Elevated Water Storage Tank Assessment and Rehabilitation

Extending the Service Life of our Most Visible Infrastructure

AWWA-PNWS Spring Conference,
Kennewick, WA May 4, 2023

Presented by Matt Hickey and Ed Ling

consor

PSE
PETERSON STRUCTURAL ENGINEERS

Introduction

Matt Hickey

Technical Practice Leader, Reservoirs
(Consor)

Ed Ling

Firm Principal
(Peterson Structural Engineers)

Agenda

01 Intro/Purpose

02 Background

03 Seismic Considerations

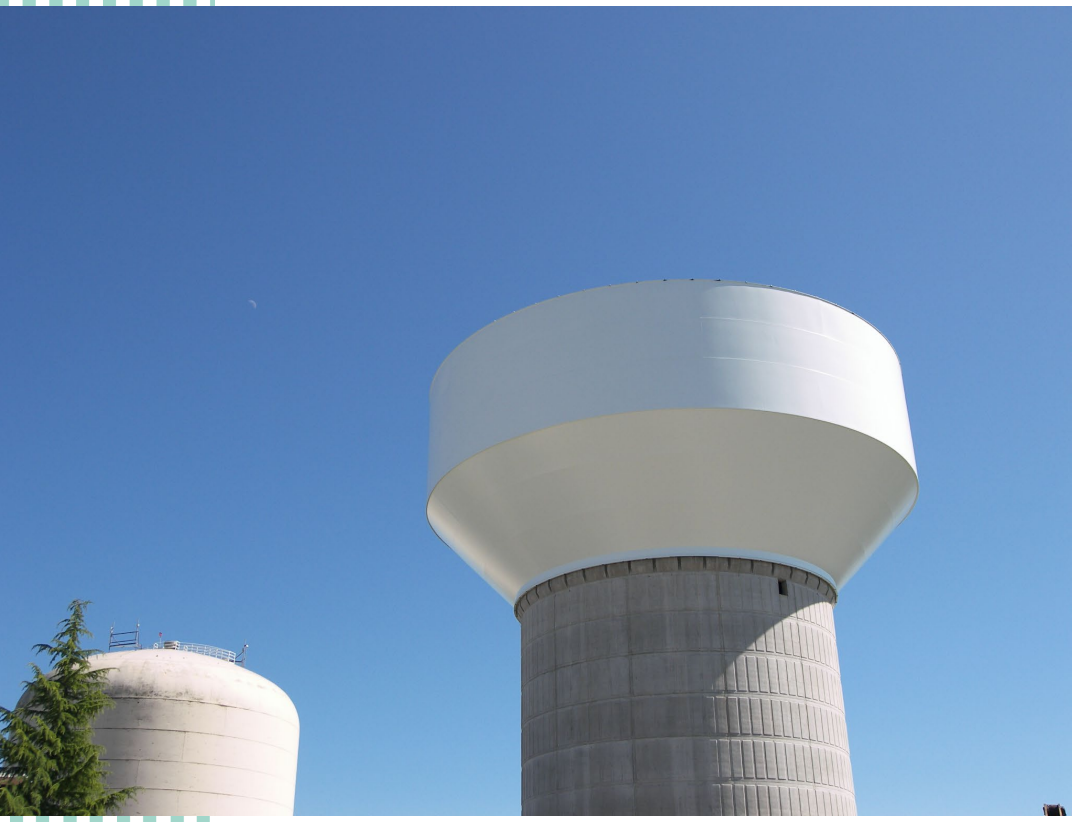
04 Conditions Assessments

05 Improvements

06 Conclusion/Summary

07 Q&A

Purpose



- Describe the importance of these facilities in water systems
- Discuss some of the different styles of elevated tanks
- Outline Assessments and Improvements to keep these critical facilities resilient and operational

Brief History of Elevated Tanks & Towers

- Important part of water systems in late 19th Century
- Need based on concentrated populations
- Need for dependable reserve supplies
- High costs of system operations led to search for most efficient means of operations
- Fire protection and maintaining system pressures
- Common practice began in 1880's

Source: *The Architecture and Engineering of Elevated Water Storage Structures 1870-1940 (Dubie, 1975)*

Water Towers

Elevated Tanks

Critical for Operations!

