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# Evaluation of Monolith #26 at Olmsted Locks

Evaluation of a New Lock  
Monolith for a Post-  
Construction Change in Its  
Design Criteria and Seismic  
Performance Requirements

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U.S. Army Corps of Engineers, Louisville District



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# Evaluation of Monolith #26 at Olmsted Locks



Project Location



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# Evaluation of Monolith #26 at Olmsted Locks



**Artist Rendering of Completed Project**



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# Evaluation of Monolith #26 at Olmsted Locks



Aerial View of Nearly Complete Olmsted Locks Structures



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# Evaluation of Monolith #26 at Olmsted Locks

## Problem Statement:

Due to a change from a floating approach wall to a fixed, backfilled lower approach wall, and due to re-evaluated operational considerations, it became desirable to provide an engineered backfill to a higher elevation adjacent to the landward wall of Monoliths #24 thru #26 at the Olmsted Locks Project.

Originally, the backfill against these monoliths topped out at El. 260. The new requirement would raise the elevation by 50 feet, to El. 310 , which is even with the top of the wall.



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# Evaluation of Monolith #26 at Olmsted Locks



Aerial View of Nearly Complete Olmsted Locks Structures



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# Evaluation of Monolith #26 at Olmsted Locks

## At Issue:

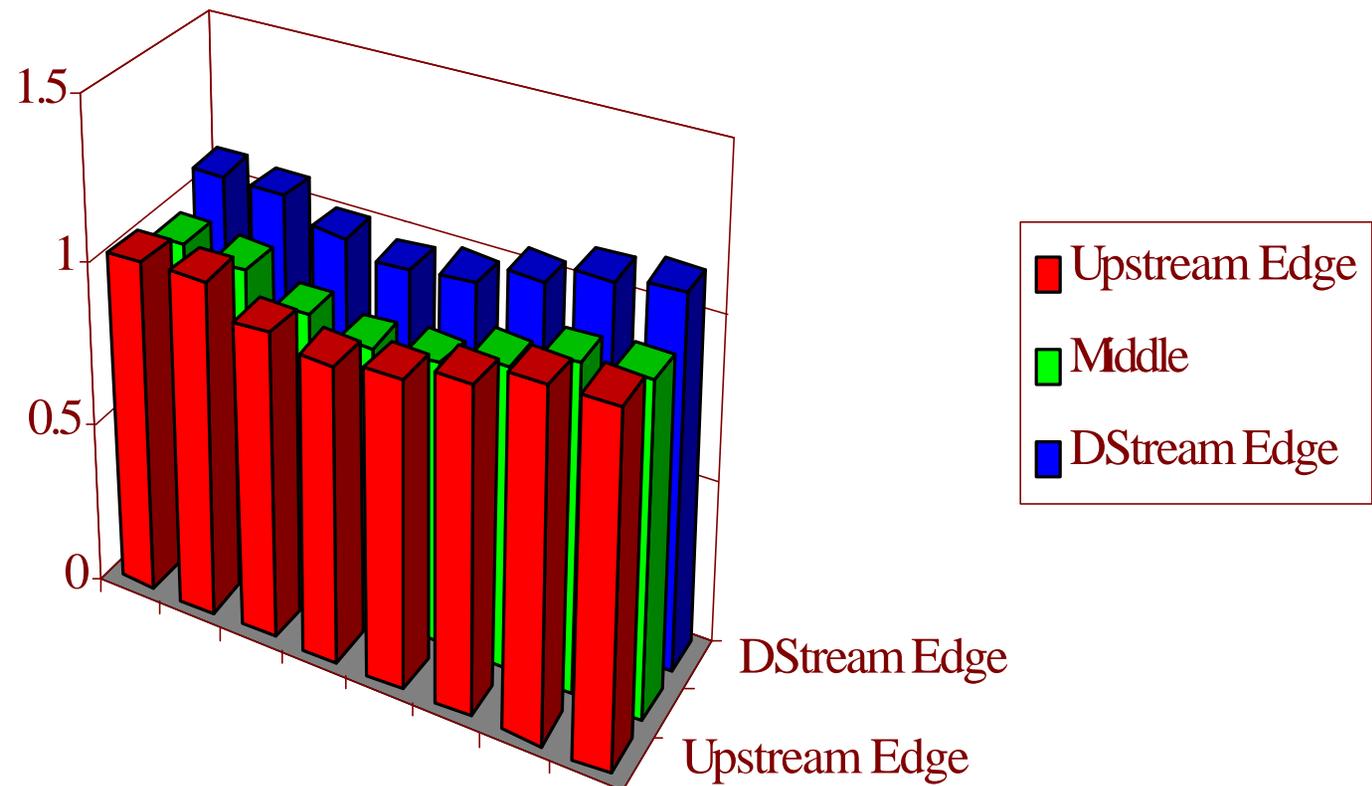
Monolith #26 was already built at the time of the decision, and construction was proceeding aggressively.

“PED” had been completed and we were in “EDC” so design money was not necessarily available for such a change.

The original analyses had shown forces up to the capacity of the Pile Foundation as it was with no added backfill.



# Evaluation of Monolith #26 at Olmsted Locks



Pile Combined Bending Factors for CPGD with 100% Static, 100% Across Chamber, 100% Vertical



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## *Constraints:*

\$

Time / Schedule

Tools / Procedures

Methodology



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Cofferdam at Beginning of Lock Contract



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Cofferdam Flooding in early 1997



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**Flooded Cofferdam**



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Elements of Lock Monolith Foundations



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View Upstream at Lock W-FRAME Monoliths



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## *Constraints:*

\$

Time / Schedule

Tools / Procedures

Approach / Methodology



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# Evaluation of Monolith #26 at Olmsted Locks

## *Tools:*

What is State of the Art?

What is comprehensive enough, yet manageable.

Linear Elastic Analysis

Nonlinear Analysis



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## *Methodology:*

Do Nothing: Do not allow new  
backfill.

Design Approach

Evaluation Approach



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Evaluation Approach:

3-D Linear Elastic Analysis Model

To update static loads with 3-D effects,  
and to make nodes in the static analysis model  
coincident with the Dynamic Analyses Models' nodes  
in order to ease the load combination effort.

Two 2-D Linear Elastic Dynamic Analysis Models

Cross stream direction Model

Upstream/Downstream direction Model



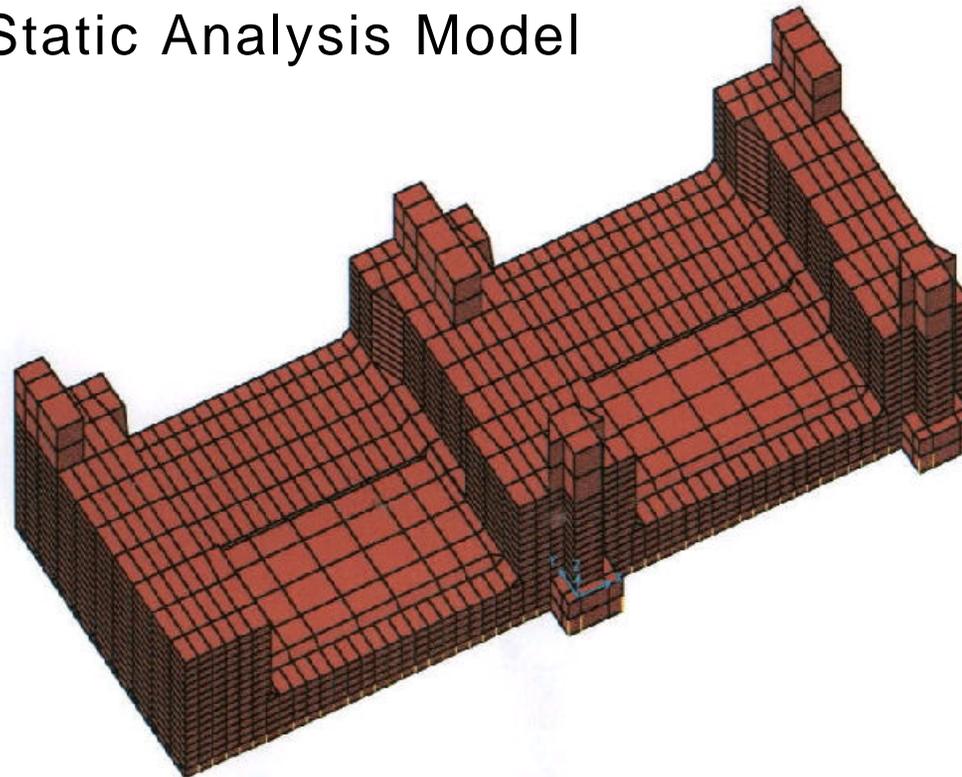
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SAP2000

August 26, 1

3-D Static Analysis Model





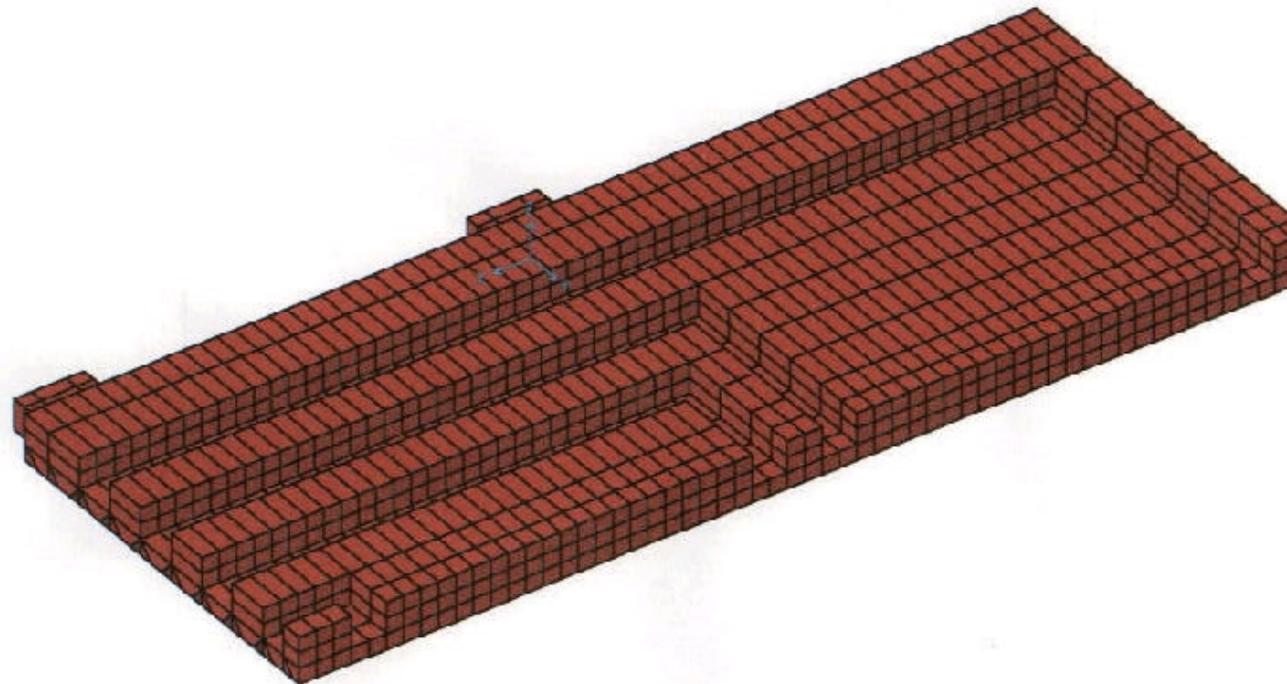
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SAP2000

