

TERRA ASSOCIATES, Inc.

Consultants in Geotechnical Engineering, Geology
and
Environmental Earth Sciences

February 13, 2025
Revised March 11, 2025
Project No. T-7768-1

Mr. Gardner Morelli
Mercer Island Beach Club
8326 Avalon Drive
Mercer Island, Washington 98040

Subject: Geotechnical Engineering Study
Marina Rebuild
8326 Avalon Drive
Mercer Island, Washington

Dear Mr. Morelli:

As requested, we performed a geotechnical study for the subject project. Our scope of work included subsurface exploration and geotechnical analyses to develop design values for the various piles that will be used in rebuilding the existing marina.

SURFACE CONDITIONS

The project site is located offshore in the existing marina area of the Mercer Island Beach Club. The club is located on a 7.52-acre parcel located at 8326 Avalon Drive in Mercer, Washington. The site location is shown on Figure 1.

The existing marina located along the eastern shoreline of the beach club consists of five docks, a day dock, a swimming platform, and a log boom which encloses the swimming area west of the docks. Water levels within Lake Washington typically fluctuate from 22 feet in the summer to 20 feet in the winter. Topographic conditions of the Lake Washington lakebed within the project area consist of a slope descending from the shore in the west/northwest to the east/southeast with an overall vertical relief of approximately 40 feet, or from approximate elevations 20.0 feet to -20.0 feet. As we understand, vegetation in the lakebed below the existing marina area consists of a thick vegetative mat composed predominantly of milfoil.

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As we understand, the project will consist of replacing three of the existing docks, floating dock, swimming platform, and log boom with a new shoreward dock, floating dock, swimming platform, and log boom along with new moorage piers.

SUBSURFACE CONDITIONS

On November 18, 2024, and November 19, 2024, we observed soil and groundwater conditions at three test borings advanced from a barge into the lakebed with a hollow-stem auger to maximum depths of approximately 40 feet below existing ground surface grades. The approximate test boring locations are shown on Figure 2. Test Boring Logs are attached as Figure 4 through 6.

A geotechnical engineer from our office conducted the field exploration. Our representative classified the soil conditions encountered, maintained a log of the test borings, obtained representative soil samples, and recorded water levels observed during excavation. All soil samples were visually classified in accordance with the Unified Soil Classification System (USCS) described on Figure 3.

Soils

The soils observed in the test borings below approximately 18 to 29 feet of water generally consisted of approximately 5 to 12 feet of lakebed deposits composed of soft to stiff clayey silt and loose silty sand overlying approximately 7 to 12 feet of soft to stiff, fractured clayey silt interpreted to be mass wastage deposits. Pre-glacial deposits were observed below the mass wastage debris which typically consisted of medium stiff to very stiff, massive silt and clay with varying gravel content which transitioned to medium dense to very dense sand with silt, silty sand, and gravel with silt and sand deposits beginning at depths of approximately 34 to 62 feet below existing lakebed grades. There were two exceptions to this general condition. No mass wastage deposits were observed in Test Boring B-3. The upper approximately 10 feet of the underlying pre-glacial deposits observed in Test Boring B-3 consisted of medium dense to dense sand and gravel with varying silt content.

The subsurface geology within the existing marina area is not currently mapped by USGS or AASG. However, nearby subsurface data obtained from the Washington Geologic Information Portal indicates the subsurface geology underlying the project area consists of lakebed deposits composed of silt and clay. The nearby subsurface data is consistent with our own observations made during our subsurface explorations. Moreover, deep scarping shown on LIDAR imagery northwest of the site indicates landsliding of the upper plateau of Mercer Island towards the southeast into Lake Washington. Based on the blow counts observed in the mass wastage deposits and on available data obtained from the Washington Department of Natural Resources *Geologic Information Portal*, it is our opinion that the relative age of the landslide would be considered pre-historic.

DISCUSSION

In our opinion, the native soils we observed underlying the alluvial lake sediments and mass wastage deposits are suitable for support of the new piers, docks, and platform. Piles will need to be driven through the upper compressible and/or loose soil strata to gain suitable support for lateral and vertical loading that will be imposed.

A proposed site plan, prepared by Waterfront Construction, Inc., and dated December 1, 2023, indicates that the swimming platform, shoreward dock, and replacement mooring structure will be supported by 8-inch diameter piles, and the new moorage structure supported by 16-inch diameter piles. All piles will be Schedule 80 steel. We were provided with the following pile loading by Pacific Engineering Technologies, Inc., the structural engineer of record:

Pile Type	Maximum Lateral Force at Dredge Line	Maximum Moment at Dredge Line	Maximum Axial Load
Swimming Platform	1.5 kips	32 kip-ft	8.8 kips
Shoreward Dock	1.2 kips	35 kip-ft	12.6 kips
Mooring Piles	1 kip	36 kip-ft	3 kips
Floating Dock	3 kips	120 kip-ft	3 kips

PILE DESIGN

Lateral Analysis

Our analysis of the lateral pile deflections with the above loading criteria was completed using the LPILE computer program, version 2018.10.07, published by Ensoft, Inc. The driven steel piles will not be fixed at the lakebed elevation and lateral movement will be from a combination of horizontal translational movement and rotation. Therefore, our analysis of the lateral deflections was based on a free head condition for piles extending into the very stiff, massive silt deposits. The resulting deflections, along with the associated points of fixity, are given below:

Swimming Platform (8-inch Diameter)			
Deflection at lakebed	Point of Fixity Below lakebed Zero Defl.	Point of Fixity Below lakebed Max. Moment	Maximum Moment Kip-ft
1.10 inches	13.4 feet	4.4 feet	36.3

Shoreward Dock (8-inch Diameter)			
Deflection at lakebed	Point of Fixity Below lakebed Zero Defl.	Point of Fixity Below lakebed Max. Moment	Maximum Moment Kip-ft
1.10 inches	13 feet	3.8 feet	38.2

Mooring Piles (8-inch Diameter)			
Deflection at lakebed	Point of Fixity Below lakebed Zero Defl.	Point of Fixity Below lakebed Max. Moment	Maximum Moment Kip-ft
1.04 inches	12.6 feet	3.4 feet	38.1

Floating Dock (16-inch Diameter)			
Deflection at lakebed	Point of Fixity Below lakebed Zero Defl.	Point of Fixity Below lakebed Max. Moment	Maximum Moment Kip-ft
.75 inches	18 feet	6 feet	130.8

We extrapolated the potential lateral movement at the lake surface in five-foot increments above the lakebed using the calculated pile slope or angle of rotation. Results are as follows:

Swimming Platform (8-inch Diameter)						
Deflection at lakebed	Deflection at water surface 5' of Water	Deflection at water surface 10' of Water	Deflection at water surface 15' of Water	Deflection at water surface 20' of Water	Deflection at water surface 25' of Water	Deflection at water surface 30' of Water
1.10 inches	1.89 inches	2.69 inches	3.48 inches	4.28 inches	5.07 inches	5.87 inches

Shoreward Dock (8-inch Diameter)						
Deflection at lakebed	Deflection at water surface 5' of Water	Deflection at water surface 10' of Water	Deflection at water surface 15' of Water	Deflection at water surface 20' of Water	Deflection at water surface 25' of Water	Deflection at water surface 30' of Water
1.10 inches	1.92 inches	2.74 inches	3.56 inches	4.38 inches	5.20 inches	6.01 inches

Mooring Piles (8-inch Diameter)						
Deflection at lakebed	Deflection at water surface 5' of Water	Deflection at water surface 10' of Water	Deflection at water surface 15' of Water	Deflection at water surface 20' of Water	Deflection at water surface 25' of Water	Deflection at water surface 30' of Water
1.04 inches	1.83 inches	2.63 inches	3.42 inches	4.21 inches	5.01 inches	5.80 inches

Floating Dock (16-inch Diameter)						
Deflection at lakebed	Deflection at water surface 5' of Water	Deflection at water surface 10' of Water	Deflection at water surface 15' of Water	Deflection at water surface 20' of Water	Deflection at water surface 25' of Water	Deflection at water surface 30' of Water
0.75 inches	1.13 inches	1.50 inches	1.88 inches	2.25 inches	2.63 inches	3.00 inches

Typically, for buildings, allowable lateral deflection at the ground surface is limited to one inch or less. With the proposed loading and pile dimensions, this one-inch maximum would be exceeded at the water surface under the provided loading in most cases. However, it's likely the pile connections to the structures would restrain or limit a portion of this movement.

