Ricks 1983

# REDWOOD CREEK ESTUARY
# FLOOD HISTORY, SEDIMENTATION AND IMPLICATIONS FOR AQUATIC HABITAT

C.L. Ricks

## ABSTRACT

The mouth of Redwood Creek has suffered a drastic reduction in quantity and quality of aquatic habitat due to the accumulation of sediment since the early 1950s. Sedimentation at the mouth results primarily from flood control levees constructed along the lowermost reach of Redwood Creek in 1968. Floods in 1953, 1955, and 1964 deposited sediment adjacent to the tidally influenced embayment but the volume of the embayment was maintained by scour during high discharge. The lower reach of Redwood Creek is presently confined by levees which extend beyond the downstream meander, creating a south slough with little circulation. The sources, rates, and types of events responsible for sediment transport have been examined using surveyed profiles, field observations of sedimentary structures and morphology, wave power, discharge and tide height data, and texture and mineralogy of sediments. In addition to filling areas which were formerly productive fish-rearing habitat, excess sediment has reduced the potential for development of estuarine conditions.

## INTRODUCTION

Increasing concern about the productivity of the estuarine habitat at the mouth of Redwood Creek led to the initiation of interdisciplinary studies by Redwood National Park. The objective of this phase of the estuary project has been to identify the processes, sources, and rates of sediment accumulation in order to recommend restoration alternatives.

Coastal river mouths or estuaries are very dynamic features. Marine processes interact with highly variable fluvial sediment and water discharge. In northern California, climatic, tectonic, and lithologic characteristics result in suspended sediment yields among the highest in North America for basins of comparable size. Large volumes of sediment supplied to these river mouths are subject to extreme seasonal variations in runoff and wave energy.

The mouth of Redwood Creek is located 4.0 river km (2.5 mi) west of Orick, California (Fig. 1). Redwood Creek drains a long, narrow basin with an area of 720 km$^2$ (280 mi$^2$). It is one of several rivers oriented along north-northwest trending fault zones which have steep gradients due to rapid erosion in the region. The steep stream gradient limits the upstream extent of tidal influence, resulting in a rather small estuary. Accumulation of excess sediment at the mouth is accompanied by a reduction in quantity of the already limited estuarine habitat.

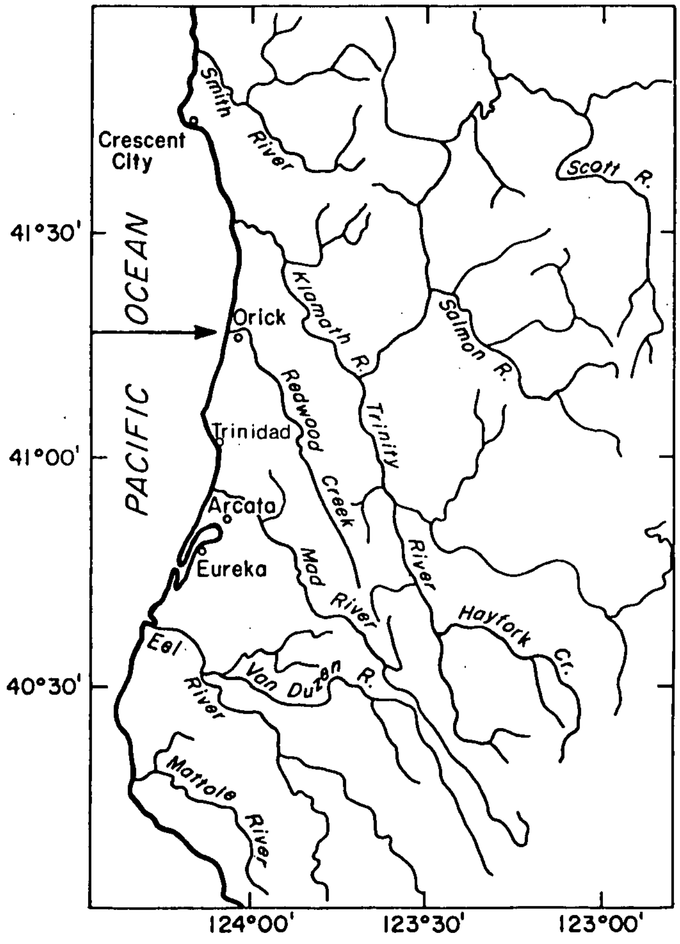
In recent years, the texture and quantity of sediment delivered to the estuary has been altered by land use practices and flood damage in the basin (Best et al. 1983). Floods in 1953, 1955, and 1964 prompted channelization of Redwood Creek in the vicinity of Orick. The lowermost section of the levee extends beyond the downstream meander and diverts the flow directly to the ocean. Separating the long-term effects of increased sediment supply from the effects of channelization of the creek is crucial for management and restoration efforts. It is also important to consider the short-term or seasonal variability when assessing the magnitude of long-term sediment accumulation.

