Underwater Inspection of Bridge Substructures Using Underwater Imaging Technology

TRANSPORTATION POOLED FUND
RESEARCH STUDY TPF-5(131)

July, 2012

Phase I: Field Test Plan

(Select Portions to be used in Final Study Report)

Caltrans

MoDOT

NDDOT
North Dakota
Department of Transportation

Texas Department of Transportation

Wisconsin Department of Transportation

SCDOT
South Carolina Department of Transportation

U.S.Department of Transportation
Federal Highway Administration

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McLean, VA 22101-2296

Form DOT F 1700.7 (8-72)

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1.0 FIELD TEST PROCEDURES

Field testing at each bridge will include both inspections by use of sonar and by use of inspection diver. The work will be conducted as three completely separate operations to avoid influencing the inspection findings. All sonar field testing will be performed by trained manufacturer's representatives who are most familiar with their equipment and a qualified team leader/notetaker (who is capable of utilizing proper bridge inspection terminology). The imaged substructure units will be inspected by a separate team consisting of commercially certified inspection divers. Both the sonar teams and diving team will be allowed to review as-built construction plans, but will not be given previous inspection reports or other information relating to any existing conditions or possible structural defects. Man-hours and equipment costs associated with each task will be tracked for comparison. Additionally, the environmental variables listed in this document will be estimated and recorded at each substructure unit inspected. The environmental conditions will be evaluated along with each team's inspection findings.

The four inspection teams (Divers, CodaOctopus, Kongsberg Mesotech, and BlueView) will be present at the bridge sites at separate times to avoid congestion while maintaining relatively consistent environmental variables. Additionally, members of each team will be directed not to share findings with each other in an effort to uphold the integrity and objectiveness of each test.

An objective observer will be present during all field testing to document the procedures, findings, problems encountered, and methods used to overcome those problems for each team. The observer will also document level of effort and associated costs related to each team's tasks for future comparison. Final analysis of all the observer notes and inspection team findings/documentation will discuss the safety aspects as well as gage the quality of the inspection obtained by each test method.

1.1 Environmental Variables

A number of site specific environmental conditions will be estimated at each bridge site. The variables will be compared to determine how each affects the results obtained by the sonar equipment and by diver inspection. Variables that should be estimated during each test include water velocity, water turbidity, and water temperature. Additional notes will be gathered by the dive team and by the sonar teams (when possible) documenting typical aquatic growth present on various bridge elements and type of channel bottom material.

Water sound velocity will be measured at each test location by a sound velocity probe and will be recorded in feet per second as a function of water depth. The data will be used to calibrate the sonar units.

1.2 Defect Documentation

Because none of the inspection teams will have access to pre-existing conditions, each inspection team must perform an inspection that will adequately document any structural defects or channel bottom conditions. When possible, this data will include documentation of surface condition, cracks, areas of section loss, scour depressions, foundation exposure measurements, and limits of foundation undermining.

2.0 TEST INSPECTION OVERSIGHT AND TEAM COMPOSITION

Primary On-Vessel Observer (POVO) – Roy Forsyth of Collins Engineers will act as the study project manager, primary vessel operator, inspection crew coordinator, and field test documentation notetaker.

TFHRC Representative/ Independent On-Vessel Observer – – Jerry Shen of Turner Fairbanks Highway Research Center will take action photos, equipment photos, crew photos, general overall photos, maintain a photo log, operations time log, and equipment inventory log, and assist the POVO as needed. Additionally, a nightly download of photos will be scheduled with the POVO.

Sonar Imaging Teams – Each sonar manufacturer is expected to supply a team of operators that they feel will represent their equipment in the best manner. It should be noted that the team size should not be made unnecessarily large because extra people will be counted for cost comparative purposes.

Diving Team – The dive inspection team will be composed of a four-man surface supplied air crew in accordance with OSHA regulations.

2.1 Field Evaluation Objectives

- Safe Operations (Document any accidents or near misses)
- Highest Quality
- Cost Evaluation
    - Field Inspection Efficiency (Man-hours + Equipment Costs)
    - Office/Post Processing Efficiency (Number of days for final product to be delivered, estimated man-hours, software needs)
    - Equipment Inventory – The purchase price will be recorded for all field and office equipment for information only. However, standard equipment rental rates (when available) will be utilized for all equipment in determining daily project costs.
    - Pre-planning Office Activities - Permits, coordination, and background data gathering will be considered the same for each inspection team.
    - Per Diem/Lodging Costs – Will be calculated based on crew size and will utilize standard GSA rates.

2.1.1 Time Criteria

- All team crew sizes will be documented. Only the team members on the vessel will be recorded (Including the vessel operator but excluding the Independent observer).
- Inspection Time will start at the launch site when the inspection team begins setting up equipment. Setup and calibration time will be differentiated from actual inspection time. Time spent to moor at the structure or deploy equipment will be counted as inspection time. Any system failures/repairs will not be considered inspection time, but will be recorded and may affect the ability to complete all four bridges within the allotted time frame.

- Office time will include the number of days for the final product delivery and an estimation by the Sonar Manufacturer/Dive Team Leader of man-hours spent in the office for post processing.

2.2 Work Schedule

Each manufacturer will be given two full days with the boat. During that timeframe, the manufacturer will image as many of the bridges as possible. The anticipated field schedule is listed below. Additionally, each manufacturer will have access to the boat (out of water) the night before their field work begins to work through bracket mounting and equipment layout issues.

Sonar Inspection Team A **(CodaOctopus)** two days on-site to image as many bridges as feasible (4 Bridges Anticipated) **July 27 - 28**

Sonar Inspection Team B **(BlueView)** two days on-site to image as many bridges as feasible (4 Bridges Anticipated) **July 29 - 30**

Sonar Inspection Team C **(Kongsberg)** two days on-site to image as many bridges as feasible (4 Bridges Anticipated) **July 31 – Aug. 1**

Diving Inspection Team D **(Collins Engineers)** two days on-site to dive as many bridges as feasible (4 Bridges Anticipated) **Aug. 2 – 3** **(Note: Divers will fly out on Saturday Aug. 4 due to decompression time required before flying.)**

2.3 Home Base of Operations

Home base of operations is centrally located at the Holiday Inn Express Lodi, CA which is located 50 miles south of Sacramento International Airport. The hotel is located approximately 70 minutes from the Carquinez Bridges, 30 minutes from the Georgiana Bridge, and 95 minutes from the James Roberts Bridge. The hotel has a block of rooms set aside under the group name “FHWA Imaging Group” which is available on a first come first served basis. Contact information is listed below to reserve your room.

Holiday Inn Express: Lodi
1337 East Kettleman Lane
Lodi, CA 95240
(290) 210-0150

3.0 BRIDGE TEST SITE SUMMARY

The bridges selected for field testing include:

		Anticipated Site Conditions									
Bridge Name	**Bridge #**	**Water Depth**	**Visibility**	**Current**	**Marine Growth**	**Conc. Monolith**	**Concrete Piles**	**Steel Piles**	**Timber Piles**	**Fender System**	**Pile Cap**
Georgiana Slough	24C0039	25'	Low	Slow	Light		X	X	X (Fender)	X	X
James E Roberts	32 0018	up to 200'	High	None	None		X				
Carquinez (Old)	23-0015R	Up to 100'	Low	Swift Tidal	Light	X					
Carquinez (New)	23-0352L	Up to 100'	Low	Swift Tidal	Light		X	Shell			X

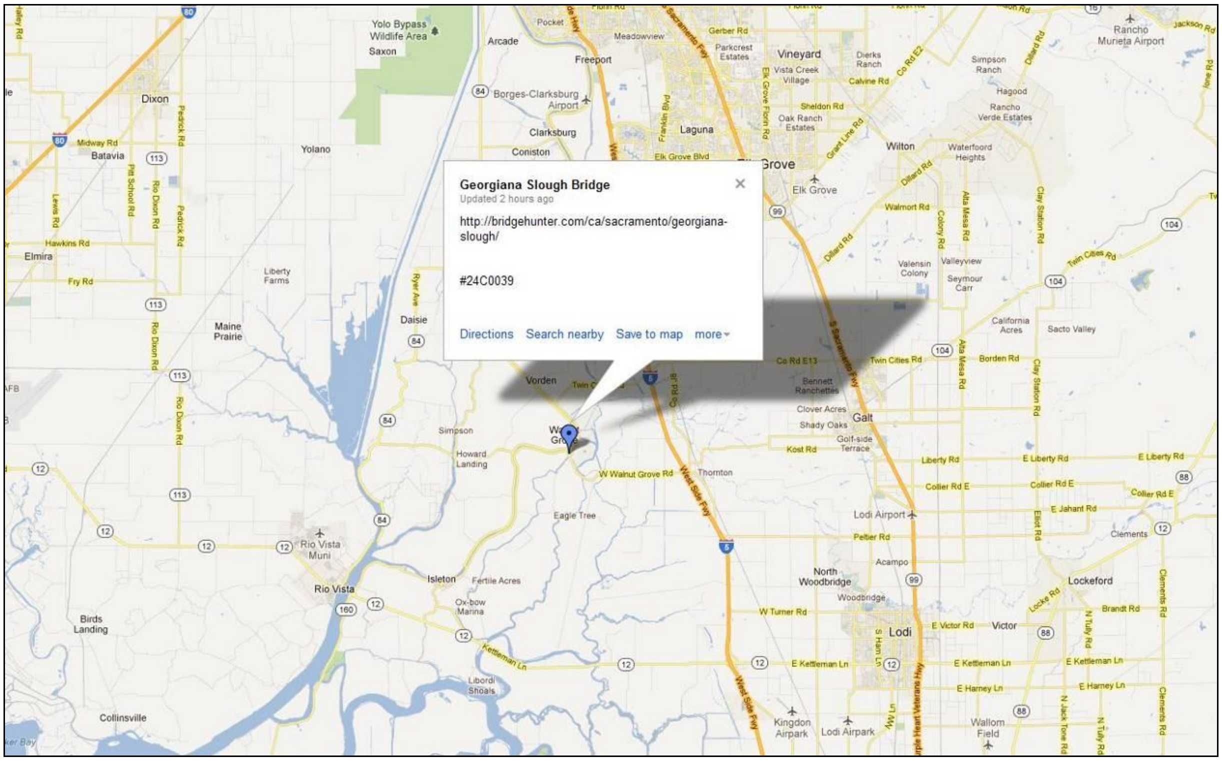
4.0 BRIDGE SITE #1 (GEORGIANA SLOUGH BRIDGE)

The waterway at the Georgiana Slough Bridge can be characterized as a non-tidal meandering stream. The bridge was selected based on the bridge being constructed utilizing multiple construction materials. Because the bridge is non-tidal, current and other environmental factors will not deviate substantially throughout the course of a day. For these reasons, the Georgiana Slough Bridge allows the research team to demonstrate differences in data obtained on concrete, steel, and timber while maintaining all other environmental conditions at nearly constant values. Crews are not expected to perform an inspection of the entire fender system; however, the portion of the fender directly adjacent to each pier should be inspected.