Why are Elevated Tanks Important?

Spheroid Elevated Tank

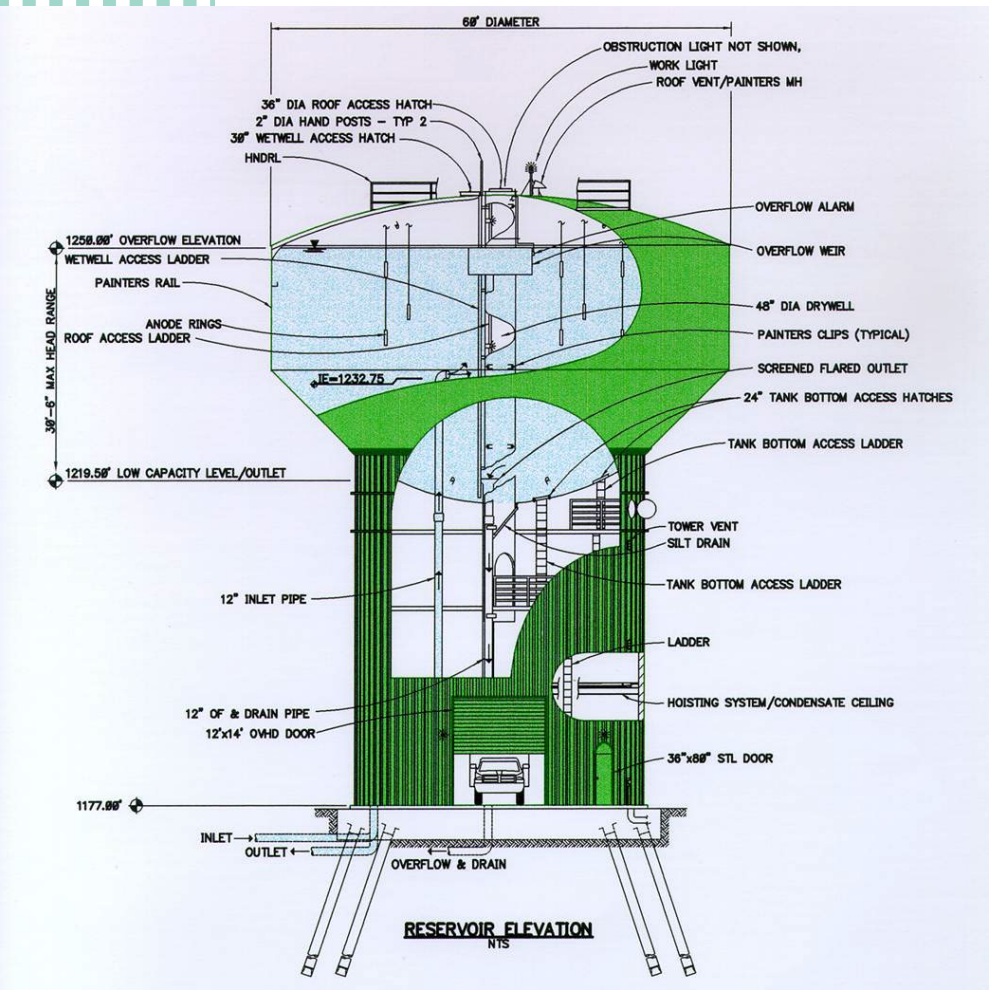
Typical Standpipe

- Provide consistent pressure in the system by reliable gravity flow.
- Provides supply for peak hour flows to reduce pumping needs
- Provides reliable storage during power outages or following a seismic event when pumping is not an option.
- Advantages over standpipes

Current Types of Elevated Tanks

Types of Elevated Tanks

Fluted Column Tanks (200,000 gallon to 4 MG+)



