

Rehabilitation Options for Aging Concrete Water Storage Reservoirs

MYRON BASDEN, P.E., S.E.

JAMIN ANKNEY, P.E.



Gray & Osborne, Inc.
CONSULTING ENGINEERS

Overview

- ▶ Common Concerns of Existing Concrete Reservoirs
- ▶ Case Study – Background
- ▶ Case Study – Evaluation and Rehabilitation Options
- ▶ Other Rehabilitation Options
- ▶ Case Study – Follow Up
- ▶ Final Thoughts



Common Concerns

- ▶ Concrete reservoir built 20-50+ years ago
 - ▶ Corroded piping
 - ▶ Concrete deterioration
 - ▶ Access and security deficiencies
 - ▶ Leakage of reservoir contents
- ✓ *How to proceed?*



Comprehensive Reservoir Evaluation

- ▶ Condition evaluation
 - ▶ Seismic evaluation
 - ▶ Piping and valves assessment
 - ▶ Safety and access assessment
 - ▶ Other improvements
-
- ✓ *How much will it cost?*
 - ✓ *How does that cost compare to a new reservoir?*
 - ✓ *Which improvements are priority?*

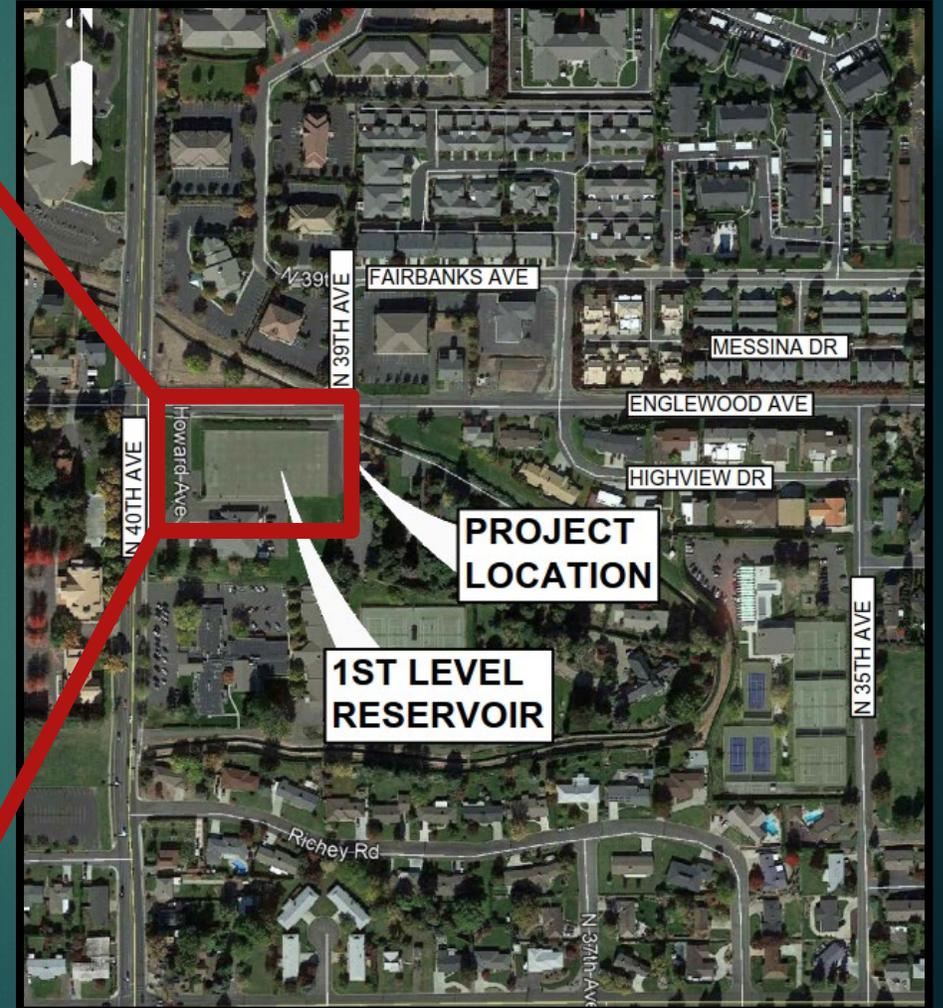


Case Study - Background

- ▶ Yakima 1st Level Reservoir
- ▶ 6 MG buried concrete tank constructed 1971
- ▶ No significant upgrades since original construction
- ▶ Known concrete damage at floor
- ▶ Known leakage from reservoir



Case Study - Background



Case Study - Background

- ▶ City also interested in the following:
 - ▶ Seismic evaluation
 - ▶ Condition assessment
 - ▶ Distribution system modeling
 - ▶ New isolation valve to add operational flexibility
- ▶ Summarize findings and rehabilitation options in Pre-Design Report
- ▶ Proceed to design phase after the City selects the desired improvements

Case Study Timeline

Date	Activity
December 2020	Begin Reservoir Evaluation
January 2021	Distribution System Modeling
March 2021	Site Visits to Assess Reservoir
April 2021	Valve Installation
August 2021	Complete Pre-Design Report Providing Rehabilitation Options
September 2021	Rehabilitation Options Selected, Begin Design Phase
May 2022	Pre-Procurement, Order of Selected Piping
September 2022	Project Bids
October 2022	Delivery of Pre-Procured Piping
October 2022	Notice to Proceed
November 2022	Start Construction
March 2023	Substantial Completion

Reservoir Evaluation Methods

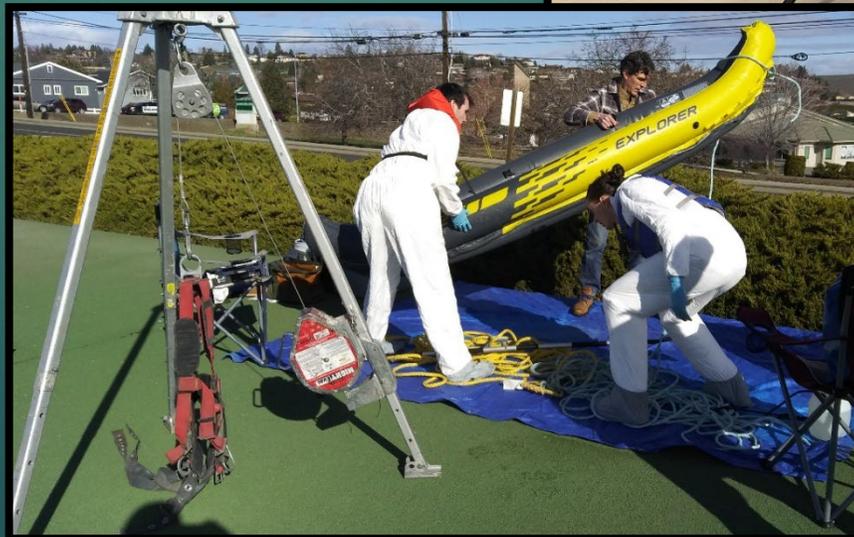
Goals:

- ▶ Define required and desired improvements
- ▶ Collect information as needed to develop an accurate cost estimate for improvements



Methods:

- ▶ Drain tank for interior inspection
- ▶ Diver
- ▶ ROV
- ▶ Raft



Reservoir Evaluation Methods

- ▶ Raft allows up-close inspection of underside of roof



Assess Optimum Timing for Repairs

- ▶ Assess criticality of recommended improvements
- ▶ Consider availability of funding
- ▶ Consider constraints on reservoir being out of service
- ▶ Deferring improvements can reduce initial cost
 - ▶ Accepts interim risk of seismic failure
 - ▶ Accepts interim risk of continuing deterioration and damage
 - ▶ May increase overall cost

Concrete Evaluation and Repairs

- ▶ Important to perform regular inspections
- ▶ If concrete deterioration exposes rebar, rate of deterioration can increase, resulting in:
 - ▶ repair cost increases
 - ▶ Increased risk of change orders
- ▶ Exact extent of damage will not be known until removal of deteriorated concrete during construction – set up bid items accordingly



Concrete Evaluation and Repairs

Failure Types - Concrete deterioration – at surface or extends deeper?



