SEISMIC RISK ANALYSIS OF FERRY TERMINAL BRIDGE STRUCTURES

Western Bridge Engineers' Seminar 2017
Session 7D

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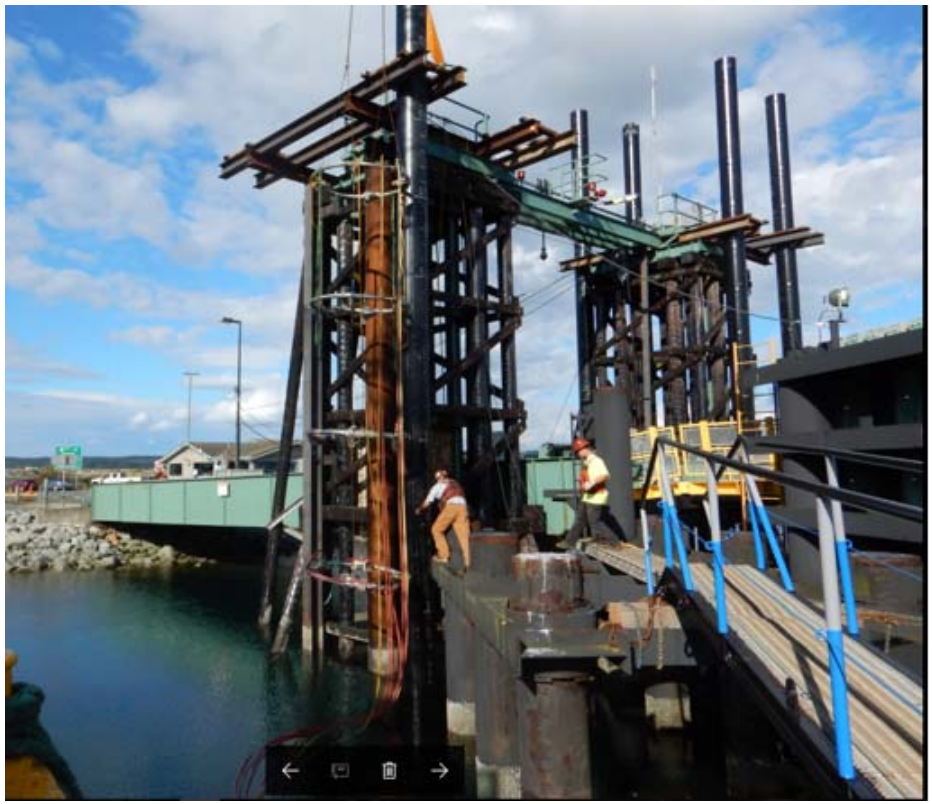
PRESENTATION OUTLINE

1. INTRODUCTION
2. WASHINGTON STATE FERRIES OVERVIEW
3. TERMINAL ENGINEERING (TE) ASSET MANAGEMENT MODEL OVERVIEW
4. SEISMIC RISK ANALYSIS FOR EXAMPLE TERMINALS
5. QUESTIONS / DISCUSSION



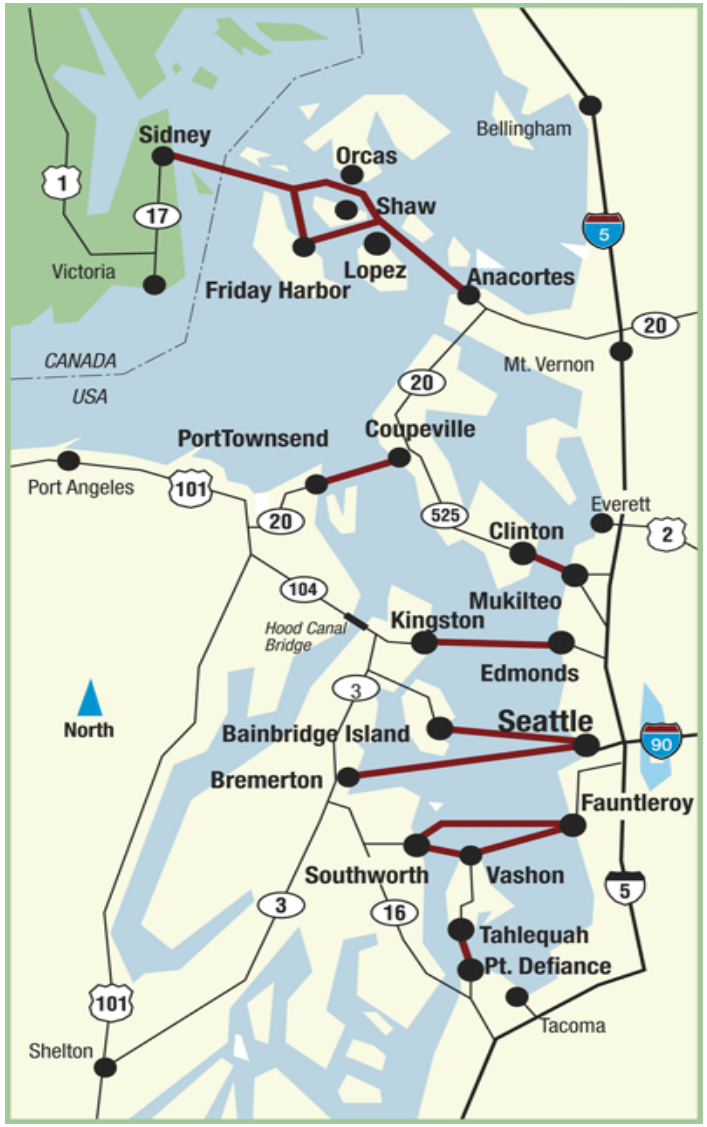
WASHINGTON STATE FERRIES

Largest Fleet of Vessels in the United States.

2016: 24.2 Million Riders
10.5 Million Vehicles

Operates 20 Terminals on 10 Routes. This presentation relates to the Terminals.

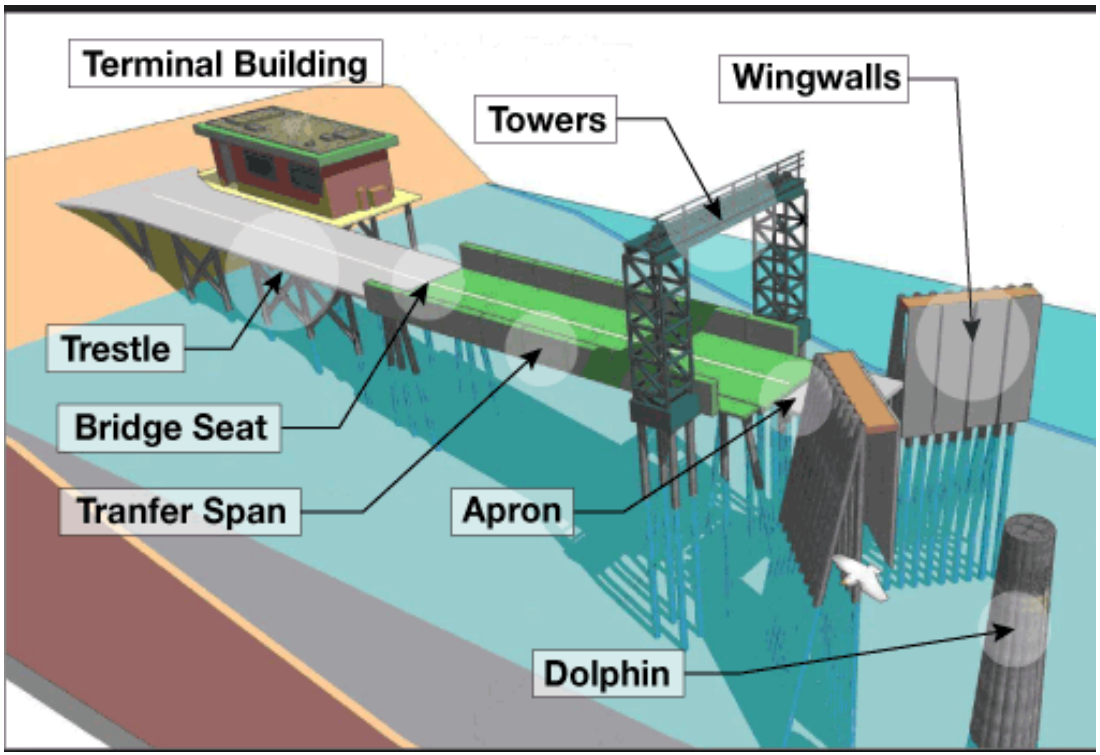
Part of WSDOT (State Highway Network) - Serving 8 counties and Canada



