

Redwood Creek Estuary Monitoring 2000 Annual Progress Report

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Introduction

This annual report summarizes Redwood National and State Parks' Fish and Wildlife Branch monitoring activities in the Redwood Creek estuary for the calendar year 2000. Monitoring activities have occurred in the Redwood Creek estuary since 1980. The purpose of the monitoring is to determine fish utilization of the estuary, monitor estuary water quality and water and sand berm elevations, and document breaching incidents. This report serves as the annual report for the parks' Division of Resource Management and Science and the U.S. Army Corps of Engineers (Corps). The annual report fulfills special condition seven of Corps permit No. 21881N. The permit authorizes breaching of the mouth of Redwood Creek. The eight special conditions of the permit are addressed in this report. A copy of the permit is in Appendix I.

Location

Redwood Creek estuary is located 2.5 miles west of Orick, California at the mouth of Redwood Creek at the Pacific Ocean (Figure 1). Redwood Creek is 108 km long and the basin is 720 km² in area. U.S. Army Corps of Engineers constructed 3.4 miles of flood control levees in 1968 on lower Redwood Creek, which bisect and terminate in the estuary. The estuary consists of the north and south sloughs, and the embayment. The south slough was the last oxbow of the river bypassed by the south levee.

Methods

Fish Monitoring

Population Estimates - The Peterson mark and recapture method (Youngs and Robson 1978) was used to estimate numbers of juvenile salmonid fish in the Redwood Creek embayment. Fish were seined with a 150-long, 15-foot wide, ¼ inch mesh beach seine net deployed off the bow of a 16-foot motor boat. A blue mark was applied to the upper or lower caudal fin or anal fin of captured fish using a Panjet needleless injector and Alcian Blue dye. Captured fish were marked the first two days, allowed to mix the third day, and seined on the fourth day to determine the ratio of marked to unmarked fish. Population and 95 percent confidence interval (95% CI) estimates are rounded off to the nearest 10. Three estimates were conducted during the summer.

Growth Estimates - Fork lengths (mm) were measured from 200 each of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*), and weight (g) measurements were taken from 30 juveniles of each species. Other salmonid species, coastal cutthroat trout (*O. clarki*) and coho salmon (*O. kisutch*), though not as numerous as chinook or steelhead, are also measured. Four growth estimates were done, three in conjunction with the population estimates, and one day later in the fall.

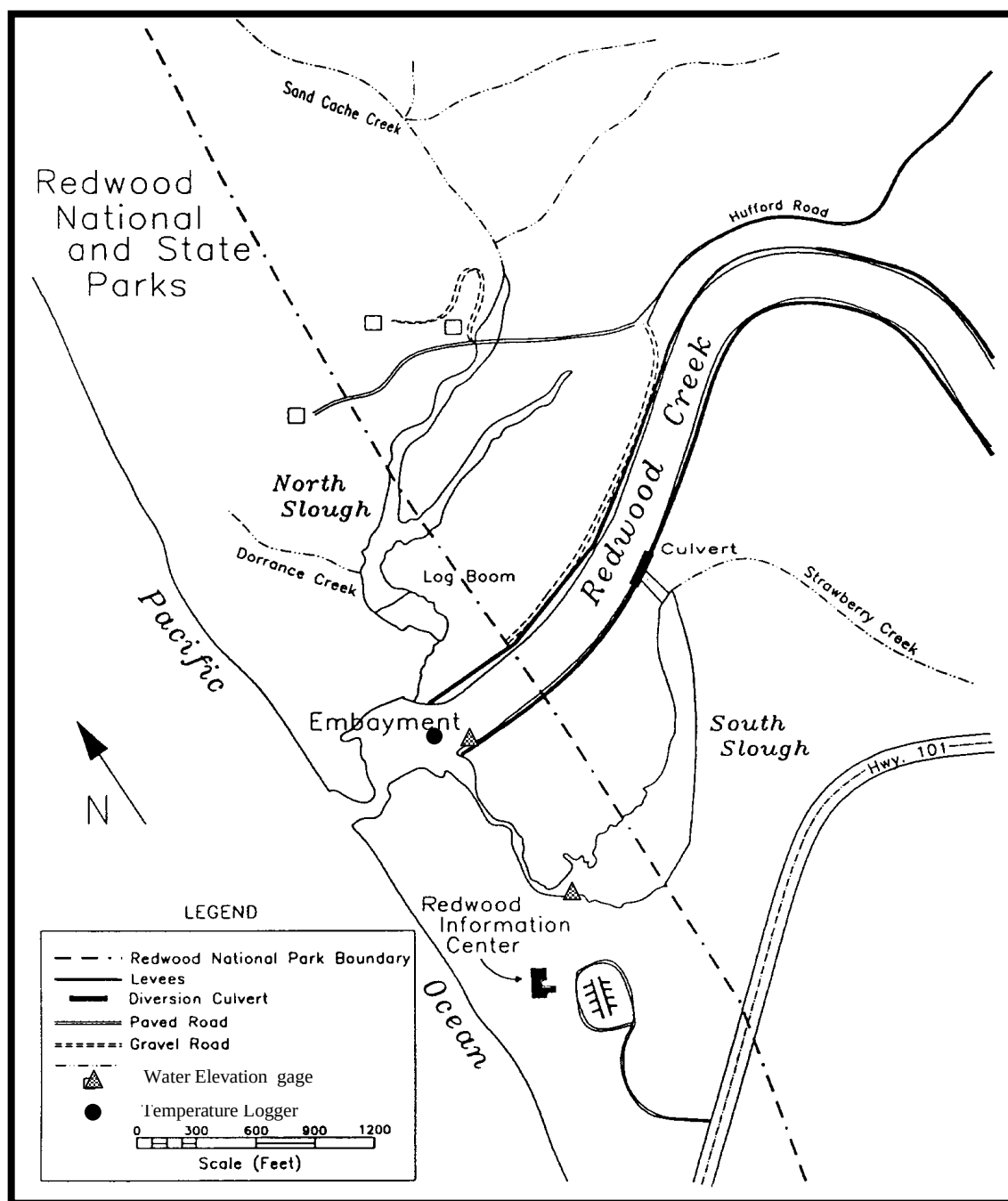


Figure 1. Map of the Redwood Creek Estuary, Humboldt County, California, including the embayment, north and south sloughs, and location of water elevation gages and temperature logger.

Water Quality Monitoring

Water Temperature - Water temperature (°C) was measured in the Redwood Creek embayment. A Onset TIDBIT™ temperature logger was located in the middle of the Redwood Creek channel between the ends of the north and south flood control levees at one foot or less from the bottom (Figure 1). It recorded water temperature once every hour. Temperature monitoring is special condition # 8 of the Corps permit. Dissolved oxygen (mg/l) and temperature (°C) was measured between the ends of the levees in the channel at one foot intervals with a YSI Model 57 oxygen meter in October.

Tide and Stream Flow Data

Tide Data: Calendar year 2000 tide data for the mouth of Redwood Creek was compiled from Crescent City Harbor, California tide data. It was corrected for the locality of the mouth of Redwood Creek [$CC\ tide \times 0.98$] and transformed to feet Mean Sea Level (MSL) [$tide - 3.65 = ft\ MSL$].

Stream Flow Data: Hourly Redwood Creek flow data at Orick for calendar year 2000 was downloaded from the California Department of Water Resources, Division of Flood Management website (<http://cdec.water.ca.gov>). Water Resources has not yet reviewed the preliminary flow data for accuracy. The Orick gaging station (ORK) is located on Redwood Creek downstream of the confluence of Prairie Creek just north of the community of Orick. Maintaining daily records of water flows in Redwood Creek is special condition # 3 of the Corps permit.

Estuary Water Levels

South slough water elevations (feet Mean Sea Level [MSL]) were recorded at 30-minute intervals by a continuous recording gage using a pressure transducer and ENMOS logger. The gage site is located at the end of the Redwood Information Center boardwalk trail (Figure 1). A seasonal gage site was installed at the end of the south slough levee to measure the water elevation in the estuary embayment. The south levee gage, a Global Water WL-14 Water Level Logger, measured embayment water levels every 10-minutes. The embayment site measures lower water elevations (to approximately -1 ft MSL) than the gage in the south slough. Low water levels in the south slough are limited by the invert of the south slough culvert gates and sand deposited in the south slough outlet channel. Water elevation monitoring is special condition # 3 of the Corps permit.

Estuary Cross Sections

As a special condition # 6 of the Corps permit, five permanent cross-sections in the main embayment of the estuary perpendicular to the flow were surveyed. Established in 1998 and located along the base of the hill, the northside cross section endpoints are buried 8 ft t-bar fence posts, or monumented partially buried sea-stacks. The permanent endpoints are surveyed and referenced to a BLM benchmark located at the park boundary fence separating the pasture from the parking area adjacent to the north levee. Each cross section was shot at a bearing of 170° using a Sokkisha Set 4 Total Station. A diver with a rod and prism took measurements in the embayment at breaks in slope. Transects were measured to at least 11ft MSL in elevation.

Sand Berm Elevation Monitoring

Special condition #4 of the Corps permit specified a survey of sand berm elevations parallel to the shore, along the highest ridge of the sand dunes, once per month from May to September. The survey extended from a minimum of 100 feet north of the estuary to 100 feet south of the Redwood Information Center (RIC), approximately 3,000 ft in length. Surveys were conducted with a Sokkisha Set 4 Total Station and rod with prism. Measurements were taken at breaks in slope along the sand berm. Survey elevations were referenced in the south to *Melch* 3, a permanent NOAA benchmark located west of RIC, to the end of the RIC west boardwalk, and in the north to the BLM benchmark, and the western most estuary cross-section endpoint, RM2 (a.k.a. E-5).

***Corophium* Monitoring**

Special condition #8 of the Corps permit specified *Corophium* abundance be documented prior to and one week after a planned breaching event. No diver transects were conducted in 2000 as the mouth unexpectedly breached naturally.

Other Activities

Coastal Cutthroat Trout Sonic Tagging

During the week of July 17, 2000, USFS Redwood Sciences Laboratory personnel (Rod Nakamoto and Jason White) placed sonic tags in the body cavity of four coastal cutthroat trout. They tracked the fish till September 22 (Nakamoto 2000).

Adipose Clipped Pit-tagged Coho Salmon and Cutthroat Trout

Humboldt State Fisheries Coop graduate students pit-tagged adipose clipped coho salmon juveniles in Prairie Creek and coastal cutthroat trout in Boyes, Streelaw, and upper Prairie Creek the previous fall. With their assistance and equipment, we looked for tagged coho smolts and cutthroat in the estuary seine hauls.

2000 Results

Fish Monitoring

Presence – During the summer and fall of 2000, four salmonid species were seined in the Redwood Creek embayment; chinook and coho salmon, and steelhead and coastal cutthroat trout. Unlike other years, no half-pounder or adult sized steelhead were captured. Eight other fish species were captured. One amphibian, 17 bird, and 3 mammal species were observed. A complete list of all fish and other species captured or observed in and around the Redwood Creek estuary is presented in Table 1. No tidewater gobies (*Eucyclogobius newberryi*) were found in the estuary (Anderson 2000).

Population Estimates -Three population estimates were conducted in the embayment the summer of 2000 during the weeks of June 5, July 17, and September 11, 2000 (Table 2). The number of fish and location of marks are presented in Appendix II.

Table 1. List of salmonid and non-salmonid fish seined, birds, amphibians, and mammals observed at the Redwood Creek estuary, Redwood National and State Parks, Humboldt County,

California during summer/fall 2000 sampling.

	2000 Date (Week of)			
	June 5	July 17	Sept 11	Oct 26
Salmonid Fish				
Coastal Cutthroat Trout	X	X	X	X
Steelhead Trout	X	X	X	X
Chinook Salmon	X	X	X	X
Coho Salmon	X		X	
Non-Salmonid Fish				
Three Spine Stickleback	X	X	X	X
Surf Smelt	X			
Night Smelt	X			
Shiner Surfperch	X			
Staghorn Sculpin		X	X	X
Prickly Sculpin	X	X	X	
Sucker			X	
Starry Flounder		X	X	
Amphibians				
Pacific Tree Frog			X	
Birds				
Brown Pelican		X	X	X
Double Crested Cormorant		X	X	
Turkey Vulture	X	X	X	
Osprey	X	X	X	
Western Sandpiper			X	
Killdeer	X	X	X	
Sanderlings			X	
Heerman Gull		X	X	
Western Gull	X	X	X	X
California Gull				X
Caspian Tern	X	X	X	
Cliff Swallow	X	X		
Barn Swallow	X	X		
Corvids (Crows and Ravens)		X	X	
Wood Duck			X	
Geese (White Fronted?)				X
Merganser		X		
Mammals				
River Otter	X		X	
Bairds Beaked Whale (Dead)			X	
Gray Whale (Decomposing)	X	X	X	X

Table 2. Population estimates and 95 percent confidence intervals for juvenile chinook and coho salmon, juvenile steelhead trout, and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, summer 2000. Mouth of creek denotes if Redwood Creek mouth was open or closed to the Pacific Ocean during the estimate.

