TECHNICAL MEMORANDUM

Broadway Bridge Feasibility Study Geotechnical and Constructability Considerations

PREPARED FOR: City of West Sacramento, in cooperation with the City of Sacramento

PREPARED BY: WRECO

Project Understanding

Project Overview

The City of West Sacramento and City of Sacramento (Cities) have partnered to prepare a feasibility study (Study) for a new crossing of the Sacramento River, connecting the Cities in the vicinity of Broadway on the east side and 15th/5th streets on the west. The study analyzed four crossing alignments, three bridge cross-section alternatives, and three movable-bridge types that meet the marine navigation requirements of the U.S. Coast Guard (USCG). The alignments and bridge parameters included in the Study are a result of stakeholder coordination, public outreach, and technical input since the Study phase began in March 2015.

Site Soils

As there was no site-specific soils data at this time, available as-built soils data from adjacent structures was used for this Study. The as-built boring data from the following sources were available at the time this study was prepared:

- Pioneer Bluff Bridge.
- Railyards 5th Street and 6th Street Bridges.
- Caltrans riverfront seal slab as-built Log of Test Borings (LOTBs).
- Caltrans Sacramento River viaduct (east ramp) as-built LOTBs.
- Caltrans river viaduct Unit II as-built LOTBs.

Based on the available as-built near-site soils data, the site subsurface conditions are relatively uniform with four trending major geologic strata. These geologic strata were identified to only have minor deviations in the elevation at the contacts based on the as-built near-site soils data.

The soils at the proposed Broadway Bridge site are anticipated to consist of:

- Very loose/soft silty clayey sand/silty clay/clayey silt which are anticipated to be 5 to 30 feet in thickness, depending on invert of the Sacramento River and any local scour and redisposition.
- Medium dense to dense silty to poorly graded sand which will have an average thickness of between 50 to 70 feet.
- Very dense gravels which will generally be about 20 feet in overall thickness.
- Hard silty clays to depths of approximately 120 feet below existing ground where the deepest borings were terminated.

Preliminary Seismic Analysis

WRECO also performed a preliminary seismic analysis using the as-built data to calculate a shear wave velocity (V_{s30}) for the site soils which was 200 meters per second (m/s) in the upper 100 feet of the soil strata. The result of the preliminary seismic analysis indicates the peak ground acceleration for the site is approximately 0.30 g (where "g" is the acceleration due to gravity) with the controlling seismic case the USGS 5 percent in 50-year exceedance. The preliminary ARS curve is attached to this technical memorandum.

A preliminary liquefaction evaluation was performed on two of the as-built borings to better quantify the liquefaction potential in the general vicinity of the proposed bridge site. To better capture the potential at this level of study, two borings from different structures were used in the liquefaction analysis. Additionally, each of the borings was analyzed using current existing grade and then considering the boring transferred to the bottom of channel elevation to determine if due to overburden removal, there was a difference in the liquefaction results from the top of the bank to the bottom of the river channel as bridge foundations will be at both of these elevations.

The results of the preliminary analyses show the site is susceptible to liquefaction under the design seismic event and liquefaction will occur. Additionally, using the as-built soils data, without the benefit of percent passing the #200 sieve and any plasticity testing on the fines, settlement due to liquefaction is on the order of 12 to 18 inches as measured from existing ground and also from bottom of channel invert. Based upon the preliminary analyses, the majority of the predicted liquefaction and seismically induced settlements are occurring in the medium dense sands identified in the majority of the borings. Additionally, based upon the liquefaction profile, the approaches are expected to undergo lateral spreading when subjected to the design earthquake event and at this time spreading is expected to be greater than 12 inches.

Based on the as-built data used for the lateral spreading preliminary analyses, the identified layer which is predicted to undergo liquefaction and induce lateral spreading assumed to encompass the entire project site. This coupled with the free-face condition at the riverbank makes any kind of remedial measure such as stone column installation or compaction grouting not feasible as this layer was identified in borings on both sides of the river. Taking into account the data used to perform the analyses was not site specific and no laboratory soils testing, at this time, the abutment substructures should be designed to resist any soil flow from lateral spreading until a time where site specific data can be obtained and the depth and extent of any lateral spreading be better quantified with site specific subsurface exploration consisting of soil borings and Cone Penetration Test (CPT) soundings.

Preliminary Foundations

Information provided by CH2M and Hardesty & Hanover shows the main span piers will be supported by large-diameter driven steel pipe piles (Caltrans cast-in-steel-shell [CISS]) which are required due to the large axial and lateral demands of the movable bridge main span piers. For preliminary cost determination at this level of study, 4-foot- and 6-foot-diameter CISS piles were analyzed for axial and lateral resistances as these are expected to be typical foundation piles for the main span piers. **Table 1** provides the pile type and dimensions, preliminary design tip elevation, and preliminary ultimate axial capacities.

Table 1. Preliminary Main Span Pile Data

The analysis for the driven piles is an "idealized" engineering soil profile using the available boring data. The preliminary ultimate axial capacities do not have any reduction factors nor take into account any effects of loss of bearing due to liquefaction.

Main Span Movable Bridge Pile Type	Preliminary Ultimate Axial Capacity (kips)		Preliminary Tip Elevation (feet)
	Compression	Tension	
48-inch-diameter, 1-inch wall, driven CISS pile	2,300	900	-145
60-inch-diameter, 1.5-inch wall, driven CISS pile	2,700	1,100	-145

Based on the preliminary bridge plans, the approach spans are shown to be supported on 24-inch-diameter CISS piles below the approach span piers and abutments. For preliminary cost determination, these piles were analyzed for axial and lateral resistances and are presented in **Table 2**, below.

Table 2. Preliminary Approach Span Pile Data

The analysis for the driven piles is an "idealized" engineering soil profile using the available boring data. The preliminary ultimate axial capacities do not have any reduction factors nor take into account any effects of loss of bearing due to liquefaction.

Main Span Movable Bridge Pile Type	Preliminary Ultimate Axial Capacity (kips)		Preliminary Tip Elevation (feet)
	Compression	*Tension*	
24-inch-diameter, 0.5-inch wall, driven CISS pile	650	300	-105

Preliminary lateral resistances were evaluated for the proposed foundation piles and the developed lateral resistance for 0.25, 0.5, and 1 inch of movement is provided in **Table 3**, below.

Table 3. Preliminary Lateral Pile Capacity Data

The analysis for the lateral pile capacities is an "idealized" engineering soil profile using the available boring data. The preliminary lateral pile capacities assumes a "pinned" connection between the top of the pile and bottom of the footing.

Pile Type	Lateral Pile Resistance (kips) at Specified Pile Head Movements		
	0.25 Inch	0.5 Inch	1 Inch
48-inch-diameter, 1-inch wall, driven CISS pile	79	144	227
60-inch-diameter, 1.5-inch wall, driven CISS pile	125	235	375
24-inch-diameter, 0.5-inch wall, driven CISS pile	16	27	38

Also at this time due to Central Valley Flood Control Board requirements, it is understood that any foundation elements within the limits of the levees cannot be driven piles and will have to be drilled cast-in-drilled-hole (CIDH) piles as driven pile foundations are not allowed to be constructed within the limits of the levees. If a foundation element such as an approach span footing or abutment footing were to be founded within the limits of the existing levees, the piles would have to be drilled piling. If this pile type were to be used for any substructures within the limits of the levees, we anticipate the construction requiring a full length segmental casing with a permanent casing through the levee to prevent a pile blowout failure and help reduce the chance of any anomalies forming during concrete placement based on the wet loose sandy nature of the soils identified on the as-built soils information. As CIDH piles do not develop side friction as efficiently as a driven pile and per Caltrans requirements regarding end-bearing development in a wet pile condition, CIDH piles would not be as efficient a foundation system as driven piles and be more cost per unit substructure.

Construction

As the majority of the construction work will occur over water using barges, there are two predominant construction methods, including the use of 1) float in/precast segmental type piers for the main spans, and 2) driven steel sheet pile cofferdams for the approach spans.

Main Span Piers

Prefabricated Bridge Element Systems (PBES) have been used successfully for the last 50 years to accelerate and reduce costs of bridges, especially bridges in water and marine environments. Precast piers are the preferred foundation system for the proposed bridge because, as a movable bridge, it will have:

- Larger than normal piers,
- Heavier axial demands combined with the significant cost savings from a traditional sheet piling cofferdam, and
- Dewatering and environmental benefits.

There are four main types of prefabricated piers which are suitable for this bridge construction:

1. Full height float-in precast concrete pier
2. Shallow height float-in precast concrete pier
3. Crane in precast concrete pier.
4. Segmental precast concrete pier

A full height float-in precast concrete pier consists of essentially an open-topped, precast concrete box which is cast on dry land and then launched and towed by tug to the pier location. The pier is then set in position using alignment piles and sunk by internal flooding to rest on the river bottom. Foundation piles are driven through template punch outs in the bottom of the box. Once the piles are installed, the bottom is sealed using a tremie pour which creates a dry working area to complete the pier construction. This type of pier system works well in relatively shallow-water environments like the Sacramento River, and also acts as the pile-driving template. This type of pier system does require either a large launching area or dry dock in order to construct and float.

A shallow height float-in precast concrete pier is the foundation system for the Port Mann Bridge in Vancouver, British Columbia and the new Carquinez Bridge between Crockett and Vallejo. The main difference between this type and a full height float-in is the bearing piles are driven with a template before the pier is placed and the piles extend below the bottom of the pier to the river bottom. This type of pier does not require a dry dock and can be craned into the water at the casting yard depending on the size of the pier and available cranes at the casting yard.

A crane-in pier is similar to a shallow float-in pier except it is brought to the pier location on a barge and set in place with a crane. Typically, these are for smaller piers unless very large barge cranes and large barges for transport are available. The other major difference is this type of precast pier does not have to be watertight for transport like a float-in does.

The segmental pier is similar to a crane-in pier with the exception that the precast pier system is made up of multiple sections and placed sequentially and not in one unit like the crane-in pier. The advantage is the segmental pier requires the smallest cranes, barges, and casting yards due to multiple smaller pieces. This pier system brings the multiple pieces of the precast pier via barge and are set on the piles in pieces. The pieces are made locked together and watertight with seals and a sealing concrete pour.

All of these systems can be cast locally and barged to the pier locations which reduces cost. Additionally, since a sheet pile cofferdam is not required with these system and significantly less dewatering, and permitting, storing, treating, and disposing of the water, these precast systems are significantly cheaper and faster than traditional construction.

Approach Span Piers

The approach spans shown on the preliminary plans have a traditional footing with two rows of piles beneath each footing and columns extending from the top of the footing up to the bent cap which is out of the water. The typical way to construct these footings is to install a steel sheet pile cofferdam to work in during the construction. Typically, once the cofferdam is complete, soils within the cofferdam are excavated using a clam shell bucket and then the piles are driven inside underwater. A slurry seal is then placed in the bottom of the cofferdam around the piles which makes the cofferdam sealed and allows it to be pumped dry and creates a dry work space. The footing steel and concrete is placed in the dry along with any cutting of the piles to fit within the footing and then traditional column construction up to the top of bent cap. Typically, the steel sheet piles are burned off at top of footing because, due to adhesion between the slurry seal and footing concrete in contact with the steel sheet piles, they cannot be pulled.

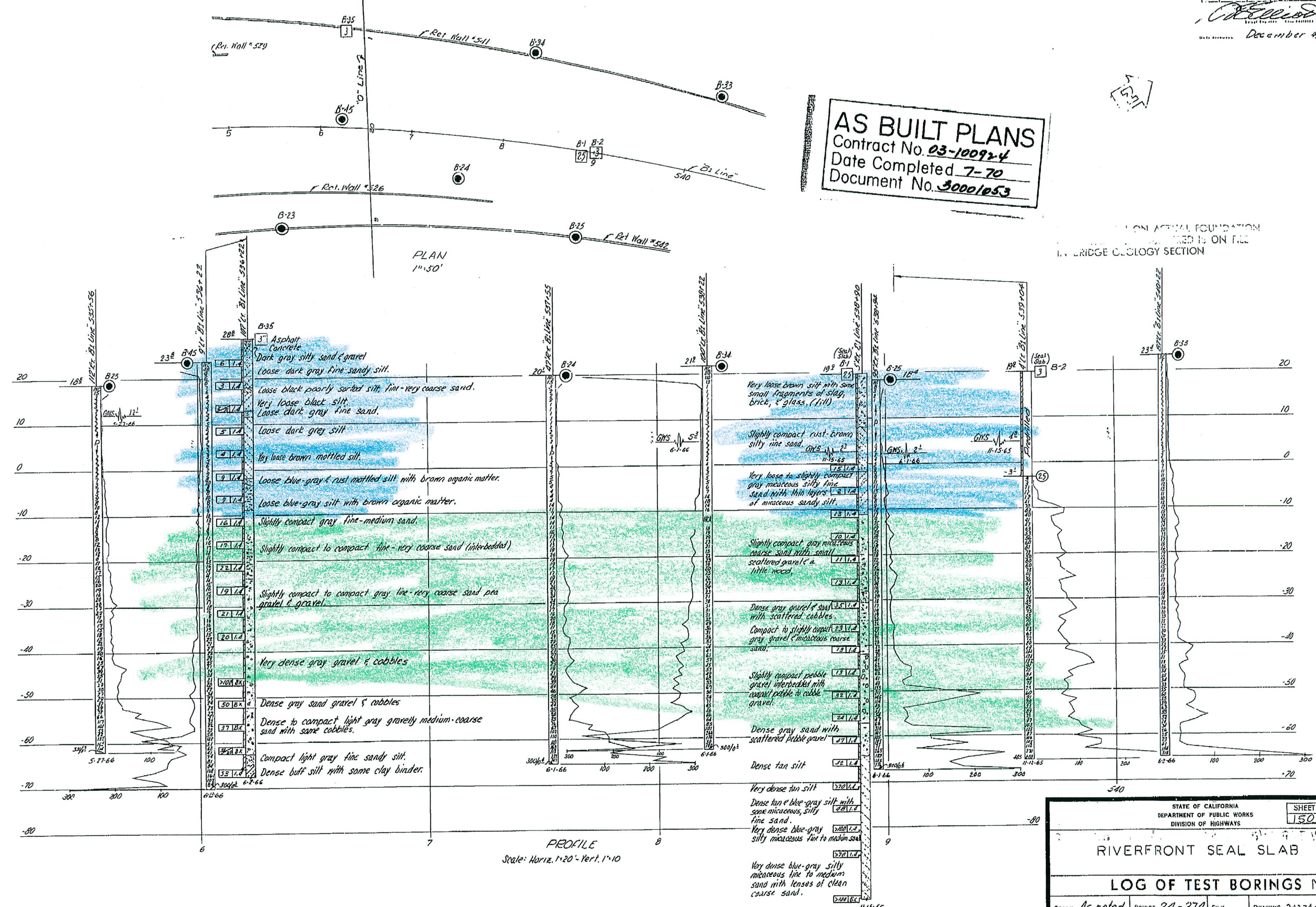
SELECT AS-BUILT LOTB SOILS DATA

FED. ROAD DIV. NO.	STATE	F A PROJECT NO	SHEET NO	TOTAL SHEETS
7	CALIF.			