June 7

Slice through Slab in Monolith #26





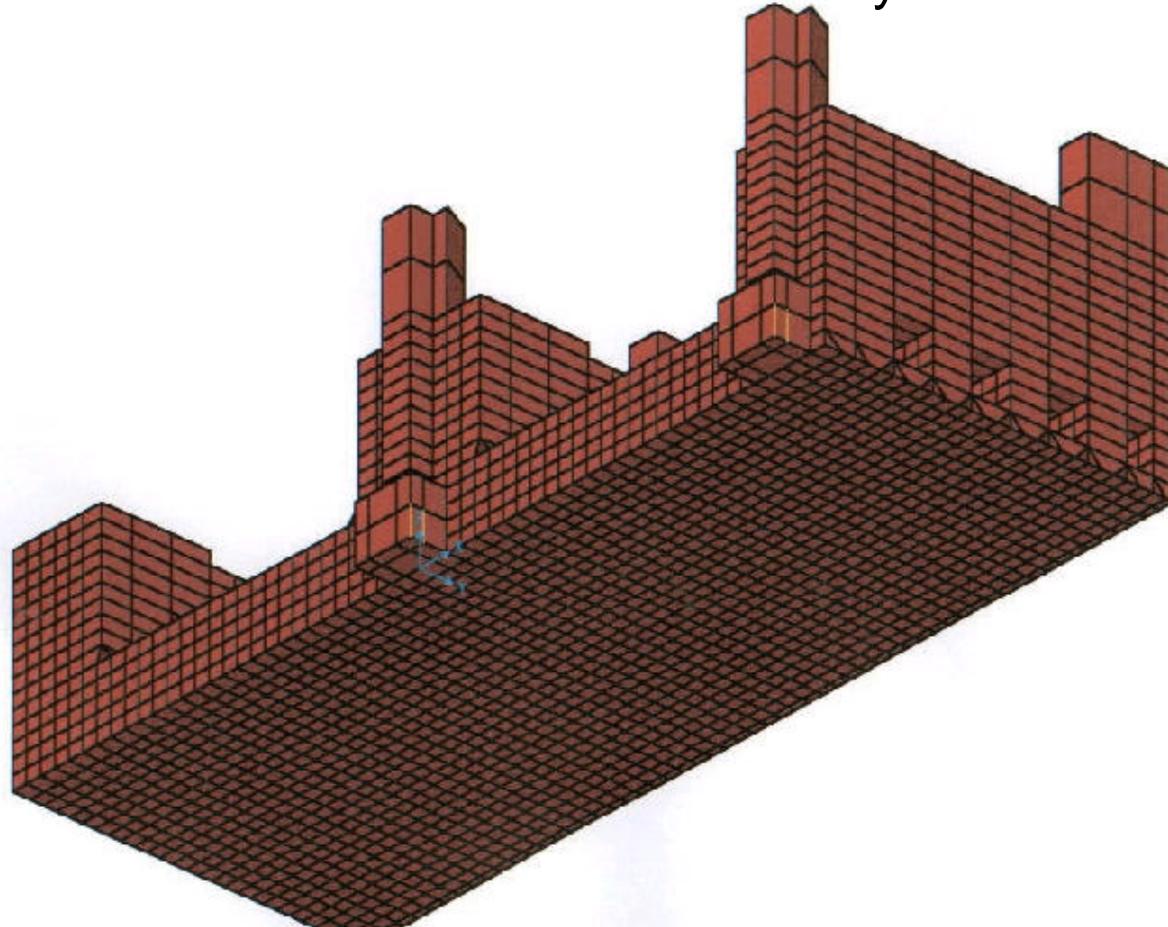
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SAP2000

August 26, 1

View of underside of 3-D Static Analysis Model





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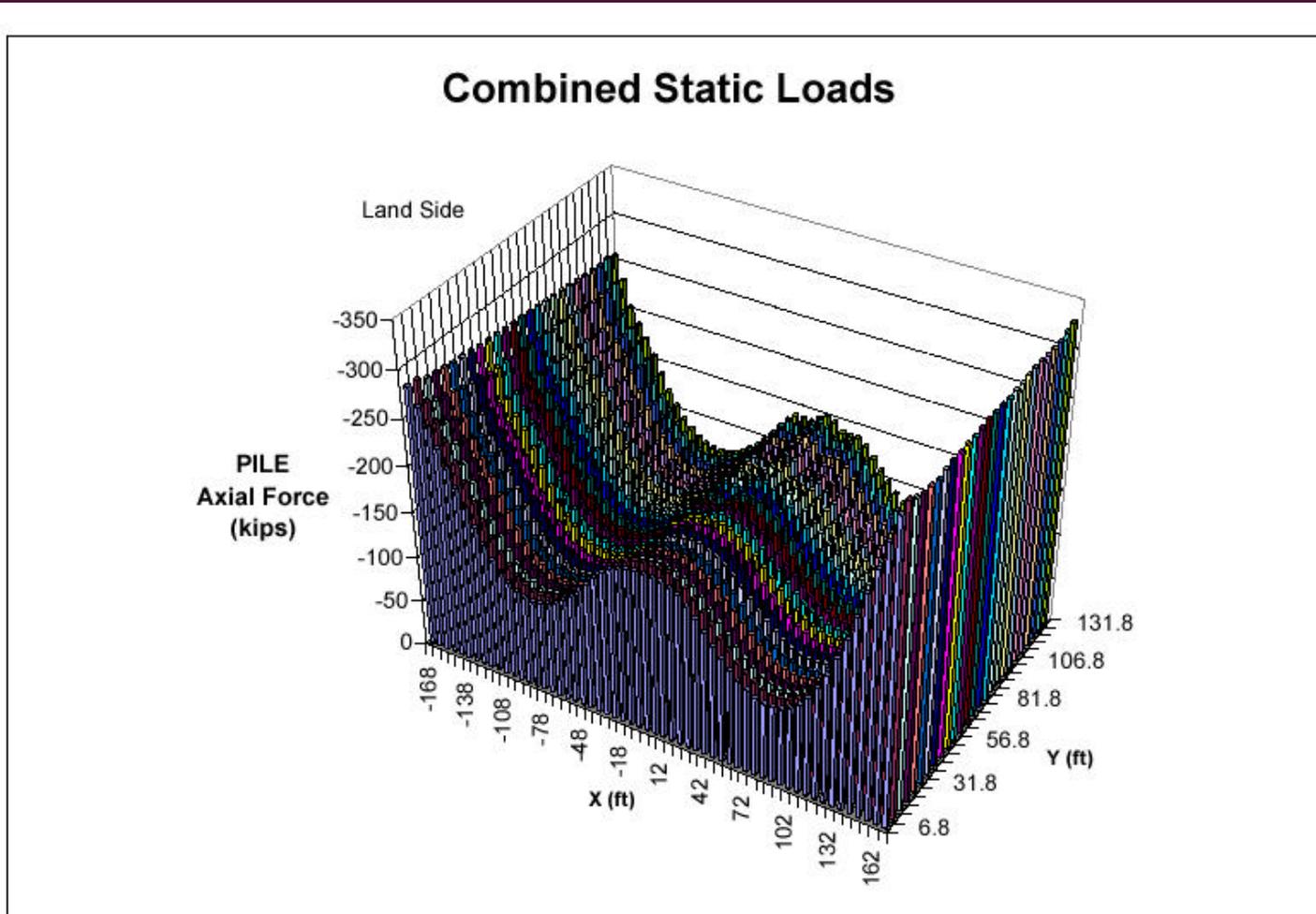
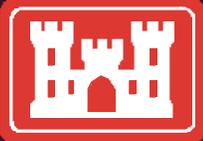


Fig. 5-4.9 Piles axial forces due to combined static loads



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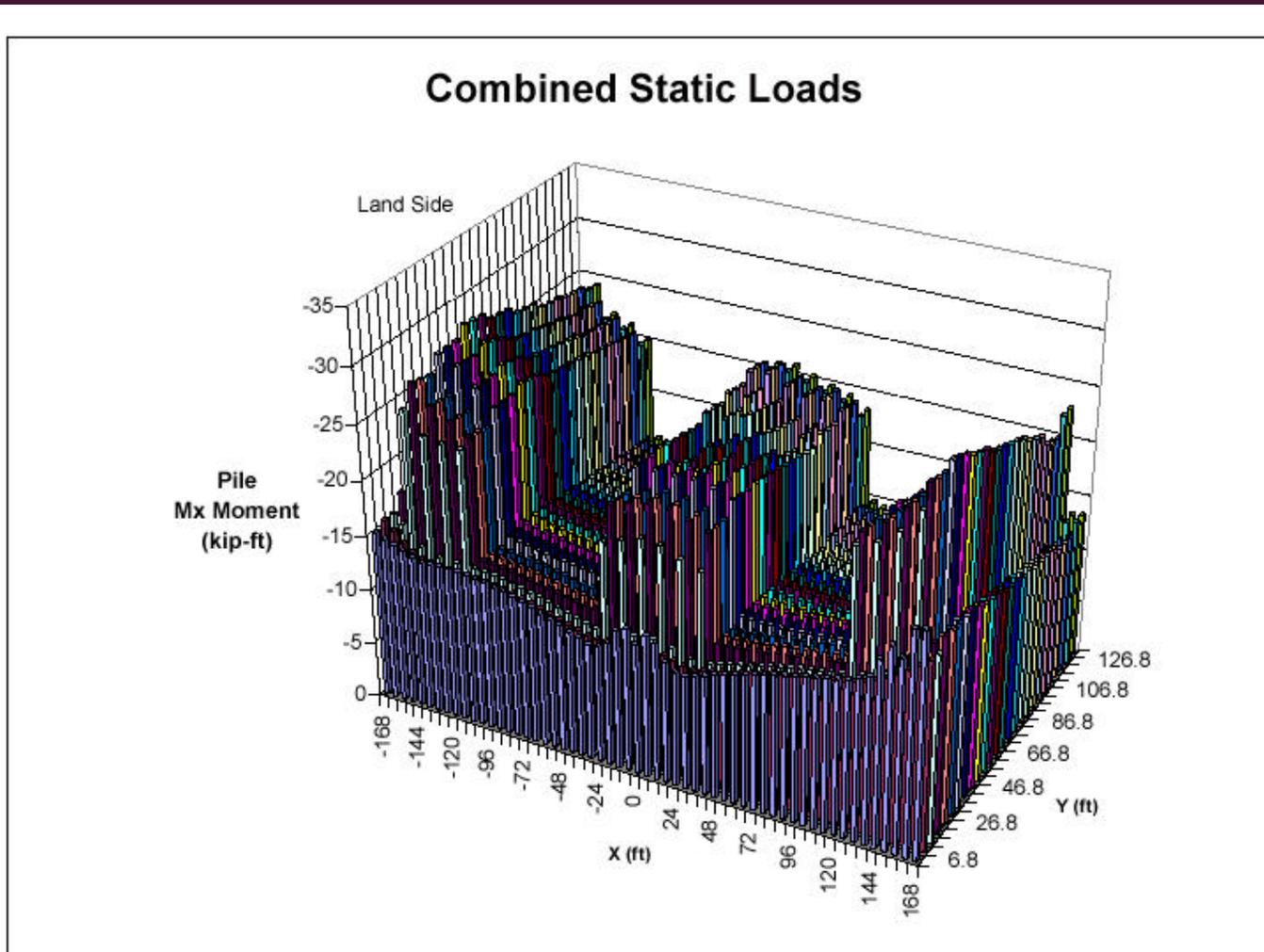