Graphical results from the LPILE analysis detailing shear, moment, and deflection curves are attached to this report for reference.

Axial Capacities

Required axial capacities of the piles are relatively small and will be readily achieved with the proposed pile diameters. We recommend the piles be driven to tip elevations equal to 35 feet below the lakebed. With piles driven to these depths, the following allowable axial capacities would be provided:

Pile Diameter (inches)	Allowable Axial Capacity (F.S.=2) (kips)	
	Compression	Uplift
8	18	6
16	50	12

Pile driving criteria depends upon several factors including pile driving hammer energy, efficiency and pile head cushioning. However, in this case axial capacity does not govern the design and therefore driving criteria other than the recommended minimum tip elevations need apply. However, if desired, we can provide driving criteria to verify the design axial capacities once the specifics of the type of hammer that would be used are known.

LIMITATIONS

We prepared this report in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made. This report is the copyrighted property of Terra Associates, Inc., and is intended for specific application to the Marina Rebuild project in Mercer Island, Washington, and for the exclusive use of the Mercer Island Beach Club and its authorized representatives.

Mr. Gardner Morelli
February 13, 2025
Revised March 11, 2025

We trust the information presented in this report is sufficient for your current needs. If you have any questions or require additional information, please call.

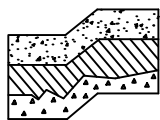
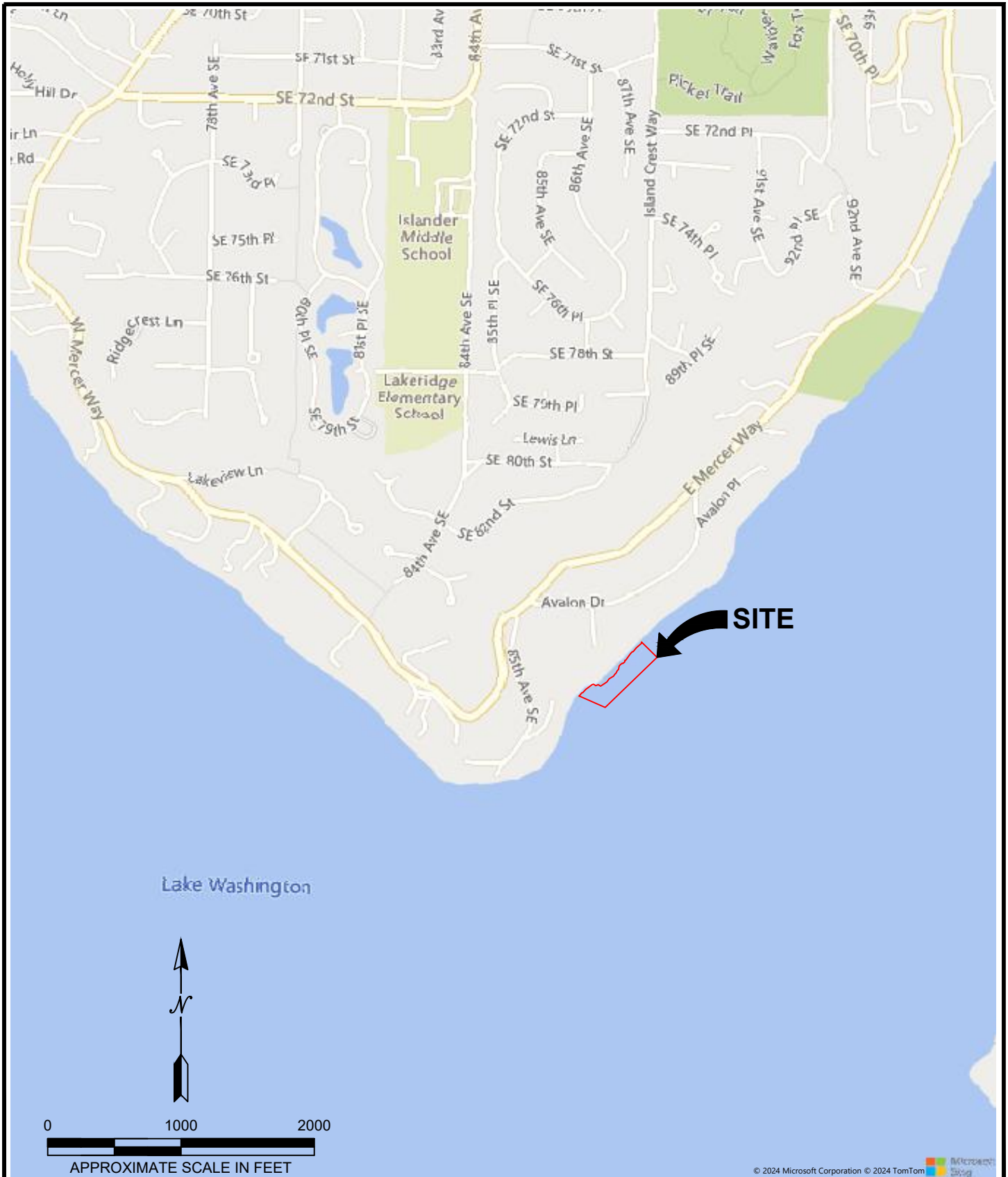
Sincerely yours,
TERRA ASSOCIATES, INC.



Michael J. Xenos, P.E.
Project Engineer



- Encl:
- Figure 1 – Vicinity Map
 - Figure 2 – Exploration Location Plan
 - Figure 3 – Unified Soil Classification System
 - Figures 4 through 6 – Test Pit Log
 - Figure 7 – Grain Size Analyses
 - LPILE Graphical Output



