SEASONAL WATER QUALITY IN THE KLAMATH RIVER ESTUARY AND SURROUNDING SLOUGHS, 2001 - 2003

FINAL REPORT
MARCH 2006

Prepared by:
Monica Hiner
Yurok Tribe
PO Box 1027
Klamath, California 95548
Phone (707) 482-1350

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

SEASONAL WATER QUALITY IN THE KLAMATH RIVER ESTUARY AND SURROUNDING SLOUGHS, 2001 - 2003

INTRODUCTION

The Klamath River watershed drains approximately 12,100 square miles and empties into the Pacific Ocean (Figure 1). The Klamath River estuary serves as a nursery and physiological staging area for spring and fall-run chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). It is likely that tens of millions of juvenile salmonids migrate through the Klamath estuary every year on their way to the ocean (Wallace 1995). The estuary also serves as a migration corridor for anadromous salmonids as they return to the Klamath Basin to spawn, and may provide vital habitat during various life history stages for other species of importance such as eulachon (*Thaleichthys pacificus*), Pacific lamprey (*Lampetra tridentata*), and green sturgeon (*Acipenser medirostris*).

Water quality within the estuary, which is a culmination of waters from the Klamath and Trinity Rivers and numerous tributaries along the way, is a key component in the suitability of estuarine habitat for juvenile salmonids, and the Klamath River Basin Fisheries Task Force has identified the Klamath River estuary as a key habitat for Klamath and Trinity River anadromous salmonids (KRBFTF 1991). During summer months, chronically elevated water temperatures in the mainstem of the Klamath and Trinity Rivers point to an even greater significance of Klamath estuary habitats as refugia from poor riverine conditions. While water quality within the Klamath River estuary is likely an important factor in the suitability of available habitat for outmigrating salmonids, few data have been collected. The California Department of Fish and Game (CDFG) studied water quality in the Klamath River estuary during 1991-1994 and concluded that high water temperatures from the mainstem Klamath were a concern (Wallace 1998). In addition, CDFG recommended the continuation of a "…monitoring program to assess the response of water quality parameters to…river flow and river mouth location along the spit…(Wallace 1998)."

Numerous other estuaries on the west coast of North America have been documented to be essential in the rearing, maturation, and physiological functioning of anadromous salmonids and countless other fishes. Estuaries serve as an interface between fresh and salt water, and as such allow for the gradual physiological adaptation of juvenile salmonids (i.e. smoltification) prior to ocean entry. Historical reports from CDFG indicate that juvenile chinook emigrating from the Klamath basin generally took up residency in the estuary through the late summer and early fall and were typically well distributed throughout the estuary, but preferred the freshwater current (Snyder 1931). Growth of these juveniles is reported to have been rapid in the estuary due to the abundant food supply available, and juveniles sampled in late summer and early fall averaged six to seven inches long and were often longer. Scale analysis of these individuals showed an inner nucleus of upstream growth followed by larger growth rings resembling pond-reared chinook (Snyder 1931). Not only did the juvenile fish sampled exhibit this growth pattern on their scales, but also "….among the returning adults in Klamath River are large numbers which bear scales of this

Figure 1. Location of the Klamath River Estuary, Klamath River, California.

type (Snyder 1931)", suggesting that estuarine rearing historically increased success of outmigrants. Conditions have changed drastically since the early 1900's for fish utilizing the Klamath River estuary. Studies conducted by the Yurok Tribe and CDFG have observed smaller average lengths than historically reported (Snyder 1931, Wallace 1993, Wallace 1997, Hiner and Brown 2004), with emigration occurring earlier and peak emigration coinciding with hatchery releases from Iron Gate and Trinity River Hatcheries (Wallace 1993). In addition to arriving in the estuary earlier, current studies of juvenile chinook outmigrants collected indicate that juvenile chinook residency within the estuary tends to be brief, with mean residency time ranging between 8.7-16.2 days (Wallace 2000). Preliminary water quality and food availability studies conducted by CDFG reported high surface water temperatures reaching 24°C during summer months and a lack of preferred prey items for emigrating juvenile chinook during periods of outmigration (Wallace 1995; Wallace 1998).

The purpose of this study is to further our understanding of the current conditions present within the Klamath River estuary. Our specific objectives were to: 1) establish GIS-based sampling locations within the estuary and surrounding sloughs; 2) monitor water quality parameters (salinity, temperature, conductivity, dissolved oxygen) throughout the water column at each sampling location to determine baseline conditions; and 3) determine whether water quality conditions were related to river flow. Results from our current and ongoing studies, in conjunction with upriver studies, may be useful for recommending specific management actions that address identified water quality problems within the estuary and surrounding slough regions.

METHODS

Study Area

The Klamath River estuary is relatively small in comparison to the overall drainage size (approximately 31,080 km^2), with most studies delineating estuarine influence to the lower 6.5 km of river. Sampling was also conducted in the several sloughs associated with the estuary: the south slough, Salt Creek slough, and Hunter Creek slough (Figure 2). The south slough region of the estuary is approximately 2 km in length and is located on the south side of the estuary, separated from the main channel by a large island. Salt Creek is the lowermost tributary to the Klamath River (rkm 1.21) with a watershed area of 5.85 km^2 and Hunter Creek, just upstream of Salt Creek, is the second tributary to the Lower Klamath River and has an overall watershed size of 66.67 km^2.

Average river flow in the lower Klamath River varies both seasonally and annually, with summertime flows in the lower river largely influenced by upriver flow releases from Iron Gate and Lewiston dams. Like other coastal rivers, the Klamath River experiences high flows during winter and spring months due to excessive rainfall and snowmelt (Figure 3). Periods of low flow occur during summer months and are substantially influenced by upriver water management. In 2001, flows near Klamath ranged between 2560 – 3720 cfs in August and 2500 – 3060 cfs in September (Datasource: USGS). Flows in 2002 were lower, ranging

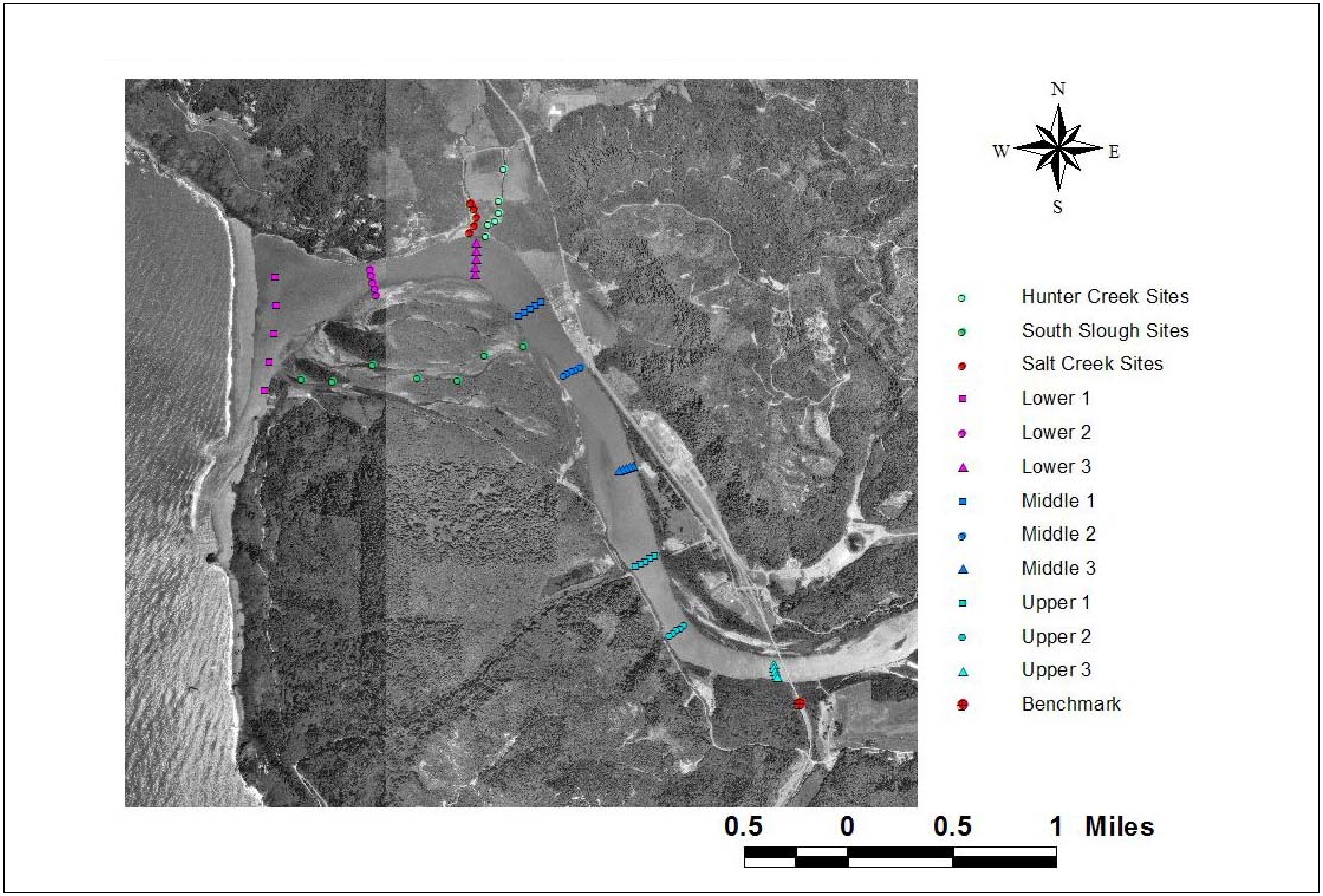


Figure 2. Water quality monitoring stations in the Klamath River Estuary and surrounding sloughs.

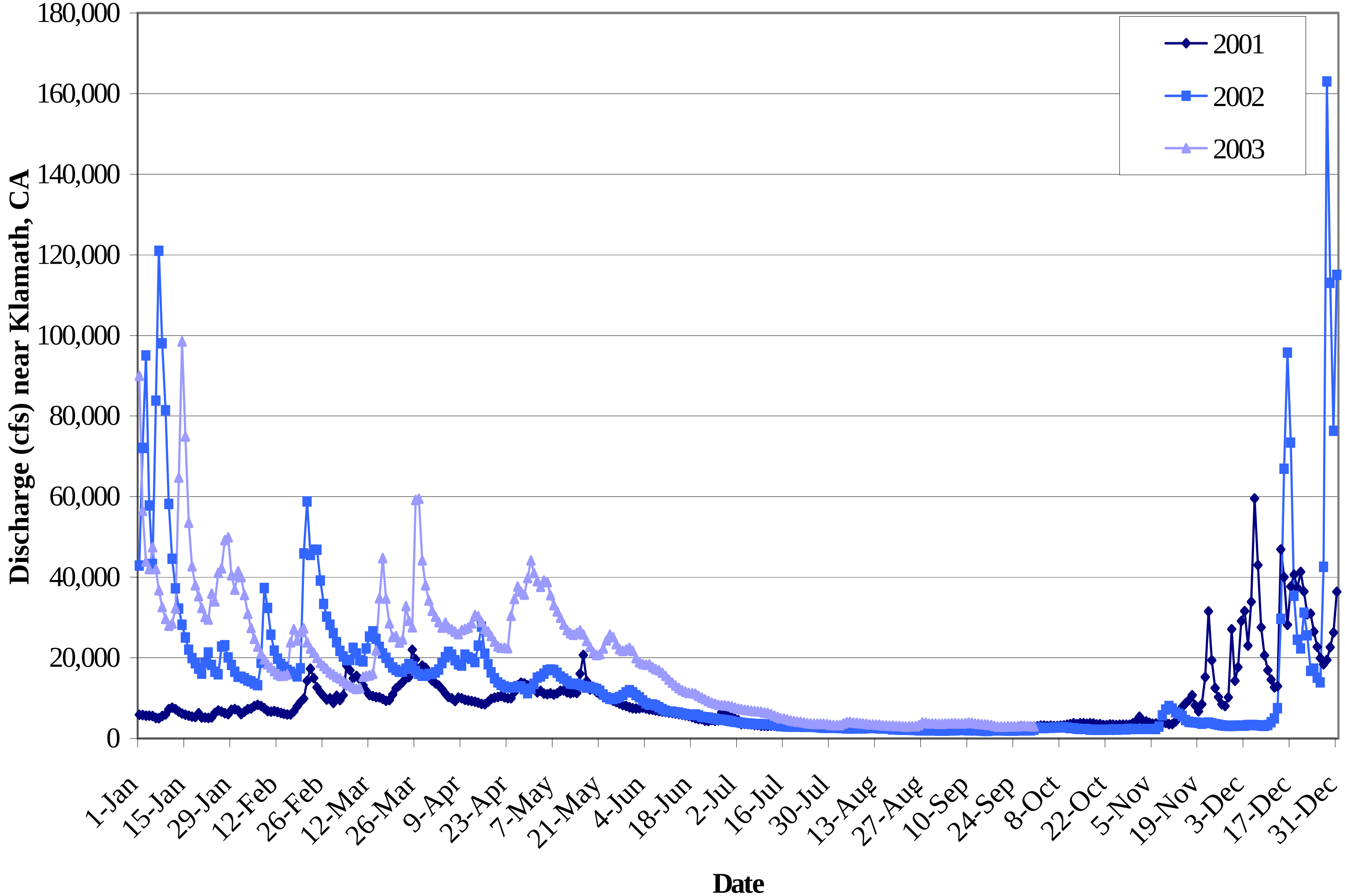


Figure 3. Daily streamflow in the Klamath River near Klamath during 2001 – 2003 (Datasource: USGS Station 11530500).

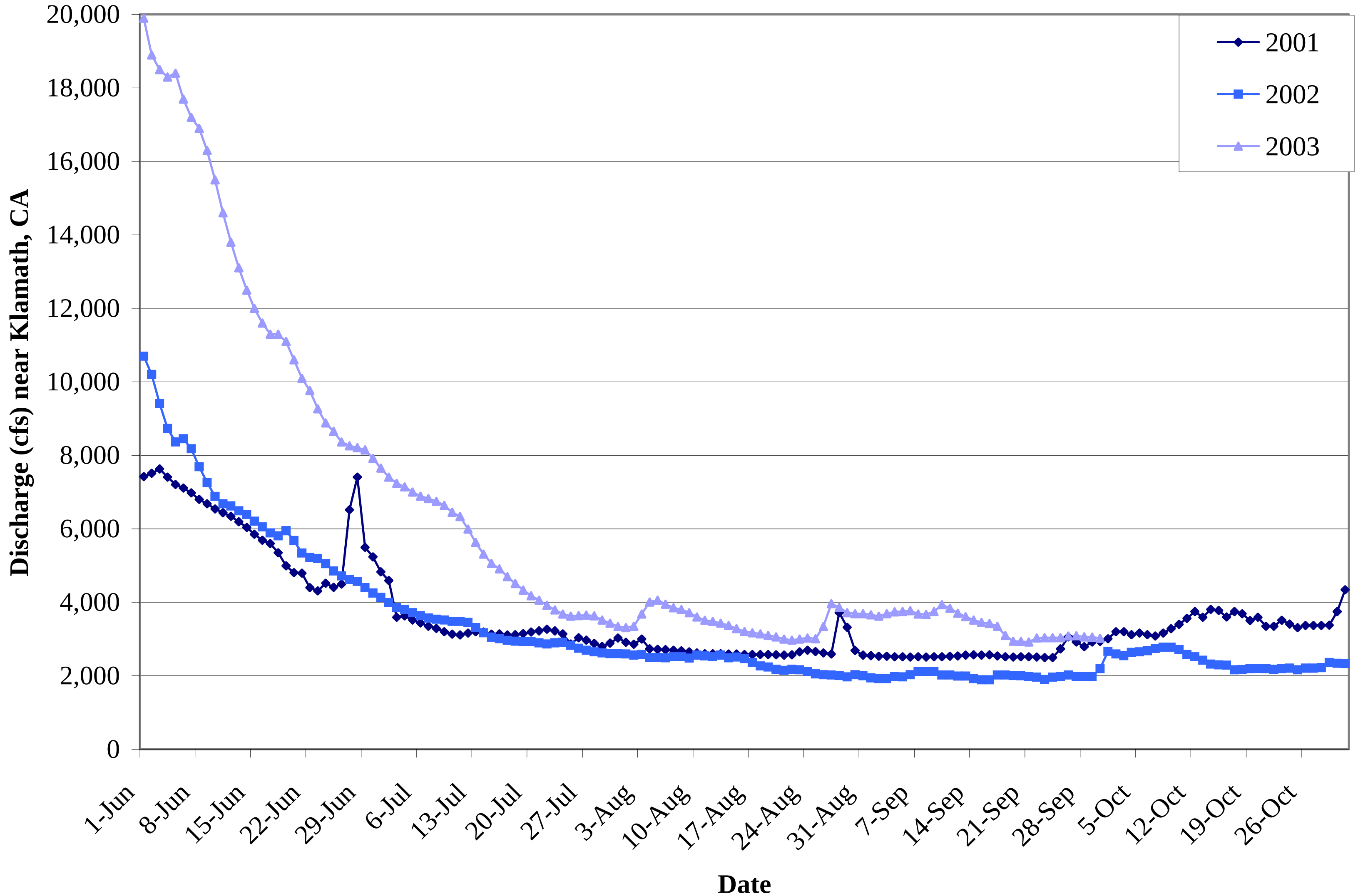


Figure 4. Daily streamflow during summer months in the Klamath River near Klamath during 2001 – 2003 (Datasource: USGS Station 11530500).

between 1970 – 2590 cfs during August and 1890 – 2190 in September. During 2003, flows ranged between 2970 – 4060 cfs in August and 2920 – 3930 cfs in September (Figure 4).

During late summer months, low river flows coupled with ocean currents can result in the formation of a sand berm that blocks the river mouth and results in an embayment of the estuary. These conditions reduce the outflow and inhibit tidal influence, causing the formation of a mostly freshwater "lagoon-like" water body. (Wallace 1993, YTFP unpublished data). This situation occurred during the summer months of 2001 when the mouth of the river was angled sharply south. During the summer months of 2002 and 2003, however, the river mouth was located to the north and remained open, thereby allowing tidal fluctuation in the estuary.

Sampling Locations

Sampling locations were established using a handheld Geographic Positioning System (GPS)(Trimble, GeoExplorer 3). The estuary was divided into three main regions for sampling, and also to remain consistent with previous CDFG studies: Lower (mouth upstream to Hunter Creek), Middle (Hunter Creek upstream to the Townsite Boat Ramp), and Upper (Townsite Boat Ramp upstream to the Highway 101 Bridge). Three sampling transects were established within each region, running perpendicular to river flow, and are abbreviated as follows: Lower (L1, L2, L3); Middle (M1, M2, M3); and Upper (U1, U2, U3). GPS Pathfinder software was used to establish five equally spaced sampling waypoints across each transect: a (nearest to left bank looking upriver), b, c (center), d, and e (nearest to right bank looking upriver)(Figure 2). It should be noted that the photograph used to depict site locations was not taken during the study period, and the location of the river mouth can change annually.

Sampling locations were also established in the south slough region of the estuary and lower reaches of Hunter and Salt creeks that were characteristic of slough-like habitat and experienced tidal fluctuation. Five sampling locations were set-up in lower Salt Creek from the mouth upstream approximately 250 m. Six sampling locations were established in lower Hunter Creek from the mouth upstream approximately 0.6 km, ending just downstream of the bridge on Requa Rd. Sampling locations in the Hunter and Salt Creek sloughs were situated with Station 1 located at the creek mouth and successively upstream locations numbered accordingly. Seven equidistant sampling locations were established in the south slough between the inlet of the slough and its' outlet in the lower estuary. Sampling station locations in the south slough were numbered 1 through 7, with Station 1 located near the inlet of the slough (approximate rkm 1.5) and Station 7 located at the slough mouth in the southeast corner of the estuary embayment (Figure 2).

Water Quality Parameters

Water quality monitoring was initiated in July 2001 and continued through October 2003. Conditions and flow permitting, water quality was monitored bi-weekly throughout the year, except during summer months when sampling occurred more frequently. Between the months of May and September, water quality data was collected during the highest (flood) and lowest (ebb) tide cycles of each month that were most feasible to sample. “Mid” tide cycles, in which there was little difference between high and low tides, were also sampled. Monitoring during high and low tide cycles was conducted on two consecutive days (approximately 1-2 hours before the tide, during slack tide, and 1-2 hours after the tide) in order to sample the targeted tide effectively. “Mid” tide sampling was completed in one day since water levels did not fluctuate greatly.

Water temperature (°C), dissolved oxygen (% saturation and mg/L), conductivity (µS), specific conductivity (µS), and salinity (ppt) data were collected using an YSI® 85 water quality meter. Dissolved oxygen was calibrated before each sampling event, and probe membranes were replaced frequently. At each sampling location, measurements were collected at the surface and every successive meter in the water column to the channel bottom. Water temperature was also recorded electronically at 30-minute intervals using Optic StowAway TidbiT temperature recorders (Onset, -5° to 37°C Model) within each estuary region and in each slough. In the Lower estuary, temperatures were recorded at Requa; in the Middle estuary temperatures were recorded at the Townsite Boatramp; and in the Upper estuary temperature data was collected at the Highway 101 Bridge. Temperature dataloggers deployed in the sloughs were at the following locations: Midway upstream in the south slough between stations 3 and 4; Lower Hunter Creek between stations 1 and 2; Salt Creek slough at station 5. Temperature loggers were secured to the bank using cable and anchored on the bottom substrate several meters from the bank. Temperature records from each location were used to calculate mean, minimum, and maximum daily temperature.

RESULTS

Due to the extent of data collected, each geographic location (Estuary, South Slough, Salt Creek Slough, and Hunter Creek Slough) will be presented independently, separated by year.

Estuary Water Quality Monitoring

2001

Temperature

Electronic temperature records from the estuary, especially the lower and middle sites, show very little variation from mean daily temperature beginning on 25-Jul-01 (Figure 5). Temperatures from these regions are usually the most variable due to saltwater intrusion and stratification of the water column, which results in the formation of a cooler saltwater layer along the bottom of the channel. However, the sharp angle of the river mouth coupled with the formation of a sand berm effectively blocked both saltwater intrusion and outflow out of the river into the ocean. This created lagoon-like conditions in the estuary and resulted in uniform temperatures throughout the water column at most locations. Temperature in the lower estuary during late July ranged between 16.0 – 23.5°C, with daily temperatures averaging between 19.9 – 22.2°C. Temperatures recorded in the upper estuary were higher, ranging between 19.9 – 24.9°C with mean daily temperatures between 20.6 – 23.59°C (Figure 5). During August, temperatures ranged between 19.2 – 23.3°C in the lower estuary and 20.2 – 24.4° in the upper estuary, with mean daily temperatures between 20.7 – 22.8 in the lower region and 21.1 – 23.3°C in the upper region.

Temperatures observed during water quality monitoring were similar to electronic records, with surface temperatures exceeding 20°C through July, August, and mid-September (Figure 6). Lack of saltwater intrusion resulted in uniform temperatures throughout the water column beginning in early August (Table 1). However, a storm event in late August resulted in rough ocean conditions and waves that crashed over the north spit, temporarily re-establishing the salt wedge in the lower estuary and resulting in cooler temperatures along the channel bottom upstream to transect M1 (Figure 6, Appendix 1). Thermal stratification was observed to be limited again during sampling on 28-Aug, 7-Sept, and 13-Sept due to lack of an open channel to facilitate saltwater intrusion, but the estuary became stratified again when the river mouth broke open on 27-Sept-01 after a rain event increased mainstem river flows. In addition, water temperatures began to decrease in September, with average daily temperatures at the beginning of the month exceeding 21°C and averaging approximately 17.5°C at the end of the month, with maximum temperature ranging between 18 - 19°C (Figure 5).

Temperatures in the estuary cool substantially during late fall and winter months. Mean daily temperature dropped 4.5°C during October in the lower estuary, with daily temperatures ranging between 12 - 14°C in all regions of the estuary by the end of the month. Surface temperatures observed during water quality monitoring were slightly elevated from electronic temperature data due to thermal stratification, but also cooled substantially during the month. Surface water temperatures ranged between 17.5 – 19.7°C during sampling on 3-Oct (among all monitoring stations), and successively lower temperatures were observed during the following weeks. On 25-Oct, surface temperatures ranged between 13.4 – 15.7°C, with bottom temperatures averaging 1 - 2°C cooler. Mean daily temperature records from all regions of the estuary in November show average daily temperatures decreasing to 8°C by the end of the month. Little variation was observed during December in both electronic and monitoring data, with all observations ranging between 7 - 9°C (Figure 5).

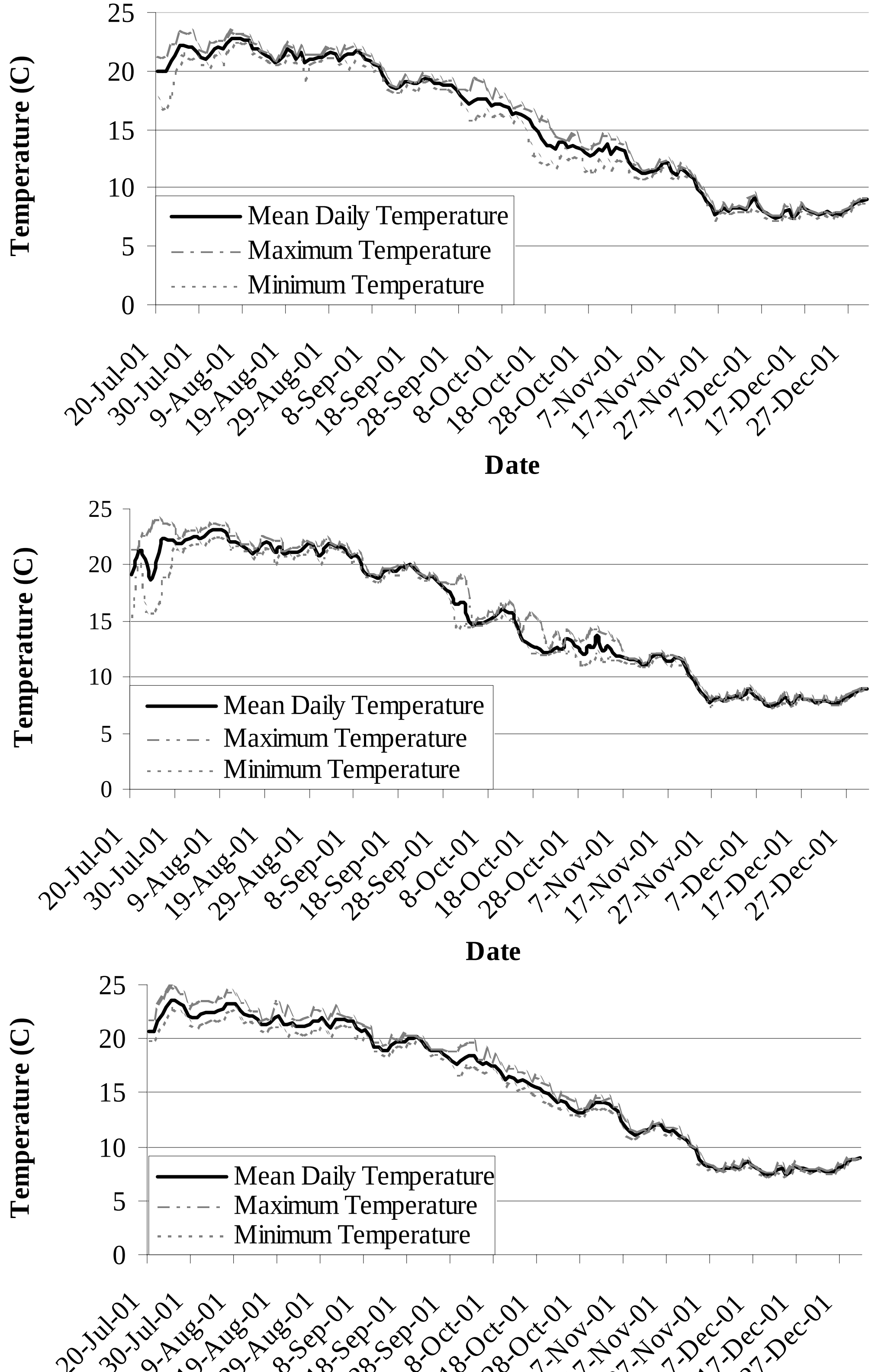


Figure 5. Minimum, maximum, and mean daily temperatures recorded in the Lower (top graph), Middle (middle graph), and Upper (lower graph) Regions of the Klamath River estuary between 20-Jul and 20-Dec, 2001.

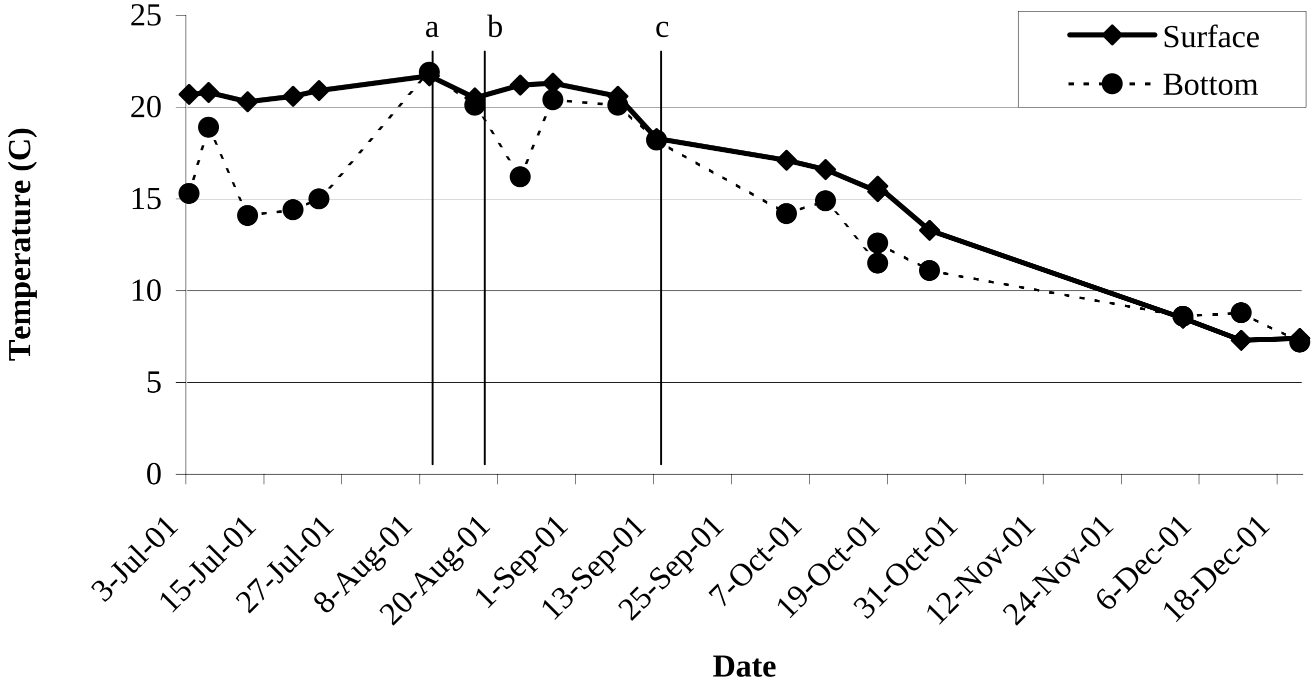


Figure 6. Surface and bottom temperatures observed during water quality monitoring at Station L1c during 2001 (a = Sand berm blocking tidal influence in estuary; b = ocean waves crash over north spit and reestablish salt wedge; c = estuary mouth breaks open).

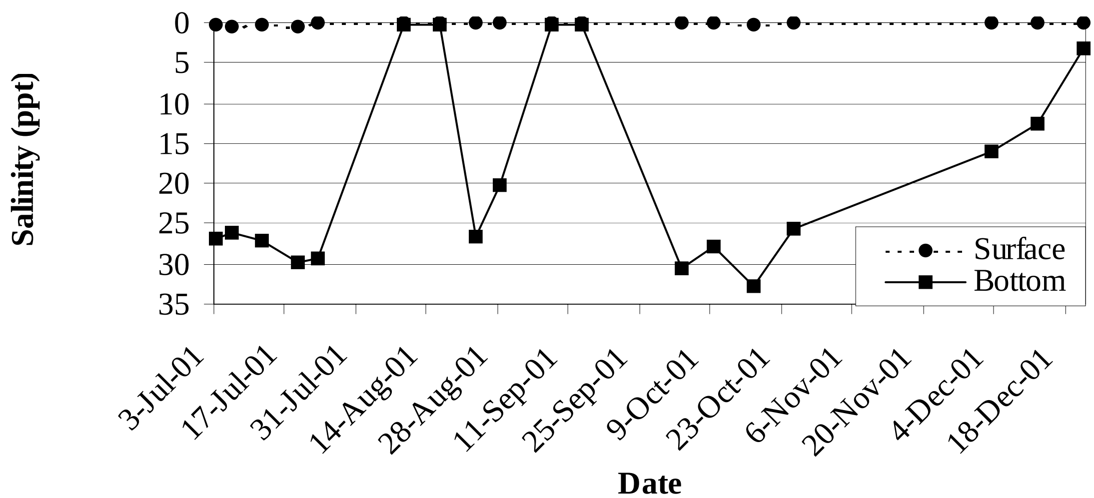
Salinity

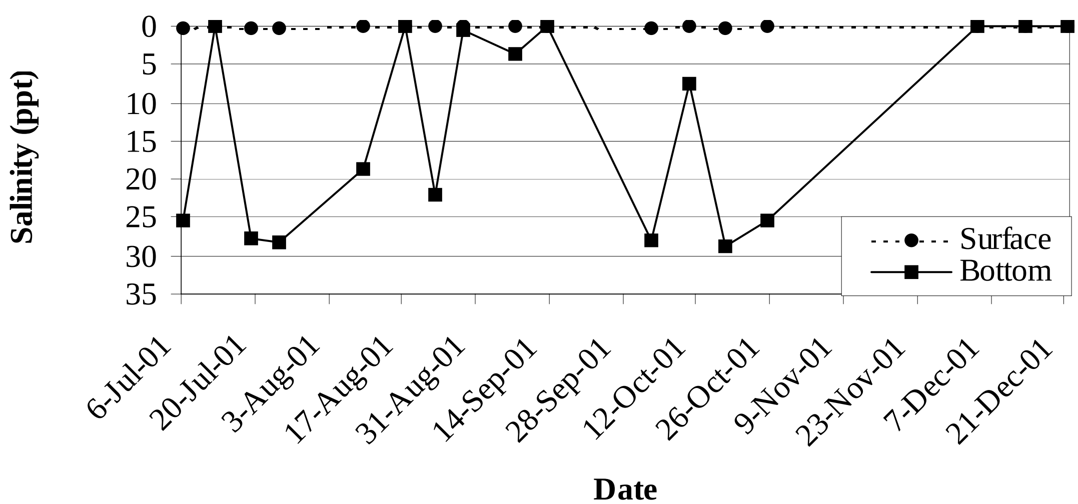
Salinity in the estuary is variable and largely influenced by freshwater flow, configuration of the river mouth, tidal stage, and time of year. Saltwater intrusion in the estuary results in stratification of the water column, creating a salt wedge with freshwater overlying a layer of saltwater near the channel bottom. In general, surface salinity varied between 0.1 – 1.0 ppt in the lower and middle regions of the estuary (L1 – M3, Figure 2) and 0.0 – 0.1 ppt in the upper transects (U1 – U3). Bottom salinity was variable, and as mentioned in the above section, tidal influx into the estuary was observed to be limited between late July and late September due to constriction of the river mouth (Figure 7).

During sampling on 3-Jul, bottom salinity measurements observed at Transect L1 ranged between 19 – 21.6 ppt, and the saltwedge extended upriver into the thalweg at stations L2 and L3 (Appendix A). Measurements were not taken above L3 on 3-Jul, so the upper extent of the saltwedge was unknown. The extent of the saltwedge was variable during July, with the upper limit of saltwater intrusion ranging between L3 and U1 (Appendix A). On 9-Aug, the extent of the saltwedge was limited to the bottom of station L2a (25.1 ppt), L2b (24.1 ppt), L3e (13.2 ppt), M1e (18.7 ppt), and M3a (20.3 ppt, Appendix A). During sampling on 16-17-Aug, the highest salinity observation was at station L2a, corresponding with a deep hole near the Requa Boatramp, where salinity at the channel bottom was measured at 13.5 ppt and 0.6 m above the channel bottom was 3.1 ppt. Measurements at all other stations and depths ranged between 0.0 – 0.2 ppt.

The saltwedge was reestablished during sampling on 23-Aug upriver to Transect M1 (M2 – U3 not sampled) due to an ocean storm that created waves crashing over the north spit. Bottom salinity observations exceeded 20 ppt at all monitoring stations along Transect L1, and upriver into the thalweg of Transects L2, L3, and M1 (Appendix A). Sampling on 28-Aug indicated that the saltwedge was again limited to the bottom of stations L1d (20.2 ppt), L2a (23.8 ppt), L2b (23.5 ppt), L3e (18.8 ppt), and M3a (17.1 ppt), and M3b (14.9 ppt)(Appendix A). All other salinity measurements observed on 28-Aug ranged between 0.0 – 4.4 ppt, with the majority of observations 0.1 ppt. The saltwedge was limited to L2a (22.2 ppt), L2b (21.3 ppt), L3e (20.0 ppt), M2c (15.0 ppt), and M3b (14.9 ppt) on 7-Sept, with all other measurements ranging between 0.0 – 3.5 ppt. During sampling in mid-September, salinity exceeding 0.2 ppt was only observed along the channel bottom at Station L2a (18.5 ppt)(Appendix A).

The saltwedge was reestablished after a storm event on 27-Sept, which opened the river mouth and reconnected tidal influence (Figure 7, Appendix B). During sampling on 3-Oct, the saltwedge was well established at Transect L1, with bottom measurements ranging between 26.0 – 30.5 ppt. Bottom salinity measurements in the thalweg of Transects L2 (stations a and b), Transect L3 (stations d and e), Transect M1 (stations c,d, and e), Transect M2 (stations a, b, and c), and Transect M3 (stations a and b) exceeded 20 ppt. The saltwedge also extended into the Upper Transects U1 (station b, 24.2 ppt) and U2 (station e, 19.4 ppt), but all salinity measurements from Transect U3 ranged between 0.0 – 0.1 ppt. Sampling during an outgoing high tide the following week (9-Oct and 10-Oct) indicated that the saltwedge only extended upstream to Transect M3. Subsequent high tide sampling the





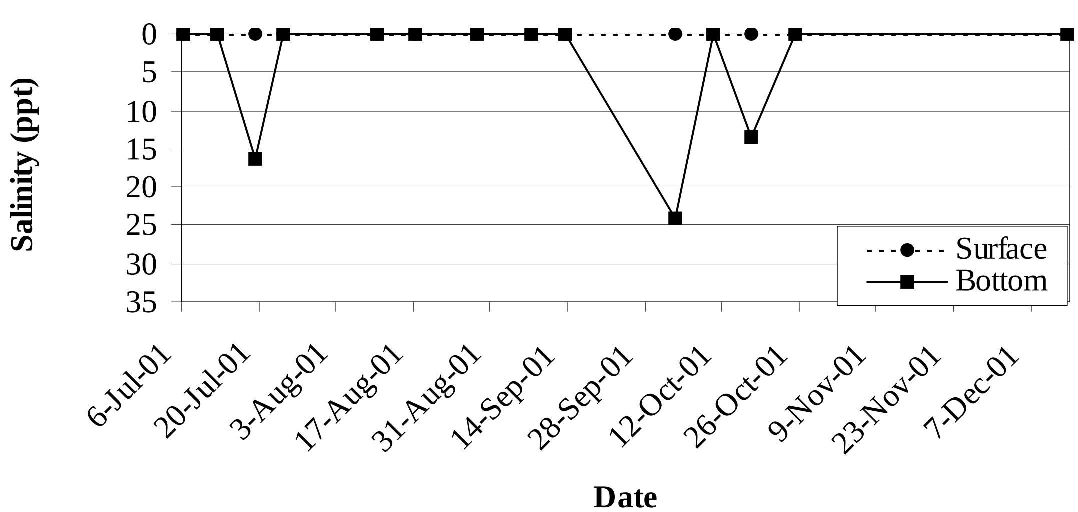


Figure 7. Range of surface and bottom salinity measurements observed during water quality monitoring in Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2001.

following week indicated that the saltwedge extended upstream to Transect U3 (Station e), although the maximum salinity measurement observed along the channel bottom was only 7.6 ppt. As freshwater flows increased during winter months, salinity measurements ranged between 0.0 – 0.4 ppt at all transects except L1. Maximum salinity observations at Transect L1 were 16.0 ppt, 12.6 ppt, and 3.3 ppt during sampling on 3-Dec, 12-Dec, and 21-Dec (respectively).

Dissolved Oxygen

Dissolved oxygen (DO) levels were lowest in the lowermost sampling transects, especially L1 and L2, where measurements were frequently below 6 mg/L near the channel bottom (Figure 8). Observations at Transect L1 were generally between 6 – 10 ppt between July and October, however, eighteen measurements were below 6 mg/L (Figure 8). Dissolved oxygen was observed below 6 mg/L at Station L1a on 23-Jul at the water's surface (3.09 mg/L) and 1 m below the surface (3.57 mg/L), and again on 9-Oct near the channel bottom (4.02 mg/L). Dissolved oxygen was never observed below 6 mg/L at L1b. Data from Station L1c indicate that DO was below 6 mg/L near the channel bottom on 6-Jul (5.51 mg/L), 7-Sept (5.54 mg/L), and 13-Sept (4.57 mg/L). The lowest observations were observed at Stations L1d and L1e, where DO was observed below 6 mg/L on eleven occasions between July and October. At Station L1d, dissolved oxygen was observed $\leq$ 6 mg/L near the channel bottom on 6-Jul (4.45 mg/L), 23-Jul (5.51 mg/L), 23-Aug (2.70 mg/L), 28-Aug (1.73 mg/L), 13-Sept (5.44 mg/L), and 9-Oct (1.76 mg/L). Observations below 6 mg/L were observed at L1e on 3-Jul (2.85 mg/L), 6-Jul (5.93 mg/L), 23-Jul (5.00 mg/L), 9-Aug (4.36 mg/L), and 28-Aug (3.66 mg/L). Observations at Transect L1 during December monitoring ranged between 7.23 – 10.35 mg/L on 12-Dec and 7.73 – 11.44 mg/L on 21-Dec.

Conditions were more favorable in the middle estuary for dissolved oxygen, with observations generally ranging between 6 – 10 mg/L during monitoring in July, August, and mid-September. However, dissolved oxygen at Transect M1 was observed below 6 mg/L on 6-Jul, 9-Aug, 23-Aug, and 7-Sept (Figure 8). On 6-Jul, DO levels near the channel bottom of Stations M1c, M1d, and M1e were 5.36 mg/L, 3.51 mg/L, and 4.96 mg/L (respectively). Dissolved oxygen was also low 1m above the channel bottom at Station M1d (4.96 mg/L). During sampling on 9-Aug, the only observation $\leq$ 6 mg/L was observed near the channel bottom at Station M1e (3.1 mg/L, Figure 8). Dissolved oxygen measurements collected on 23-Aug and 7-Sept exceeded 6 mg/L at all stations and depths, except near the channel bottom of M1d, where DO was observed to be 5.23 mg/L on 23-Aug and 5.08 mg/L on 7-Sept.

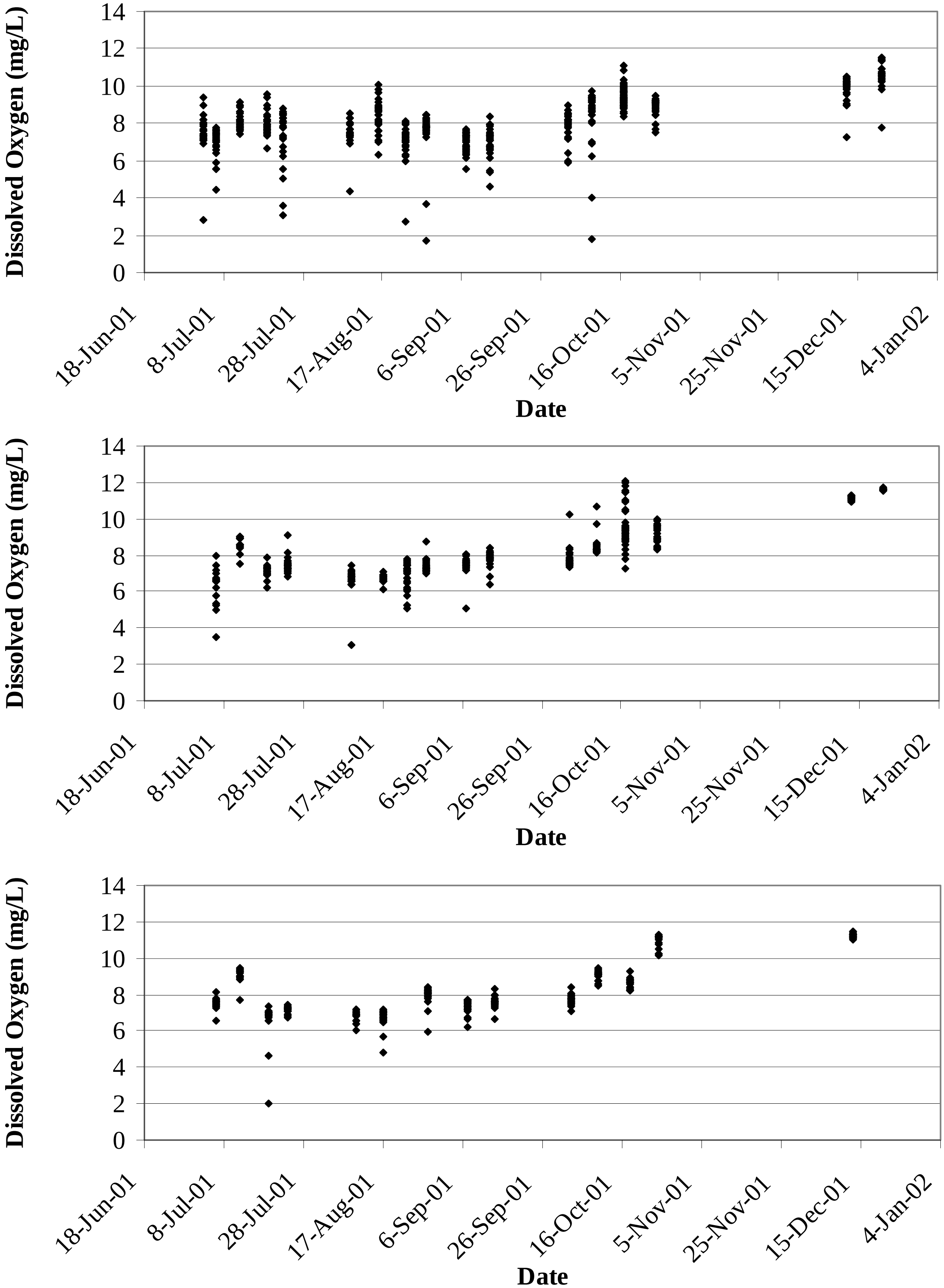


Figure 8. Dissolved oxygen measurements observed throughout the water column during water quality monitoring at Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2001.

2002

Temperature

Due to equipment failure during 2002, the only electronic temperature data retrieved was from the upper estuary Onset Tidbit recorder. Records indicate that water temperature remained below 10°C through mid-March, with mean monthly temperatures of 6.84°C, 7.56°C, and 8.29°C calculated from electronic temperature data for January, February, and March, respectively. Mean monthly temperatures during April and May were 11.27°C and 13.35°C, respectively. Temperatures in the upper estuary began warming significantly in June, when the minimum and maximum temperatures recorded were 15.73°C and 23.37°C, respectively (Figure 9). Mean monthly temperatures in the upper estuary during June, July and August were 17.89°C, 20.97°C, and 20.19°C, respectively. Maximum temperatures recorded during July and August were 24.74°C and 23.88°C, respectively.

Temperatures in the upper estuary began cooling in September, when the mean monthly temperature dropped to 18.84°C and minimum and maximum temperatures were 16.68°C and 23.37°C (respectively). Water temperatures were averaging between 16-17.45°C in early October, were cooled to 14°C by mid-month and had dropped to 10°C by the end of the month. Average daily temperature during November and December were 9.52°C and 7.99°C, respectively (Figure 9).

Temperature is most variable in the lower region of the estuary due to saltwater intrusion and the formation of a salt wedge, which stratifies the water column. During winter months, stratification of the water column results in warmer ocean waters on the bottom of the channel with cooler freshwater on top. During sampling in December of 2001, there was a 0.8°C difference between surface and bottom temperatures. During January of 2002, temperature differences ranged between 0.1 – 1.2°C, and during November 2002 water on the bottom of the channel was between 0.4 – 1.6°C warmer than surface temperatures.

During summer months, the presence of a salt wedge in the estuary forms a cooler saltwater layer along the bottom of the channel, which may provide thermal refugia from warm surface temperatures. During June, July, and August of 2002, differences of 0.7-5.6°C were observed between surface and bottom temperatures in the lower estuary, except on 3-Jul. During Jul-3, uniform temperatures were observed throughout the water column except at sampling stations L2a and L2b. At these stations, bottom temperatures were 14.1°C and 14.6°C (respectively) and surface temperatures were 20.9°C.