---

Redwood National Park, P.O. Box SS, Arcata, CA 95521, and Department of Geology, Oregon State University, Corvallis, OR 97331

Figure 1

Northern California Location Map



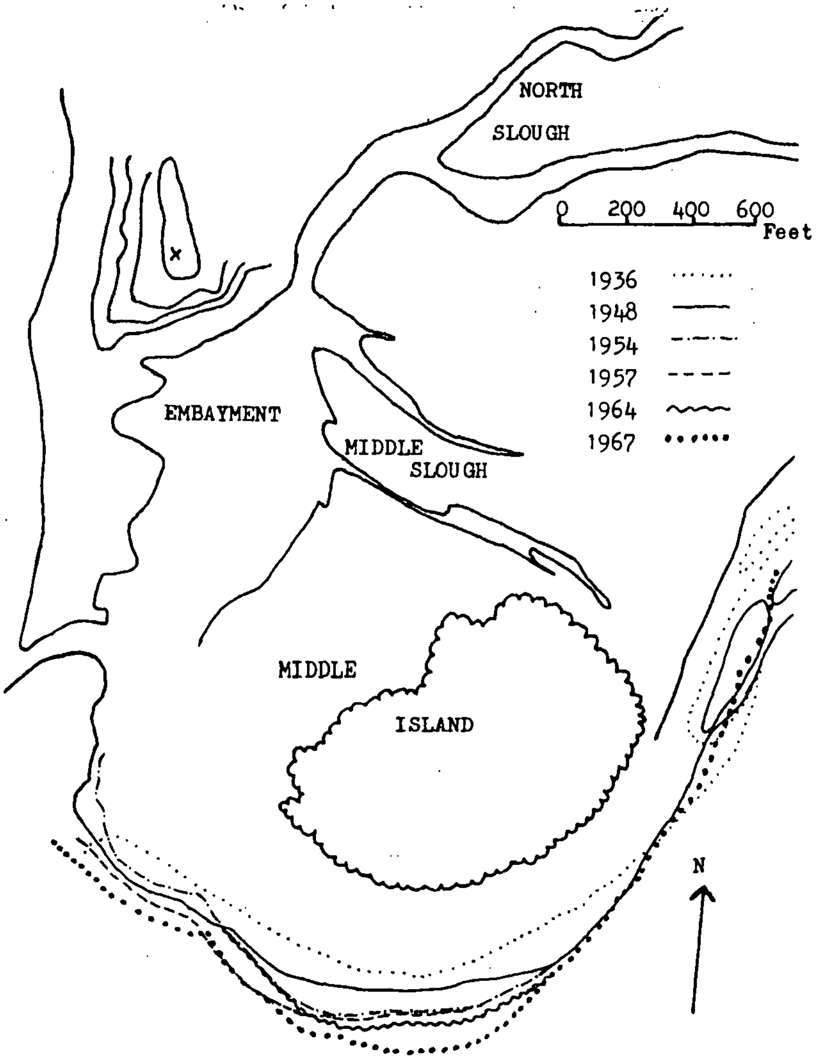
## METHODS

Various methods were employed to distinguish among changes in mouth configuration resulting from high-magnitude floods, levee construction, and seasonal processes. Long-term changes were documented by dendrochronological techniques, aerial photo interpretation, survey comparisons, and interviews with local residents. In order to evaluate the stability of the unchannelized configuration, the spruce-alder forest located on the middle island was mapped using aerial photos (see Fig. 2). Annual growth rings were visible on many stumps left after spruce was harvested in 1978. Standing alive spruce and selected alder were dated from increment cores taken at breast height.

Historical photos were obtained from a variety of sources. Photo interpretations were supplemented by interviews and streamflow gauging data when available. The dates and magnitudes of early floods on Redwood Creek have been inferred from regional precipitation and streamflow data (McGlashan and Briggs 1939, Paulson 1953, U.S. Army Corps of Engineers 1961—Table A-2, A-4; Harden et al. 1978). After 1949, peak flood stages were measured by the U.S. Army Corps of Engineers on a staff gauge at the Orick bridge, prior to establishment of the U.S. Geological Survey station in October, 1953. Precipitation gauges in the Redwood Creek basin have provided details of storm intensity, duration and distribution for floods since the early 1950s.

Figure 2

Streambank Positions Along the Downstream-Most Meander at the Mouth of Redwood Creek



Soil surveys following the December, 1964 flood included maps of the depth and texture of flood posits in Humboldt County (McLaughlin and Harradine 1965—Map Sheet 1). Mapped units and sample locations obtained from the original field overlays have been plotted on a Redwood Creek plain map (Fig. 3).

Aggradation following levee construction was documented by comparing profiles surveyed by the Army Corps of Engineers (1964 and 1966 surveys, Drawing No. 85-33-6, Sheets 8 and 16, San cisco District Corps of Engineers) with profiles reconstructed from detailed raphic/bathymetric maps surveyed during summer, 1980 and spring, 1981. The maps and profiles surveyed using a self-level or theodolite, Brunton compass and stadia rod (see Fig. 4 for profile ons).

Interviews with local residents provided information on the historic fishery and effects of floods edwood Creek (Feranna and Ricks, unpublished report). Oral records describe flood magnitudes, deposits, channel configuration changes, marine conditions, and water depth at the mouth of ood Creek.