2000 DATE	Mouth of Creek (Open or Closed)	Chinook Salmon		Coho Salmon	
		Population Estimate	95% Confidence Interval	Population Estimate	95% Confidence Interval
06/05, 06, 08	OPEN	55,640	37,930 – 73,360	1,390	760 - 2,020
07/17, 18, 20	CLOSED	18,350	490 ^a – 38,840	---	---
09/11, 12, 14	CLOSED	2,910	1,960 – 3,860	2 ^b	---
		Steelhead Trout		Cutthroat Trout	
06/05, 06, 08	OPEN	12,780	9,820 – 15,740	550	160 - 940
07/17, 18, 20	CLOSED	8,950	1,310 - 16,590	40	13 ^a - 110
09/11, 12, 14	CLOSED	4,270	3,780 – 4,760	220	42 ^a - 490
a. Actual minimum count, calculated 95% lower interval was below what was actually caught					
b. Actual count of fish captured in seine net hauls. No marked fish were recaptured.					

The first juvenile chinook salmon estimate, the week of June 5, was 55,640 (95% Confidence Interval [CI] 37,930 to 73,360). On July 17, the population had decreased to 18,350 (95% CI 490 to 38,840). The CI was poor because only three marked fish were recaptured. On September 11, the population had declined to 2,910 (95% CI 1,940 to 3,860).

The initial juvenile steelhead trout estimate the week of June 5 was 12,780 (95% CI 9,820 to 15,740). The population decreased to 8,950 (95% CI 1,310 to 16,590) on July 17. The CI was poor because only five marked fish was recaptured. The population further decreased to 4,270 (95% CI 3,780 to 4,760) on September 11.

A large number of coho salmon smolt, 278, were captured the first sample week of June 6. None were captured the week of July 17, and two were captured the week of September 11. Though not a population estimate, no coho were captured on October 26, the later growth estimate. A population of 1,390 coho smolt (95% CI 760 to 2,020) were estimated to be in the embayment on June 5.

A total of 182 coastal cutthroat trout were captured; 120 in June, 13 in July, 42 in September, and 7 in October. The initial cutthroat population estimate the week of June 5 was 550 (95% CI 160 to 940). The estimate for July 17 was 40 (95% CI 13 to 110). The estimate was poor because only 1 marked fish was recaptured. The estimate for the week of September 11 was 220 (95% CI 42 to 490).

Growth Estimates – Four growth estimates were conducted; three in conjunction with population estimates during the weeks of June 5, July 17, and September 11, and a fourth on October 26, 2000 (Table 3). The fourth growth estimate was three days before the estuary breached and represents the mean size at which they migrated into the ocean.

Chinook salmon mean fork length increased from 72 to 111 mm, an increase of 39 mm, between the June and October sample dates (144 days). Minimum and maximum chinook fork lengths ranged between 49 and 134 mm during summer and fall. Mean weight rose from 4.3 to 14.5 g, an increase of 10.2g between June and October. Minimum and maximum chinook weights ranged between 1.3 and 20.5 g during summer and fall.

Coho salmon smolt mean fork length from the week of June 5 was 108 mm (n = 176). On September 11, two coho were captured with a fork length of 100 and 142 mm. Minimum and maximum fork length ranged between 60 and 142 mm during the summer. Mean weight the week of June 5 was 14.8 g, and on the September 11, 22.5 g. Minimum and maximum weights ranged between 9.5 and 32.8 g.

Steelhead trout mean fork length increased one millimeter from 126 to 127mm, between June and October. Minimum and maximum fork length ranged between 53 and 191 mm during the summer and fall. Large standard deviations and length ranges indicate several age classes were present. Mean weight increased 7.4 g, from 22.8 to 30.2 g. Minimum and maximum weights ranged between 1.4 and 70.4 g.

Table 3. Mean fork length (mm), mean weight (g), standard deviation, range, and dates and numbers sampled of juvenile chinook and coho salmon, and steelhead and coastal cutthroat trout seined in the Redwood Creek estuary embayment, Humboldt County, California, during summer and fall sample dates of 2000. Mouth denotes if Redwood Creek mouth was open or closed to the ocean.

Redwood Creek Estuary –Summer/Fall 2000							
2000 DATE	MOUTH	Mean Fork Length (mm) (No. Measured)	Std. Dev. (mm)	Range (mm)	Mean Weight (g) (No. Weighed)	Std Dev. (g)	Range (g)
JUVENILE CHINOOK SALMON							
06/05	OPEN	72 (199)	9.0	49 - 95	4.3 (33)	1.5	1.3 - 6.7
07/17, 18, 20	CLOSED	74 (209)	6.8	52 - 91	4.8 (30)	1.1	2.4 - 7.3
9/11, 12	CLOSED	94 (203)	5.0	76 - 105	9.1 (30)	1.1	6.7 - 11.5
10/26	CLOSED	111 (98)	6.3	90 - 134	14.5 (30)	3.0	7.2 - 20.5
JUVENILE COHO SALMON							
06/05, 06, 08	OPEN	108 (176)	10.7	60 - 139	14.8 (46)	3.9	9.5 - 27.9
07/17, 18, 20	CLOSED	---	---	---	---	---	---
09/11	CLOSED	121 (2)	29.7	100 - 142	22.5 (2)	14.6	12.1 - 32.8
10/26	CLOSED	---	---	---	---	---	---
JUVENILE STEELHEAD TROUT							
06/05	OPEN	126 (201)	18.5	83 - 177	22.8 (33)	10.8	8.0 - 53.3
07/17, 18, 20	CLOSED	99 (202)	32.7	53 - 185	9.1 (30)	7.2	1.4 - 26.4
09/11	CLOSED	127 (220)	27.0	70 - 177	21.4 (30)	13.3	4.2 - 53.6
10/26	CLOSED	127 (94)	31.3	80 - 191	30.2 (30)	20.6	6.2 - 70.4
CUTTHROAT TROUT							
06/05, 06, 08	OPEN	182 (120)	43.1	128 - 386	67.9 (119)	58.4	20.0 - 302.1
07/18, 20	CLOSED	239 (13)	66.5	123 - 339	180.3 (13)	134.1	41.6 - 448.0
09/11, 12, 14	CLOSED	261 (42)	45.7	197 - 394	220.8 (42)	152.6	79.1 - 821.0
10/26	CLOSED	276 (7)	30.2	230 - 306	135.7 (2) ^a	12.8	126.6 - 144.7
a. Larger fish exceeded the capacity of the 200g balance.							

Cutthroat trout mean fork length increased from 182 to 239 to 261 to 276 mm for June to July to September to October, respectively, an increase of 94 mm. Throughout the summer and fall, cutthroat trout fork length ranged from 123 to 394 mm. During the period June through September, mean weight increased from 67.9 to 180.3 to 220.8g. The October weight of 135.7 g is biased as 5 of 7 fish captured exceeded the 200g balance capacity. During the summer and fall, weight ranged between 20.0 and 821.0 g.

Water Quality Monitoring

Water Temperature - In 2000, water temperature (°C) was the only water quality parameter monitored continuously in the Redwood Creek estuary. The TidBit temperature logger recorded water temperature every 1-hour from June 21 through October 19, 2000 (Figure 2). The maximum and minimum water temperatures were 21.9°C (on June 26) and 13.6°C (on September 28 and October 8), respectively. The average water temperature for the period of was 17.1°C. Percent temperature exceedence is shown in Table 3. Water temperature between June 21 and October 19 exceeded 14°C 99 percent of the time. Water temperatures exceeded 20°C 1.4 percent of the time, and 21°C 0.4 percent of the time. Exceedence percentages at higher temperatures decreased from June on.

For the sampling period June 21 through June 26, when the estuary embayment was subject to tidal influence, water temperature ranged between 14.5 and 22°C during a tidal cycle. When the mouth closed, daily fluctuations were much less (Figure 2.)

Table 3. Percent of time water temperature (°C) exceeded or equaled temperature value in the Redwood Creek estuary embayment, Humboldt County, California, during June 21 through October 19, 2000. Temperatures recorded by an Onset Tidbit temperature logger.

Month YR 2000	Redwood Creek Estuary										
	Percent of Time Water Temperature (°C) Exceeds or Equals Temperature Value										
	≥12	≥13	≥14	≥15	≥16	≥17	≥18	≥19	≥20	≥21	≥22
June 21-30	100	100	100	96.5	75.1	57.6	45.9	26.6	14.8	5.2	0
July 1-31	100	100	100	100	94.4	61.6	21.0	1.3	0.4	0	0
August 1-31	100	100	100	100	99.7	82.0	39.0	3.9	0.4	0	0
September 1-30	100	100	98.6	93.6	90.1	70.8	32.8	3.5	0	0	0
October 1-19	100	100	95.3	41.3	17.0	10.5	4.9	0	0	0	0
Jun 21 to Oct 19	100	100	99.0	89.0	81.2	60.9	28.1	4.3	1.4	0.4	0

On October 26, 2000 at 8:30 am when the sun was rising, dissolved oxygen (mg/l) and water temperature (°C) were measured in the channel between the ends of the levees. Measurements were taken at the surface and at one-foot intervals to the bottom.

Depth (Feet)	Surface	1	2	3	4	5	6	6.5
DO ₂ (mg/l)	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.8
Temperature (°C)	8	8	8	8	8	8	8	8

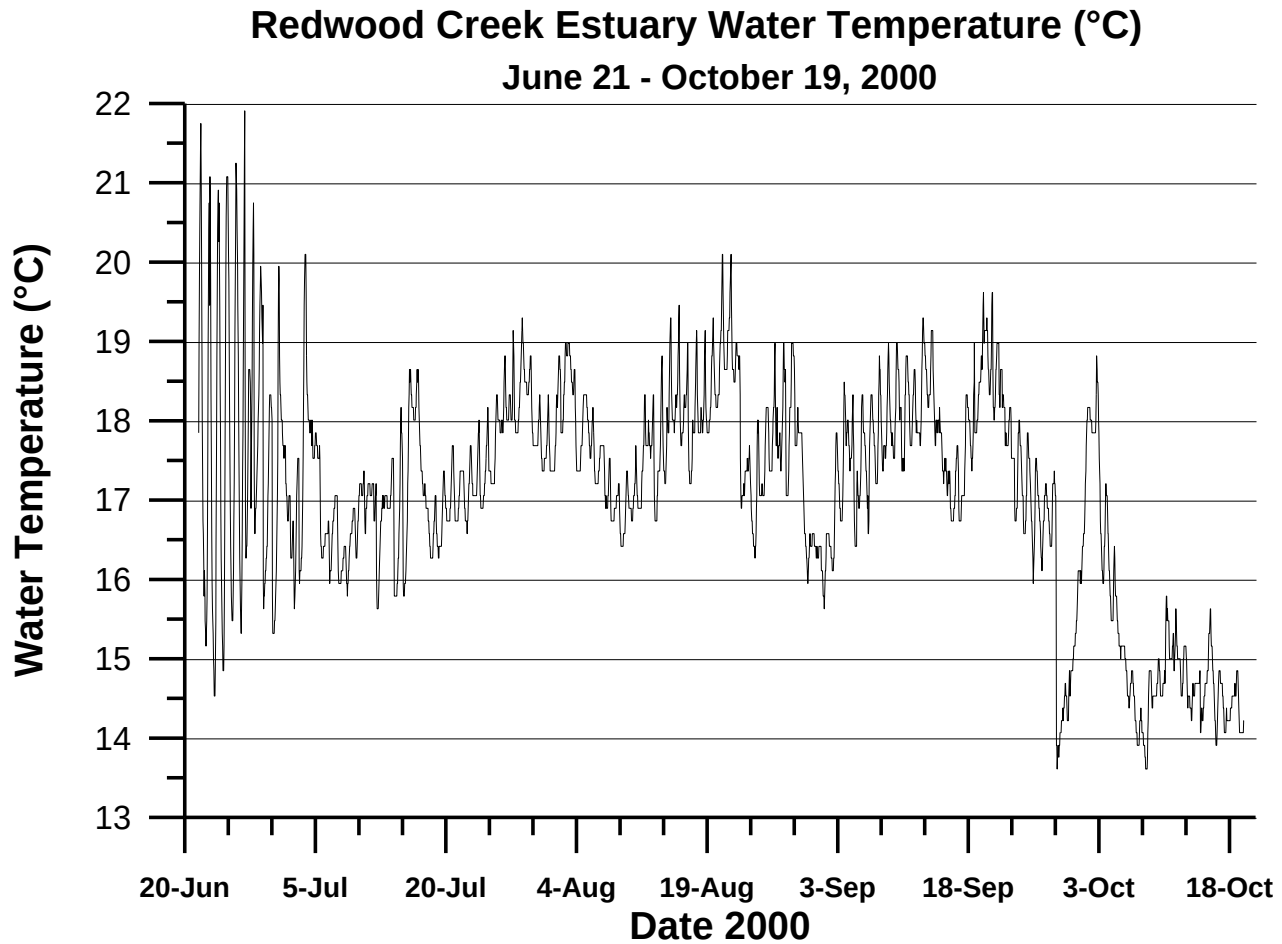


Figure 2. Redwood Creek estuary water temperatures (°C) measured by an Onset Tidbit temperature logger located in the embayment between the ends of the north and south flood control levees. The temperature logger, located one foot from the bottom, recorded water temperature every 1-hour from June 21 through October 19, 2000.