DIST.	COUNTY	ROUTE	SECTION	SHEET NO.	TOTAL SHEETS
03	Sac	05		368	370

December 4, 1969

AS BUILT PLANS
Contract No. 03-100924
Date Completed 7-70
Document No. 30001053



... ON ACTUAL FOUNDATION ... ED IS ON FILE IN BRIDGE GEOLOGY SECTION

LEGEND OF BORING OPERATIONS

Penetrometer; $2\frac{1}{2}$" Cone Penetrometer; Sampler boring (dry); Rotary boring (wet); Auger boring (dry); Jet boring; Core boring; Test pit

1" Soil Tube — Rotary Boring — Penetration Boring

LEGEND OF EARTH MATERIALS

Gravel; Sand; Silt; Clay; Sandy clay or clayey sand; Sandy silt or silty sand; Silty clay or clayey silt; Peat and/or organic matter; Fill material; Igneous rock; Sedimentary rock; Metamorphic rock

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRADE SIZE LIMITS

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

FIELD STUDY	By Hager 6/66
DRAWN	By Lew 8/66
CHECKED	By

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

368

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

SHEET 150 OF 152

RIVERFRONT SEAL SLAB

LOG OF TEST BORINGS NO. 7

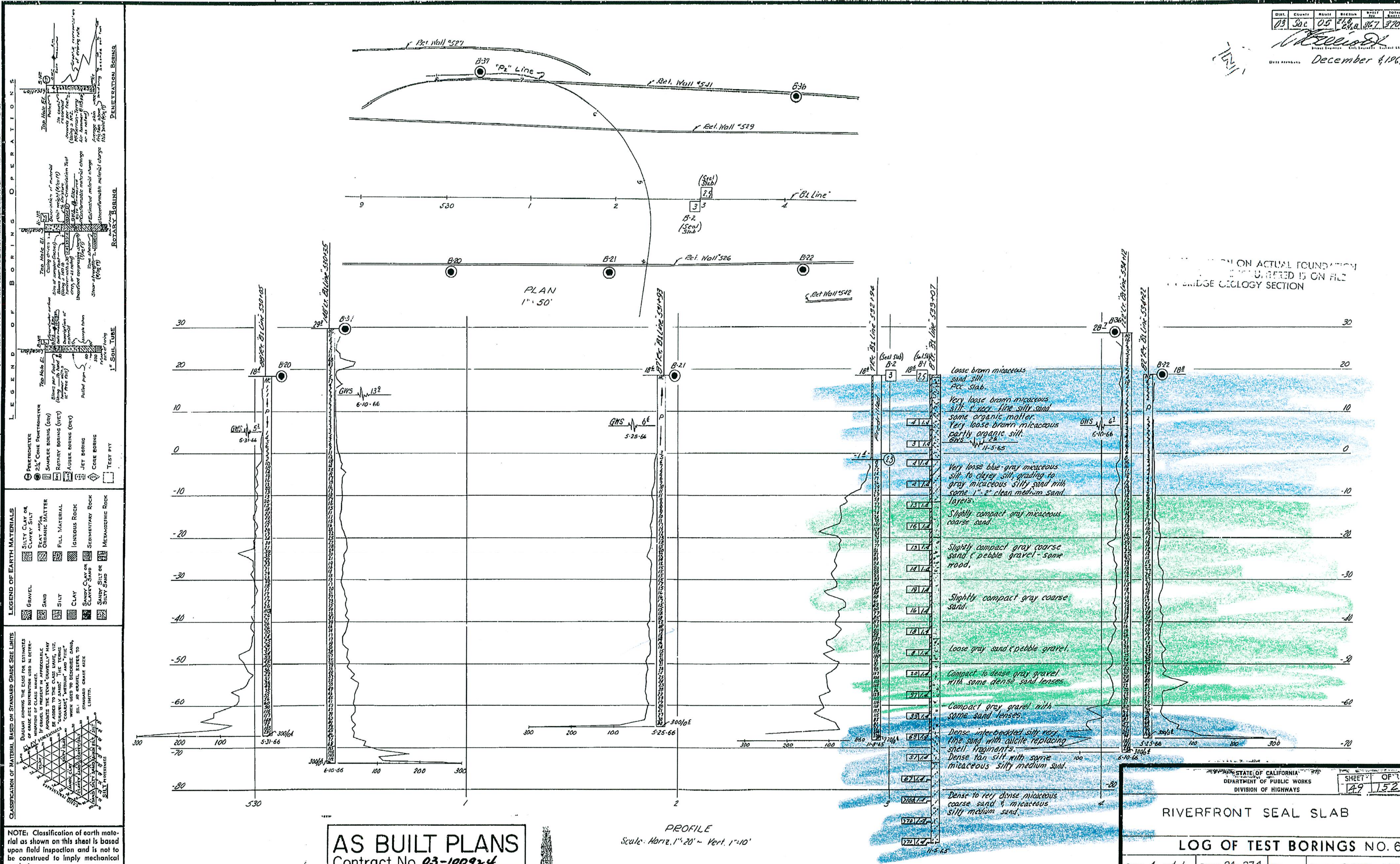
SCALE As noted | BRIDGE 24-274 | FILE | DRAWING 24274-148

03207
100921

Disregard prints bearing earlier numbers → PREL. DRAWING NO. PR-24274-2F

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF PUBLIC WORKS.

DATE 10/14/71 SIGNATURE [signature] TITLE HAO II



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

SHEET 49 OF 152

RIVERFRONT SEAL SLAB

LOG OF TEST BORINGS NO. 6

SCALE As noted	BRIDGE 24-274	FILE	DRAWING 24274-147

03207
100921

Disregard prints bearing earlier numbers ——→ PREL. DRAWING No. PR-24274- 2E

AS BUILT PLANS
Contract No. 03-100924
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Document No. 30001053

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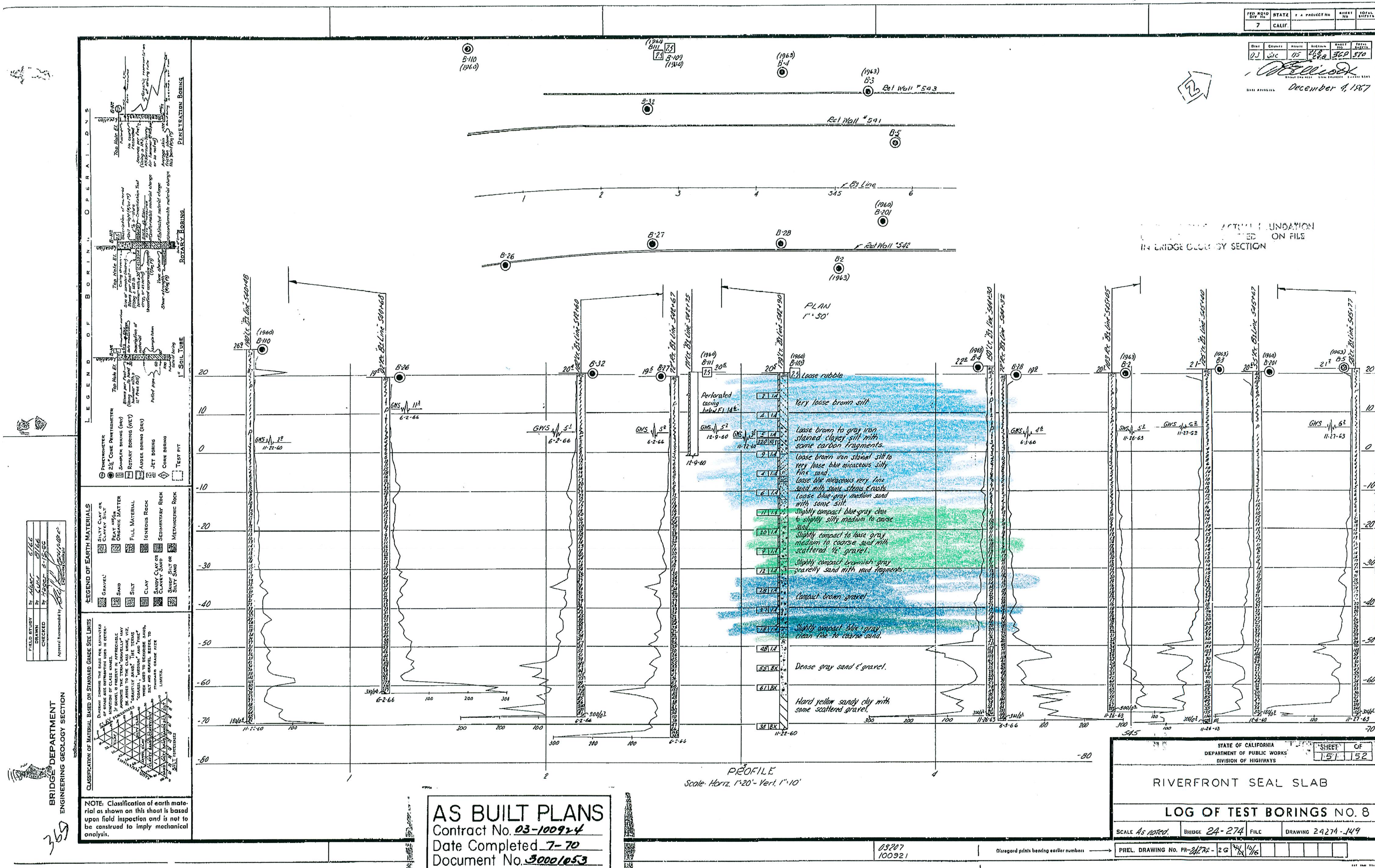

AS BUILT PLANS
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Date Completed 7-70
Document No. 30001053

