APPENDIX F-4

Chelsea Wetland Restoration Project
Entrance Culvert Scour Analysis
Technical Memorandum (Questa, 2015)

Technical Memorandum

Date: February 11, 2015

To: Ducks Unlimited

From: Questa Engineering Corporation

Subject: Chelsea Wetland Restoration Project – Entrance Culvert Scour Analysis

The project proposes the removal of fill and the re-establishment of the tidal influence within the Chelsea project area. In order to establish tidal connection, a prefabricated, concrete arch culvert with a concrete bottom will be installed in the north levee of Pinole Creek some 1,900 feet upstream of the San Francisco Bay. This culvert will span 12 feet and rise 6.9 feet and have approximate cross sectional area of 80 square feet. On a daily basis, tidal action enters the Pinole Creek channel and will flow through the proposed culvert into the new wetland. During high storm water flows in Pinole Creek, flow may enter the new tidal areas through the culvert. Eventually, during events larger than the 25-yr, Pinole Creek flows over the top of the trail and enters the new wetland. As flows drop in Pinole Creek, water stored in the Chelsea area drains through the culvert back into the Pinole Creek channel. The culvert will be located at Station 19+50, with the specific design details shown on the Conceptual Plans. This analysis is primarily concerned with the flow dynamics and scour potential of the culvert during runoff and tidal events.

Photo 1. The northern bank of Pinole Creek ending at Chelsea Wetland; photo taken from new pedestrian bridge looking upstream to the east.

Scour conditions in the proposed culvert depend on the flow dynamics between Pinole Creek and Chelsea. These dynamics are driven by the stage in Pinole Creek as well the stage in the new wetlands. If the water surface on one side of the culvert is higher than the other, then a positive hydraulic head exists, accelerating velocity and hence scour conditions in around the culvert. The first question that needs to be answered is does the culvert have capacity so that water surface elevations in Pinole Creek match or closely match those in Chelsea wetlands.

A simple HEC-RAS model was developed for the channel and culvert connecting Chelsea Wetland and Pinole Creek. This model was used to analyze the capacity of the culvert under various Pinole Creek backwater conditions (i.e. flood stage). Culvert capacity is more than enough to fill or drain the lower wetland area below 6.5 NGVD or the soffit of the culvert. Under submerged conditions on either side of the culvert, flow through the culvert varies between 200 and 300 cfs. This assumes that is only minor head differential between either side of culvert. Under these conditions the culvert has very low head differential and may or may not be under outlet control flow condition. Under greater head conditions flow through the culvert is increased. Therefore, an average flow of 250 cfs between 7 and 11 feet NGVD, represents conservative flow conditions. Under these flow conditions velocities through the culvert vary between 6-8 ft/sec.

Using 250 cfs as a benchmark flow rate, outflow of the Chelsea Wetland will rise or fall a foot of stage in between 17-24 minutes, depending on the elevation and volume of the wetland. In order for significant head differential to occur, the Pinole Creek would have to increase or lose a foot of flood stage quicker than 17-24 minutes. This study does not examine specific hydrograph trends in Pinole Creek but the watershed is 15 square miles with over 33 miles of blue line creeks and is not likely to decrease or increase 1 foot of stage, much faster than 15 to 20 minutes. Following this logic, it can be assumed that water levels in Chelsea Wetland will closely mimic water levels in Pinole Creek as stage rises and falls during a runoff event or tidal cycle.

