A. FIELD DATA

A.1 Symbols Used on Boring Information

COHESIVE SOILS (Modified after ASTM D2487-93 and D 2488-93)

Table 1: Fine Grained Soil Subclassification	Percent (by weight) of Total Sample
<u>Terms</u>	
SILT, LEAN CLAY, FAT CLAY, ELASTSIC SILT	PRIMARY CONSTITUENT
Sandy, gravelly, abundant cobbles, abundant boulders,	>30-50%
with sand, with gravel, with cobbles, with boulders,	>15-30%-Secondary coarse grained constituents
scattered sand, scattered gravel, scattered cobbles, scattered boulders,	5-15%
a trace sand, a trace gravel, a few cobbles, a few boulders	<1
*The relationship of clay and silt constituents is based on plasticity and normally determined by performing index tests. Refined classifications are based on Atterberg Limits tests and the Plasticity Chart.	

(Modified after Ref. Oregon DOT 1987, DM 7.1 1982 and FHWA 1997)

TERM	Number Of Blows Per 1 ft.	POCKET PENETROMETER (tsf)	FIELD TEST
Very Soft	0-1	0.25 or less	Squeezes between fingers when fist is closed, penetrated sever inches by fist.
Soft	2-4	0.25-0.50	Easily molded by fingers, easily penetrated several inches by thumb.
Medium Stiff	5-8	0.50-1.00	Molded by strong pressure of fingers, can be penetrated several inches by thumb with moderate effort.
Stiff	9-15	1.00-2.00	Dented by strong pressure of fingers, readily indented by thumb but can be penetrated only with great effort.
Very Stiff	16-30	2.00-4.00	Readily indented by thumbnail.
Hard	30-60	Over 4.00	Indented with difficulty by thumbnail.
Very Hard	61-		

MOISTURE CONDITION (Modified after ASTM D 2488-93)

DESCRIPTIVE TERM	GUIDE
Dry	No indication of water
Moist	Indication of water
Wet	Visible water

CRITERIA FOR DESCRIBING STRUCTURE (Modified after ASTM D 2488-93)

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 1/6 inch (6mm) thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometime striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Indication of small pockets of different soils, such as small lenses of sand scattered through a mass of clay, note thickness
Homogeneous	Same color and appearance throughout.
Layer	Inclusions greater than 3 inches thick (7.5 cm).
Seam	Inclusions 1/3 to 3 inches (3 to 75 mm) thick extending through the sample.
Parting	Inclusion less than 1/8 (3 mm) inch thick

NON-COHESIVE (GRANULAR) SOILS (Modified after ASTM D 2487-93 and D 2488-93)

Coarse Grained Soil Subclassification	Percent (by weight) of Total Sample
<u>Term</u>	
GRAVEL, SAND, COBBLES, BOULDERS	PRIMARY CONSTITUENT
Sandy, gravelly, abundant cobbles, abundant boulders	>30-50%
With gravel, with sand, with cobbles, with boulders	>15-30% - Secondary coarse grained constituents
Scattered gravel, scattered sand, scattered cobbles, scattered boulders	5-15%
A trace gravel, a trace sand, a few cobbles, a few boulders	< 5%
Silty (MH, & ML)[a], clayey (CL & CH)[a]	<15%
(with silt, with clay)[a]	5-15%
(trace silt, trace clay)[a]	<5 %
[a]Index tests and/or plasticity tests are performed to determine whether the term "silt" or "clay" is used.	

GRAIN SIZE IDENTIFICATION (Modified after Oregon DOT 1987 and FHWA 1997)

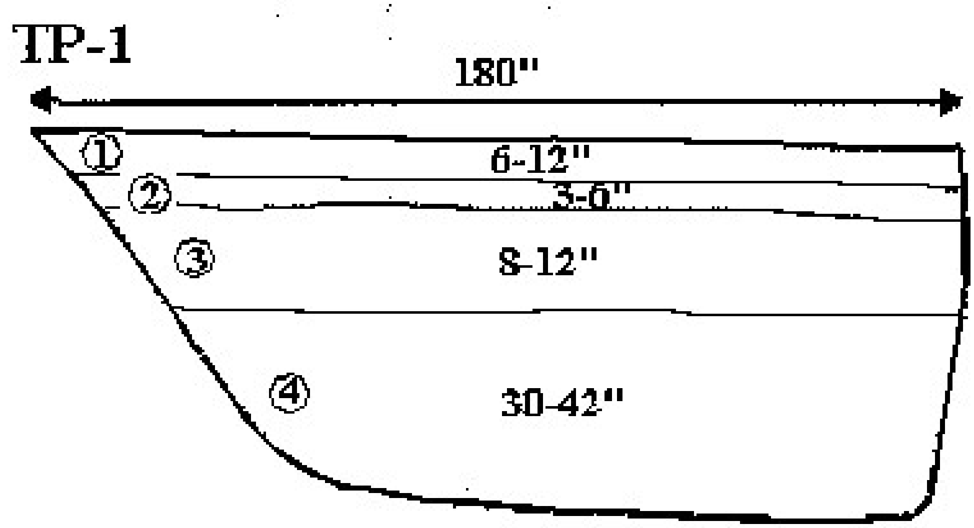
NAME	SIZE LIMITS	FAMILIAR EXAMPLE
Boulder	12 in. (30 cm) or more	Larger than basketball
Cobbles	3 in (76 mm) – 12 in. (30 cm)	Grapefruit
Coarse Gravel	¾ in. (19 mm) – 3 in (76 mm)	Orange or lemon
Fine Gravel	4.75 mm (No. 4 sieve) – ¾ in. (19 mm)	Grape or Pea
Coarse Sand	2 mm (No. 10 sieve) 4.75 mm (No. 4 sieve)	Rocksalt
Medium Sand	0.42 mm (No. 40 sieve) – 2 mm (No. 10 sieve)	Sugar, Table Salt
Fine Sand	0.075 mm (No. 200 sieve) – 0.42 mm (No. 40 sieve)	Powdered Sugar
Fines	Less than 0075 mm (No. 200 sieve)	
*Particles finer than fine sand cannot be discerned with the naked eye at a distance of 8 in. (20 cm).		

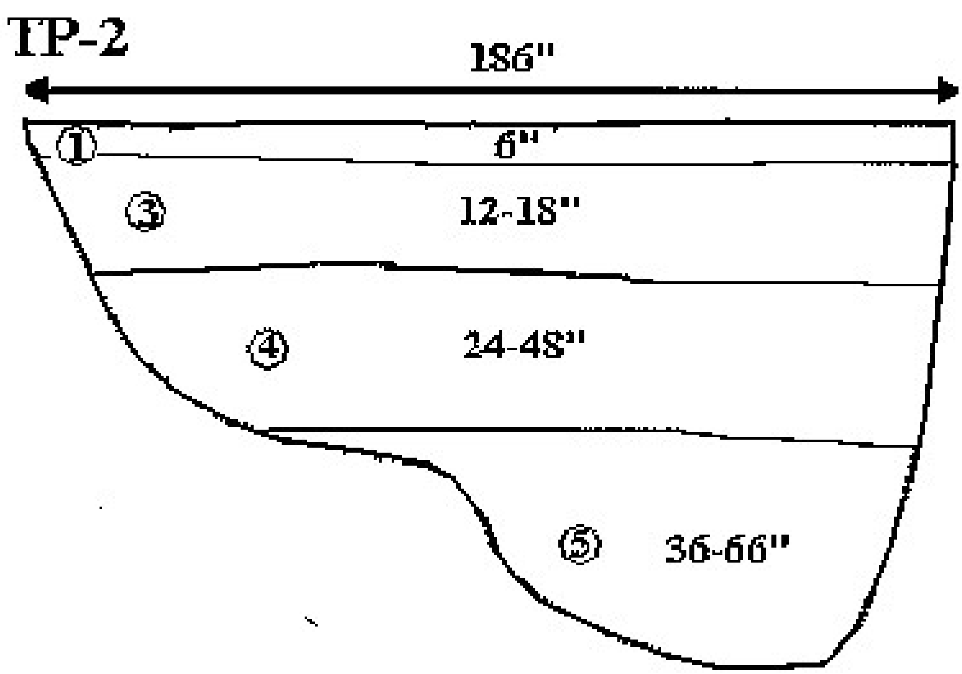
(Modified after FHWA 1997)

MOISTURE CONTITION		DENSITY	
DESCRIPTIVE TERM	GUIDE	TERM	N-VALUE (bpf)
Dry	No indication of water	Very Loose	00-04
Moist	Damp but no visible water	Loose	05-10
Wet	Visible free water, usually soil below water table	Medium Dense	11-24
		Dense	25-50
		Very Dense	Over 51

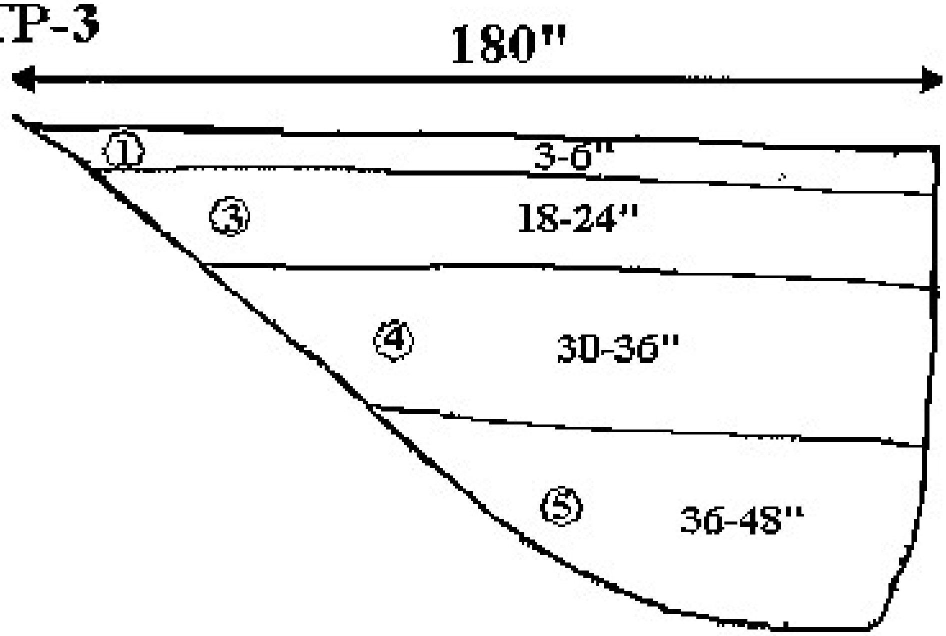
A.2 St. Francis River Bridge Site Test Pits

1. Brown, clayey Silt with roots, moist
2. Gray, Gravel Base course, dry
3. Light brown, silty Clay, very stiff, dry
4. Gray-brown, silty Clay, soft to slightly stiff, moist, rootlets present
5. Light to dark mottled silty Clay, soft to slightly stiff, moist

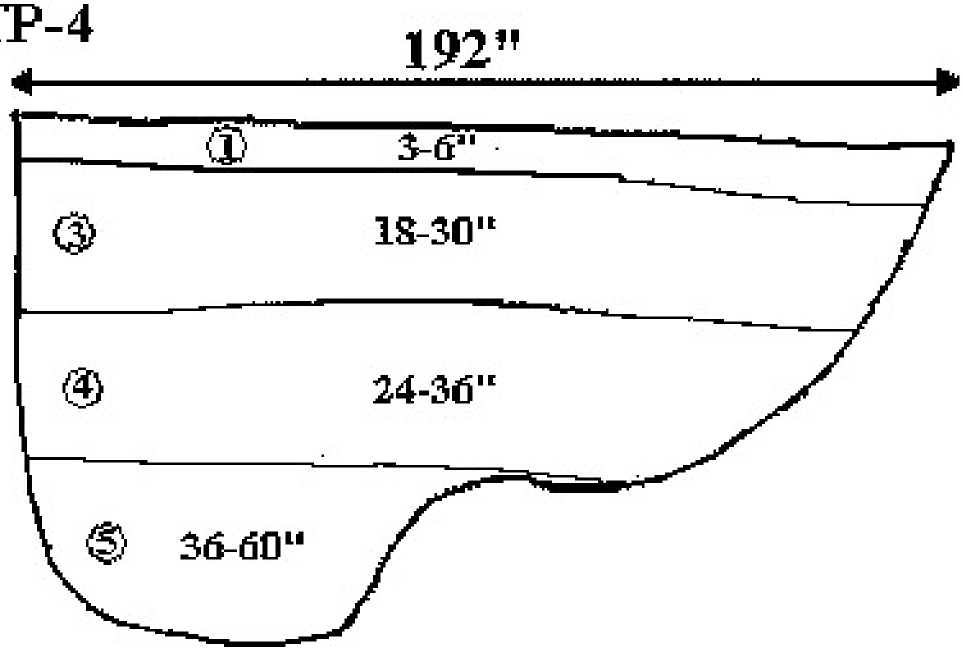




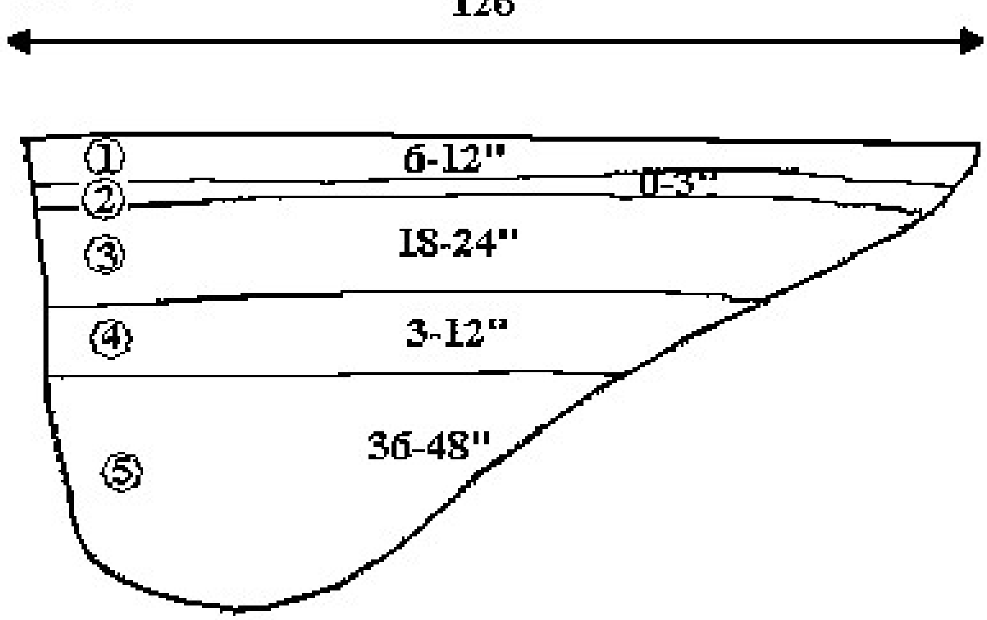
TP-3



TP-4

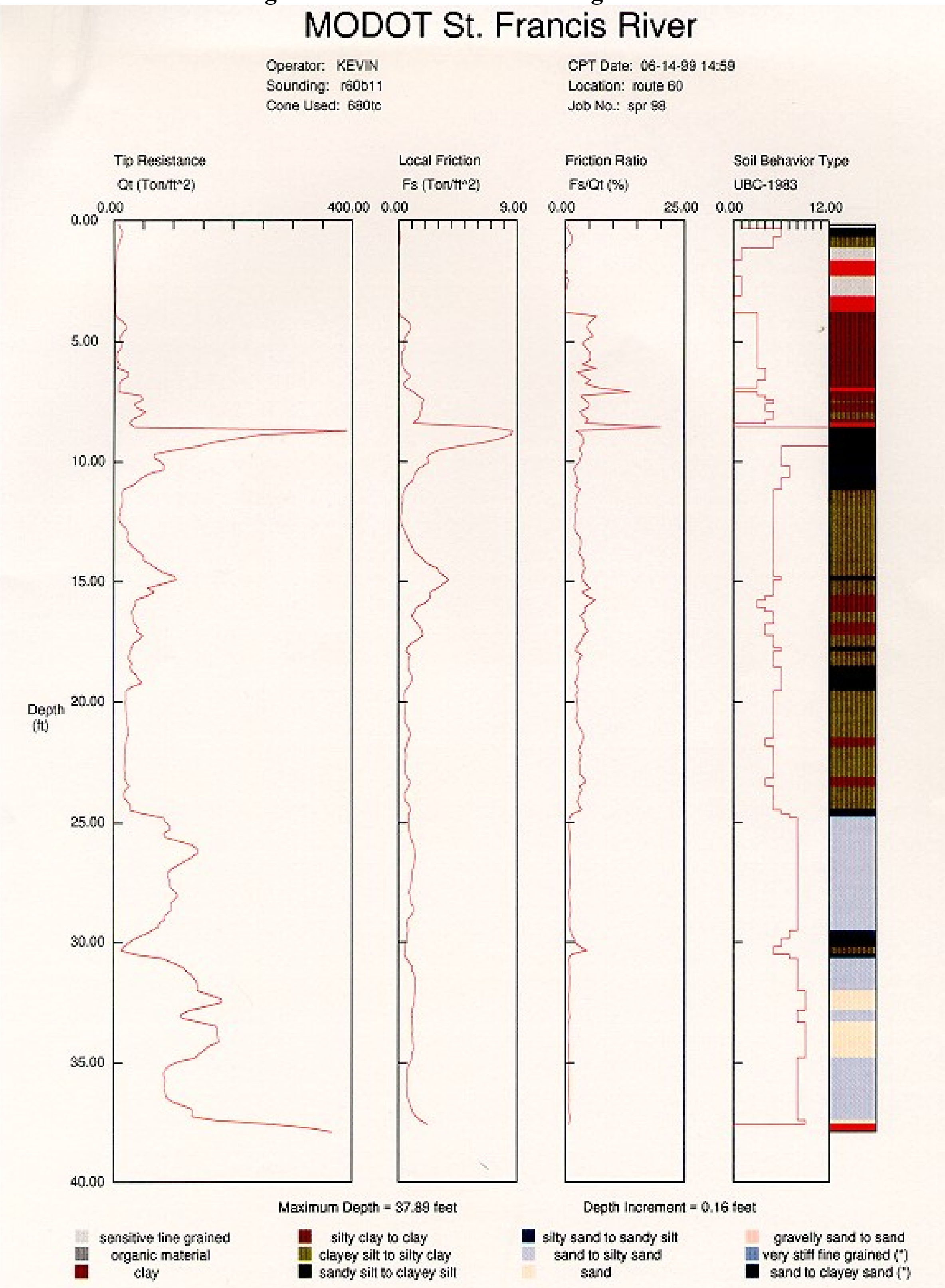


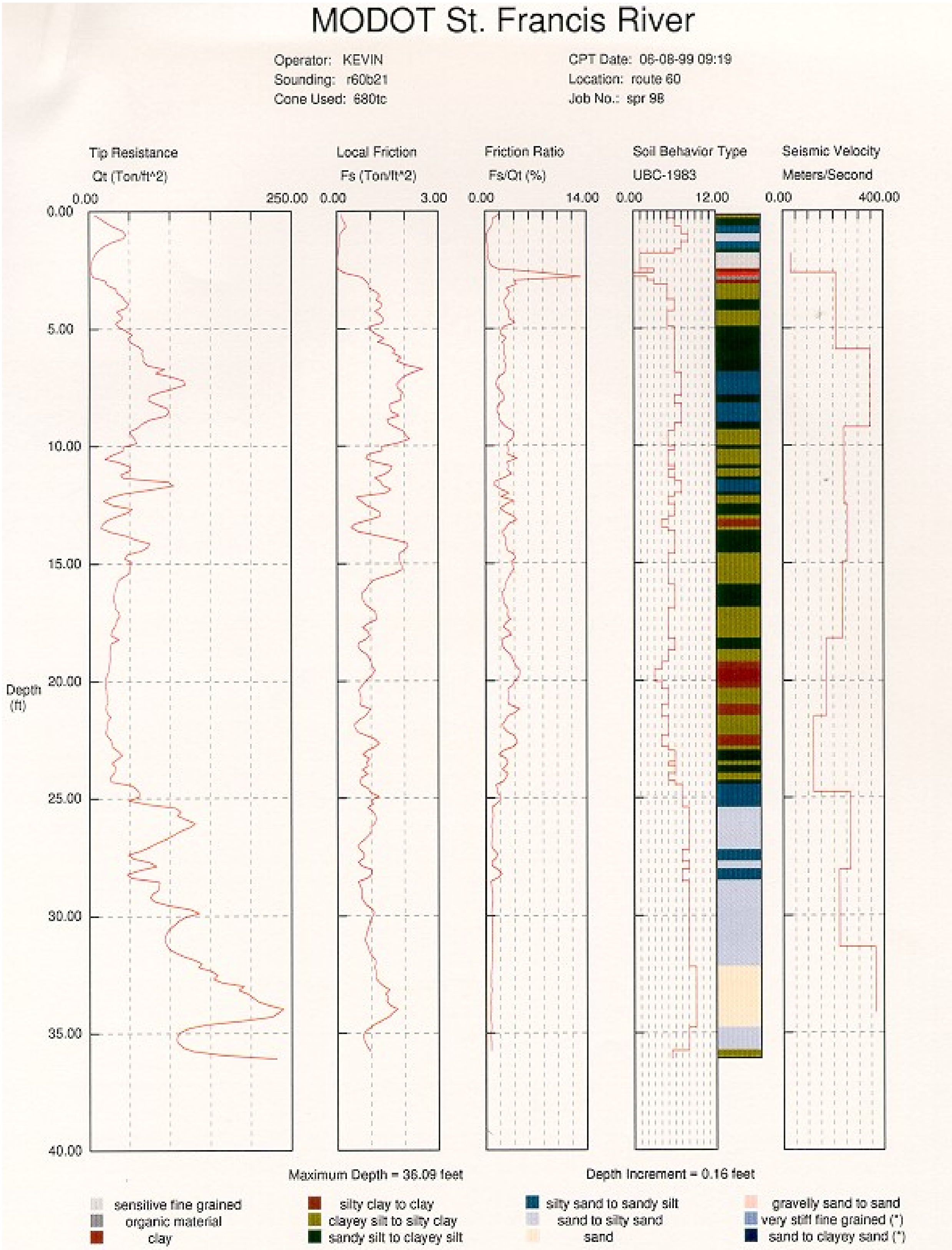
TP-5



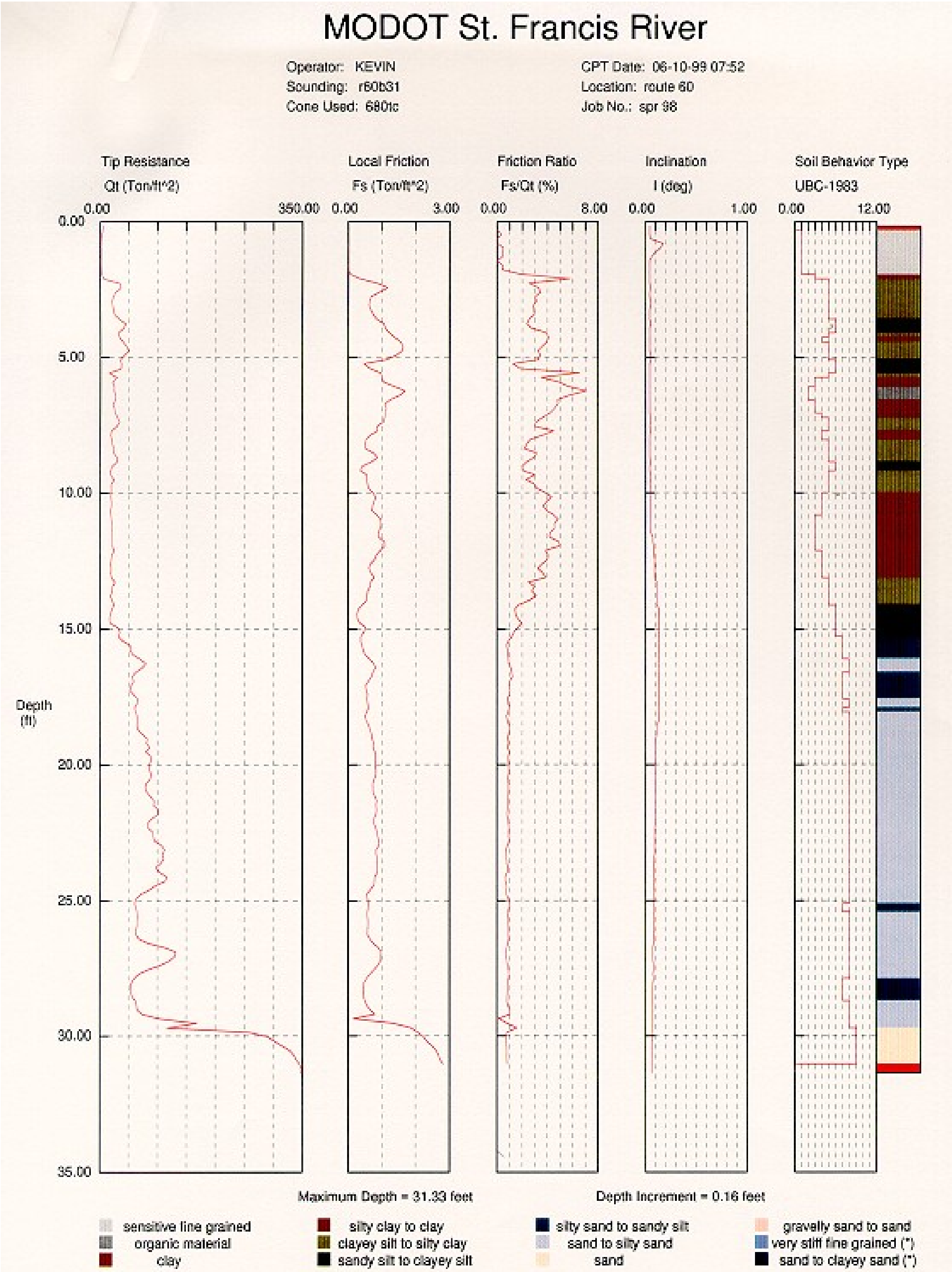
A.3 St. Francis River Bridge Site Boring Logs

A.4 St. Francis River Bridge Site Cone Penetrometer Logs

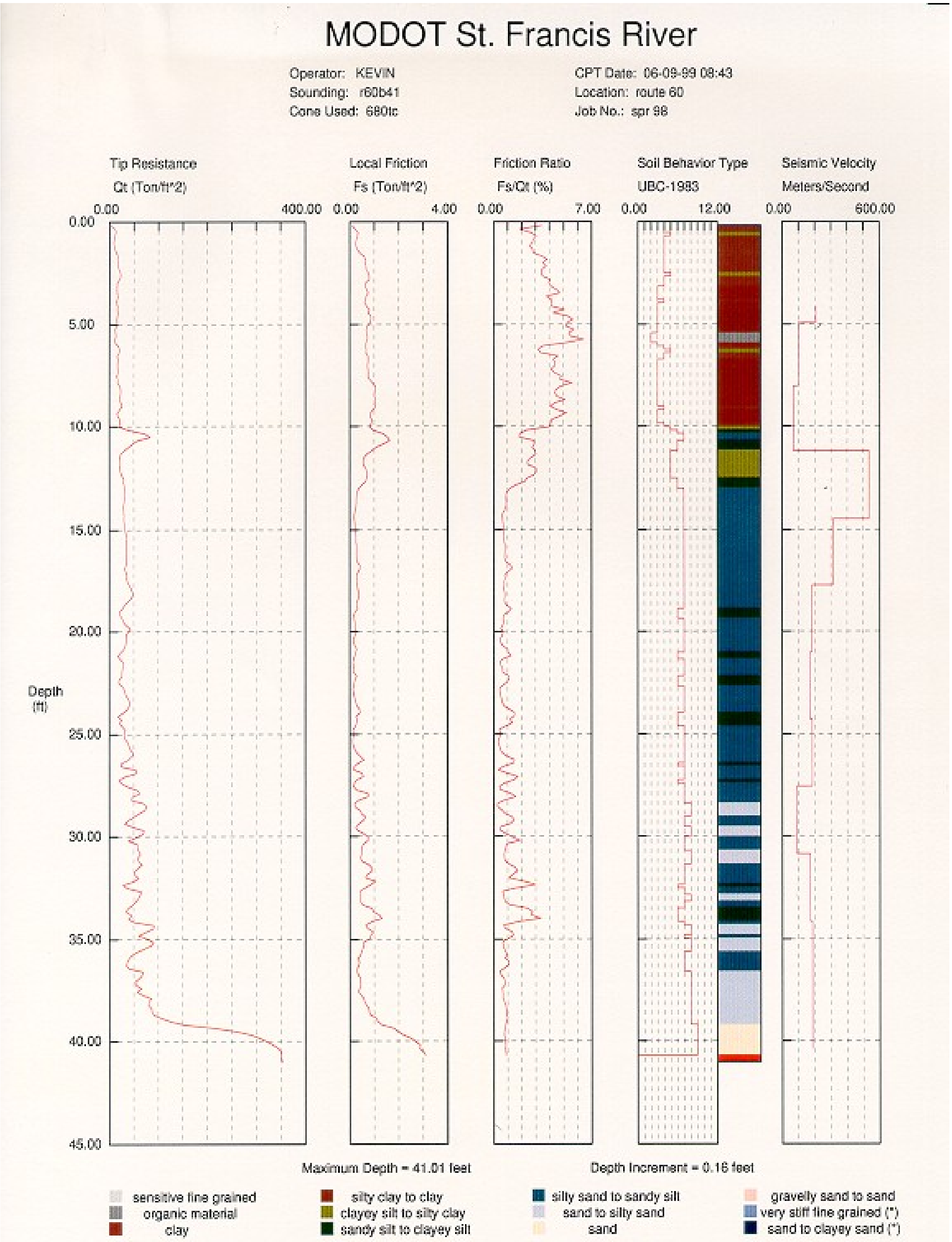


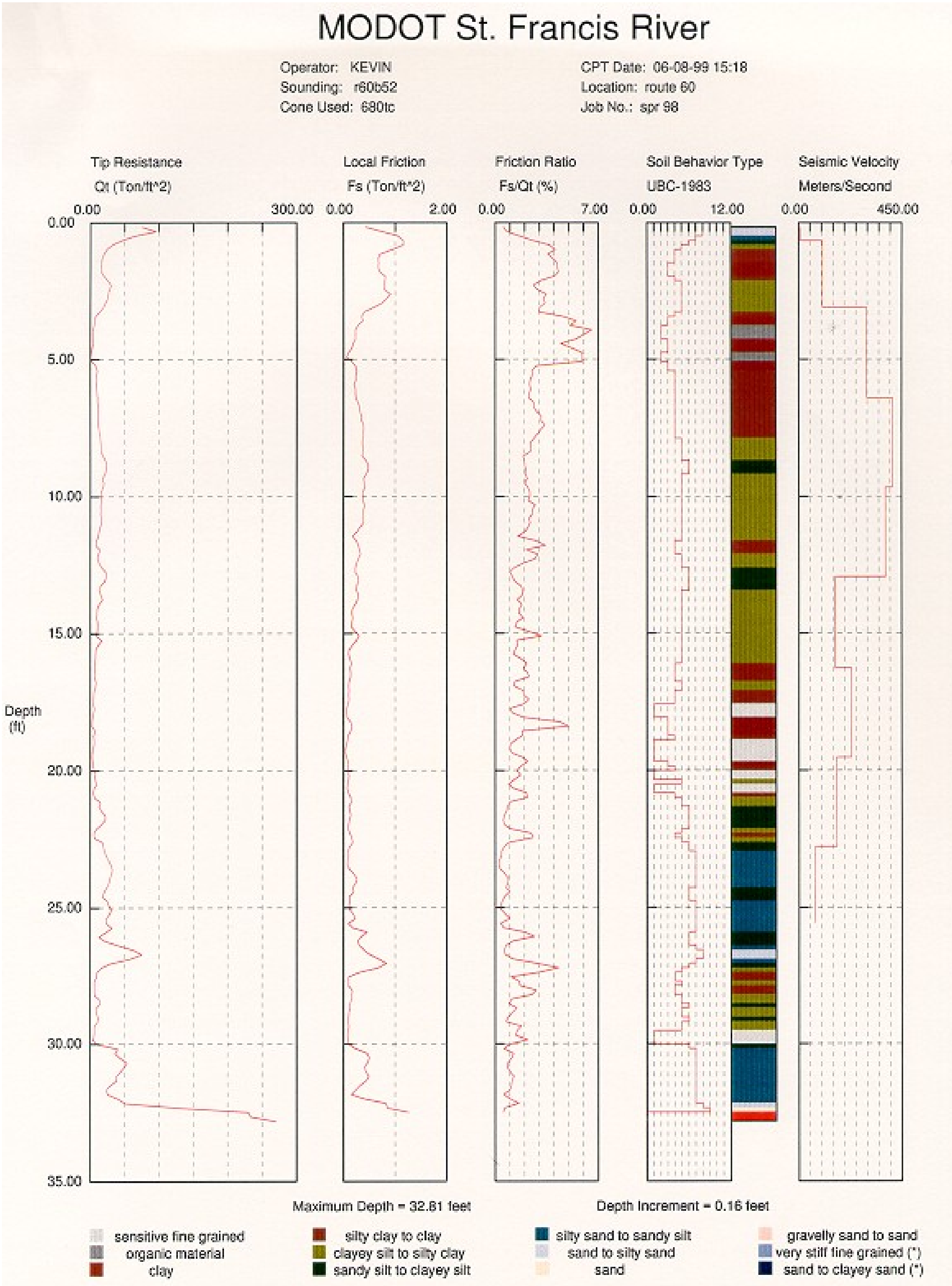


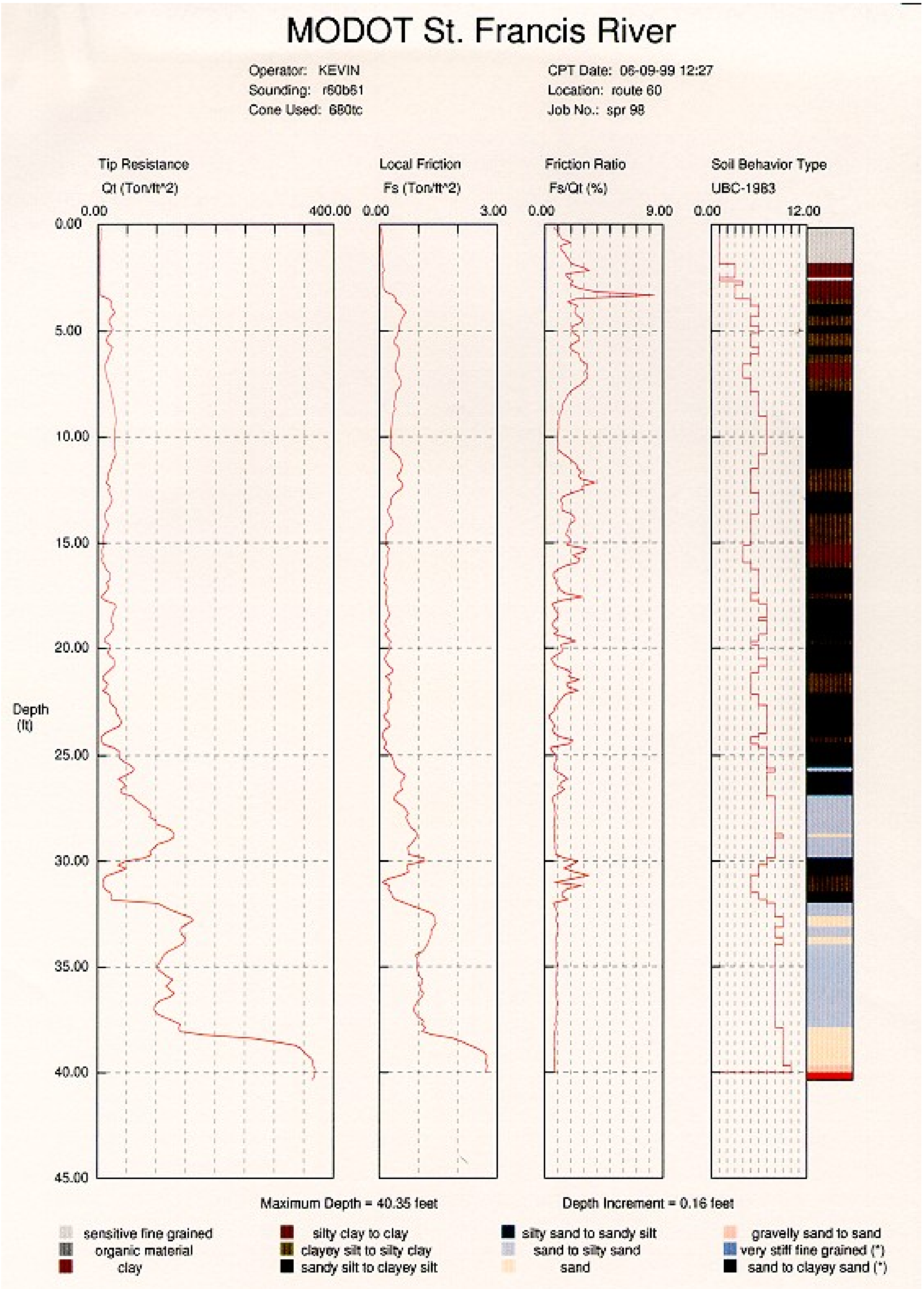
MODOT St. Francis River
Operator: KEVIN
Sounding: r60b21
Cone Used: 680tc
CPT Date: 06-08-99 09:19
Location: route 60
Job No.: spr 98
Tip Resistance
Qt (Ton/ft^2)
0.00
250.00
Local Friction
Fs (Ton/ft^2)
0.00
3.00
Friction Ratio
Fs/Qt (%)
0.00
14.00
Soil Behavior Type
UBC-1983
0.00
12.00
Seismic Velocity
Meters/Second
0.00
400.00
Depth
(ft)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Maximum Depth = 36.09 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)



MODOT St. Francis River
Operator: KEVIN
Sounding: r60b31
Cone Used: 680tc
CPT Date: 06-10-99 07:52
Location: route 60
Job No.: spr 98
Tip Resistance
Qt (Ton/ft^2)
Local Friction
Fs (Ton/ft^2)
Friction Ratio
Fs/Qt (%)
Inclination
I (deg)
Soil Behavior Type
UBC-1983
Depth
(ft)
Maximum Depth = 31.33 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)


MODOT St. Francis River
Operator: KEVIN
Sounding: r60b41
Cone Used: 680tc
CPT Date: 06-09-99 08:43
Location: route 60
Job No.: spr 98
Tip Resistance
Qt (Ton/ft^2)
0.00
400.00
Local Friction
Fs (Ton/ft^2)
0.00
4.00
Friction Ratio
Fs/Qt (%)
0.00
7.00
Soil Behavior Type
UBC-1983
0.00
12.00
Seismic Velocity
Meters/Second
0.00
600.00
Depth
(ft)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Maximum Depth = 41.01 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)

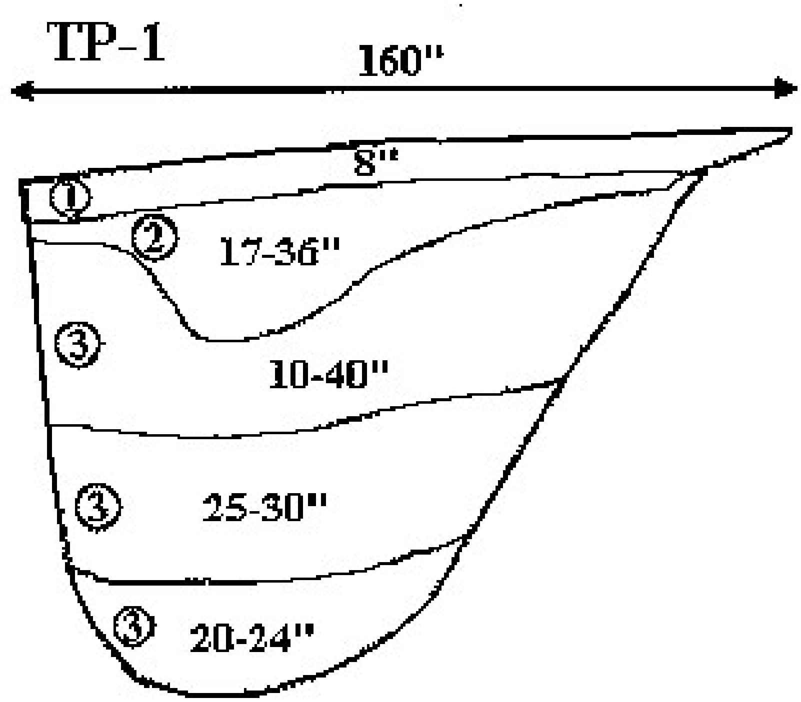

MODOT St. Francis River
Operator: KEVIN
Sounding: r60b52
Cone Used: 680tc
CPT Date: 06-08-99 15:18
Location: route 60
Job No.: spr 98
Tip Resistance
Qt (Ton/ft^2)
Local Friction
Fs (Ton/ft^2)
Friction Ratio
Fs/Qt (%)
Soil Behavior Type
UBC-1983
Seismic Velocity
Meters/Second
Depth
(ft)
Maximum Depth = 32.81 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)

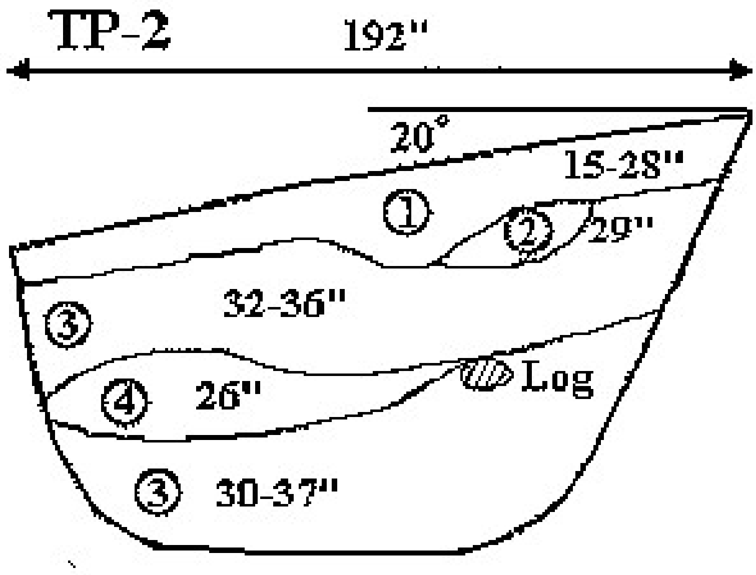

MODOT St. Francis River
Operator: KEVIN
Sounding: r60b61
Cone Used: 680tc
CPT Date: 06-09-99 12:27
Location: route 60
Job No.: spr 98
Tip Resistance
Qt (Ton/ft^2)
Local Friction
Fs (Ton/ft^2)
Friction Ratio
Fs/Qt (%)
Soil Behavior Type
UBC-1983
Depth
(ft)
Maximum Depth = 40.35 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)

A.5 Wahite Ditch Bridge Site Test Pits

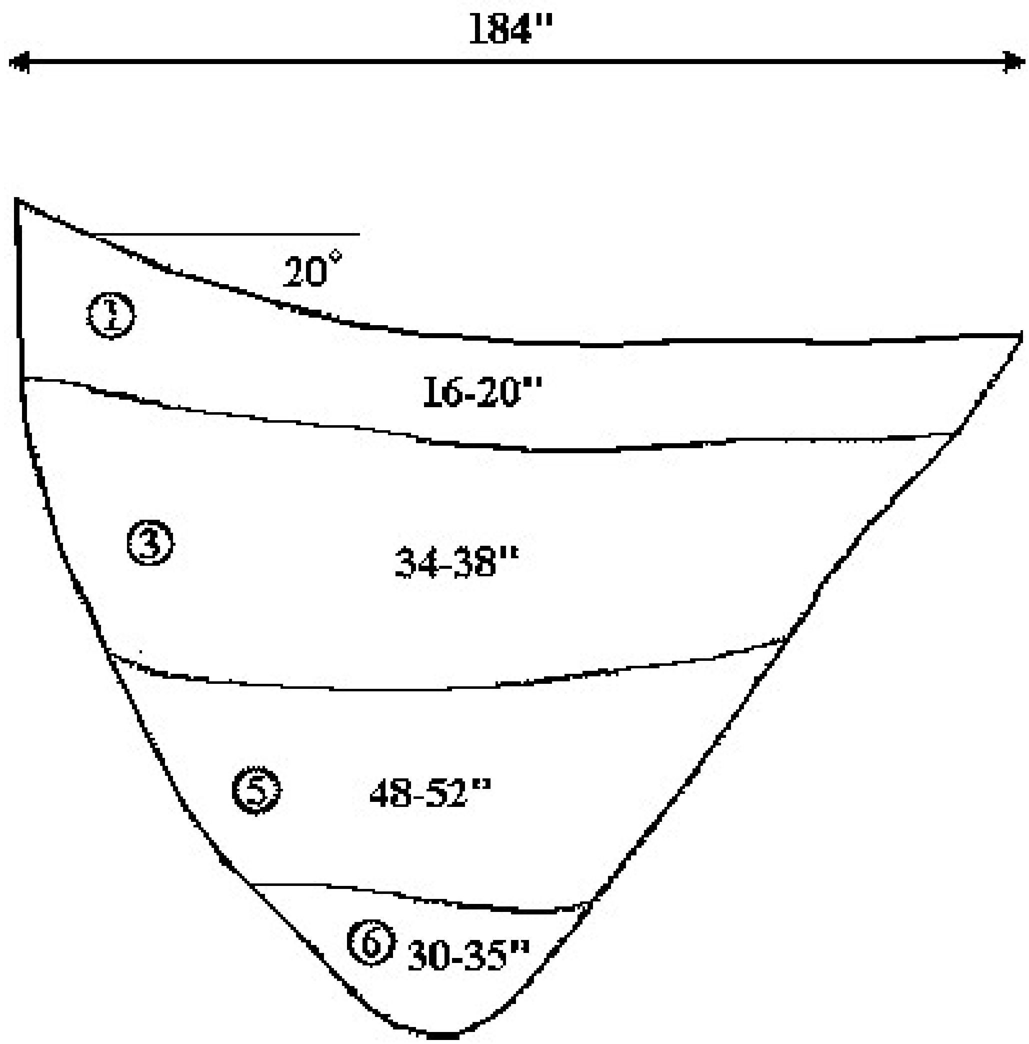
Not To Scale

1. Brown, sandy Gravel, with silt, dry, organics, angular to rounded
2. Brown-tan, medium coarse Sand, sub angular gravel, loose, dry, organics
3. Gray, mottled Clay, very plastic, moist, organics
4. Tan Sand, loose, very moist, rounded
5. Grey sandy Clay, soft, moist
6. Brown-red, clayey Sand, moist, gravel present

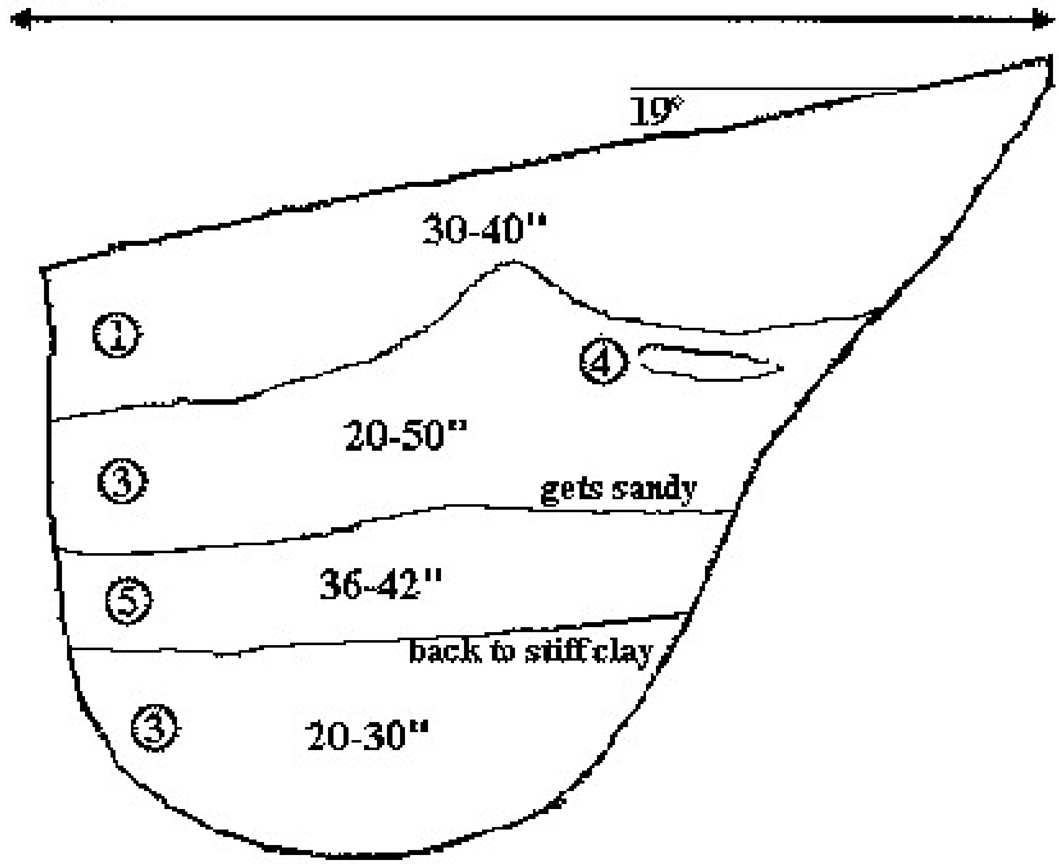


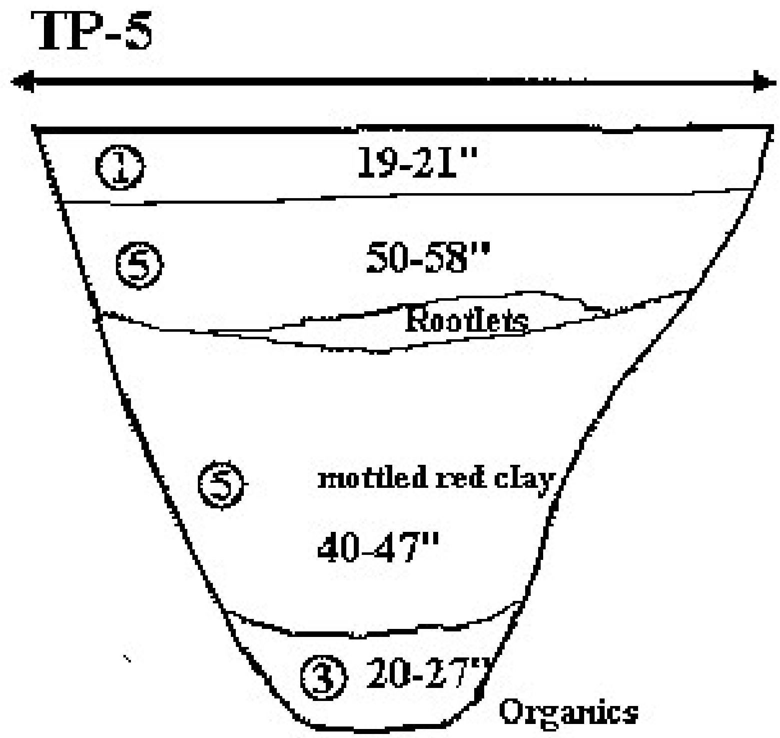

TP-2
192"
20°
15-28"
1
2
29"
3
32-36"
4
26"
Log
3
30-37"

TP-3



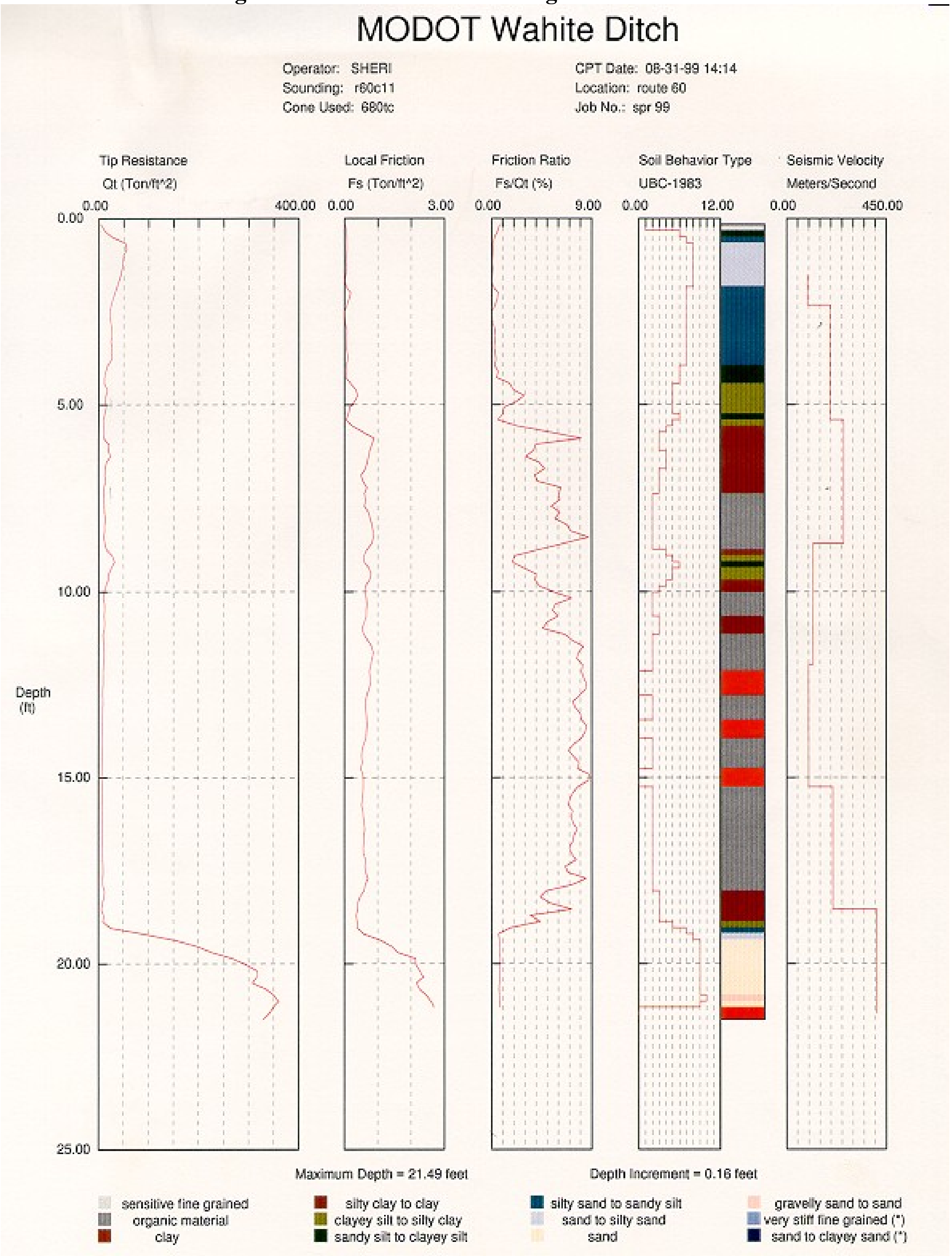
TP-4

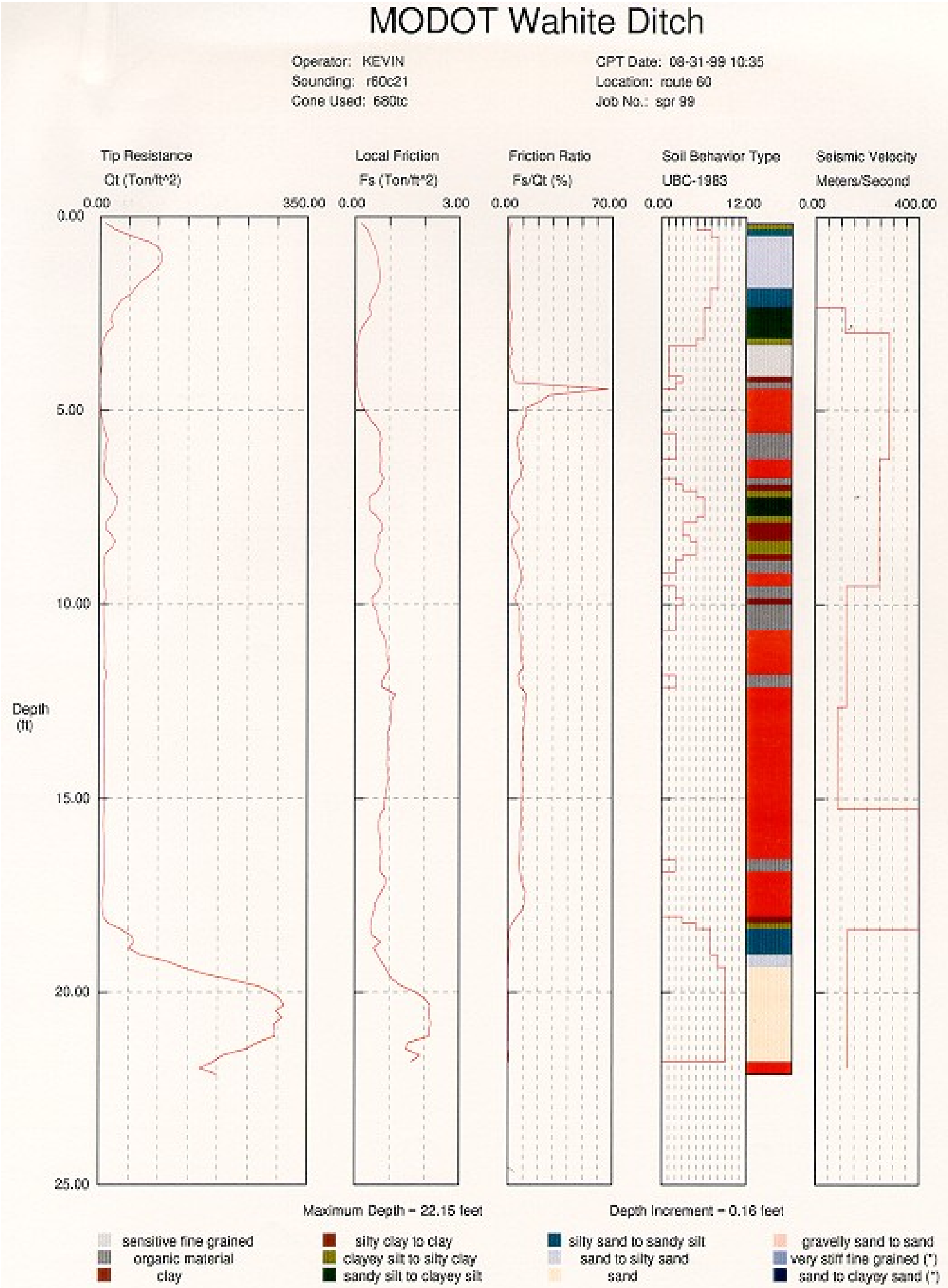


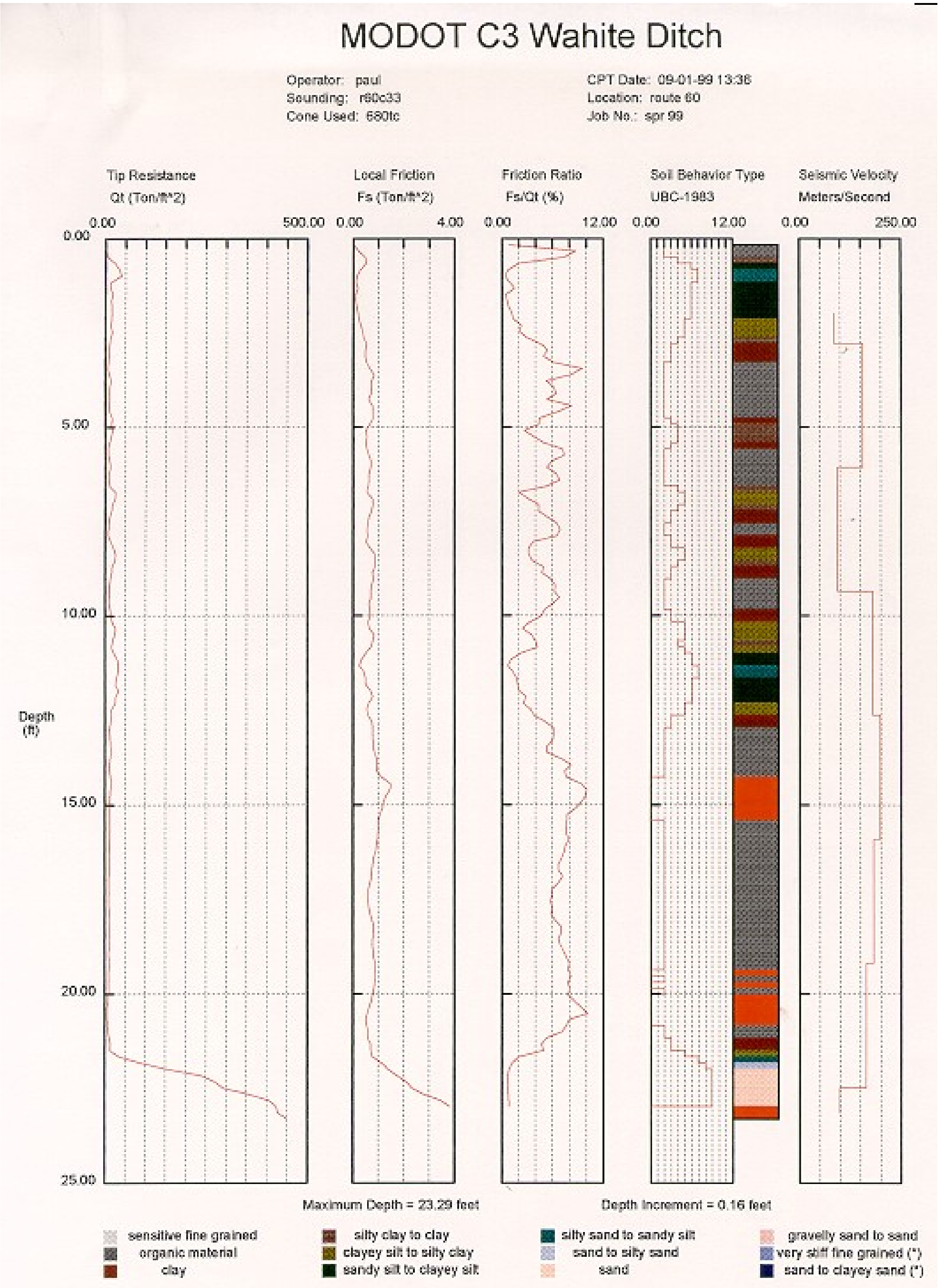

TP-5
① 19-21"
⑤ 50-58"
Rootlets
⑤ mottled red clay
40-47"
③ 20-27"
Organics

A.6 Wahite Ditch Bridge Site Boring Logs

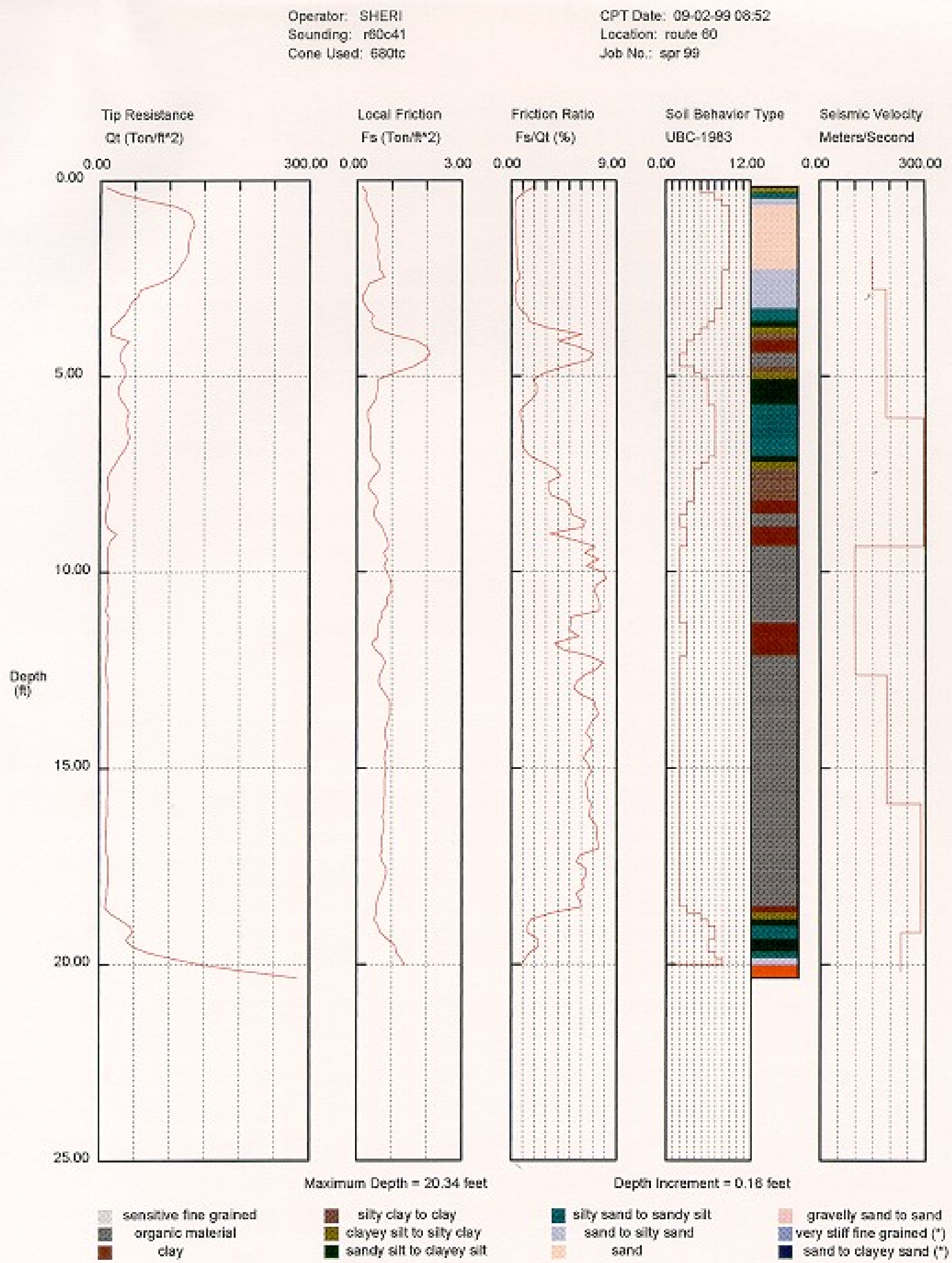
A.7 Wahite Ditch Bridge Site Cone Penetrometer Logs