Fig. 5-4.10 Piles moments about cross-stream axis due to combined static loads



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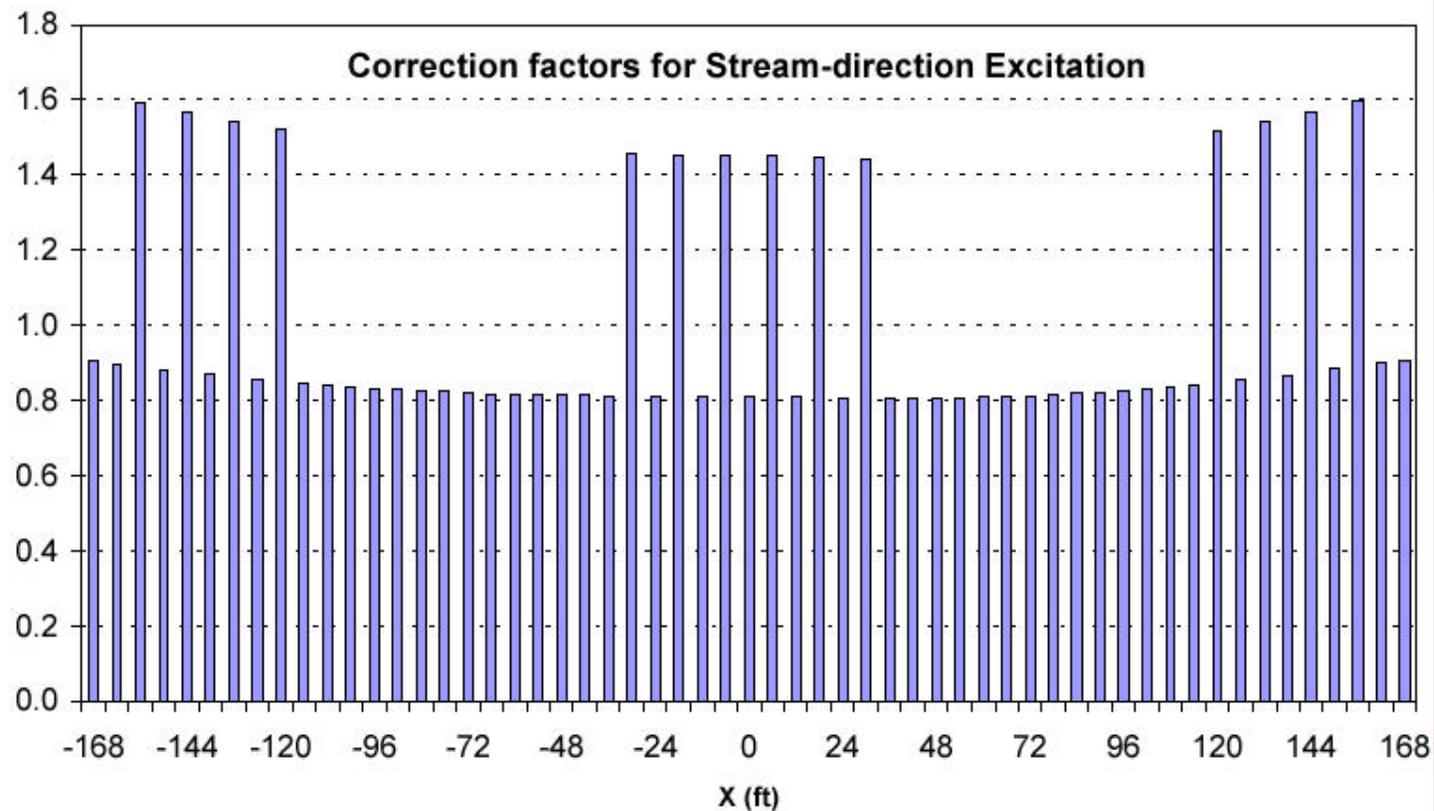
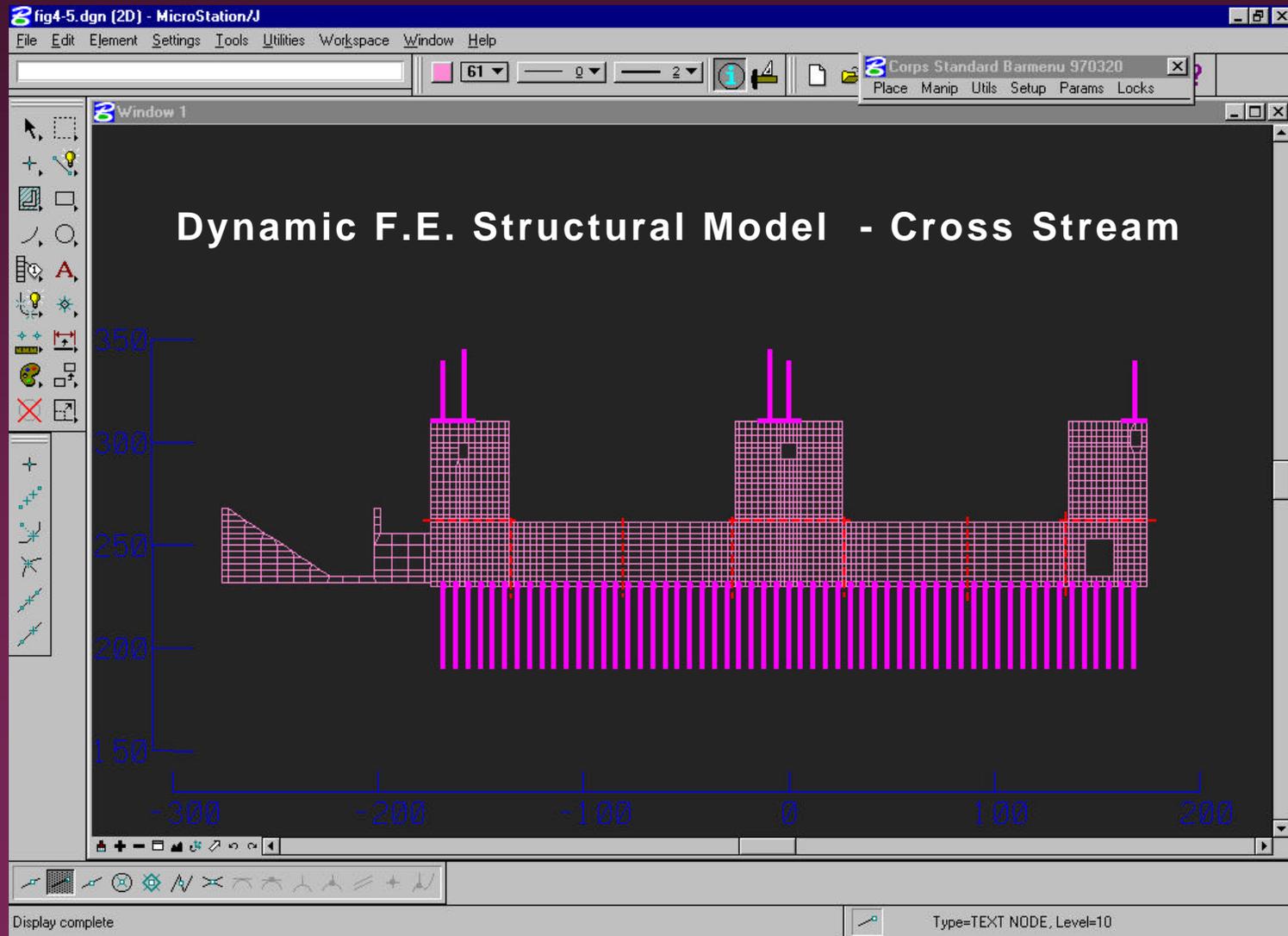


Fig. 6-3.1 Pile moment correction factors for FLUSH stream-direction smeared model