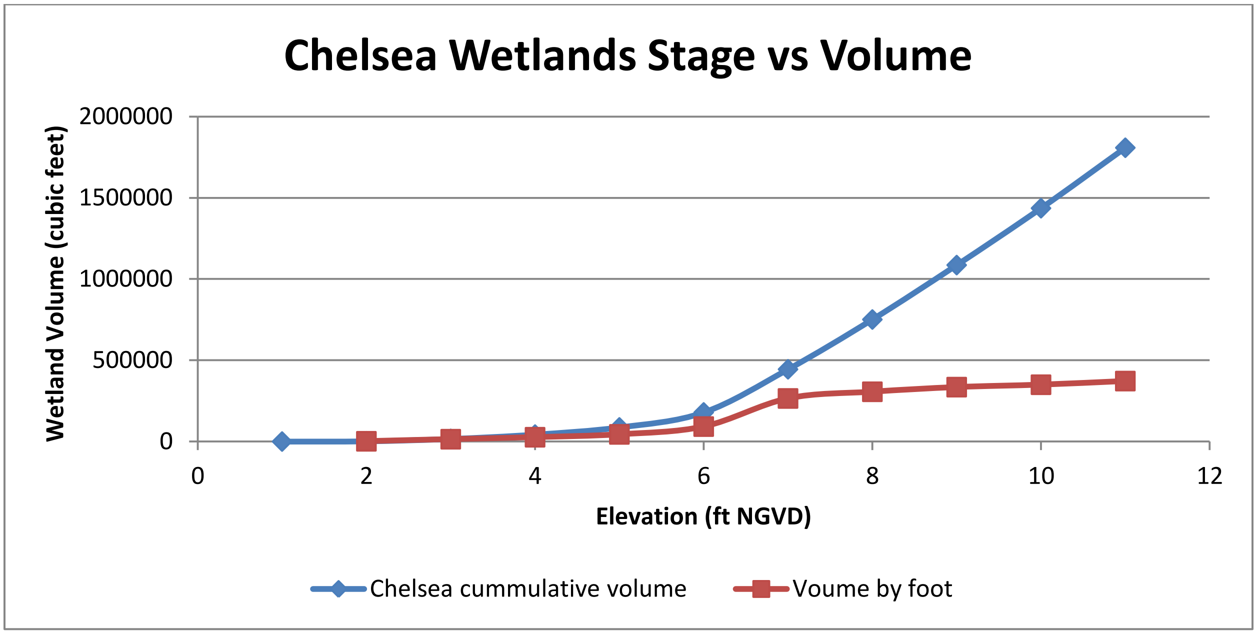

Figure 1. Chelsea Wetland cumulative and per stage volumes.

SCOUR ANALYSIS

In order to complete scour calculation it is valuable to assume a worst case scenario. In a worst case scenario, the wetlands would be completely filled but Pinole Creek would drop so quickly as to make a significant head differential between the two sides of culvert. Maximum head differential was assumed 3.5 feet that would assume that water surface elevations in Chelsea would be full or at 11 feet NGVD and Pinole Creek would at 7.5 feet which would equate to a high tide plus high winter base flow. This condition would force water into the culvert at much greater velocities with greater scour potential. HEC-RAS modeling indicates that between 700 and 900 cfs could be forced through the culvert. At this rate of flow, a foot drop in stage in Chelsea would take approximately 7 minutes.

