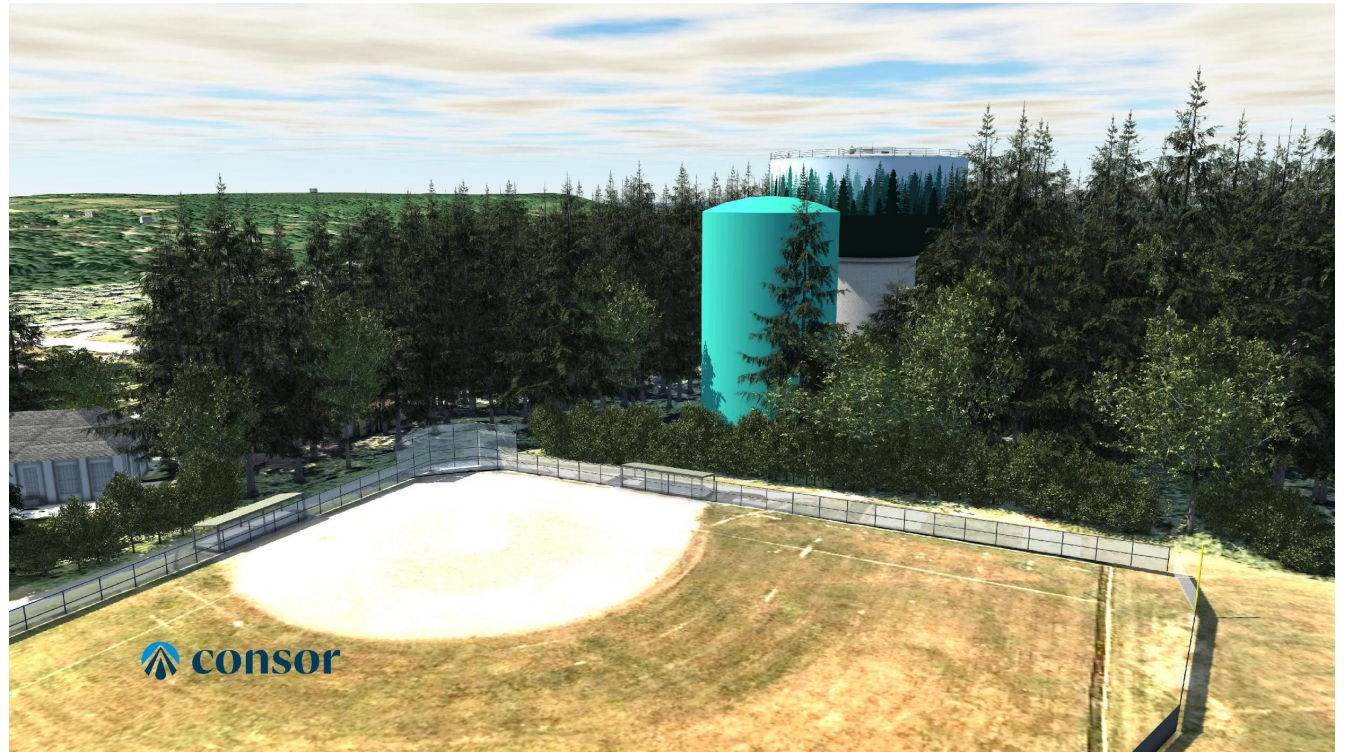


PNWS-AWWA CONFERENCE 2025

Bainbridge Island 2.0 MG Elevated Storage Tank & PRVs

Justin Ford, Consor
Mackenzie Lostra, Peterson Structural Engineers

May 9, 2025



Presenters



Justin Ford, Consor



Mackenzie Lostra,
PSE

Agenda

- COBI Winslow Water System – Current and Future
- Standpipe Structural Analysis
- Elevated Tank Comparison & Selection
- Elevated Tank Structural & Geotechnical Considerations
- 2.0 MG Hydropillar Construction (Ongoing)

Key Takeaways

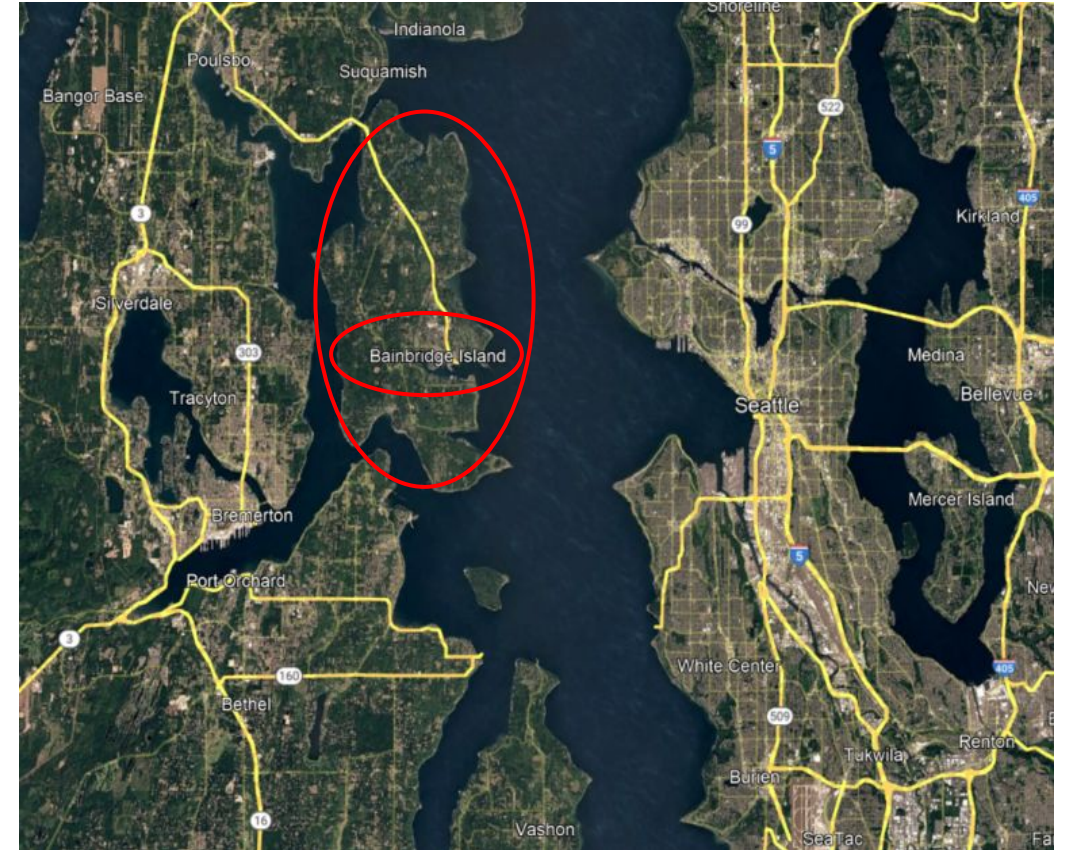
- Benefits of hydraulic modeling and proper planning
- Existing reservoir seismic analysis
- Elevated tank design elements and style options