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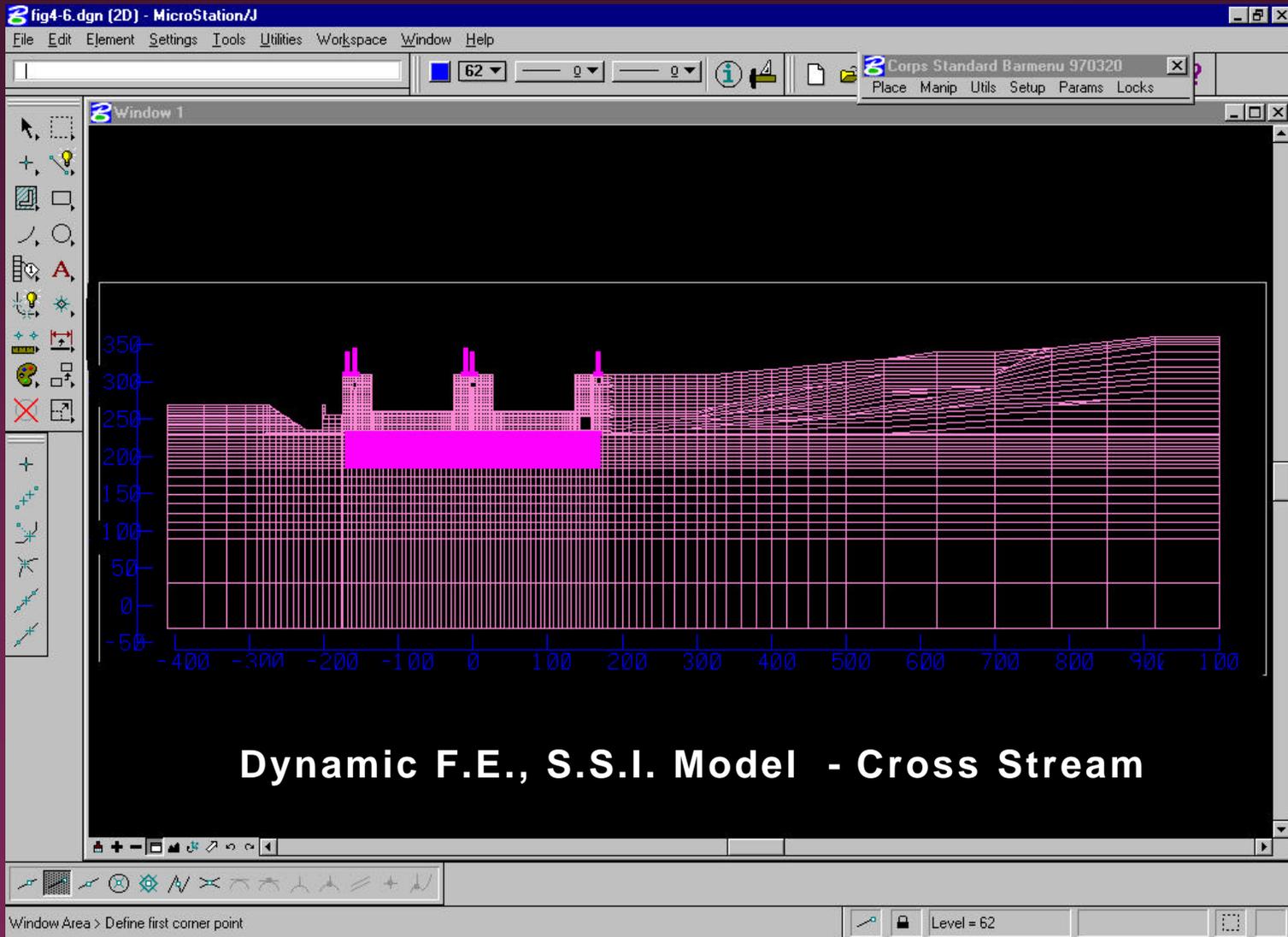
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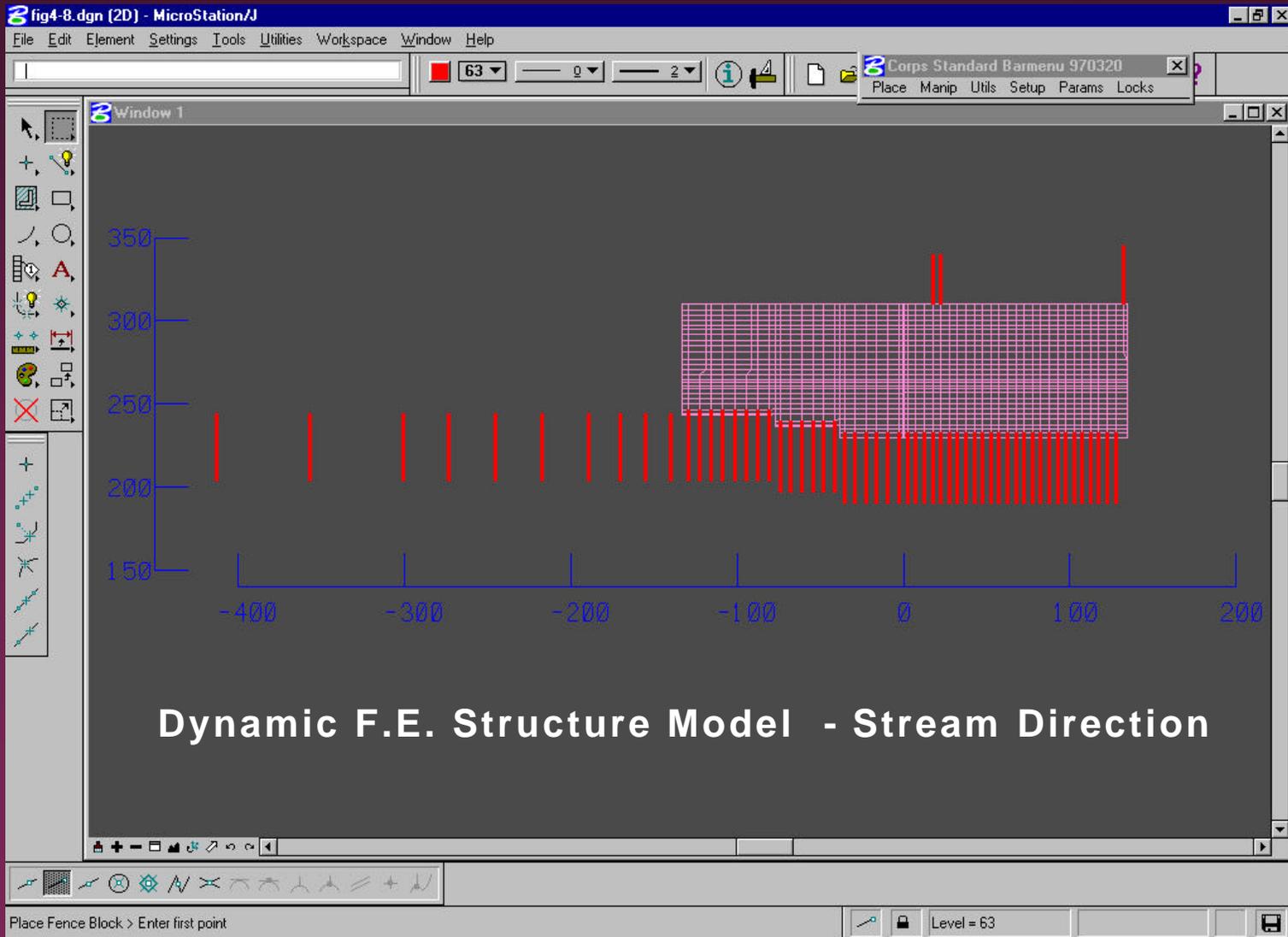
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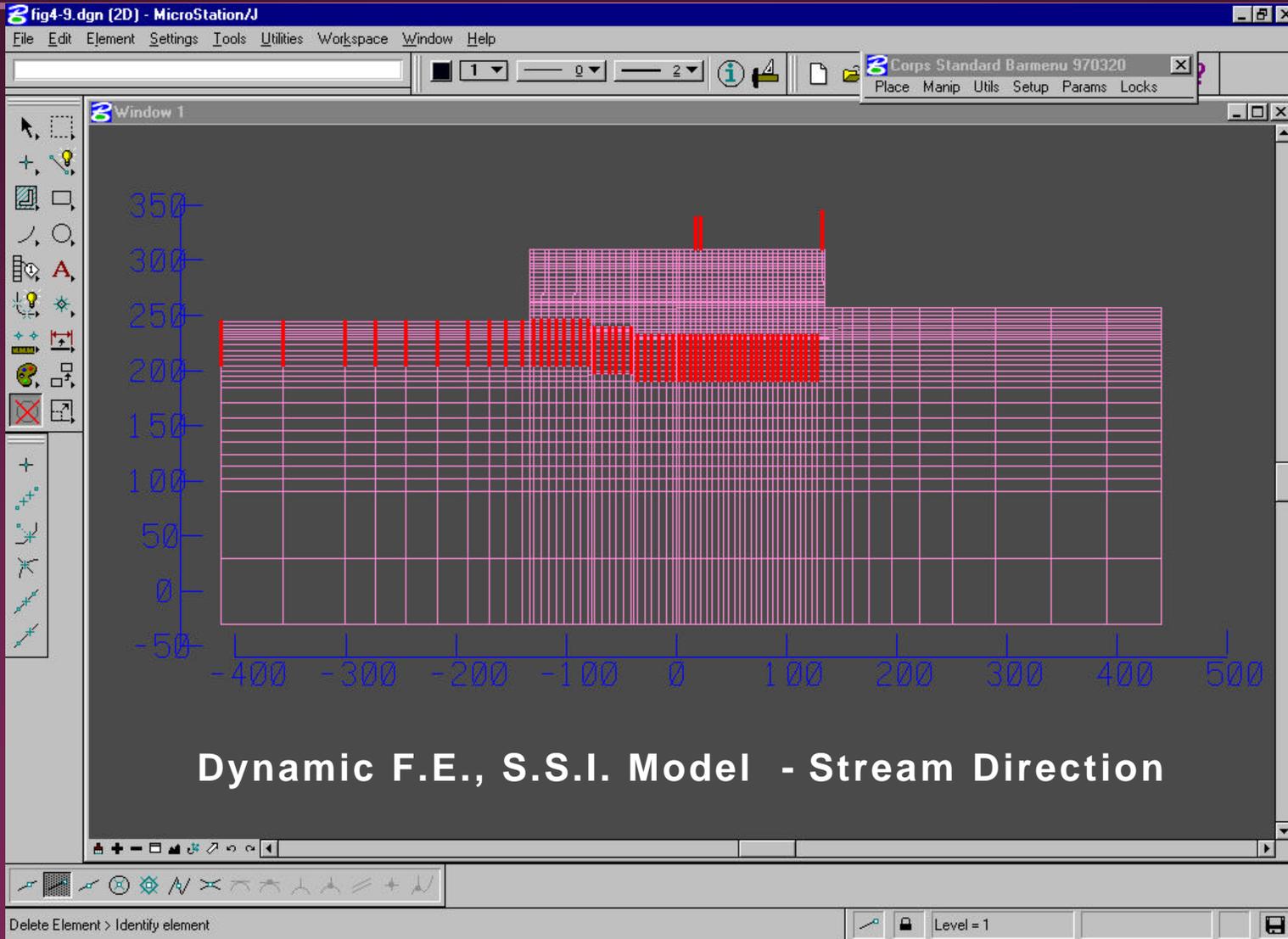
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# Evaluation of Monolith #26 at Olmsted Locks