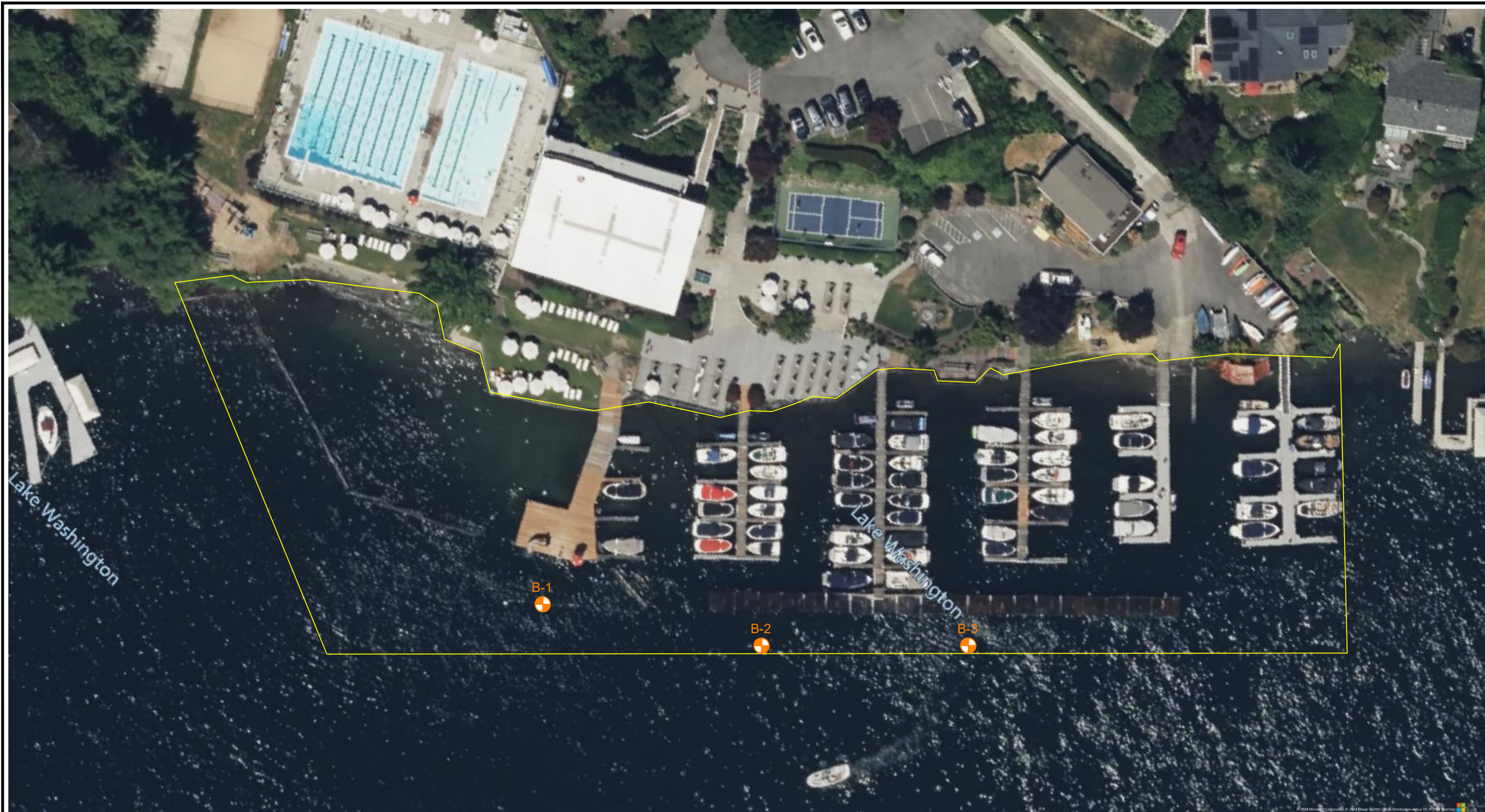
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VICINITY MAP
 MARINA REBUILD
 MERCER ISLAND, WASHINGTON

Proj.No.T-7768-1

Date: MAR 2025

Figure 1



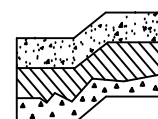
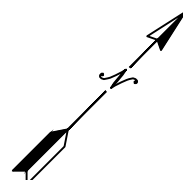
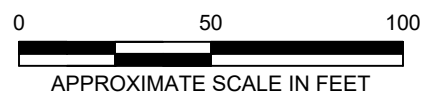
NOTE:

THIS SITE PLAN IS SCHEMATIC. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE. IT IS INTENDED FOR REFERENCE ONLY AND SHOULD NOT BE USED FOR DESIGN OR CONSTRUCTION PURPOSES.

REFERENCE: SITE PLAN PROVIDED BY BING MAPS.

LEGEND:

 APPROXIMATE BORING LOCATION



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EXPLORATION LOCATION PLAN
 MARINA REBUILD
 MERCER ISLAND, WASHINGTON




Proj.No.T-7768-1

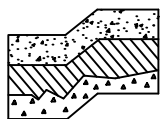
Date: MAR 2025

Figure 2

MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTION	
COARSE GRAINED SOILS	More than 50% material larger than No. 200 sieve size	GRAVELS More than 50% of coarse fraction is larger than No. 4 sieve	Clean Gravels (less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
				GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.
			Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures, non-plastic fines.
				GC	Clayey gravels, gravel-sand-clay mixtures, plastic fines.
	More than 50% of coarse fraction is smaller than No. 4 sieve	SANDS More than 50% of coarse fraction is smaller than No. 4 sieve	Clean Sands (less than 5% fines)	SW	Well-graded sands, sands with gravel, little or no fines.
				SP	Poorly-graded sands, sands with gravel, little or no fines.
			Sands with fines	SM	Silty sands, sand-silt mixtures, non-plastic fines.
				SC	Clayey sands, sand-clay mixtures, plastic fines.
FINE GRAINED SOILS	More than 50% material smaller than No. 200 sieve size	SILTS AND CLAYS Liquid Limit is less than 50%	ML	Inorganic silts, rock flour, clayey silts with slight plasticity.	
			CL	Inorganic clays of low to medium plasticity. (Lean clay)	
			OL	Organic silts and organic clays of low plasticity.	
		SILTS AND CLAYS Liquid Limit is greater than 50%	MH	Inorganic silts, elastic.	
			CH	Inorganic clays of high plasticity. (Fat clay)	
			OH	Organic clays of high plasticity.	
HIGHLY ORGANIC SOILS			PT	Peat.	

DEFINITION OF TERMS AND SYMBOLS

COHESIONLESS	<u>Density</u>	<u>Standard Penetration Resistance in Blows/Foot</u>		2" OUTSIDE DIAMETER SPILT SPOON SAMPLER
	Very Loose Loose Medium Dense Dense Very Dense	0-4 4-10 10-30 30-50 >50		2.4" INSIDE DIAMETER RING SAMPLER OR SHELBY TUBE SAMPLER
COHESIVE	<u>Consistency</u>	<u>Standard Penetration Resistance in Blows/Foot</u>		WATER LEVEL (Date)
	Very Soft Soft Medium Stiff Stiff Very Stiff Hard	0-2 2-4 4-8 8-16 16-32 >32	Tr	TORVANE READINGS, tsf
			Pp	PENETROMETER READING, tsf
			DD	DRY DENSITY, pounds per cubic foot
			LL	LIQUID LIMIT, percent
			PI	PLASTIC INDEX
		N	STANDARD PENETRATION, blows per foot	



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UNIFIED SOIL CLASSIFICATION SYSTEM
 MARINA REBUILD
 MERCER ISLAND, WASHINGTON

Proj.No.T-7768-1

Date: MAR 2025

Figure 3

LOG OF BORING NO. B-1

Figure No. 4

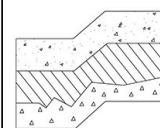
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 18, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: 34 feet Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)	
				10	30	50		
0		(Approximately 18 feet of water)					2	39.5
		Bluish-gray clayey SILT, moist to wet, trace small-sized organic fragments, occasional fine gravel, occasional sand seam. (ML) (Lakebed Deposits)	Soft				3	40.4
5			Soft				2	35.1
			Soft				4	30.5
10			Stiff				9	38.3
		Gray clayey SILT, moist, trace gravel, blocky structure. (ML) (Mass Wastage Deposits)	Soft				3	35.6
15			Medium Stiff				5	31.6
20			Stiff				10	29.7
		Continued on Next Page						

NOTE: This borehole log has been prepared for geotechnical purposes. This information pertains only to this boring location and should not be interpreted as being indicative of other areas of the site



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LOG OF BORING NO. B-1

Figure No. 4

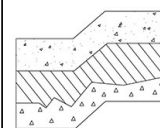
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 18, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: 34 feet Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)
				10	30	50	
25		Gray clayey SILT, moist, massive. (ML) (Pre-Fraser Deposits Undifferentiated?)	Stiff	•		11	27.4
30		*Oxidation observed in sample* *Trace gravel observed in bottom 1-inch of sample*	Very Stiff	•		16	29.3
35		Gray SAND with silt, fine to medium sand, saturated, trace gravel, occasional silt layer. (SP-SM) (Pre-Fraser Deposits Undifferentiated?)	Medium Dense	•		25	16.8
40		Gray silty SAND with gravel, fine to coarse sand, fine to coarse gravel, moist, occasional silt layer. (SM) (Pre-Fraser Deposits Undifferentiated?)	Dense	•		35	13.8
45		Test Boring terminated at approximately 40 feet. Heavy perched groundwater seepage observed at approximately 34 feet.					

