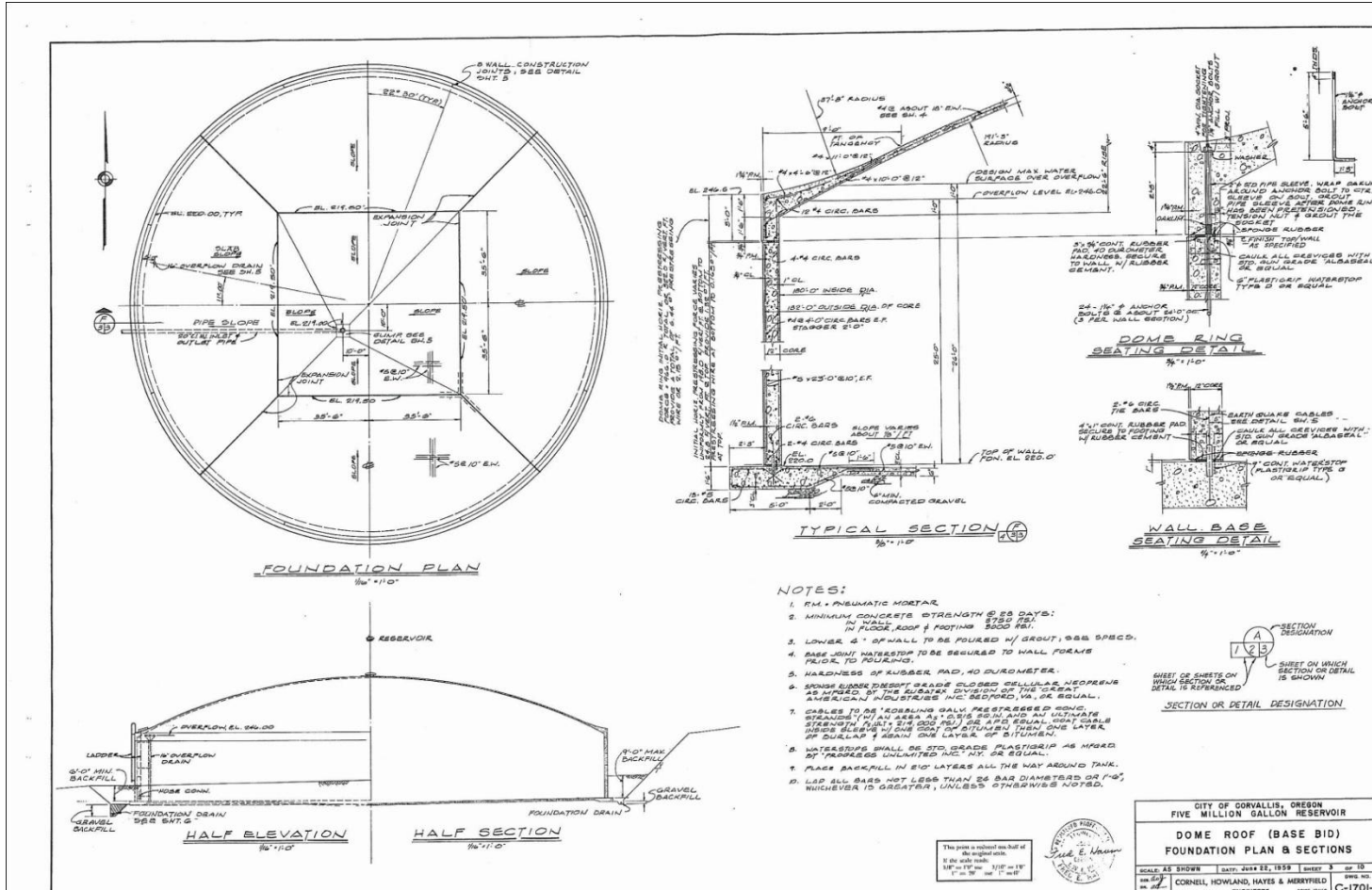
SHEET NO.	TITLE
1.	VICINITY MAP & PLOT PLAN
2.	GENERAL LAYOUT, PIPING AND TEST HOLE DATA
3.	DOMB ROOF (BASE BID) FOUNDATION PLAN & SECTIONS
4.	DOMB ROOF (BASE BID) ROOM PLAN & DETAILS
5.	GENERAL DETAILS
6.	PIPING DETAILS
7.	PLAT SLAB ROOF (ALTERNATE) FOUNDATION & ROOF PLANS
8.	PLAT SLAB ROOF (ALTERNATE) STRUCTURAL DETAILS
9.	VALVE HOUSE PIPING, PLAN & SECTIONS
10.	VALVE HOUSE ELECTRICAL & MISCELLANEOUS DETAILS



CITY OF CORVALLIS, OREGON			
FIVE MILLION GALLON RESERVOIR			
VICINITY MAP & PLOT PLAN			
SCALE AS SHOWN	DATE: JUNE 22, 1959	SHEET 1	OF 10
DESIGNED BY	CORNELL, HOWLAND, HAYES & MERRYFELD	DRW. BY	
		PROJECT NO.	C-1701-3