4.1 Georgiana Slough Bridge – Vicinity Map

GPS Location: N 38^{o} 14’ 14.4’’

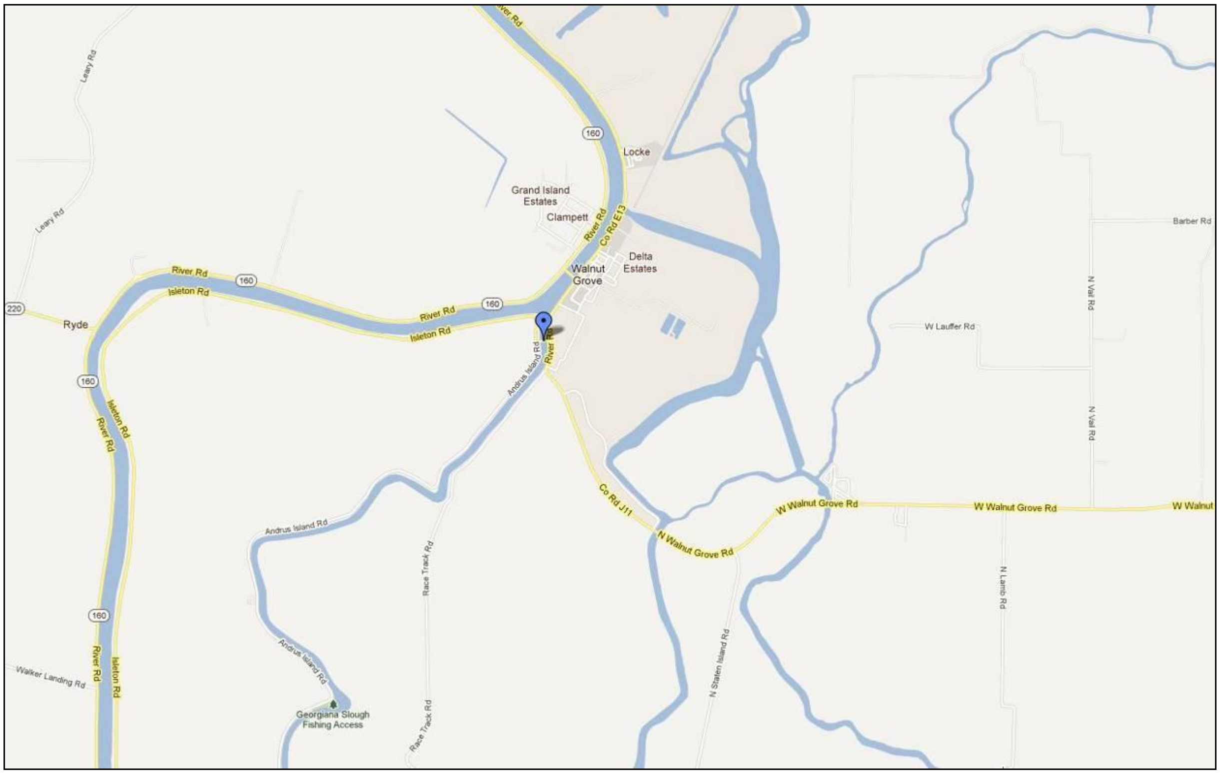
W 121^{o} 31’ 03.05’’



4.2 Georgiana Slough Bridge – Location Map

GPS Location: N 38^{o} 14’ 14.4’’

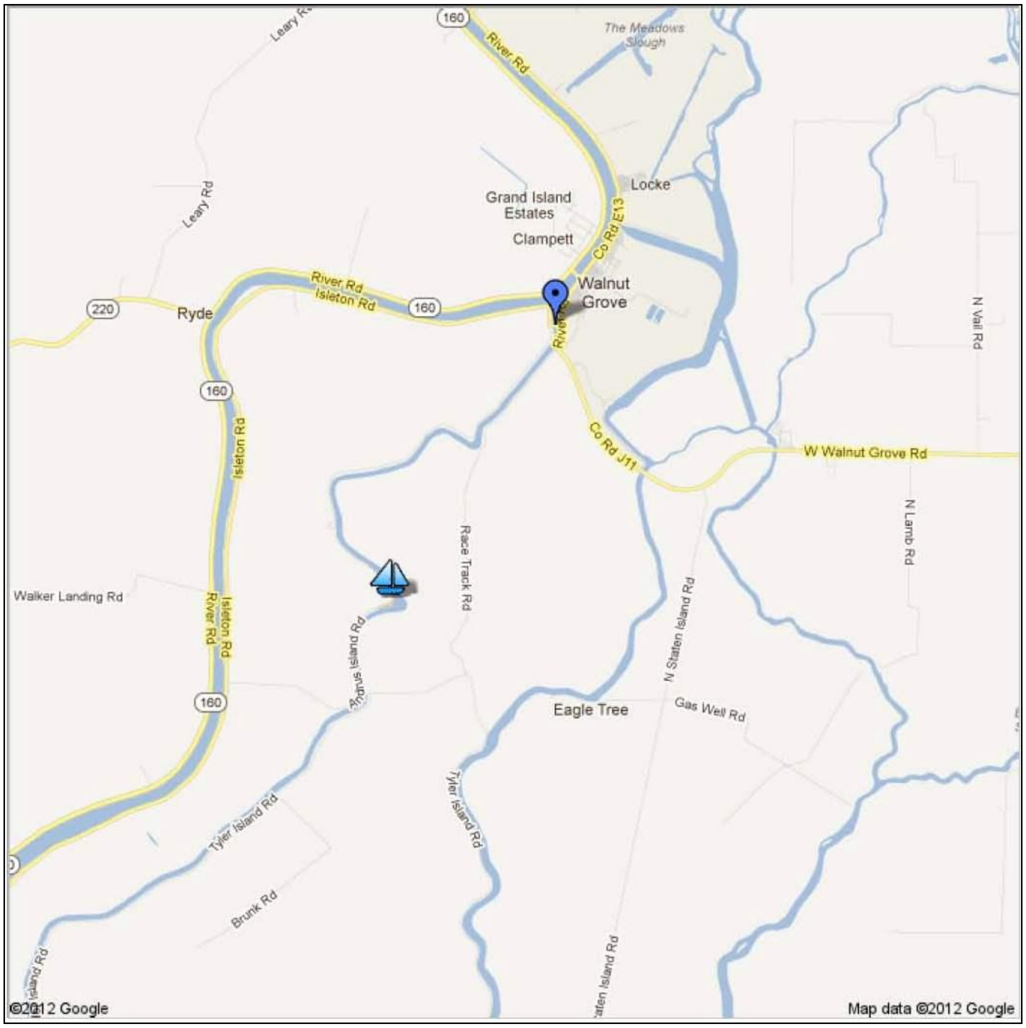
W 121^{o} 31’ 03.05’’



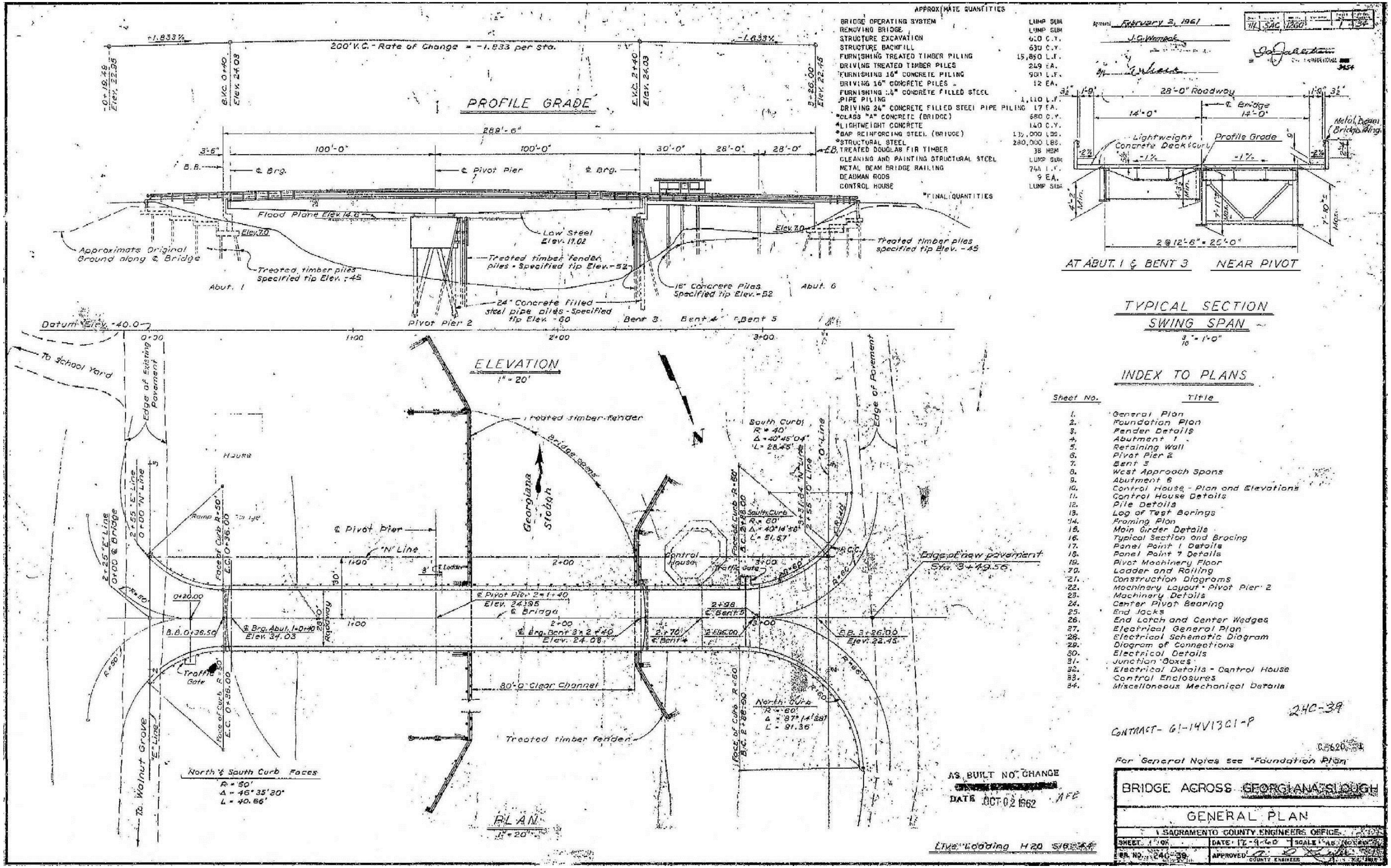
4.3 Georgiana Slough Bridge – Boat Launch Map

GPS Location: N 38^{o} 12' 40.23''

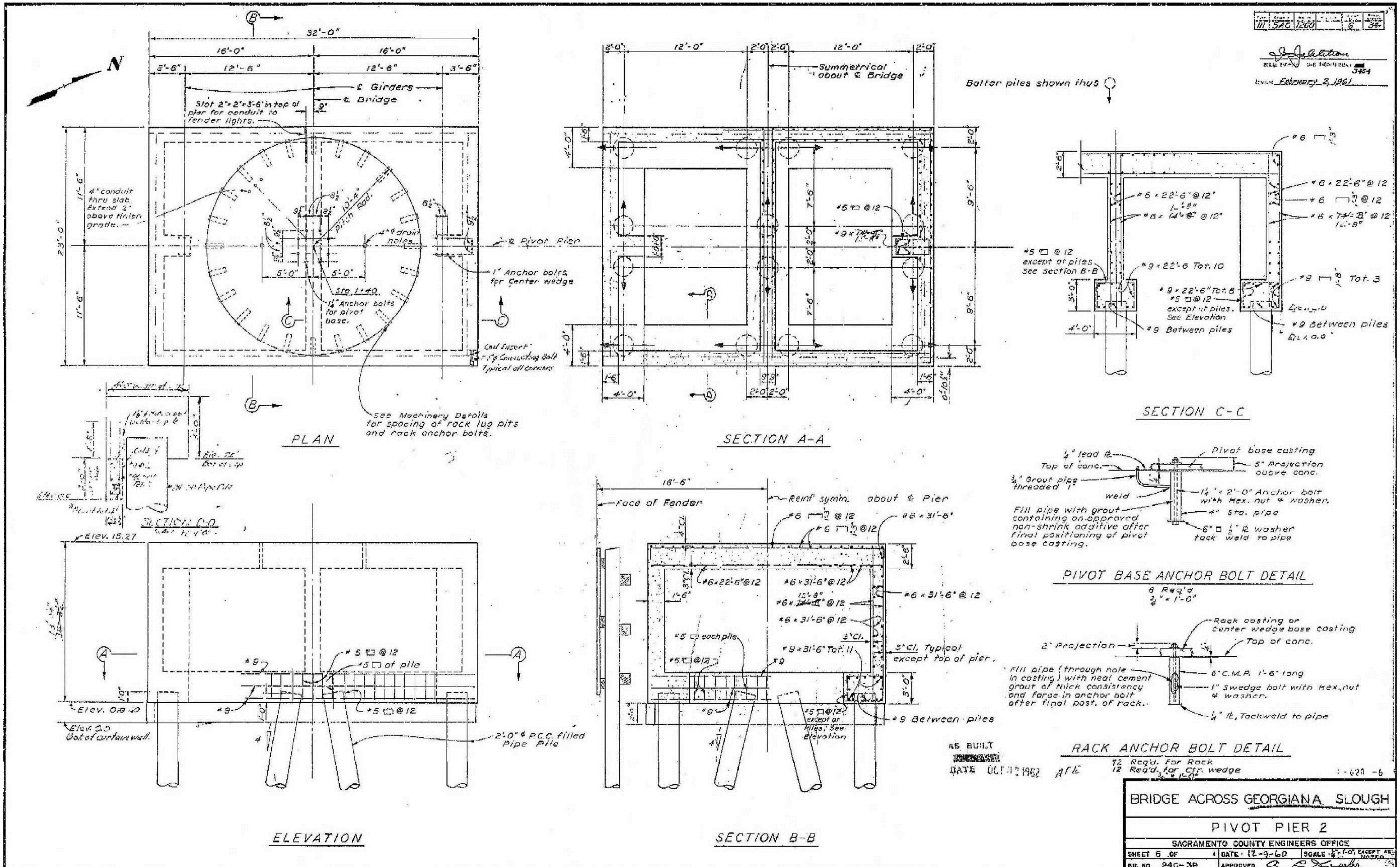
W 121^{o} 32' 13.3''