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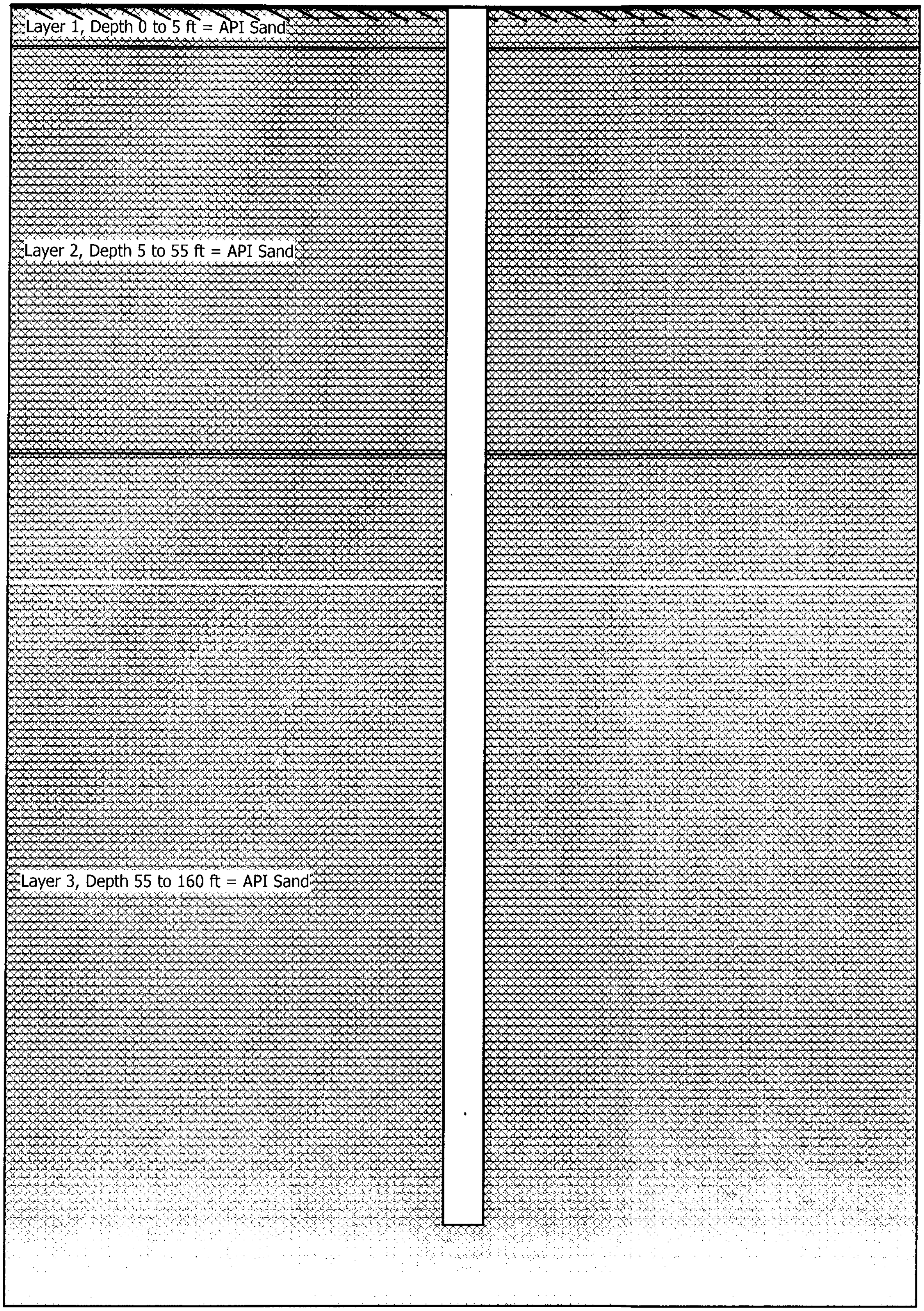
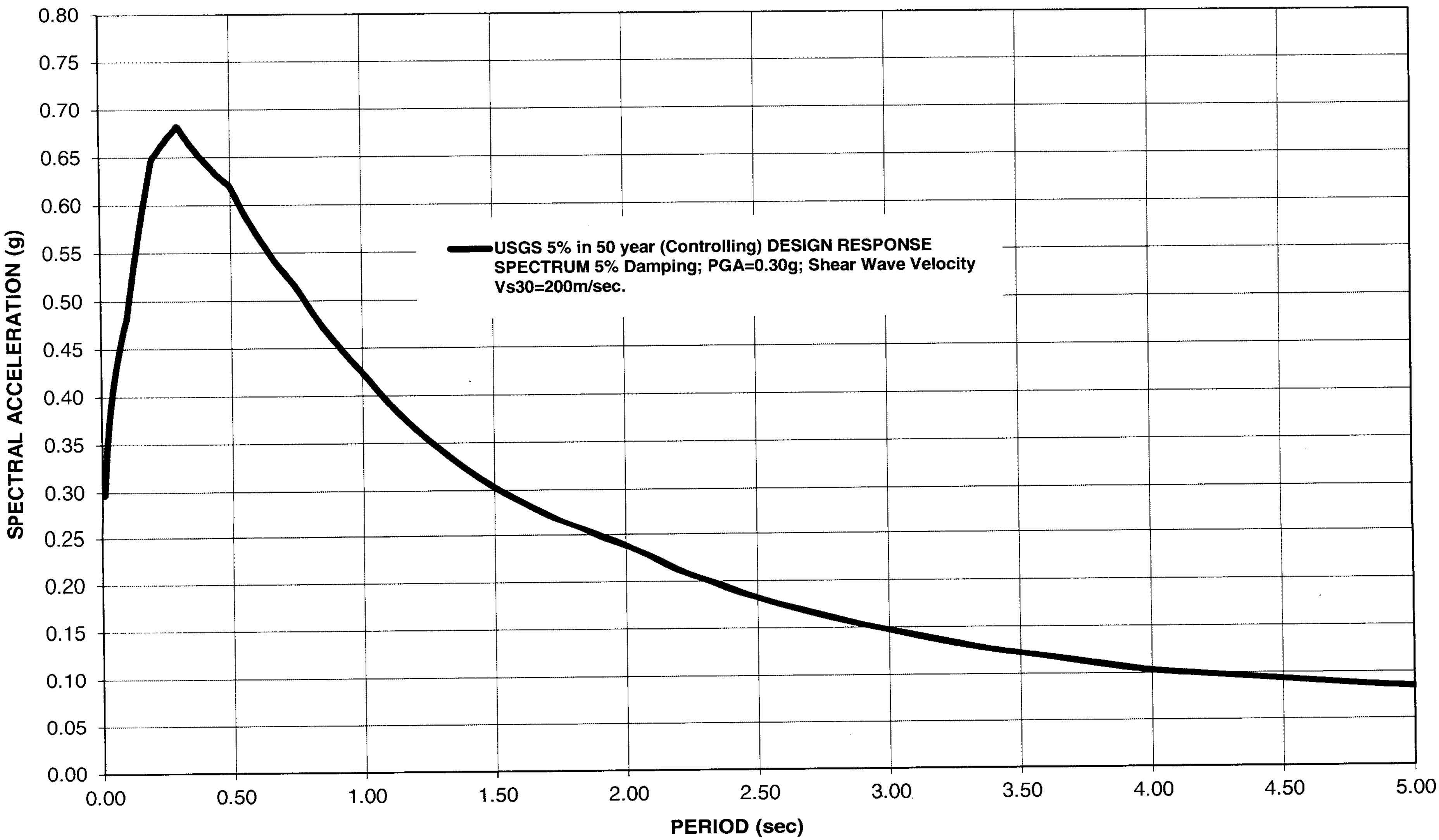
DATE 10/14/71 SIGNATURE [illegible] TITLE HAO II

IDEALIZED SOIL PROFILE


Layer 1, Depth 0 to 5 ft = API Sand
Layer 2, Depth 5 to 55 ft = API Sand
Layer 3, Depth 55 to 160 ft = API Sand

PRELIMINARY SEISMIC ANALYSIS

Broadway Bridge Preliminary Seismic Analysis Using As-built Near Site Soils Data
By: WRECO
Date: 09/25/15

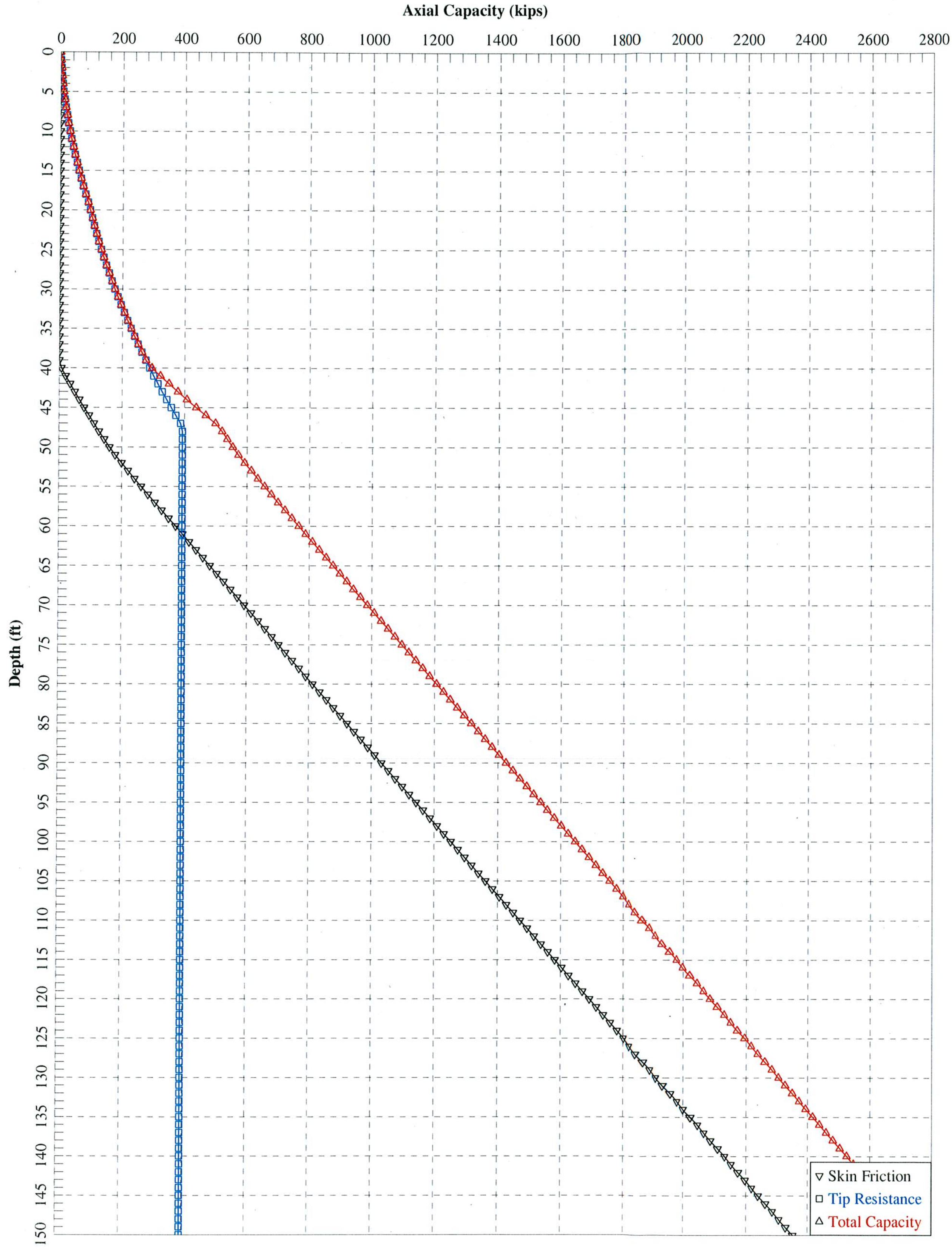


Tabular Data

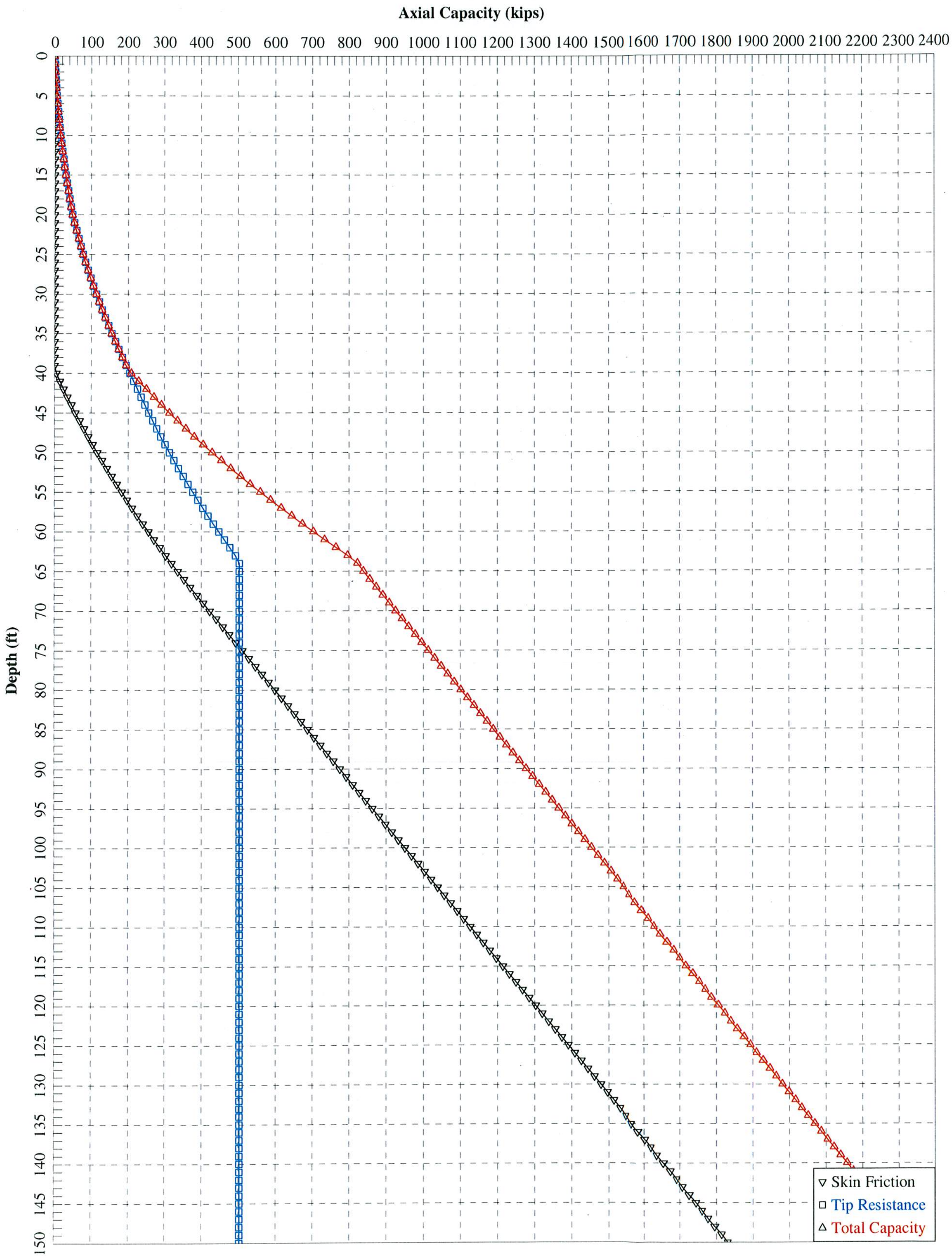
T(Sec)	Spectral Accelerations
0.01	0.30
0.02	0.34
0.02	0.35
0.03	0.36
0.03	0.37
0.03	0.37
0.03	0.38
0.04	0.39
0.04	0.39
0.04	0.40
0.04	0.40
0.04	0.41
0.05	0.41
0.05	0.41
0.05	0.41
0.05	0.42
0.06	0.43
0.06	0.43
0.07	0.44
0.07	0.44
0.07	0.45
0.08	0.45
0.08	0.46
0.09	0.47
0.09	0.47
0.10	0.48
0.10	0.48
0.11	0.50
0.12	0.52
0.13	0.54
0.13	0.54
0.14	0.56
0.15	0.57
0.16	0.59
0.17	0.60
0.18	0.62
0.19	0.63
0.20	0.65
0.22	0.66
0.24	0.66
0.25	0.67
0.26	0.67
0.28	0.68
0.29	0.68
0.30	0.68
0.32	0.67
0.34	0.67
0.35	0.66
0.36	0.66