Figure 3

Redwood Creek Floodplain, 1964 Flood Deposits and Selected Cultural Features

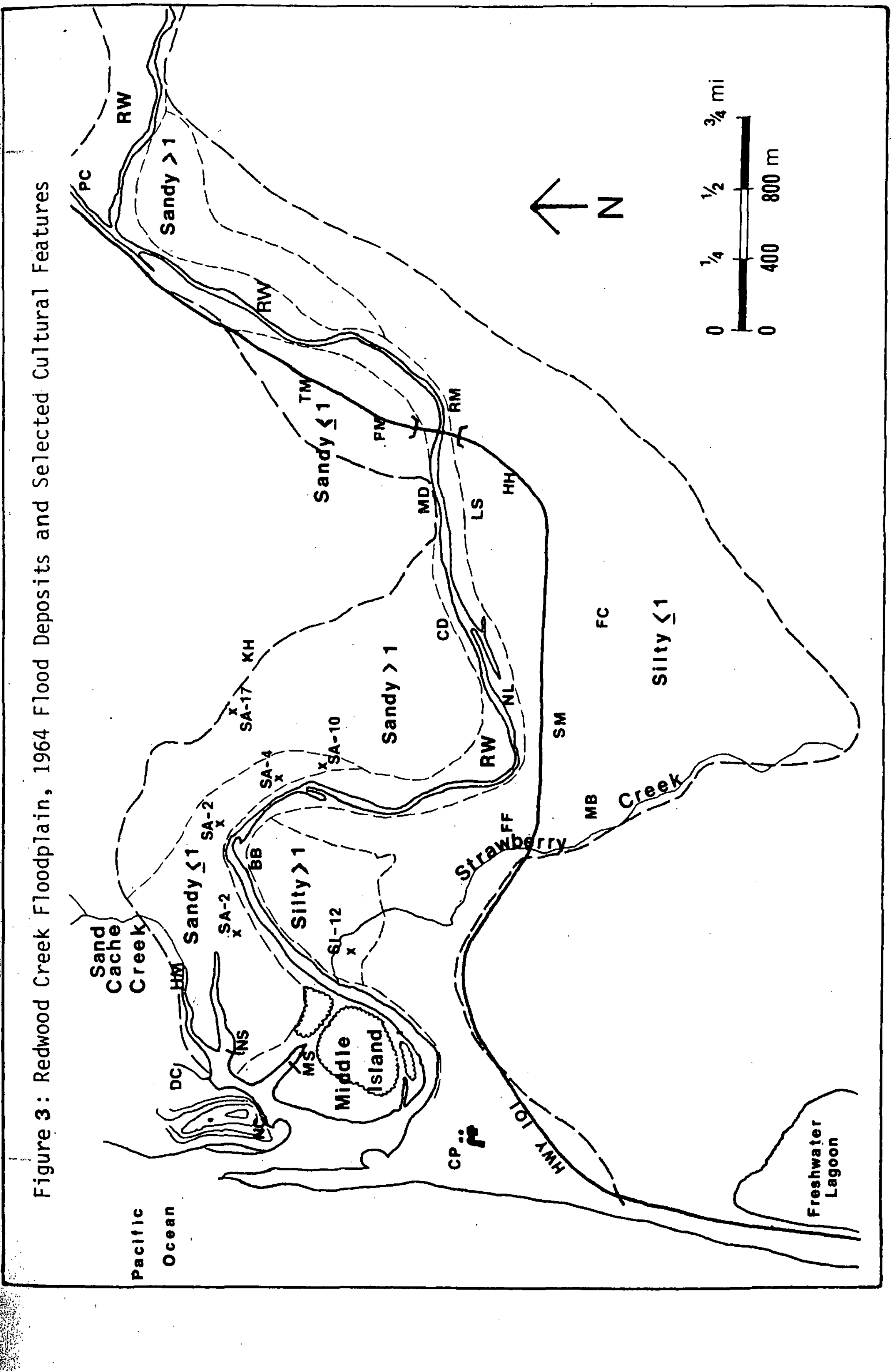


Figure 4

Topographic/Bathymetric Profile Location Map

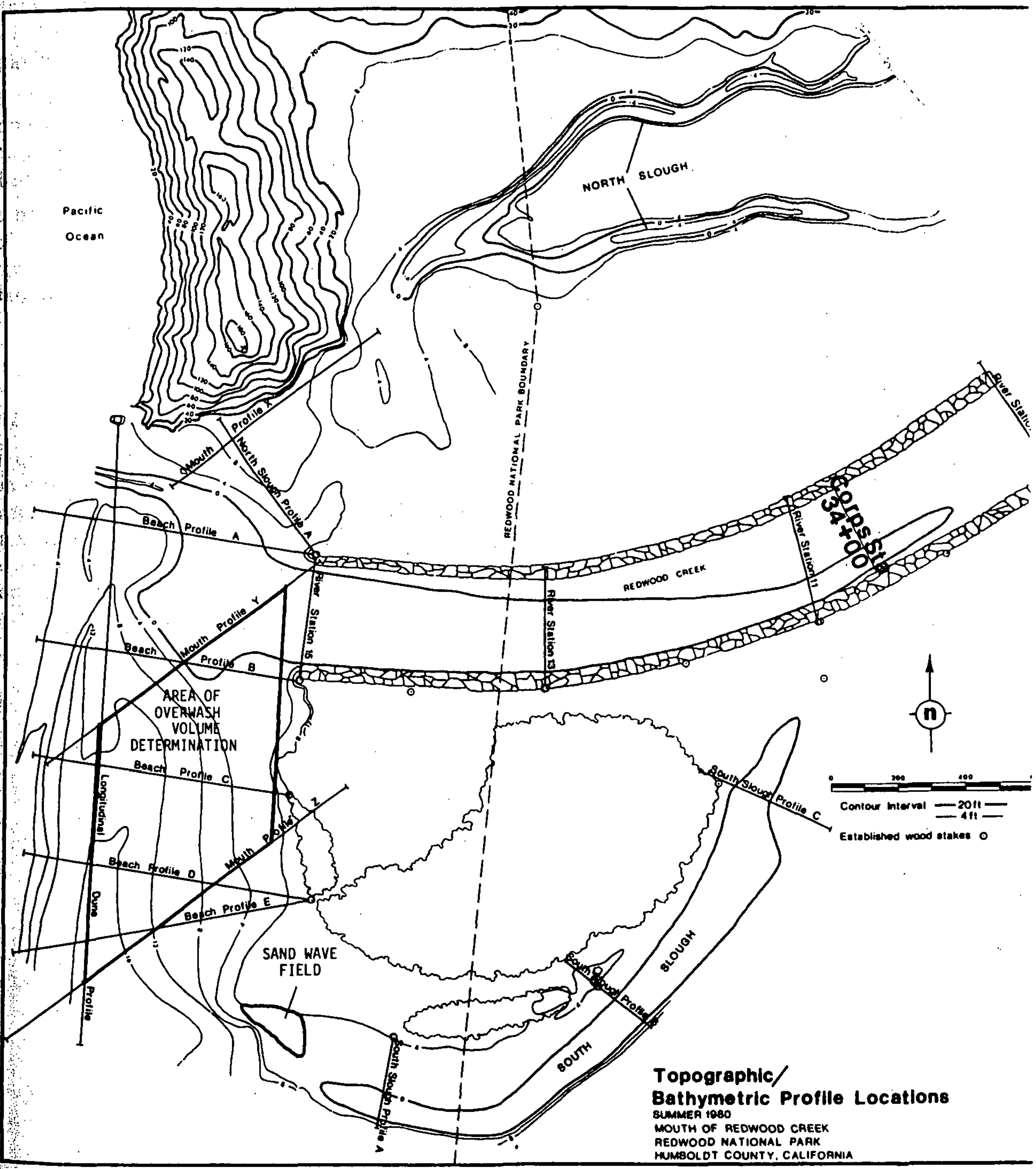


Photo coverage from established photo points supplemented field observations of seasonal ges in mouth morphology and sedimentary structures from November, 1979 through May, 1982.

Wave conditions were characterized by calculating wave power from data published for the mboldt Bay Inner WAVERIDER Buoy (Seymour et al. 1980, 1982). Wave power values represent ocal seas and swells in terms of wave period and wave height (for further explanation of wave see Komar 1976,[p. 46] or Johnson 1976,[p. 22]).

Sediment was sampled during the 1980 summer and 1981 spring using surveys for mineralogical extural analysis. Where the water depth prohibited scooping the upper 2 cm (1 in) of sediment by a gravity grab sampler was used from a rowboat.

The size distribution at one phi (Φ) intervals was analyzed for 113 samples using standard aration and sieving techniques (Folk 1980). Sediment size distribution maps were prepared by touring percentages of gravel and mud for each sample location on the topographic/bathymetric base These size maps depict transport processes and substrate types for late summer and early spring.

The heavy mineral compositions of fine sands (0.250 - 0.125 mm) were examined to determine es of sediment in the estuary. Heavy minerals were separated from 56 estuarine, river and beach mples by gravity settling in tetrabromoethane ($\rho$ = 2.96). The heavy fraction was mounted in ada Balsam and distinguishing minerals were identified and counted under a polarizing microscope.