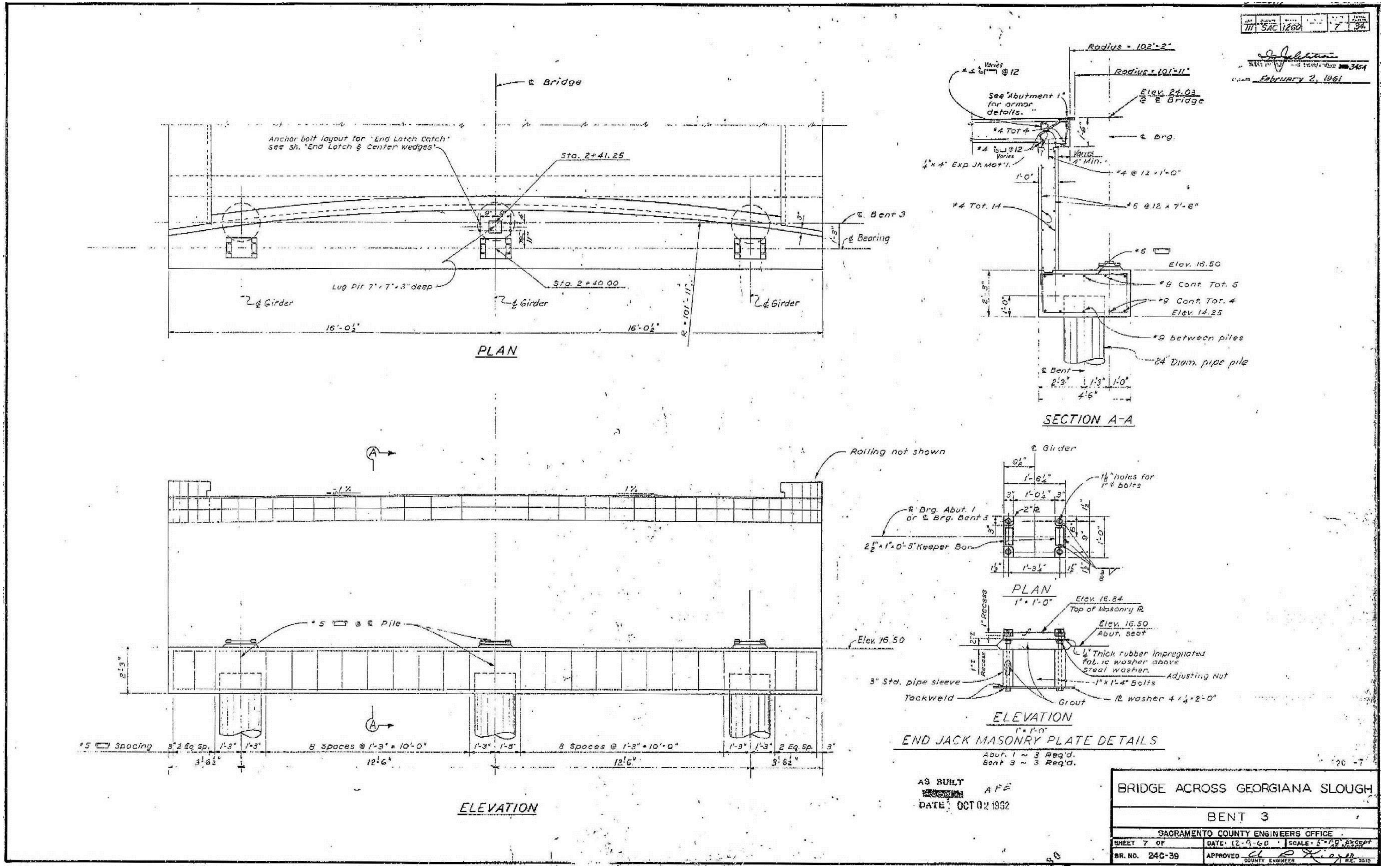
4.4 Georgiana Slough Bridge – Bridge Plan



4.5 Georgiana Slough Bridge – Pivot Pier 2 Drawings



4.6 Georgiana Slough Bridge – Bent 3 Drawings



5.0 BRIDGE SITE #2 (JAMES E ROBERTS BRIDGE – TUOLUMNE RIVER)

The James E Roberts Bridge over the Tuolumne River is characterized by deep clear water. The bridge was also selected due to the ease of reproducing environmental factors (non-tidal waterway) throughout the course of a day. The bridge is supported by cast-in-place reinforced concrete piers founded on footings keyed into bedrock. Each crew will perform an inspection of all faces of Bent 4.

- **Upper Portion - (0 to 100 ft)**

  The dive inspection will be conducted to 100 ft. The results of this dive inspection in extremely clear water are expected to produce good quality underwater photographs and measurements. The dive inspection will be used as an accurate baseline for a comparison check of the data produced by the sonar systems.

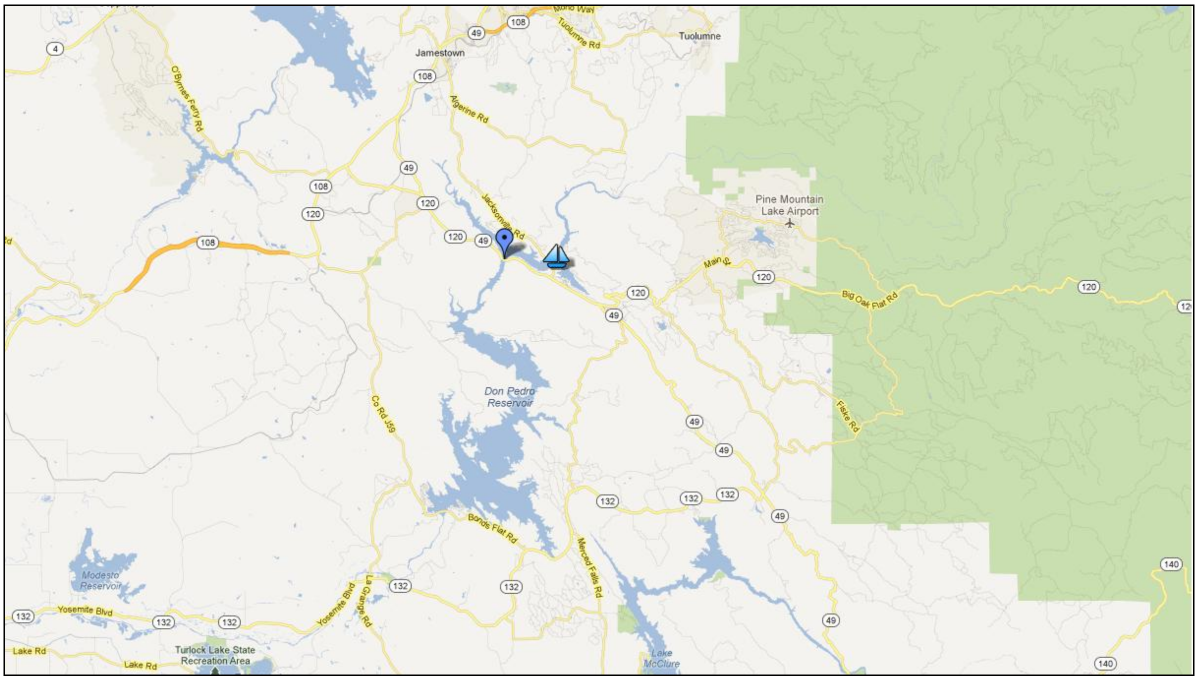
- **Lower Portion - (100 ft to 200 ft)**

  A cost estimate for inspection by divers will substitute for actually deploying dive inspectors to 200 ft. The inspection results will be used to illustrate the difference in cost, safety, and quality of inspection between divers and imaging sonar at a bridge site exhibiting extreme depth (where diving may not be economically practical). The results produced by the sonar systems will be compared to previous CalTrans underwater inspection reports that were obtained by divers when reservoir water levels were significantly lower and diving was economically feasible without the need for a chamber. It should be noted that OSHA requires a chamber on-site for dives greater than 100 ft and ADCI Consensus Standards restricts diving to 190 ft.

5.1 James E Roberts Bridge – Tuolumne River – Vicinity Map

GPS Location: N 37º 50’ 13.88’’

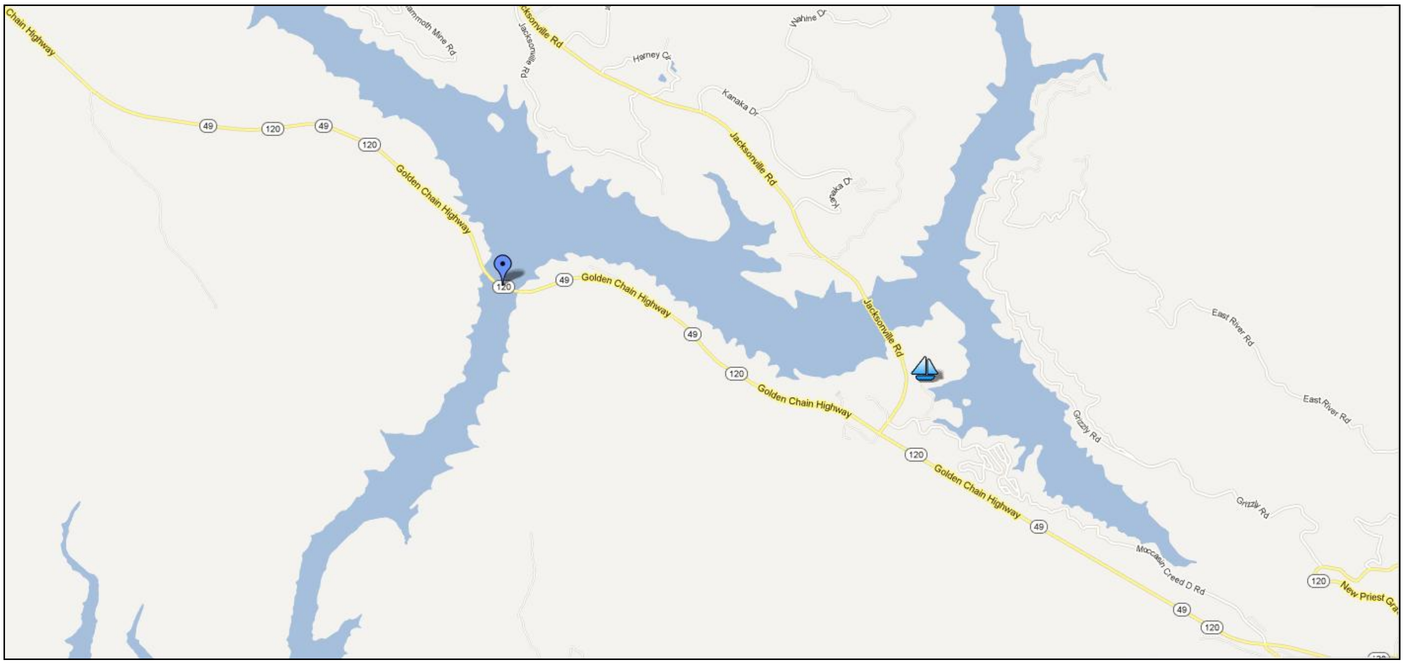
W 120º 20’ 43.88’’