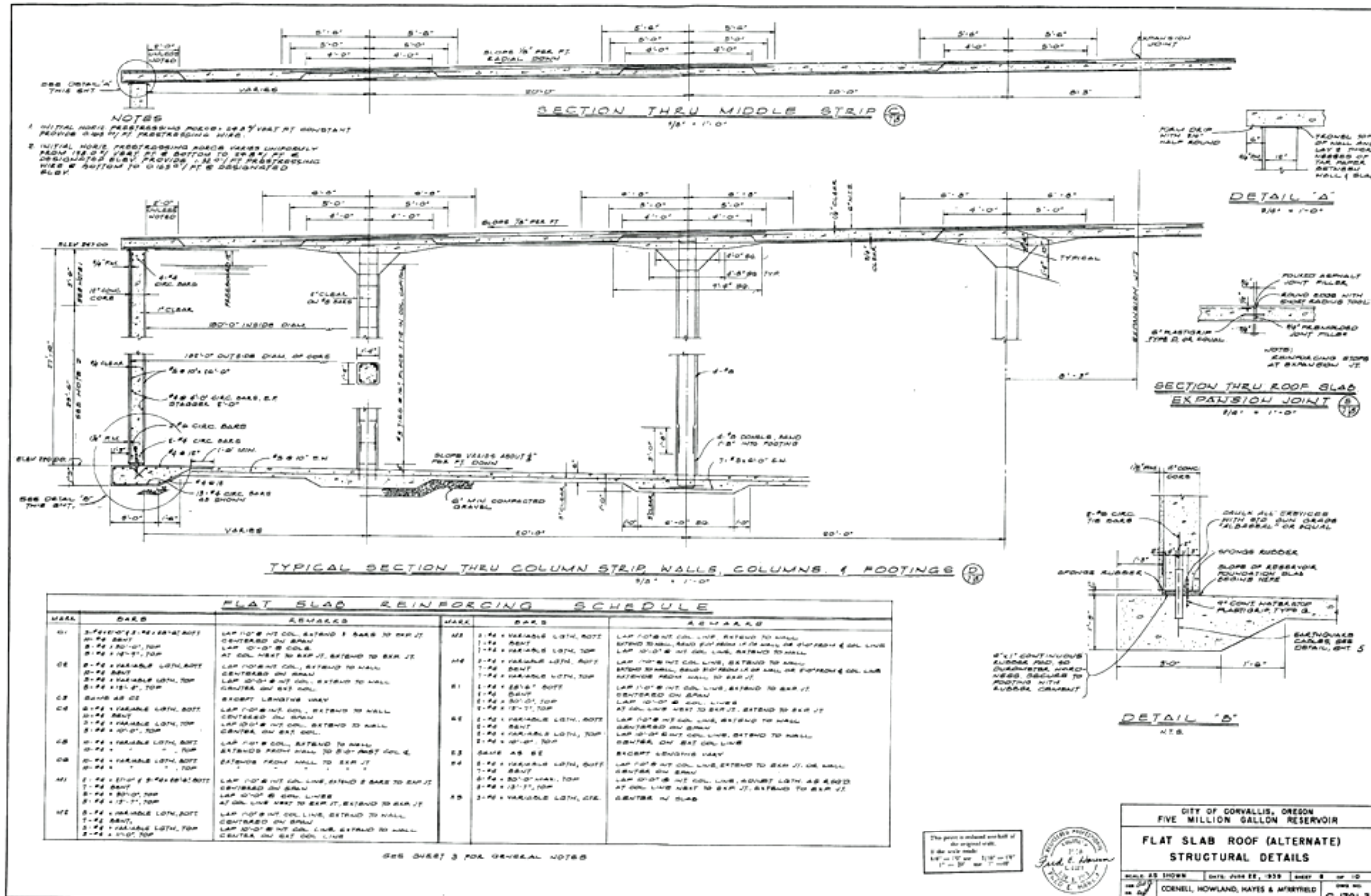
North Hills East Reservoir is a 5 MG prestressed wire wrapped, domed roof concrete tank constructed in early 1960's in Corvallis' North Hills

# North Hills East Reservoir



Inside Diameter = 180-feet; Water Depth to Overflow = 26-feet

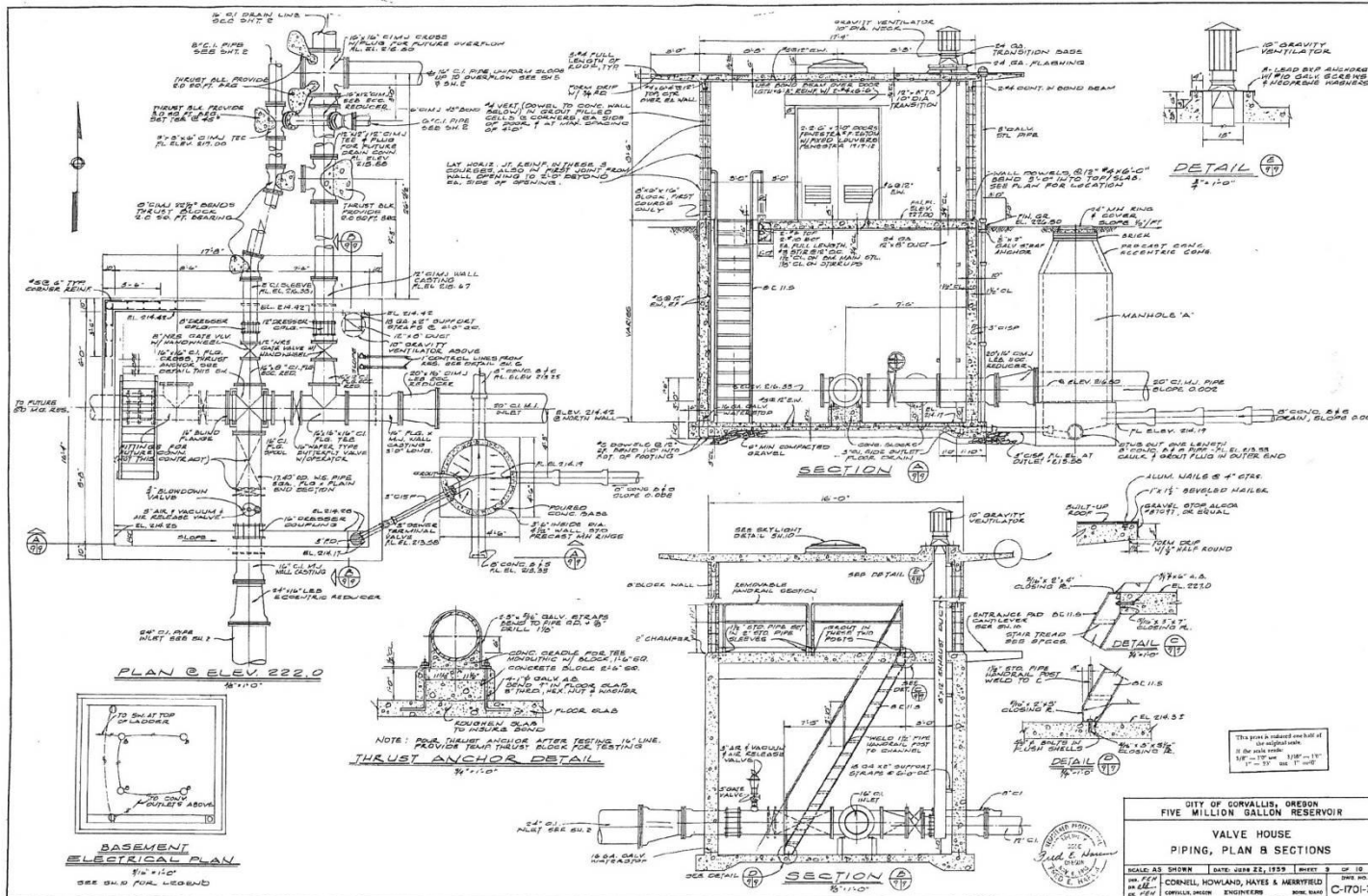
# North Hills East Reservoir



## Column Supported Slab Roof Alternate



# North Hills East Reservoir



CITY OF CORVALLIS, OREGON FIVE MILLION GALLON RESERVOIR			
VALVE HOUSE PIPING, PLAN 8 SECTIONS			
SCALE: AS SHOWN	DATE: JUNE 22, 1959	SHEET: 3 OF 10	DWG. NO.
BY: J.E.P.	CORNELL, HOWLAND, HAYES & MERRIFIELD	DATE: 6/22/59	C-170-3
CH: J.E.P.	CORNELL, HOWLAND, HAYES & MERRIFIELD	ENGINEERS	SCALE: NONE

This print is subject to the full set of specifications for the project.