Tide and Stream Flow

Tides at the Mouth of Redwood Creek - The maximum and minimum calculated tide at the mouth was 4.9 ft MSL and -5.9 ft MSL, respectively, a range of 10.8 feet. Tidal data is included in Figure 3).

Stream Flow - Calendar year 2000 stream flow data, January 1 through December 31, is presented in Appendix III. The maximum flow was 20,413 cfs on January 11, 2000. The gage measured a minimum flow of 11 cfs during the summer, but was unable to measure lower flows. No streamflow events occurred between late June and late October.

Estuary Water Level

South Slough and South Levee/Embayment Water Level Gaging

South slough water elevations (feet MSL) were recorded for the period January 1 to December 31, 2000, excluding February 23 through 29, 2000 (Figure 3). A temporary south levee gage was installed on July 13 and removed on November 30. Because of what later turned out to be a faulty download cable, we were only able to retrieve data for July 13 to August 22, August 25 to 28, September 14 to 16, and October 6 through November 30, 2000 (Figure 4). Based on south slough and embayment water elevation data, with the south slough culverts open, the lowest slough elevation was limited to about 3 ft MSL. With the culverts closed, the lowest south slough elevation was 4.5 ft MSL. The culvert openings are lower than the south slough channel thalweg. With the culverts closed, sand in the neck of the slough limits the water circulation between the embayment and the slough. The lowest embayment water elevation, 0.8ft MSL, was lower than those in the south slough.

The estuary water level began to rise on June 27 in conjunction with channel migration to the south. Based on observations of the mouth, it was open on July 12, but closed from July 17 through July 20. Water started flowing down the old channel on July 20. The water level peaked at 8.6 ft MSL on July 21 and 22. The mouth was reported open on July 22 and 25. Subsequent observations reported the mouth closed on August 10 till it breached on October 29, a closure of at least 81 days. Once closed, the water level gradually decreased from 7.4 ft to 5.3 ft MSL due to seepage through the berm and water evaporation. From June 27 to October 29, the estuary provided 125 days of increased rearing volume to salmonid fish utilizing the embayment and south slough.

After late September, there are three distinct increases in the water level preceding the natural breach. (Figure 3). These are associated with the corresponding series of extreme high tides. Waves washing over the berm at high tides would raise the water level. Water would seep out through the berm, and the pattern would repeat again at the next series of extreme high tide.

Breaching and Estuary Response

The estuary breached naturally on October 29, 2000 at 9:30 p.m. at a height of 9.5 ft MSL (Figure 4). A small flow event, the first of the season, was the cause. Redwood Creek flow rose from 19 cfs on October 29 to 224 cfs when the breach occurred (Appendix III). The event peaked at 390 cfs, the next day, October 30. Almost 2.8 inches of rain in 43 hours was recorded at the ORK gage prior

South Slough Water Level and Tide 01/01/00 - 12/31/00

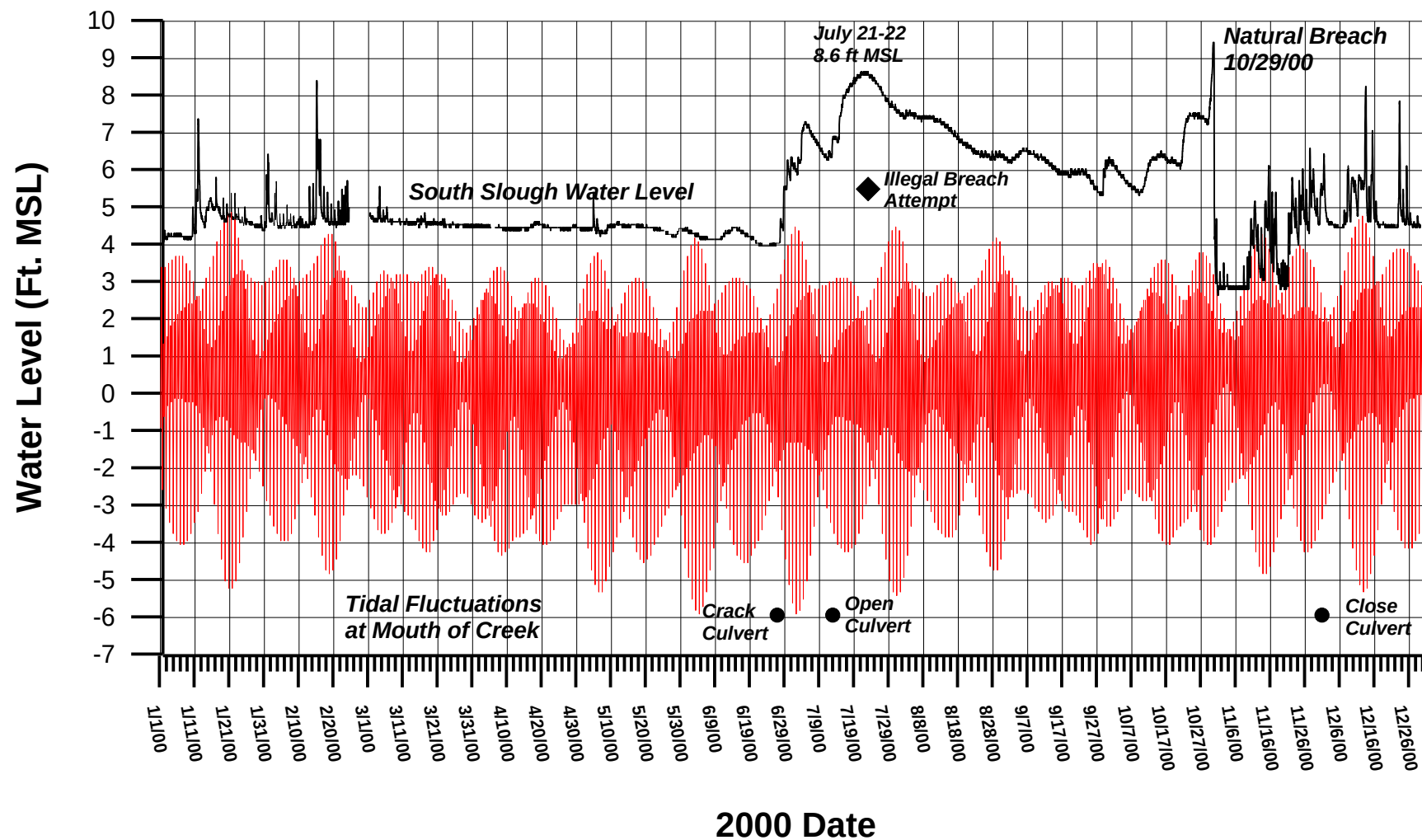


Figure 3. South slough water elevations (feet Mean Sea Level [MSL]) of the Redwood Creek estuary, Humboldt County for the period January 1 to December 31, 2000, excluding February 23 through 29, 2000. Estimated ocean tidal elevations are corrected for the coastal locality at the mouth of Redwood Creek and adjusted to feet MSL

Embayment Water Level Tides at the Mouth of Redwood Creek 07/13/00 - 11/30/99

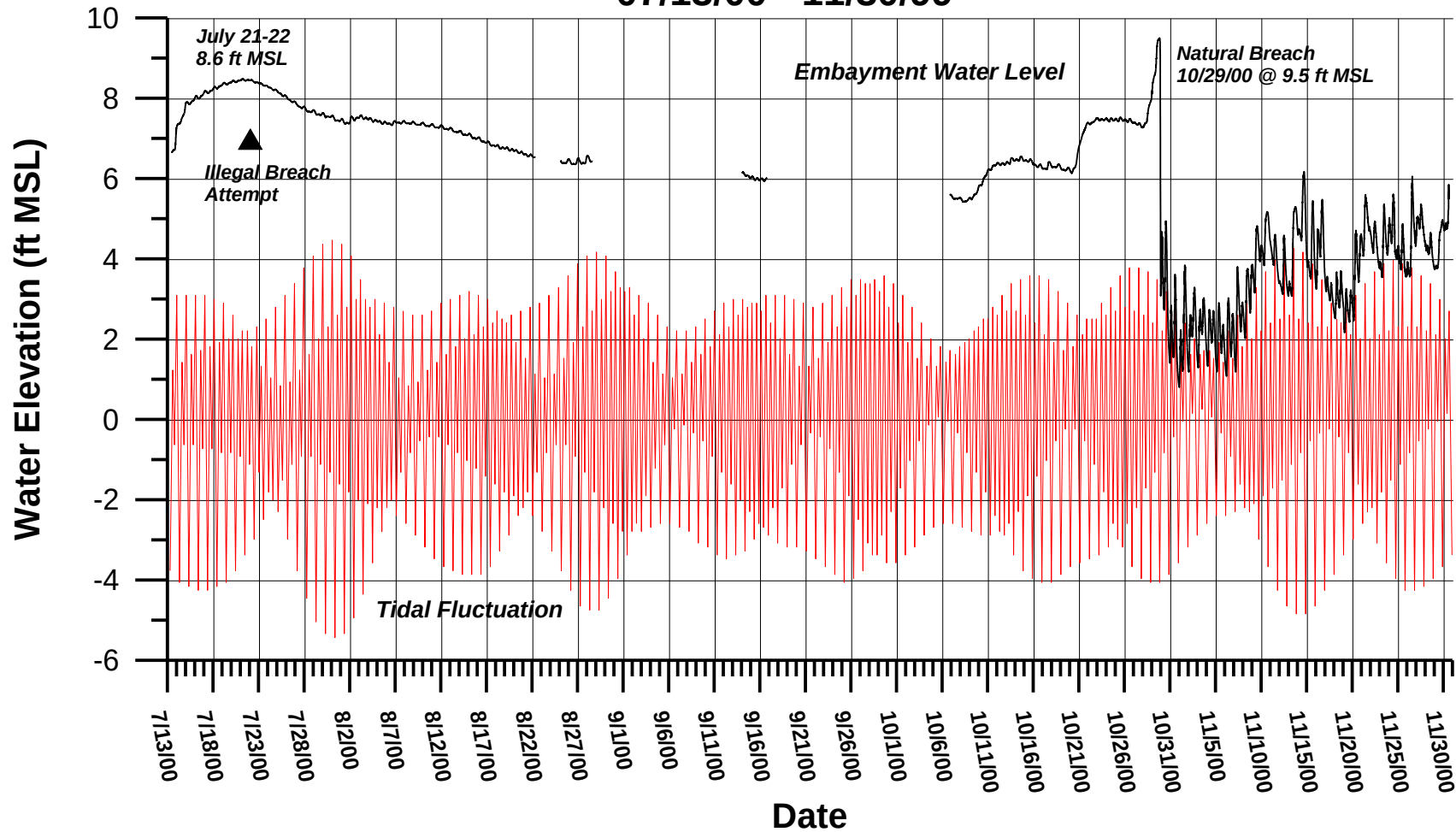


Figure 4. Embayment water elevations (feet Mean Sea Level [MSL]) for the Redwood Creek estuary, Humboldt County for the period the seasonal gage data was retrievable, July 13 to August 22, August 25 to 28, September 14 to 16, and October 6 through November 30, 2000. Estimated ocean tidal elevations are corrected for the coastal locality at the mouth of Redwood Creek and adjusted to feet MSL.

to the breach. By 11 p.m., after the breach started, the water level dropped fast, 1 foot every 10 minutes, from 8 ft at 11p.m. to 5 ft at 11:30 p.m.. The water level bottomed out at 3.1 ft at 12:10 am. The water level had dropped 6.4 ft in 2 hours and 40 minutes. That represents a volume loss of 2,366,000 ft³ (87,600 yd³) of water from the embayment (east of the berm to the ends of the levees), not including the volume upstream between the levees and the north and south sloughs. With tidal influence, the estuary water level dropped to a low of 0.8 ft MSL on November 1 at 1 am, a drop of 8.7 ft in two days, before increasing. Thereafter, water level was influenced by the tide, position and length of the mouth north of the estuary, the damming effect of the sea stacks in the channel, and small rain events (Figure 3 and 4).