0.38	0.65
0.40	0.65
0.42	0.64
0.44	0.63
0.45	0.63
0.46	0.63
0.48	0.62
0.50	0.62
0.55	0.59
0.60	0.57
0.65	0.55
0.67	0.54
0.70	0.53
0.75	0.51
0.80	0.49
0.85	0.47
0.90	0.46
0.95	0.44
1.00	0.42
1.10	0.39
1.20	0.37
1.30	0.34
1.40	0.32
1.50	0.30
1.60	0.29
1.70	0.27
1.80	0.26
1.90	0.25
2.00	0.24
2.20	0.21
2.40	0.19
2.50	0.18
2.60	0.17
2.80	0.16
3.00	0.15
3.20	0.14
3.40	0.13
3.50	0.12
3.60	0.12
3.80	0.11
4.00	0.10
4.20	0.10
4.40	0.10
4.60	0.09
4.80	0.09
5.00	0.08

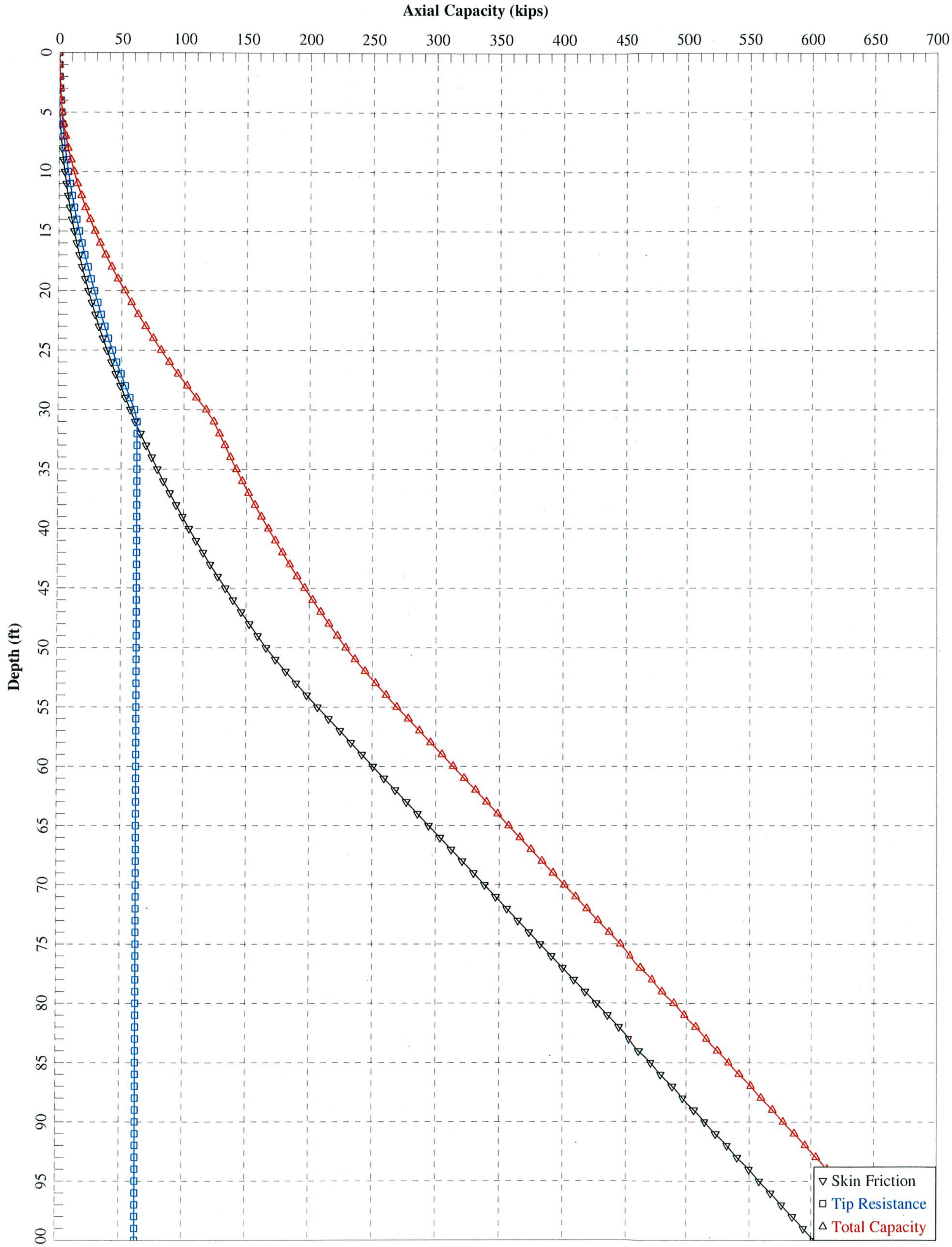
PRELIMINARY AXIAL PILE CAPACITY



BROADWAY BRIDGE MAIN SPAN 60" DIAMETER, DRIVEN CISS PILE



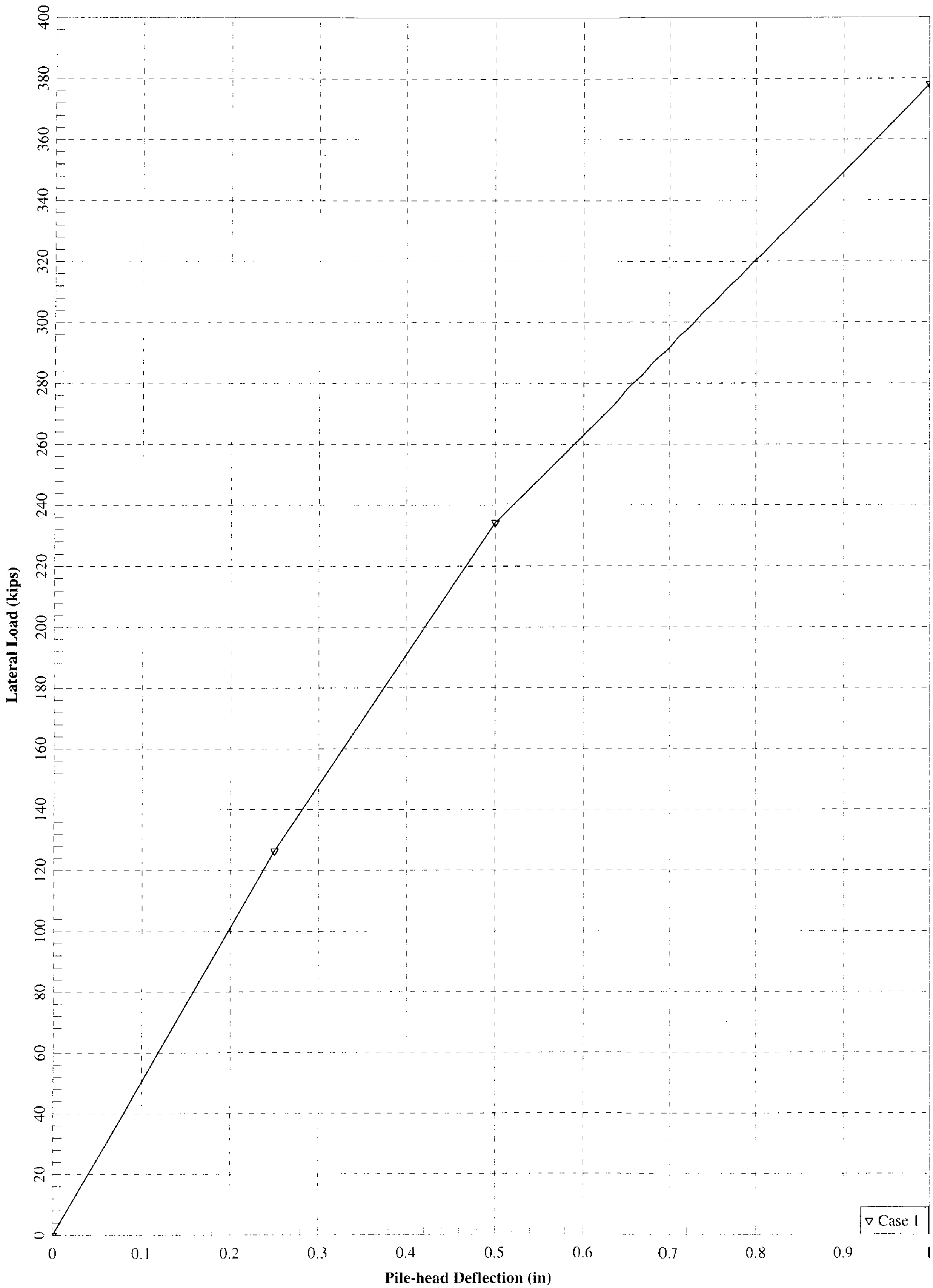
P15015 Broadway Bridge Main Pier 48" Dia., 1" Wall Steel Pipe Pile



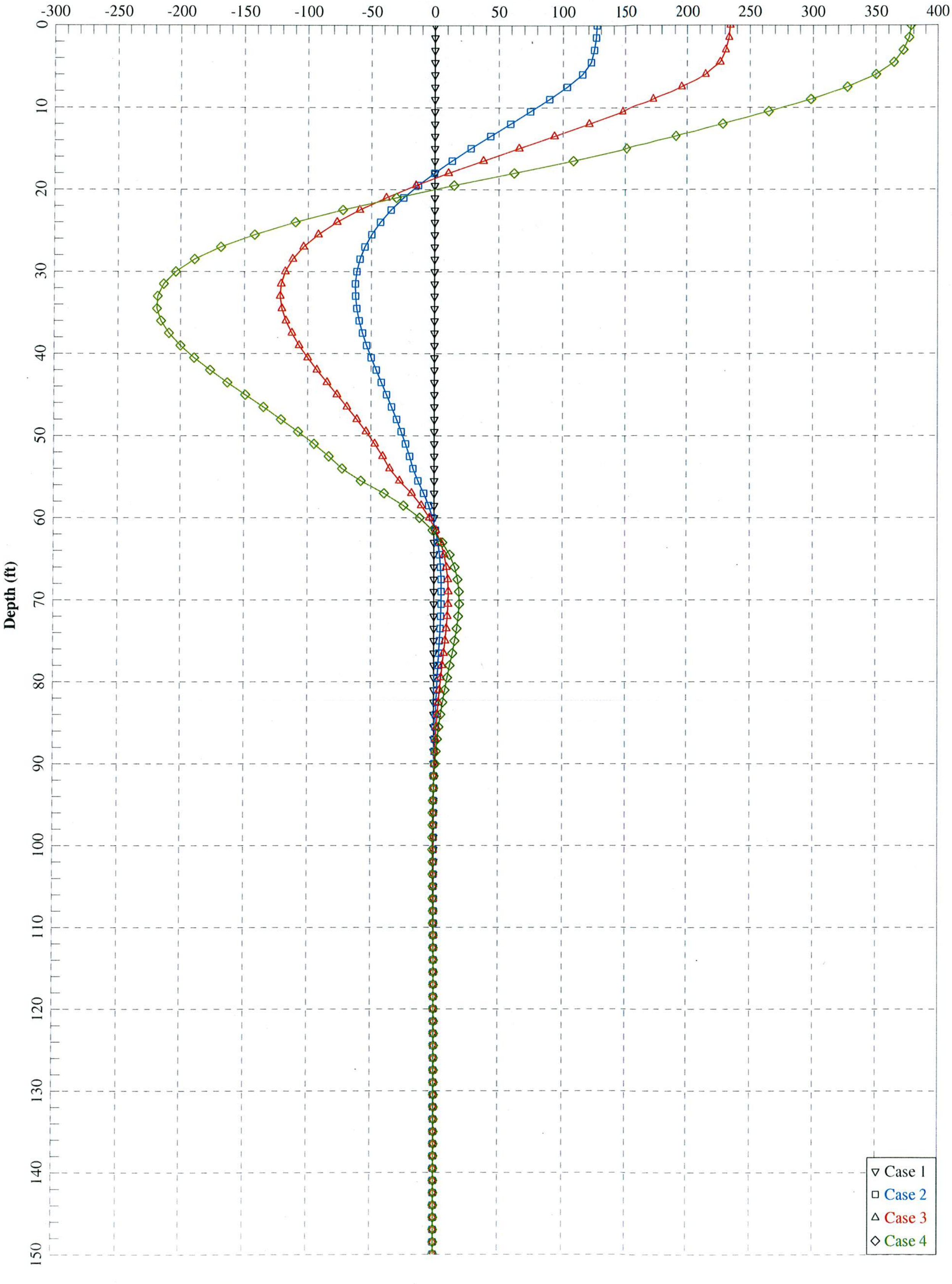
BROADWAY BRIDGE MAIN SPAN 24" DIAMETER, DRIVEN CISS PILE