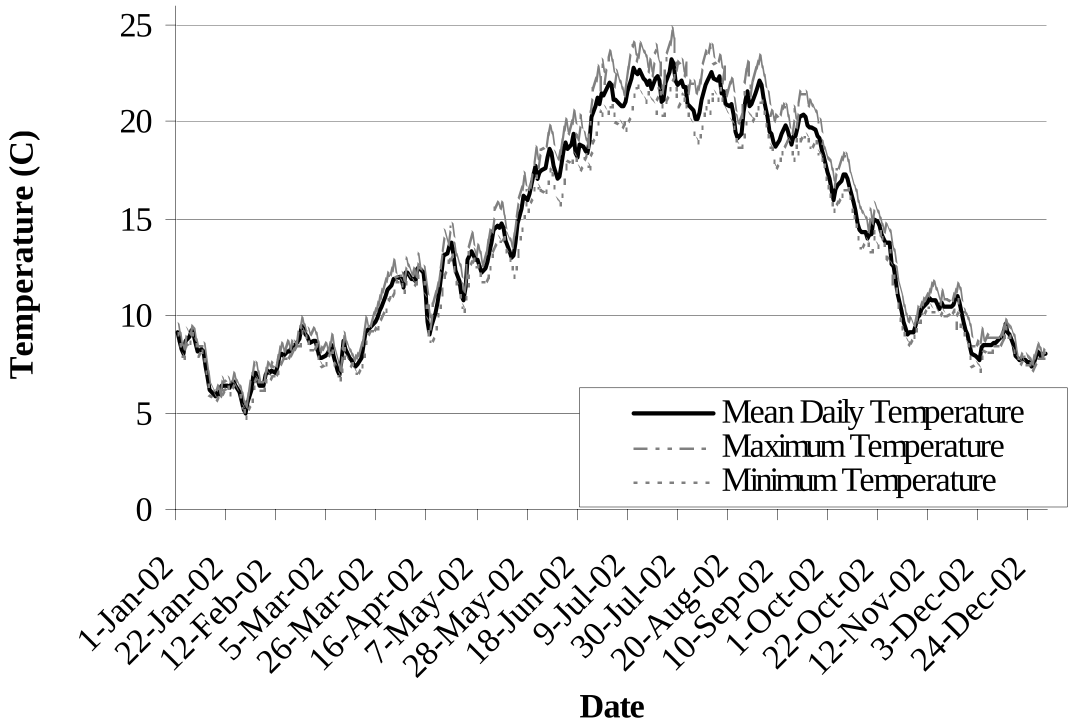
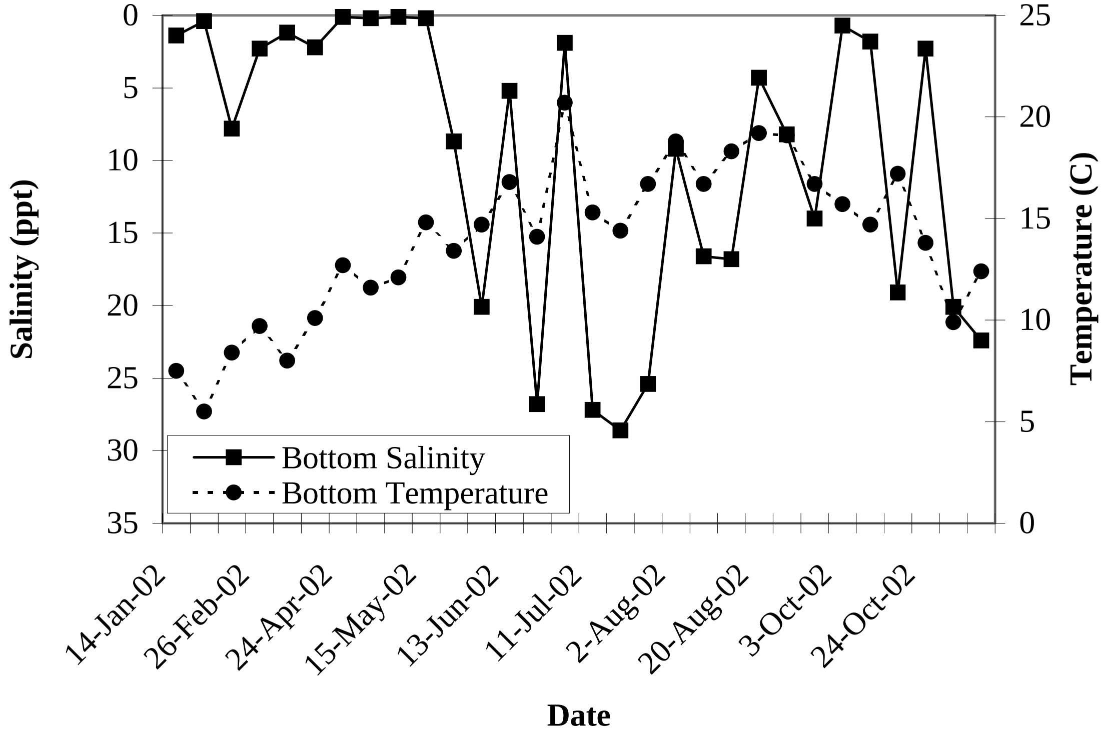


Figure 9. Minimum, maximum, and mean daily temperatures recorded in the Klamath River estuary at the Highway 101 Bridge during 2002.

Salinity

Stratification in the estuary varies seasonally, but to some extent is almost always present due to tidal influence. Between January and mid-June, saltwater intrusion was only present at the sampling transect closest to the ocean (L1), probably due to increased freshwater flow prohibiting tidal influx. Salinity measurements collected in the L1 during those months were between 0.0 – 0.1 ppt in surface readings and ranged between 0.2 – 25.1 ppt along the river bottom. The saltwedge moved upstream beyond Transect 1 during June, at which time low salinity levels between 0.3-0.5 ppt were observed upstream to Transect M3 (Townsite Boatramp; Figure 2).

The presence of a saltwedge in the middle and upper estuary occurs mainly during summer months when freshwater flows are lowest. The first substantial salinity observation above Transect L1 occurred on 18-Jun, when salinity measurements of 24.5 ppt were observed along the bottom of the channel at Transect M1 (Figure 11, Appendix B). Sampling on 3-Jul showed that the saltwedge did not extend beyond L2, however, a saltwedge was reestablished by sampling on 11-Jul up to Transect M3 and was persistent into the middle transects through October. Sampling on 3-Oct only detected saltwater intrusion up to Transect L2, where a salinity measurement of 20.7 was observed along the bottom of the channel. Subsequent sampling during October and early November showed that the saltwedge reestablished up to Transects M2 and/or M3 until 13-Nov, when it was only detected upstream to Transect L3 (Figure 11).



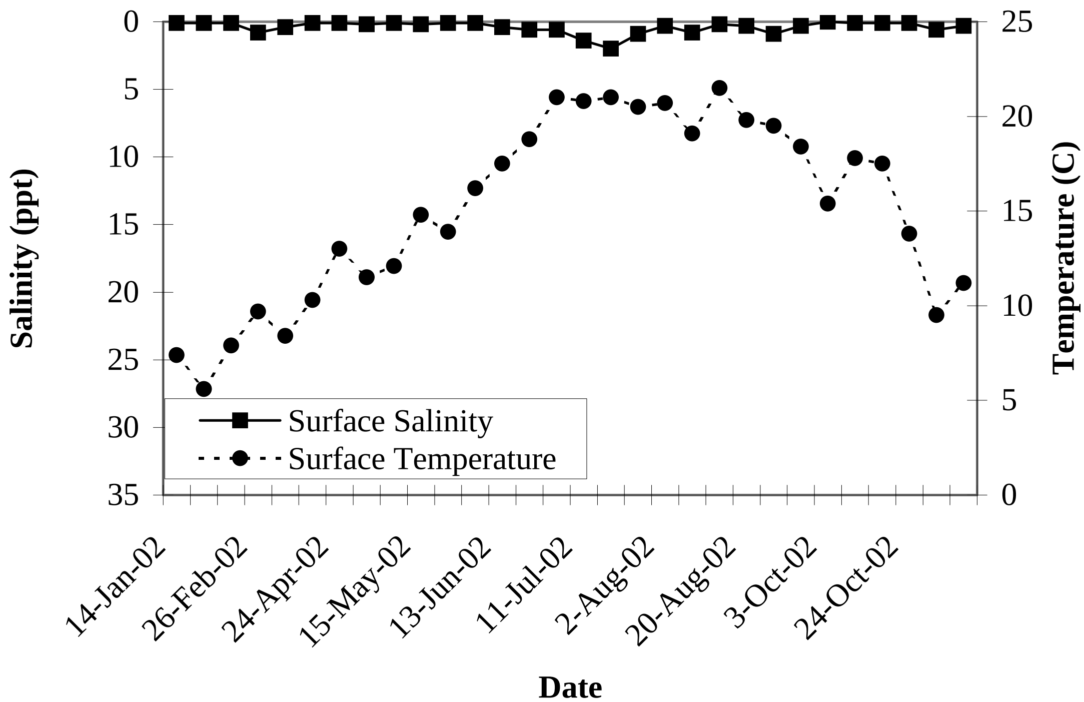


Figure 10. A comparison of bottom temperature/salinity (top graph) and surface temperature/salinity (bottom graph) observed during water quality monitoring at Station L1d during 2002.

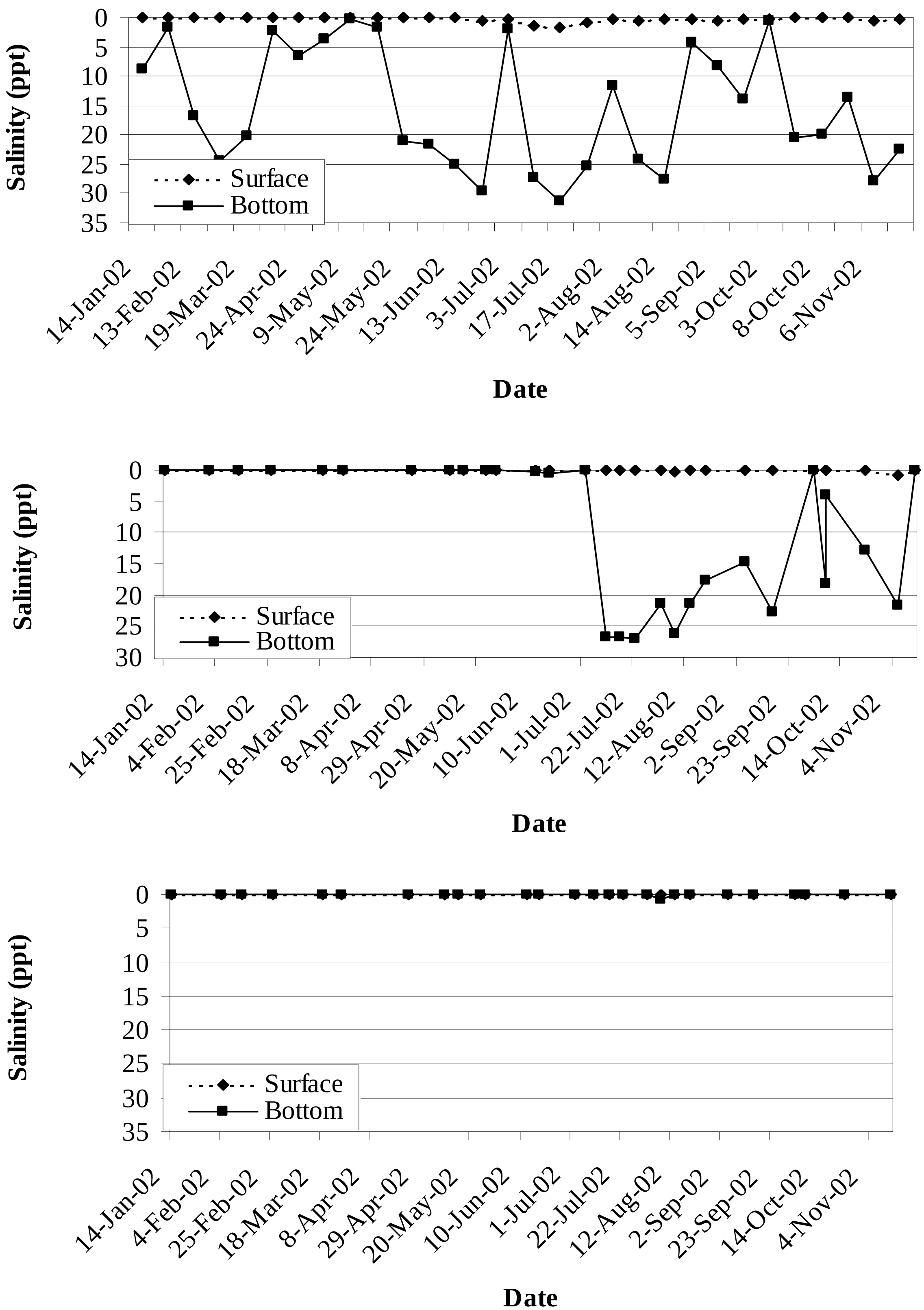


Figure 11. Surface and bottom salinity measurements observed during water quality monitoring at Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2002.

Dissolved Oxygen

Dissolved oxygen (DO) levels were lowest in the lower most estuary transects, especially Transect 1, where levels were frequently observed to be less than 6 mg/L near the channel bottom (Figure 12). DO measurements ranged between 0.06 – 12.78 mg/L during sampling between January and mid-June (13-Jun). All measurements below 6 mg/L were observed at stations a, d, and e, which are embayment areas to the north (station a) and south (stations d and e) of the main channel (Figure 2). Dissolved oxygen levels observed between July and mid-September (16-Sept) were generally between 6 – 10 mg/L, however, ten measurements at stations d and e were below 6 mg/L during this period (Figure 12). Dissolved oxygen levels at Transect 1 increased during October and November, ranging between 6.74 – 15.53 mg/L.

Dissolved oxygen values observed at Transect M1 were generally higher compared with Transect L1. Between January and mid-June (14-Jun), DO observations ranged between 8 – 12.5 mg/L, except on 14-Feb when dissolved oxygen was observed as low as 4.08 mg/L (Figure 12). Dissolved oxygen during summer and early fall (18-Jun – 8-Oct) at Transect M1 was generally between 5 – 10.5 mg/L, except on five occasions when levels dropped below 6 mg/L (range 4.45 – 5.99) and once when levels were as high as 13.31 at Station a on 17-Jul. During October and November, DO values ranged between 6.5 – 15 mg/L (Figure 12).

Dissolved oxygen levels were consistently higher in the Upper Transects of the estuary sampling stations, where dissolved oxygen levels were never observed below 6 mg/L (Figure 12). Measurements observed at Transect U1 ranged between 8 – 13 mg/L between January and mid-June (14-Jun) sampling. During the summer and early fall months (late June through early October), dissolved oxygen at Transect U1 ranged between 6 – 10 mg/L and increased to between 10 – 15 mg/L during the months of October and November (Figure 12).

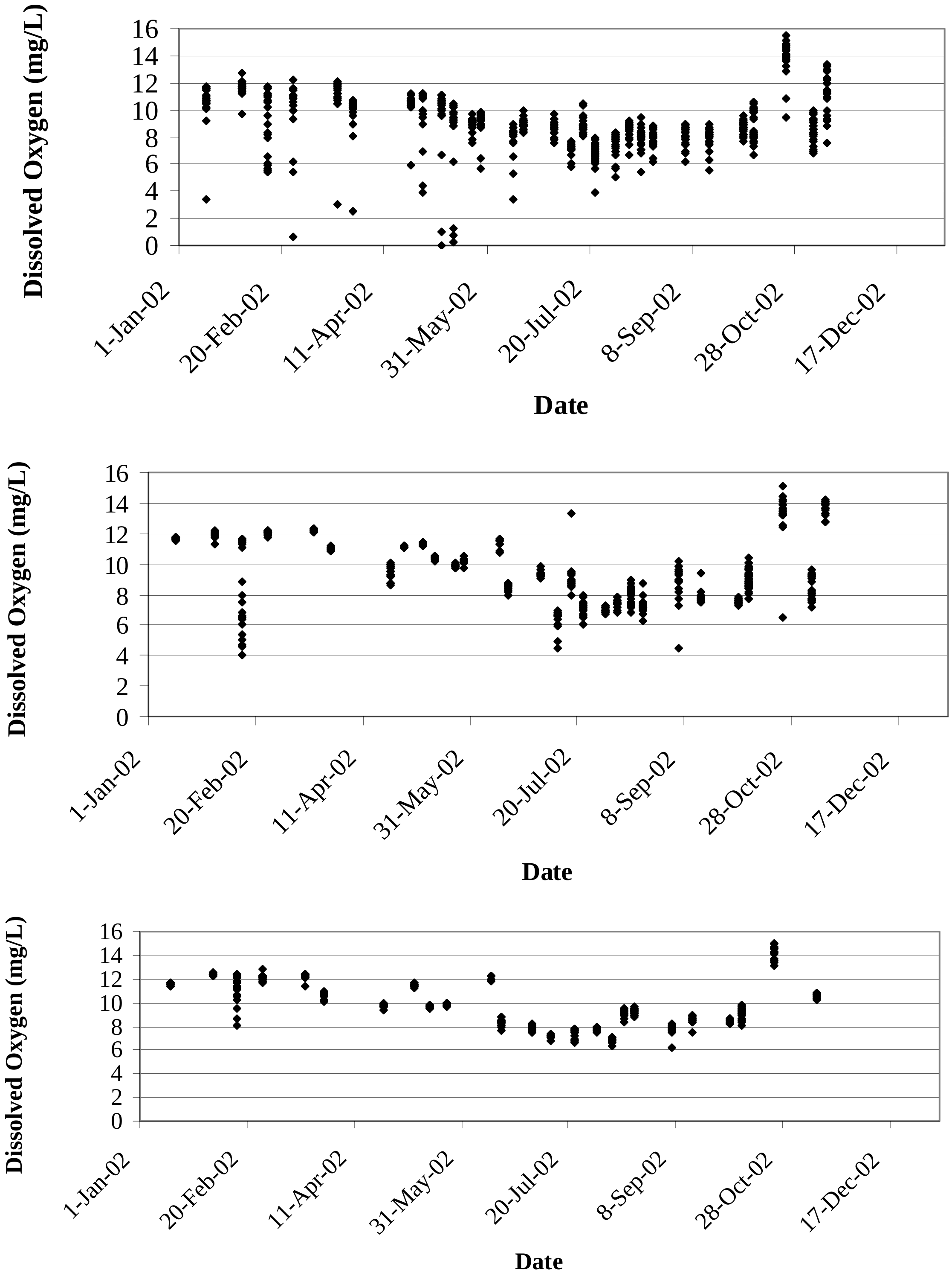


Figure 12. Dissolved oxygen measurements observed throughout the water column during water quality monitoring at Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2002.

2003

Temperature

Electronic temperature records from the lower and upper estuary regions indicate that temperatures in the lower estuary were greatly influenced by saltwater intrusion, especially during summer months. In the lower region of the estuary, mean daily temperatures ranged between 8 – 10°C in January and February and 8.29 – 11.45°C in March and April. Temperatures in the lower estuary began increasing in late April. Mean daily temperature on 1-May was 10.76°C, subsequently increasing to 17 - 18°C by the beginning of June (Figure 13). The maximum temperature recorded in the lower estuary was 19.73°C on 9-Jun (it should be noted that electronic records from the lower estuary are missing for 12-Jun through 19-Jun and 25-Sept through 24-Oct). Records beginning on 20-Jun indicate that the bottom of the water column was dominated by saltwater influence, resulting in cooler temperatures and very little fluctuation between minimum and maximum daily temperatures. Mean daily temperatures between 20-Jun – 24-Sept ranged from 12 – 17.5°C, with less than 2°C variation between daily minimum and maximum temperatures.

Temperature records from the upper region of the estuary were more indicative of river condition and showed no influence from saltwater intrusion. Water temperatures in the upper estuary were similar to records from the lower estuary through late May, however, data is missing for the upper region between 31-May – 19-June and 25-Sept – 22-Oct. Data from both regions beginning 20-Jun indicates that at that time the lower estuary was largely dominated by saltwater influence and the upper estuary was more indicative of warmer riverine conditions (Figure 13). Temperatures began to warm through June, with the maximum temperature recorded at 24.74 on both 30-Jul and 1-Aug. Due to the lack of data for June, mean monthly temperature was not calculated; however mean monthly temperatures for July and August were 21.24°C and 21.74°C, respectively. Temperatures began slowly decreasing in September, with mean daily temperatures exceeding 21°C at the beginning of the month and cooling to 18.48°C by 24-Sept (subsequent data from 25-Sept through 23-Oct is missing; Figure 13). Data from 24-Oct shows a sharp decline in temperature through 1-Nov, with mean daily temperatures decreasing from 16.3°C to 11.03°C. During November and December, temperatures continued to gradually decline, with mean monthly temperatures for November and December 10.14°C and 8.06°C (respectively).

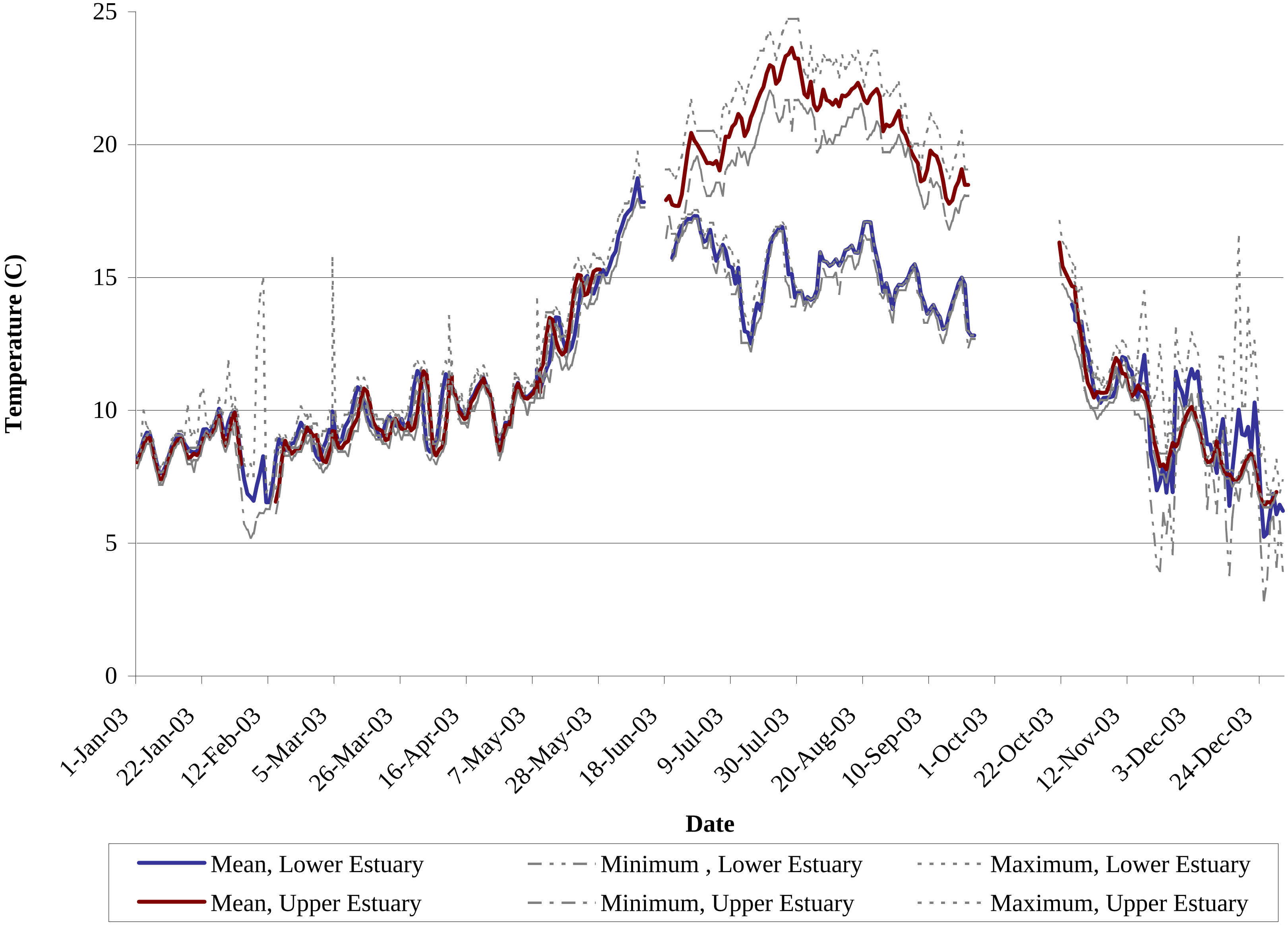


Figure 13. A comparison of minimum, maximum, and mean daily temperatures recorded in the Lower (Requa) and Upper (Highway 101 Bridge) Regions of the Klamath River Estuary during 2003.

Salinity

Saltwater influence in the estuary was minimal during monitoring through July. Salinity was not detected above 1.0 ppt until 16-Jun, when a measurement of 1.2 ppt was observed near the channel bottom of Transect L1 (Figure 14). Salinity recorded at all other transects on 16-Jun was 0.1 ppt. Salinity ranged between 0.1 – 0.7 ppt on 24-Jun, and between 0.1 – 2.5 ppt on 2-Jul. The first indication of a saltwedge forming in the estuary was detected during monitoring on 15-Jul, when salinity at the bottom of Transect L1 measured 30.4 ppt (Figure 14). The saltwedge extended upstream to Transect L2, where measurements ranged between 0.3 – 12 ppt.

Tidal influence moved upriver as the summer progressed, with the saltwedge observed in Transect M1 during sampling on 16-Jul (Appendix C). Maximum salinity measurements observed along the channel bottom were 31.5, 30.7, 29.2, and 27.5 ppt in Transects L1, L2, L3, and M1 (respectively). Salinity at all remaining transects (M2 – U3) was 0.1 ppt. As previously stated, the formation of a saltwedge in the estuary creates drastic differences between surface and bottom temperatures (Figure 15). On 24-Jul, the saltwedge was contained within the lower region of the estuary, with maximum salinity measurements of 27.2, 25.8, and 9.9 ppt observed in Transects L1, L2, and L3 (respectively). Salinity at all other sampling transects was 0.1 ppt. The upriver extent of the saltwedge varied between M1 – M3 during August, and was only observed in the lower estuary during sampling on 18-Sept. The saltwedge extended into the Transect U1 (9.3 ppt) on 29-Sept. During sampling on 14-Oct and 20-Oct, bottom salinity measurements from all lower and middle transects (L1 – M3) exceeded 25 ppt. On 29-Oct, the upriver extent of the saltwedge was Transect M2, where a maximum salinity measurement of 27.9 ppt was observed (Figure 14).

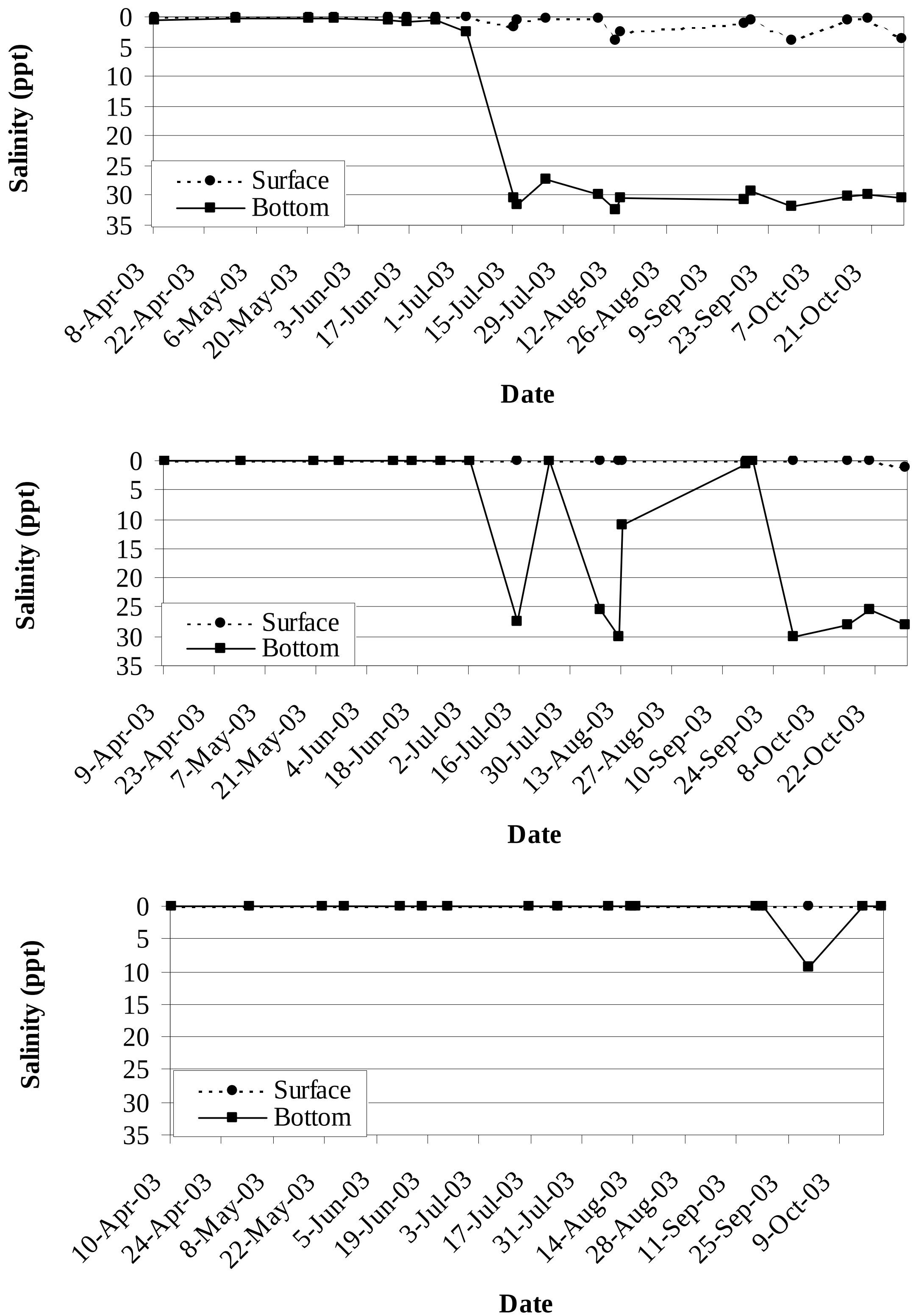
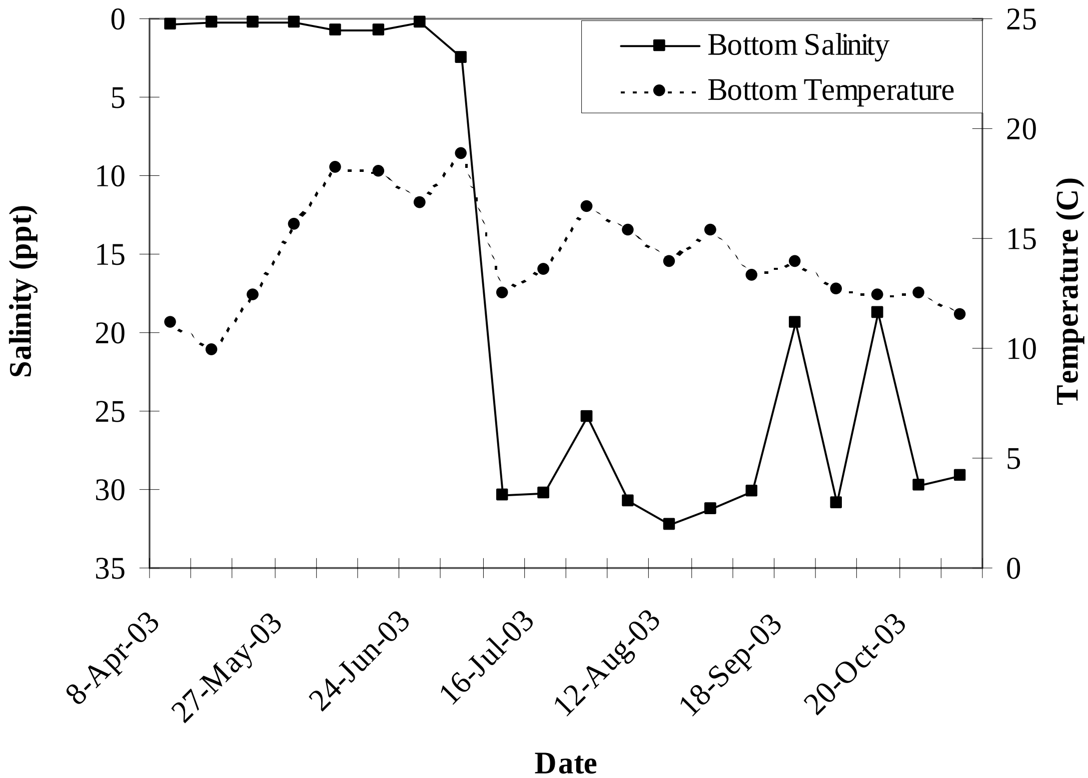


Figure 14. Range of surface and bottom salinity measurements observed during water quality monitoring in Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2003.



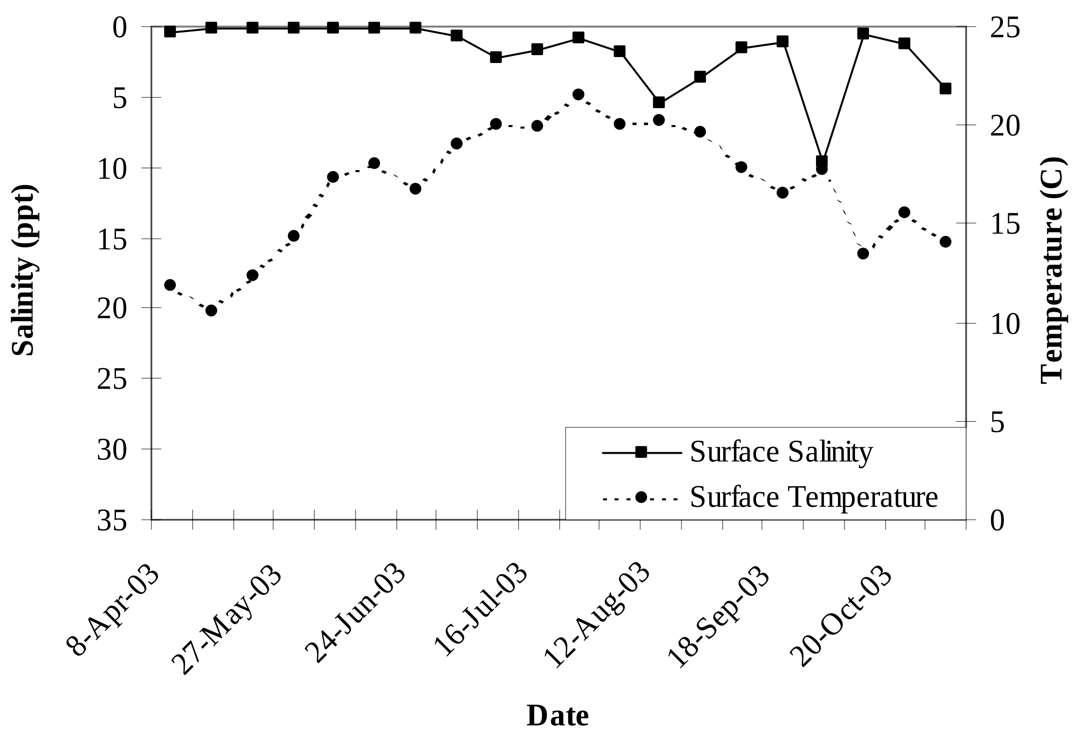


Figure 15. A comparison of bottom temperature/salinity (top graph) and surface temperature/salinity (bottom graph) observed during water quality monitoring at Station L1d during 2003.

Dissolved Oxygen

Dissolved oxygen (DO) levels were lowest and most variable in the lower estuary, with measurements frequently observed below 6 mg/L. In Transect L1, DO gradually decreased during early spring, ranging between 9.73 – 11.83 on 8-Apr, 9.36 – 10.87 mg/L on 30-Apr, and 8.36 – 10.04 mg/L on 20-May (Figure 16). Dissolved oxygen measurements on 27-May ranged between 4.12 – 10.33 mg/L, with the lowest DO measurement (4.12) observed near the channel bottom of Station L1e. DO fluctuated greatly during summer months (June – September), ranging between 2.83 – 12.53 mg/L. Nine measurements were below 6 mg/L during this time, all of which were observed near the channel bottom. Low dissolved oxygen was most common at Station L1e, where 6 of the 9 measurements below 6 mg/L were taken. Dissolved oxygen less than 6 mg/L was also observed at Station L1d (24-Jul and 18-Sept) and L1a (18-Sept). Conditions improved during mid-October, with DO ranging between 7.65 – 9.18 mg/L on 20-Oct and 8.20 – 10.13 mg/L on 29-Oct (Figure 16).

Dissolved oxygen measurements at Transect M1 were generally higher and less variable compared to Transect L1. DO ranged between 1.00 – 11.15 mg/L during initial sampling on 8-Apr and gradually decreased during each successive sampling event. However, DO remained above 7.5 mg/L through mid-July (Figure 16). Observations on 24-Jul ranged between 6.24 – 6.66 mg/L. During monitoring in August through October, DO generally ranged between 6 – 11.5 mg/L, except on 29-Sept at Station M1e where two DO measurements dropped below 6 mg/L (5.02 and 5.92 mg/L).

DO was least variable and consistently higher in the Upper Transects of the estuary. Measurements ranged between 11.00 – 11.32 on 8-Apr, 10.82 – 10.86 mg/L on 30-Apr, and 9.47 – 9.63 mg/L on 20-May, and 9.69 – 10.75 mg/L on 27-May (Figure 16). DO observations ranged between 7.97 – 10.35 during monitoring in June, and 6.84 – 8.92 mg/L during July, except one measurement on 16-Jul at the channel bottom of Station U1a (2.26 mg/L). Dissolved oxygen levels increased during September and October, with observations ranging between 7.25 – 11.39 mg/L (Figure 16).

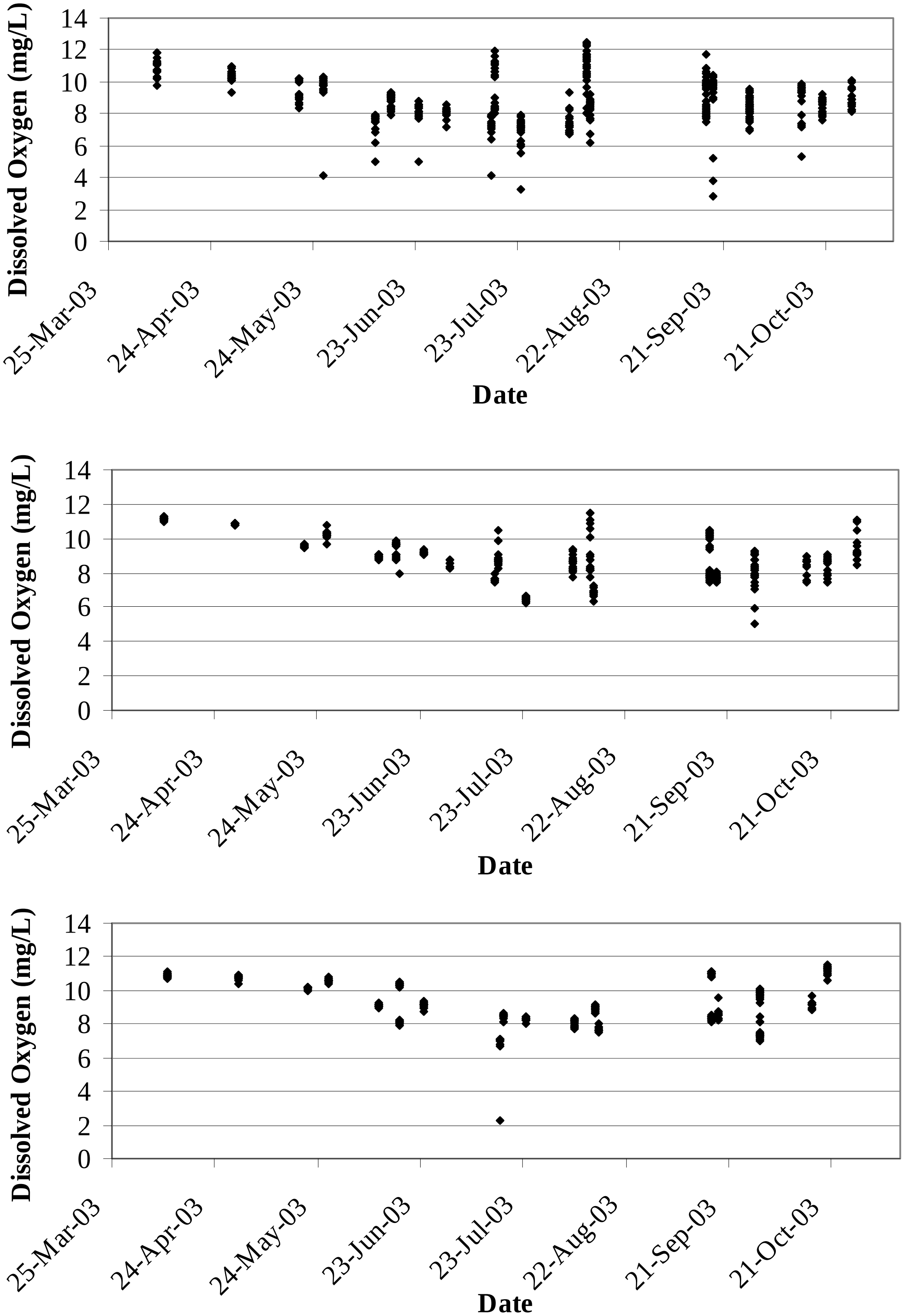


Figure 16. Dissolved oxygen measurements observed throughout the water column during water quality monitoring at Transects L1 (top graph), M1 (middle graph), and U1 (bottom graph) during 2003.

South Slough Water Quality Monitoring

2001

Temperature

Electronic temperature data from the south slough was collected from 12-Aug through 31-Dec. Mean daily temperatures ranged between 18.9 – 20.3°C from 12-Aug through 9-Sept, with a maximum temperature of 21.01°C recorded on 28-Aug (Figure 17). Higher temperatures were observed during water quality monitoring in July. Surface water temperatures ranged between 20.4 – 21.8°C on 18-Jul, 21.6 – 22.3°C on 25-Jul, and 22.4 – 23.3°C on 7-Aug. Results from water quality monitoring and electronic temperature records indicate that temperatures began to cool during September, with mean daily temperatures ranging between 18.9 - 20.3°C during the beginning of the month and dropping to 16 - 17°C by the end of September. During this time, minimum and maximum daily temperatures were similar to mean daily temperatures, usually with less than a 0.3°C change in temperatures observed each day. Variation between minimum and maximum temperatures is observed after 27-Sept (Figure 17). Temperatures continued to cool through October, with mean daily temperatures by the end of the month ranging between 11.5 – 12.5°C. Mean monthly temperatures observed during November and December were 10.09°C and 8.46°C (respectively).

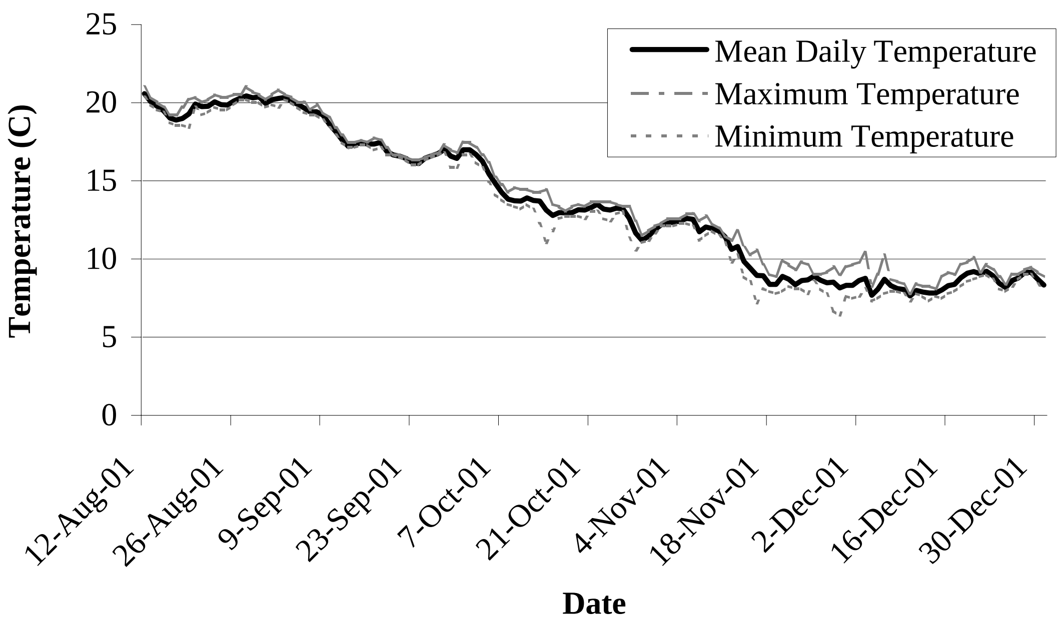


Figure 17. Minimum, maximum, and mean daily temperatures recorded in the south slough of the Klamath River estuary between 12-Aug and 31-Dec, 2001.

Salinity

Surface salinity in the slough was usually less than or equal to salinity measurements observed on the channel bottom. In general, salinity was lowest at Station 1, where salinity ranged between 0.0 – 1.7 ppt during monitoring (Figure 18). Salinity observations were highest at depth measurements near the outlet of the slough at Stations 5, 6, and 7. During July, surface measurements across all monitoring stations ranged between 0.2 – 0.8 ppt and bottom measurements ranged between 0.4 – 3.1 ppt. Observations during August were similar, with surface measurement ranging between 0.0 – 0.5 ppt and bottom measurements ranging between 0.1 – 2.5 ppt. Salinity observations in September ranged between 0.0 – 1.3 ppt for surface readings and 0.1 – 2.4 ppt at the bottom of sampling locations. Salinity increased during October monitoring, when surface measurements up to 4.1 ppt and bottom measurements up to 10.0 ppt were observed (Figure 18).

Dissolved Oxygen

Dissolved oxygen conditions were variable among the sampling stations, however, observations were consistently highest at Stations 1 (inlet) and 7 (outlet) during monitoring events (Table 1). DO at Station 1 generally ranged between 7 – 8.8 mg/L during July and August monitoring throughout the water column, except on 16-Aug near the channel bottom (4.75 mg/L). During mid-August through mid-September, DO levels ranged between 6.02 – 7.37 mg/L, and were slightly higher (between 0.5 – 1.0 mg/L) at surface compared with bottom measurements. On 25-Sept, water levels were markedly higher (1.5 m) due to the partial closure of the river mouth, and dissolved oxygen near the channel bottom decreased to 0.13 mg/L (Figure 19). Conditions on 4-Oct were improved and dissolved oxygen observations ranged between 7.84 – 8.53 mg/L. Conditions at Stations 2 through 6 were similar, with DO levels decreasing throughout the sampling season. Dissolved oxygen levels were highest at the surface and bottom DO rarely exceeding 6 mg/L (Table 1). Surface observations at Station 7 ranged between 7.10 – 13.69 mg/L throughout the season. DO near the channel bottom varied throughout the season, ranging between 8.93 – 9.48 mg/L on 18-Jul, 25-Jul, and 7-Aug, but decreasing during mid-August through mid-September to between 1.75 – 6.35 mg/L. Bottom conditions improved during October sampling, ranging between 8.36 – 8.91 mg/L (Table 1).

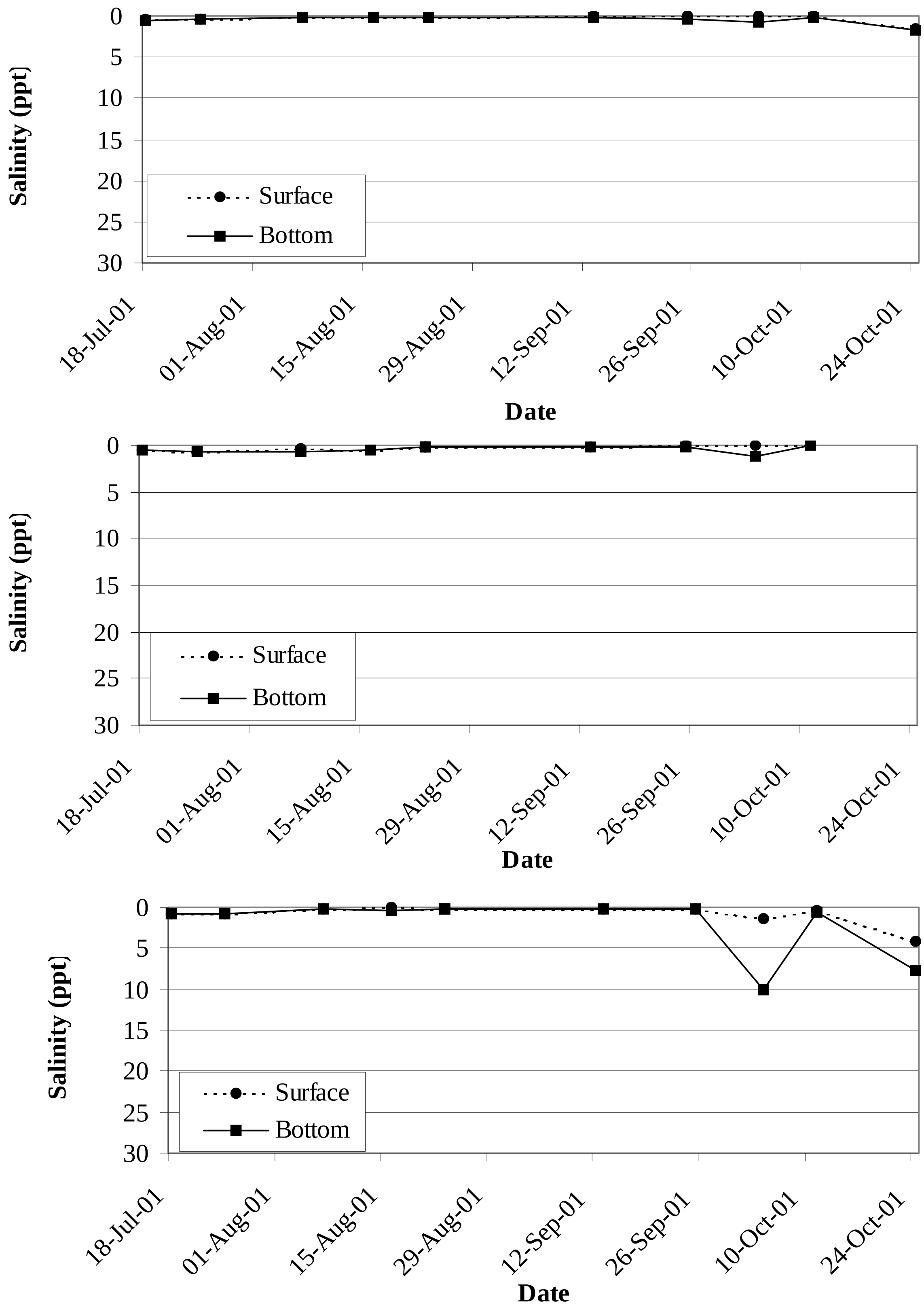


Figure 18. Surface and bottom salinity (ppt) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2001.

Table 1. Surface and bottom dissolved oxygen (mg/L) measurements observed in the south slough of the Klamath River estuary during 2001.