COBI Winslow Water System



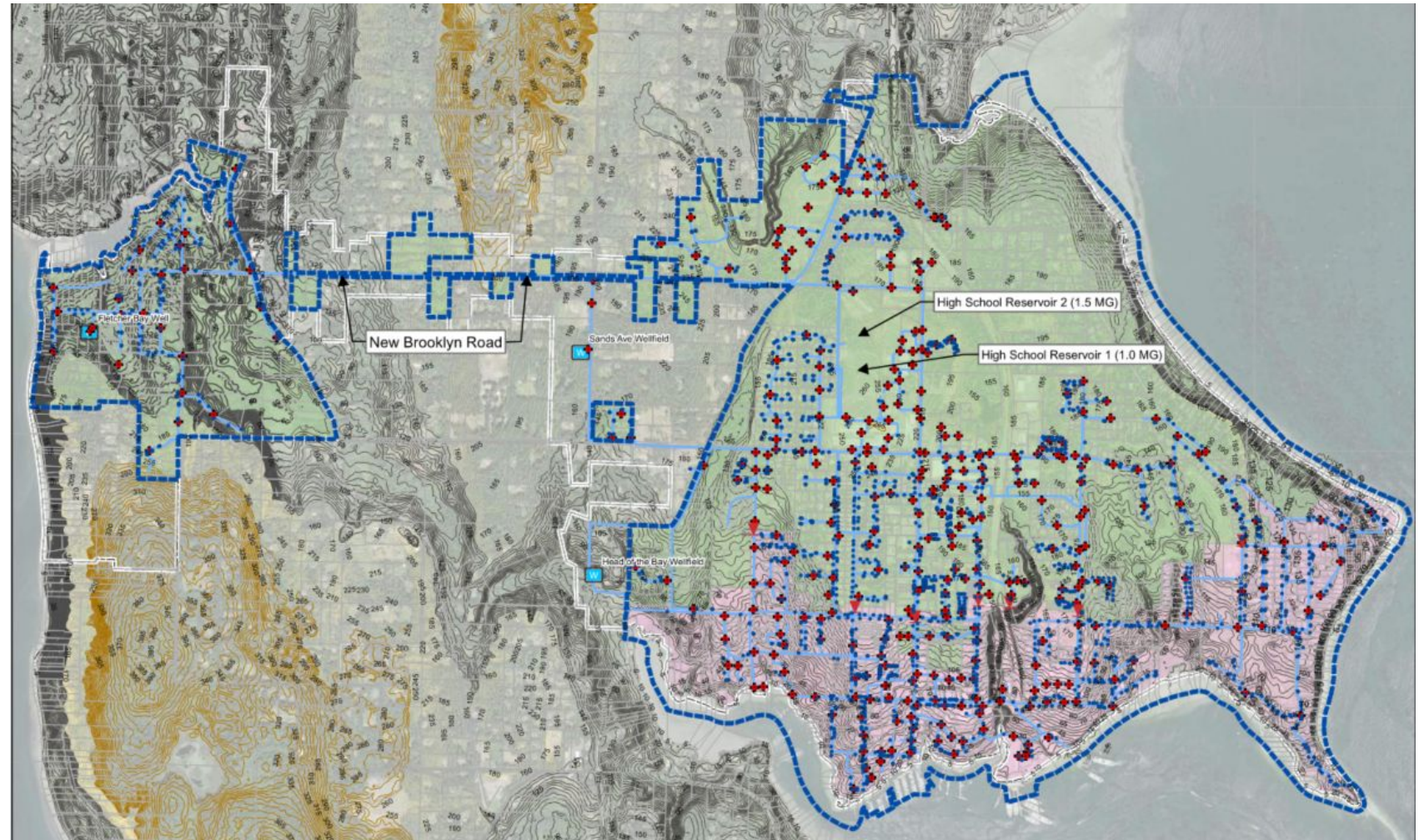
Bainbridge Island

- PWS served by City
- Some residents by Kitsap PUD, other PWS, wells
- Two distinct service areas
- 2017 WSP by Carollo
- 2017-2021 Tank Planning work by Gray & Osborne
- 2022-Current Tank and System Improvements work by Consor

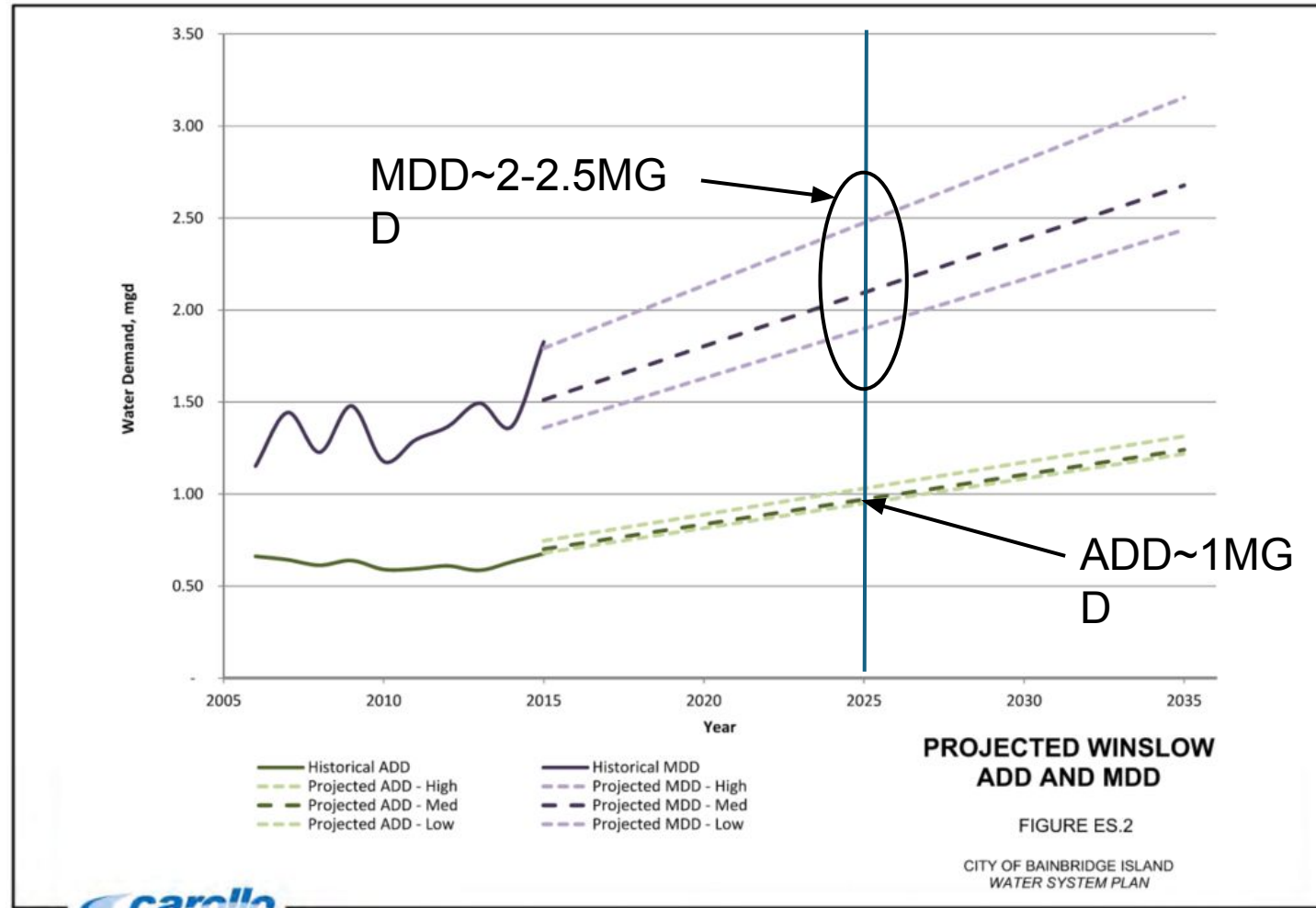


Winslow Water System

- 2 Pressure Zones
- 8 PRV Stations
- 11 wells at 4 sites
- 2 Reservoirs
- ~2,500 connections served
- Over 6,000 customers (2024)