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LOG OF BORING NO. B-2

Figure No. 5

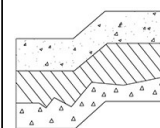
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 18, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: NA Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)	
				10	30	50		
0		(Approximately 21 feet of water)	Soft				2	32.4
		Gray clayey SILT, moist to wet, occasional fine gravel, occasional sand seam, occasional small-sized organic fragment. (ML) (Lakebed Deposits)					5	31.5
5			Medium Stiff				6	32.8
		Gray clayey SILT, moist to wet, generally massive, some localized blocky structure, occasional fine gravel. (ML) (Mass Wastage Deposits)					5	32.8
10							7	33.7
		Occasional small-sized organic fragments observed in sample					6	34.5
15		Gray clayey SILT, moist, massive. (ML) (Pre-Fraser Deposits Undifferentiated?)	Stiff				9	30.6
20							10	29.8
		Continued on Next Page						

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LOG OF BORING NO. B-2

Figure No. 5

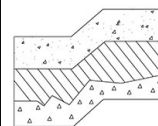
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 18, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: NA Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)
				10	30	50	
25		Gray clayey SILT, moist, massive. (ML) (Pre-Fraser Deposits Undifferentiated?)	Stiff	•		12	27.3
30		Gray silty CLAY, moist, massive. (CL) (Pre-Fraser Deposits Undifferentiated?)	Medium Stiff	•		6	42.9
35		*Slight oxidation observed in sample*	Stiff	•		11	34.7
40		Gray clayey SILT, moist, massive. (ML) (Pre-Fraser Deposits Undifferentiated?)	Very Stiff	•		16	32.2
45		*Continued on Next Page*	Stiff	•		14	32.4

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LOG OF BORING NO. B-2

Figure No. 5

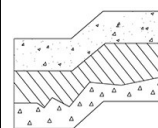
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 18, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: NA Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)	
				10	30	50		
50		Gray clayey SILT, moist, massive. (ML) (Pre-Fraser Deposits Undifferentiated?)	Stiff	•			12	30.1
55				•			15	30.7
60		Gray silty CLAY, moist, massive, trace gravel. (CL) (Pre-Fraser Deposits Undifferentiated?)	Medium Dense	•			10	37.2
65		Gray silty SAND with gravel, fine to coarse sand, fine to coarse gravel, moist, occasional silt layer. (SM) (Pre-Fraser Deposits Undifferentiated?)		•			21	11.1
70		Test Boring terminated at approximately 65 feet. No groundwater seepage observed.						

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LOG OF BORING NO. B-3

Figure No. 6

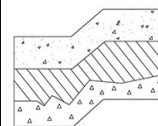
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 19, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: -2.5 feet Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)	
				10	30	50		
0		(Approximately 29 feet of water)	Medium Stiff	•			5	35.1
		Gray clayey SILT, moist to wet, occasional small-sized organic fragment, interbedded sand layers. (ML) (Lakebed Deposits)	Loose	•			6	24.6
		Gray silty SAND, fine to coarse sand, saturated, occasional fine gravel, interbedded clayey silt layers. (SM) (Lakebed Deposits)			•			17
5		Gray SAND with silt to SAND with silt and gravel, fine to coarse sand, fine to coarse gravel, saturated, trace clayey silt layers, occasional gravel layer. (SP-SM) (Pre-Fraser Deposits Undifferentiated?)	Medium Dense	•			15	17.6
			Dense		•			31
10		Gray SAND with gravel to GRAVEL with sand, fine to coarse sand, fine to coarse gravel, saturated, occasional clayey silt layer. (SP/GP) (Pre-Fraser Deposits Undifferentiated?)	Medium Dense	•			10	12.8
			Stiff		•			11
15				•			15	28.1
					•			13
20								
25		*Continued on Next Page*						

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LOG OF BORING NO. B-3

Figure No. 6

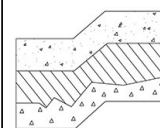
Project: Marina Rebuild Project No: T-7768-1 Date Drilled: November 19, 2024

Client: Mercer Island Beach Club Driller: BoreTec 1 Logged By: MJX

Location: Mercer Island, Washington Depth to Groundwater: 2.5 feet Approx. Elev: NA

Depth (ft)	Sample Interval	Soil Description	Consistency/ Relative Density	SPT (N) Blows / foot			Moisture Content (%)
				10	30	50	
30		Gray SILT, moist, massive, occasional fine gravel. (ML) (Pre-Fraser Deposits Undifferentiated?)	Stiff			15	30.6
35							12
40		Gray silty SAND with gravel, fine to coarse sand, fine to coarse gravel, moist. (SM) (Pre-Fraser Deposits Undifferentiated?)	Dense			31	14.5
45		Gray GRAVEL with silt and sand, fine to coarse sand, fine to coarse gravel, moist, interbedded silt seams. (GP-GM) (Pre-Fraser Deposits Undifferentiated?)	Very Dense			53	9.6
50		Test Boring terminated at approximately 45 feet. Heavy groundwater seepage observed at approximately 2.5 feet.					

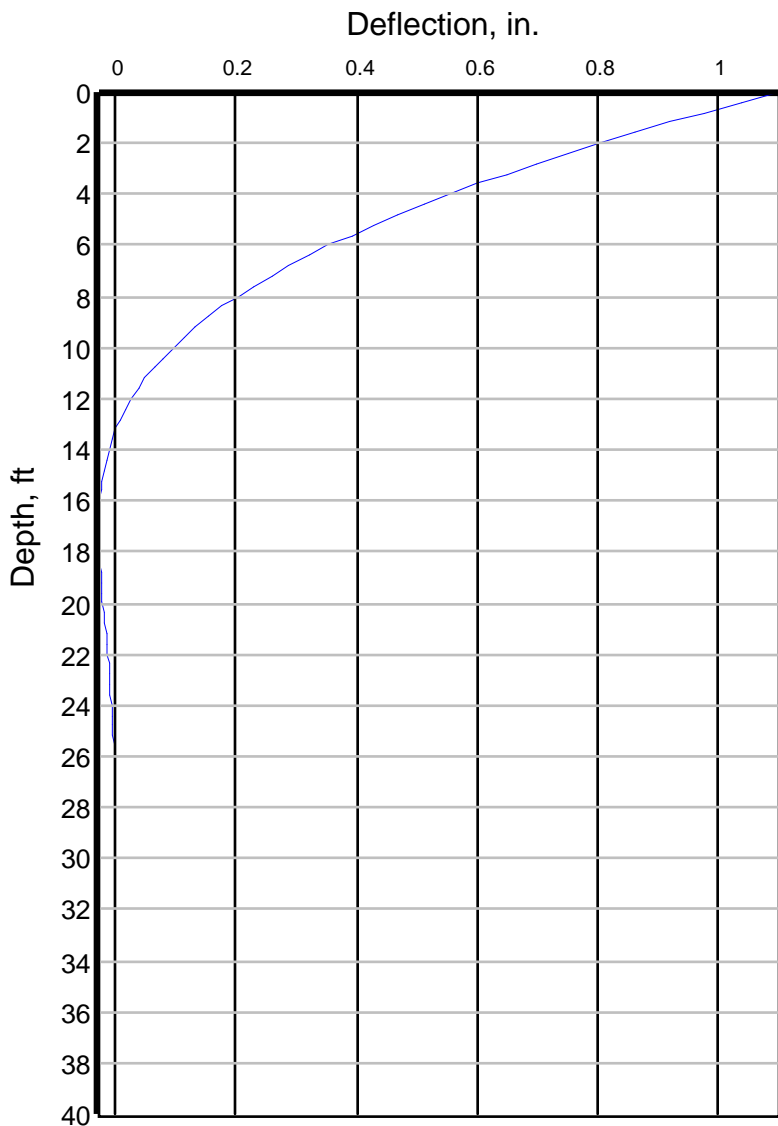
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 Environmental Earth Sciences