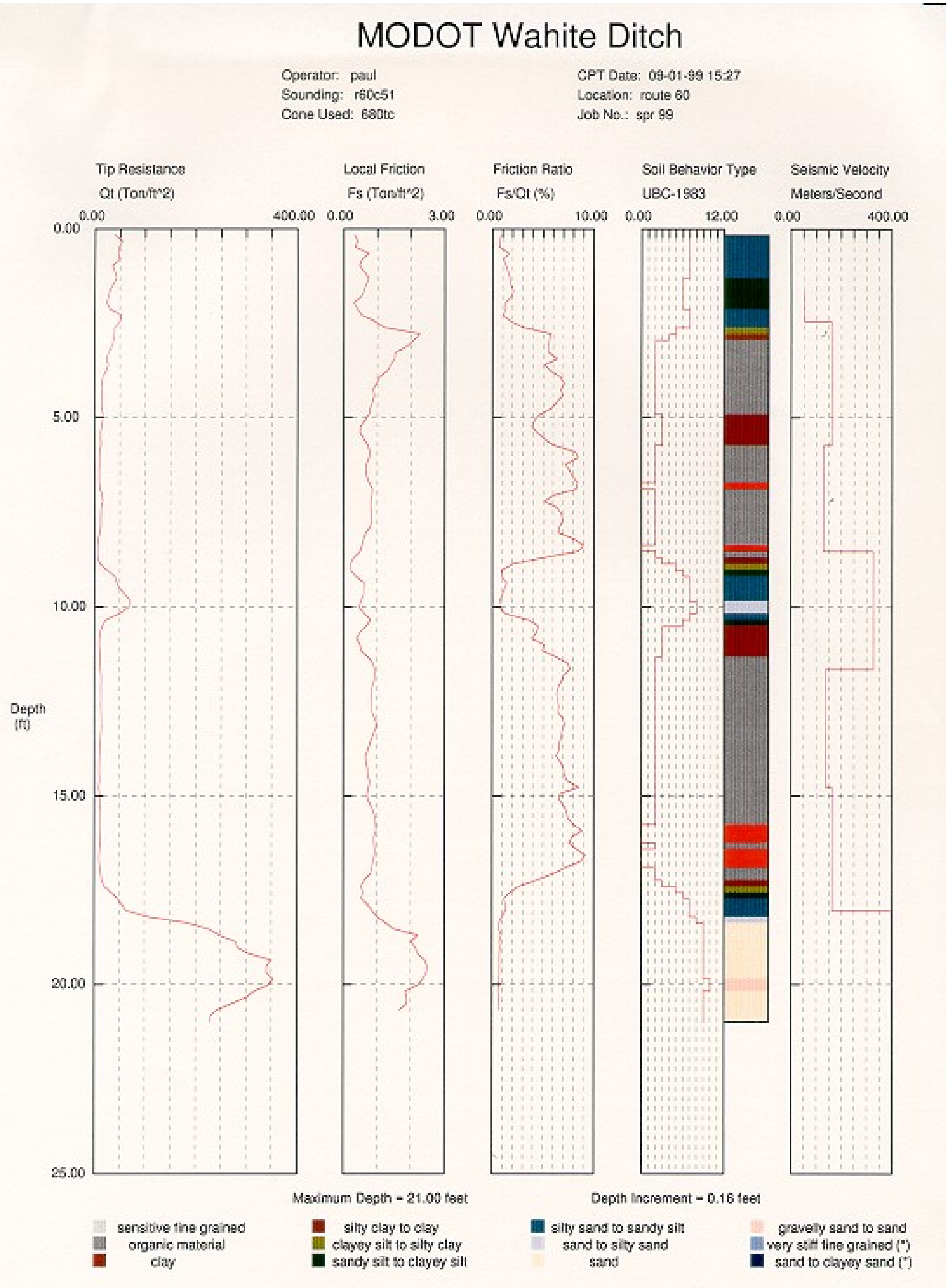



MODOT Wahite Ditch
Operator: KEVIN
Sounding: r60c21
Cone Used: 680tc
CPT Date: 08-31-99 10:35
Location: route 60
Job No.: spr 99
Tip Resistance
Qt (Ton/ft^2)
0.00
350.00
Local Friction
Fs (Ton/ft^2)
0.00
3.00
Friction Ratio
Fs/Qt (%)
0.00
70.00
Soil Behavior Type
UBC-1983
0.00
12.00
Seismic Velocity
Meters/Second
0.00
400.00
Depth
(ft)
0.00
5.00
10.00
15.00
20.00
25.00
Maximum Depth = 22.15 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)


MODOT C3 Wahite Ditch
Operator: paul
Sounding: r60c33
Cone Used: 680tc
CPT Date: 09-01-99 13:36
Location: route 60
Job No.: spr 99
Tip Resistance
Qt (Ton/ft^2)
Local Friction
Fs (Ton/ft^2)
Friction Ratio
Fs/Qt (%)
Soil Behavior Type
UBC-1983
Seismic Velocity
Meters/Second
0.00
500.00
4.00
12.00
250.00
Depth
(ft)
5.00
10.00
15.00
20.00
25.00
Maximum Depth = 23.29 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)

MODOT C4 Wahite Ditch





MODOT Wahite Ditch
Operator: paul
Sounding: r60c51
Cone Used: 680tc
CPT Date: 09-01-99 15:27
Location: route 60
Job No.: spr 99
Tip Resistance
Qt (Ton/ft^2)
Local Friction
Fs (Ton/ft^2)
Friction Ratio
Fs/Qt (%)
Soil Behavior Type
UBC-1983
Seismic Velocity
Meters/Second
0.00
400.00
3.00
10.00
12.00
5.00
15.00
20.00
25.00
Depth
(ft)
Maximum Depth = 21.00 feet
Depth Increment = 0.16 feet
sensitive fine grained
organic material
clay
silty clay to clay
clayey silt to silty clay
sandy silt to clayey silt
silty sand to sandy silt
sand to silty sand
sand
gravelly sand to sand
very stiff fine grained (*)
sand to clayey sand (*)

B. LABORATORY DATA

B.1 Cyclic Stress Test Results

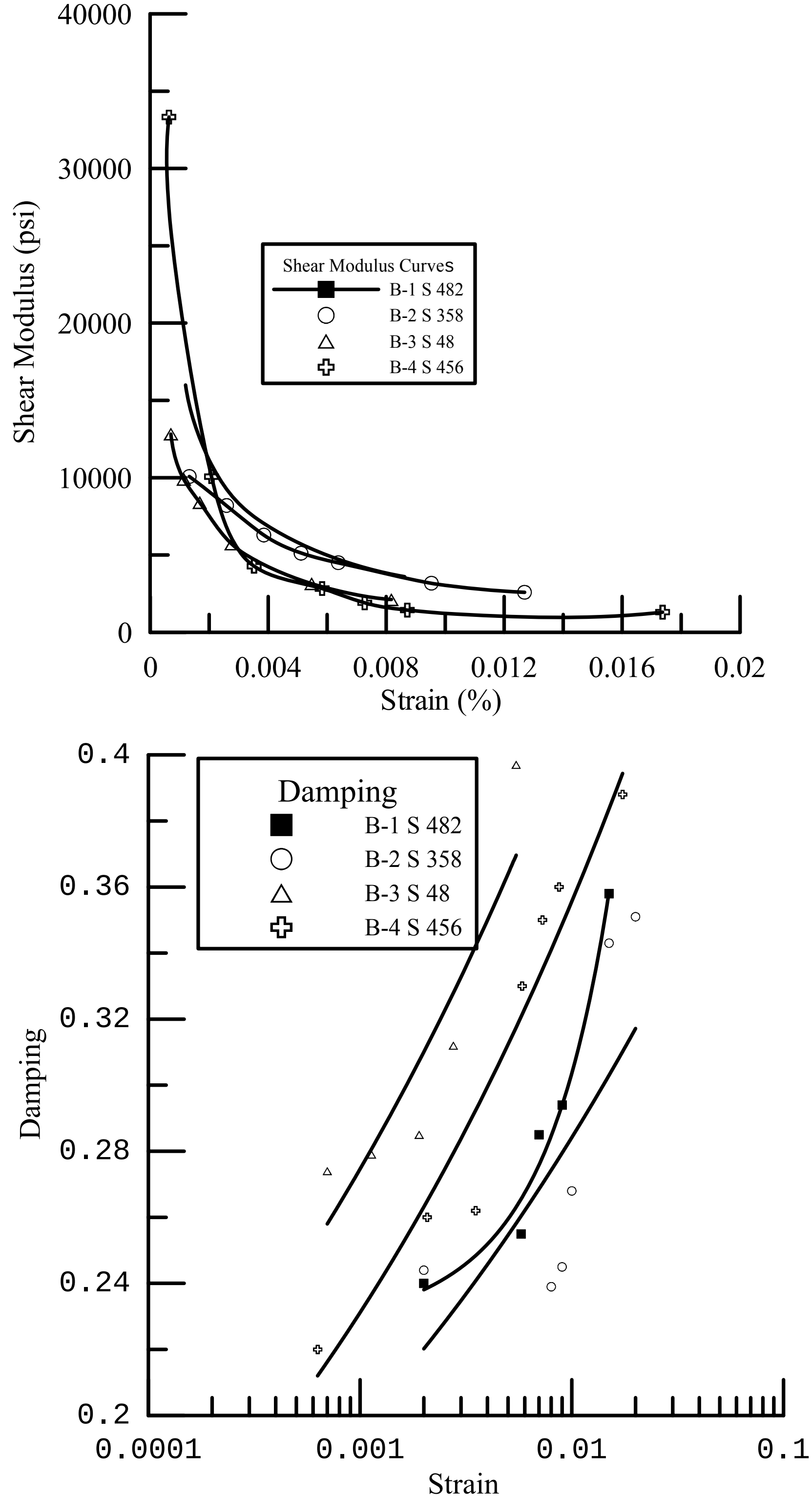


Figure B.1 Shear Modulus and Damping

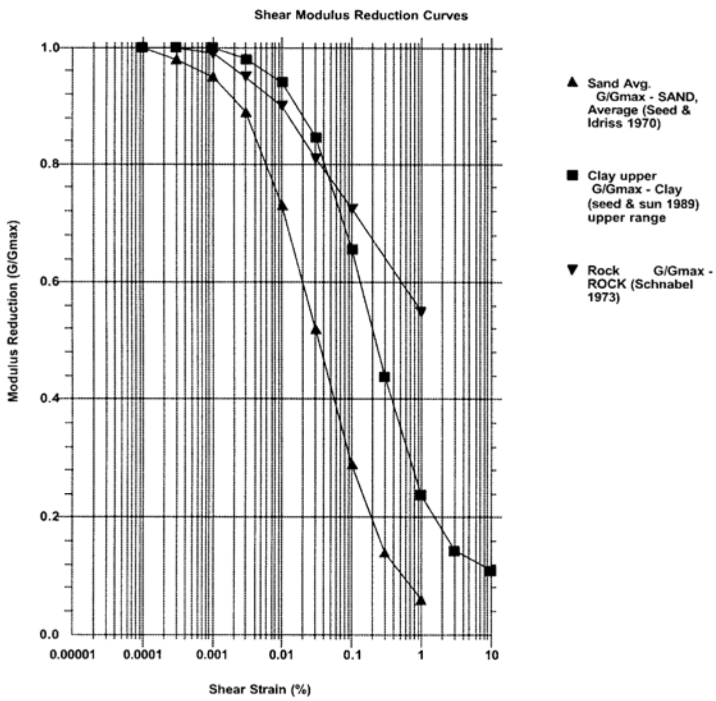


Figure B.2 Strain Dependent Modulus

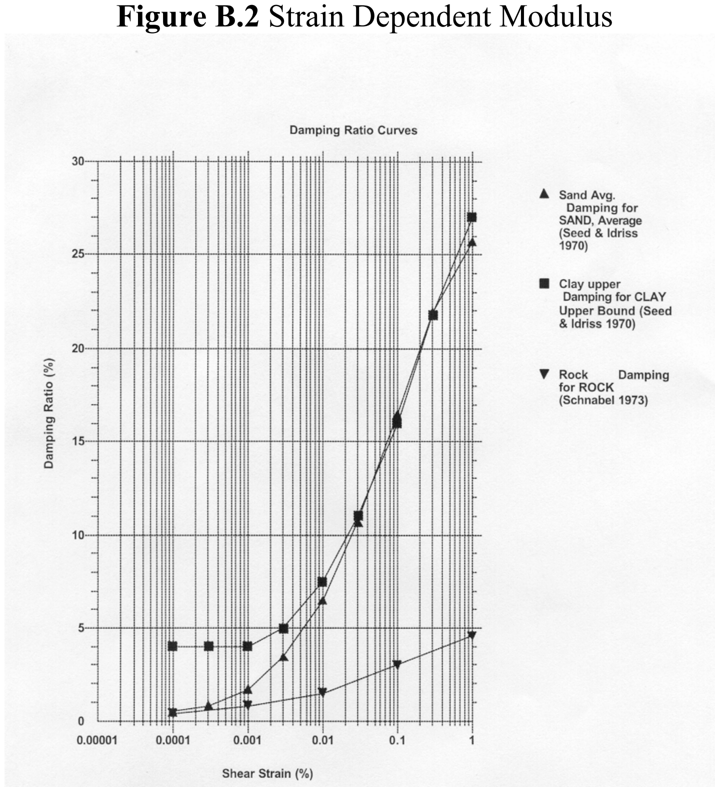


Figure B.3 Strain Dependent Damping

B.2 St. Francis River Site Laboratory Results

St. Francis River

BORING	SAMPLE	UMR	Depth	Description	PP (TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	q_u (PSF)	Cyclic TX	CU(psi)	Φ
B-1	473		0.0-1.0	Brn silty CLAY w/ gravel	4.3	0.60		11.3						
	474	*	0.0-1.0	Br. si lean CLAY					31/10					
	pen		1.0-2.5	Brn Silty lean CLAY	4.5		21							
	475		2.5-5.0	Brown silty lean CLAY	9.0	0.60		15.8	31/10	CL			**300**	**32**
	476		2.5-5.0	Brown silty lean CLAY	3.5	0.65					6446			
	pen		5.0-6.5	Br, silty lean CLAY	5.0	-	12	17.4						
	477		6.5-8.4	Br,gray mottled si CLAY	1.5	0.55								
	478	*	6.5-8.4	Br, gray mottled si CLAY		1.50		21.4						
	pen		8.4-9.9	Br/gr mottled si CLAY, intermix siltstone	9.0	-	73	19.5						
	479		10.0-12.5	Gray Clayey SILT	8.0	0.70		17.8						
	480		10.0-12.5	Gray Clayey SILT	4.5	0.35					6532			
	pen		12.5-14.0	Gray clayey SILT	1.2	-	10							
	481		14.0-15.5	Gray clayey SILT	3.0	0.40		19.1						
	482	*	14.0-15.5	Gray clayey SILT					29/12	CL		**X**		
	pen		15.5-17.0	Gray SILT to clayey SILT	2.5	-	19	20.6						
	483		17.0-19.5	Gray SILT to clayey SILT	2.8	0.65		22.5						
	484		17.0-19.5	Gray SILT to clayey SILT	2.8	0.65					2603			
	pen		19.5-21.0	Gray SILT, stiff to v. stiff	3.0	-	17	25.9						
	485		21.0-23.5	Gray SILT v. stiff	4.0	0.45		24.6						
	486	*	21.0-23.5	Gray SILT very stiff										
	pen		23.5-25.0	Gray SILT to 24.5, gray fine SAND	3.3	-	26	23.9						
	487		25.0-27.5	Brown Silty sand, too brittle to wrap										
	489		27.5-29.0	Brown fine grained Sand, dense, wet			28							
	490		35.0-36.5	Brown/grey fine grained Sand, dense, wet			26							
	491		40.0-41.5	Gray fine grained Sand, very dense, wet			75							
	492		45.0-46.5	Gray fine grained Sand, very dense, wet			71							
	493		50.0-51.5	Gray fine-medium Sand, very dense, wet			75							
	494		55.0-56.5	Gray medium Sand, dense, wet			38							
	495		60.0-61.5	Gray medium Sand, very dense, wet			82							
	496		65.0-66.5	Gray medium Sand, dense			33							
	497		70.0-71.5	Gray medium Sand, dense			40							
	498		75.0-76.5	Gray medium Sand, dense			35							
	499		80.0-81.5	Drk gray fine-med silty sand, dense			38							

St. Francis River

Boring	Sample	UMR	Depth	Description	PP(TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	qu(psf)	CYCLIC TX	CU(psi)	Φ
	501		100.0-101.5	Gray med Sand, fine gravel, v. dense			73							
	369		110.0-111.5	Gray med-coarse Sand w/ f. gravel v. dense			72							
	370		120.0-121.5	Gray Coase Sand w/ m. sand and f. grav.			123							
	371		130.0-131.5	Brownish-gry coarse Sand w/ m. sa and fine grav			56							
			140.0-142.0	Coarse Sand and cobbles										
	372		143.0-144.5	Gray coarse Sand and coarse grav			142							
	373		153.0-157.5	Gray medium Sand, v. dense			91							
	374		163.0-164.5	Gray medium Sand, v. dense			92							
	375		170.0-171.5	Gray medium Sand, v. dense			139							
			180.0-180.2	Cobble										
			190.0-191.5	Cobbles and boulders										
B-2	pen		0.0-2.5	lt grey silty clay	1.8	0.65		17.0						
	346		2.5-4.0	reddish brn mottled CLAY	5.1		10							
	347		4.0-6.5	med. Grey lean CLAY v. stiff	3.8	0.46		20.0						
	348	*	4.0-6.5	Med. gray lean CLAY w/ silt, v. stiff										
	jar		6.5-7.5				6	16.4						
			10.5-12.0	no recovery			16							
	349		12.0-14.5		7.0	0.45		17.9						
	350	*	12.0-14.5	Med. gray lean CLAY w/ silt, v. stiff									**380**	**34**
	351		14.7-16.0	lt to brn lean CLAY w/ silt v. stiff	2.0		12							
	bag		16.0-16.6											
	352		16.0-16.6		8.0	0.60								
	353		17.0-19.5	lt tan andy SILT	2.0	0.40								
	354		17.0-19.5	lt tan andy SILT				24.1			1328			
	358	*	21-23.5	Lt. Tan sa SILT stiff to v. stiff				25.5				**X**		
	359		24.5-25.0	Lt grey SILT			8							
	360		25.0-25.8	missing										
	361		25.8-27.5	lt brn silty SAND	0.5	0.23								
	362		25.8-27.5	lt brn silty SAND										
	363		27.5-28.5	lt brn med. Sand			15							

St. Francis River

Boring	Sample	UMR	Depth	Description	PP(TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	qu(psf)	CYCLIC TX	CU(psi)	Φ
	364		29.0-31.5	lt. Gray medium Sand			15							
	365		35.0-36.5	lt. Gray medium Sand			18							
	366		40.0-41.5	lt. Gray medium Sand			59							
	367		45.0-46.5	lt. Gray medium Sand			35							
	368		50.0-51.5	lt. Gray medium Sand			50							
B-3	AL		0.0-1.2	Brn sandy lean CLAY	4.5	0.95		10.9						
	jar		1.2-2.7	brn lean CLAY, V. stiff	4.5		19	15.7						
	42		3.0-5.5	ln Brn CLAY, v. stiff	1.3			23.2						
	43	*	3.0-5.5	ln Brn CLAY, v. stiff									**280**	**35**
	jar		5.5-7.0	ln Brn CLAY, v. stiff			6	23.2						
	44		7.0-9.5	ln Brn CLAY, v. stiff	2.8	0.90		23.5						
	45	*	7.0-9.5	Moist SILT										
	46		7.0-9.5	Moist SILT										
	jar		9.5-11.0	Moist SILT	2.5		7	21.9						
	jar		10.5-14.0	Gray Clayey SILT	2.3		9	23.5						
	47		11.0-13.5	Gray Clayey SILT	2.8	0.90								
	48	*	11.0-13.5	Gray clayey SILT								**X**		
	jar		13.5-15.0	Gray clayey SILT			10							
	jar		14.5-15.0	tan fine SAND			19							
	49		15.0-16.1	gry brn fine SAND										
	50		16.1-17.6	Gray brown f. Sand, loose to med dense			16							
	51		18.0-19.5	Gray brown f. Sand, loose to med dense			9							
	52		19.5-21.0	Gray brown f. Sand, loose to med dense			9							
	53		21.0-22.5	gry-brn to tan f. Sand w/ lean clay			15							
	54		22.5-24.0	gry-brn to tan f. Sand w/ lean clay			24							
	55		24.0-25.5	Gray fine-med Sand			16							
	56		25.5-27.0	Gray fine-med Sand			28							
	57		275.0-28.5	Gray fine-med Sand			28							
	58		28.5-30.0	Gray fine-med Sand			23							
	59		30.0-31.5	Gray fine-med Sand			50							
	60		35.0-36.5	Gray fine-med Sand			56							
	61		40.0-41.5	Gray fine-med Sand			78							
	62		45.0-46.5	Gray fine-med Sand			26							
	63		50.0-51.5	Medium Sand			26							
	64		55.0-56.5	Gray fine-med Sand			41							

St. Francis River														
Boring	Sample	UMR	Depth	Description	PP(TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	qu(psf)	CYCLIC TX	CU(psi)	Φ
	65		60.0-61.5	Gray fine-med Sand			47							
	66		65.0-66.5	Gray fine-med Sand			46							
	67		70.0-71.5	Gray fine-med Sand			41							
	68		75.0-76.5	Gray fine-med Sand			49							
	69		80.0-81.5	Gray fine-med Sand			41							
	70		90.0-91.5	Gray fine to med Sand w/ trace gravel			52							
	71		100.0-101.5	med to coarse Sand w. trace gravel			62							
B-4	80		0.0-2.5	brn lean CLAY w/ sa & grvl	4.5	0.86		12.4						
	81		4.0-6.5	med brown lean CLAY sft to me.	0.8	0.43		27.1					**200**	**30**
	82	*	4.0-6.5	Lean CLAY soft to med. stiff										
	jar		6.5-8.0					37.9						
	83		8.0-10.5	Lean CLAY soft to med. stiff										
	84	*	8.0-10.5	v. stiff lean CLAY				23.6	48/25	CL				
	Jar		10.5-12.0	Lean CLAY, v. stiff	2.8		12	23.5	36/15					
	85		10.5-12.0	Lean CLAY, v. stiff			15							
	jar		11.5-12.5	gry, brn lean CLAY, v. stiff and silty										
	86		12.5-14.5	lt brn lean Clay very silty and stiff	2.5	0.54	7	24.2					**150**	**33**
	87	*	12.0-14.5	Light brn lean silty CLAY v. stiff										
	88		14.5-16.0	Lt brn clayey SILT, stiff, moist			9?		23/4					
	450	*	16.0-18.5	Lt brn sandy silty CLAY			11	10.6	19/2					
	453	*	20.0-22.5	Br lean silty sandy CLAY				12.6				**X**		
	456	*	24.0-26.5	Brn gray sandy SILT, med. stiff				23.0						
	459	*	28.0-30.5	Brn gray fine grained				25.3						
	461		35.0-36.5	grey, fine SAND, med			16							
	462		40.0-41.5	Gry fine Sand, v. dense			29							
	463		45.0-46.5	Gr fine SAND v. dense			63							
	464		50.0-51.5	Gr fine SAND, m. dense			23							
	465		55.0-56.5	med SAND			75							
	466		60.0-61.5	med SAND, dense			26							
	467		65.0-66.5	med SAND, dense			55							
	468		70.0-71.5	med SAND, dense			47							
	469		75.0-76.5	med SAND, dense			47							
	470		80.0-81.5	fine to med SAND, v. dense			85							
	471		90.0-91.5	fine to med SAND, v. dense			55							
	472		100.0-101.5	fine to med SAND, v. dense			45							

St. Francis River														
Boring	Sample	UMR	Depth	Description	PP(TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	qu(psf)	CYCLIC TX	CU(psi)	Φ
B-5	-		0.0-2.5	brn, lean CLAY										
	250		2.5-4.0	brn, lean CLAY			10							
	251		4.0-5.5	brn, lean CLAY										
	253		6.5-8.0	brn, lean CLAY										
	255		8.0-10.5	brn, clayey SILT, m. stiff			7							
	256		10.5-12.0	brn, clayey SILT, m. stiff			5							
	258	*	12.0-14.5	Brn clayey SILT, med. stiff to stiff										
	259		14.0-16.0	Brn clayey SILT, med. stiff to stiff			4							
	260		16.0-18.5	Brn clayey SILT, med. stiff to stiff										
	261		18.5-20.0	br silty fine SAND			4							
	262		20.0-21.5	br silty fine SAND			4							
	263		25.0-26.5	gray fine silty SAND			3							
	264		30.0-31.5	gray fine silty SAND			2							
	265		35.0-36.5	gray fine SAND, dense										
	266		40.0-41.5	gray fine SAND, dense										
	267		45.0-46.5	gray fine SAND, dense			30							
	268		50.0-51.5	gray fine SAND, dense			15							
B-6	10		0.0-2.3	Br, lean CLAY w/ f. Sand										
			2.3-4.8	Gravel										
	13	*	5.0-7.5	Brn clayey SILT, v. stiff										
	14		7.5-10.0	Brn clayey SILT, v. stiff										
	16	*	10.0-12.5	Brn clayey SILT, v. stiff										
	17		12.5-15.0	Brn clayey SILT, v. stiff										
	20	*	15.0-17.5	Brn clayey SILT, v. stiff										
	22		17.5-20.0	Brn silty fine SAND, trace clay										
	23		20.0-21.5	Brn silty fine SAND, trace clay			4							
	24		21.5-23.0	Brn silty fine SAND, trace clay			2							
	25		23.0-24.5	Brn silty fine SAND, trace clay			5							
	26		24.5-26.0	Brn silty fine SAND, trace clay			21							
	27		26.0-27.5	Brn silty fine SAND, trace clay			17							
	28		27.5-29.0	Gray brown fine to med SAND			22							
	29		29.0-30.5	Gray brown fine to med SAND			17							
	30		30.5-32.0	gray fine SAND			14							
	31		35.0-36.5	gray fine SAND			28							
	32		40.0-41.5	gray fine SAND			75							

St. Francis River															
Boring	Sample	UMR	Depth	Description	PP(TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	qu(psf)	CYCLIC TX	CU(psi)	Φ
	33		45.0-46.5	Gray brown fine SAND			75							
	34		50.0-51.5	Gray brown fine SAND			80							

B.3 Wahite Ditch Bridge Site Laboratory Results

Wahite Ditch												
BORING	SAMPLE	UMR	Depth	Description	PP (TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	q_u (PSF)	CYCLIC TX
B-1	743	*	0.0-2.5	Br. gray fat clay with sand	9.0+	0.95		10.1%	51/29	CH		
	744		2.5-5.0	Br. gray fat clay with sand	1.50	0.55		15.4%				
	745		2.5-5.0	Br. gray fat clay with sand	-	-						
	746	*	5.0-7.3	Br. gray fat clay with sand	1.50	0.50		32.2%	33/17	CL		
	747		5.0-7.3	Br. gray fat clay with sand				29.1%			1783	
	748		7.5-10.0	Br. Fat clay with sand, stiff	1.50	0.75		35.6%				
	749		7.5-10.0	Br. Fat clay with sand, stiff								
	750	*	10.0-12.5	Br. Fat clay with sand, stiff	1.25	0.70		32.0%	73/46	CH		
	751		10.0-12.5	Br. Fat clay with sand, stiff				34.7%			1282	
	752		10.0-12.5	Br. Fat clay with sand, stiff								
	753		12.5-15.0	Br. Fat clay with sand, stiff	1.75	0.75		35.0%				
	754		12.5-15.0	Br. Fat clay with sand, stiff								
	755	*	15.0-17.5	Gr. Tan fat clay with sand, stiff	1.00	0.70		30.8%	81/50	CH		
	756		15.0-17.5	Gr. Tan fat clay with sand, stiff				30.6%			2101	
	757		15.0-17.5	Gr. Tan fat clay with sand, stiff								
	758		17.5-20.0	Gr. Tan fat clay with sand, stiff	1.50	0.70		35.1%				
	759		17.5-20.0	Gr. Tan fat clay with sand, stiff								
	760		20.0-21.5	Tan firm to med sand			58					
	761	*	21.5-23.0	Tan firm to med sand			51					
	762		23.0-24.5	Tan firm to med sand			72					
	763		24.5-26.0	Gr. & tan fine to med sand			63					
	764	*	26.0-27.5	Gr. & tan fine to med sand			49					
	765		27.5-29.0	Fine Sand			46					
	766		29.0-30.5	Gr. & tan fine to med sand			65					
	90	*	35.0-36.5	Scattered gravelly layers			66					
	91		40.0-41.5	Scattered gravelly layers			73					
	92		45.0-46.5	Thin gravelly layers, medium with coarse sand			47					
	93	*	50.0-51.5	Thin gravelly layers, medium with coarse sand			46					
	94		55.0-56.5	Thin gravelly layers, medium with coarse sand			39					
	95	*	60.0-61.5	black with organics from 60.6-61.05, gravelly @ 62			38					
	96		65.0-66.5	Gr. & Tan medium sand			54					
	97	*	70.0-71.5	Gr. & Tan medium sand			51					
	98		75.0-76.5	Gr. & Tan medium sand			54					
	99	*	80.0-81.5	Gr. & Tan medium sand			51					
	100		90.0-91.5	Gr. & Tan medium sand			51					
	101	*	100.0-101.5	Gr. & Tan medium sand			52					
	102		110.0-111.5	cobbles & Gravel @ 108			73					
	103	*	120.0-121.5	Tan fine to coarse sand with trace silt			24					

Wahite Ditch												
BORING	SAMPLE	UMR	Depth	Description	PP (TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	q_u (PSF)	CYCLIC TX
	104		130.0-131.5	Tan fine to coarse sand with trace silt			29					
	105		140.0-141.5	Tan fine to coarse sand with trace silt			61					
	106	*	150.0-151.5	cobbles & gravel @ 148.6			74					
	107		160.0-161.5	Tan fine to coarse sand with trace silt			56					
	108		170.0-171.5	Lt gr. and tan fine sand			82					
	109	*	180.0-181.5	Lt gr. and tan fine sand			96					
	110		190.0-191.5	Lt gr. and tan fine sand			82		38/22	CL		
	111	*	200.0-201.5	Gr. Lean clay with sand					42/19	CL		
	112		200.0-201.5	200-201.5 gr brown fat clay								
B-2	680		2.5-5.0	Gray br fat clay	4.50	0.95						
	681	*	5.0-7.5	Gray br fat clay	2.00	0.50			53/33	CH		
	682		7.5-10.0	Gray br fat clay	1.50	0.80						
	683		7.5-10.0	Gray br fat clay								
	684	*	10.0-12.5	Gray br fat clay	1.25	0.65			57/35	CH		
	685	*	12.5-15.0	Bluish grey fat clay with sand in lenses	1.25	0.70			75/46	CH		
	686		12.5-15.0	Bluish grey fat clay with sand in lenses								
	687		15.2-17.5	Gray to tan fat clay with sand	1.50	0.65						
	688		15.2-17.5	Gray to tan fat clay with sand				35.2%			1807	
	689	*	17.5-19.5	Gray to tan fat clay with sand	1.25	0.65			79/50	CH		
	690	*	20.0-20.7	Tan fine to med sand								
	691		20.7-22.20	Tan fine to med sand			52					
	692		22.0-23.5	Tan fine to med sand			56					
	693		23.5-25.0	Tan fine to med sand			52					
	694		25.0-26.5	tan and light grey fine to med sand			39					
	695		26.5-28.0	tan and light grey fine to med sand			42					
	696		28.0-29.5	tan and light grey fine to med sand			49					
	697	*	29.5-31	tan and light grey fine to med sand			53					
	698		35.0-36.5	tan and light grey fine to med sand			57					
	699	*	40.0-41.5	tan and light grey fine to med sand								
	700		45.0-46.5	tan and light grey fine to med sand			52					
	701	*	50.0-51.5	tan and light grey fine to med sand			60					
	702		60.0-61.5	tan and light grey fine to med sand			82					
	703	*	65.0-66.5	tan and light grey fine to med sand			56					
	704		70.0-71.5	tan and light grey fine to med sand			108					
	705	*	75.0-76.5	tan and light grey fine to med sand			96					
	706		80.0-81.5	tan and light grey fine to med sand			75					

Wahite Ditch												
BORING	SAMPLE	UMR	Depth	Description	PP (TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	q_u (PSF)	CYCLIC TX
	707		90.0-91.5	tan and light grey fine to med sand			39					
	708	*	100.0-101.5	tan and light grey fine to med sand			73					
B-3	-		0.0-2.9	Tan sand with scattered gravel								
	591	*	2.90-4.0	Grey lt br. fat clay	2.75	0.95		23.4%				
	592	*	8.5-10.0	Grey fat clay stiff	1.50	0.70		37.3%				
	593		8.5-10.0	Grey fat clay stiff								
	594		10.0-12.3	Grey fat clay stiff				32.6%				
	595	*	14.1-15.0	Bluish grey fat clay, stiff	1.50	0.75		33.1%				
	596		14.1-15.0	Bluish grey fat clay, stiff								
	597	*	17.5-19.0	Bluish grey fat clay, stiff	1.50	0.70		32.3%	73/53	CH		
	598	*	22.5-242.0	tan mediuim sand			53					
	599		24.0-25.5	tan mediuim sand			61					
	600	*	25.5-27.0	tan mediuim sand			42					
	601		27.0-28.5	tan mediuim sand			45					
	602	*	28.5-30.0	tan mediuim sand			42					
	603		30.0-31.5	tan mediuim sand			53					
	604		35.0-36.5	tan mediuim sand			54					
	605	*	40.0-41.5	tan mediuim sand			51					
	606	*	45.0-46.5	tan mediuim sand			53					
	607		50.0-51.5	tan mediuim sand			36					
B-4	608	*	2.5-5.0	Drk Brown fat clay	10+	0.95		13.8%	39/22	CL		
	609		2.5-5.0	Drk Brown fat clay								
	610		5.0-5.7	Drk Brown fat clay	4.00	0.90		24.0%				
	611		5.0-5.7	Drk Brown fat clay	1.00	0.60						
	614	*	7.5-10.0	bluish gray fat clay	0.75	0.50		19.1%	33/17	CL		
	615		7.5-10.0	bluish gray fat clay								
	616		10.0-11.9	bluish gray fat clay	1.00	0.50		21.2%				
	617		10.0-11.9	bluish gray fat clay				22.9%			966	
	618	*	11.9-12.5	Drk gray fat clay	1.50	0.70		23.3%	45/21	CL		
	619	*	12.5-14.9	Bluish gray fat clay	1.25	0.55		21.7%	52/35	CH		
	620		12.5-14.9	Bluish gray fat clay								
	621	*	15.0-17.5	Gray fat clay	1.50	0.75		25.0%	59/37	CH		
	622		15.0-17.5	Gray fat clay								
	623		15.0-17.5	Gray fat clay								
	624	*	17.5-19.4	Gray fat clay	1.25-			21.6%	46/27	CL		
	625		17.5-19.4	Gray fat clay								
	626	*	19.5-21.0	Tan fine to med sand			24					
	627		21.0-22.5	Tan fine to med sand			26					
	628		22.5-242.0	Tan fine to med sand			46					
	629		24.0-25.5	Tan fine to med sand			39					
	630	*	25.5-27.0	Tan fine to med sand			35					
	631		27.0-28.5	Tan fine to med sand			39					
	632		28.5-30.0	Tan fine to med sand			39					

Wahite Ditch												
BORING	SAMPLE	UMR	Depth	Description	PP (TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	q_u (PSF)	CYCLIC TX
	633		30.0-31.5	Tan fine to med sand			38					
	634	*	35.0-36.5	Tan fine to med sand			43					
	635		40.0-41.5	Tan fine to med sand			42					
	636		45.0-46.5	Tan fine to med sand			56					
	637	*	50.0-51.5	Tan fine to med sand			42					
B-5	709	*	2.5-5.0	Gray & brown to tan fat clay	8.00	0.95		20.6%	55/31	CH		
	710		2.5-5.0	Gray & brown to tan fat clay								
	711		5.0-7.5	Gray & brown to tan fat clay	2.00	0.90		26.1%				
	712		5.0-7.5	Gray & brown to tan fat clay				21.3%			1747	
	713	*	7.5-10.0	Gray & brown to tan fat clay	1.75	0.60		30.9%	63/38	CH		
	714		7.5-10.0	Gray & brown to tan fat clay								
	715		7.5-10.0	Gray & brown to tan fat clay								
	716		10.8-12.5	bluish gray fat clay	1.25	0.45		40.0%				
	717		10.8-12.5	bluish gray fat clay								
	718	*	12.5-13.4	bluish gray fat clay	1.50	0.70		30.6%	69/41	CH		
	719		12.5-13.4	bluish gray fat clay								
	720	*	15.0-17.5	Gray and tan fat clay	1.75	0.75		22.1%	60/39	CH		
	721		15.0-17.5	Gray and tan fat clay				27.1%			1157	
	722		15.0-17.5	Gray and tan fat clay								
	723		17.5-18.1	Gray and tan fat clay	1.50	0.70		22.5%				
	724	*	20.0-212.5	Tan fine to med sand			53					
	725		21.5-23.0	Tan fine to med sand			56					
	726		23.0-24.4	Tan fine to med sand			55					
	727	*	24.5-26.0	Tan and gray fine to med sand			48					
	728		26.0-27.5	Tan and gray fine to med sand			44					
	729		27.5-29.0	Tan and gray fine to med sand			48					
	730	*	29.0-30.5	Tan and gray fine to med sand			58					
	731		35.0-36.5	Tan and gray fine to med sand			62					
	732		40.0-41.5	Tan and gray fine to med sand			41					
	733	*	45.0-46.5	Tan and gray fine to med sand			46					
	734		50.0-51.5	Tan and gray fine to med sand			41					
	735	*	55.0-56.5	Tan and gray fine to med sand			68					
	736		60.0-61.5	Tan and gray fine to med sand			51					
	737		65.0-66.5	Tan and gray fine to med sand			54					
	738		70.0-71.5	Tan and gray fine to med sand			51					
	739	*	75.0-76.5	Tan and gray fine to med sand			80					
	740		80.0-81.5	Tan and gray fine to med sand			60					
	741	*	90.0-91.5	Tan and gray fine to med sand			43					
	742		100.0-101.5	Tan and gray fine to med sand			71					
B-6	638	*	2.5-5.0	Drk Brown Fat clay	7.00	0.95		17.8%	49/27	CL		
	639		2.5-5.0	Drk Brown Fat clay								
	640		5.0-7.5	Drk Brown Fat clay	2.50	0.85		24.5%				
	641	*	7.5-10.0	Drk Brown Fat clay	2.50	0.90		19.8%	35/19	CL		
	642		7.5-10.0	Drk Brown Fat clay								

Wahite Ditch												
BORING	SAMPLE	UMR	Depth	Description	PP (TSF)	Torvane (TSF)	N_{60}	wc(%)	LL/PI	USC	q_u (PSF)	CYCLIC TX
	643	*	10.4-11.3	Gray Fat Clay	2.00	0.70		28.2%	64/40	CH		
	644	*	12.5-14.8	Bluish gray fat clay	1.50	0.75		22.2%	49/30	CL		
	645		12.5-14.8	Bluish gray fat clay								
	646	*	15.0-17.3	Gray and tan fat clay	2.00	0.80		21.5%	51/34	CH		
	647		15.0-17.3	Gray and tan fat clay				20.5%			2883	
	648		15.0-17.3	Gray and tan fat clay								
	649	*	17.5-20.0	Gray clayey sand	2.00	0.35		16.0%	34/17	CL		
	650		20.0-20.4	Gray clayey sand								
	651	*	20.0-21.5	Tan fine to med sand			27					
	652	*	21.5-23.0	Tan fine to med sand			34					
	653		23.0-24.5	Tan fine to med sand			38					
	654	*	242.5-26.0	Tan fine to med sand			42					
	655		26.0-27.5	Tan fine to med sand			39					
	656		27.5-29.0	Tan fine to med sand			41					
	657	*	29.0-30.5	Tan fine to med sand			39					
	658	*	35.0-36.5	Tan fine to med sand			55					
	659		40.0-41.5	Tan fine to med sand			58					
	660	*	45.0-46.5	Tan fine to med sand			58					
	661		50.0-51.5	Tan fine to med sand			34					

C. SOFTWARE DESCRIPTION

Descriptions of the major analysis software are given below.

C.1 *SHAKE91* and *SHAKEDIT*

C.1.1 *SHAKE9*1

SHAKE91 is a computer program for conducting equivalent linear seismic response analyses of horizontally layered soil deposits. Modified program is based on the original SHAKE program (Schnabel, Lysmer and Seed, 1972) and modifications by Idriss and Sun (1991).

C.1.2 *SHAKEDIT* Program

SHAKEDIT is a Windows based "pre- "and "post-"processor for *SHAKE91*. In a typical application, *SHAKEDIT* is used to create an input file for *SHAKE9*1. User-friendly screens are provided to input the data for the different *SHAKE91* options, and then to create an input file. After executing *SHAKE91*, *SHAKEDIT* is used to process the output files, and to create a series of files containing acceleration and/or stress/strain time history data, response spectrum and amplification data, etc. The results can also be viewed graphically in *SHAKEDIT*, and the graphics created can be saved/printed for inclusion in documents. On-line help is provided for most editing and graphing operations. The information presented in this manual assumes that the reader is are familiar with *SHAKE91* and the different options used in the program. However, all the results have been added to E-files.

C.2 Modified *DDRW2* Program

The modified *DDRW2* program is used to calculate displacement of rigid retaining walls during real earthquake loading and considering nonlinear soil properties. The DDRW2 program is a modification of DDRW1 program in which only dry soil and sinusoidal ground motion were used. The former has been modified to include deck loads and their time dependent inertia forces as for bridge abutments for simply supported decks and assumed restrained by the deck with integral construction. Soil is considered non-linear. Therefore both material and radiation damping are included in the solution.

The following stiffness and damping factors were calculated by appropriate methods for 2-dimensional case.

k_z, k_x, k_ϕ, $k_{y\theta}$ and c_z, c_x, c_ϕ, $c_{y\theta}$

Where;

k_z = stiffness of single pile for translation along z axis
k_x = stiffness of single pile for translation along x axis
k_ϕ = stiffness of single pile for rocking about y axis
$k_{y\theta}$ = cross couple stiffness of single pile for sliding along x-axis and rocking about y axis
c_z = damping of single pile for translation along z axis
c_x = damping of single pile for translation along x axis
c_ϕ = damping of single pile for rocking about y axis
$c_{y\theta}$ = cross couple stiffness of single pile for sliding along x-axis and rocking about y axis

These stiffness and damping parameter had been computed both as function of strain and linear-displacement.

The results give displacements (sliding, rocking and total displacement) of bridge abutment as a function time.

C.3 *PCSTABL5*

The following program description is modified from the *STABL* homepage at http://www.ecn.purdue.edu/STABL/. Version 5 of the program was used for this study.

PCSTABL is a computer program written in FORTRAN for the general solution of slope stability problems by two-dimensional limiting equilibrium methods. The calculation of the factor of safety against instability of a slope is done using one of the following methods: Bishop Simplified Method (applicable to circular shaped failure surfaces), Janbu Simplified Method (applicable to failure surfaces of general shape), and Spencer's Method (applicable to any type of surface). The Janbu Simplified Method has an option to use a correction factor, developed by Janbu, which can be applied to the factor of safety to reduce the conservatism produced by the assumption of no interslice forces.

PCSTABL features unique random techniques for generation of potential failure surfaces for subsequent determination of the more critical surfaces and their corresponding factors of safety. One technique generates circular; another, surfaces of sliding block character; and a third, more general irregular surfaces of random shape. The user can also specify specific trial failure surface.

For this study, PCSTABL5 was coupled with *STEDwin*, a pre- and post-processing program that simplifies data entry into the *PCSTABL5* program and improves the quality of graphical output diagrams.

C.4 *SAP2000*

SAP2000 is a powerful structural analysis software tool. Many types of analyses may be completed in SAP2000, including static, dynamic, linear and nonlinear seismic, P-Delta, and vehicle live loads for bridges. A wide variety of frame and shell structural sections may be used in modeling, including beam-columns, membranes, and plates. SAP2000 also offers multiple coordinate systems, a variety of joint constraints, many loading options, and capacity for very large structural models.

D. DETAILS OF SYNTHETIC GROUND MOTION

D.1 Task

The requirements are as follow:

Provide site-specific hard rock motions for two bridge sites in southeastern Missouri:

- St. Francis River Bridge (36.8°N, 90.2°W)
- Wahite Ditch Bridge (36.8°N, 89.7°W)

The rock motions are to be for annual probabilities of 2% probability of exceedance in 50 years, and 10% probability of exceedance in 50 years. The motions should consist of 5-horizontal and 5-vertical ground motions, considering both near-field and far-field earthquake events.

D.2. Overview of problem

The location of the two sites is shown in Figure D.4.1 together with neighboring earthquake locations for the time period 1974-1995. The St. Francis site is about 37 - 150 km from possible earthquakes in the active part of the current seismicity zone, while the Wahite Ditch is about 15 - 150 km from active seismicity.

In the preparation of the 1996 NEHRP maps, the USGS considered other possible locations obtained by moving the 'Z' seismicity pattern westward slightly to the edge of the ancient right and eastward to the eastern boundary. They then assigned weights of 1/3 to each of the three patterns.

D.3. Defining earthquakes

The USGS 1996 maps equally weighted two ground motion magnitude - distance relations: one based of the Toro and McGuire model for EPRI and the other a purely USGS model. The 1996 maps were generated for a nationwide NEHRP B-C soil condition boundary so that one could use the methodology in FEMA-273, for example, to adjust the mapped values to sites with other than the B-C soil condition in the upper 30 meters. The FEMA site adjustment factors are not applicable to these two bridges for two reasons: first, the surface soil conditions have shear-wave velocities closer to 150-200 m/sec (Paul Mayne and Glenn Rix, Georgia Tech, MAE Center research) and second, the soils are much deeper than 30 meters thick -- the depth to rock at the St. Francis and Wahite bridges site may be about 100 m and 200 m, respectively. Thus the ground motion values and the NEHRP site factors are not applicable to this study. The effect of the deep sediments on surface motions consists of two competing effects. The reduction of shear-wave going from the hard rock to the overlying soil introduces a site amplification that increases with frequency (basically amplitude increases as a wave propagates into a medium with lower impedance). This amplification is counteracted by a reduction in high frequency content due to intrinsic and scattering Q (damping) in the soil column. These effects are discussed in MAE

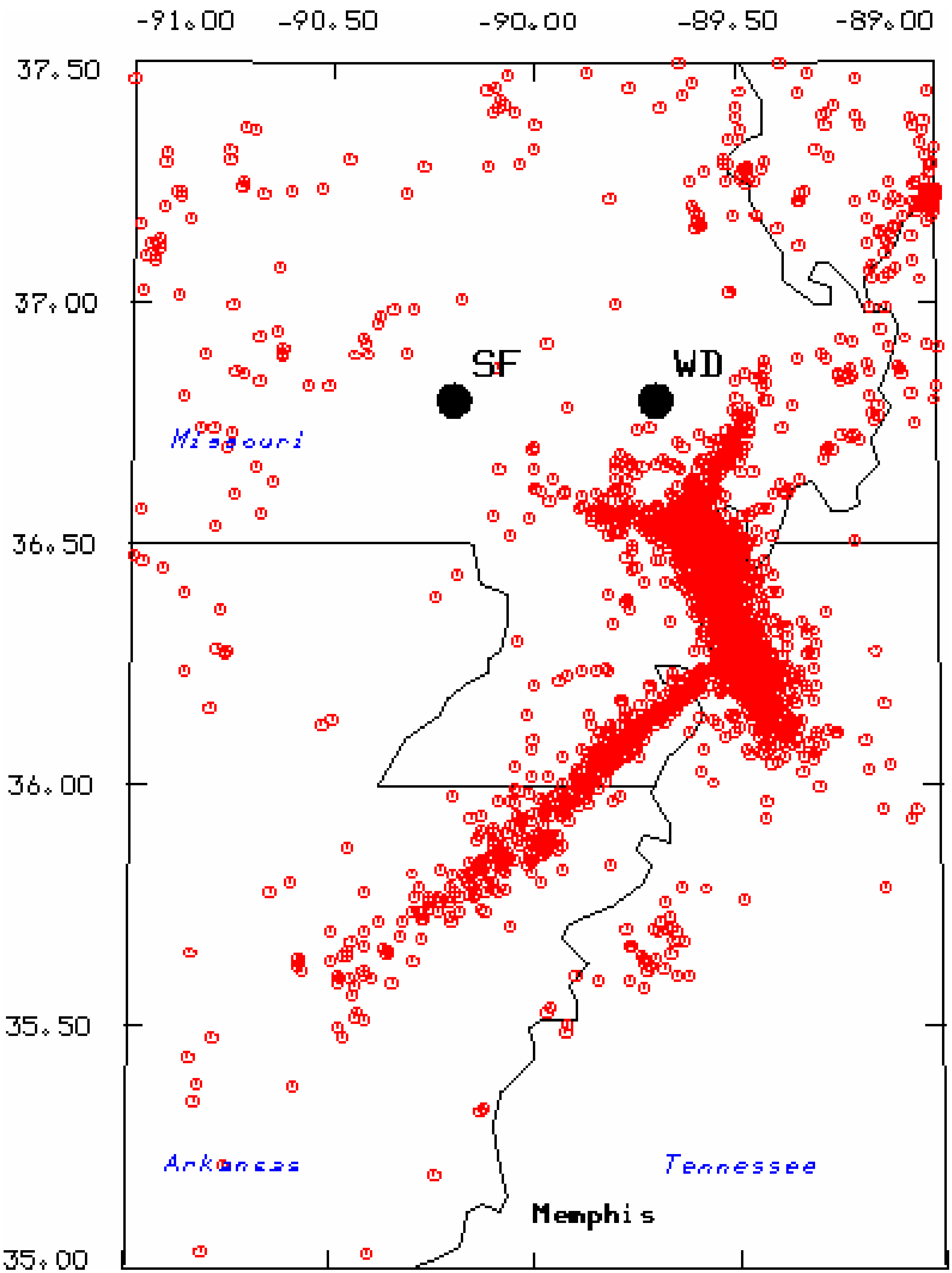


Fig. D.1 Seismicity in the 1974 - 1995 time period in the vicinity of the St. Francis River Site (SF) and the Wahite Ditch site (WD**)**

Center Ground Motion Models , Prototype CUS Hazard Maps , Prototype CUS Hazard Maps, Mmax effect , CUS Hazard Maps Project and FEMA Site Factors vs. Deep Soil . These studies used linear wave propagation theory to test the sensitivity of expected ground motions to the deep soil structure.

For site-specific studies, the effect of non-linear soil response must be considered though. The question is at what depth in a deep soil column, should one start using non-linear analysis. This is no easy response since fundamental experimental work must be done on the behavior of materials at the high confining pressures encountered at such depths. The Mid-America Earthquake Center is addressing this issue. It seems that linear motions can be propagated upward to about 100 - 200 meters depth, at which point non-linear analysis is required. Since the St. Francis and Wahite Bridge site soil sections are not excessively thick, standard non-linear or pseudo-non-linear analyses should be performed. However, the shear-wave velocity profile should be similar to that available from (MAEC GT-1 Deep Soil Model). In addition the non-linear analysis should have a low-strain damping floor of about 2.5% (Q=20).

To provide suitable time series, we start with the USGS 1996seismic hazard maps. By entering a latitude and longitude at the USGS - National Seismic Hazard Mapping Project , I obtained the following results:

Table D.1 Time Series for Study Sites

	10 % PE in 50 Year (%g)	**2 % PE in 50 Year (%g)**
St. Francis River		
PGA	15.83	64.32
0.2 sec SA	31.37	125.21
0.3 sec SA	24.01	105.10
1.0 sec SA	7.72	37.92
Wahite Ditch		
PGA	19.62	134.33
0.2 sec SA	38.17	275.53
0.3 sec SA	27.56	226.43
1.0 sec SA	18.68	89.11

The excess precision is the table is not meaningful, though. The next step is to find a suite of distances and magnitudes that provide these values. This is easy to do by a table lookup of the ground motion parameter as a function of magnitude and distance (the USGS ground motion model enters into the hazard analysis code by a table lookup) ; one need only search through this table for the best fit to these surface B-C mapped values. Performing this exercise, the following are acceptable combinations:

These magnitudes and distances will not be used to generate time series for each site and probability. To accomplish this, I use the band-limited Gaussian white noise technique of Boore (1922) (see CUS ground motion page for links to D. Boore's programs). Specifically I use the program dorvt180 and td_drvr together with auxiliary programs for display. I also use the CUS deep soil ground motion model with F96 (USGS96 source scaling) given on the CUS ground motion web page, with a soil thickness of 0 meters. Because the CUS model includes 1 km of Paleozoic layers, there is as light frequency dependent site amplification. The model uses recently determined, CUS specific, crustal wave propagation from the source to the site.

Table D.2 Magnitude and Distance for Design Earthquakes

a. St. Francis River Site

Probably Exceedance	Magnitude Mw	Distance, R (km)
10 % in 50 years	6.2	40
10 % in 50 years	7.2	100
2 % in 50 years	6.4	10
2 % in 50 years	8.0	40

b. Wahite Ditch Site

Probably Exceedance	Magnitude Mw	Distance, R (km)
10 % in 50 years	6.4	40
10 % in 50 years	7.0	65
2 % in 50 years	7.8	16
2 % in 50 years	8.0	20

For a given moment magnitude and distance, I first choose a random number seed and then perform 100 time domain simulations, saving the mean response spectra.

Next I perform one time domain simulation for each of five random number seeds. I examine the resultant time series by computing the corresponding response spectra to the mean of 100 simulations. If the comparison is good, then this time series is saved. The results for all the simulations are contained in the following table. The plot presents the time series acceleration, velocity and displacement time histories, the realized and target pseudo-acceleration, the Fourier acceleration spectra form the trace and an indicator of the magnitude, distance and random number seed. By clicking on the table the individual time series is presented.

Table D.3 St. Francis River Site 10 % Probability of Exceedance in 50 Years

M	DIST	SEED	Graph	Name
6.2	40	1234	Fig. D.2a	SF100101
6.2	40	2345	Fig. D.2b	SF100102
6.2	40	123	Fig. D.2c	SF100103
6.2	40	345	Fig. D.2d	SF100104
6.2	40	78	Fig. D.2e	SF100105
7.2	100	1234	Fig. D.3a	SF100201
7.2	100	2345	Fig. D.3b	SF100202
7.2	100	123	Fig. D.3c	SF100203
7.2	100	345	Fig. D.3d	SF100204
7.2	100	78	Fig. D.3e	SF100205

Table D.4 St. Francis River Site 2 % Probability of Exceedance in 50 Years

M	DIST	SEED	Graph	Name
6.4	10	1234	Fig. D.4a	SF020101
6.4	10	2345	Fig. D.4b	SF020102
6.4	10	123	Fig. D.4c	SF020103
6.4	10	345	Fig. D.4d	SF020104
6.4	10	78	Fig. D.4e	SF020105
8.0	40	1234	Fig. D.5a	SF020201
8.0	40	2345	Fig. D.5b	SF020202
8.0	40	123	Fig. D.5c	SF020203
8.0	40	345	Fig. D.5d	SF020204
8.0	40	78	Fig. D.5e	SF020205

Table D.5 Wahite Ditch Site 10% Probability of Exceedance in 50 Years

M	DIST	SEED	Graph	Name
6.4	40	1234	Fig. D.6a	WD100101
6.4	40	2345	Fig. D.6b	WD100102
6.4	40	123	Fig. D.6c	WD100103
6.4	40	345	Fig. D.6d	WD100104
6.4	40	78	Fig. D.6e	WD00105
7.0	65	1234	Fig. D.7a	WD100201
7.0	65	2345	Fig. D.7b	WD100202
7.0	65	123	Fig. D.7c	WD100203
7.0	65	345	Fig. D.7d	WD100204
7.0	65	78	Fig. D.7e	WD100205

Table D.6 Wahite Ditch Site 2% Probability of Exceedance in 50 Years

M	DIST	SEED	Graph	Name
7.8	16	1234	Fig. D.8a	WD020101
7.8	16	2345	Fig. D.8b	WD020102
7.8	16	123	Fig. D.8c	WD020103
7.8	16	345	Fig. D.8d	WD020104
7.8	16	78	Fig. D.8e	WD020105
8.0	20	1234	Fig. D.9a	WD020201
8.0	20	2345	Fig. D.9b	WD020202
8.0	20	123	Fig. D.9c	WD020203
8.0	20	345	Fig. D.9d	WD020204
8.0	20	78	Fig. D.9e	WD020205

Time series file format. An example of the first few lines of one time series file is

```
Acceleration acc.in
16384    0.0050
 -0.89331E-08  -0.53218E-08  -0.78847E-08  -0.95266E-09  -0.45549E-08
  0.18960E-08   0.13551E-10   0.41705E-08   0.30585E-08   0.75637E-08
  0.43945E-08   0.89134E-08   0.61092E-08   0.10998E-07   0.10490E-07
  0.14416E-07   0.12970E-07   0.16878E-07   0.16777E-07   0.20852E-07
  0.19644E-07   0.23510E-07   0.20594E-07   0.24264E-07   0.22504E-07
```

The first line is a comment line, which is the same for all simulations. The second line gives the number of data points (16384) and the sample interval (0.005 sec). The acceleration time series (units of g) follow on the succeeding lines. The reason for the long time series is that large earthquakes have long duration because of the total time of faulting.

D.4 Discussion

I have not presented vertical component time histories. I believe I know how to do this for the deep soil soils for which the surface vertical component motion in the shear-wave window is actually caused by the shear-wave in the hard rock converted into a P wave at the rock sediment interface. For motion on hard rock, though, the vertical motion is only slightly less than the horizontal. So use the horizontal motion for the vertical. The major site modifier is the deep soil condition.

The simulations have not addressed any issues of coherency of ground motion, since the bridges are not very long in comparison to a seismic wavelength for the propagating wave (4000 meters/sec x period).

Prof. Robert Herrmann
Professor of St. Louis University
St. Louis (MO)

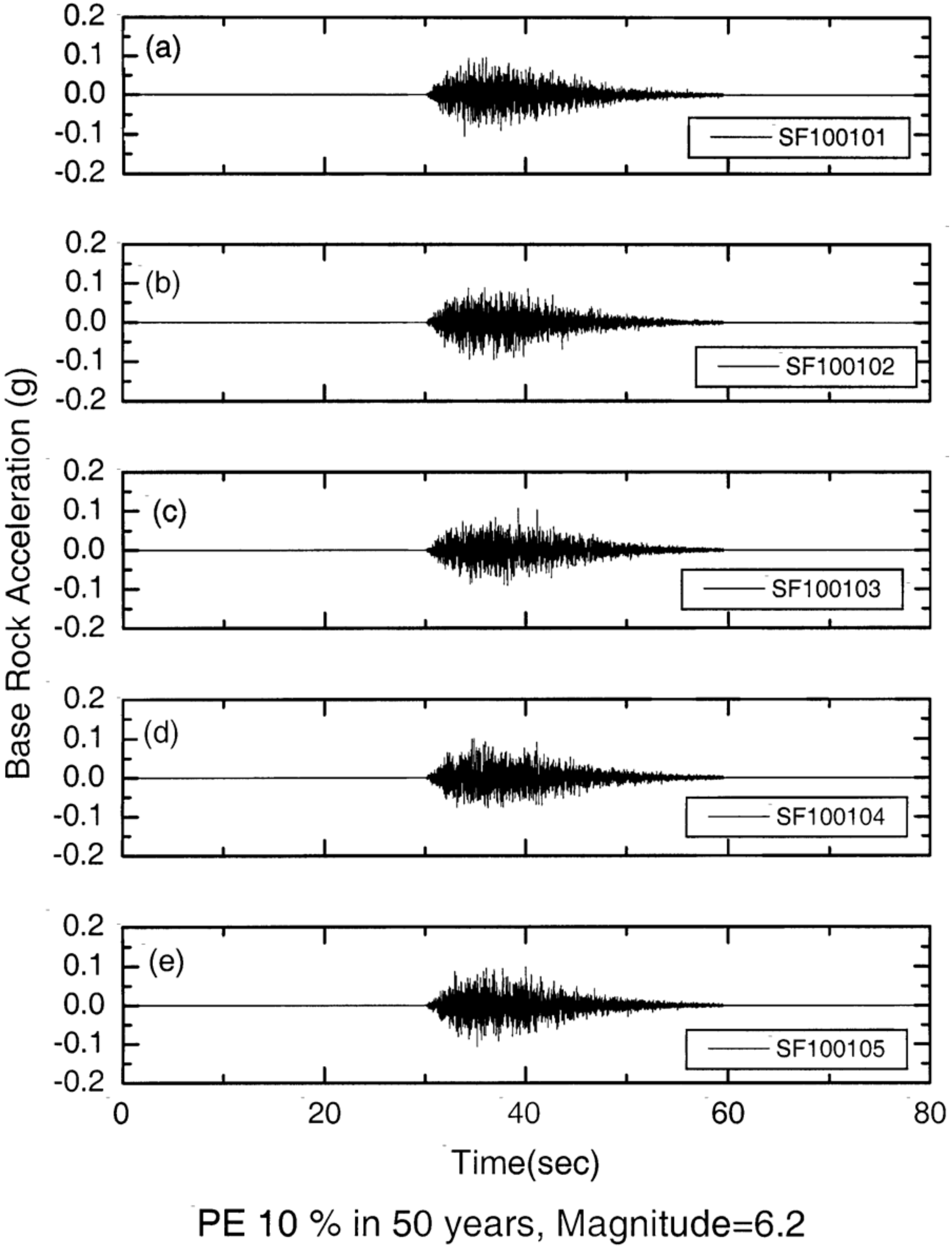


Figure D.2 Acceleration Time Histories for St. Francis River Site, PE 10% in 50 Years M=6.2

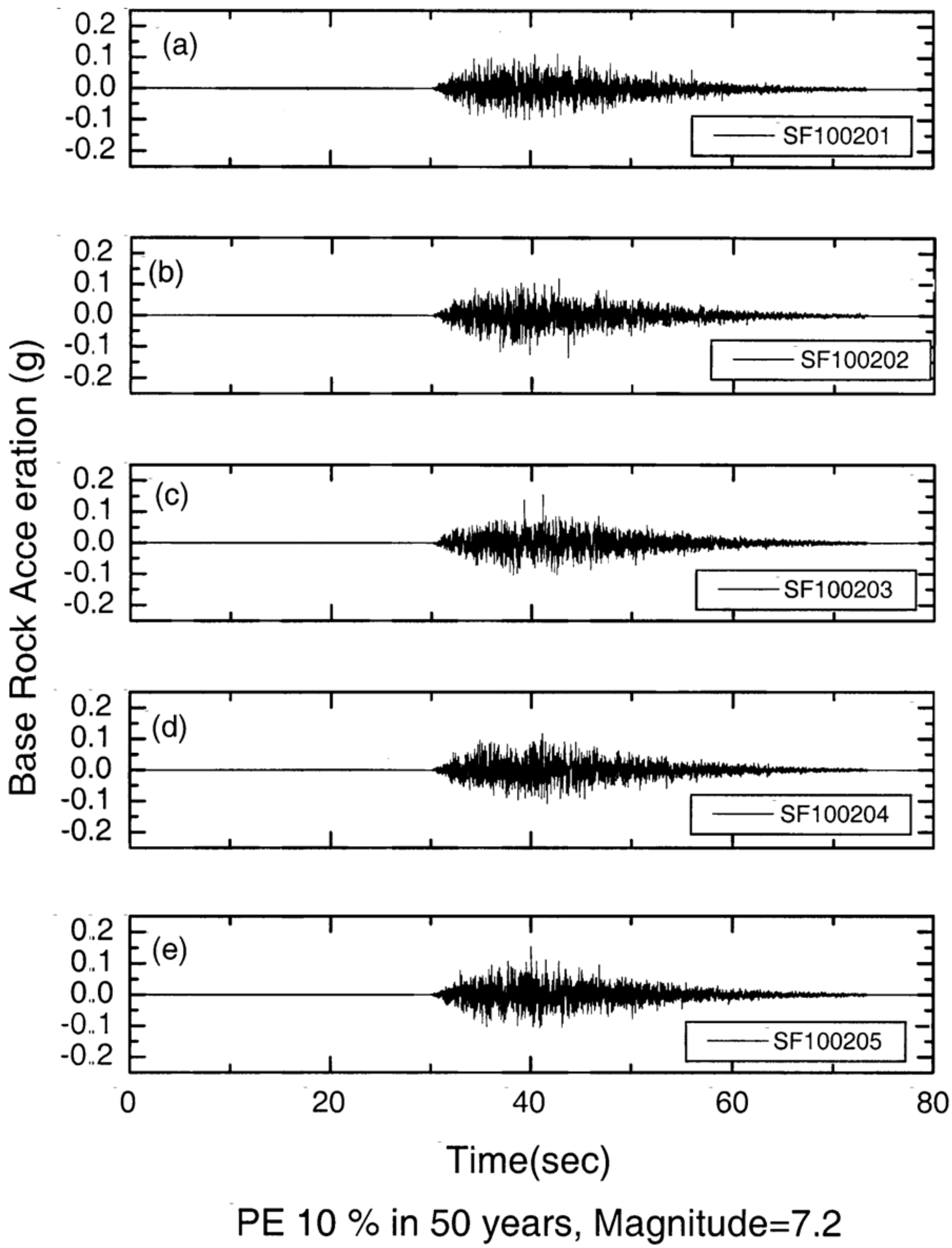


Figure D.3 Acceleration Time Histories for St. Francis River Site, PE 10% in 50 Years M=7.2

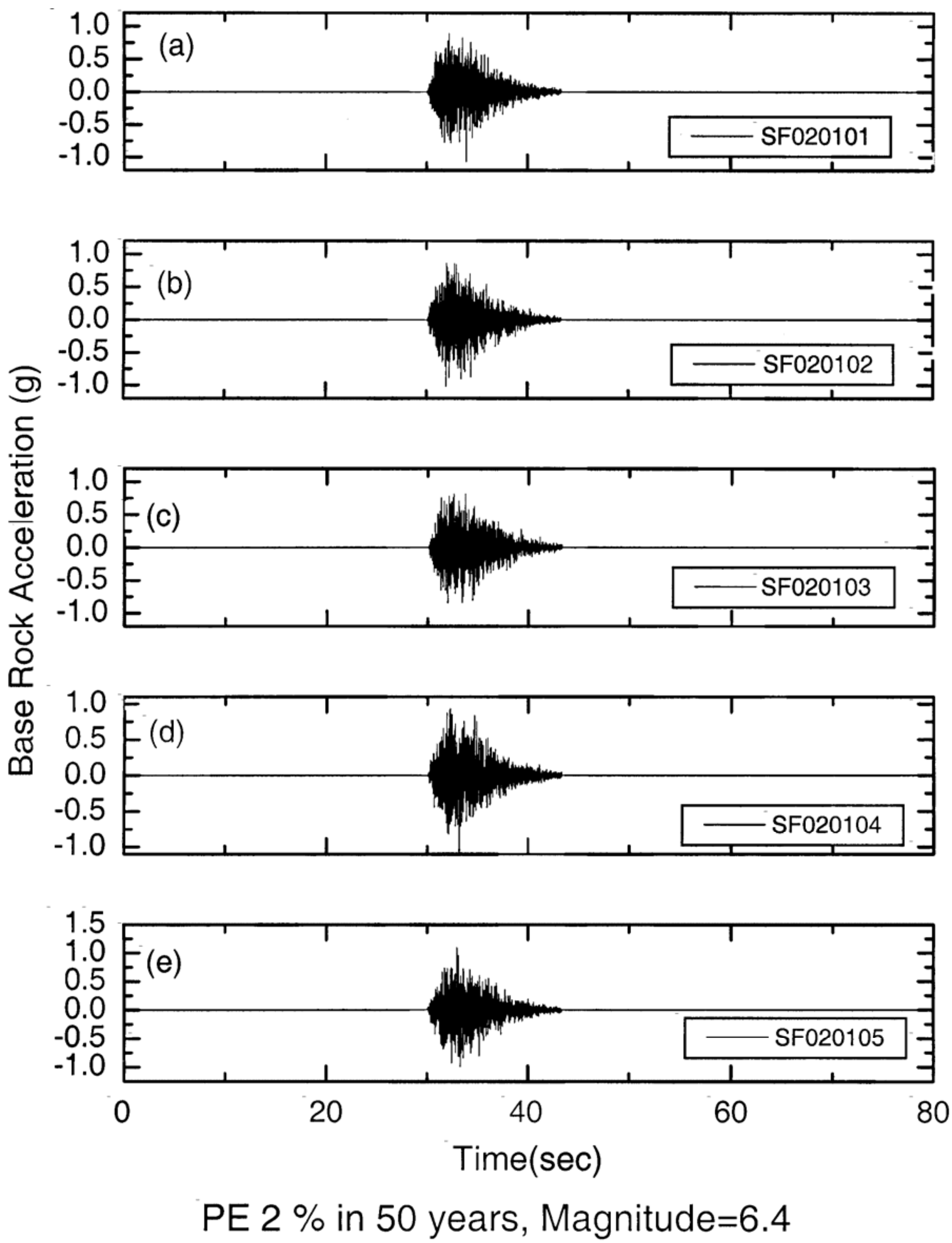


Figure D.4 Acceleration Time Histories for St. Francis River Site, PE 2% in 50 Years M=6.4