Concrete Evaluation and Repairs

Failure Types – joints and cracks



Concrete Evaluation and Repairs

Failure Types - active leakage at floor joints



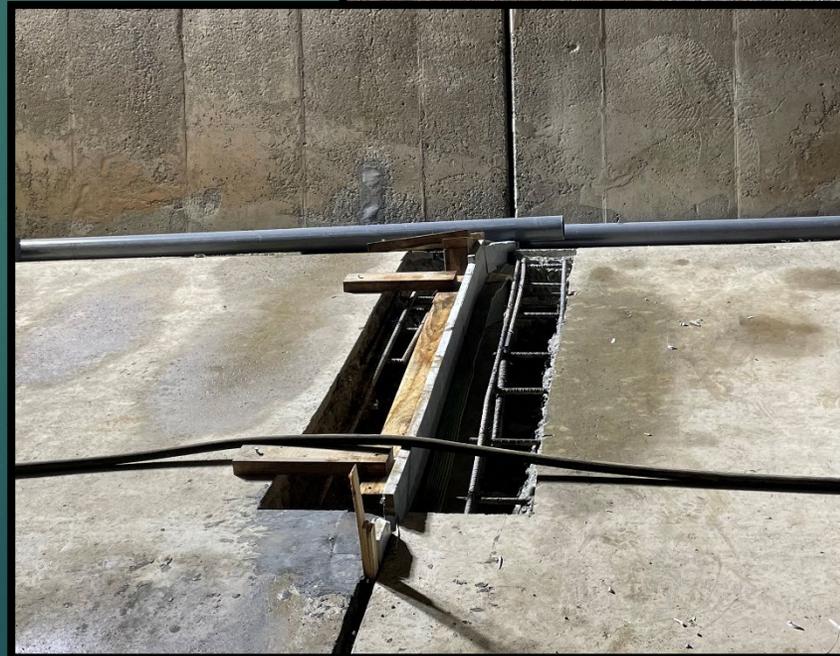
Concrete Evaluation and Repairs



Concrete Evaluation and Repairs

Several Types of Concrete Repair

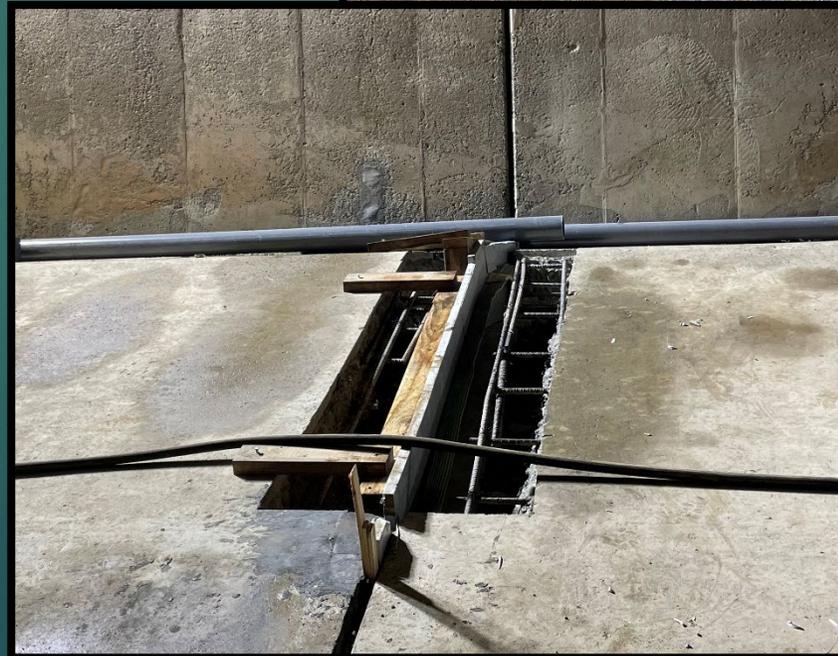
- ▶ Fill Voids Under Floor
- ▶ Crack injection
- ▶ Surface Repair
- ▶ Demo and Repair
 - ▶ Patching Product
 - ▶ Shotcrete



Concrete Evaluation and Repairs

Several Types of Concrete Repair

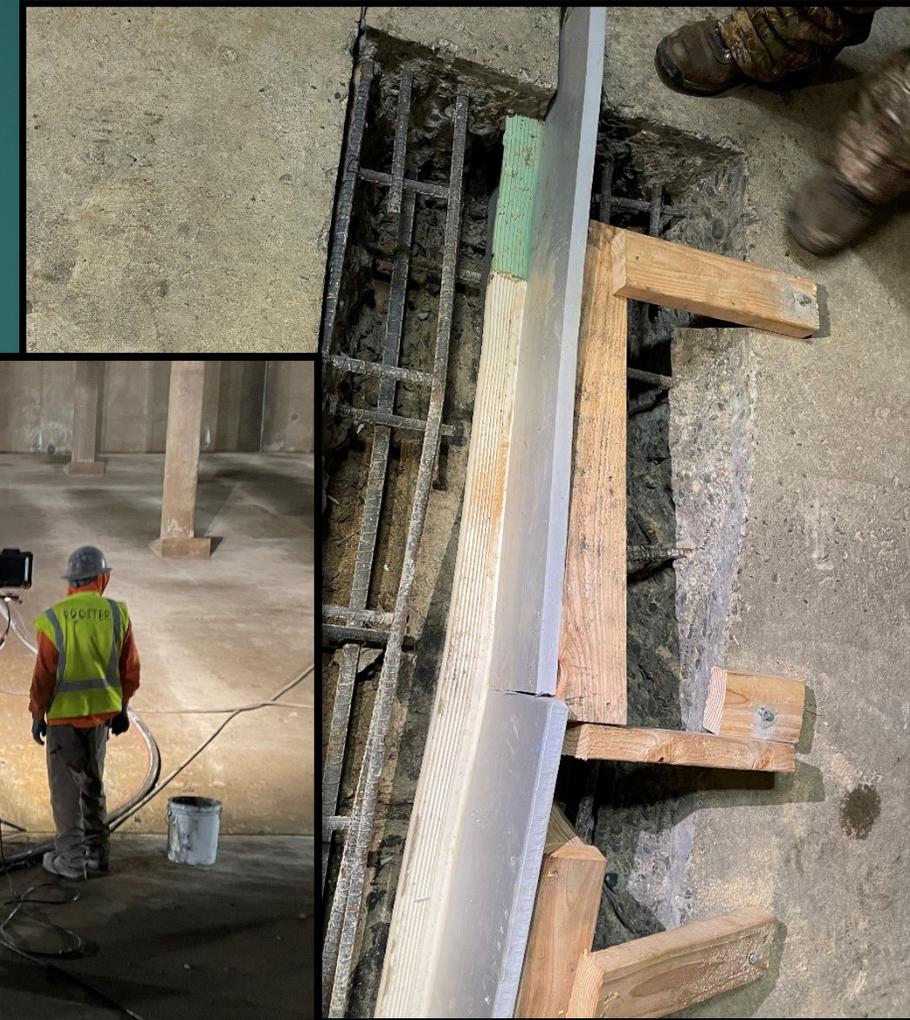
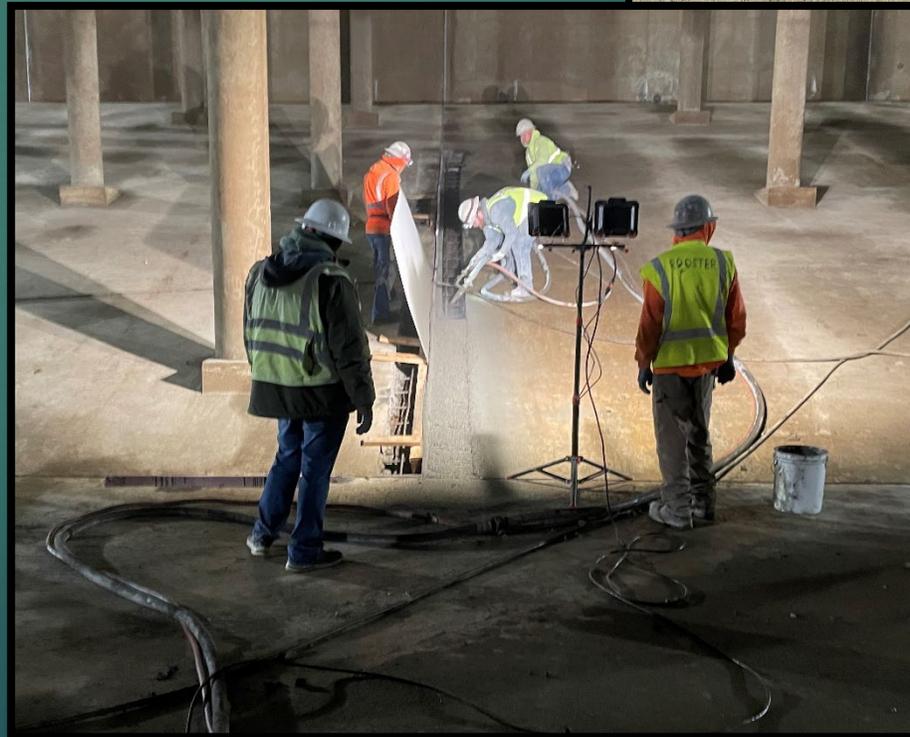
- ▶ Fill Voids Under Floor
- ▶ Crack injection
- ▶ Surface Repair
- ▶ **Demo and Repair**
 - ▶ Patching Product
 - ▶ Shotcrete