# Evaluation of Monolith #26 at Olmsted Locks

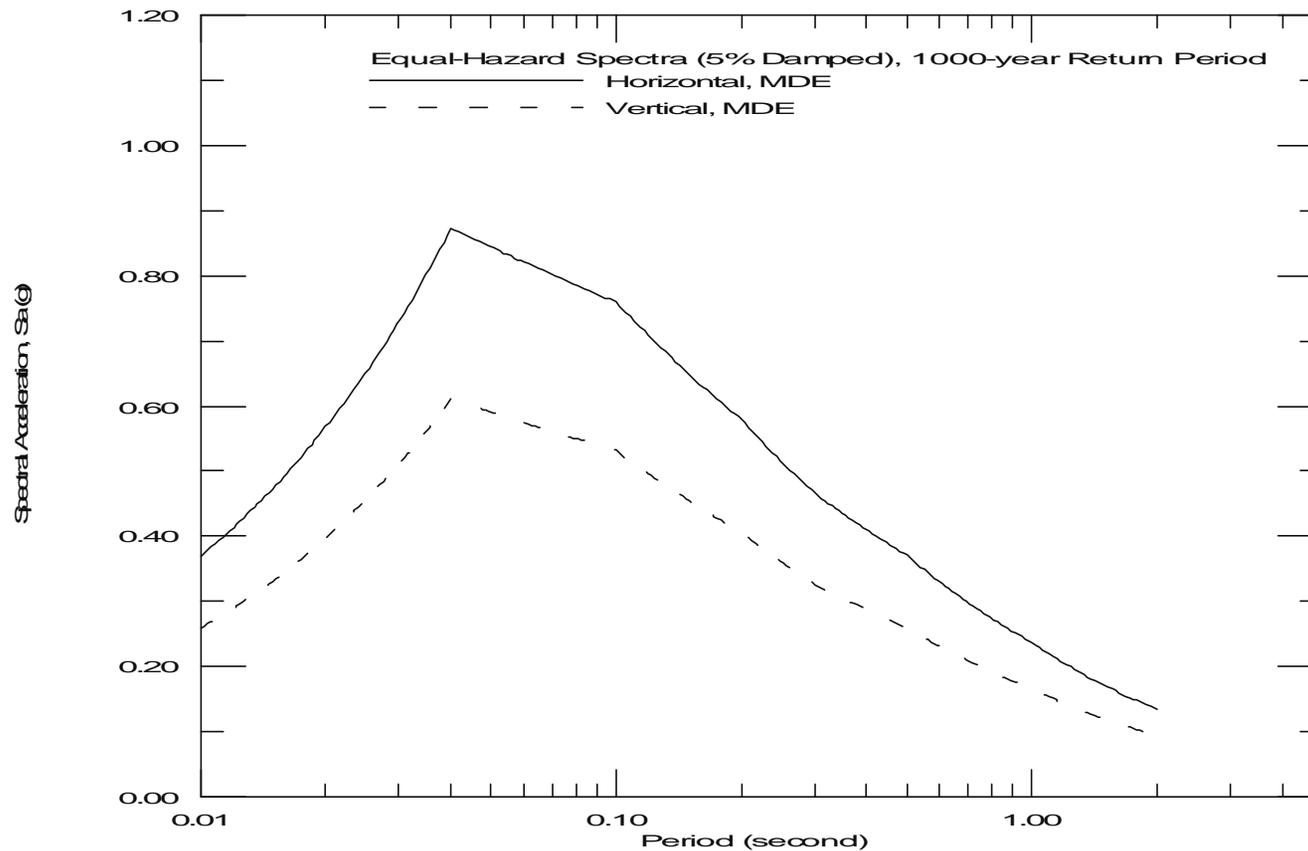


Figure 2-1 Design Response Spectra (5% Damped) for MDE, Olmsted Locks and Dam



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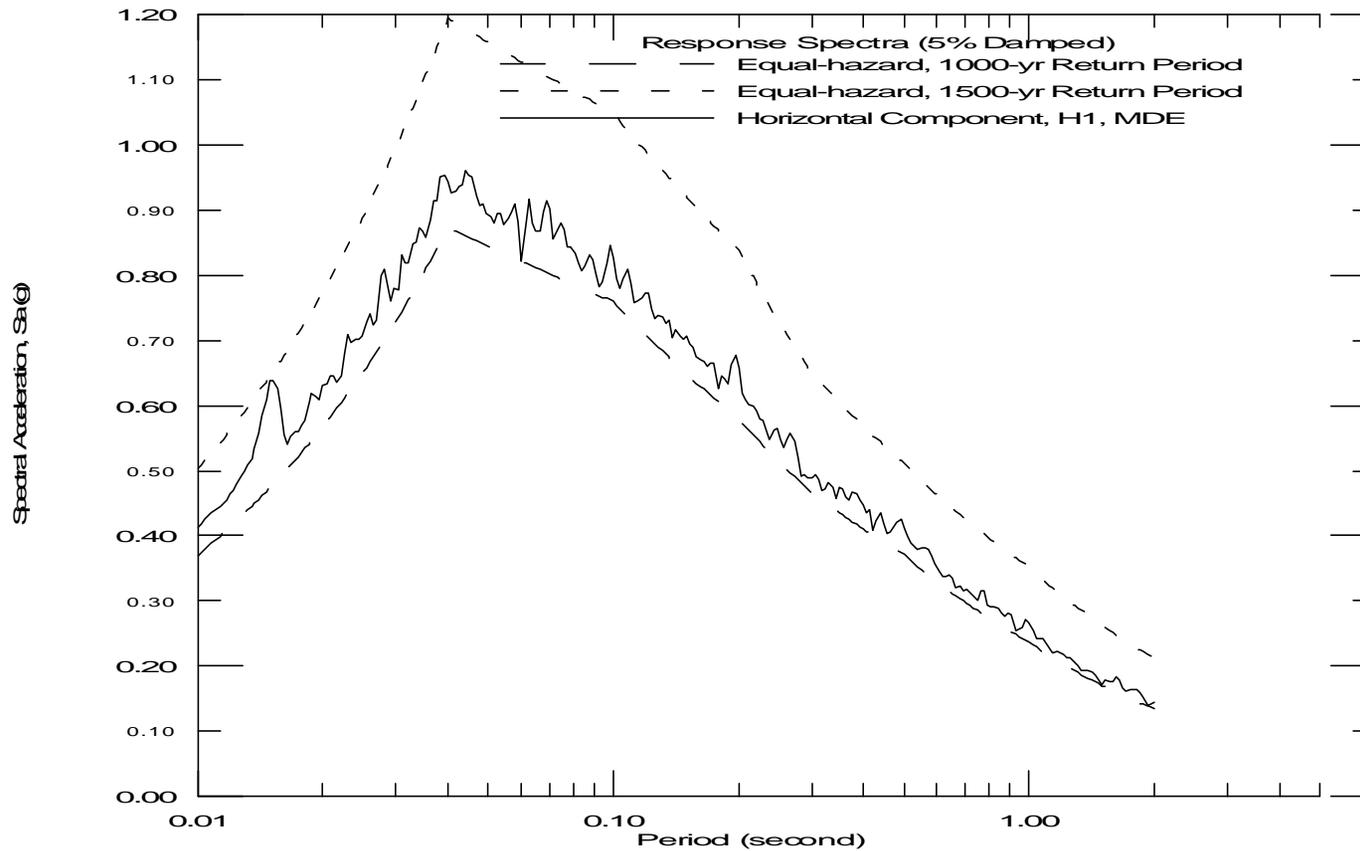


Figure 2-5 Comparison of Response Spectra (5% Damped) of Horizontal Component, H1, with Equal-hazard Spectra, MDE, Olmsted Locks and Dam



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## Pile Yield Strength?

Extreme Allowable =  $F_y$  of 36 ksi with F.S. = 1.15

Minimum Yield =  $F_y$  of 36 ksi with F.S. = 1.00

\*Expected Yield =  $F_y$  of 41 ksi with F.S. = 1.00

\*41 ksi is determined from a statistical average minus 1 standard deviation of data resulting from the rolling mill's heat number certificates.



# Evaluation of Monolith #26 at Olmsted Locks

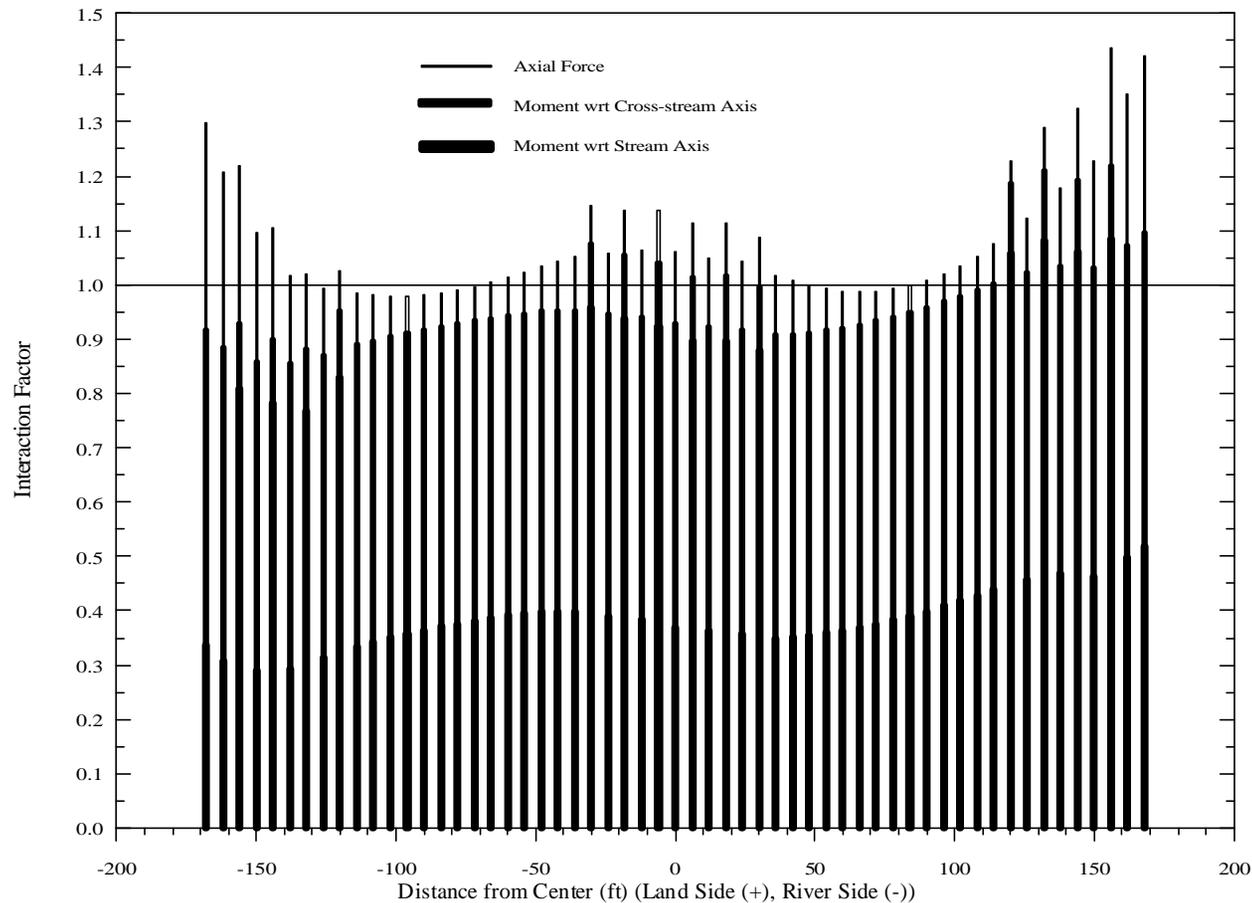


Figure 5-7 Combined Static and Dynamic Interaction Factors for H-Piles under Lower Miter Gate Monolith Subjected to MDE; Extreme Allowable Case, F.S.= 1.15; Distance to Downstream Face= 131.74 ft