WASHINGTON STATE FERRIES

TYPICAL TERMINAL STRUCTURES / ASSETS

- DOLPHIN
- WINGWALL
- MOVABLE BRIDGE (WITH MECH+ELEC SYSTEMS)
- TRESTLE (CONCRETE OR TIMBER)
- PASSENGER ONLY LOADING
- PAVING
- SYSTEMS AND UTILITIES (LIGHTING)
- BUILDINGS (OCCUPIED & UNOCCUPIED)



ASSET MANAGEMENT MODEL

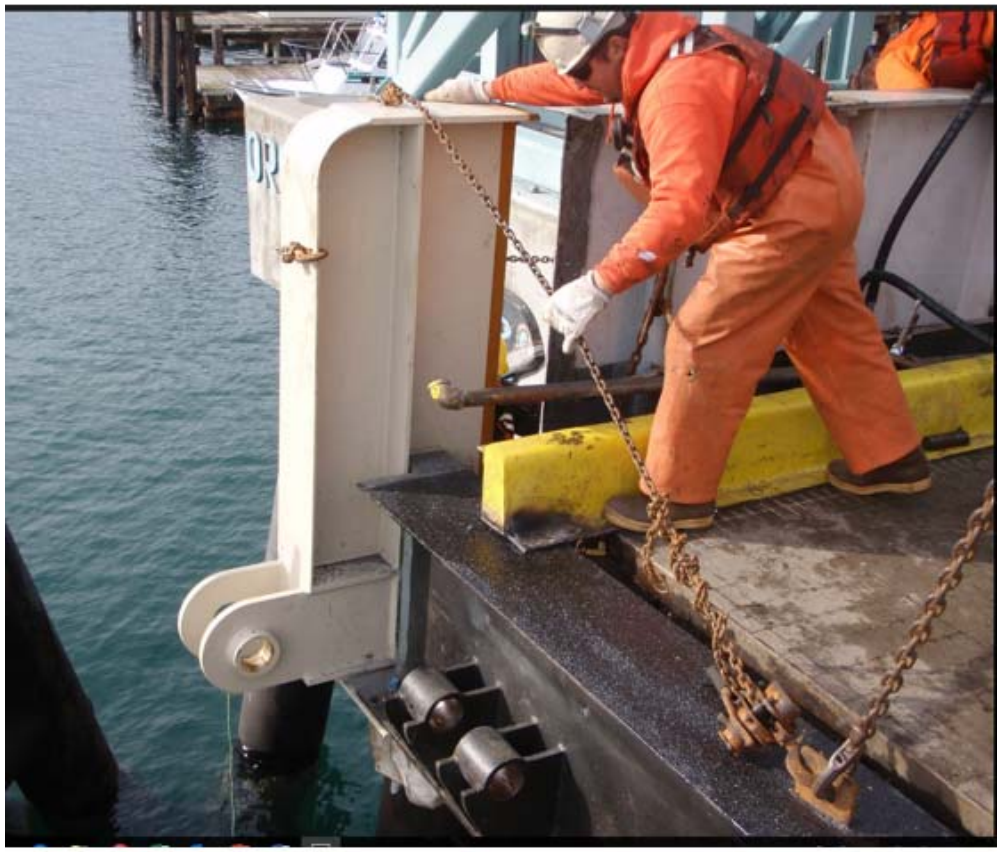
PROJECT TITLE	TERMINAL	RIDERSHIP COSTS	CAPITAL COSTS	EXISTING SEISMIC	PROJECT NET COST	BENEFIT/COST RATIO
Friday Harbor Bridge Seat Only	Friday Harbor	$484,163	$1,108,000	$578,516	$7,593,442	5.8
Edmonds Mech+Elec Only	Edmonds	$131,592	$1,504,000	$1,100,230	$2,685,841	2.6
Orcas Mech+Elec Only	Orcas	$136,950	$1,561,000	$289,983	$2,778,726	2.6
Edmonds Tower Only	Edmonds	$789,552	$2,619,000	$1,100,230	$4,420,438	2.3
Lopez Mech+Elec Only	Lopez	$67,350	$1,625,000	$160,373	$2,159,385	2.3
Anacortes Mech+Elec Only	Anacortes	$182,698	$1,491,000	$265,071	$2,040,351	2.2
Southworth Mech+Elec Only	Southworth	$26,928	$1,493,000	$322,576	$1,188,781	1.8
Seattle Towers 2+3, ME3	Seattle	$0	$8,432,000	$2,486,610	$6,510,434	1.8

- Asset Management Model is an economic business model usually developed and run inside a spreadsheet.
- This model identifies the best projects for replacement or preservation. It also prioritizes projects for replacement or preservation.
- Projects can be an individual asset or a combination of Assets

ASSET MANAGEMENT MODEL

FACTORS INCLUDED

- CONDITION OF ASSET
- DEMOGRAPHICS INFO
- MAINTENANCE COSTS
- UNPLANNED MAINTENANCE
  - FAILURE PROBABILITY
  - CONSEQUENCES OF FAILURE
- REPLACEMENT COSTS



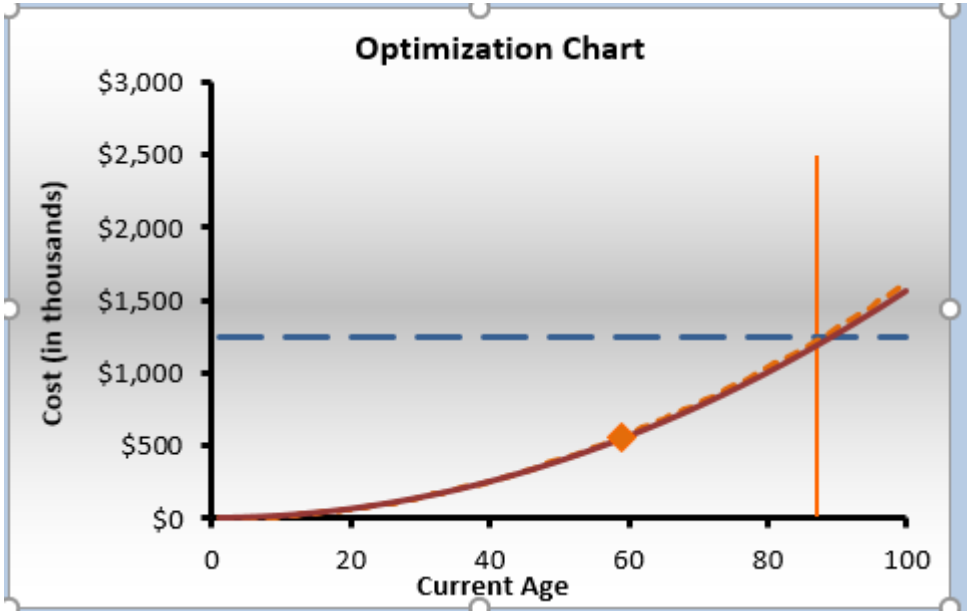
VASHON FERRY TRESTLE

CURRENT TRESTLE
AGE = 60 YEARS

REPLACEMENT COST
= $22,341,000

EAC = EQUIVALENT
ANNUAL COST = $1.25
MILLION

(BASED on 5% DISCOUNT
RATE)



Cost of Planned Maintenance, Unplanned Maintenance and Ridership losses due to Planned and Unplanned Maintenance

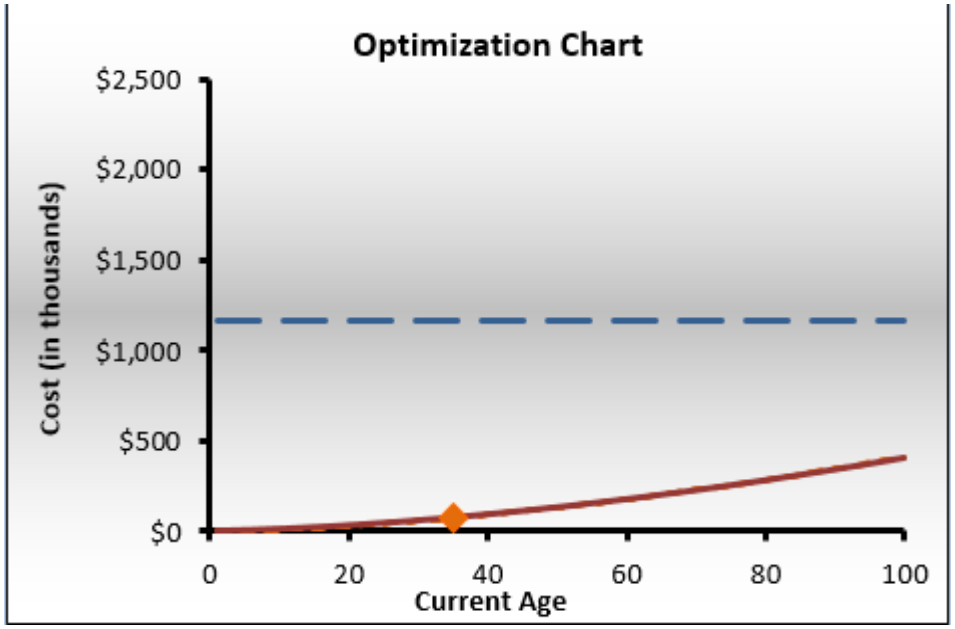
PORT TOWNSEND FERRY TRESTLE

CURRENT TRESTLE
AGE = 35 YEARS

REPLACEMENT
COST = $22,078,000

EAC = EQUIVALENT
ANNUAL COST =
$1.16 MILLION

(BASED on 5% DISCOUNT RATE)



Cost of Planned Maintenance, Unplanned Maintenance and Ridership losses due to Planned and Unplanned Maintenance.