Illegal Breaching Attempt – While seining on July 20, we observed water starting to flow down the old original southern channel and sink into the sand. By late afternoon, water was starting to fill the pool at the end of the channel. Before then, no water had been flowing into the channel. On the morning of Saturday July 22, while checking an arson fire at Hidden Beach north of the estuary, an illegal breach attempt was detected by a park firefighter. A hand-dug ditch at the narrowest part of the berm and perpendicular to the berm was present. He reported, however, the original channel was then flowing into the ocean. On Monday morning, July 24, the ditch which was about a shovel width wide and had very low flow, was filled in with sand by RNSP fishery biologists using shovels. The original natural channel to the south was shallow (<1ft deep) and had a few small (<1ft) standing waves. The estuary would have breached through the illegal ditch if not for the water flowing through the original channel.

This illegal breach attempt was probably associated with protests against the Parks' implementation of its new General Management Plan that week. The Park was installing gates at Freshwater Lagoon to restrict vehicle access to the beach. A person protesting the gates had also blocked the seining crew's access to the estuary for a short period of time.

South Slough Culvert Gates

The culvert gates are opened to increase circulation between the south slough and the embayment after the last storms of spring. The three south slough culvert gates were cracked open from 0.5 to 1 ft on June 26, 2000. Unlike other years, the embayment and slough were at the same water level as no water flowed through the culverts when the gates were opened. The gates were completely opened on July 12. The gates were closed on November 30, 2000 to prevent sedimentation in the south slough from large storm events.

Estuary Cross Sections

Five permanent parallel cross-sections (perpendicular to flow) in the embayment were surveyed on June 21 (cross sections E-2 through E-4) and June 26, 2000 (cross sections E-1 and E-5). Starting at the ends of the levees with E-1 and ending to the west with E-5 at the sea stack adjacent to the berm, the surveys extended south through the embayment to the sand dunes. They are surveyed annually as specified by the Corps permit. Estuary cross sections are presented in Appendix IV. The lowest bottom elevation (i.e. deepest point MSL) at E-1 was -1.17 ft, at E-2 -1.63 ft, at E-3 -1.46 ft, at E-4 -3.31, and at E-5 -2.54 ft. Based on the cross sectional data, at its greatest water elevation of 9.5 ft MSL, the deepest point in the embayment was 12.8 ft deep.

The net change (scour or fill) compared to 1999 cross sections were as follows: E-1 +61.0 ft², E-2

+431.5 ft², E-3 +39.6 ft², E-4 -367.4 ft², and E-5 +2,381.7 ft².

Also calculated for the embayment (excluding the north and south sloughs and the area of the embayment/channel upstream of the ends of the levees) was embayment volume (ft³) and wetted width for the cross sections for varying water elevations (Appendix V). The embayment volume ranged from 540 ft³ at -3 ft MSL to 4,177,581 ft³ at 11 ft MSL.

Sand Berm Elevation Monitoring

A longitudinal profile of the sand berm parallel to the ocean shore separating the estuary from the ocean was surveyed the required five times during the summer and fall of 2000, on May 30, June 26, July 25, August 28, and October 3, 2000. The longitudinal berm surveys, profiles 1 through 5, are presented in Appendix VI. Both the winter storm berm, denoted as the high berm, and summer swell berm, denoted as the low berm, were surveyed when present. Because of the depth of the channel and flow, it was not always possible to wade into and survey the channel bottom.

At May, June, and August surveys, the mouth was open to the ocean. On May 30, the low berm was not very developed. The water elevation at the right edge of channel was -0.3 ft MSL (see profile 1).

On June 26, the channel thalweg of the channel at the high berm was at -2.54 ft MSL, but the creek mouth at the ocean was -0.68 ft MSL. The channel was approximately 740 ft long between the high berm and the mouth of Redwood Creek (see profile 2). On July 25, the thalweg was 3.8 ft MSL at the mouth, and the water elevation was 7.99 ft MSL at the waters edge of the high berm (see profile 3). The channel was approximately 660 ft long between the high berm and the mouth of Redwood Creek.

On August 28, with the mouth closed, the water elevation at the high berm was 6.1 ft MSL and the lowest depression on the low berm was 5.9 ft MSL (see profile 4). By October 3, the beach had receded and the low berm was gone. The mouth was still closed and the embayment water elevation was at 5.81 ft MSL. The lowest depression on the lower high berm was 8.53 ft MSL, a difference of 2.72 ft (see profile 5). The lowest berm depression represents the height at which the estuary would naturally breach on its own. Even with the mouth closed, seepage through the berm into the ocean occurred.

The survey points plotted on 1 : 6000 aerial photos for each survey are presented in Appendix VII.

Other Activities

Adipose Clipped Pit-tagged Coho Salmon and Cutthroat Trout – During the week of June 6th, 19 adipose clipped pit-tagged coho smolts were captured. They were read by Steve Tussing (HSU-Fish Coop). The two coho smolts captured on September 11 were not adipose clipped. No adipose clipped pit-tagged cutthroat trout were captured in the estuary.

Conclusions

- Mean lengths and weights of chinook, coho, and cutthroat residing in the estuary increased during the summer indicating the estuary provided rearing habitat. However, steelhead mean lengths

remained about the same. Those fish that resided in the estuary during the summer and migrated to the ocean in the fall were larger than those that emigrated prior to the closure of the mouth. Their larger size would confer an increased chance of survival in the ocean (Reimers 1973).

- All fish populations decreased during the summer, mortality likely occurring as with the mouth closed, fish loss could not be attributed to migration into the ocean.
- Coho salmon did not rear in the estuary in mid-summer. We sampled the end of the coho smolt out migration in June as only two coho were captured later in the summer. This was similar to past years (Anderson 1995).
- The estuary provided 125 days of increased rearing volume to salmonid fish before a natural breach occurred on October 29, 2000 at a water elevation of 9.5 ft MSL. The breach caused the water level to drop 6.4 ft in 2 hours and 40 minutes.
- Based on three years of embayment cross section data, the embayment has not changed much since 1999, but its volume is less than that estimated in 1998 (Table 4).

Table 4. Calculated 1998, 1999, 2000 volume (ft³) of the Redwood Creek embayment at water elevations -3 to 11 ft MSL. Volume of the embayment is the area west of the ends of the north and south levee to the berm and not including the north or south sloughs.(Compiled from Anderson 1998 and 1999)

Water Elevation (ft MSL)	1998 Volume (ft3)	1999 Volume (ft3)	2000 Volume (ft3)
11	10,441,569	3,872,874	4,177,581
10	4,976,663	3,809,759	3,496,947
9	4,216,846	3,059,301	2,917,624
8	3,491,578	2,450,967	2,580,270
7	2,843,996	1,981,568	2,139,865
6	2,320,103	1,617,018	1,754,518
5	1,886,777	1,296,799	1,408,439
4	1,495,882	1,014,197	1,097,161
3	1,134,128	760,089	819,706
2	798,888	527,405	572,810
1	464,790	332,726	362,282
0	226,903	171,681	182,379
-1	53,794	63,343	57,126
-2		22,052	13,012
-3		5,733	540

- The berm profile surveys determined the high berm (winter berm) did not change between May and October unlike the lower berm profiles (Appendix VI high and low berm profiles 1-5). Location of the mouth changed as the channel migrated south and lengthened. Portions of the low berm

increased in height after closure of the mouth, but later when the beach receded, the low berm disappeared.

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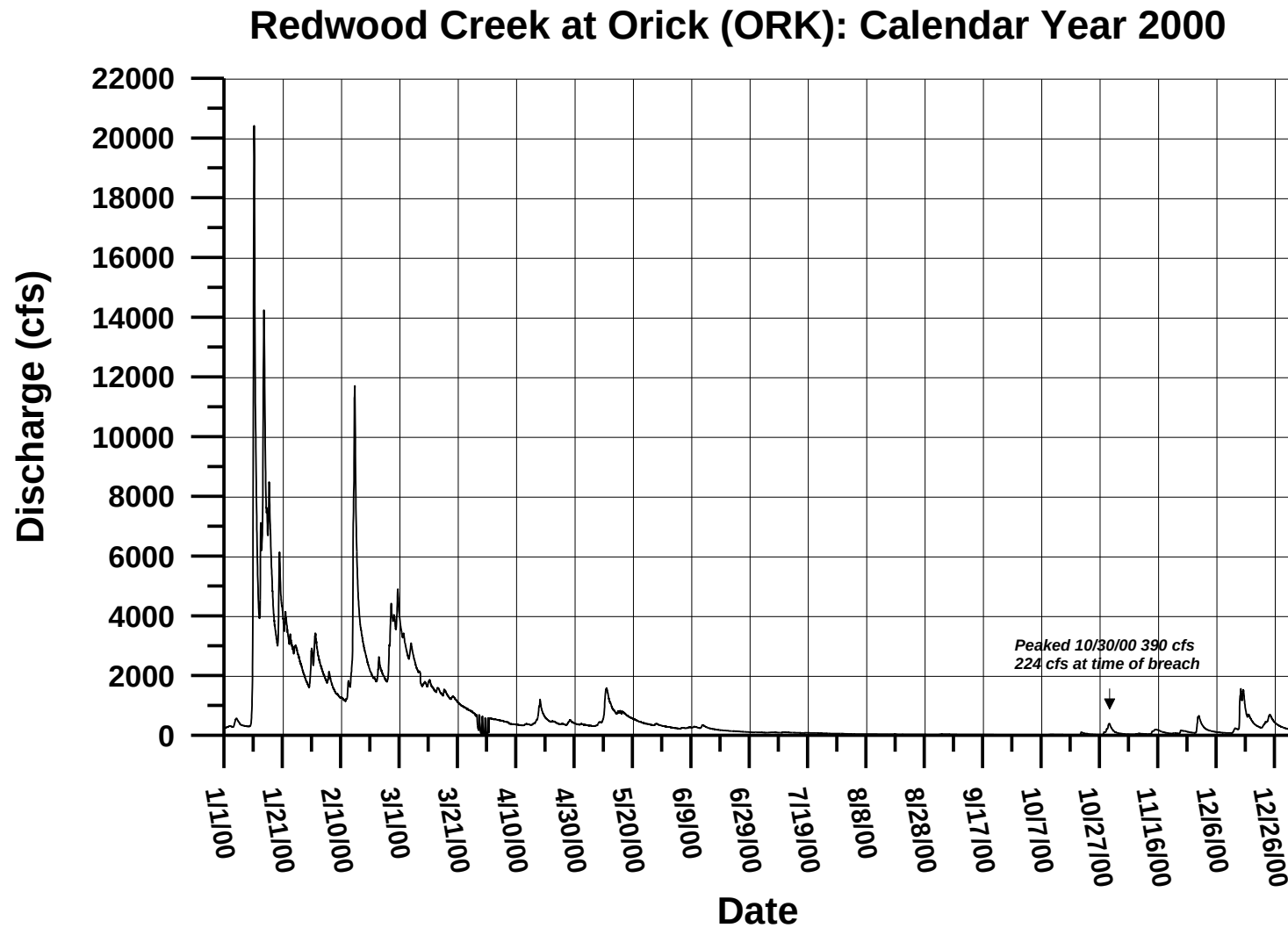
Prepared by: David G. Anderson – REDW Fishery Biologist
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(707) 464-6101 x 5271
[03/2001]

Appendix I. U.S. Army Corps of Engineers permit No. 21881N, effective until December 31, 2002. The permit authorizes the Redwood National and State Parks to breach the mouth of Redwood Creek. It includes eight special conditions.

Appendix II. Number of salmonid fish marked from the RNSP Redwood Creek estuary mark and recapture population estimates during the summer of 2000. Fish fins, top and bottom caudal, anal, and right pelvic fins were marked with a Panjet needleless injector using Alcian Blue dye. Mark appearance ranged from a blue dot to a pigment streak along the fin rays.