## RESULTS

### History and Channelization

Infrequent, high-magnitude floods cause rapid erosion and deposition on the lower Redwood floodplain, changing the configuration of the mouth. The earliest evidence of flood deposits was on the middle island (Fig. 2) where tree-ring ages from a recently harvested stand of Sitka spruce *sitchensis* cluster around 65-80 yrs. These young ages may indicate spruce establishment wing flood deposition on the middle island during the 1861-62 and 1890 floods. More recently, the floods of 1953, 1955, and 1964 (Table 1) left extensive overbank deposits across the lower

**Table 1**

**Instantaneous Peak Discharge for Recent Floods**
**Redwood Creek @ Orick**

| Date | Peak Discharge | |
|---|---|---|
| | $m^3/sec$ | cfs |
| 18 January 1953 | 1415 | 50,000 |
| 25 December 1955 | 1415 | 50,000 |
| 22 December 1964 | 1430 | 50,500 |
| 22 January 1972 | 1285 | 45,300 |
| 3 March 1972 | 1410 | 49,700 |
| 18 March 1975 | 1420 | 50,200 |

plain from Prairie Creek to the ocean. The aerial extent, depth and texture of deposits at the mouth varied for each flood due to interactions among ocean waves, tides, rate of flood recession, and sediment load. The infamous flood of December, 1964 deposited the thickest layers but also scoured the entire beach from the north cliffs almost to the Cal-Pacific Mill site (NC to CP, Fig. 3).