SEISMIC RISK INTRODUCTION

ASSET MANAGEMENT MODEL

- CONDITION OF ASSET
- DEMOGRAPHICS INFO
- FAILURE PROBABILITY
- CONSEQUENCES OF FAILURE
- MAINTENANCE COSTS
- REPLACEMENT COSTS
- **SEISMIC RISK**

- RIDERSHIP COSTS
- REPAIR STRUCTURES
- REPAIR COSTS
- REPAIR DURATION

NET COST OF PROJECT EXECUTION

RIDERSHIP COSTS

AMOUNT THE CUSTOMER WOULD HAVE BEEN WILLING TO SPEND (OR COMPENSATED)TO AVOID THE DISTRUPTION

WALKON + VEHICLE RIDERSHIP BASED ON ANNUAL STATISTICS

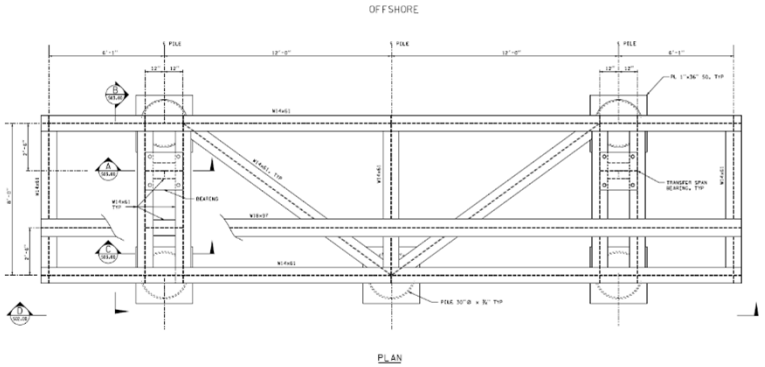
DELAY COSTS BASED ON WSDOT STANDARD DELAY COST

LOSS COSTS BASED ON COST TO DRIVE AROUND AND CUSTOMER SURVEY

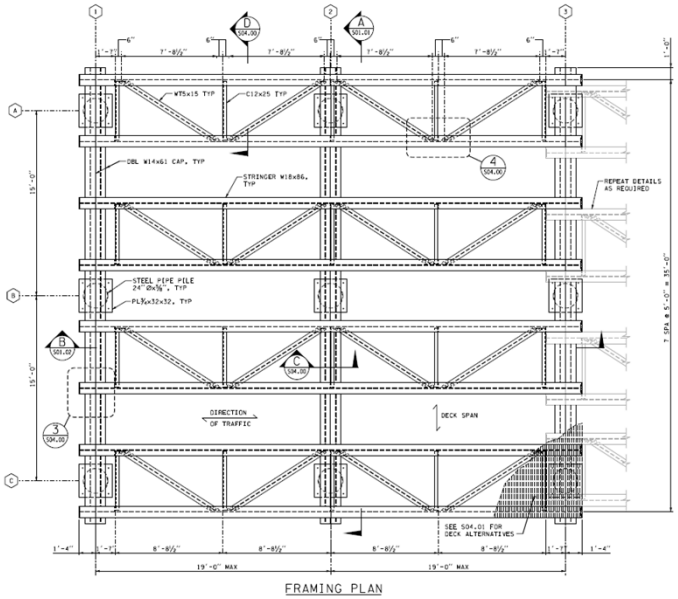
Ridership Costs

TERMINAL	WALKON RIDERSHIP	VEHICLE RIDERSHIP	WALKON DELAY	WALKON TRIP LOSS	VEHICLE DELAY	VEHICLE TRIP LOSS
Anacortes	1053	4258	$32	$45	$32	$30
Bainbridge	8460	8858	$32	$68	$32	$45
Bremerton	4318	2593	$32	$44	$32	$29
Clinton	1289	9532	$32	$83	$32	$55
Edmonds	1505	9461	$32	$60	$32	$40
Eagle Harbor	0	0	$32	$0	$32	$0
Fauntleroy	1060	6481	$32	$53	$32	$35
Friday Harbor	571	1851	$32	$150	$32	$100
Keystone	292	1689	$32	$113	$32	$75
Kingston	1505	9461	$32	$60	$32	$40
Lopez	115	783	$32	$150	$32	$100
Mukilteo	1289	9532	$32	$83	$32	$55
Orcas	218	1608	$32	$150	$32	$100
Point Defiance	213	1717	$32	$53	$32	$35
Port Townsend	292	1689	$32	$113	$32	$75
Seattle	12778	11450	$32	$68	$32	$45
Shaw	15	75	$32	$150	$32	$100
Southworth	306	1938	$32	$53	$32	$35
Tahlequah	213	1717	$32	$53	$32	$35
Vashon	200	256	$32	$105	$32	$70

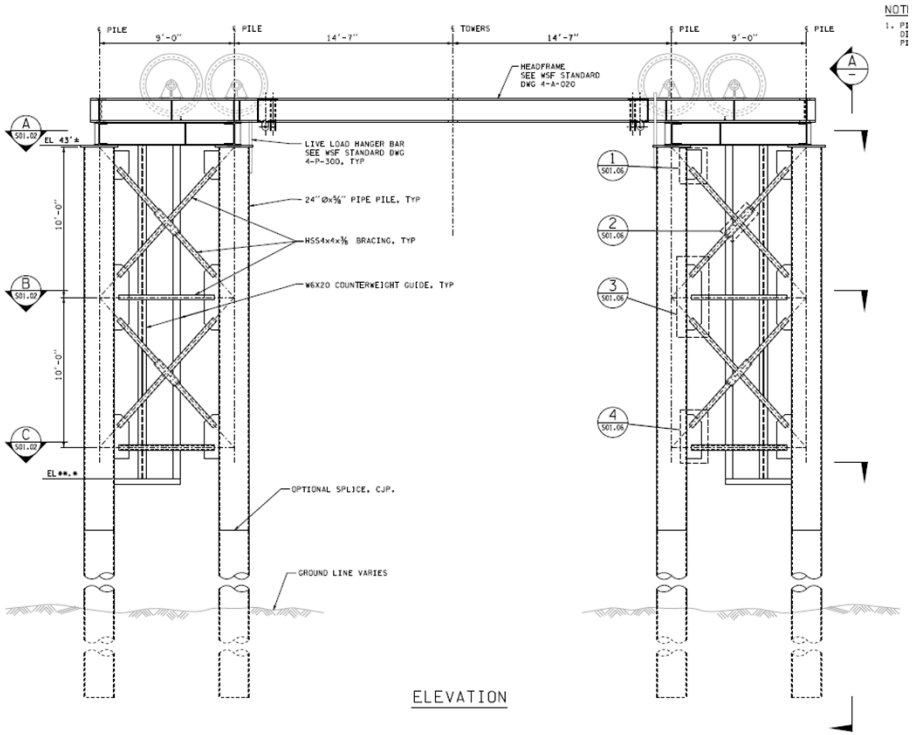
REPAIR STRUCTURES



BRIDGE SEAT



TRESTLE



TOWERS

REPAIR COSTS

BRIDGE SEAT - $2,563,000
TOWERS - $3,668,000
TRESTLE - $1,541,000 per panel

INCLUDES

- MATERIAL + LABOR
- PRELIMINARY ENGINEERING
- MOBILIZATION
- MISCELLANEOUS ALLOWANCES
- SALES TAX
- CONSTRUCTION ENGINEERING
- CHANGE ORDER CONTINGENCY