Concrete Evaluation and Repairs

Shotcrete:

- ▶ Works well for walls and sloped slabs
- ▶ Significant setup – not efficient for small areas
- ▶ Can be installed to range of depths
- ▶ Requires experienced crew
- ▶ Requires tight control of concrete mix



Concrete Evaluation and Repairs

Shotcrete:

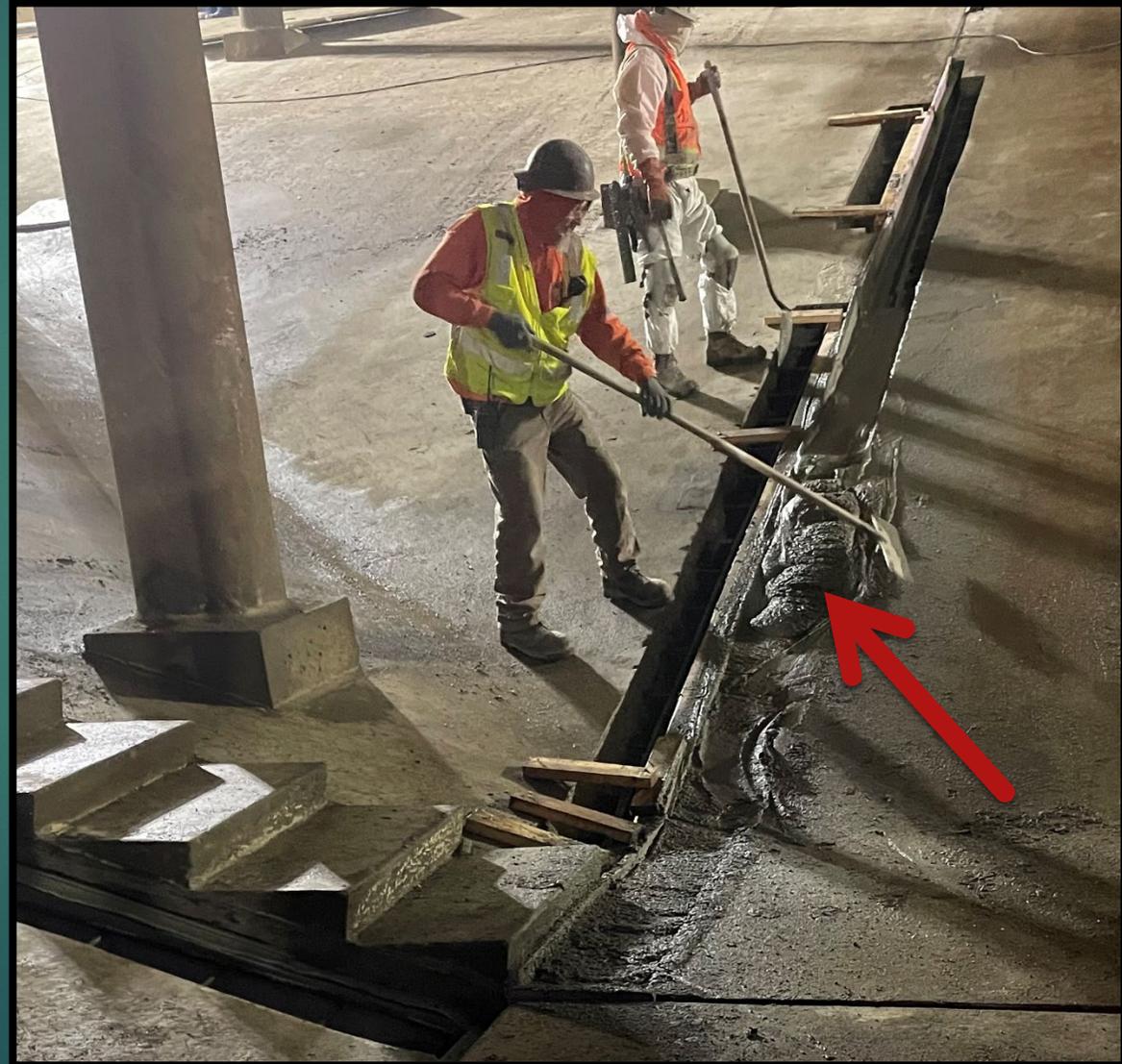
- ▶ Test panels and cores to verify consolidation and to perform strength testing



Concrete Evaluation and Repairs

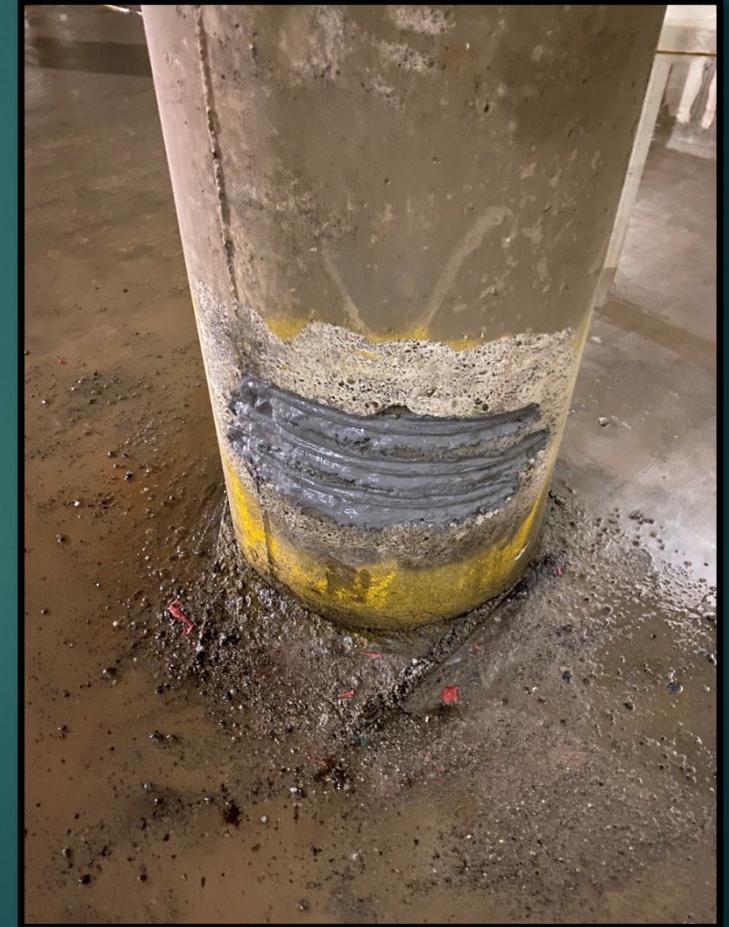
Shotcrete:

- ▶ Example of shotcrete mix that was too fluid
- ▶ Long supply line



Other Common Corrosion Issues

- ▶ Repair of exposed rebar
- ▶ Prep and coat rebar with primer containing corrosion inhibitor prior to grout repair



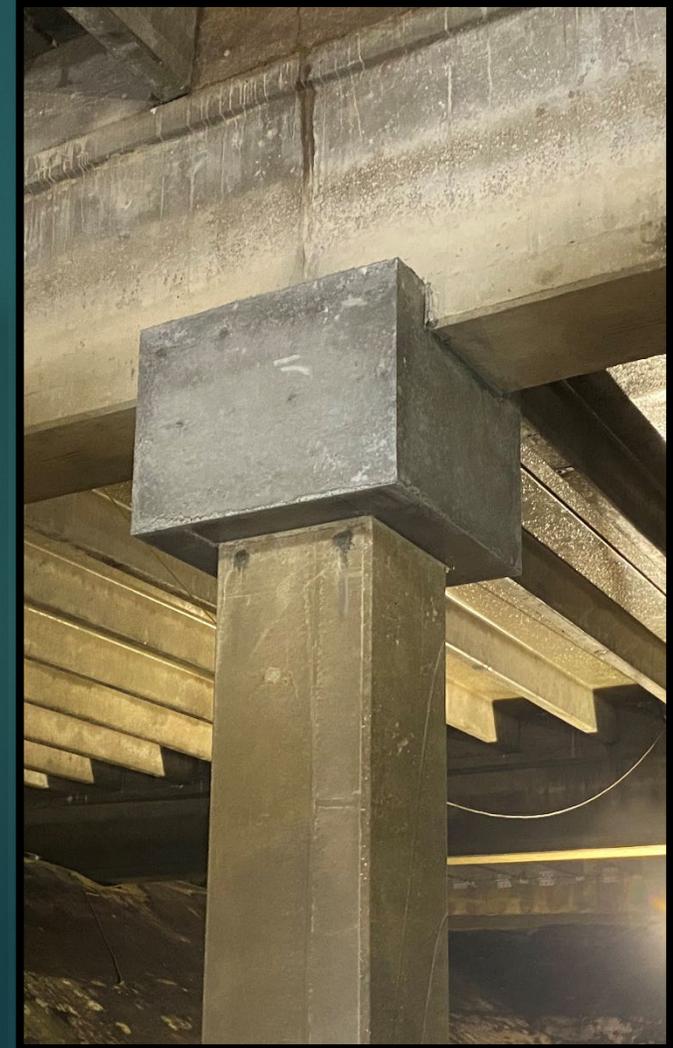
Roof to Wall Connection Issues

- ▶ Prestressed circular concrete reservoirs –
roof to slab connection
– radial and tangential effects



Other Crack Repair Concerns

- ▶ Temperature expansion/contraction and restraint cracking
- ▶ Design repairs to address problematic restraint



Other Crack Repair Concerns

Crack Repair Considerations

- ▶ Structural vs. sealing repair
- ▶ Surface vs. injection repair
- ▶ Important for contractor to follow repair product instructions
- ▶ Some products allow repair while crack is under water pressure
- ▶ Injection repair requires certified/experienced installer
- ▶ Poorly installed injection repair is difficult to remedy

Other Options to Address Leakage

- ▶ Groundwater/Surface water intrusion example



Other Options to Address Leakage

- ▶ Liner to address watertightness



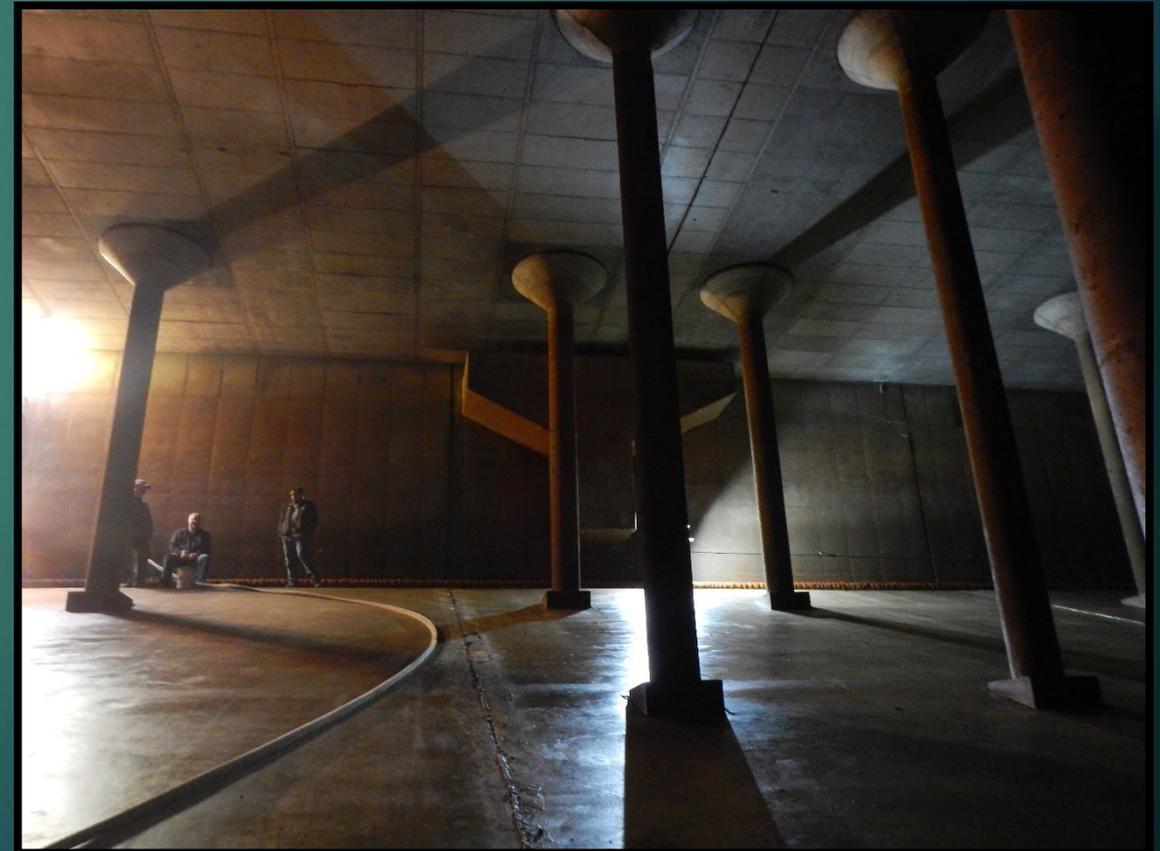
Seismic Evaluation

- ▶ Verify existing reservoir geometry
- ▶ Perform seismic evaluation in accordance with ASCE 41 and appropriate ACI or AWWA standard.