Sketches of bank positions from aerial photos since 1936 show the frequency of bank erosion along the downstream meander of Redwood Creek (Fig. 2). Migration of the meander by erosion of the outer bank and deposition of a point bar along the inner bank occurred during high-magnitude floods. The recent series of damaging floods caused accelerated bank erosion and aggradation of the stream channel in much of the Redwood Creek basin. A long-term accretion of sediment adjacent to the embayment prior to levee construction is evident despite difficulties in interpreting aerial photos due to seasonal variability.

After the December, 1964 flood, local pressure from the town of Orick prompted the Army Corps of Engineers to finalize plans for channelization of Redwood Creek. Levee construction along the lower 5.3 km reach was completed in September, 1968. The direct and immediate effects included removal of riparian vegetation, destruction of pools and riffles, and alteration of the circulation pattern. Loss of circulation in the last meander created a south slough when the main flow was confined to a straight exit. Between the levees, the change in channel shape, decrease in roughness, and increase in channel gradient have increased the mean velocity and frequency of mobilization of the substrate.

Other effects of levee construction developed cumulatively, resulting from natural marine processes interacting with the changed fluvial system. Prior to channelization, high stream discharge kept the south meander open and created an eddy against the cliffs on the north side of the mouth. By confining the flow of Redwood Creek between levees, a trap for sediment was created in the sloughs. Sand Cache and Strawberry Creeks (Fig. 3) provide the only circulation and flushing of sediment from the sloughs. Discharge from Sand Cache and Strawberry Creeks through the north and south sloughs is tidally dependent. When a high tide coincides with high discharge, water may back up into the sloughs over the bankfull level. The sloughs remain stagnant until the tide and/or discharge recedes. Sediment stored in the slough necks is then eroded to a degree, depending on the rate of recession.

Surveyed profiles across the beach berm and south slough illustrate the quantity of sediment accumulated since the 1964-66 Army Corps surveys (Figs. 5 and 6). Between 0 and 4 ft above mean sea level (below Corps Station 34+00, see Fig. 4), approximately 50% of the volume of aquatic habitat filled with sediment or became isolated from the main channel. According to local residents, the channel along the north cliffs was at least 6 m (20 ft) deep, where today sand deposits of 1.2 to 2.4 m (4-8 ft) elevation occur. Sedimentation has resulted in isolation of the two sloughs and loss of access to the only undisturbed habitat remaining at the mouth.

Waves washing over the beach berm probably deposited large amounts of sediment in the south slough during winter storms in the years following channelization. Within the area of overwash volume determination (Fig. 4), the average rate of deposition was 3,400 $m^3$/yr (2,600 $yd^3$/yr) from 1966 to 1980. During the 1980-81 winter, overwash deposited 4,200 $m^3$ (3,200 $yd^3$) of sediment. Sedimentary structures provide evidence that tidal currents continue to transport sediment into the sloughs (e.g., sand wave field, see Fig. 4).

Most sediment transport by overwash and tidal currents occurs during periods of high tides and waves during marine storms. The effectiveness of tidal current transport also depends on the opposing force of stream discharge and the width of the mouth (determined by the magnitude of previous peakflows). Therefore, daily discharge, maximum daily tide height, and wave power values were plotted for each month (e.g., Fig. 7). These graphs provide the means to examine differences between 4 yrs of field observation, identify extreme events during this period, and evaluate conclusions based on these years with respect to storm conditions in the future.

Fluvial and marine sources of sediment to the mouth of Redwood Creek can be distinguished by mineralogy. The heavy mineral composition of sediment from Redwood Creek differs significantly with that of nearby beaches. The Klamath River contributes a distinctive mineral, blue-green hornblende, to the beaches from the north. From preliminary analyses it appears that surface sediments in the sloughs bear a large beach sand component. These data confirm the hypothesis of a marine origin for most of the sediment accumulating in the sloughs.