Demands



Storage

- Two tanks in easements on high school property
- Set the HGL for the High Zone
 - But too low for adequate fire flow at highest elevation (immediate area)
- Adjacent to residential neighborhood, Public Involvement helpful
- Need more usable storage



Existing Standpipes

- Built in 1973
- 1.0 MG
- Significant seismic deficiencies
- Interior coating delamination
- Exterior coating also failing
- Tank to be decommissioned, area given back to HS



Tank No. 1

Existing Standpipes

- Built in 1989
- 1.5 MG
- Interior coating OK
- Exterior coating OK
- Cell Equipment
- Significant seismic deficiencies
- Tank to be mothballed, kept as backup for when new tank is taken down for maintenance



Tank No. 2



Tank 2 Structural/Seismic Analysis

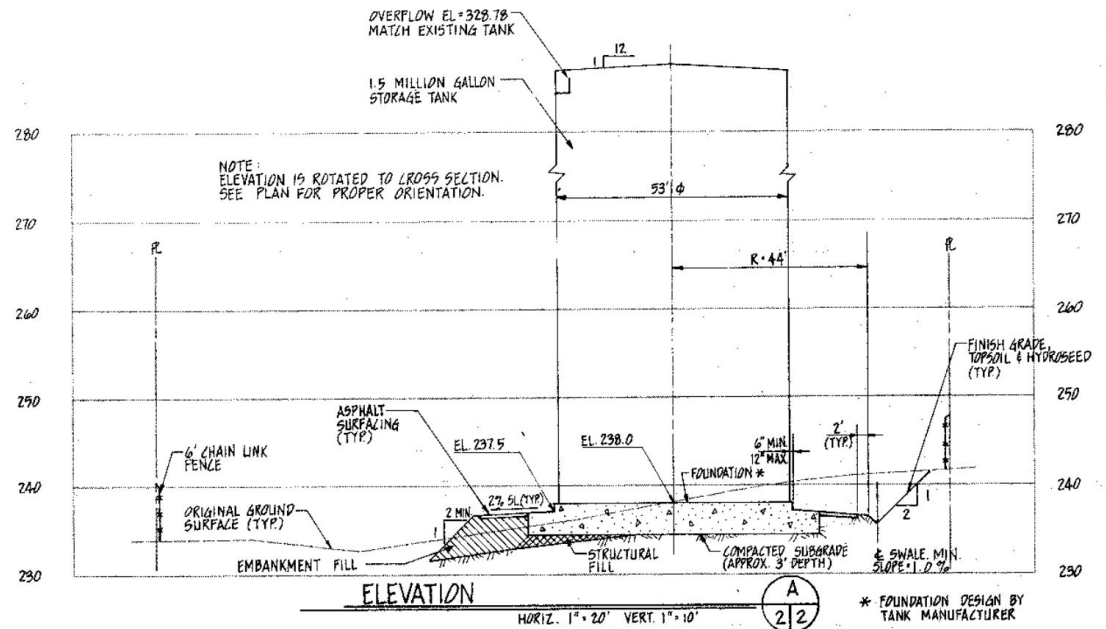
- Evaluation per current IBC / ASCE 7
 - AWWA D100 Standard
- The assessment was based on in-situ conditions and documentation provided.
- Evaluated as an Essential Facility
- Evaluated components:
 - Foundation and anchorage
 - Steel walls
 - Steel roof
- Presented viable retrofit options to the City of Bainbridge Island following the analysis findings including cost estimates
 - \$3.7M for full seismic upgrades + \$2.7M for nonstructural upgrades



Tank 2 Structural/Seismic Analysis

- Tank 2 Geometry
 - 53' diameter standpipe reservoir of welded steel construction built in 1989
 - Anchored to 3.5' thick spread footing
- Overflow Analysis findings:
 - Static bearing pressure check, DL+FL
 - Seismic bearing pressure check
 - Overturning risk
 - Insufficient anchor tension capacity
- Conduct additional analysis for reduced operating levels
 - Severely reduced the tank water storage capacity +
 - Created zone static pressure issues

= Impractical Solution for the Owner





Tank 2 Structural/Seismic Analysis

- Recommendations for **full** seismic retrofit:
 - Option 1 (\$3.7M)
 - Maintain current max. Operating level of **89'**
 - Shell strengthening, pile foundation, upgraded anchors
 - Roof upgrades
 - Option 2 (\$3.3M)
 - Full Retrofit + Reduce max. Operating level to 87'
 - No roof upgrades
- Recommendations for **reduced** seismic retrofit (\$0.8M):
 - Extend existing spread foundation, upgraded anchors
 - Reduce max. Operating level to **66'**
- Recommendations for the **minimum** seismic retrofit (\$0.1M):
 - Upgrade anchors only
 - Reduce max. Operating level to **52'**