PRELIMINARY LATERAL PILE CAPACITY

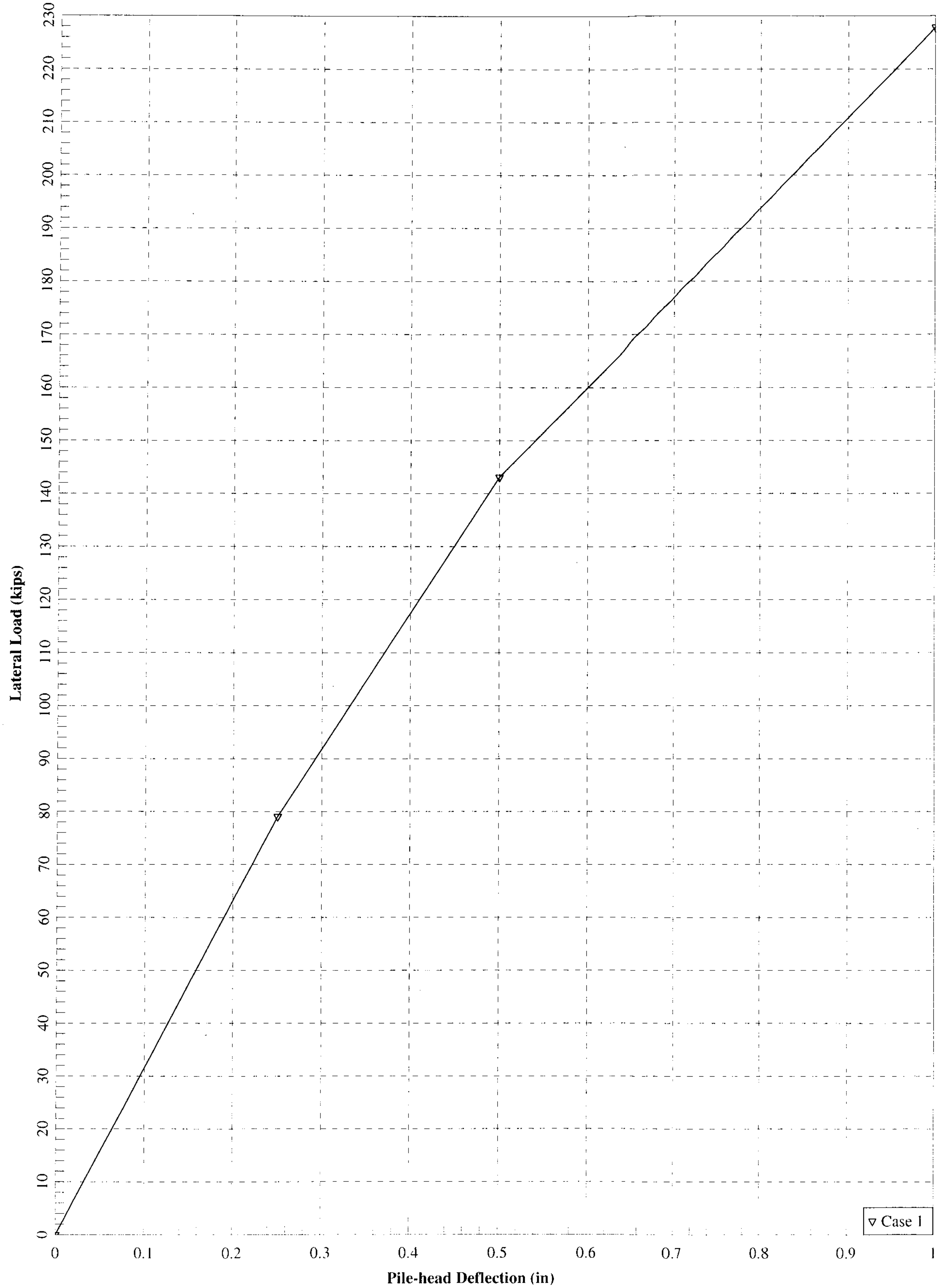
P15015 Broadway Bridge Main Pier 60" Dia., 1.5" Wall Concrete Filled Steel Pipe Pile w/ 1% Steel Reinforcement



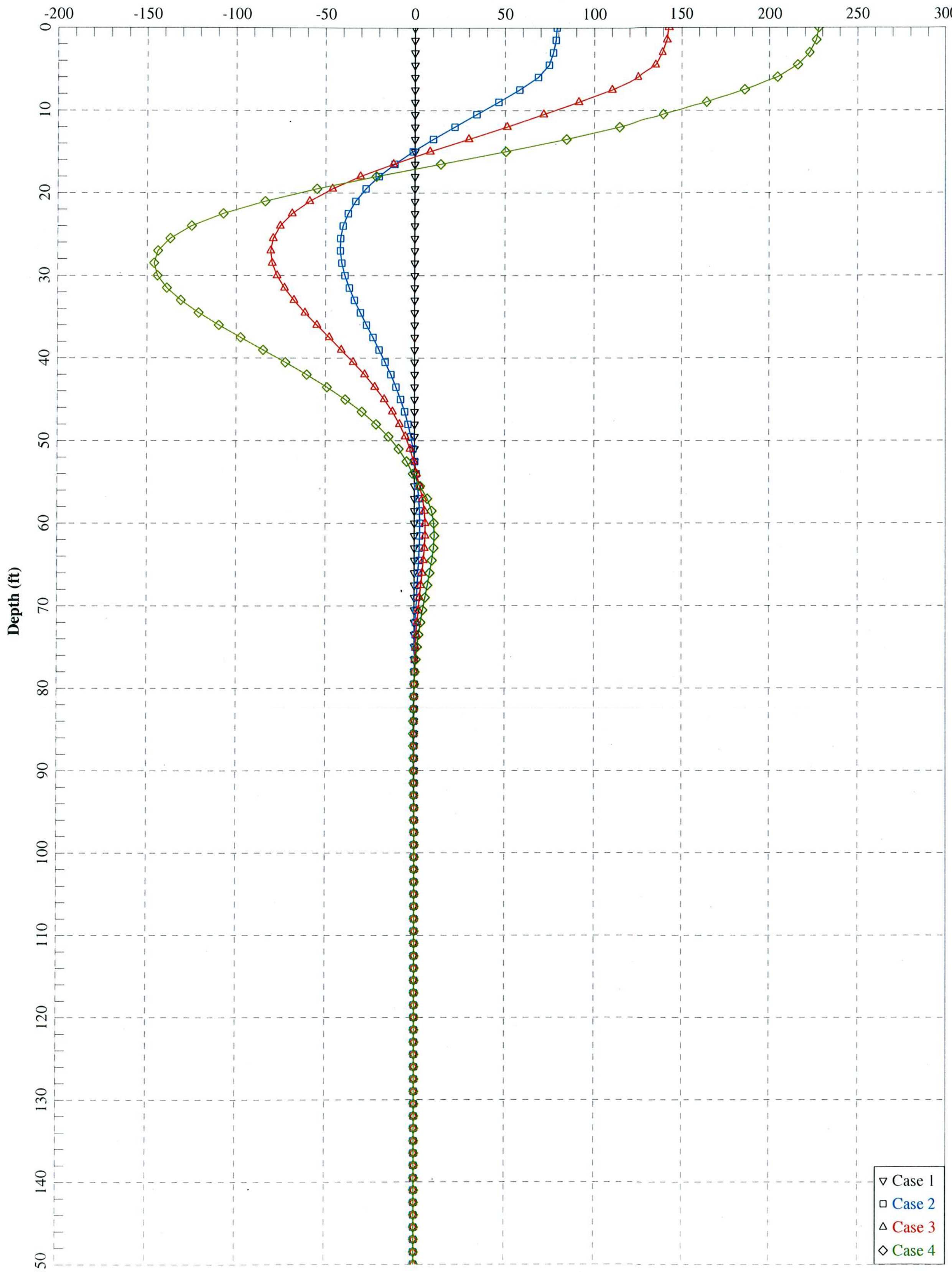
P15015 Broadway Bridge Main Pier 60" Dia., 1.5" Wall Concrete Filled Steel Pipe Pile w/ 1% Steel Reinforcement
Shear Force (kips)

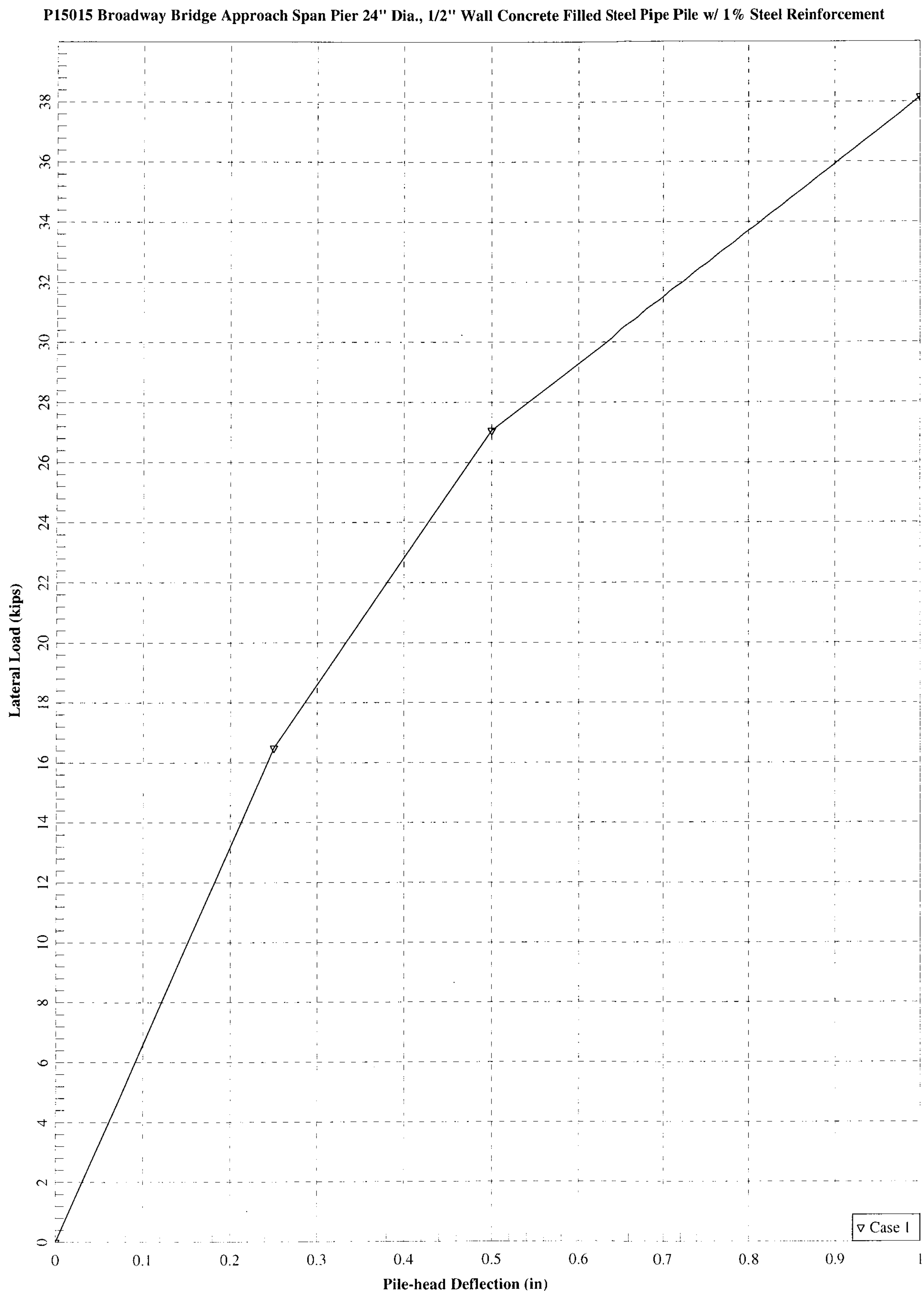


P15015 Broadway Bridge Main Pier 48" Dia., 1" Wall Concrete Filled Steel Pipe Pile w/ 1% Steel Reinforcement