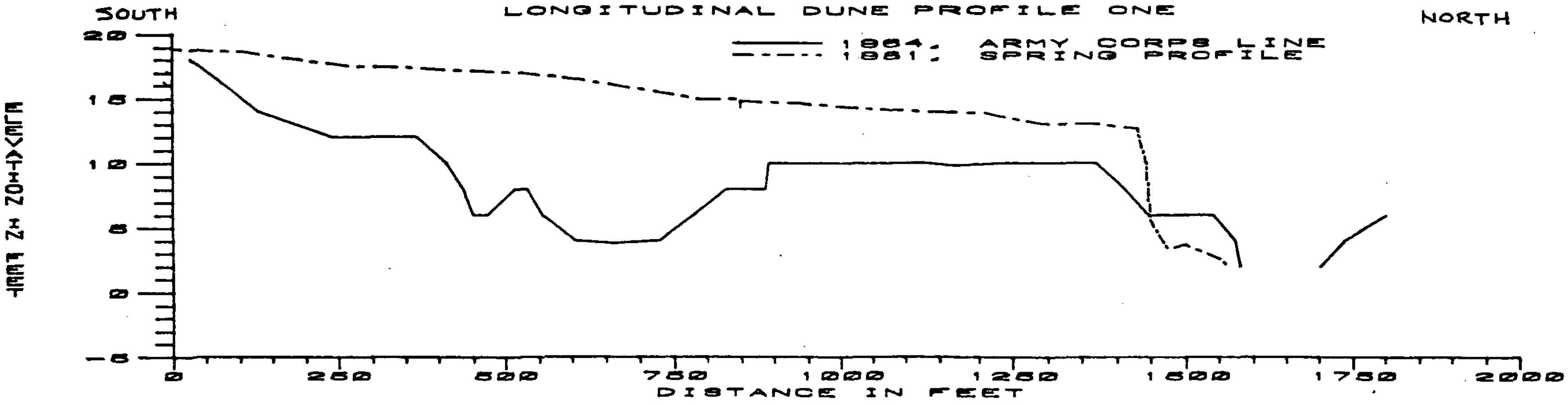


Figure 5

Profile Along Crest of Dune, Oriented With a Downstream View
(See Figure 4 for Profile Location)

Figure 6

Profiles Oriented With a Downstream View Along the Former Channel of Redwood Creek, Now the South Slough (See Figure 4 for Profile Location)