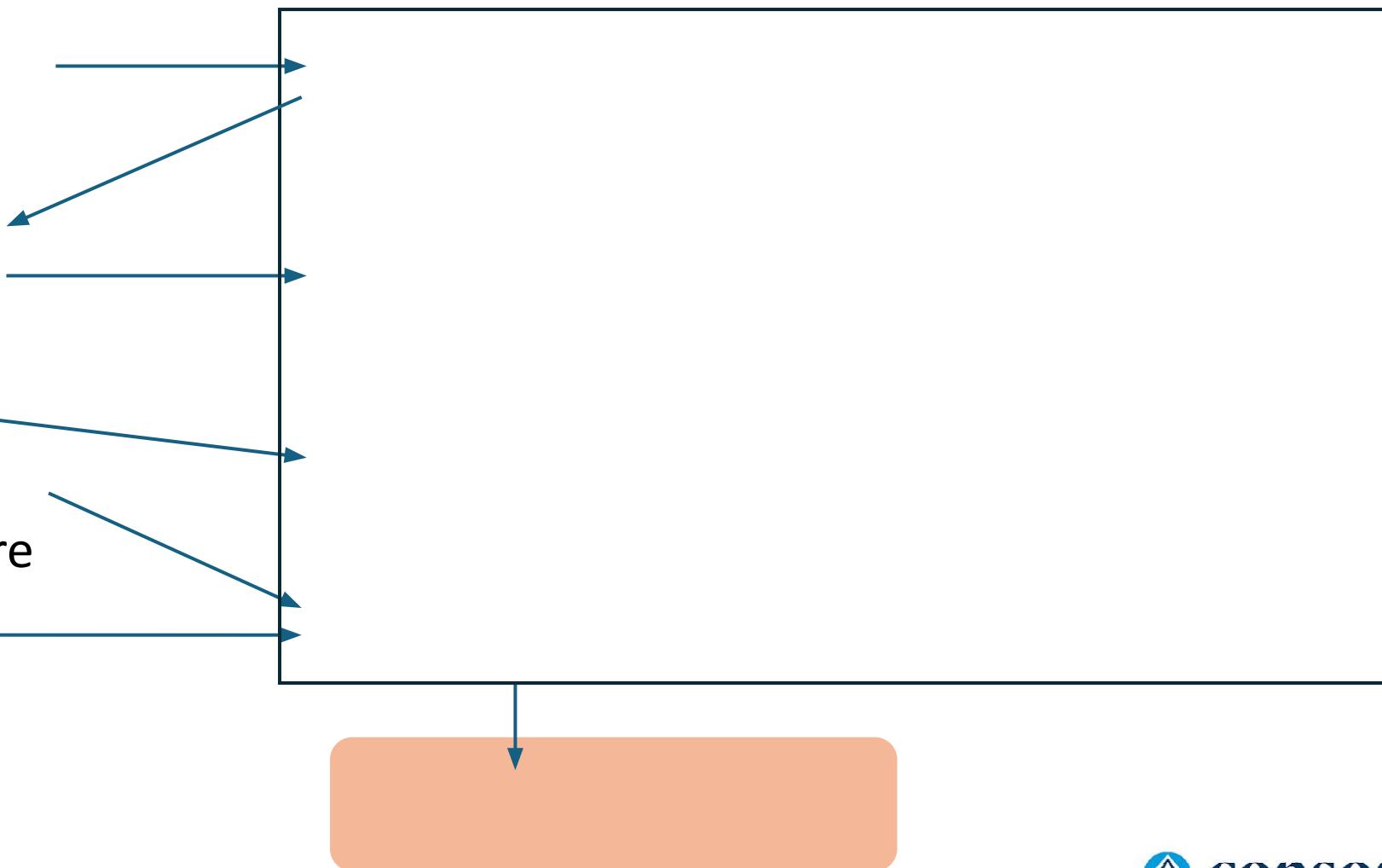
Tank 2 Findings

- Full retrofit to Tank 2 not cost effective
- Reducing max. Operating level was not a practical solution for the Owner
- A new elevated tank was evaluated to be more cost effective and provided the City with the following advantages:
 - Additional water volume storage
 - A current code compliant seismic system
 - Elevated tank alleviates water pressures issues and the need for a booster station
- **Elevated tank was the answer!**