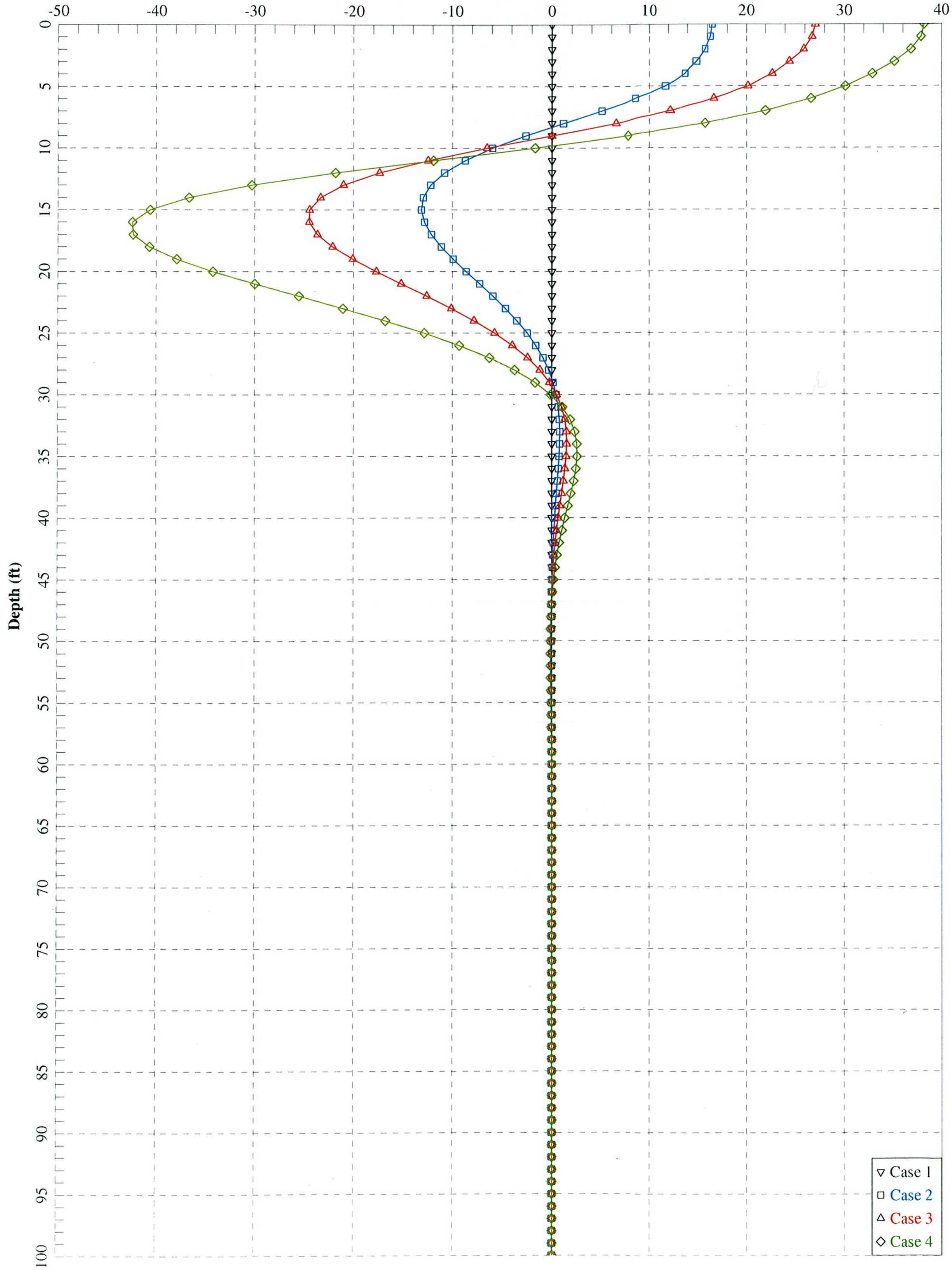


P15015 Broadway Bridge Main Pier 48" Dia., 1" Wall Concrete Filled Steel Pipe Pile w/ 1% Steel Reinforcement
Shear Force (kips)




P15015 Broadway Bridge Approach Span Pier 24" Dia., 1/2" Wall Concrete Filled Steel Pipe Pile w/ 1% Steel Reinforcement
Lateral Load (kips)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Pile-head Deflection (in)
▽ Case 1

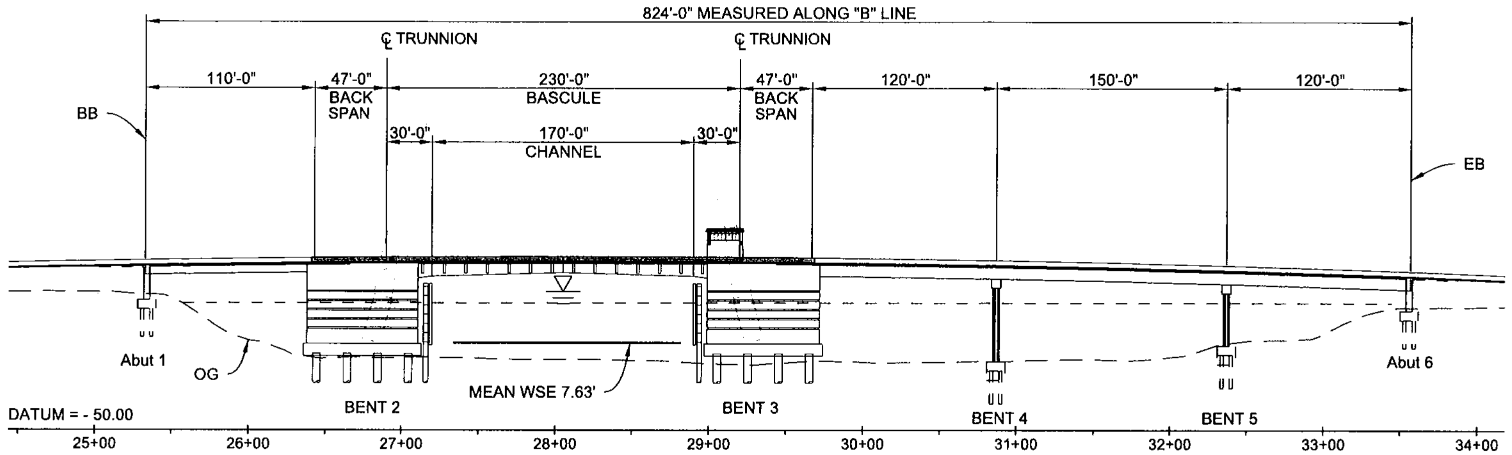
P15015 Broadway Bridge Approach Span Pier 24" Dia., 1/2" Wall Concrete Filled Steel Pipe Pile w/ 1% Steel Reinforcement
Shear Force (kips)



PRELIMINARY BRIDGE LAYOUTS

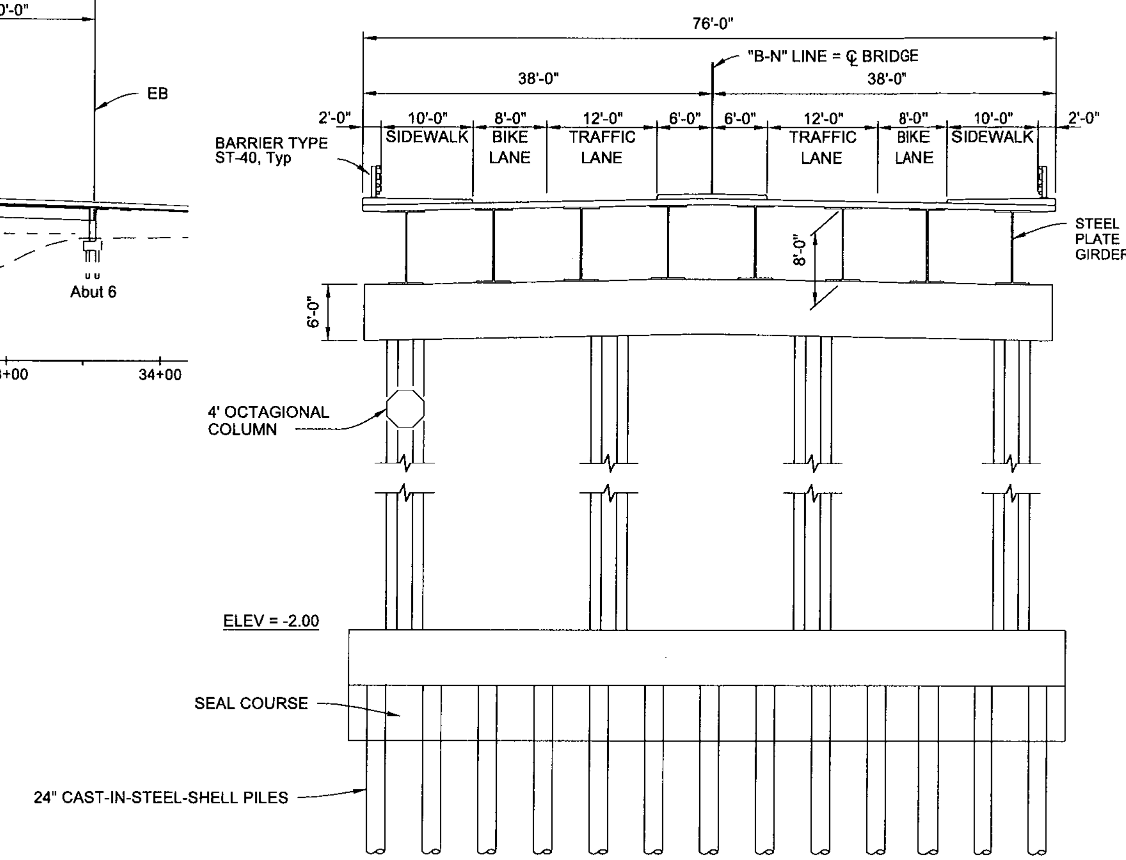
SACRAMENTO

CITY OF WEST SACRAMENTO



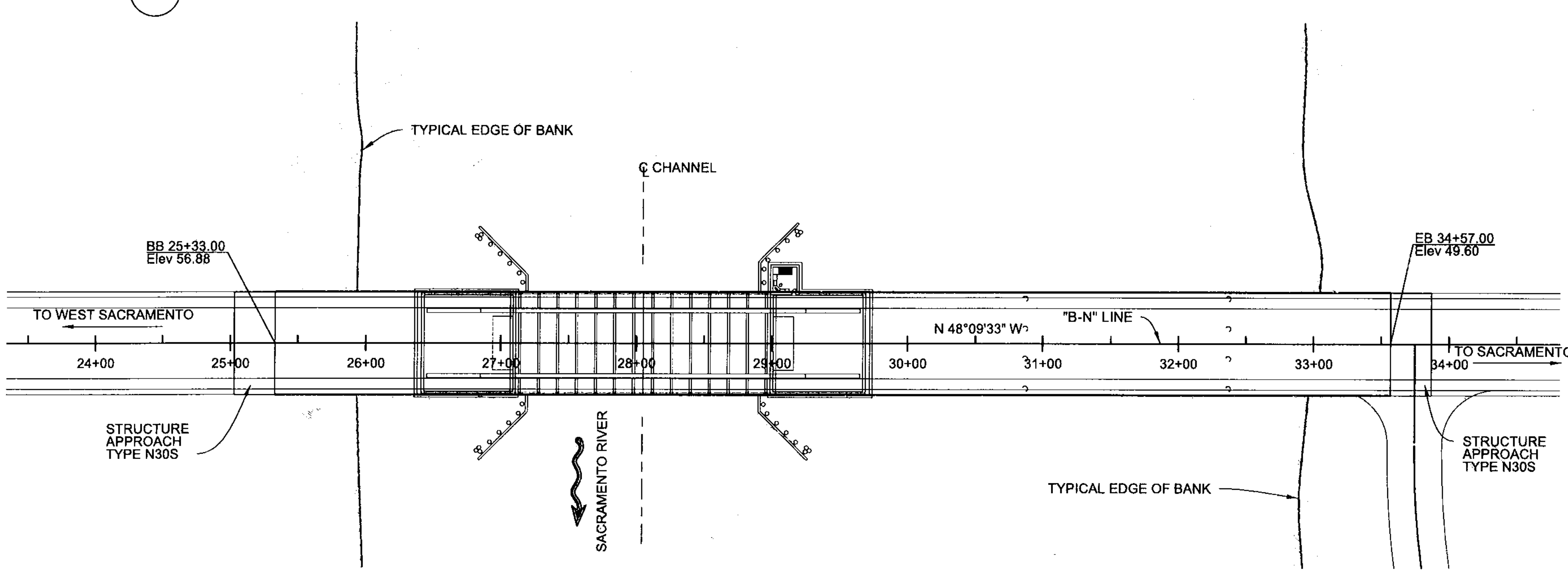
DEVELOPED ELEVATION

1" = 60'-0"



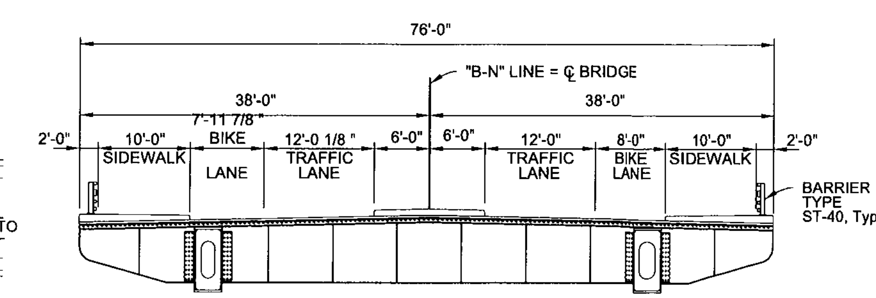
TYPICAL SECTION (APPROACH SPAN)