REPAIR DURATION

FABRICATION – 60 DAYS

BRIDGE SEAT – 6 DAYS INSTALL
TOWERS – 15 DAYS FAB, 15 DAYS INSTALL
TRESTLE – 15 DAYS FAB, 10 DAYS INSTALL

ANNUAL SEISMIC RISK

EVALUATING THE EXPECTED STRUCTURAL PERFORMANCE OF THE ASSET WHEN SUBJECTED TO A RANGE OF SEISMIC EVENTS, THEN ESTIMATING THE CONSEQUENCE COSTS DUE TO EACH EVENT CONSIDERED

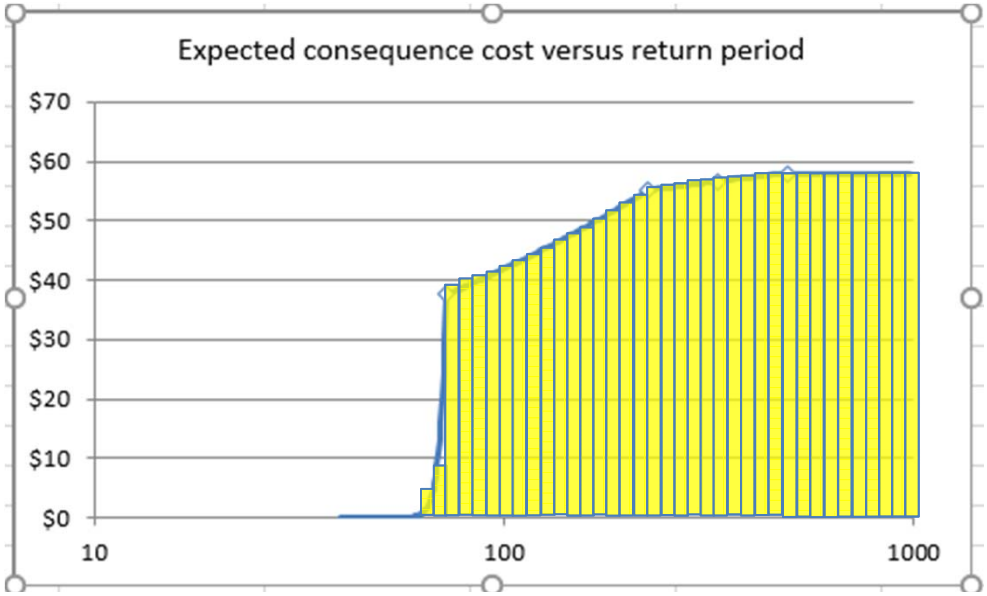
Seismic Risk Cost = (Probability of Occurrence) x (Consequence Cost)

72-Year: 50% in 50-Years

224-Year: 20% in 50-Years

475-Year: 10% in 50-Years

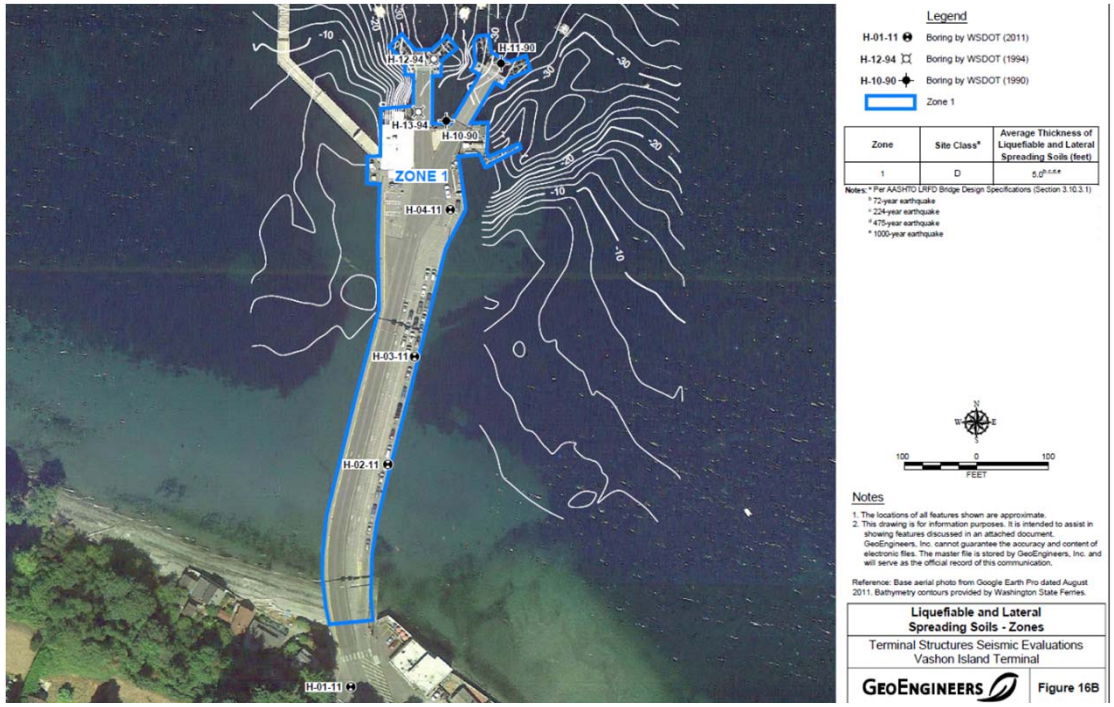
975-Year: 5% in 50-Years



VASHON FERRY TERMINAL

VASHON FERRY TERMINAL

RESPONSE SPECTRUM +
LIQUEFACTION DATA



Legend

H-01-11 Boring by WSDOT (2011)
H-12-94 Boring by WSDOT (1994)
H-10-90 Boring by WSDOT (1990)
Zone 1

Zone	Site Class*	Average Thickness of Liquefiable and Lateral Spreading Soils (feet)
1	D	5.0[a,c,d,e]

Notes: * Per AASHTO LRFD Bridge Design Specifications (Section 3.10.3.1)
[a] 72-year earthquake
[c] 224-year earthquake
[d] 475-year earthquake
[e] 1000-year earthquake

100 0 100
FEET

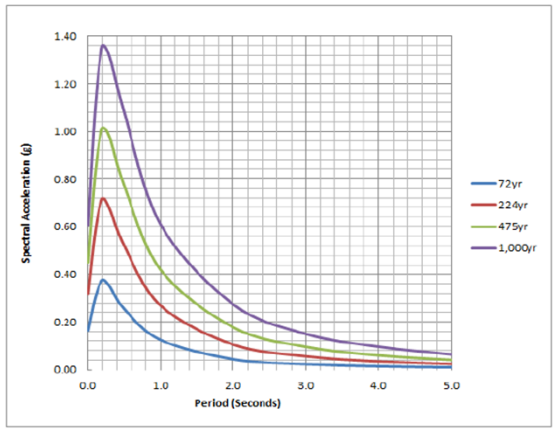
Notes

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Reference: Base aerial photo from Google Earth Pro dated August 2011. Bathymetry contours provided by Washington State Ferries.

Liquefiable and Lateral Spreading Soils - Zones
Terminal Structures Seismic Evaluations
Vashon Island Terminal
GeoEngineers | Figure 16B

Period of Vibration	72Yr Return Period SA	224Yr Return Period SA	475Yr Return Period SA	1,000Yr Return Period SA
0.0000	0.1645	0.3177	0.4503	0.6067
0.1000	0.3002	0.5778	0.8221	1.0967
0.2000	0.3747	0.7158	1.0126	1.3565
0.3000	0.3494	0.6750	0.9763	1.3144
0.5000	0.2548	0.5208	0.7729	1.0807
1.0000	0.1246	0.2685	0.4190	0.6096
2.0000	0.0438	0.1052	0.1776	0.2740
3.0000	0.0227	0.0561	0.0955	0.1498
4.0000	0.0141	0.0345	0.0600	0.0959
5.0000	0.0097	0.0241	0.0411	0.0640



Zone 1 (Average Vs_{30} = 294 m/s)

Ground Surface Response Spectra
Terminal Structures Seismic Evaluation
Vashon Island Ferry Terminal
GeoEngineers | Figure 16C