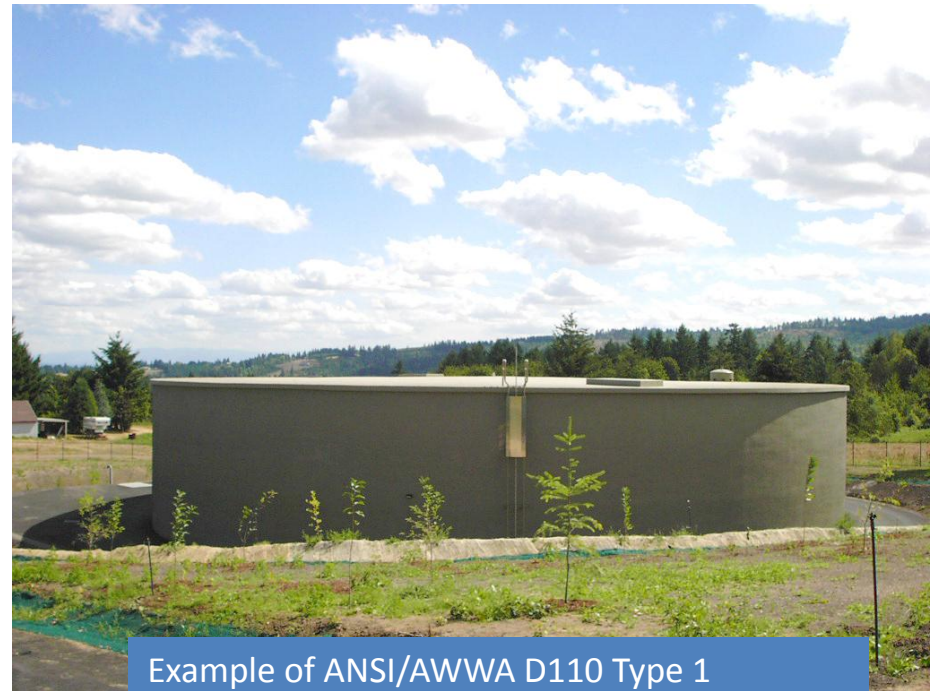


Original Yard Piping Layout

# Prestressed Wire Wrapped Reservoir Design Overview

ANSI/AWWA D110 Standard For Wire-Wound Circular Prestressed Water Tanks, first published in 1986.

- Specifies standards for strand (Type 1) and wire (Type 3) wrapped tanks.
- North Hills East Reservoir wall and dome compression ring is wrapped with non-galvanized wire constructed prior to formal ANSI/AWWA D110 Standard being developed.



Example of ANSI/AWWA D110 Type 1  
Sherwood's 3.0 MG Kruger Road Reservoir



# Prestressed Wire Wrapped Reservoir Design Overview



**Core Wall and Roof Slab Construction**

**Forming for Core Wall: Note Seismic Cables Cast in Footing**



# Prestressed Wire Wrapped Reservoir Design Overview



**Circumferential Prestressing Machine (Wrapping Machine) Preparing to Wrap Strand**



**Wrapping Machine Used to Spray on Shotcrete Coating Over Strand**



# North Hills East Reservoir Project Background

In 2003 reservoir structural evaluation was completed by CH2M Hill with following recommendations:

## Seismic Structural Improvements:

- Installing new interior ring beam at wall base to floor joint to increase capacity of seismic cables
- Strengthen wall to dome roof connection (seismic cable installation similar to wall base detail proposed)
- Applying additional wrapping strand on wall and dome compression ring

## Structural Repairs and Reservoir Improvements:

- Patching existing shotcrete in delaminated areas
- Upgrading roof edge detail to direct flow of water runoff away from shotcrete interface at dome ring and wall top joint
- Miscellaneous equipment upgrading, including ladder and fall protection equipment



# North Hills Reservoir Project Overview

Murray, Smith & Associates, Inc. with Peterson Structural Engineers, Inc. (PSE) as the project structural engineer, was selected by the City of Corvallis in 2010 to design seismic upgrades and reservoir maintenance repairs and improvements to the North Hills 1st Level East Reservoir.

- Project Scope initially based on CH2M Hill's 2003 reservoir assessment and recommended work
- MSA and PSE conducted site visits to determine reservoir existing conditions with reservoir drained
- PSE reviewed CH2M Hill's 2003 structural analysis and conducted updated structural analysis based on current codes



# Conducting Reservoir Structural Analysis and Condition Assessment



Exposing wire wrap for inspection

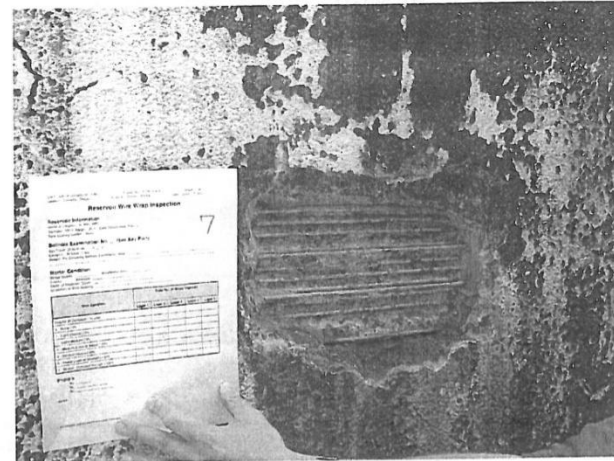


Photo No. 10. Bellhole No. 7.



Photo No. 10. Bellhole No. 7.