Date	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
18-Jul-01	8.80	8.42	9.87	0.15	9.69	8.86	11.35	8.48	9.18	3.75	10.76	5.82	9.40	9.47
25-Jul-01	7.59	7.07	8.20	3.04	8.45	3.18	9.79	5.31	10.34	1.42	9.40	9.28	9.27	9.48
7-Aug-01	7.33	7.85	8.00	0.21	9.46	1.70	10.60	0.63	11.93	0.04	9.97	0.06	8.83	8.93
16-Aug-01	7.89	4.75	9.74	3.52	9.72	0.25	13.20	3.99	10.60	0.36	15.69	0.92	13.69	4.79
23-Aug-01	7.21	6.27	7.35	2.34	7.92	0.05	11.55	0.25	8.46	0.23	7.67	0.02	7.22	6.35
23-Aug-01	7.37	6.48	7.03	5.77	7.46	5.86	9.81	6.57	10.37	0.12	7.99	3.80	7.45	5.91
13-Sep-01	6.69	6.16	4.17	0.08	4.49	0.01	5.14	0.66	6.85	0.02	4.41	0.02	7.10	1.75
25-Sep-01	7.70	0.13	7.50	0.06	6.94	0.04	7.83	0.16	9.15	1.34	8.50	1.50	7.94	2.63
4-Oct-01	8.53	7.84	7.77	0.12	4.83	0.18	3.45	2.83	9.19	3.94	9.14	8.00	8.94	8.46
11-Oct-01	8.82	8.14	8.73	7.13	6.11	0.08	4.90	4.90	6.75	3.78	8.83	5.44	8.97	8.91
24-Oct-01	9.94	9.82	Inaccessible due to excessive channel vegetation						8.44	4.80	8.63	7.26	8.46	8.36

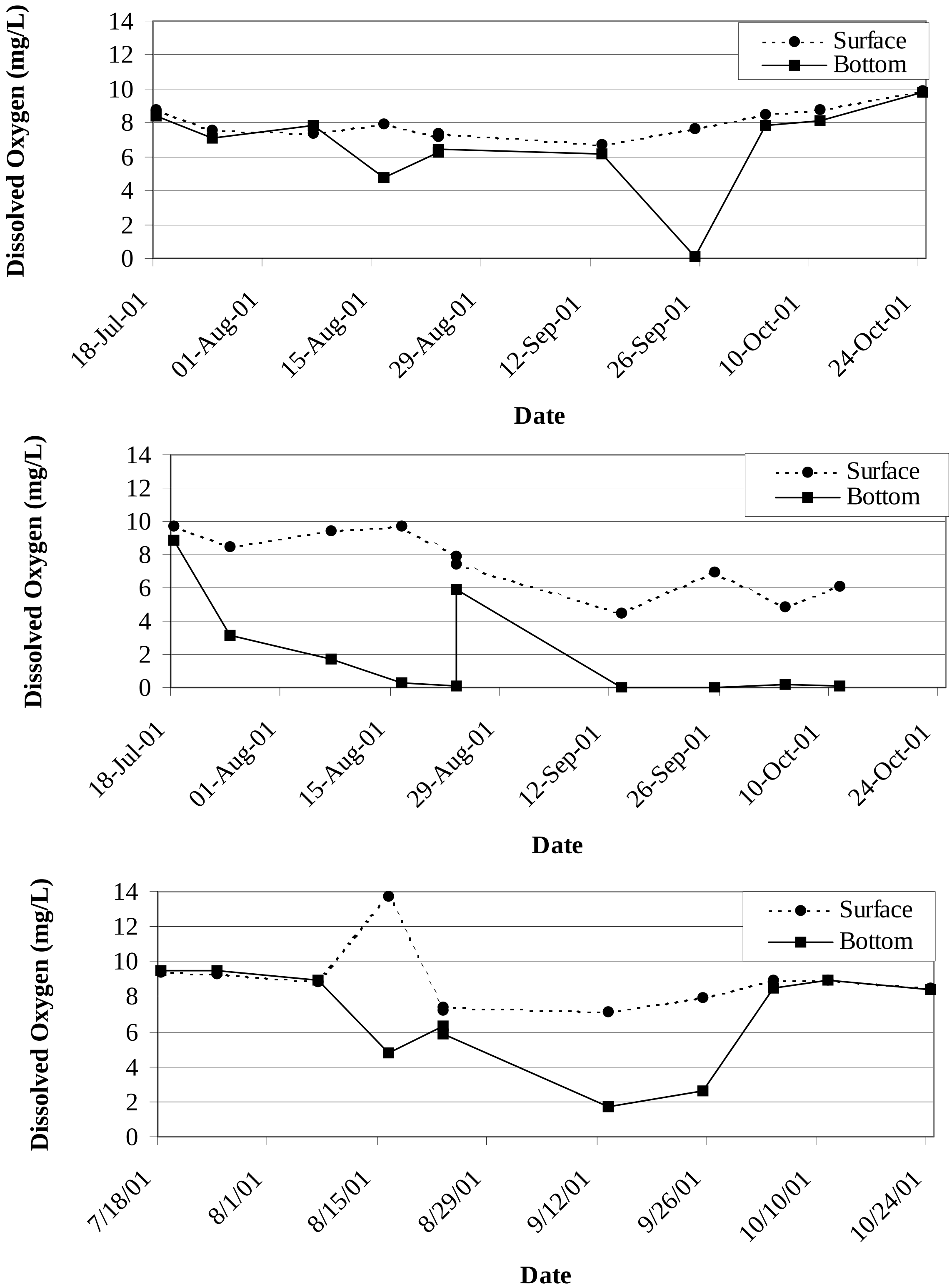


Figure 19. Surface and bottom dissolved oxygen (mg/L) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2001.

2002

Temperature

Electronic temperature records from the south slough indicate that mean daily temperatures stayed below 10°C through mid-March, when temperature began gradually increasing (Figure 20). Mean daily temperatures during April and May were 14.28°C and 16.74°C, respectively. Through May, temperature records exceeding 20°C were not observed. Temperatures warmed during June, with average daily temperatures ranging between 18.13°C on 1-Jun and 21.45°C on 30-Jun. Temperatures peaked between 30-Jun and 2-Jul, with maximum daily temperatures above 23°C and mean daily temperatures between 21-44 – 21.73°C (Figure 20). Mean daily temperature observed between 3-Jul and 11-Jul ranged from 19.81 – 21.68°C, with a maximum temperature of 22.89°C observed on 8-Jul. Water temperatures during late July were significantly cooler, with temperatures ranging between 15 - 17°C. Another warming event was observed in mid-September, when mean daily temperatures ranged between 17.38 – 18.55°C and a maximum temperature of 18.94°C was observed on 27-Sept. In October, a progressive cooling trend began and continued for the remainder of the year. Mean monthly temperatures calculated for October, November, and December were 15.18°C, 11.08°C, and 10.13°C (respectively).

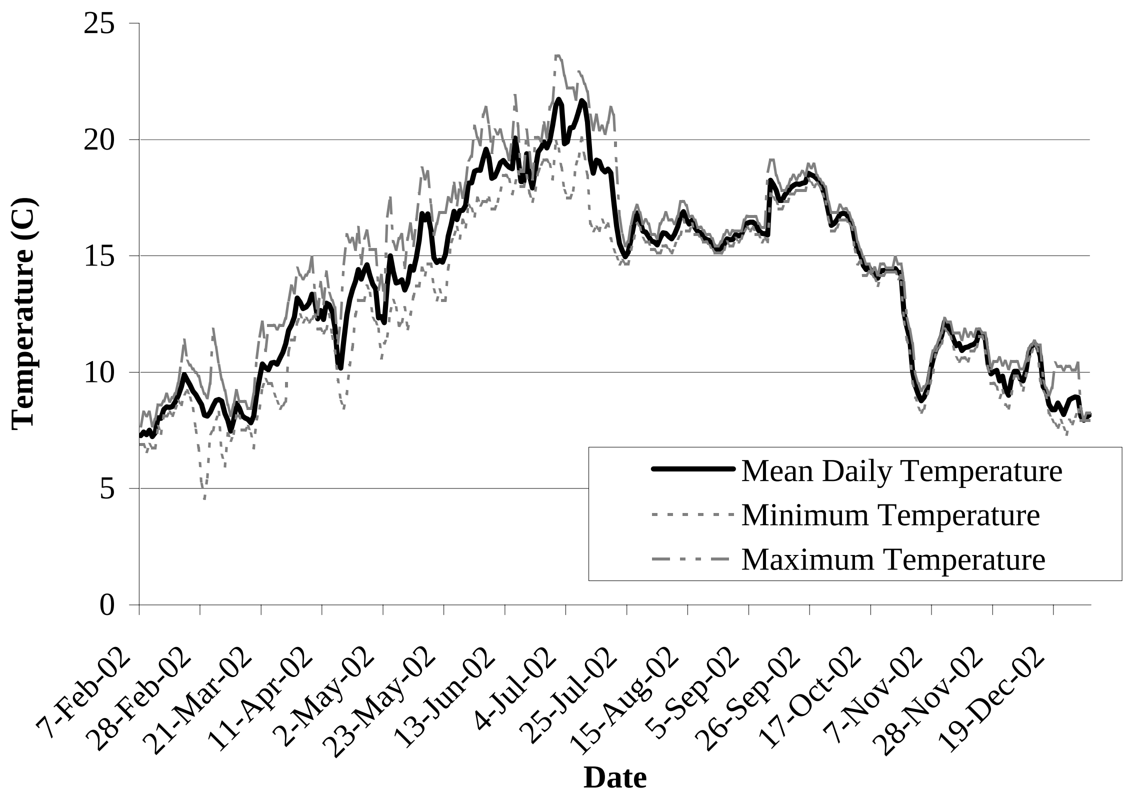


Figure 20. Minimum, maximum, and mean daily water temperatures recorded in the south slough of the Klamath River estuary during 2002 (7-Feb – 31-Dec).

Salinity

Surface salinity in the slough was always less than or equal to salinity measurements observed on the channel bottom. Salinity in the slough ranged between 0.0 – 0.9 ppt through late May across all sampling stations and depths (Figure 21). During June, surface salinity ranged between 0.0 – 0.5 ppt and bottom salinity was observed between 0.2 – 2.5 ppt. Salinity increased during July, when surface measurements up to 3.9 ppt and bottom measurements up to 10.7 ppt were observed. Salinity observations between August and October ranged between 0.0 – 0.7 ppt for surface readings and 0.2 – 3.6 at the bottom of sampling locations. Salinity increased during November and December, especially at Station 7, which is closest to the river mouth (Figure 21). During these winter months, surface salinity measurements ranged between 0.6 – 2.8 ppt and bottom salinity ranged between 3.4 – 23.4 ppt (Figure 21).

Dissolved Oxygen

Dissolved oxygen measurements in the south slough were always above 6.0 mg/L for surface and mid-channel readings, although bottom readings were frequently below 6.0 mg/L, especially during summer months. At Station 1 (farthest upstream at the slough inlet), bottom readings during sampling on 5-Jun, 18-Jun, and 8-Jul were 4.63 mg/L, 3.94 mg/L, and 4.60 mg/L (respectively). At Station 2, bottom readings observed on 18-Jun, 8-Jul, and 17-Jul were 0.19 mg/L, 3.15 mg/L, and 4.78 mg/L (respectively). Low DO was observed along the channel bottom during October at Station 2. Sampling on 4-Oct and 25-Oct resulted in dissolved oxygen measurements of 0.18 mg/L and 4.90 mg/L. Low measurements were observed at Station 3 during sampling conducted in June, October, and November. On 18-Jun, dissolved oxygen was 3.99 mg/L along the channel bottom, and on 25-Oct and 18-Nov readings were 0.46 mg/L and 4.17 mg/L (respectively). Dissolved oxygen readings along the channel bottom at Station 4 were below 6 mg/L on 13-Aug, and 4-Oct when readings were 3.54 mg/L and 5.85 mg/L (respectively). Results from the channel bottom at Station 5 show that DO dropped below 6 mg./L during sampling on 23-Apr, 18-Jun, and 17-Jul. Dissolved oxygen measurements for those dates were 3.29 mg/L, 5.95 mg/L, and 5.87 mg/L (respectively). At Station 6, DO was only observed below 6 mg/L on the channel bottom once, during sampling on 18-Jun when a measurement of 4.81 mg/L was observed. Dissolved oxygen was never less than 6 mg/L at Station 7, which is the outlet of the slough (Figure 22).

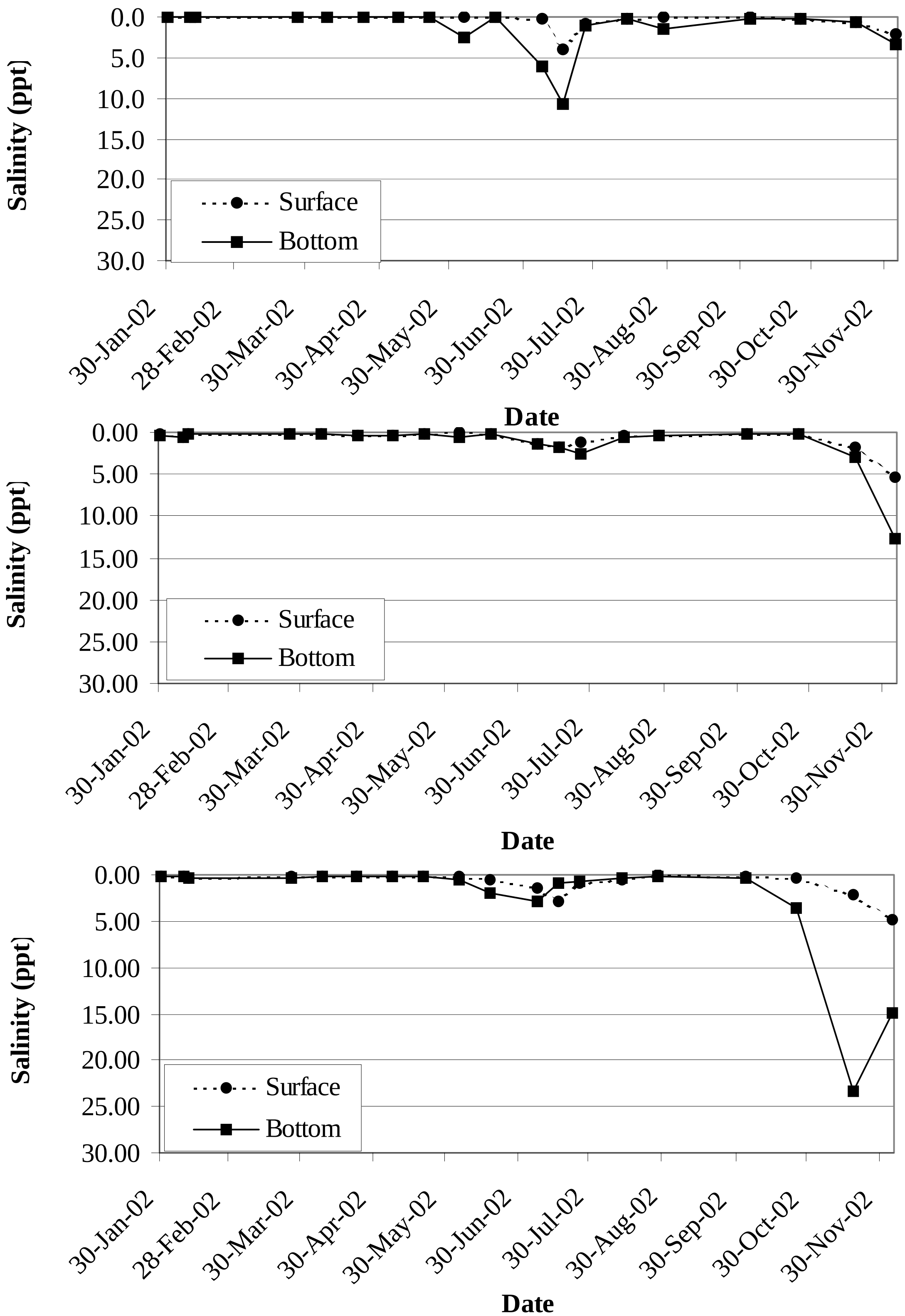
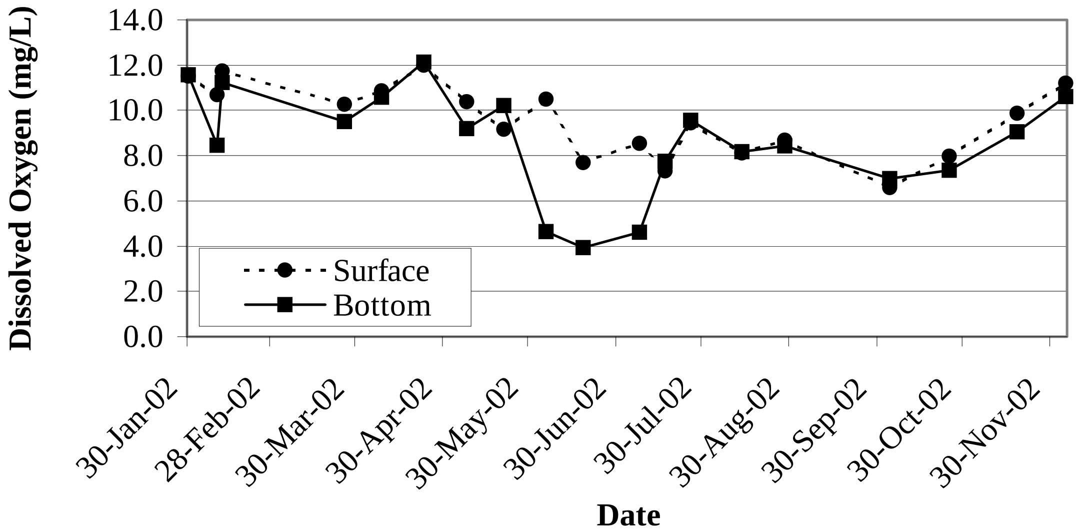
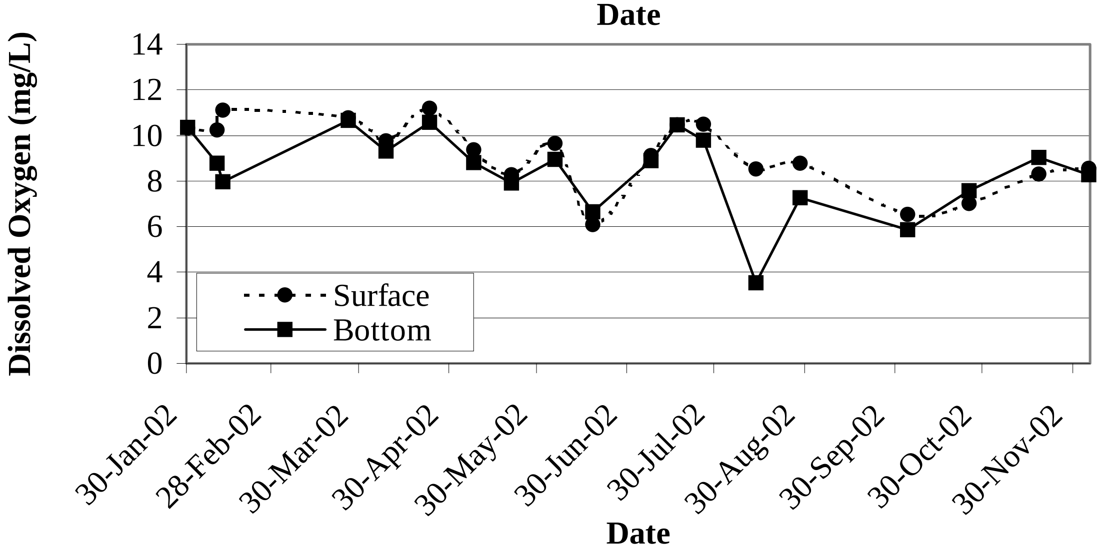


Figure 21. Surface and bottom salinity (ppt) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2002.





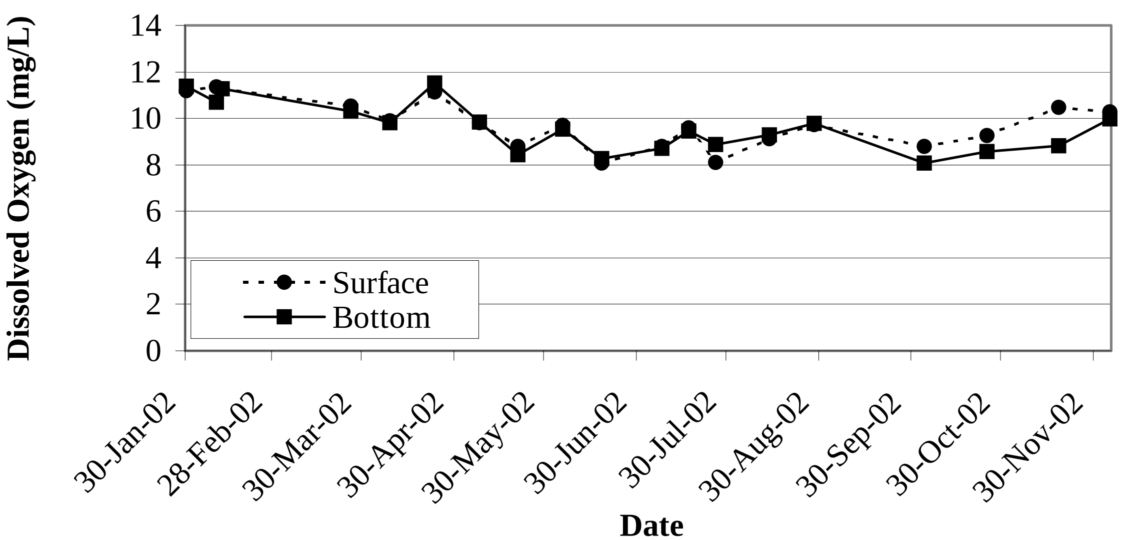


Figure 22. Surface and bottom dissolved oxygen (mg/L) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2002.

2003

Temperature

Electronic temperature records are not available for 2003; however, temperature was recorded during water quality monitoring events between March and November. Temperatures ranged between 8.7 – 10.2°C during March, 11.3 – 14.3°C during April, and 14.3 – 15.4°C during May monitoring. Temperatures during June ranging between 17.7 – 19.5°C, with the warmest temperatures occurring in surface measurements of Stations 1 and 2. Temperatures ranged between 18.1 – 18.8 and 20.4 – 22.1°C during monitoring events on 8-Jul and 23-Jul, respectively. During monitoring on 18-Aug, temperatures across all sites and depths ranged between 17.4 – 23.6°C, with the warmest temperatures occurring at Stations 1, 2, and 3. A cooling trend was observed during September, with temperatures ranging between 17.3 – 18.4°C on 9-Sept and 15.3 – 18.6°C on 25-Sept. Temperatures observed during the subsequent and final monitoring event on 3-Nov ranged between 9.5 – 13.4°C.

Salinity

Salinity measurements during March monitoring were 0.1 ppt at all stations and depths. Tidal influence was first detected in 2003 during monitoring on 8-Apr, and salinity measurements ranged between 0.6 – 12.4 ppt, with salinity increasing throughout the water column at all sample stations. Salinity ranged between 0.1 – 9.9 ppt across all sites and depths on 22-Apr. Observations during sampling on 22-May and 25-Jun ranged between 0.1 – 0.8 ppt and 0.1 – 1.5 ppt, respectively. Low salinity concentrations were continually detected during July, ranging between 0.1 – 0.7 ppt on 8-Jul and 0.1 – 1.0 ppt on 23-Jul. Monitoring on 18-Aug was similar, with salinity ranging between 0.2 – 3.0 ppt. Salinity concentrations were higher during September monitoring, ranging between 0.5 – 21.9 ppt on 9-Sept and 0.6 – 19.2 ppt on 25-Sept, with salinity highest at depth measurements of Stations 5,6, and 7. During monitoring on 3-Nov, salinity was slightly lower, ranging between 0.6 – 6.9 ppt across all sites and depths (Figure 23).

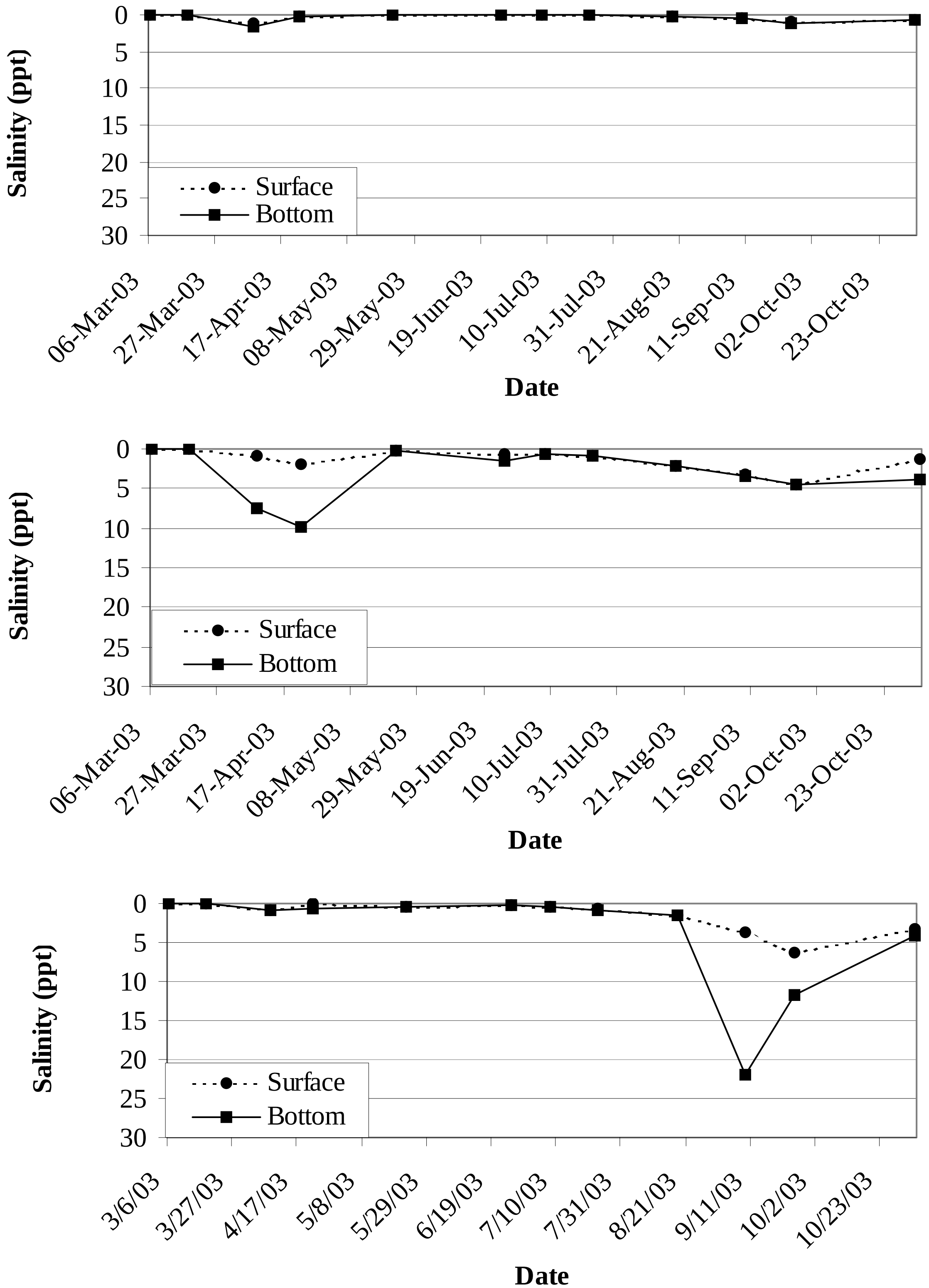


Figure 23. Surface and bottom salinity (ppt) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2003.

Dissolved Oxygen

Dissolved oxygen varied during the monitoring season. DO levels observed during March ranged between 8.14 – 11.45 mg/L across all stations and depths. Low dissolved oxygen measurements were first observed on 8-Apr, where DO ranged between 2.17 – 11.01 mg/L. DO fell below 6 mg/L at the channel bottom of Stations 2 (2.17 mg/L), 3 (4.09 mg/L), 5 (5.27 mg/L), and 6 (5.3 mg/L). Observations on 22-Apr were similar, with DO ranging between 3.82 – 10.99 mg/L, dropping below 6 mg/L at the channel bottom of Stations 3 (4.22 mg/L) and 4 (3.82 mg/L). Conditions were improved during monitoring events on 22-May, 25-Jun, and 8-Jul with DO ranging between 7.11 – 10.6 mg/L (Figure 24).

Dissolved oxygen levels were lowest during monitoring on 23-Jul, ranging between 2.57 – 8.34 mg/L. DO at Stations 1, 6, and 7 ranged between 7.02 – 8.34 mg/L but dropped below 6 mg/L at Stations 2, 3, 4, and 5. DO fell below 6 mg/L at all channel depths at Stations 3 and 4, ranging between 5.36 – 5.93 mg/L. Conditions were improved during monitoring on 18-Aug, with all measurements exceeding 8 mg/L except at the channel bottom of Station 2 (4.01 mg/L). Observations during September ranged between 7.94 – 9.38 mg/L on 9-Sept and 6.95 – 12.54 mg/L on 25-Sept. DO on 3-Nov ranged between 2.94 – 14.33 mg/L, dropping below 6 mg/L at Station 2 (2.94 and 4.94 mg/L near channel bottom).

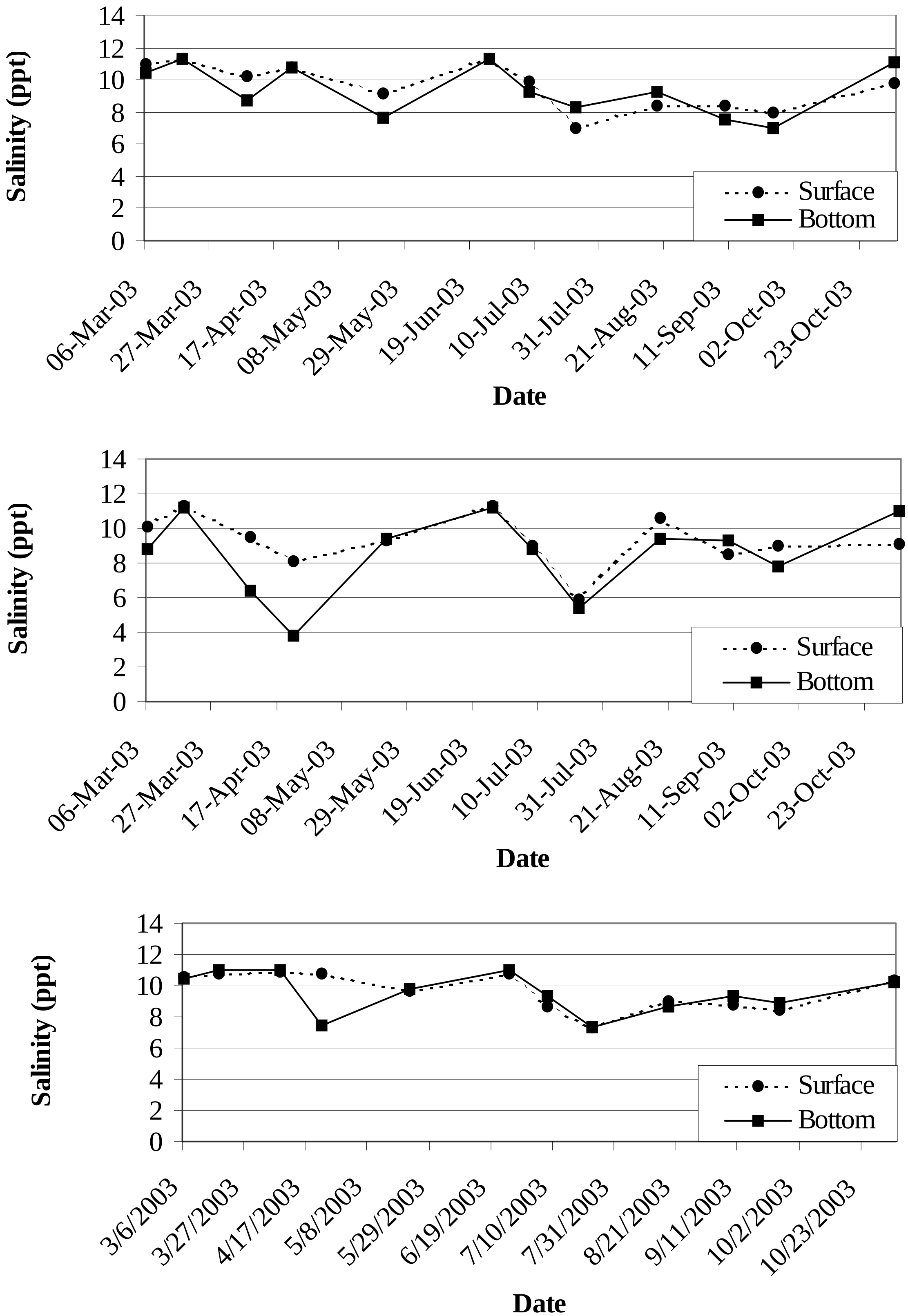


Figure 24. Surface and bottom dissolved oxygen (mg/L) measurements observed in the south slough of the Klamath River estuary at Station 1 (top graph), Station 4 (middle graph) and Station 7 (bottom graph) during 2003.

Water Quality Monitoring, Salt Creek

<u>2001</u>

Temperature

Electronic temperature records beginning in mid-June (19-Jun) show little diurnal temperature fluctuation between 19-Jun and 20-Aug, except between 18-Jul – 24-Jul when maximum daily temperatures reached 17.36 – 18.64°C. Mean daily temperatures ranged between 12.92 – 15.55°C between 19-Jun and 24-Aug. Minimum, maximum, and mean daily temperatures rose sharply on 21-Aug, presumably due to lack of tidal influence in the estuary (Figure 25). Temperatures slowly decreased during September and notable differences were observed after the estuary mouth was re-established, with minimum daily temperatures dropping from 18°C to 11 - 12°C. Maximum daily temperatures during September cooled from >21°C at the beginning of the month to 16 - 17°C in the beginning of October (Figure 25).

Results from water quality monitoring indicate that temperatures at the mouth of Salt Creek (Station 1) were more influenced by estuarine conditions. Little variation was observed between surface and bottom temperatures compared with monitoring Station 2 – 5, where bottom temperatures were frequently 5 - 7°C cooler near the channel bottom (Figure 26).

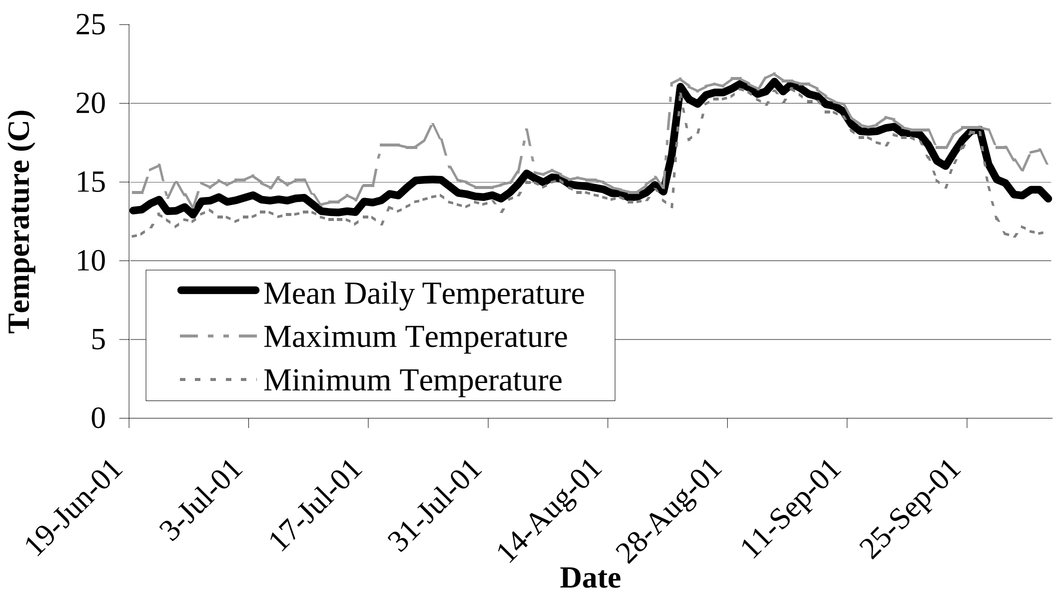


Figure 25. Minimum, maximum, and mean daily water temperatures recorded in the Salt Creek slough of the Klamath River estuary during 2001 (18-Jun – 4-Oct).

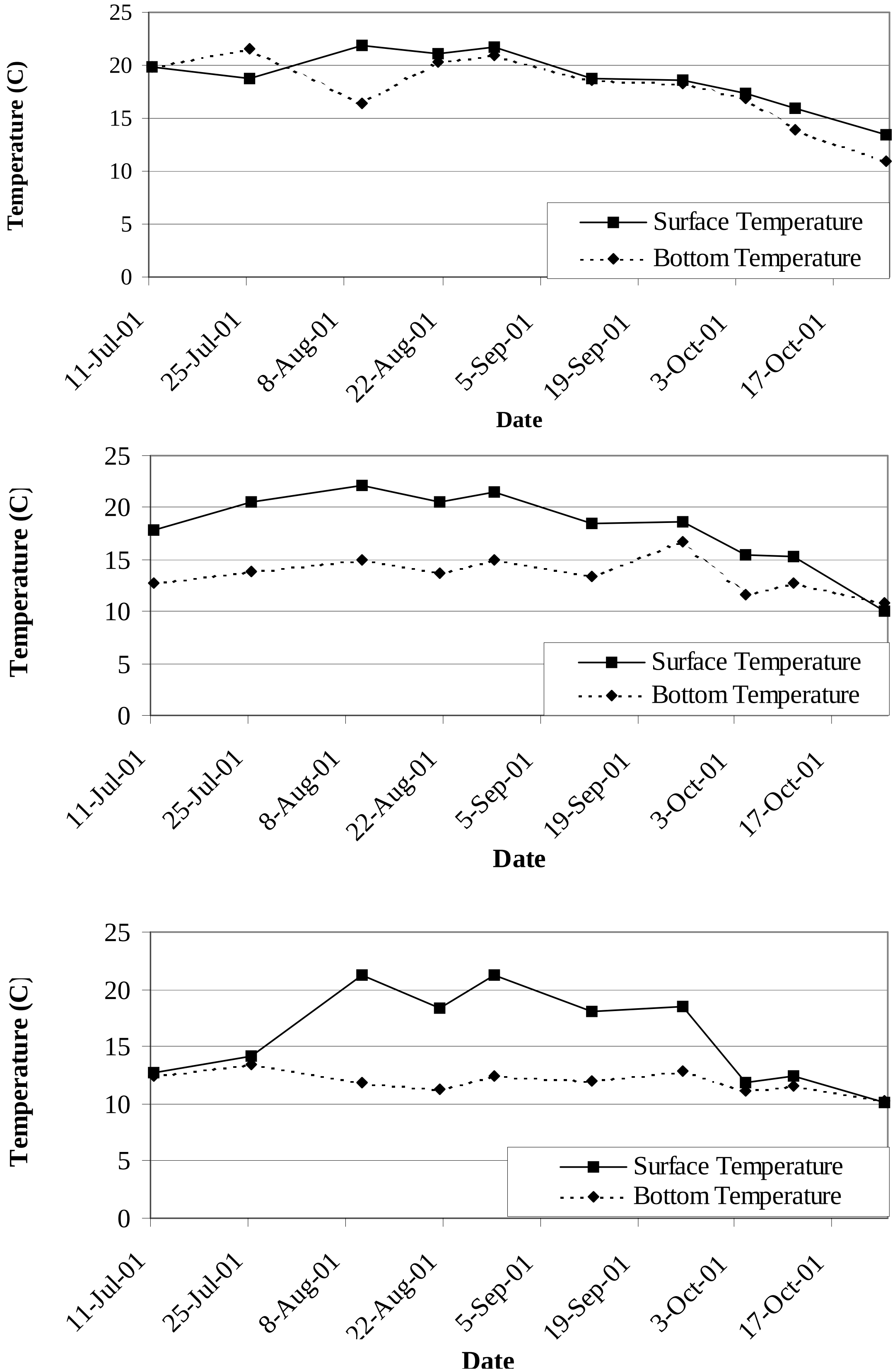


Figure 26. Surface and bottom temperatures observed in the Salt Creek slough at Station 1 (top graph), Station 3 (middle graph), and Station 5 (bottom graph) during 2001.

Salinity

Salinity was lowest during summer months in the Salt Creek slough and increased after tidal influence was re-established in the estuary in late September. Salinity measurements ranged between 0.0 – 0.1 ppt across all stations and depths on 11-Jul and 0.0 – 0.3 ppt on 25-Jul, with salinity concentration decreasing at each successively upstream monitoring station. Measurements ranged between 0.0 – 0.1 ppt at all sites during August and September monitoring. Saltwater influence was re-established during late September and was detected during monitoring on 4-Oct. Salinity concentration decreased at each successively upstream monitoring station, ranging between 0.6 – 0.7 ppt at Station 1 and 0.0 – 0.1 ppt at Station 5. Salinity concentration was highest in surface measurements indicating estuarine influence and cooler freshwater from Salt Creek flowed along the channel bottom. Salinity observations during monitoring on 11-Oct ranged between 0.0 – 0.3 across all stations and depths. The highest salinity observations were made during monitoring on 24-Oct, with measurements ranging between 0.7 – 0.8 ppt at Station 1; 0.4 – 1.7 ppt at Station 2; 0.3 – 1.2 ppt at Station 3; and no salinity was detected at Stations 4 or 5. Unlike depth profiles during 4-Oct, salinity concentrations on 24-Oct were greatest along the channel bottom with a cooler freshwater layer along the surface.

Dissolved Oxygen

Dissolved oxygen conditions in the Salt Creek slough were variable among sites, but generally decreased at each successively upstream monitoring station. Surface DO at Station 1 ranged between 6 – 9 mg/L during July, August, and September monitoring; however, bottom DO was consistently lower and was observed as low as 0.92 mg/L on 29-Aug (Figure 27). Conditions improved in October at Station 1, ranging between 7.36 – 8.25 mg/L on 4-Oct, 5.95 – 9.12 mg/L on 11-Oct, and 8.89 – 11.27 mg/L on 24-Oct. At Station 2, surface DO ranged between 6.63 – 8.51 mg/L between July – September, and DO near the channel bottom was below 6 mg/L during every sampling date except 21-Aug, ranging between 0.25 – 6.49 mg/L. Surface observations at Station 2 exceeded 8 mg/L on during all sampling events in October, and bottom measurements ranging between 3.38 – 6.30 mg/L.

At Station 3, dissolved oxygen measurements were similar throughout the monitoring season, with surface DO ranging between 6.94 – 8.42 mg/L. Bottom DO measurements at Station 3 were below 6 mg/L during all sampling events except 21-Aug, ranging between 0.86 – 6.78 mg/L (Figure 27). Conditions at Station 4 were also similar during all sampling events, with surface measurements ranging between 6.48 – 8.67 mg/L and bottom measurements ranging between 0.34 – 5.95 mg/L. Mid-channel and bottom dissolved oxygen measurements at Station 5 (farthest upstream from creek mouth) were almost always below 6 mg/L, ranging between 0.54 – 5.12 mg/L between 11-Jul and 11-Oct. Surface measurements during the same sampling events ranged between 4.85 – 8.95 mg/L. Conditions at Station 5 were slightly improved during monitoring on 24-Oct, when all observations exceeded 6 mg/L (6.04 – 6.91 mg/L; Figure 27).

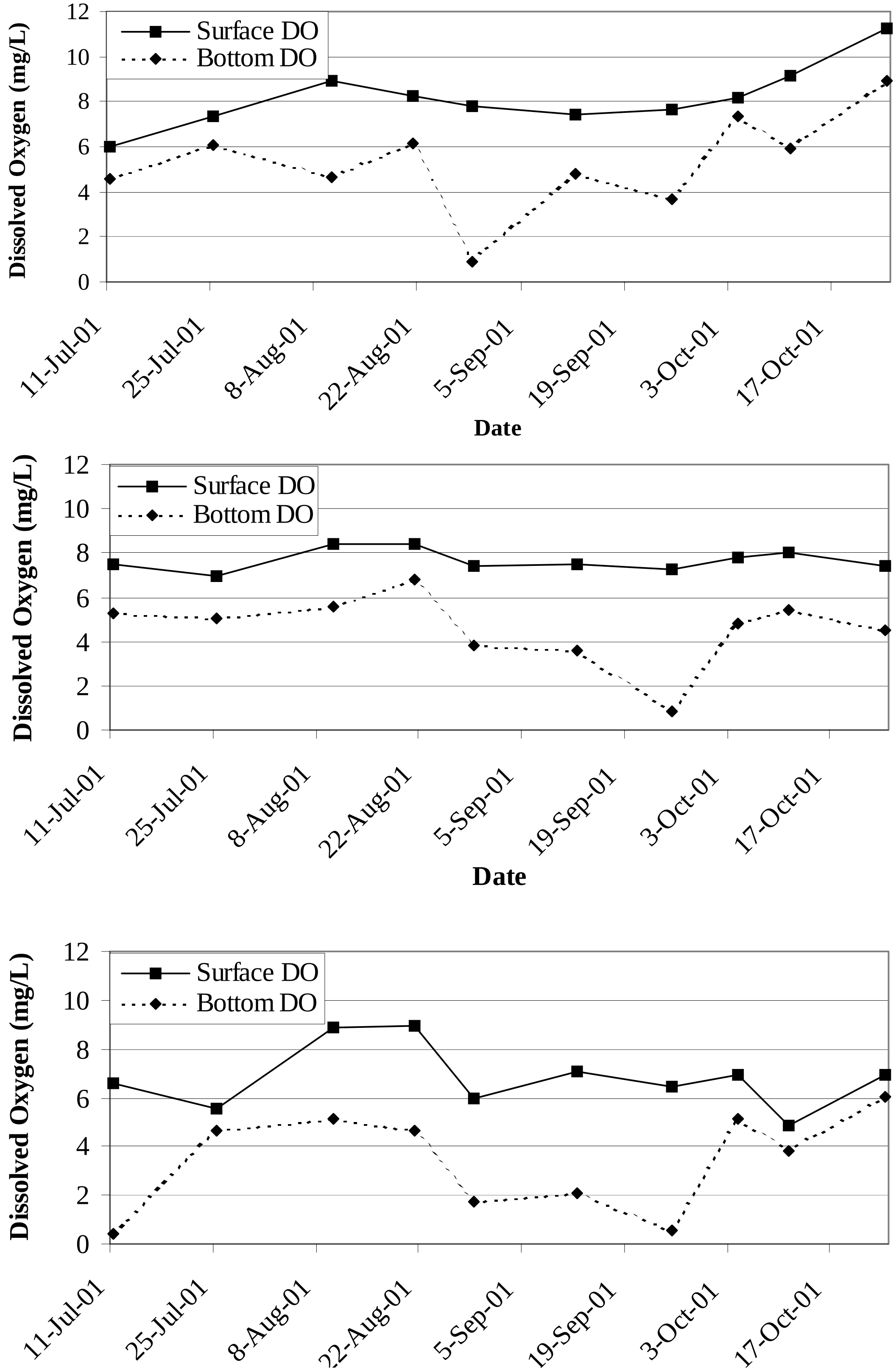


Figure 27. Surface and bottom dissolved oxygen (mg/L) measurements observed in the Salt Creek slough at Station 1 (top graph), Station 3 (middle graph) and Station 5 (bottom graph) during 2001.

2002

Temperature

Electronic temperature records from lower Salt Creek indicate that bottom temperatures remain fairly cool, even during summer months (Figure 28). Mean daily temperature fluctuated between 8 - 11°C during February and March. A small peak in temperature was observed between 1-Apr – 15-Apr, during which time mean daily temperatures were between 11.26 – 12.79°C. During late April through mid May, mean daily temperatures remained between 9.5 - 12°C. Temperatures began increasing during late May, but generally remained between 12 - 15°C through the end of September (Figure 28). The highest temperature observed was 15.58°C on 1-Jul. Temperatures began cooling in October and continued through the end of the year, with mean daily temperatures ranging between 8 – 11.5°C.

Results from water quality monitoring show that surface temperatures in the downstream reach of the slough are much warmer during summer months, likely due to estuarine influence. Noticeable decreases in surface temperatures are observed at each subsequent monitoring station upstream from the estuary (Figure 29).

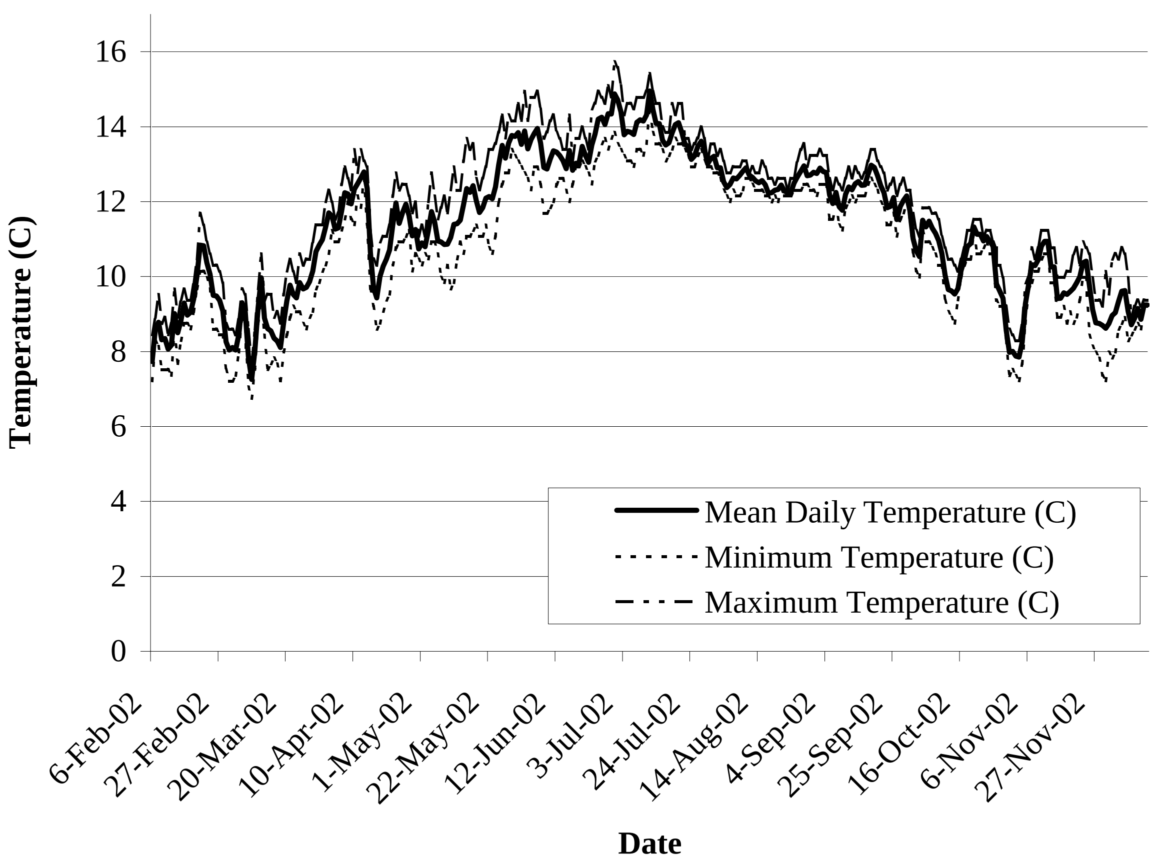


Figure 28. Minimum, maximum, and mean daily temperatures recorded in the Salt Creek slough during 2002 (6-Feb – 13-Dec).