Types of Elevated Tanks

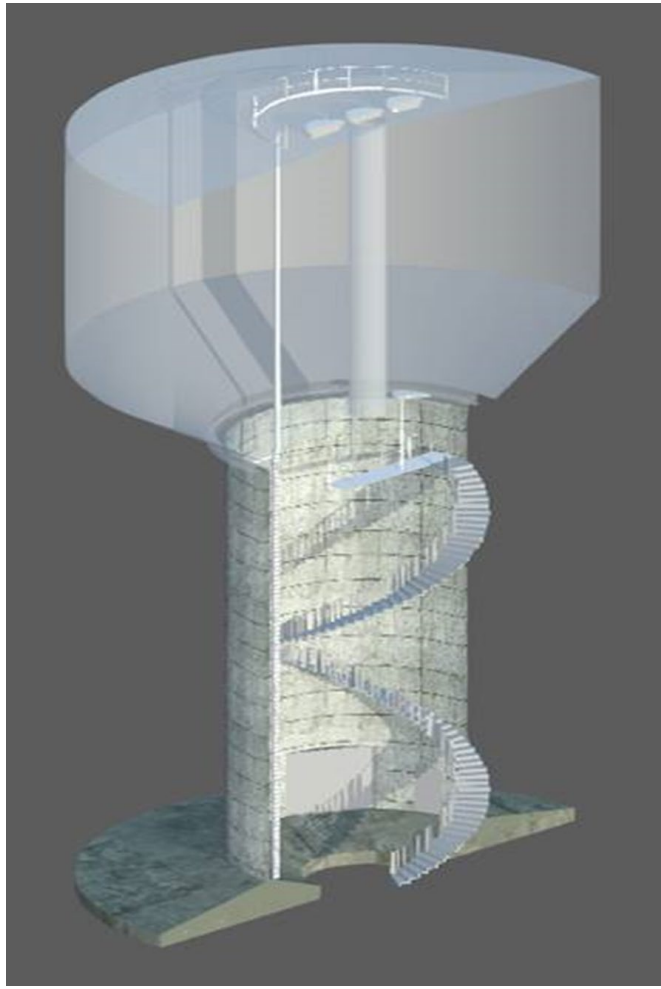
Multi-Column Tanks (50,000 gallon to 4 MG)

Types of Elevated Tanks

Spheroids (50,000 Gallon to 1.5 MG)

Types of Elevated Tanks

Composite Elevated Tanks (200,000 to 4 MG+)



History of Codes and Changes to Seismic Requirements of Elevated Tanks

- First AWWA code on elevated tanks published in 1935
- 1960's era construction common candidates for retrofits/improvements
- Gravity design relatively unchanged
- Many changes to seismic, wind, and detailing requirements

History of Codes and Changes to Seismic Requirements of Elevated Tanks

- Prior to 1990s, seismic loads applied as a percentage of total weight applied laterally.
- Current code accounts for hydrodynamic convective and invective motions. Loads typically closer to 10-15% of total weight
- Concrete anchor capacity significantly diminished since 2005 code.
- Detailing requirements introduced to ensure ductile failure.
- Wind loads increased. Only a concern for empty tanks.
- Future code considerations– design snow loads increasing.

PSE
PETERSON STRUCTURAL ENGINEERS

Common Structural Deficiencies - Anchors

Concrete Anchors – Common deficiency in almost all reservoirs due to code reductions in capacity:

- Breakout capacity
- Ductility requirements
- Detailing requirements

Common Structural Deficiencies - Foundations

Foundations

- Undersized for bearing and sliding under seismic loads

Common Structural Deficiencies - Cross Bracing

Cross bracing & Struts (Multi-Column Tanks)

- Cross bracing and struts undersized for current seismic loads

Common Structural Deficiencies - Panel Joint Connections

Panel Joint Connections

- Gussets and connections Inadequate for higher cross-bracing and strut loads.
- Column stiffening required at joints

Common Structural Deficiencies - Inadequate Freeboard

Inadequate Freeboard

- Standpipes, flat roofs

Common Non-Structural Seismic Deficiencies - Pipe Bracing

- Pipe bracing
- Protection from draining the tank after an event
- Pipe connections
- Other types of deficiencies we'll discuss