LPILE GRAPHICAL OUTPUT – SWIMMING PLATFORM

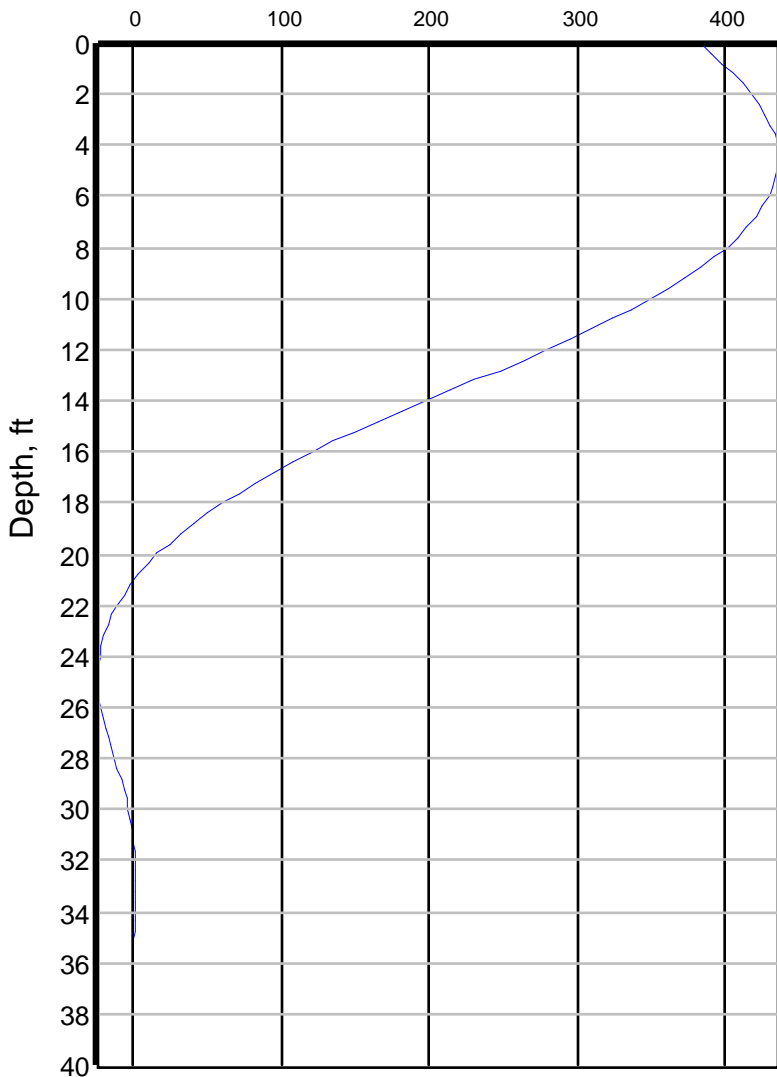
Swimming Platform Lateral Deflection vs. Depth