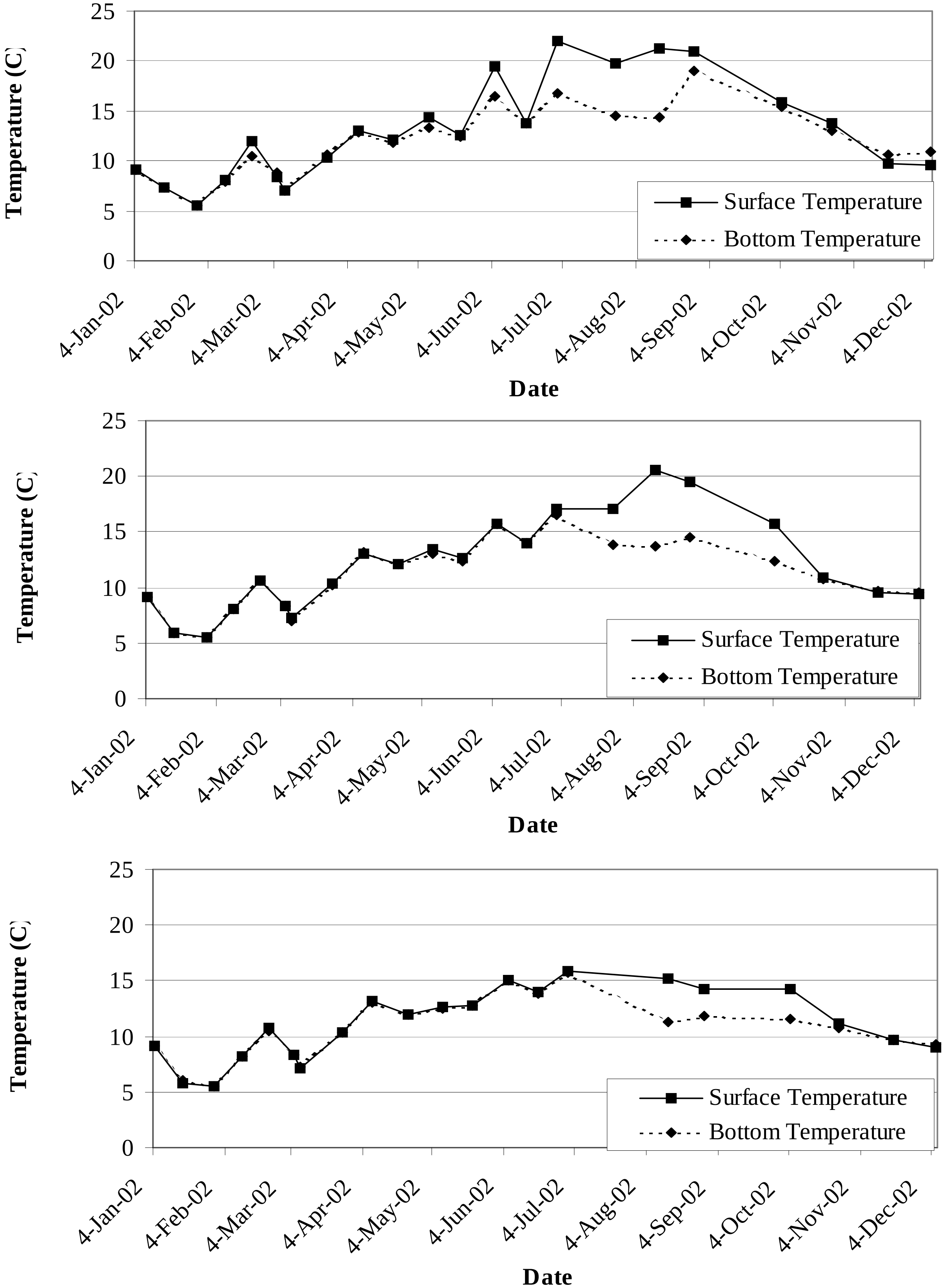


Figure 29. Surface and bottom temperatures observed in the Salt Creek slough at Station 1 (top graph), Station 3 (middle graph), and Station 5 (bottom graph) during 2002.

Salinity

Salinity was observed in the highest concentration at Station 1 (creek mouth) and generally decreased at each successively upstream monitoring station. Observations were between 0.0 – 0.3 at all stations during sampling through 4-Oct. On 26-Jul, surface salinity at the downstream sites (Stations 1-3) was slightly more concentrated ranging between 0.2 – 0.3ppt compared with bottom measurements of 0.1ppt. Sampling at Station 1 on 25-Oct indicated a stratified water column, with surface measurements of 0.2ppt and bottom measurements of 17.1ppt recorded. Observations at all other sites ranged between 0.0 – 0.2ppt. Measurements taken on 18-Nov were 0.2ppt and 1.7ppt for surface and bottom readings at Station 1 (respectively). Surface and bottom observations at Station 2 were 0.1ppt and 0.4ppt (respectively), and salinity ranged between 0.0 – 0.2ppt at Stations 3-5. Salinity concentrations were greatest during sampling on 6-Dec, with surface and bottom measurements of 0.6ppt and 24.9ppt observed at Station 1. Surface salinity measurements for Stations 2-5 were 0.7ppt, 0.8ppt, 0.8ppt, and 0.9ppt (respectively). Bottom salinity concentrations observed on 6-Dec at Stations 2-5 were 23.7ppt, 7.5ppt, 3.2ppt, and 3.8ppt (respectively).

Dissolved Oxygen

Dissolved oxygen levels in Salt Creek were variable during the year and among the sites. Surface and mid-channel observations were nearly always above 6.0 mg/L, although bottom measurements were frequently below 6 mg/L and were observed as low as 1.09 mg/L. During sampling on 4-Jan, DO values ranging between 6.7 – 8.09 mg/L. Observations between mid January (16-Jan) and early March (8-Mar) were generally between 8 – 10 mg/L. During sampling on 26-Mar, DO at the bottom of Station 2 was 4.08 mg/L and subsequent sampling on 8-Apr showed similar results, with 1.09 mg/L observed at the bottom of Station 2 and 3.00 mg/L observed at the bottom of Station 1 (creek mouth). Conditions improved through early July, with readings ranging between 9.11 – 10.51 mg/L on 23-Apr; 8.38 – 10.04 mg/L on 8-May; 6.55 – 9.16 mg/L on 21-May; 7.41 – 9.97 mg/L on 5-Jun; 6.13 – 7.48 mg/L on 18 Jun; and 7.59 – 9.83 mg/L on 1-Jul.

Consistently low DO levels were observed from late July through late October near the channel bottom (Figure 30). During sampling on 26-Jul, DO levels at the bottom of Stations 1 and 5 were 5.73 and 5.63 mg/L (respectively). On 13-Aug, DO was <6mg/L at all five sampling stations on the channel bottom, dropping as low as 2.28 mg/L at Station 5. Conditions were also poor at Station 5 on 28-Aug, when levels near the channel bottom were 3.83 mg/L. Subsequent sampling on 4-Oct indicated that dissolved oxygen levels at the channel bottom were < 6mg/L at Stations 2 through 5, ranging between 4.24 – 5.42 mg/L. Sampling on 25-Oct revealed that DO levels throughout the water column were below 6 mg/L at Stations 3, 4, and 5, and bottom measurements at 1 and 2 were 3.91 and 5.93 mg/L (respectively). Conditions improved during November and December sampling, with observations ranging between 6.95 – 9.51 mg/L on 18-Nov and 7.3 – 11.12 mg/L on 6-Dec.

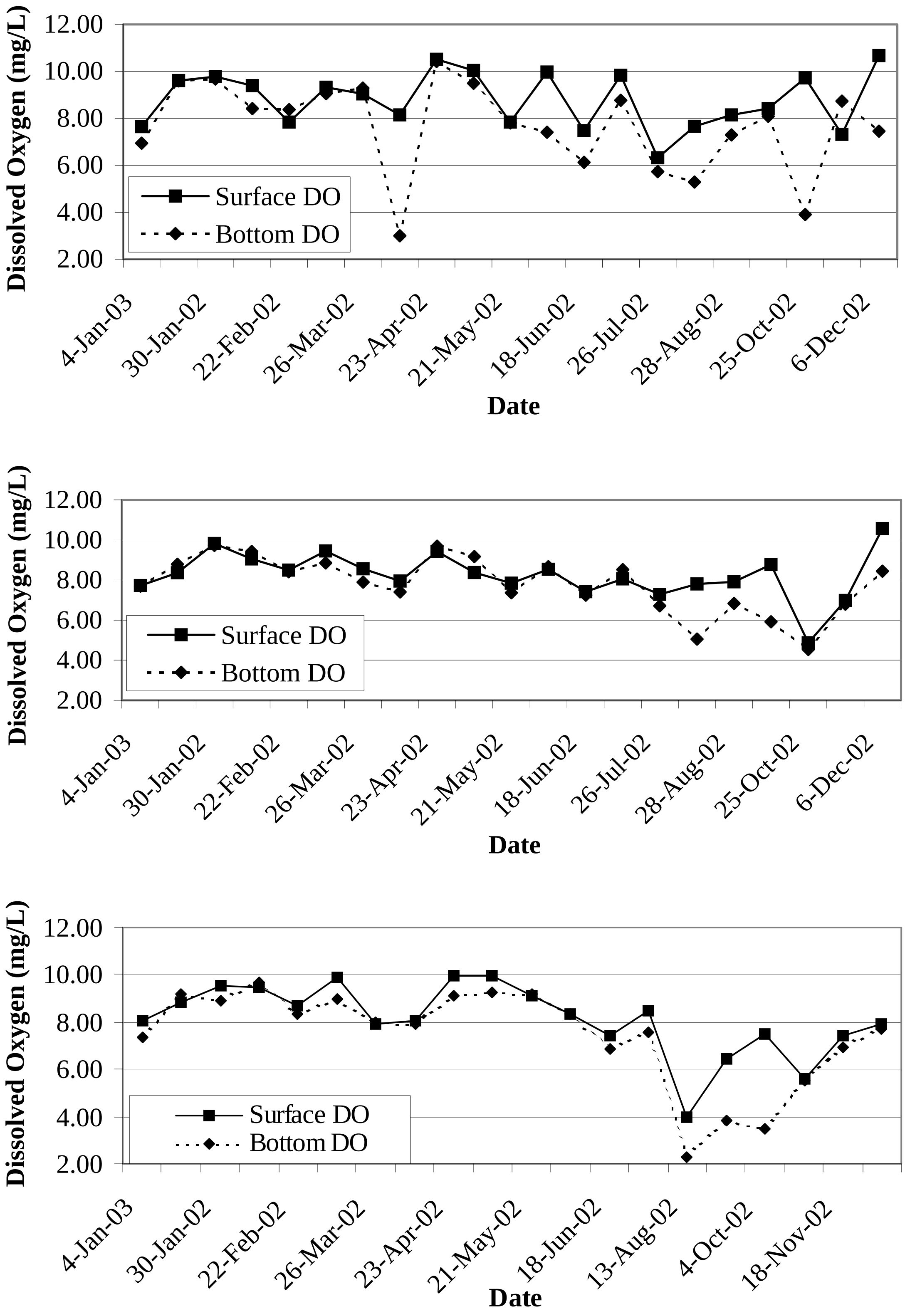


Figure 30. Surface and bottom dissolved oxygen (mg/L) measurements observed in the Salt Creek slough at Station 1 (top graph), Station 3 (middle graph) and Station 5 (bottom graph) during 2002.

2003

Temperature

Electronic temperature records are not available for 2003; however, temperature was recorded during water quality monitoring events between March and November. Temperatures were 8.2 – 9.0°C on 6-Mar, 10.5°C on 18-Mar, and ranged between 10.7 – 10.9°C on 7-Apr. Observations on 22-Apr and 20-May ranged between 10.2 – 11.5°C and 12.5 – 12.8°C (respectively). Increased water temperatures were observed during monitoring on 25-Jun at Station 1, where temperatures were 17.0°C; however, temperatures at all other monitoring stations ranged from 12.9 – 14.0°C.

During summer months, temperatures were generally warmer at Station 1 compared with upstream monitoring stations. On 8-Jul, temperatures at Station 1 ranged between 12.7 – 17.4°C and observations at Stations 2 – 5 were 13.0 – 14.7°C. Temperatures at Station 1 on 23-Jul were 21.6 – 21.7°C, with cooler temperatures ranging between 14.1 – 15.5°C at upstream stations. Observations on 18-Aug were similar at Stations 1 – 3, ranging between 21.0 – 21.6°C, and water temperature decreased at Stations 4 (18.4 – 20.5°C) and 5 (15.1 – 18.4°C). Water temperatures were cooler during monitoring on 9-Sept, ranging between 17.0 – 18.0°C at Stations 1 – 3, 16.3 – 16.4°C at Station 4, and 12.3 – 13.1°C at Station 5. Water temperatures during late September ranged between 13.1 – 18.5°C among all monitoring stations and 9.1 – 10.6°C on 3-Nov.

Salinity

Salinity observations were generally highest at Station 1 and decreased at upstream monitoring stations. Monitoring between 6-Mar and 23-Jul ranged from 0.0 – 0.1ppt at all monitoring stations. On 18-Aug, salinity was 0.6ppt throughout the water column at Stations 1 and 2, ranged between 0.3 – 0.5ppt at Station 3, 0.1 – 0.4ppt at Station 4, and 0.0 – 0.1ppt at Station 5. During monitoring on 9-Sept, salinity ranged between 0.6 – 3.8ppt at Stations 1 – 4 and 0.1 – 0.2ppt at Station 5. Salinity concentrations were highest during monitoring on 25-Sept, with surface observations ranging between 0.8 – 2.3ppt across all stations and bottom salinity concentrations ranging from 1.0ppt at Station 5 (farthest upstream) to 29.4ppt at Station 1 (creek mouth). Similar observations were observed on 3-Nov, with surface salinity measurements highest (0.8ppt) at Station 1 and decreasing at each successively upstream monitoring station to 0.1ppt at Station 5. Bottom salinity observations on 3-Nov were 28.3ppt at Station 1, 12.0ppt at Station 2, and ranged from 1.2 – 1.6ppt at Stations 3 – 5.

Dissolved Oxygen

Dissolved oxygen observations during monitoring events were similar among sampling stations, and DO levels rarely dropped below 6 mg/L (Figure 31). DO on 6-Mar ranged between 7.0 – 9.0 mg/L among sampling stations at all depths, except one mid-channel observation at Station 2 (5.97 mg/L). Slightly higher DO levels were observed on 18-Mar, ranging between 8.49 – 9.13 mg/L. DO levels on 7-Apr ranged between 9.56 – 10.33 mg/L and observations on 22-Apr were generally between 7.5 – 10.0 mg/L (Figure 31). Observations on 20-May, 25-Jun, and 8-Jul usually ranged between 7.0 – 9.5 mg/L across all sampling stations and depths, except one surface measurement on 20-May at Station 2 (5.78 mg/L). All DO observations on 23-Jul ranged between 6.5 – 8.0 mg/L except one measurement taken near the channel bottom of Station 5 (3.29 mg/L). Measurements on 18-Aug, 9-Sept, and 25-Sept were similar and ranged from 6.78 – 9.35 among all sampling stations and depths, except one observation near the channel bottom of Station 5 on 9-Sept (5.67 mg/L). DO observations varied between 6.30 – 10.01 mg/L on 3-Nov (Figure 31).

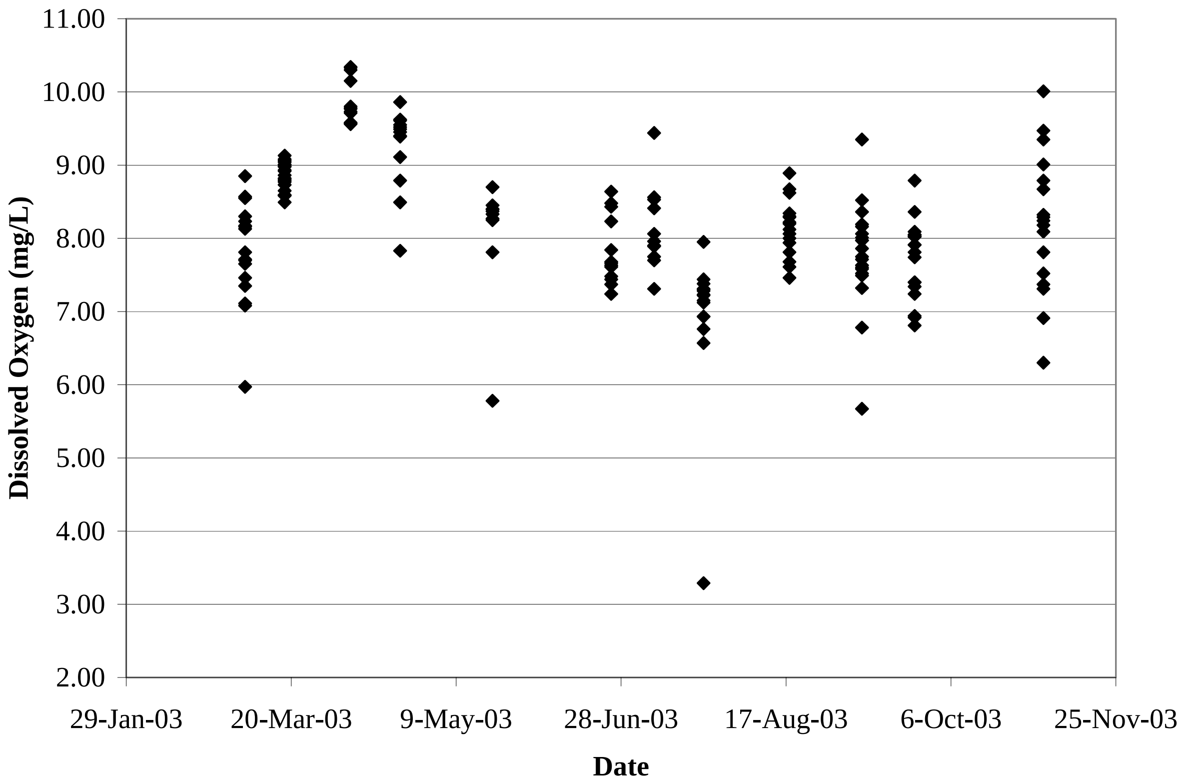


Figure 31. Dissolved oxygen (mg/L) measurements observed in the Salt Creek slough at all monitoring stations (1 through 5) during 2003.

Water Quality Monitoring, Hunter Creek

2001

Temperature

Mean daily water temperature calculated from electronic records from June through December ranged between 9.40 – 16.54°C (Figure 32). Mean daily temperatures from the beginning of monitoring (19-Jun) to 20-Jul ranged between 11.63 – 12.94°C, with the lowest minimum daily temperature recorded at 10.31°C and maximum daily temperatures reaching 15.43°C. Temperatures warmed gradually during late July, and mean daily temperatures peaked in late August through mid September. The highest electronic temperature record in Hunter Creek during 2001 was 18.38°C on 2-Sept (Figure 32). Mean daily temperatures decreased from 15.89°C on 27-Sept to 13.46°C on 28-Sept in response to breaching of the sand spit at the mouth of the Klamath River, which had been slowing freshwater outflow into the ocean and impeding saltwater intrusion into the estuary, creating lagoon-like conditions. Maximum daily temperatures between 27-Sept and 28-Sept dropped from 17.74°C to 15.2°C and minimum daily temperatures also decreased from 14.88°C to 12.08°C. Temperatures continued to decrease through October and November, and all temperatures recorded during December ranged between 8.83 – 11.47°C (Figure 32).

Water quality monitoring in the Hunter Creek slough indicates that thermal stratification is present during summer months, with significant differences in surface and bottom temperatures observed at all but the uppermost station (Station 5). Surface temperatures were observed to be highest during August. At Station 1, surface temperatures of 22°C, 20.9°C, and 21.5°C were observed on 8-Aug, 21-Aug, and 29-Aug (respectively). Bottom temperatures during those same dates at Station 1 were 14.3°C, 13.6°C, and 15.5°C (Figure 33). The degree of thermal stratification decreased both as the season progressed and at each upstream monitoring station, with very little difference observed at Station 5 (Figure 33).

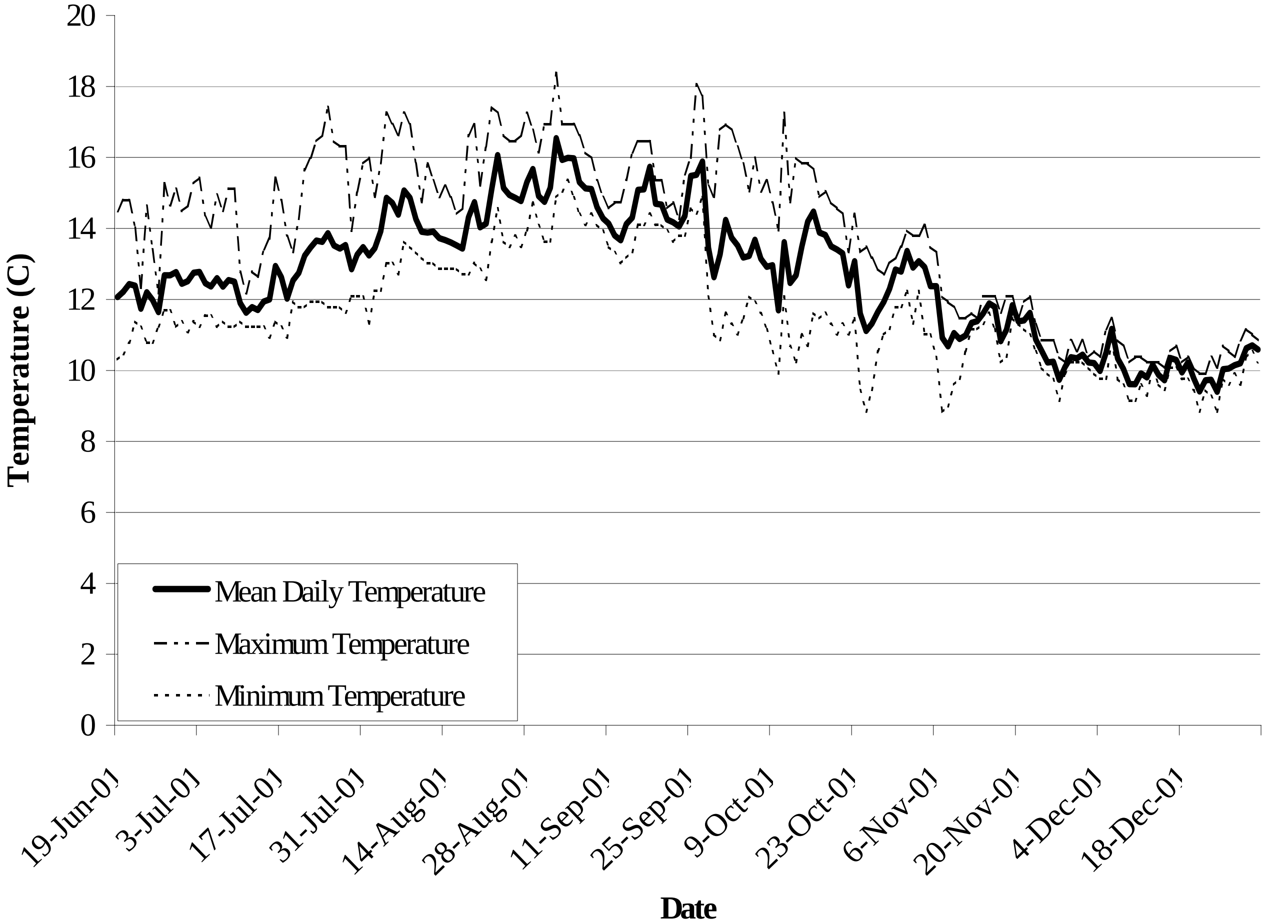
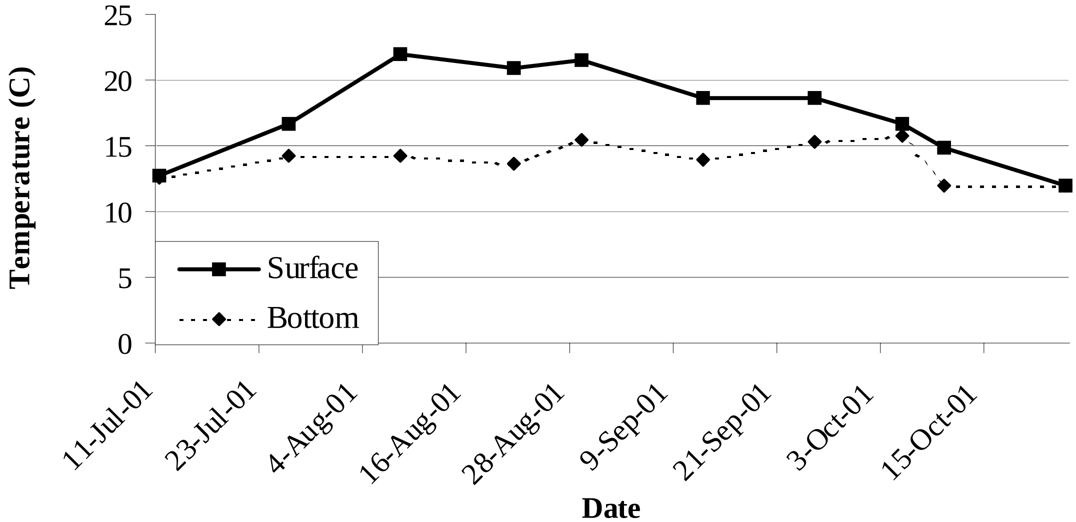
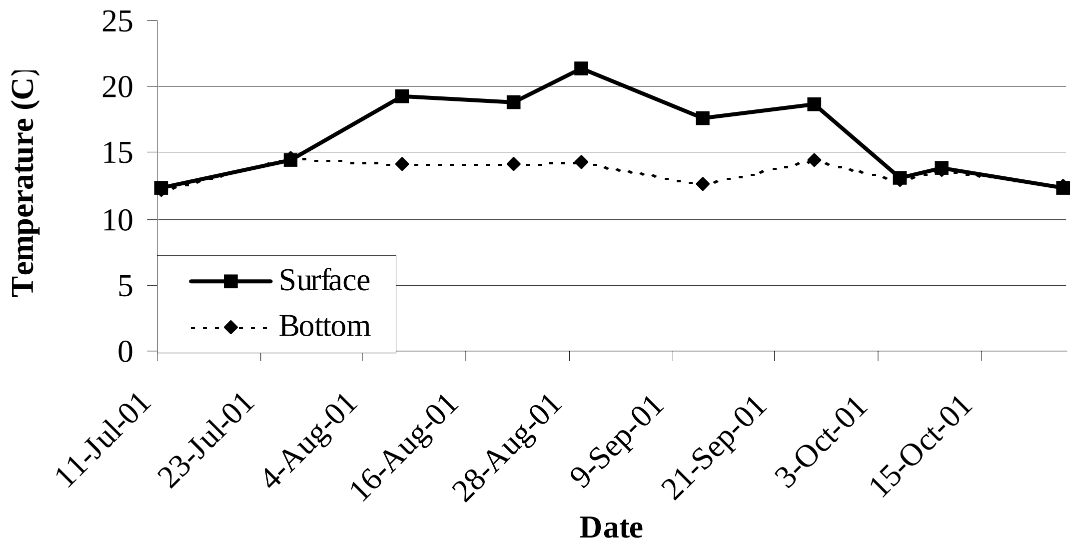


Figure 32. Minimum, maximum, and mean daily temperatures recorded in the Hunter Creek slough during 2001 (19-Jun – 31-Dec).





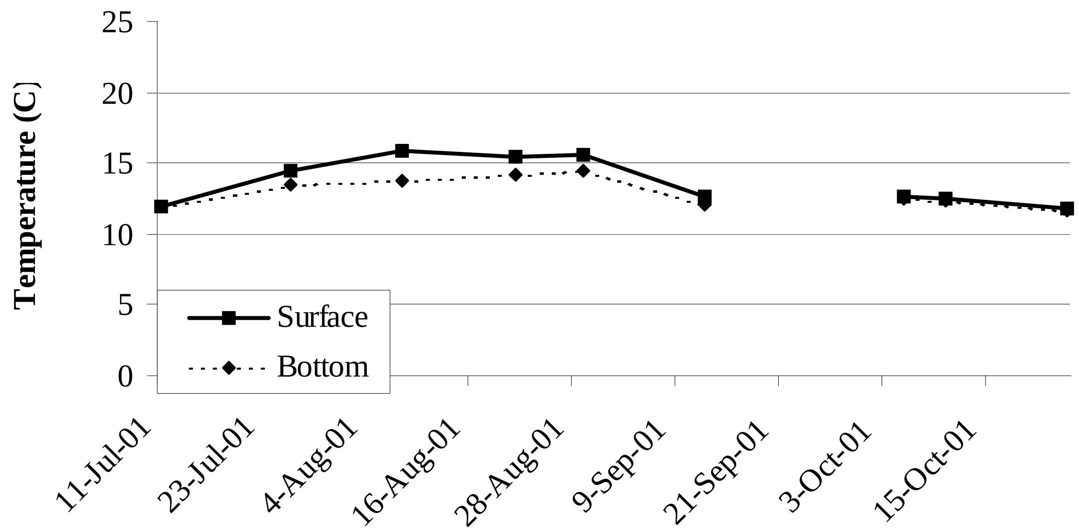


Figure 33. Surface and bottom temperatures observed in the Hunter Creek slough at Station 1 (top graph), Station 3 (middle graph), and Station 5 (bottom graph) during 2001.

Salinity

Salinity at Station 1 ranged between 0.0 – 0.1 ppt during monitoring between 11-Jul and 25-Sept. During monitoring on 5-Oct, surface salinity was 0.3 ppt, mid-channel salinity was 0.6 ppt, and salinity near the channel bottom was 0.5 ppt. Measurements at Station 1 on 10-Oct ranged between 0.1 – 0.2 ppt and salinity at all depths on 24-Oct was 0.1ppt. Salinity at Station 2 ranged between 0.0 – 0.1 between 11-Jul and 25-Sept, 0.1 – 0.3 ppt during monitoring on 5-Oct, and was 0.0 ppt during monitoring on 10-Oct and 24-Oct. At Station 3, measurements ranged between 0.0 – 0.1 between 11-Jul and 25-Sept, and then decreased to 0.0 ppt at all sample depths on 5-Oct, 10-Oct, and 24-Oct. Observations at Station 4 were 0.0 ppt between 11-Jul and 21-Aug, ranged between 0.0 – 0.1 ppt during monitoring in late August through late September, and decreased to 0.0 ppt during October sampling. All salinity measurements taken at Station 5 were 0.0 ppt.

Dissolved Oxygen

Dissolved oxygen observations in Hunter Creek were highest during July and early August monitoring, and decreased noticeably between late August through late September (Figure 34). Measurements on 11-Jul ranged between 9.73 – 10.13 mg/L at all sites and sample depths. DO observations during monitoring on 26-Jul, 8-Aug, and 21-Aug ranged between 8.73 – 10.55, 8.95 – 11.30, and 7.45 – 11.34 mg/L (respectively). Dissolved oxygen levels were significantly lower during subsequent monitoring on 29-Aug, when observations ranged between 5.5 – 9.1 mg/L. On 29-Aug, DO was observed below 6 mg/L near the channel bottom of Stations 1 (5.50 mg/L) and 3 (5.95 mg/L). During monitoring on 12-Sept, dissolved oxygen measurements ranged between 6.06 – 9.11 mg/L across all sites and depths. DO conditions were lowest during monitoring on 25-Sept when observations ranged between 5.27 – 7.84 mg/L. During sampling on this date, DO was below 6 mg/L near the channel bottom of every sampling station. Dissolved oxygen levels were improved during monitoring on 5-Oct, ranging between 7.32 – 9.71 mg/L (Figure 34). Observations on 10-Oct and 24-Oct ranged between 8.86 – 10.56 and 8.33 – 10.27 mg/L (respectively).

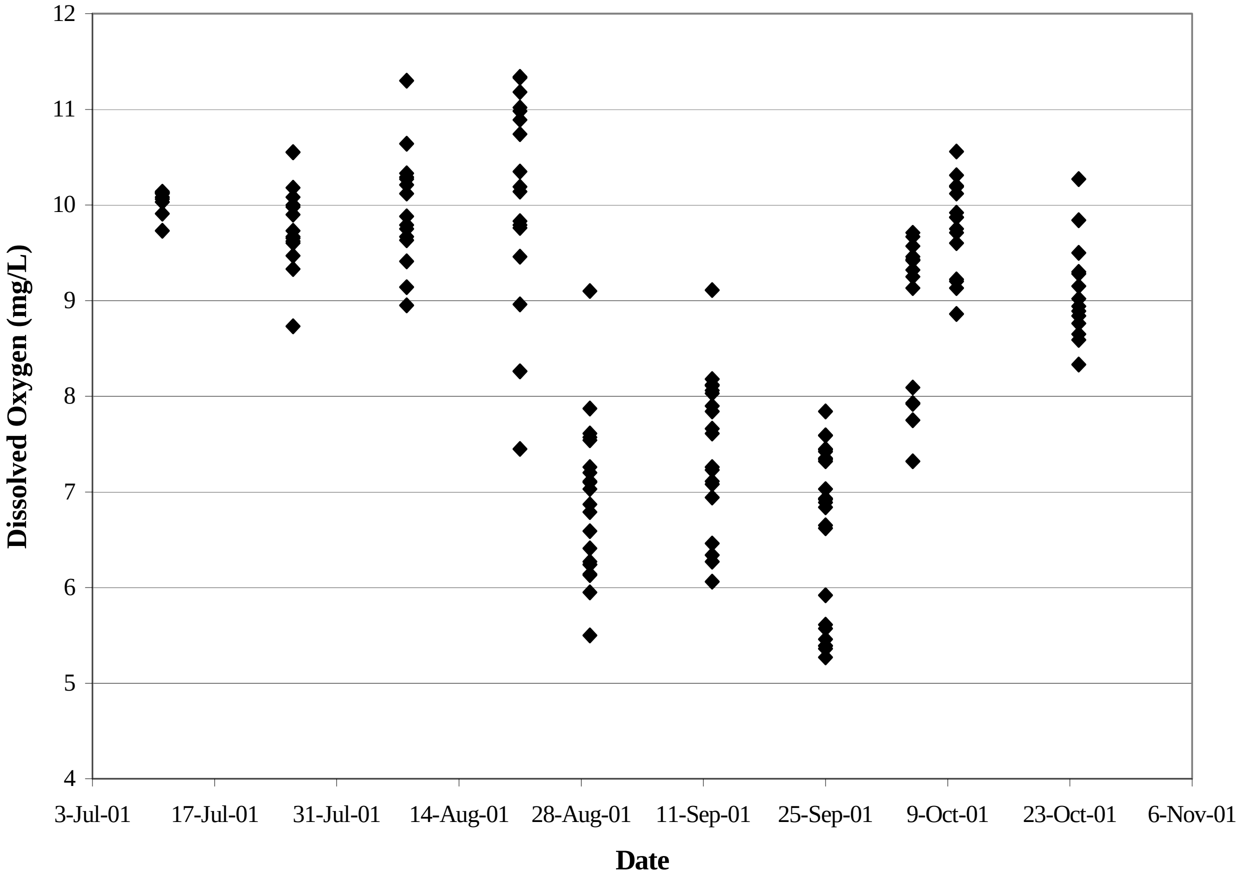


Figure 34. Dissolved oxygen (mg/L) measurements observed in the Hunter Creek slough at all monitoring stations (1 through 5) during 2001.

2002

Temperature

Mean daily water temperature calculated from electronic records ranged between 7.80 – 16.18°C, with the warmest temperatures occurring during September (Figure 35). Bottom temperatures generally remained below 14°C through 26-May, with the exception of maximum temperatures recorded on 2-Apr, 11-May, and 15-May of 15.67°C 14.57°C, and 15.04°C (respectively). Mean daily temperature remained below 12°C through 26-May (Figure 35). Mean daily temperatures between 27-May – 25-Jun ranged between 11.23 – 12.92°C, during which time the minimum/maximum temperatures observed were 8.37°C (8-Jun) and 15.99°C (16-Jun). Temperatures gradually warmed through the summer months. Mean daily temperatures reached a high of 14.34°C on 11-July, corresponding with the maximum daily temperature of 18.06°C. A slight cooling event occurred during early August, when a mean daily temperature of 12.60°C was observed on 5-Aug (min 11.47°C / max 13.79°C).

Gradual warming occurred during late summer and temperatures peaked in the Hunter Creek slough during September (Figure 35). Mean daily temperatures from electronic records ranged between 13.47 – 16.18°C, with minimum daily temperatures varying between 10.85 – 14.1°C and maximum temperatures between 15.20 – 18.06°C. Water quality monitoring showed that surface temperatures at downstream sampling stations was much higher than bottom temperatures during summer months (Table 2). During monitoring in late July and August, surface temperatures at Station 1 exceeded 21°C, while bottom temperatures were between 13.6 – 15.8°C (Table 2).

Temperatures in the Hunter Creek slough cooled significantly through October (Figure 35) and the thermograph during November and December resembled temperatures from January through March. During November and December, all electronic temperature records ranged between 7.76 – 11.78°C.

Table 2. Surface and bottom temperatures (°C) observed during water quality monitoring in the Hunter Creek slough during 2002 at Stations 1 (mouth) through 6 (site furthest upstream) on 26-Jul, 13-Aug, and 28-Aug.

Site	26-Jul Surface / Bottom	13-Aug Surface / Bottom	28-Aug Surface / Bottom
Station 1	21.0 / 15.3	21.4 / 13.6	21.1 / 15.8
Station 2	15.6 / 14.1	21.3 / 13.2	20.5 / 13.0
Station 3	12.6 / 12.5	19.9 / 13.1	18.6 / 13.0
Station 4	12.6 / 12.5	14.4 / 13.9	14.9 / 14.8
Station 5	12.6 / 12.5	14.5 / 14.1	14.7 / 14.6
Station 6	12.6 / 12.3	13.6 / 13.6	14.2 / 14.0

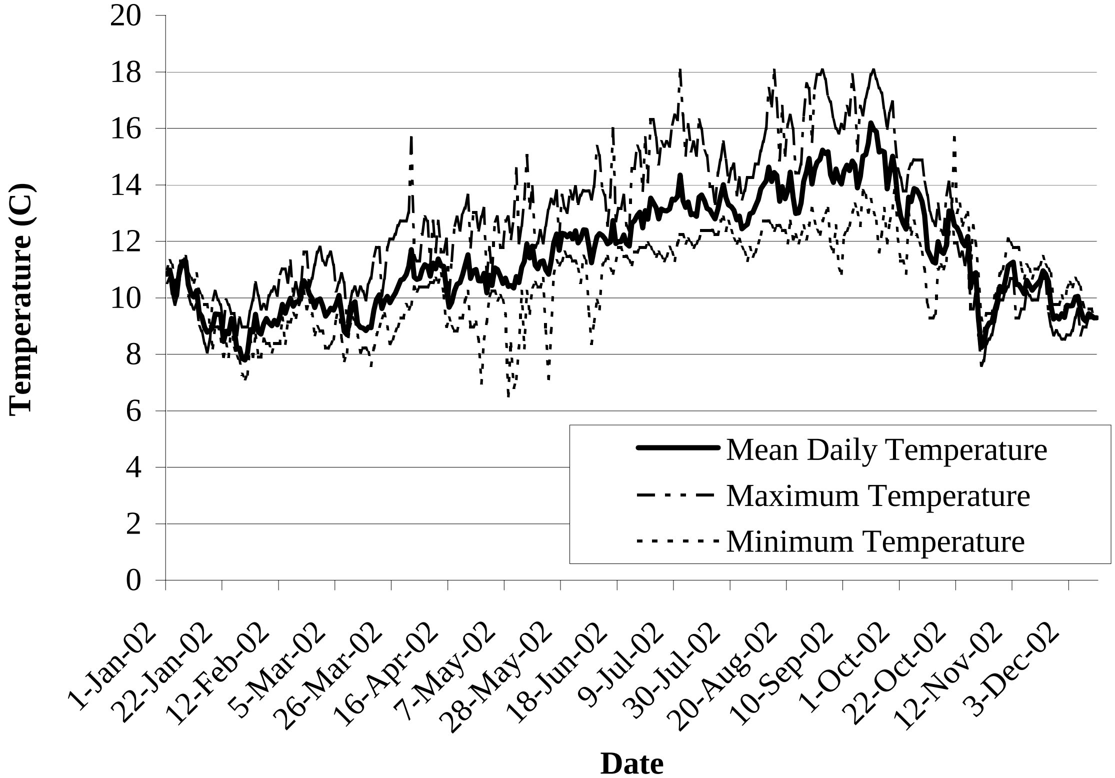


Figure 35. Minimum, maximum, and mean daily temperatures recorded in the Hunter Creek slough during 2002 (1-Jan – 13-Dec).

Salinity

Salinity was observed in the highest concentration at Stations 1 (creek mouth) and generally decreased at each successively upstream monitoring station. Salinity was never observed during sampling at the uppermost station and was not detected at the lower stations until 26-Jul. Salinity measurements ranged between 0.0 – 0.3ppt between 26-Jul and 4-Oct sampling. During sampling on 25-Oct, surface and bottom observations at Station 1 were 0.2ppt and 1.0ppt (respectively), and measurements were 0.0ppt throughout the water column at Stations 2 through 6.

Salinity was most prevalent in the Hunter Creek slough during November sampling. On 6-Nov, surface / bottom salinity observations were 0.9 / 3.0ppt at Station 1; 0.9 / 1.6ppt at Station 2; 0.7 / 1.7ppt at Station 3; 0.4 / 3.1ppt at Station 4; and 0.1 / 1.0ppt at Station 5. No salinity was observed at Station 6 on 6-Nov. Surface and bottom measurements observed on 18-Nov were 0.7 / 1.0ppt at Station 1; 0.9 / 1.0ppt at Station 2; 0.6 / 0.6ppt at Station 3; and 0.4 / 0.5ppt at Station 4. Salinity was not observed at Stations 5 or 6 on 18-Nov.

Dissolved Oxygen

Dissolved oxygen levels were highest during late winter and spring and declined during summer and fall months. Measurements during January through March ranged between 9 – 11 mg/L at all stations during every monitoring event, except during sampling on 6-January, when measurements at Station 4 were 7.79 – 8.73 mg/L and observations at Station 5 were 7.98 – 8.67 mg/L. Between April and mid-July, DO measurements were greater than 8.5 mg/L at all stations throughout the water column during all sampling events. Dissolved oxygen measurements on 26-Jul ranged between 7.69 – 9.79 mg/L at all stations, and observations on 13-Aug were similar, ranging between 7.65 – 9.99 mg/L. On 28-Aug, observations ranged between 6.98 – 10.19mg/L.

Dissolved oxygen levels began to drop in early October, when measurements were frequently below 7 mg/L and several times were observed below 6 mg/L. A measurement of 3.93 mg/L was recorded at Station 3 on 4-Oct, and observations at Station 2 were as low as 6.54 mg/L. All measurements from Station 4 ranged between 6.35 – 6.85 mg/L, and dissolved oxygen at Stations 1, 5, and 6 ranged between 7 – 10 mg/L. Observations on 25-Oct ranged between 5.64 – 9.06 mg/L, with the lowest measurements taken at Stations 1 (5.64 mg/L), Station 3 (6.14 – 6.92 mg/L throughout the water column), and Station 6 (6.90 mg/L). Measurements at Stations 2, 4, and 5 ranged between 7 – 8.5 mg/L. Readings observed on 6-Nov ranged between 7.25 – 10.01 mg/L at all sampling stations and water depths. Observations on 18-Nov were similar, with most measurements ranging between 7.06 – 10.27 mg/L, except DO near the channel bottom of Station 5, which was 5.92 mg/L. No sampling occurred during December.

<u>2003</u>

Temperature

Electronic temperature records are not available for 2003; however, temperature was recorded during water quality monitoring between March and November. Water temperatures on 6-Mar ranged between 10.1 – 10.2°C, and between 11.7 – 12.1°C during monitoring on 18-Mar, 22-Apr, and 20-May. During monitoring on 25-Jun, water temperature ranged between 11.6 – 12.0°C across all stations and depths except at the surface of Station 1, where water temperature was 16.5°C. Observations on 23-Jul were similar, when surface temperatures at Station 1 were 19.0°C and all other observations ranged between 13.2 – 13.7°C. Water temperatures were observed to be the warmest during monitoring on 18-Aug, ranging between 15.9 – 21.4°C. The warmest temperatures were observed at Stations 1 (20.9 – 21.4°C), 2 (16.1 – 21.0°C), and 3 (16.4 – 19.3°C) and were coolest at Stations 4 and 5. A similar trend was observed on 9-Sept, when water temperatures at Stations 1, 2, and 3 ranged between 15.8 – 18.0°C and temperatures at upstream stations 4 and 5 ranged between 12.7 – 13.1°C. Water temperatures during monitoring on 25-Sept ranged between 14.2 – 18.4°C at all monitoring stations and cooled to between 9.2 – 11.6°C on 3-Nov.

Salinity

Saltwater intrusion into the Hunter Creek slough was limited and was not observed until monitoring on 25-Jun (all previous monitoring results were 0.0 ppt at all stations and depths). During monitoring on 25-Jun and 23-Jul, salinity was 0.0 ppt across all monitoring stations and depths except at the surface of Station 1 where salinity was observed at 0.1 ppt. Salinity during monitoring on 18-Aug ranged between 0.0 – 0.6 ppt, with salinity decreasing at each progressively upstream station and not detected at Stations 4 or 5. A similar pattern was observed during monitoring on 9-Sept, 25-Sept, and 3-Nov, when salinity ranged between 0.0 – 1.4 ppt, 0.0 – 1.8 ppt, and 0.0 – 1.4 ppt (respectively).

Dissolved Oxygen

Dissolved oxygen measurements in Hunter Creek exceeded 6 mg/L across all sample sites on all sample dates, ranging predominantly between 7 – 12 mg/L (Figure 36).

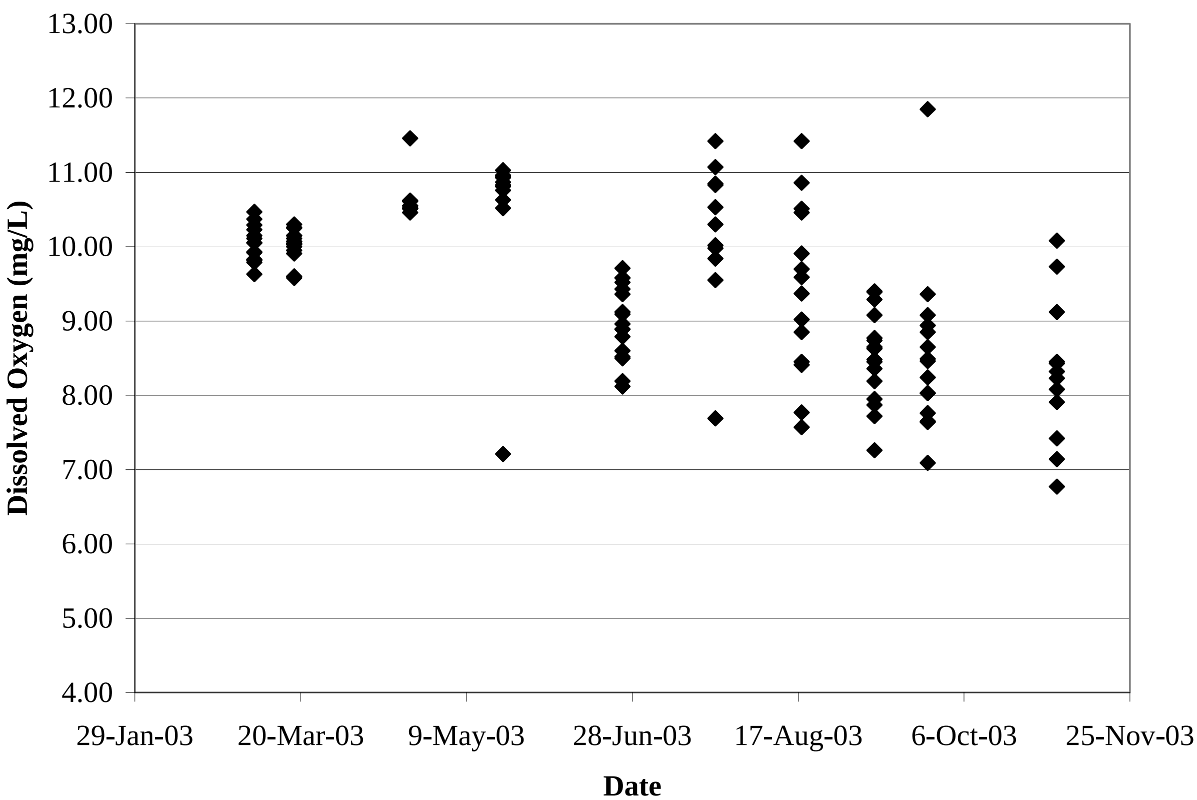


Figure 36. Dissolved oxygen (mg/L) measurements observed in the Hunter Creek slough at all monitoring stations (1 through 5) during 2003.