Common Non-Structural Seismic Deficiencies – Pipe Connections

- Typically, not restrained
- Flexibility and expansion not provided

Existing Unrestrained Joint

Typical Unrestrained Flexible Coupling on Piping at Reservoir Footing

Common Non-Structural Deficiencies – Seismic Isolation

Lack of seismically actuated shut-off capabilities

Structural Retrofits

- Operational Retrofit - Lower operating level to bring overstressed elements into compliance
- Decommissioning – Empty and preserve as telecommunications tower or landmark.
- Foundations – expansion, confinement collars, replacement

Decommissioned Reservoir Maintained as City Landmark

Replacing Foundation for Seismic Conditions

Expansion Foundation for Seismic Conditions

Structural Retrofits

- Anchors – epoxy anchors, earth anchors, micropiles
- Cross-bracing & Struts – replacement, strengthening

Structural Retrofits

- Connections – strengthen or replace, stiffening jackets or rings to column legs, larger connection hardware

- Freeboard – lower operating level, strengthen roof with supplemental framing, new roof

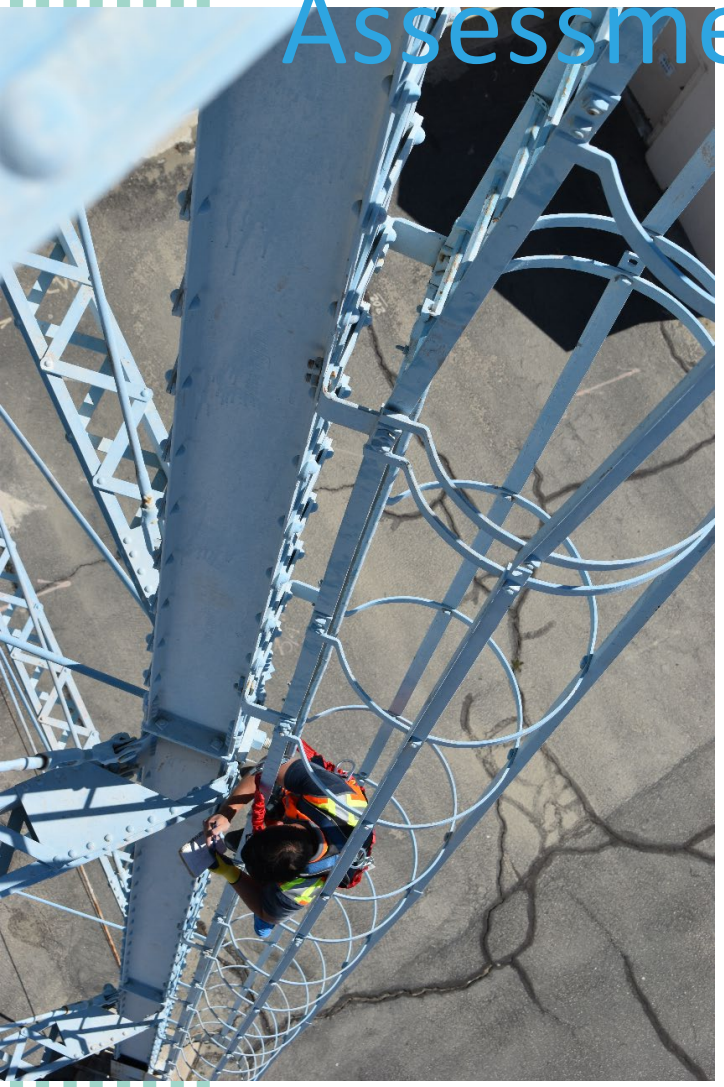
Non-Structural Seismic Retrofits – Flexible Pipe Connections