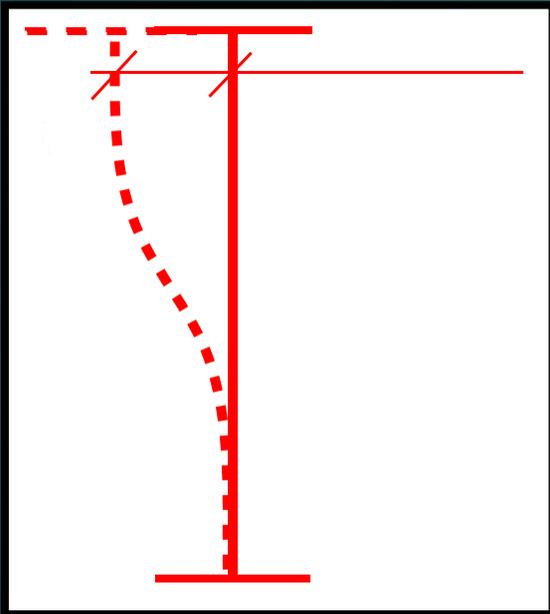
Seismic Evaluation

- ▶ Conditions evaluated by seismic analysis include:
 - ▶ Roof to wall joint
 - ▶ Roof to column joint
 - ▶ Walls
 - ▶ Wall to foundation slab joint
 - ▶ Columns
 - ▶ Freeboard
 - ▶ Flexible piping connections



Seismic Evaluation

- ▶ Check roof slab to column connection
- ▶ Deformation compatibility



Seismic Evaluation

- ▶ Example of seismic retrofit at joint between roof slab and column

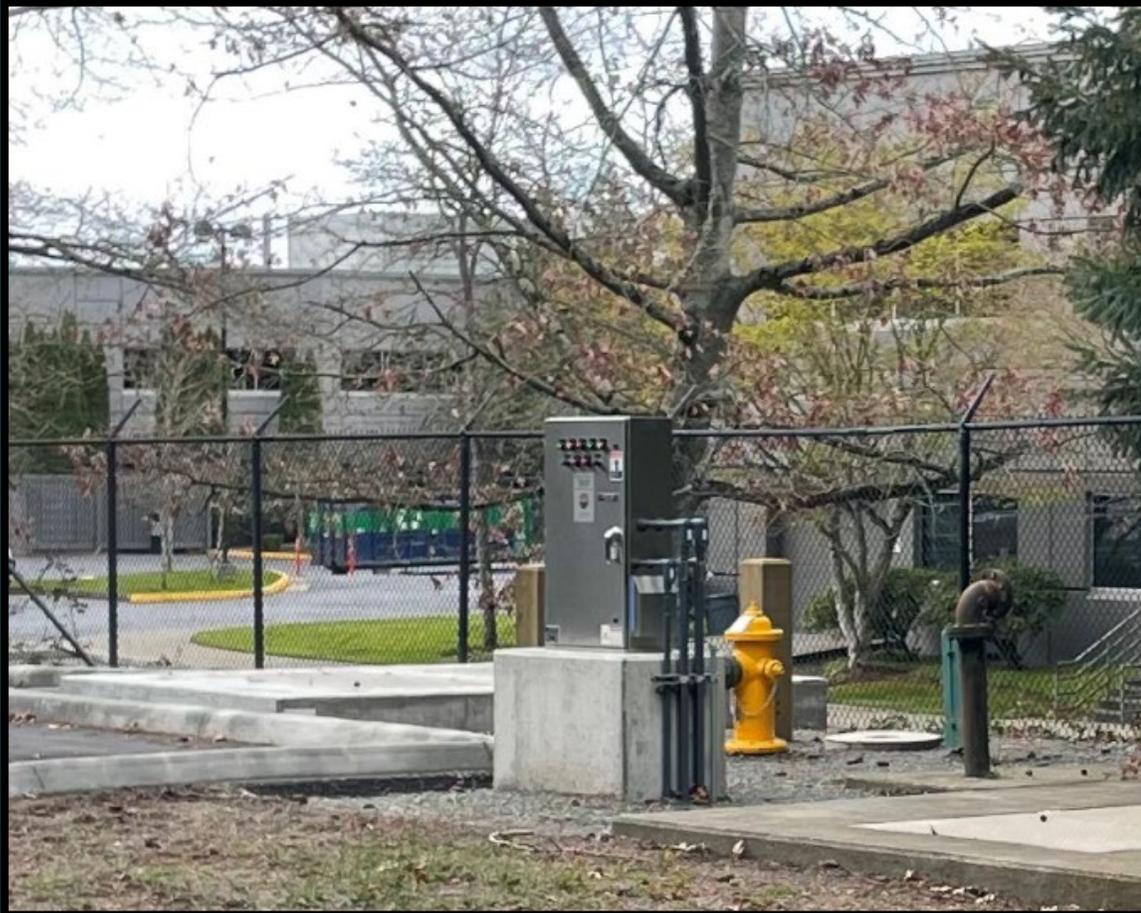


Seismic Evaluation

- ▶ ASCE 41 provides several risk levels for evaluation/design
- ▶ Performance Objective
 - ▶ Structural vs. Non-structural
 - ▶ Life Safety vs. Operational
- ▶ Seismic Hazard Level
 - ▶ Select earthquake level for evaluation/design
 - ▶ 2,475, 975, 475, and 225 year return periods
- ▶ Can be useful to evaluate risk and find threshold where significant retrofit costs are triggered.

Other Options for Seismic Protection

- ▶ Seismic sensor and valves



Piping Rehabilitation

- ▶ Inlet/Outlet Piping
- ▶ Overflow Piping
- ▶ Washdown Piping
- ▶ Drain Valves
- ▶ Valves and Operators