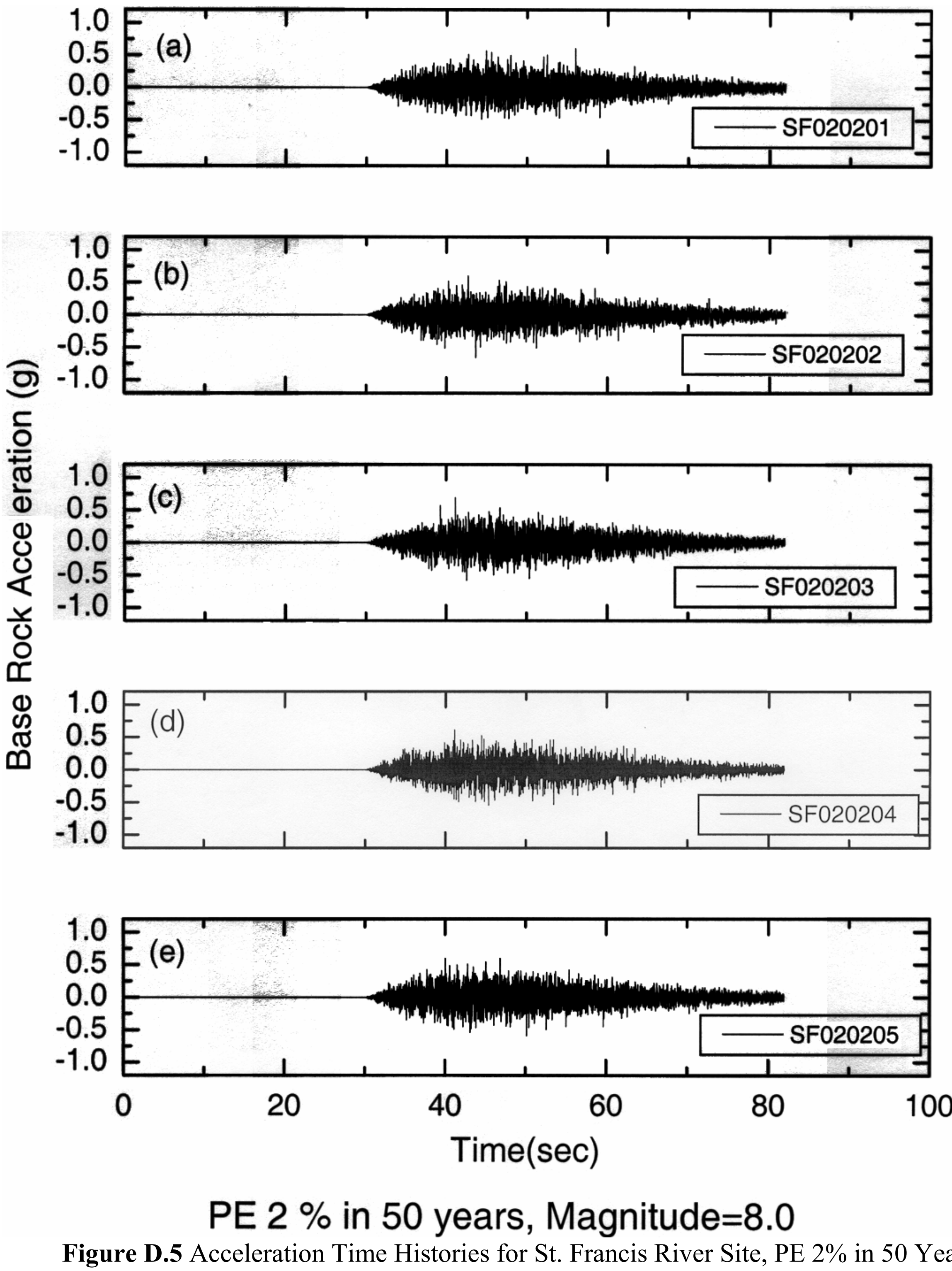


Figure D.5 Acceleration Time Histories for St. Francis River Site, PE 2% in 50 Years M=8.0

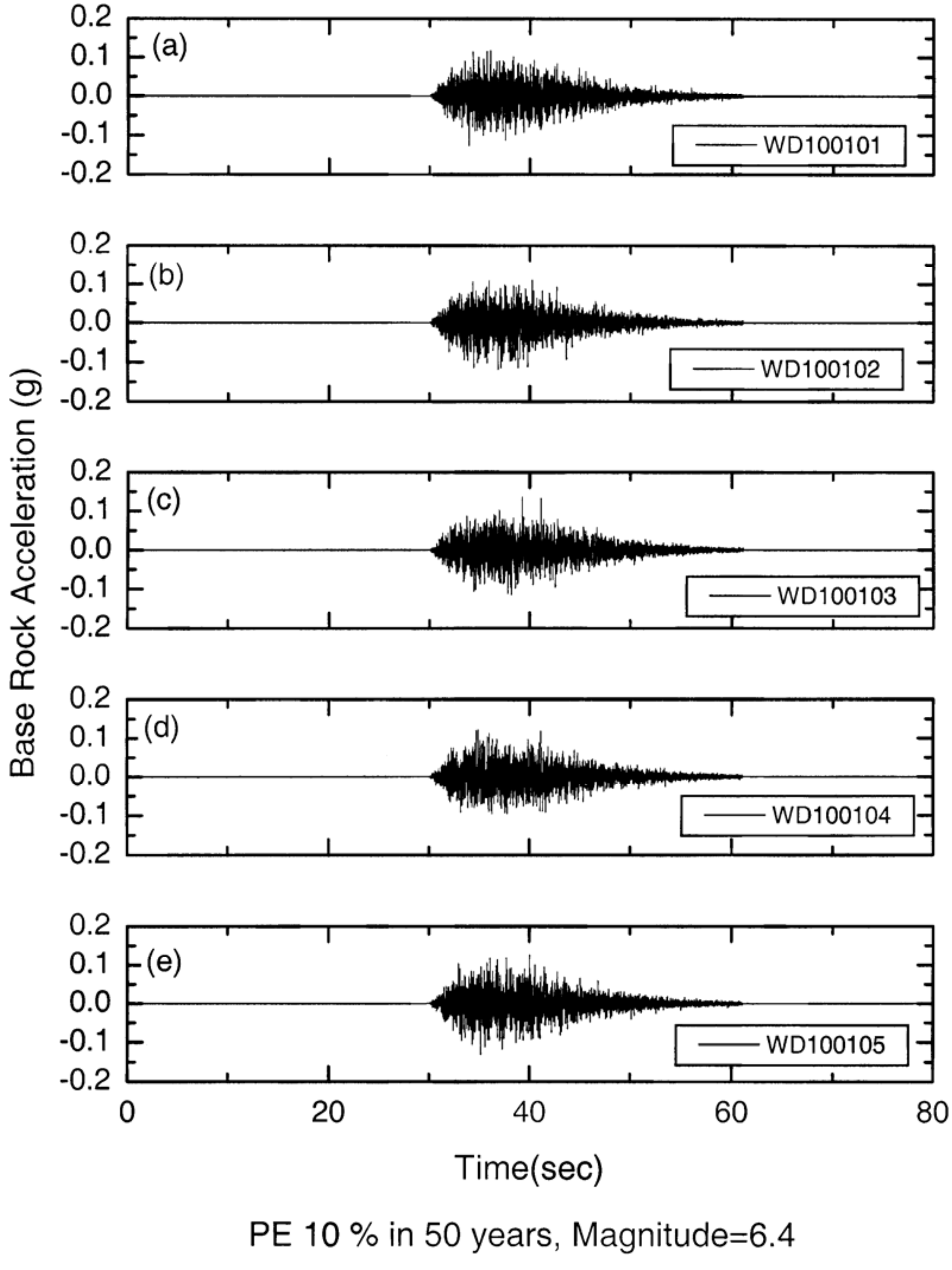


Figure D.6 Acceleration Time Histories for St. Francis River Site, PE 10% in 50 Years M=6.4

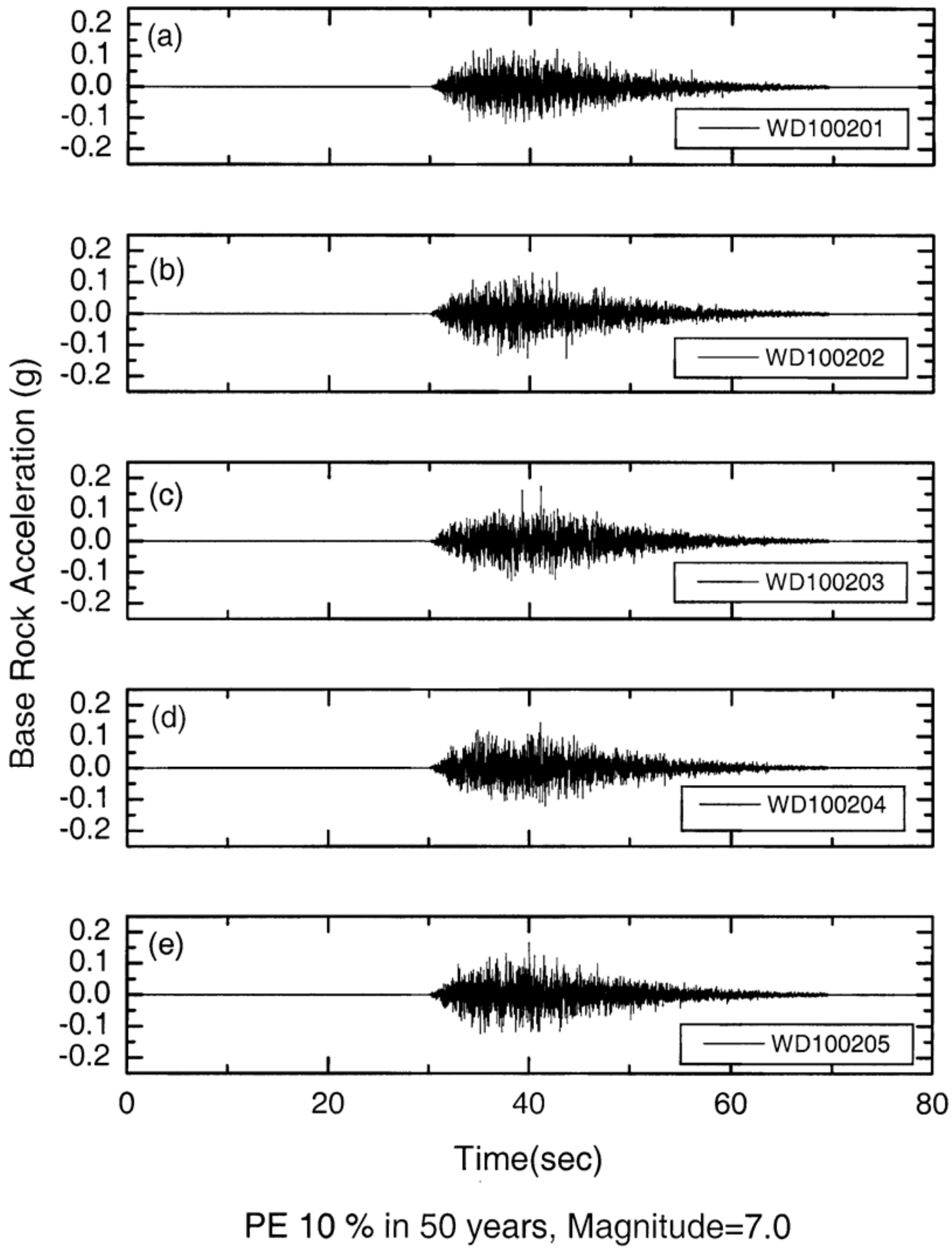


Figure D.7 Acceleration Time Histories for St. Francis River Site, PE 2% in 50 Years M=7.0

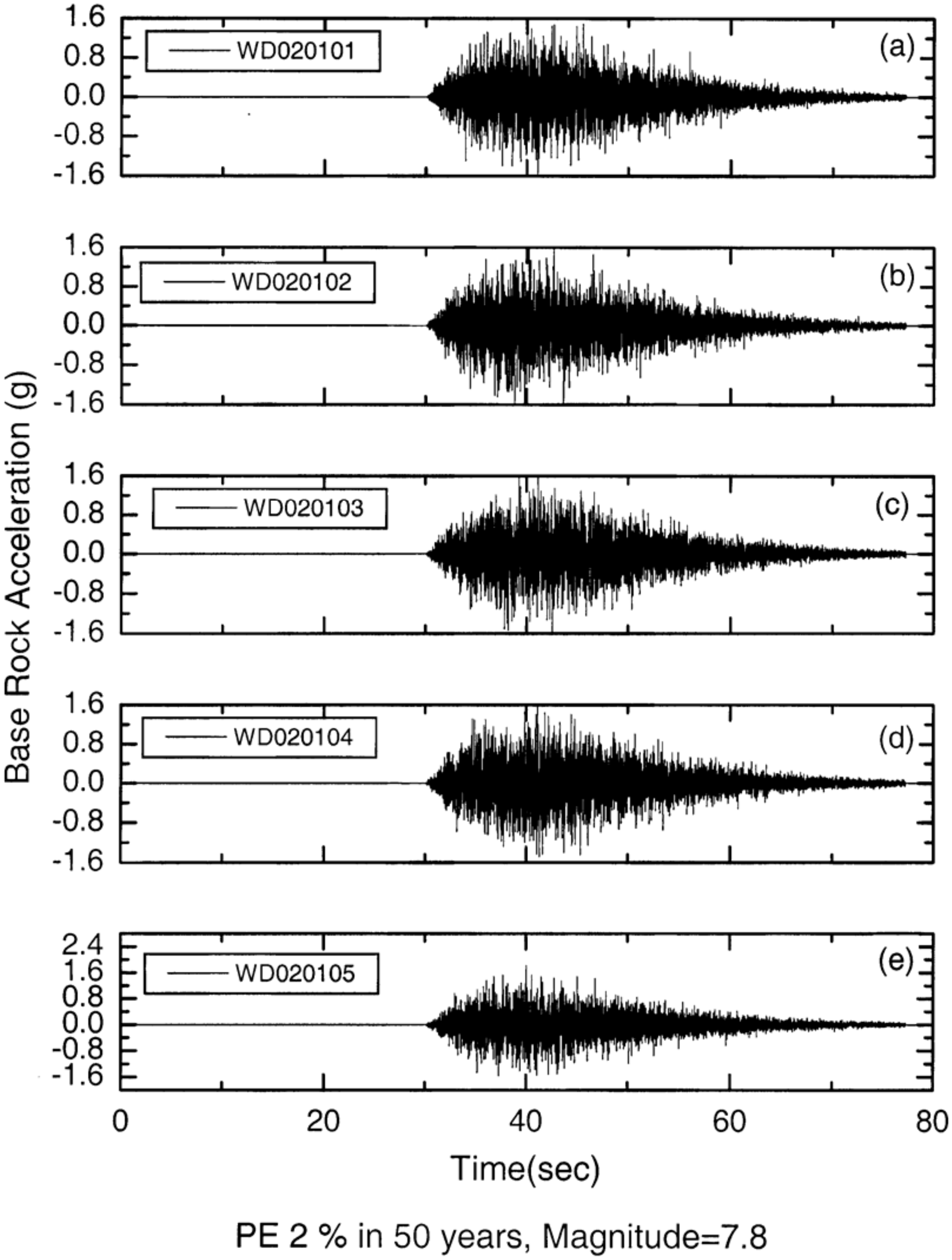


Figure D.8 Acceleration Time Histories for St. Francis River Site, PE 2% in 50 Years M=7.8

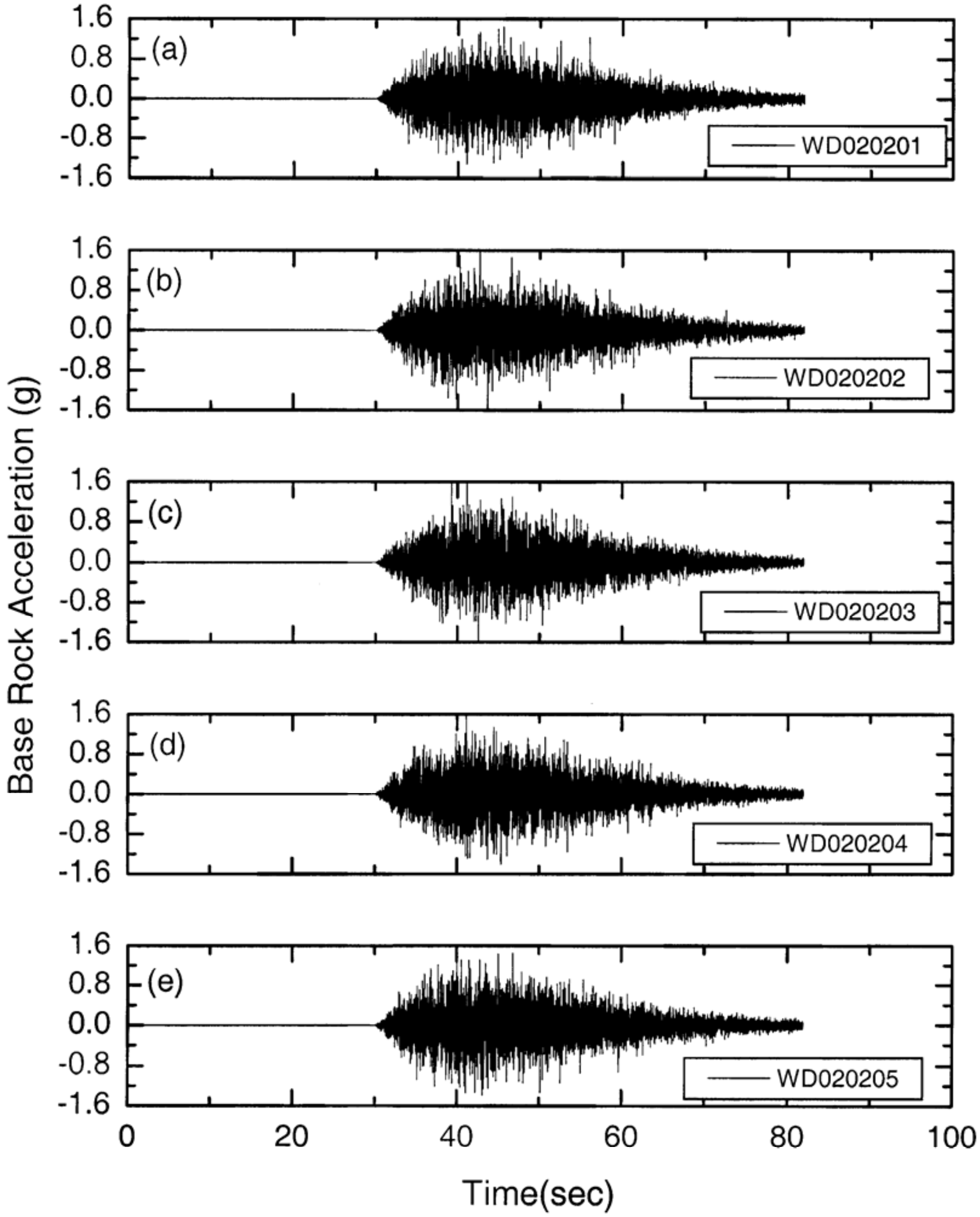
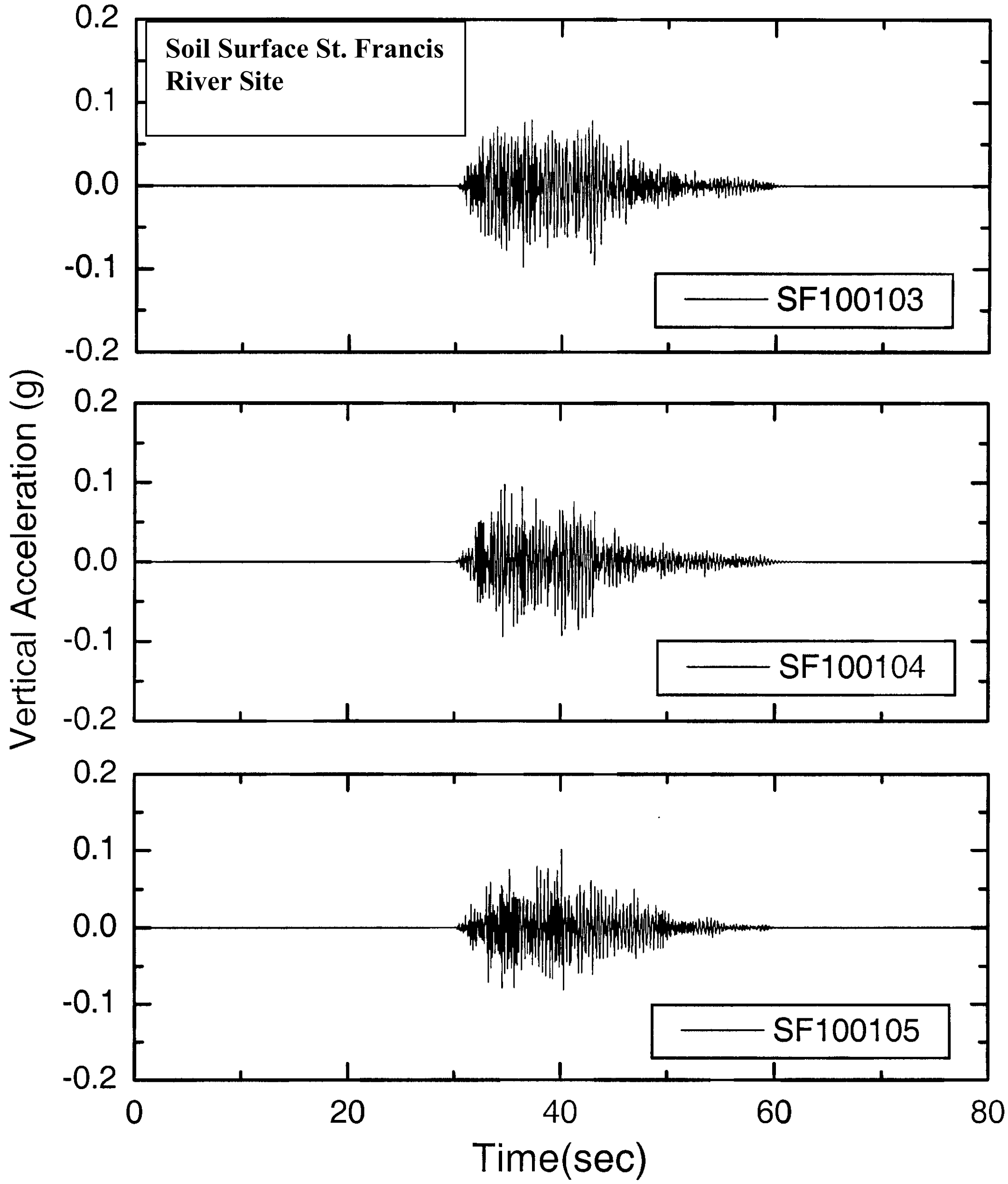


Figure D.9 Acceleration Time Histories for St. Francis River Site, PE 2% in 50 Years M=8.0



a. PE 10 % in 50 years, Magnitude = 6.2

Figure D.10a Time histories vertical acceleration at the soil surface of the St. Francis River Site, PE 10 % in 50 years, Magnitude=6.2

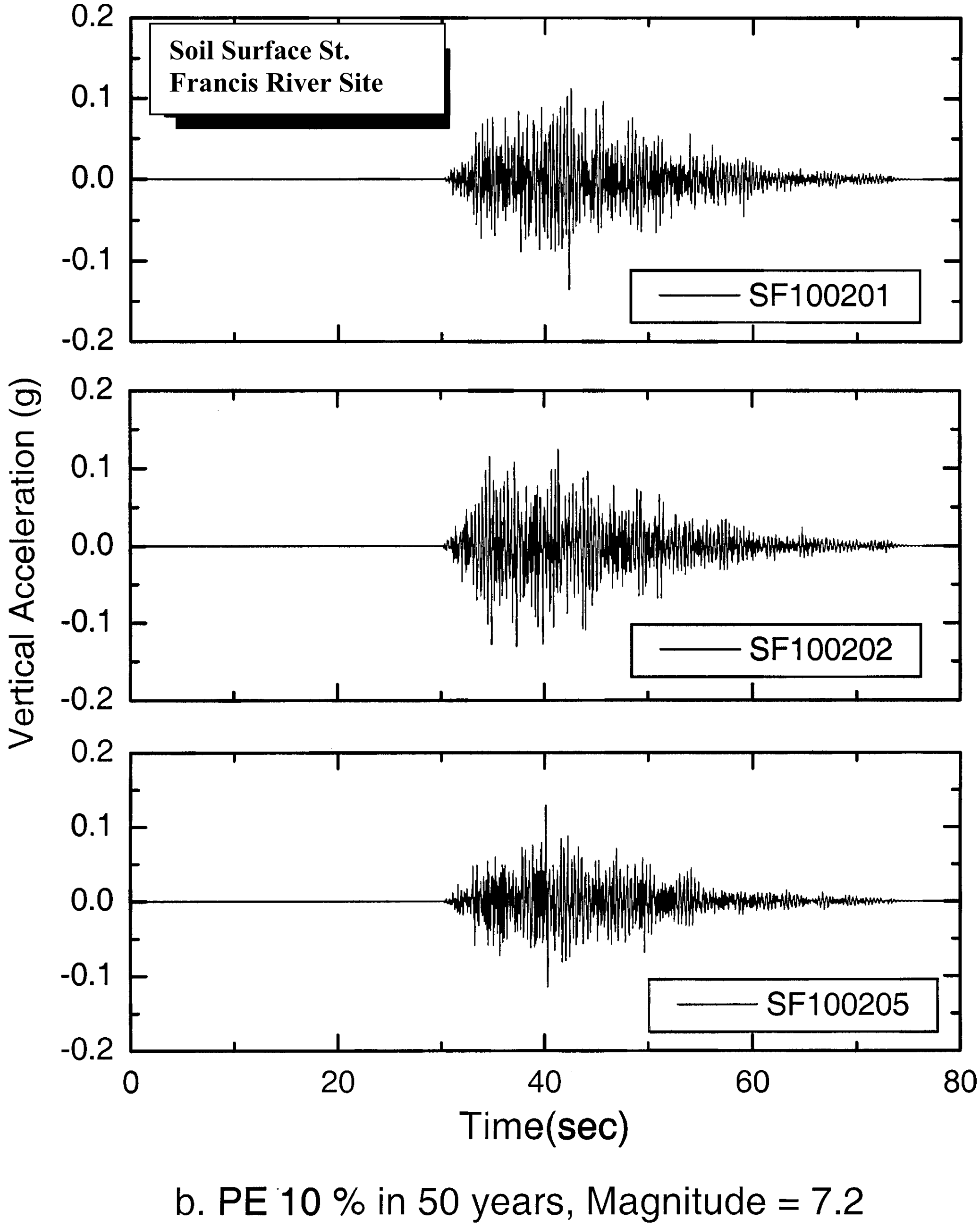
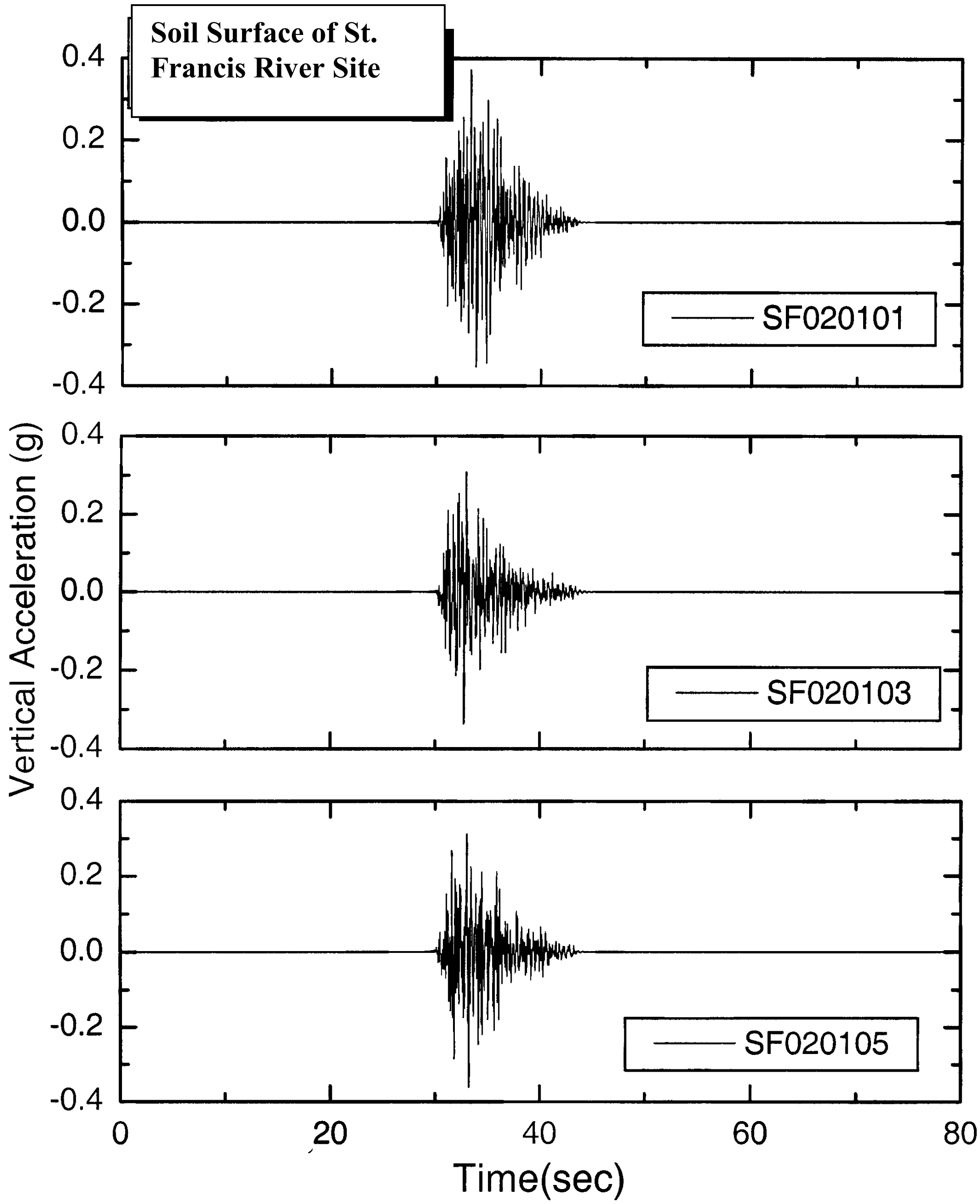
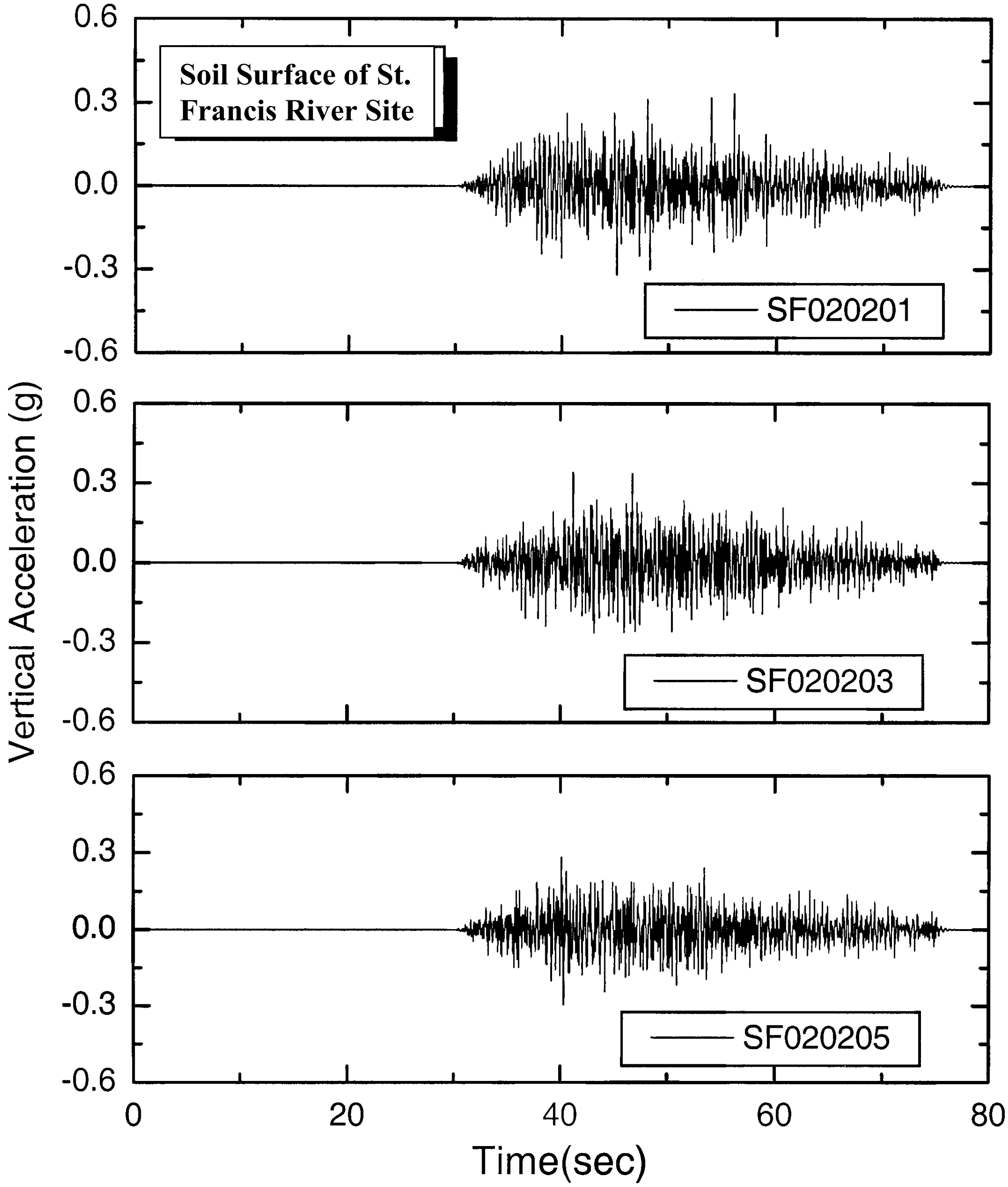


Figure D.10b Time Histories Vertical Acceleration at the Soil Surface of the St. Francis River Site, PE 10 % in 50 years, Magnitude=7.2



c. PE 2 % in 50 years, Magnitude = 6.4

Figure D.10c Time histories vertical acceleration at the soil surface of the St. Francis River Site, PE 10 % in 50 years, Magnitude=6.4



d. PE 2 % in 50 years, Magnitude = 8.0

Figure D.10d Time histories vertical acceleration at the soil surface of the St. Francis River Site, PE 10 % in 50 years, Magnitude=8.0

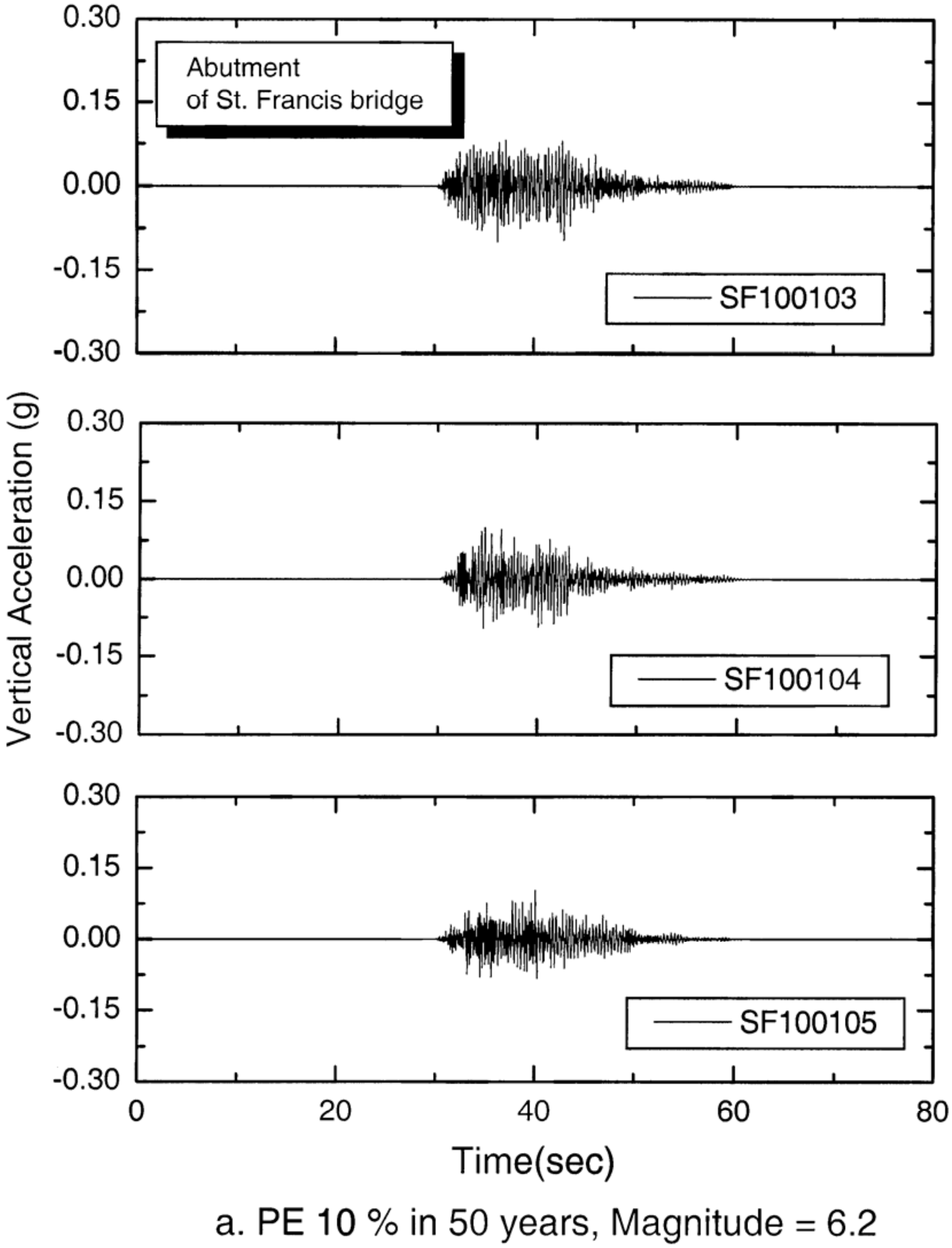


Figure D.11a Time histories vertical acceleration at the bridge abutment of the St. Francis River Bridge, PE 10 % in 50 years, Magnitude=6.2

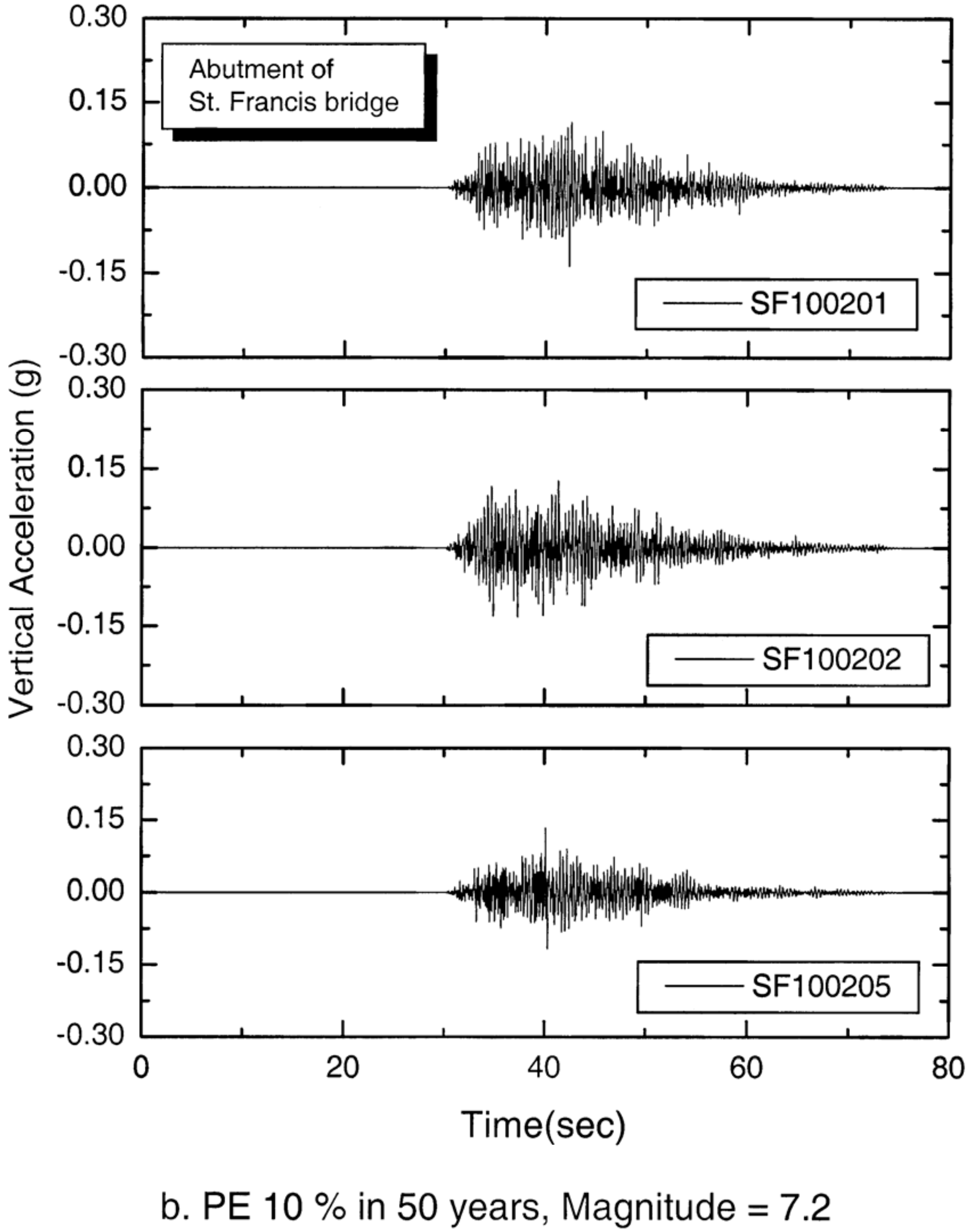


Figure D.11b Time histories vertical acceleration at the bridge abutment of the St. Francis River Bridge, PE 10 % in 50 years, Magnitude=7.2

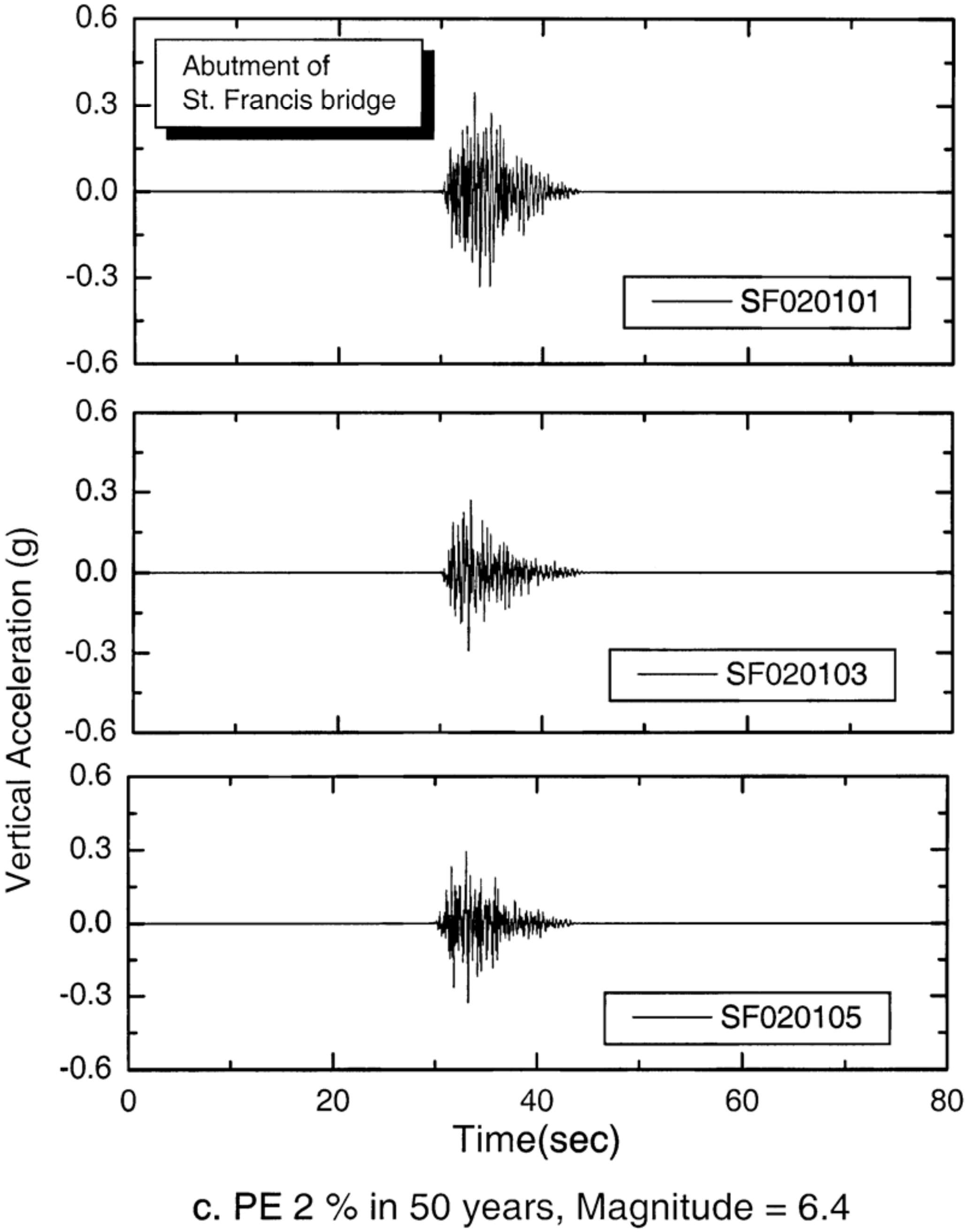


Figure D.11c Time histories vertical acceleration at the bridge abutment of the St. Francis River Bridge, PE 10 % in 50 years, Magnitude=6.4

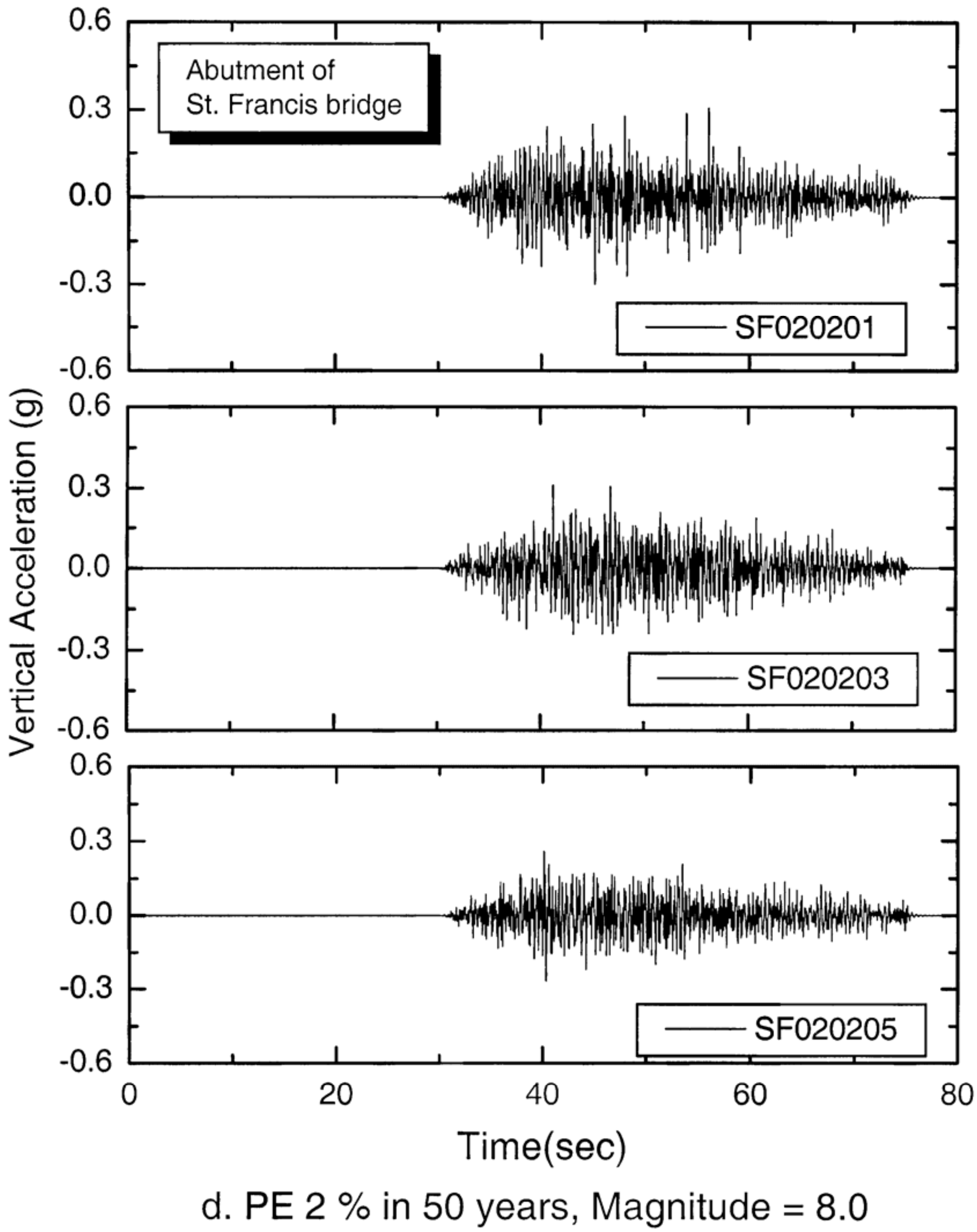


Figure D.11d Time histories vertical acceleration at the bridge abutment of the St. Francis River Bridge, PE 10 % in 50 years, Magnitude=8.0

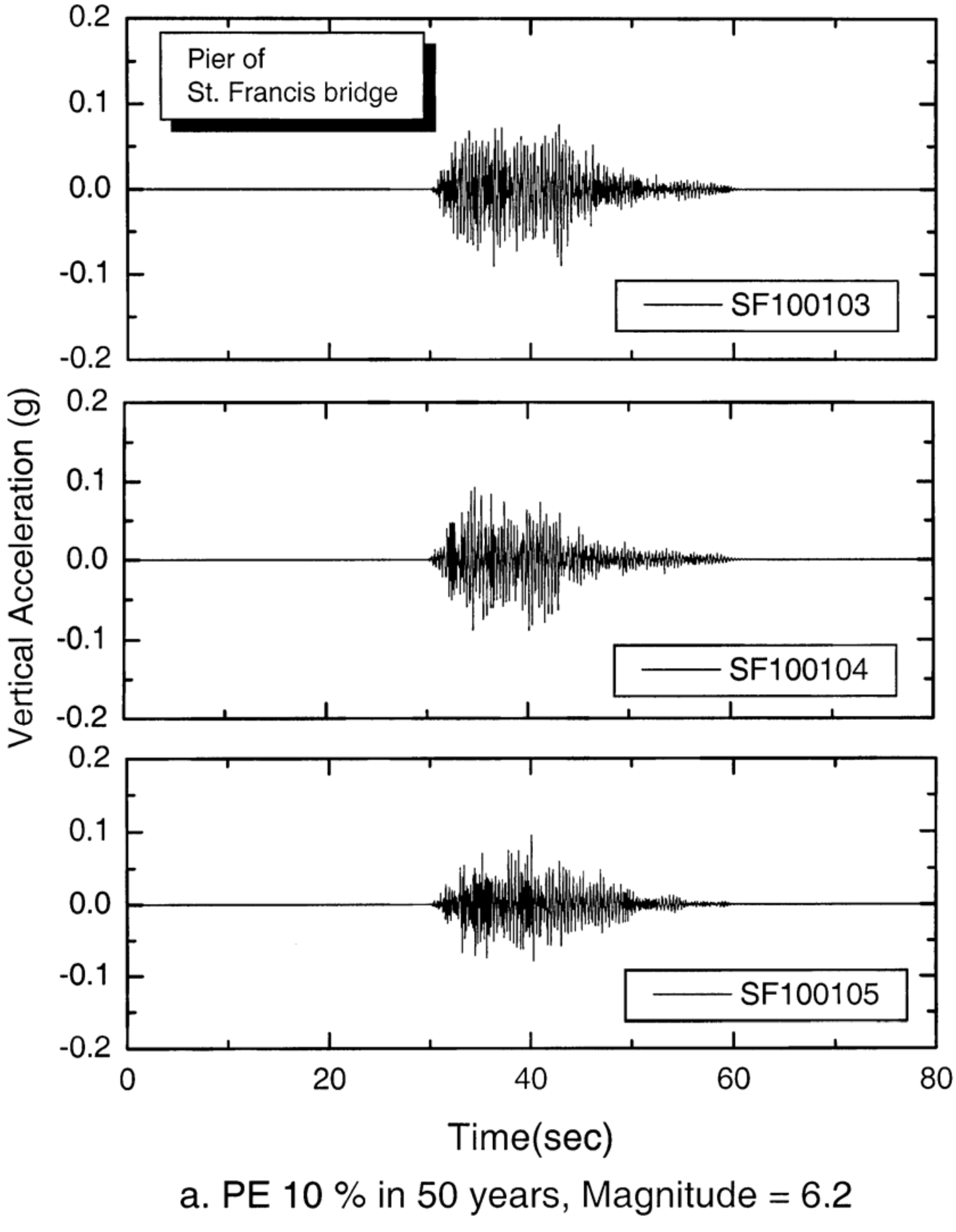


Figure D.12a Time Histories Vertical Acceleration at the Bridge Pier, St. Francis River Bridge, PE 10 % in 50 years, Magnitude=6.2

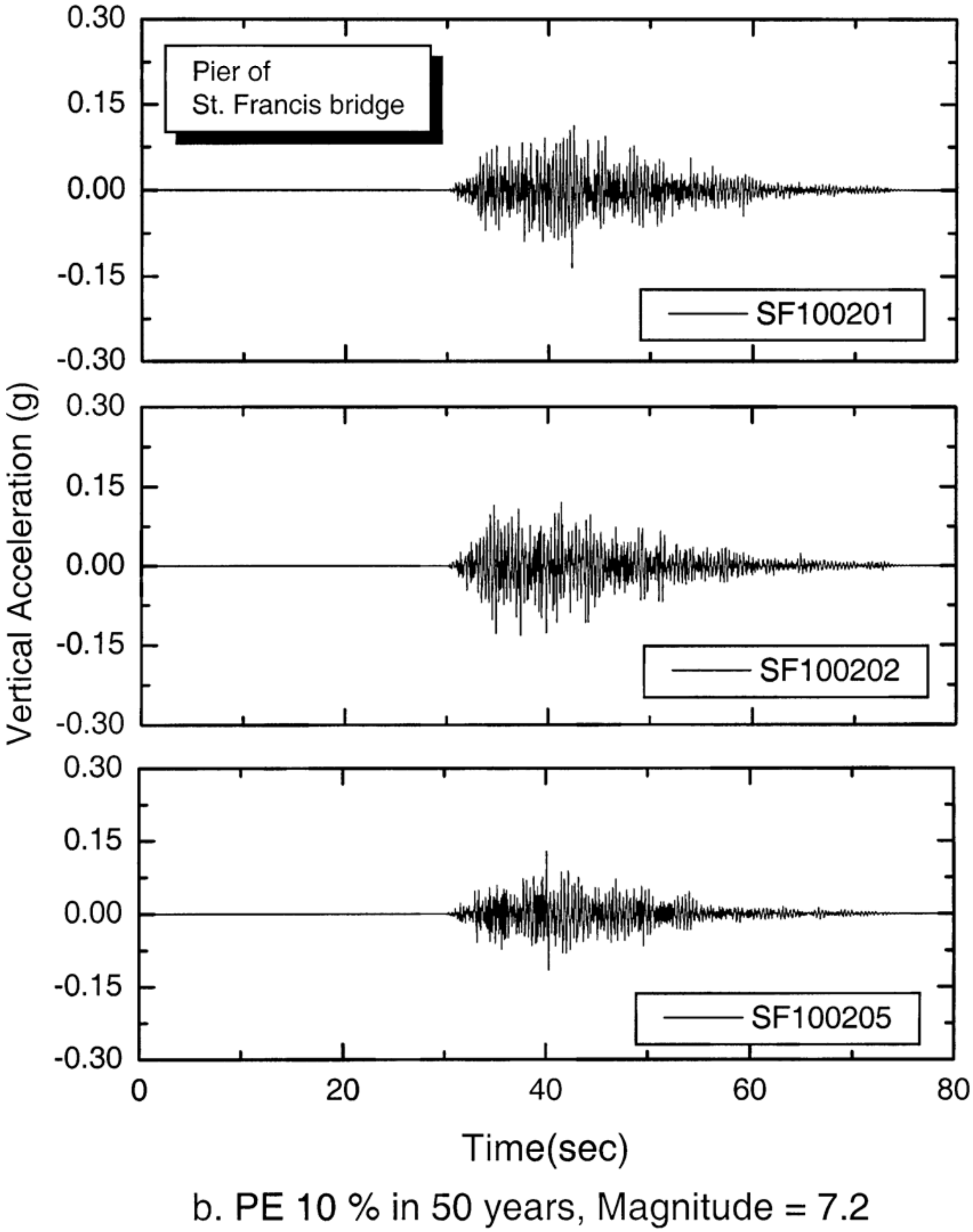
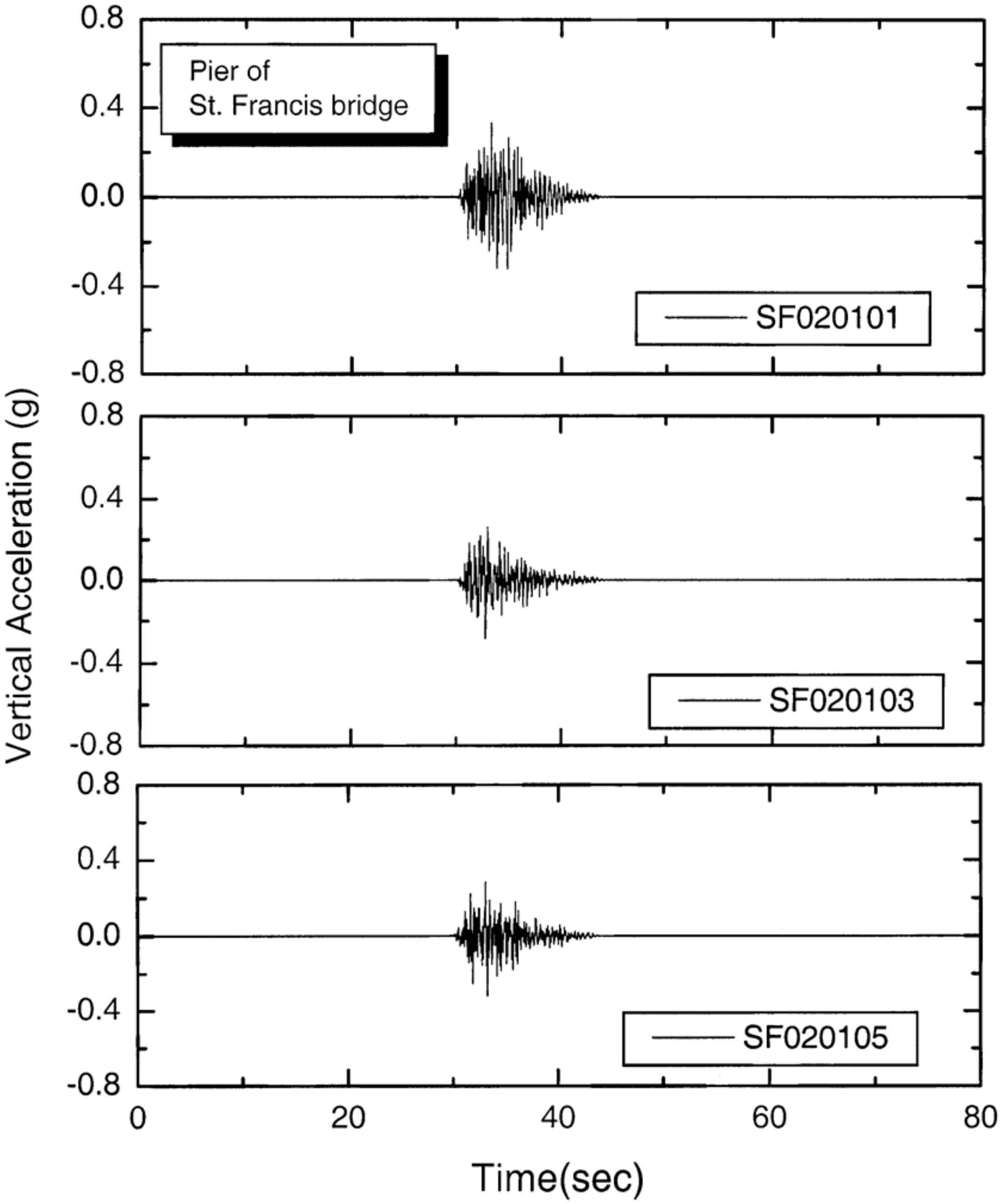
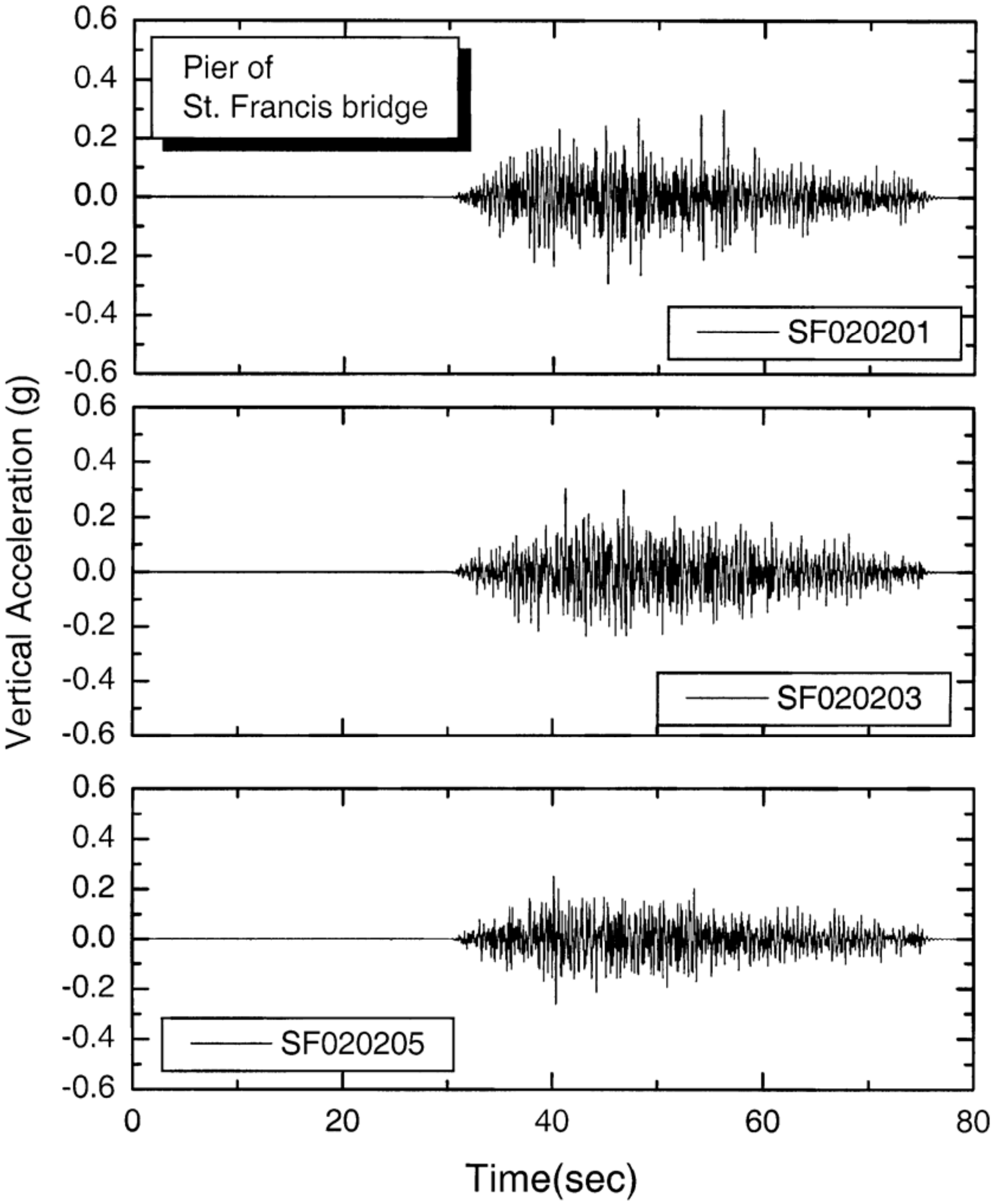


Figure D.12b Time Histories Vertical Acceleration at the Bridge Pier, St. Francis River Bridge, PE 10 % in 50 years, Magnitude=7.2



c. PE 2 % in 50 years, Magnitude = 6.4

Figure D.12c Time Histories Vertical Acceleration at the Bridge Pier, St. Francis River Bridge, PE 2 % in 50 years, Magnitude=6.4



d. PE 2 % in 50 years, Magnitude = 8.0

Figure D.12d Time Histories Vertical Acceleration at the Bridge Pier, St. Francis River Bridge, PE 2 % in 50 years, Magnitude=8.0