5.2 James E Roberts Bridge – Tuolumne River – Location Map

GPS Location: N 37^{o} 50’ 13.88’’

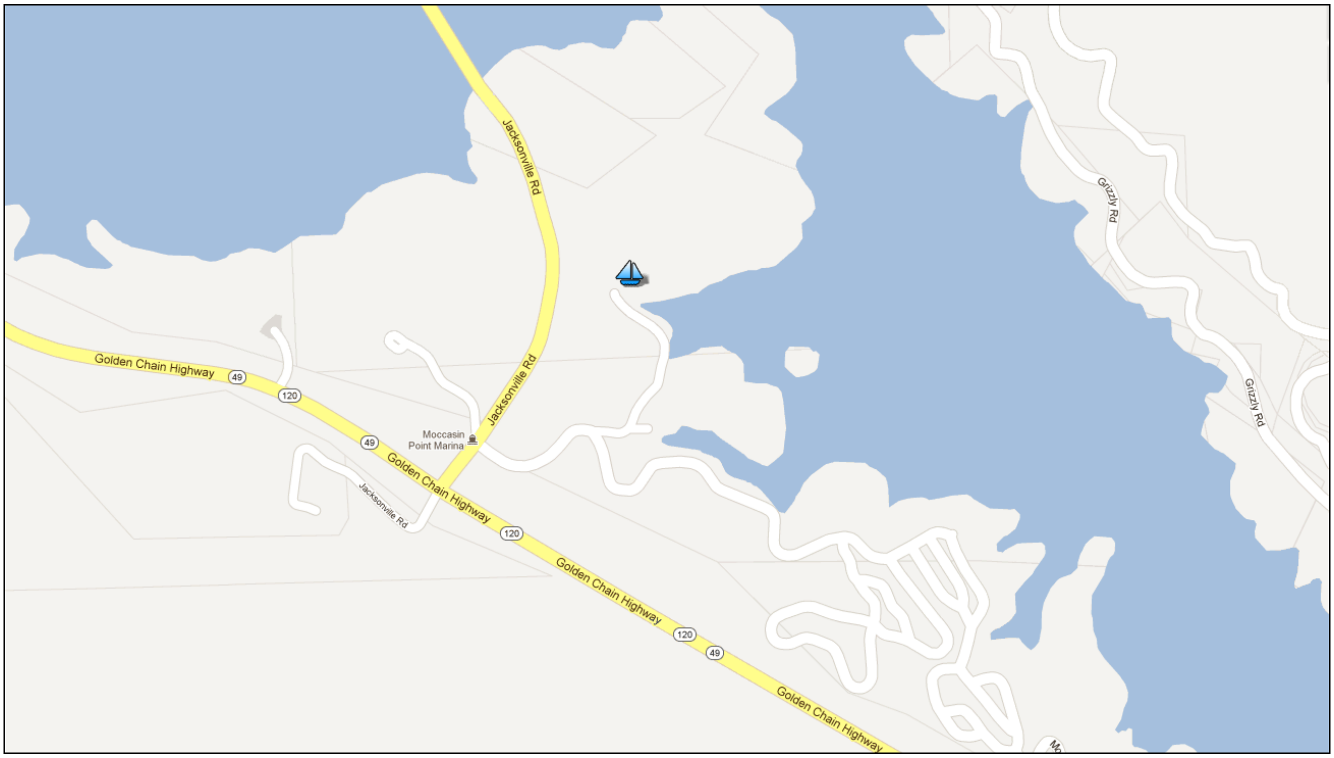
W 120^{o} 20’ 43.88’’



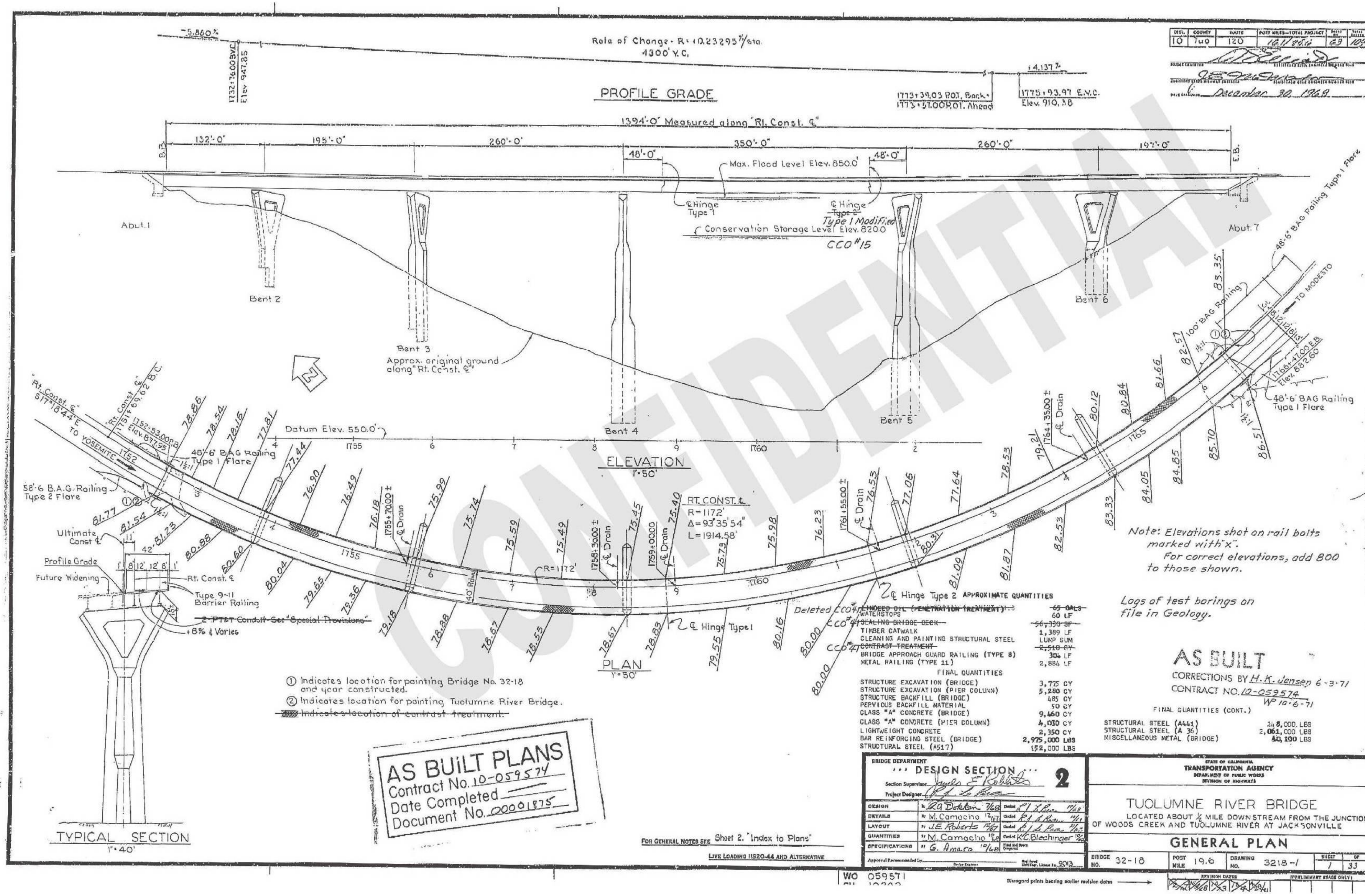
5.3 James E Roberts Bridge – Tuolumne River – Boat Launch Map

GPS Location: N 37° 49’ 57.38’’

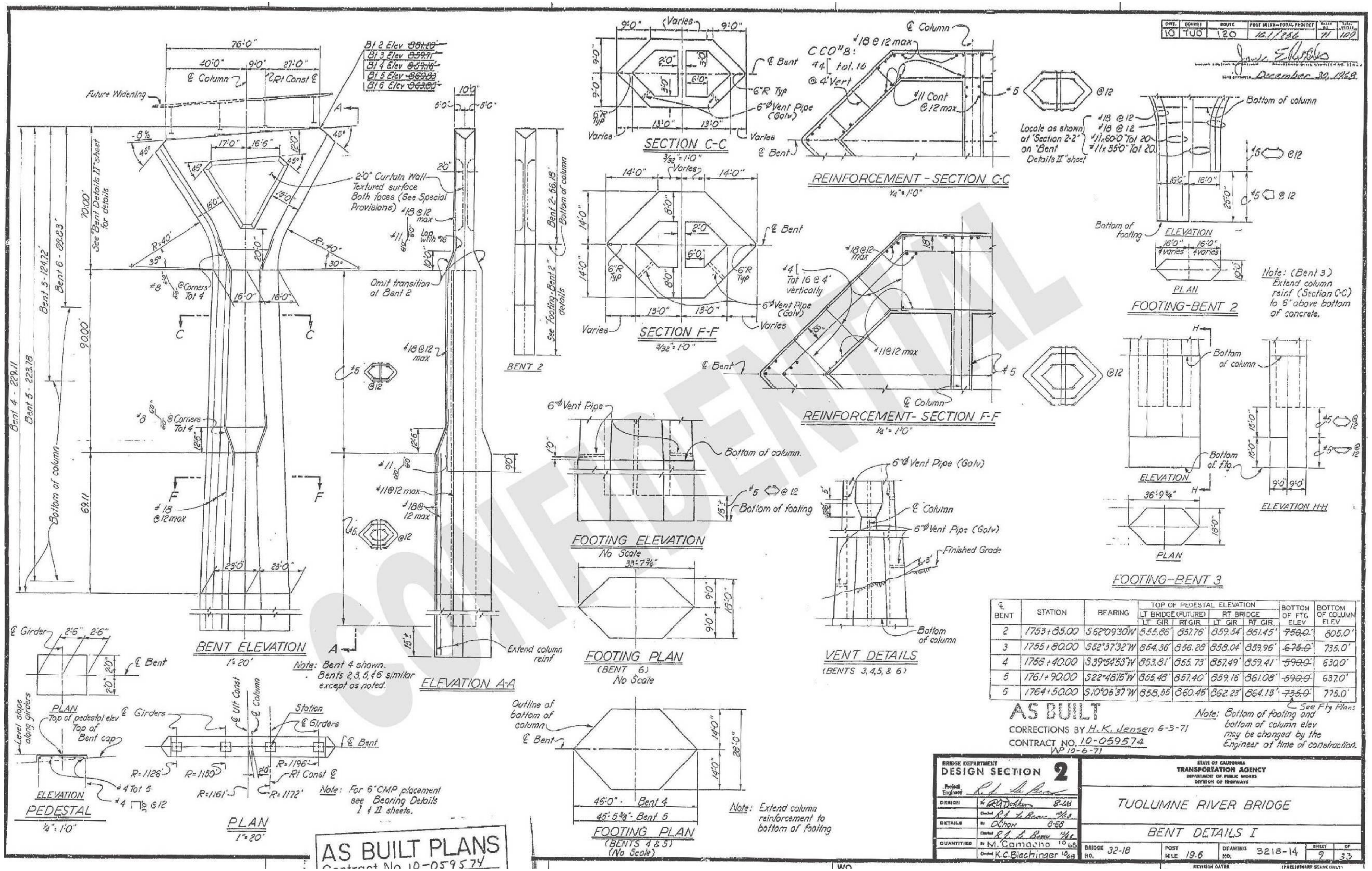
W 120° 20’ 28.97’’