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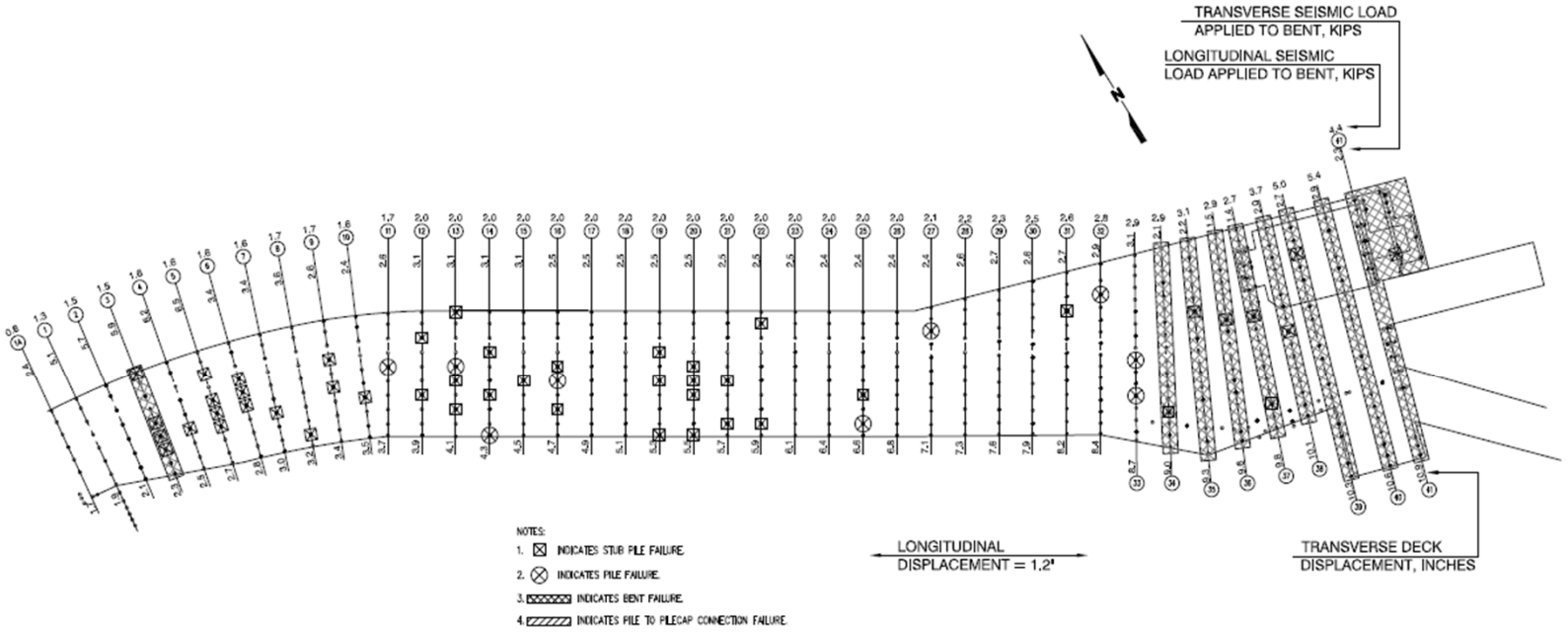
VASHON FERRY TRESTLE