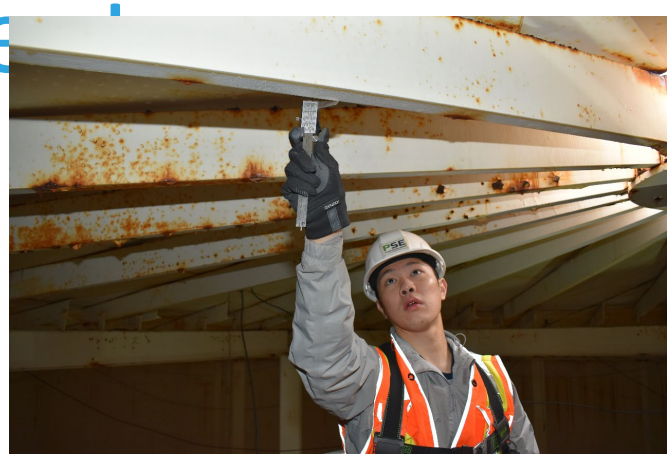
Non-Structural Retrofits – Seismic Isolation

Electric Actuator
Added to Existing BFV

- Seismic sensor
- Signals Actuator to shut valve
- Partial or full closure

Structural Condition Assessme



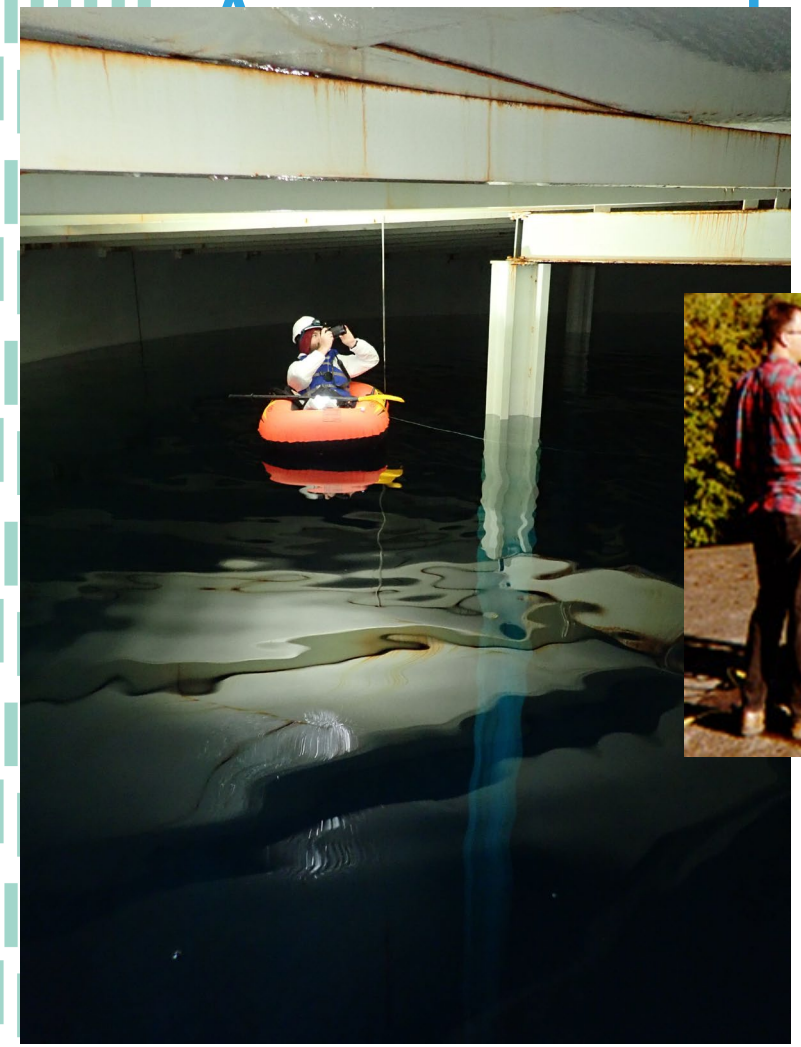


- Historical Records Review – Record drawings, shop drawings, design specs, prior assessments, geotechnical reports, maintenance records
- Site Investigation
  - General measurement and collection of field data
  - Verification of conformance with record documents
  - Steel plate thicknesses using an ultrasonic thickness gauge
  - Damage to members – warping, impact damage, ovaling, buckling