# Conducting Reservoir Structural Analysis and Condition Assessment

## Exterior Wall and Roof Inspection



**Circumferential Roof Cracks Observed**

**Existing Roof Vent**



**Sounding shotcrete to locate voids that identify delaminating areas**



# Conducting Reservoir Structural Analysis and Condition Assessment



**Example of Delaminating Shotcrete Coating Failure of the Mt Solo Reservoir, City of Longview**

# Conducting Reservoir Structural Analysis and Condition Assessment

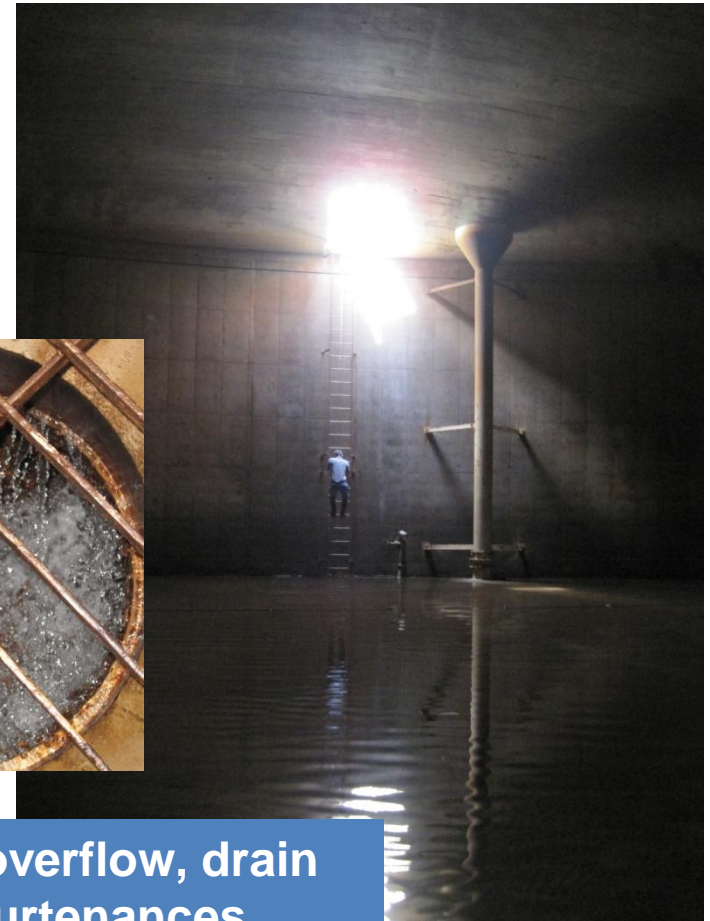
## Conducted Interior Inspection



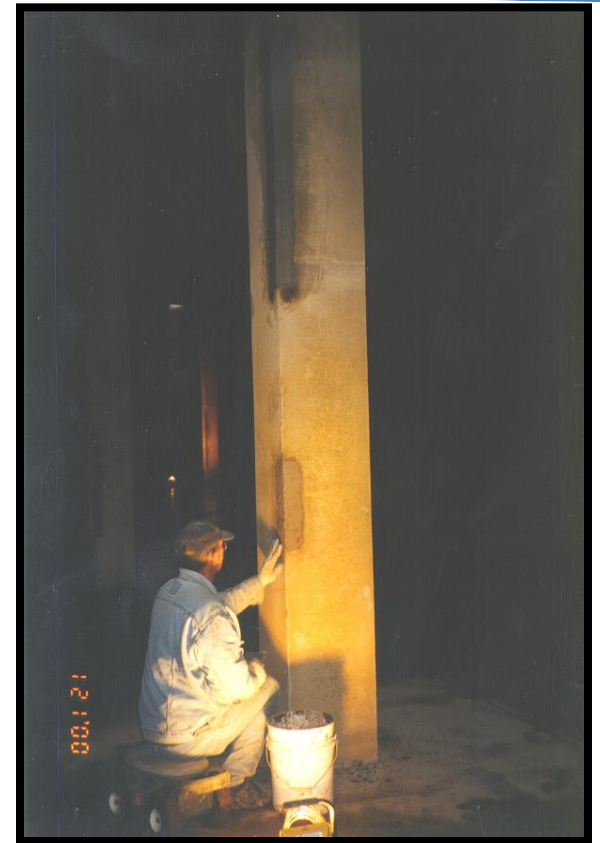
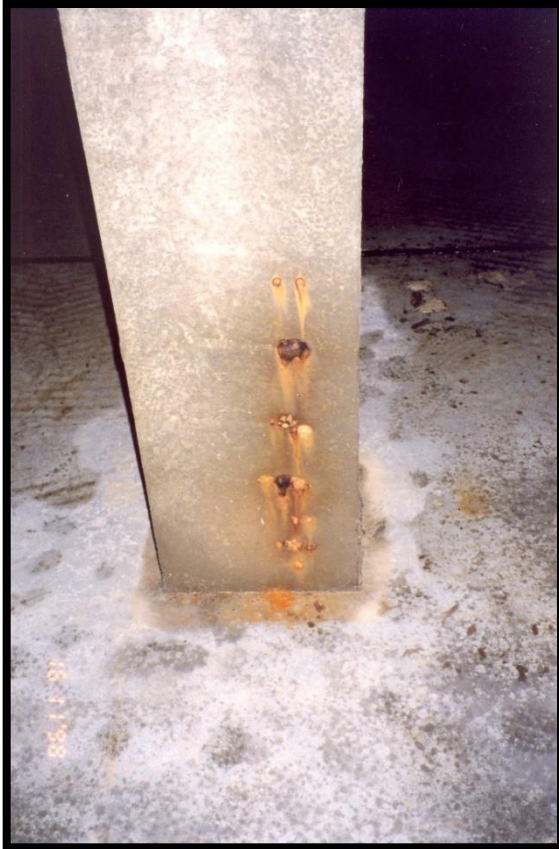
**Corrosion observed  
Determined not to be  
rebar**



**Inspect ladders, overflow, drain  
and other appurtenances**



# Conducting Reservoir Structural Analysis and Condition Assessment



Example of corroded rebar and concrete repair, Sexton Mountain Reservoir, City of Beaverton