1" = 10'-0"



PLAN

1" = 60'-0"



TYPICAL SECTION (LIFT SPAN)

1" = 10'-0"

NO.	DATE	REVISION	BY	APVD

DSGN M. NEGRETTE | DR P. WALKER | CHK | APVD

ch2m. Hardesty & Hanover

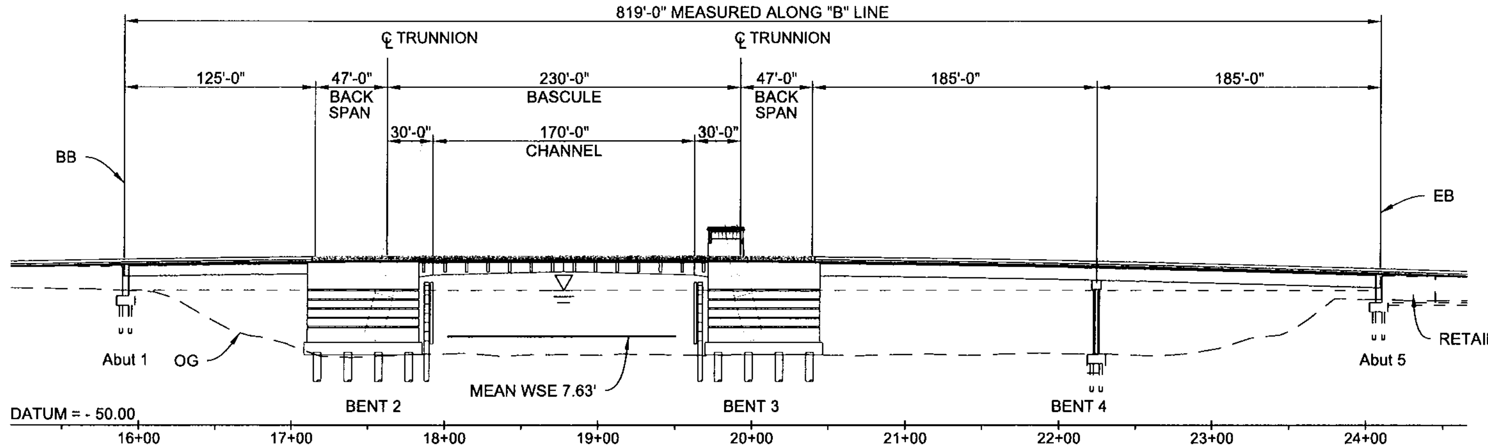
BROADWAY BRIDGE FEASIBILITY STUDY
SACRAMENTO RIVER
3-SPAN-EAST APPROACH
NORTH ALIGNMENT

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

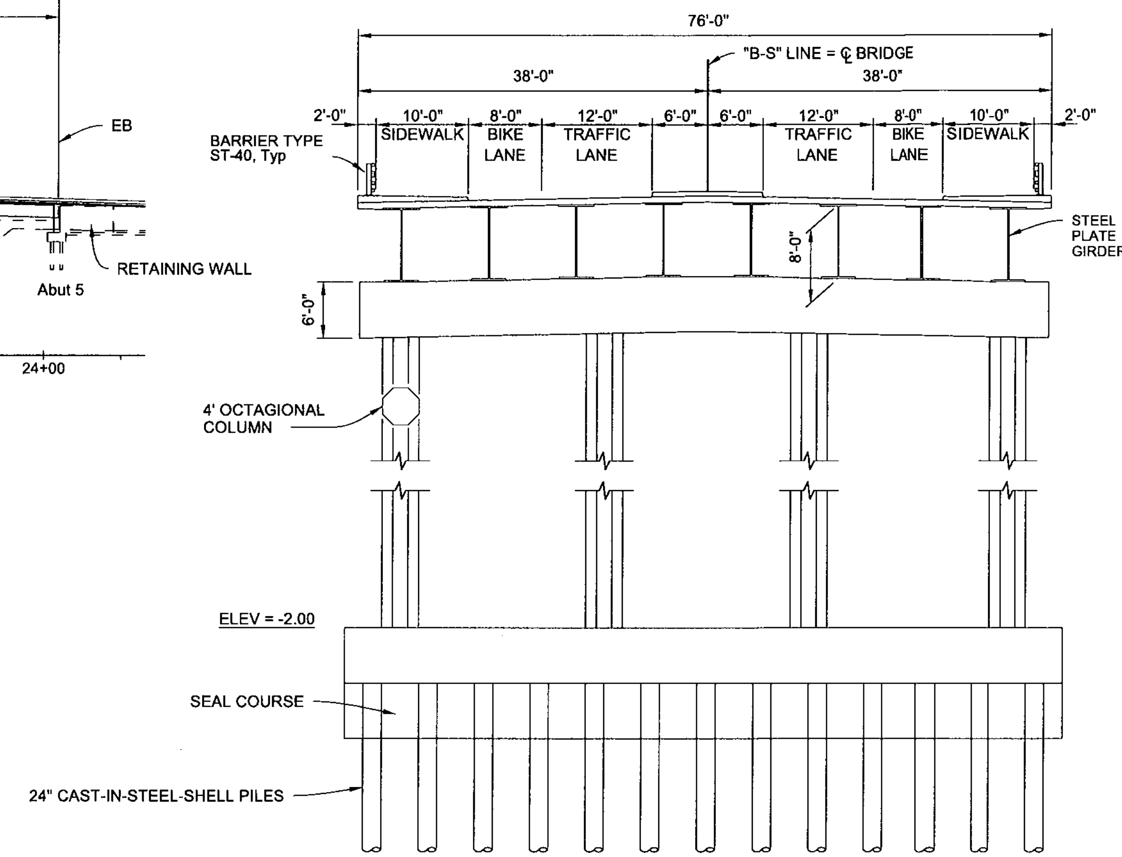
DATE
PROJ
DWG
SHEET of

SACRAMENTO

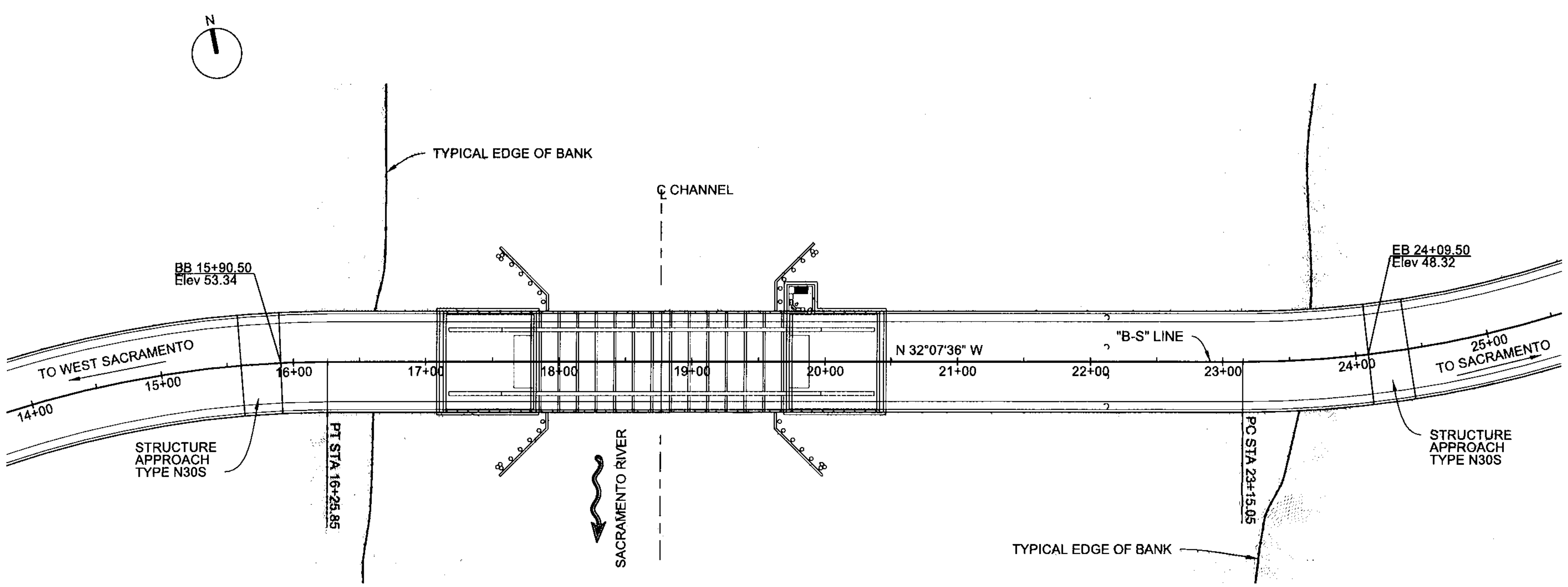
CITY OF
WEST SACRAMENTO



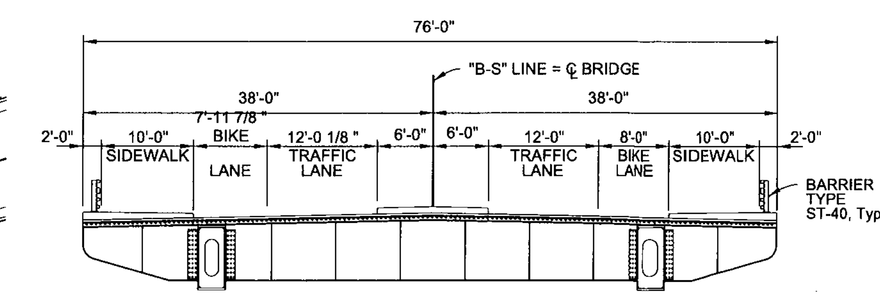
DEVELOPED ELEVATION
1" = 60'-0"



TYPICAL SECTION (APPROACH SPAN)
1" = 10'-0"



PLAN
1" = 60'-0"



TYPICAL SECTION (LIFT SPAN)
1" = 10'-0"

NO.	DATE	REVISION	BY	CHK	APVD

DSGN M. NEGRETTE | DR P. WALKER | CHK | APVD

ch2m: Hatch Mott MacDonald / Hanover

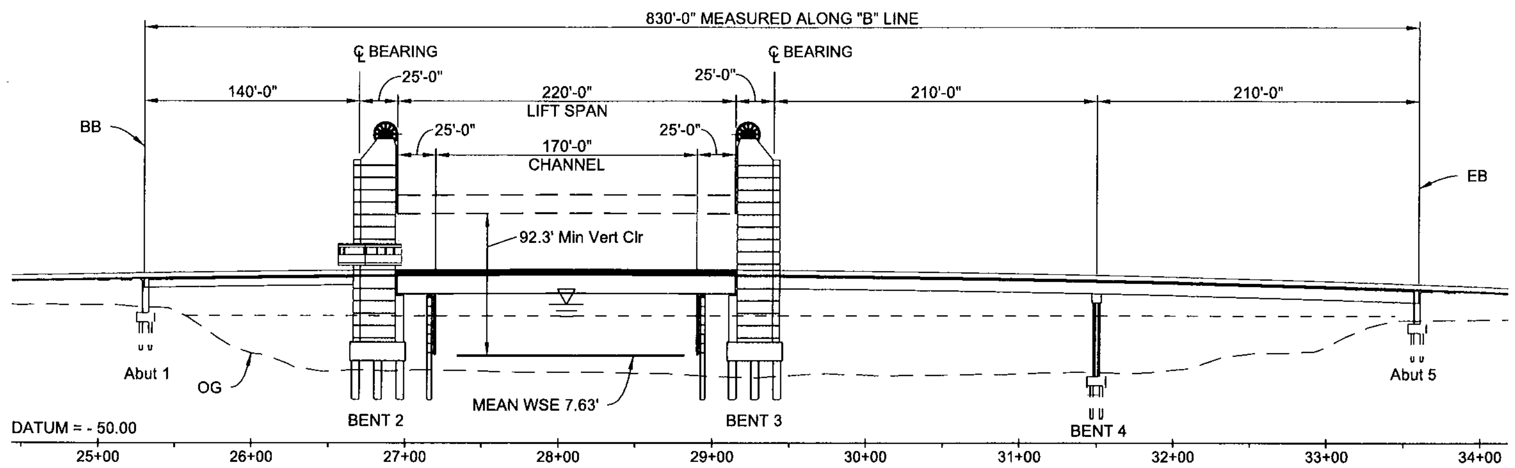
BROADWAY BRIDGE FEASIBILITY STUDY
SACRAMENTO RIVER
2-SPAN-EAST APPROACH
SOUTH ALIGNMENT