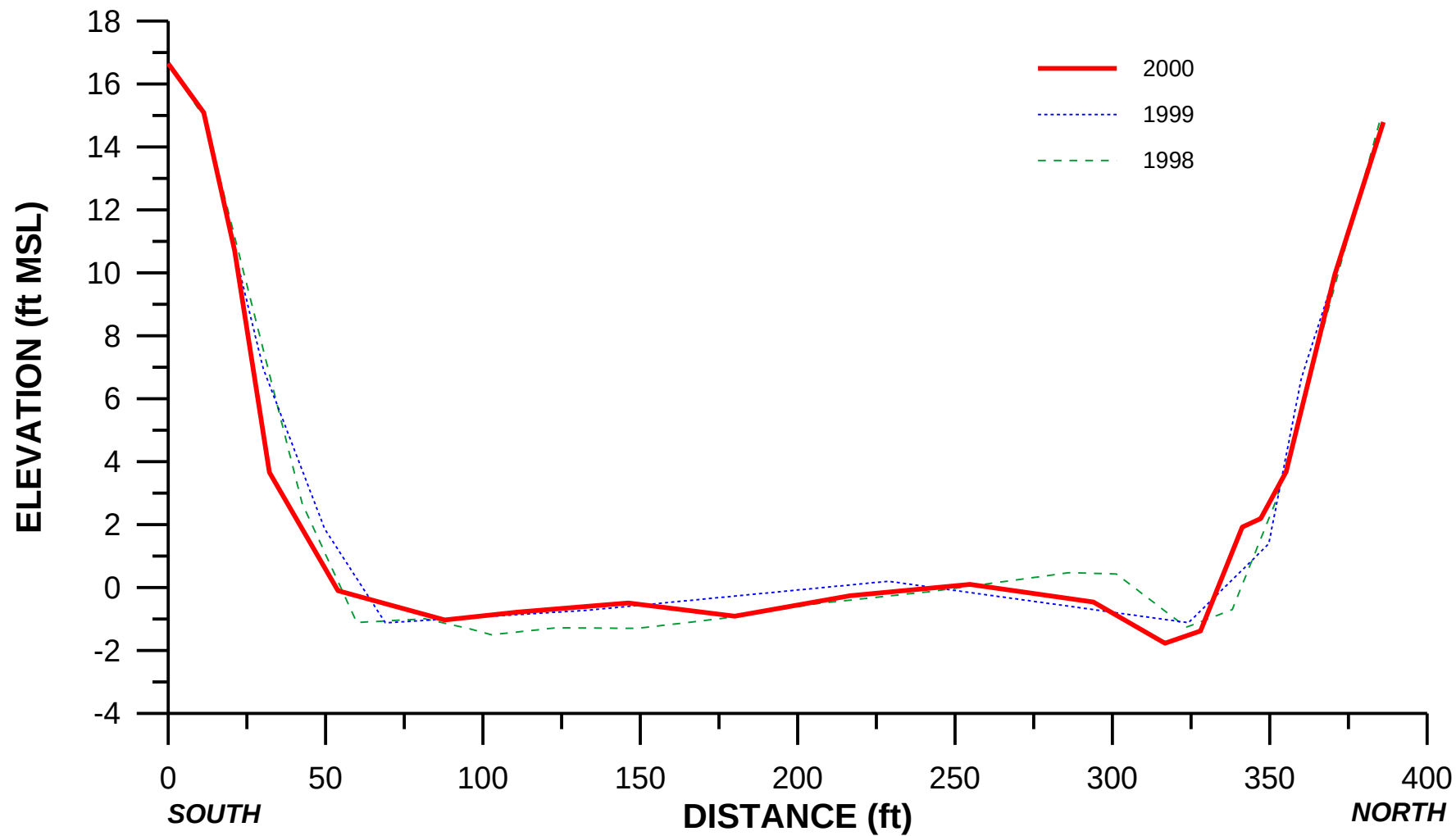
2000 Date	Fin Mark	Number Marked			
		Chinook	Coho	Steelhead	Cutthroat
June 5 & 6	Top caudal	1,359	172	1,040	89
July 17 & 18	Bottom caudal	322	0	136	4
Sept 11 & 12	Anal – KS and SHD Right Pelvic – CUT	353	2	1,040	29

Appendix III. Hourly Redwood Creek flow data for calendar year 2000, January 1 through December 31, 2000. Data is from the California Department of Water Resources Orick (ORK) gaging station located on Redwood Creek downstream of the confluence of Prairie Creek and north of the community of Orick, California.

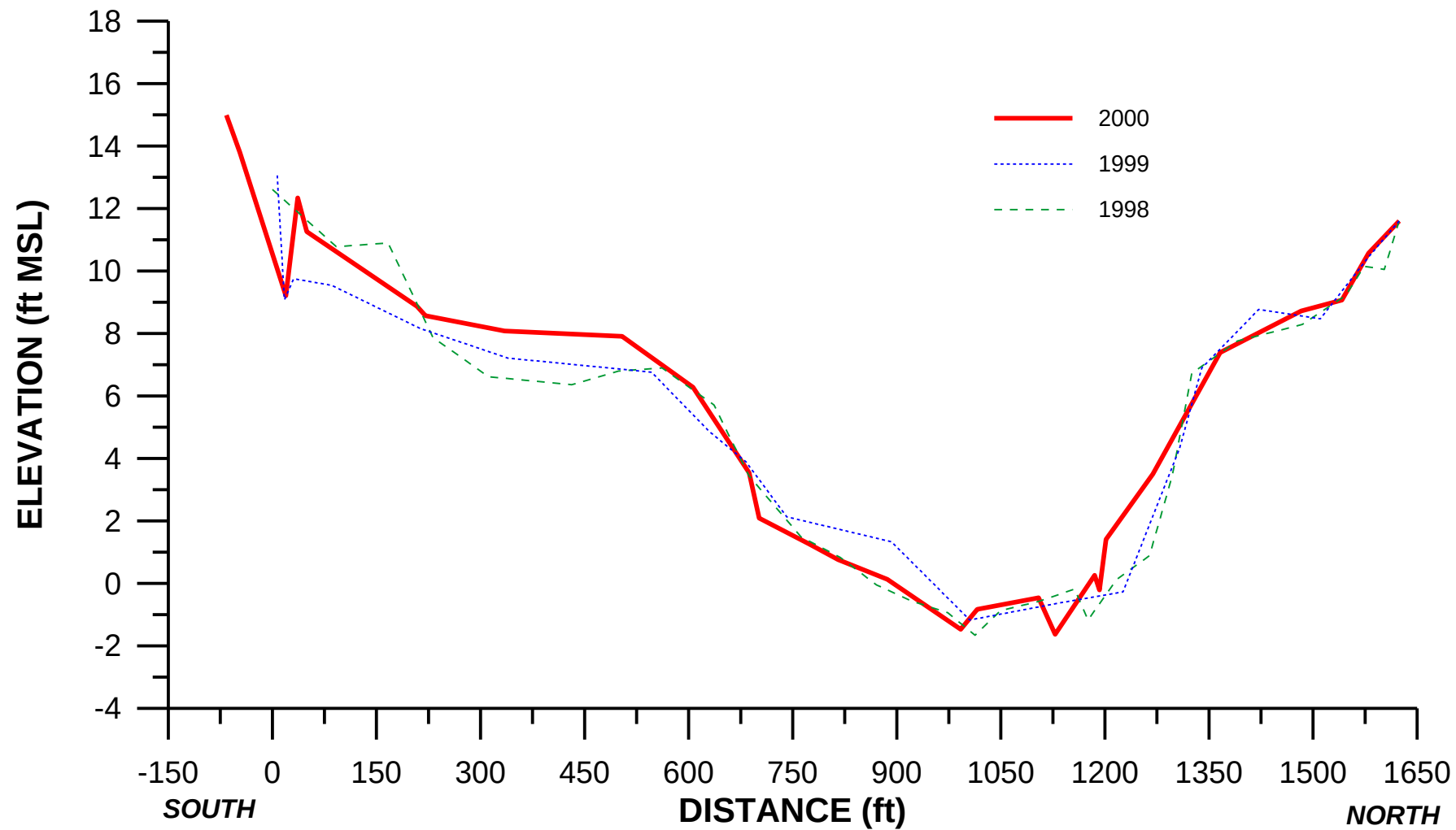


Appendix IV . The five permanent cross-sections surveyed on June 21 and 26, 2000 in the Redwood Creek estuary embayment perpendicular to the flow. Established in June of 1998, each cross section was shot at a bearing of 170° from the north endpoints through the embayment to the sand dunes on the south. The parallel cross sections start between the ends of the levees with E-1 and end to the west with E-5 at the seastack adjacent to the berm.

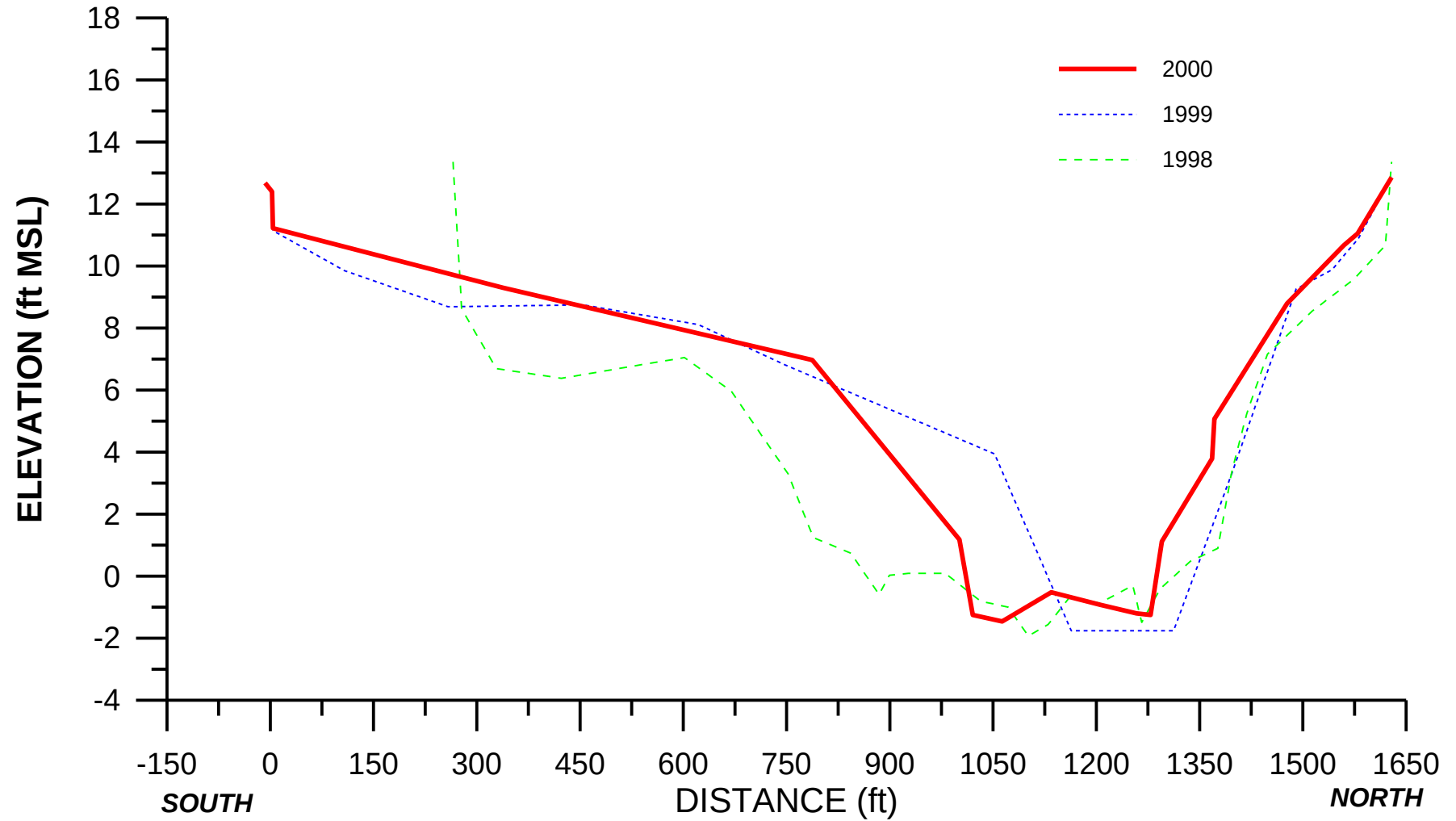
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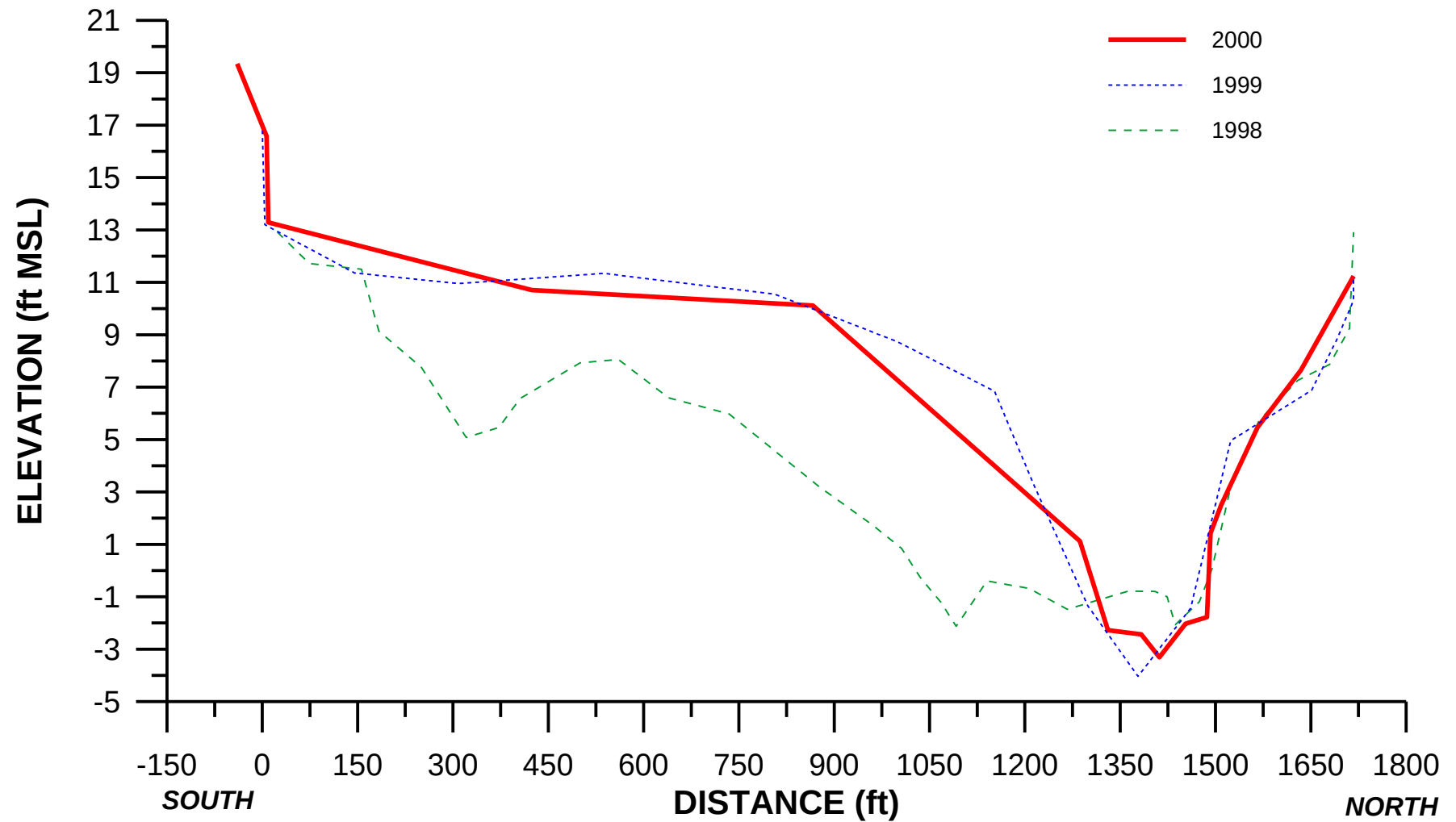
ESTUARY CROSS SECTION E-2