DISCUSSION

We observed the formation of a sand berm across the river mouth during the late summer months of 2001 when the position of the river chute ran south diagonally between the two sand spits. The formation of this berm has often been noted by Yurok People and is the basis of a Yurok legend. In 1994, CDFG documented the formation of a sand berm across the river mouth when it extended south from the estuary (Wallace 1998). Yurok Tribal biologists also observed the formation of a berm during the summer months of 1997 while conducting marine mammal studies. During 1994 and 2001, the angle of the chute and berm formation inhibited saltwater intrusion and created a “lagoon-like” situation in the estuary.

Water quality conditions in the Klamath River estuary during 2001 - 2003 were similar to results obtained by CDFG during monitoring between 1991 - 1994. Dissolved oxygen readings from the CDFG study indicated that dissolved oxygen exceeded 6-7 ppm throughout the year, except for occasional readings ranging between 2.5-5.5 ppm near the bottom of deep pools or in heavily vegetated side channels (Wallace 1998), which are concurrent with our observations. Temperature observed during the CDFG monitoring in 1991-1994 showed that surface water temperatures ranged between 6-8°C during winter months (December-February) and 20-24°C during summer months (June-August). While these results are similar with data collected during our study, we observed higher maximum daily temperatures, which peaked at 24.4°C in 2001, 24.74°C in 2002, and 24.74°C in 2003. Monitoring conducted by Wallace also indicated that temperatures were approximately 5-8°C cooler near the channel bottom compared with surface temperatures when a salt wedge was present, coinciding with our results.

Temperature and salinity are strongly related in the estuary, and the lack of a salt wedge in the estuary during late summer months results in high water temperatures throughout the water column. When a salt wedge is present, such as during the summer months of 2003, cooler saltwater from the ocean (which is denser than freshwater) sinks to the bottom of the water column, resulting in thermal stratification. Previous results from Wallace (1995) indicate that chinook appeared to be most abundant near the freshwater/saltwater interface, which may serve as a thermal refuge from high summer temperatures. In summers similar to 1994 and 2001 when the saltwater intrusion is absent from the estuary, juvenile fish may be forced to enter the ocean earlier or may stack up in high numbers around the mouths of Salt and Hunter Creeks, the two lowermost tributaries to the Klamath River, which serve as a thermal refugia for fish when temperatures in the estuary are unfavorable.

Numerous studies indicate that temperatures this high can cause stress, increase metabolic demand, and decrease growth rates for juvenile salmonids such as chinook and ESA listed coho salmon (Brett 1952; Brett et al. 1982; Armor 1990; Marine and Cech 1998). High water temperatures may also cause juvenile salmonids to move into the ocean earlier, which may result in increased mortality rates if fish are too small or not physiologically ready for ocean conditions. Previous studies indicate that extended estuary rearing may increase the likelihood of survival to adult for juvenile salmonids (Snyder 1931, Reimers 1973). Studies conducted in Oregon suggest that ocean survival of juvenile chinook salmon was greatly increased when fish entered the ocean at larger sizes (120 - 160 mm)(Nicholas and Hankin

1989). Observations in the 1930's describe juvenile chinook residing in the Klamath River estuary during September and October that were commonly between six and seven inches in length (150 – 175 mm). Results from Wallace in recent years indicate that peak migration is much earlier and fish are smaller, although it is difficult to discern differences between wild and hatchery migrants (Wallace 2003).

Water temperatures observed during summer months in the estuary may also be related to the extent of disease observed in juvenile salmonids in the estuary. Increased water temperatures increases susceptibility of fish to bacteria and pathogens, which are often present in natural environments but become problematic when the immune systems of fish are compromised due to stressful environmental conditions. Infections from the bacteria *Flavobacterium columnare* (causing columnaris) and myxozoan parasite *Ceratomyxa shasta*, both of which are present and have been observed in moribund fish collected in the Klamath River, are significantly related with temperature (Holt et al. 1975, Bartholomew 1998, Williamson and Foott 1998). A study by Holt et al. (1975) showed that juvenile chinook infected with *F. columnare* resulted in 50% mortality at 17.8°C, and mortality increased to 92% when temperatures were increased to 23.3°C.

Upon completion of his study in the Klamath River estuary, Wallace (1998) concluded that high summer temperatures were probably the most serious problem for juvenile salmonids in the Klamath River estuary. Our observations of mean daily temperatures ranging between 18-22°C during the summer months of 2001 and 2002 and maximum temperatures in excess of 23-24°C corroborate his findings. The Environmental Protection Agency (EPA 1986) set 20°C as the water quality standard for temperature, which was exceeded much of the time during summer months in the estuary. In 2003, however, mean daily temperatures in the lower estuary ranged between 12 – 17.5°C (June – September). This was the result of the presence of a salt wedge, as mean daily temperatures in the upper estuary were much higher, ranging between 17 - 24°C. The continued presence of the saltwedge in 2003 is likely due to a myriad of factors which will require further study, although the most notable difference between the three years that we monitored water quality was increased spring flows in 2003 along with sustained flows between 3,000 – 4,000 cfs during summer months.

The south slough of the estuary provides potential rearing habitat for juvenile salmonids, although current water quality conditions are not suitable during summer months. Temperatures in the slough were similar with those documented in the estuary, however, dissolved oxygen observations were much lower. Dense aquatic macrophytes and algae in the channel are likely the cause of very low dissolved oxygen observations near the channel bottom and at sampling stations 2, 3, and 4, which are in the middle of the slough. Dissolved oxygen conditions improved during late fall and winter as flows increased, presumable due to the removal of dead and dying vegetation inhabiting the slough.

In Salt Creek, temperatures during the summer of 2001 showed little variation until 21-Aug when they rose sharply from 15°C to 21°C. The increase in temperature was likely due to lack of tidal influence and marks when the warm estuary waters backed up into the Salt Creek channel to the location of the temperature probe. Very little diurnal temperature fluctuation was observed until 28-Sept when the mouth of the Klamath River was reestablished, which allowed the flooded Salt Creek slough to drain. Summertime temperatures during 2002 and 2003 were much lower in Salt Creek than 2001, staying below 16°C during both years. There were also differences in salinity among the three years during the summer months. During 2001 salinity ranged between 0.0 – 1.7 ppt; however, during the summer months of 2002 and 2003 salinity exceeded 20 ppt during monitoring. This indicates that during years that the mouth of the Klamath River remains connected with the ocean, the Salt Creek slough received tidal interface and also provides a potential thermal refugia for fish. Recent studies conducted in lower Salt Creek suggest that substantial numbers of juvenile coho and chinook salmon utilize Salt Creek during late spring and early summer (Beesley and Fiori 2004). Dissolved oxygen conditions may limit fish utilization of Salt Creek during late summer and early fall.

Of the sloughs studied, conditions in lower Hunter Creek were most conducive to juvenile salmonid rearing. Dissolved oxygen conditions were favorable and temperatures during summer months may provide valuable thermal refugia for juvenile salmonids when conditions become less than favorable in the estuary. During his studies of juvenile salmonid outmigration in the Klamath River estuary, Mike Wallace (CDFG) observed the highest densities of subyearling chinook near the mouth of Hunter Creek (Wallace 2003). In addition to subyearling chinook, coho, steelhead, and coastal cutthroat were also observed utilizing this area of thermal refugia.

Our results indicate that the south slough and Salt Creek sloughs may provide habitat for juvenile salmonids if dissolved oxygen conditions are improved. Increasing the amount of habitat available for outmigrating juvenile salmonids may increase their overall success by providing additional foraging area and increasing the carrying capacity of the Klamath River estuary. It is unknown whether the carrying capacity of the Klamath River estuary is exceeded during summer months, when millions of outmigrating juvenile chinook released from upriver hatcheries on the Klamath and Trinity Rivers travel through the river, potentially displacing wild chinook and steelhead competing for resources. Future studies should work to determine the carrying capacity of the estuary for juvenile outmigrating salmonids and improve habitat conditions in the estuary and surrounding sloughs.

LITERATURE CITED

Allee, Rebecca J. and eleven co-authors. 2000. Marine and Estuarine Ecosystem and Habitat Classification. NOAA Technical Memorandum NMFS-F/SPO-43, 43 pp.

Armour, C.L. 1990. Guidance for evaluating and recommending temperature regimes to protect fish. U.S. Fish and Wildlife Service. Fort Collins, Colorado. Technical Report 90(22). 13pp.

Bartholomew, J.L. 1998. Host resistance to infection by the myxosporean parasite *Ceratomyxa shasta*: a review. Journal of Aquatic Animal Health. 10:112-120.

Beacham, T.D. and R.E. Withler. 1991. Genetic variation in mortality of chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), challenged with high water temperatures. Aquaculture Fisheries Management. 22(2):125-133.

Beesley, S. and R. Fiori. 2004. Habitat assessment and restoration planning in the Salt Creek Watershed, Lower Klamath River Subbasin California. Yurok Tribal Fisheries Program, Habitat Assessment and Biological Monitoring Division. Technical Report No. 12.

Brett, J.R. 1958. Implications and assessments of environmental stress. Pages 69 – 83 *in* P.A. Larkin, editor. Investigations of fish-power problems. H.R. MacMillan Lectures in Fisheries. University of British Columbia.

Environmental Protection Agency. 1986. Quality Criteria for Water. PB87-226759. EPA 440/5-86-001. 395 pp.

Hayes, M.L. 1983. Active fish capture methods. Pages 123 – 145 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society. Bethesda, Maryland. 468 pp.

Holland, Alfred E. 1996. William E. Dougherty and salmon fishing on the Klamath River, 1886 – 1898. Master's Thesis. California State University, Sacramento.

Holt, R.A., J.E. Sanders, J.L. Zinn, J.L. Fryer, and K.S. Pilcher. 1975. Relationship of water temperature to *Flexibacter columnaris* infection in steelhead trout (*Salmo gairdneri*), coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*). Journal Fisheries Research Board of Canada. 32:1553-1559.

Horne, A.J. and C.R. Goldman. 1994. Limnology, Second edition. McGraw-Hill, Inc. New York.

Hubert, W.A. 1983. Passive capture techniques. Pages 95 – 122 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society. Bethesda, Maryland. 468 pp.

Klamath River Basin Task Force. 1991. Long range plan for the Klamath River basin conservation area fishery restoration program. U.S. Fish and Wildlife Service. Yreka, California.

Marine, K.R. and J.J. Cech, Jr. 1998. Effects of elevated water temperature on some aspects of the physiological and ecological performance of juvenile chinook salmon (*Oncorhynchus tshawytscha*): implications for management of California's chinook salmon stocks. Stream temperature monitoring and assessment workshop. January 12 – 14, 1998. Sacramento, California. Forest Science Project, Humboldt State University, Arcata, California.

McBeth, F.T. 1950. Lower Klamath Country. Anchor Press. Berkeley, California. 76 pp.

McCullough, D.A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. EPA Document 910-99-010. 279 pp.

Nicholas, J.W. and D.G. Hankin. 1989. Chinook salmon populations in Oregon coastal river basins: Descriptions of life histories and assessment of recent trends in run strengths. United States Fish and Wildlife Service. Corvallis, Oregon.

Remiers, P.E. 1971. The length of residence of juvenile fall chinook in the Sixes River, Oregon. PhD Thesis. Oregon State University, Corvallis, Oregon.

Snyder, J.O. 1931. Salmon of the Klamath River California. Division of Fish and Game of California. Fish Bulletin No. 34. 130 pp.

Stickney, R.R. 1983. Care and handling of live fish. Pages 85 – 94 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society. Bethesda, Maryland. 468 pp.

United States Army Corps of Engineers. 1997. Project information report, Klamath River, Del Norte County, California.

United States Committee on Public Works. 1965. Report of the special subcommittee to inspect flooded areas in the Northwestern United States. United States Printing Office. Washington D.C.

Wallace, M. 1993. Distribution, abundance, size, and coded-wire tag recovery of juvenile chinook salmon in the Klamath River estuary, 1986-1989. Final Performance Report. Federal Aid in Sport Fish Restoration Act. Project No. F-51-R; Subproject No. IX; Study No. 10; Job No. 3. 75pp.

Wallace, M. 1994a. Assessment of fish habitat types within the Klamath River estuary. Annual Performance Report. Federal Aid in Sport Fish Restoration Act. Project F-51-R-5; Study No. 22; Job No. 1. 9pp.

Wallace, M. 1994b. Assessment of fish habitat types within the Klamath River estuary. (Bathymetric mapping project). Annual Performance Report. Federal Aid in Sport Fish Restoration Act. Project F-51-R-6; Project No. 33; Job No. 1. 3pp.

Wallace, M. 1995a. Habitat type utilization of juvenile salmonids in the Klamath River Estuary. Final Performance Report. Federal Aid in Sport Fish Restoration Act. Project F-51-R-7; Project No. 32; Job No. 7. 33pp.

Wallace, M. 1995b. The emigration timing of juvenile salmonids through the Klamath River estuary. Pages 54-72 in T.J. Hassler (ed.), Proceedings of the Klamath Basin Fisheries Symposium. March 23-24, 1994. Eureka, California.

Wallace, M. 1998. Seasonal water quality monitoring in the Klamath River Estuary, 1991-1994. Administrative Report No. 98-9, Inland Fisheries Division, California Department of Fish and Game, Arcata, California. 49 p.

Wallace, M. 2000. Length of residency of juvenile chinook salmon in the Klamath River Estuary. Final Performance Report. Federal Aid in Sport Fish Restoration Act. Project F-51-R-7; Project No. 32; Job No. 5. 21 pp.

Wallace, M. 2003. Natural vs. hatchery proportions of juvenile salmonids migrating through the Klamath River Estuary and monitor natural and hatchery juvenile salmonid emigration from the Klamath River Basin. Project F-51-R-6; Project No. 17; Job No. 1 & 2. 50 pp.

Williamson, J.D. and J.S. Foott. 1998. Diagnostic evaluation of moribund juvenile salmonids in the Trinity and Klamath Rivers (June-September 1998). U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA.

<u>Personal Communications</u>

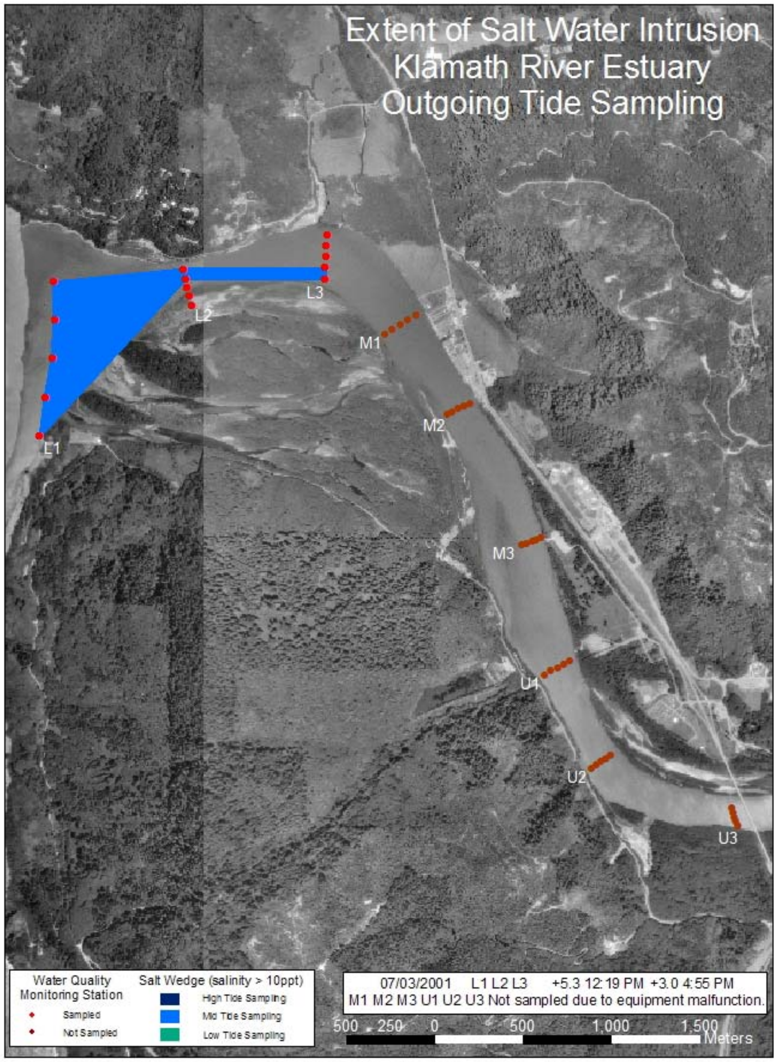
De Vol, Don. February 25, 2004. Longtime owner of Panther Creek Resort, property adjacent to Salt Creek and the mainstem Klamath River.

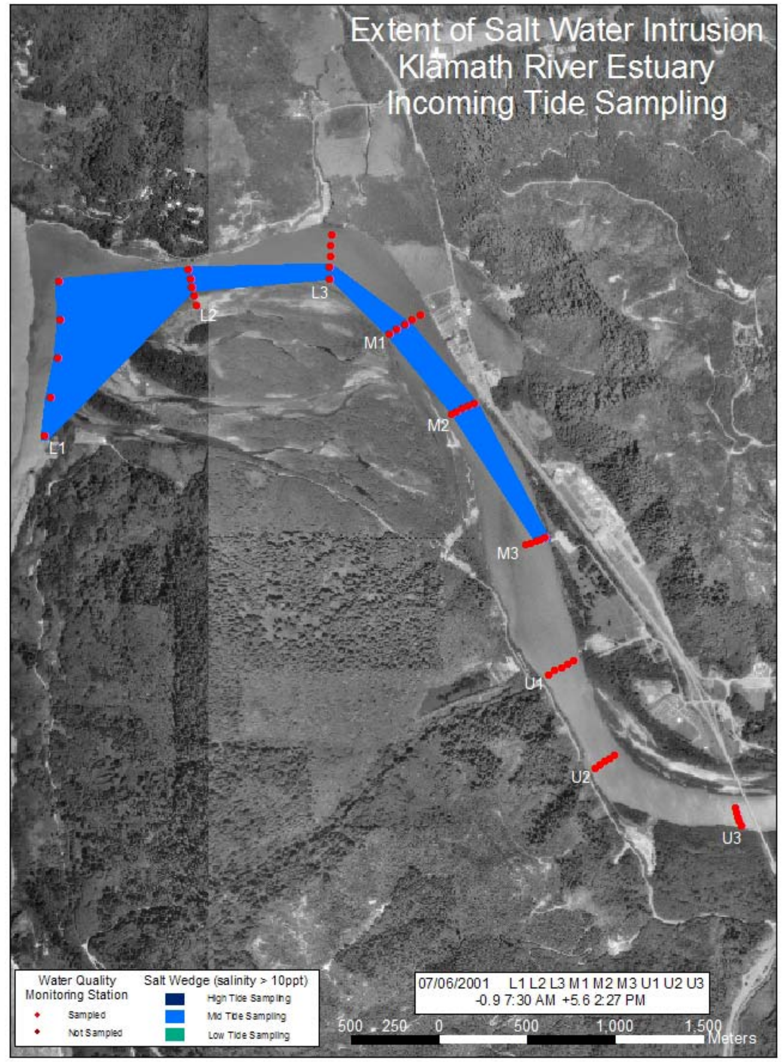
Wallace, M. April 17, 2001. Development of Yurok Tribal Fisheries Program Klamath River Estuary study plan.

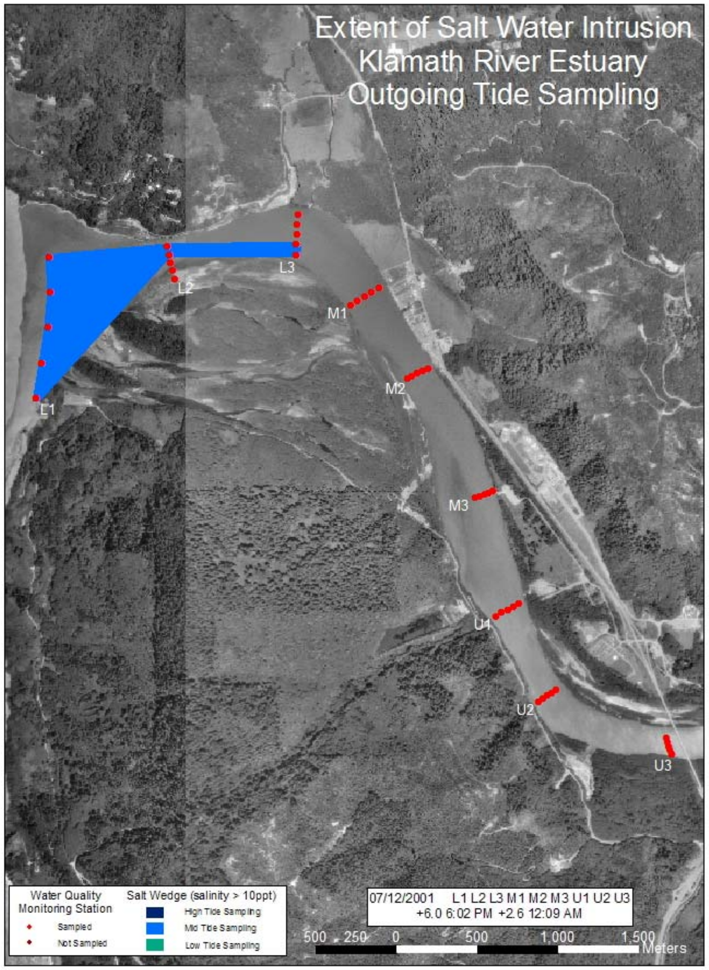
Williams, Chuck. April 7, 2004. Longtime resident and previous owner of Dad's Camp.

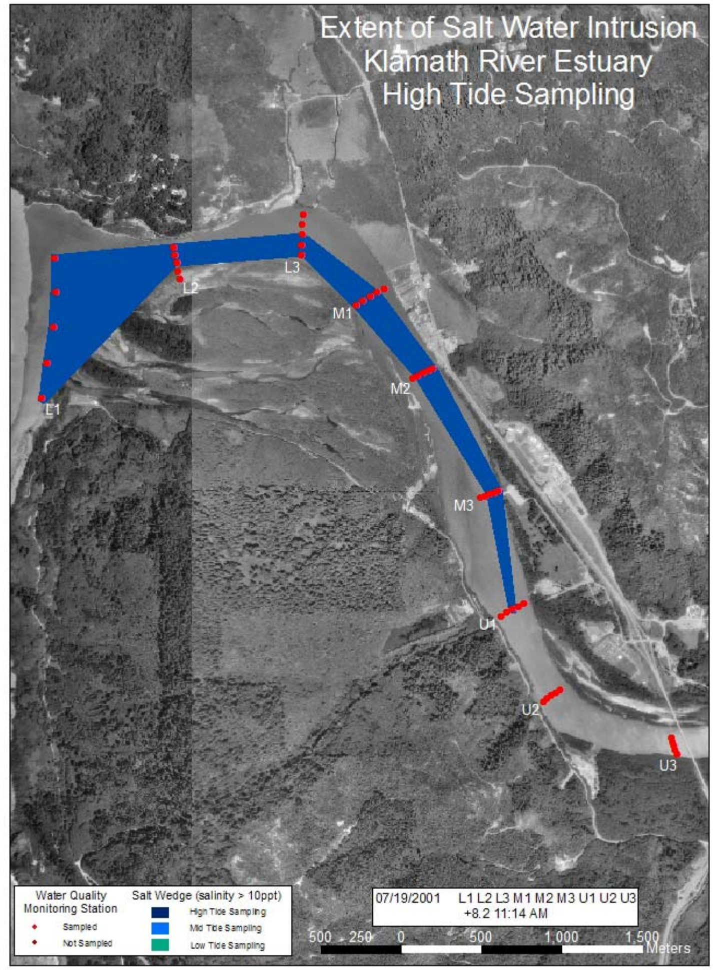
Appendix A

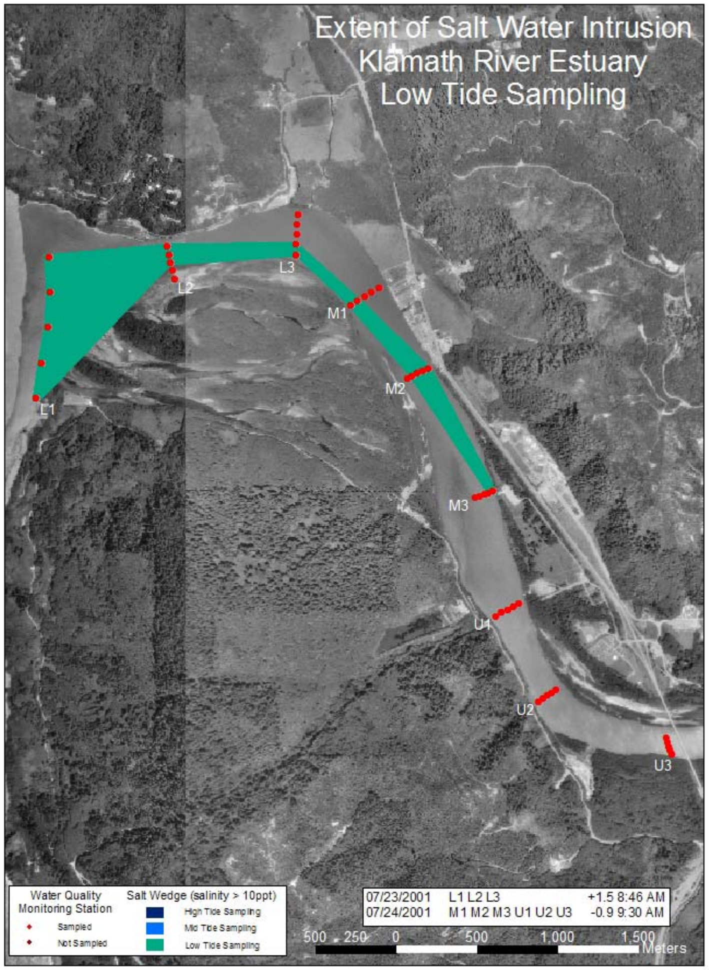
Extent of Saltwater Intrusion
Klamath River Estuary, 2001

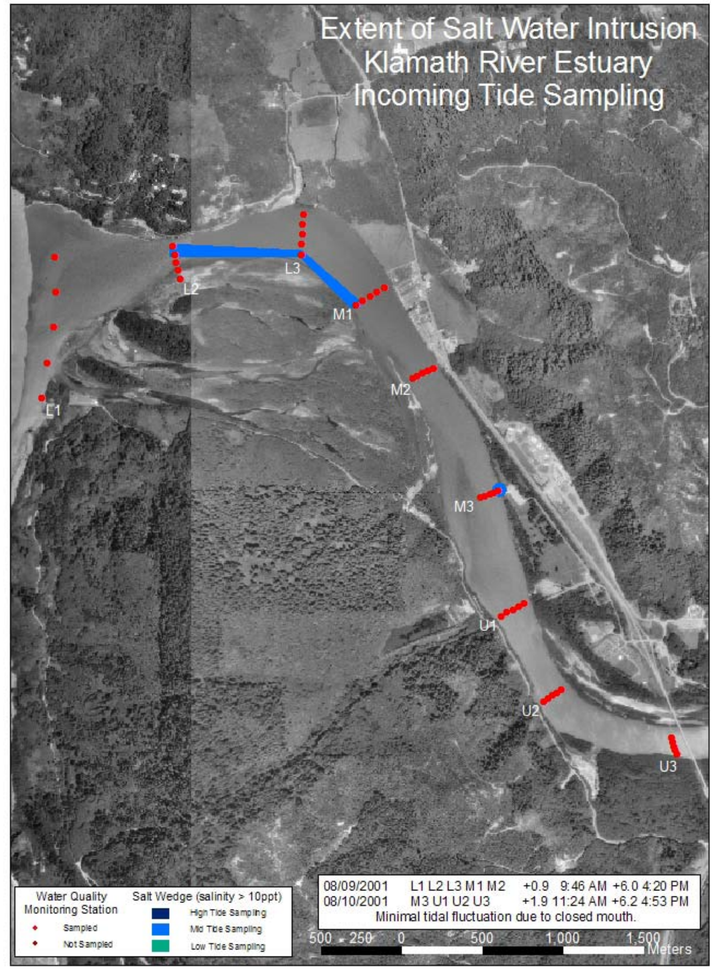

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/03/2001 L1 L2 L3 +5.3 12:19 PM +3.0 4:55 PM
M1 M2 M3 U1 U2 U3 Not sampled due to equipment malfunction.
500 250 0 500 1,000 1,500
Meters

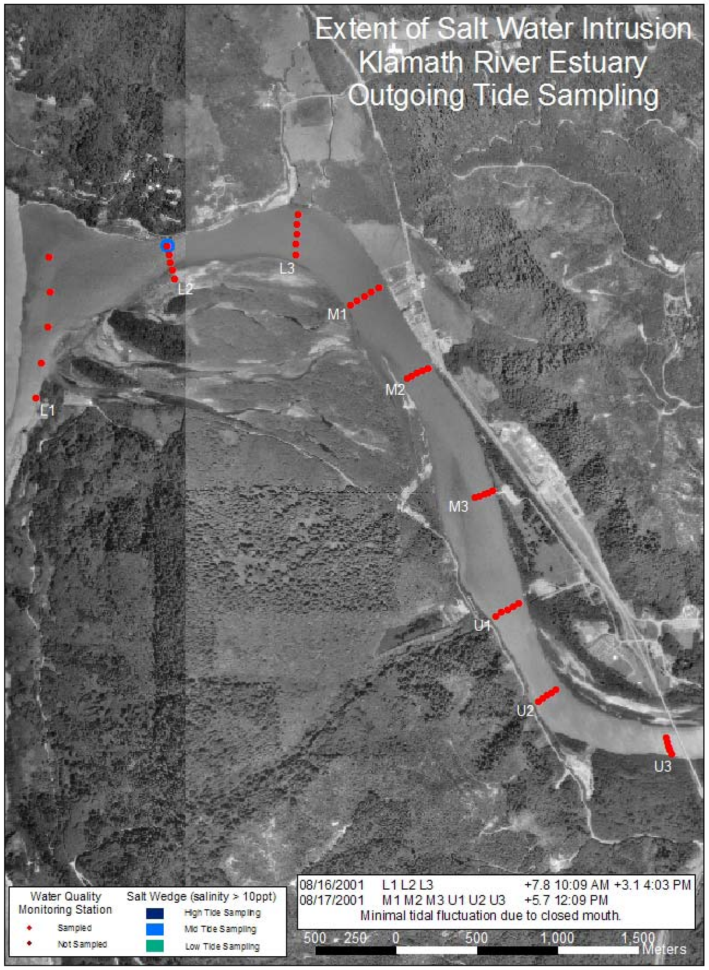

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/06/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
-0.9 7:30 AM +5.6 2:27 PM
500 250 0 500 1,000 1,500
Meters

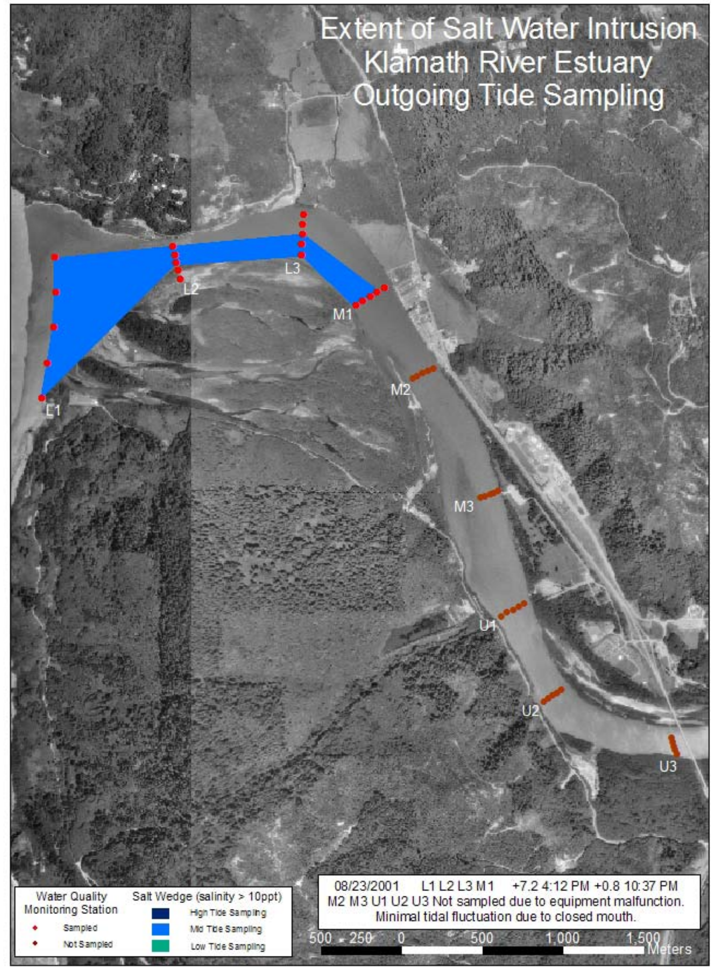

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/12/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
+6.0 6:02 PM +2.6 12:09 AM
500 250 0 500 1,000 1,500
Meters

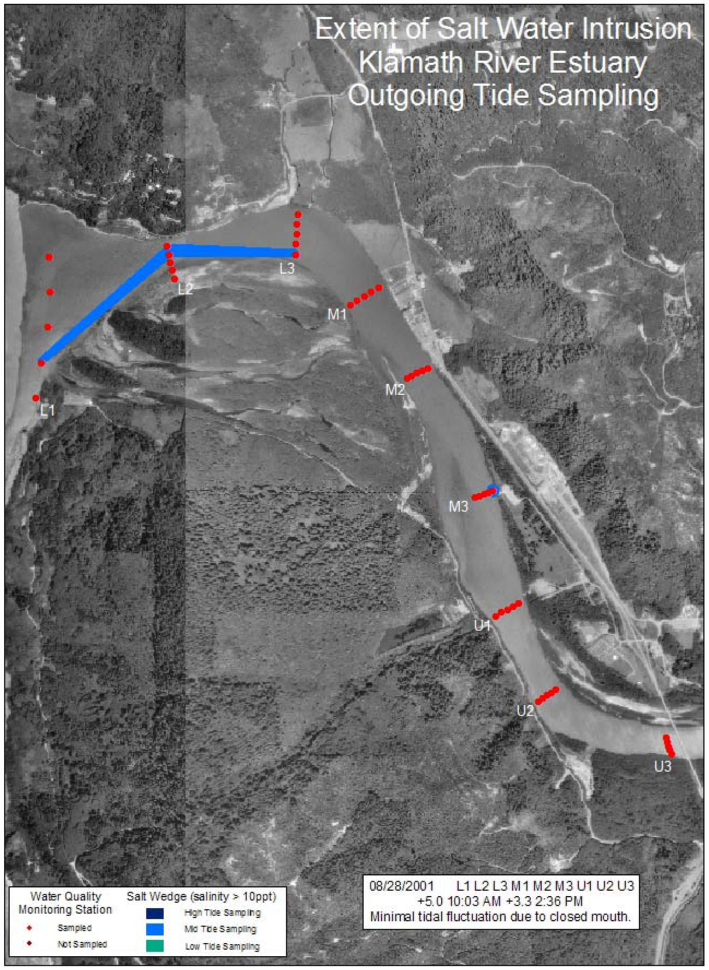

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/19/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
+8.2 11:14 AM
500 250 0 500 1,000 1,500
Meters

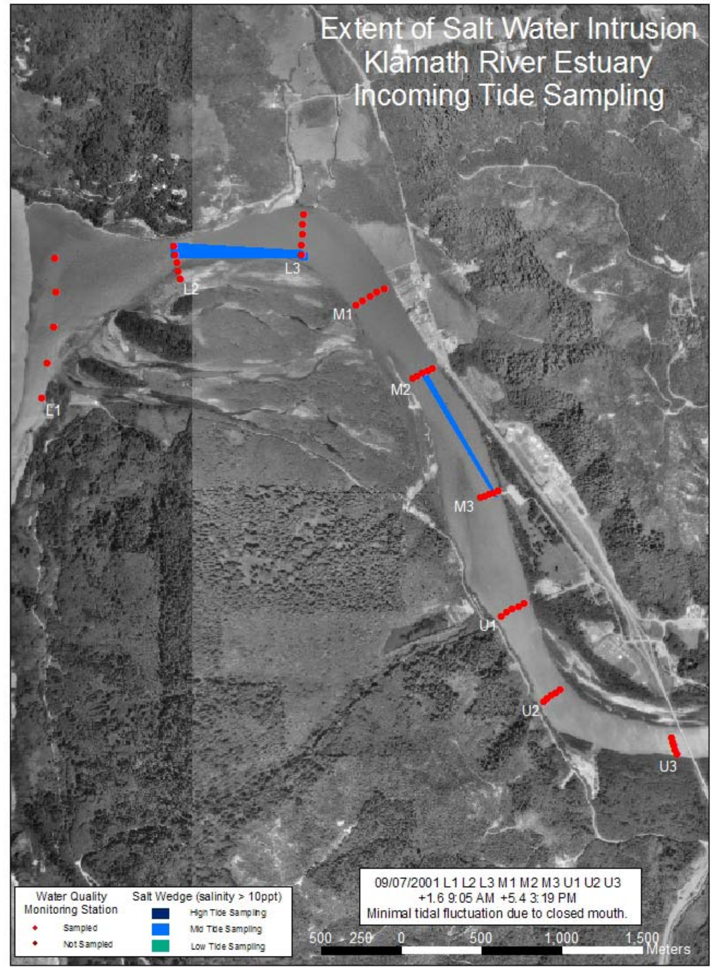

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/23/2001 L1 L2 L3 +1.5 8:46 AM
07/24/2001 M1 M2 M3 U1 U2 U3 -0.9 9:30 AM
500 250 0 500 1,000 1,500
Meters

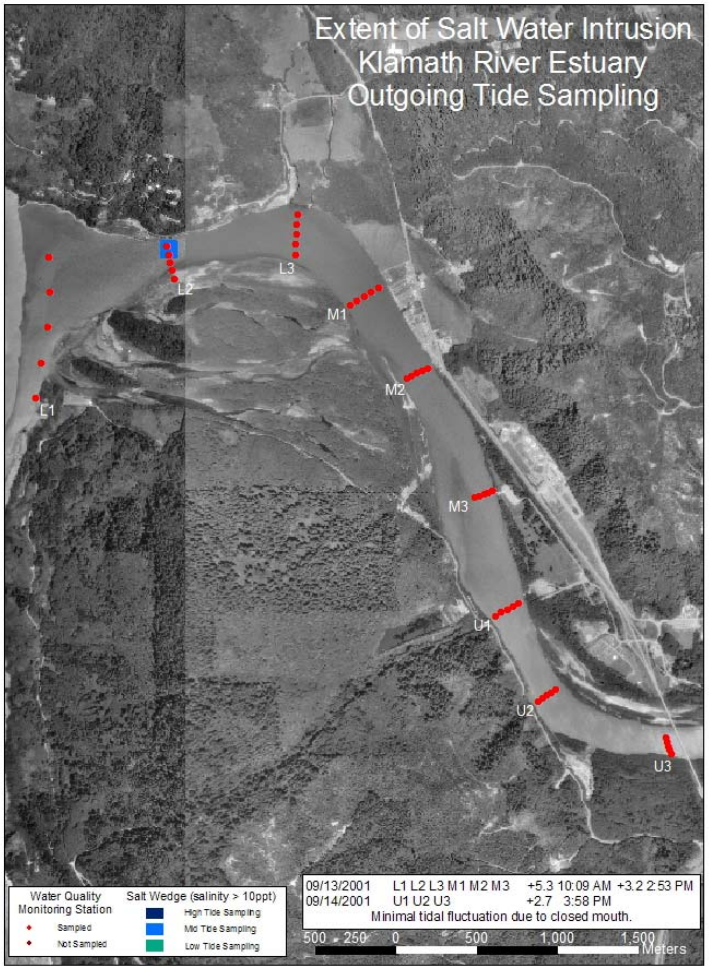

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/09/2001 L1 L2 L3 M1 M2 +0.9 9:46 AM +6.0 4:20 PM
08/10/2001 M3 U1 U2 U3 +1.9 11:24 AM +6.2 4:53 PM
Minimal tidal fluctuation due to closed mouth.
500 250 0 500 1,000 1,500
Meters

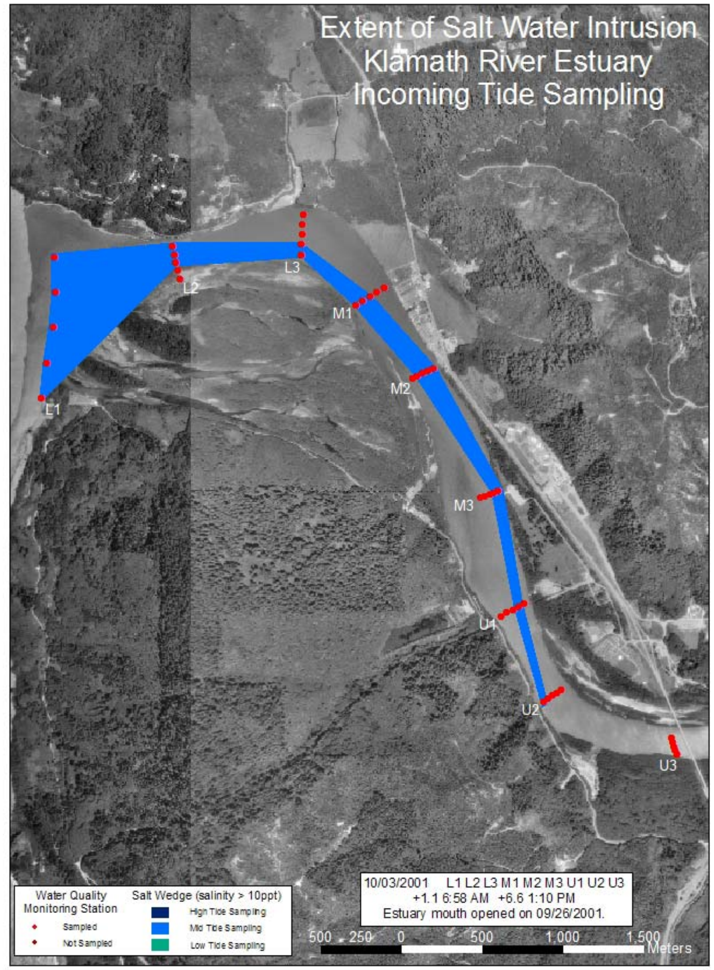

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/16/2001 L1 L2 L3 +7.8 10:09 AM +3.1 4:03 PM
08/17/2001 M1 M2 M3 U1 U2 U3 +5.7 12:09 PM
Minimal tidal fluctuation due to closed mouth.
500 250 0 500 1,000 1,500
Meters

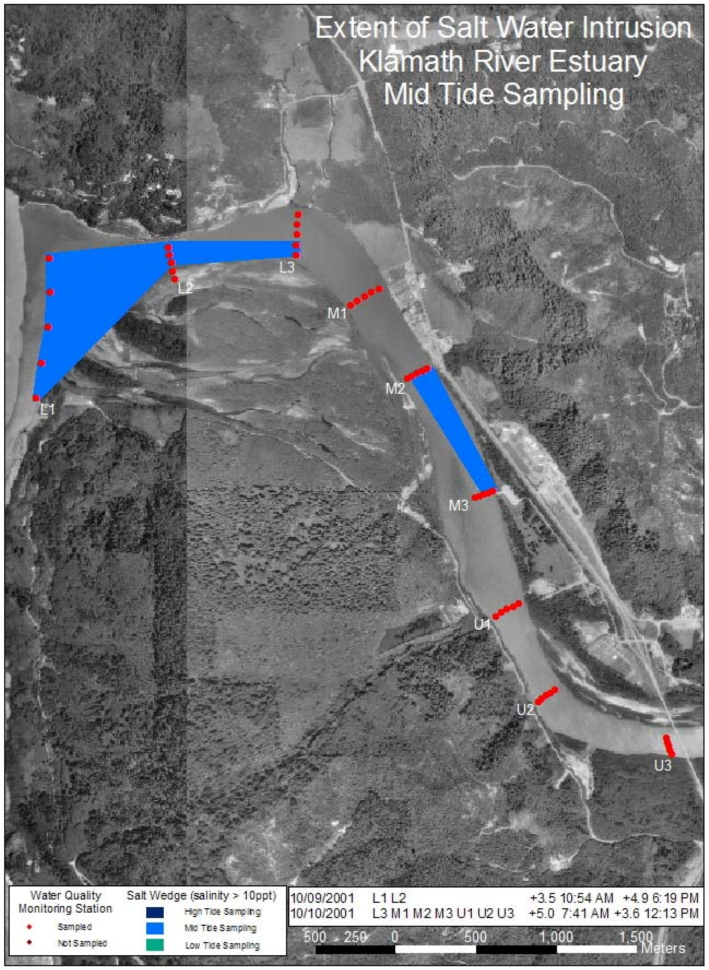

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/23/2001 L1 L2 L3 M1 +7.2 4:12 PM +0.8 10:37 PM
M2 M3 U1 U2 U3 Not sampled due to equipment malfunction.
Minimal tidal fluctuation due to closed mouth.
500 250 0 500 1,000 1,500
Meters

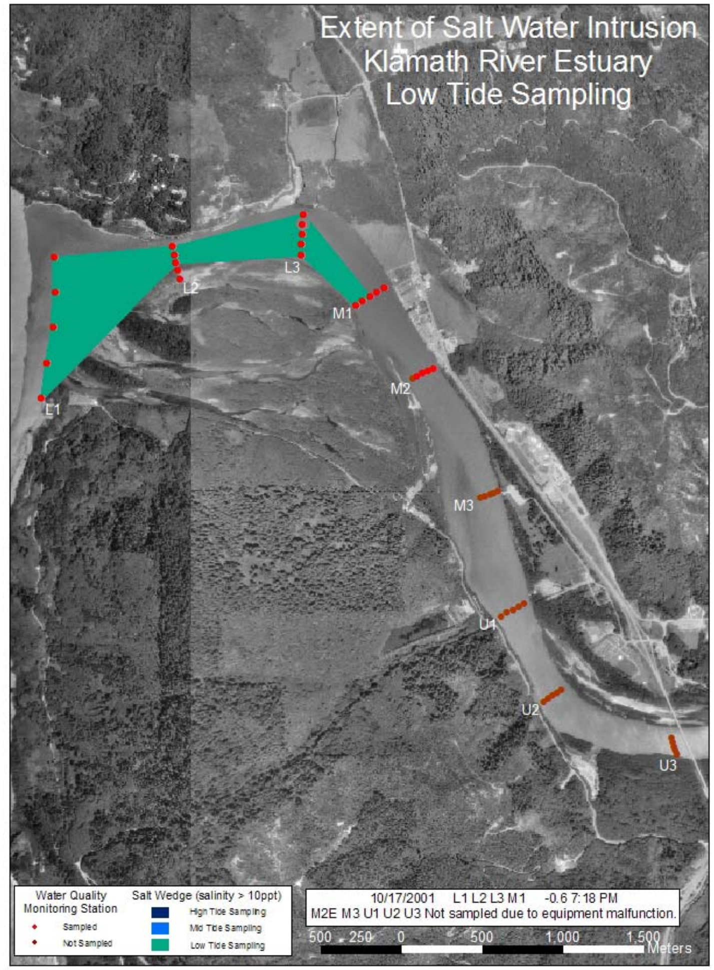

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/28/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.0 10:03 AM +3.3 2:36 PM
Minimal tidal fluctuation due to closed mouth.