# Conducting Reservoir Structural Analysis and Condition Assessment

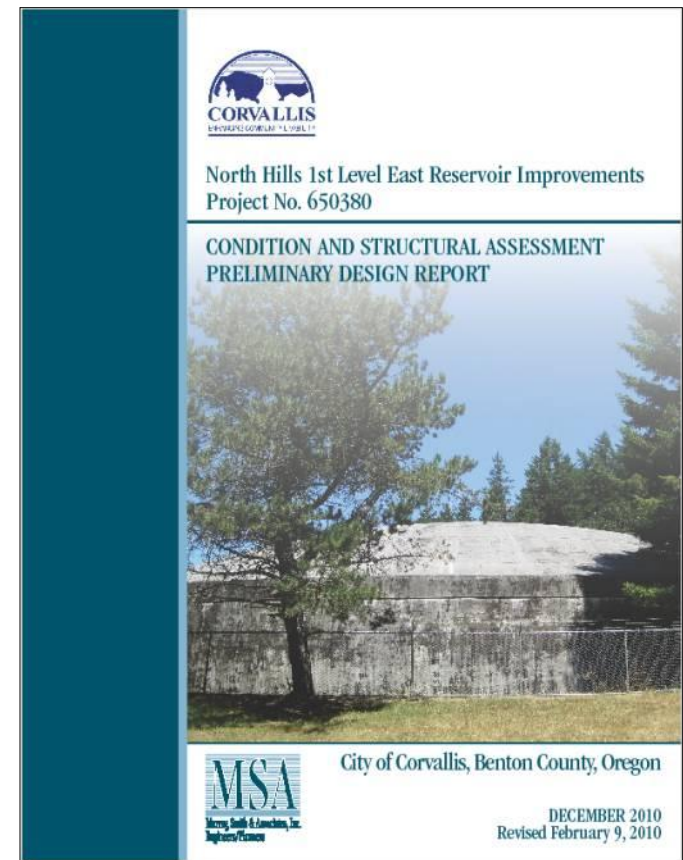
## Conducting Underwater Reservoir Inspection With Divers (Photos From Previous Projects)



# Condition and Structural Assessment Results

The results of the structural analysis showed if the reservoir operating water level is reduced to 23 feet, 3 feet below the reservoir's overflow depth of 26 feet, the amount of structural improvements to provide seismic upgrades can be significantly reduced thereby:

- Eliminating need to wire wrap walls;
- Eliminating the need for wall base connection improvements
- Providing potential savings of \$1 M of construction costs
- Regardless, the structural improvements to the dome compression ring and wall to dome roof connection would still be required



# Condition and Structural Assessment Results

After extensive review with City Public Work staff, the City selected to adopt normal operation of the reservoir at a reduced water depth of 23 feet thereby reducing the amount of structural improvements.

Results of the condition assessment found:

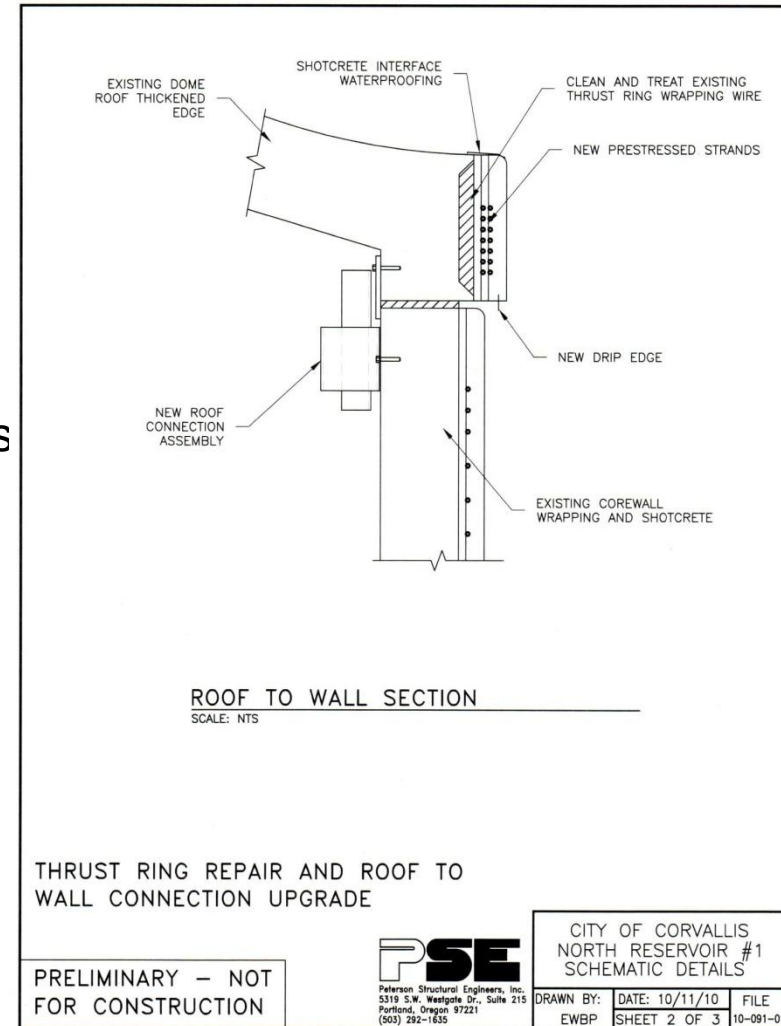
- Voids from delaminating of the wall shotcrete is confined to the upper 2 to 4 feet of the wall. Wire exposed in the wall show no signs of corrosion though some wire in dome compression ring are corroded.
- Roof cracks appear to fully penetrate roof likely providing pathway for water to reinforcement
- Though floor expansion joint sealant appears to be functioning properly, it is reaching the end of its service life
- Overall, condition of concrete floor and core wall appear in good condition.

# Condition and Structural Assessment Results

The City agreed to move forward with design of the following recommended reservoir improvements:

## Structural Repairs and Improvements

- Roof dome compression ring repairs including removing delaminating shotcrete coating, install additional prestressed strands and apply new shotcrete coating
- Install interior roof to wall connection system
- Modify dome compression ring roof edge profile to improve water drainage
- Inject epoxy grout to seal and fill the delaminated shotcrete coating voids



## Maintenance and Appurtenance Upgrades

- Upsize existing roof vent
- Recoat all steel appurtenances
- Remove existing skim coat inside roof access hatch and recoat with an epoxy coating
- Coat exterior walls and roof including concrete surface repair as required
- Modify overflow piping brackets
- Replace interior access ladder
- Replace floor joint sealant
- Seal dome roof cracks