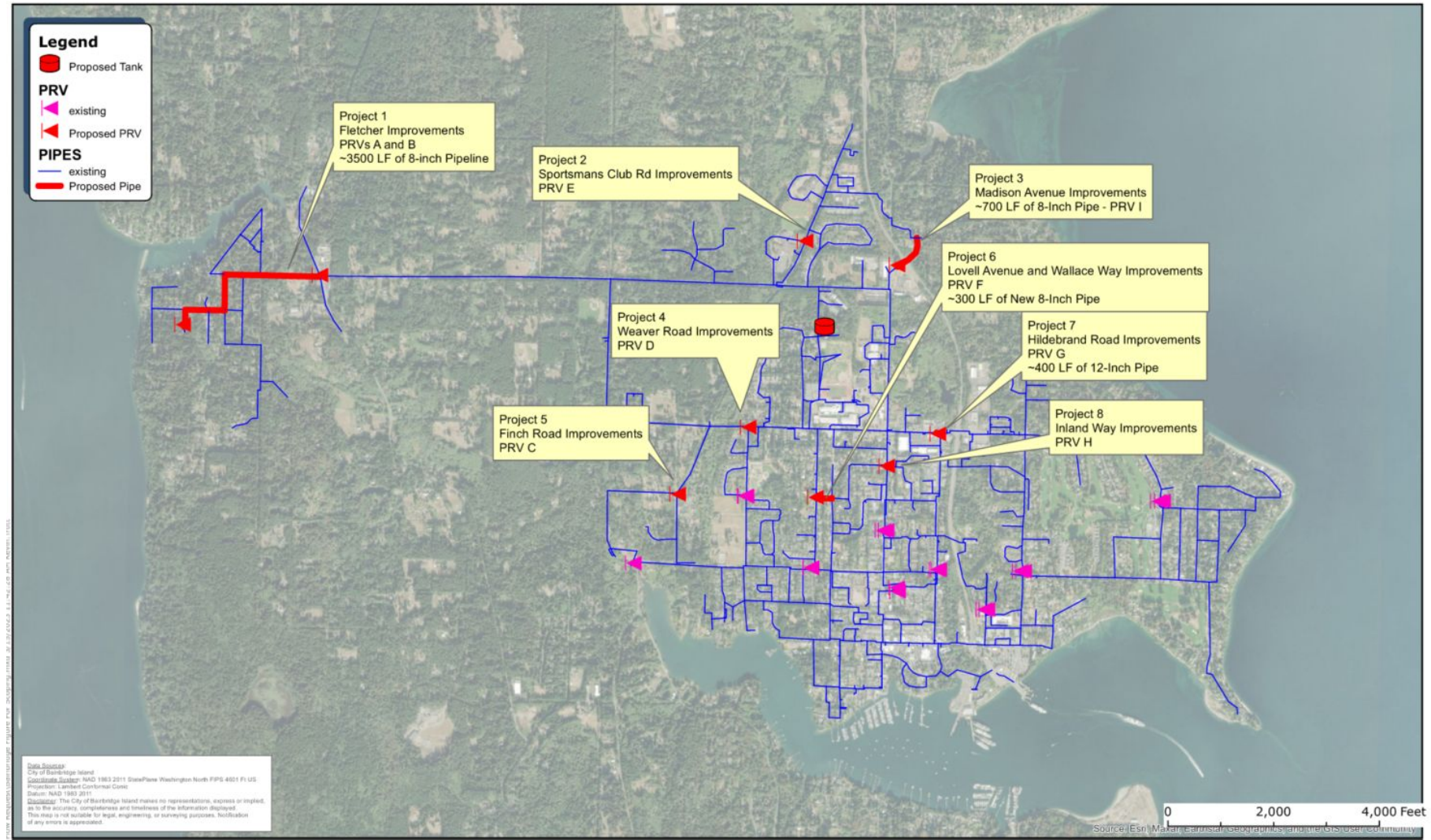


Winslow WS Challenges and Opportunities

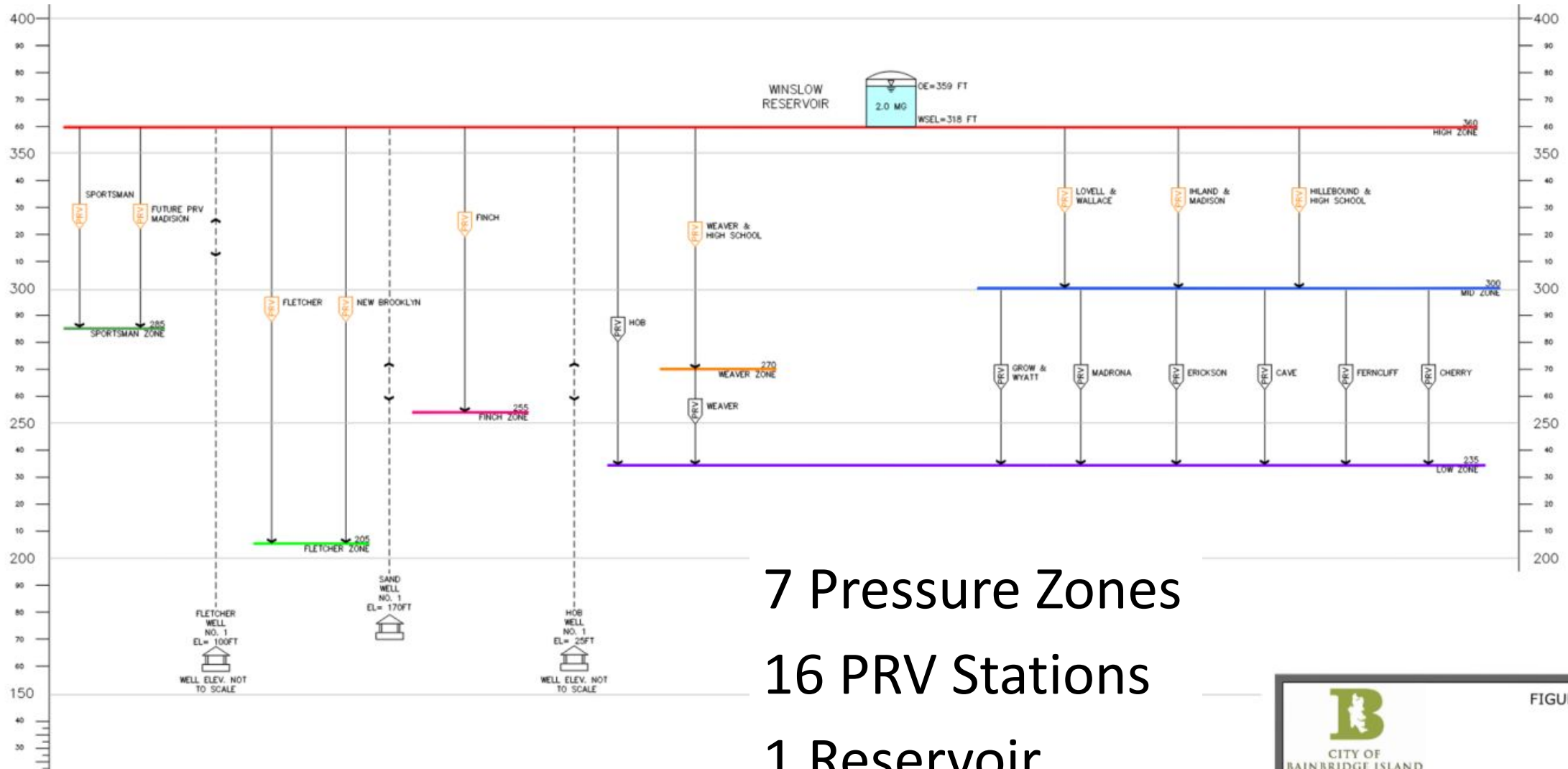
- HPZ customers experiencing less than 30 psi
- Once HGL is raised, customers will experience over 80 psi
- Fire flow deficiencies
- Aging storage infrastructure
- Projected storage deficiencies



Future System Map



Future System Schematic



Elevated Tank Comparison



Figure 1 | Coating surface areas for CETs

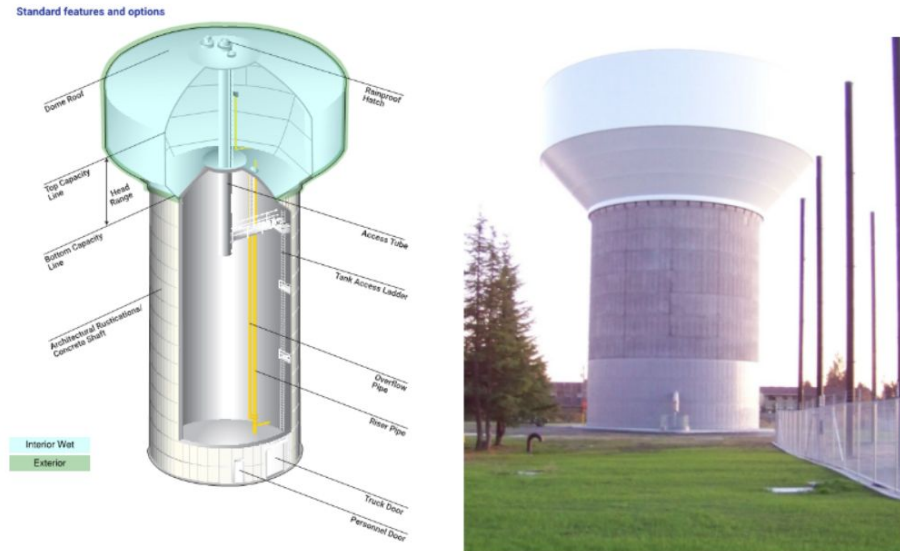


Image Source: Tank diagram, left, from CB&I: <https://www.mcdermott.com/>, markup added by Murraysmith

Composite Elevated Tank

Figure 2 | Coating surface areas for hydropillar tanks

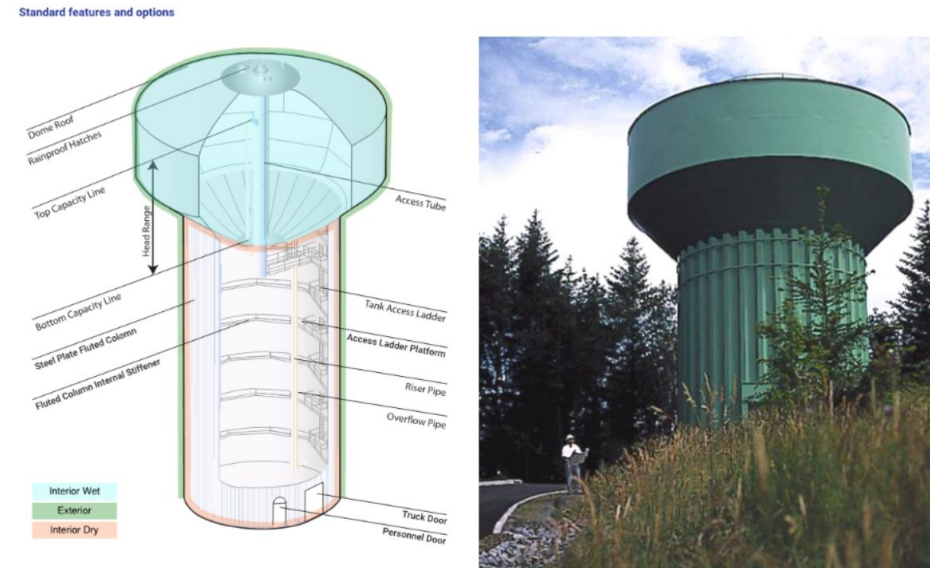


Image Source: Tank diagram, left, from CB&I: <https://www.mcdermott.com/>, markup added by Murraysmith

Fluted Column Elevated Tank

Other styles not really considered for this project



- Standpipe – Too much dead storage
- Multi-Column Elevated Tank – Historically yes in this size range, but market has gone away from these
- Pedosphere – Typically for smaller capacities ≤ 1.0 MG





Winslow Water Tank

– CET vs. FCET?

