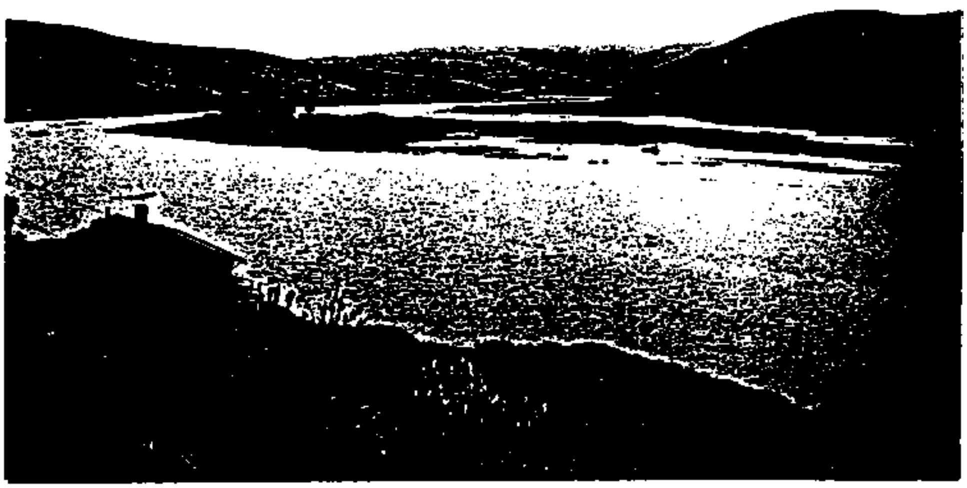
RUSSIAN RIVER ESTUARY STUDY 1992-1993



Sonoma County

Russian River Estuary Study 1992-1993

prepared for

Department of Planning
Sonoma County
Melanie Heckel, Project Manager

and

California State Coastal Conservancy
Julia McIver, Grant Manager

Under the direction of the Russian River
Estuary Interagency Task Force*

Hydrological Aspects of an Estuary
Management Plan

prepared by

Peter Goodwin, Ph.D., P.E. and C. Kelly Cuffe, M.S.

Philip Williams and Associates, Ltd.
Consultants in Hydrology
Pier 35, The Embarcadero
San Francisco, CA 94133

Limnological and Biological Aspects
of an Estuary Management Plan

prepared by

Jennifer L. Nielsen** and Theo Light

** Research Fisheries Scientist
USDA U.S. Forest Services
Pacific Southwest Research Station
800 Buchanan St.
Albany, CA 94710

Social Impacts of an Estuary Management Plan

prepared by

Melanie Heckel
Planner IV
Sonoma County Planning Department
with assistance from the
Russian River Estuary County Task Force***

* Russian River Estuary Interagency Task Force Members

Bill Cox, California Dept. of Fish and Game
Valerie Gizinski, State Dept. of Parks and Recreation
Bob Merrill, California Coastal Commission
Jennifer Vick, U.S. Army Corps of Engineers
Chris Mobley, National Marine Fisheries Service
Mike Long, U.S. Fish and Wildlife Service
Diana Jacobs, State Lands Commission
Julia McIver, California Coastal Conservancy
Melanie Heckel, Sonoma County Planning Department

*** Russian River Estuary County Task Force Members

John Schrad, Public Works
Eric Mays, Building Department
Ed Rogers, County Assessor
Doug Gow, Risk Management
Mike Treinen, Environmental Health
Randy Poole/Bob Morrison, Water Agency
Melanie Heckel, Planning Department

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OVERVIEW

The Russian River Estuary Study was prepared in accordance with a Work Program developed by the Russian River Estuary Interagency Task Force to evaluate the impacts of artificially breaching the River mouth and to select a preferred estuary management program.

The majority of the Study was prepared by two separate consultants: hydrology and flooding by Phil Williams and Associates Ltd. under the direction of Peter Goodwin and the biology and limnology by Jennifer Nielsen, a biologist with the U.S. Forest Service. The hydrological and biological components of the Study were coordinated by the County. The two separate reports are presented herein and supplemented by social impact data on flooding, public safety and recreation assembled by the County through a public participation program.

Conclusions and Recommendations are presented in the first section of the report followed by discussion of the hydrological, limnological, biological, and social aspects of the Estuary management. A description of the management alternatives is included followed by a preferred alternative developed by the Task Force.

A summary report has also been prepared for a wider circulation than this complete report.