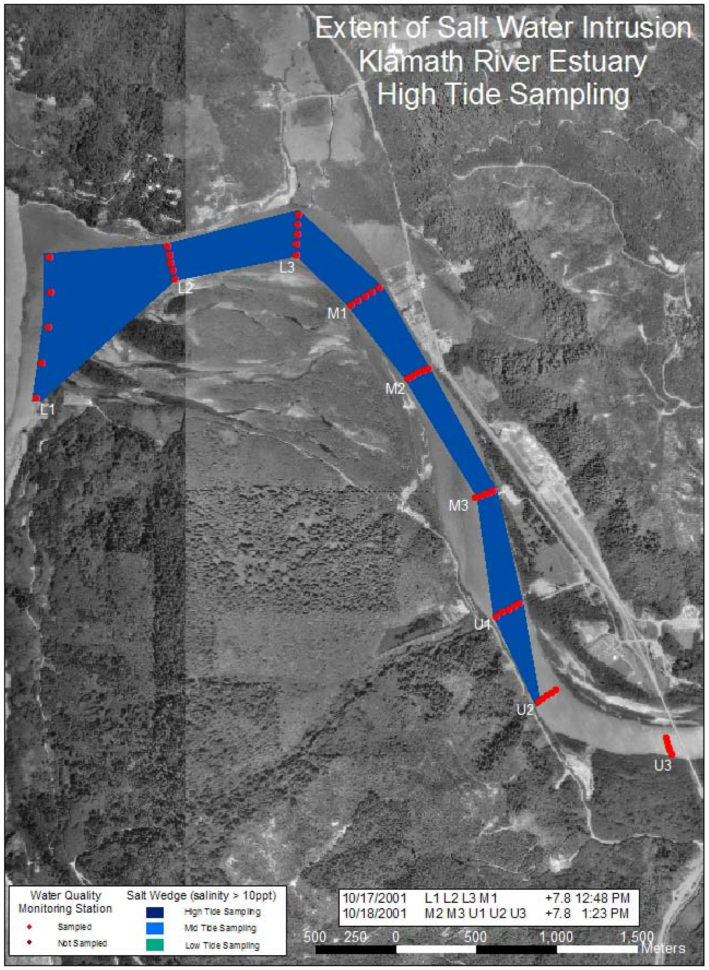

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
09/07/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
+1.6 9:05 AM +5.4 3:19 PM
Minimal tidal fluctuation due to closed mouth.
500 250 0 500 1,000 1,500
Meters

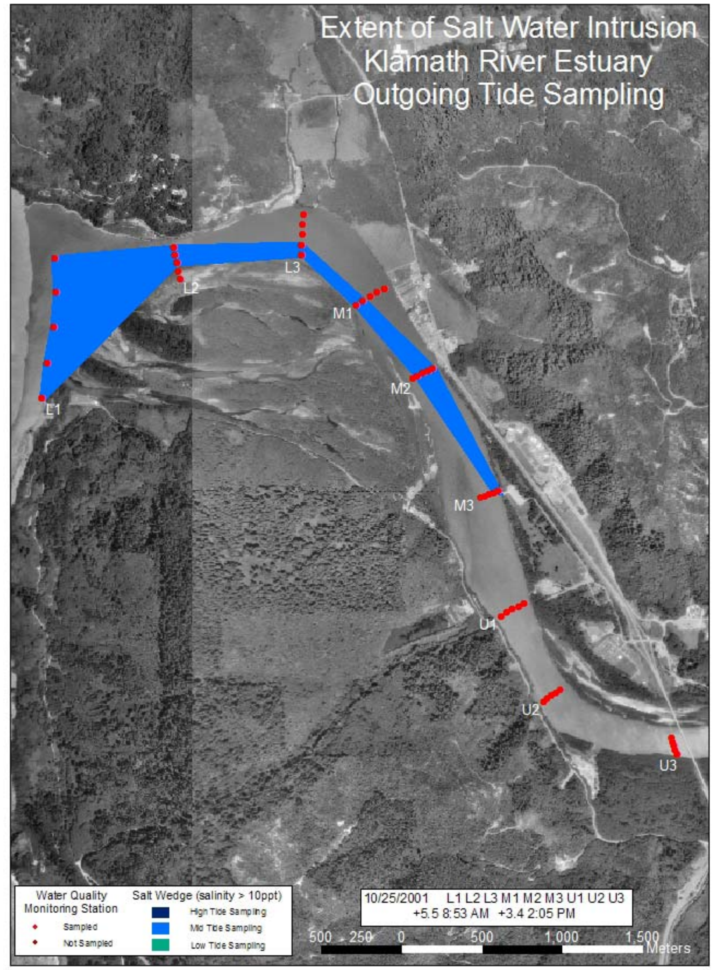

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
09/13/2001 L1 L2 L3 M1 M2 M3 +5.3 10:09 AM +3.2 2:53 PM
09/14/2001 U1 U2 U3 +2.7 3:58 PM
Minimal tidal fluctuation due to closed mouth.
500 250 0 500 1,000 1,500
Meters

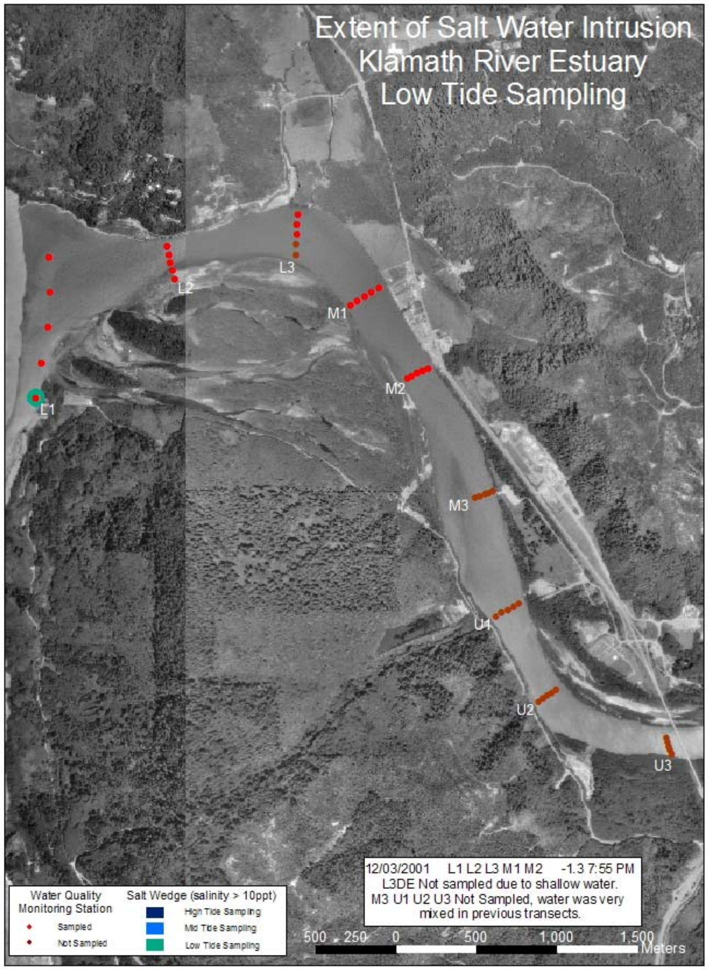

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/03/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
+1.1 6:58 AM +6.6 1:10 PM
Estuary mouth opened on 09/26/2001.
500 250 0 500 1,000 1,500
Meters

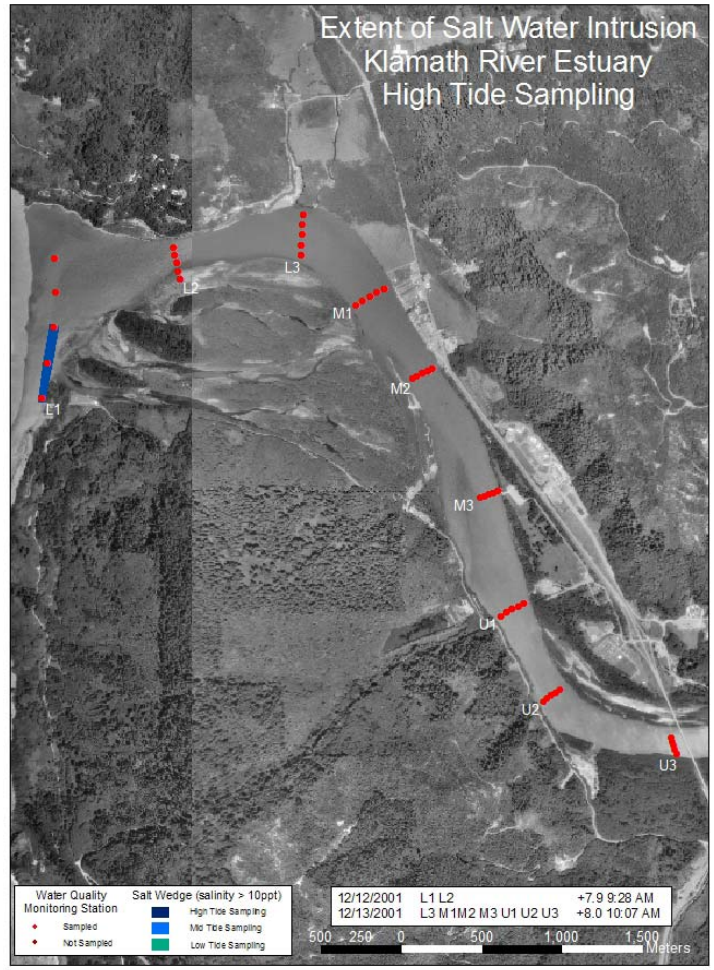

Extent of Salt Water Intrusion
Klamath River Estuary
Mid Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/09/2001 L1 L2 +3.5 10:54 AM +4.9 6:19 PM
10/10/2001 L3 M1 M2 M3 U1 U2 U3 +5.0 7:41 AM +3.6 12:13 PM
500 250 0 500 1,000 1,500
Meters

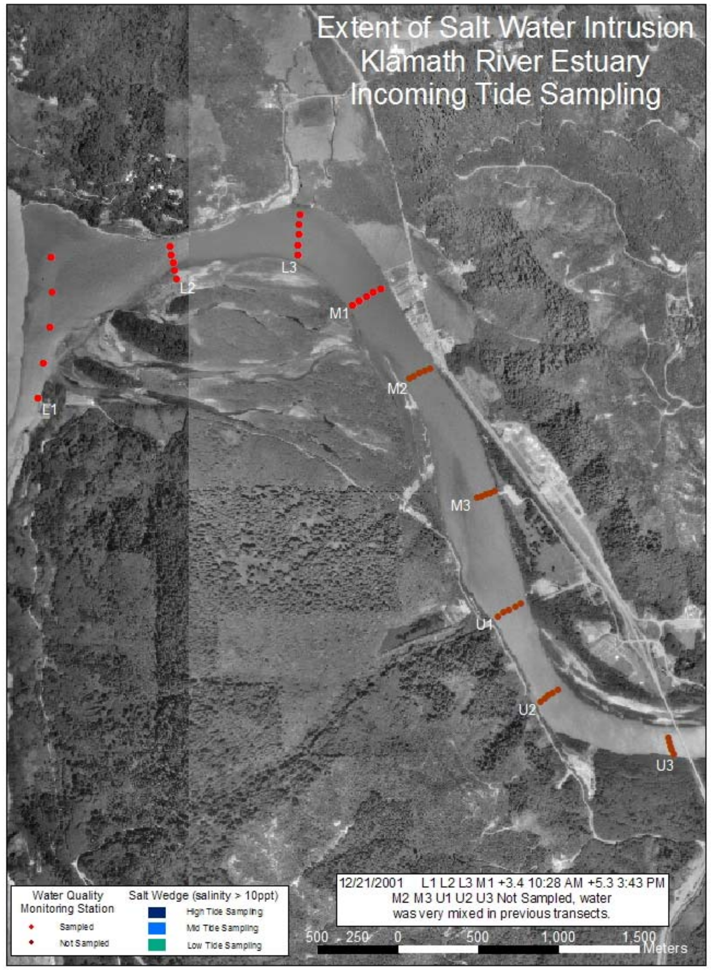

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/17/2001 L1 L2 L3 M1 -0.6 7:18 PM
M2E M3 U1 U2 U3 Not sampled due to equipment malfunction.
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/17/2001 L1 L2 L3 M1 +7.8 12:48 PM
10/18/2001 M2 M3 U1 U2 U3 +7.8 1:23 PM
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/25/2001 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.5 8:53 AM +3.4 2:05 PM
500 250 0 500 1,000 1,500
Meters

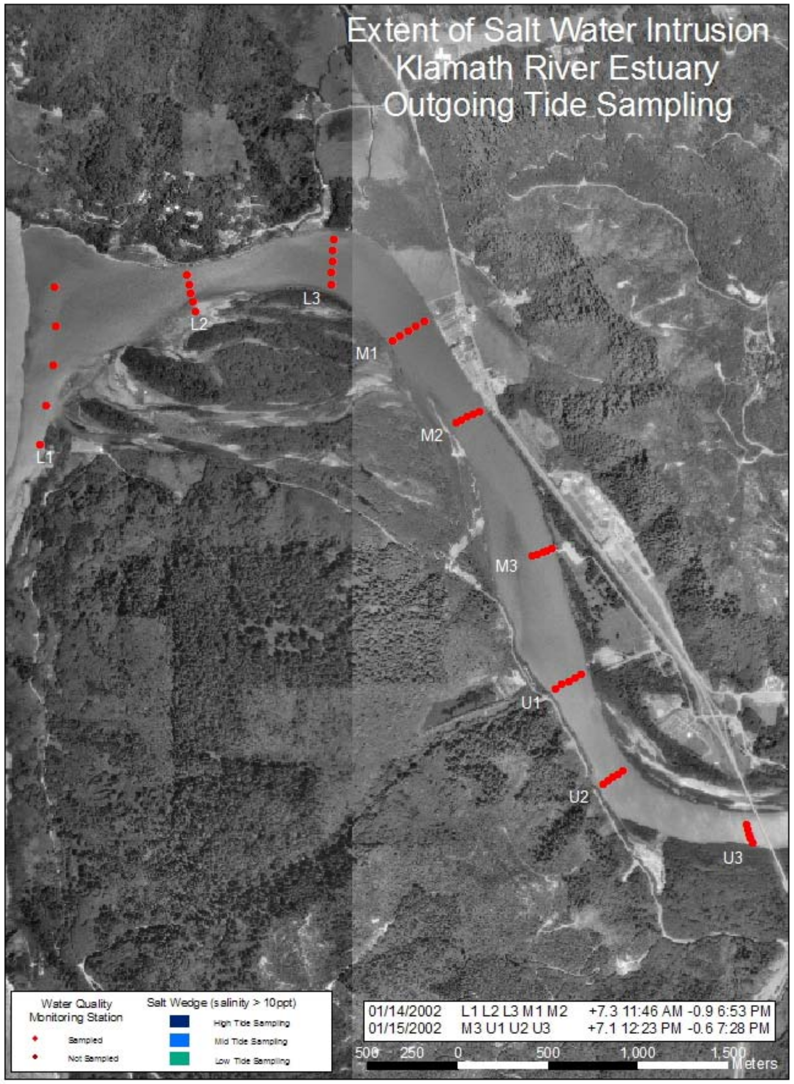

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
12/03/2001 L1 L2 L3 M1 M2 -1.3 7:55 PM
L3DE Not sampled due to shallow water.
M3 U1 U2 U3 Not Sampled, water was very mixed in previous transects.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500 Meters


Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
12/12/2001 L1 L2 +7.9 9:28 AM
12/13/2001 L3 M1M2 M3 U1 U2 U3 +8.0 10:07 AM
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500 Meters

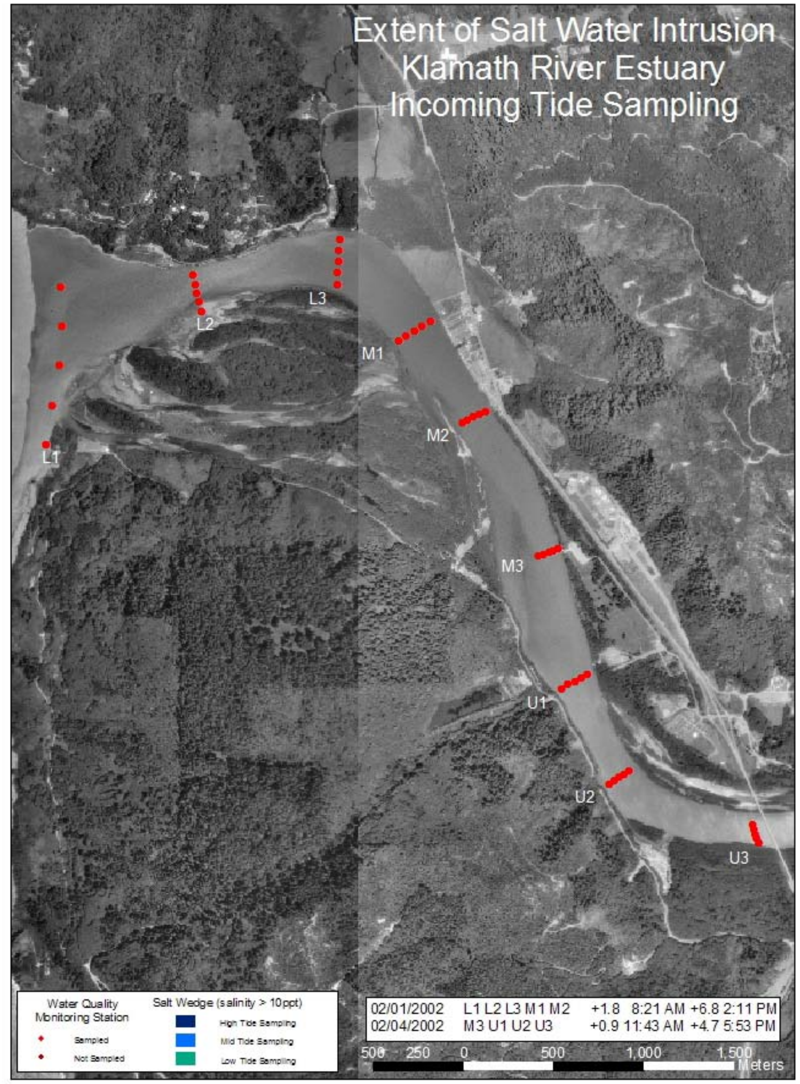

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
12/21/2001 L1 L2 L3 M1 +3.4 10:28 AM +5.3 3:43 PM
M2 M3 U1 U2 U3 Not Sampled, water
was very mixed in previous transects.
500 250 0 500 1,000 1,500
Meters

Appendix B

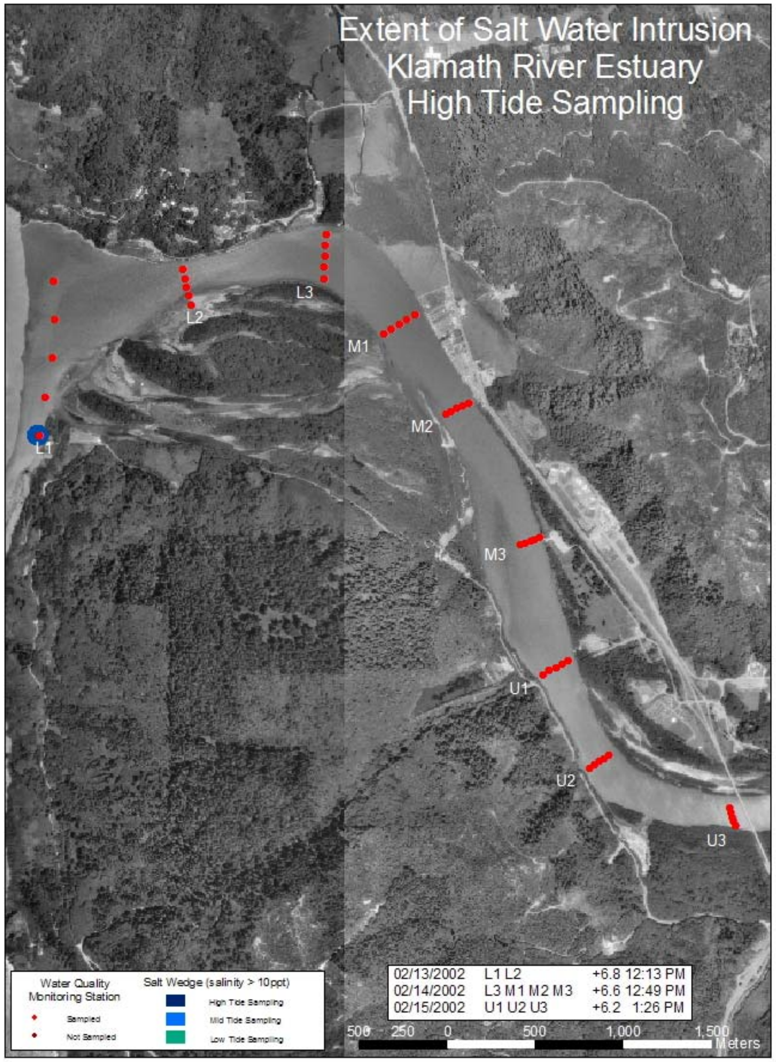
Extent of Saltwater Intrusion
Klamath River Estuary, 2002

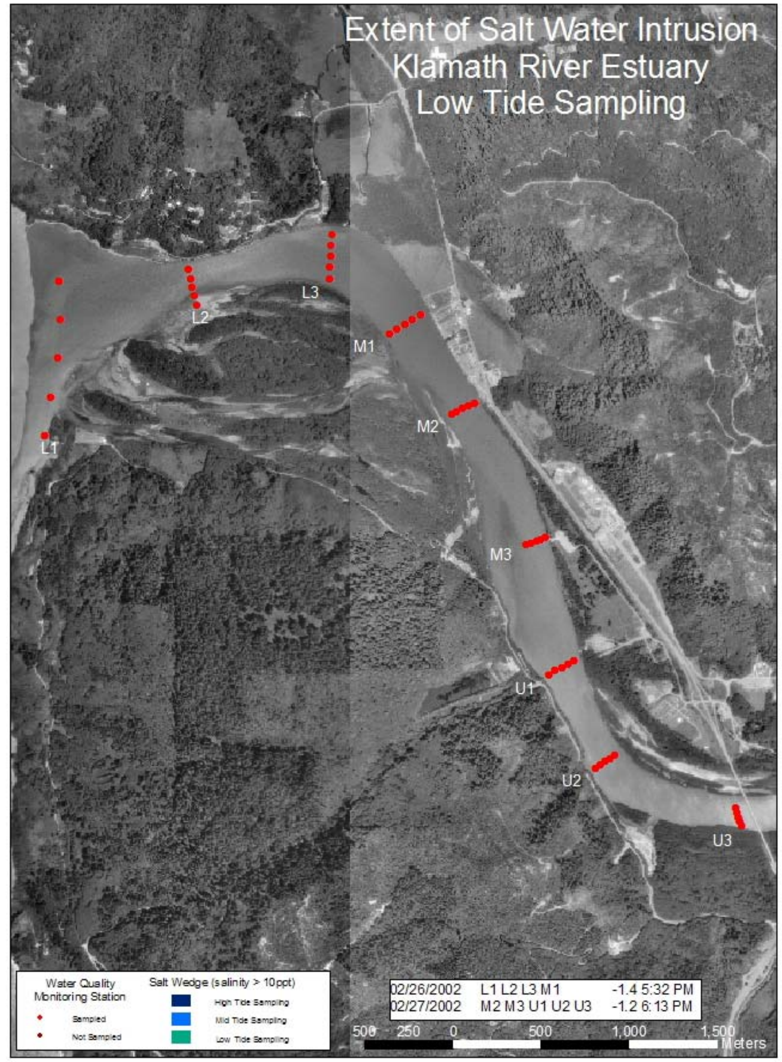


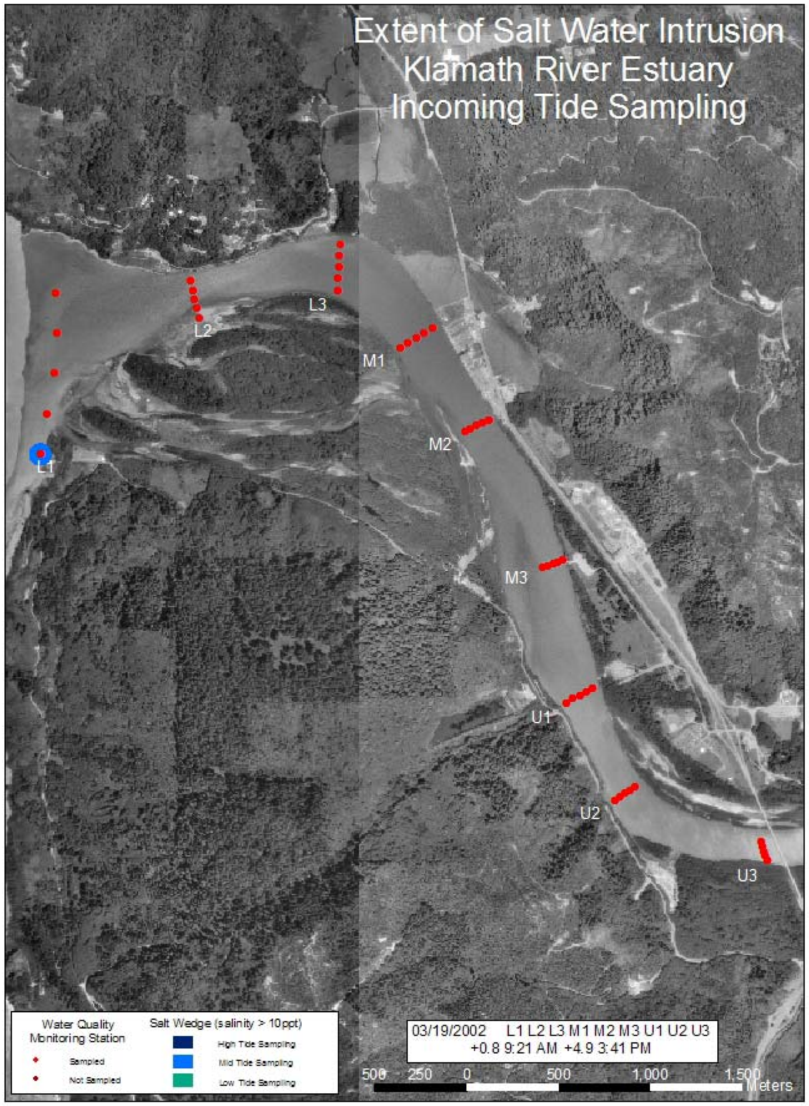
Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
01/14/2002 L1 L2 L3 M1 M2 +7.3 11:46 AM -0.9 6:53 PM
01/15/2002 M3 U1 U2 U3 +7.1 12:23 PM -0.6 7:28 PM
500 250 0 500 1,000 1,500
Meters

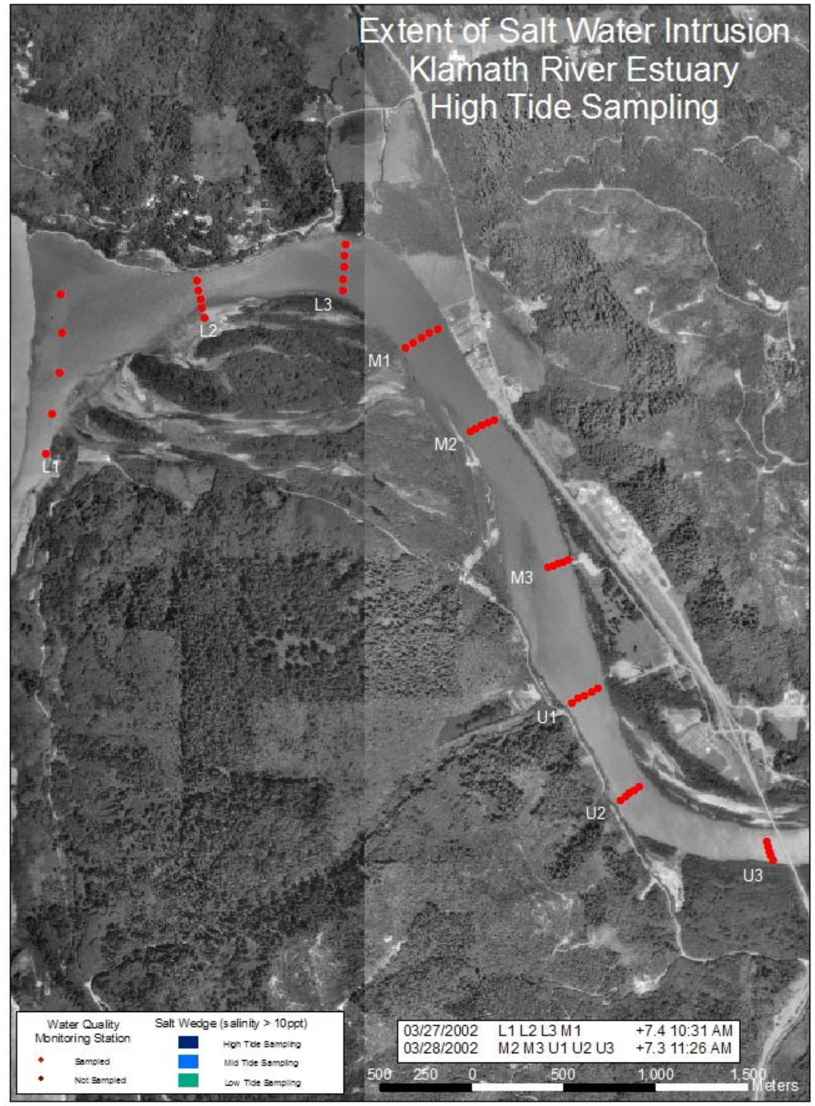


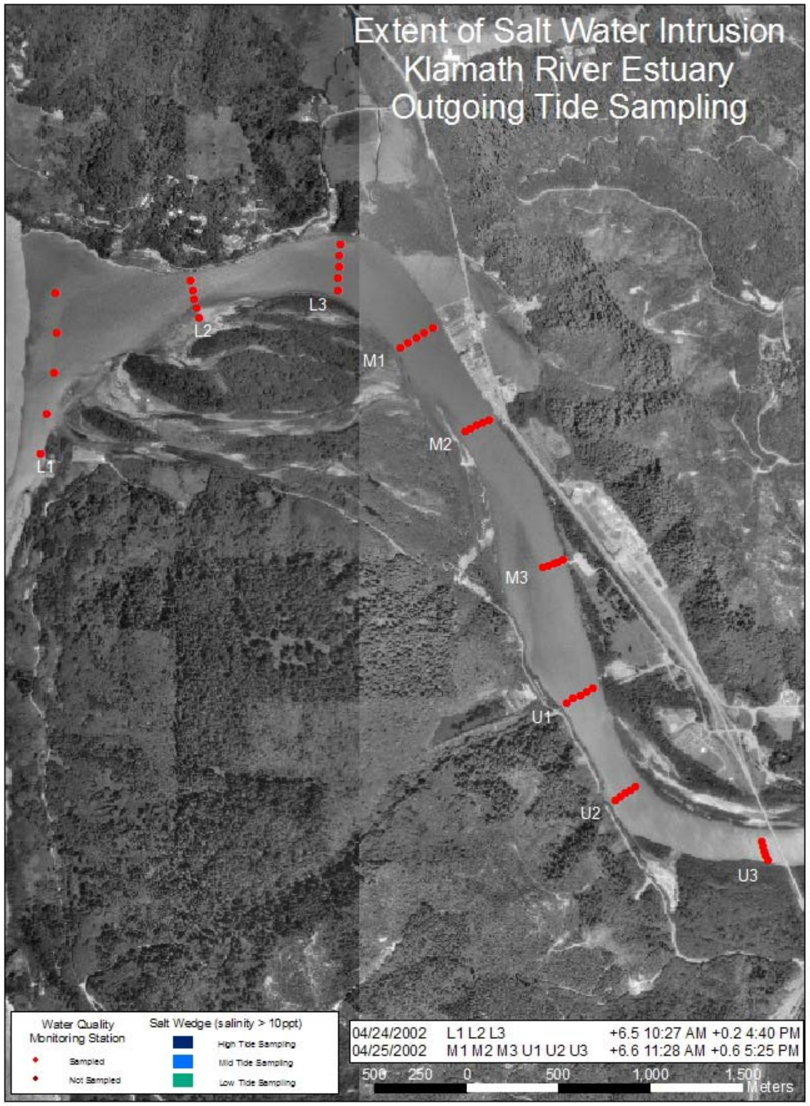
Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
02/01/2002 L1 L2 L3 M1 M2 +1.8 8:21 AM +6.8 2:11 PM
02/04/2002 M3 U1 U2 U3 +0.9 11:43 AM +4.7 5:53 PM
500 250 0 500 1,000 1,500
Meters

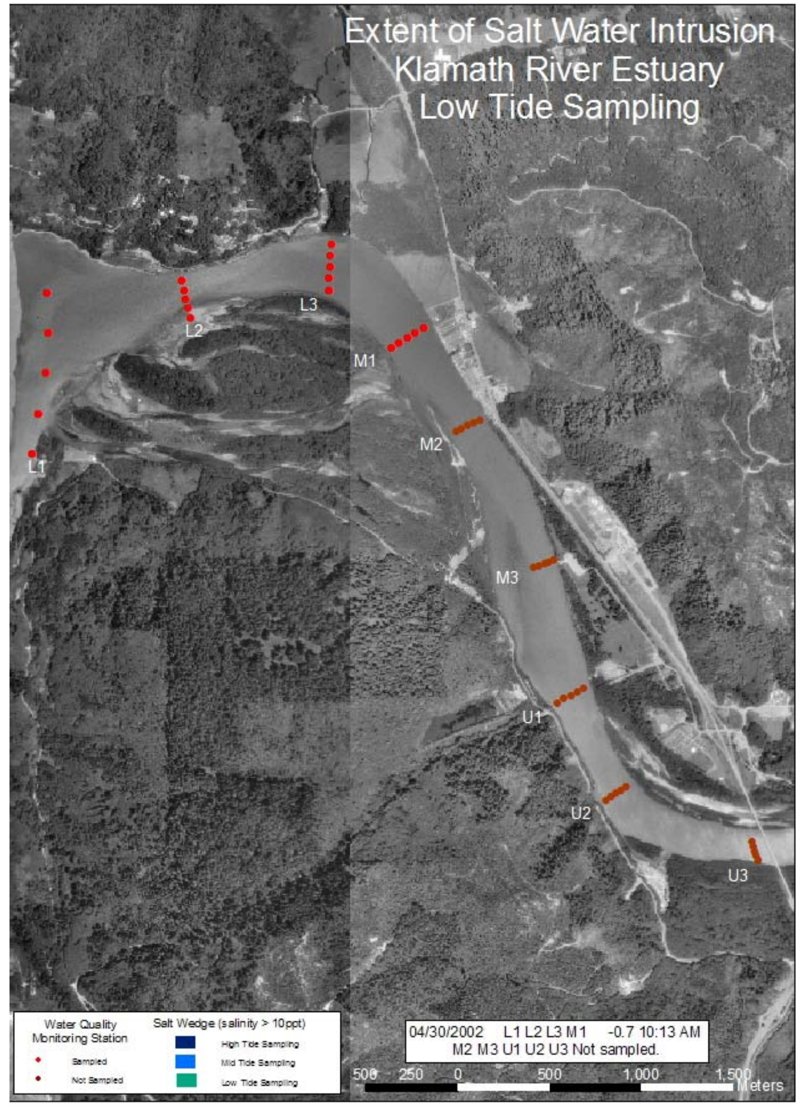

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
02/13/2002 L1 L2 +6.8 12:13 PM
02/14/2002 L3 M1 M2 M3 +6.6 12:49 PM
02/15/2002 U1 U2 U3 +6.2 1:26 PM
500 250 0 500 1,000 1,500
Meters

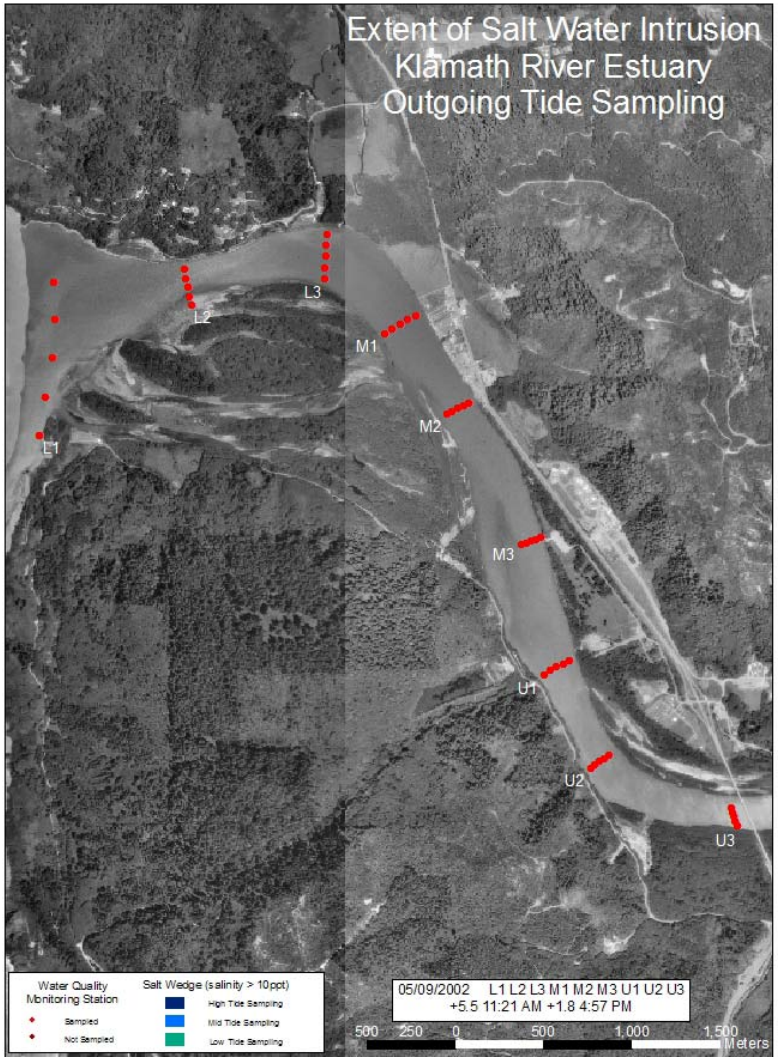

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
02/26/2002 L1 L2 L3 M1 -1.4 5:32 PM
02/27/2002 M2 M3 U1 U2 U3 -1.2 6:13 PM
500 250 0 500 1,000 1,500
Meters

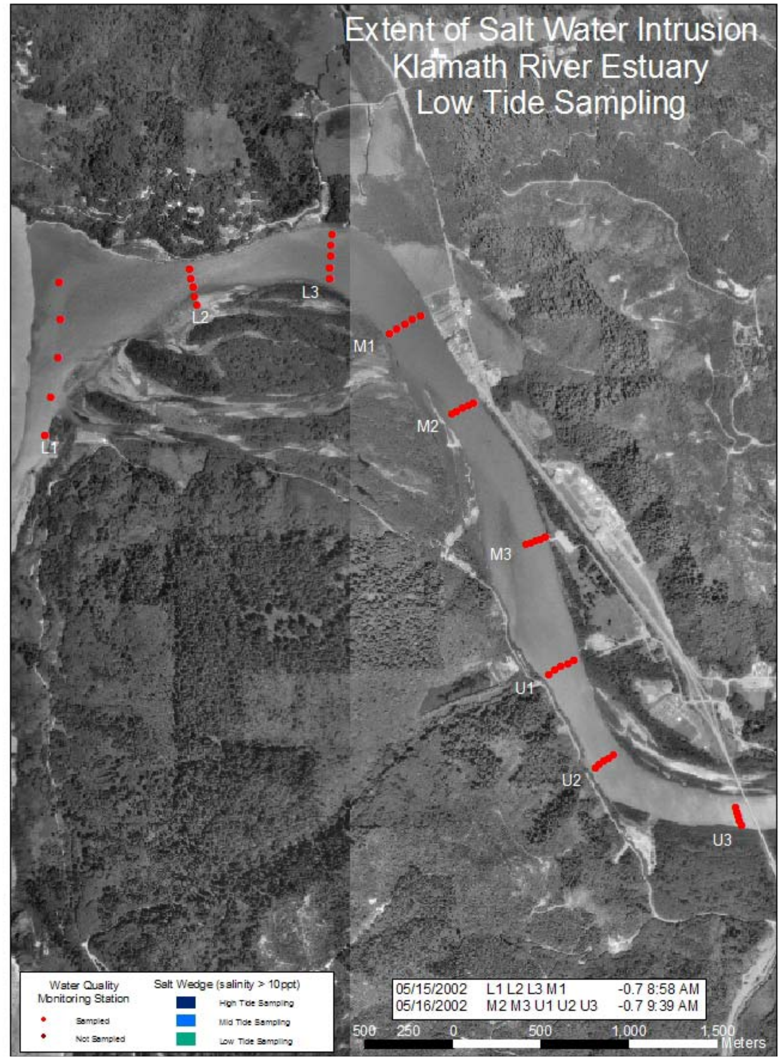

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
03/19/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+0.8 9:21 AM +4.9 3:41 PM
500 250 0 500 1,000 1,500
Meters

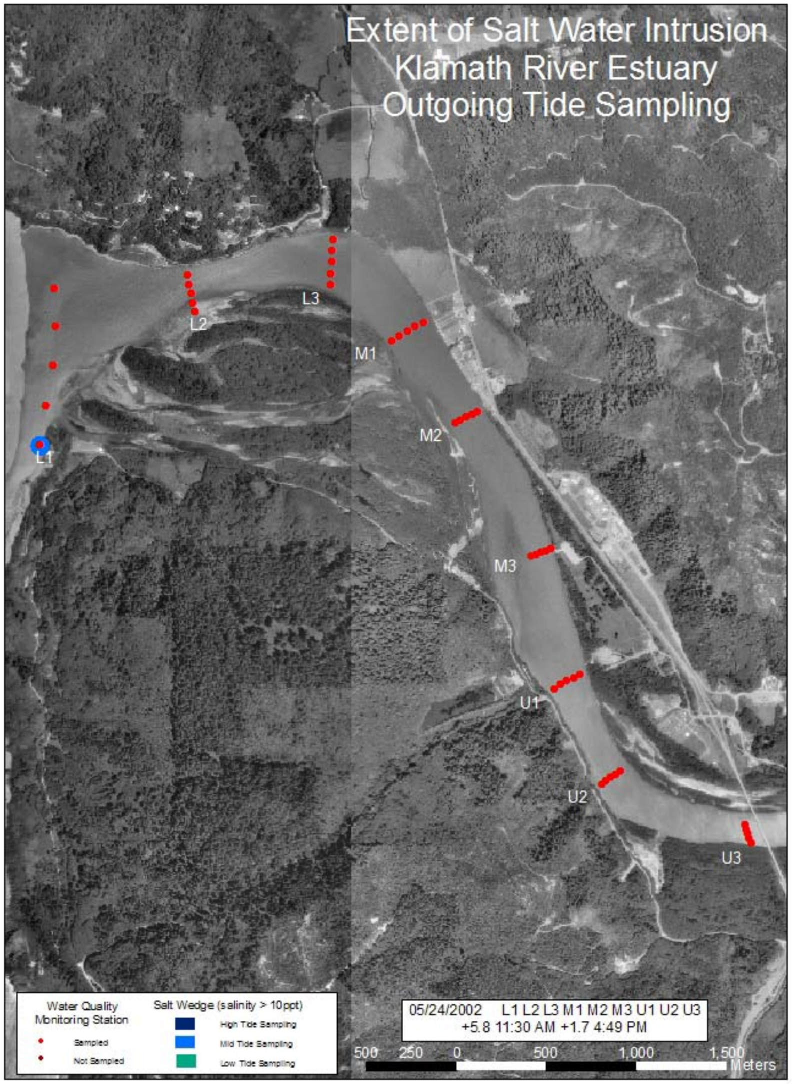

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
03/27/2002 L1 L2 L3 M1 +7.4 10:31 AM
03/28/2002 M2 M3 U1 U2 U3 +7.3 11:26 AM
500 250 0 500 1,000 1,500
Meters

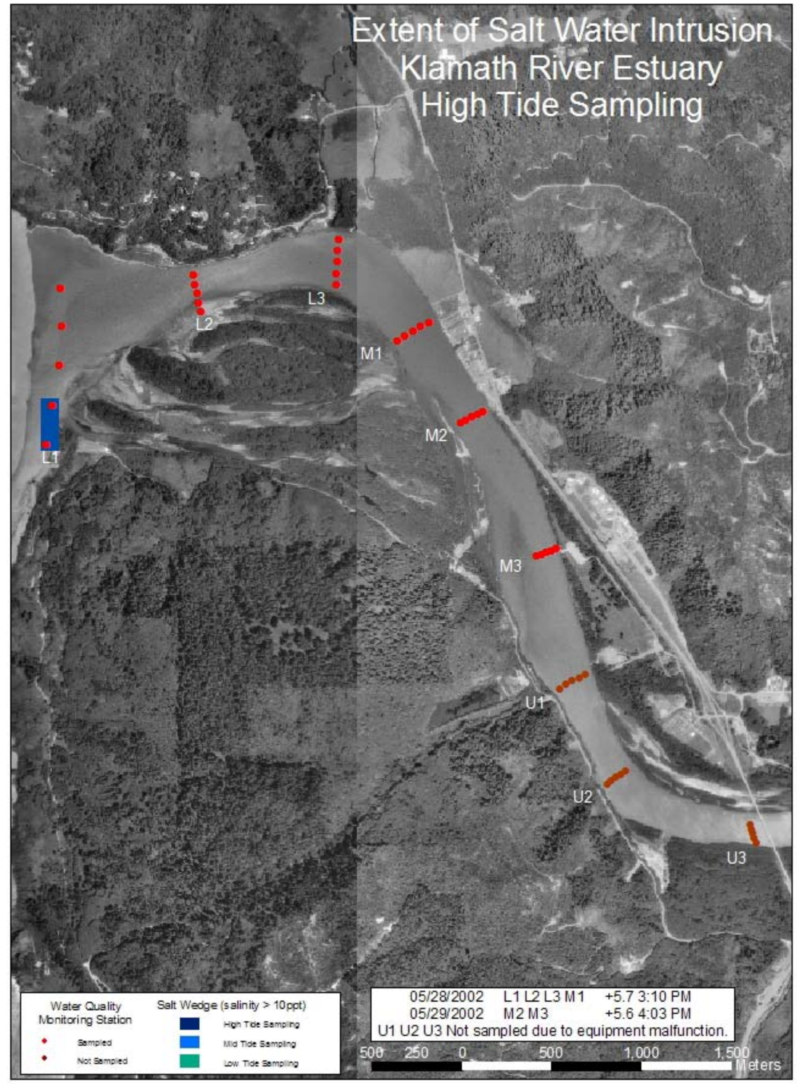

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
04/24/2002 L1 L2 L3 +6.5 10:27 AM +0.2 4:40 PM
04/25/2002 M1 M2 M3 U1 U2 U3 +6.6 11:28 AM +0.6 5:25 PM
500 250 0 500 1,000 1,500
Meters

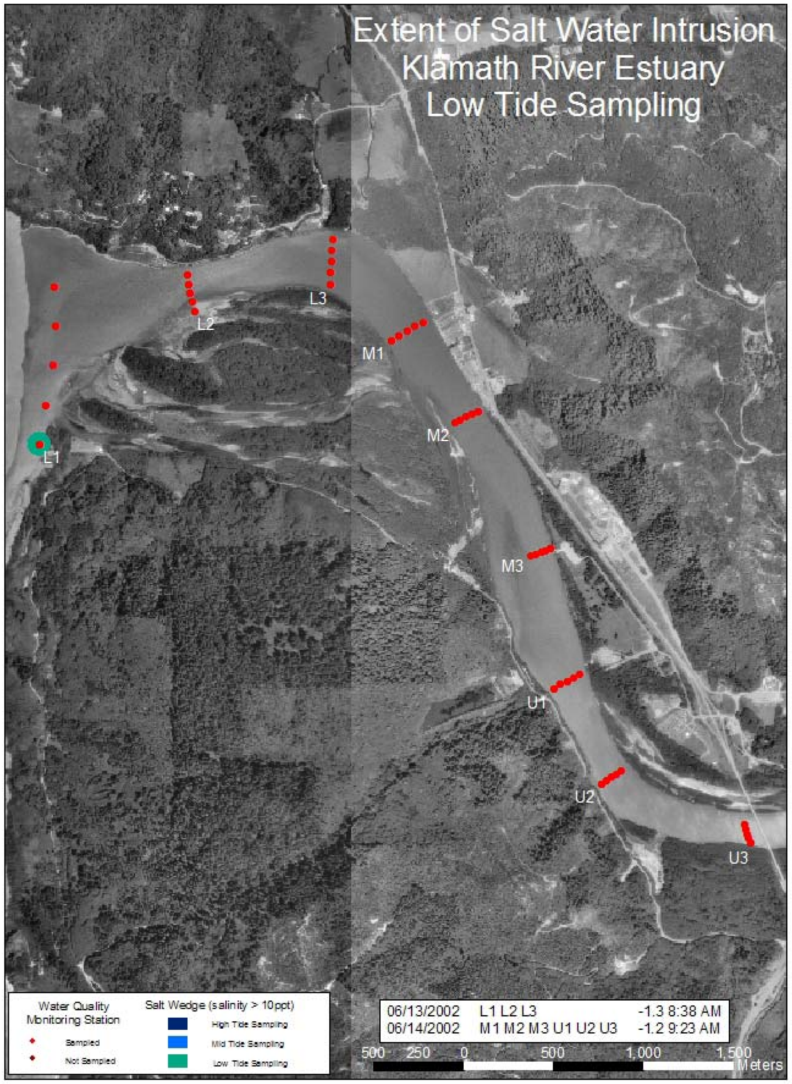

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
04/30/2002 L1 L2 L3 M1 -0.7 10:13 AM
M2 M3 U1 U2 U3 Not sampled.
500 250 0 500 1,000 1,500
Meters

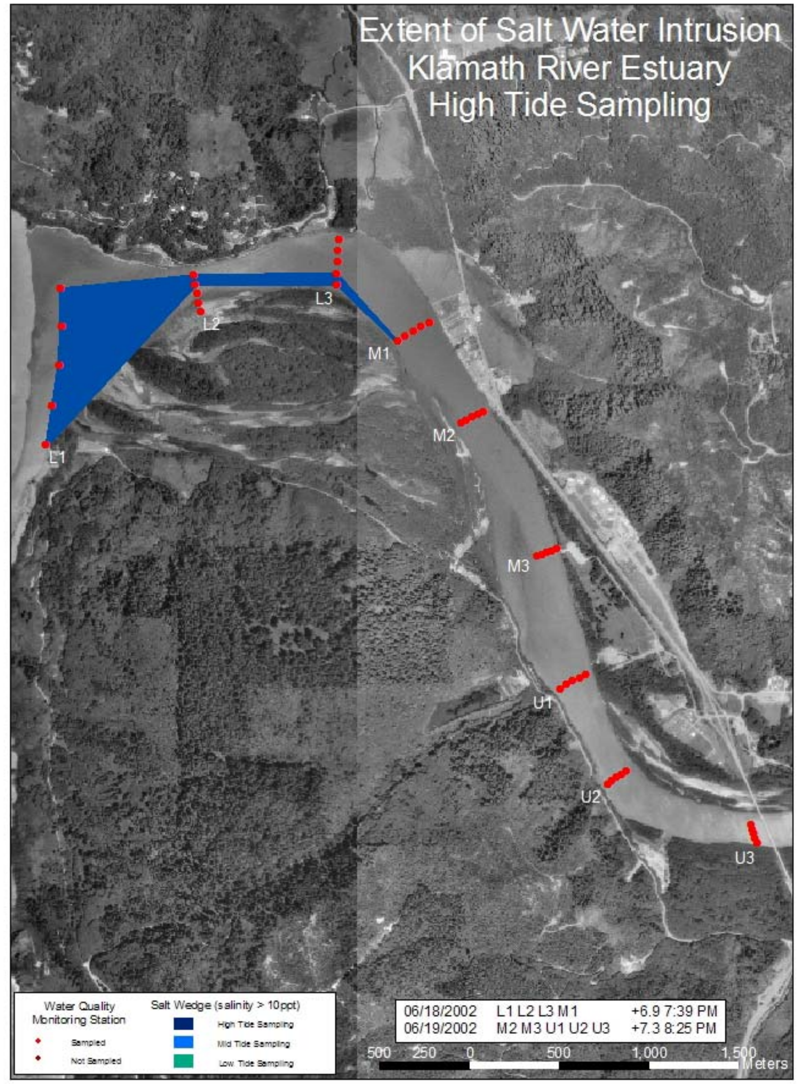

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
05/09/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.5 11:21 AM +1.8 4:57 PM
500 250 0 500 1,000 1,500
Meters