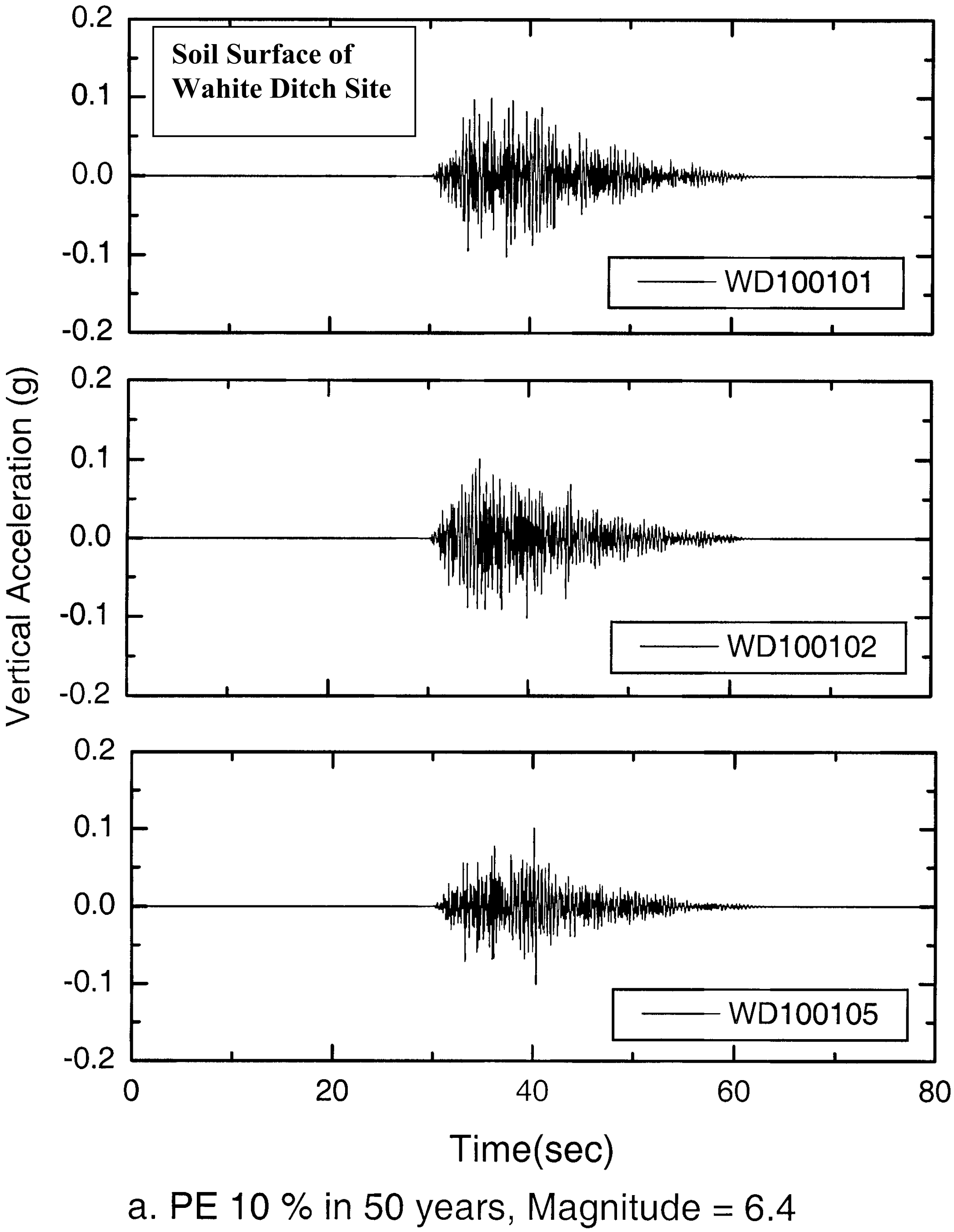
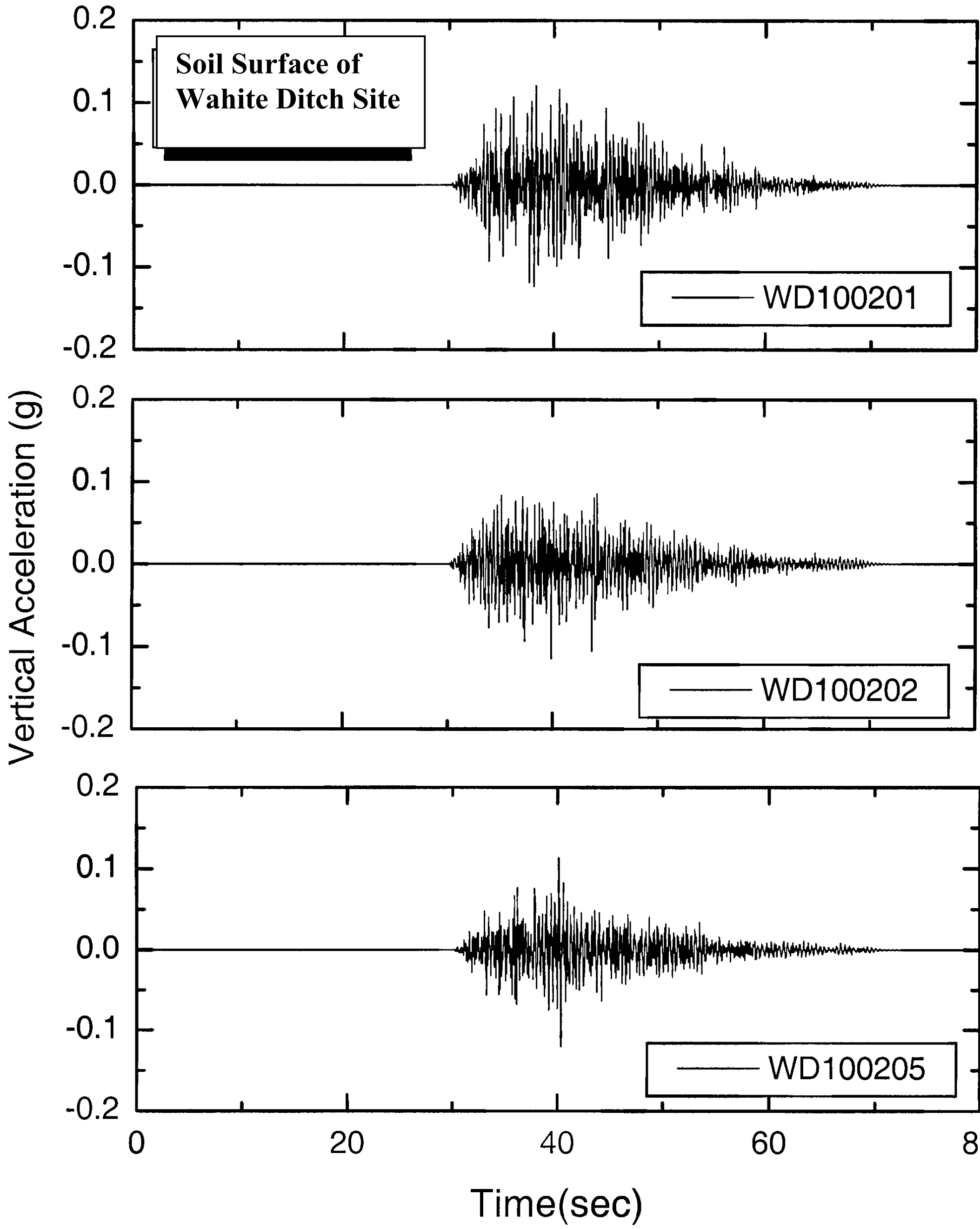
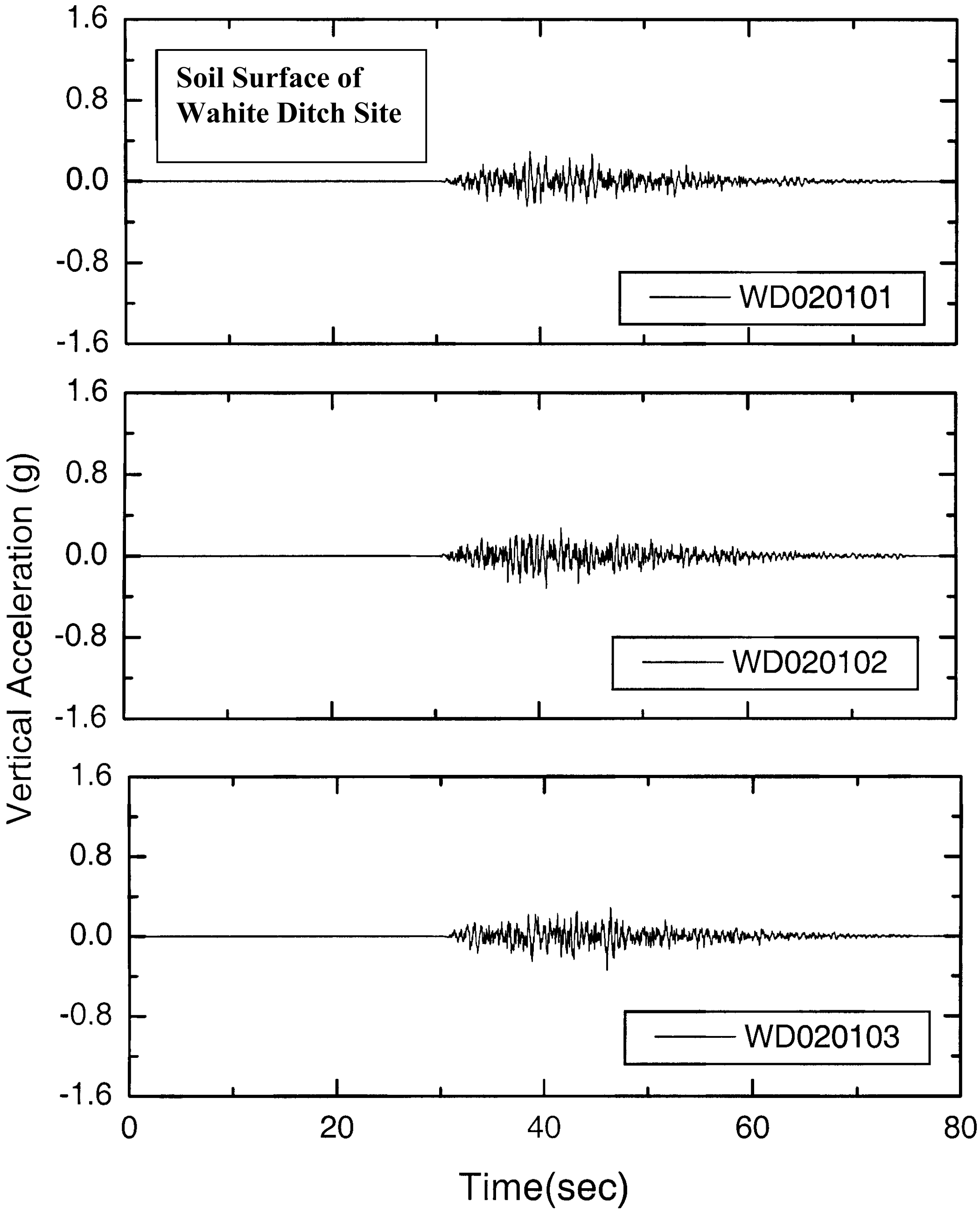


Figure D.13a Time Histories Vertical Acceleration at the Soil Surface, Wahite Ditch Site, PE 10 % in 50 years, Magnitude=6.4



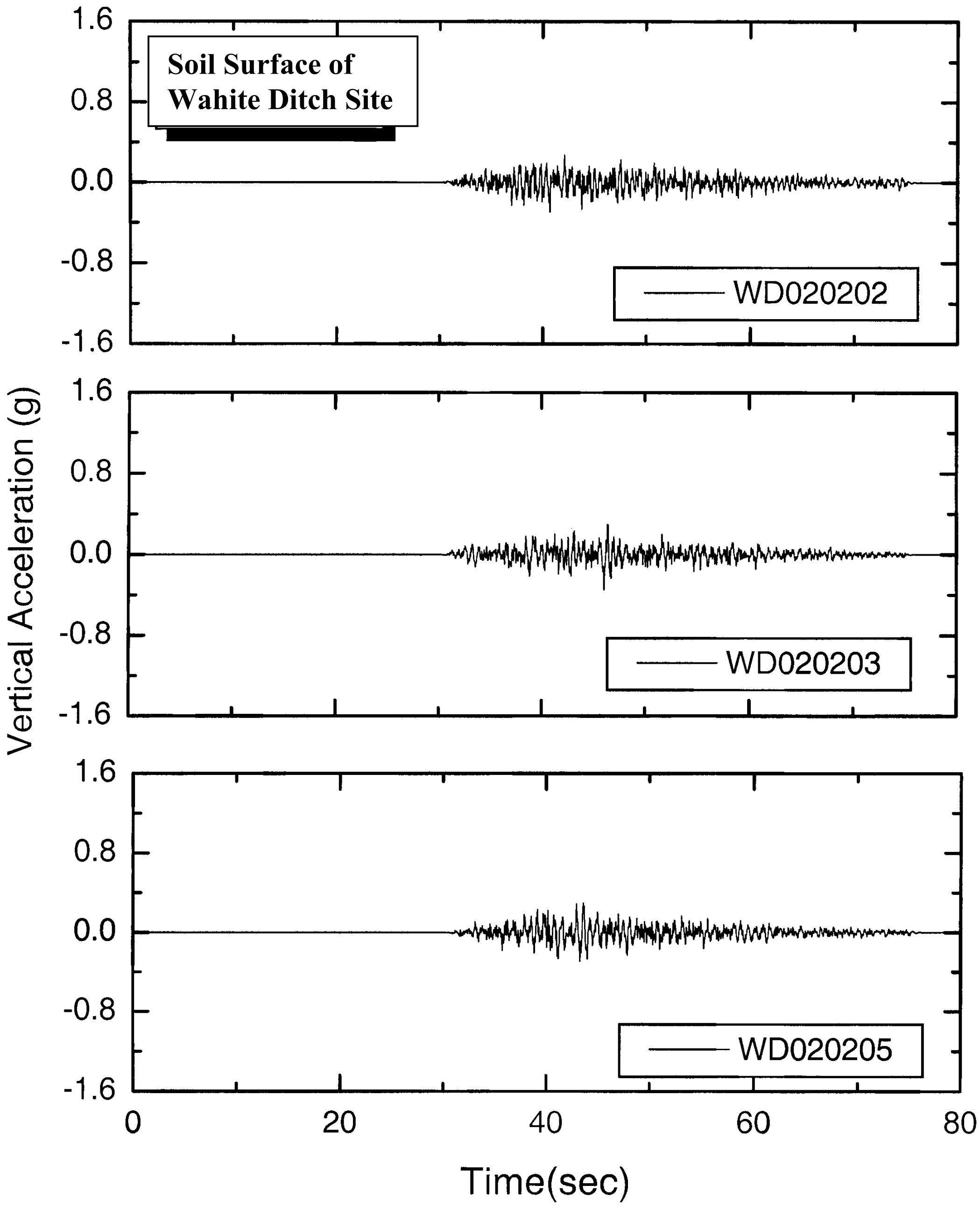
b. PE 10 % in 50 years, Magnitude = 7.0

Figure D.13b Time Histories Vertical Acceleration at the Soil Surface, Wahite Ditch Site, PE 10 % in 50 years, Magnitude=7.0



c. PE 2 % in 50 years, Magnitude = 7.8

Figure D.13c Time Histories Vertical Acceleration at the Soil Surface, Wahite Ditch Site, PE 2 % in 50 years, Magnitude=7.8



d. PE 2 % in 50 years, Magnitude = 8.0

Figure D.13d Time Histories Vertical Acceleration at the Soil Surface, Wahite Ditch Bridge Site, PE 2 % in 50 years, Magnitude=8.0

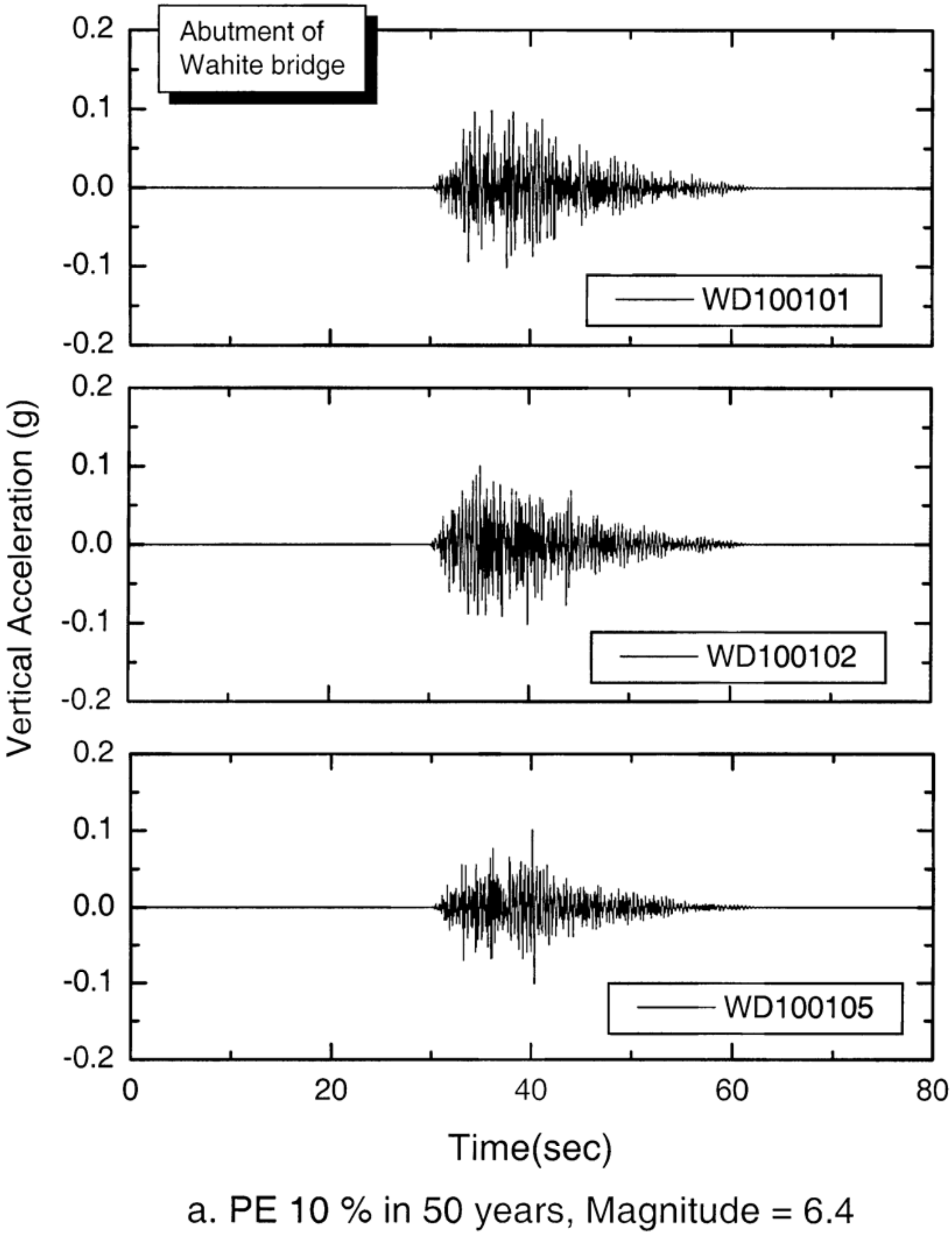


Figure D.14a Time Histories Vertical Acceleration at the Bridge Abutment, Wahite Ditch Site, PE 10 % in 50 years, Magnitude=6.4

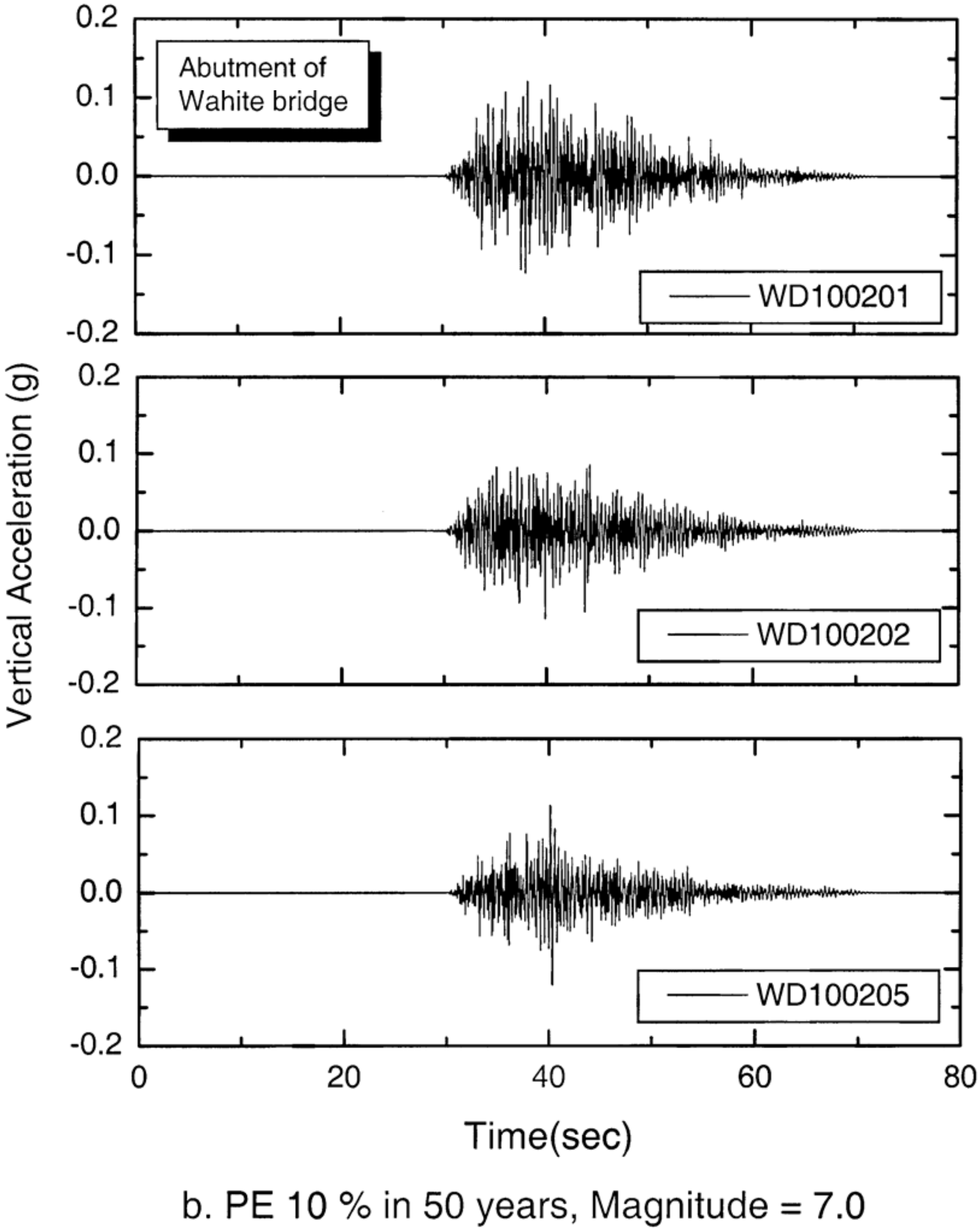


Figure D.14b Time Histories Vertical Acceleration at the Bridge Abutment, Wahite Ditch Site, PE 10 % in 50 years, Magnitude=7.0

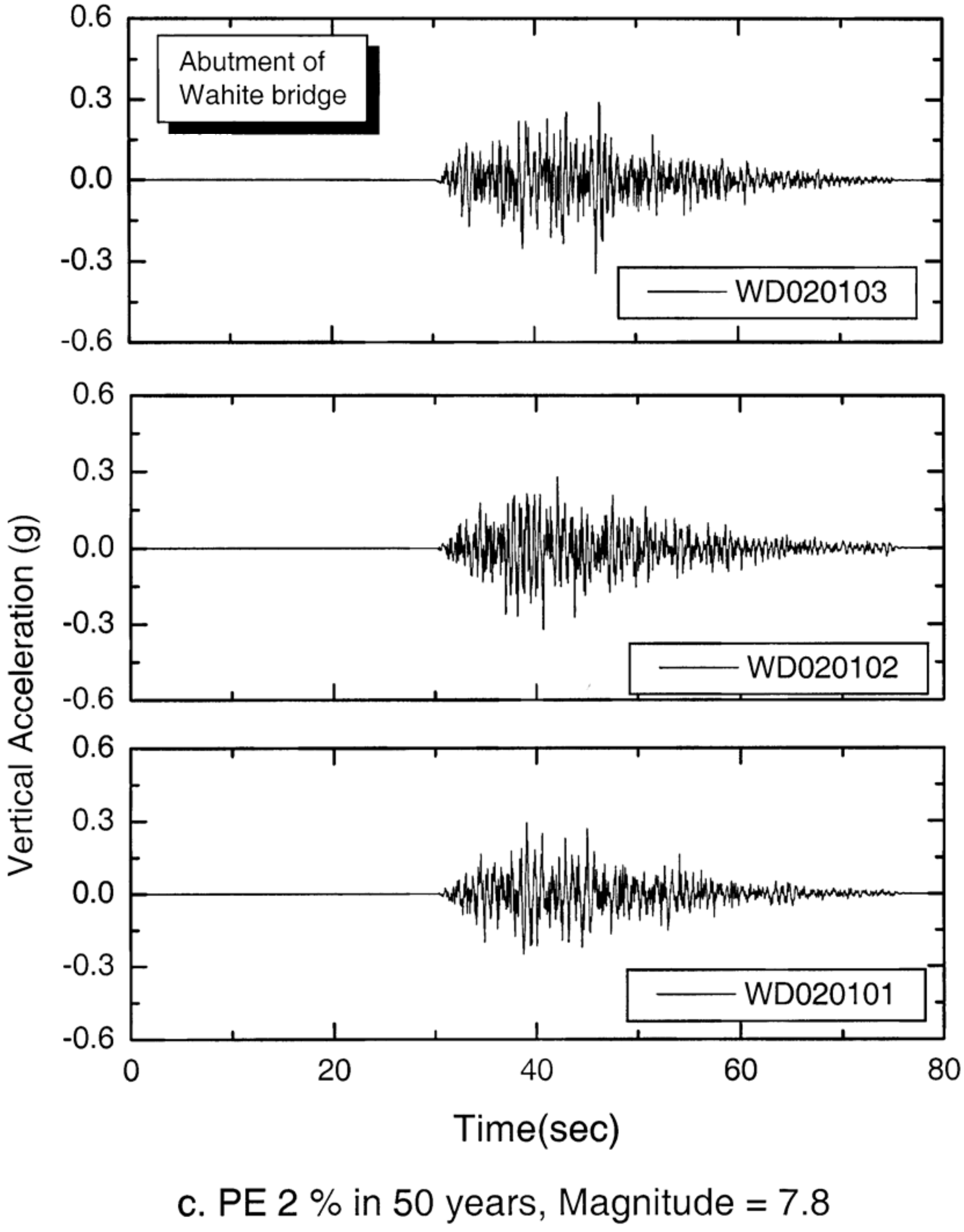
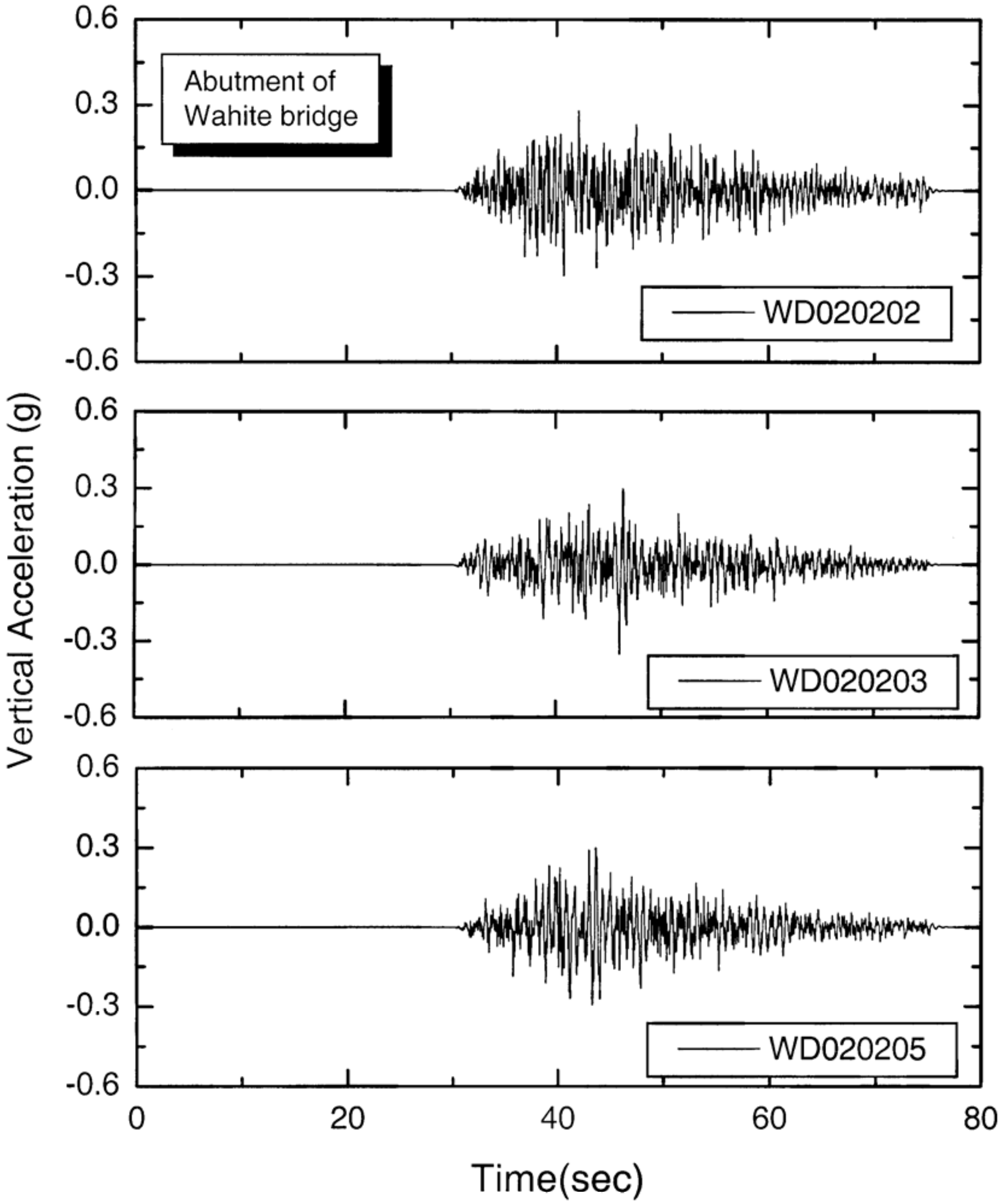


Figure D.14c Time Histories Vertical Acceleration at the Bridge Abutment, Wahite Ditch Site, PE 2 % in 50 years, Magnitude=7.8



d. PE 2 % in 50 years, Magnitude = 8.0

Figure D.14d Time Histories Vertical Acceleration at the Bridge Abutment, Wahite Ditch Site, PE 2 % in 50 years, Magnitude=8.0

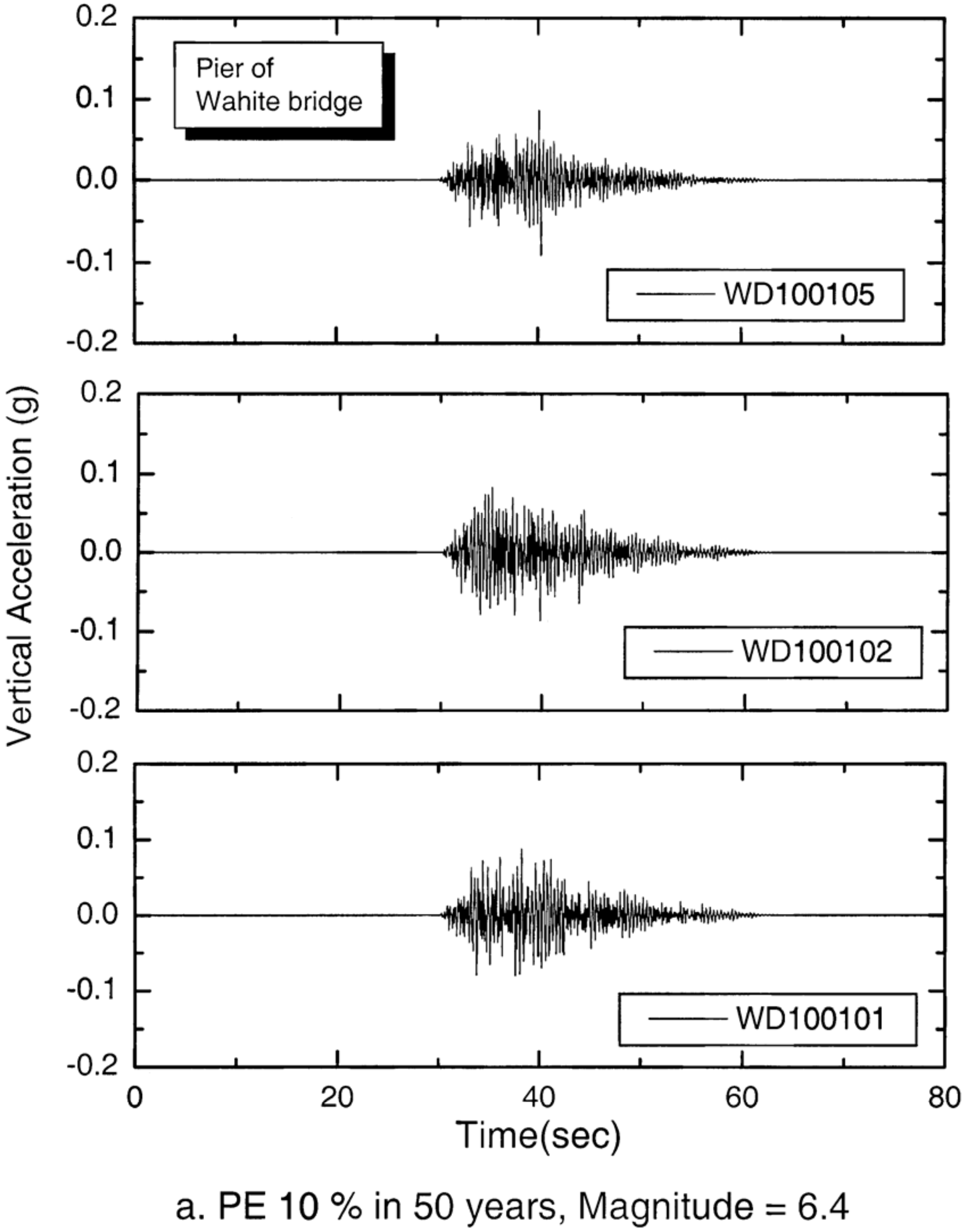
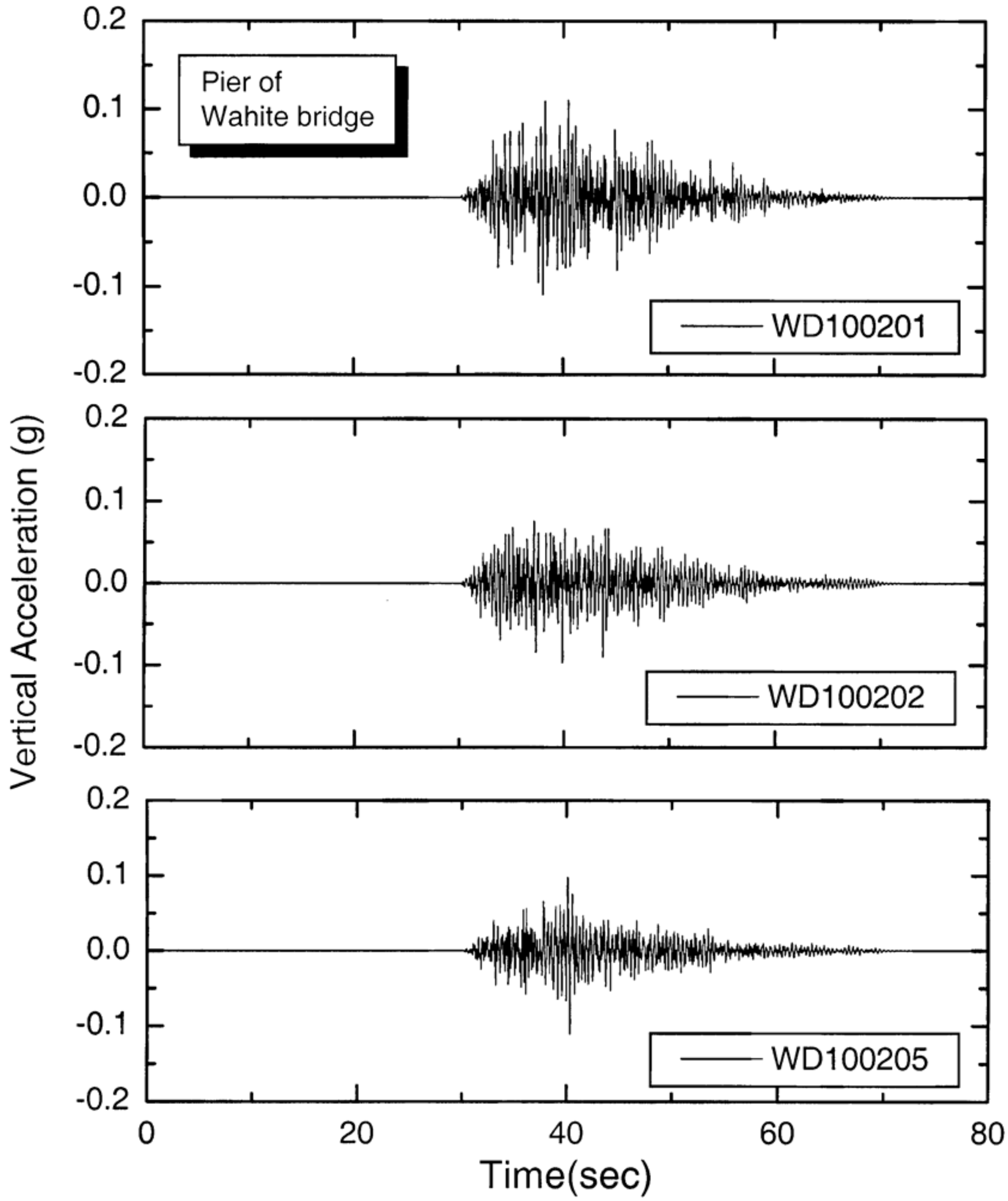


Figure D.15a Time Histories Vertical Acceleration at the Bridge Pier, Wahite Ditch Bridge, PE 10 % in 50 years, Magnitude=6.4



b. PE 10 % in 50 years, Magnitude = 7.0

Figure D.15b Time Histories Vertical Acceleration at the Bridge Pier, Wahite Ditch Bridge, PE 10 % in 50 years, Magnitude=7.0

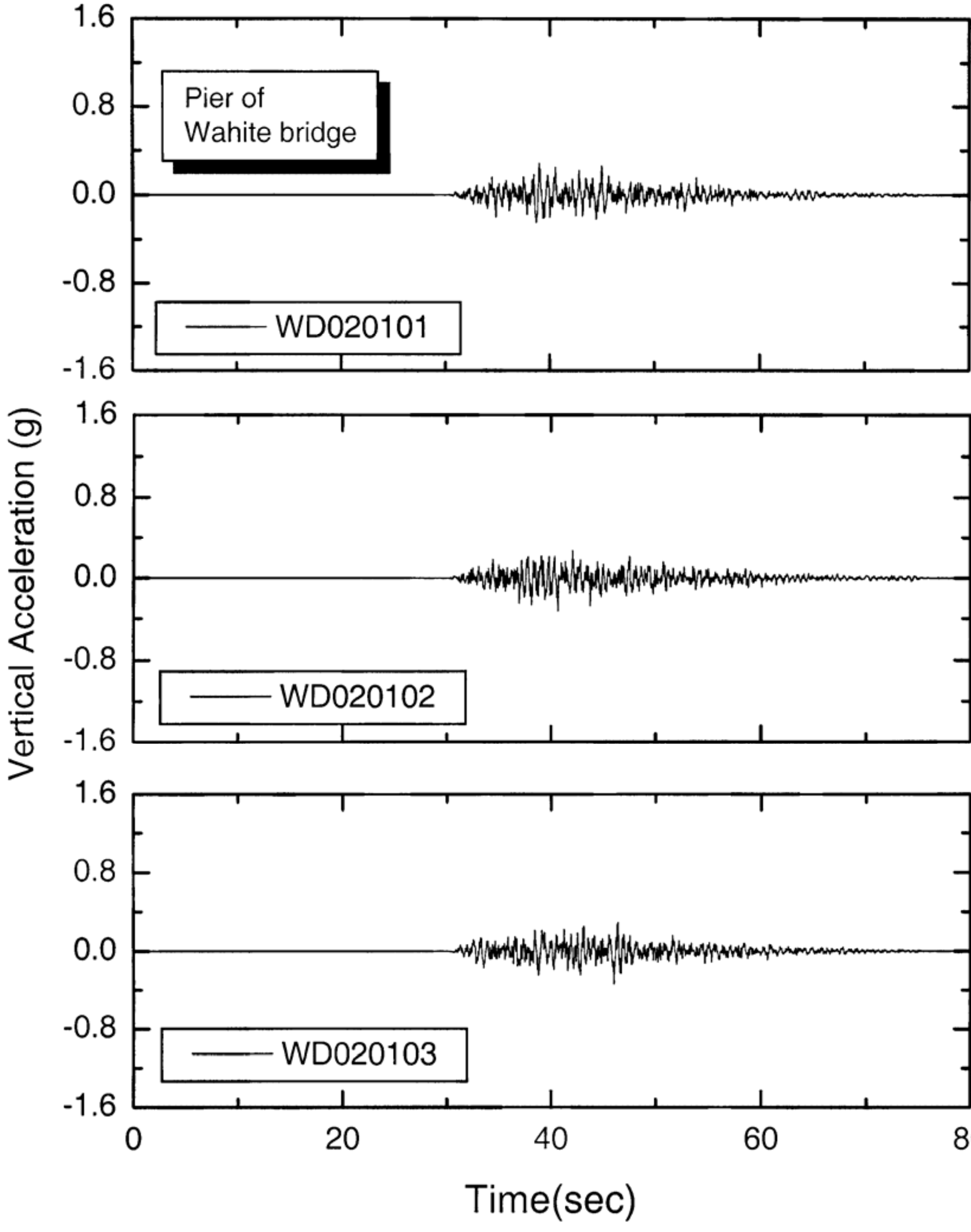


Figure D.15c Time Histories Vertical Acceleration at the Bridge Pier, Wahite Ditch Site, PE 2 % in 50 years, Magnitude=7.8

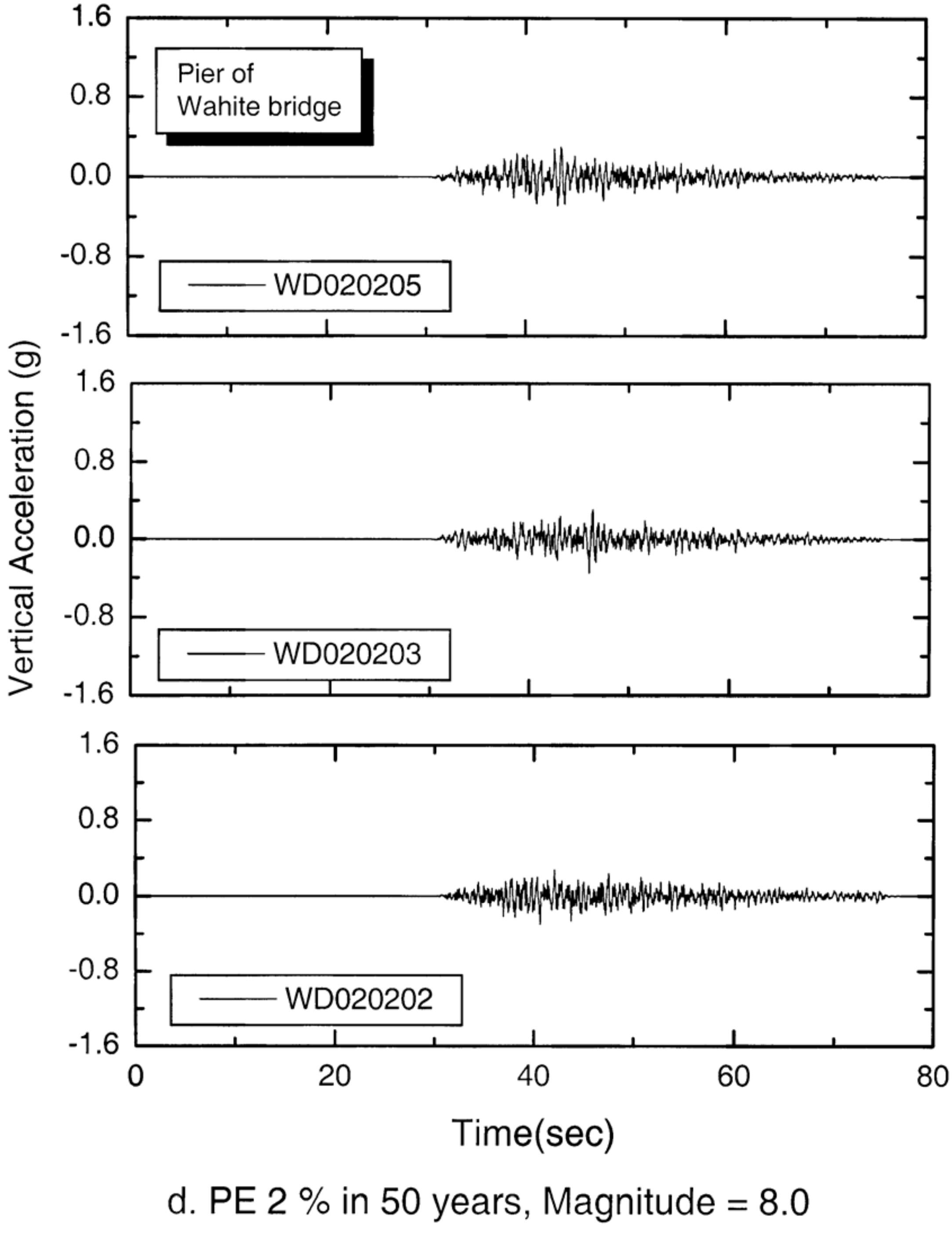


Figure D.15d Time Histories Vertical Acceleration at the Bridge Pier, Wahite Ditch Site, PE 2 % in 50 years, Magnitude=8.0

E. DATABASE FOR EARTHQUAKE ANALYSIS

5	sv	Efective vertical stress (midle layer)	N	10	2	9?	99?	kPa	10?	
6	less_than 0.075	percent that passes 0.075 mm	N	5	2	0	100.00	%	20.00	
7	PI	Plasticity Index	N	3	0	0	200		50	Table 4.9 (Mitchell)
8	a_th	Acceleration time histories	A						Elcentro	NISEE

F. BRIDGE ABUTMENT AND PIER SUPPORTED ON A PILE GROUP

Novak's (1974) model has been used for the computation of stiffness and damping of single pile and a pile group, with appropriate interaction factors. Stiffness and damping in all the modes i.e. vertical, horizontal, rocking and torsion and cross coupling in both the x and y direction have been evaluated for the bridge abutments and the piers. (See Figure F.1 for sign convention).

The main assumptions in Novak's model are;

1. The pile is a circular and solid in cross section. For other than circular section, an equivalent radius r_o is determined in each mode of variation.
2. The pile material is linear elastic
3. The pile is perfectly connected to the soil (i.e., there is no separation between soil and pile during vibration).

F.1 Stiffness and Damping Factors of Single Pile

F.1.1 Vertical Stiffness (k_z) and Damping Factors (c_z)

$$k_z = \left[\frac{E_p A}{r_o}\right] f_{w1} \tag{F.1a}$$

$$c_z = \left[\frac{E_p A}{V_s}\right] f_{w2} \tag{F.1b}$$

Where;

E_p = modulus of elasticity of pile material
A = cross section of single pile
r_o = radius of a solid pile or equivalent pile radius
V_s = shear wave velocity of soil along of the floating pile

f_{w1} and f_{w2} are obtained from Figure F.2

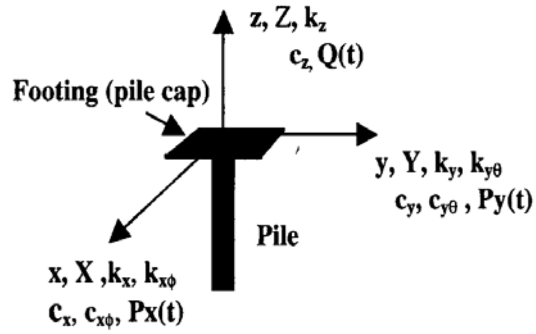
F.1.2 Torsional Stiffness (k_ψ) and Damping Factors (c_ψ)

$$k_\psi = \left[\frac{G_p I_{p_p}}{r_o}\right] f_{T,1} \tag{F.2a}$$

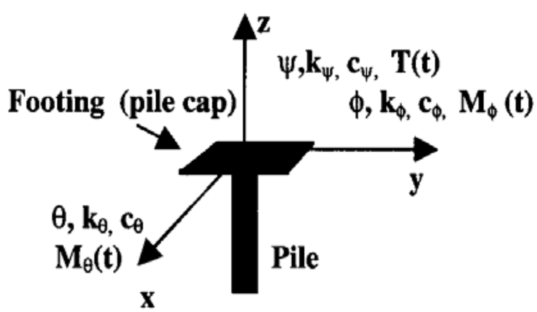
$$c_\psi = \left[\frac{G_p I_{p_p}}{V_s}\right] f_{T,2} \tag{F.2b}$$

Where;

G_p = shear modulus of elasticity of pile material
Ip_p = Polar moment of inertia of single pile about z axis
$f_{T,1}$ and $f_{T,2}$ are obtained from Figure F.3



a) Translational and coupled constants



b) Rotational constants

Figure F.1 Sign Convention

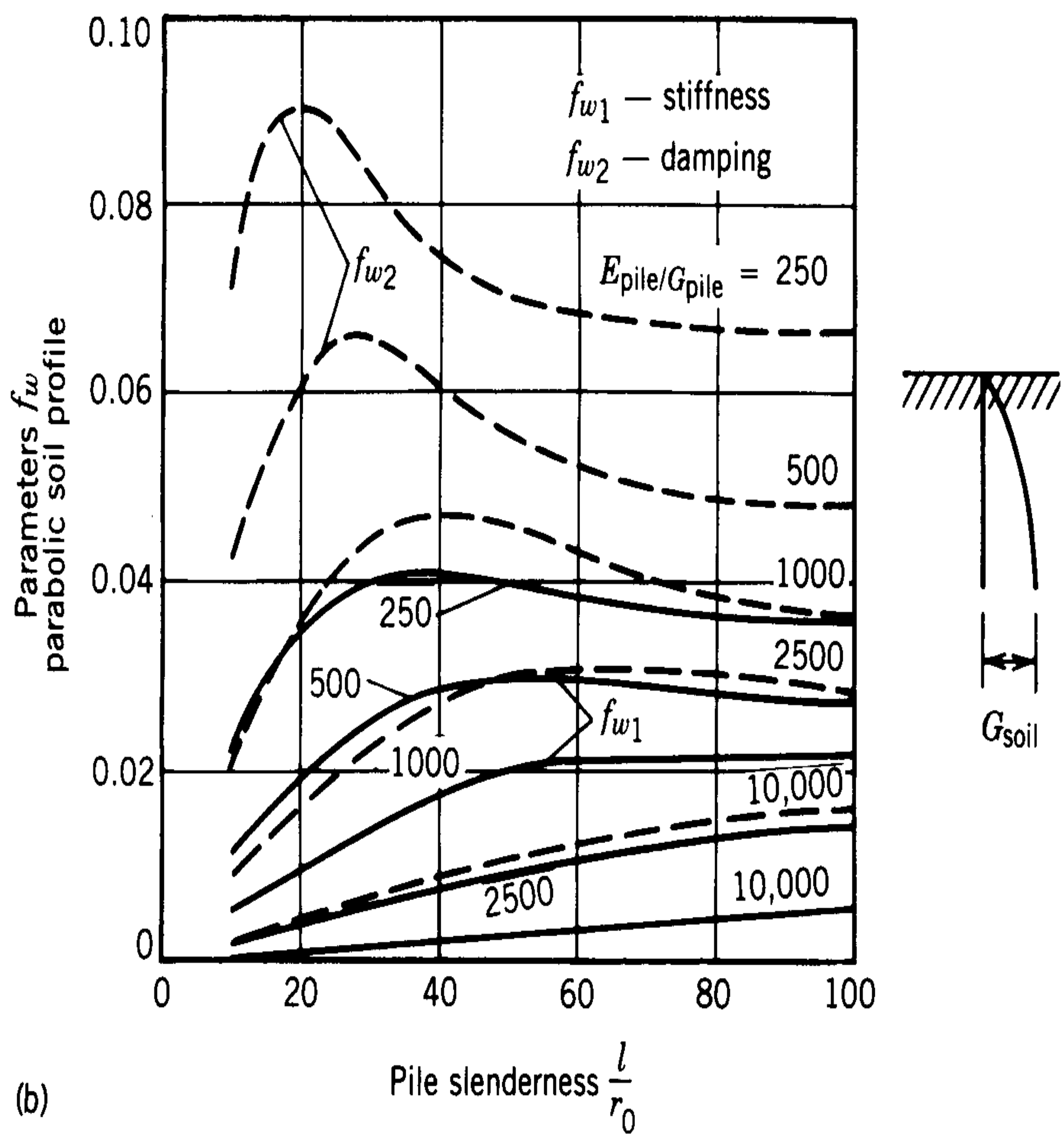


Figure F.2 Stiffness and Damping Parameters for Vertical Response of Floating Piles (Novak and El-Shornouby, 1983)

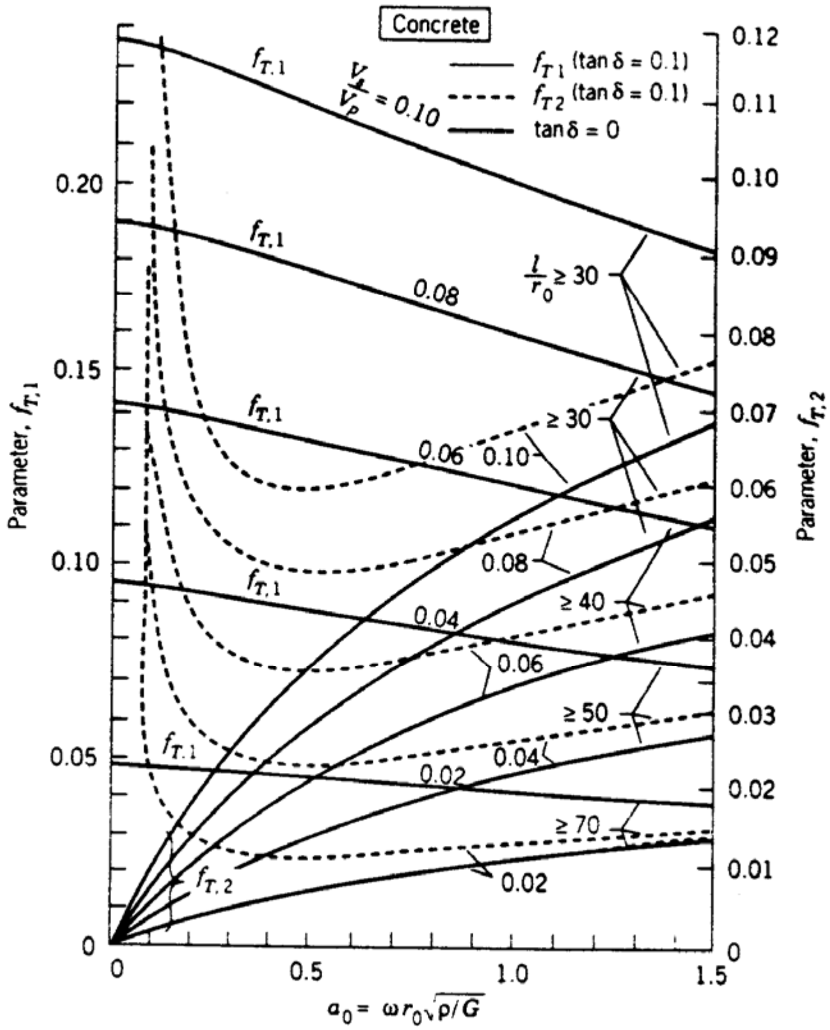


Figure. F.3 Torsional Stiffness and Damping Parameters for Reinforced Concrete (Novak and Howell, 1977)

F.1.3 Sliding and Rocking Stiffness and Damping Factors

Because, the pile is assumed to be cylindrical with a radius r_o, its stiffness and damping factors in any horizontal direction are the same. However, in the pile group, the number of piles in the x and y directions may be different. Therefore the stiffness and damping factors of a pile group are dependent on the number of piles and their spacing in each direction.

Sliding (k_x, c_x)

$$k_x = \left[\frac{E_p I_p}{r_o^3}\right] f_{x1} \qquad \text{(F.3a)}$$

$$c_x = \left[\frac{E_p I_p}{r_o^2 V_s}\right] f_{x2} \ldots \qquad \text{(F.3b)}$$

Rocking (k_ϕ, c_ϕ) and (k_θ, c_ϕ)

$$k_\varphi = k_\theta = \left[\frac{E_p I_p}{r_o^2}\right] f_{\phi 1} \qquad \text{(F.4a)}$$

$$c_\phi = c_\theta = \left[\frac{E_p I_p}{r_o^2 V_s}\right] f_{\phi 2} \qquad \text{(F.4b)}$$

Cross-coupling ($k_{x\phi}$, $c_{x\phi}$) and ($k_{y\theta}$, $c_{y\phi}$)

$$k_{x\phi} = k_{y\theta} = \left[\frac{E_p I_p}{r_o^2}\right] f_{x\theta 1} \qquad \text{(F.5a)}$$

$$c_{x\phi} = c_{y\theta} = \left[\frac{E_p I_p}{r_o V_s}\right] f_{x\phi 2} \qquad \text{(F.5b)}$$

Where;

I_p = moment of inertia of single pile about x or y axis
r_o = pile radius

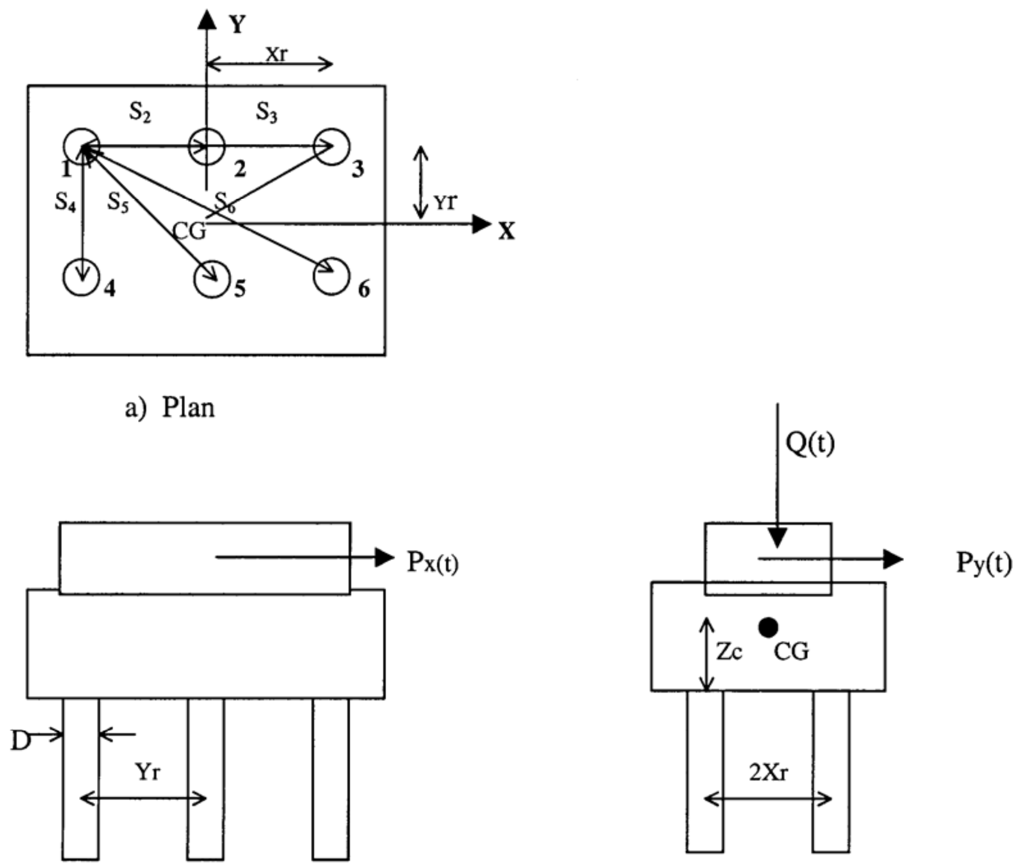
f_{x1}, f_{x2}, $f_{\phi 1}$, $f_{\phi 2}$, $f_{x\phi 1}$, $f_{x\phi 2}$ Novak's coefficient and have obtained from Table F.1 for parabolic soil profile, with appropriate interpolation and for $\nu = 0.25$

F.2 Group Interaction Factor

To consider group effect, (Paulos, 1968) assume a pile in the group as reference pile. In the illustration Figure F.4, pile No. 1 is assumed as a reference pile and distance 'S' is measured from the center of other pile to center of the reference pile.

For vertical direction use Figure F.5 to obtain α_A for each pile for appropriate $S/2r_o$ values α_A's are function of length of the pile (L) and radius (r_o).

Use Figure F.6 (Paulos, 1971), to obtain α_L for each pile in the horizontal x-direction, considering departure angle β (degree). α_L's are a function of L, r_o and flexibility K_R as defined in Figure F.6 and departure angle (β). This procedure will also apply for horizontal direction.



b) Cross section

Figure F.4 Plan and Cross Section of Pile Group

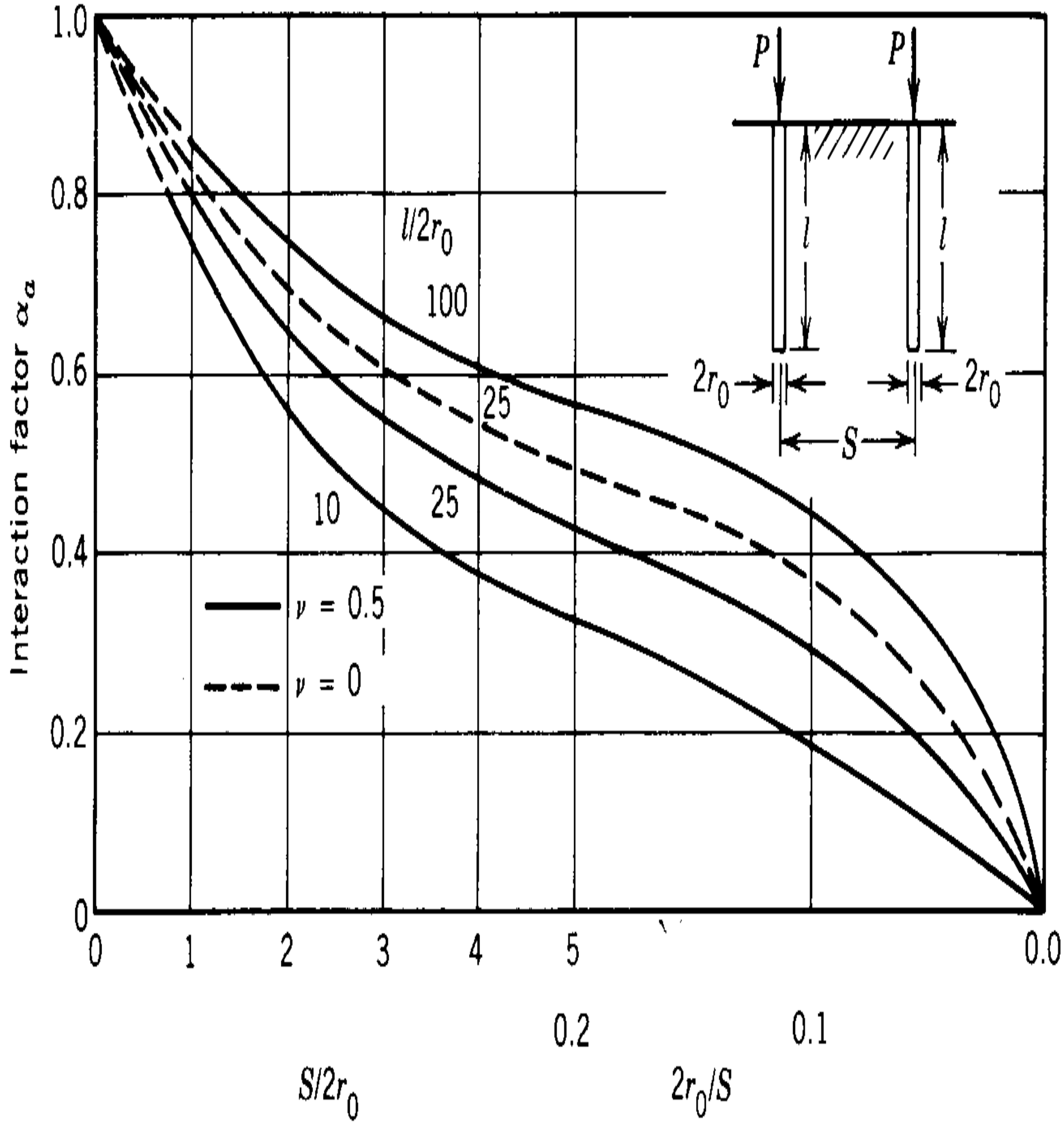


Figure F.5 α_A as a Function of Pile Length and Spacing (Poulos, 1968)

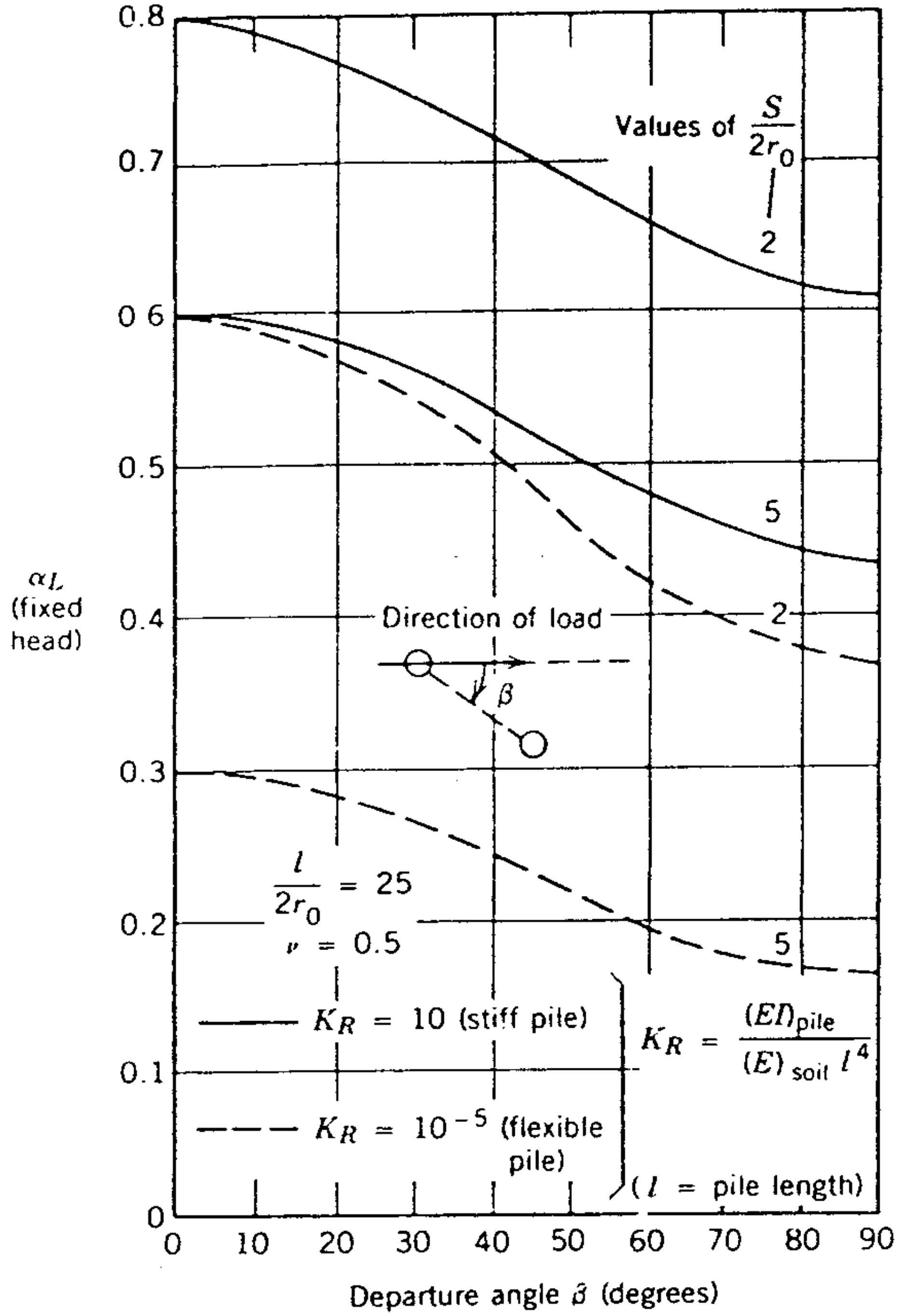


Figure F.6 Graphical Solution of α_L (Poulus, 1972)

Table F.1 Stiffness and Damping Parameters of Horizontal Response For Pile With $L/R_o>25$ For Homogeneous Soil Profile and $L/R_o>30$ For Parabolic Soil Profile

ν (1)	E_{pile}/G_{soil} (2)	Stiffness Parameters $f_{\phi 1}$ (3)	$f_{x\phi 1}$ (4)	f_{x1} (5)	f^p_{x1} (6)	Damping Parameters $f_{\phi 2}$ (7)	$f_{x\phi 2}$ (8)	f_{x2} (9)	f^p_{x2} (10)
				(a) Homogeneous Soil Profile					
0.25	10,000	0.2135	−0.0217	0.0042	0.0021	0.1577	−0.0333	0.0107	0.0054
	2,500	0.2998	−0.0429	0.0119	0.0061	0.2152	−0.0646	0.0297	0.0154
	1,000	0.3741	−0.0668	0.0236	0.0123	0.2598	−0.0985	0.0579	0.0306
	500	0.4411	−0.0929	0.0395	0.0210	0.2953	−0.1337	0.0953	0.0514
	250	0.5186	−0.1281	0.0659	0.0358	0.3299	−0.1786	0.1556	0.0864
0.40	10,000	0.2207	−0.0232	0.0047	0.0024	0.1634	−0.0358	0.0119	0.0060
	2,500	0.3097	−0.0459	0.0132	0.0068	0.2224	−0.0692	0.0329	0.0171
	1,000	0.3860	−0.0714	0.0261	0.0136	0.2677	−0.1052	0.0641	0.0339
	500	0.4547	−0.0991	0.0436	0.0231	0.3034	−0.1425	0.1054	0.0570
	250	0.5336	−0.1365	0.0726	0.0394	0.3377	−0.1896	0.1717	0.0957
				(b) Parabolic Soil Profile					
0.25	10,000	0.1800	−0.0144	0.0019	0.0008	0.1450	−0.0252	0.0060	0.0028
	2,500	0.2452	−0.0267	0.0047	0.0020	0.2025	−0.0484	0.0159	0.0076
	1,000	0.3000	−0.0400	0.0086	0.0037	0.2499	−0.0737	0.0303	0.0147
	500	0.3489	−0.0543	0.0136	0.0059	0.2910	−0.1008	0.0491	0.0241
	250	0.4049	−0.0734	0.0215	0.0094	0.3361	−0.1370	0.0793	0.0398
0.40	10,000	0.1857	−0.0153	0.0020	0.0009	0.1508	−0.0271	0.0067	0.0031
	2,500	0.2529	−0.0284	0.0051	0.0022	0.2101	−0.0519	0.0177	0.0084
	1,000	0.3094	−0.0426	0.0094	0.0041	0.2589	−0.0790	0.0336	0.0163
	500	0.3596	−0.0577	0.0149	0.0065	0.3009	−0.1079	0.0544	0.0269
	250	0.4170	−0.0780	0.0236	0.0103	0.3468	−0.1461	0.0880	0.0443

Source: Novak and El-Sharnouby (1983). f^p_{x1} and f^p_{x2} are parameters for pinned end.