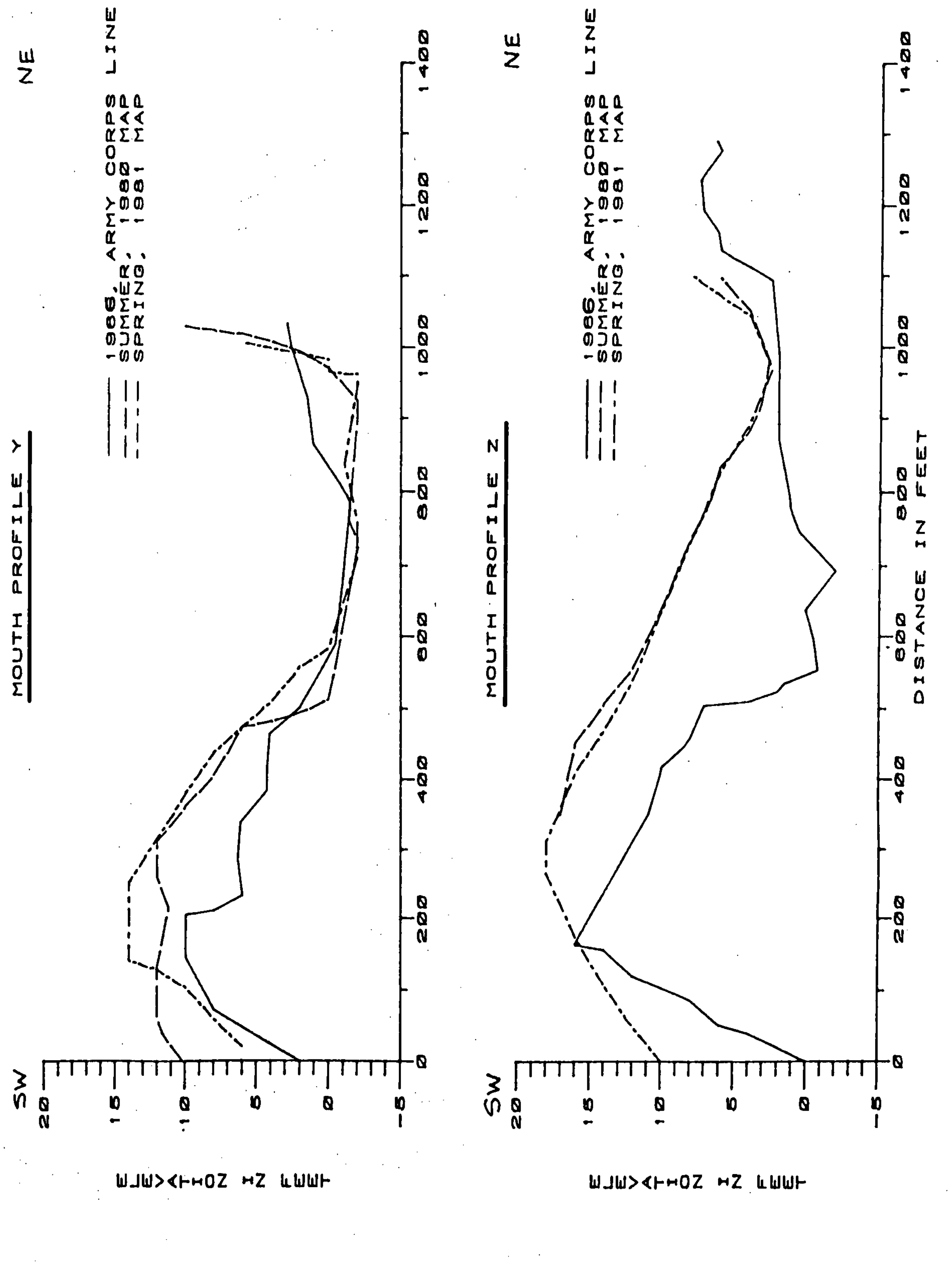
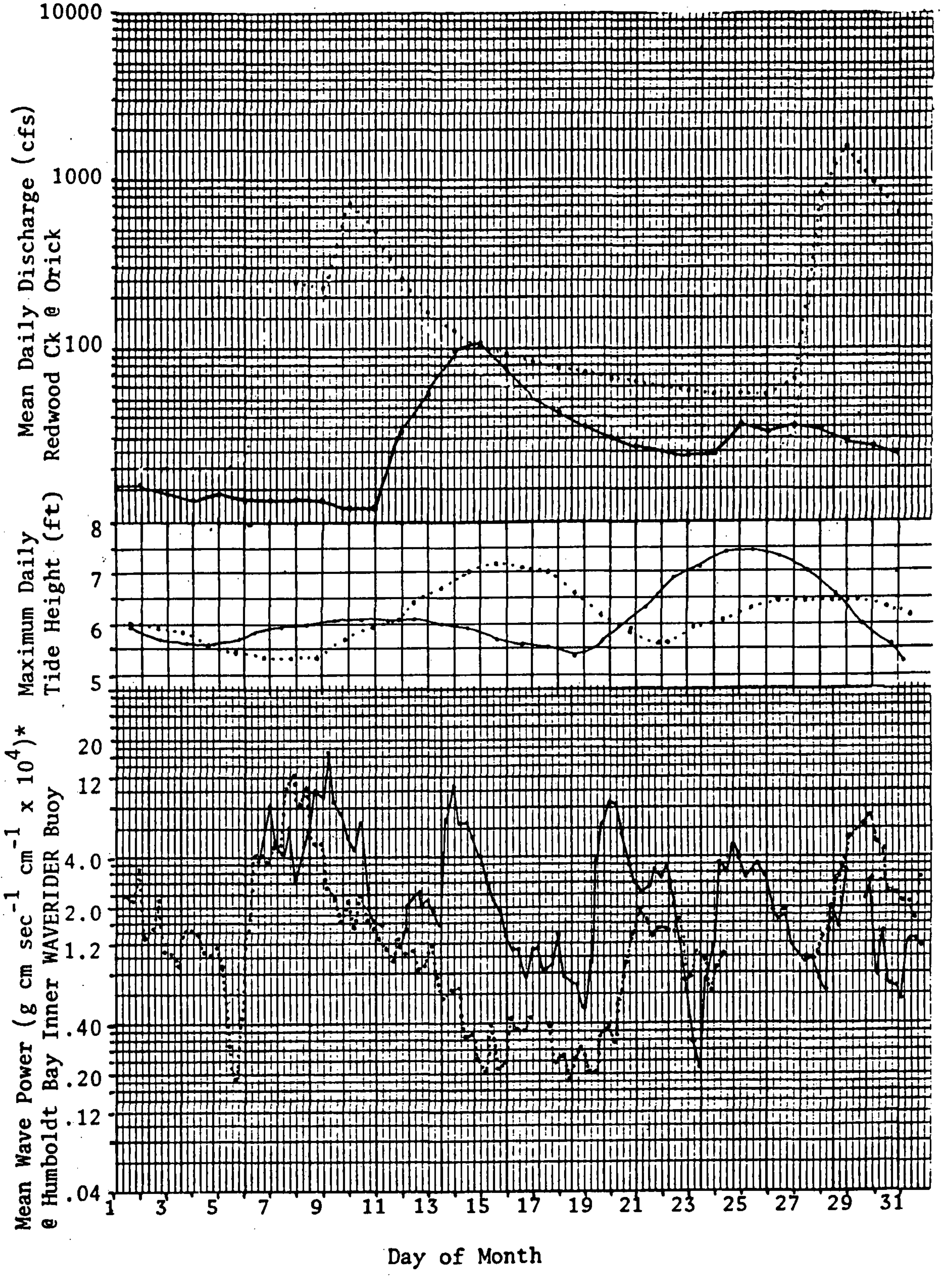


Figure 7

Mean Daily Discharge, Maximum Daily Tide Height and Mean Wave Power, October 1980 and 1981



### Seasonal Sedimentation

During winter, high flows transport gravel and finer sediment through the mouth, scouring a straight gravelly outflow channel. As discharge decreases through the spring months, the straight outflow channel is modified by incoming waves and tidal currents. Diffraction of waves around the berm results in deposition of a lobe of sand into the deep water embayment.

When prevailing north-northwest winds and high seas occur during high tides, the outflow channel migrates along shore rapidly to the south. Waves deflect the flow against the shoreward channel bank, eroding the bank while depositing a berm on the seaward side. Wave swash also raises the channel bed above its former level. The height of the outflow channel restricts the rate of outflow, causing expansion of the embayment when rates of outflow, seepage, and evaporation are less than stream discharge. Continued onshore sediment transport causes the outflow channel to close and builds the berm further into the embayment.