Structural Condition Assessment

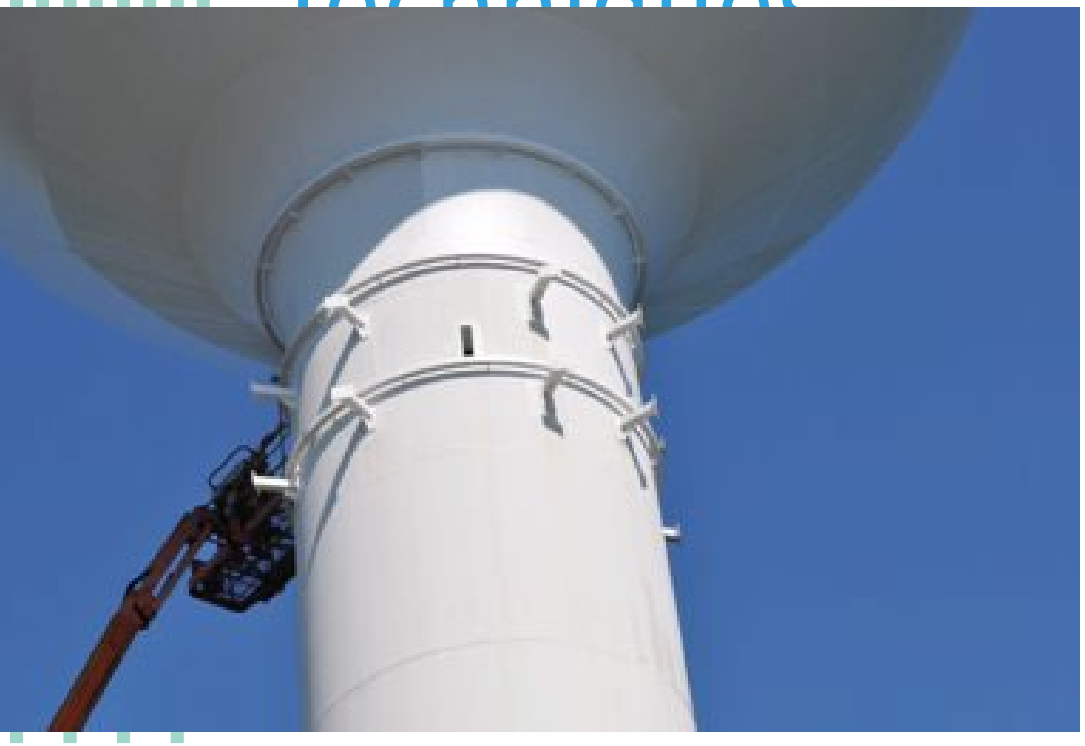
- Drained Investigation – investigation of interior surfaces
- Float Investigation – to observe roof structure
- Other non-destructive investigation tools
  - Pitting gauge measurements
  - GPR of foundation reinforcing
  - XRF analysis to determine steel material
  - Diver or ROV
  - Ropes team Inspection