The group interaction factor ($\Sigma\alpha_L$) is the summation α_L for all the piles. Note that the group interaction factor in horizontal x-direction and y-direction may be different depending on number and spacing of piles in each direction.

F.3 Group Stiffness and Damping Factors

Figure F.4 shows schematically the plan and cross sections of an arbitrary pile group foundation. This figure will be used to explain and obtain the stiffness and damping factors group of pile for all direction. They are presented as follows:

F.3.1 Vertical group stiffness (k_z^g) and damping factors (c_z^g)

$$k_z^g = \frac{\sum k_z}{\sum \alpha_A} \qquad \text{(F.6.a)}$$

$$c_z^g = \frac{\sum c_z}{\sum \alpha_A} \qquad \text{(F.6.b)}$$

F.3.2 Torsional group stiffness (k_ψ^g)and damping factors (c_ψ^g)

$$k_\psi^g = \frac{1}{\sum \alpha_A}\left[k_\psi + k_x\left(x_r^2 + y_r^2\right)\right] \qquad \text{(F.7a)}$$

$$c_{\psi}^{g} = \frac{1}{\sum \alpha_A}\left[c_{\psi} + c_x\left(x_r^2 + y_r^2\right)\right] \quad \text{(F.7b)}$$

F.3.3 Sliding and Rocking and Cross Coupled Group Stiffness and Damping Factors

Sliding and Rocking and Cross Coupled Group Stiffness and Damping Factors)

$$k_x^g = \frac{\sum k_x}{\sum \alpha_{Lx}} \quad \text{(F.8a)}$$

$$c_x^g = \frac{\sum c_x}{\sum \alpha_{Lx}} \quad \text{(F.8b)}$$

Translation Along Y Axis (k_y^g, c_y^g)

$$k_y^g = \frac{\sum k_y}{\sum \alpha_{LA}} \quad \text{(F.9a)}$$

$$c_y^g = \frac{\sum c_y}{\sum \alpha_{Ly}} \quad \text{(F.9b)}$$

Rocking About Y Axis (k_ϕ^g, c_ϕ^g)

$$k_\phi^g = \frac{1}{\sum \alpha_{Lx}}\left[k_\phi + k_z x_r^2 + k_x z_c^2 - 2 z_c k_{x\phi}\right] \quad \text{(F.10a)}$$

$$c_\phi^g = \frac{1}{\sum \alpha_{Lx}}\left[c_\phi + c_z x_r^2 + c_x z_c^2 - 2 z_c c_{x\phi}\right] \quad \text{(F.10b)}$$

Rocking About X Axis (k_θ^g, c_θ^g)

$$k_\theta^g = \frac{1}{\sum \alpha_{Ly}}\left[k_\theta + k_z y_r^2 + k_y z_c^2 - 2 z_c k_{y\theta}\right] \quad \text{(F.11a)}$$

$$c_\theta^g = \frac{1}{\sum \alpha_{Ly}}\left[c_\theta + c_z y_r^2 + c_x z_c^2 - 2 z_c c_{y\theta}\right] \quad \text{(F.11b)}$$

Cross-Coupling Translation in X Axis and Rotation About Y Axis. ($k_{x\phi}^g$, $c_{x\phi}^g$)

$$k_{x\phi}^g = \frac{1}{\alpha_{Lx}}\sum\left(k_{x\phi} - k_x z_c\right) \quad \text{(F.12a)}$$

$$c_{x\phi}^g = \frac{1}{\alpha_{Lx}}\sum\left(c_{x\phi} - c_x z_c\right) \quad \text{(F.12b)}$$

Cross-Coupling Translation in Y-Axis and Rotation About X Axis. ($k_{y\theta}^g$, $c_{y\theta}^g$)

$$k_{y\theta}^g = \frac{1}{\alpha_{Ly}}\sum\left(k_{y\theta} - k_y z_c\right) \qquad \text{(F.13a)}$$

$$c_{y\theta}^g = \frac{1}{\alpha_{Ly}}\sum\left(c_{y\theta} - c_y z_c\right) \qquad \text{(F.13b)}$$

F.4 Strain-Displacement Relationships

The shear strain and displacement relationship is not well defined in practical problems occurring in the field. However, the relationship has been recommended by Prakash and Puri (1981) as:

γ= amplitude of foundation vibration/average width of foundation (F.14)

Because evaluation of shear strain in the field is, in many cases, not clear, reasonable expressions must be assumed and used as the basis for evaluating the shear strain in each particular case.

Kagawa and Kraft (1980) used a following relationship for horizontal displacement

$$\lambda_x = \frac{(1+\nu)X}{2.5D} \qquad \text{(F.15)}$$

Where, ν = Poisson's ratio
X = horizontal displacement in x-direction
D = diameter of pile

Rafnsson (1992) stated that, the shear strain due to rocking can be reasonably determined as;

$$\gamma_\phi = \frac{\phi}{3} \qquad \text{(F.16)}$$

Where,

ϕ = rotation of foundation about y axis

The shear strain- displacement relationship for couple sliding and rocking can be determined as:

$$\gamma_x = \frac{(1+\nu)X}{2.5D} + \frac{\phi}{3} \qquad \text{(F.17)}$$

Note that, equations F.15, F.16 and F.17 have been adopted for other directions respectively.

F.5 Solution Technique for Displacement Dependent k"s and c's

START

↓

OBTAIN

Unit weight, shear wave velocity, poison ratio, initial shear modulus
Shear modulus degradation curve as function of soil

↓

OBTAIN

Pile length, pile diameter, Elastic modulus of pile, shear wave velocity

DETERMINE

↓

Half space stiffness and damping parameters as function of soil parameters and pile dimensions

↓

DETERMINE

Strain-Displacement Relationship

↓

DETERMINE

Stiffness and damping factor for single pile

↓

CALCULATE

Group efficiency factor

↓

CALCULATE

Group piles stiffness and damping factors

↓

STOP

The stiffness and damping factors are plotted against displacement for bridge abutment and pier of old St Francis, new St. Francis, new Wahite and old Wahite bridges. They are presented in Figure F.7a through F.25c.

F.6 Equations of Motion

Under dynamic loading, the equilibrium of forces is derived based on the second Newton's law. This equilibrium in two-dimensional analysis will give three-equations of motion in the vertical and two horizontal directions.

Vertical equation of motion

$$m.Z + c_z^g.\ Z + k_z^g\ Z = Q(t) \quad (F.18)$$

Torsional equation of motion

$$m.\ \psi + c_\psi^g.\ \psi + k_\psi^g.\ \psi = T(t) \quad (F.19)$$

Two-Dimensional Sliding and Rocking Equation of Motion

In the horizontal x direction

$$\begin{Bmatrix} m & 0 \\ 0 & Mm \end{Bmatrix}\begin{Bmatrix} X \\ \phi \end{Bmatrix} + \begin{Bmatrix} c_x^g & -c_{\phi x}^g \\ -c_{\phi x}^g & c_\phi^g \end{Bmatrix}\begin{Bmatrix} X \\ \phi \end{Bmatrix} + \begin{Bmatrix} k_x^g & -k_{\phi x}^g \\ -k_{\phi x}^g & k_\phi^g \end{Bmatrix}\begin{Bmatrix} X \\ \phi \end{Bmatrix} = \begin{Bmatrix} P_x(t) \\ M_\phi(t) \end{Bmatrix} \quad (F.20)$$

In the horizontal y direction

$$\begin{Bmatrix} m & 0 \\ 0 & Mm \end{Bmatrix}\begin{Bmatrix} Y \\ \theta \end{Bmatrix} + \begin{Bmatrix} c_y^g & -c_{y\theta}^g \\ -c_{\theta y}^g & c_\theta^g \end{Bmatrix}\begin{Bmatrix} Y \\ \theta \end{Bmatrix} + \begin{Bmatrix} k_y^g & -k_{y\theta}^g \\ -k_{\phi y}^g & k_\phi^g \end{Bmatrix}\begin{Bmatrix} Y \\ \theta \end{Bmatrix} = \begin{Bmatrix} P_y(t) \\ M_\theta(t) \end{Bmatrix} \quad (F.21)$$

where:

- m = mass of bridge abutment
- Mm = mass inertia of bridge abutment about the axis of rotation
- Q(t) = total vertical force
- $P_x(t)$ = total horizontal force x-direction
- T(t) = total torsional force
- $P_y(t)$ = total horizontal force y-direction
- $M_\phi(t)$ = moment about y-axis
- $M_\theta(t)$ = moment about x-axis

Three-Dimensional Equation of Motion

$$[m]\{X\}+[C]\{X\}+[K]\{X\}=\{P(t)\} \quad (F.22)$$

where, matrix mass [m] is

$$\{m\} = \begin{Bmatrix} m & 0 & 0 & 0 & 0 & 0 \\ 0 & m & 0 & 0 & 0 & 0 \\ 0 & 0 & m & 0 & 0 & 0 \\ 0 & 0 & 0 & Mm & 0 & 0 \\ 0 & 0 & 0 & 0 & m & 0 \\ 0 & 0 & 0 & 0 & 0 & Mm \end{Bmatrix} \quad (F.22a)$$

Matrix damping [C] is

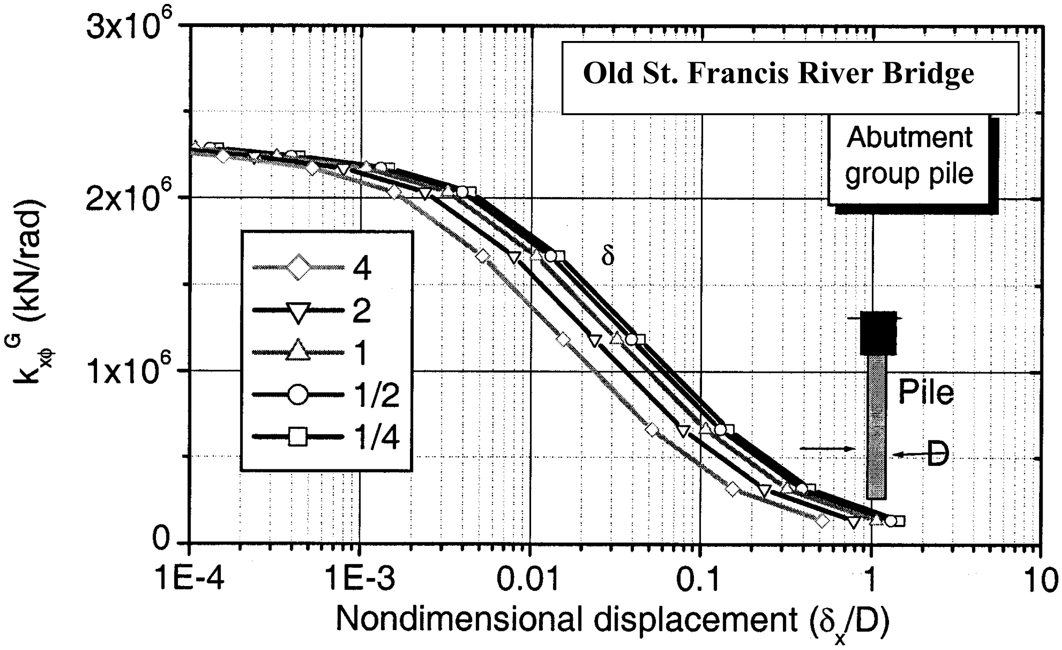
$$\{C\} = \begin{Bmatrix} c_z^g & 0 & 0 & 0 & 0 & 0 \\ 0 & c_\psi^g & 0 & 0 & 0 & 0 \\ 0 & 0 & c_x^g & -c_{\phi x}^g & 0 & 0 \\ 0 & 0 & -c_{\phi x}^g & c_\phi^g & 0 & 0 \\ 0 & 0 & 0 & 0 & c_y^g & -c_{\theta y}^g \\ 0 & 0 & 0 & 0 & -c_{\theta y}^g & c_\theta^g \end{Bmatrix} \quad \text{F.22b)}$$

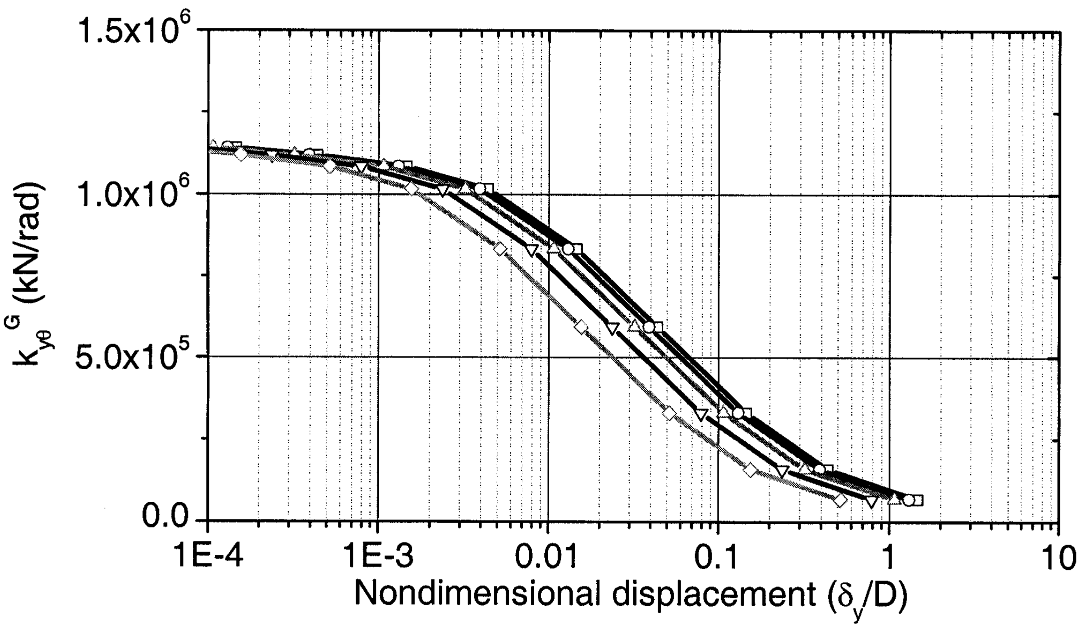
Matrix stiffness [K] is

$$\{K\} = \begin{Bmatrix} k_z^g & 0 & 0 & 0 & 0 & 0 \\ 0 & k_\psi^g & 0 & 0 & 0 & 0 \\ 0 & 0 & k_x^g & -k_{\phi x}^g & 0 & 0 \\ 0 & 0 & -k_{\phi x}^g & k_\phi^g & 0 & 0 \\ 0 & 0 & 0 & 0 & k_y^g & -k_{\theta y}^g \\ 0 & 0 & 0 & 0 & -k_{\theta y}^g & k_\theta^g \end{Bmatrix} \quad \text{(F.22c)}$$

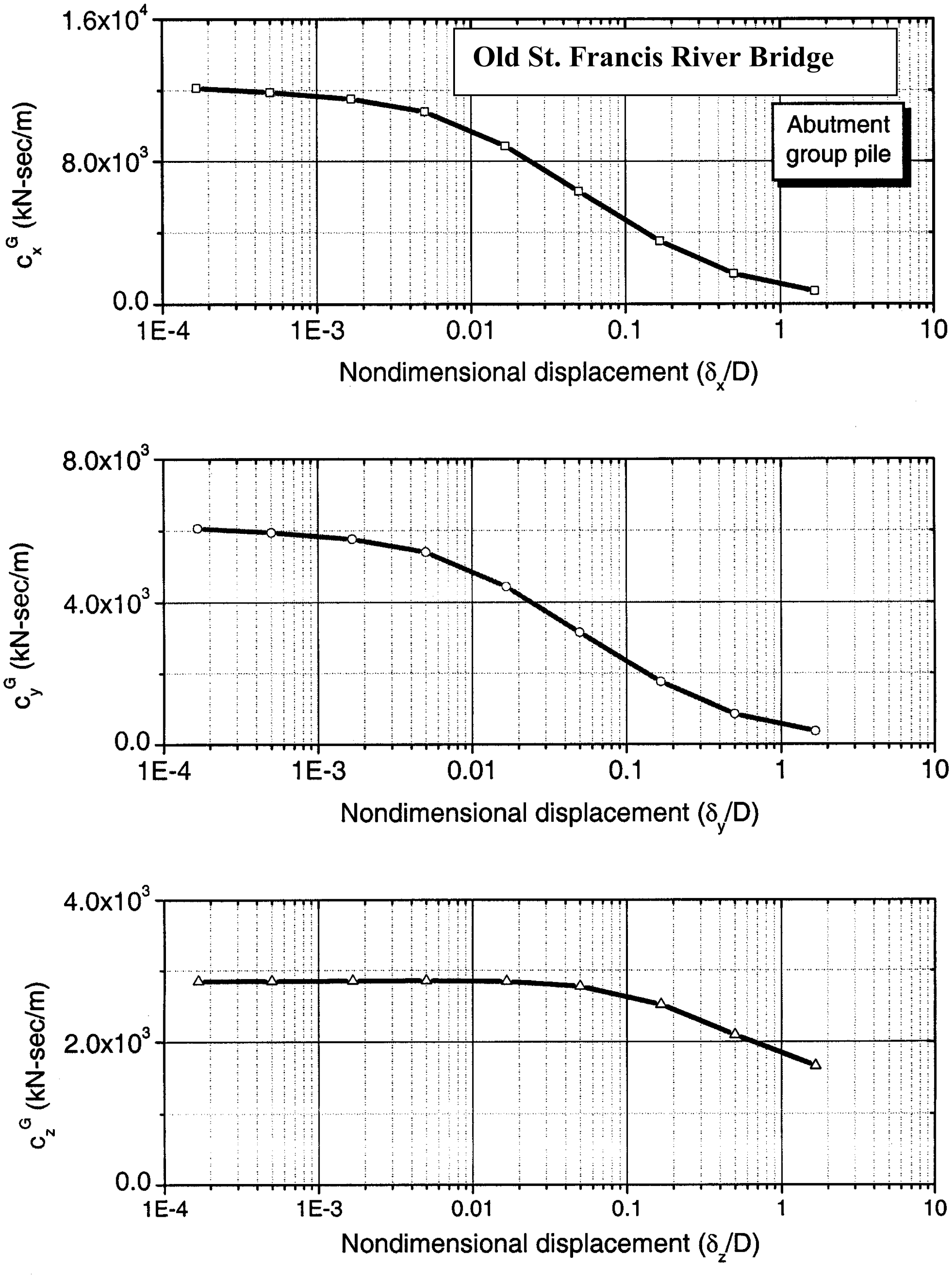
Vector load {P(t)} is; Vector displacement {X} is

$$\begin{Bmatrix} Q(t) \\ T(t) \\ P_x(t) \\ M_\phi(t) \\ P_y(t) \\ M_\theta(t) \end{Bmatrix} \qquad \begin{Bmatrix} Z \\ \psi \\ X \\ \varphi \\ Y \\ \theta \end{Bmatrix} \quad \text{(F.22d)}$$

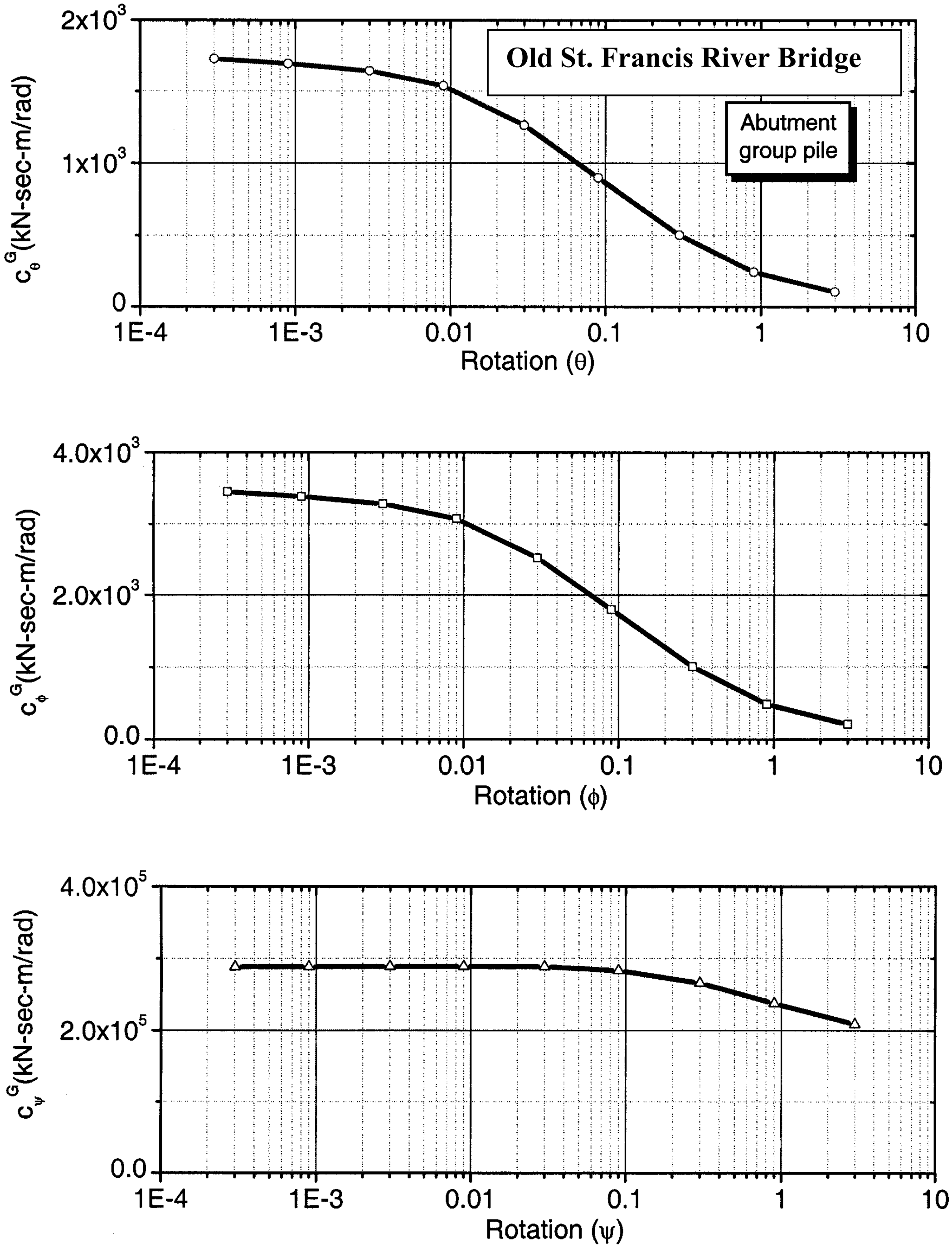




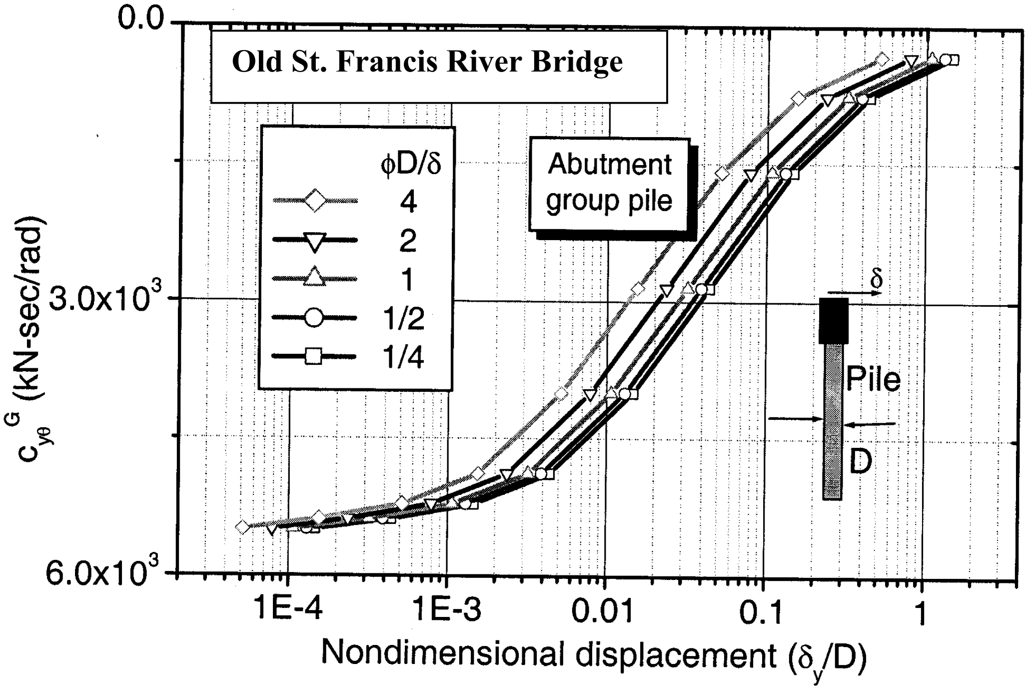
F.7a Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Abutment Group Pile, Old St. Francis River Bridge

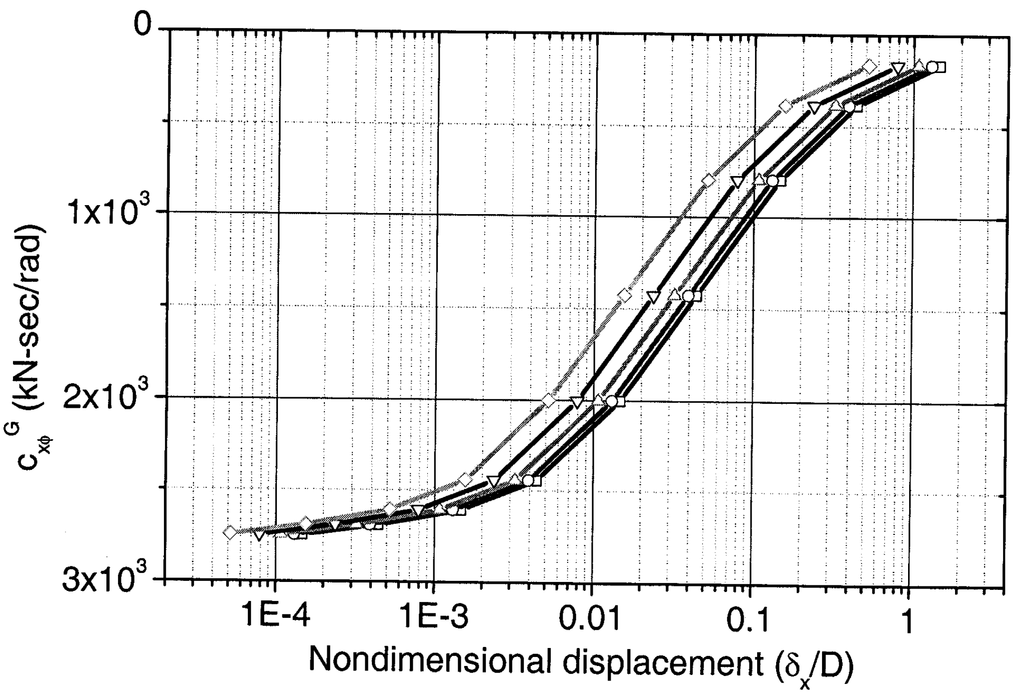


F.7b Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Abutment Group Pile, Old St. Francis River Bridge

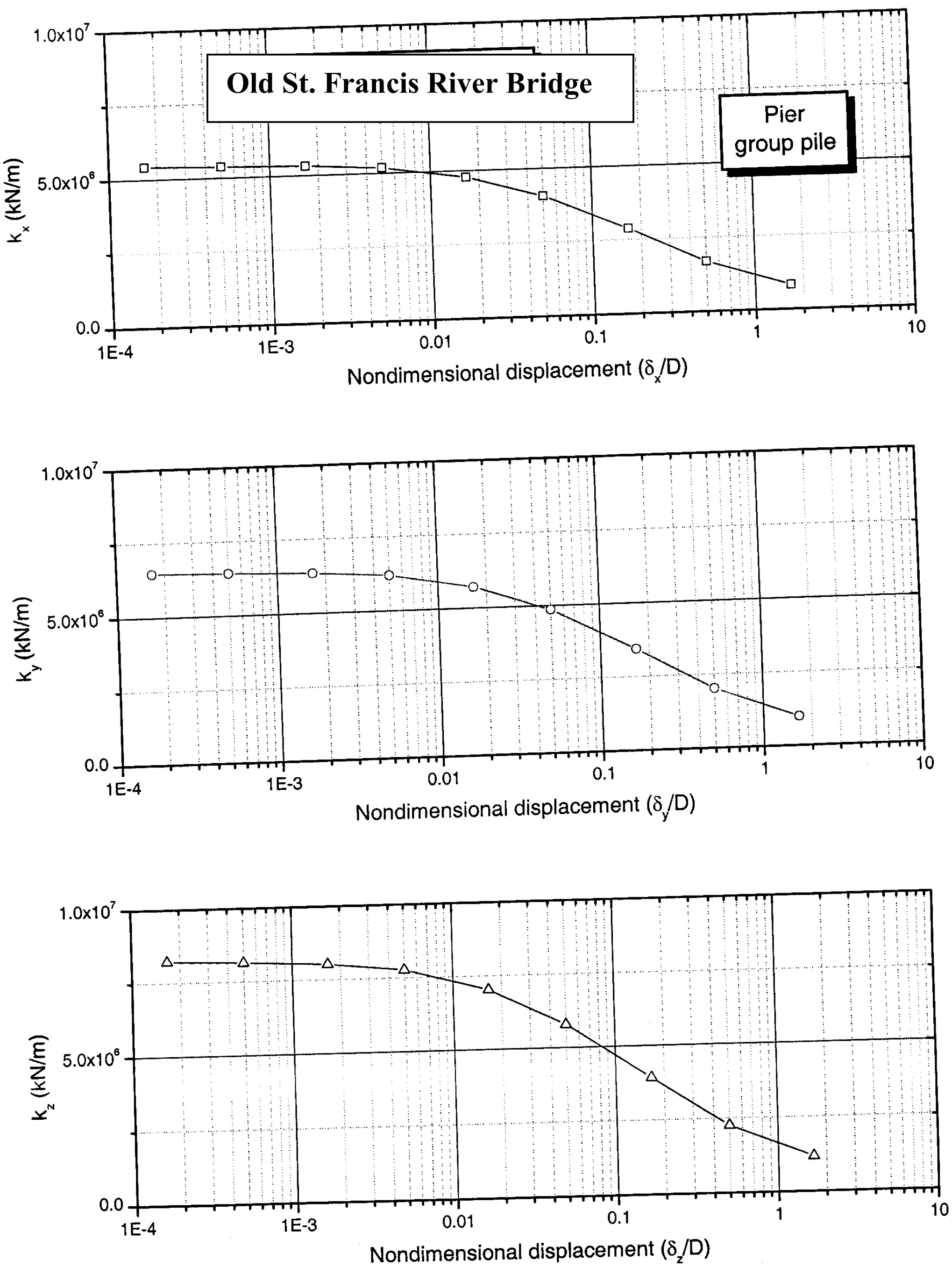


F.7c Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, Old St. Francis River Bridge

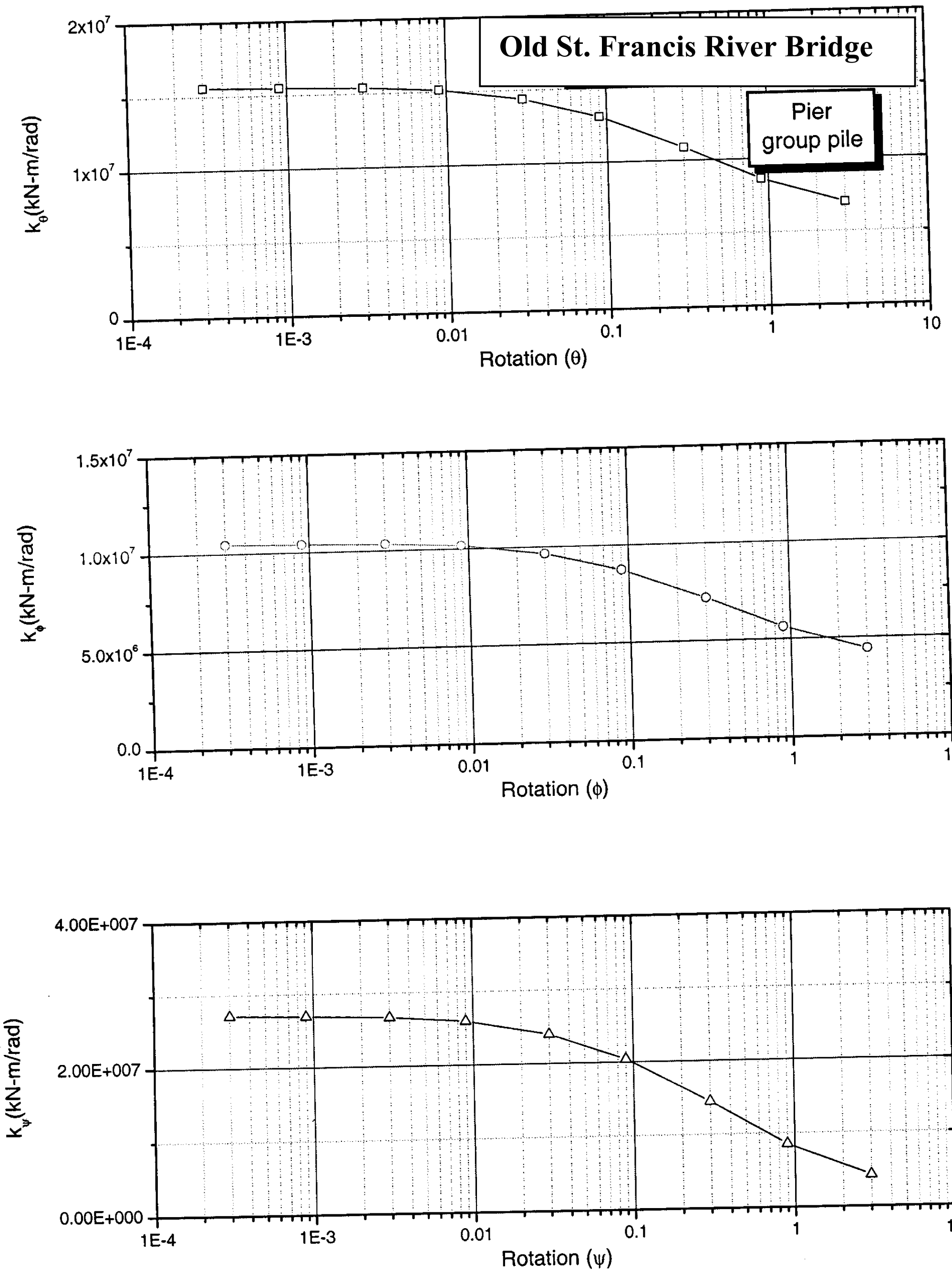




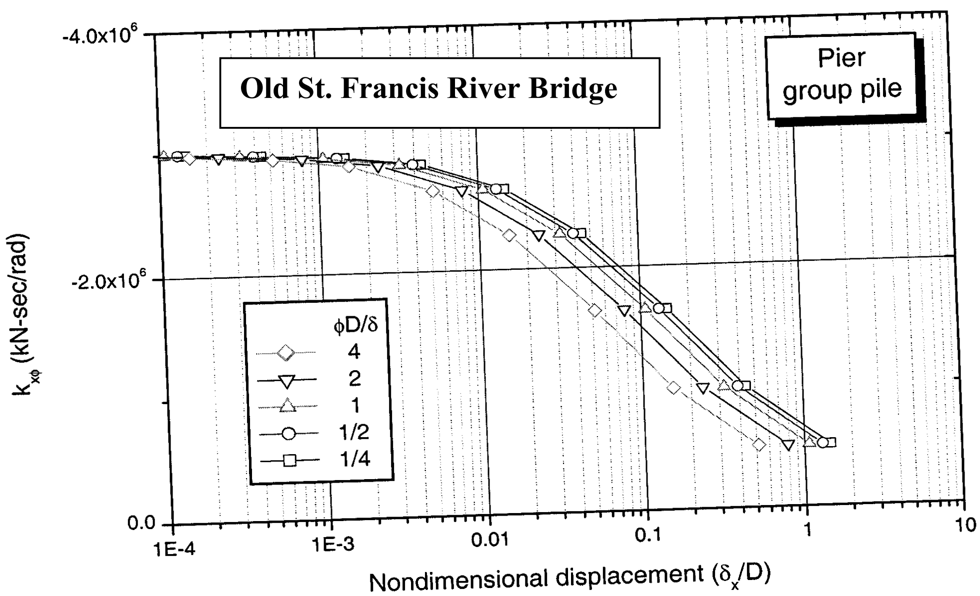
F.7d Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Abutment Group Pile, Old St. Francis River Bridge

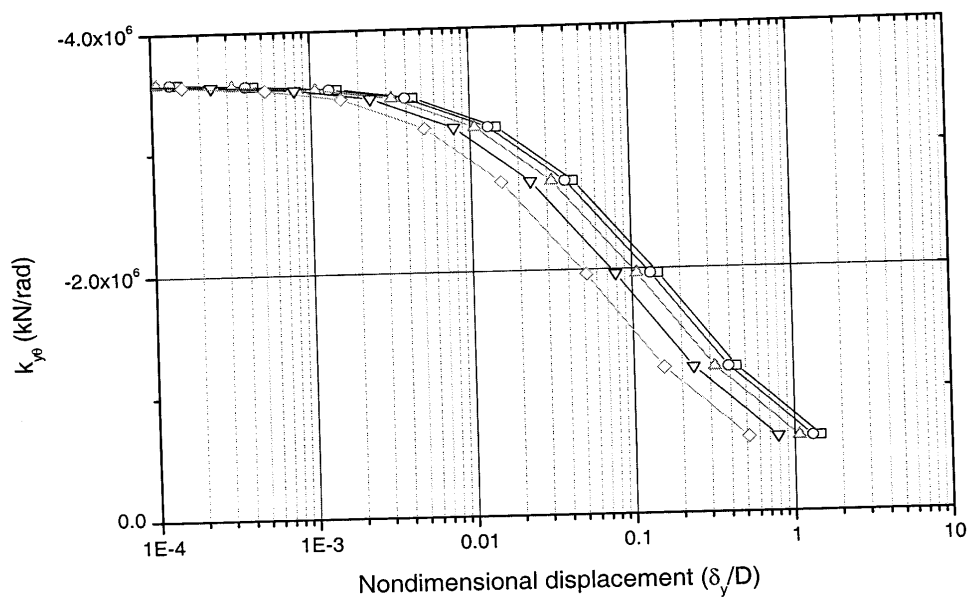


F.7e Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Pier Group Pile, Old St. Francis River Bridge

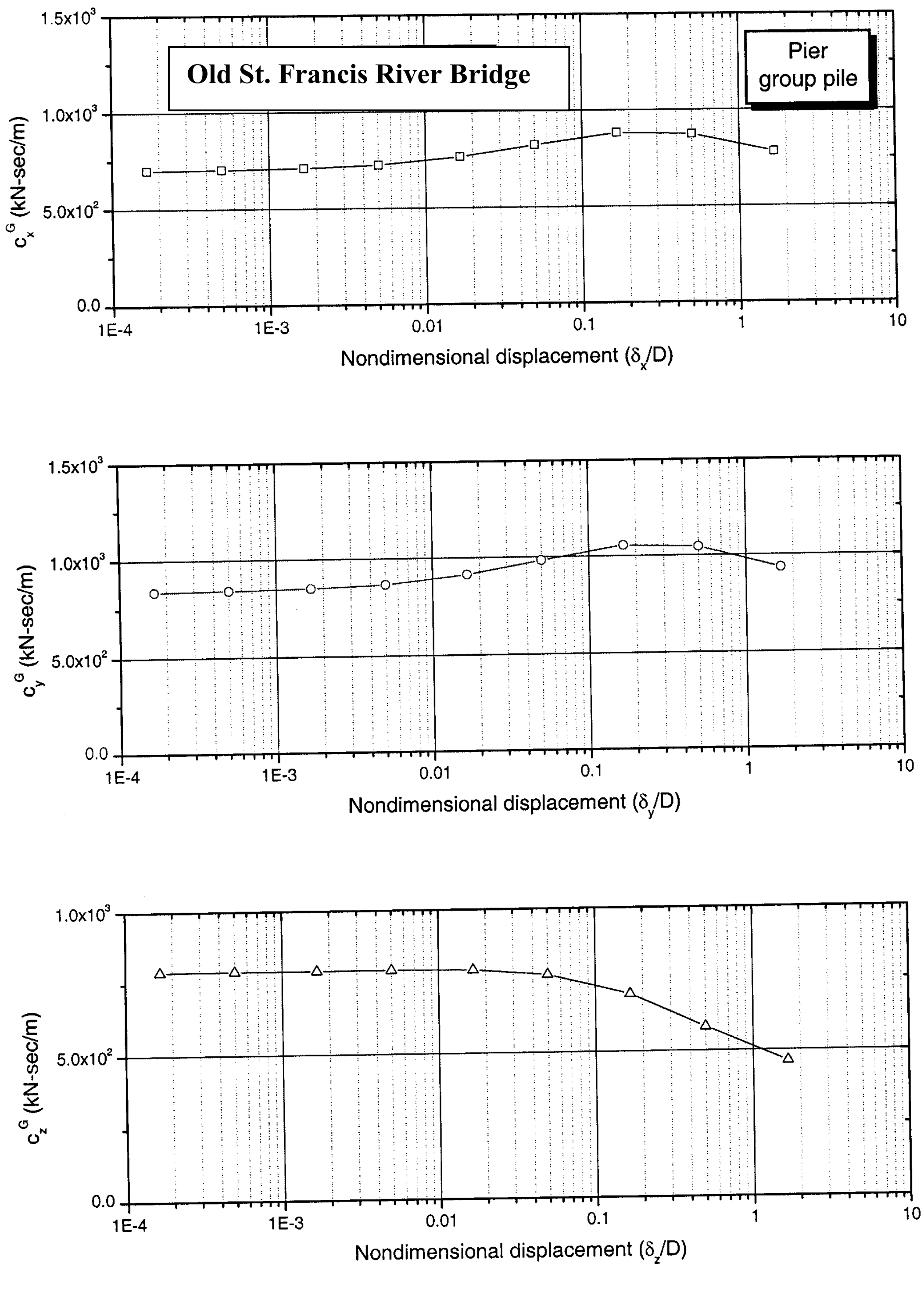


F.7f Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier Group Pile, Old St. Francis River Bridge

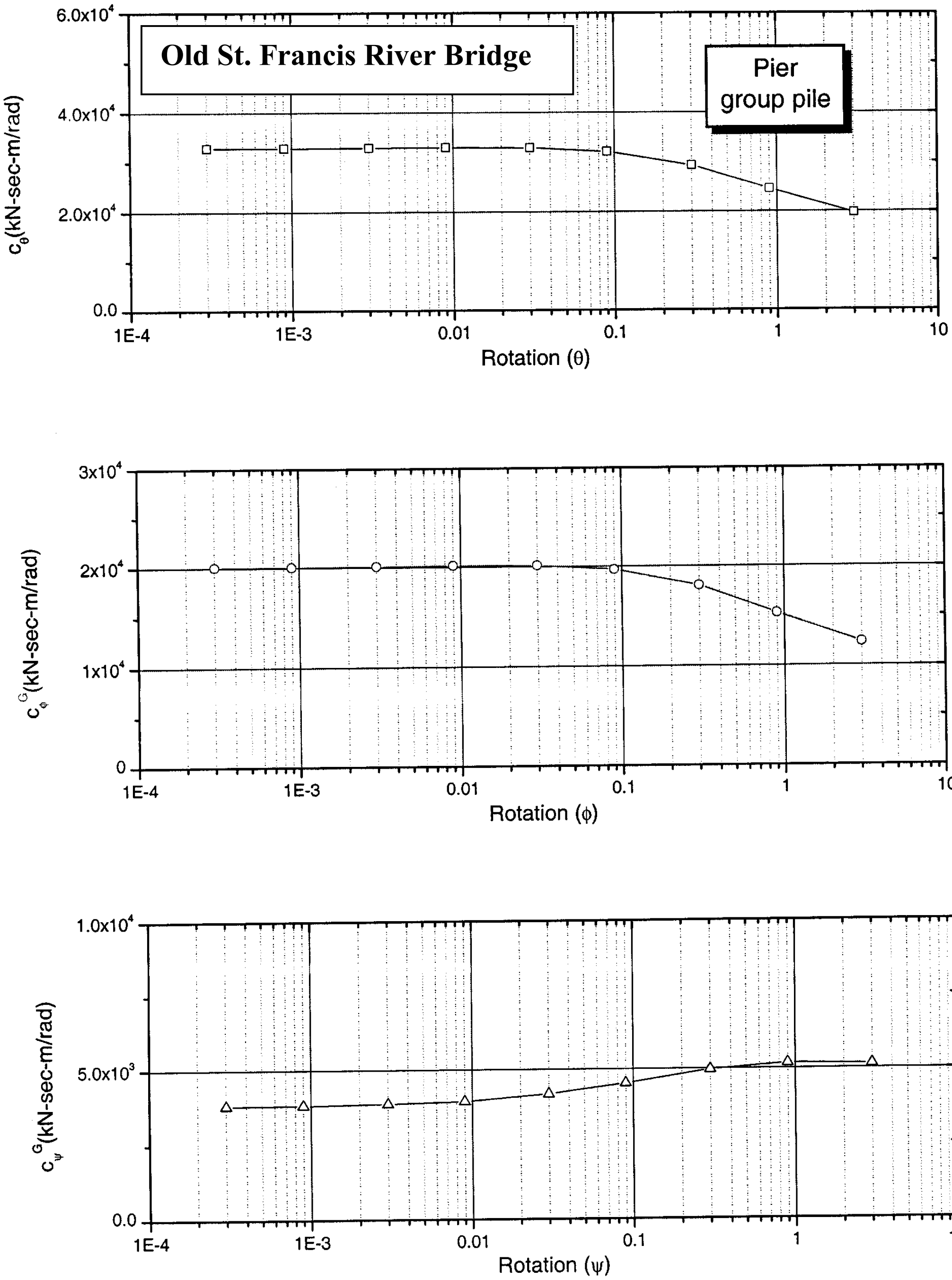




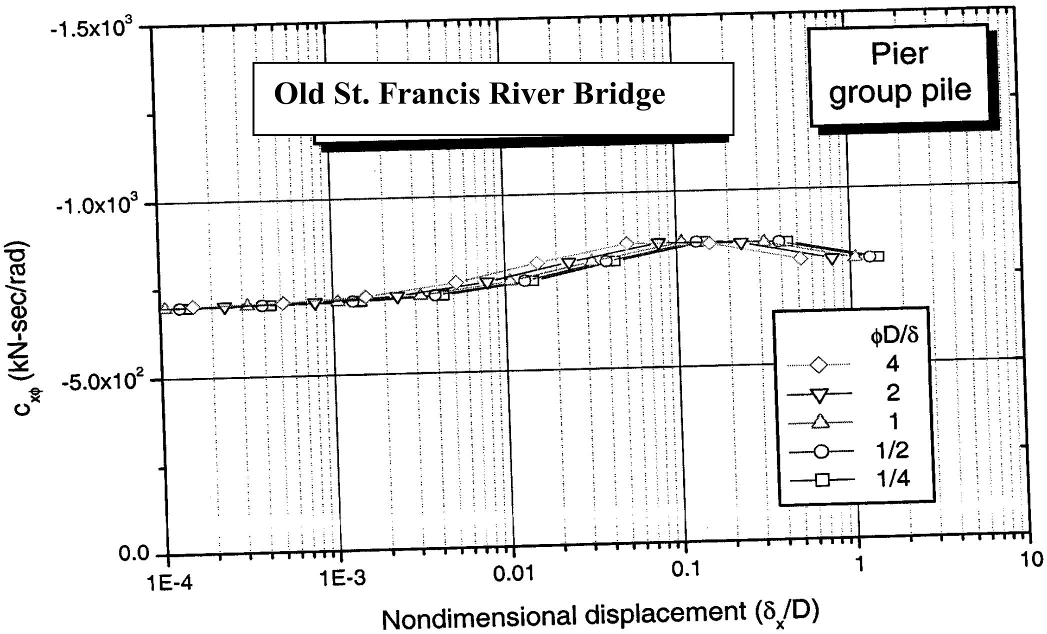
F.7g Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Pier Group Pile, Old St. Francis River Bridge

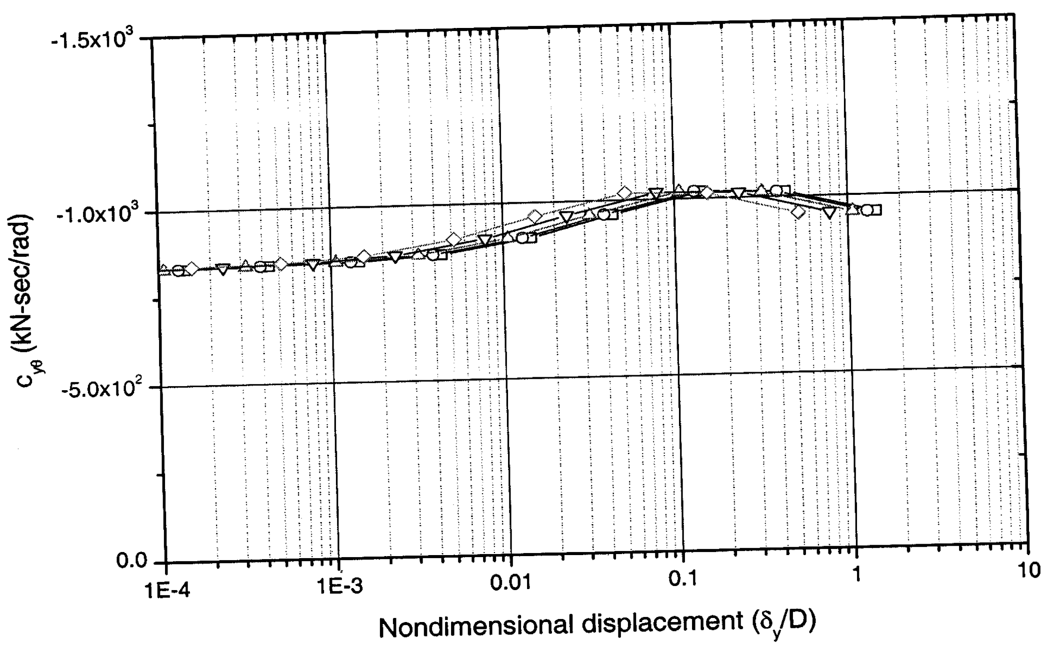


F.7h Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Pier Group Pile, Old St. Francis River Bridge

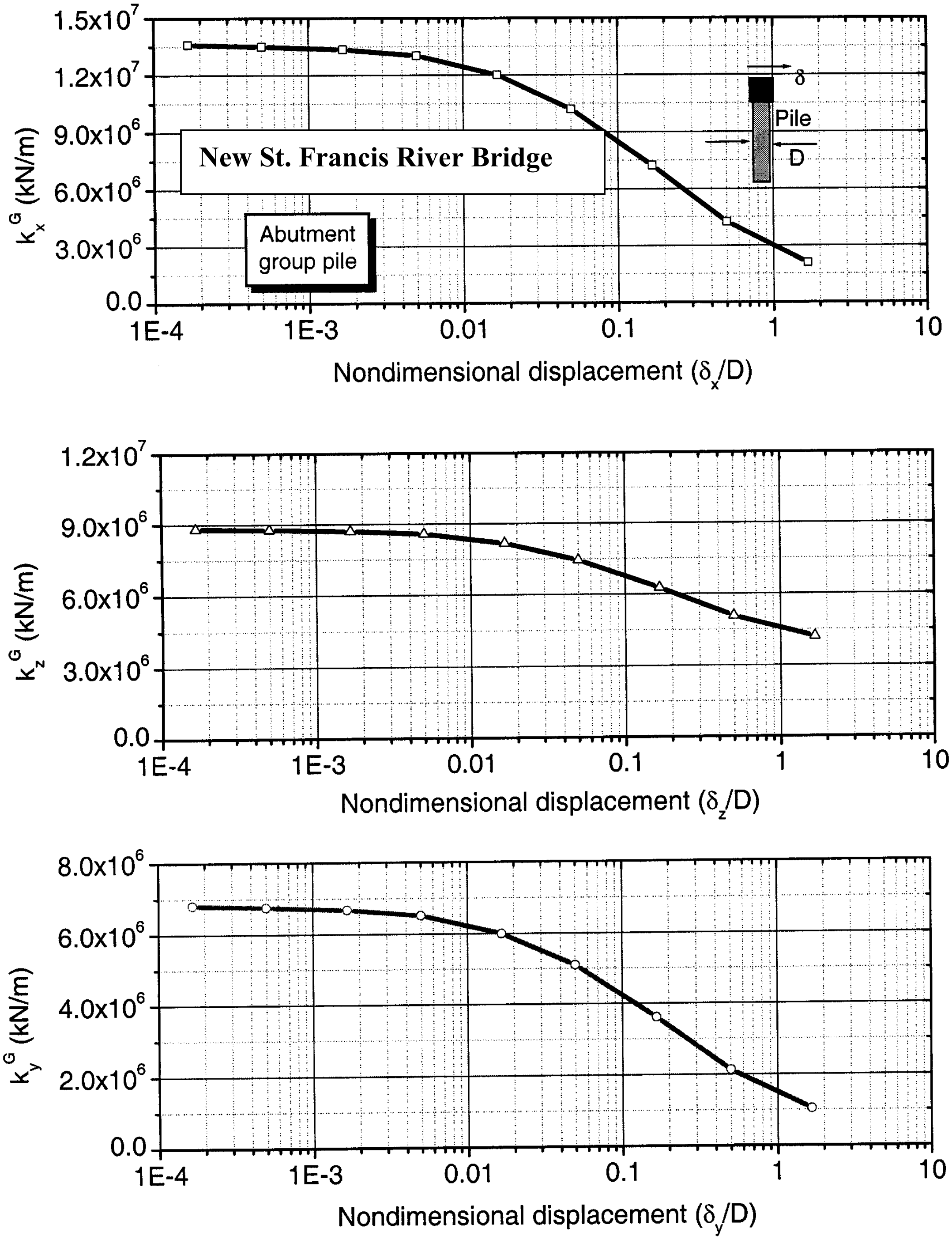


F.7i Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier Group Pile, Old St. Francis River Bridge

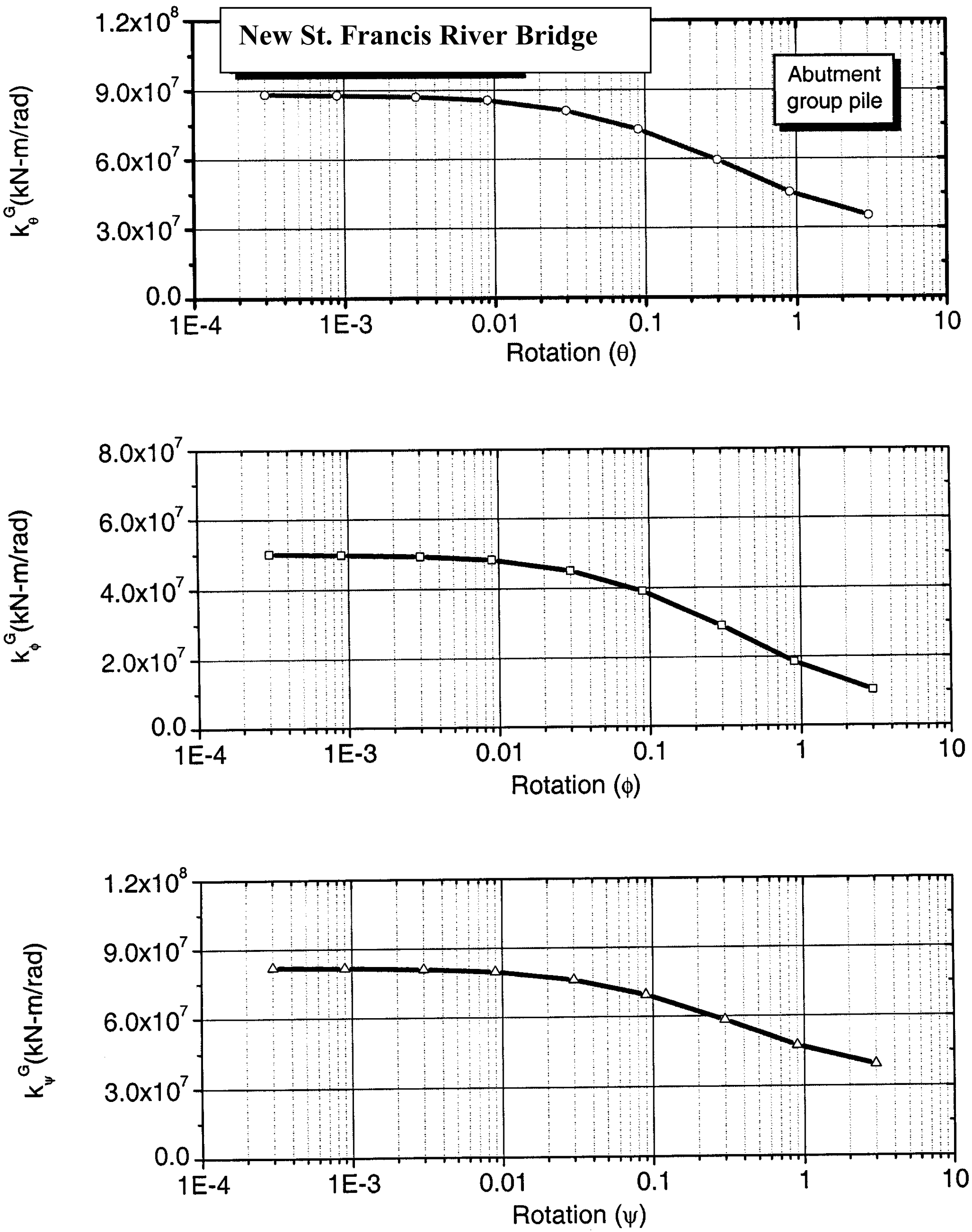




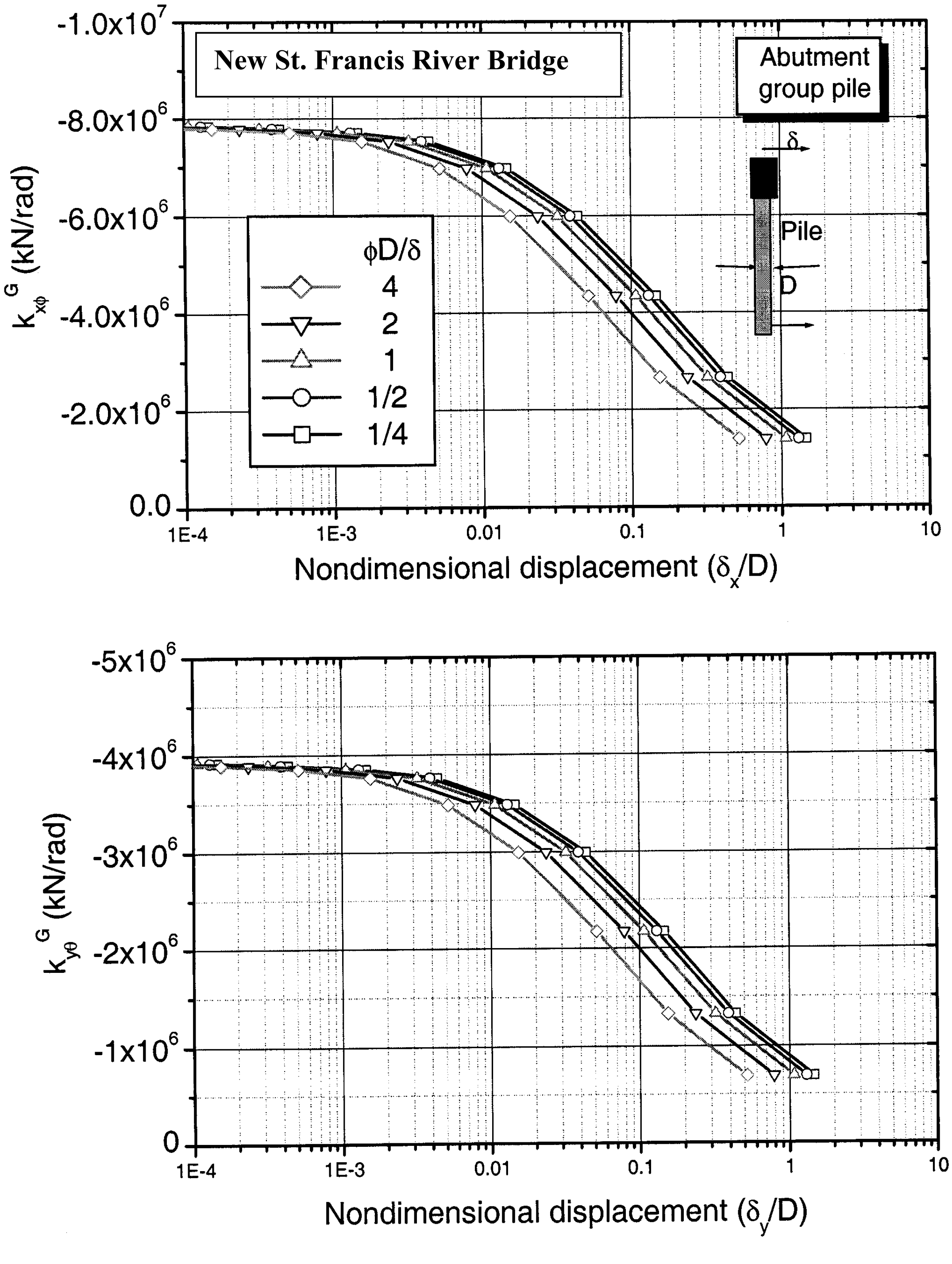
F.7j Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Pier Group Pile, Old St. Francis River Bridge



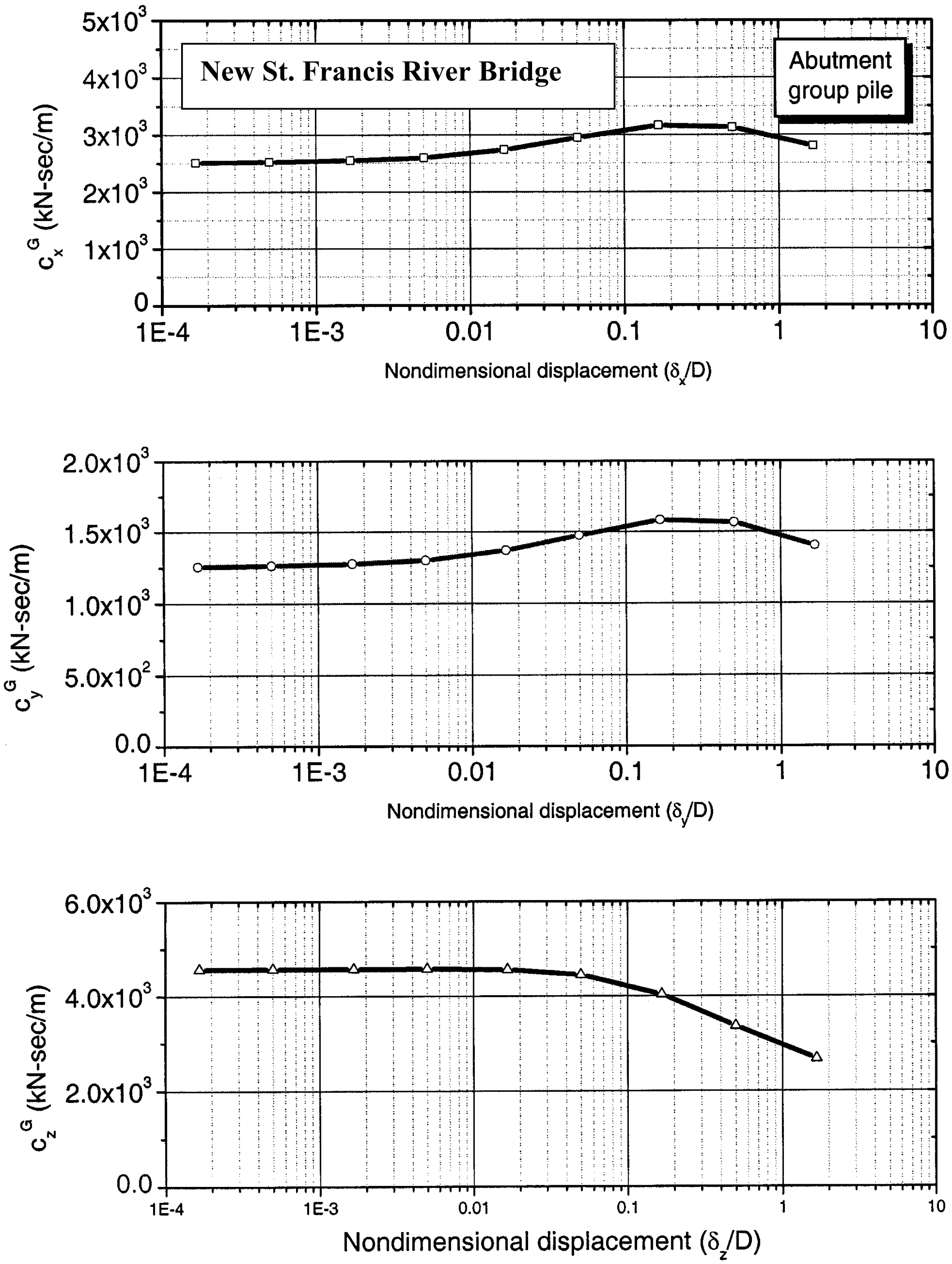
F7.k Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Abutment Group Pile, New St. Francis River Bridge