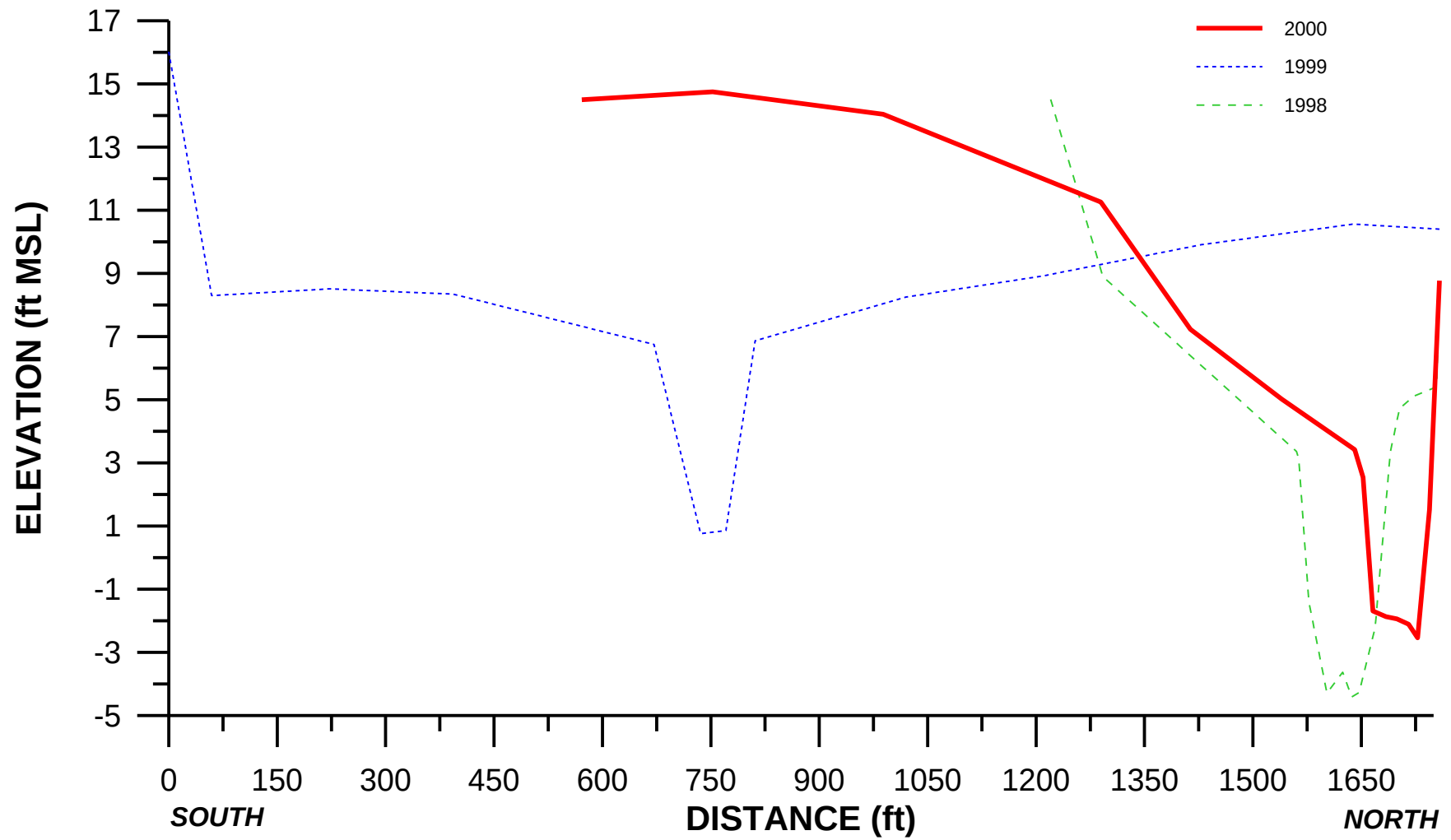
ESTUARY CROSS SECTION E-3



ESTUARY CROSS SECTION E-4



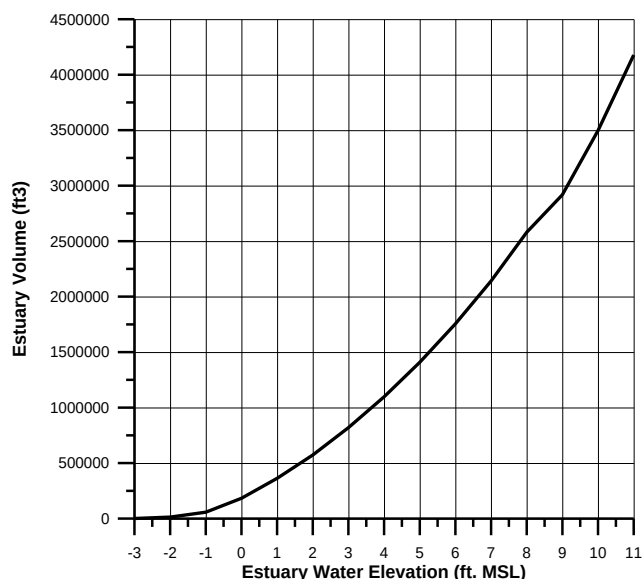
ESTUARY CROSS SECTION E-5



Appendix V. Calculated wet width (ft) and volume (ft³ and yd³) of the Redwood Creek embayment at water elevations of -3 to 11 ft MSL based of the five cross sections E-1 through E-5 surveyed on June 21 and 26, 2000. Volume of embayment is the area west of the ends of the north and south levee and not including the north or south outlet channels or sloughs.

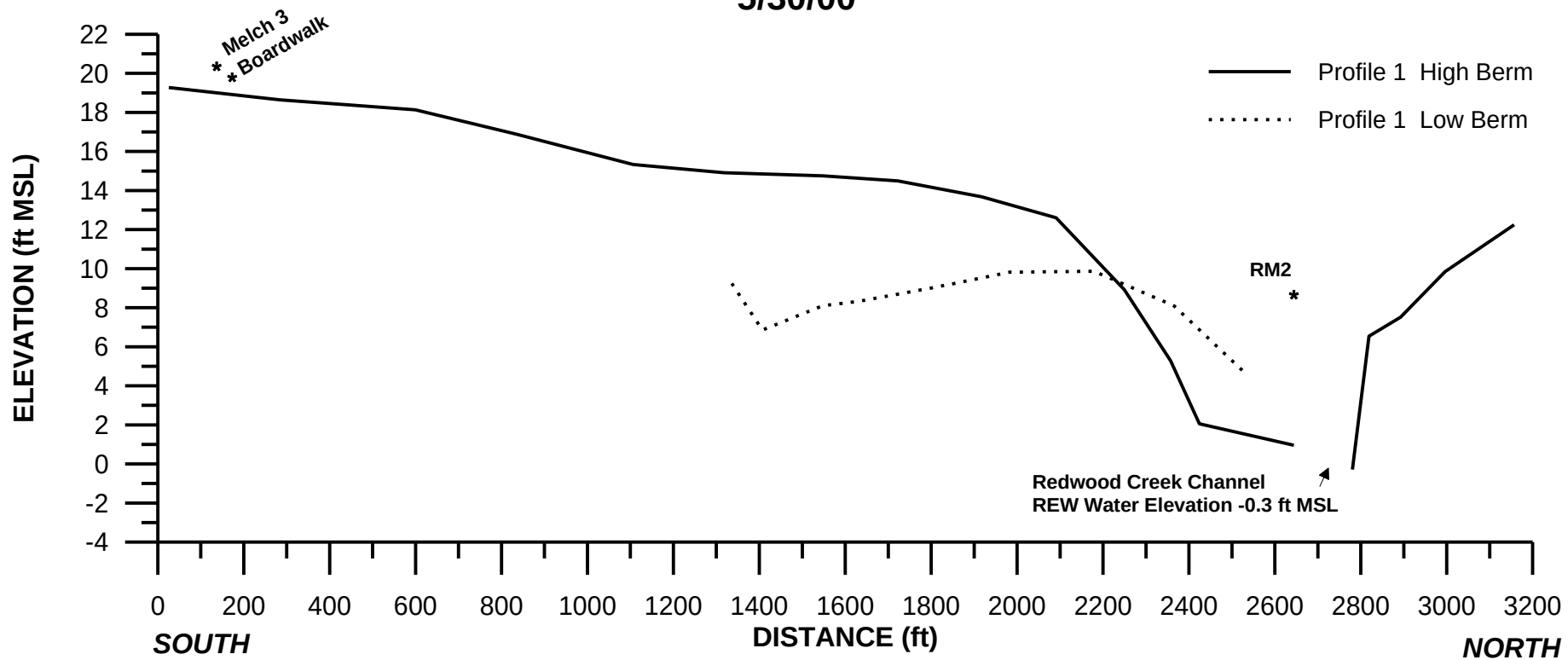
Width and Volume for Varying Water Elevations – Redwood Creek Estuary 2000							
Water Elev. (ft MSL)	X/S E1 Wet Width (ft)	X/S E2 Wet Width (ft)	X/S E3 Wet Width (ft)	X/S E4 Wet Width (ft)	X/S E5 Wet Width (ft)	Estuary Volume (ft ³)	Estuary Volume (yd ³)
11	353.58	1567.37	1534.91	1334.64		4,177,581	154,725
10	348.63	1448.01	1314.06	816.76		3,496,947	129,517
9	344.56	1330.28	1090.42	747.01		2,917,624	108,060
8	340.53	1005.50	865.87	677.26	366.72	2,580,270	95,566
7	336.50	795.46	644.58	602.18	327.98	2,139,865	79,254
6	332.48	717.12	574.64	524.12	269.00	1,754,518	64,982
5	328.45	662.55	511.18	451.73	209.91	1,408,439	52,164
4	324.42	607.98	471.63	385.74	144.90	1,097,161	40,636
3	315.59	560.35	412.65	319.75	100.87	819,706	30,359
2	301.29	511.17	348.49	255.63	91.21	572,810	21,215
1	290.05	403.69	291.97	203.22	84.99	362,282	13,418
0	262.69	286.72	277.04	188.51	77.74	182,379	6,755
-1	30.11	80.46	140.16	173.80	70.49	57,126	2,116
-2				129.79	25.22	13,012	482
-3				20.13		540	20