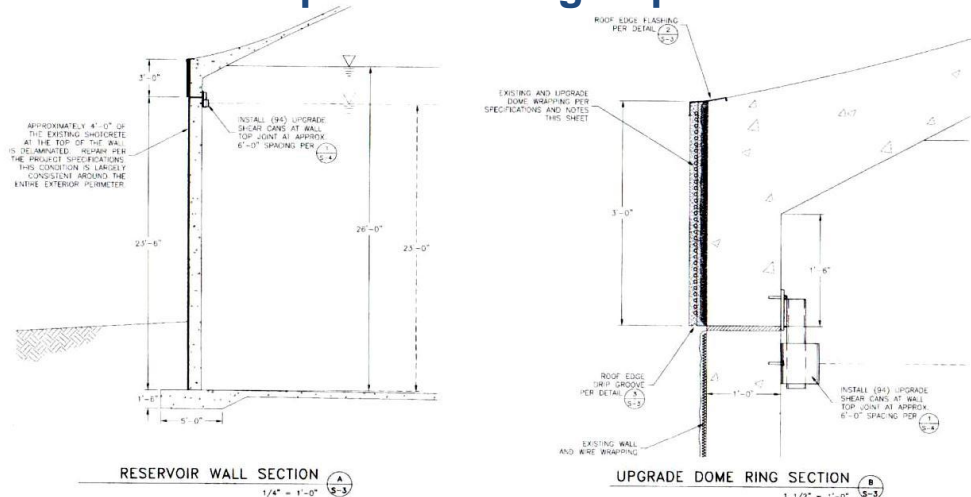
## Yard Piping Improvements

- Install flexible expansion joint fittings on the reservoir's existing inlet, outlet, drain and overflow yard piping
- Install a seismic controlled valve housed in a buried vault on the existing overflow piping
- Line the existing cast iron combination drain, outlet/inlet pipe with a cured-in-place pipe (CIPP) system



# North Hills 1st Level East Reservoir Improvements Project

## Roof Dome Compression Ring Repairs



### DOME COMPRESSION WRAPPING REPAIR/UPGRADE

**DESCRIPTION:**  
BASED ON HISTORICAL INVESTIGATION THE UNEXPECTED PRESTRESSING WRAPPING ON THE DOME COMPRESSION RING HAS EXPERIENCED LOCALIZED CORROSION AND LOSS OF RING SECTION. THE PURPOSE OF THESE DOCUMENTS IS PROVIDE SPECIFICATIONS AND REPAIR/UPGRADE OPTIONS FOR THE DOME RING WRAPPING WHICH INCLUDES A SEQUENTIAL STEP BY STEP EXPLANATION OF THE PROPOSED REPAIR AND STRUCTURAL CALCULATIONS SUPPORTING THE PROCESS AND FINAL DOME STRESSES BASED ON THE PROPOSED AMOUNT OF WRAPPING TO BE ADDED TO THE DOME COMPRESSION RING. INSTALLATION OF ROOF EDGE FLASHING AND A DRIP GROOVE ARE TO BE INCORPORATED WITH THE REPAIR AS DETAILED IN THESE DRAWINGS.

**PROPOSED DOME RING REPAIR/UPGRADE PROCESS:**

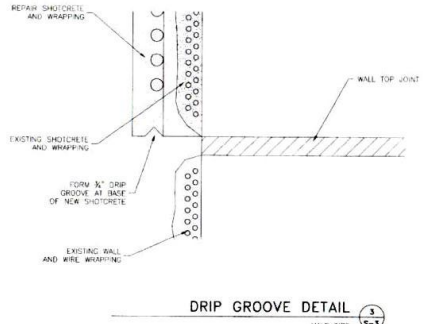
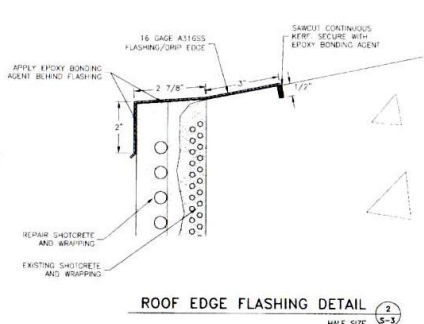
1. USING HYDROBLAST METHODS REMOVE DELAMATED/DAMAGED AREAS OF EXISTING SHOTCRETE FROM OUTSIDE SURFACE OF DOME RING TO EXPOSE WIRE WRAPPING AND DETERMINE ACTUAL % LOSS OF EXISTING WRAPPING MATERIAL. (NOTE: PREVIOUS INVESTIGATIONS ESTIMATE % LOSS OF WRAPPING TO BE BETWEEN 20% AND 50%).
2. REMOVE CORROSION FROM ALL EXPOSED WIRE SURFACES.
3. APPLY NEW SHOTCRETE OVER EXISTING WIRE SURFACES.
4. COVER AND FLUSH SURFACE UPON WHICH TO APPLY NEW GALVANIZED STRAND.
5. APPLY NEW GALVANIZED SEVEN WIRE STRAND AS SPECIFIED IN THE APPROVED CONTRACTOR SUBMITTAL. IF MULTIPLE LAYERS OF STRAND ARE REQUIRED APPLY SHOTCRETE LAYERS WITH 1/2" COVER BETWEEN LAYERS.
6. FINAL SHOTCRETE LAYER TO BE A MINIMUM OF 1 1/2" COVER OVER FINAL WRAPPING LAYER.

**ORIGINAL WRAPPING SPECIFICATION:**  
THE ORIGINAL RESERVOIR DESIGN DOCUMENTS SPECIFY THE 3'-0" TALL DOME RING HAVE AN INITIAL HORIZONTAL PRESTRESSING FORCE OF 3220 KIPS/FT OR A TOTAL OF 9660 KIPS. REFERENCE THE PROVIDED COPY OF ORIGINAL DRAWINGS FOR MORE INFORMATION.

**REPAIR/UPGRADE WRAPPING MINIMUM REQUIREMENTS:**  
THE MINIMUM REQUIRED FINAL WRAPPING FORCE AFTER REPAIR (WHICH INCLUDES THE REMAINING FORCE IN THE EXISTING WRAPPING) SHALL BE EQUAL TO THE ORIGINAL WRAPPING FORCE PLUS AN ADDITIONAL 16 KIPS/FT OR A TOTAL OF 227 KIPS.

**ROOF EDGE FLASHING NOTES:**

1. MIN. 10' LUNG #316SS SECTIONS - 16 GAGE - BENT AS SHOWN.
2. SAWCUT 1/2" DEEP KEIF AS SHOWN.
3. APPLY EPOXY ADHESIVE IN KEIF IMMEDIATELY PRIOR TO INSTALLING FLASHING SECTION. THE EPOXY SHOULD BE THICK AND VISCIDUS SO AS TO BE ADEQUATELY TROWELED AND RETAINED IN THE KEIF DURING FLASHING INSTALLATION.
4. CALL OUT END JOINTS AT SECTION OVERLAPS.