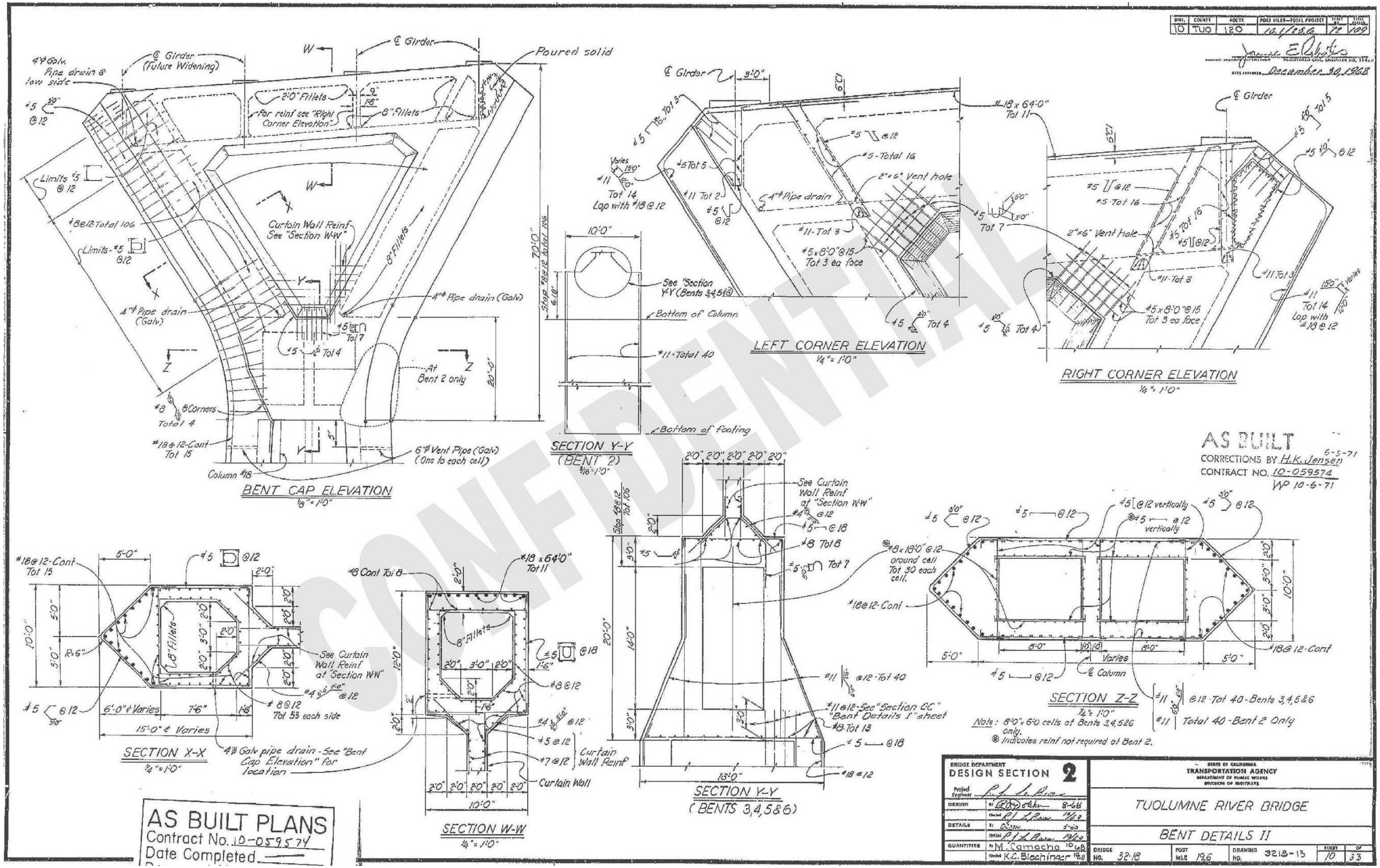
5.4 James E Roberts Bridge – Tuolumne River – Bridge Plan



5.5 James E Roberts Bridge – Tuolumne River – Typical Pier Drawings



5.6 James E Roberts Bridge – Tuolumne River – Typical Pier Drawings



6.0 BRIDGE SITE #3 (OLD AND NEW CARQUINEZ BRIDGES)

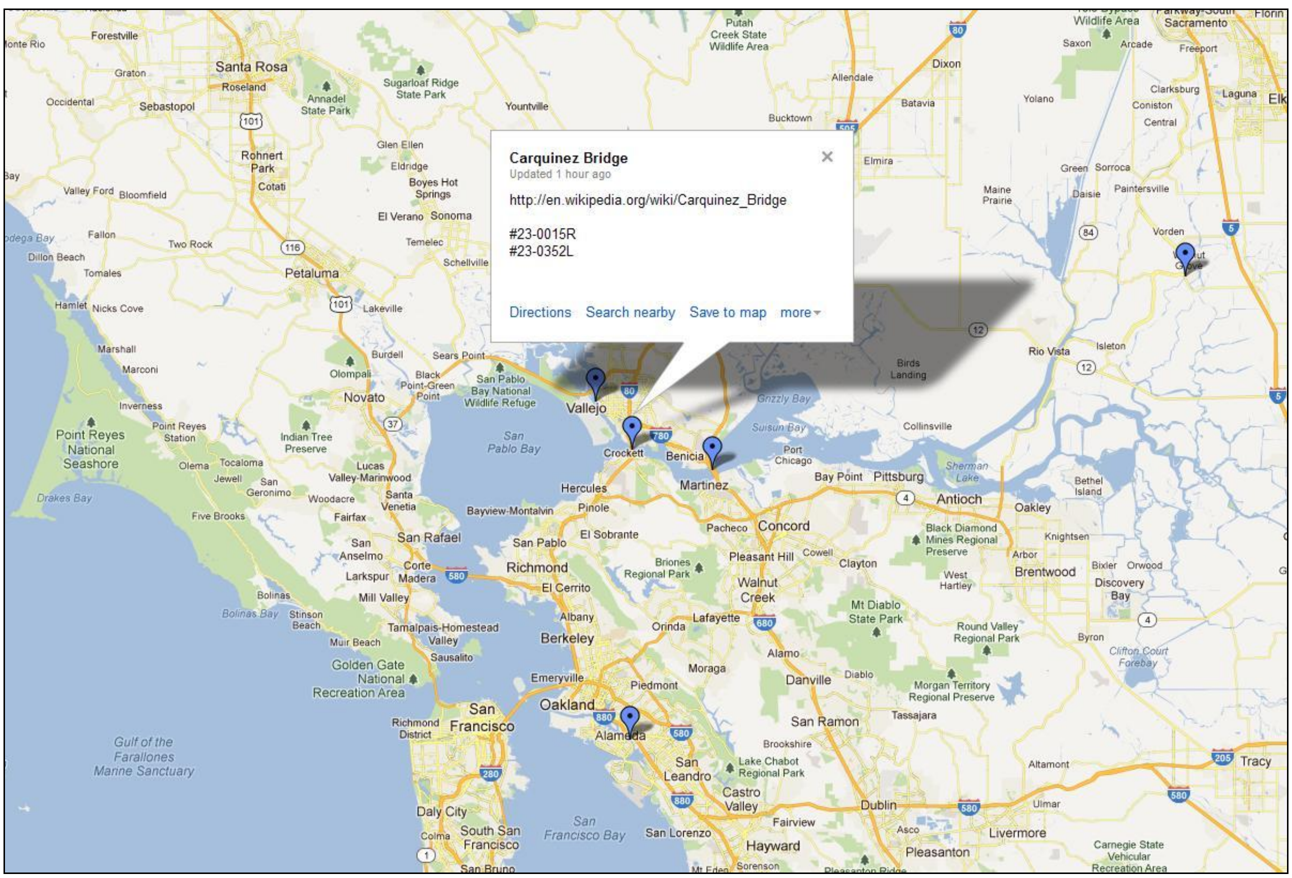
The Carquinez Straight can be characterized as a deep, turbid, and swift moving tidal waterway. The bridges were preliminarily selected based on the ability to perform field testing on two types of construction in swift current with limited visibility (when scanning sonar may have an advantage over dive inspectors).

Each crew will perform inspection work on separate bridges during the morning tide cycle and then swap bridges during the afternoon tide cycle in an attempt to have similar currents present during each test. The intent of this study is to replicate inspection of non-tidal bridges with fast currents and turbid water where inspections cannot be scheduled around slack tide. The inspection will include all faces of Tower T3 at the New Carquinez Bridge and all faces of Pier 3 at the Old Carquinez Bridge.

6.1 Carquinez Bridge – Vicinity Map

GPS Location: N 38^{o} 03’ 39.23’’

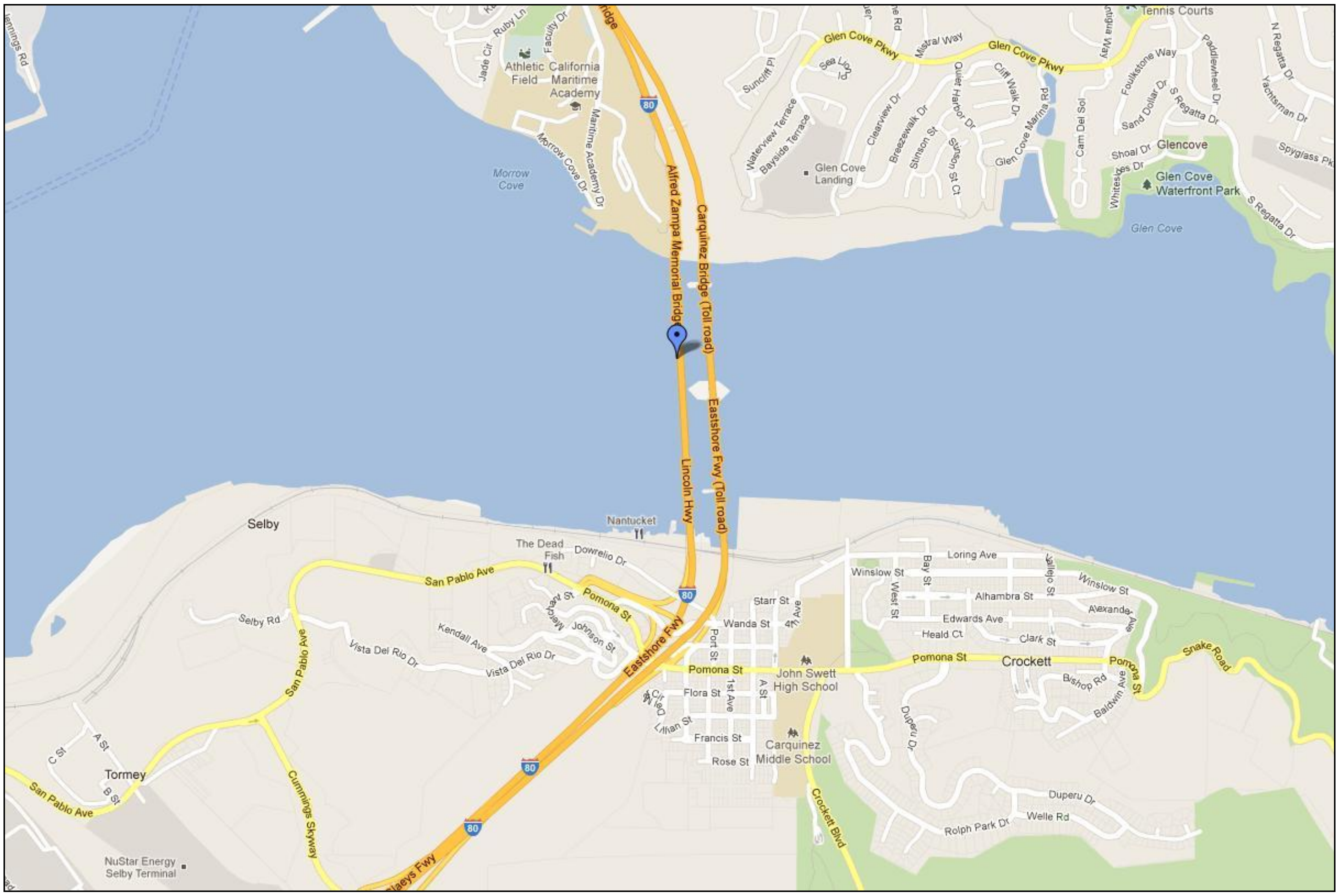
W 122^{o} 13’ 32.85’’