For Reference:
X/S e1 at end of Redwood Creek levees
X/S e5 near large sea stack on beach, X/S closest to ocean

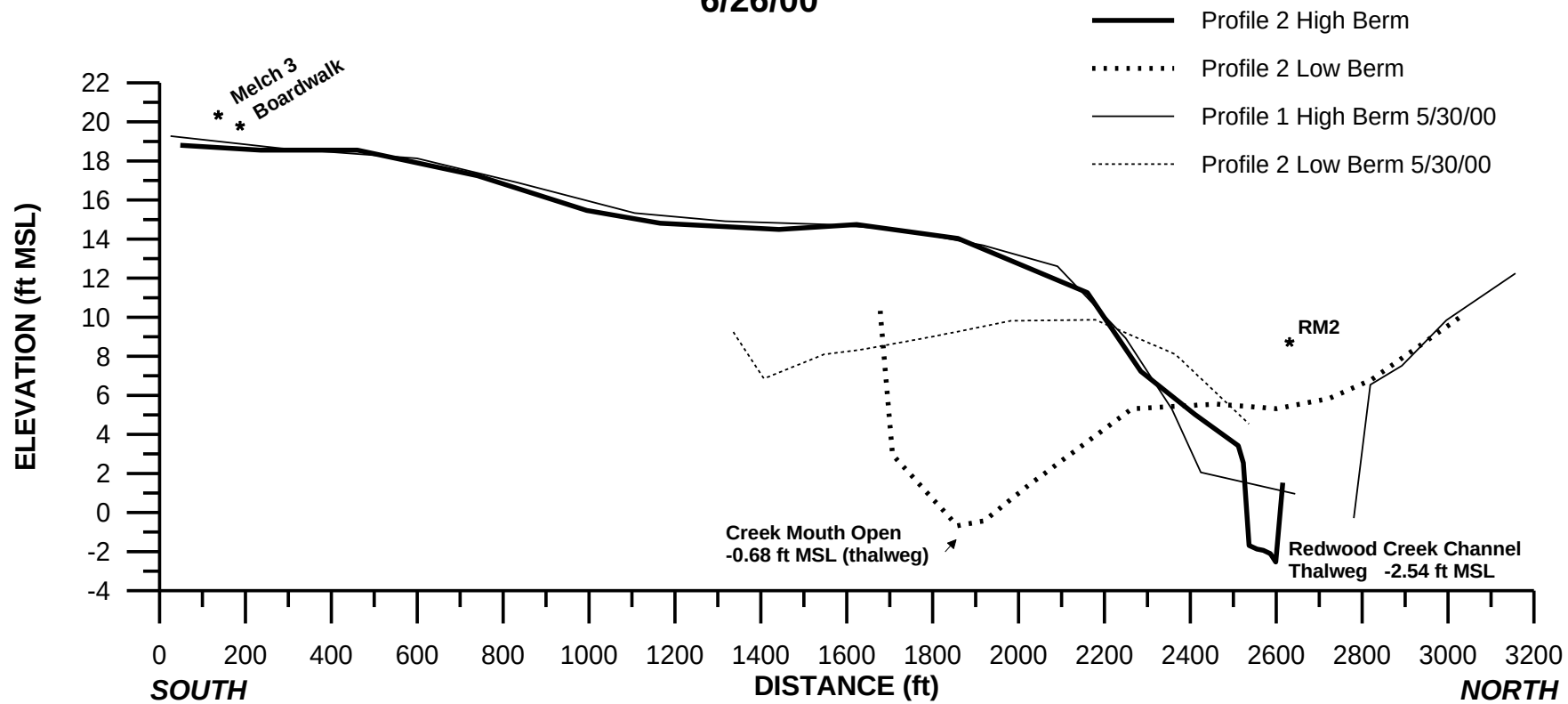


Appendix VI. Longitudinal profiles of the sand berm along the highest ridge parallel to the shore and separating the estuary from the ocean for May 30, June 26, July 25, August 28, and October 3, 2000 (Profiles 1 through 5 respectively). The profiles extended from a minimum of 100 feet north of the estuary to 100 feet south of the Redwood Information Center (RIC). . Measurements were taken at breaks in slope along the sand berm. The elevations in feet MSL were referenced in the south to a permanent NOAA benchmark referred to as Melch 3 located west of RIC and to the end of the RIC boardwalk. In the north, they were referenced to a BLM benchmark, and the western most estuary cross section endpoint of E-5, RM2, a monumented rock seastack. The winter storm berm, denoted as the high berm, and the summer swell berm, denoted as the low berm, were surveyed. The mouth was completely closed to the ocean on August 28 and October 3, 2000 surveys.

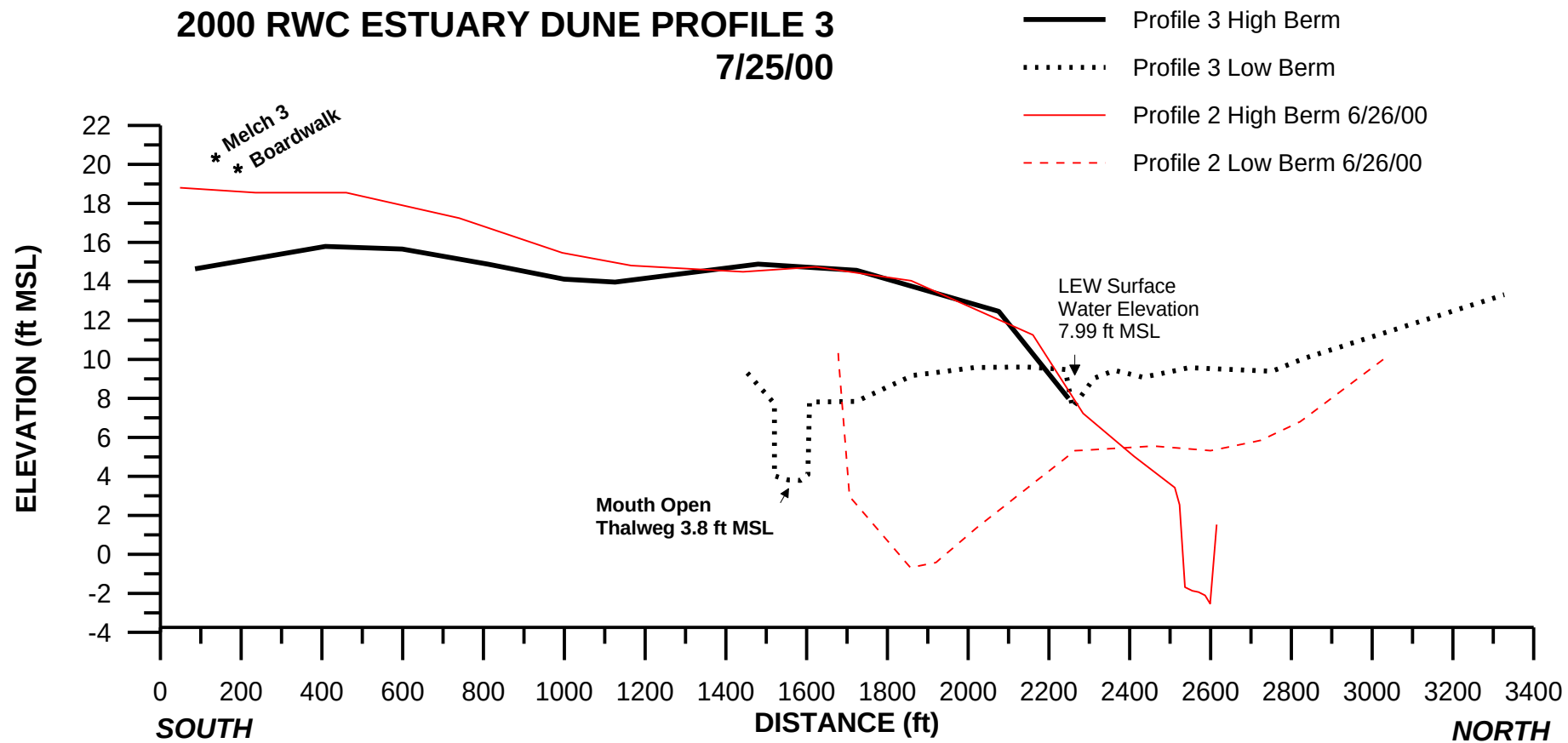
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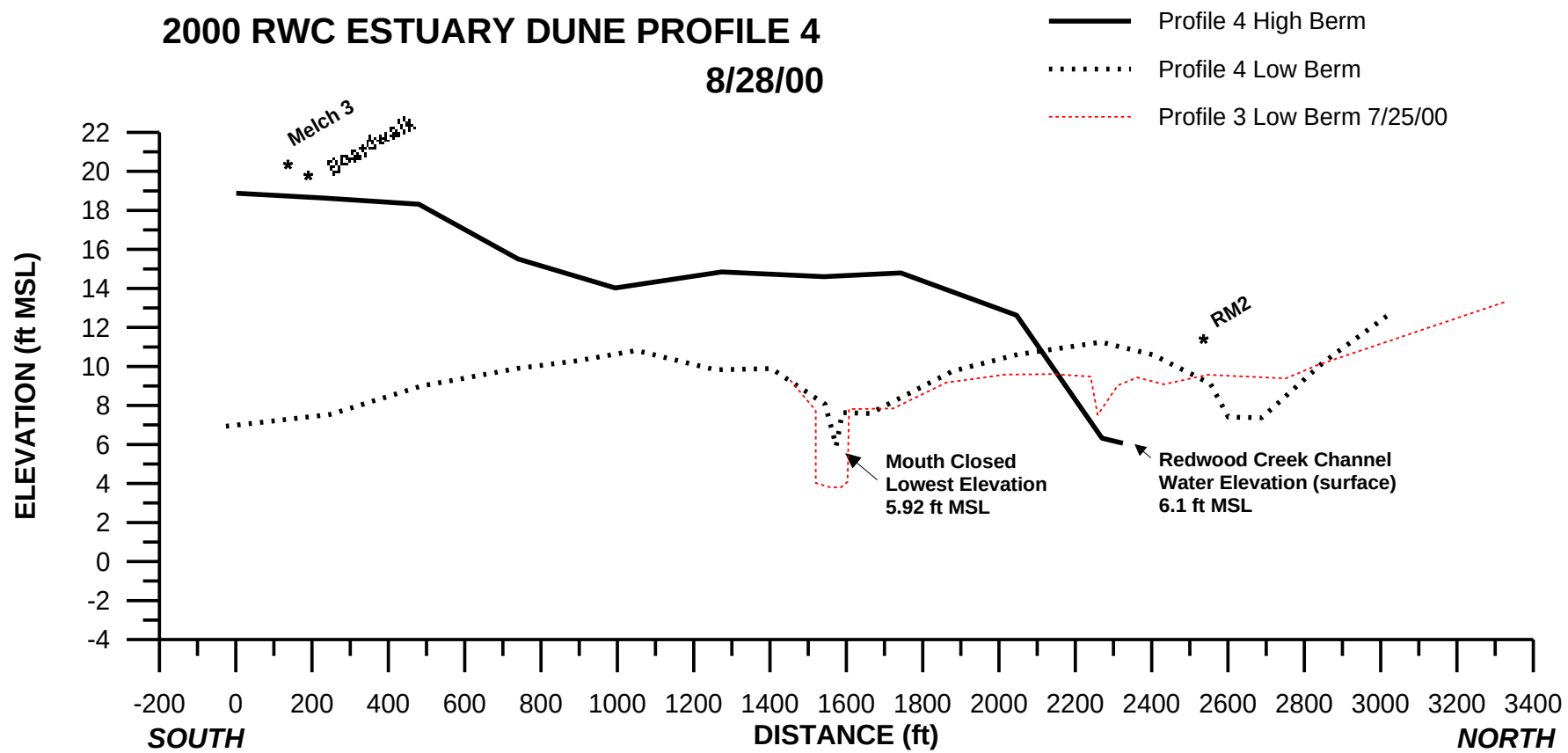
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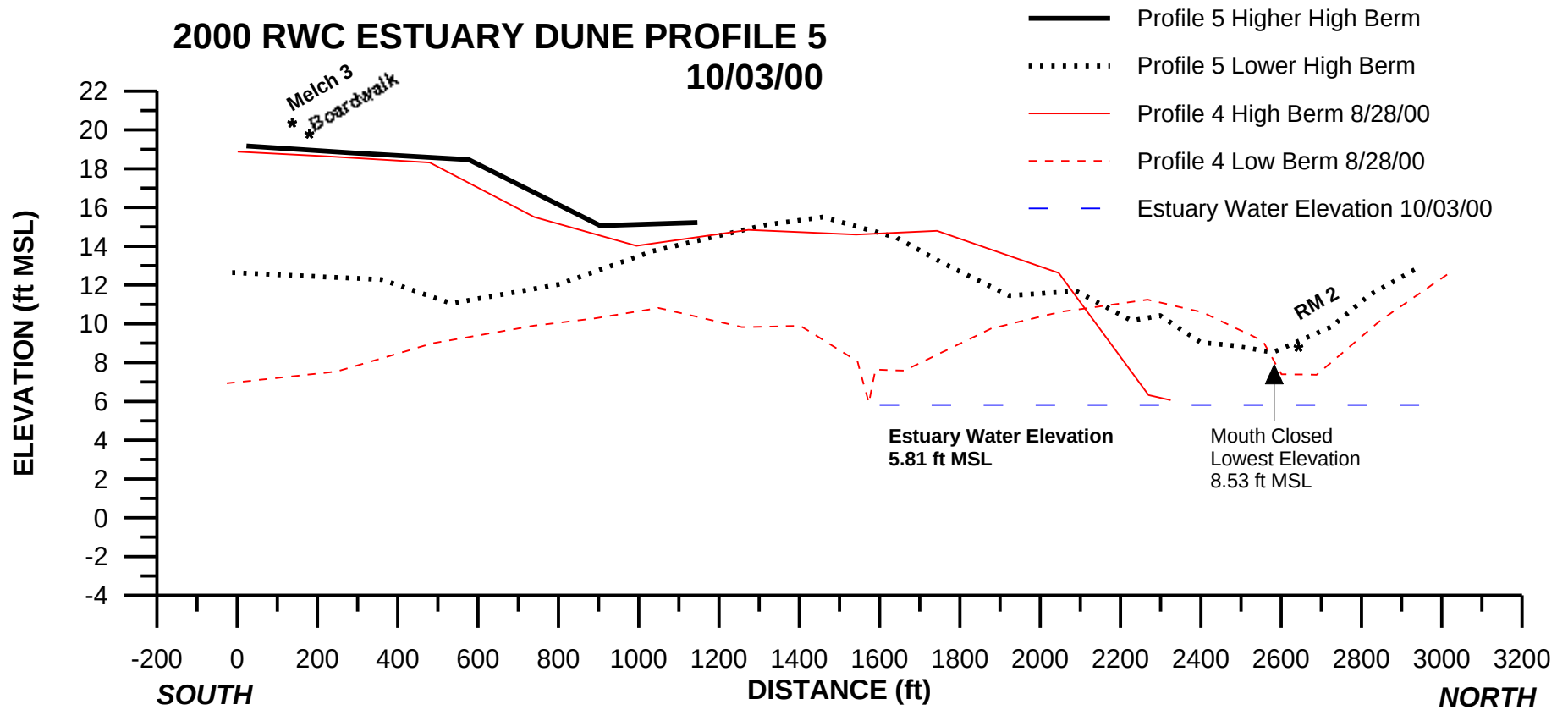