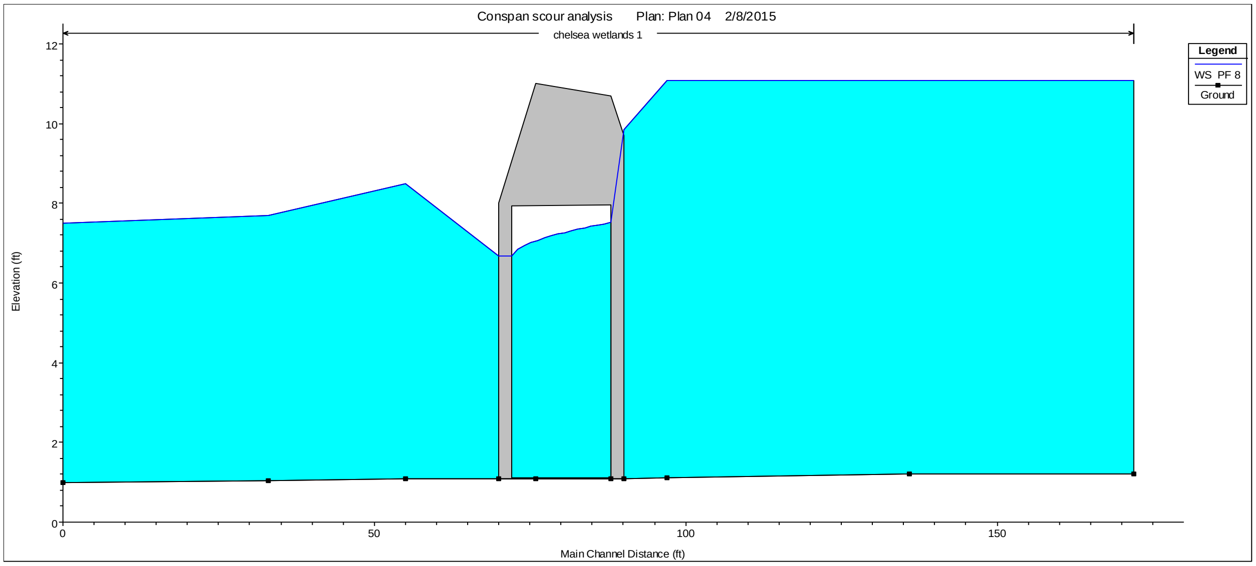

Figure 2. Profile view of Maximum stage differential between Chelsea and Pinole Creek.

Under this condition some 900 cfs is flowing through the culvert at 13 ft/sec. Based on these conditions scour could be a possibility.

Potential Culvert Scour

Two potential scour sources were considered; contraction scour and general bed scour. Because of fine grained nature of the soils and the potential for localized high velocities at the entrance and exit of the culvert, the potential scour depths were calculated to be in excess of 10 feet. We believe this is conservative because we have shown that these conditions my only be present for less than 30 minutes, it does indicate the potential scour sensitivity of the structure and site. The new culvert structure will require scour protection from the culvert to the end of the wing walls to ensure its long-term stability. Though the depth and specific rock size is not specified on the plans, this analysis should be used to finalize the anti-scour protection for the culvert.

Anti –scour sizing and design section

Utilizing a maximum velocity of 13 ft/sec, determined from HEC- RAS runs (see attached output), the Federal Highway Administration Hydraulic Engineering Circular No. 23 was used to size the median size of the rock rip rap. The calculations are attached to this Memorandum. The D_{50} of the rip rap size calculates out to 18 to 20 inch diameter stone or ¼ ton rock. This is the median size of rock that should be used for scour protection. However, it recommended that a variety of size material be used with at least 10 percent of Caltrans number 1 or 2 of backing class rock and at least 90 percent of the rock should be excess of 18 inches in diameter. A filter fabric, such as a Mirafi® HP570 or Mirafi® FW500 should be placed on the native soil prior to rock placement. A general design section of the scour protection is attached.

Using this rock size and section should eliminate any potential scour issues that could occur in and around the wetlands entrance culvert.