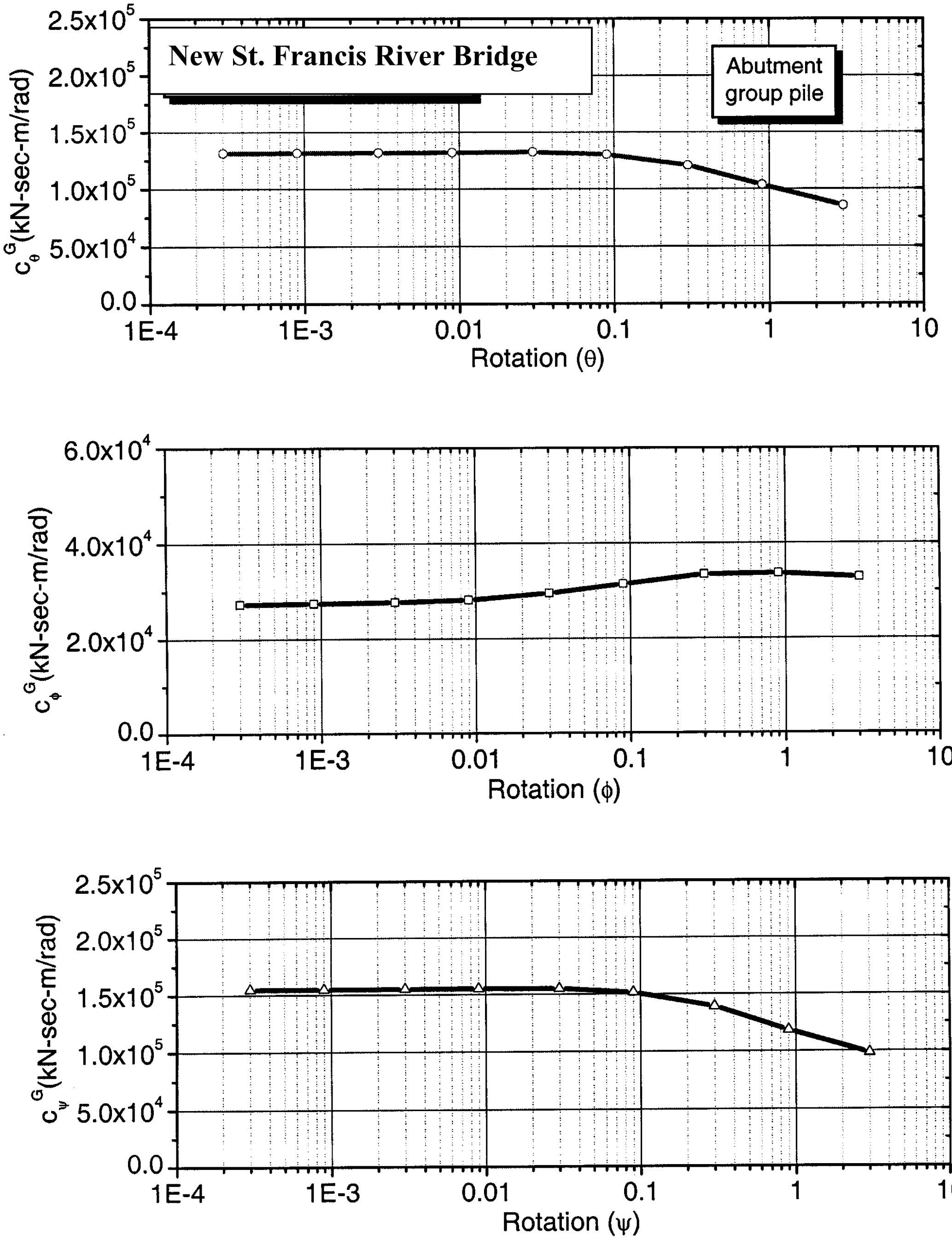
F.7l Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, New St. Francis River Bridge



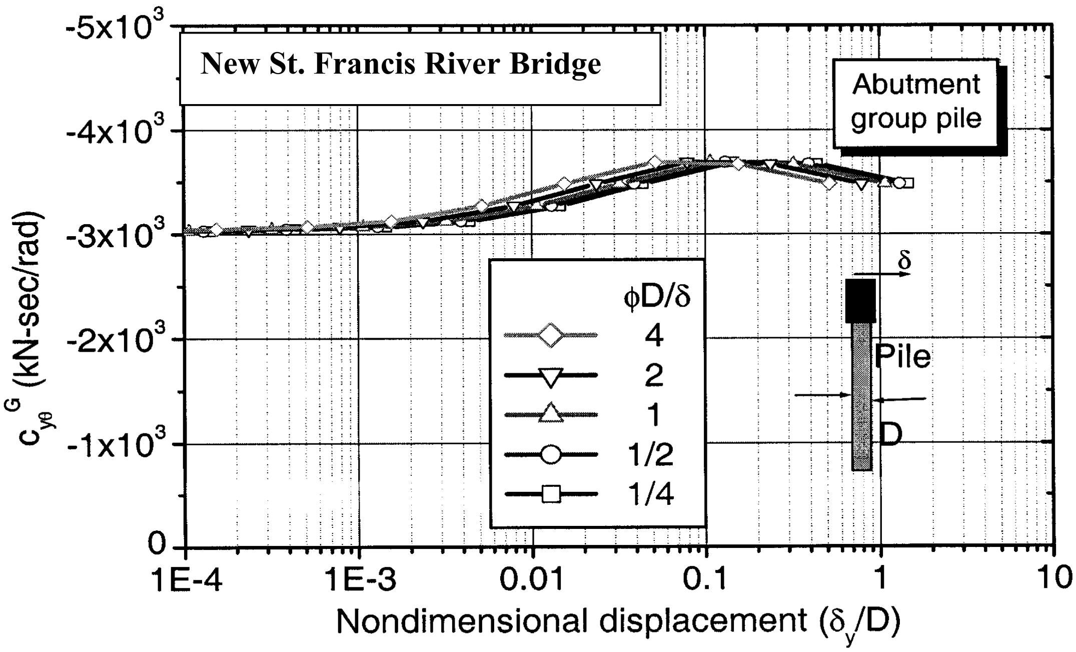
F.7m Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Abutment Group Pile, New St. Francis River Bridge

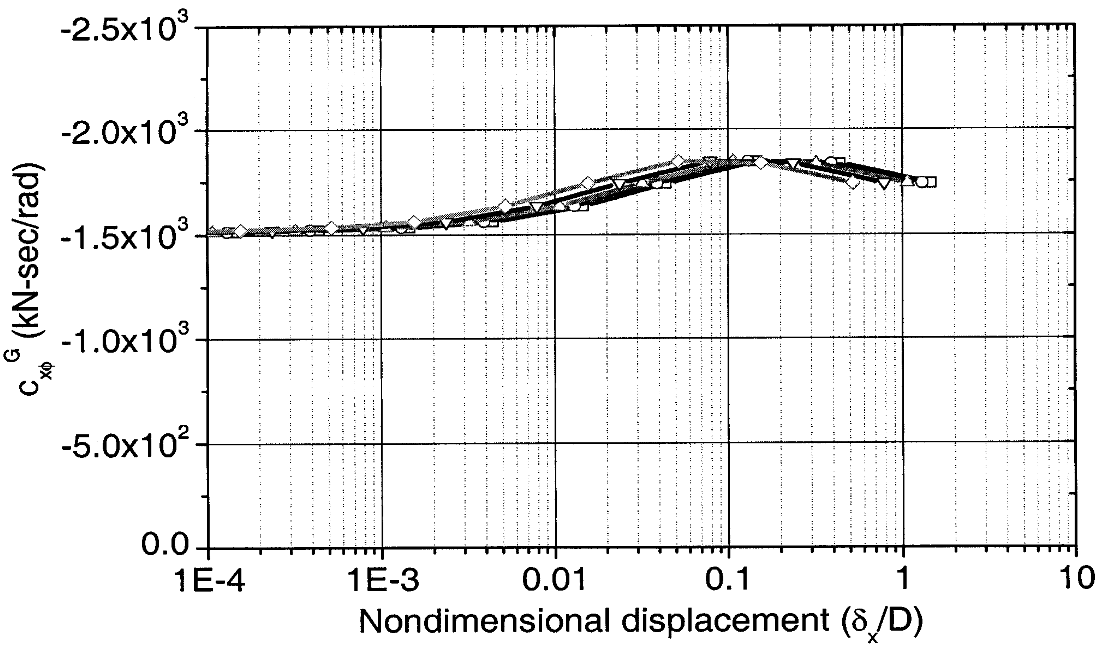


F.7n Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Abutment Group Pile, New St. Francis River Bridge

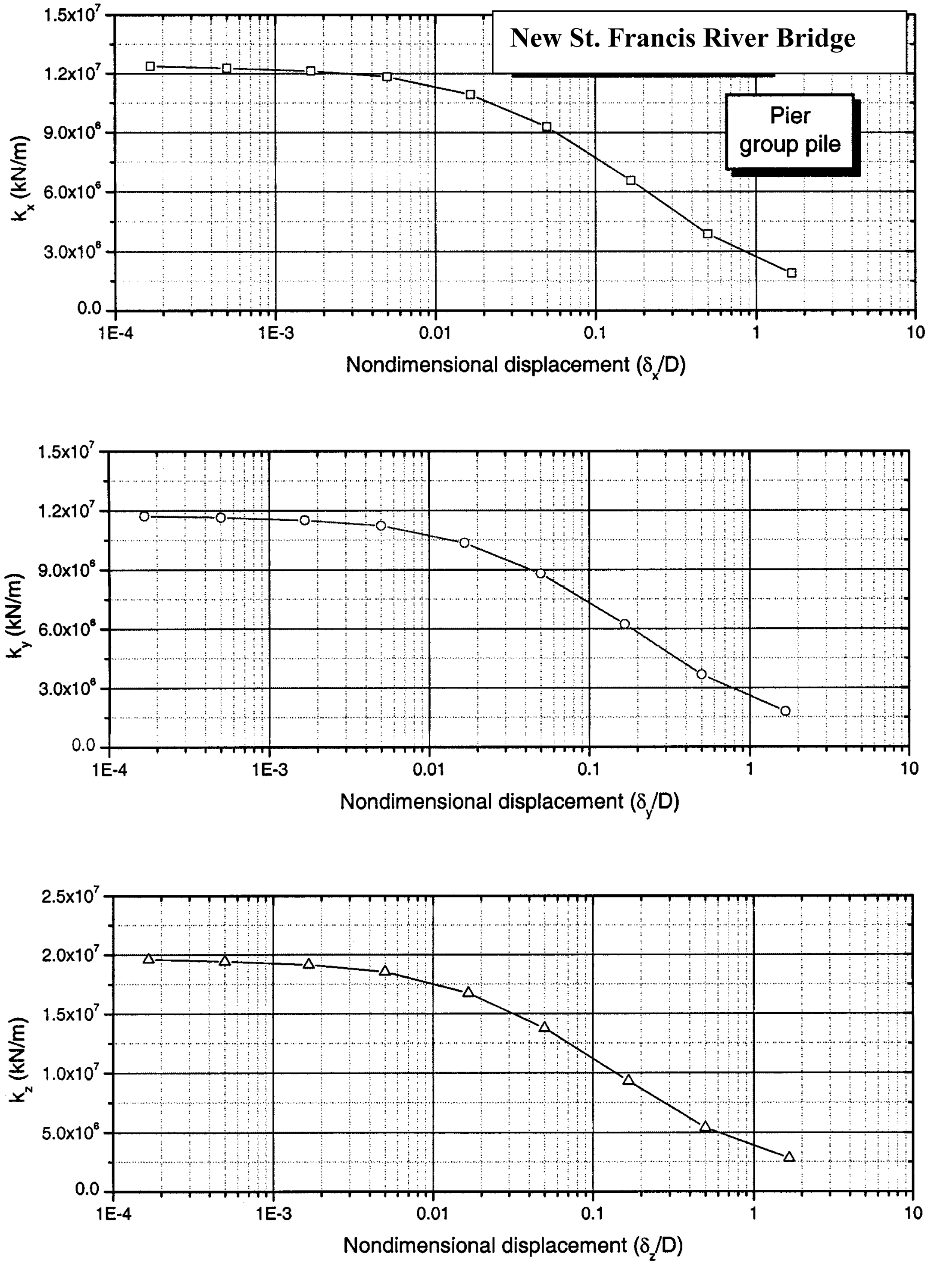


F.7o Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, New St. Francis River Bridge

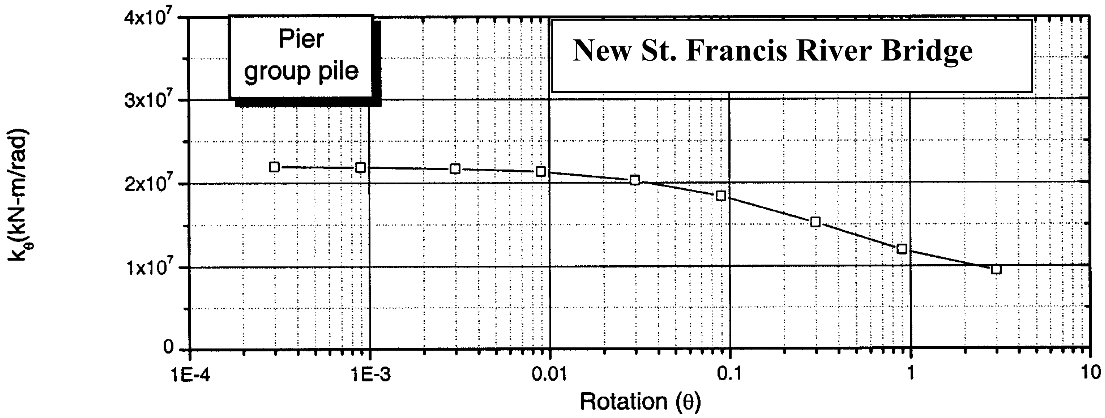


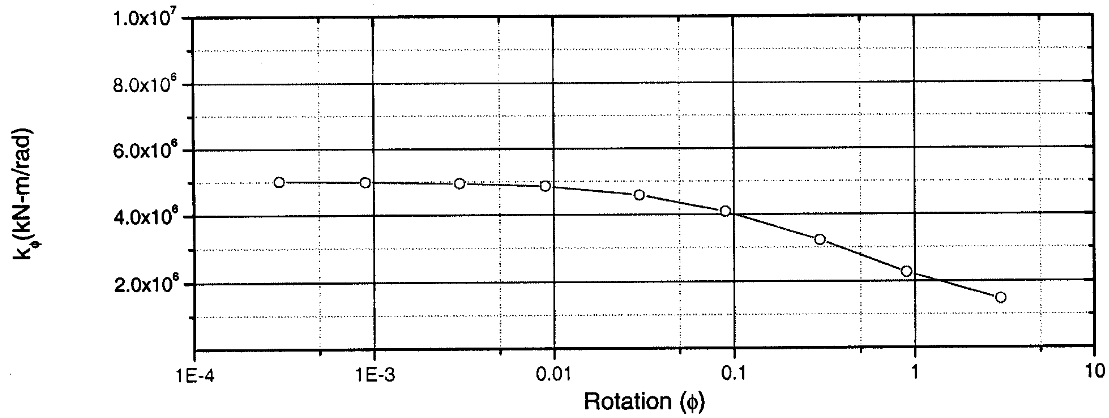


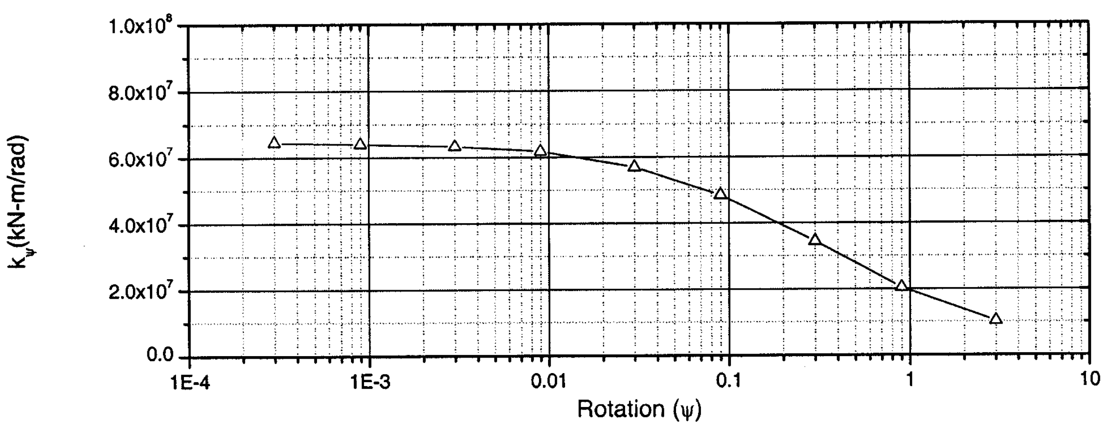
F.7p Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Abutment Group Pile, New St. Francis River Bridge



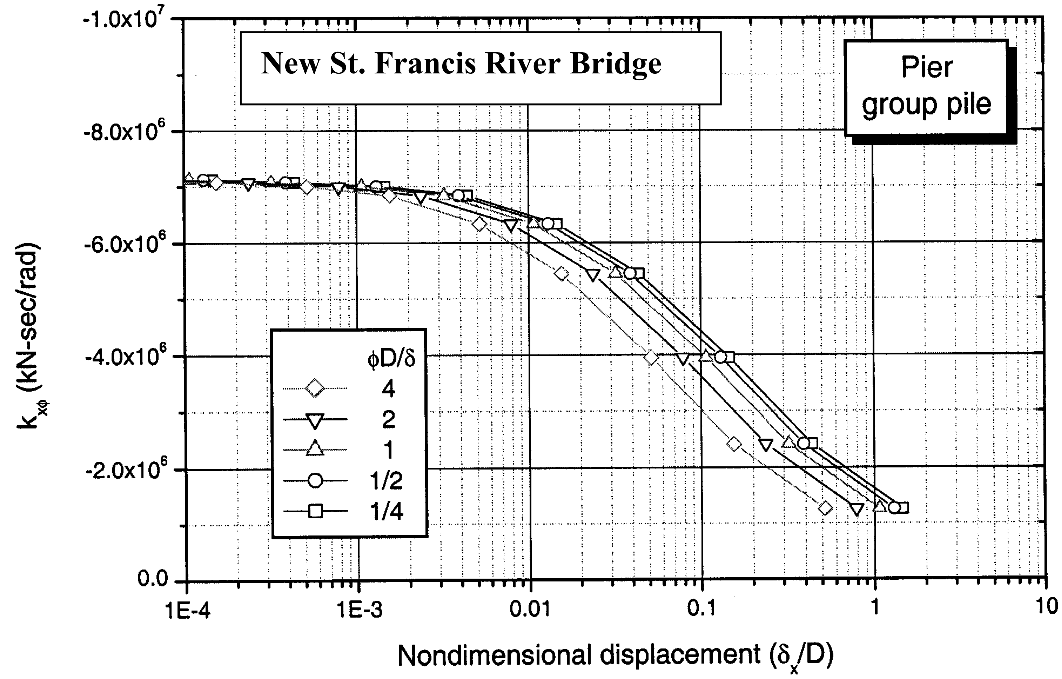
F.7q Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Pier Group Pile, New St. Francis River Bridge

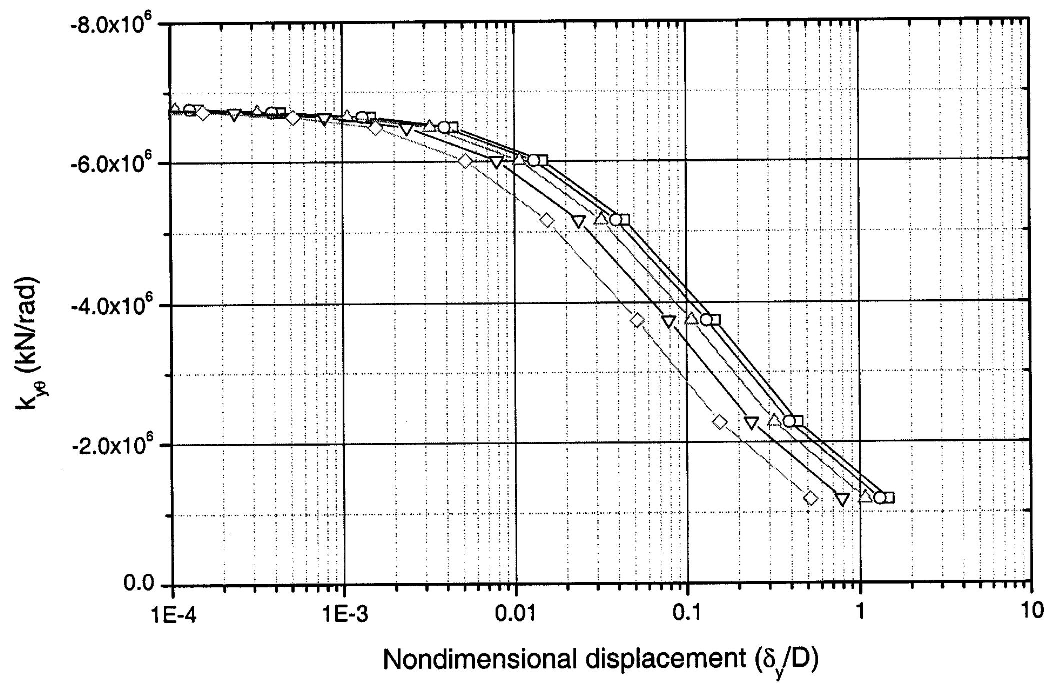




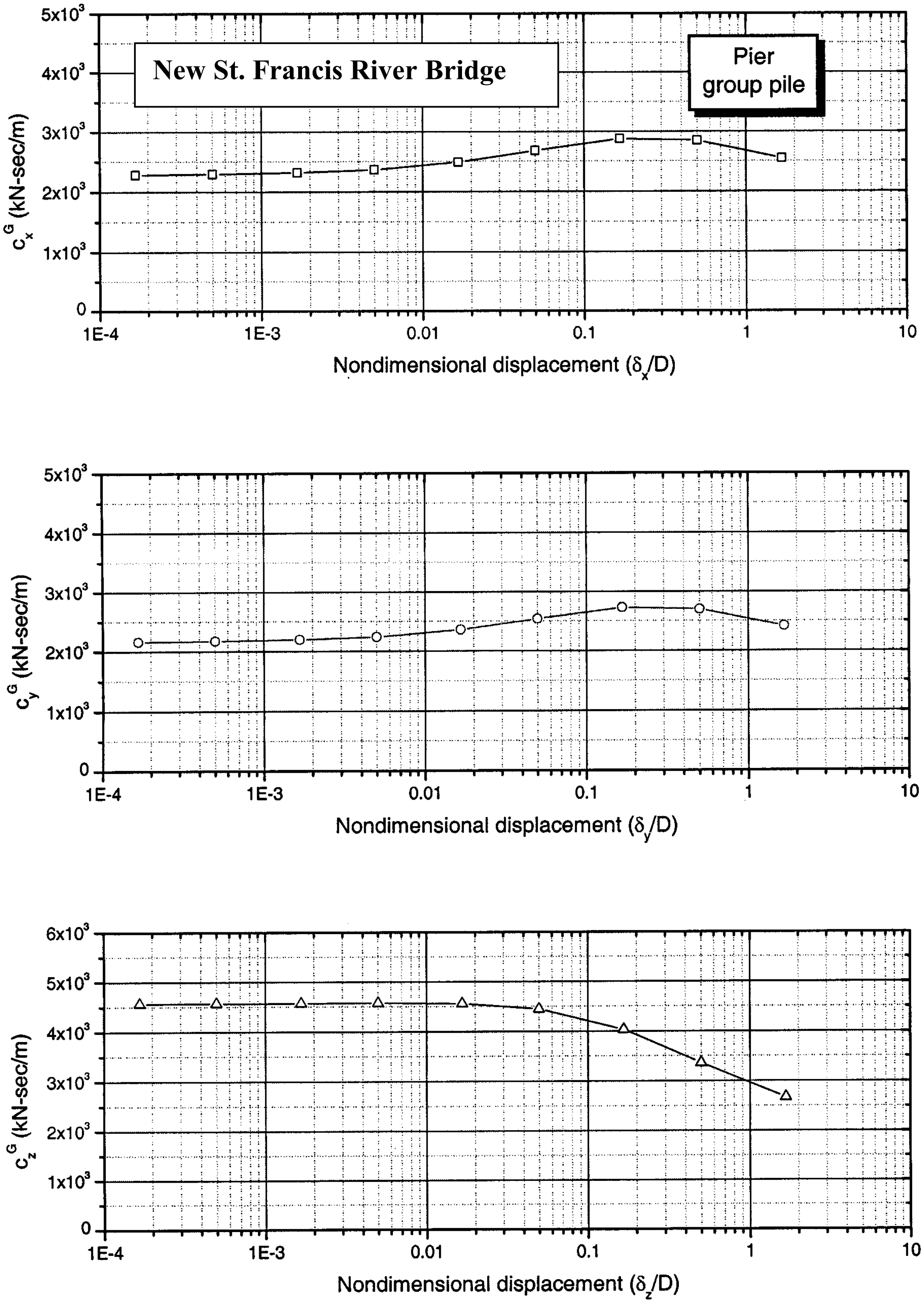


F.7r Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier Group Pile, New St. Francis River Bridge

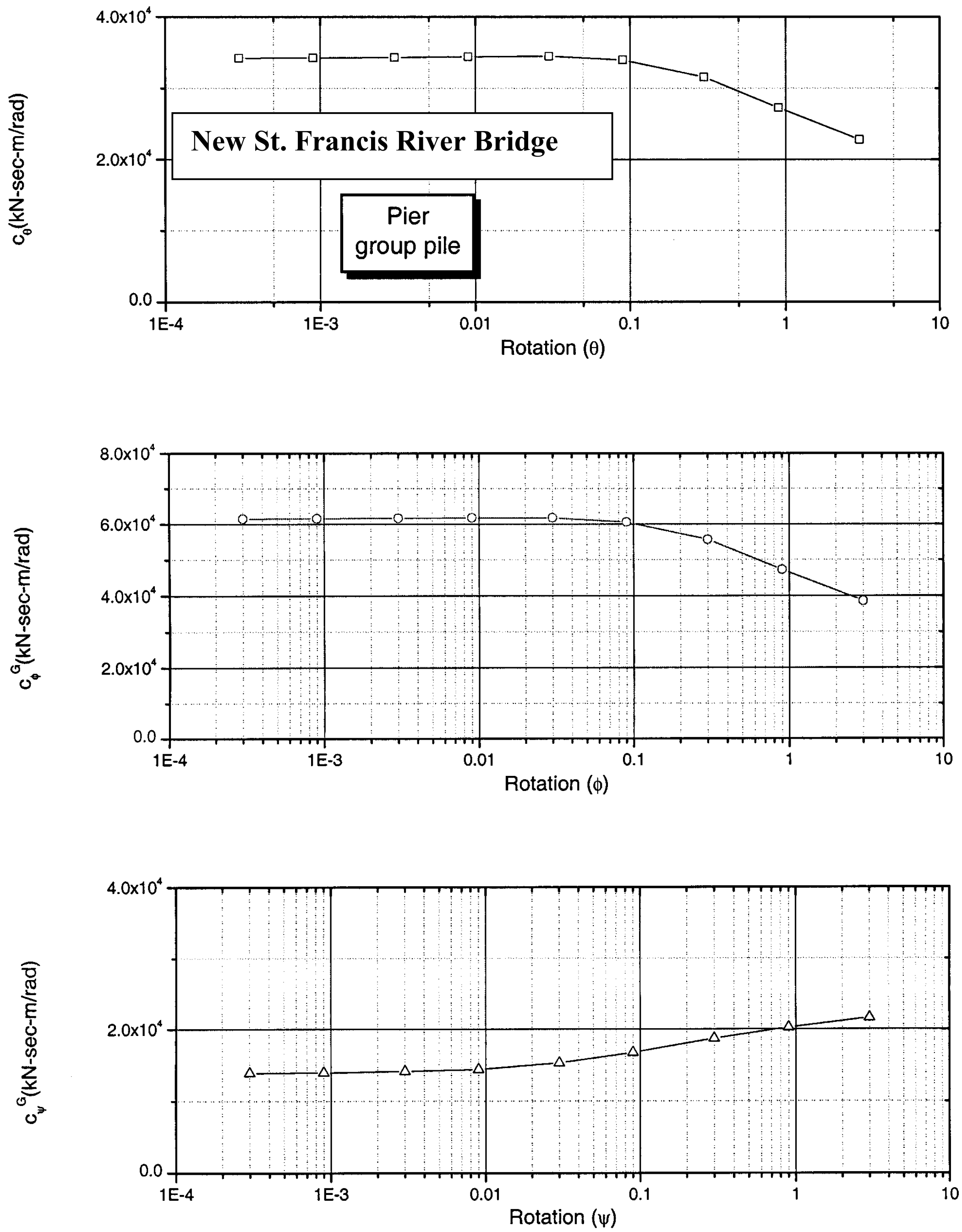




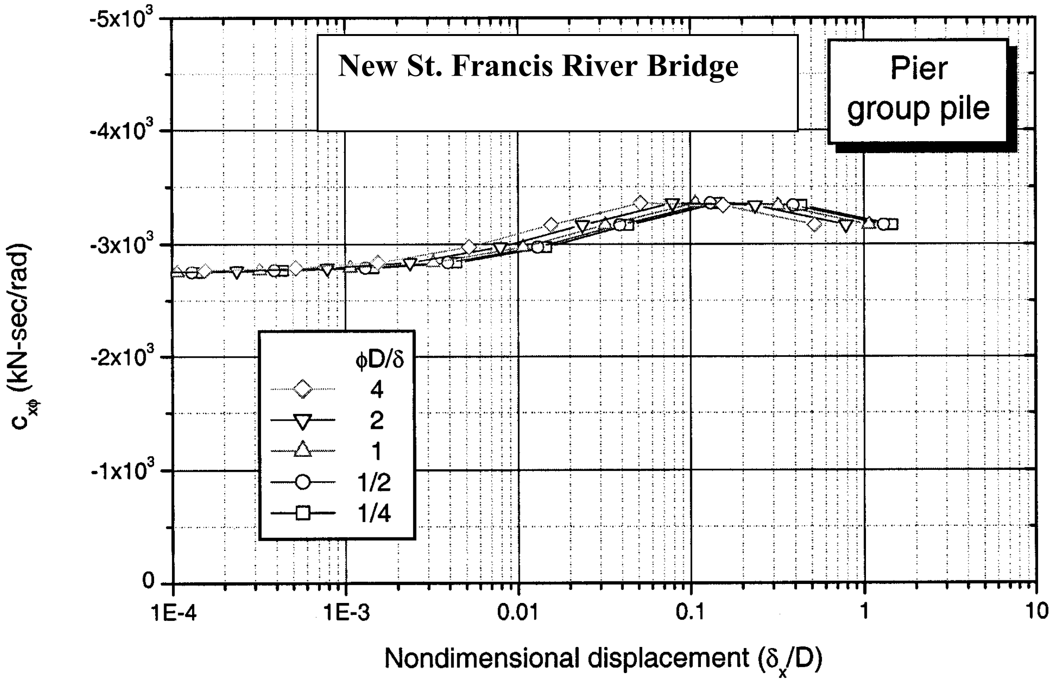
F.7s Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Pier Group Pile, New St. Francis River Bridge

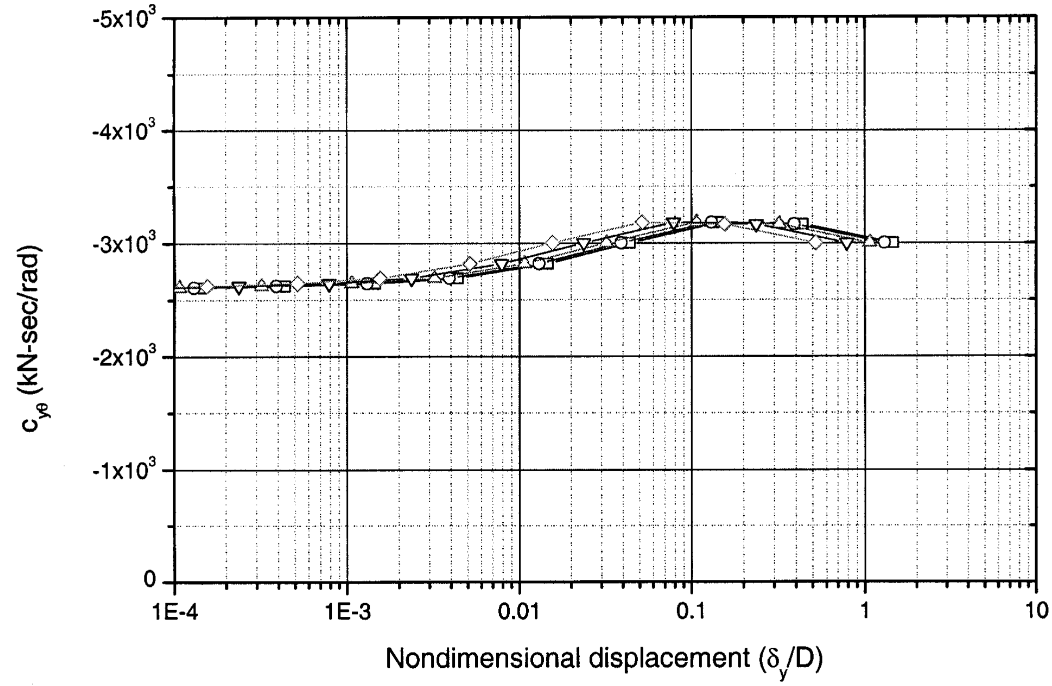


F.7t Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Pier Group Pile, New St. Francis River Bridge

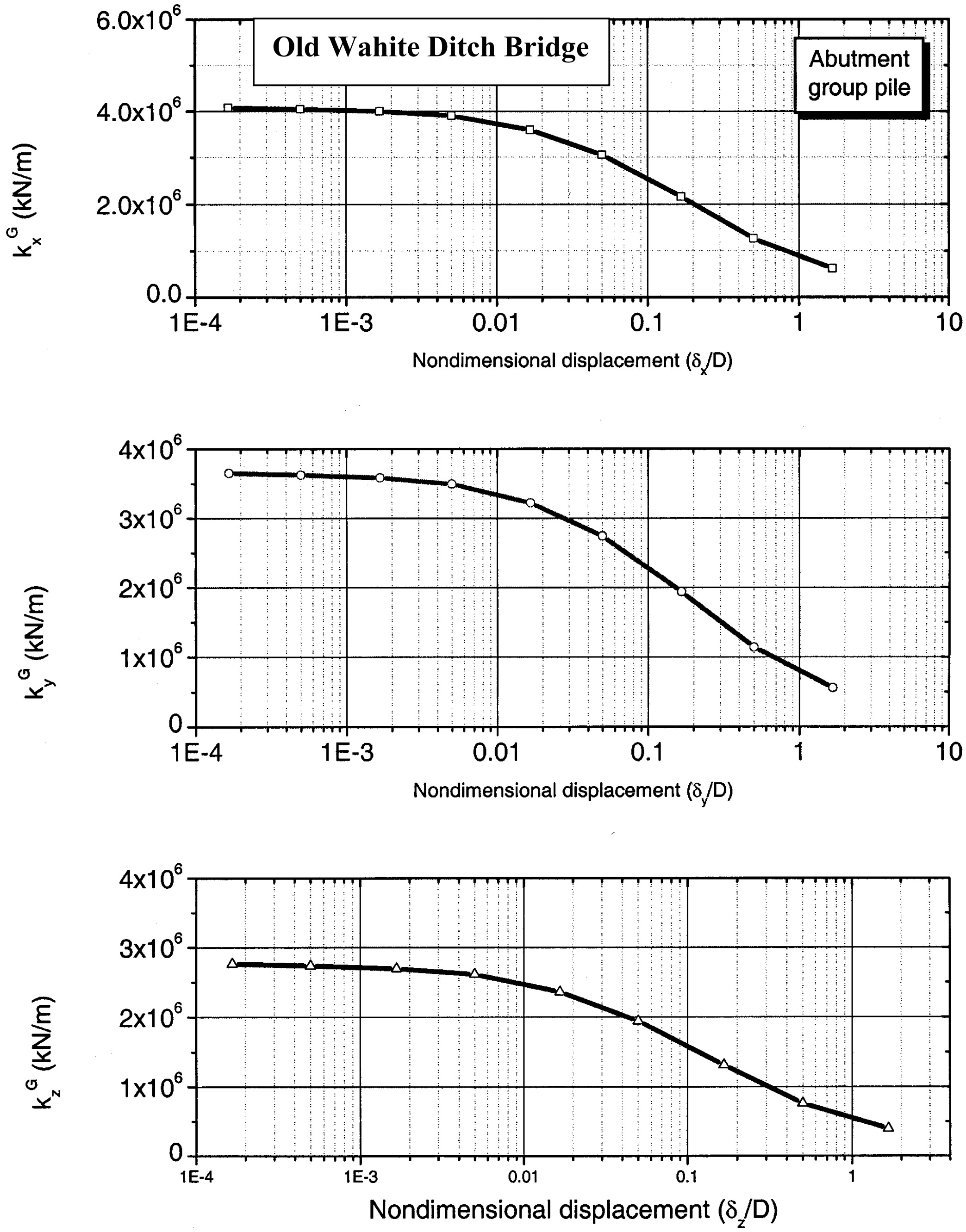


F.7u Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier Group Pile, New St. Francis River Bridge

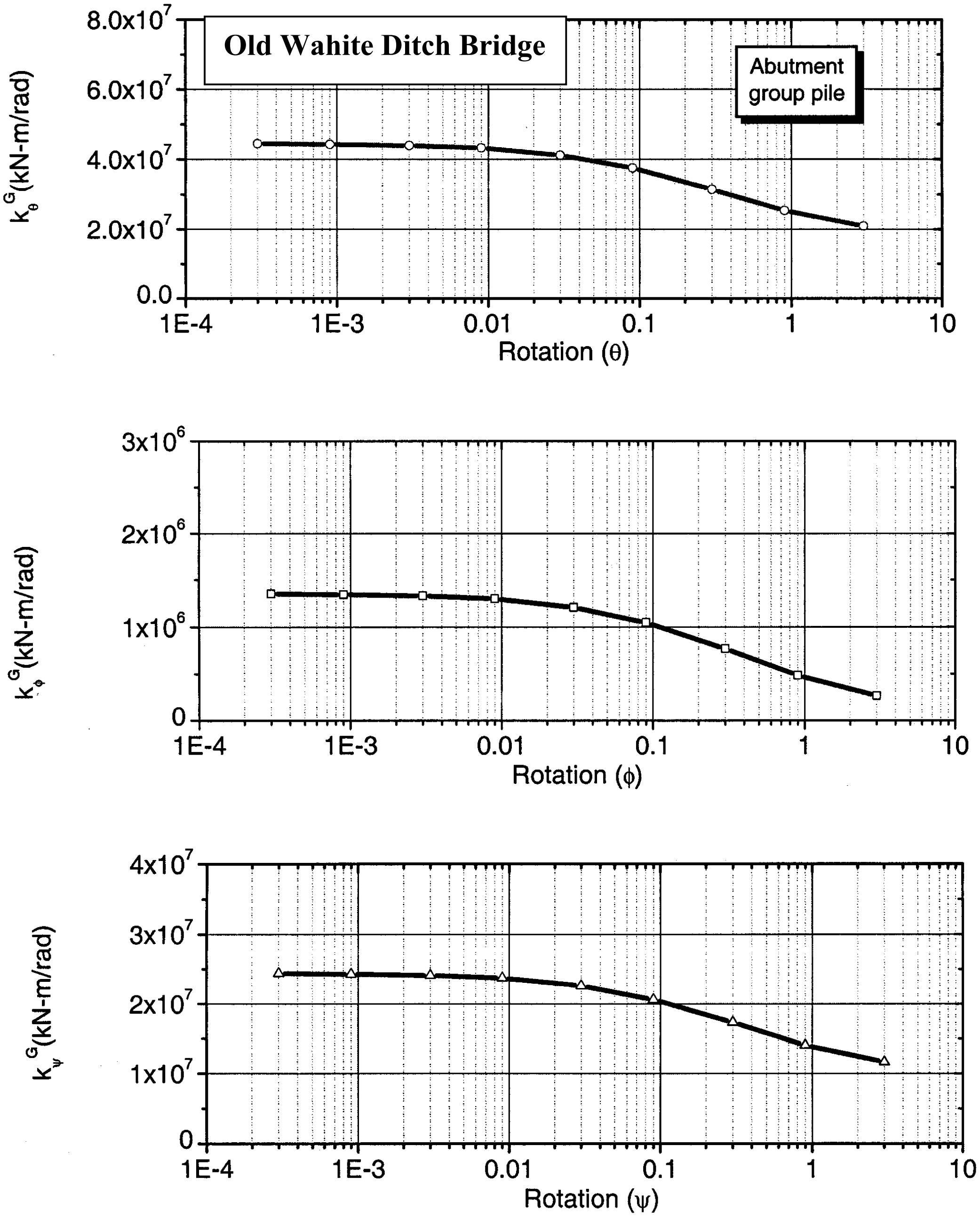




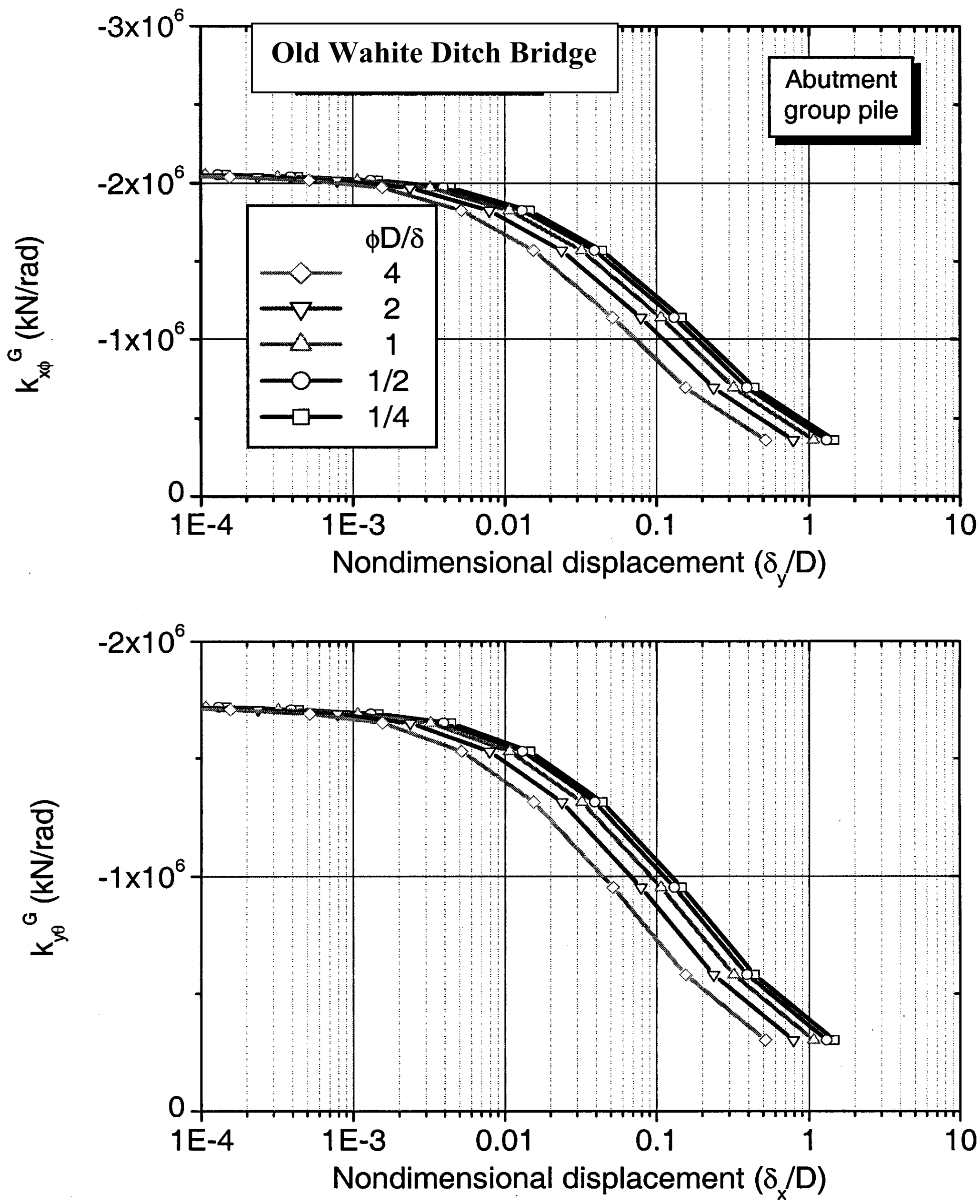
F.7v Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Pier Group Pile, New St. Francis River Bridge



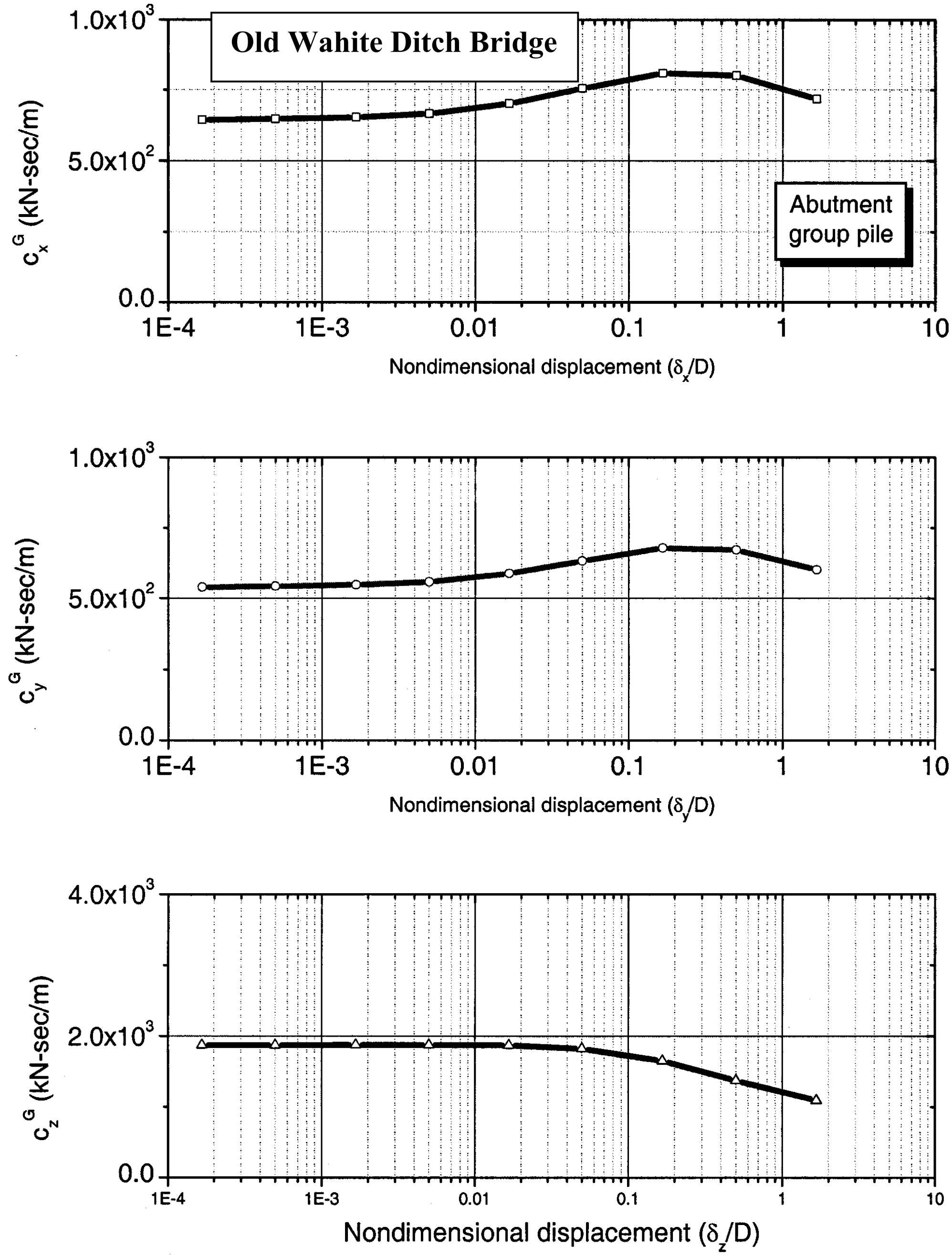
F.7w Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Abutment Group Pile, Old Wahite Ditch Bridge



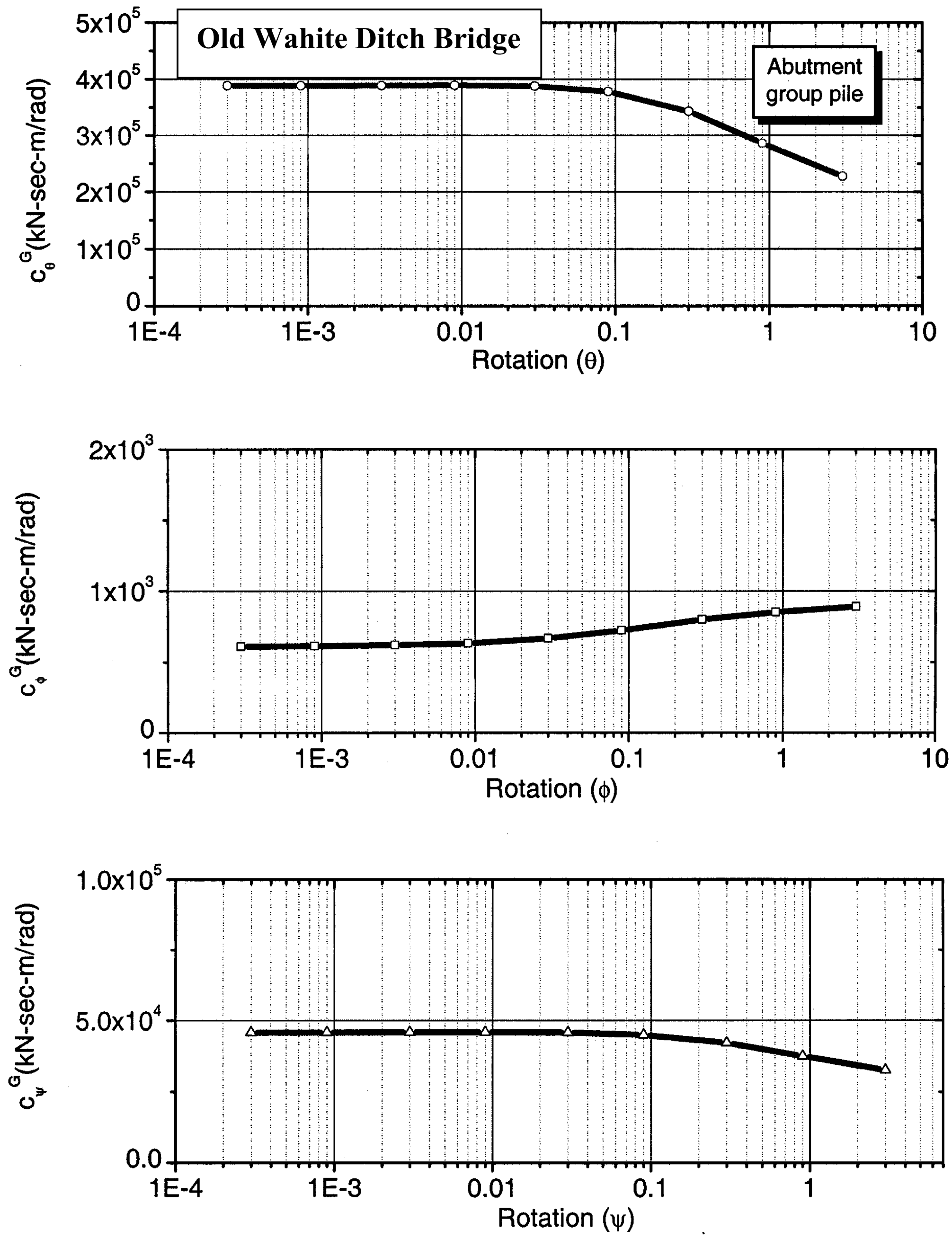
F.7x Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, Old Wahite Ditch Bridge



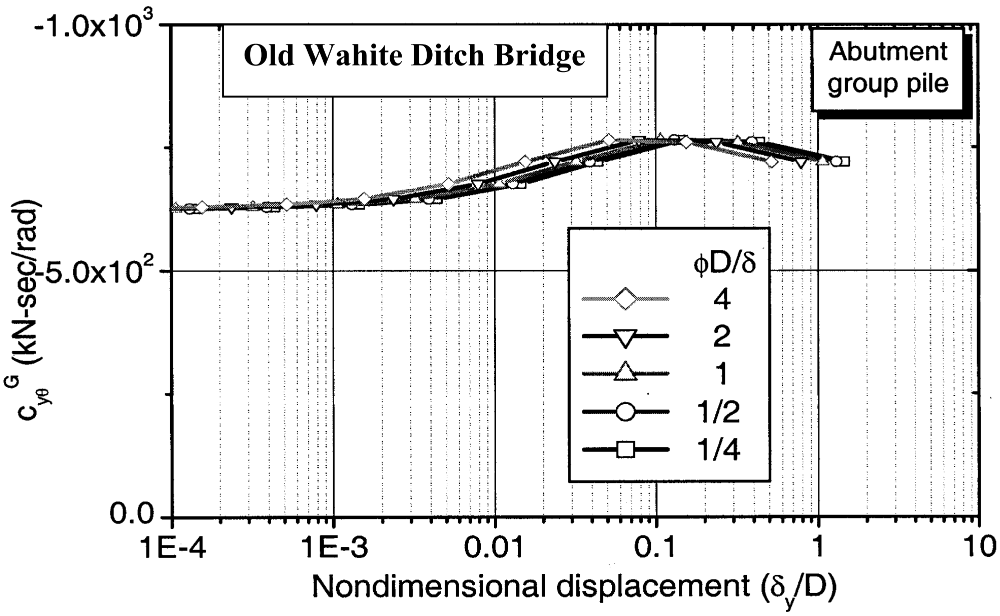
F.7y Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Abutment Group Pile, Old Wahite Ditch Bridge

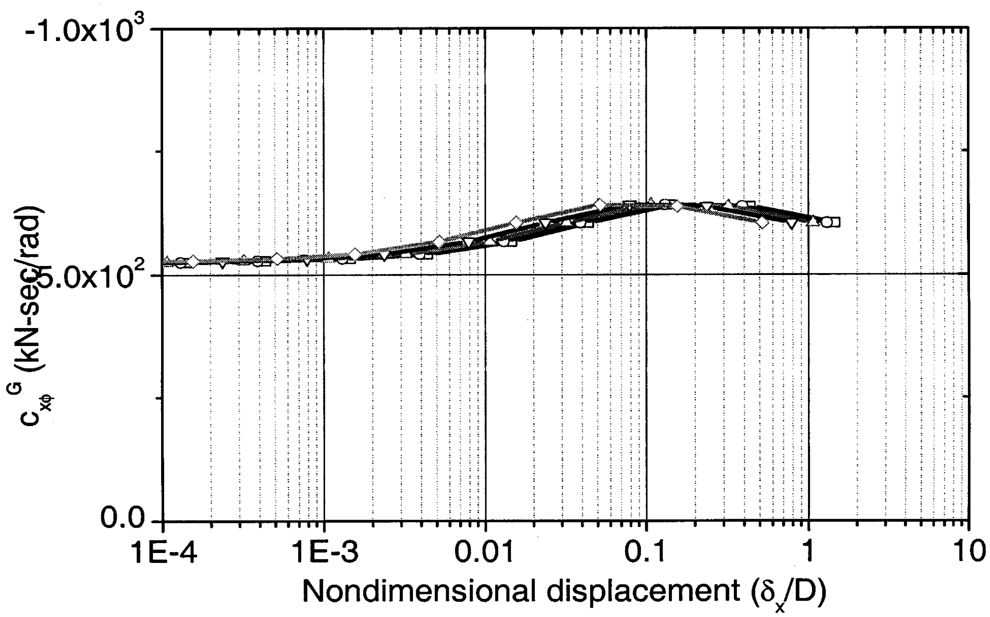


F.7z Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Pier Group Pile, Old Wahite Ditch Bridge

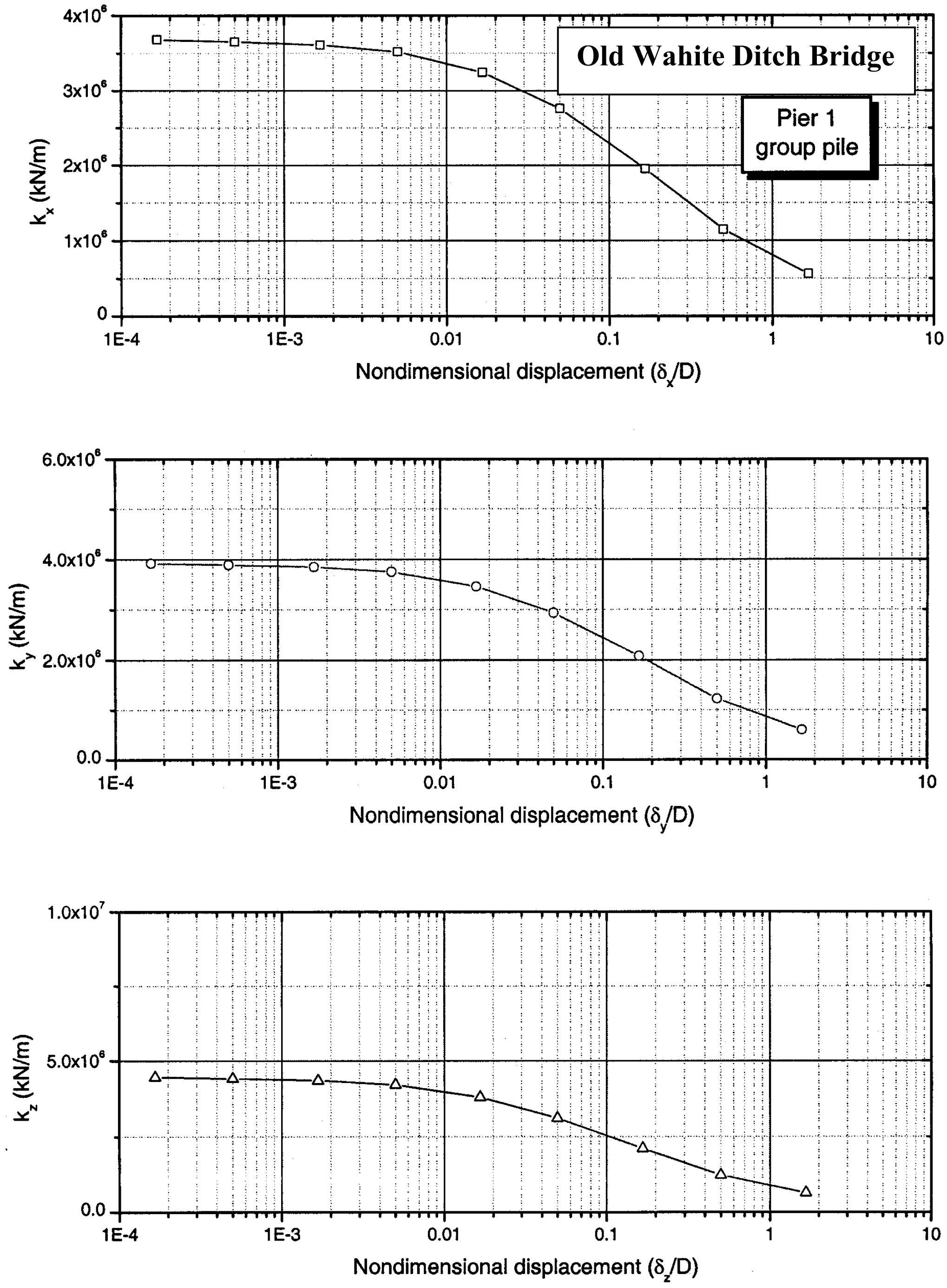


F.7aa Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, Old Wahite Ditch Bridge

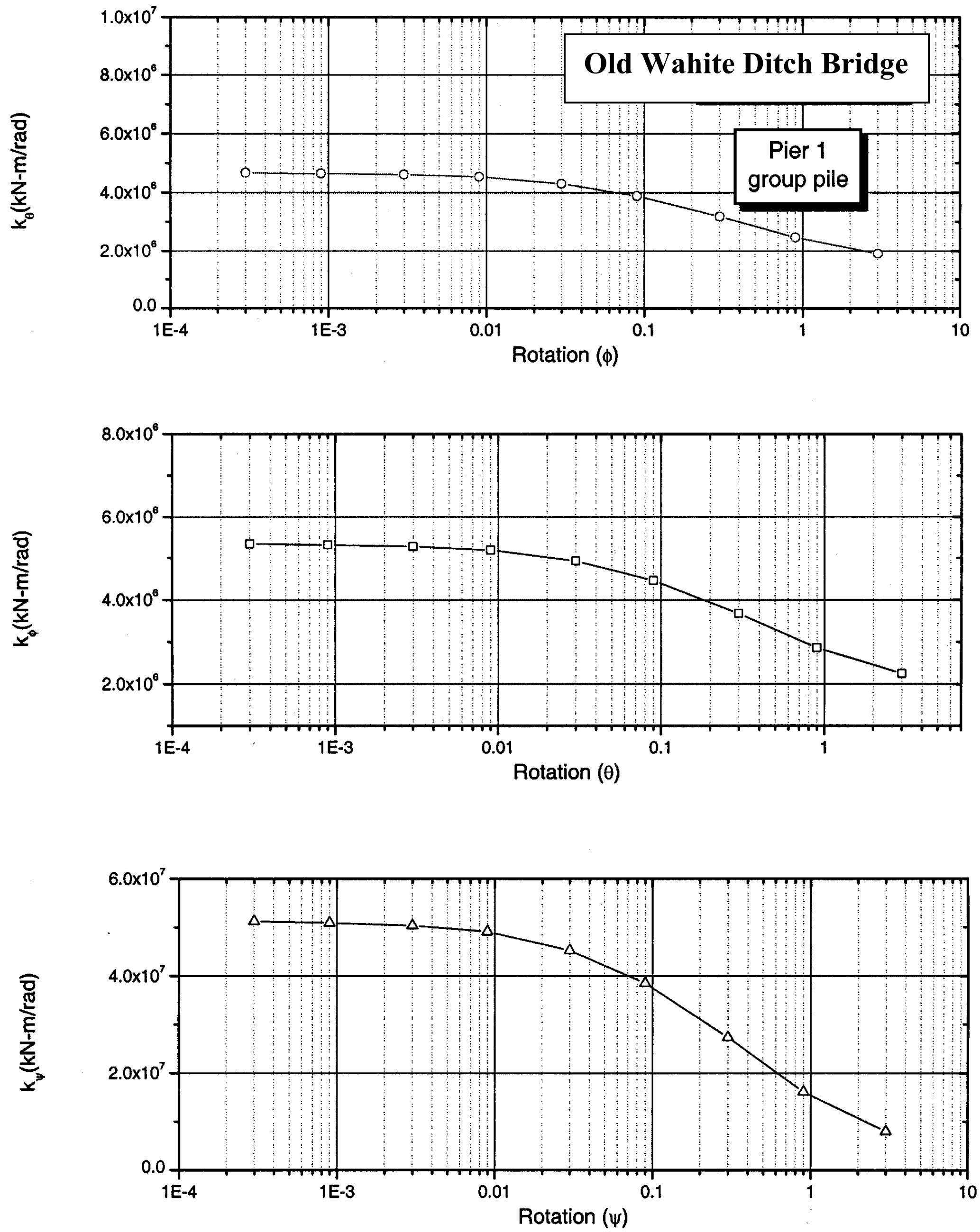




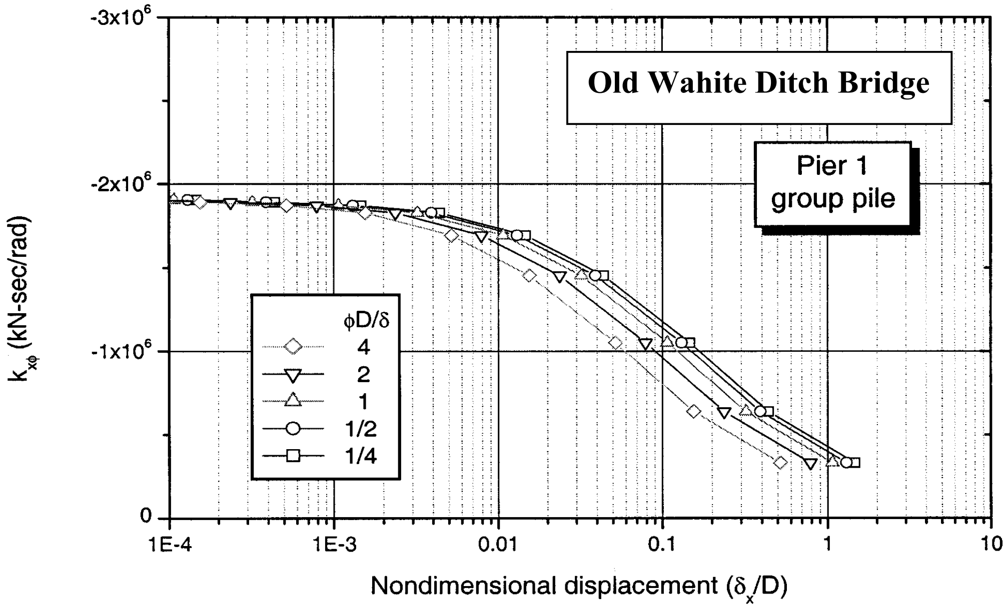
F.7ab Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Abutment Group Pile, Old Wahite Ditch Bridge

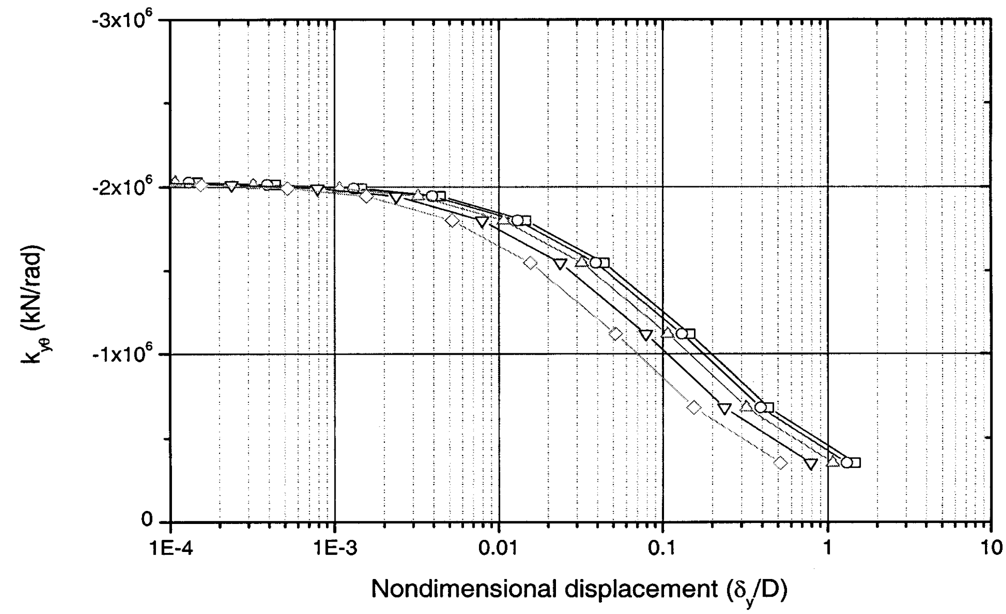


F.7ac Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Pier 1 Group Pile, Old Wahite Ditch Bridge