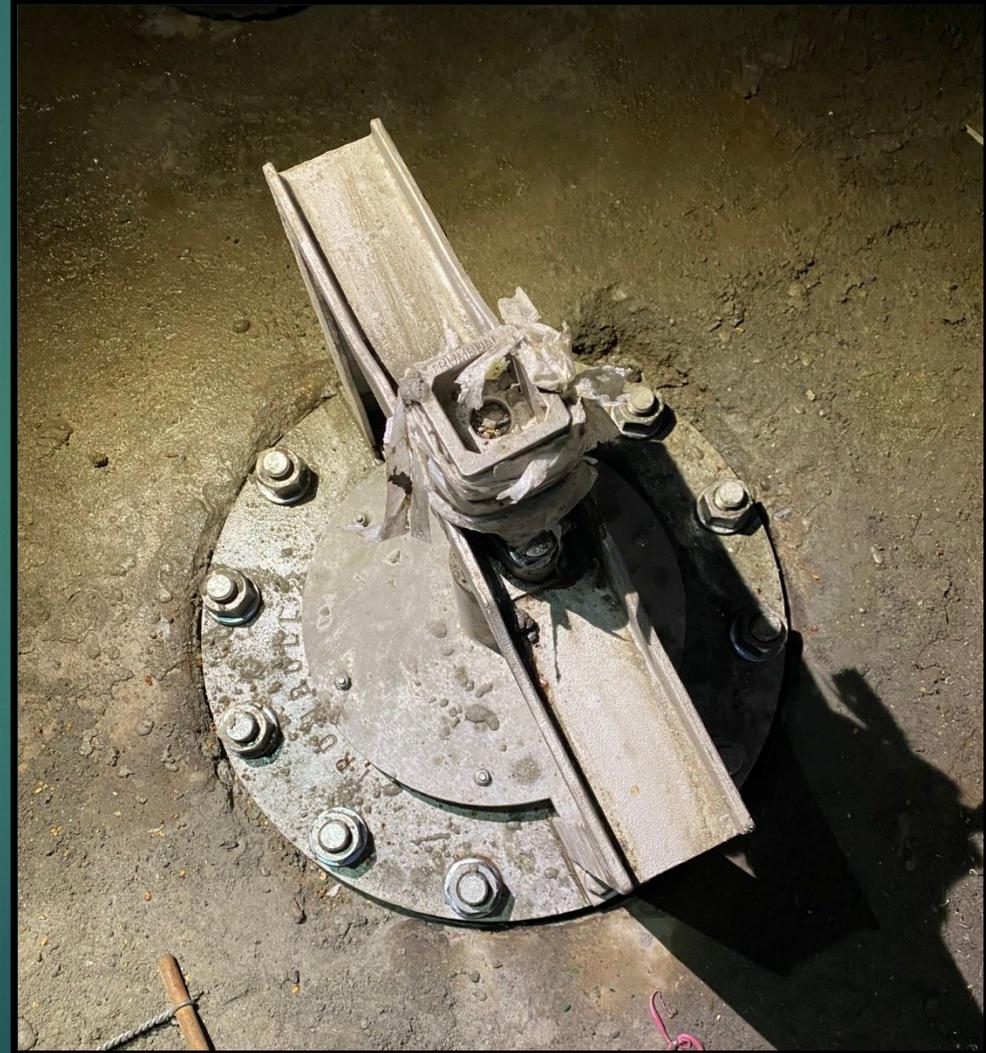
Piping Rehabilitation

- ▶ Washdown and Other Piping



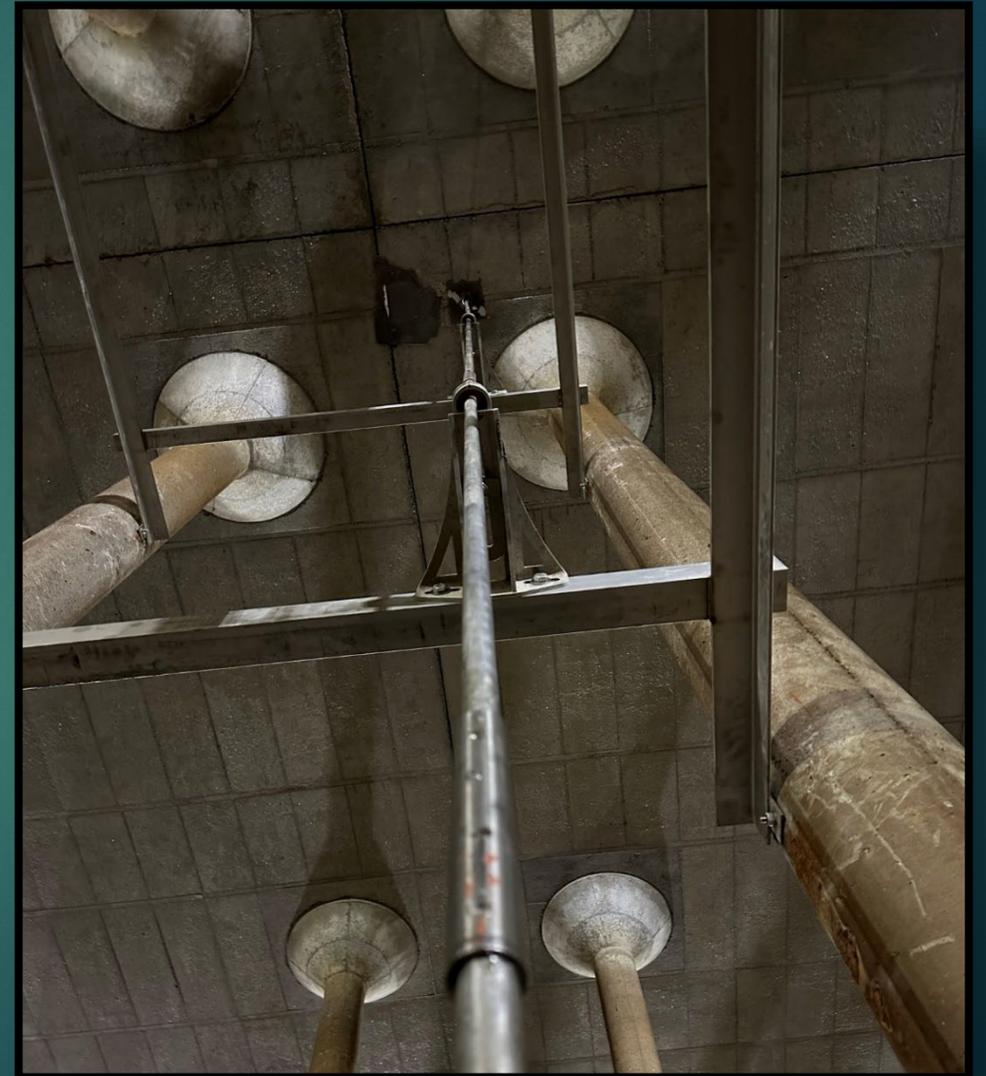
Piping Rehabilitation

- ▶ Drain Valves



Piping Rehabilitation

- ▶ Valves and Operators



Piping Rehabilitation

- ▶ Valves and Operators



Piping Rehabilitation

► Overflow Piping



Safety and Access

Regulatory Compliance

- ▶ Hatches/Ladders
- ▶ Fall arrest systems
- ▶ Guardrails

Potential Improvements

- ▶ Additional access hatches/ladders



Vent Improvements

Roof Vent:

- ▶ Existing vents were undersized
- ▶ City opted for locating at side of reservoir rather than on roof



Security Improvements

- ▶ Security Cameras
- ▶ Intrusion Switches
- ▶ Security Fencing
 - ▶ Degree of protection
 - ▶ Aesthetics
 - ▶ Cost



Other Improvements

- ▶ Water Quality Features
- ▶ Tank Operation Appurtenances
- ▶ Mixing

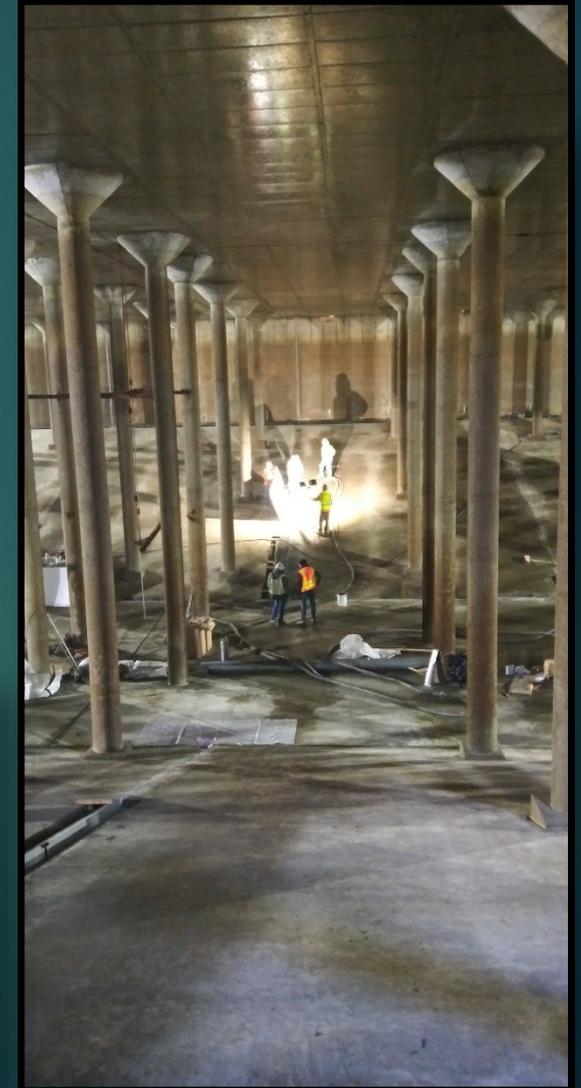


Constructability

- ▶ Access for repairs
- ▶ Debris removal
- ▶ Define access constraints for contractors