- Where are elevated tanks most commonly constructed?
- Improved designs in recent years have made them seismic competitors
 - Tank designers are breaking into new markets in high seismic regions
 - Cost effective alternative to other elevated tank styles
- Increasing number of pedestal-style elevated tanks in the PNW, where there is an overlap between **seismically-resilient structures** and **higher water pressure needs**
- Elevated tanks are economic competitors with new functionality and enhanced safety



Fluted Column Elevated Tank

(FCET)

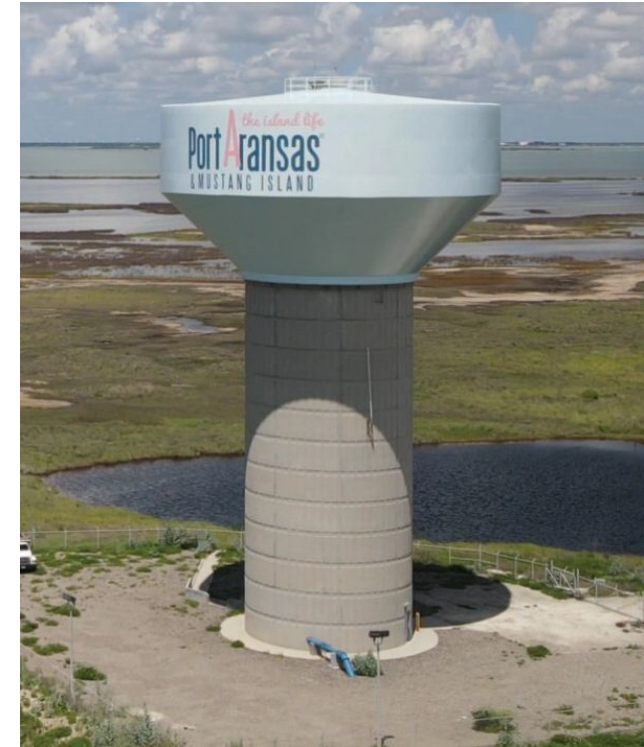


Composite Elevated Tank

(CET)

Structural Loads – FCET vs. CET

- Loads are important!
- Dictate the size and severity of your foundation style and their capital costs.
- Elevated tanks = Large impulsive mass high above grade.
 - Generates large seismic moment and overturning on the foundation.
- Your foundation will need to be larger and deeper as your tank demands increase and depending on the seismicity in your region.
- In Oregon and Washington, seismic loads control over wind.



Structural Loads – FCET vs. CET Comparison

Design Considerations:

- Tank & Pedestal
- Foundation: Sliding and Overturning Stability
- Slosh Height

General Takeaways:

- Seismic design loads on CETs are generally higher when comparing similarly sized tanks
- Lower Design Loads = Less Expensive Structure

	Fluted Column Tank (FCET)	VS.	Composite Elevated Tank (CET)
AWWA Standard	AWWA D100-11/21 Welded Carbon Steel Tanks for Water Storage		AWWA D107-16 Composite Elevated Tanks for Water Storage
Design Loads	<p>Lower Steel Pedestal Weight ↓</p> <p>Lower Vertical Centroid ↓</p> <p>Tank Weight + Contents = <i>Impulsive</i> Mass</p>		
	<p>• Response Modification Factor ---> D100 Table 28, $R_i = 3.0$</p> <p>• Seismic Importance Factor ---> D100 Table 24, $I_E = 1.5$</p>		<p>D107 4.2.8.6, $R_i = 3.0$</p> <p>D107 4.2.7.7, $I_E = 1.5$</p>
Horizontal Loads	$V = C_s W$ (Eq 4-15) (C_s , A_i = function of structure's stiffness properties and regional seismicity)		
Analysis Methods - ELF Permitted?	Yes		
Slosh Height	<p>Min. Freeboard = Slosh wave height per D100 13.5.4.4</p> <p>Min. Freeboard = Slosh wave height * I_E per D107 4.2.8.8.1</p>		



Structure Selection – FCET vs. CET

Structural Considerations:

- Both tank styles are seismically resilient
- D107 CETs are typically **stiffer & heavier** structures
 - Higher seismic demands
- Lower demands on foundation and structural elements for D100 FCET's
 - **Designers like this!**
- Both tank styles up to **~4.5-5.0MG**
- Sloshing and freeboard considered similarly



Practical Considerations:

- Optimal Safety & Access
- Comparable maximum capacity
- Pumps and mechanical equipment housed within pedestal interior
 - Environmental / Public protection
- Aesthetic alternative to traditional steel or concrete tanks
- Additional storage landings or maintenance areas
- Both styles designed and constructed by **Elevated Tank specialists**



Proprietary Elevated Tank Designers

- Final Design and Construction by the awarded tank contractor
- Turnkey product
- Performance Specification
- Construction oversight by the Owner representatives and its Engineers of Record



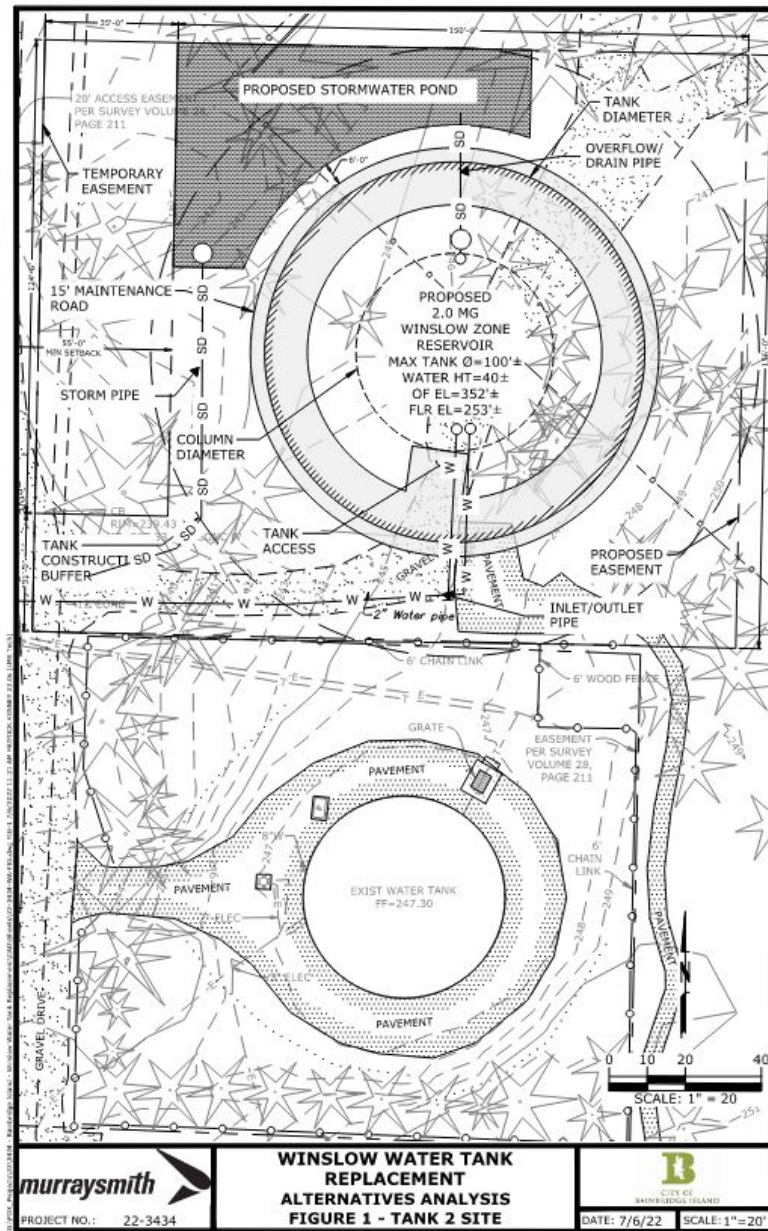
Others to come?