# Evaluation of Monolith #26 at Olmsted Locks

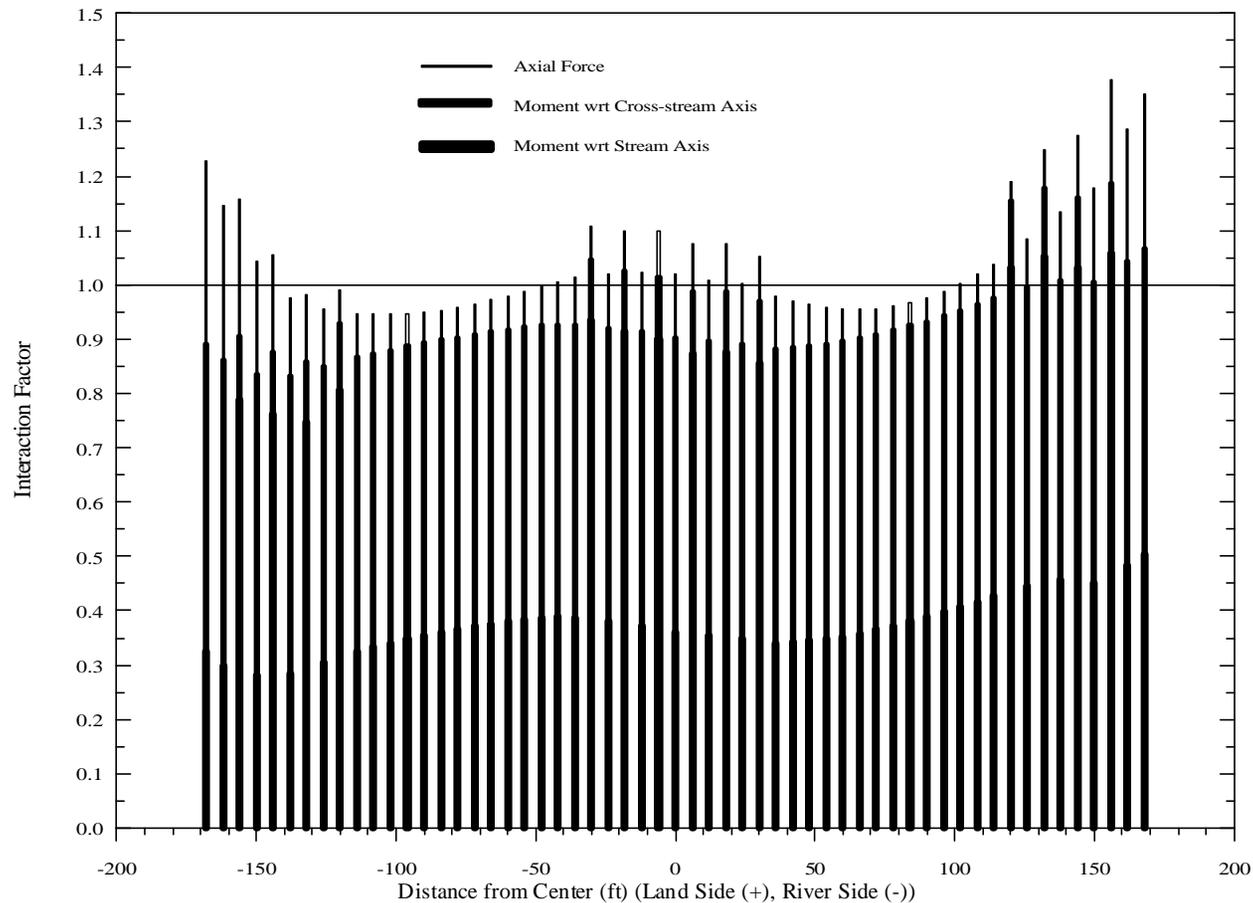


Figure 5-33 Combined Static and Dynamic Interaction Factors for H-Piles under Lower Miter Gate Monolith Subjected to MDE; Minimum Yield Case, F.S.= 1.00; Distance to Downstream Face= 131.74 ft



# Evaluation of Monolith #26 at Olmsted Locks

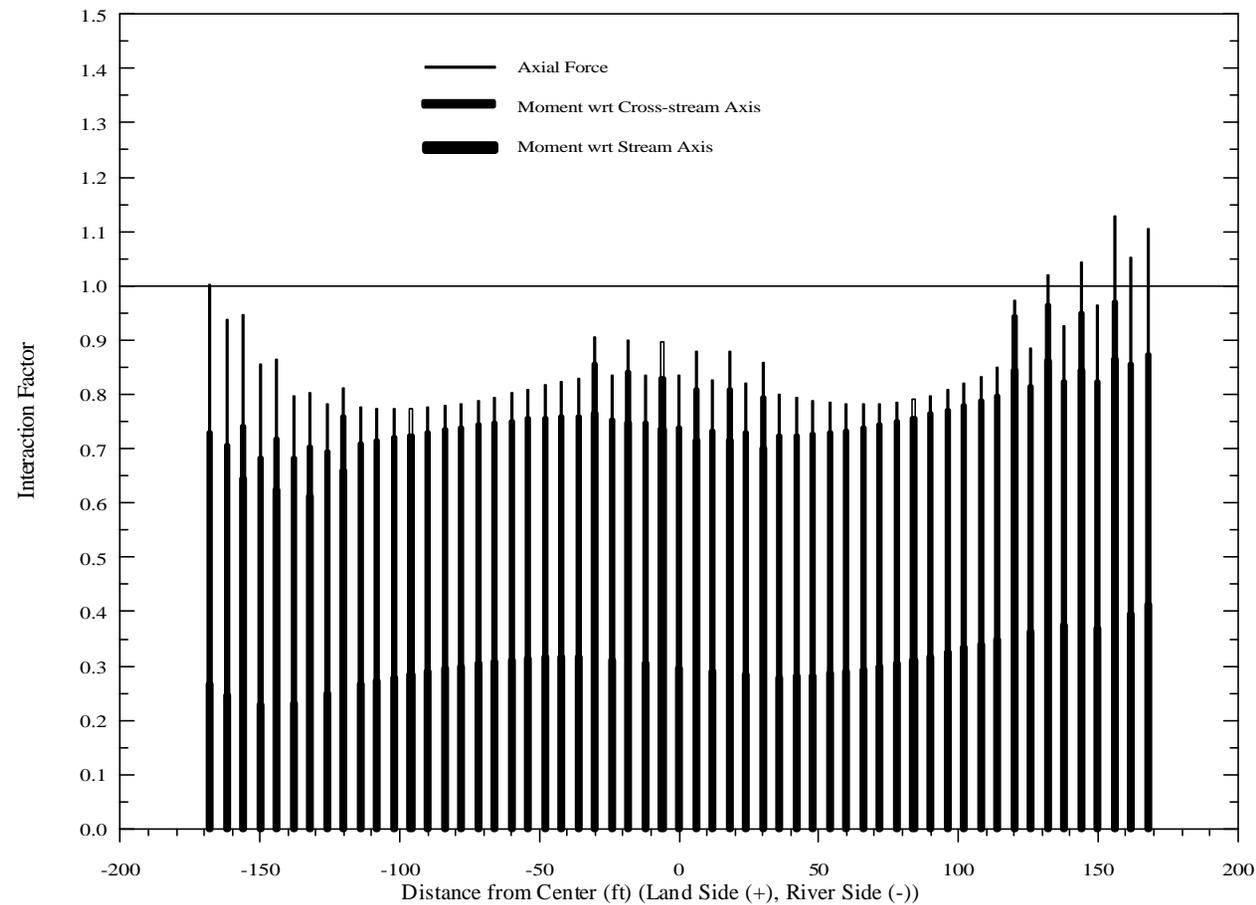


Figure 5-59 Combined Static and Dynamic Interaction Factors for H-Piles under Lower Miter Gate Monolith Subjected to MDE; Expected Yield Case; Distance to Downstream Face= 131.74 ft