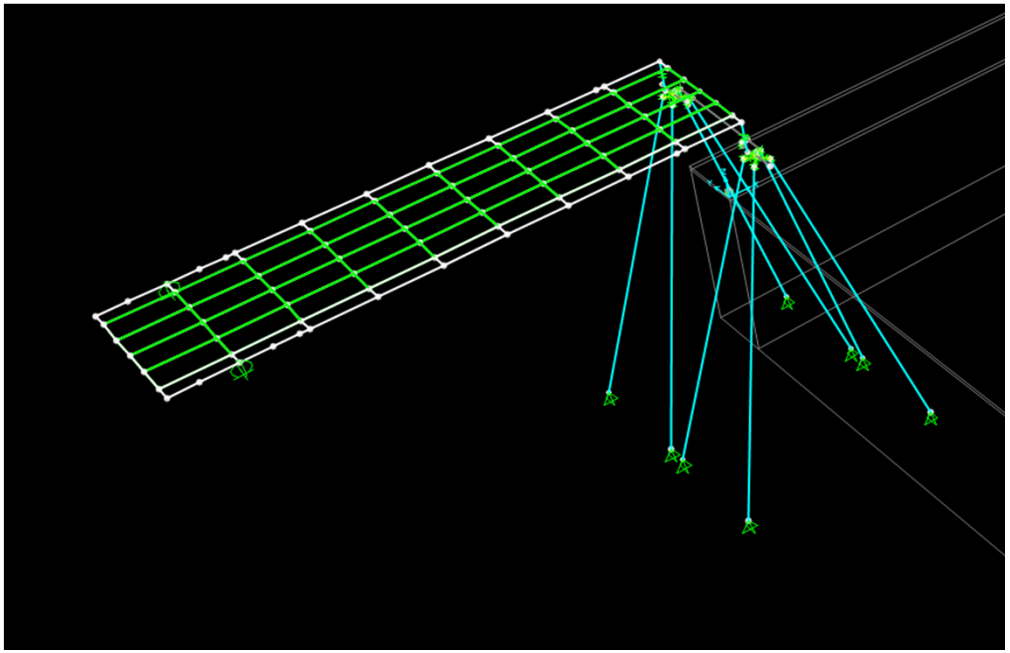
TRESTLE ANALYSIS

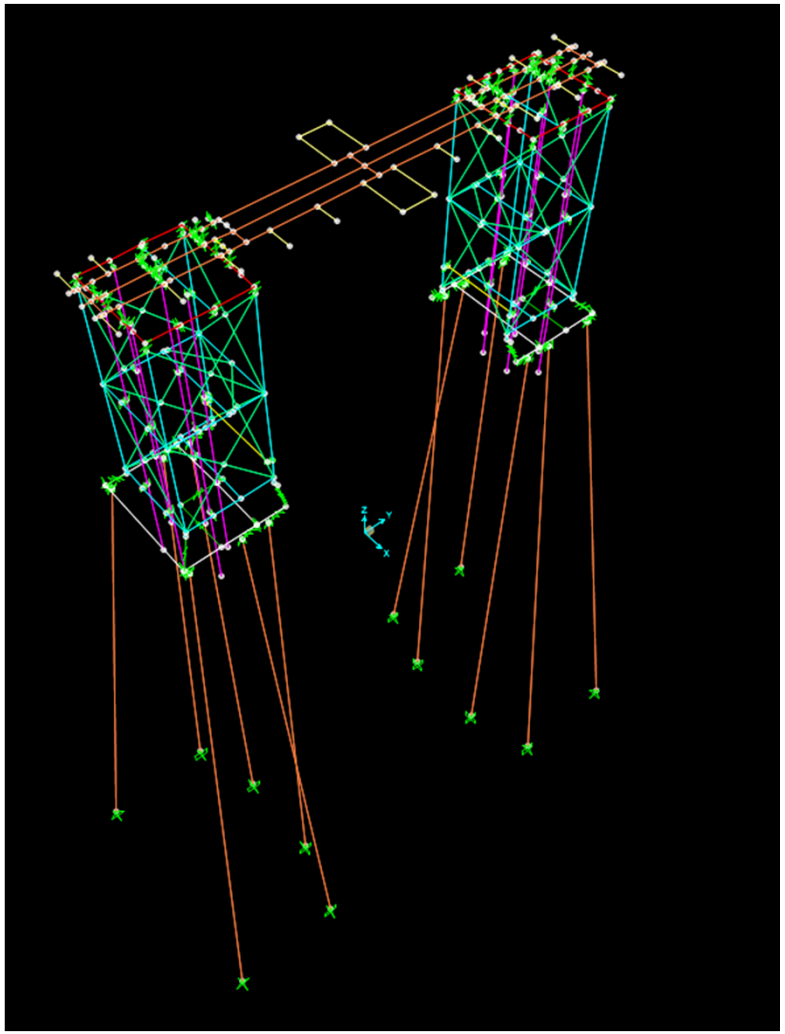


1 VASHON TERMINAL PERFORMANCE 72-YR SEISMIC EVENT
EXISTING CONDITION

VASHON FERRY TERMINAL

BRIDGE SEAT + TOWER ANALYSIS
SAP2000 / CSIBRIDGE



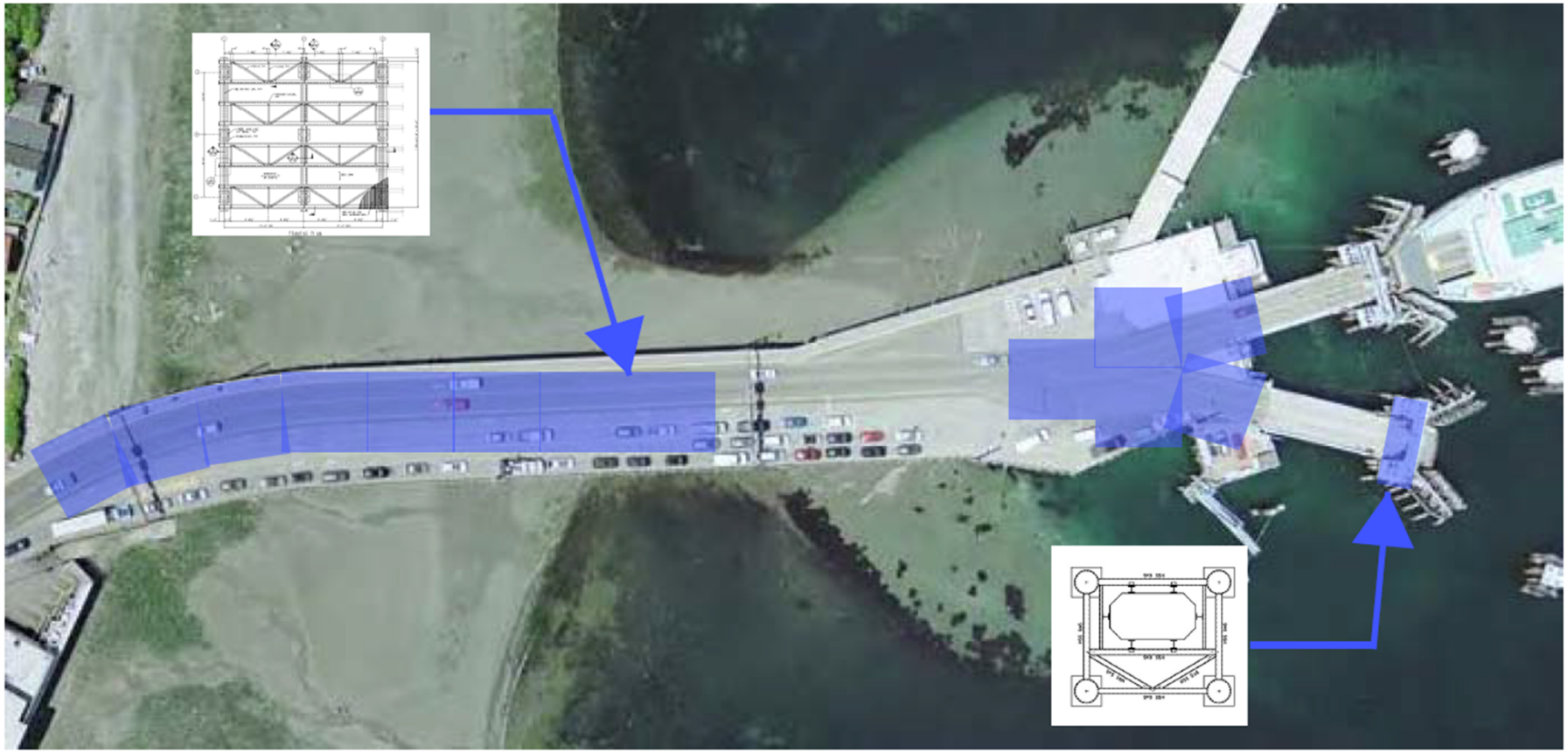


VASHON FERRY TERMINAL

72-YEAR DAMAGE MAP

VASHON FERRY TERMINAL

72-YEAR REPAIR MAP

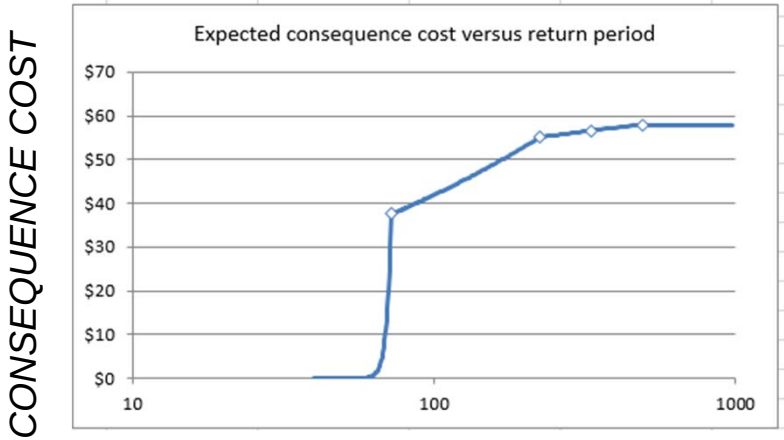


VASHON FERRY TERMINAL

SEISMIC RISK COSTS

CONSEQUENCE COST

VASHON	RETURN PERIOD				
	10	100	225	475	1000
Trestle	$0	$20,033,000	$26,197,000	$26,197,000	$26,197,000
DAYS FAB	0	240	300	300	300
DAYS INSTALL	0	130	170	170	170
Bridge Seat	$0	$0	$2,563,000	$5,126,000	$5,126,000
DAYS FAB	0	0	0	0	0
DAYS INSTALL	0	0	6	12	12
Tower	$0	$3,668,000	$7,336,000	$7,336,000	$7,336,000
DAYS FAB	0	15	30	30	30
DAYS INSTALL	0	15	30	30	30
ransfer Span Relocat	$0	$0	$78,000	$156,000	$156,000
TOTAL $	$0	$23,701,000	$36,174,000	$38,815,000	$38,815,000
DAYS LOSS	0	345	475	481	481
DAYS DELAYED	0	55	61	61	61
TOTAL COST	**$0**	**$37,529,680**	**$55,106,056**	**$57,980,576**	**$57,980,576**