Tank Siting & Style Selection



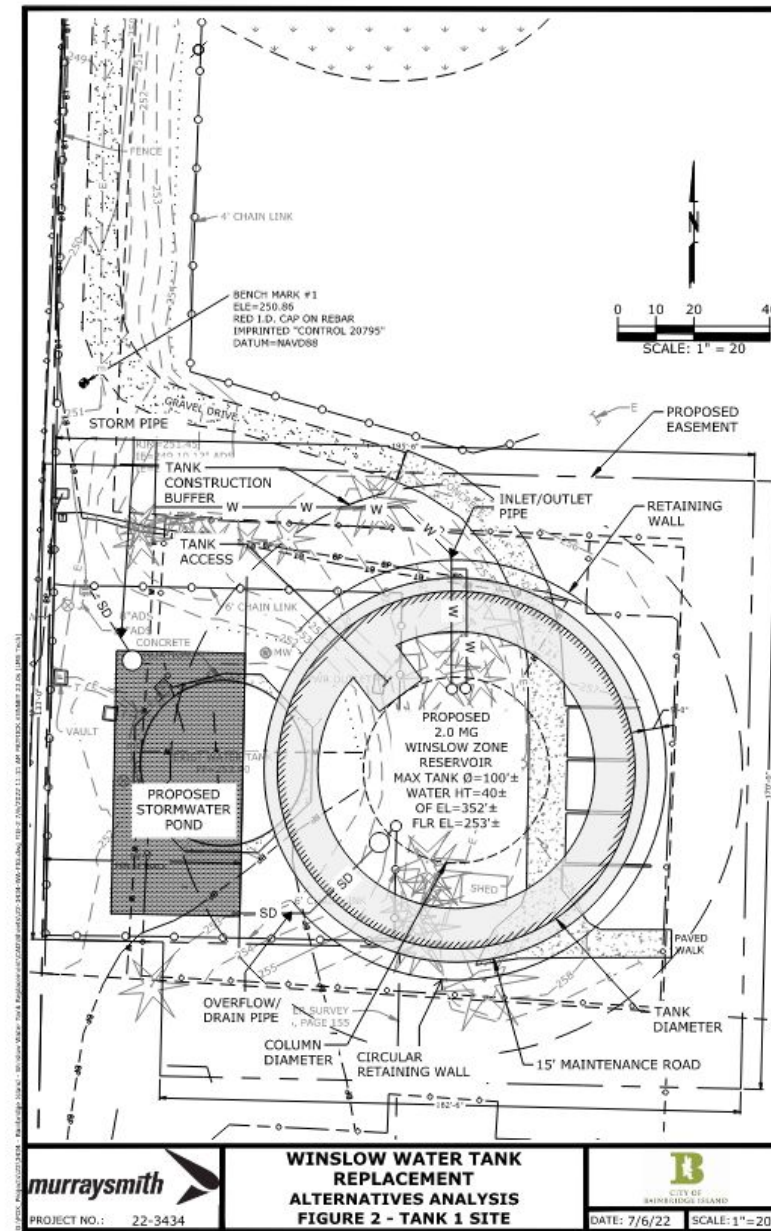
New Site north of Tank 2

- Undeveloped Area
- More tree removal
- Consolidates tank locations



Existing Tank 1 Site

- Tank can't stay online during construction
- Impact to School Fields
- Larger easement footprint due to required setbacks



Triple Bottom Line

- Consider more than just cost
- Collaborative effort with the owner
- Rank options through a systematic process

Criteria	(A) Criteria Weight (1 - 3)	Tank Site			
		Alt 1: Tank 1 Site		Alt 2: Tank 2 Site	
		(B) Score (1 - 3)	Weighted Score (1 - 9)	(B) Score (1 - 3)	Weighted Score (1 - 9)
Permitting and Project Risks					
P1 Land Use Permitting	1	2	2	2	2
P2 Environmental & Tree Removal Permitting	3	2	6	1	3
P3 Easement Requirements	2	1	2	2	4
Constructability and Cost (Financial)					
C1 Site Constraints for Construction Activities	3	1	3	2	6
C2 Foundation Conditions (Rock, Fill, Geotech Risks)	2	1	2	2	4
C3 Potable Water Alignment Complexity	1	3	3	3	3
C4 Stormwater Treatment & Discharge	2	1	2	3	6
C5 Utility Conflicts/Overhead Power Lines	2	2	4	2	4
C6 Differential Capital Cost	3	2	6	3	9
Outside Impacts (Social and Environmental)					
O1 Environmental Impacts	3	2	6	1	3
O2 Stakeholder Impacts	3	1	3	2	6
Operations and Resiliency					
R1 Permanent Site Access	1	2	2	3	3
R2 Increases Water System Flexibility & Resiliency	3	3	9	3	9
R3 Life-Cycle Maintenance Required	3	3	9	2	6
(C) Total Weighted Score		Alt 1 = 59		Alt 2 = 68	
(A) Criteria Weight Factors: 1 = Least important 2 = Average importance 3 = Most important (B) Criteria Scoring Approach: 1 = least satisfies criteria, 2 = somewhat satisfies criteria, 3 = mostly satisfies criteria (C) Evaluation Results: Highest Total Weighted Score is associated with the alternative that best meets the criteria					



Style Comparison

- Very similar look
- Both can sustain high seismic loads
- FCET has more steel surface area = higher long term maintenance cost
- CET has historically had a slightly higher capital cost, but these have normalized

Cost Analysis

- Capital Cost (Estimating Challenges)
- Maintenance (Painting)
- Coating surface areas and recurrence interval
- More cost in future to maintain steel column for FCET

Summary of 2.0 MG Tank Alternatives
Present Worth Cost Comparison

	Present Worth Capital Cost ¹	Present Worth Maintenance Painting ²	Present Worth
Alternative 1 - 2.0 MG Composite	\$8,660,000	\$730,000	\$9,390,000
Alternative 2 - 2.0 MG Pedisphere	N/A ³	N/A ³	N/A ³
Alternative 3 - 2.0 MG Hydropillar	\$10,500,000	\$1,830,000	\$12,330,000

Notes:

1. Present Worth Capital Costs per Landmark quote (May 2022), tank only (does not include electrical/I&C, yard piping, site work, etc.)
2. Present Worth Maintenance Painting from Maintenance Painting Matrix
3. Pedisphere tanks not recommended for storage applications greater than 1 MG in areas with seismic activity, per manufacturers



Elevated Tank Site and Style Selection

- New site north of Tank 2 selected
- A composite tank was initially recommended due to easier maintenance requirements and lower life cycle costs/efforts.
- City decided they only wanted to consider capital costs.
- The City of Bainbridge Island decided to bid for either an FCET or a CET with performance specifications for both tank styles – Contractor puts their best foot forward.
- Two Bids Received, one for each style.
- The project was awarded to Redside Construction (General Contractor) who teamed with Tank Contractor CB&I for an FCET design.
- **The new tank design consists of a 2 MG, 100' diameter steel tank atop a 78' diameter fluted steel base**
- **40' head range and ~111' high water level**