# Evaluation of Monolith #26 at Olmsted Locks

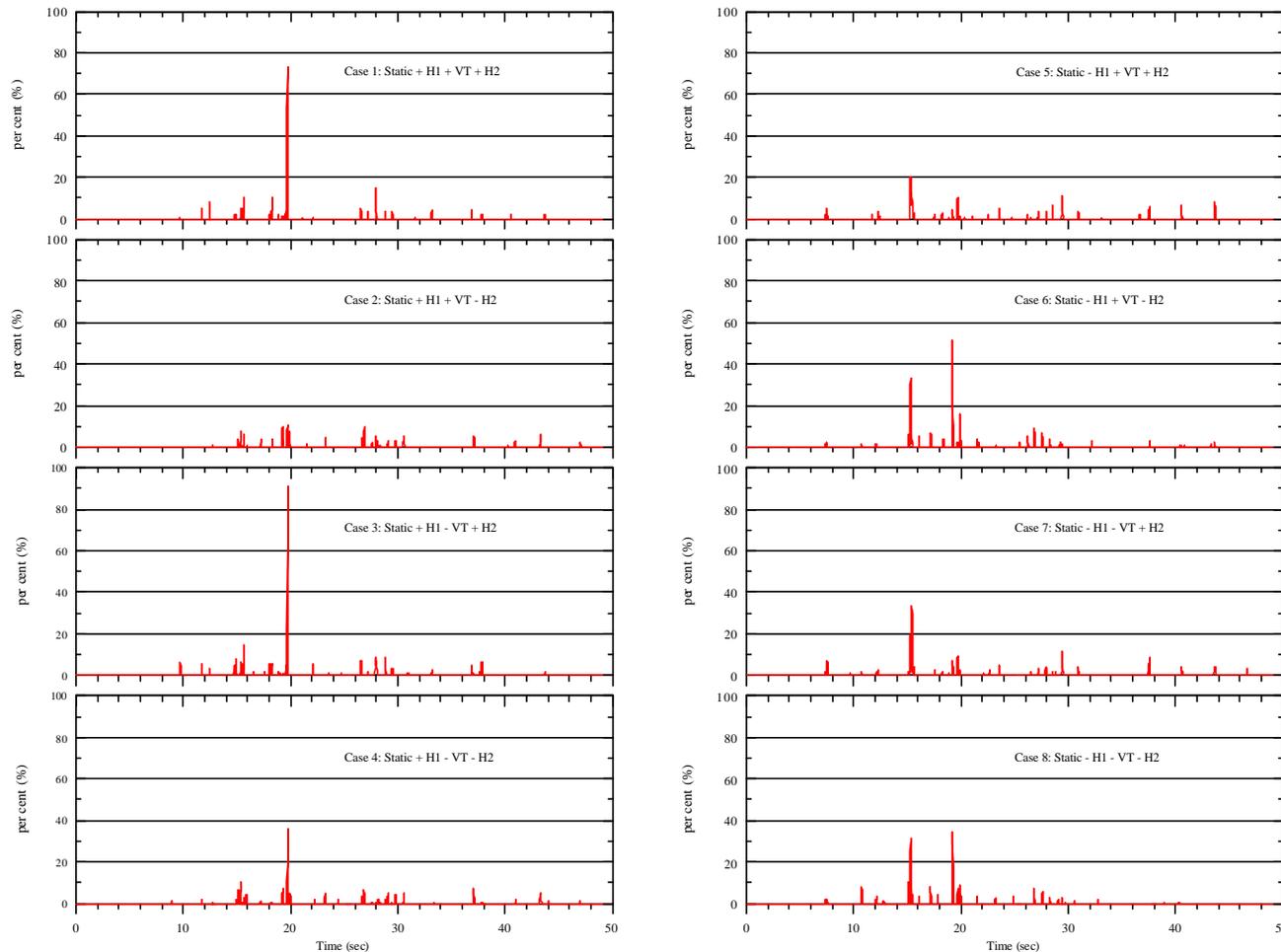


Figure 5-85: Percentage of H-Piles Whose Combined Interaction Factor Values Exceed 1.0; Extreme Allowable Case; Lower Miter Gate Monolith for MDE



# Evaluation of Monolith #26 at Olmsted Locks

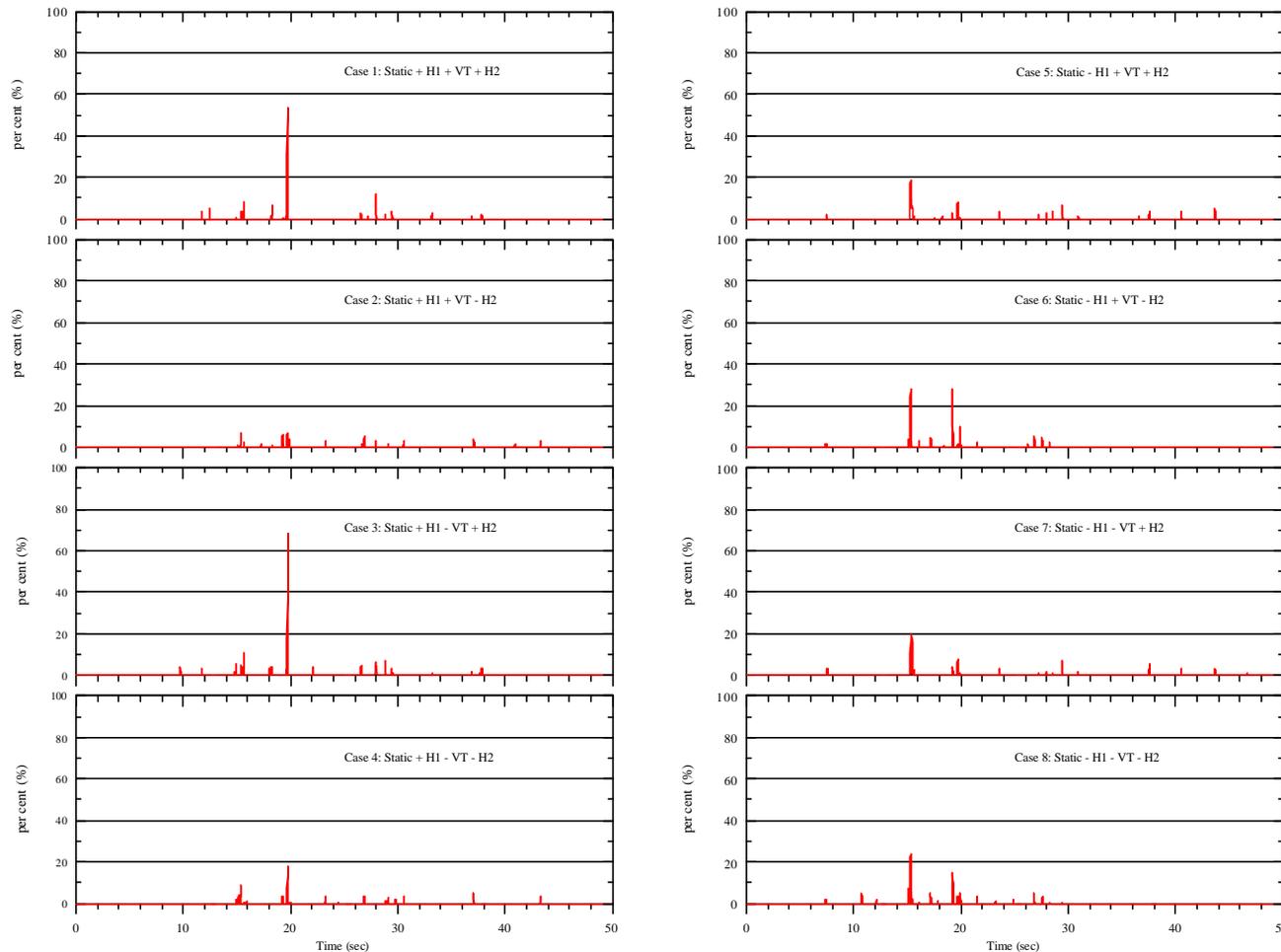


Figure 5-89: Percentage of H-Piles Whose Combined Interaction Factor Values Exceed 1.0; Minimum Yield Case; Lower Miter Gate Monolith for MDE



# Evaluation of Monolith #26 at Olmsted Locks

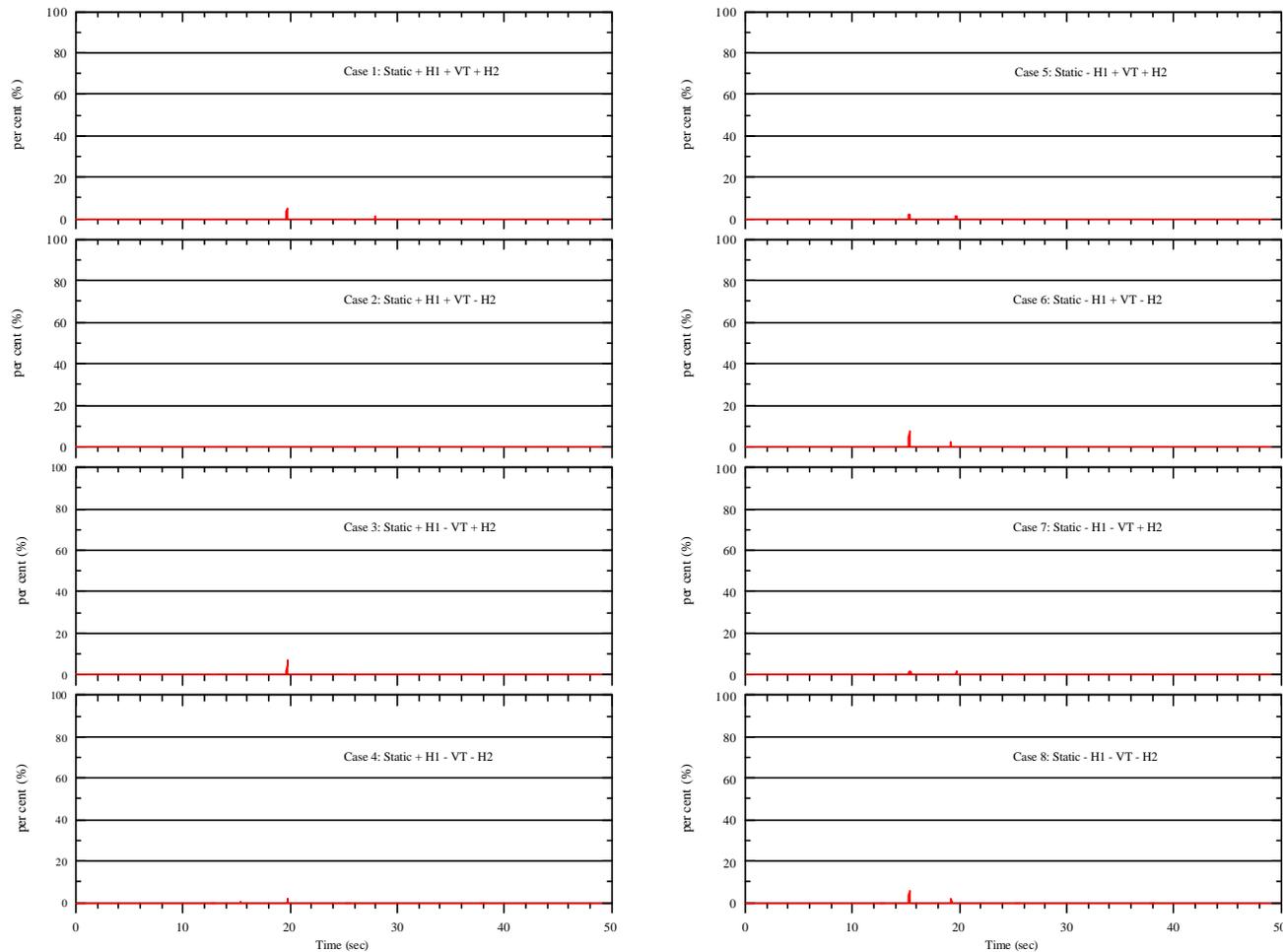


Figure 5-93: Percentage of H-Piles Whose Combined Interaction Factor Values Exceed 1.0; Expected Yield Case; Lower Miter Gate Monolith for MDE