While the outflow channel is straight and open, marine sands are transported into the embayment and deposited over the gravelly river sediments. Migration of the outflow channel reduces the tidal range in the embayment, resulting in less disturbance of the bottom sediments by tidal currents. Several inches of mud, fine sand and marine organic detritus may accumulate in the embayment following migration of the outflow channel.

## DISCUSSION

### Implications for Aquatic Habitat

Accumulation of sediment in the sloughs and the increase in the main channel gradient have reduced the volume of water subject to tidal fluctuations (tidal prism). When high flows periodically scoured the entire mouth area, the beach berm was lower and the tidal prism was larger, allowing more frequent and extensive saltwater intrusion. The volume of potential habitat in the embayment still depends on the peak stream discharge for the season. The actual volume of aquatic habitat depends on the configuration of the outflow channel.

With outflow channel migration and/or closure, the embayment expands and becomes connected with the productive north and south sloughs. This provides physical access to the sloughs, increases invertebrate productivity and creates a large rearing area with cover for juvenile chinook salmon *Oncorhynchus tshawytscha* and steelhead *Salmo gairdneri* (see Larson et al. 1983). When the outflow channel does not close or the berm is prematurely breached, the embayment volume is extremely limited. Juvenile fish migrate directly to sea with a lower chance for survival than those able to spend several months in a productive rearing area (Reimers 1973).

For many years, local ranchers have breached the berm to drain flooded pastures. Water levels in the pastures probably rise higher and more frequently now due to the high berm and filled sloughs. The highest backup of water ever observed by local residents occurred in January, 1981, before high discharge eroded the berm naturally. High water levels may be a factor in the recent encroachment of rushes *Juncus* onto pastures and the death of spruce adjacent to the north slough.

## CONCLUSIONS

Sediment has filled areas which were formerly productive fish-rearing habitat, increased the frequency of premature breaching and reduced the potential for development of estuarine conditions. Processes related to the channelization of peak flows are primarily responsible for the accumulation of sediment. The pattern of sediment deposited since levee construction has isolated the productive sloughs from the creek throughout most of the year. Restoration of the natural circulation pattern will be necessary to remove the sediment, increase the frequency and extent of saltwater intrusion, and thereby promote the productivity of the estuary.

## MANAGEMENT RECOMMENDATIONS

The success of rehabilitation efforts depends on the cooperation of many agencies and individuals having regulatory or ownership interests at or near the mouth of Redwood Creek. Redwood National Park manages a quarter-mile strip of the coast. Humboldt County controls the levee and intertidal zone while private inholders own grazing land and forest near the mouth. The California Department of Fish and Game, Coastal Commission and U.S. Army Corps of Engineers will also be involved in management decisions.

Flood control will continue to be a major concern. In the past, high flows that flushed the north and south sloughs also caused bank erosion (Fig. 2), damage to fences and bridges from floating logs, and deposition of sand, mud and organic debris across roads and pastures.

The alternative to restoring the natural circulation pattern would be dredging material from the sloughs and berm. The rates of deposition by overwash and tidal currents depend on the timing of high tides and storms as well as the height of the berm. Overwash deposition rates calculated from the volume of sediment accumulated since the Corps of Engineers 1964 - 1966 surveys (Fig. 4) are conservative, since deposition was probably most rapid in the storm seasons immediately following levee construction. The heavy mineral data which show a large component of beach sand also suggest that dredging the sloughs would be a continuing maintenance effort.

When proposing to alter a segment of the levee for circulation enhancement, the concentration of sediment transported at high stream discharge should be evaluated. The natural force of high flows in Redwood Creek could be harnessed by constructing a spillway or flood gate through the levee to the south slough. The amount of sediment delivered to the south slough would depend on the dimensions of the spillway or timing of opening of the flood gate. Properly designed improvements would not result in loss of flood control as the levees would continue to contain high flows within the channel. Managers should also recognize that studies of movement of the present anomalously high sediment load through the Redwood Creek basin are relevant to the timing of plans for levee alteration.

As a temporary means of maintaining an adequate volume of aquatic habitat with connection to the sloughs, Redwood National Park manipulated the outflow channel from May to August, 1982. In response to local ranchers' concerns about flooding fields, park managers agreed to attempt a controlled breach of the mouth. The objective was to prevent a catastrophic breach of the type that released 75% of the water volume in July, 1980. When the outflow channel migrated to the south in the spring, the low channel gradient caused water to back up in the embayment. The outflow channel was shortened by about one-third of its length by digging a channel through the berm to capture the flow. The small increase in channel gradient and flow lowered the water level in the embayment. Later in the summer when the mouth closed completely, digging a new long, narrow outflow channel to the south also drained the embayment in a controlled manner.

## ACKNOWLEDGEMENTS

The estuary project was generously funded by the Aquatic and Wildlife Resources Branch of the Technical Services Division of Redwood National Park. The enthusiasm shown for the estuary project by RNP employees of diverse interests was much appreciated. My work would have been very difficult without the support of the Humboldt State University Fred Telonicher Marine Laboratory facilities and staff. Dick Janda, Fred Swanson, Curt Peterson, and Paul Bodin each supplied the intellectual stimulation that means so much. Finally, I would like to acknowledge the residents of Orick for sharing their past with us and for always being fascinating folks.