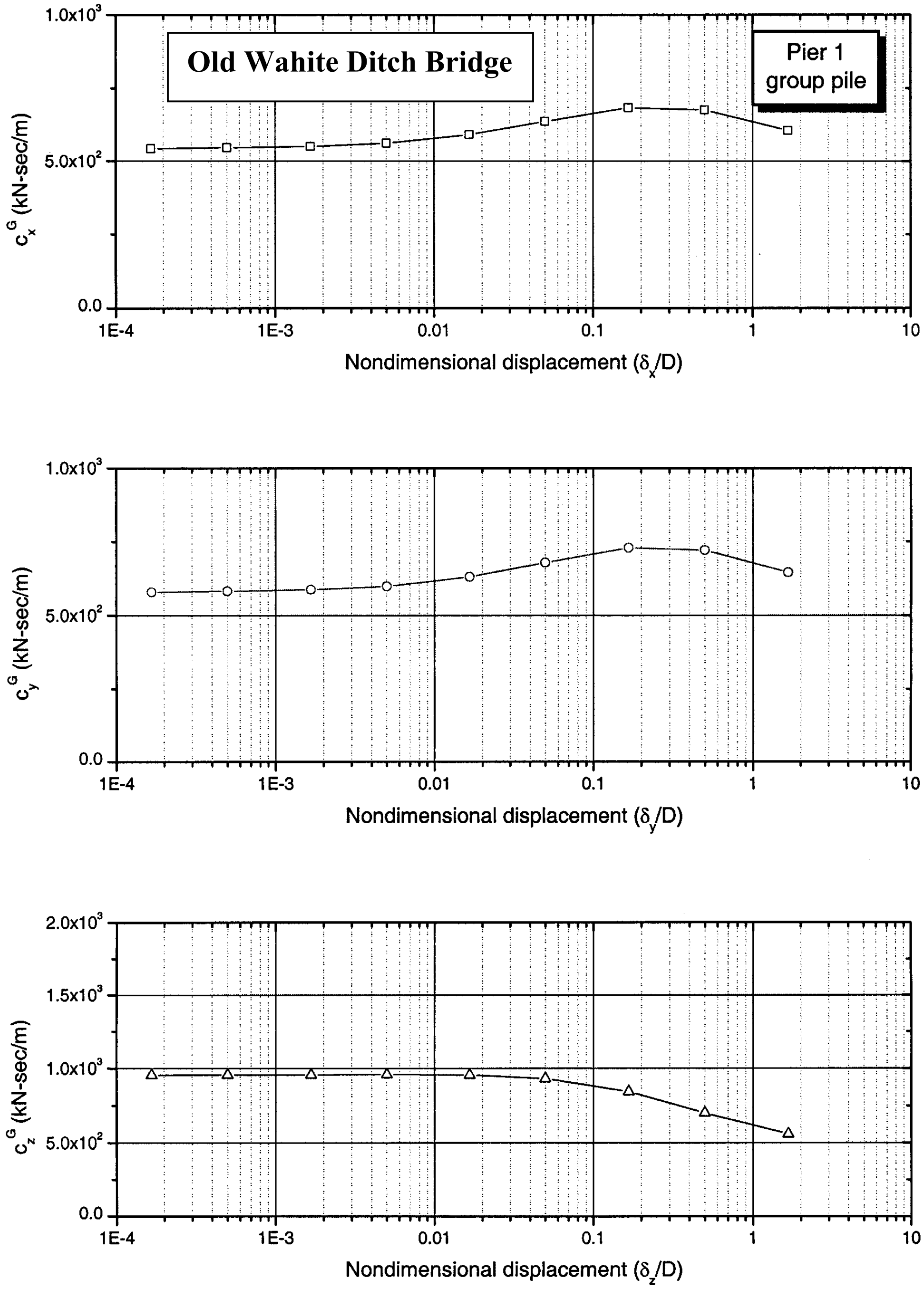


F.7ad Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier 1 Group Pile, Old Wahite Ditch Bridge

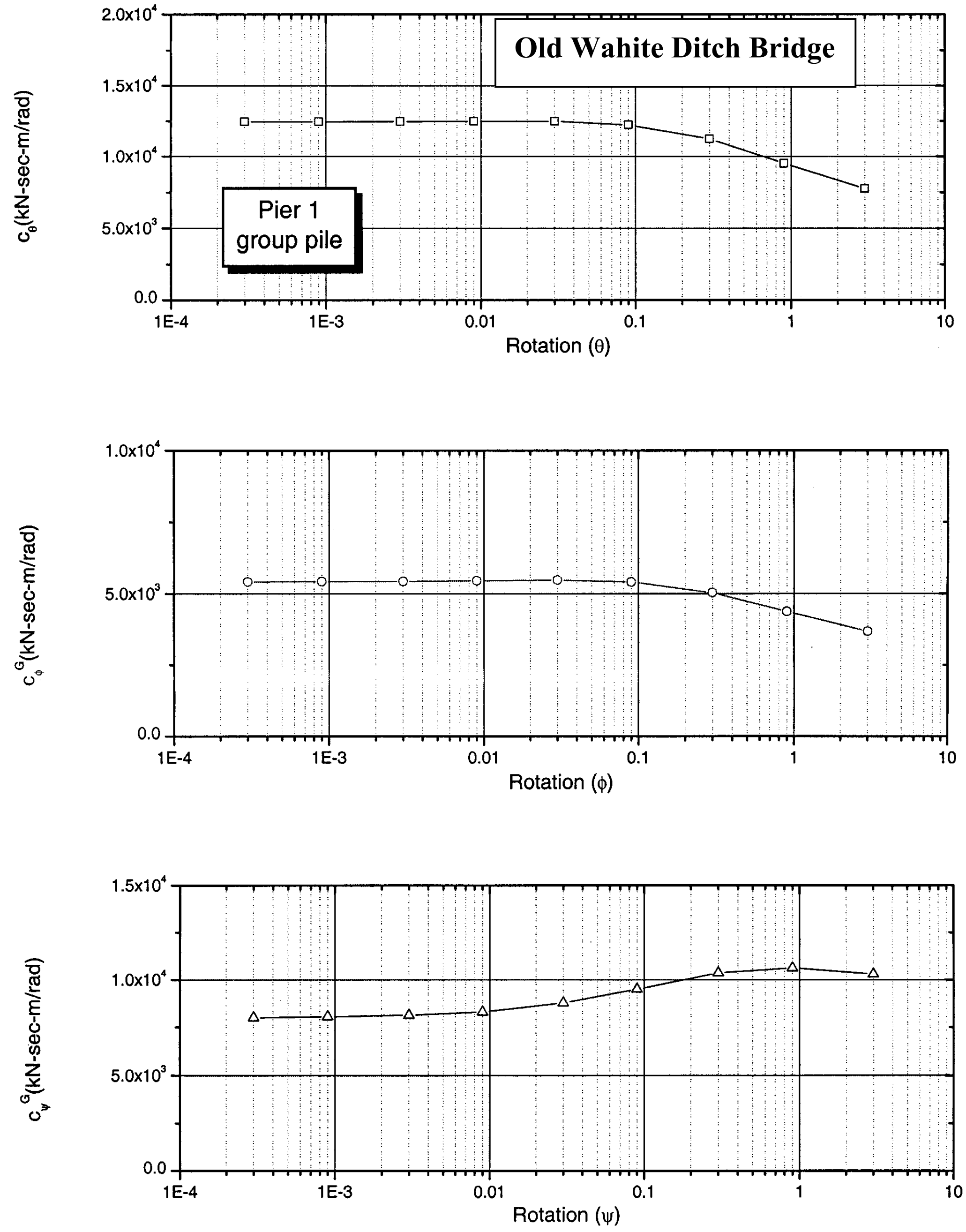




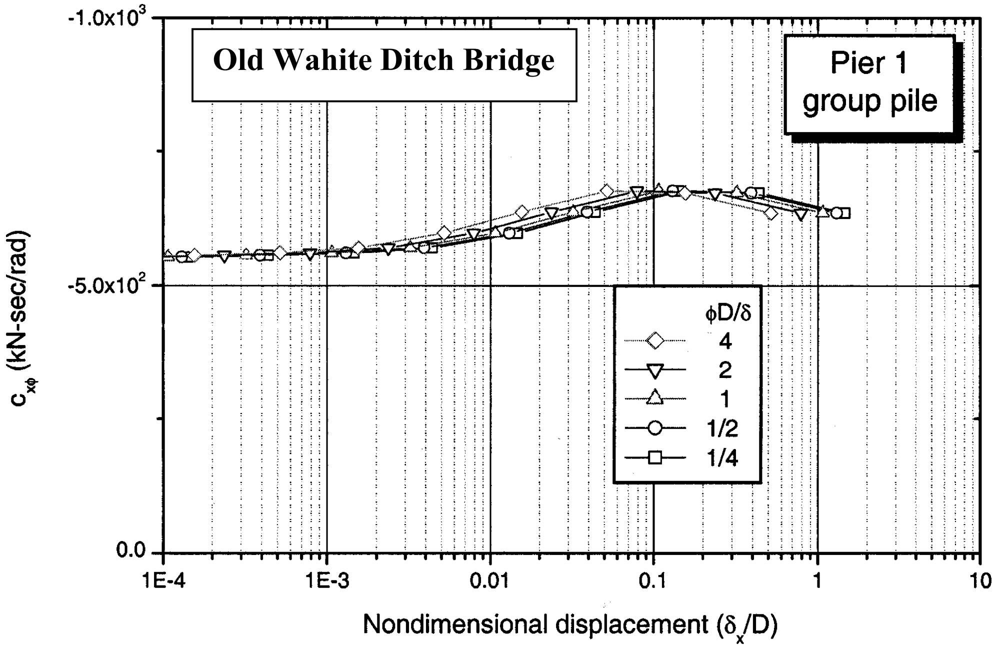
F.7ae Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Pier 1 Group Pile, Old Wahite Ditch Bridge

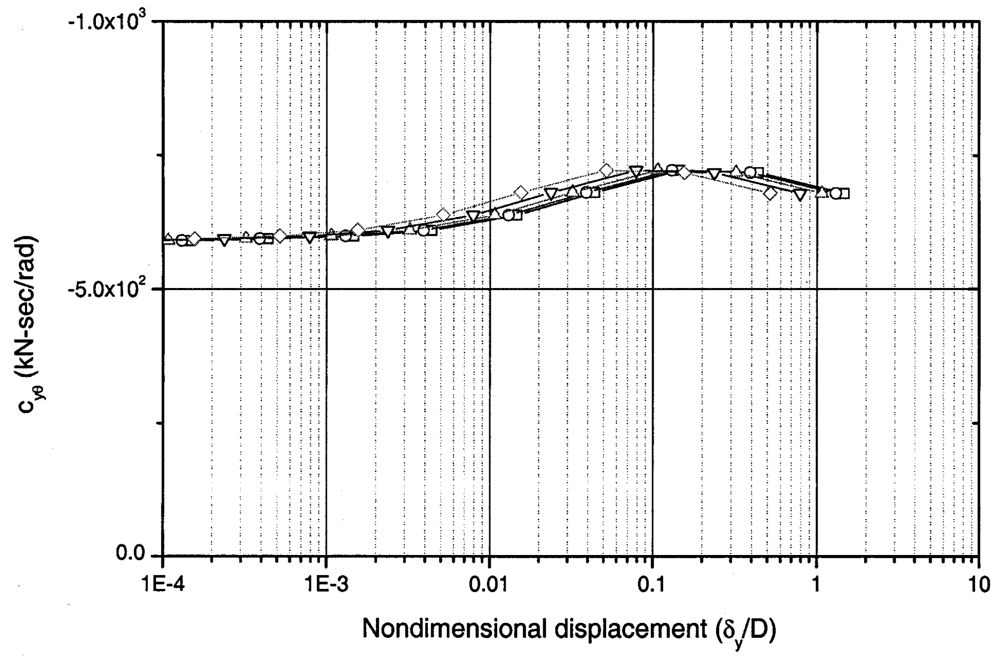


F.7af Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Pier 1 Group Pile, Old Wahite Ditch Bridge

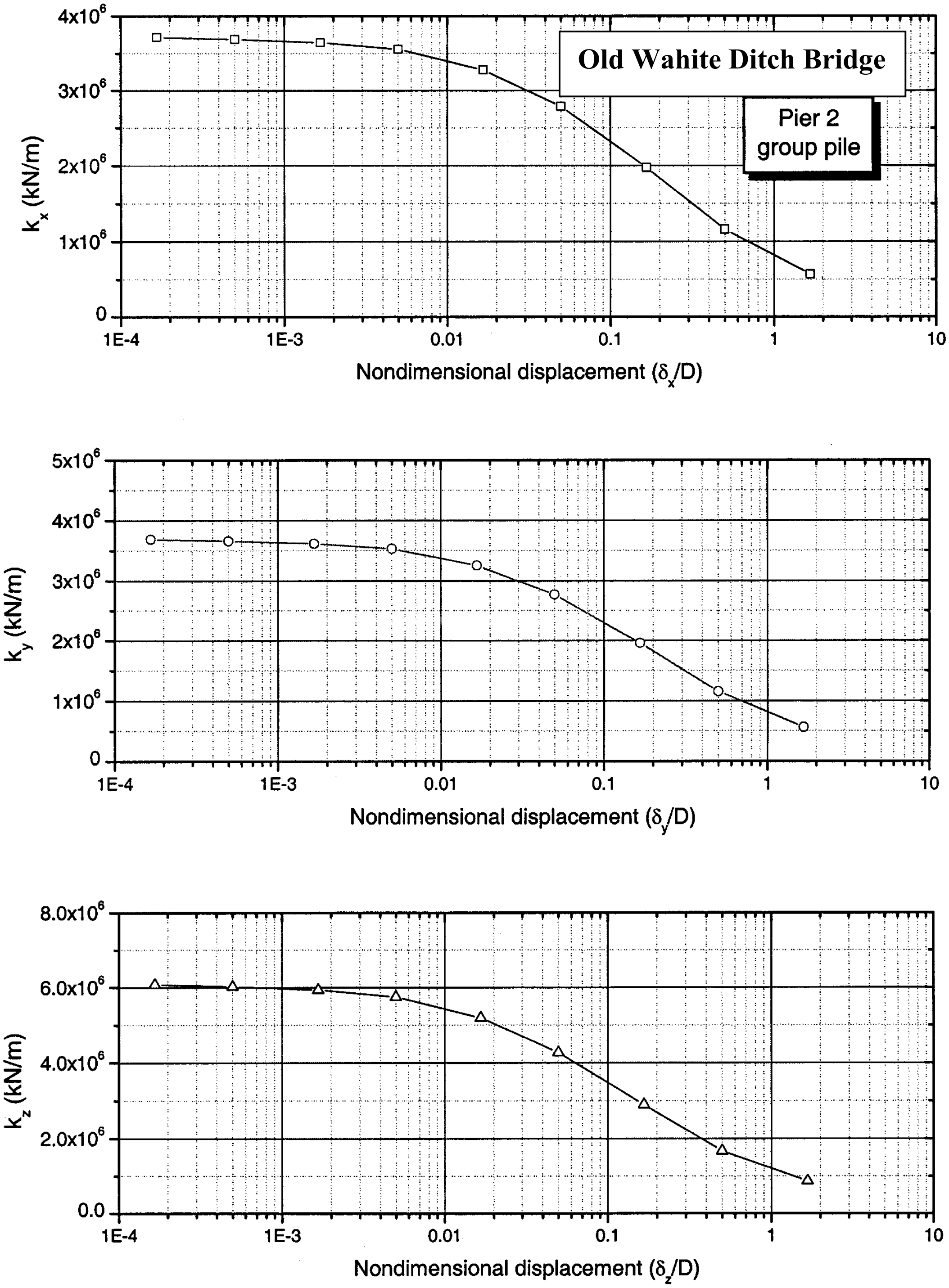


F.7ag Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier 1 Group Pile, Old Wahite Ditch Bridge

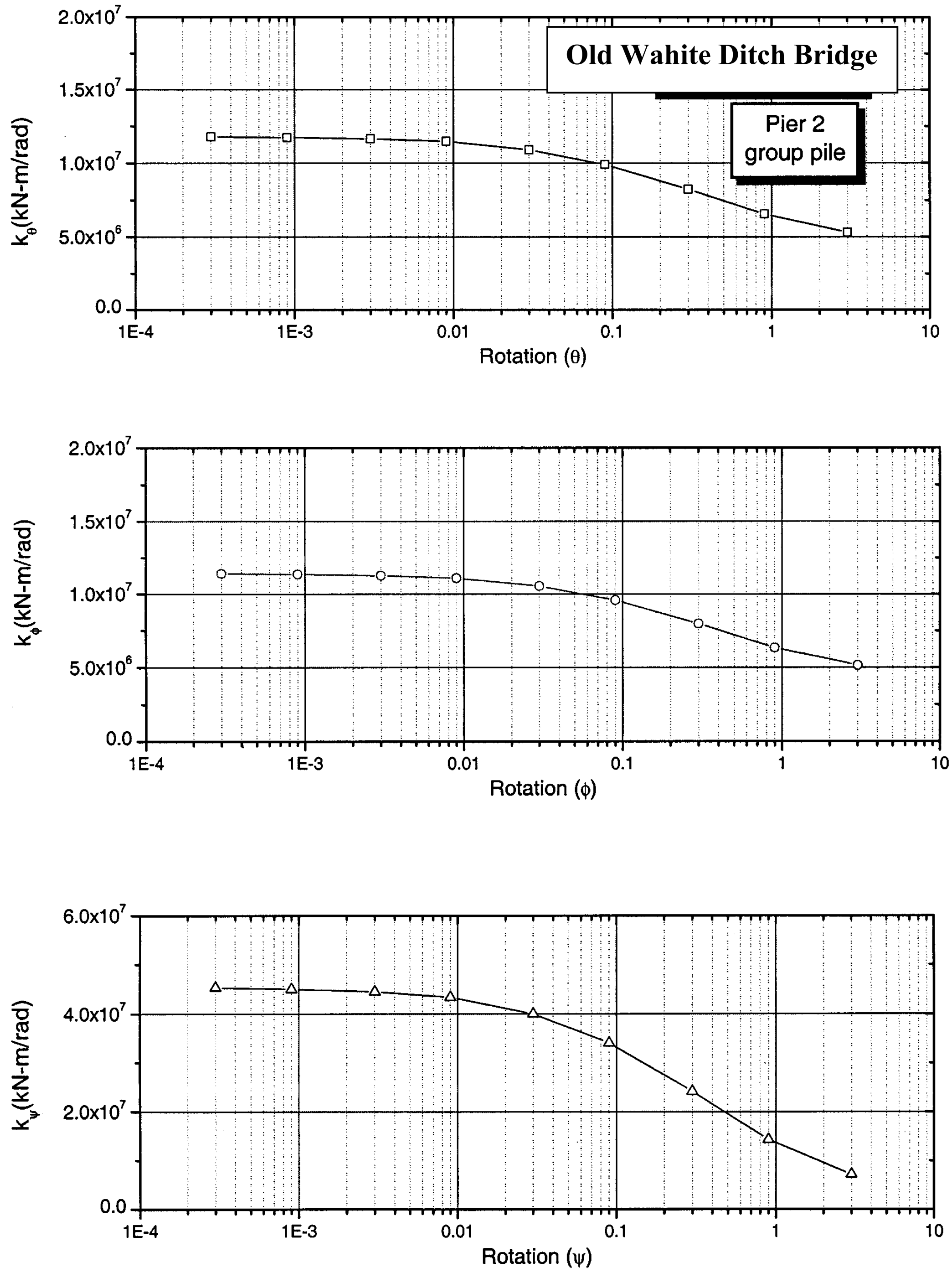




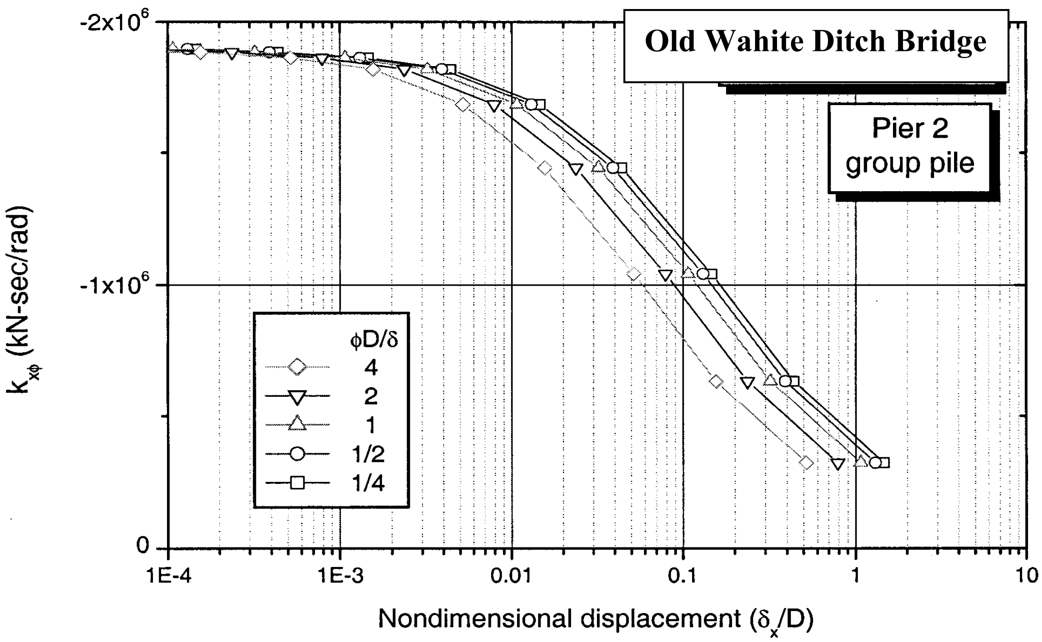
F.7ah Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Pier 1 Group Pile, Old Wahite Ditch Bridge

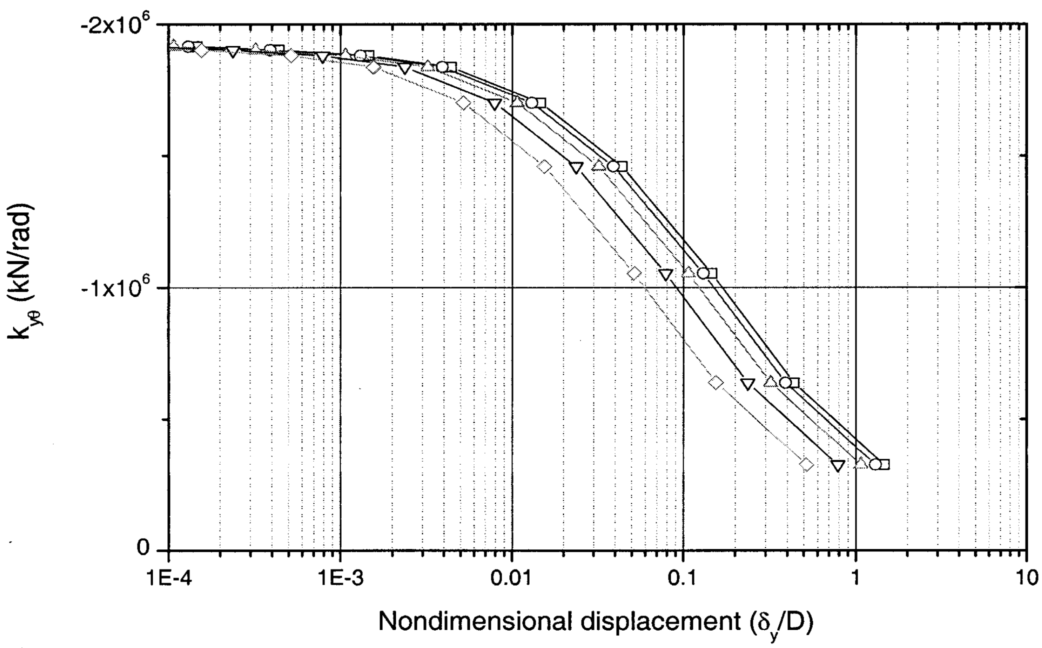


F.7ai Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Pier 2 Group Pile, Old Wahite Ditch Bridge

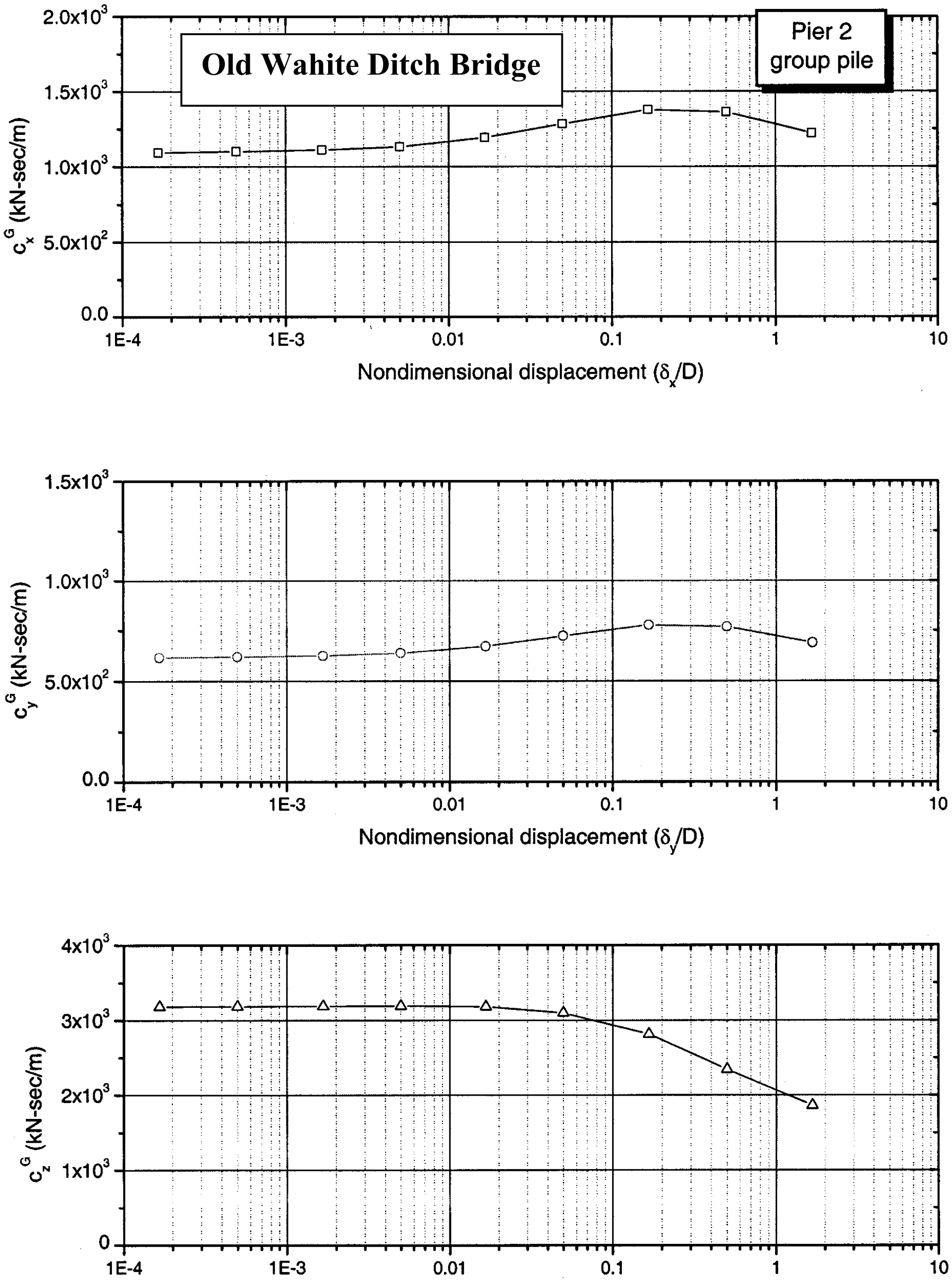


F.7aj Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier 2 Group Pile, Old Wahite Ditch Bridge

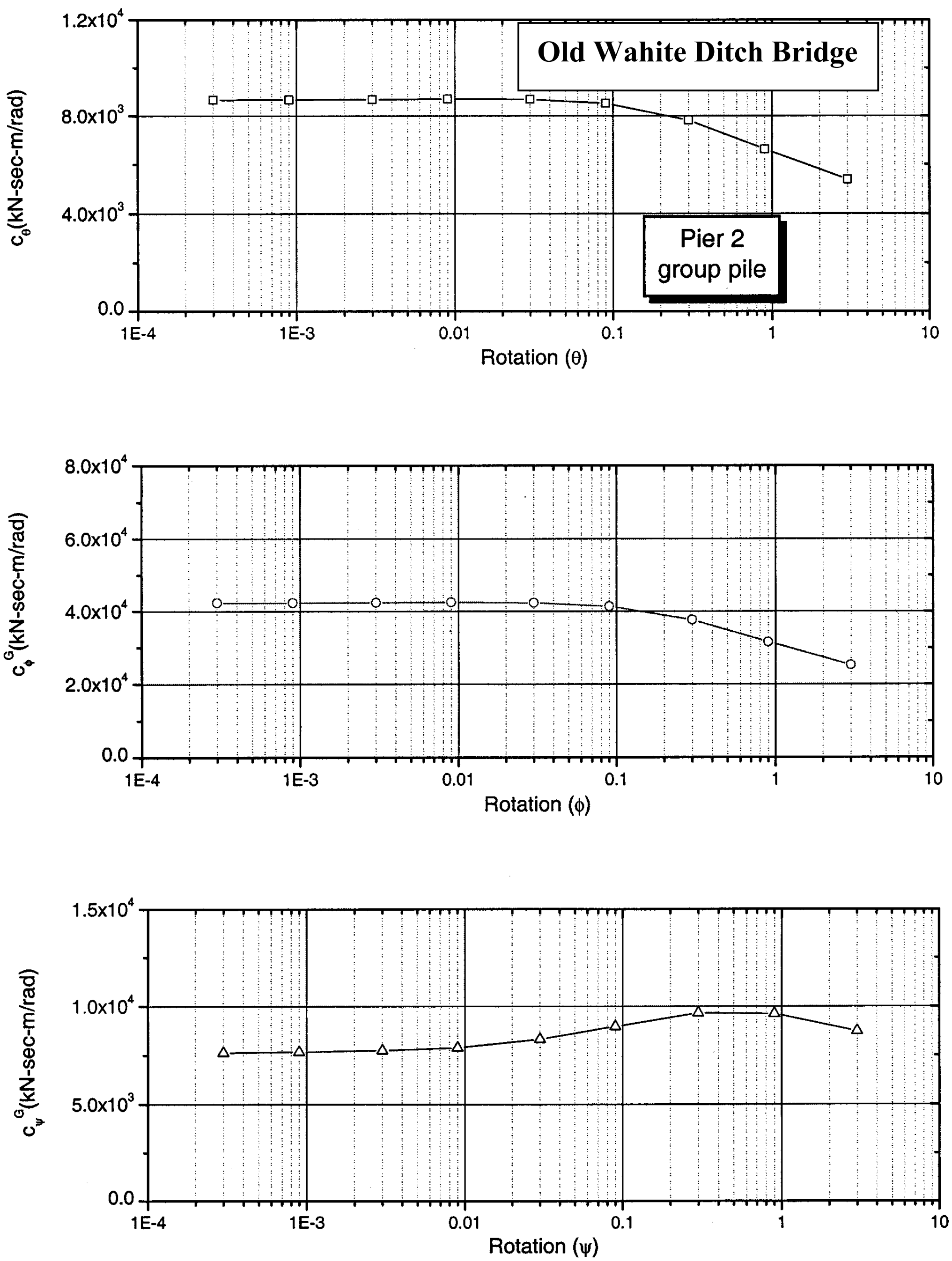




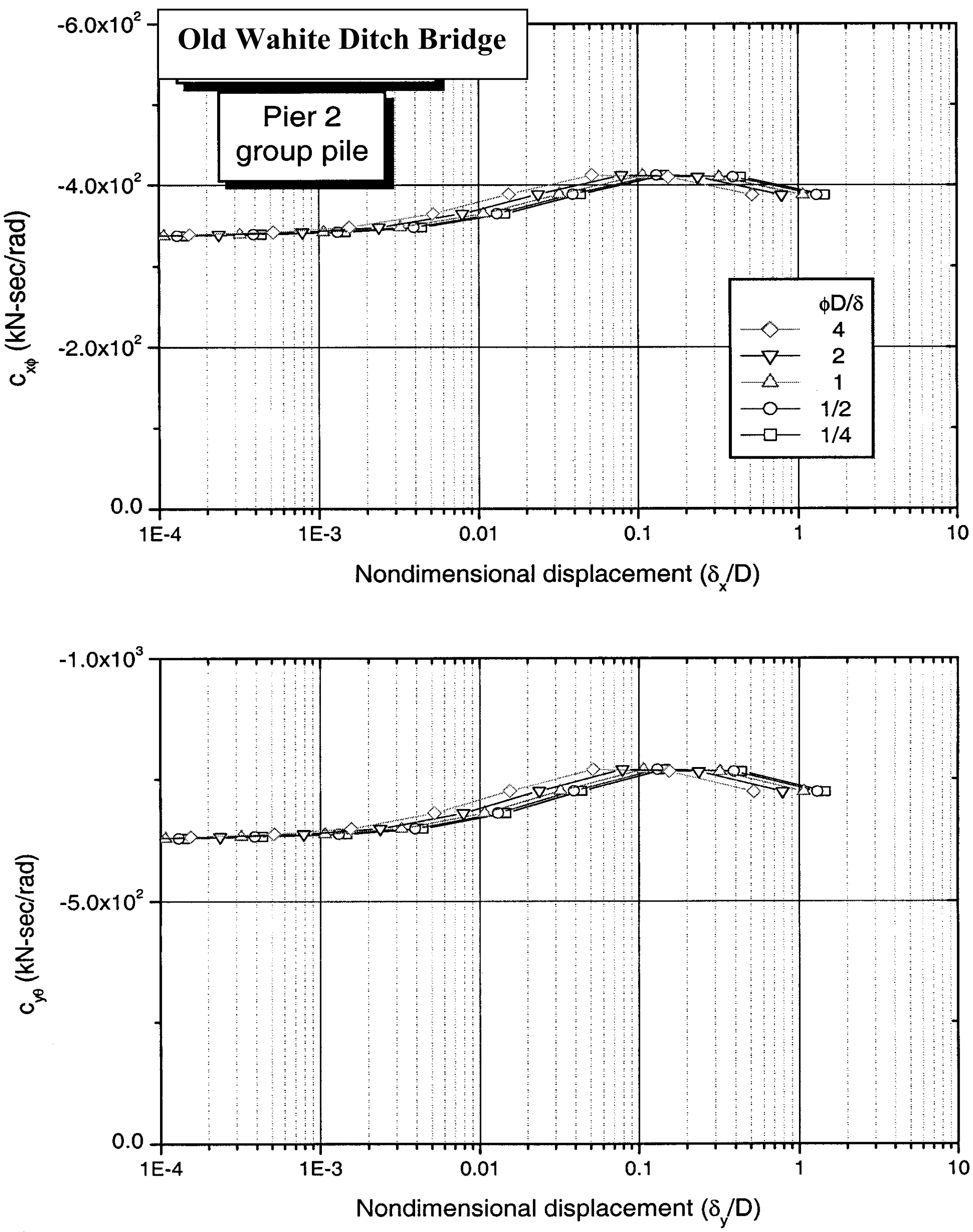
F.7ak Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Pier 2 Group Pile, Old Wahite Ditch Bridge



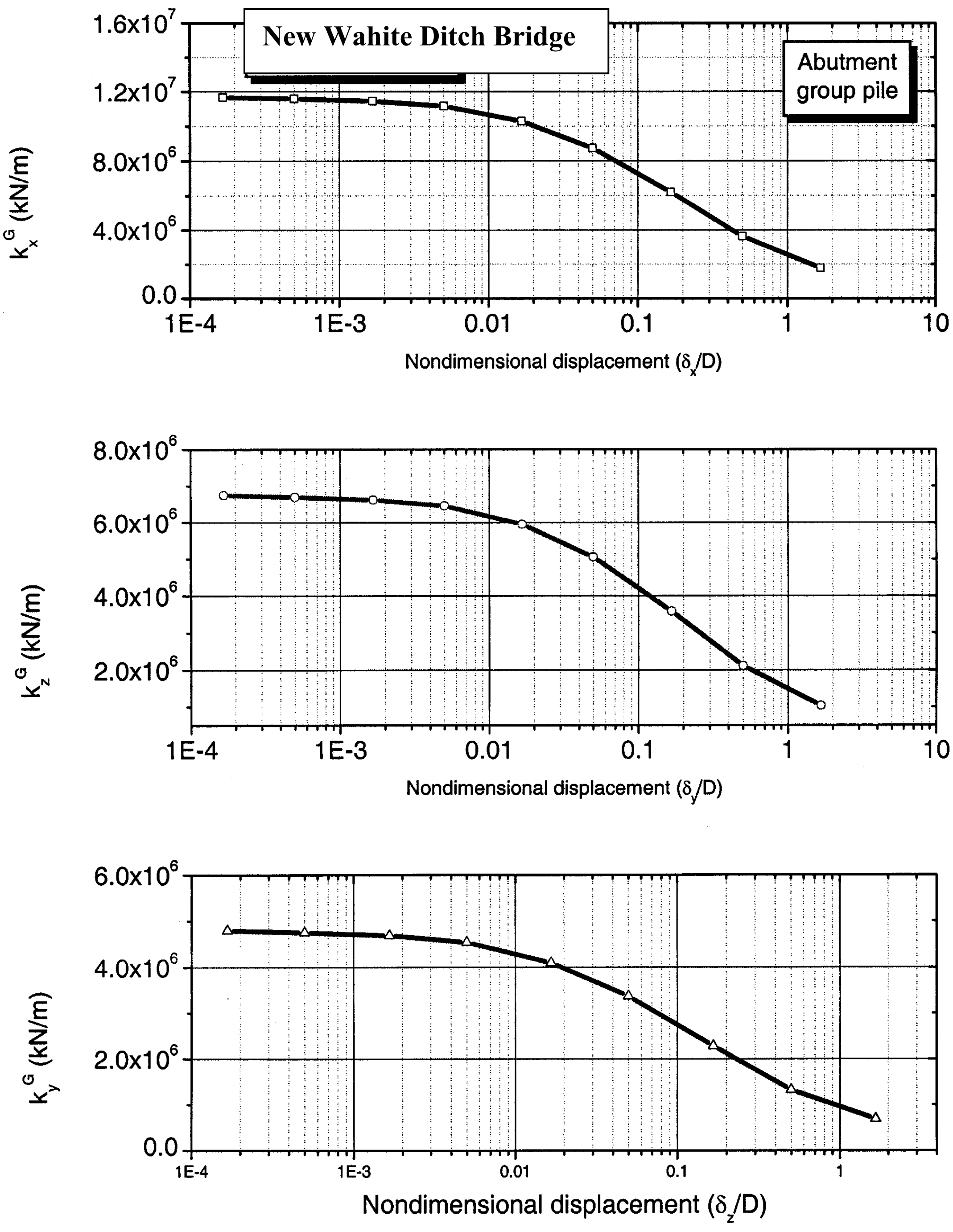
F.7al Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Pier 2 Group Pile, Old Wahite Ditch Bridge



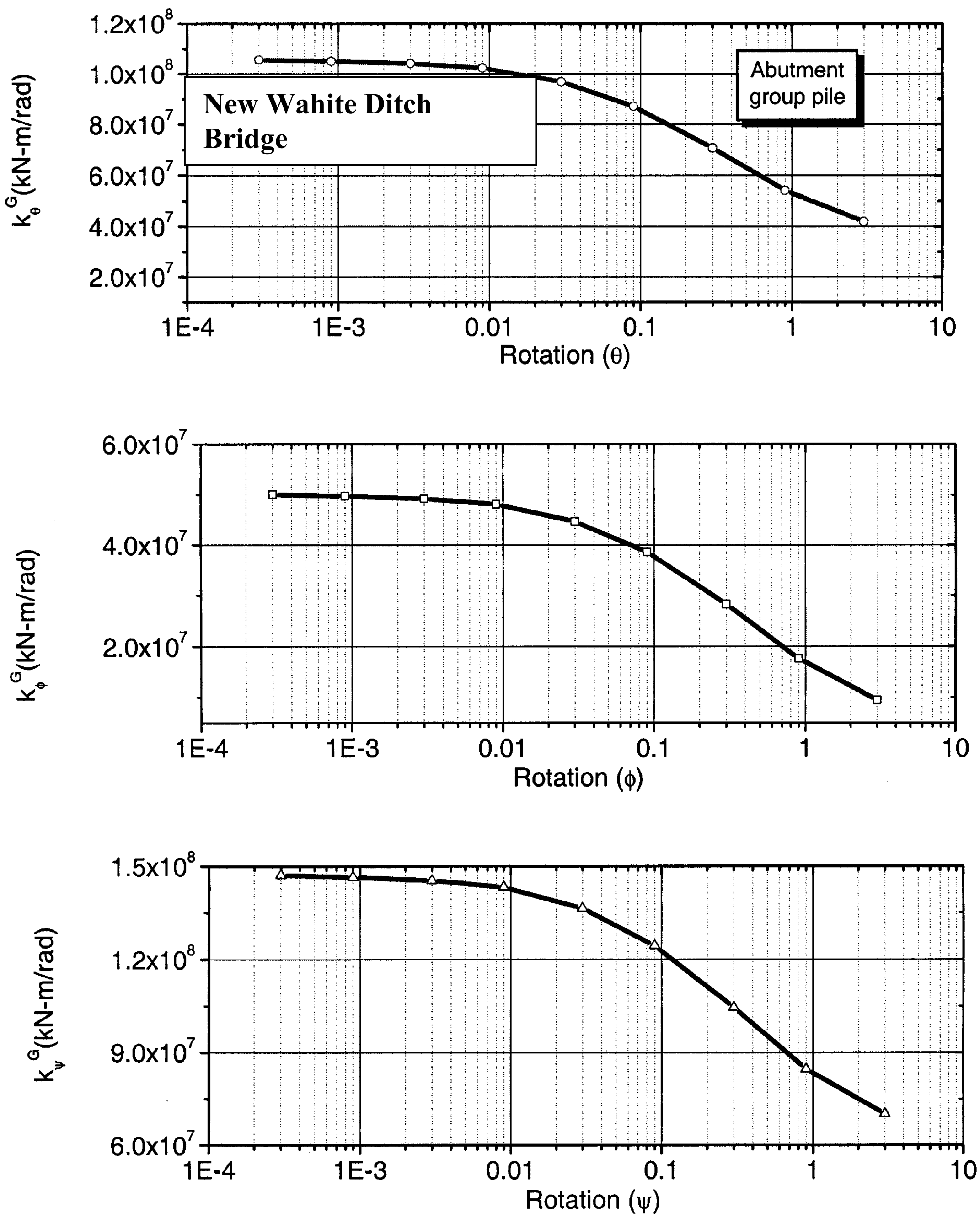
F.7am Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier 2 Group Pile, Old Wahite Ditch Bridge



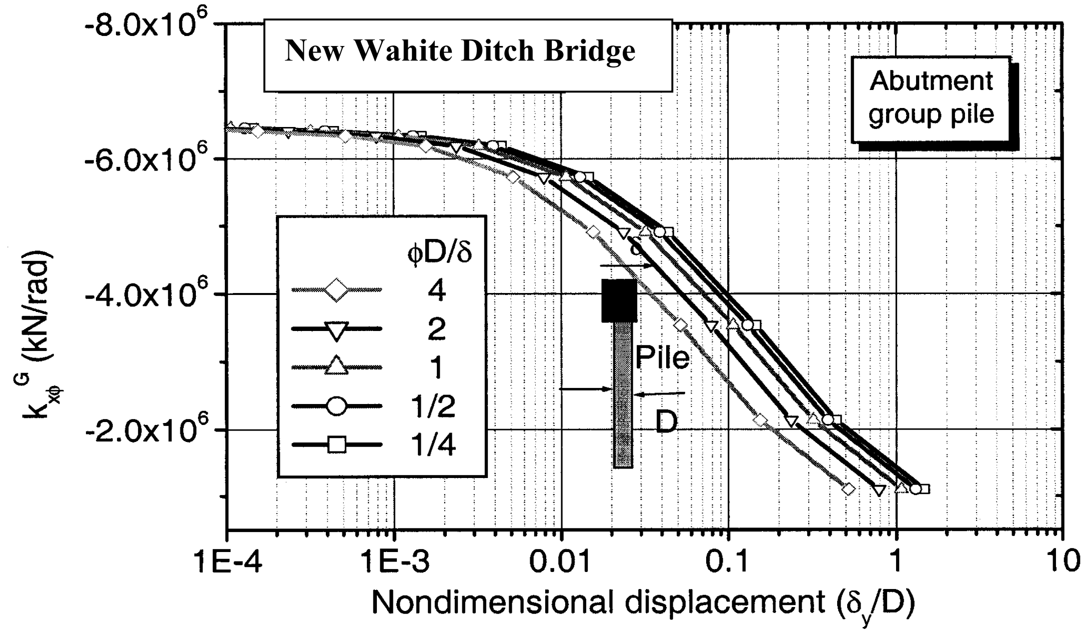
F.7an Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Pier 2 Group Pile, Old Wahite Ditch Bridge

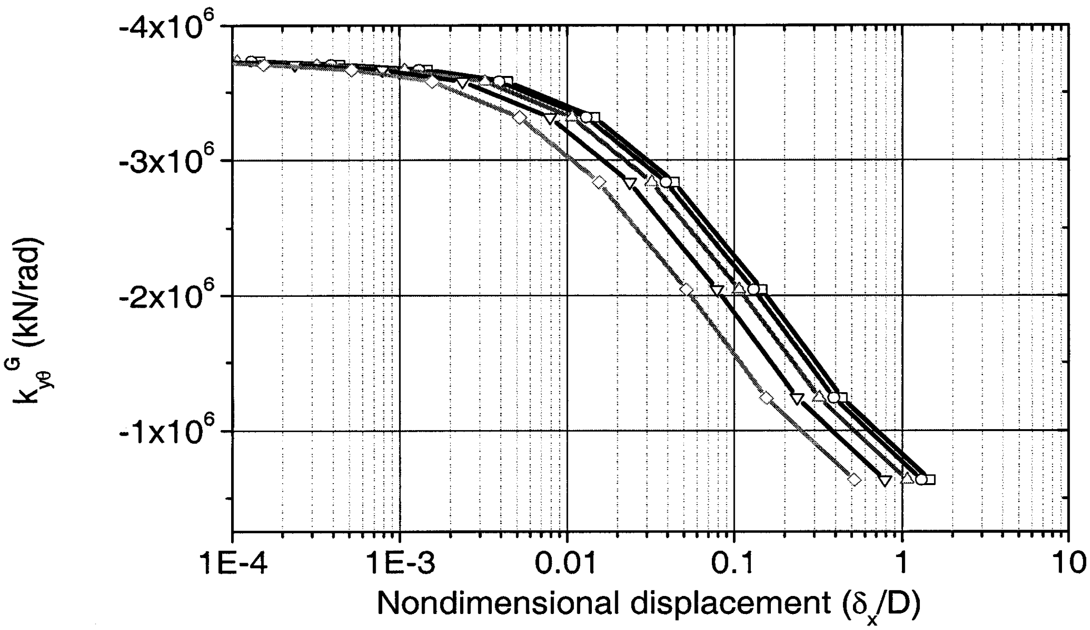


F.7ao Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Abutment Group Pile, New Wahite Ditch Bridge

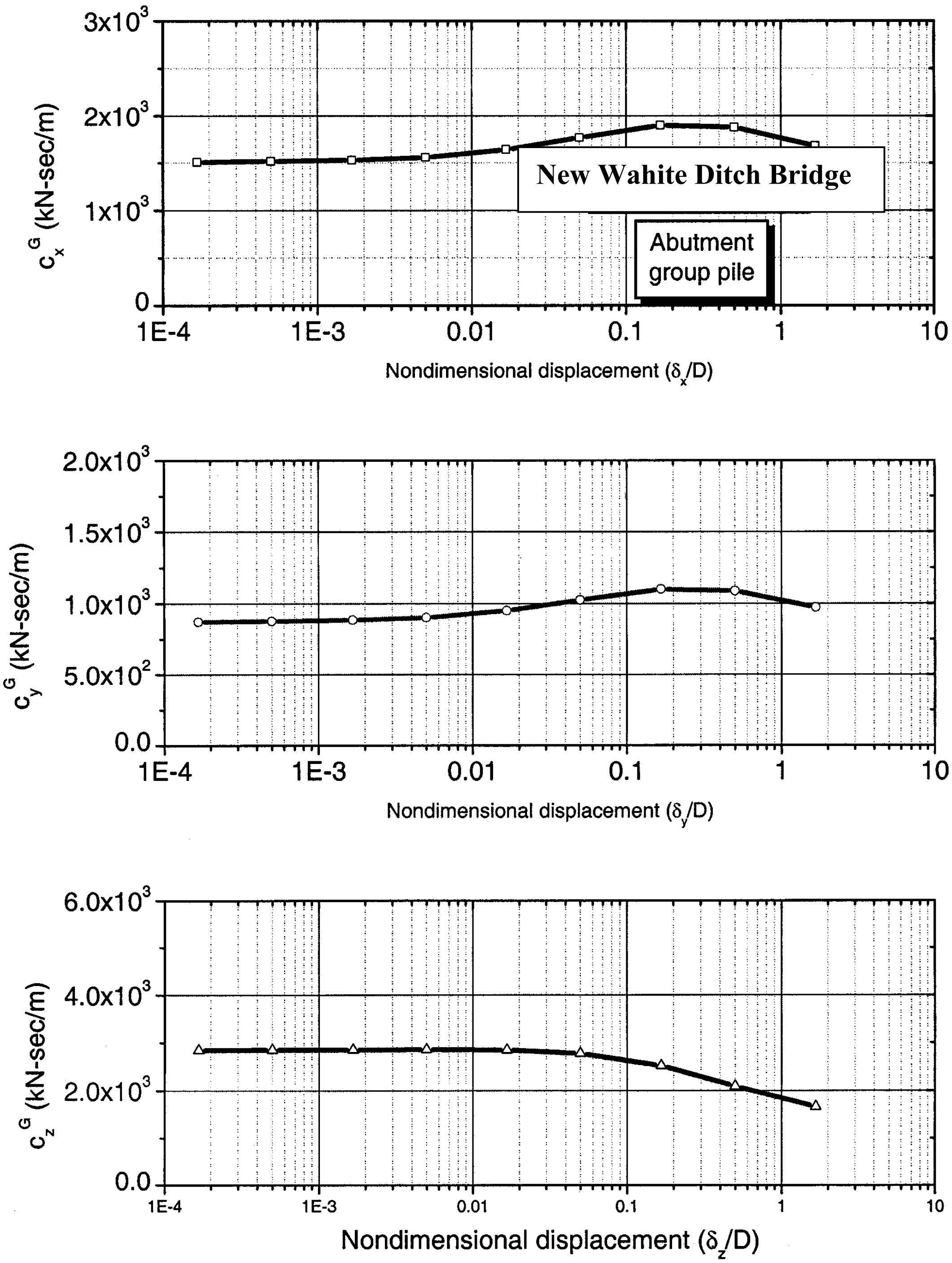


F.7ap Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, New Wahite Ditch Bridge

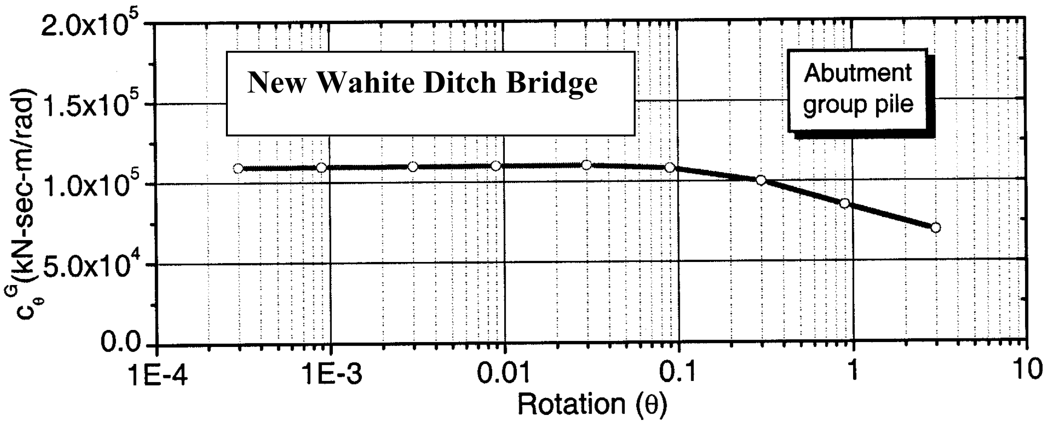


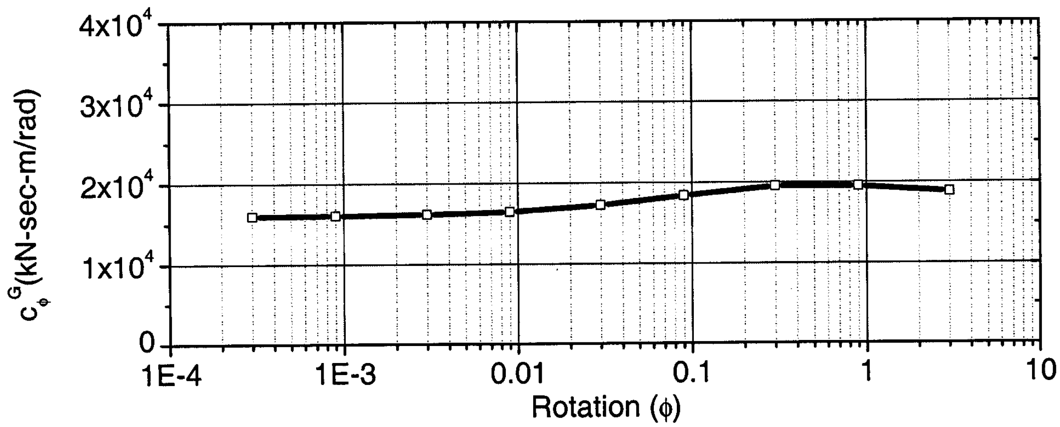


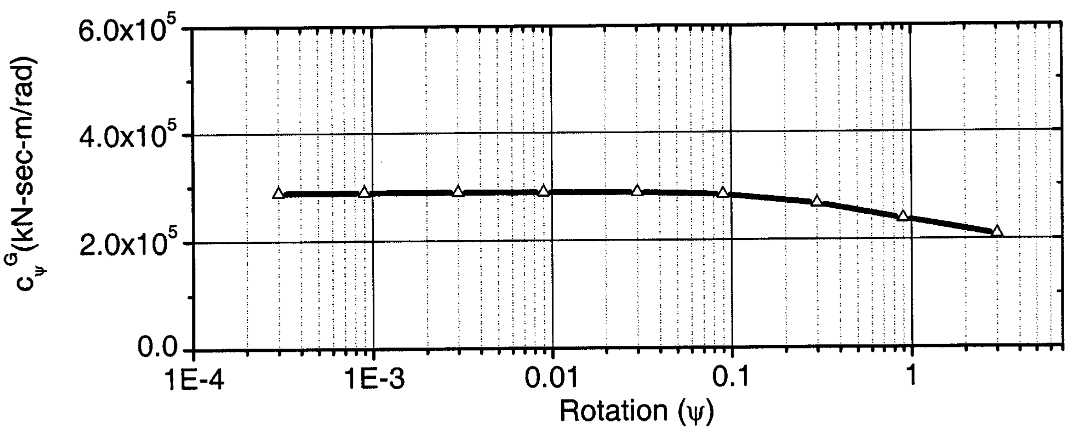
F.7aq Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Abutment Group Pile, New Wahite Ditch Bridge



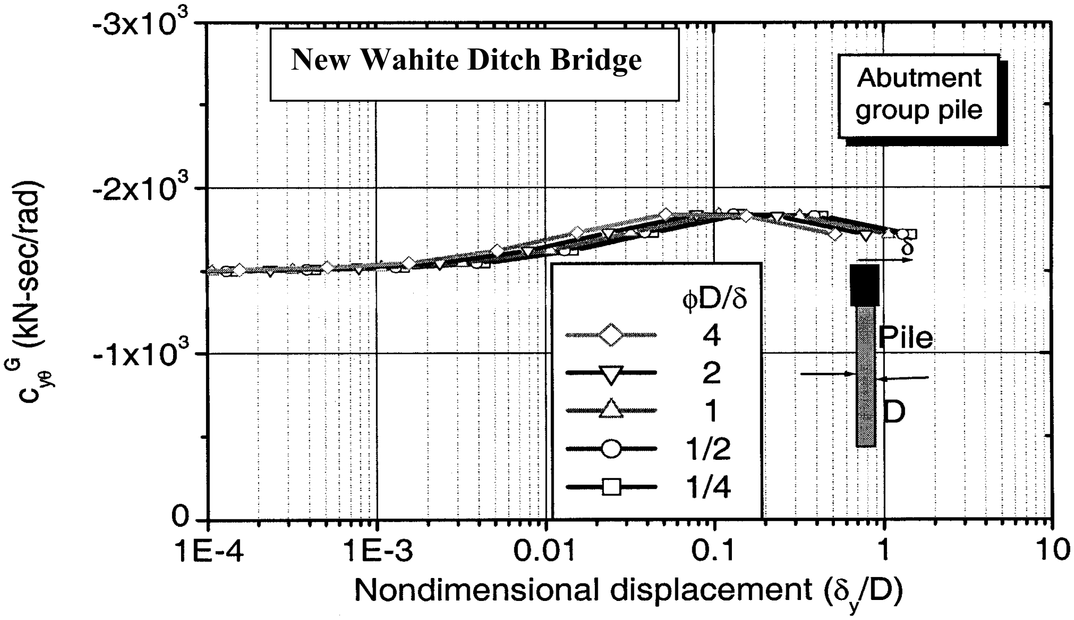
F.7ar Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Abutment Group Pile, New Wahite Ditch Bridge

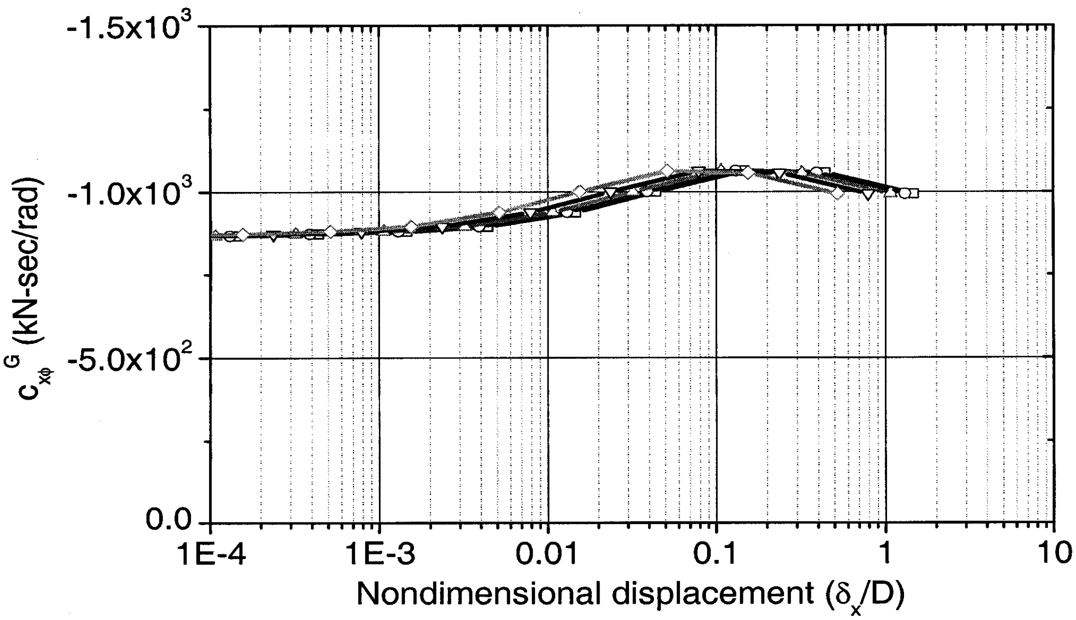




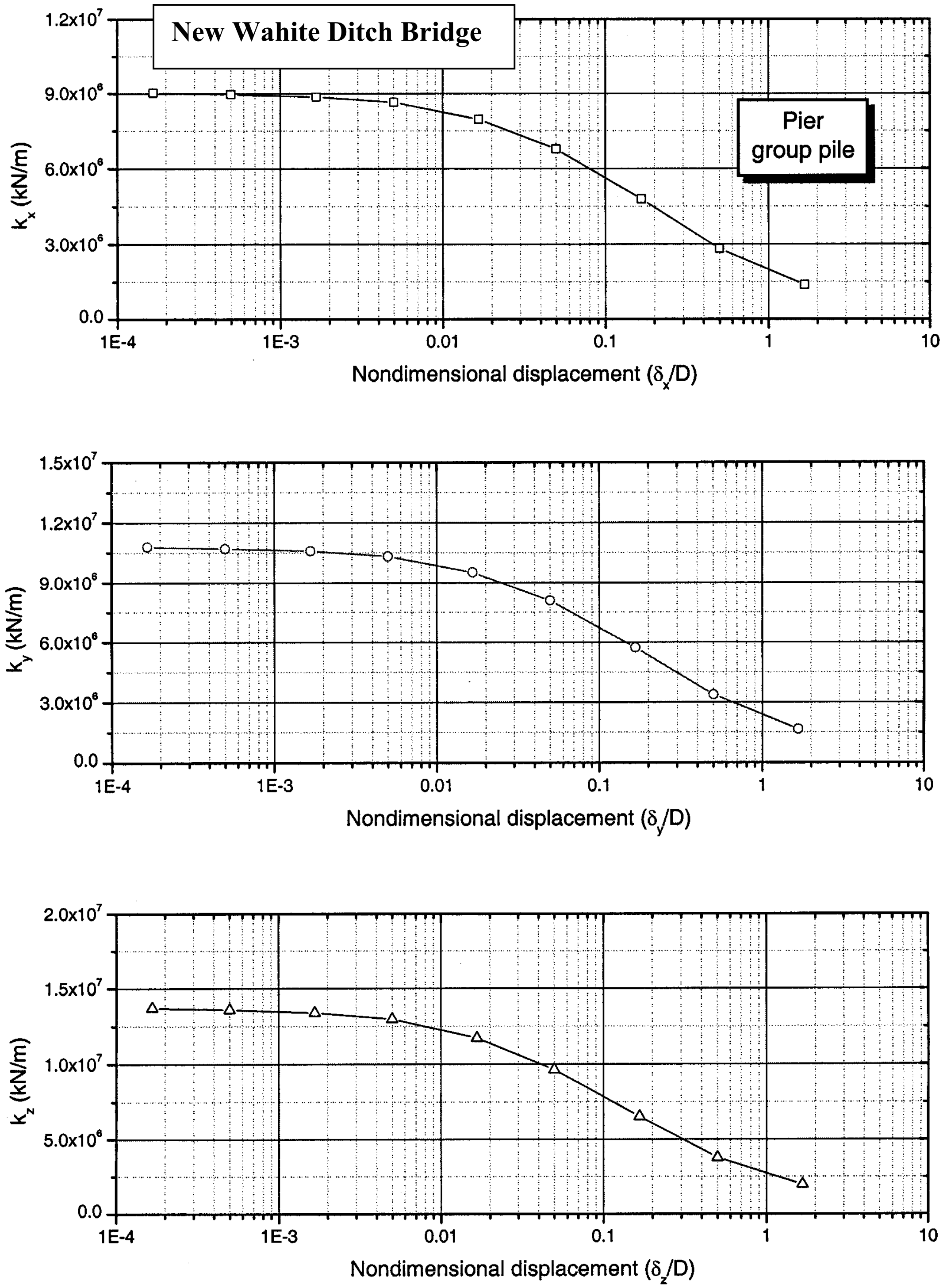


F.7as Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Abutment Group Pile, New Wahite Ditch Bridge

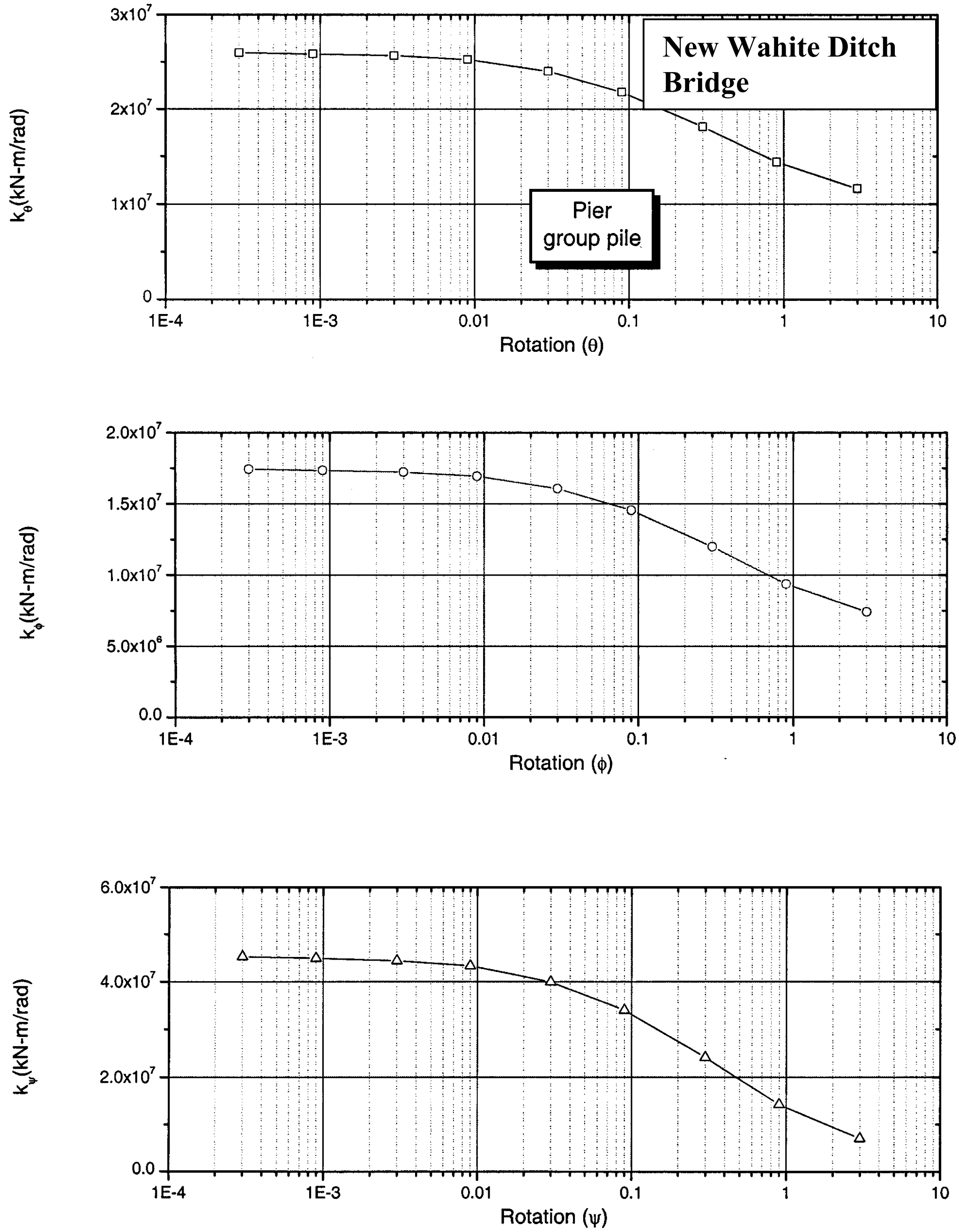




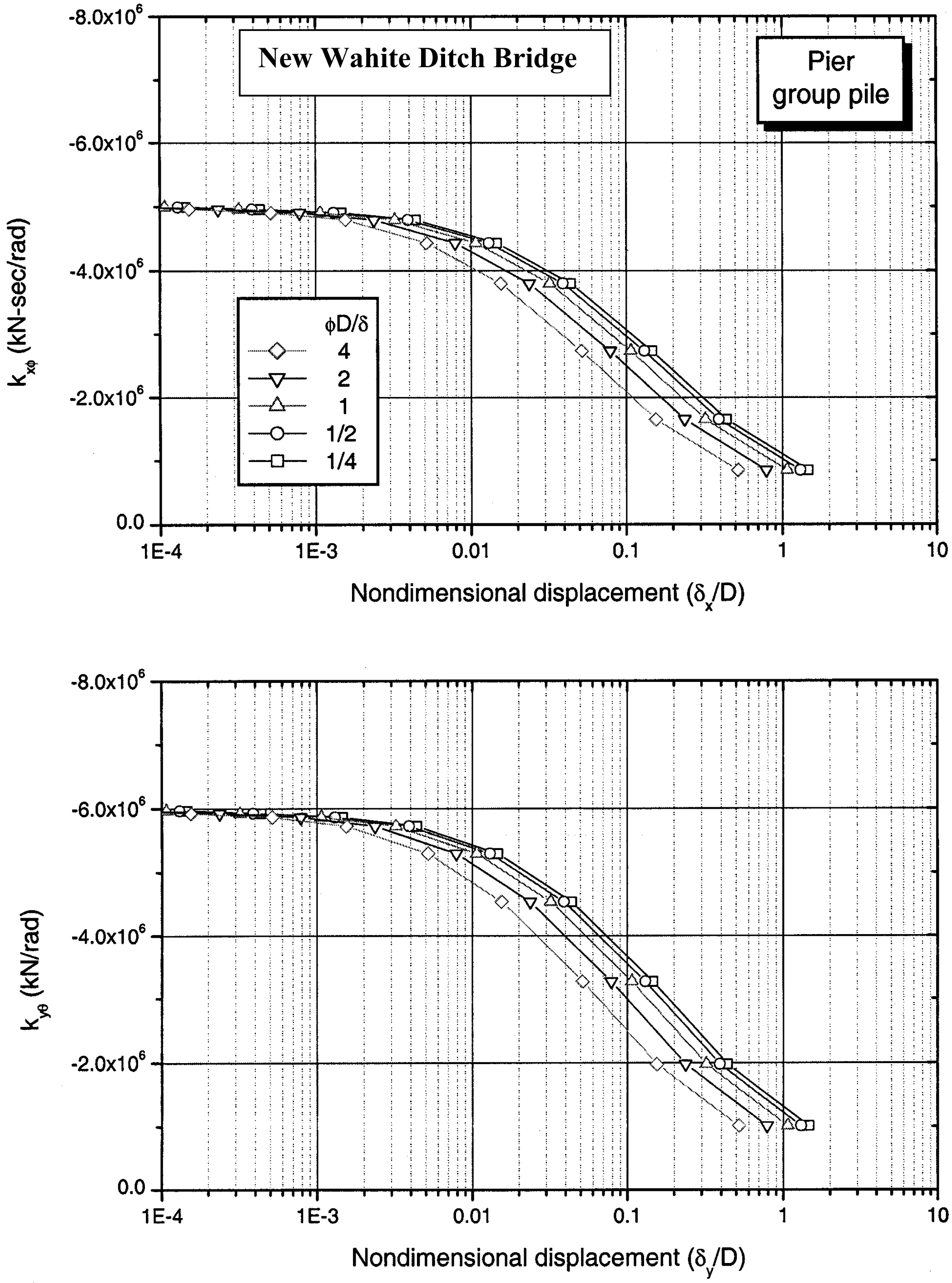
F.7at Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Abutment Group Pile, New Wahite Ditch Bridge