Chelsea Wetlands

HEC-RAS Plan: Plan 03 River: chelsea wetlands Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	272	PF 1	200.00	1.20	7.67		7.68	0.000044	0.62	325.16	124.58	0.07
1	272	PF 2	300.00	1.20	7.88		7.89	0.000078	0.85	351.59	125.04	0.09
1	272	PF 3	400.00	1.20	8.19		8.21	0.000099	1.03	390.04	125.69	0.10
1	272	PF 4	500.00	1.20	8.58		8.60	0.000105	1.14	439.25	126.53	0.11
1	272	PF 5	600.00	1.20	9.06		9.08	0.000100	1.20	499.98	127.55	0.11
1	272	PF 6	700.00	1.20	9.63		9.65	0.000088	1.22	572.87	128.77	0.10
1	272	PF 7	800.00	1.20	10.29		10.32	0.000073	1.21	659.17	130.20	0.10
1	272	PF 8	900.00	1.20	11.08		11.10	0.000059	1.18	762.30	131.89	0.09
1	236	PF 1	200.00	1.20	7.67		7.68	0.000044	0.62	324.96	124.58	0.07
1	236	PF 2	300.00	1.20	7.88		7.89	0.000078	0.85	351.24	125.03	0.09
1	236	PF 3	400.00	1.20	8.19		8.20	0.000099	1.03	389.59	125.68	0.10
1	236	PF 4	500.00	1.20	8.58		8.60	0.000105	1.14	438.76	126.52	0.11
1	236	PF 5	600.00	1.20	9.05		9.08	0.000100	1.20	499.52	127.54	0.11
1	236	PF 6	700.00	1.20	9.62		9.65	0.000088	1.22	572.46	128.76	0.10
1	236	PF 7	800.00	1.20	10.29		10.31	0.000074	1.21	658.82	130.19	0.10
1	236	PF 8	900.00	1.20	11.08		11.10	0.000059	1.18	762.02	131.88	0.09
1	197	PF 1	200.00	1.12	7.67		7.67	0.000019	0.47	422.25	124.58	0.05
1	197	PF 2	300.00	1.12	7.88		7.89	0.000035	0.67	448.59	125.03	0.06
1	197	PF 3	400.00	1.12	8.19		8.20	0.000047	0.82	486.99	125.69	0.07
1	197	PF 4	500.00	1.12	8.58		8.59	0.000054	0.93	536.20	126.52	0.08
1	197	PF 5	600.00	1.12	9.06		9.07	0.000056	1.01	596.96	127.55	0.08
1	197	PF 6	700.00	1.12	9.63		9.64	0.000053	1.04	669.89	128.77	0.08
1	197	PF 7	800.00	1.12	10.29		10.31	0.000047	1.06	756.24	130.20	0.08
1	197	PF 8	900.00	1.12	11.08		11.10	0.000040	1.05	859.41	131.88	0.07
1	190	PF 1	200.00	1.10	7.56	3.15	7.66	0.000226	2.58	77.52	20.61	0.18
1	190	PF 2	300.00	1.10	7.64	3.79	7.87	0.000487	3.82	78.46	20.72	0.26
1	190	PF 3	400.00	1.10	7.77	4.36	8.16	0.000810	5.00	80.06	20.90	0.34
1	190	PF 4	500.00	1.10	7.96	4.88	8.53	0.001153	6.07	82.34	21.15	0.41
1	190	PF 5	600.00	1.10	8.23	5.37	9.00	0.001459	7.01	85.60	21.51	0.46
1	190	PF 6	700.00	1.10	8.61	5.82	9.55	0.001670	7.76	90.16	22.02	0.50
1	190	PF 7	800.00	1.10	9.13	6.27	10.20	0.001744	8.30	96.41	22.71	0.52
1	190	PF 8	900.00	1.10	9.84	6.69	10.98	0.001668	8.58	104.87	23.65	0.51
1	180		Culvert									
1	170	PF 1	200.00	1.10	7.48	3.15	7.59	0.000235	2.61	76.55	73.02	0.18
1	170	PF 2	300.00	1.10	7.45	3.78	7.69	0.000537	3.94	76.23	70.33	0.28
1	170	PF 3	400.00	1.10	7.41	4.36	7.85	0.000974	5.28	75.75	66.37	0.37
1	170	PF 4	500.00	1.10	7.36	4.88	8.05	0.001568	6.66	75.08	60.83	0.47
1	170	PF 5	600.00	1.10	7.28	5.36	8.30	0.002355	8.09	74.14	52.97	0.57