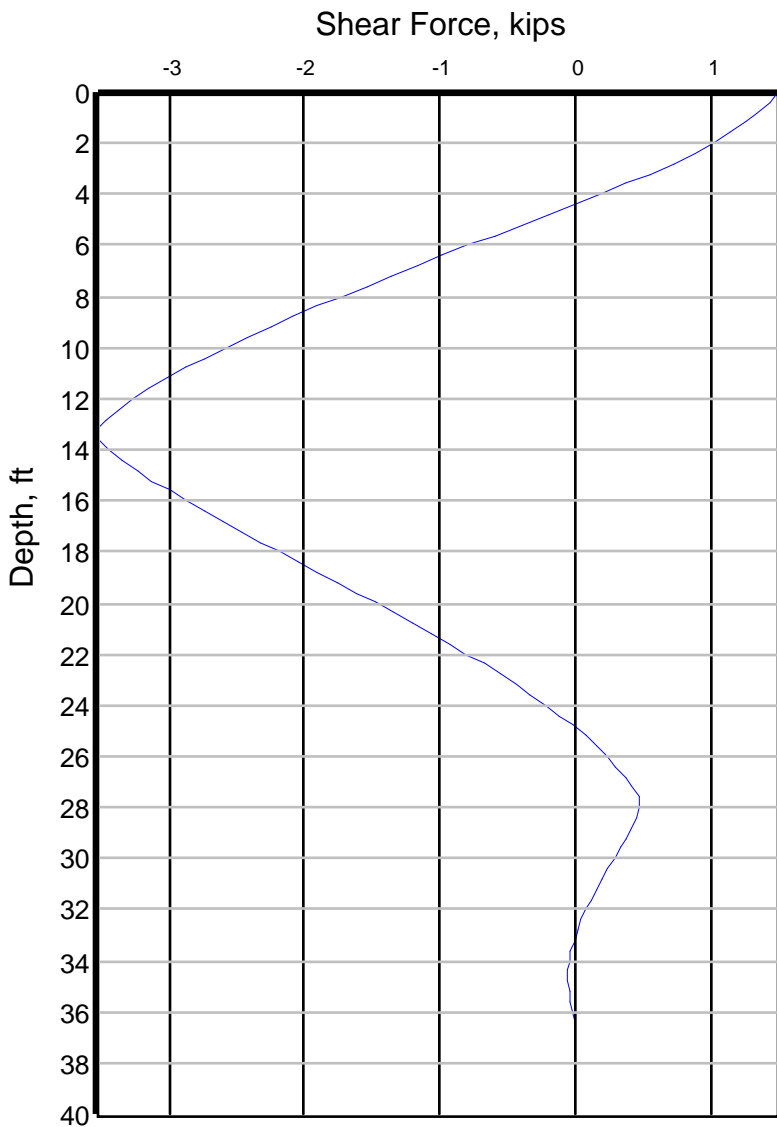
Swimming Platform

Bending Moment vs. Depth

Bending Moment, in-kips

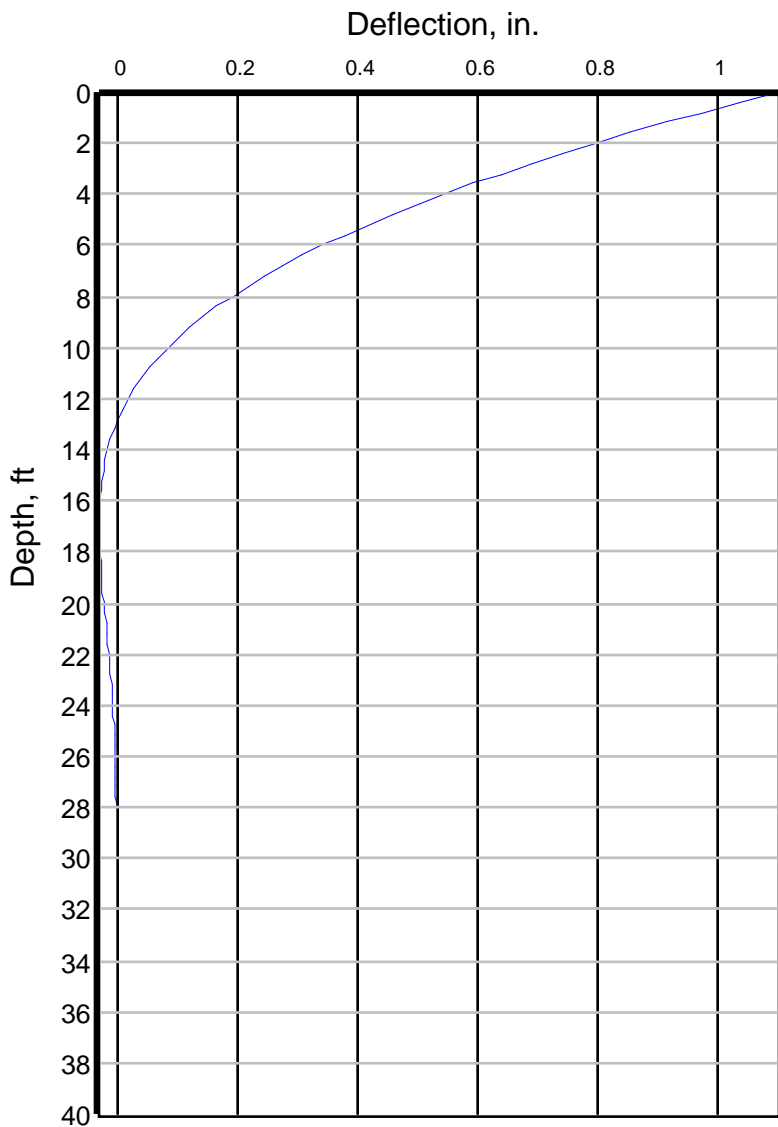


Swimming Platform Shear Force vs. Depth



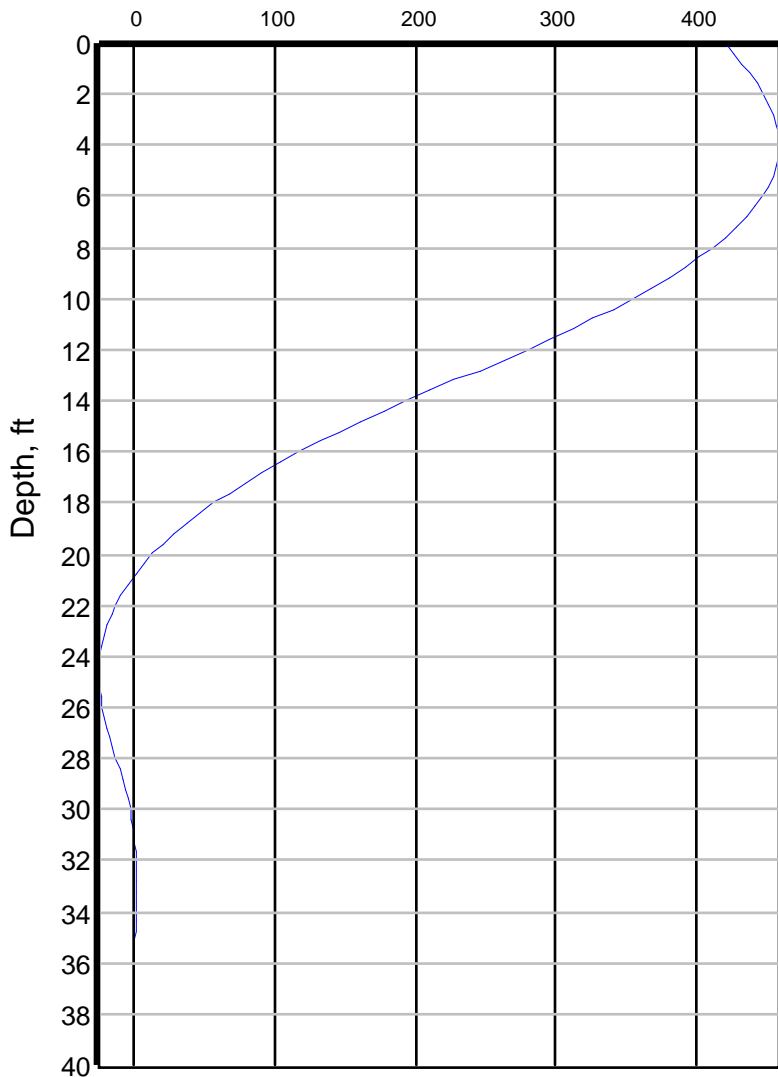
LPILE GRAPHICAL OUTPUT – SHOREWARD DOCK

Shoreward Dock Lateral Deflection vs. Depth



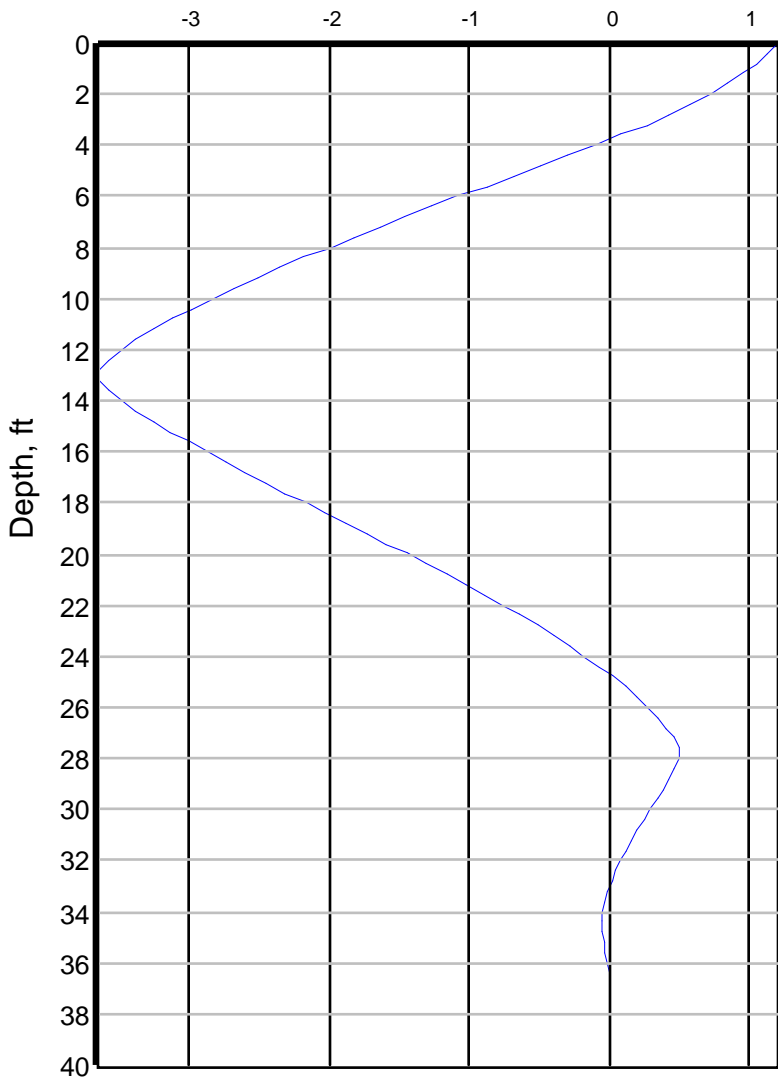