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

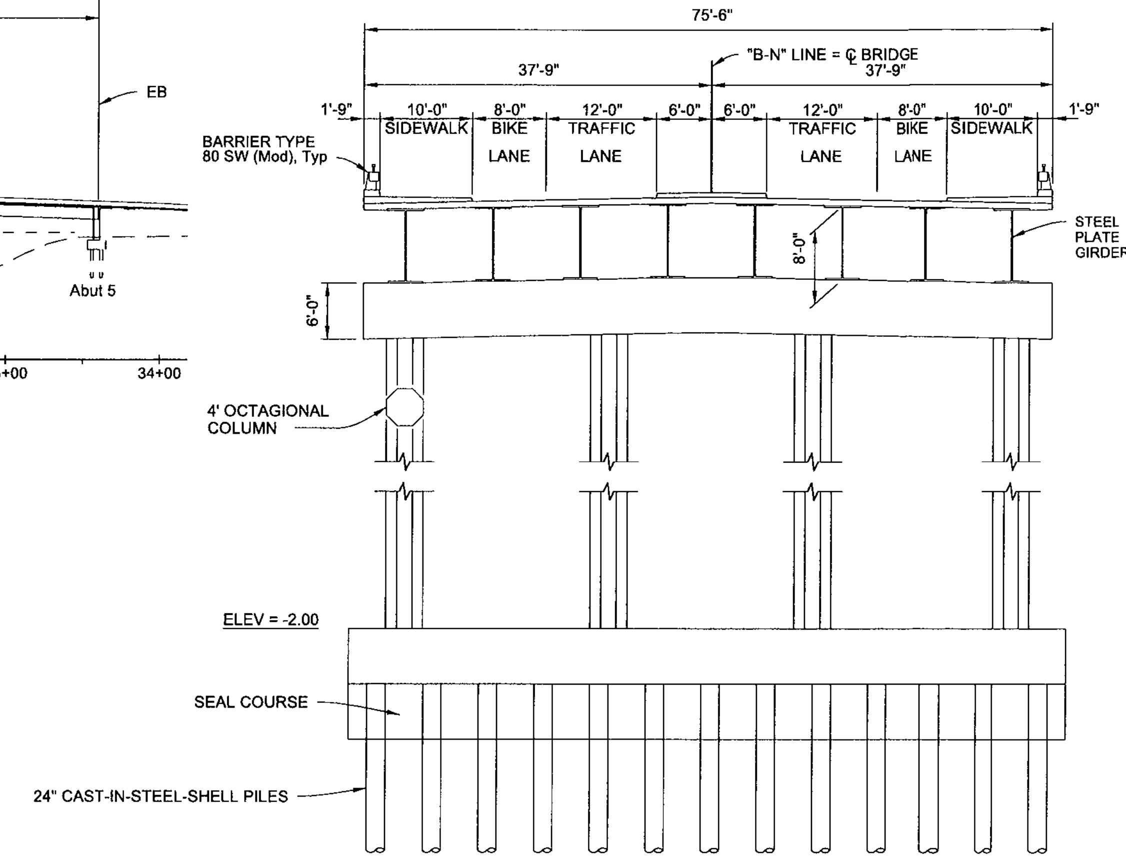
DATE
PROJ
DWG
SHEET of

SACRAMENTO

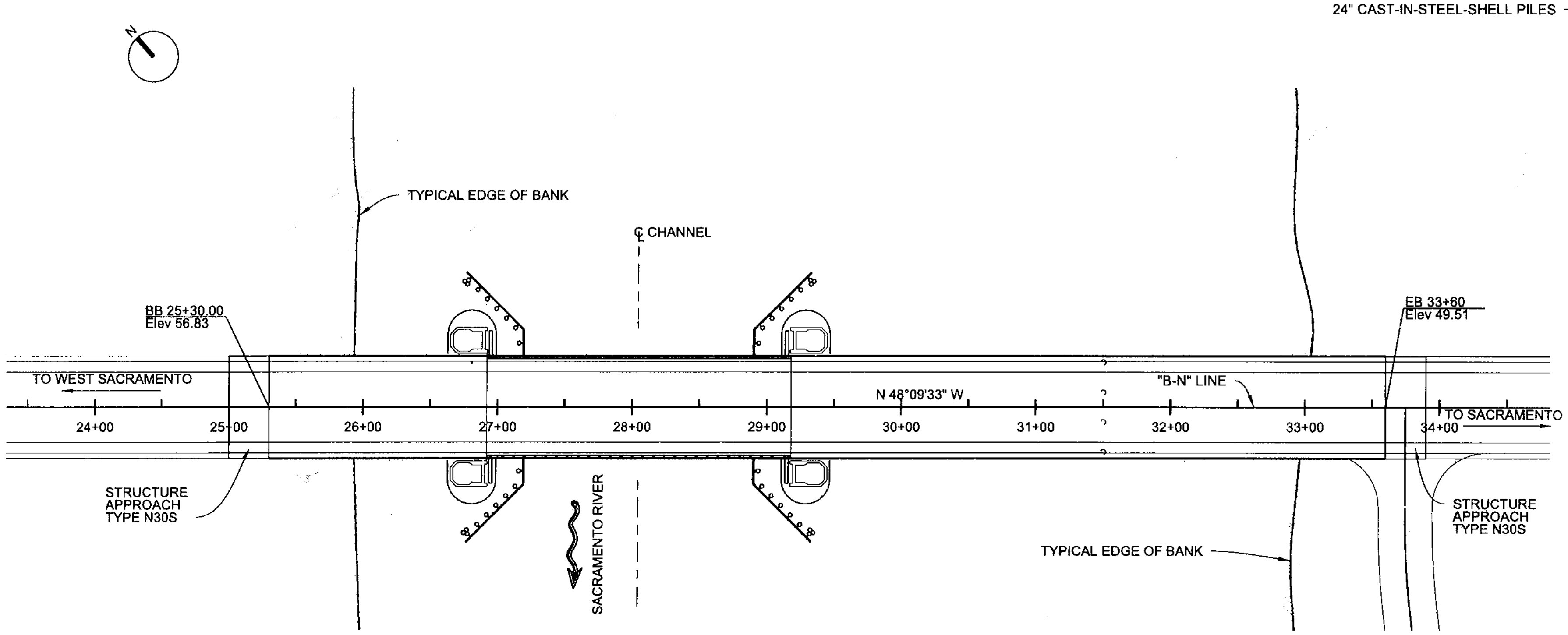
CITY OF WEST SACRAMENTO



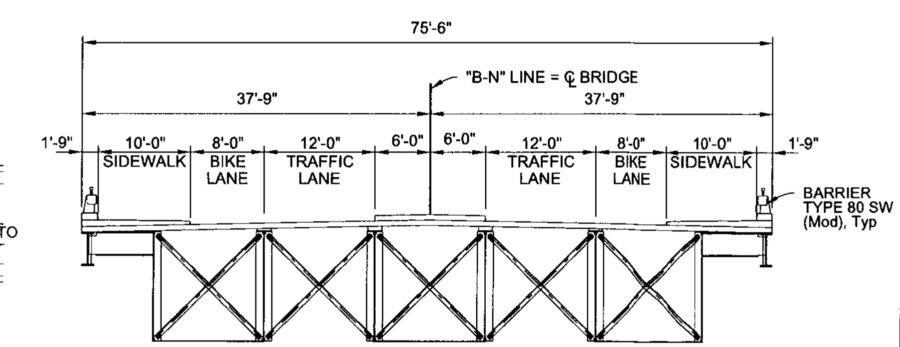
DEVELOPED ELEVATION
1" = 60'-0"



TYPICAL SECTION (APPROACH SPAN)
1" = 10'-0"



PLAN
1" = 60'-0"



TYPICAL SECTION (LIFT SPAN)
1" = 10'-0"

NO.	DATE	REVISION	BY	APVD

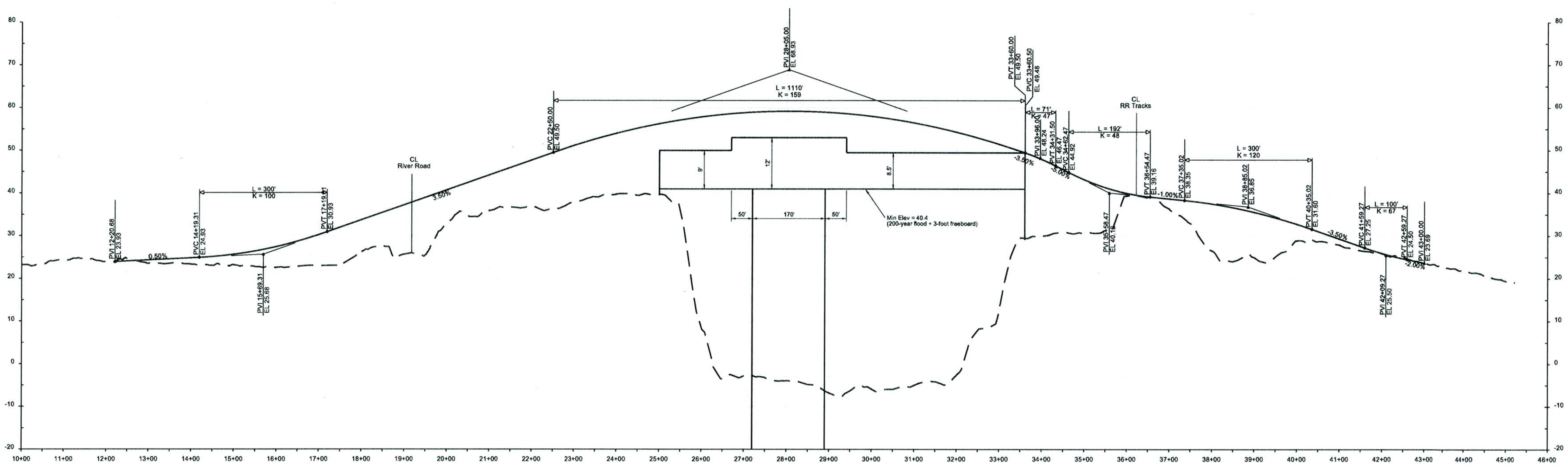
DSGN M. NEGRETTE | DR P. WALKER | CHK | APVD

ch2m: | Hanover

BROADWAY BRIDGE FEASIBILITY STUDY
SACRAMENTO RIVER
2-SPAN-EAST APPROACH
NORTH ALIGNMENT

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"

DATE
PROJ
DWG
SHEET of

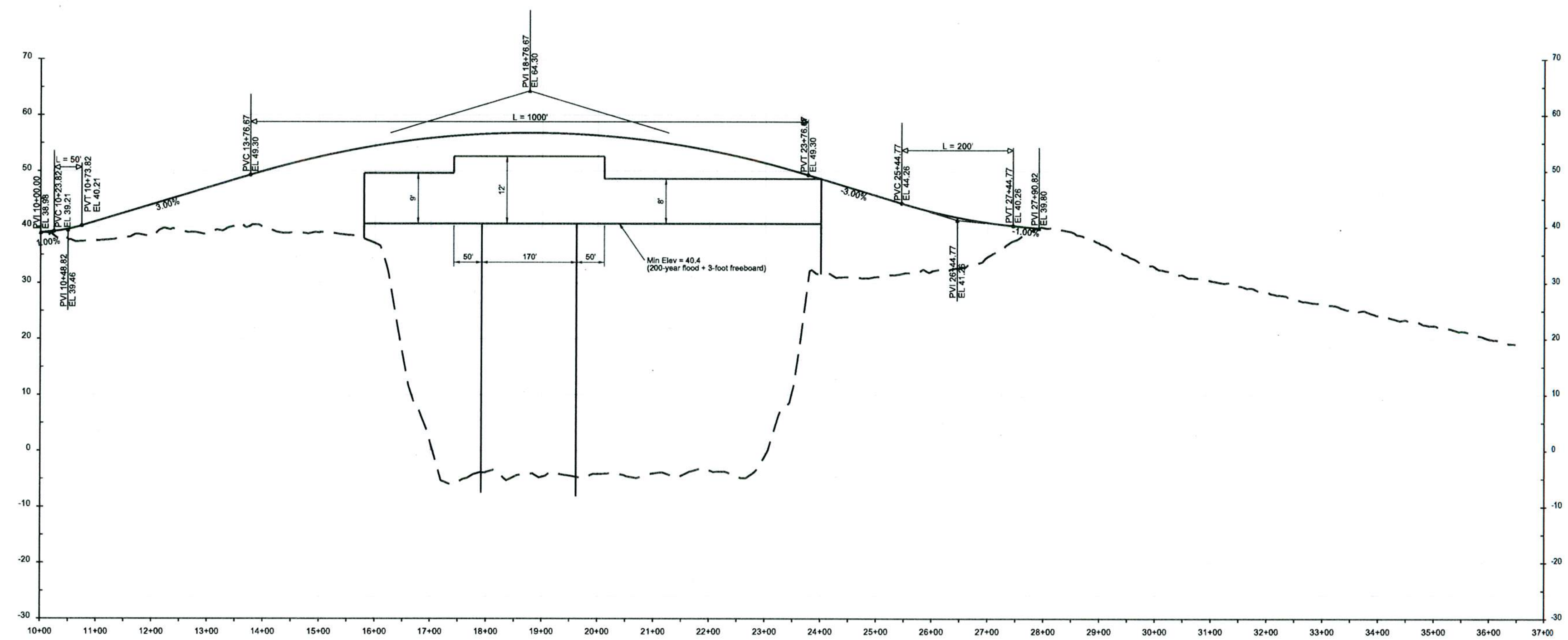


NORTH PROFILE

CITY OF
WEST SACRAMENTO

ch2m

City of
SACRAMENTO



SOUTH PROFILE

CITY OF WEST SACRAMENTO

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