6.2 Carquinez Bridge – Location Map

GPS Location: N 38° 03' 39.23''

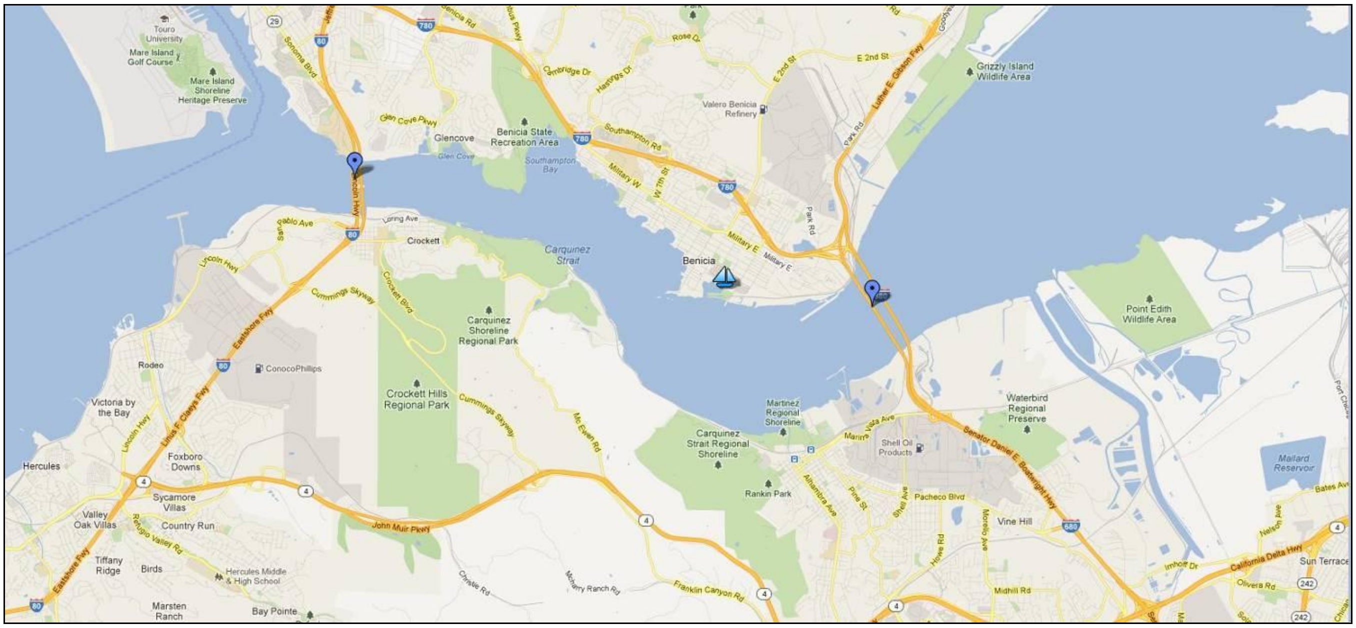
W 122° 13' 32.85''



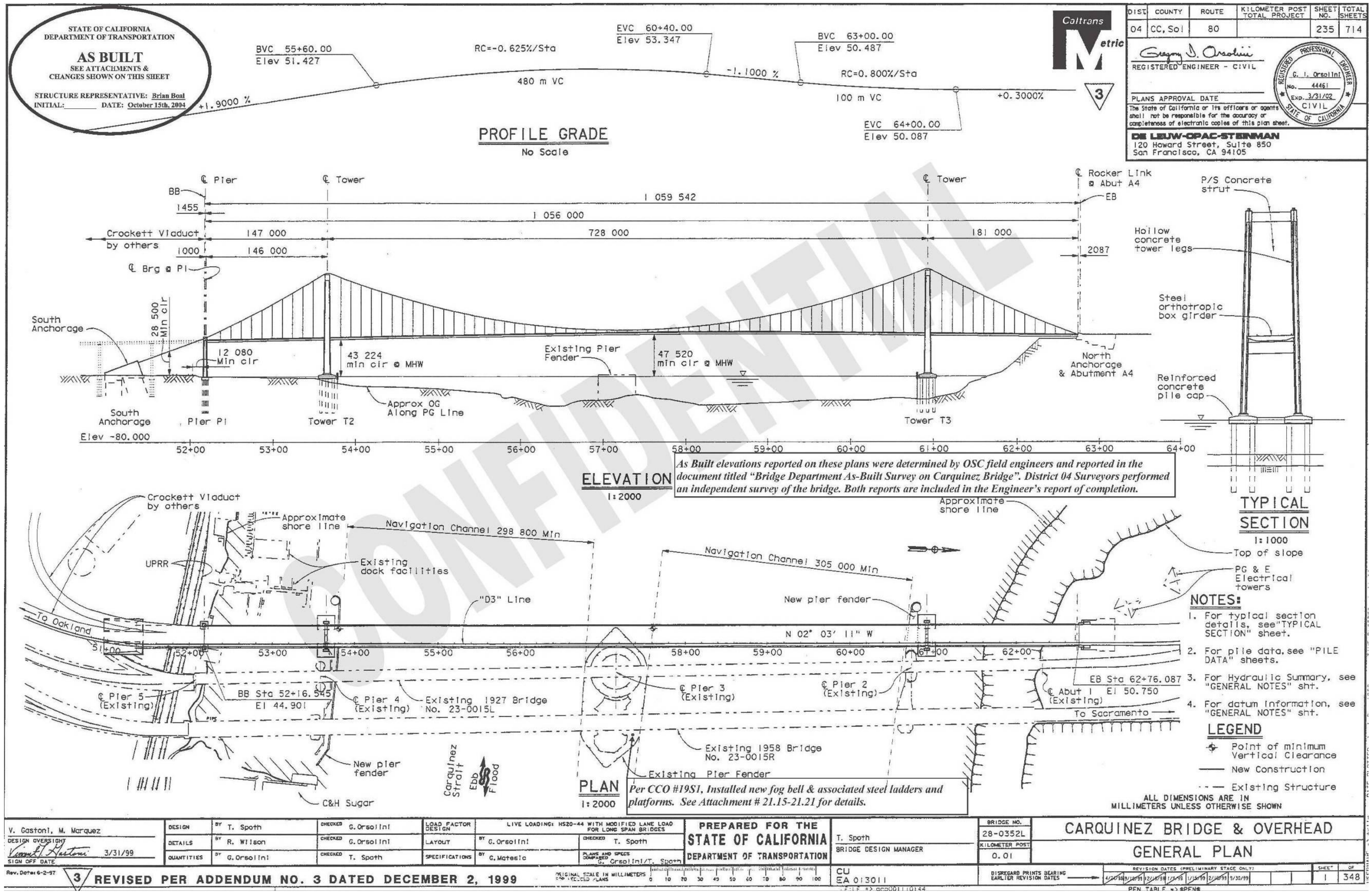
6.3 Carquinez Bridge – Boat Launch Map

GPS Location: N 38^{o} 03’ 28.3’’

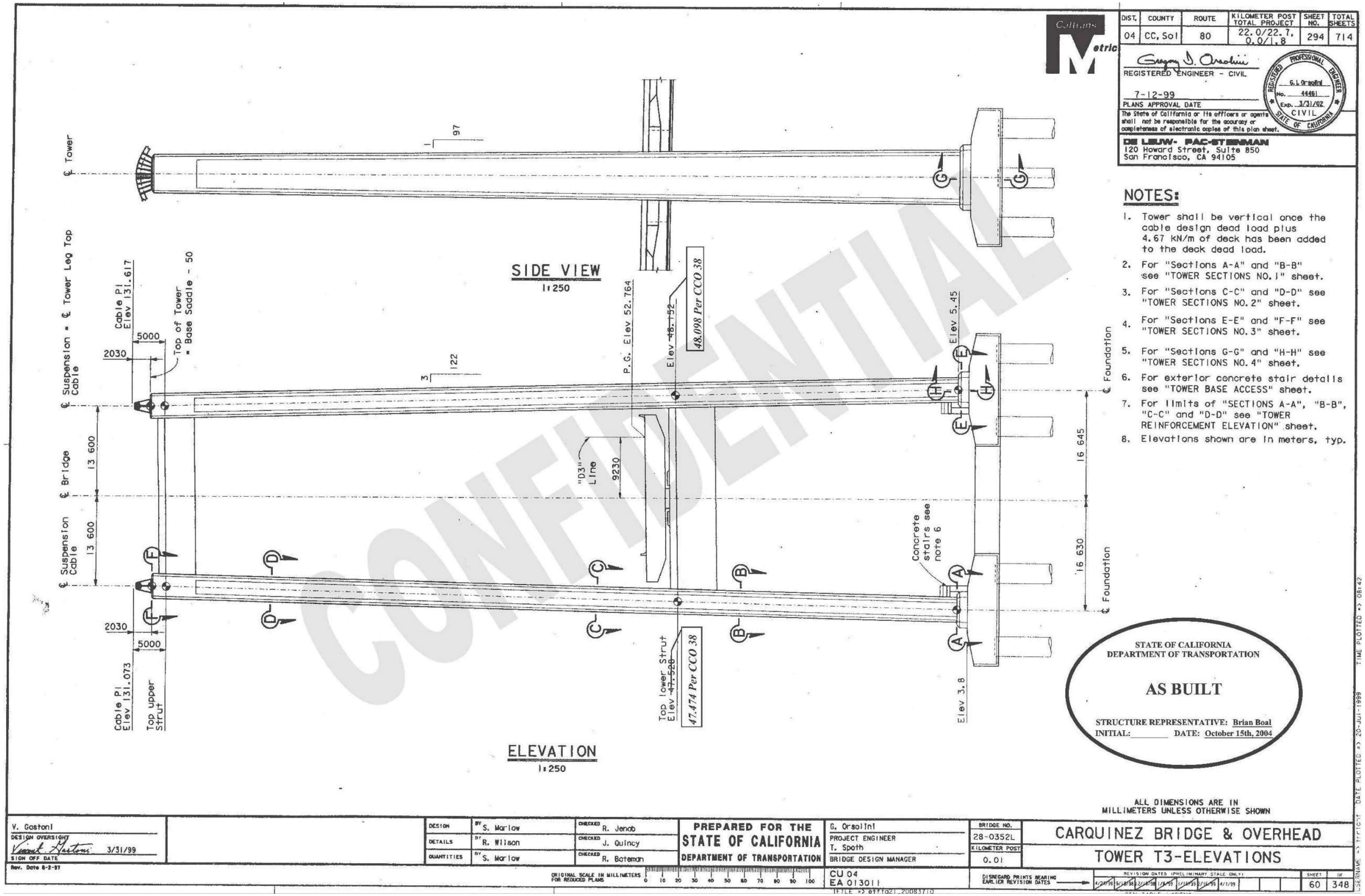
W 122^{o} 10’ 28.56’’