ANNUAL SEISMIC RISK = $686,000

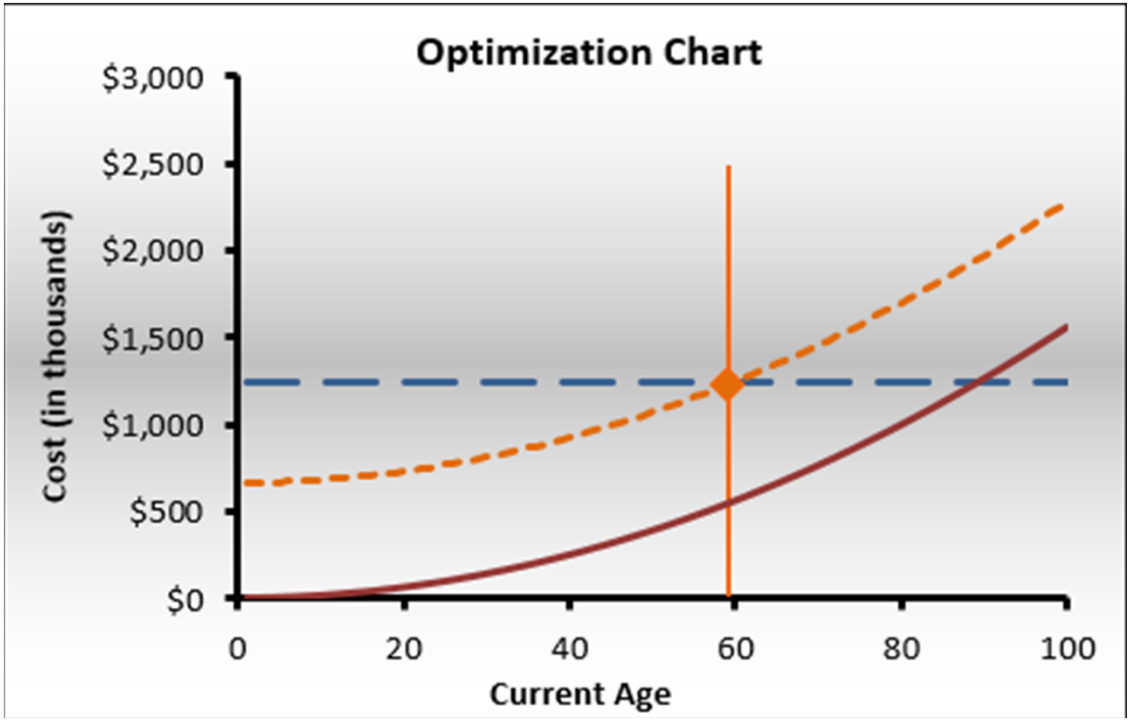
VASHON FERRY TRESTLE

CURRENT TRESTLE AGE = 60 YEARS

REPLACEMENT COST = $22,341,000

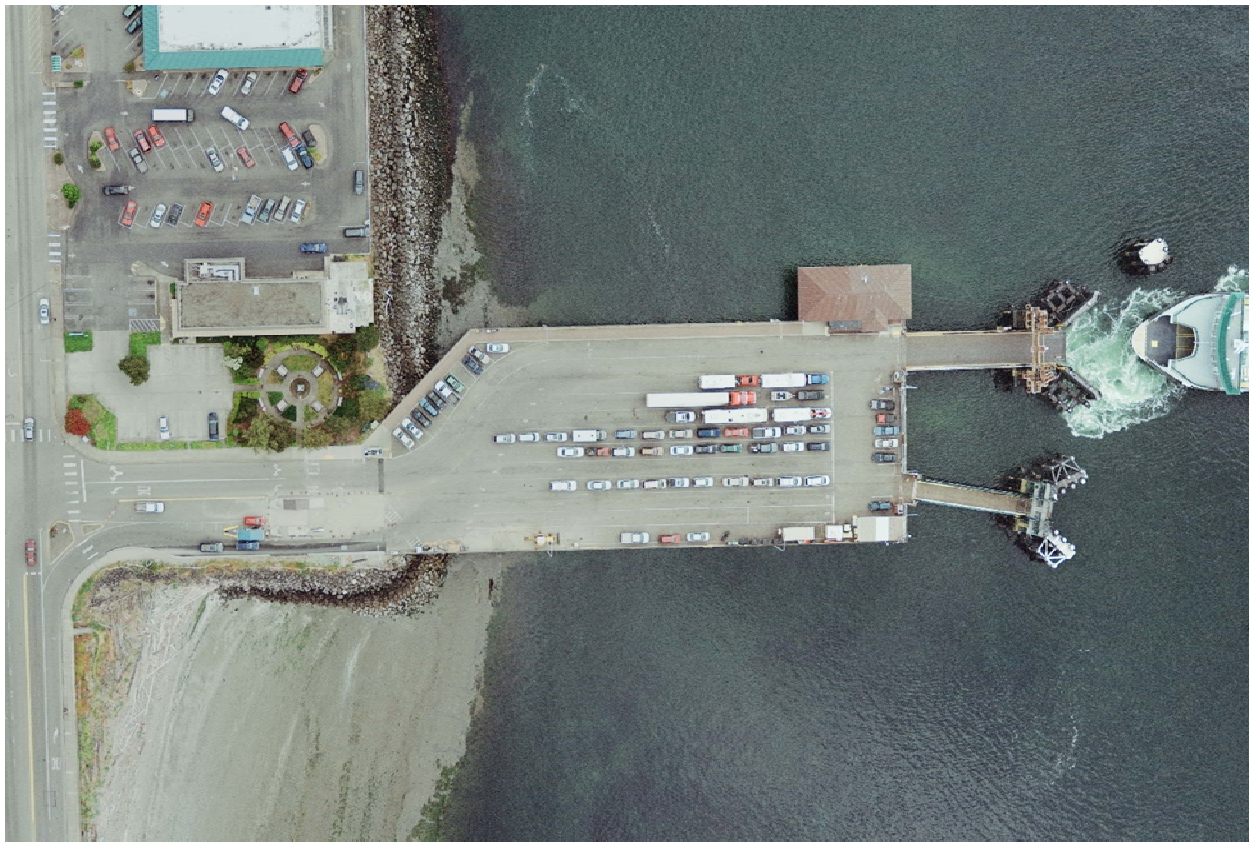
EAC = EQUIVALENT ANNUAL COST = $1.25 MILLION

(BASED on 5% DISCOUNT RATE)



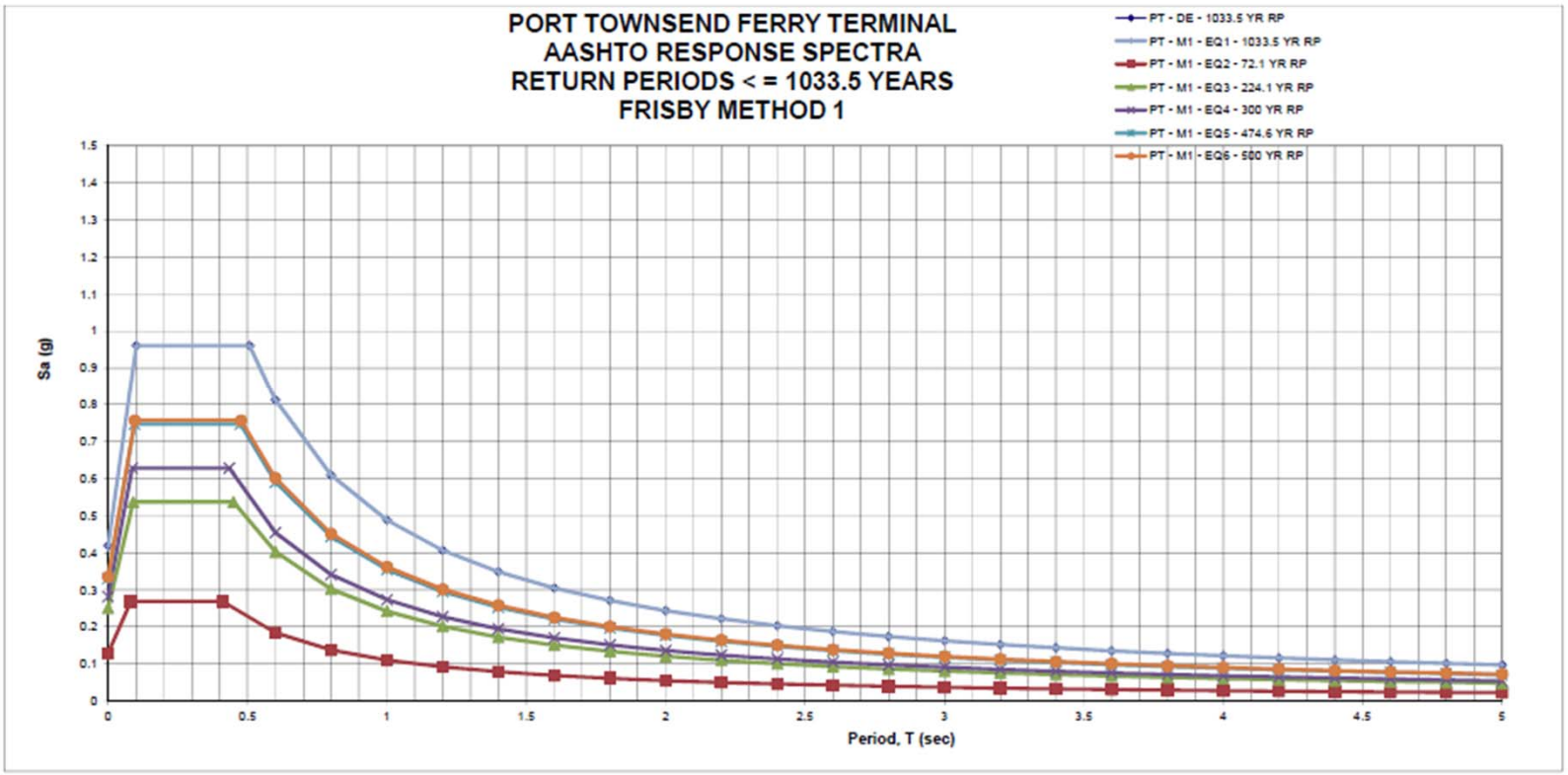
WITHOUT SEISMIC RISK - OPTIMAL AGE OF REPLACEMENT IS **87** YEARS
WITH SEISMIC RISK – OPTIMAL AGE OF REPLACEMENT IS **59** YEARS