1	170	PF 6	700.00	1.10	7.16	5.83	8.60	0.003413	9.62	72.76	41.48	0.69
1	170	PF 7	800.00	1.10	6.98	6.27	8.98	0.004934	11.34	70.57	25.16	0.82
1	170	PF 8	900.00	1.10	6.69	6.69	9.49	0.007403	13.42	67.06	24.50	1.00
1	155	PF 1	200.00	1.08	7.54		7.56	0.000084	1.20	234.24	125.27	0.10
1	155	PF 2	300.00	1.08	7.59		7.63	0.000177	1.76	240.70	125.30	0.14
1	155	PF 3	400.00	1.08	7.67		7.73	0.000285	2.25	250.26	125.33	0.18
1	155	PF 4	500.00	1.08	7.77		7.85	0.000390	2.68	263.29	125.39	0.21
1	155	PF 5	600.00	1.08	7.90		8.01	0.000477	3.01	279.90	125.45	0.24
1	155	PF 6	700.00	1.08	8.07		8.19	0.000534	3.26	300.91	125.54	0.25
1	155	PF 7	800.00	1.08	8.27		8.39	0.000560	3.42	325.61	125.63	0.26
1	155	PF 8	900.00	1.08	8.50		8.63	0.000557	3.50	354.38	125.75	0.26
1	133	PF 1	200.00	1.05	7.51		7.55	0.000198	1.70	117.58	25.20	0.14
1	133	PF 2	300.00	1.05	7.51		7.61	0.000444	2.55	117.77	25.20	0.21
1	133	PF 3	400.00	1.05	7.53		7.70	0.000784	3.39	118.08	25.20	0.28
1	133	PF 4	500.00	1.05	7.54		7.82	0.001213	4.22	118.49	25.20	0.34
1	133	PF 5	600.00	1.05	7.56		7.96	0.001724	5.04	119.00	25.20	0.41
1	133	PF 6	700.00	1.05	7.59		8.12	0.002303	5.84	119.76	25.20	0.47
1	133	PF 7	800.00	1.05	7.63		8.31	0.002936	6.62	120.77	25.20	0.53
1	133	PF 8	900.00	1.05	7.69		8.53	0.003594	7.37	122.15	25.20	0.59
1	100	PF 1	200.00	1.00	7.50	3.45	7.54	0.000195	1.69	118.20	25.20	0.14
1	100	PF 2	300.00	1.00	7.50	4.04	7.60	0.000439	2.54	118.20	25.20	0.21
1	100	PF 3	400.00	1.00	7.50	4.54	7.68	0.000781	3.38	118.20	25.20	0.28
1	100	PF 4	500.00	1.00	7.50	4.95	7.78	0.001220	4.23	118.20	25.20	0.34
1	100	PF 5	600.00	1.00	7.50	5.32	7.90	0.001757	5.08	118.20	25.20	0.41
1	100	PF 6	700.00	1.00	7.50	5.67	8.04	0.002392	5.92	118.20	25.20	0.48
1	100	PF 7	800.00	1.00	7.50	5.96	8.21	0.003124	6.77	118.20	25.20	0.55
1	100	PF 8	900.00	1.00	7.50	6.22	8.40	0.003954	7.61	118.20	25.20	0.62

Starting watersurface elevation

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Project No: ChelSEA
Date:
Project Name:
By:
Checked by:
Subject: Rip-rap Sizing

FHA Hydraulic Engineering Circular No. 23

Rip-Rap DESIGN Calcs

$$D_{50} = \frac{0.692\,(KV)^2}{(2g\,(S_s - 1))}$$

K = 1.2 Flat bottom, No piers

V = Velocity worst case = 13 ft/s

S_s = Specific gravity of Rock = 2.65

g = 32.174 ft/s²

$$= \frac{0.692\,(1.2 * 13)^2}{64.34\,(2.65 - 1)}$$

$$= \frac{168.405}{106.16}$$

D_{50} = 1.59 ft

≈ 18"–20" diameter Stone

Weight Conversion

$$W = 0.85\,(160\ \text{lbs/ft}^3\,(1.59\ \text{ft})^3)$$

W = 546 lbs

So Class V = 1/4 ton (500 lb) rock Size

Page of

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Project No: Date:
Project Name: Chelsea Wetlands
By: Checked by:
Subject: Culvert Anti-Scour Section