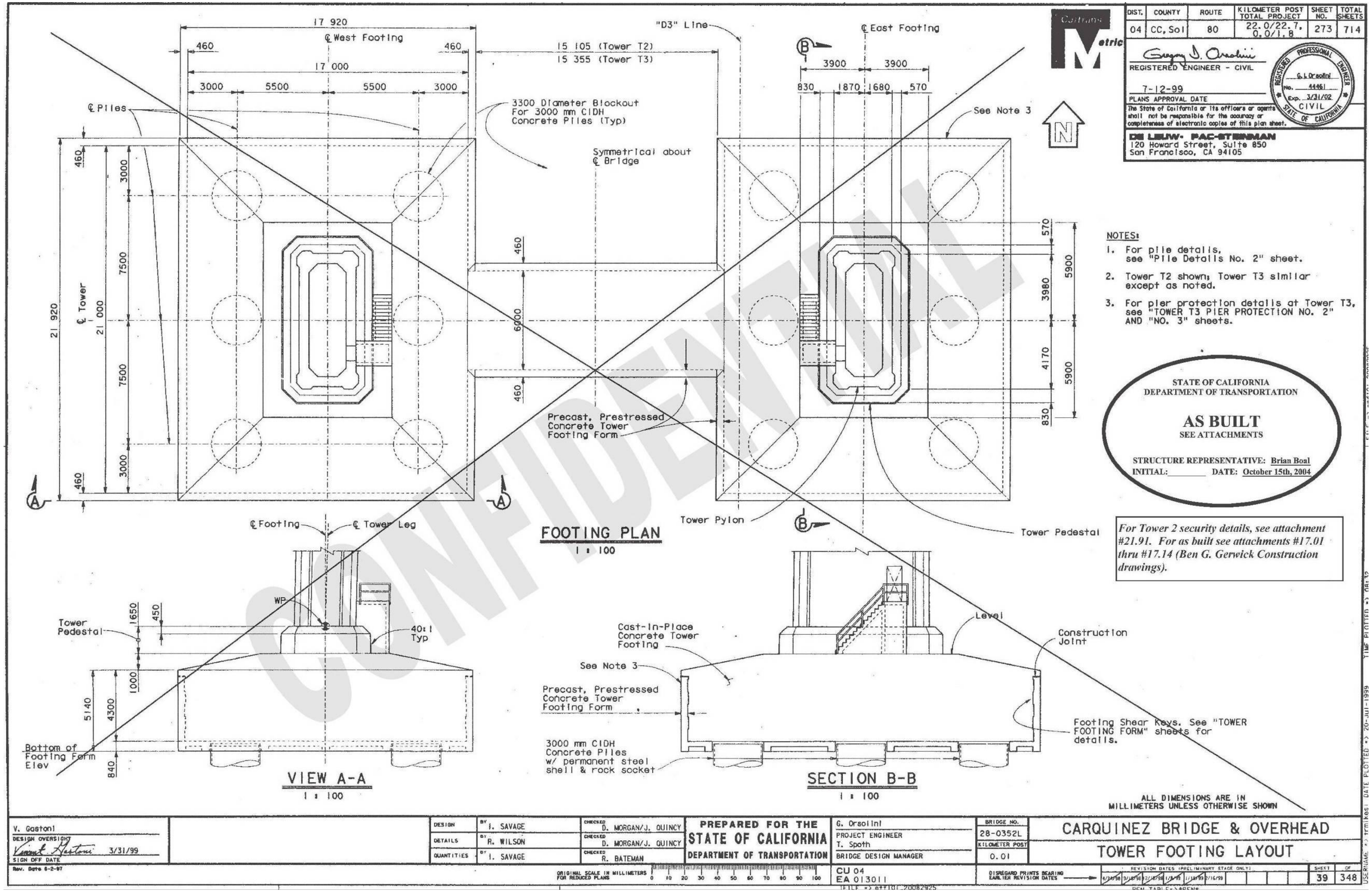
6.4 Carquinez Bridge (New) – Bridge Plan



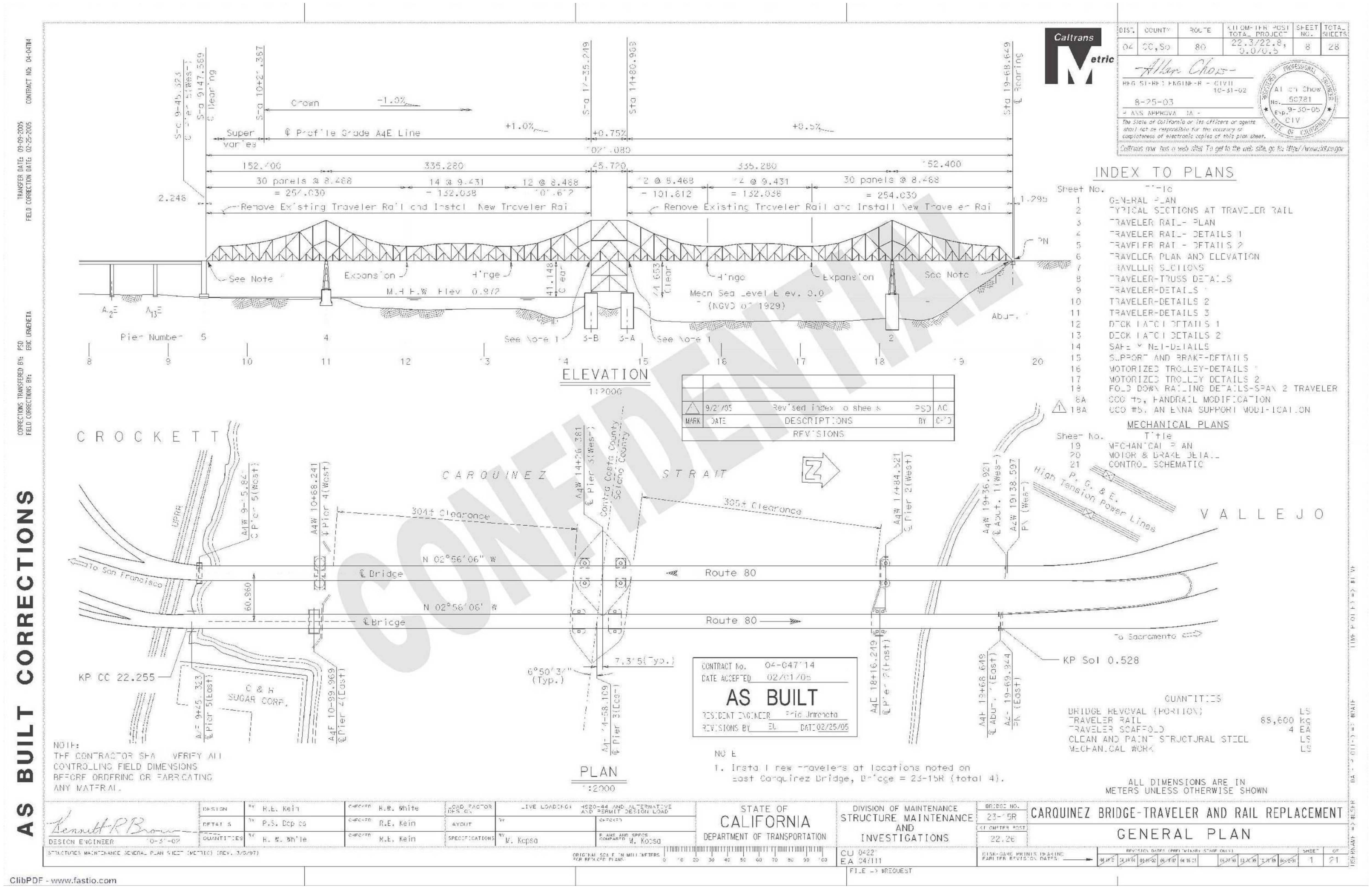
6.5 Carquinez Bridge – Tower T3 Elevations



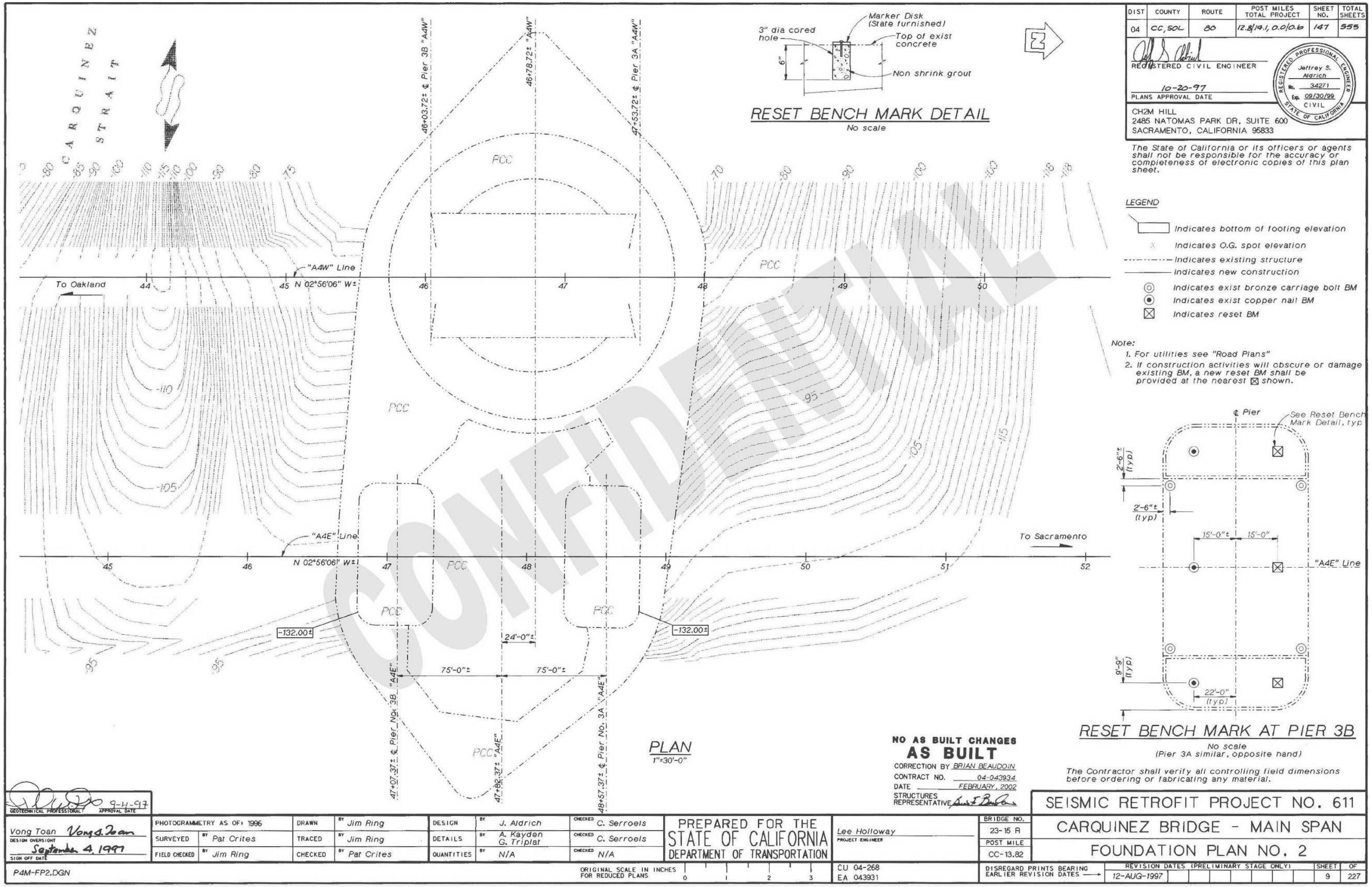
6.6 Carquinez Bridge (New) – Tower T3 Footing Layout