PORT TOWNSEND FERRY TERMINAL



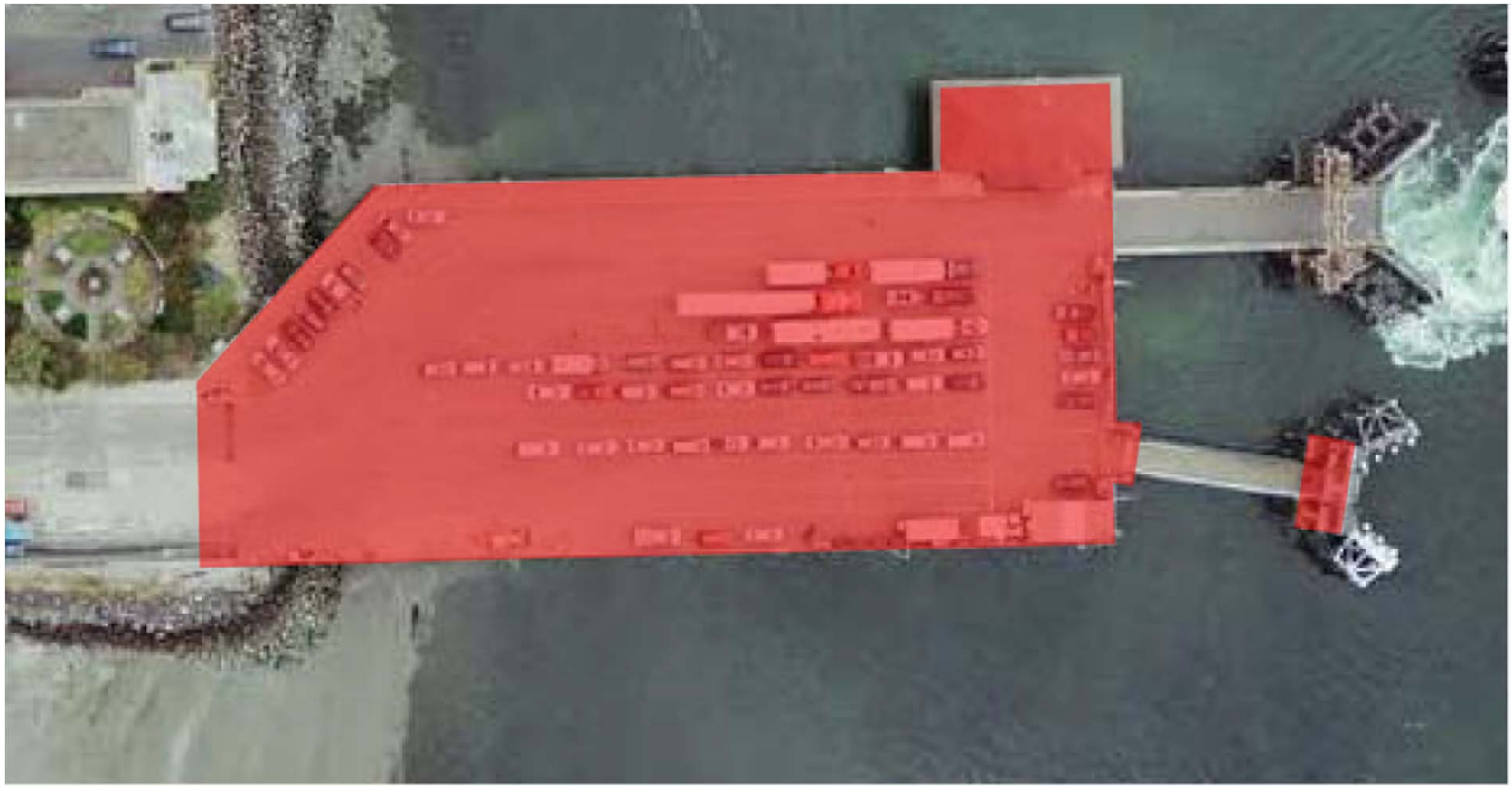
PORT TOWNSEND FERRY TERMINAL

RESPONSE SPECTRUM



PORT TOWNSEND FERRY TERMINAL

72-YEAR DAMAGE MAP



PORT TOWNSEND FERRY TERMINAL

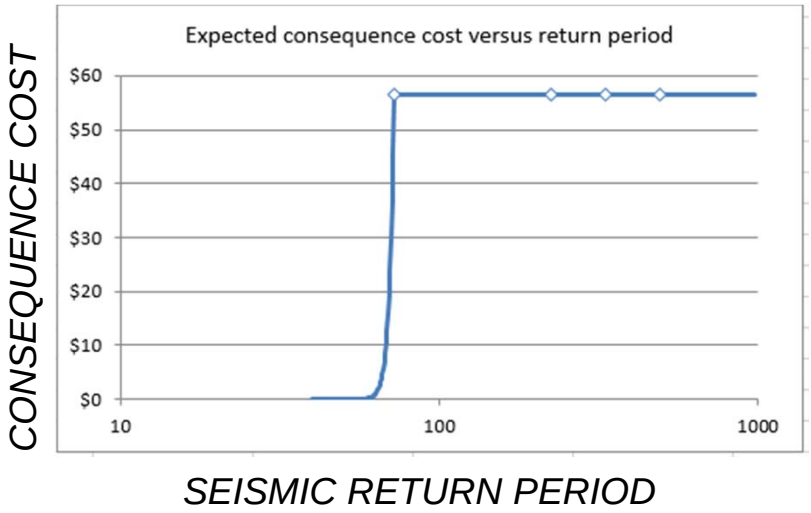
72-YEAR REPAIR MAP

PORT TOWNSEND FERRY TERMINAL

SEISMIC RISK COST

CONSEQUENCE COST

PORT TOWNSEND	RETURN PERIOD				
	10	100	225	475	1000
Trestle	$0	$13,410,000	$13,410,000	$13,410,000	$13,410,000
DAYS FAB	0	180	180	180	180
DAYS INSTALL	0	90	90	90	90
Bridge Seat	$0	$0	$0	$0	$0
DAYS FAB	0	0	0	0	0
DAYS INSTALL	0	0	0	0	0
Tower	$0	$0	$0	$0	$0
DAYS FAB	0	0	0	0	0
DAYS INSTALL	0	0	0	0	0
ransfer Span Relocat	$0	$0	$0	$0	$0
TOTAL $	$0	$13,410,000	$13,410,000	$13,410,000	$13,410,000
DAYS	0	270	270	270	270
TOTAL COST	**$0**	**$56,481,750**	**$56,481,750**	**$56,481,750**	**$56,481,750**
Consequence Cost per Day			$159,525		



ANNUAL SEISMIC RISK = $808,000

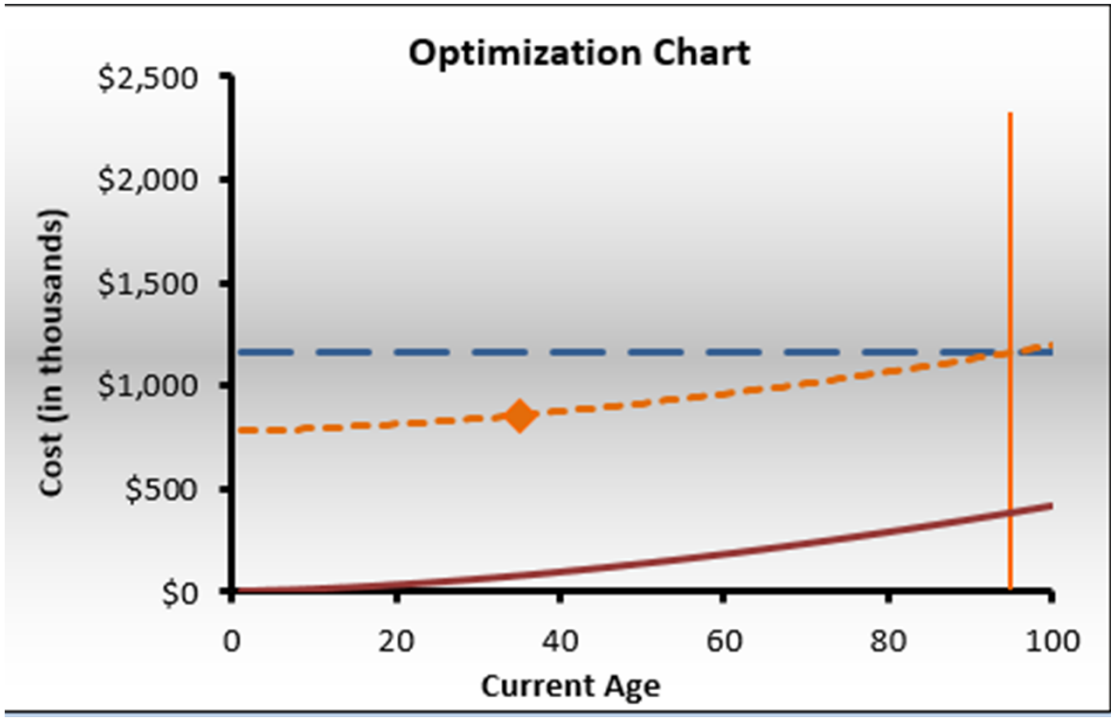
PORT TOWNSEND FERRY TRESTLE

CURRENT TRESTLE AGE = 35 YEARS

REPLACEMENT COST = $22,078,000

EAC = EQUIVALENT ANNUAL COST = $1.16 MILLION

(BASED on 5% DISCOUNT RATE)



WITHOUT SEISMIC RISK - OPTIMAL AGE OF REPLACEMENT IS **186** YEARS
WITH SEISMIC RISK – OPTIMAL AGE OF REPLACEMENT IS **95** YEARS

QUESTIONS/DISCUSSION?

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