Non-Structural Condition



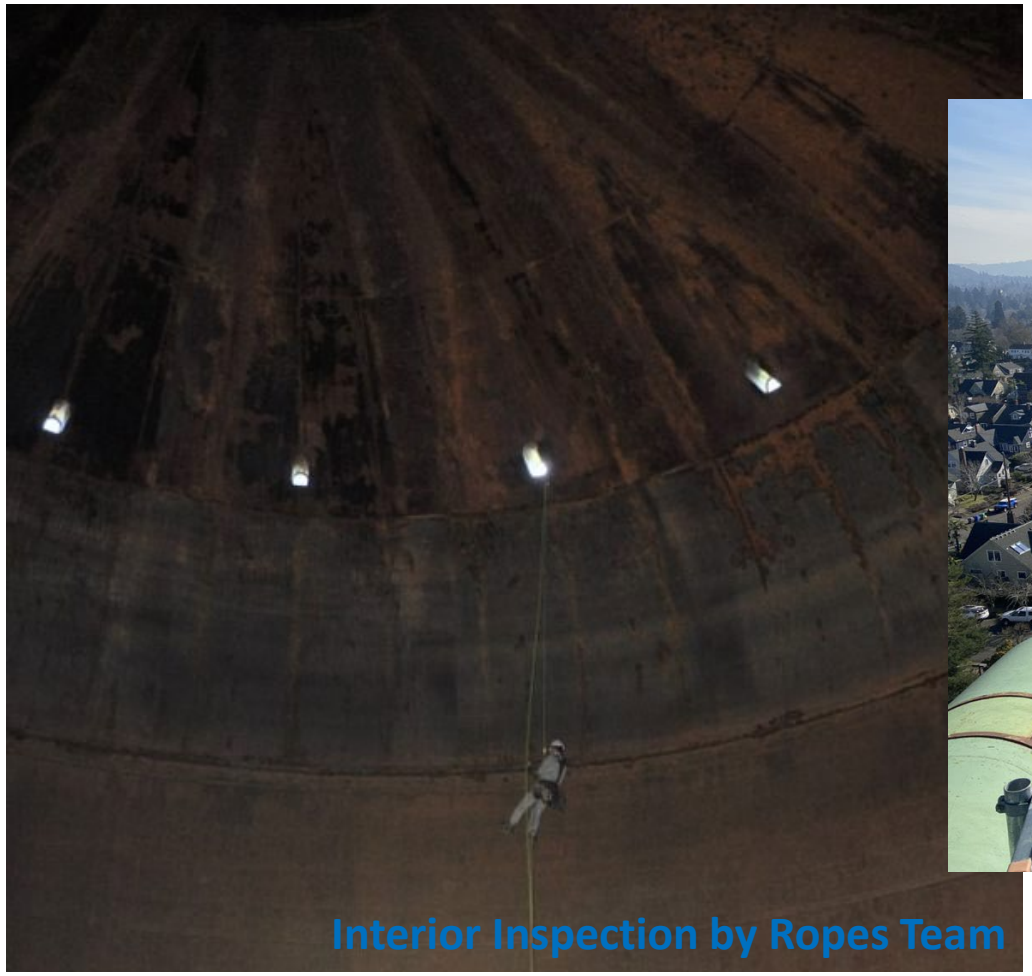
- Similar to structural assessment
- Detailed checklists
- Assess coatings, piping and appurtenances
- Review record drawings, shop drawings, previous assessments and dive reports.
- Drained inspection - Observe Coatings and Piping
- Dive inspection if it can't be drained.
- Float inspection – Interior Roof Corrosion

Non-Structural Condition Assessment Techniques



- Accessing elements using existing fixed ladders
- Using high lifts
- Use of drones for an overview