NO.	DATE	BY	REVISION

**NOTICE:**  
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

**EWSP DESIGNED:** EWSP DRAWN: TON CHECKED:



**NORTH HILLS 1ST LEVEL RESERVOIR EAST IMPROVEMENTS**

<b>RESERVOIR DOME RING UPGRADE DETAILS</b>		SHEET <b>S-3</b>
PROJECT NO. 10-1147-202	SCALE: AS SHOWN	DATE: JUNE 2011

## Roof Dome Compression Ring Repairs

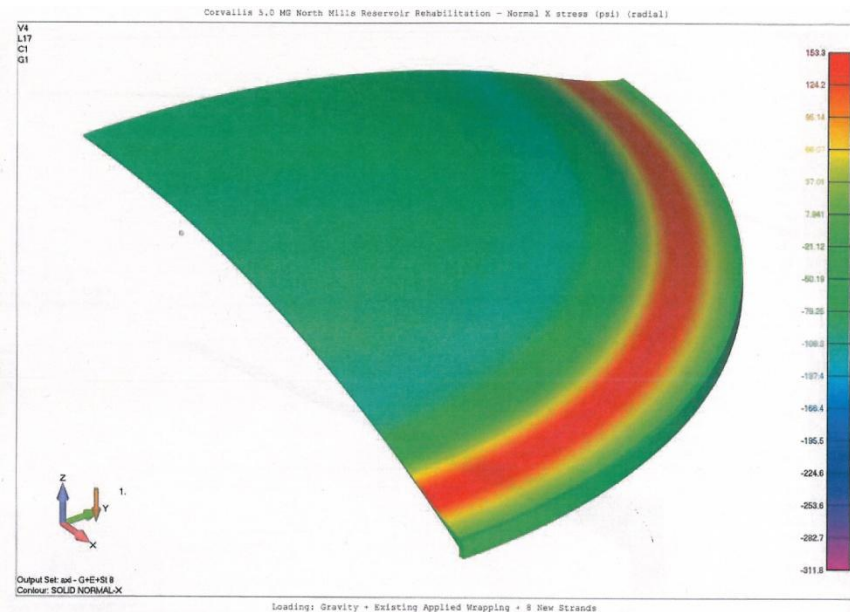
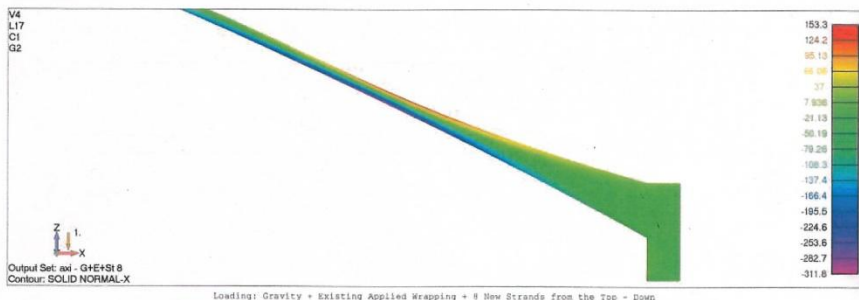
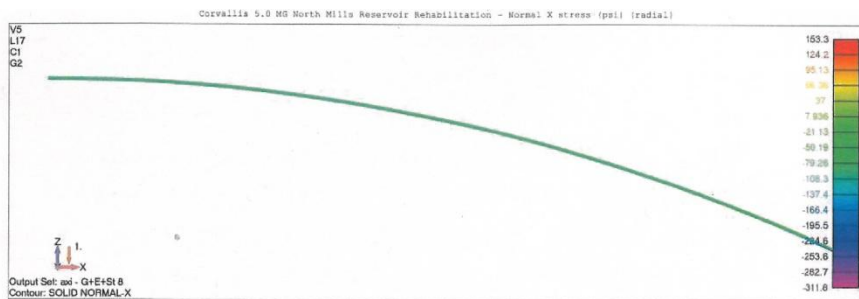
DYK and structural engineer conducted field investigation to determine existing wire wrap corrosion loss.



**Full Circumferential Scaffolding Erected  
for Dome Ring Repair**

## Roof Dome Compression Ring Repairs

Based on corrosion loss of 15%, DYK performed three-dimensional Finite Element Analysis (FEA) of the dome and dome ring, submits for structural engineer review.



### Typical Radial Loading Diagrams

Eight Strands of Galvanized 7 Wire Cable with an Applied Force of 24.41 k/Strand Was Adopted.