Shoreward Dock Bending Moment vs. Depth

Bending Moment, in-kips



Shoreward Dock Shear Force vs. Depth

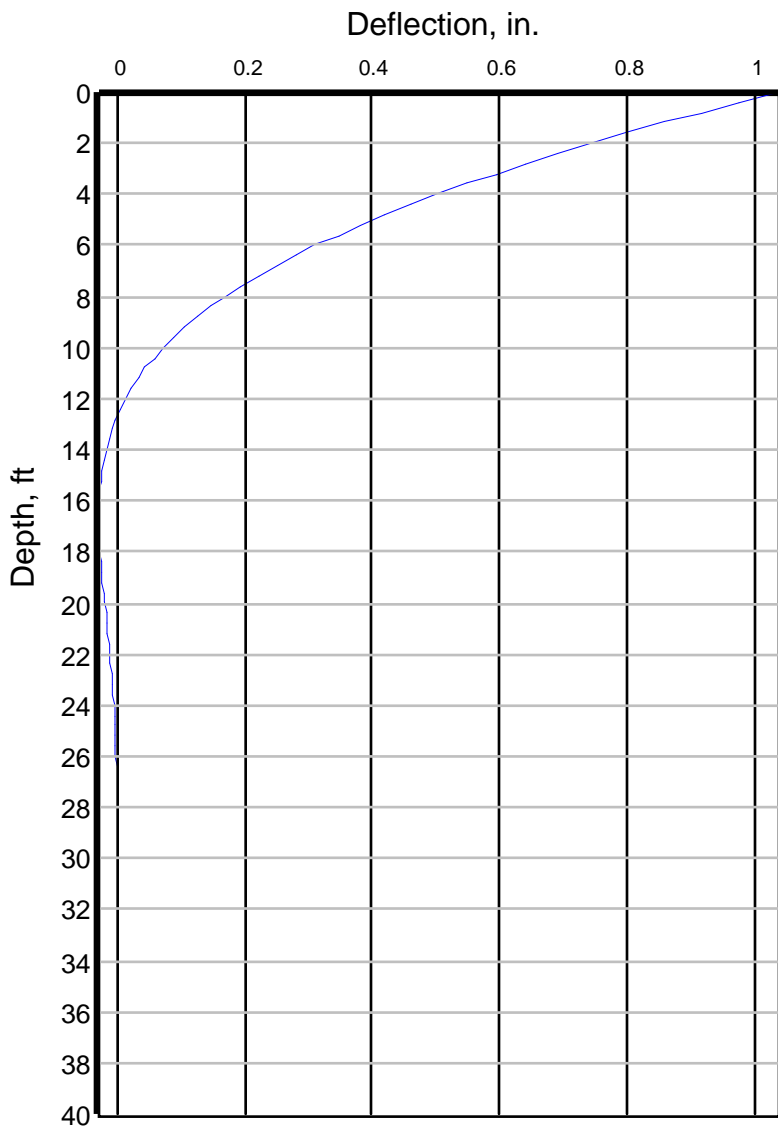
Shear Force, kips



LPILE GRAPHICAL OUTPUT – MOORAGE PIERS

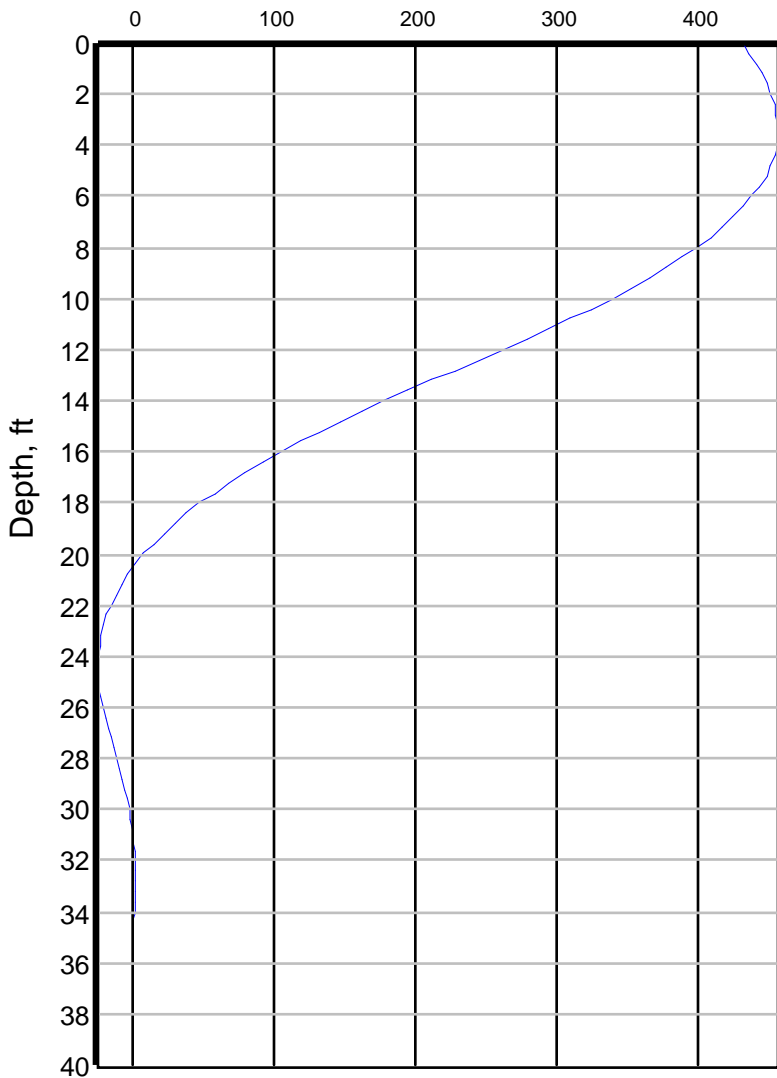
Mooring Piles

Lateral Deflection vs. Depth

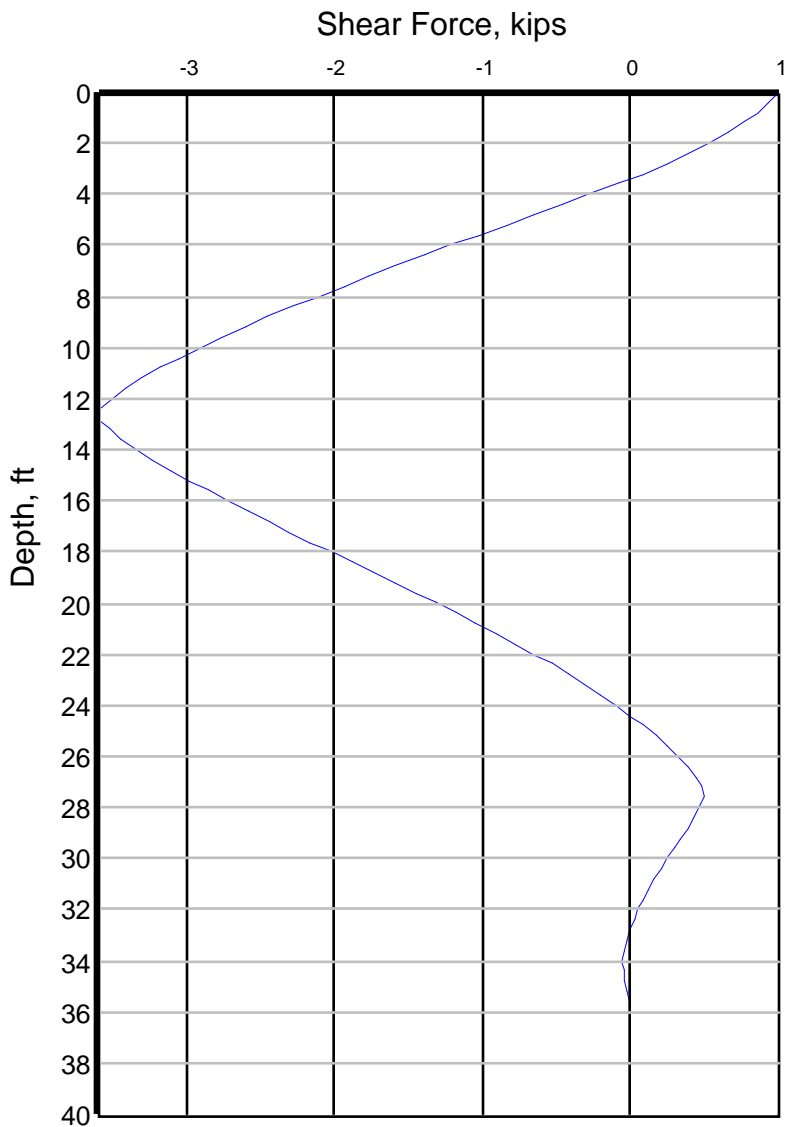


Mooring Piles Bending Moment vs. Depth