Geotechnical Considerations / Subsurface Improvements



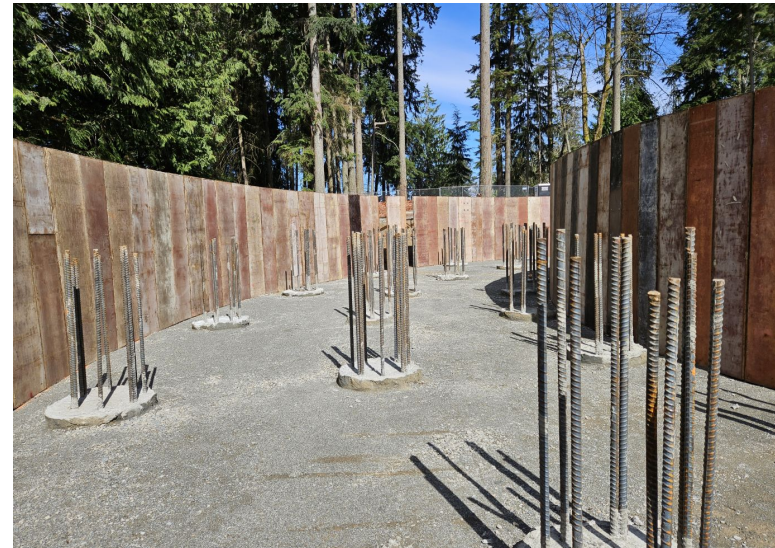
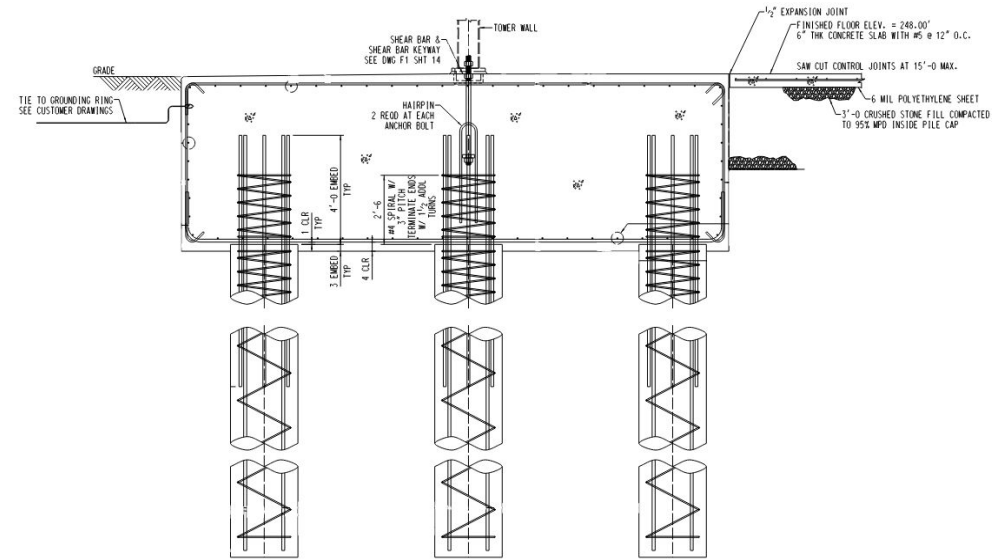
Foundation Selection – FCET vs. CET

- **Shallow foundations**
 - Easiest and cheapest to construct
- **Rigid inclusions or aggregate pier ground improvements**
 - May be a good alternative to the high cost of pile foundations where weak soil layers exist
- **Pile foundations**
 - More costly but provide excellent vertical and lateral foundation support
 - Excellent stabilization to large elevated tanks in high seismic regions with or without good soils
- Both tanks can require deep concrete caps (6'-10' thick) regardless of foundation style



Deep Foundations

- The Winslow Tank is a 2.0MG FCET located in a high seismic region with insufficient soils
- Founded on 30" diameter auger cast piles (CFA or ACIP)
- Driven steel piles were also permitted in the performance specification



Pictured Above: Pile foundation section view from Contractor submitted drawings

Pictured Left: auger pile compression testing (February 2024)

Pictured Right: 30" diameter auger cast reinforced concrete piles, Winslow Water Tank (March 2024)

Tank Construction





Construction

- The Tank Contractor is a full-service outfit – this means less work for the Owner (hopefully!)
- Owners select special inspectors for project oversight in addition to their own inspectors and representative engineers.
- Required inspections and testing are covered in the AWWA standards D107 Ch. 9 and D100 Ch. 11





Construction

- The project opened for bidding in November 2023 and was awarded later that month
- Construction followed very quickly, beginning in February 2024 with pile installation and foundation pouring, which was completed by early summer
- The final configuration of 72 piles was installed successfully over the course of about 3 days.





Construction

- Tank erection began late fall and is still in progress today!
- Construction is expected to be mostly complete by mid-2025 and the tank is to be put into service in late 2025



(Beginning of Pedestal construction - November 2024)



(Completion of Pedestal Walls - January 2025)



(Begin Bowl Plates and Ringbeam - February 2025)



Construction

- Currently, the fluted pedestal walls and bowl plates are complete. The cone and tank shell plates are in progress.



(Both photographs taken in March 2025)

Construction – Lessons Learned

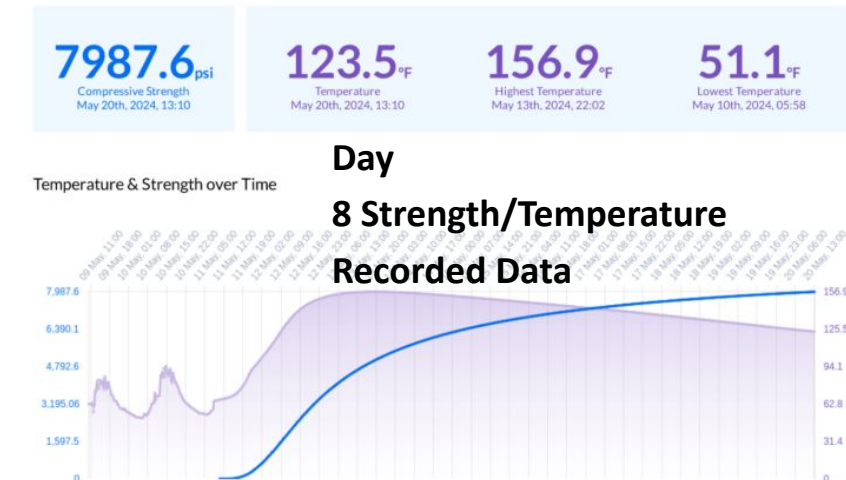
- Thermal control plan - early planning required!
 - In-Situ Strength sensors
 - Mass concrete is vulnerable to high temps during curing
 - Contractor means/methods for regulating temperatures
- The mass concrete foundation done in a single pour – no cold joints!
 - 1,620 CY
 - 12 Hrs. Continuous Pouring
- Steel construction vs. Concrete construction
 - Steel design tends to be more predictable
 - Concrete work takes proper forming, placing, and curing
- Contractors like to move quickly!
 - Routinely communicate construction schedules and changes
 - Appropriate personnel on-site for inspections



(In-Situ Strength & Temperature monitoring probes)

Winslow Water Tank Mass Pour / ...

Report generated on May 20th, 2024 by Karen McCarthy



An aerial photograph of a bridge under construction, surrounded by dense green trees. A semi-truck is visible on the right side of the bridge. The image is overlaid with a semi-transparent white box containing text and a logo.

Thank You

Flowing with new ideas