# Evaluation of Monolith #26 at Olmsted Locks

Table -1

Number of Time Steps (0.01 sec) at which Combined Interaction Factors for H-Piles Exceed Unity  
Minimum Yield Case; Distance to Downstream Face= 131.74; Lower Miter Gate Monolith for MDE

DIRECTION	Pile Number	Distance to Center (ft)	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	
			Static	Static							
			+H1+VT+H2	+H1+VT-H2	+H1-VT+H2	+H1-VT-H2	-H1+VT+H2	-H1+VT-H2	-H1-VT+H2	-H1-VT-H2	
Land Side	28	168.00	44	42	61	46	76	63	66	76	
	27	162.00	27	15	30	23	43	36	30	49	
	26	156.00	32	18	37	24	41	37	36	37	
	25	150.00	10	2	8	5	6	14	14	19	
	24	144.00	8	4	14	7	11	9	10	11	
	23	138.00	6	0	6	4	0	7	4	8	
	22	132.00	5	3	8	5	8	8	6	7	
	21	126.00	4	0	6	3	0	3	0	3	
	20	120.00	2	0	5	4	7	7	4	6	
	19	114.00	1	0	4	0	0	0	0	0	
	18	108.00	0	0	2	0	0	0	0	0	
	17	102.00	0	0	2	0	0	0	0	0	
	16	96.00	0	0	0	0	0	0	0	0	
	15	90.00	0	0	0	0	0	0	0	0	
	14	84.00	0	0	0	0	0	0	0	0	
	13	78.00	0	0	0	0	0	0	0	0	
	12	72.00	0	0	0	0	0	0	0	0	
	11	66.00	0	0	0	0	0	0	0	0	
	10	60.00	0	0	0	0	0	0	0	0	
	9	54.00	0	0	0	0	0	0	0	0	
8	48.00	0	0	0	0	0	0	0	0		
7	42.00	0	0	0	0	0	0	0	0		
6	36.00	0	0	0	0	0	0	0	0		
5	30.00	0	0	0	0	0	4	0	3		
4	24.00	0	0	1	0	0	0	0	0		
3	18.00	0	0	0	0	2	4	2	3		
2	12.00	0	0	1	0	0	0	0	0		
1	6.00	0	0	0	0	2	4	2	3		
Center	0	0.00	0	0	2	0	0	0	0	0	
	1	-6.00	0	0	0	0	3	5	2	4	
	2	-12.00	0	0	3	0	0	0	0	0	
	3	-18.00	0	0	0	0	3	5	2	4	



# Evaluation of Monolith #26 at Olmsted Locks

Table 5-7

Dynamic Pile Forces and Moments

Lower Miter Gate Monolith, Cross-Stream Model for MDE

DIRECTION	Pile Number	Distance to Center (ft)	Dynamic Peak Values			at Peak Moment		at Peak Axial		at Peak Shear	
			Moment (ft-kips)	Axial (kips)	Shear (kips)	Axial (kips)	Shear (kips)	Moment (ft-kips)	Shear (kips)	Moment (ft-kips)	Axial (kips)
Land Side	28	168.00	269.80	217.00	137.80	92.75	137.80	159.76	82.82	269.80	92.75
	27	162.00	256.00	176.00	111.20	65.30	111.20	148.83	62.44	256.00	65.30
	26	156.00	131.35	143.00	78.83	42.80	78.16	72.39	39.73	130.80	33.45
	25	150.00	243.55	101.60	95.75	10.55	95.00	137.36	49.32	242.90	5.90
	24	144.00	132.05	89.55	77.20	-19.30	77.17	3.21	2.46	130.85	-20.30
	23	138.00	257.60	87.36	101.45	-34.06	101.45	-29.30	-13.64	257.60	-34.06
	22	132.00	137.65	86.15	80.40	-41.00	80.40	-16.47	-11.23	137.65	-41.00
	21	126.00	262.20	86.00	100.15	-46.55	100.15	-30.80	-13.88	262.20	-46.55
	20	120.00	138.45	90.35	80.00	-49.75	80.00	-80.53	-44.36	138.45	-49.75
	19	114.00	263.35	93.50	99.70	-51.50	99.60	-152.97	-54.72	260.05	-48.45
	18	108.00	262.25	95.25	99.20	-52.90	99.20	-151.54	-54.38	259.45	-49.30
	17	102.00	261.00	96.65	98.40	-52.75	98.40	-149.95	-53.17	261.00	-52.75
	16	96.00	260.30	96.70	97.38	-51.70	97.30	-148.84	-52.15	258.00	-47.20
	15	90.00	259.45	96.55	96.78	-49.85	96.60	-147.10	-51.22	257.30	-45.10
	14	84.00	258.60	95.80	96.63	-47.45	95.94	-145.89	-50.43	257.05	-42.55
	13	78.00	257.80	94.10	96.09	-44.55	95.86	-144.65	-49.78	256.85	-39.65
	12	72.00	257.45	92.55	95.88	-41.40	95.11	-143.38	-49.04	256.65	-36.54
	11	66.00	257.10	90.70	95.76	-37.99	94.95	-142.12	-48.46	256.45	-33.29



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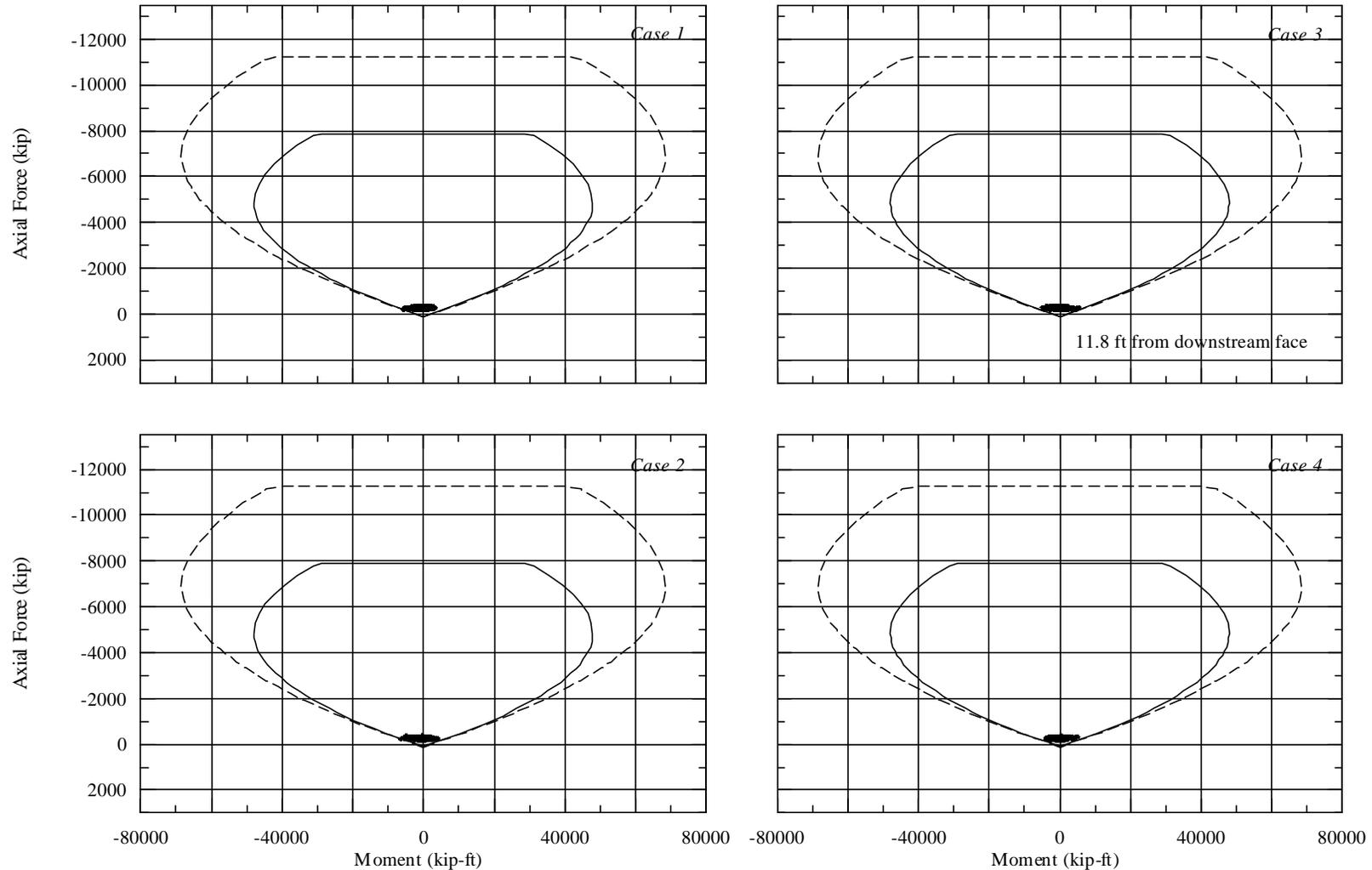


Figure 5-95: Axial Force vs. Bending Moment of Concrete Section 1 due to Combined Static, Horizontal H1 and Vertical Excitation for MDE, Olmsted Lower Miter Gate Monolith - Cross-Stream Model



# Evaluation of Monolith #26 at Olmsted Locks

Location	Node Number	Combined In-Phase Motions		Combined Out-Phase Motions	
		Horizontal+Vertical		Horizontal-Vertical	
		Horizontal (cm)	Vertical (cm)	Horizontal (cm)	Vertical (cm)
Top of Lock - Base of Lock	566/594	0.743	0.058	0.733	0.059
	1181/1208	0.695	0.049	0.678	0.043
	2091/2119	0.192	0.024	0.168	0.038
	2976/3004	0.180	0.036	0.182	0.025
	3887/3914	0.517	0.053	0.766	0.059
	4464/4492	0.789	0.062	0.838	0.066
Pile Head - Pile Tip	676/696	3.301	0.204	3.346	0.201
	2551/2571	3.342	0.073	3.461	0.068
	4403/4423	3.162	0.132	3.340	0.140



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View Downstream at Lock Chambers, Bridges and Fleet Harbor



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Aerial View of Nearly Complete Olmsted Locks Structures



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Re-watering began on October 2, 2000



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# Evaluation of Monolith #26 at Olmsted Locks



View Up-Stream



View behind land wall of LMG #26



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# Evaluation of Monolith #26 at Olmsted Locks



**Artist Rendering of Completed Project**