Bending Moment, in-kips

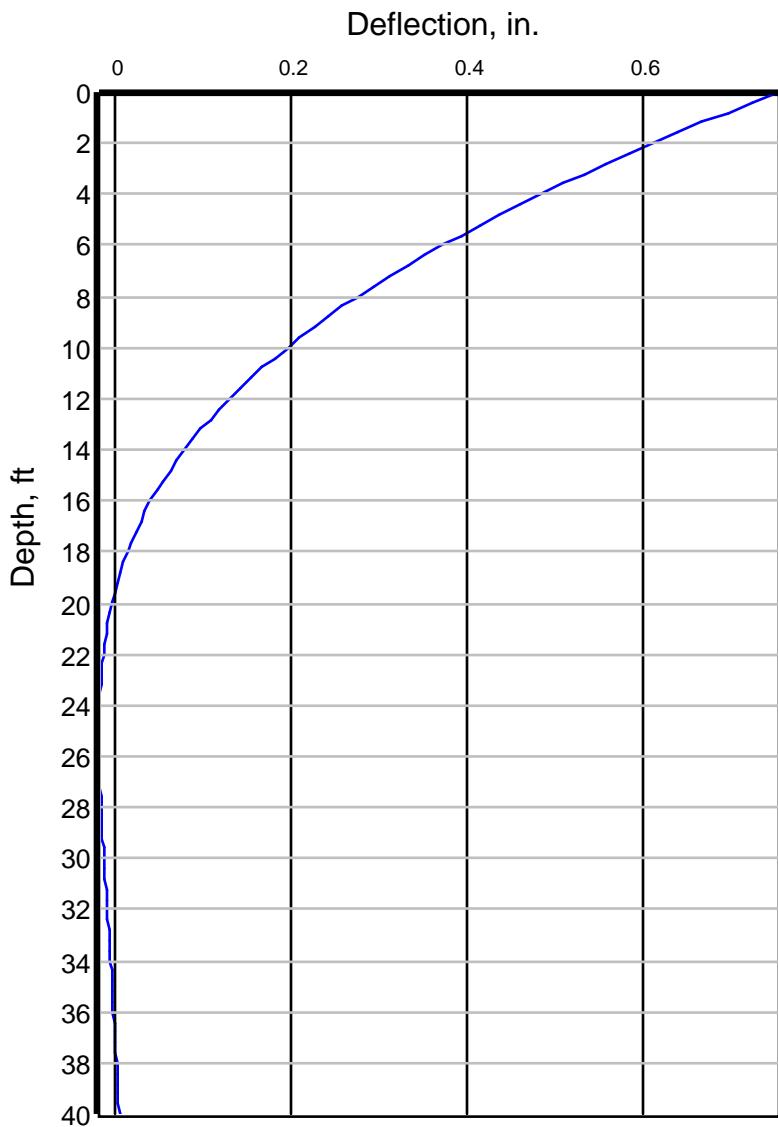


Mooring Piles Shear Force vs. Depth



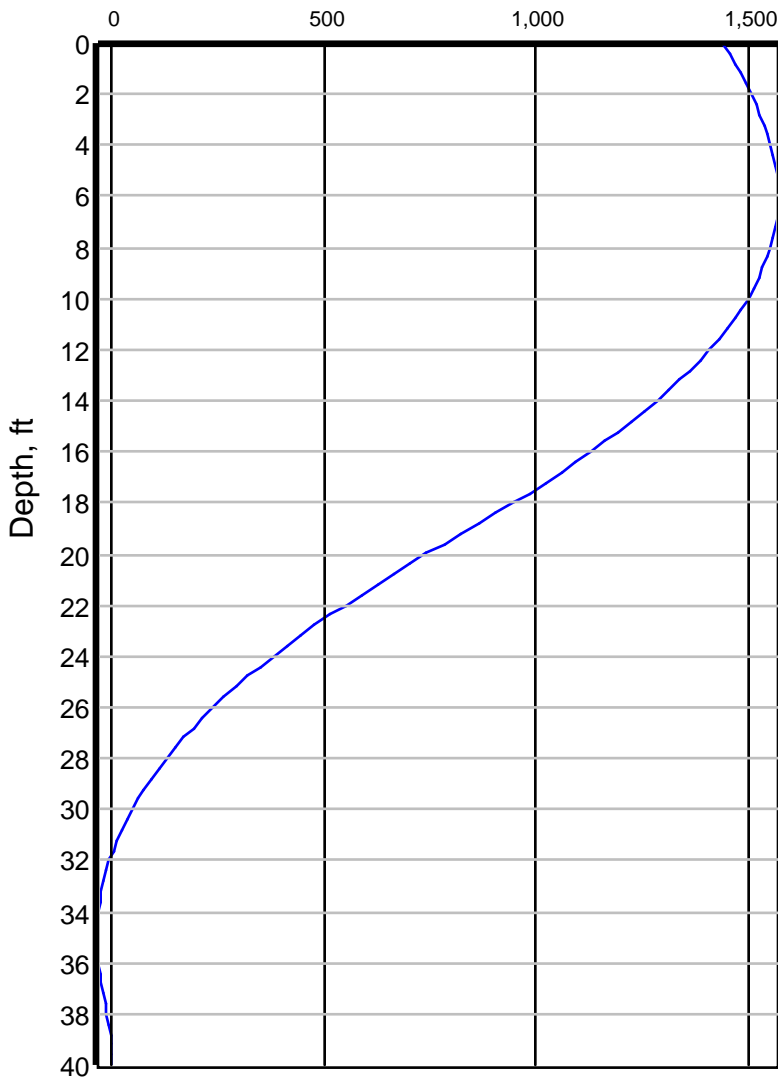
LPILE GRAPHICAL OUTPUT – FLOATING DOCK

Floating Dock Lateral Deflection vs. Depth



Floating Dock Bending Moment vs. Depth

Bending Moment, in-kips



Floating Dock Shear Force vs. Depth

Shear Force, kips