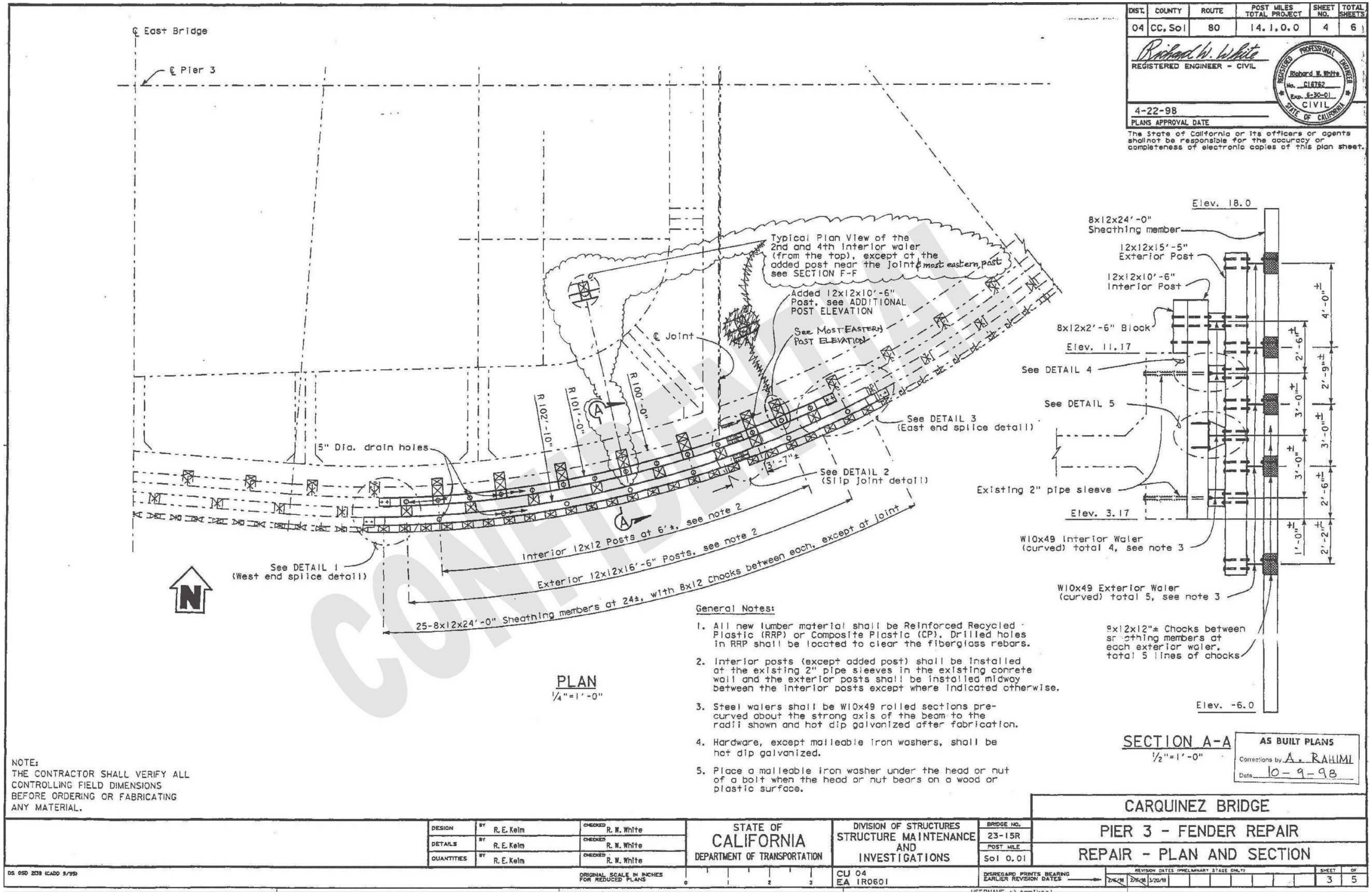
6.7 Carquinez Bridge (Old) – Bridge Plan



6.8 Carquinez Bridge (Old) – Pier 3 Foundation Plan



6.9 Carquinez Bridge (Old) – Pier 3 Fender Plan



7.0 CARQUINEZ TIDE AND CURRENT DATA

July 2012 - Carquinez Straight Tides and Currents														
Date		**Slack**	**Max**	**Current**	**Slack**	**Max**	**Current**	**Slack**	**Max**	**Current**	**Slack**	**Max**	**Current**	**Slack**
		Time	Time	(knots)	Time	Time	(knots)	Time	Time	(knots)	Time	Time	(knots)	Time
1	Su	0:59	5:02	3.3E	9:04	12:06	1.9F	15:01	17:42	1.2E	19:31	22:34	2.6F	
2	Mo	1:47	5:53	3.4E	9:54	13:00	2.0F	16:02	18:25	1.2E	20:29	23:26	2.6F	
3	Tu	2:36	6:44	3.4E	10:40	13:50	2.1F	16:58	19:24	1.2E	21:27			
4	We		0:18	2.5F	3:26	7:33	3.4E	11:23	14:35	2.2F	17:44	20:18	1.3E	22:24
5	Th		1:11	2.4F	4:17	8:19	3.3E	12:03	15:15	2.2F	18:28	21:07	1.5E	23:22
6	Fr		2:05	2.3F	5:09	9:01	3.2E	12:41	15:50	2.2F	19:08	21:55	1.7E	
7	Sa	0:21	3:00	2.1F	6:01	9:43	3.0E	13:19	16:24	2.3F	19:47	22:45	1.8E	
8	Su	1:25	3:58	1.8F	6:57	10:28	2.7E	13:57	17:00	2.3F	20:28	23:41	2.0E	
9	Mo	2:32	5:04	1.6F	7:56	11:20	2.4E	14:36	17:41	2.3F	21:10			
10	Tu		0:41	2.1E	3:46	6:25	1.3F	9:01	12:20	2.0E	15:19	18:25	2.3F	21:54
11	We		1:41	2.3E	5:03	7:47	1.3F	10:17	13:23	1.7E	16:05	19:10	2.3F	22:40
12	Th		2:42	2.5E	6:16	9:07	1.3F	11:37	14:28	1.4E	16:54	19:57	2.2F	23:25
13	Fr		3:39	2.7E	7:19	10:15	1.6F	12:52	15:34	1.2E	17:44	20:46	2.1F	
14	Sa	0:07	4:29	2.8E	8:12	11:12	1.8F	14:01	16:34	1.1E	18:34	21:34	2.1F	
15	Su	0:46	5:12	2.9E	8:59	12:02	1.9F	15:03	17:27	1.0E	19:23	22:19	2.0F	
16	Mo	1:22	5:45	2.9E	9:38	12:47	2.0F	15:55	18:15	1.0E	20:11	23:00	2.0F	
17	Tu	2:00	6:09	2.9E	10:10	13:27	2.0F	16:36	18:59	1.0E	20:59	23:41	2.0F	
18	We	2:39	6:31	2.9E	10:39	13:59	1.9F	17:08	19:38	1.1E	21:42			
19	Th		0:24	2.0F	3:19	7:00	3.0E	11:06	14:16	1.9F	17:34	20:11	1.2E	22:28
20	Fr		1:08	2.1F	4:01	7:36	3.1E	11:31	14:25	2.0F	17:59	20:42	1.4E	23:15
21	Sa		1:54	2.1F	4:17	8:16	3.1E	12:00	14:46	2.3F	18:25	21:13	1.7E	
22	Su	0:06	2:42	2.1F	5:34	8:59	3.0E	12:31	15:18	2.5F	18:56	21:49	2.0E	
23	Mo	1:00	3:32	1.9F	6:27	9:44	2.8E	13:09	15:57	2.7F	19:32	22:33	2.2E	
24	Tu	2:02	4:28	1.7F	7:25	10:35	2.5E	13:49	16:43	2.7F	20:16	23:26	2.3E	
25	We	3:12	5:35	1.4F	8:32	11:34	2.1E	14:36	17:34	2.7F	21:03			
26	Th		0:29	2.5E	4:30	6:58	1.3F	9:51	12:41	1.7E	15:29	18:29	2.6F	21:58
27	Fr		1:37	2.6E	5:47	**8:36**	**1.3F**	11:18	**13:53**	**1.4E**	16:28	**19:27**	**2.5F**	22:54
28	Sa		2:52	2.8E	6:57	**10:01**	**1.5F**	12:40	**15:11**	**1.2E**	17:29	**20:27**	**2.4F**	23:50
29	Su		**4:03**	**3.0E**	7:58	**11:04**	**1.8F**	13:51	**16:23**	**1.2E**	18:31	21:29	2.4F	
30	Mo	0:46	**5:02**	**3.1E**	8:50	**11:57**	**2.0F**	14:52	**17:25**	**1.3E**	19:32	22:29	2.4F	
31	Tu	1:39	**5:53**	**3.2E**	9:38	**12:44**	**2.1F**	15:46	**18:21**	**1.4E**	20:31	23:23	2.4F	

August 2012 - Carquinez Straight Tides and Currents														
Date		**Slack** Time	**Max** Time	**Current** (knots)	**Slack** Time	**Max** Time	**Current** (knots)	**Slack** Time	**Max** Time	**Current** (knots)	**Slack** Time	**Max** Time	**Current** (knots)	**Slack** Time
1	We	2:31	**6:40**	**3.2E**	10:19	**13:27**	**2.2F**	16:30	**19:13**	**1.6E**	21:28			
2	Th		0:15	2.4F	3:21	**7:24**	**3.2E**	10:57	**14:04**	**2.2F**	17:09	20:01	1.7E	22:20
3	Fr		1:05	2.3F	4:10	**8:03**	**3.1E**	11:30	**14:34**	**2.2F**	17:43	20:44	1.8E	23:12
4	Sa		1:56	2.2F	4:58	8:39	3.0E	12:02	14:59	2.2F	18:17	21:24	2.0E	
5	Su	0:07	2:45	2.0F	5:47	9:15	2.8E	12:34	15:24	2.3F	18:50	22:02	2.1E	
6	Mo	1:02	3:37	1.8F	6:37	9:54	2.5E	13:09	15:56	2.4F	19:26	22:44	2.1E	
7	Tu	2:02	4:35	1.6F	7:33	10:40	2.1E	13:47	16:35	2.3F	20:04	23:34	2.2E	
8	We	3:09	5:51	1.3F	8:38	11:37	1.7E	14:29	17:21	2.3F	20:48			
9	Th		0:33	2.3E	4:22	7:18	1.2F	9:53	12:44	1.4E	15:18	18:12	2.1F	21:35
10	Fr		1:37	2.3E	5:34	8:39	1.3F	11:17	13:56	1.1E	16:13	19:06	2.0F	22:27
11	Sa		2:43	2.4E	6:39	9:49	1.6F	12:33	15:06	1.1E	17:13	20:03	1.9F	23:19
12	Su		3:42	2.6E	7:31	10:45	1.8F	13:38	16:09	1.1E	18:12	21:01	1.9F	
13	Mo	0:09	4:28	2.7E	8:18	11:32	1.9F	14:30	17:03	1.2E	19:08	21:56	1.9F	
14	Tu	0:56	5:05	2.8E	8:56	12:12	2.0F	15:12	17:48	1.3E	19:59	22:44	2.0F	
15	We	1:41	5:35	2.8E	9:29	12:44	1.9F	15:46	18:29	1.4E	20:47	23:29	2.0F	
16	Th	2:27	6:05	2.8E	9:58	13:04	1.9F	16:11	19:04	1.5E	21:31			
17	Fr		0:12	2.1F	3:10	6:38	2.9E	10:23	13:14	2.0F	16:36	19:35	1.7E	22:18
18	Sa		0:56	2.2F	3:56	7:16	2.9E	10:50	13:33	2.2F	17:00	20:05	2.0E	23:03
19	Su		1:42	2.2F	4:41	7:57	2.8E	11:20	14:03	2.5F	17:28	20:37	2.3E	23:53
20	Mo		2:29	2.1F	5:30	8:41	2.7E	11:52	14:40	2.7F	18:02	21:14	2.5E	
21	Tu	0:48	3:20	2.0F	6:24	9:26	2.4E	12:31	15:22	2.8F	18:42	21:58	2.7E	
22	We	1:48	4:16	1.7F	7:25	10:18	2.1E	13:16	16:09	2.8F	19:30	22:49	2.7E	
23	Th	2:56	5:28	1.5F	8:35	11:21	1.7E	14:08	17:03	2.6F	20:23	23:55	2.6E	
24	Fr	4:12	7:04	1.4F	9:57	12:36	1.4E	15:08	18:03	2.4F	21:24			
25	Sa		1:15	2.6E	5:29	8:38	1.5F	11:22	13:58	1.3E	16:18	19:09	2.2F	22:30
26	Su		2:43	2.7E	6:37	9:51	1.8F	12:38	15:16	1.3E	17:30	20:19	2.1F	23:38
27	Mo		3:57	2.9E	7:35	10:48	2.0F	13:39	16:23	1.5E	18:38	21:31	2.1F	
28	Tu	0:40	4:54	3.0E	8:25	11:36	2.2F	14:31	17:19	1.7E	19:39	22:35	2.2F	
29	We	1:38	5:42	3.0E	9:08	12:17	2.3F	15:15	18:09	1.9E	20:37	23:28	2.3F	
30	Th	2:29	6:25	3.0E	9:46	12:53	2.3F	15:52	18:57	2.0E	21:28			
31	Fr		0:17	2.2F	3:18	7:04	2.9E	10:19	13:22	2.2F	16:25	19:40	2.1E	22:17

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