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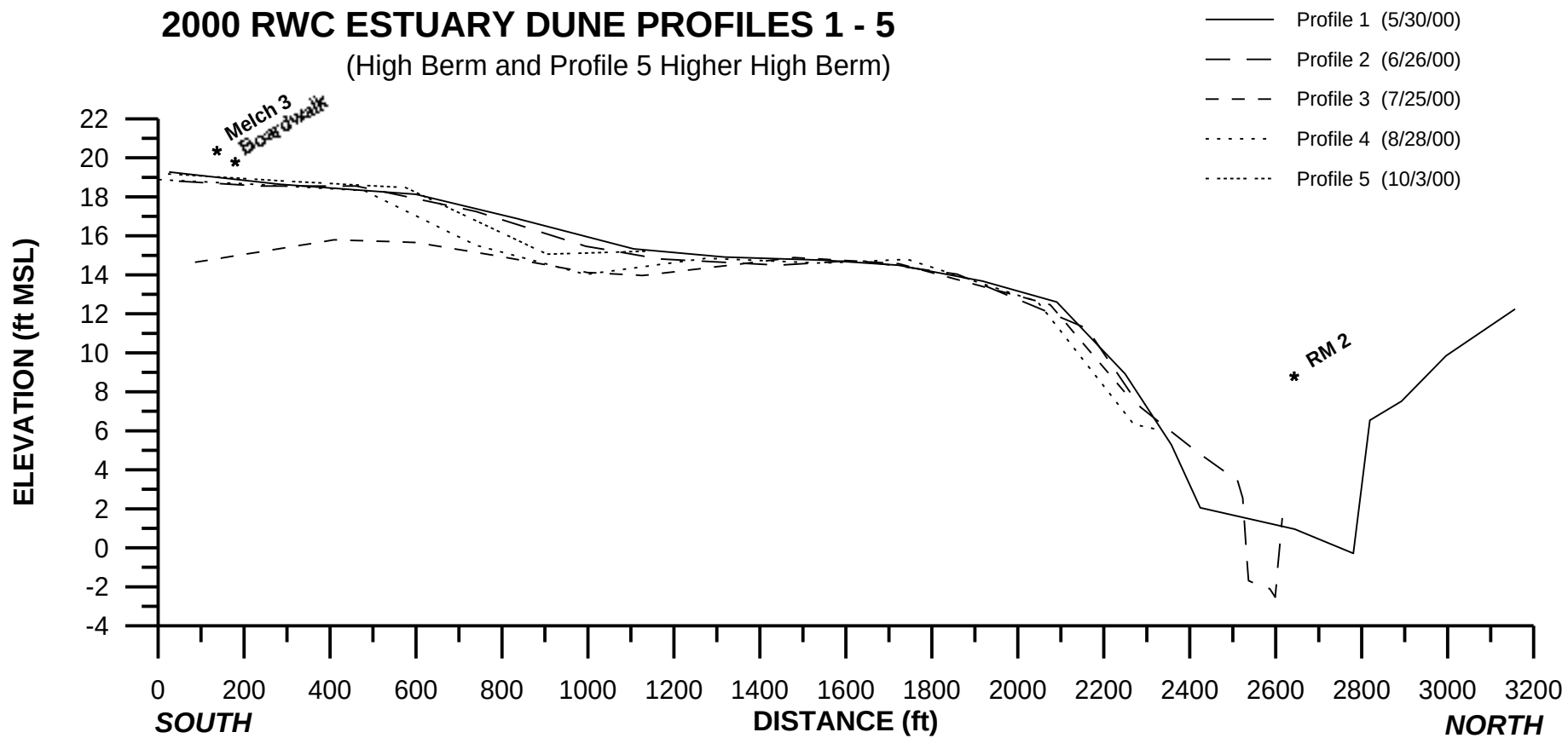
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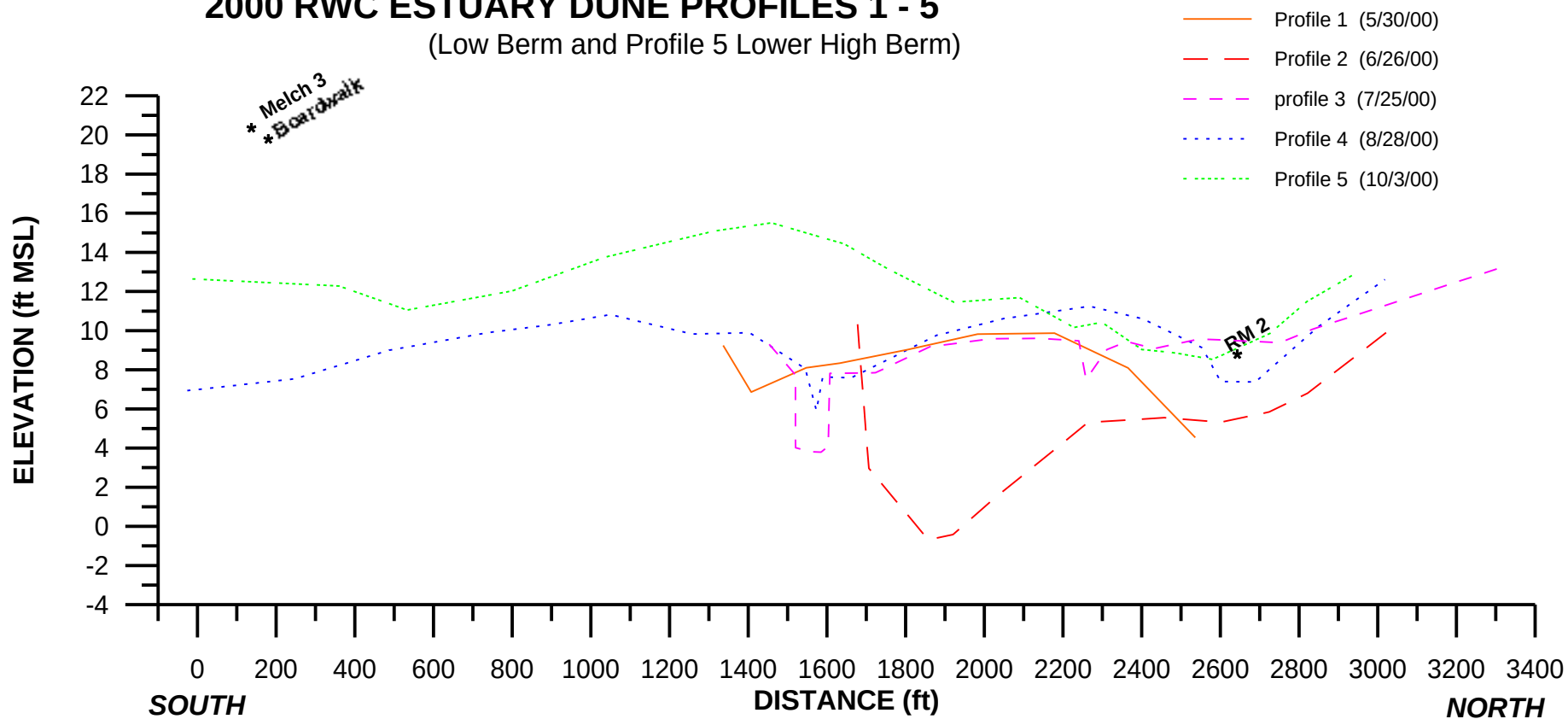
2000 RWC ESTUARY DUNE PROFILES 1 - 5

(High Berm and Profile 5 Higher High Berm)



2000 RWC ESTUARY DUNE PROFILES 1 - 5

(Low Berm and Profile 5 Lower High Berm)



Appendix VII. Survey points of the five longitudinal sand berm profiles plotted on 1:6000 aerial photo for each of the six profiles (2 cm = 407 ft). (Redwood National and State Parks photo no. 15-12 Redwood Creek 97 dated 6/19/97).

2000 Acknowledgements

David Anderson, RNSP fishery biologist, supervised estuary monitoring in the field, analyzed data, and wrote the annual report. The following people assisted, and/or contributed to the various estuary monitoring components.

Estuary Biological Monitoring (seining)

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Volunteer In the Park: Kevin Lane and Sara Fitzhugh (Science Teachers), Emily Newby (RNSP VIP)

Agency: Rod Nakamoto and Jason White (USFS-Redwood Sciences Laboratory)

Steve Tussing, Walt Duffy, Peggy Wilzbach, Erin Duffy, and Mike Sparkman (HSU- Fisheries Coop Unit)

Terry Roelofs (HSU-Fisheries Department)

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Fish and Wildlife Branch: David Anderson (South Levee Data Collection and synthesis)

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Estuary Surveying of Berm and Embayment Cross Sections

Geological Services: Vicki Ozaki and Carrie Jones

Fish and Wildlife Branch: David Anderson and Baker Holden III

VIP: Alex O'Neil and Catherine (American Geology Society Intern)

Culverts Opening and Closing

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