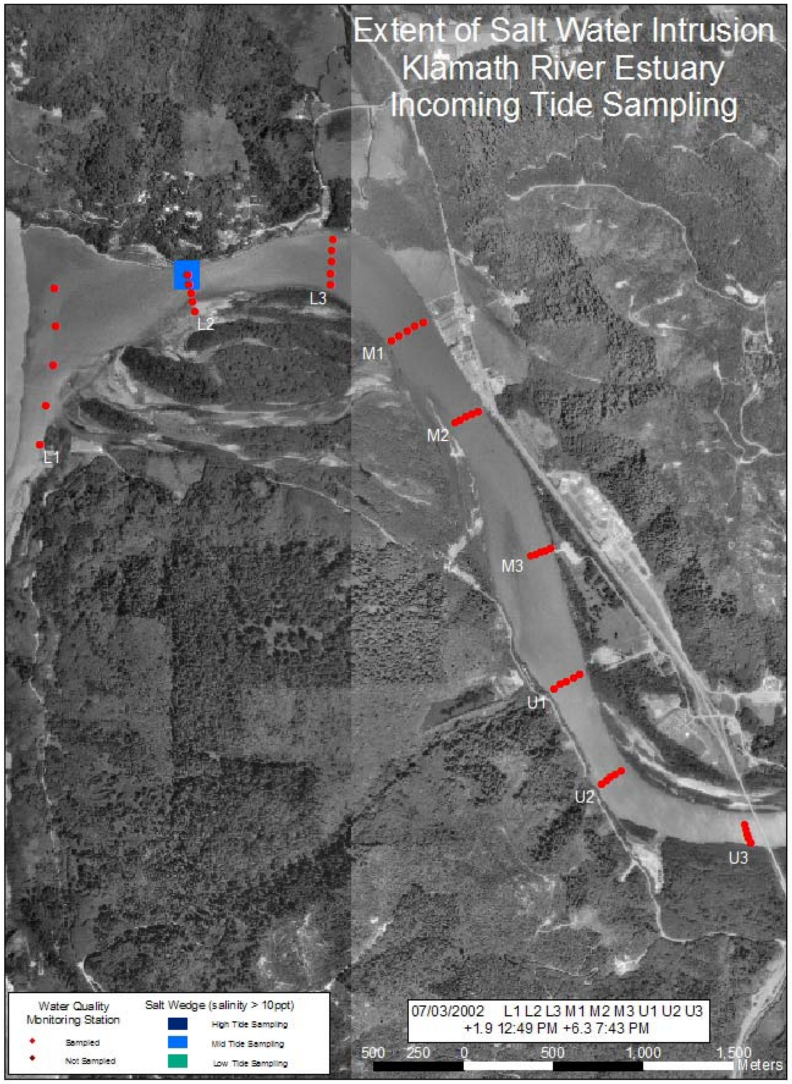

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
05/15/2002 L1 L2 L3 M1 -0.7 8:58 AM
05/16/2002 M2 M3 U1 U2 U3 -0.7 9:39 AM
500 250 0 500 1,000 1,500
Meters

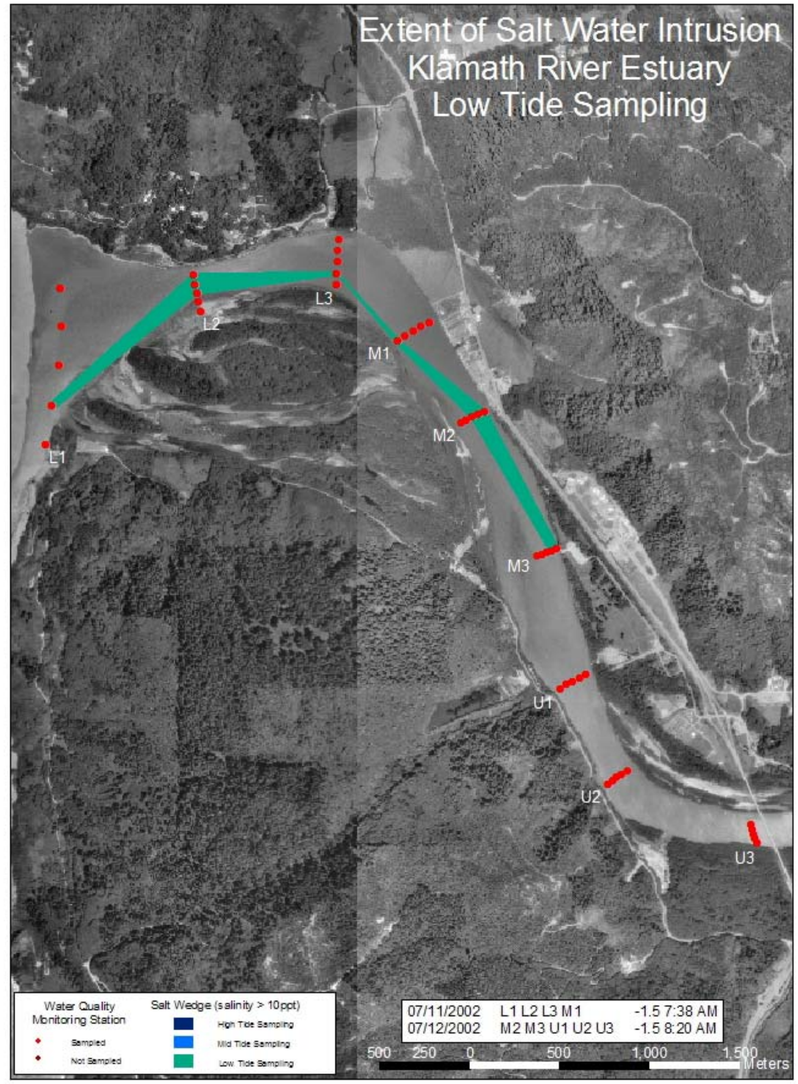

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
05/24/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.8 11:30 AM +1.7 4:49 PM
500 250 0 500 1,000 1,500
Meters

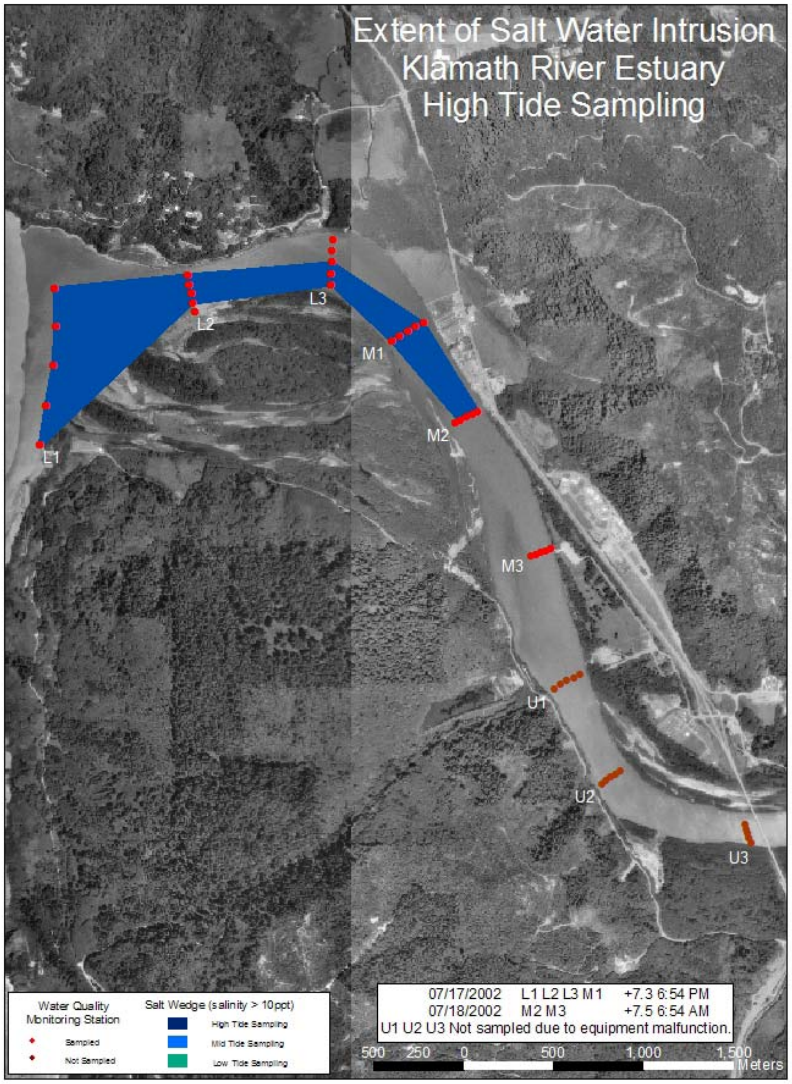

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
05/28/2002 L1 L2 L3 M1 +5.7 3:10 PM
05/29/2002 M2 M3 +5.6 4:03 PM
U1 U2 U3 Not sampled due to equipment malfunction.
500 250 0 500 1,000 1,500
Meters

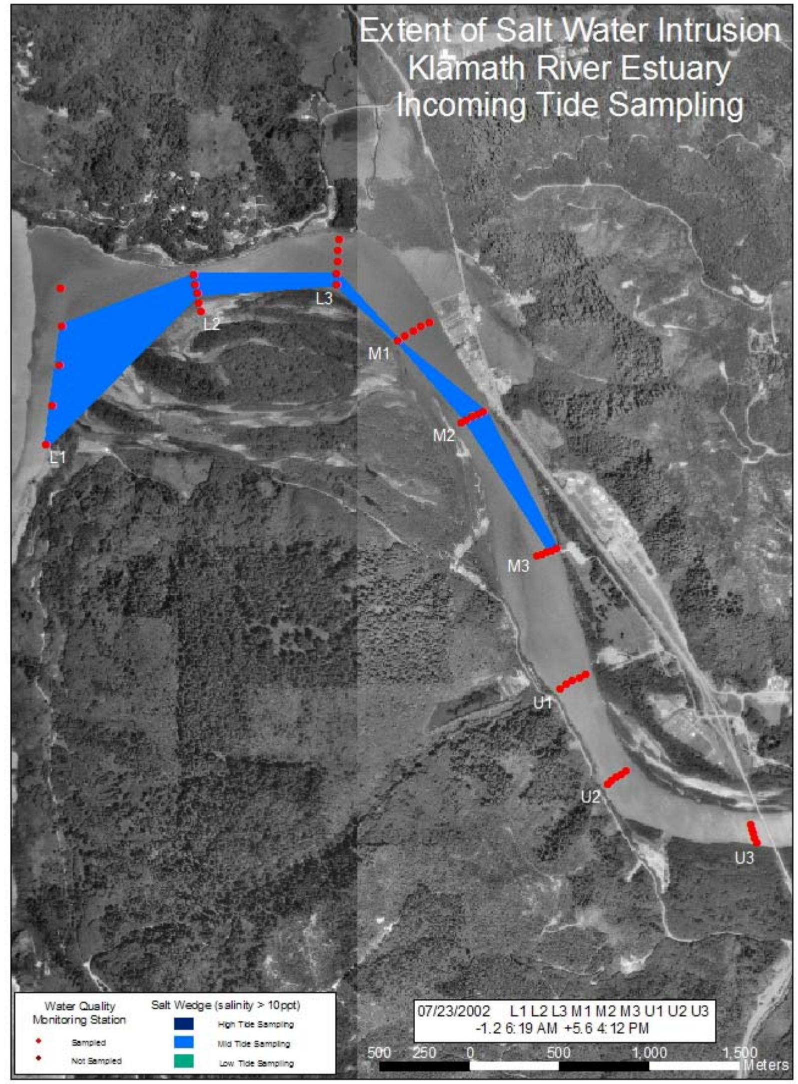

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
06/13/2002 L1 L2 L3 -1.3 8:38 AM
06/14/2002 M1 M2 M3 U1 U2 U3 -1.2 9:23 AM
500 250 0 500 1,000 1,500
Meters

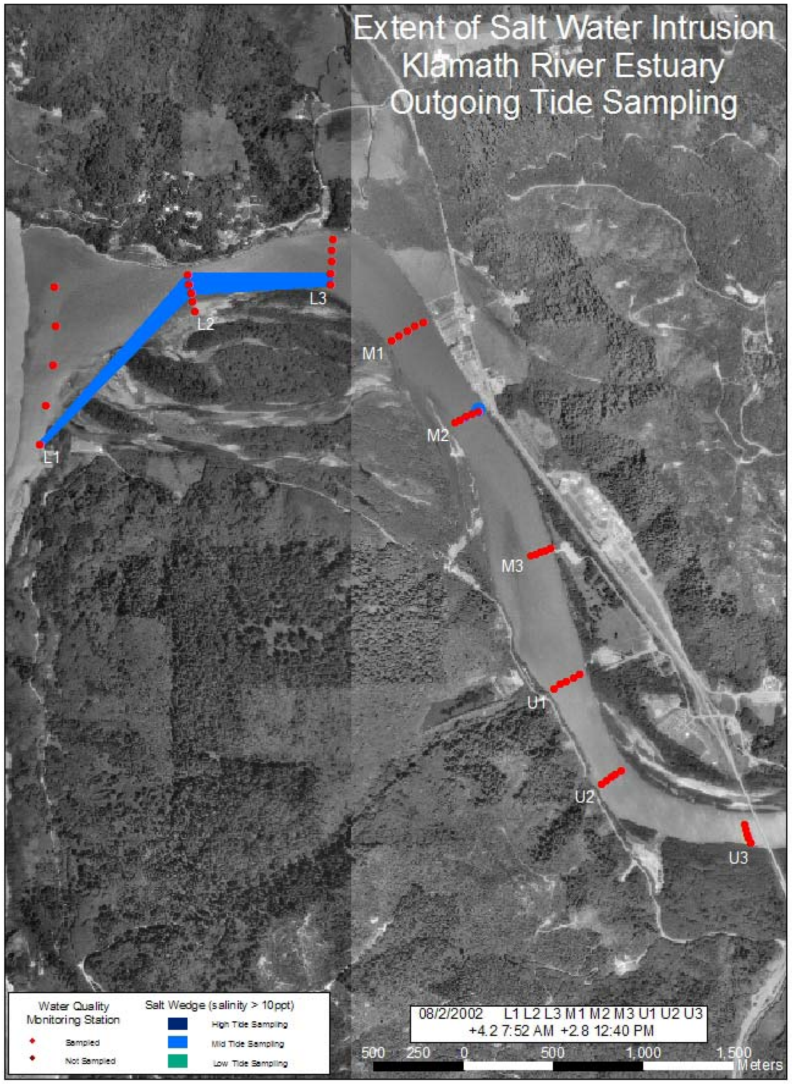

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
06/18/2002 L1 L2 L3 M1 +6.9 7:39 PM
06/19/2002 M2 M3 U1 U2 U3 +7.3 8:25 PM
500 250 0 500 1,000 1,500
Meters

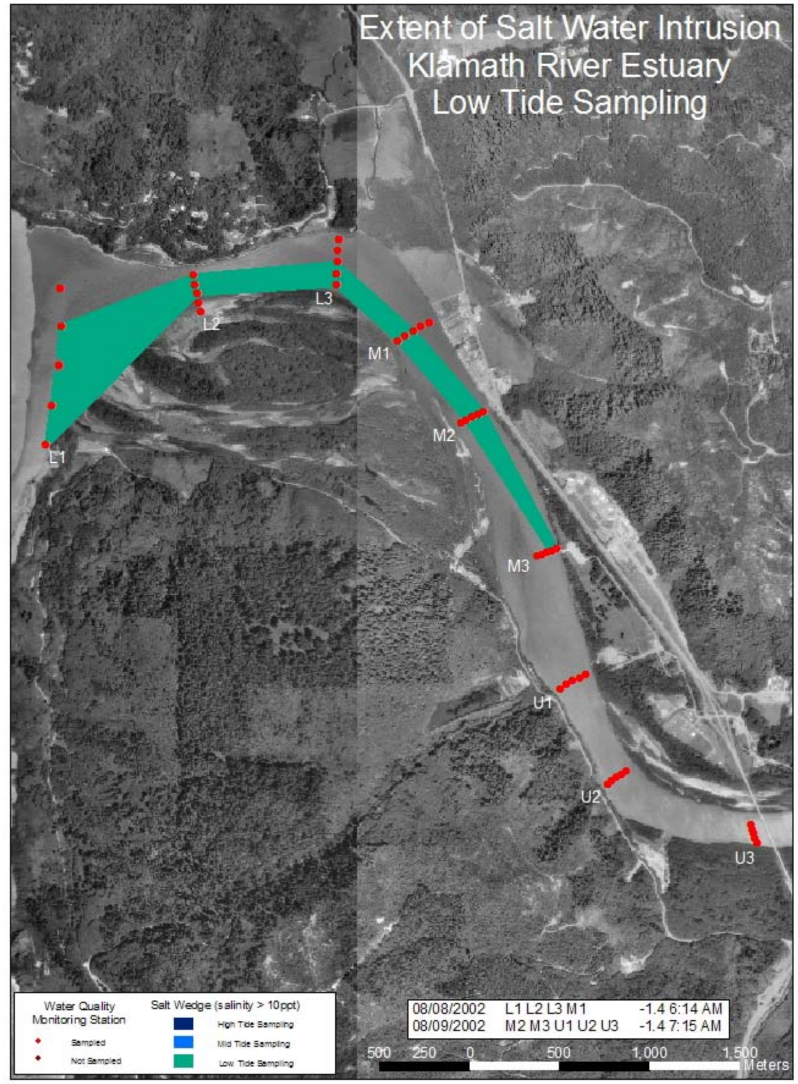

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/03/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+1.9 12:49 PM +6.3 7:43 PM
500 250 0 500 1,000 1,500
Meters

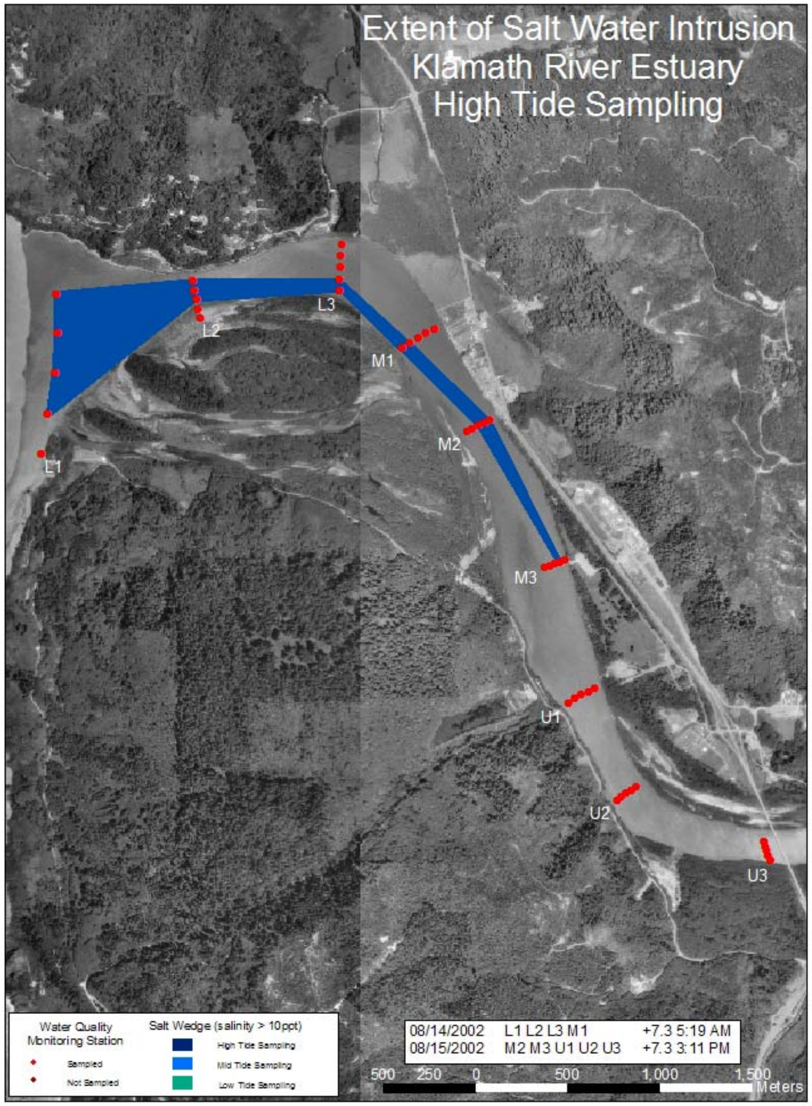

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/11/2002 L1 L2 L3 M1 -1.5 7:38 AM
07/12/2002 M2 M3 U1 U2 U3 -1.5 8:20 AM
500 250 0 500 1,000 1,500
Meters

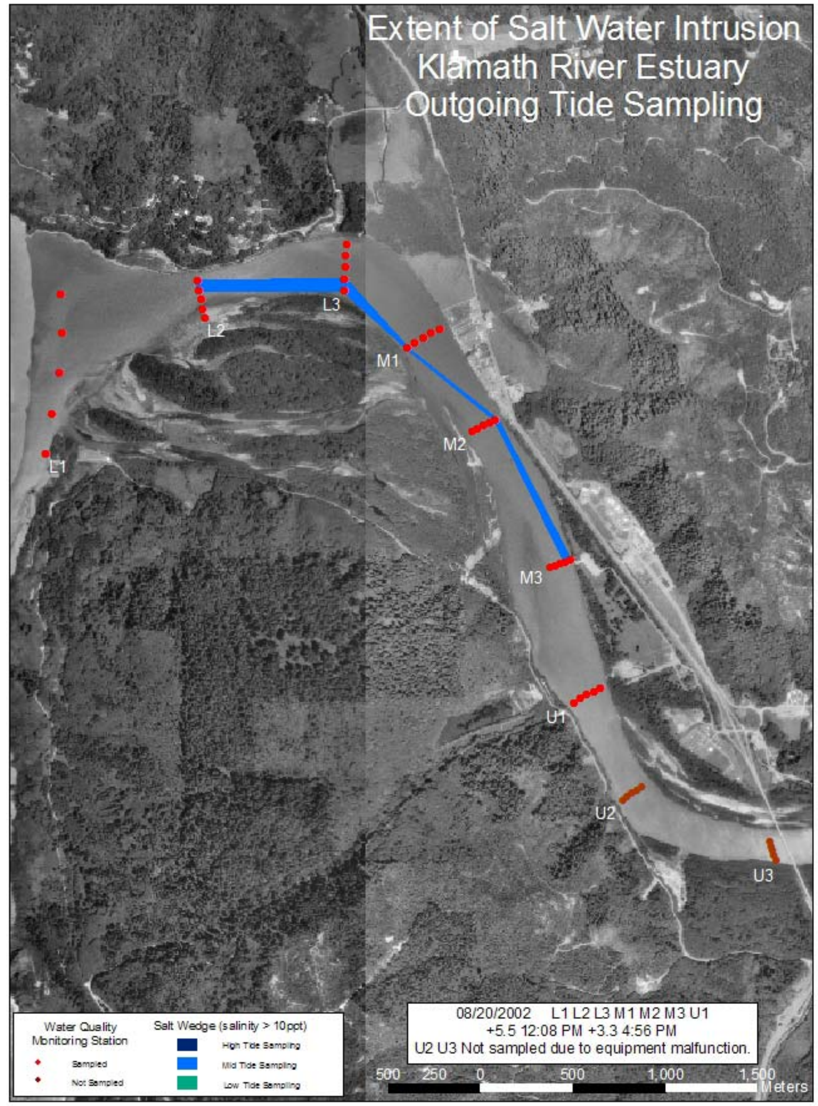

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/17/2002 L1 L2 L3 M1 +7.3 6:54 PM
07/18/2002 M2 M3 +7.5 6:54 AM
U1 U2 U3 Not sampled due to equipment malfunction.
500 250 0 500 1,000 1,500
Meters

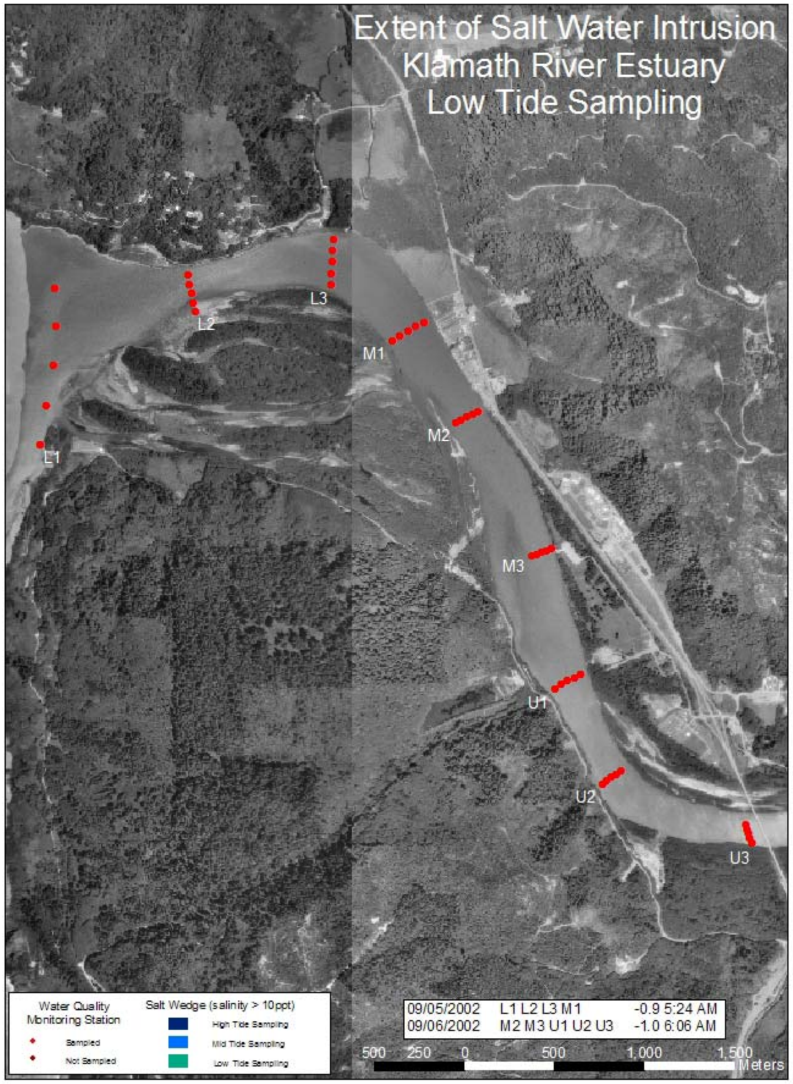

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
07/23/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
-1.2 6:19 AM +5.6 4:12 PM
500 250 0 500 1,000 1,500
Meters

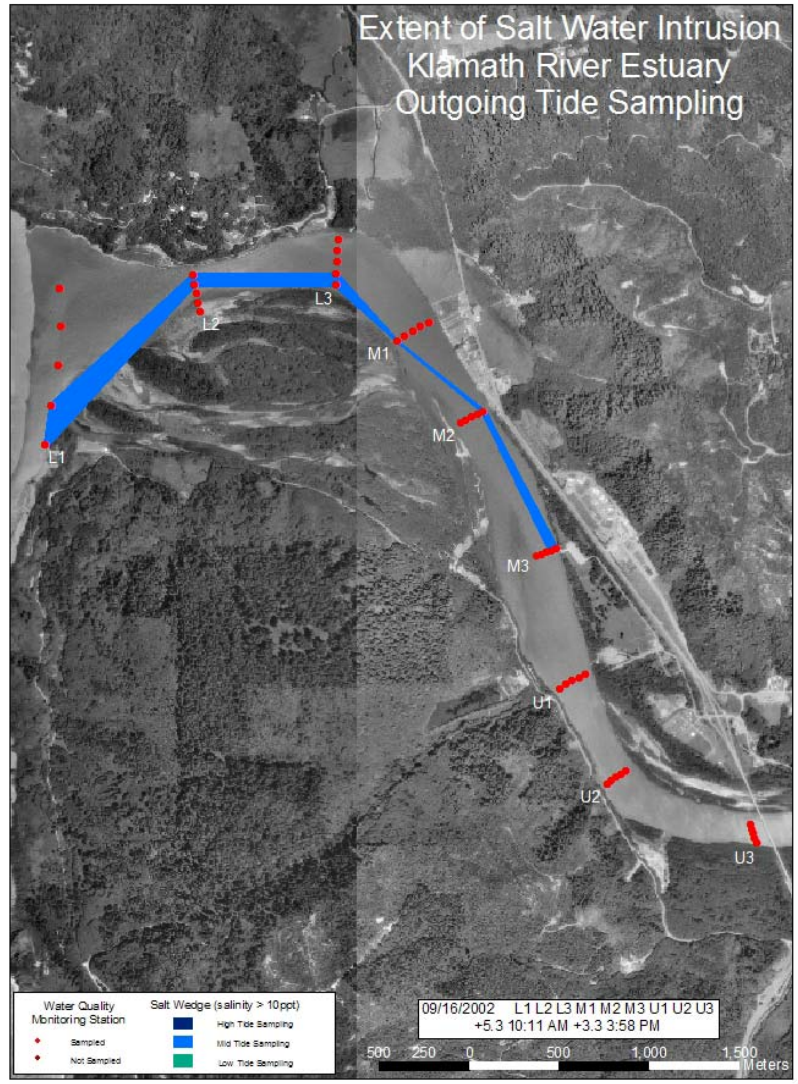

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/2/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+4.2 7:52 AM +2.8 12:40 PM
500 250 0 500 1,000 1,500
Meters

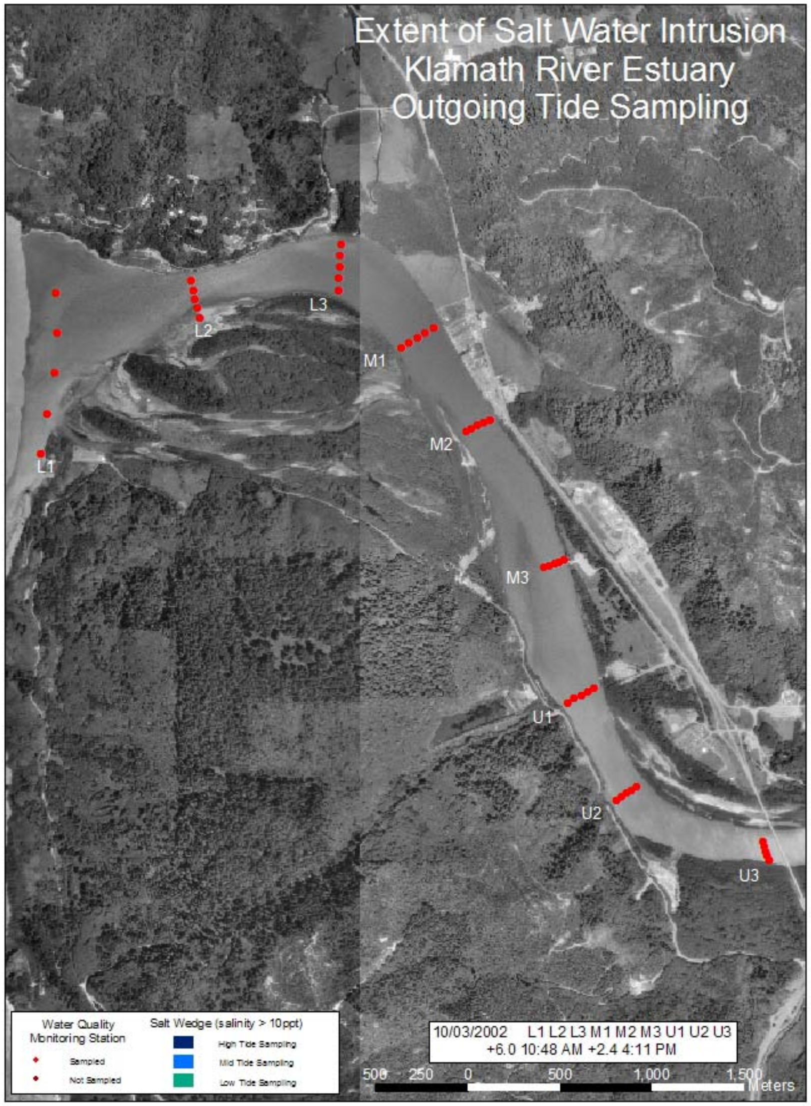

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/08/2002 L1 L2 L3 M1 -1.4 6:14 AM
08/09/2002 M2 M3 U1 U2 U3 -1.4 7:15 AM
500 250 0 500 1,000 1,500
Meters

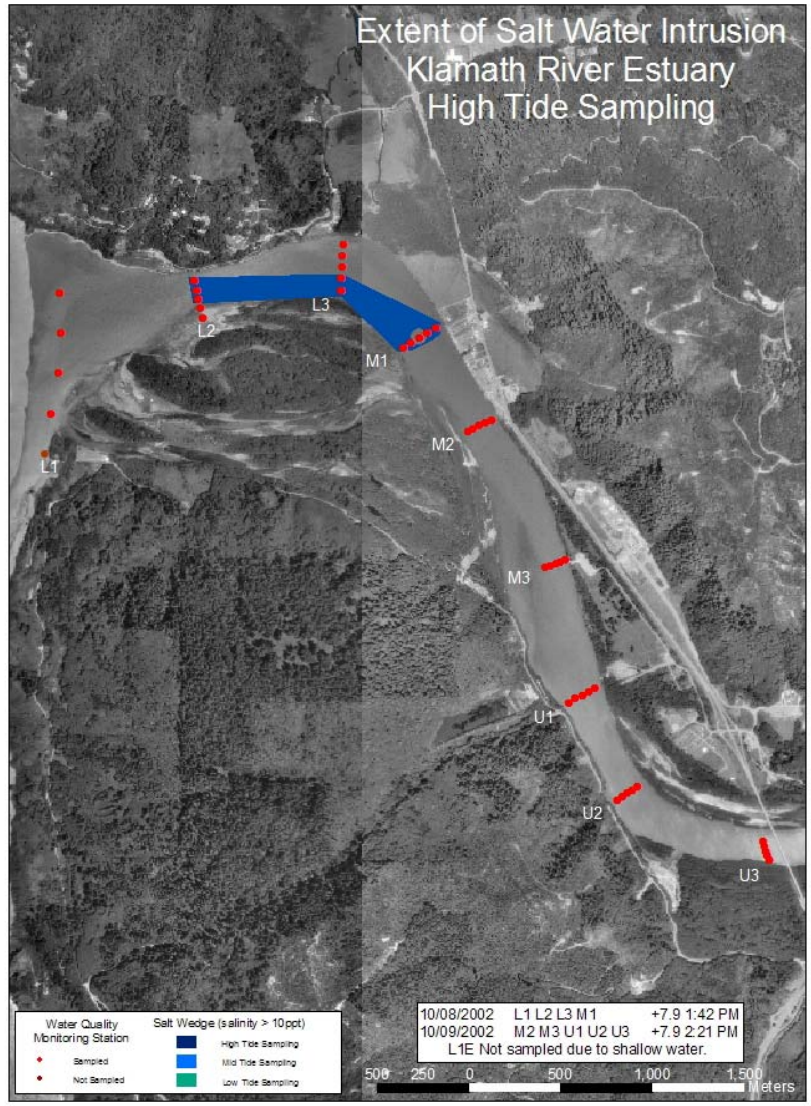

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/14/2002 L1 L2 L3 M1 +7.3 5:19 AM
08/15/2002 M2 M3 U1 U2 U3 +7.3 3:11 PM
500 250 0 500 1,000 1,500
Meters

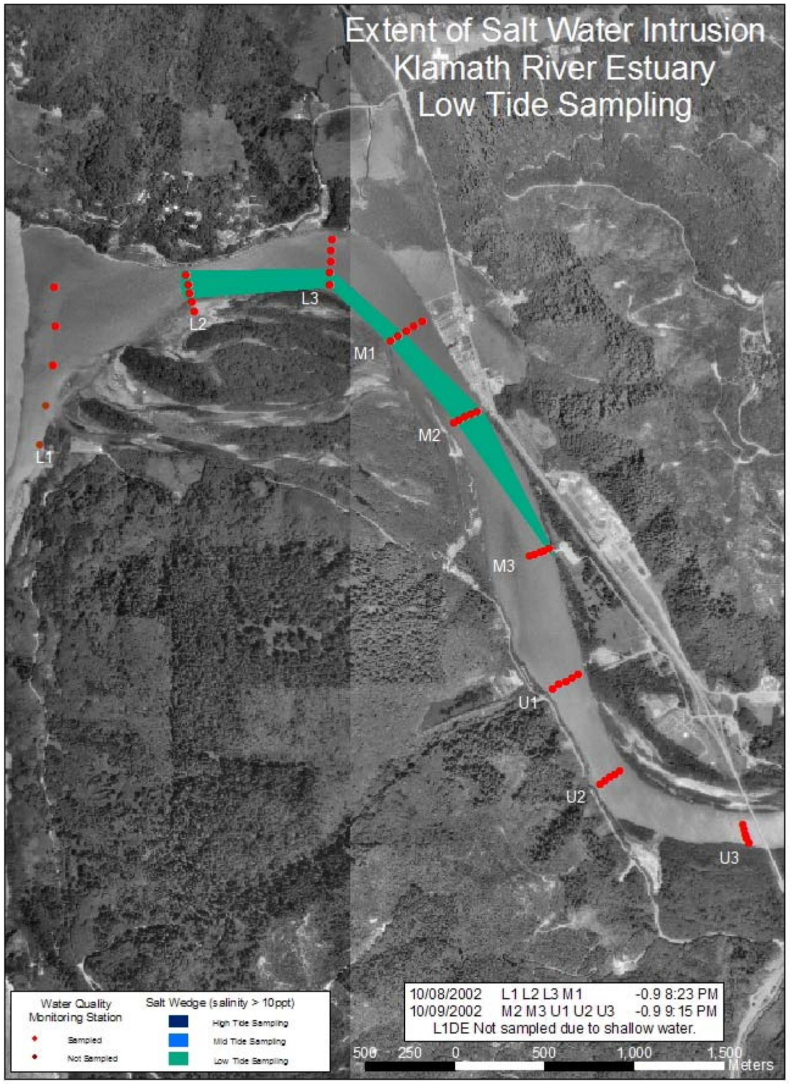

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/20/2002 L1 L2 L3 M1 M2 M3 U1
+5.5 12:08 PM +3.3 4:56 PM
U2 U3 Not sampled due to equipment malfunction.
500 250 0 500 1,000 1,500
Meters

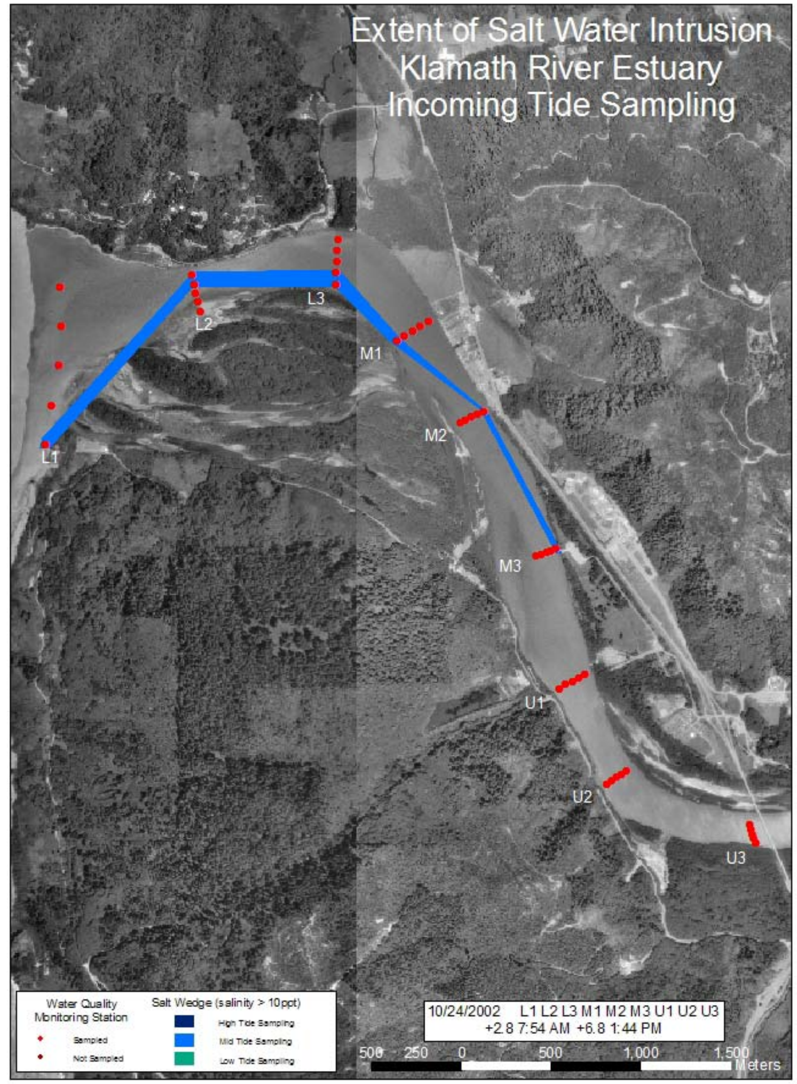

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
09/05/2002 L1 L2 L3 M1 -0.9 5:24 AM
09/06/2002 M2 M3 U1 U2 U3 -1.0 6:06 AM
500 250 0 500 1,000 1,500
Meters

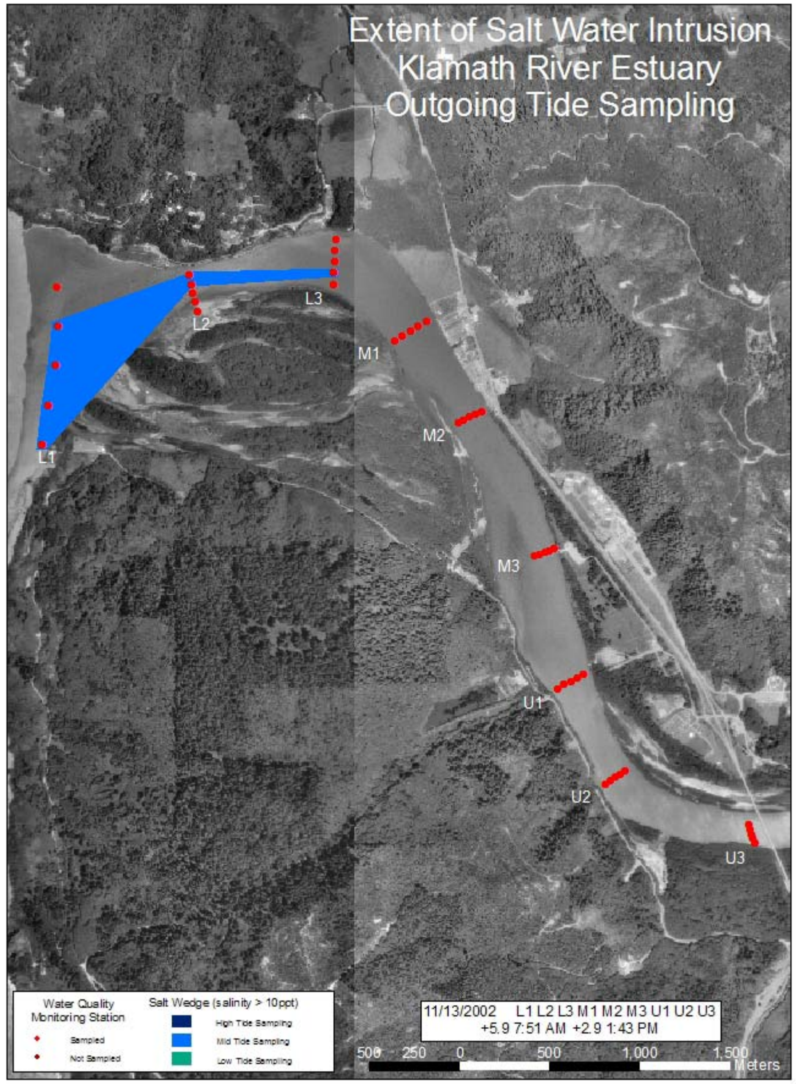

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
09/16/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.3 10:11 AM +3.3 3:58 PM
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/03/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+6.0 10:48 AM +2.4 4:11 PM
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/08/2002 L1 L2 L3 M1 +7.9 1:42 PM
10/09/2002 M2 M3 U1 U2 U3 +7.9 2:21 PM
L1E Not sampled due to shallow water.
500 250 0 500 1,000 1,500
Meters

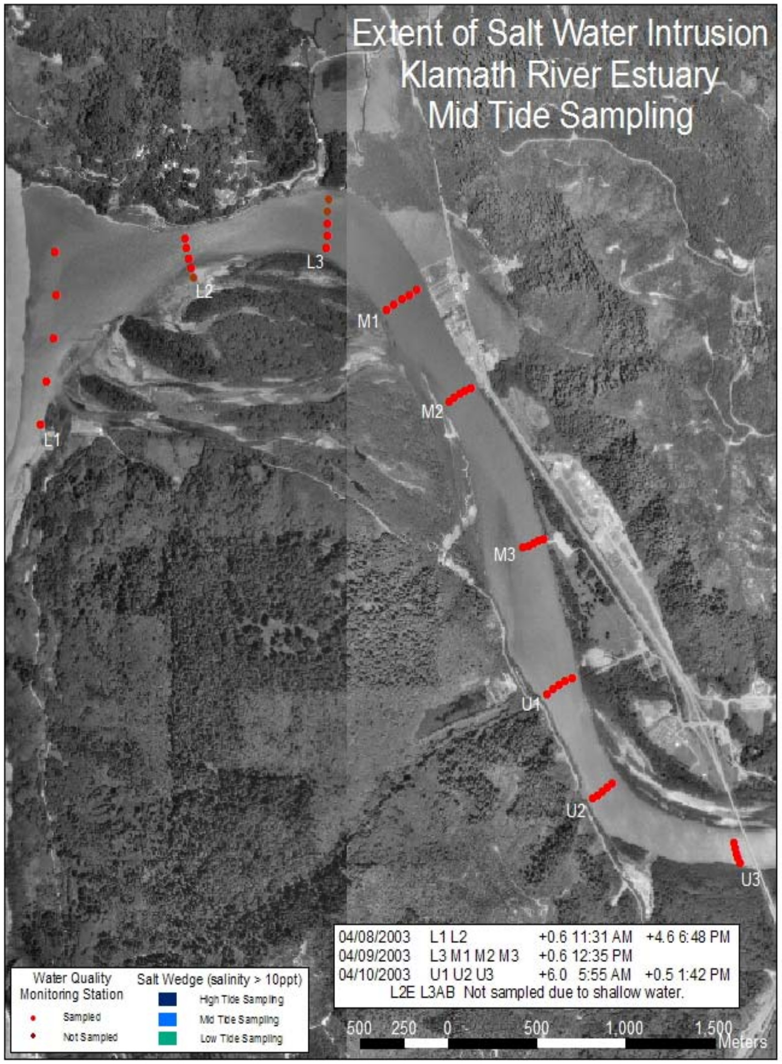

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/08/2002 L1 L2 L3 M1 -0.9 8:23 PM
10/09/2002 M2 M3 U1 U2 U3 -0.9 9:15 PM
L1DE Not sampled due to shallow water.
500 250 0 500 1,000 1,500
Meters

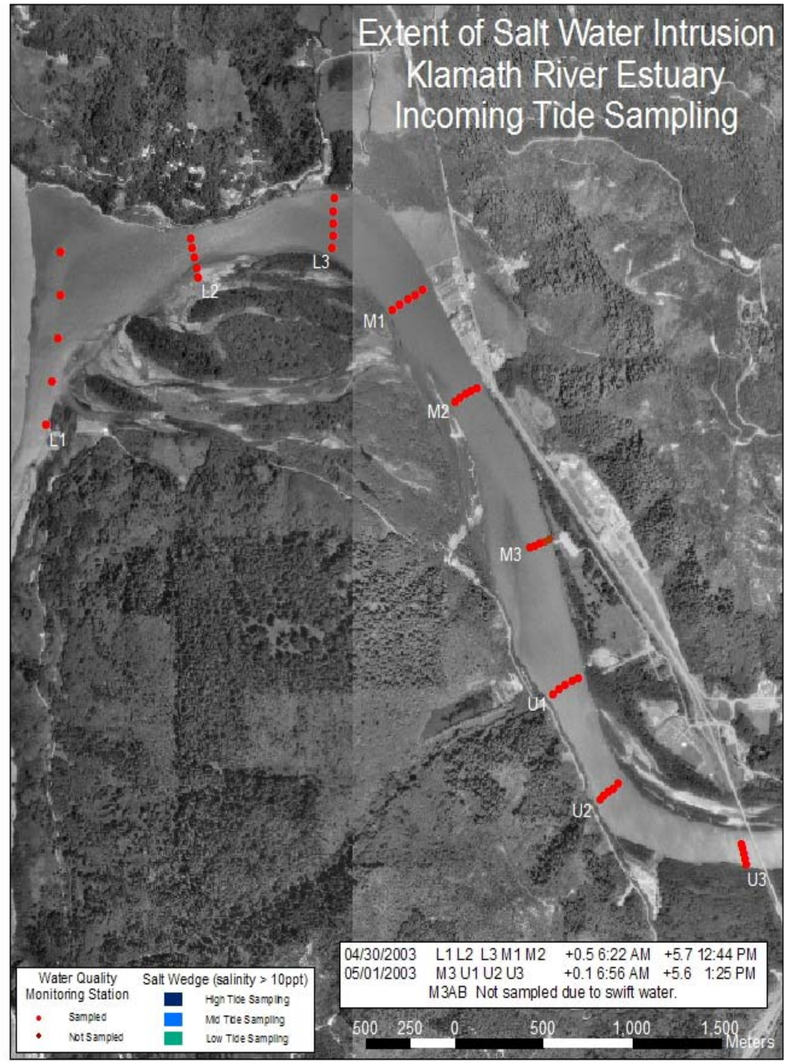

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
10/24/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+2.8 7:54 AM +6.8 1:44 PM
500 250 0 500 1,000 1,500
Meters