# North Hills 1st Level East Reservoir Improvements Project

## Installing Strand Wrap Without Wrapping Machine



“Stretching” Strand to achieve desired elongation

## Finishing Roof Dome Compression Ring Repairs



Applying Shotcrete Over Strand



Installing Flashing

# North Hills 1st Level East Reservoir Improvements Project

## Dome Roof to Wall Connection Improvements





# North Hills 1st Level East Reservoir Improvements Project



Roof Crack Injection



Epoxy Injection Ports

## Shotcrete Wall Injection



**Locating Voids and Laying out  
Injection Port Locations**

# North Hills 1st Level East Reservoir Improvements Project

## Maintenance and Appurtenance Upgrades



**New SS Ladder and Painted Overflow Piping**



**Concrete Surface Repair and Coating of Inside Access Hatch**

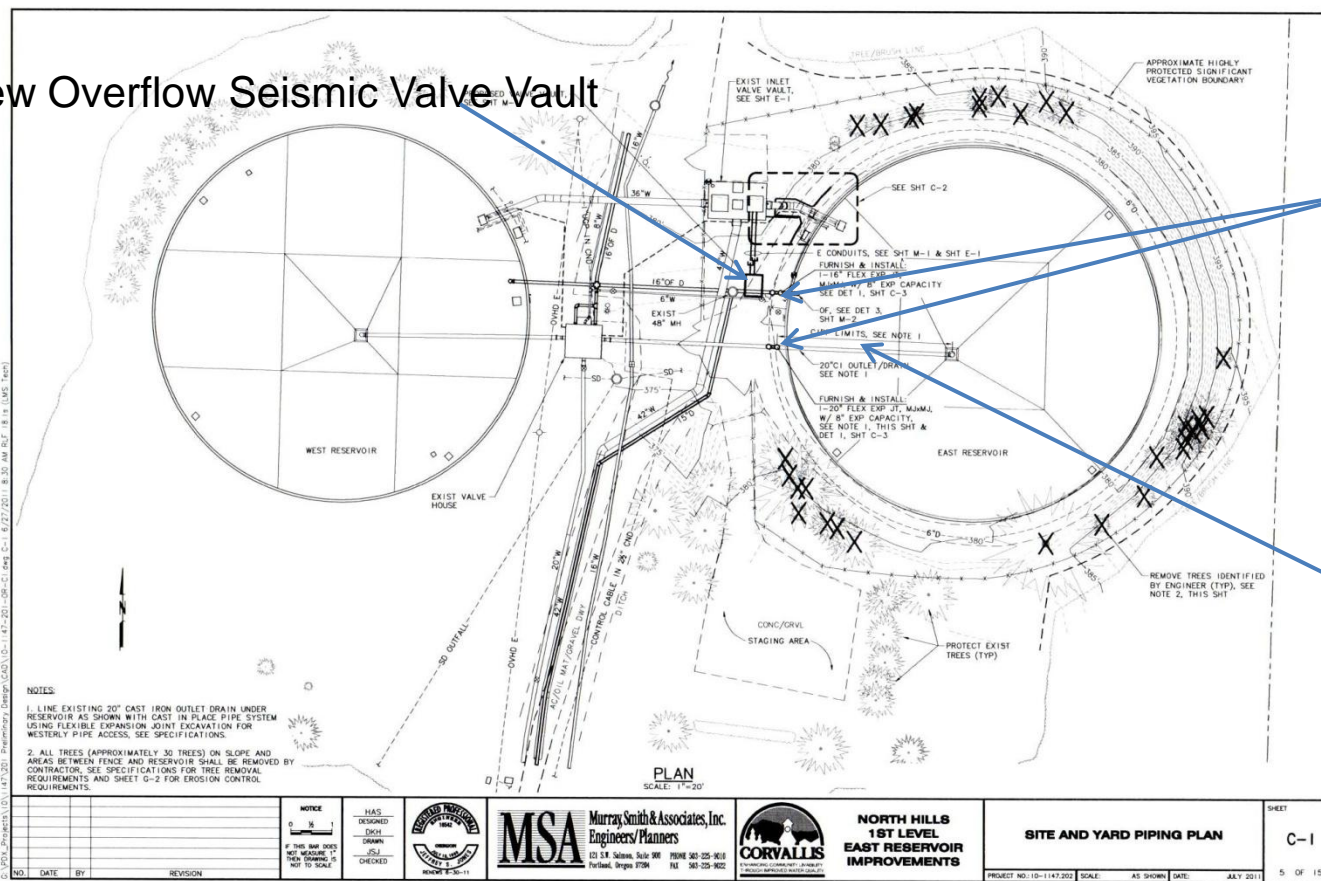
# North Hills 1st Level East Reservoir Improvements Project

## Yard Piping Improvements

New Overflow Seismic Valve Vault

Install Flexible Expansion Joints

Line Cast Iron Inlet/Outlet/Drain Pipe Under Reservoir with Structural NSF CIPP

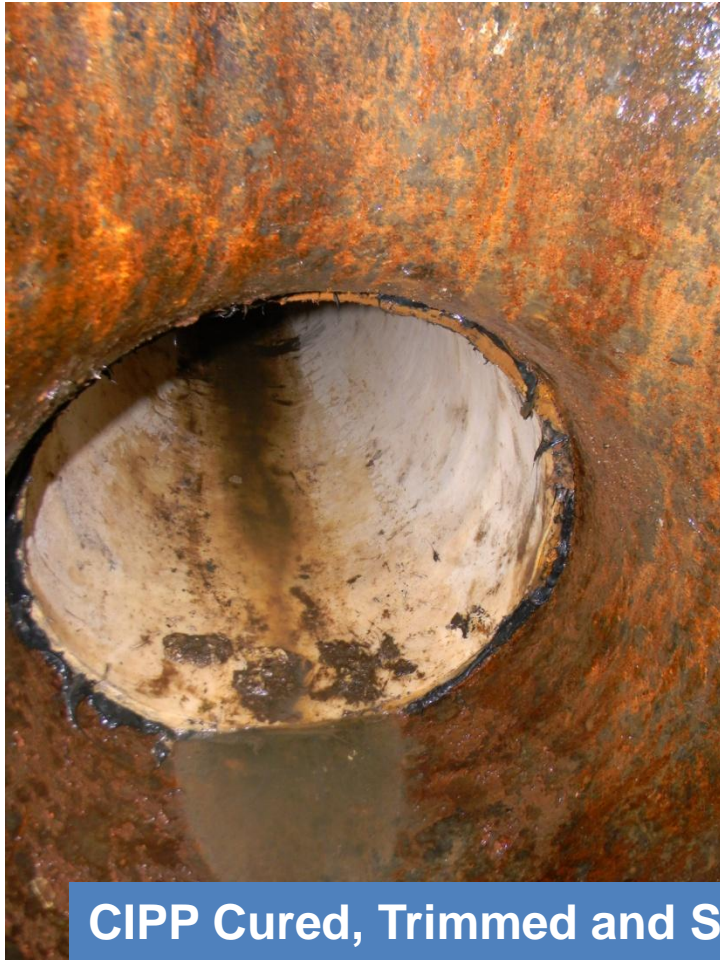


# North Hills 1st Level East Reservoir Improvements Project

Installing CIPP into 20-inch CI  
Inlet/Outlet/Drain Piping



# North Hills 1st Level East Reservoir Improvements Project



**CIPP Cured, Trimmed and Sealed at Reservoir Floor Sump**

# North Hills 1st Level East Reservoir Improvements Project



Overflow Valve Vault



Seismic Controlled  
16-inch BFV with 120  
VAC Motorized  
Actuator and UPS



# North Hills 1st Level East Reservoir Improvements Project



**Flexible Expansion Joints Installed on 16-inch CI Reservoir Overflow  
and 20-inch CI Inlet/Outlet/Drain Pipes**



# North Hills 1st Level East Reservoir Improvements Project: Summary

## Construction Cost:

- Approximately \$1m (Dome Ring Repair approximately 40% of bid)
- Engineer estimate if wall was strand wrapped: \$1.8M to 1.9M
- Change orders currently approximately 10% of bid amount (includes additional work requested by City)

## Challenges

- Selecting Qualified Contractors
- Reservoirs typically off line during periods of inclement weather: moisture and temperature affects application of coating, sealant and epoxy grouts
- As with any rehab/remodeling of existing facilities, unanticipated existing conditions come up

# QUESTIONS & ANSWERS