Constructability – Concrete Placement



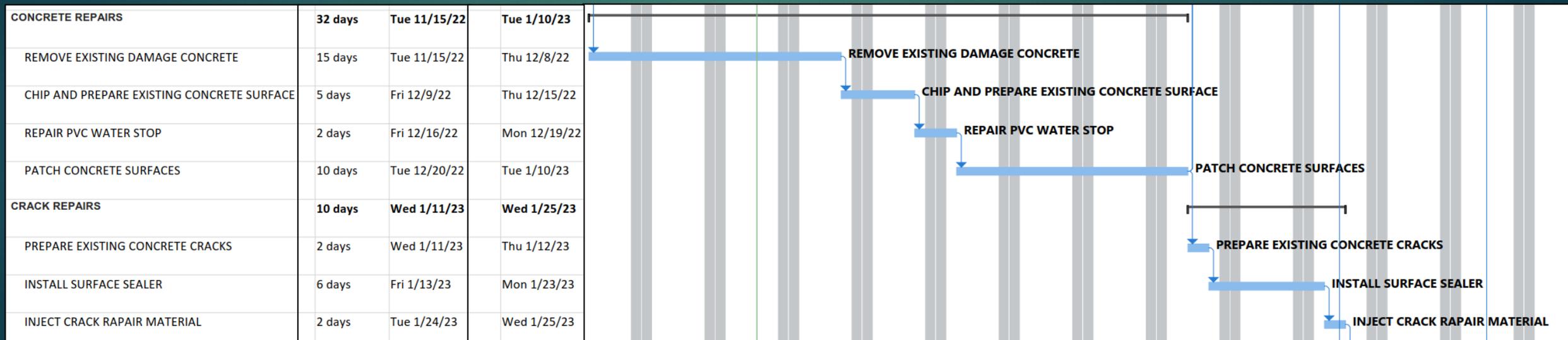
Constructability

- ▶ Coordinate inspection of surface preparation and coating application
- ▶ Ensure adequate environmental conditions for coating
- ▶ Maximizes the life of coating systems



Constructability

- ▶ Schedule constraints on when the reservoir can be out of service
- ▶ Coordination with City operation and inspection



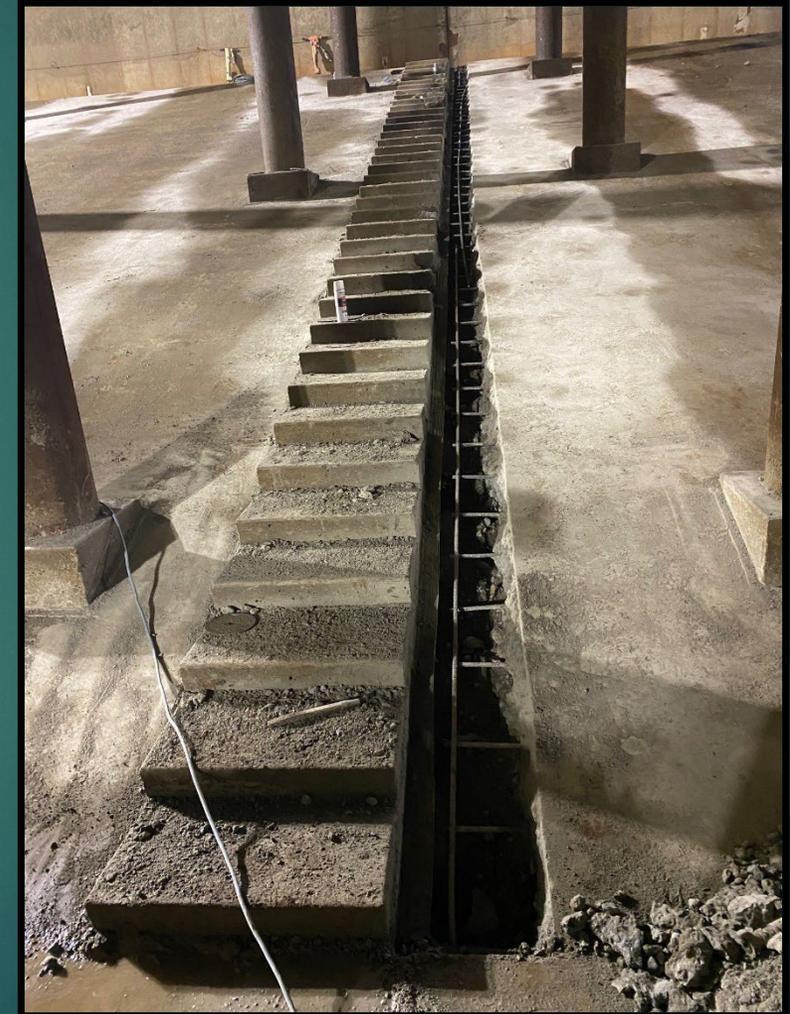
Pre-Procurement of Materials

- ▶ Large diameter piping found to have long lead times
- ▶ Short window available for construction
- ▶ Long lead time items were pre-procured to support the City's desired construction schedule



Warranty Period

- ▶ Duration: Recommend 2-year warranty period
- ▶ Warranty Inspection: Scheduled near end of warranty period
- ▶ Include key stakeholder in warranty inspection
- ▶ Address items not meeting the warranty



Case Study Follow Up

Contractor:

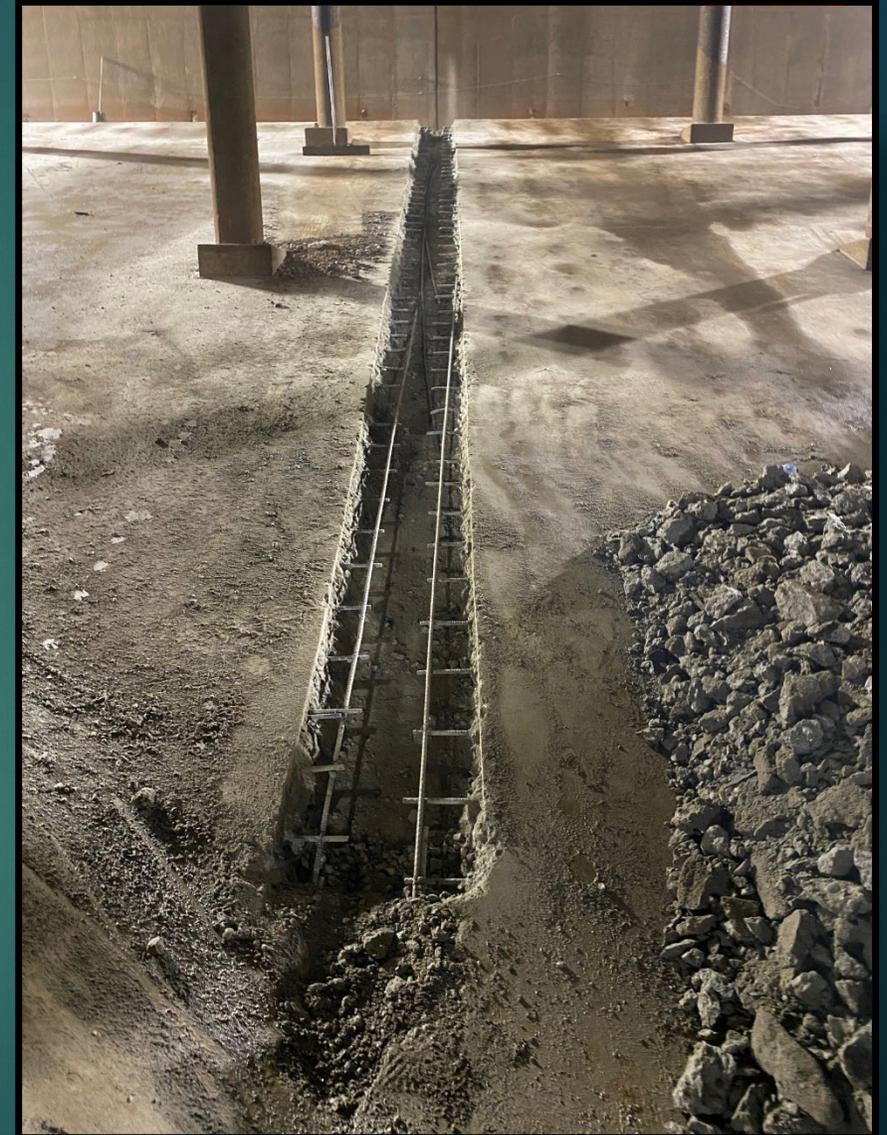
- ▶ Combined Construction, Inc. (Mukilteo, WA)