Non-Structural Condition Assessment– Ropes Team

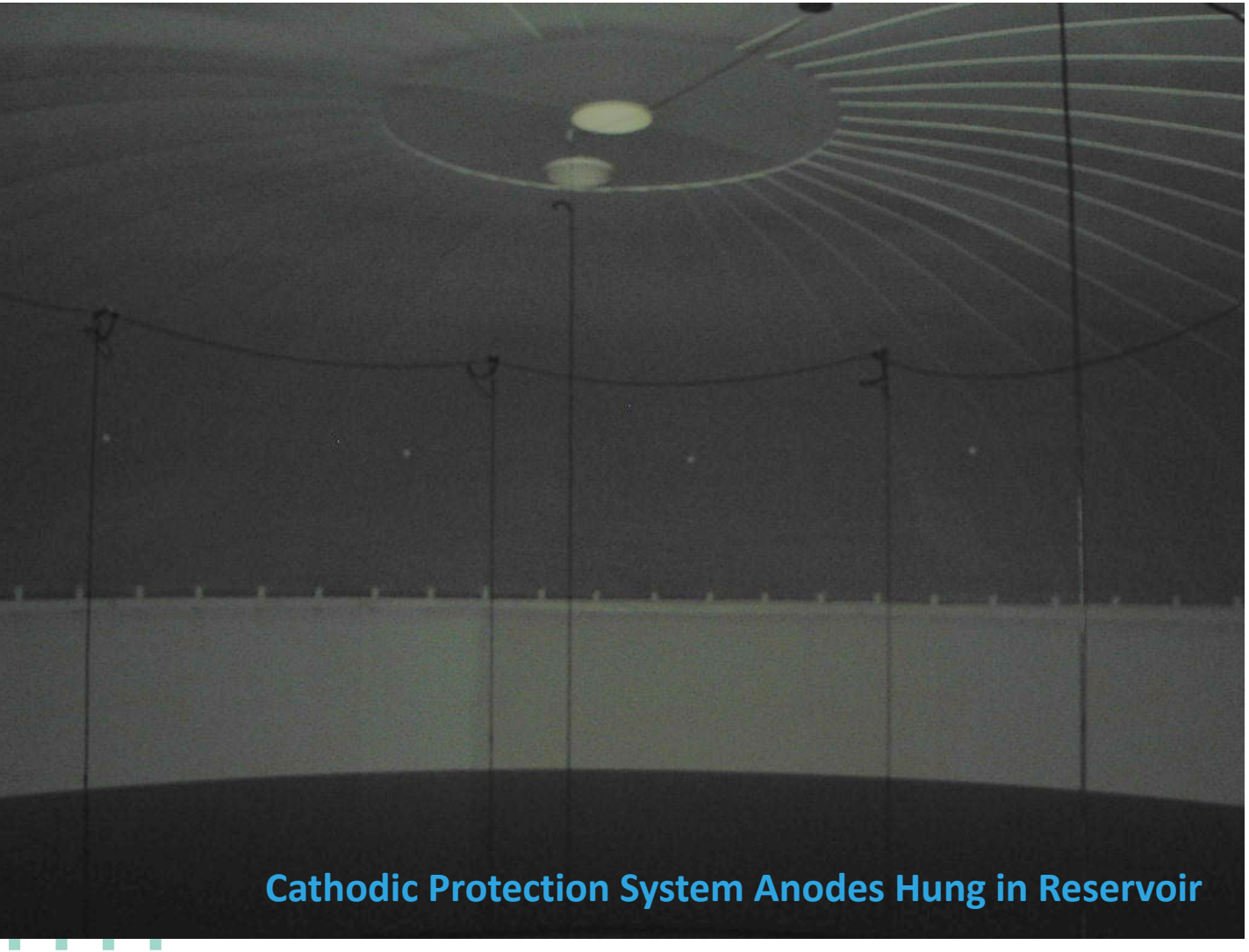


Interior Inspection by Ropes Team

Coating Systems Assessment

- Coatings are critical for performance of steel reservoirs
- Assess the type of coatings, condition, and level of coating failure
- Determine required coating improvements

Cathodic Systems



Cathodic Protection System Anodes Hung in Reservoir

- Inspect system
- Have it tested
- Replace components as needed

Safety Access Improvements

Fall Prevention Cable

Challenging Roof Access

Improved Roof Access

Security Sanitary Improvements

- Assess hatches, vents and other features
- Vandal resistant
- Preventing rainwater and critters from entering

Water Quality

Typical Passive Mixing System for Elevated Tank

- Assess operations relative to turnover and fill rates
- Assess inlet piping configuration
- Add mixing improvements as needed

Cell Equipment

Extensive Cell Equipment Attached to Catwalk and Railing

Added Cell Equipment Supports

- Elevated tanks are loved by cell companies
- Provides revenue to the tank owner
- Can add significant weight to an existing structure
- Must be accounted for in seismic weight
- Assess catwalks and railings for capacity

Accommodating Cell Equipment

- Cell Equipment Conductors Encumbering Access
- Dedicated shaft for cell equipment wiring

Dedicated Cell Cable Shaft at Top of Tank

Summary

- Critical facilities in water systems
- Important to monitor and maintain to extend service life
- Highly visible infrastructure
- Vital community asset

Thank you!