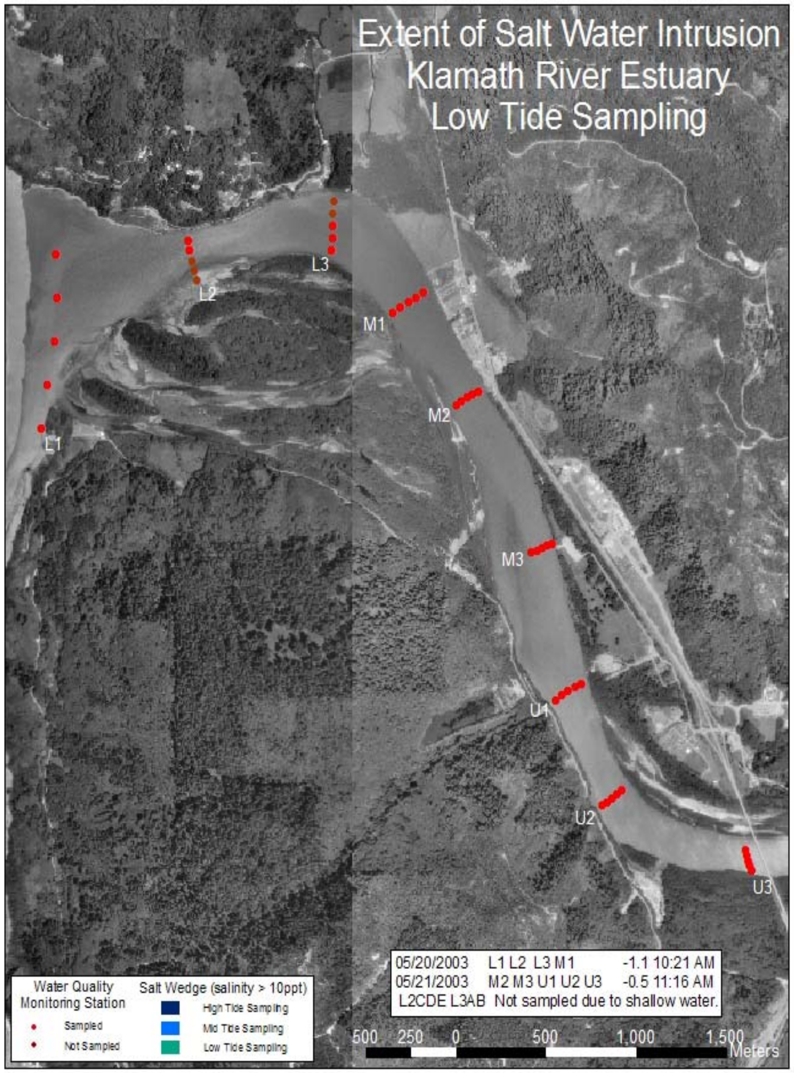

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
11/13/2002 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.9 7:51 AM +2.9 1:43 PM
500 250 0 500 1,000 1,500
Meters

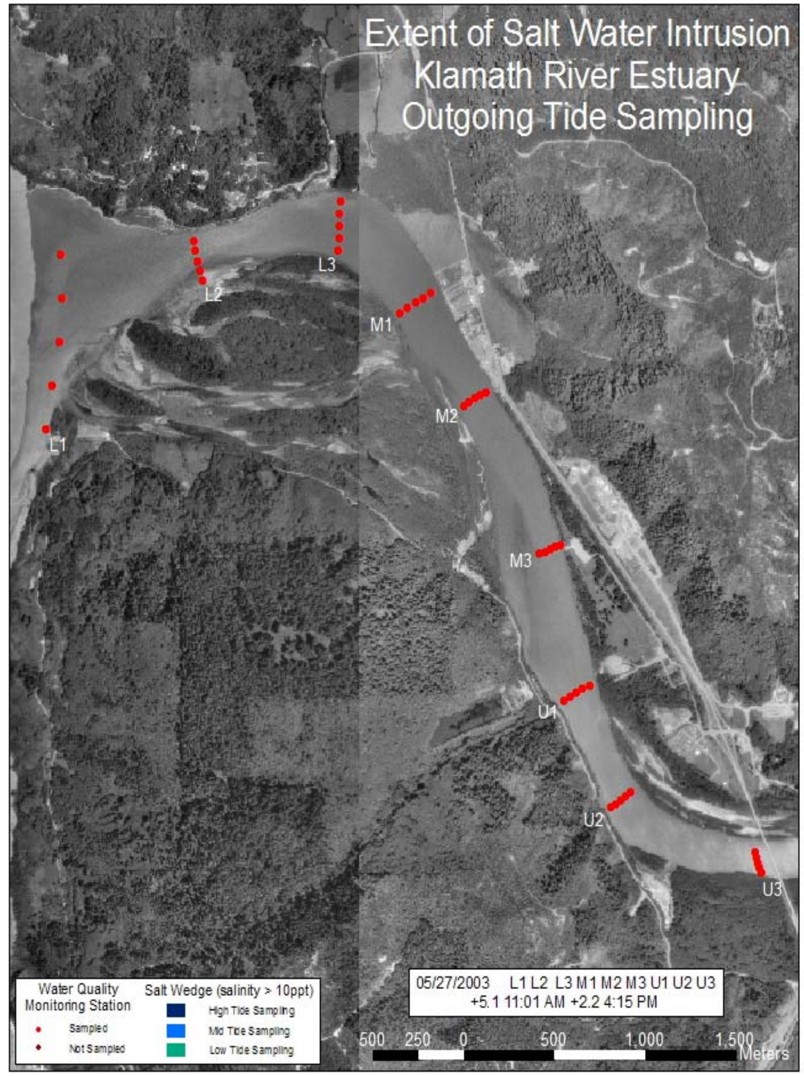
Appendix C

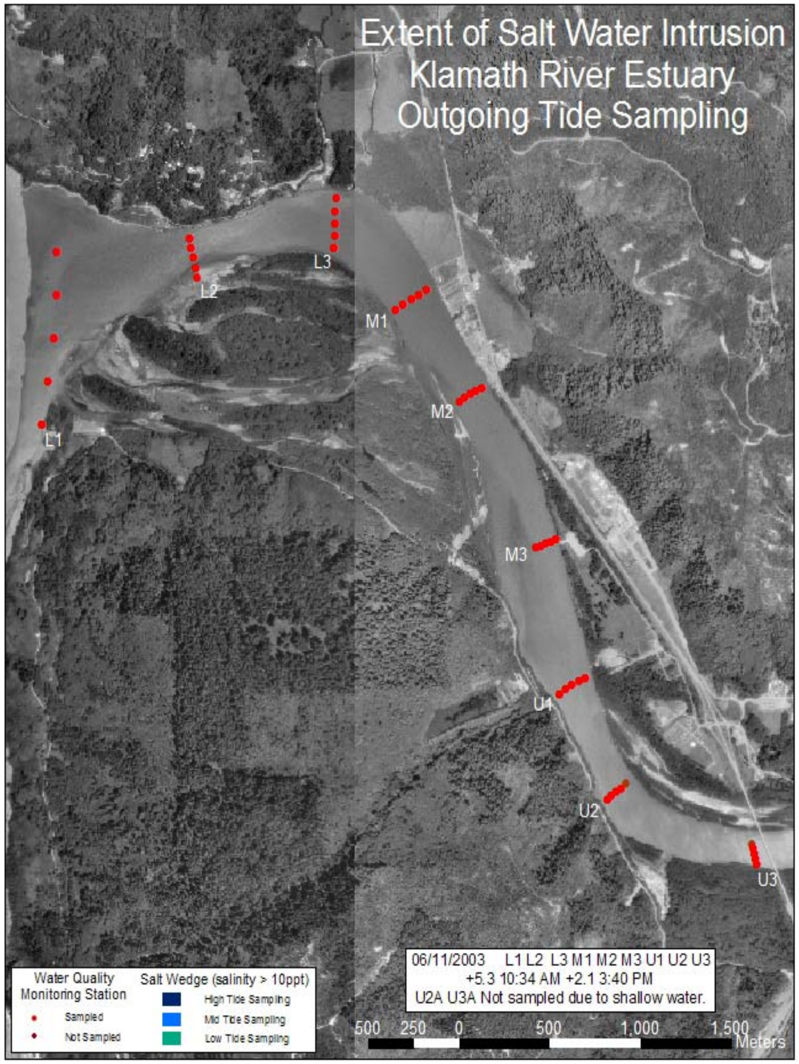
Extent of Saltwater Intrusion Klamath River Estuary, 2003

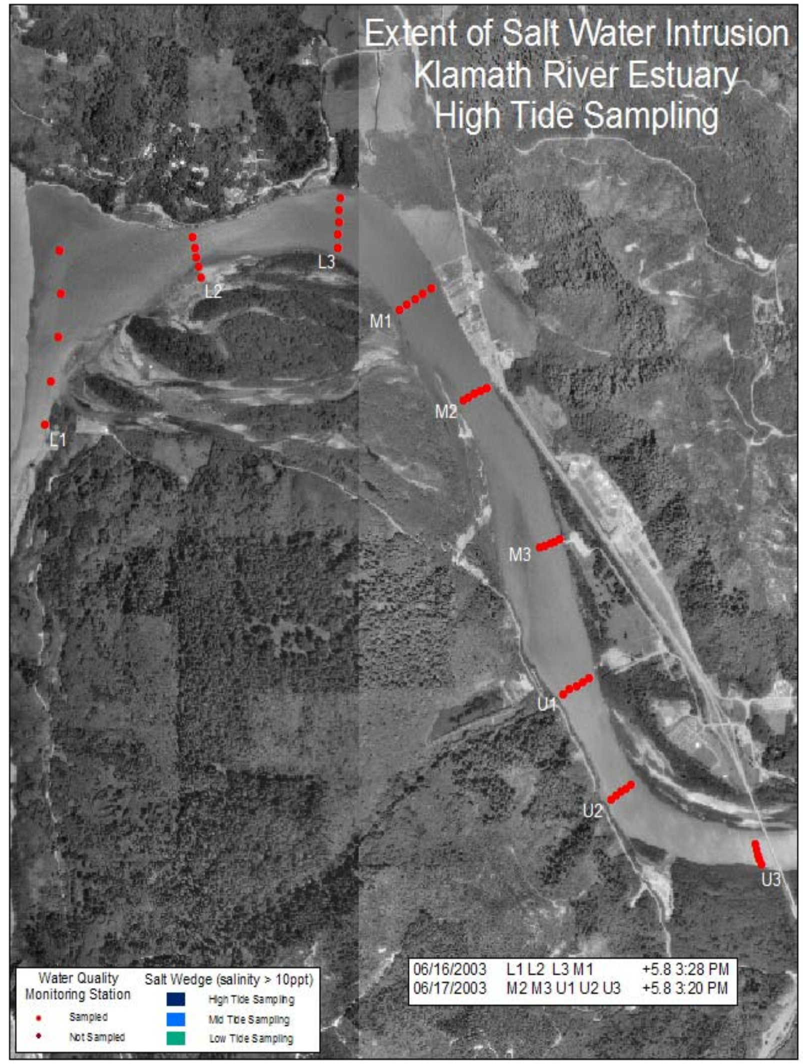

Extent of Salt Water Intrusion
Klamath River Estuary
Mid Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
04/08/2003 L1 L2 +0.6 11:31 AM +4.6 6:48 PM
04/09/2003 L3 M1 M2 M3 +0.6 12:35 PM
04/10/2003 U1 U2 U3 +6.0 5:55 AM +0.5 1:42 PM
L2E L3AB Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

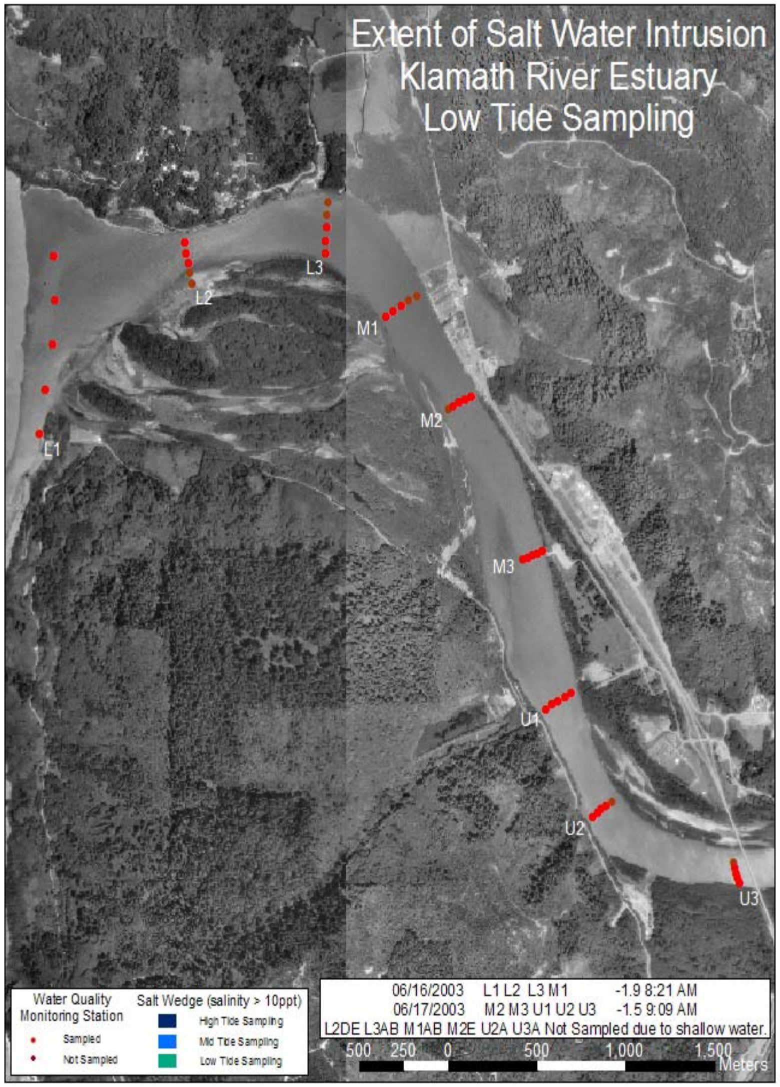

Extent of Salt Water Intrusion
Klamath River Estuary
Incoming Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
04/30/2003 L1 L2 L3 M1 M2 +0.5 6:22 AM +5.7 12:44 PM
05/01/2003 M3 U1 U2 U3 +0.1 6:56 AM +5.6 1:25 PM
M3AB Not sampled due to swift water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

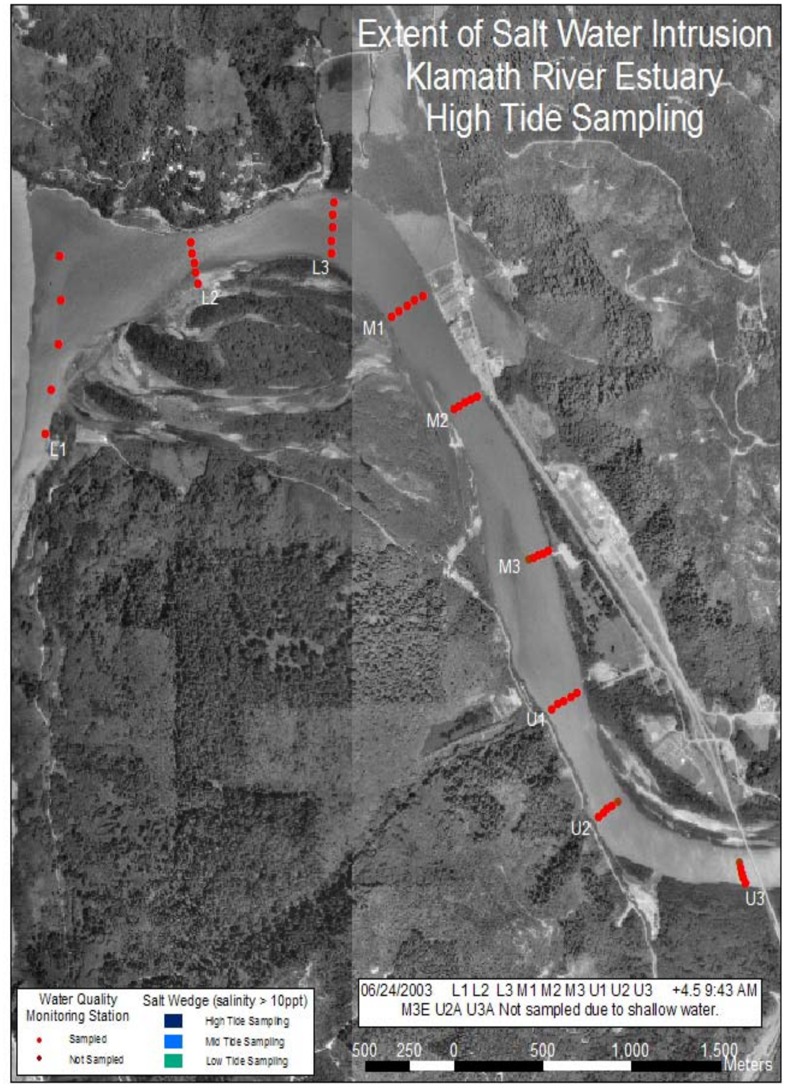

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
05/20/2003 L1 L2 L3 M1 -1.1 10:21 AM
05/21/2003 M2 M3 U1 U2 U3 -0.5 11:16 AM
L2CDE L3AB Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

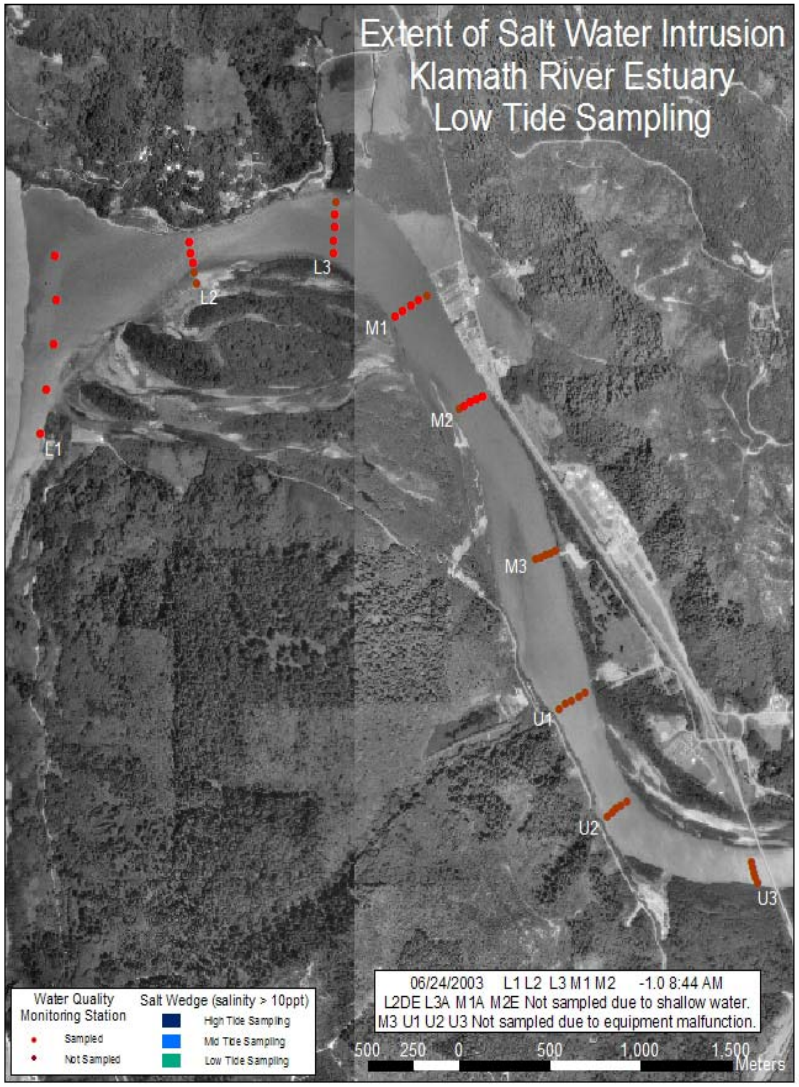

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
05/27/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.1 11:01 AM +2.2 4:15 PM
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

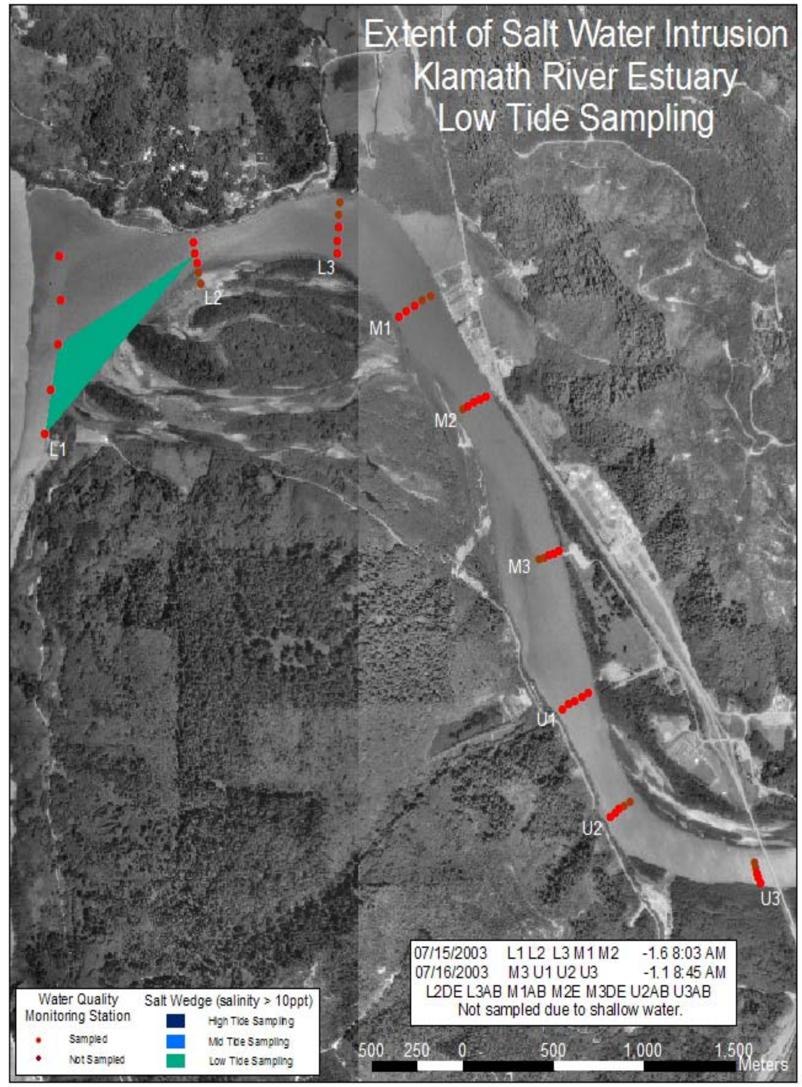

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
06/11/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.3 10:34 AM +2.1 3:40 PM
U2A U3A Not sampled due to shallow water.
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

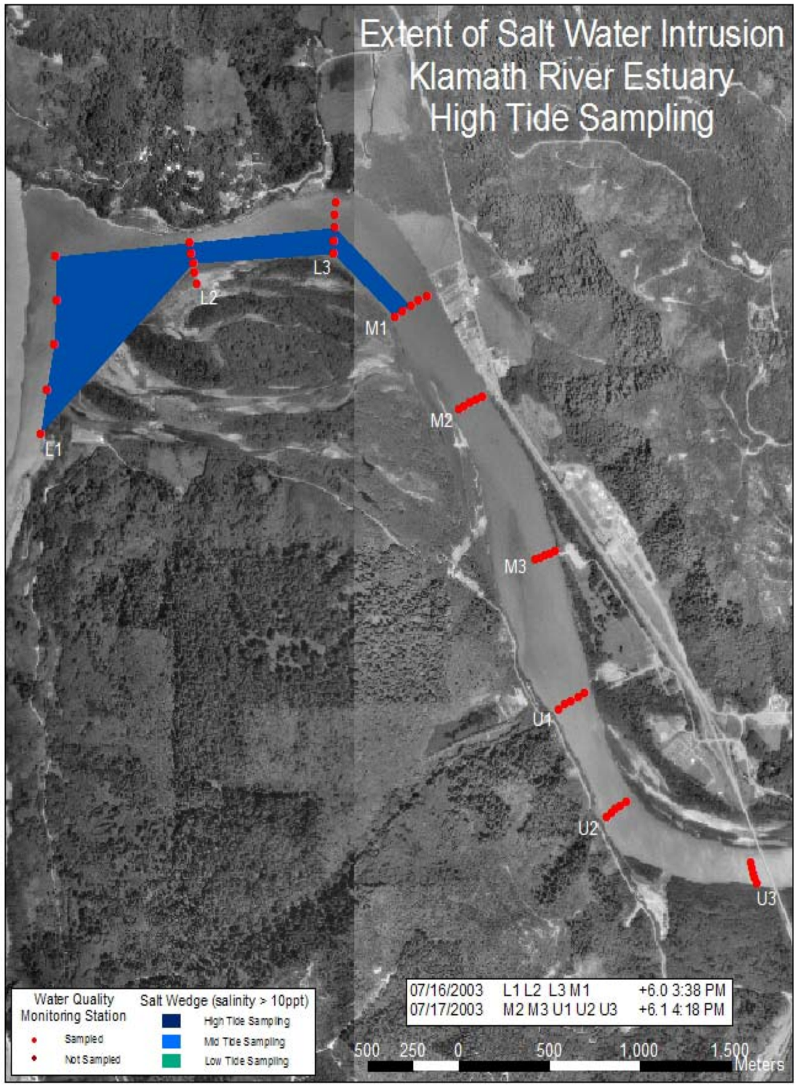

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
06/16/2003 L1 L2 L3 M1 +5.8 3:28 PM
06/17/2003 M2 M3 U1 U2 U3 +5.8 3:20 PM
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling

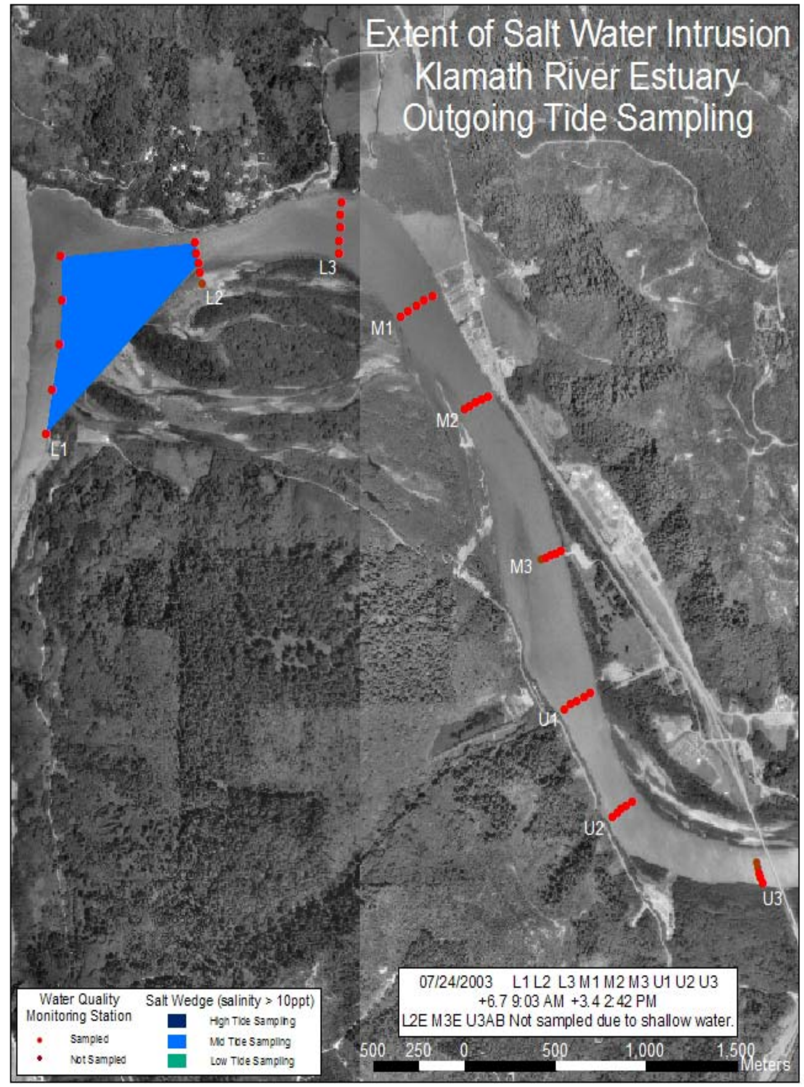

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
06/16/2003 L1 L2 L3 M1 -1.9 8:21 AM
06/17/2003 M2 M3 U1 U2 U3 -1.5 9:09 AM
L2DE L3AB M1AB M2E U2A U3A Not Sampled due to shallow water.
500 250 0 500 1,000 1,500
Meters

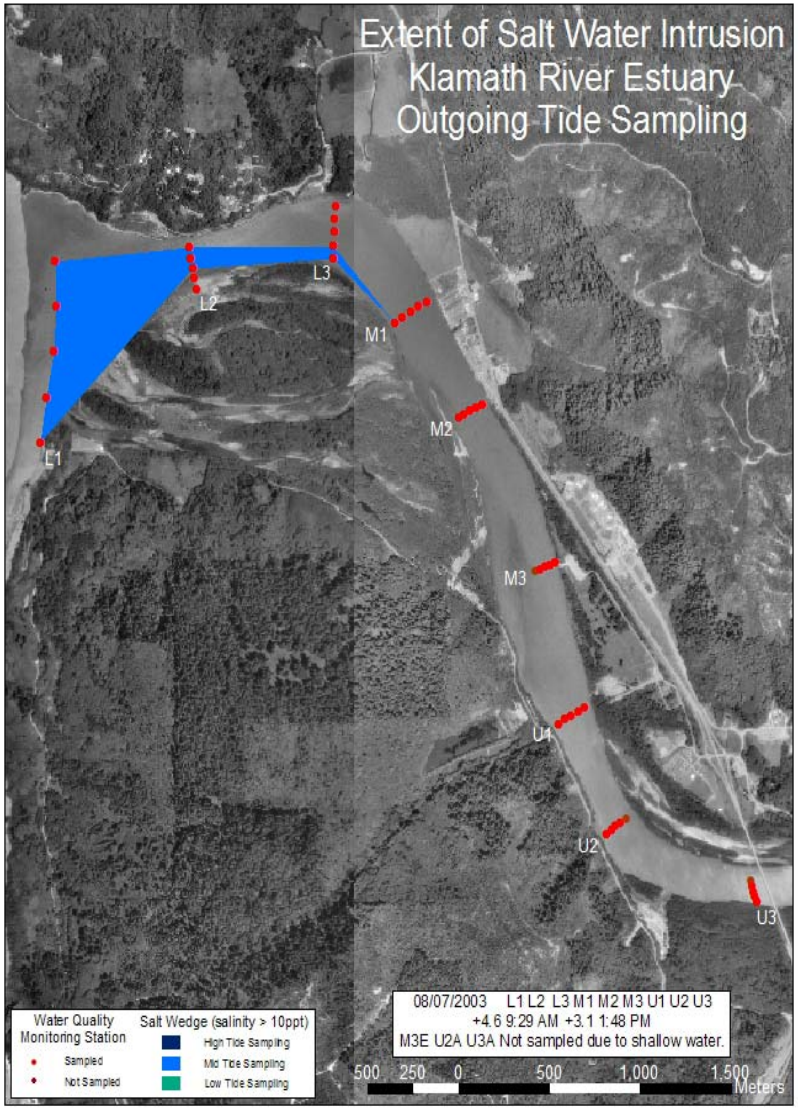

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality
Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
06/24/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3 +4.5 9:43 AM
M3E U2A U3A Not sampled due to shallow water.
500 250 0 500 1,000 1,500
Meters

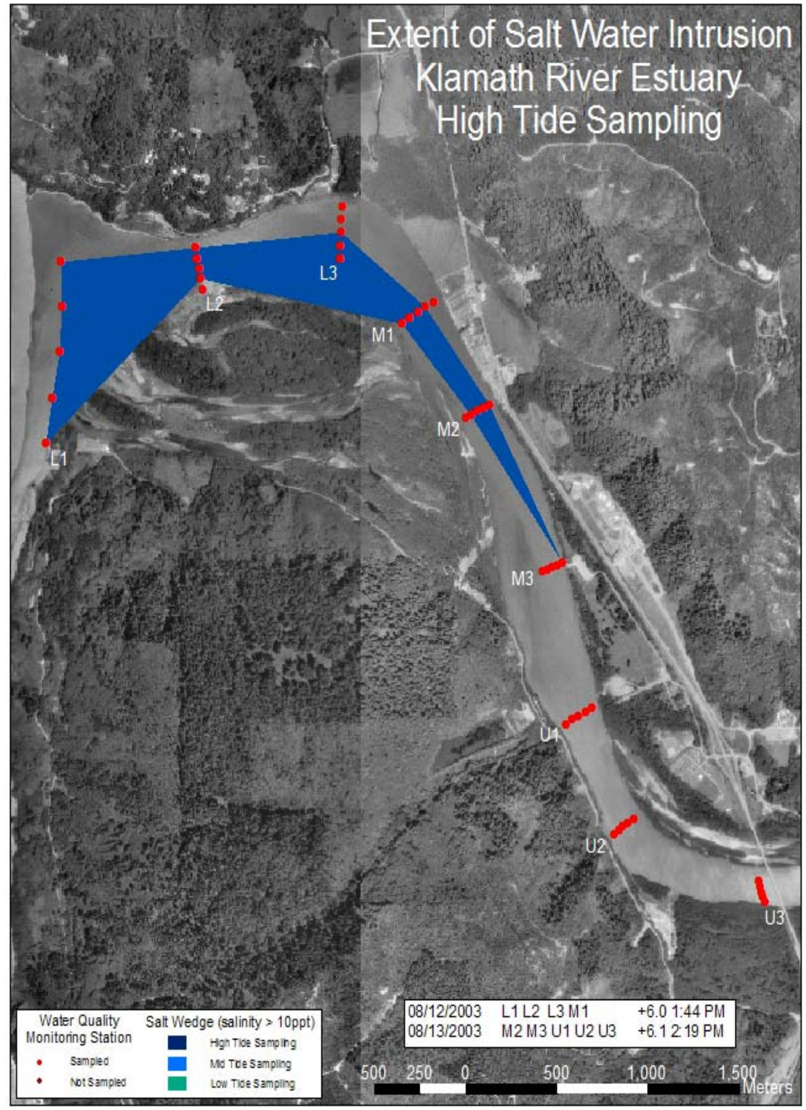

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
06/24/2003 L1 L2 L3 M1 M2 -1.0 8:44 AM
L2DE L3A M1A M2E Not sampled due to shallow water.
M3 U1 U2 U3 Not sampled due to equipment malfunction.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500 Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
07/15/2003 L1 L2 L3 M1 M2 -1.6 8:03 AM
07/16/2003 M3 U1 U2 U3 -1.1 8:45 AM
L2DE L3AB M1AB M2E M3DE U2AB U3AB
Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500 Meters


Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
07/16/2003 L1 L2 L3 M1 +6.0 3:38 PM
07/17/2003 M2 M3 U1 U2 U3 +6.1 4:18 PM
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

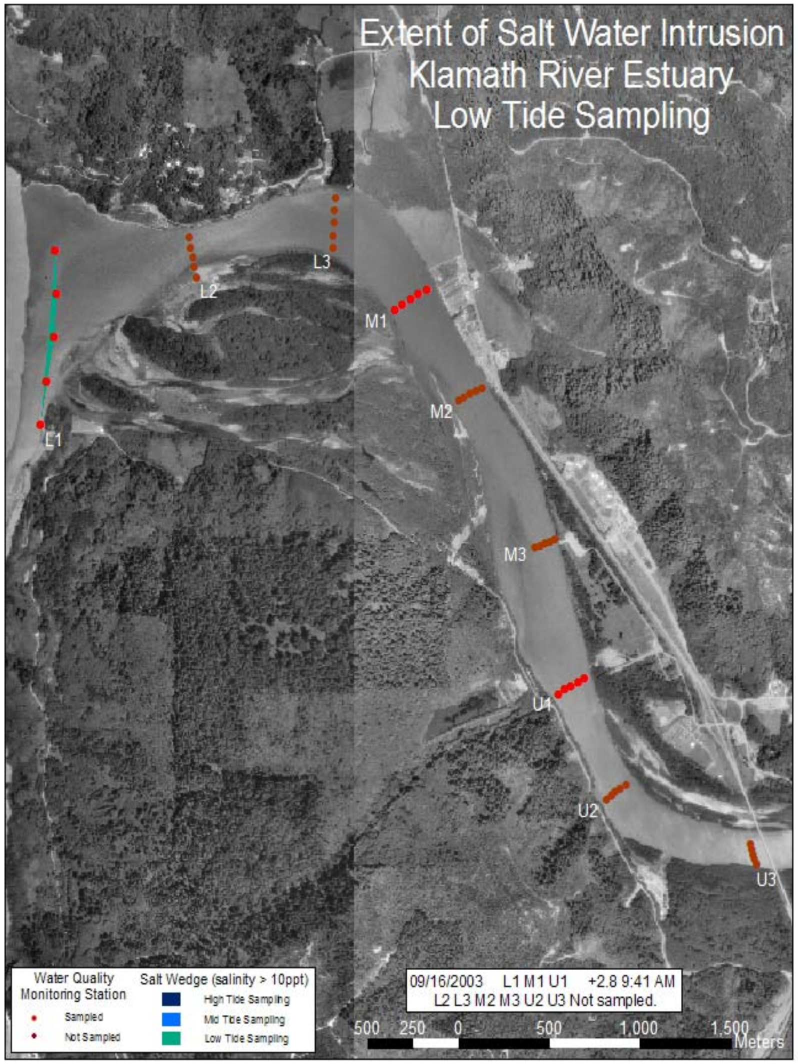

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
07/24/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3
+6.7 9:03 AM +3.4 2:42 PM
L2E M3E U3AB Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

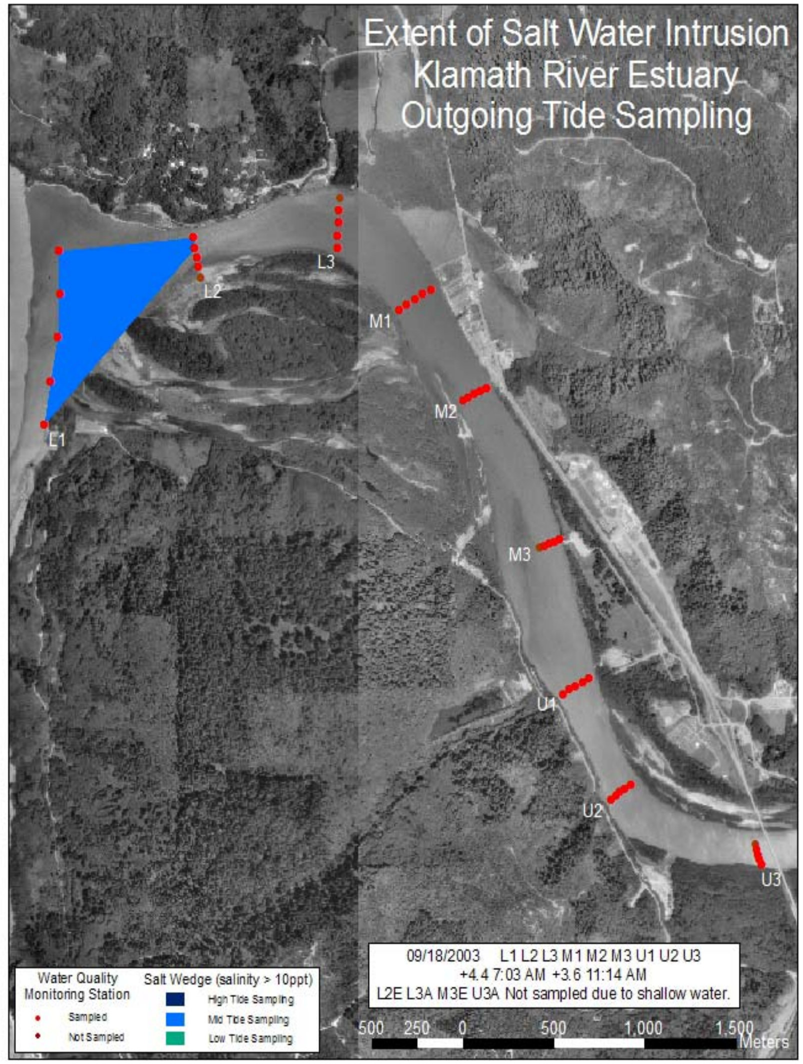

Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/07/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3
+4.6 9:29 AM +3.1 1:48 PM
M3E U2A U3A Not sampled due to shallow water.
500 250 0 500 1,000 1,500
Meters

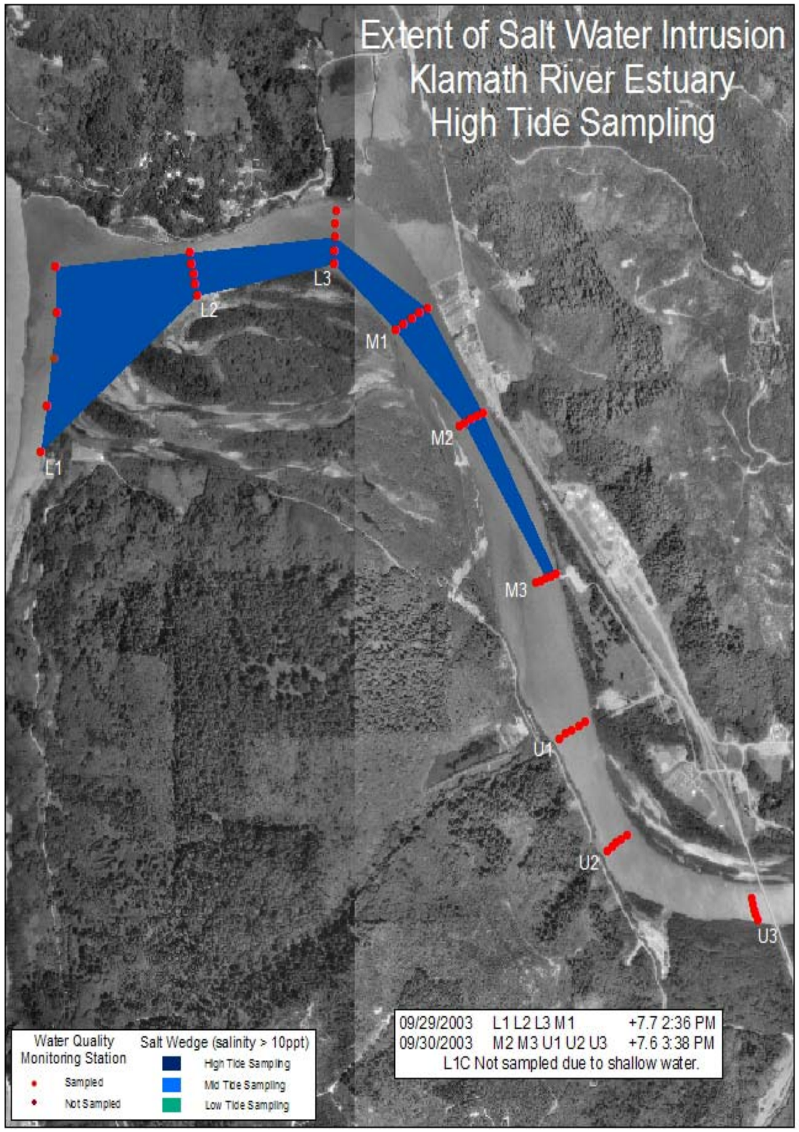

Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
08/12/2003 L1 L2 L3 M1 +6.0 1:44 PM
08/13/2003 M2 M3 U1 U2 U3 +6.1 2:19 PM
500 250 0 500 1,000 1,500
Meters

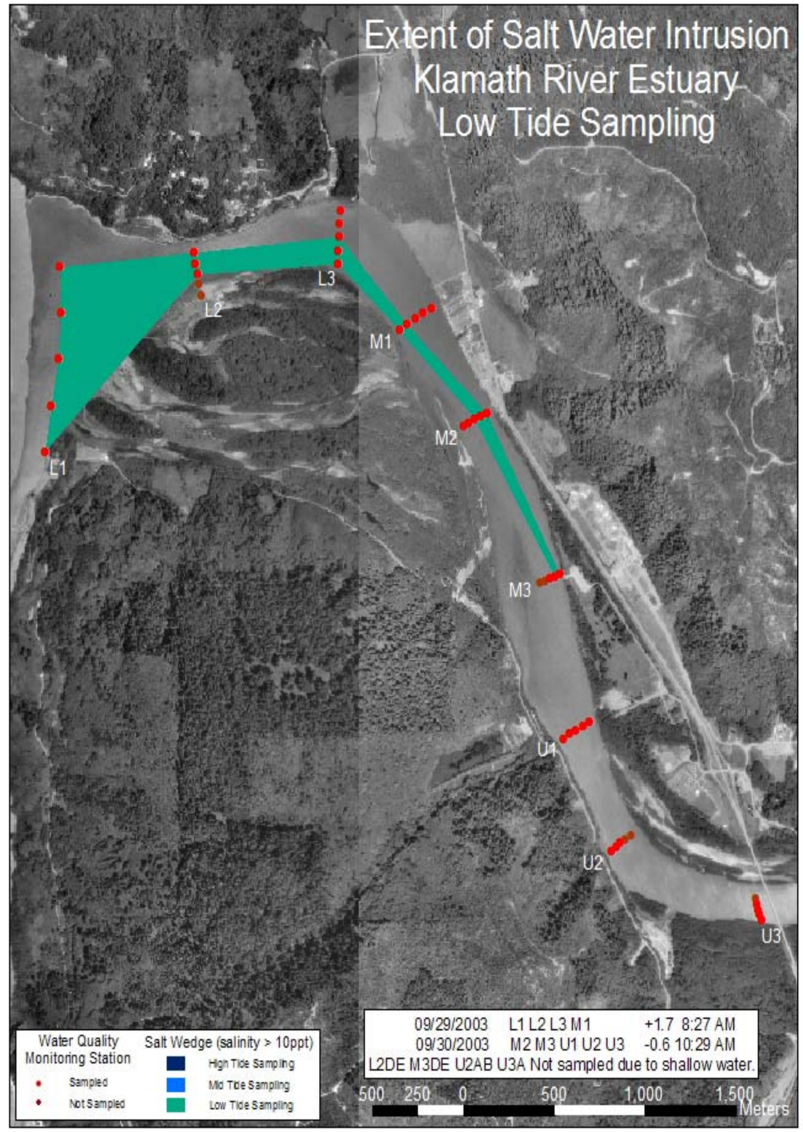

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
08/13/2003 L1 L2 L3 M1 -0.9 7:38 AM
08/14/2003 M2 M3 U1 U2 U3 -0.5 8:14 AM
L3AB L2DE M1A M3DE U2AB U3AB
Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
08/13/2003 L1 L2 L3 M1 -0.9 7:38 AM
08/14/2003 M2 M3 U1 U2 U3 -0.5 8:14 AM
L3AB L2DE M1A M3DE U2AB U3AB
Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

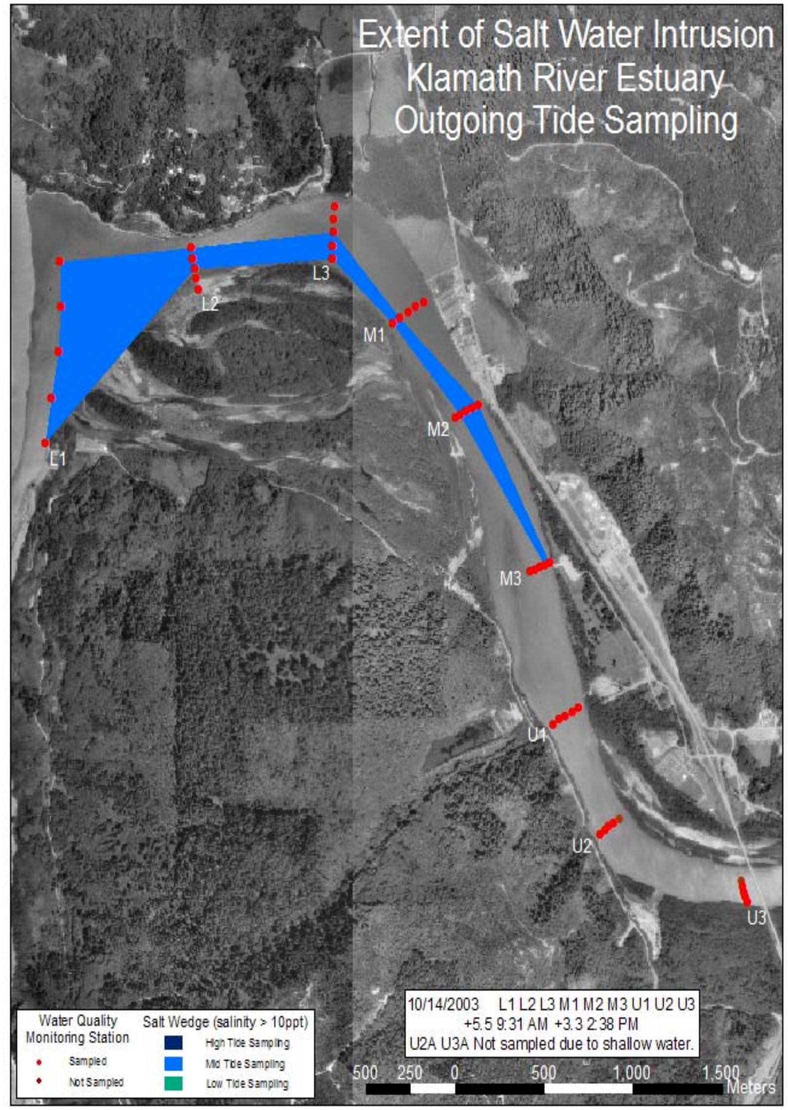

Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
09/16/2003 L1 M1 U1 +2.8 9:41 AM
L2 L3 M2 M3 U2 U3 Not sampled.
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
09/18/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3
+4.4 7:03 AM +3.6 11:14 AM
L2E L3A M3E U3A Not sampled due to shallow water.
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
High Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
09/29/2003 L1 L2 L3 M1 +7.7 2:36 PM
09/30/2003 M2 M3 U1 U2 U3 +7.6 3:38 PM
L1C Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling


Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
09/29/2003 L1 L2 L3 M1 +1.7 8:27 AM
09/30/2003 M2 M3 U1 U2 U3 -0.6 10:29 AM
L2DE M3DE U2AB U3A Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Low Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
10/14/2003 L1 L2 L3 M1 +3.0 8:28 AM
10/15/2003 M2 M3 U1 U2 U3 +3.4 9:03 AM
L2E M3E U2A U3A Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters


Extent of Salt Water Intrusion
Klamath River Estuary
Outgoing Tide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
10/14/2003 L1 L2 L3 M1 M2 M3 U1 U2 U3
+5.5 9:31 AM +3.3 2:38 PM
U2A U3A Not sampled due to shallow water.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters

Extent of Salt Water Intrusion
Klamath River Estuary
HighTide Sampling
L1
L2
L3
M1
M2
M3
U1
U2
U3
10/29/2003 L1 L2 L3 M1 +7.8 1:49 PM
10/30/2003 M2 M3 +7.3 2:44 PM
L2E Not sampled due to shallow water.
M2E M3 U1 U2 U3 Not sampled due to equipment malfunction.
Water Quality Monitoring Station
Sampled
Not Sampled
Salt Wedge (salinity > 10ppt)
High Tide Sampling
Mid Tide Sampling
Low Tide Sampling
500 250 0 500 1,000 1,500
Meters