Schedule:

- ▶ Notice to Proceed: October 13, 2022
- ▶ Start Construction: November 14, 2022
- ▶ Substantial Completion: March 10, 2023

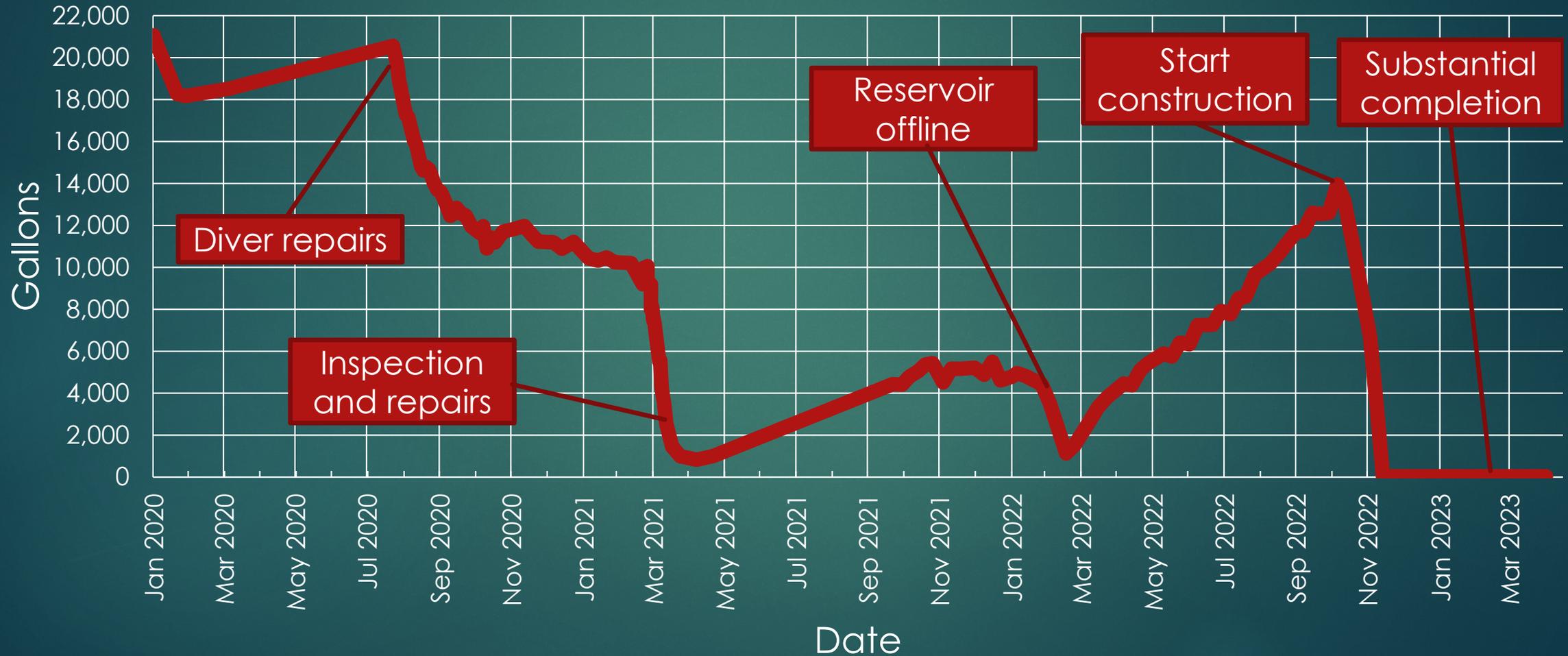
Cost:

- ▶ Engineer's Estimate: \$930,500
- ▶ Low Bid: \$1,098,000
- ▶ Final Cost: \$1,040,400



Leakage History and Current Status

Sump Pump Discharge (gpd)



Final Thoughts

- ▶ Complete regular inspections.
- ▶ Detailed evaluation can minimize risk of surprise costs during bid and construction.
- ▶ Comprehensive reservoir evaluation and detailed cost estimate lead to a successful project.
- ▶ Involve all stakeholders to address all needs in one project.
- ▶ Compare rehabilitation to a new reservoir alternative.
- ▶ Prepare designs to allow adaptation and flexibility.

Acknowledgements

City of Yakima

- ▶ Mike Shane, Interim Water/Irrigation Manager
- ▶ Jeff Bond, Water Treatment Plan Supervisor
- ▶ Emilio Lopez, Water Distribution Supervisor
- ▶ Dave Brown (retired)

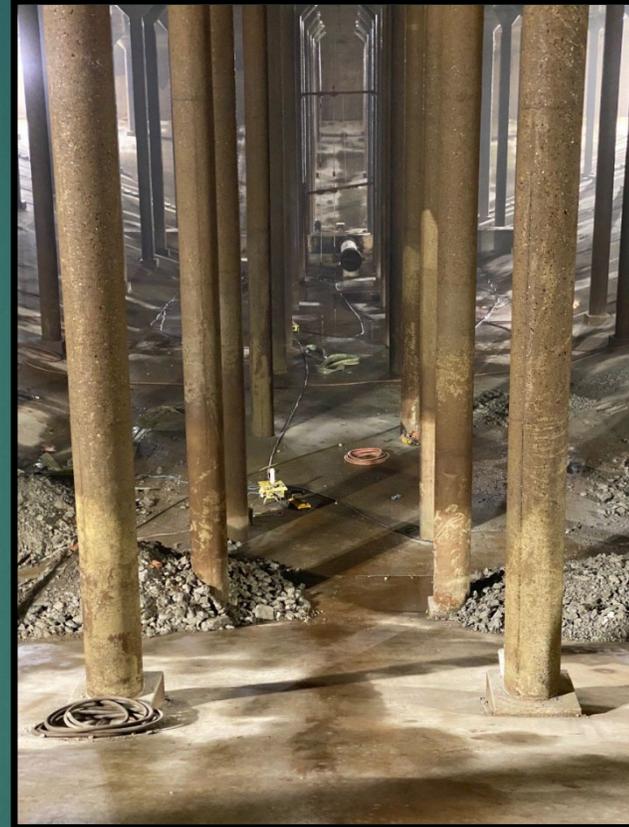
▶ Combined Construction, Inc.

▶ Gray & Osborne, Inc.

- ▶ Don Tulloch, P.E.
- ▶ Mike Johnson, P.E.
- ▶ Zara Guzmán, E.I.T
- ▶ Chad Carlson, Inspector

▶ Presenters

- ▶ Jamin Ankney, P.E., Project Manager, (509) 453-4833, jankney@g-o.com
- ▶ Myron Basden, P.E. S.E., Structural Engineer, (206) 284-0860, mbasden@g-o.com



Questions?