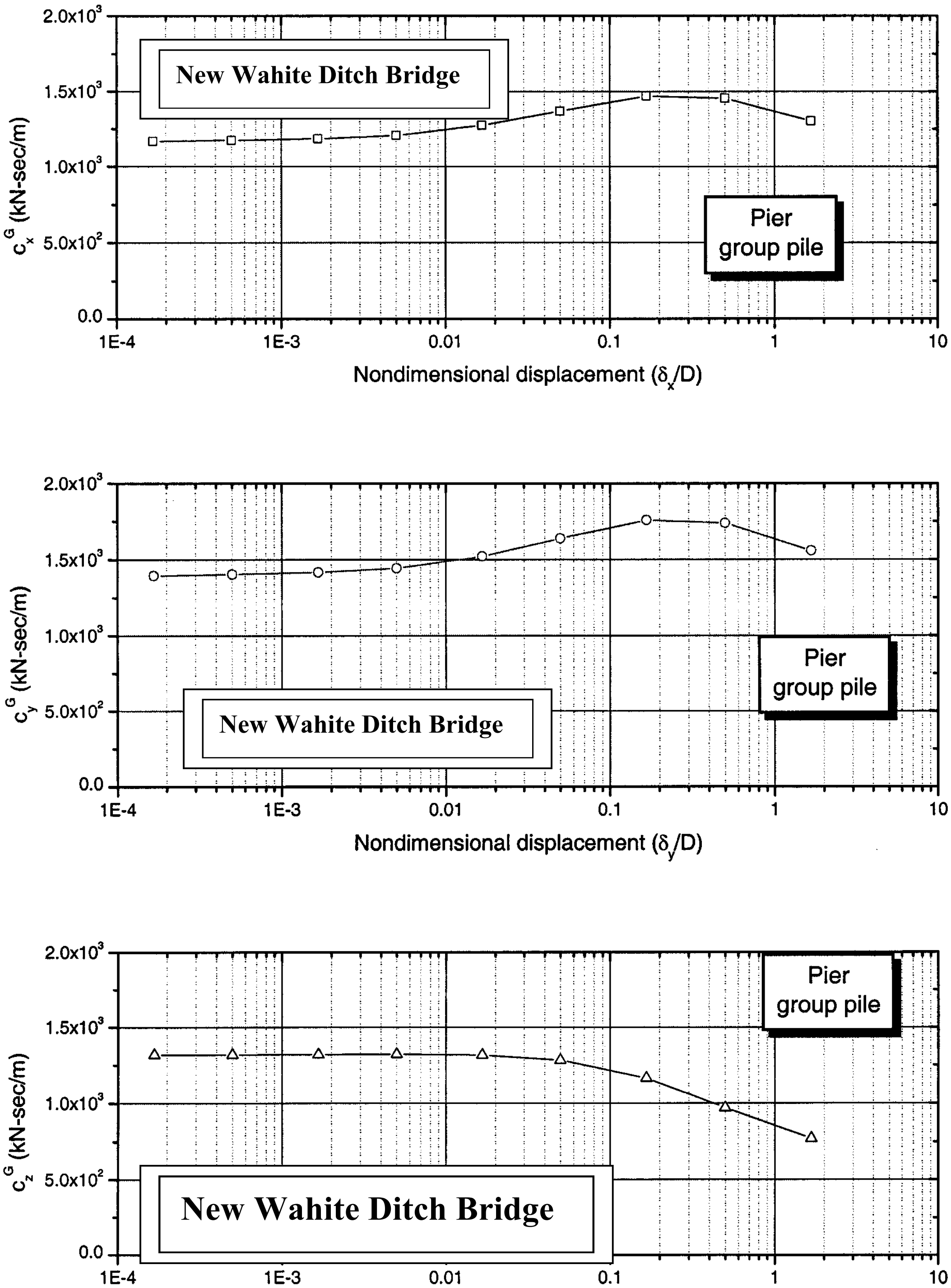
F.7au Group Stiffness in Vertical and X and Y Translation vs. Nondimensional Displacement for the Pier Group Pile, New Wahite Ditch Bridge



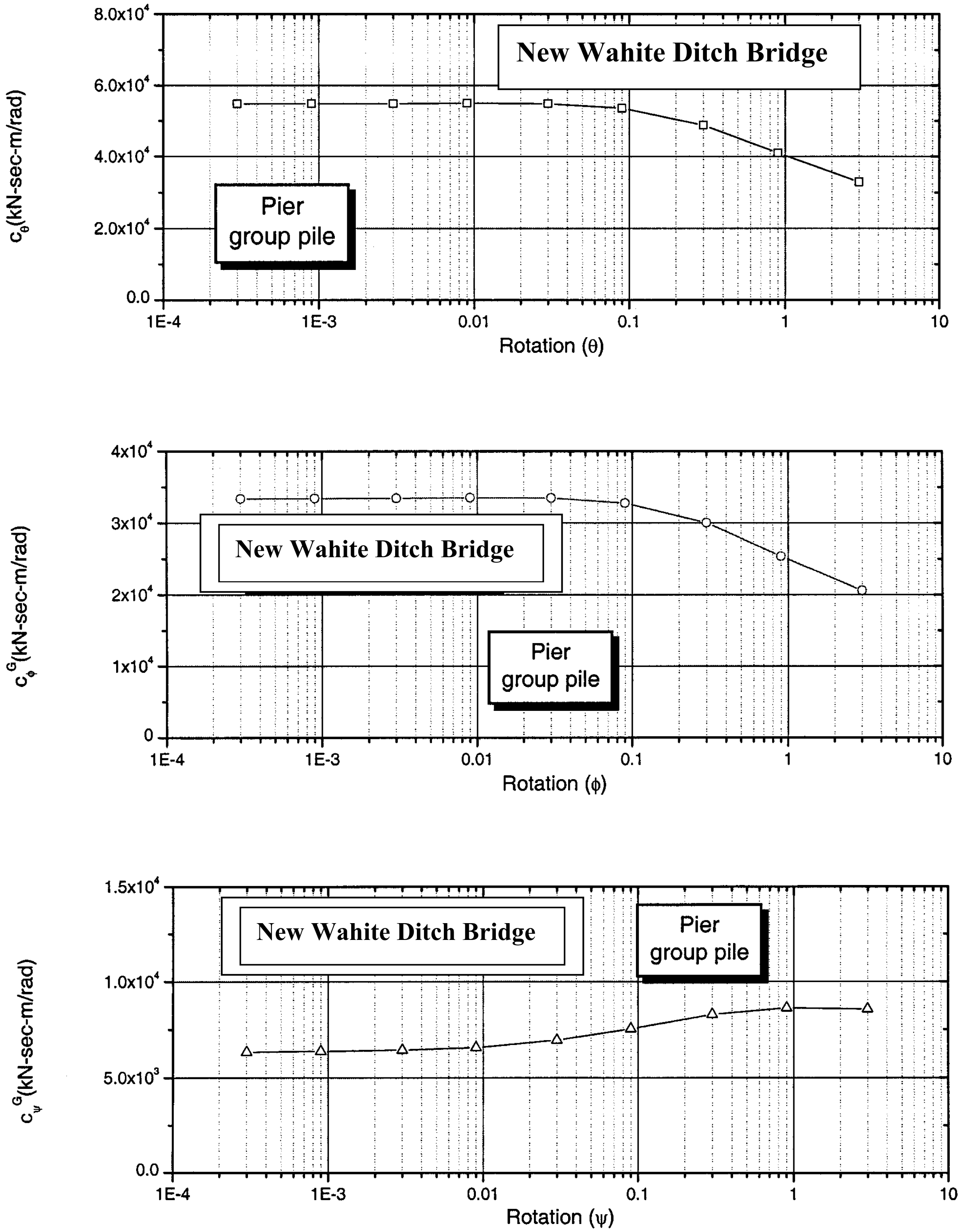
F.7av Group Stiffness Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier Group Pile, New Wahite Ditch Bridge



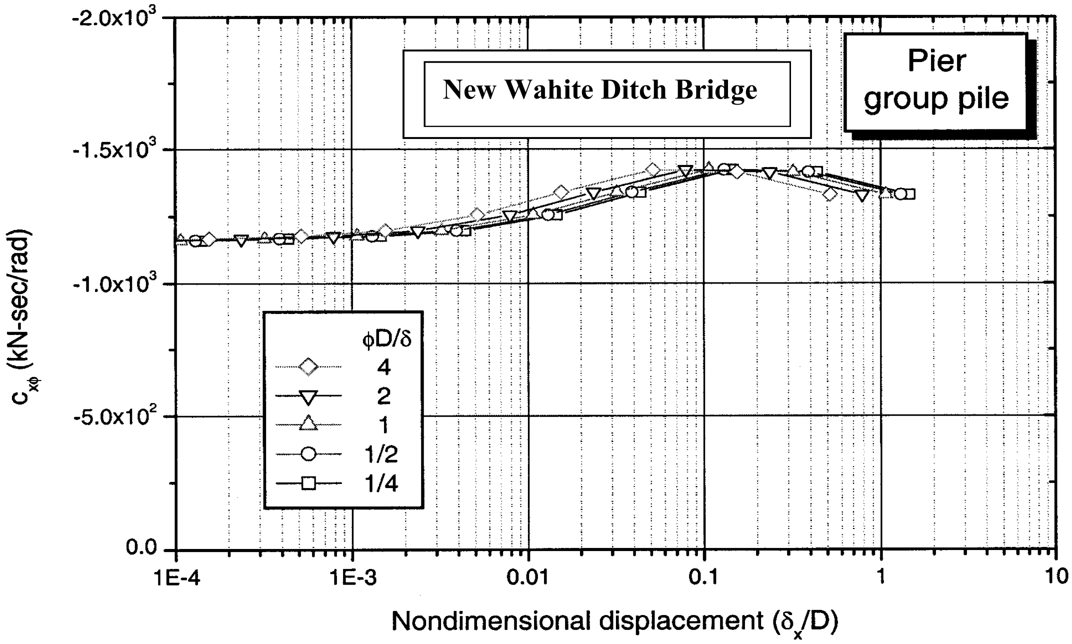
F.7aw Cross-Coupling Translation in X and Y-Axis vs. Nondimensional Displacement for the Pier Group Pile, New Wahite Ditch Bridge

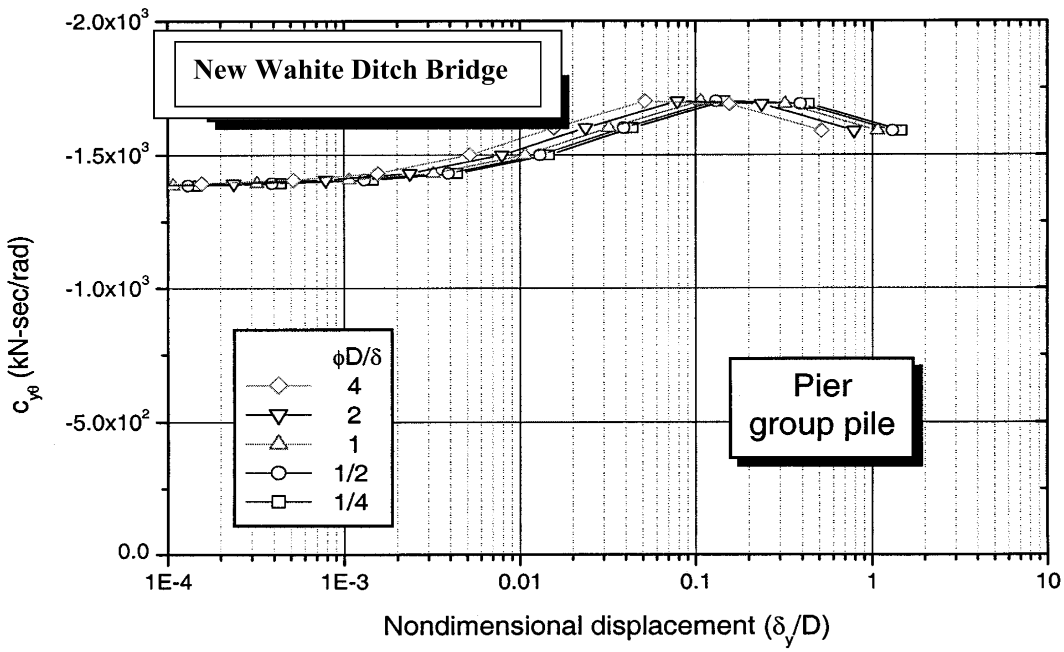


F.7ax Damping Due to Vertical and Sliding Along the X and Y Axis vs. Rotation for the Pier Group Pile, New Wahite Ditch Bridge



F.7ay Damping Due to Torsion and Rocking About the X and Y Axis vs. Rotation for the Pier Group Pile, New Wahite Ditch Bridge





F.7az Cross-Coupled Damping About the X and Y Axis vs. Nondimensional Displacement for the Pier Group Pile, New Wahite Ditch Bridge

G. LIQUEFACTION ANALYSIS

Table G.1 Liquefaction Analysis

St. Francis River Site
Ground Motion SF100103

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.81	.05	16.19
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.81	.205	3.95
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.81	.2	4.04
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.33	.189	1.74
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.81	.179	4.52
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.49	.172	2.84
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.81	.165	4.9
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.81	.157	5.15
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.81	.141	5.74
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.81	.124	6.53
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.793	.11	7.2
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.777	.101	7.69
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.753	.094	8.01
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.737	.092	8.01
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.403	.089	4.52
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.554	.087	6.36
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.381	.084	4.53
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.397	.082	4.84
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.424	.078	5.43
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.631	.075	8.41
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.615	.072	8.54
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.599	.069	8.68
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.583	.065	8.96
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.558	.061	9.14
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.55	.057	9.64
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.534	.054	9.88
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.534	.051	10.47
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.518	.048	10.79

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-O SF Pe10%\SF100103\Sf100103.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF100103.ACC
Earthquake Magnitude for CRR Analysis: 6.2
Magnitude Scaling Factor (MSF): 1.62
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.2 Liquefaction Analysis

St. Francis Site
Ground Motion SF100104

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.81	.05	16.19
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.81	.208	3.89
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.81	.201	4.02
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.33	.187	1.76
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.81	.173	4.68
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.49	.164	2.98
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.81	.156	5.19
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.81	.149	5.43
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.81	.139	5.82
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.81	.126	6.42
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.793	.112	7.08
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.777	.104	7.47
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.753	.098	7.68
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.737	.094	7.84
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.403	.09	4.47
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.554	.087	6.36
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.381	.084	4.53
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.397	.08	4.96
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.424	.075	5.65
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.631	.072	8.76
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.615	.068	9.04
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.599	.065	9.21
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.583	.061	9.55
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.558	.057	9.78
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.55	.053	10.37
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.534	.05	10.67
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.534	.048	11.12
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.518	.044	11.77

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-O SF Pe10%\SF100104\Sf100104.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF100104.ACC
Earthquake Magnitude for CRR Analysis: 6.2
Magnitude Scaling Factor (MSF): 1.62
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.3 Liquefaction Analysis

St. Francis Site
Ground Motion SF100105

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.81	.053	15.28
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.81	.218	3.71
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.81	.211	3.83
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.33	.199	1.65
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.81	.187	4.33
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.49	.176	2.78
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.81	.166	4.87
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.81	.158	5.12
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.81	.147	5.51
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.81	.137	5.91
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.793	.13	6.1
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.777	.125	6.21
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.753	.121	6.22
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.737	.118	6.24
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.403	.114	3.53
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.554	.112	4.94
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.381	.109	3.49
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.397	.106	3.74
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.424	.1	4.23
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.631	.094	6.71
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.615	.088	6.98
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.599	.083	7.21
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.583	.079	7.37
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.558	.074	7.54
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.55	.07	7.85
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.534	.066	8.09
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.534	.063	8.47
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.518	.058	8.93

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-O SF Pe10%\Sf100105\Sf100105.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF100105.ACC
Earthquake Magnitude for CRR Analysis: 6.2
Magnitude Scaling Factor (MSF): 1.62
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.4 Liquefaction Analysis

St. Francis Site
Ground Motion SF100201

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.555	.071	7.81
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.555	.3	1.84
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.555	.298	1.86
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.226	.293	.77
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.555	.288	1.92
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.336	.288	1.16
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.555	.287	1.93
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.555	.283	1.96
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.555	.272	2.04
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.555	.257	2.15
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.543	.242	2.24
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.532	.229	2.32
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.516	.219	2.35
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.505	.213	2.37
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.276	.206	1.33
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.38	.202	1.88
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.261	.196	1.33
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.272	.191	1.42
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.29	.178	1.62
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.432	.165	2.61
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.421	.152	2.76
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.41	.14	2.92
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.399	.129	3.09
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.382	.115	3.32
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.377	.109	3.45
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.366	.103	3.55
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.366	.098	3.73
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.355	.092	3.85

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-O SF Pe10%\Sf100201\Sf100201.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF100201.ACC
Earthquake Magnitude for CRR Analysis: 7.2
Magnitude Scaling Factor (MSF): 1.11
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.5 Liquefaction Analysis

St. Francis Site
Ground Motion SF100202

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.555	.071	7.81
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.555	.296	1.87
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.555	.293	1.89
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.226	.286	.79
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.555	.278	1.99
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.336	.272	1.23
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.555	.266	2.08
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.555	.259	2.14
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.555	.248	2.23
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.555	.234	2.37
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.543	.22	2.46
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.532	.21	2.53
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.516	.202	2.55
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.505	.195	2.58
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.276	.187	1.47
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.38	.181	2.09
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.261	.175	1.49
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.272	.168	1.61
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.29	.155	1.87
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.432	.142	3.04
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.421	.129	3.26
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.41	.119	3.44
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.399	.113	3.53
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.382	.107	3.57
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.377	.102	3.69
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.366	.098	3.73
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.366	.094	3.89
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.355	.09	3.94

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-O SF Pe10%\SF100202\Sf100202.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF100202.ACC
Earthquake Magnitude for CRR Analysis: 7.2
Magnitude Scaling Factor (MSF): 1.11
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.6 Liquefaction Analysis

St. Francis Site
Ground Motion SF100205

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.555	.066	8.4
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.555	.278	1.99
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.555	.275	2.01
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.226	.269	.84
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.555	.264	2.1
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.336	.263	1.27
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.555	.263	2.11
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.555	.26	2.13
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.555	.253	2.19
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.555	.241	2.3
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.543	.23	2.36
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.532	.22	2.41
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.516	.212	2.43
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.505	.208	2.42
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.276	.202	1.36
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.38	.198	1.91
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.261	.193	1.35
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.272	.189	1.43
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.29	.177	1.63
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.432	.165	2.61
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.421	.152	2.76
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.41	.141	2.9
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.399	.131	3.04
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.382	.118	3.23
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.377	.11	3.42
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.366	.102	3.58
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.366	.097	3.77
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.355	.089	3.98

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-O SF Pe10%\SF100205\Sf100205.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: C:\YT\SF100205.ACC
Earthquake Magnitude for CRR Analysis: 7.2
Magnitude Scaling Factor (MSF): 1.11
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.7 Liquefaction Analysis

St. Francis Site
Ground Motion SF020101

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.75	.178	4.21
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.75	.744	1
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.75	.736	1.01
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.306	.719	.42
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.75	.701	1.06
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.454	.691	.65
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.75	.681	1.1
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.75	.666	1.12
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.75	.638	1.17
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.75	.599	1.25
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.735	.559	1.31
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.719	.523	1.37
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.697	.49	1.42
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.682	.462	1.47
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.373	.429	.86
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.513	.407	1.26
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.353	.379	.93
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.367	.351	1.04
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.392	.322	1.21
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.585	.304	1.92
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.57	.286	1.99
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.555	.272	2.04
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.54	.265	2.03
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.517	.254	2.03
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.51	.24	2.12
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.495	.226	2.19
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.495	.216	2.29
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.48	.202	2.37

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-0 SF Pe 2%\SF020101\Sf020101.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF020101.ACC
Earthquake Magnitude for CRR Analysis: 6.4
Magnitude Scaling Factor (MSF): 1.5
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.8 Liquefaction Analysis

St. Francis Site
Ground Motion SF020103

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.75	.155	4.83
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.75	.653	1.14
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.75	.652	1.15
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.306	.647	.47
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.75	.641	1.17
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.454	.643	.7
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.75	.645	1.16
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.75	.641	1.17
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.75	.626	1.19
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.75	.597	1.25
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.735	.561	1.31
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.719	.526	1.36
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.697	.496	1.4
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.682	.475	1.43
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.373	.449	.83
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.513	.432	1.18
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.353	.411	.85
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.367	.39	.94
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.392	.364	1.07
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.585	.345	1.69
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.57	.326	1.74
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.555	.307	1.8
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.54	.288	1.87
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.517	.268	1.92
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.51	.264	1.93
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.495	.26	1.9
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.495	.258	1.91
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.48	.254	1.88

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-0 SF Pe 2%\Sf020103\Sf020103.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF020103.ACC
Earthquake Magnitude for CRR Analysis: 6.4
Magnitude Scaling Factor (MSF): 1.5
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.9 Liquefaction Analysis

St. Francis Site
Ground Motion SF020105

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.75	.168	4.46
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.75	.697	1.07
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.75	.685	1.09
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.306	.661	.46
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.75	.639	1.17
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.454	.625	.72
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.75	.612	1.22
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.75	.596	1.25
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.75	.564	1.32
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.75	.525	1.42
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.735	.491	1.49
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.719	.463	1.55
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.697	.439	1.58
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.682	.42	1.62
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.373	.397	.93
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.513	.382	1.34
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.353	.363	.97
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.367	.344	1.06
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.392	.319	1.22
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.585	.298	1.96
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.57	.278	2.05
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.555	.257	2.15
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.54	.236	2.28
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.517	.214	2.41
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.51	.212	2.4
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.495	.21	2.35
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.495	.209	2.36
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.48	.207	2.31

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-0 SF Pe 2%\Sf020105\Sf020105.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF020105.ACC
Earthquake Magnitude for CRR Analysis: 6.4
Magnitude Scaling Factor (MSF): 1.5
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.10 Liquefaction Analysis

St. Francis Site
Ground Motion SF020201

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.42	.159	2.64
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.42	.668	.62
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.42	.667	.62
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.171	.665	.25
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.42	.663	.63
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.254	.669	.37
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.42	.675	.62
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.42	.673	.62
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.42	.661	.63
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.42	.633	.66
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.411	.596	.68
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.403	.558	.72
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.39	.523	.74
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.382	.496	.77
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.209	.464	.45
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.287	.442	.64
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.197	.415	.47
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.205	.388	.52
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.219	.352	.62
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.327	.322	1.01
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.319	.292	1.09
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.31	.267	1.16
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.302	.25	1.2
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.289	.229	1.26
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.285	.218	1.3
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.277	.207	1.33
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.277	.199	1.39
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.268	.189	1.41

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 SF Pe 2%\Sf020201\Sf020201.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF020201.ACC
Earthquake Magnitude for CRR Analysis: 8
Magnitude Scaling Factor (MSF): .84
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.11 Liquefaction Analysis

St. Francis Site
Ground Motion SF020203

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.42	.159	2.64
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.42	.663	.63
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.42	.655	.64
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.171	.639	.26
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.42	.624	.67
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.254	.62	.4
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.42	.617	.68
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.42	.606	.69
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.42	.582	.72
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.42	.551	.76
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.411	.521	.78
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.403	.496	.81
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.39	.474	.82
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.382	.459	.83
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.209	.441	.47
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.287	.429	.66
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.197	.414	.47
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.205	.399	.51
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.219	.372	.58
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.327	.346	.94
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.319	.32	.99
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.31	.298	1.04
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.302	.282	1.07
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.289	.263	1.09
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.285	.252	1.13
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.277	.241	1.14
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.277	.233	1.18
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.268	.223	1.2

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 SF Pe 2%\Sf020203\Sf020203.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF020203.ACC
Earthquake Magnitude for CRR Analysis: 8
Magnitude Scaling Factor (MSF): .84
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.12 Liquefaction Analysis

St. Francis Site
Ground Motion SF020205

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	1	21	1	1	1	1		285.6	2	42	91	55.4		1		.42	.137	3.06
2	6	12	1	1	1	1	660	285.6	2	24	91	33.8		1		.42	.571	.73
3	8.4	73	1	1	1	1	923.99	399.83	2	146	0	146		1		.42	.565	.74
4	12.5	10	1	1	1	1	1375	595	1.88	18.8	0	18.8		1		.171	.553	.3
5	15.5	19	1	1	1	1	1705	737.8	1.69	32.1	0	32.1		1		.42	.543	.77
6	19.5	17	1	1	1	1	2118	901.19	1.53	26	0	26		1		.254	.546	.46
7	23.5	26	1	1	1	1	2518	1051.6	1.41	36.6	0	36.6		1		.42	.549	.76
8	27.5	28	1	1	1	1	2918	1202	1.32	36.9	0	36.9		1		.42	.547	.76
9	34	26	1	1	1	1	3584.79	1463.19	1.2	31.2	0	31.2		1		.42	.539	.77
10	40	75	1	1	1	1	4352.79	1856.79	1.06	79.4	0	79.4		1		.42	.517	.81
11	45	71	1	1	1	1	4990.29	2182.29	.98	69.5	0	69.5		.98		.411	.486	.84
12	50	75	1	1	1	1	5660.3	2540.29	.91	68.2	0	68.2		.96		.403	.458	.87
13	55	38	1	1	1	1	6330.3	2898.29	.85	32.3	0	32.3		.93		.39	.434	.89
14	60	46	1	1	1	1	7000.3	3256.29	.8	36.8	0	36.8		.91		.382	.418	.91
15	66	33	1	1	1	1	7787.1	3668.7	.75	24.7	0	24.7		.89		.209	.399	.52
16	70	40	1	1	1	1	8307.09	3939.09	.73	29.2	0	29.2		.87		.287	.386	.74
17	75	35	1	1	1	1	8957.09	4277.09	.7	24.5	0	24.5		.85		.197	.37	.53
18	80	38	1	1	1	1	9607.09	4615.09	.67	25.4	0	25.4		.84		.205	.353	.58
19	90	43	1	1	1	1	10907.1	5291.09	.63	27	0	27		.81		.219	.327	.66
20	100	73	1	1	1	1	12207.1	5967.09	.59	43	0	43		.78		.327	.302	1.08
21	110	72	1	1	1	1	13530.3	6666.3	.56	40.3	0	40.3		.76		.319	.277	1.15
22	120	100	1	1	1	1	14870.3	7382.3	.53	52.9	0	52.9		.74		.31	.259	1.19
23	130	86	1	1	1	1	16210.29	8098.29	.51	43.8	0	43.8		.72		.302	.251	1.2
24	143	100	1	1	1	1	17952.29	9029.09	.48	48	0	48		.69		.289	.24	1.2
25	153	91	1	1	1	1	19294.69	9747.49	.46	41.8	0	41.8		.68		.285	.23	1.23
26	163	92	1	1	1	1	20694.69	10523.49	.44	40.4	0	40.4		.66		.277	.219	1.26
27	170	100	1	1	1	1	21674.7	11066.69	.43	43	0	43		.66		.277	.212	1.3
28	180	100	1	1	1	1	23074.7	11842.69	.42	42	0	42		.64		.268	.201	1.33

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 SF Pe 2%\Sf020205\Sf020205.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\SF\SF020205.ACC
Earthquake Magnitude for CRR Analysis: 8
Magnitude Scaling Factor (MSF): .84
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 219.6
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 0
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.13 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100101

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.75	.336	2.23
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.75	.331	2.26
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.75	.319	2.35
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.75	.305	2.45
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.75	.292	2.56
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.75	.279	2.68
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.75	.266	2.81
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.75	.231	3.24
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.75	.207	3.62
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.735	.19	3.86
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.719	.181	3.97
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.705	.171	4.12
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.682	.164	4.15
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.682	.164	4.15
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.667	.161	4.14
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.652	.158	4.12
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.645	.154	4.18
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.63	.151	4.17
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.607	.144	4.21
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.592	.135	4.38
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.577	.125	4.61
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.156	.115	1.35
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.178	.105	1.69
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.475	.098	4.84
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.517	.09	5.74
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.303	.084	3.6
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.495	.08	6.18
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.487	.075	6.49
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.48	.071	6.76
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.472	.067	7.04

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\WH100101\Wh100101.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100101.ACC
Earthquake Magnitude for CRR Analysis: 6.4
Magnitude Scaling Factor (MSF): 1.5
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.14 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100102

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.75	.3	2.5
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.75	.292	2.56
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.75	.279	2.68
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.75	.266	2.81
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.75	.252	2.97
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.75	.238	3.15
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.75	.224	3.34
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.75	.192	3.9
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.75	.174	4.31
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.735	.159	4.62
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.719	.151	4.76
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.705	.143	4.93
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.682	.137	4.97
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.682	.137	4.97
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.667	.133	5.01
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.652	.13	5.01
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.645	.126	5.11
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.63	.123	5.12
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.607	.116	5.23
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.592	.11	5.38
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.577	.104	5.54
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.156	.099	1.57
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.178	.093	1.91
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.475	.088	5.39
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.517	.083	6.22
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.303	.079	3.83
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.495	.077	6.42
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.487	.075	6.49
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.48	.073	6.57
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.472	.07	6.74

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\Wh100102\Wh100102.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100102.ACC
Earthquake Magnitude for CRR Analysis: 6.4
Magnitude Scaling Factor (MSF): 1.5
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.15 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100105

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.75	.301	2.49
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.75	.291	2.57
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.75	.277	2.7
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.75	.262	2.86
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.75	.246	3.04
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.75	.231	3.24
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.75	.216	3.47
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.75	.182	4.12
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.75	.163	4.6
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.735	.149	4.93
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.719	.141	5.09
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.705	.133	5.3
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.682	.128	5.32
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.682	.128	5.32
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.667	.125	5.33
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.652	.123	5.3
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.645	.12	5.37
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.63	.118	5.33
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.607	.113	5.37
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.592	.108	5.48
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.577	.102	5.65
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.156	.096	1.62
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.178	.09	1.97
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.475	.084	5.65
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.517	.079	6.54
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.303	.074	4.09
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.495	.069	7.17
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.487	.064	7.6
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.48	.06	8
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.472	.056	8.42

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\Wh100105\Wh100105.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100105.ACC
Earthquake Magnitude for CRR Analysis: 6.4
Magnitude Scaling Factor (MSF): 1.5
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.16 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100201

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.595	.405	1.46
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.595	.398	1.49
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.595	.384	1.54
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.595	.368	1.61
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.595	.351	1.69
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.595	.335	1.77
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.595	.319	1.86
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.595	.276	2.15
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.595	.248	2.39
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.583	.229	2.54
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.571	.221	2.58
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.559	.214	2.61
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.541	.207	2.61
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.541	.207	2.61
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.529	.201	2.63
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.517	.196	2.63
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.511	.19	2.68
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.499	.184	2.71
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.481	.173	2.78
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.47	.161	2.91
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.458	.15	3.05
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.123	.138	.89
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.141	.126	1.11
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.376	.119	3.15
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.41	.112	3.66
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.24	.106	2.26
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.392	.101	3.88
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.386	.096	4.02
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.38	.09	4.22
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.374	.084	4.45

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\Wh100201\Wh100201.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100201.ACC
Earthquake Magnitude for CRR Analysis: 7
Magnitude Scaling Factor (MSF): 1.19
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.17 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100202

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.595	.353	1.68
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.595	.343	1.73
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.595	.329	1.8
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.595	.314	1.89
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.595	.299	1.98
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.595	.284	2.09
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.595	.27	2.2
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.595	.236	2.52
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.595	.218	2.72
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.583	.203	2.87
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.571	.192	2.97
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.559	.18	3.1
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.541	.172	3.14
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.541	.172	3.14
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.529	.166	3.18
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.517	.16	3.23
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.511	.155	3.29
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.499	.149	3.34
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.481	.138	3.48
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.47	.132	3.56
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.458	.129	3.55
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.123	.126	.97
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.141	.124	1.13
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.376	.119	3.15
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.41	.114	3.59
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.24	.109	2.2
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.392	.103	3.8
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.386	.098	3.93
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.38	.093	4.08
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.374	.088	4.25

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\Wh100202\Wh100202.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100202.ACC
Earthquake Magnitude for CRR Analysis: 7
Magnitude Scaling Factor (MSF): 1.19
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.18 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100205

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.595	.387	1.53
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.595	.38	1.56
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.595	.366	1.62
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.595	.35	1.7
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.595	.335	1.77
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.595	.319	1.86
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.595	.303	1.96
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.595	.264	2.25
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.595	.24	2.47
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.583	.223	2.61
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.571	.215	2.65
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.559	.207	2.7
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.541	.201	2.69
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.541	.201	2.69
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.529	.196	2.69
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.517	.191	2.7
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.511	.186	2.74
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.499	.181	2.75
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.481	.171	2.81
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.47	.161	2.91
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.458	.152	3.01
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.123	.144	.85
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.141	.135	1.04
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.376	.126	2.98
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.41	.116	3.53
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.24	.108	2.22
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.392	.102	3.84
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.386	.096	4.02
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.38	.09	4.22
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.374	.084	4.45

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\Wh100205\Wh100205.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100205.ACC
Earthquake Magnitude for CRR Analysis: 7
Magnitude Scaling Factor (MSF): 1.19
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.19 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD020101

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.45	.847	.53
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.45	.838	.53
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.45	.814	.55
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.45	.786	.57
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.45	.759	.59
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.45	.732	.61
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.45	.704	.63
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.45	.631	.71
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.45	.584	.77
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.441	.55	.8
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.431	.535	.8
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.422	.52	.81
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.409	.508	.8
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.409	.508	.8
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.4	.501	.79
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.391	.495	.78
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.387	.488	.79
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.378	.481	.78
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.364	.467	.77
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.355	.457	.77
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.346	.45	.76
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.093	.443	.2
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.107	.436	.24
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.285	.423	.67
25	150	71	1	1	1	1	18565.5	9205.5	.47	33.3	0	33.3		.69		.31	.411	.75
26	160	56	1	1	1	1	19904.1	9920.09	.46	25.7	0	25.7		.68		.181	.395	.45
27	170	82	1	1	1	1	21224.1	10616.1	.44	36	0	36		.66		.297	.379	.78
28	180	96	1	1	1	1	22544.1	11312.1	.43	41.2	0	41.2		.65		.292	.367	.79
29	190	82	1	1	1	1	23864.1	12008.1	.41	33.6	0	33.6		.64		.288	.359	.8
30	201	81	1	1	1	1	25403.3	12860.9	.4	32.4	0	32.4		.63		.283	.35	.8

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-O WH PE 2%\Wh020101\Wh020101.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH020101.ACC
Earthquake Magnitude for CRR Analysis: 7.8
Magnitude Scaling Factor (MSF): .9
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 225.1
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.20 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD100202

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.595	.353	1.68
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.595	.343	1.73
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.595	.329	1.8
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.595	.314	1.89
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.595	.299	1.98
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.595	.284	2.09
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.595	.27	2.2
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.595	.236	2.52
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.595	.218	2.72
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.583	.203	2.87
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.571	.192	2.97
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.559	.18	3.1
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.541	.172	3.14
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.541	.172	3.14
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.529	.166	3.18
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.517	.16	3.23
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.511	.155	3.29
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.499	.149	3.34
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.481	.138	3.48
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.47	.132	3.56
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.458	.129	3.55
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.123	.126	.97
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.141	.124	1.13
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.376	.119	3.15
25	150	71	1	1	1	1	18545.69	9185.69	.47	33.3	0	33.3		.69		.41	.114	3.59
26	160	56	1	1	1	1	19865.69	9881.69	.46	25.7	0	25.7		.68		.24	.109	2.2
27	170	82	1	1	1	1	21185.7	10577.69	.44	36	0	36		.66		.392	.103	3.8
28	180	96	1	1	1	1	22578.49	11346.49	.43	41.2	0	41.2		.65		.386	.098	3.93
29	190	82	1	1	1	1	23978.49	12122.49	.41	33.6	0	33.6		.64		.38	.093	4.08
30	201	81	1	1	1	1	25517.7	12975.29	.4	32.4	0	32.4		.63		.374	.088	4.25

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-0 WH PE10%\Wh100202\Wh100202.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH100202.ACC
Earthquake Magnitude for CRR Analysis: 7
Magnitude Scaling Factor (MSF): 1.19
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 205.9
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.21 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD020103

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.45	1.021	.44
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.45	1.01	.44
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.45	.978	.46
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.45	.942	.47
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.45	.906	.49
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.45	.87	.51
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.45	.833	.54
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.45	.749	.6
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.45	.701	.64
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.441	.662	.66
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.431	.635	.67
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.422	.609	.69
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.409	.586	.69
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.409	.586	.69
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.4	.568	.7
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.391	.55	.71
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.387	.532	.72
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.378	.514	.73
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.364	.478	.76
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.355	.454	.78
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.346	.437	.79
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.093	.42	.22
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.107	.403	.26
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.285	.395	.72
25	150	71	1	1	1	1	18565.5	9205.5	.47	33.3	0	33.3		.69		.31	.388	.79
26	160	56	1	1	1	1	19904.1	9920.09	.46	25.7	0	25.7		.68		.181	.387	.46
27	170	82	1	1	1	1	21224.1	10616.1	.44	36	0	36		.66		.297	.387	.76
28	180	96	1	1	1	1	22544.1	11312.1	.43	41.2	0	41.2		.65		.292	.384	.76
29	190	82	1	1	1	1	23864.1	12008.1	.41	33.6	0	33.6		.64		.288	.379	.75
30	201	81	1	1	1	1	25403.3	12860.9	.4	32.4	0	32.4		.63		.283	.374	.75

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-O WH PE 2%\Wh020103\Wh020103.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH020103.ACC
Earthquake Magnitude for CRR Analysis: 7.8
Magnitude Scaling Factor (MSF): .9
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 225.1
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.22 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD020202

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.42	.955	.43
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.42	.945	.44
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.42	.918	.45
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.42	.887	.47
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.42	.857	.49
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.42	.826	.5
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.42	.796	.52
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.42	.704	.59
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.42	.639	.65
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.411	.59	.69
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.403	.564	.71
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.394	.537	.73
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.382	.519	.73
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.382	.519	.73
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.373	.511	.72
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.365	.502	.72
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.361	.494	.73
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.352	.485	.72
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.34	.468	.72
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.331	.452	.73
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.323	.437	.73
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.087	.422	.2
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.1	.407	.24
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.266	.38	.7
25	150	71	1	1	1	1	18565.5	9205.5	.47	33.3	0	33.3		.69		.289	.353	.81
26	160	56	1	1	1	1	19904.1	9920.09	.46	25.7	0	25.7		.68		.169	.342	.49
27	170	82	1	1	1	1	21224.1	10616.1	.44	36	0	36		.66		.277	.332	.83
28	180	96	1	1	1	1	22544.1	11312.1	.43	41.2	0	41.2		.65		.272	.322	.84
29	190	82	1	1	1	1	23864.1	12008.1	.41	33.6	0	33.6		.64		.268	.313	.85
30	201	81	1	1	1	1	25403.3	12860.9	.4	32.4	0	32.4		.63		.264	.304	.86

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-O WH PE 2%\Wh020202\Wh020202.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH020202.ACC
Earthquake Magnitude for CRR Analysis: 8
Magnitude Scaling Factor (MSF): .84
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 225.1
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

Table G.23 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD020203

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.42	1.031	.4
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.42	1.02	.41
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.42	.986	.42
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.42	.949	.44
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.42	.911	.46
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.42	.873	.48
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.42	.836	.5
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.42	.746	.56
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.42	.694	.6
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.411	.652	.63
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.403	.624	.64
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.394	.597	.65
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.382	.575	.66
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.382	.575	.66
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.373	.562	.66
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.365	.549	.66
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.361	.535	.67
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.352	.522	.67
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.34	.495	.68
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.331	.47	.7
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.323	.447	.72
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.087	.424	.2
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.1	.4	.25
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.266	.372	.71
25	150	71	1	1	1	1	18565.5	9205.5	.47	33.3	0	33.3		.69		.289	.345	.83
26	160	56	1	1	1	1	19904.1	9920.09	.46	25.7	0	25.7		.68		.169	.348	.48
27	170	82	1	1	1	1	21224.1	10616.1	.44	36	0	36		.66		.277	.351	.78
28	180	96	1	1	1	1	22544.1	11312.1	.43	41.2	0	41.2		.65		.272	.35	.77
29	190	82	1	1	1	1	23864.1	12008.1	.41	33.6	0	33.6		.64		.268	.345	.77
30	201	81	1	1	1	1	25403.3	12860.9	.4	32.4	0	32.4		.63		.264	.339	.77

Notes:

CSR analysis using SHAKE results.
CSR File: D:\I-O WH PE 2%\wH020203\Wh020203.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH020203.ACC
Earthquake Magnitude for CRR Analysis: 8
Magnitude Scaling Factor (MSF): .84
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 225.1
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1
*Effective Stress column computed using Depth to Water Table for CRR Analysis

Table G.24 Liquefaction Analysis

Wahite Ditch Site
Ground Motion WD020205

SPT No.	Depth (ft)	N field	Energy Factor	Rod Factor	Sampler Factor	Borehole Factor	Total Stress (psf)	Effective Stress (psf)	Cn	(N1)60	Fines Content (%)	N1,60cs	Alpha	Ksigma	Kalpha	CRR	CSR	Safety Factor
1	20	58	1	1	1	1		47.6	2	116	91	144.2		1		.42	.88	.47
2	21.5	51	1	1	1	1	1932.59	590.99	1.89	96.3	91	120.5		1		.42	.869	.48
3	23	72	1	1	1	1	2072.09	636.89	1.82	131	91	162.2		1		.42	.84	.5
4	24.5	63	1	1	1	1	2219.79	690.99	1.74	109.6	91	136.5		1		.42	.808	.51
5	26	49	1	1	1	1	2420.79	798.39	1.62	79.3	91	100.1		1		.42	.776	.54
6	27.5	46	1	1	1	1	2621.79	905.79	1.52	69.9	91	88.8		1		.42	.744	.56
7	29	65	1	1	1	1	2822.79	1013.19	1.44	93.6	91	117.3		1		.42	.712	.58
8	35	66	1	1	1	1	3626.79	1442.79	1.21	79.8	26	93.9		1		.42	.632	.66
9	40	73	1	1	1	1	4291.4	1795.39	1.08	78.8	20	88.6		1		.42	.584	.71
10	45	47	1	1	1	1	4951.4	2143.39	.99	46.5	8	47.3		.98		.411	.547	.75
11	50	46	1	1	1	1	5613	2493	.92	42.3	0	42.3		.96		.403	.525	.76
12	55	39	1	1	1	1	6278	2846	.86	33.5	0	33.5		.94		.394	.503	.78
13	60	38	1	1	1	1	6942.99	3198.99	.81	30.7	0	30.7		.91		.382	.485	.78
14	60	46	1	1	1	1	6942.99	3198.99	.81	37.2	0	37.2		.91		.382	.485	.78
15	65	54	1	1	1	1	7607.99	3551.99	.77	41.5	8	42.3		.89		.373	.472	.79
16	70	51	1	1	1	1	8252.69	3884.69	.73	37.2	0	37.2		.87		.365	.459	.79
17	75	54	1	1	1	1	8882.69	4202.69	.7	37.8	0	37.8		.86		.361	.446	.8
18	80	51	1	1	1	1	9512.69	4520.69	.68	34.6	0	34.6		.84		.352	.433	.81
19	90	51	1	1	1	1	10772.69	5156.69	.64	32.6	0	32.6		.81		.34	.407	.83
20	100	82	1	1	1	1	12032.69	5792.69	.6	49.2	0	49.2		.79		.331	.389	.85
21	110	73	1	1	1	1	13292.69	6428.69	.57	41.6	0	41.6		.77		.323	.377	.85
22	120	24	1	1	1	1	14552.69	7064.69	.54	12.9	0	12.9		.74		.087	.365	.23
23	130	29	1	1	1	1	15885.49	7773.49	.52	15	7	15.2		.72		.1	.353	.28
24	140	61	1	1	1	1	17225.5	8489.5	.49	29.8	0	29.8		.71		.266	.344	.77
25	150	71	1	1	1	1	18565.5	9205.5	.47	33.3	0	33.3		.69		.289	.335	.86
26	160	56	1	1	1	1	19904.1	9920.09	.46	25.7	0	25.7		.68		.169	.335	.5
27	170	82	1	1	1	1	21224.1	10616.1	.44	36	0	36		.66		.277	.334	.82
28	180	96	1	1	1	1	22544.1	11312.1	.43	41.2	0	41.2		.65		.272	.333	.81
29	190	82	1	1	1	1	23864.1	12008.1	.41	33.6	0	33.6		.64		.268	.333	.8
30	201	81	1	1	1	1	25403.3	12860.9	.4	32.4	0	32.4		.63		.264	.332	.79

Notes:
CSR analysis using SHAKE results.
CSR File: D:\I-O WH PE 2%\Wh020205\Wh020205.grf
CRR using SPT Data and Seed et. al. Method in 1997 NCEER Workshop.
Earthquake File for SHAKE Analysis: D:\WH\WH020205.ACC
Earthquake Magnitude for CRR Analysis: 8
Magnitude Scaling Factor (MSF): .84
Depth to Water Table for CRR Analysis (ft): 0
Depth to Water Table for Cn Calculation (ft): 0
Depth to Base Layer for CSR Analysis (ft): 225.1
MSF Option: I.M. Idriss (1997)
Cn Option: Liao & Whitman (1986)
Ksigma Option: L.F. Harder & R. Boulanger (1997)
SPT Energy Ratio: USA/Safety/Rope: 1

H. STRUCTURAL ANALYSIS RESULTS

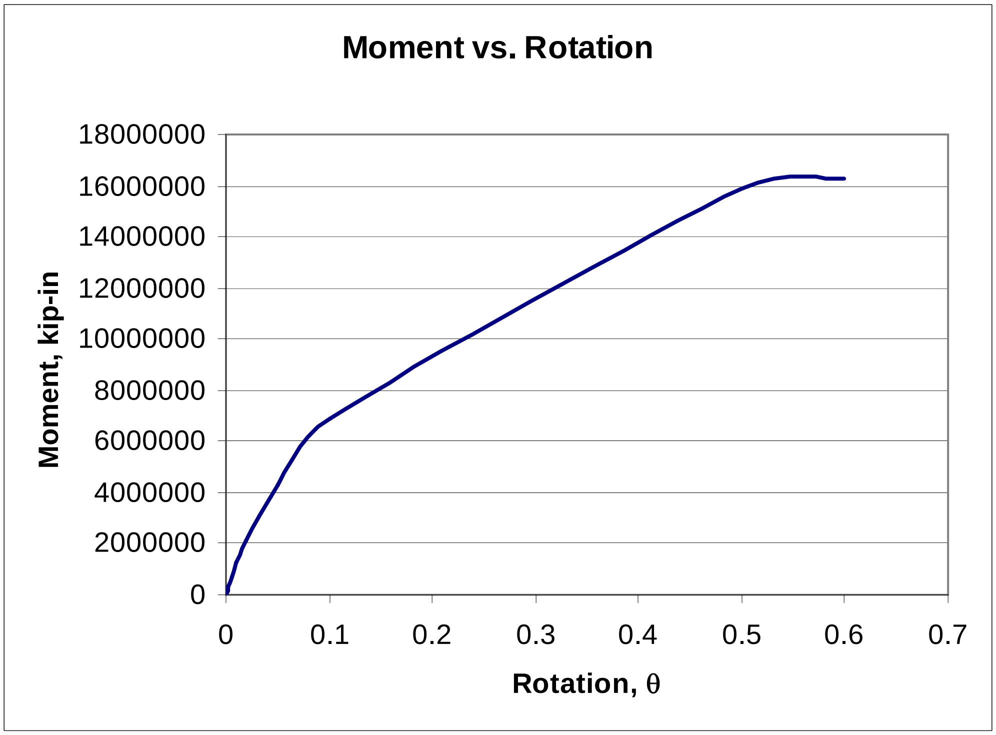
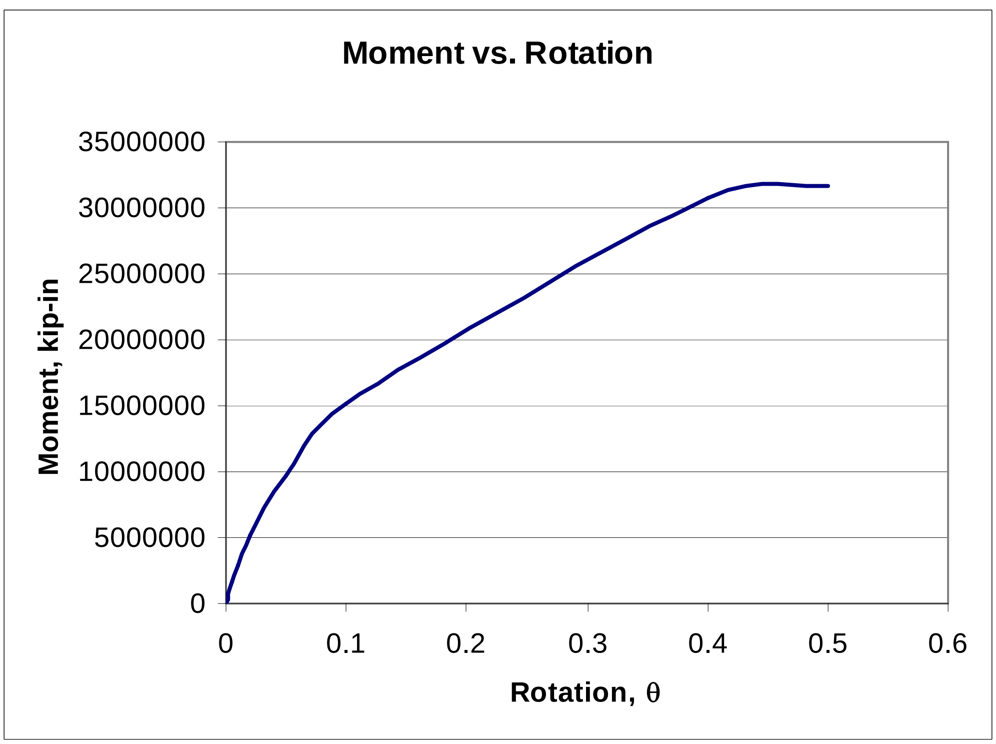


Figure H.1 New St. Francis River Bridge Four Pile Footing



. **Figure H.2** New St. Francis River Bridge Five Pile Footing

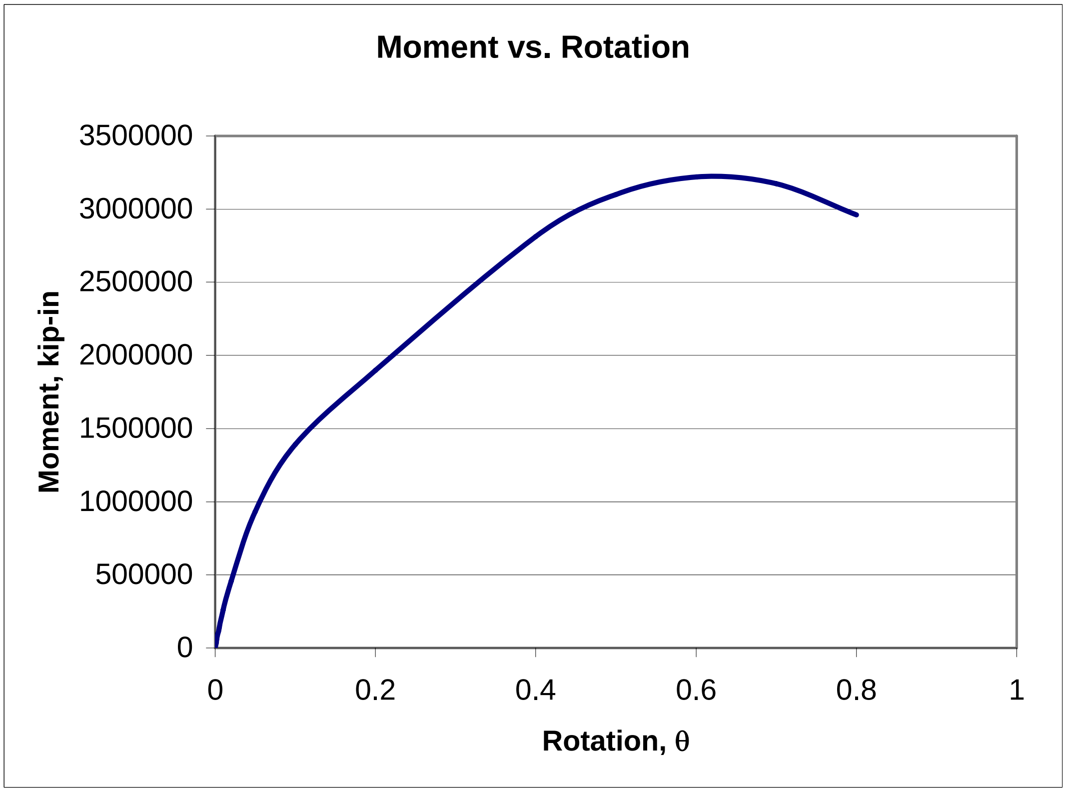


Figure H.3 Old St. Francis River Bridge Three Pile Footing

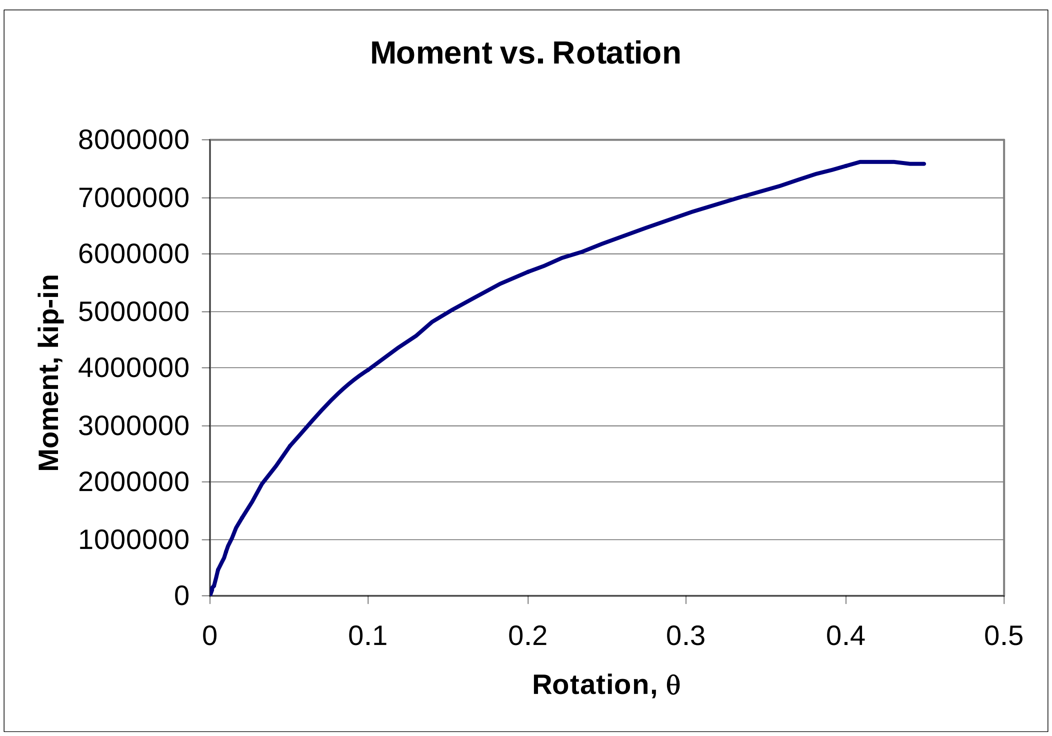


Figure H.4 New Wahite Ditch Bridge Four Pile Footing

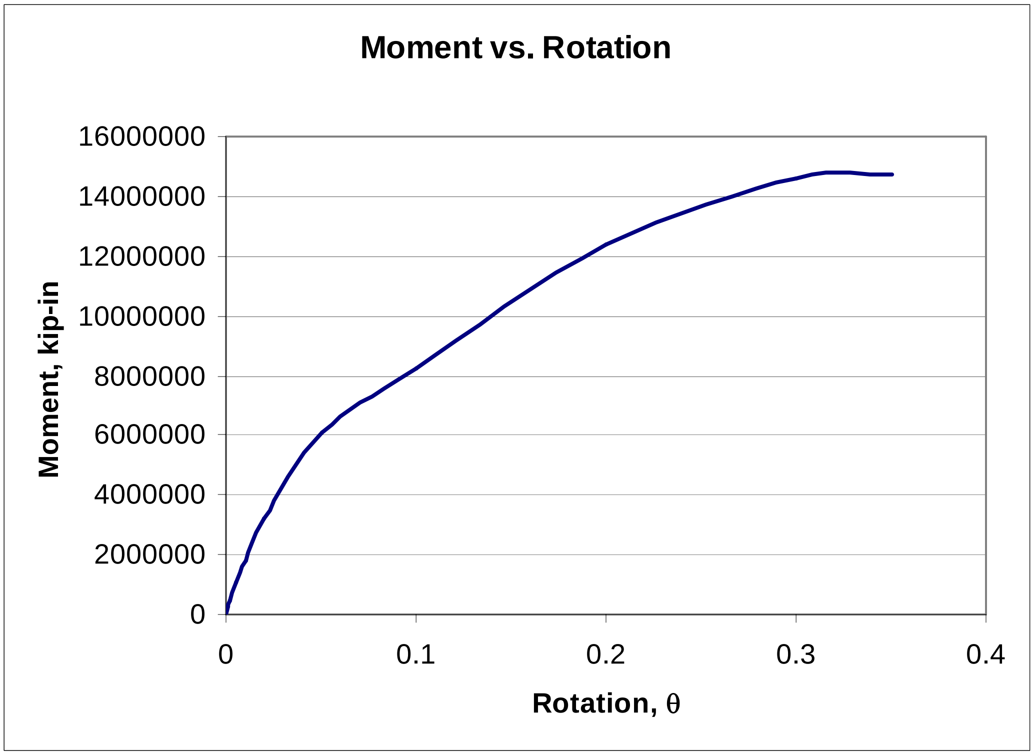


Figure H.5 New Wahite Ditch Bridge Five Pile footing

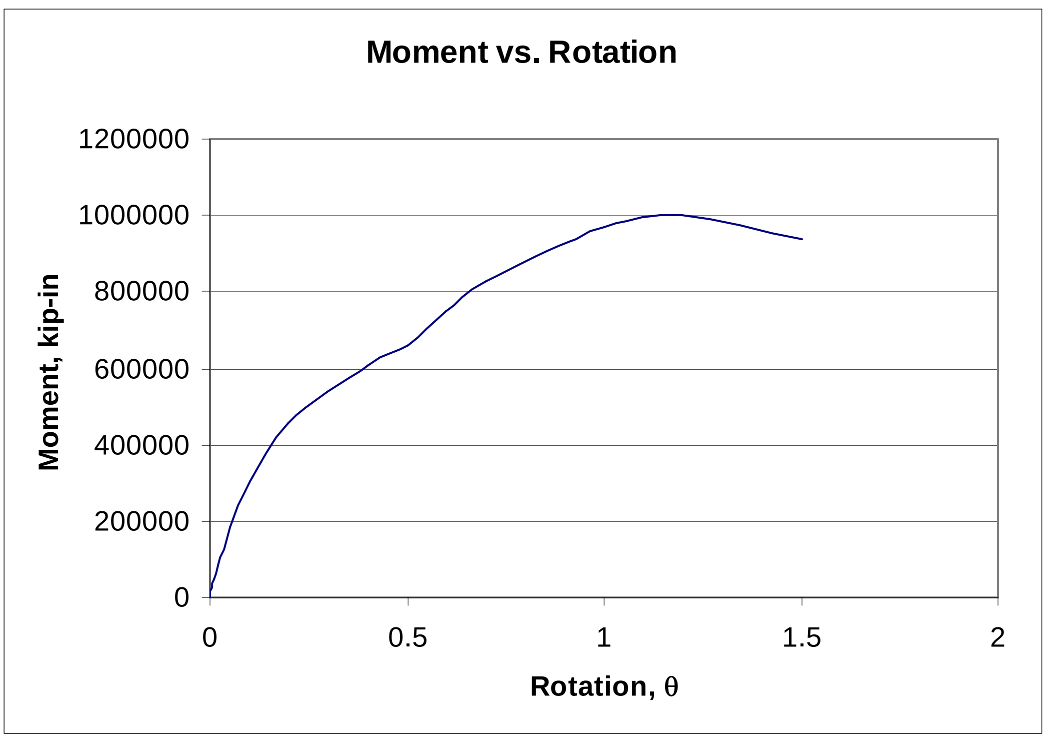


Figure H.6 Old Wahite Ditch Bridge Two Pile Footing A

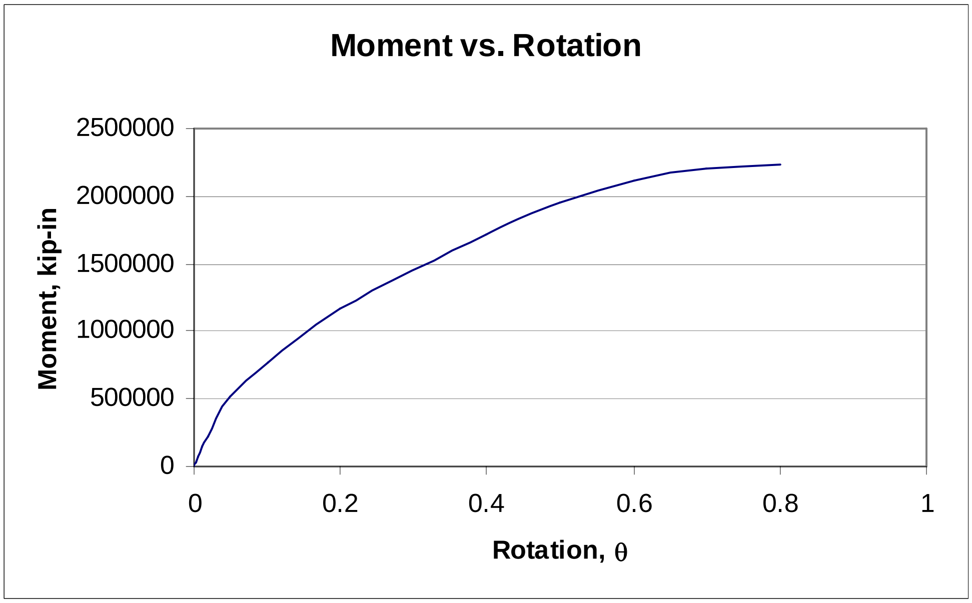


Figure H.7 Old Wahite Ditch Bridge Three Pile Footing A

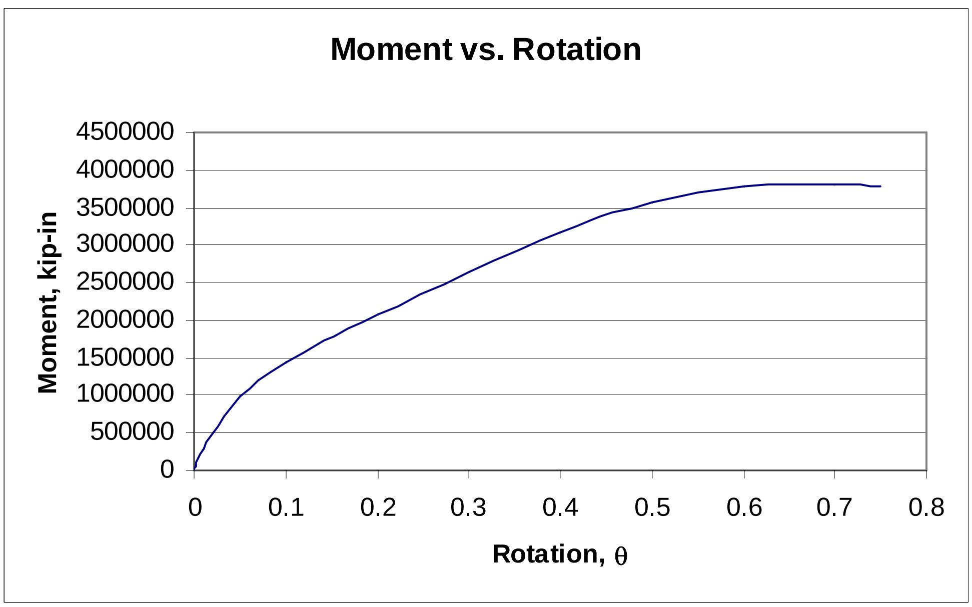


Figure H.8 Old Wahite Ditch Bridge Three Pile Footing B