I. CONCLUSIONS AND RECOMMENDATIONS

A. Hydrology and Flooding

The purpose of this study is to develop a management plan for the Russian River Estuary that represents the optimum solution for the entire estuarine ecosystem, whilst preventing local flooding during periods of closure of the mouth of the estuary. An adaptive management plan is recommended that allows the precise timing of breaching of the barrier beach to be determined by ecological needs. There is flexibility in the plan to allow for future adjustments if more data becomes available on the biological functioning of the estuary, or if it is possible to secure greater releases from the reservoirs at critical periods.

The main elements of the management plan are:

- The barrier beach should be breached in the range +4.5 to +7.0 feet NGVD.

- Timing of artificial breaches is important during the spring and fall to assure the passage of aquatic invertebrates. During periods of prolonged estuary closure, additional artificial breaching in the range +4.5 to +7.5 feet NGVD may be warranted if the biological monitoring demonstrates a need.

- Adequate warnings and public control should be exercised during the artificial breaching to assure public safety. Closing sections of the beach adjacent to the breach will also benefit the pinniped population.

- It is recommended that an automated tide gage is installed at the Visitor Center. This recorder will be linked by a telephone line to the County Offices allowing projections of the rise in water level to be made in the office. Observations and calls from residents will alert the County to high elevations in the estuary in the event of an equipment malfunction. This is the current management practice. However, the ability of the County to project water levels will enable the optimum time for breaching to be determined for ecological reasons and practical constraints such as working around weekends and holidays.

- This automated tide recorder and PC could be developed into an interpretative exhibit in the Visitor Center describing the biological and physical characteristics of the Russian River Estuary.

- The simple computer model developed herein can be used with the automated tide recorder or visual observations to predict when artificial breaching will be required and the optimum time.

- Supplemental reservoir releases could be used to prolong the periods of open entrance conditions if water is available at specific times of the years (for example, during reservoir drawdown for flood control purposes or release of hatchery fish). Agency coordination on these management opportunities are recommended.

- Monitoring is recommended and input solicited from the resource agencies to judge the performance of the management plan. Specifically, this monitoring should include:

- Biological monitoring plan outlined by Nielsen (1993).

- River discharge measurements at Monte Rio, to verify that the losses predicted by the computer model between the Guerneville Gage and the upstream boundary of the model. A correlation between flows at Guerneville and Monte Rio can be established.

- Periodic visual observations of the County Gage at the Jenner Visitors Center to validate the expected frequency of breaching predicted by the model.

B. Limnology and Biology

1. Limnological and biological data presented in this report suggest minimum impacts to the aquatic estuarine community during and immediately after the artificial breaching of the sand bar at the mouth of the Russian River during the summer of 1992 and spring of 1993.
2. Changes in the distribution and abundance of critical aquatic habitat based on temperature, salinity and dissolved oxygen due to tidal influence, stratification during

closure and channel geomorphology at the time of breaching did appear to influence the distribution and abundance of aquatic species throughout the estuary. These changes, however, did not have critical short-term impacts on the biological community as a whole.

3. The lack of historic biological data does not allow a comparison of the aquatic diversity found in the estuary today and the assemblage endemic to the system in years past. Anecdotal reference to abundance of certain fish and invertebrates species in the Russian River (coho, chinook and pink salmon, stripped bass, tidewater gobies, shad, dungeness crabs) not found at all or found to be lacking abundance in this study, suggest possible long-term impacts of management within the basin, not necessarily attributable to the artificial breaching of the mouth.
4. The unusual nature of the climatic conditions during this study, with a wet winter breaking the seven-year drought cycle, is a problem when projecting our results on to the broader issue of artificial breaching over longer temporal scales. We suggest limited biological and limnological monitoring continue in the estuary to add verification to our conclusions.
5. Overall the Russian River estuary and the freshwater marsh on Willow Creek provide habitat and food for a substantially diverse fauna and flora which appear adapted to the limnological shifts occurring with periodic closure of the river mouth. The role of Willow Creek marsh in sustaining the productivity and viability of the estuary should not be overlooked and the natural biological function of this marsh should be protected throughout time.
6. Public access should be curtailed during breaching events. Breaching creates unpredictable hazardous conditions for spectators at the river mouth, increasing public safety concerns and liability for regulatory agencies. Restricted access during breaching lowers disturbance levels for harbor seals and allows expedient re-haul.
7. Correlation between the timing of smolt releases at Warm Springs hatchery and artificial breaching during spring will prevent impoundment of out migrating salmon which become prey for local pinniped populations when delayed in their movement to the ocean.

II. INTRODUCTION

A. Hydrology

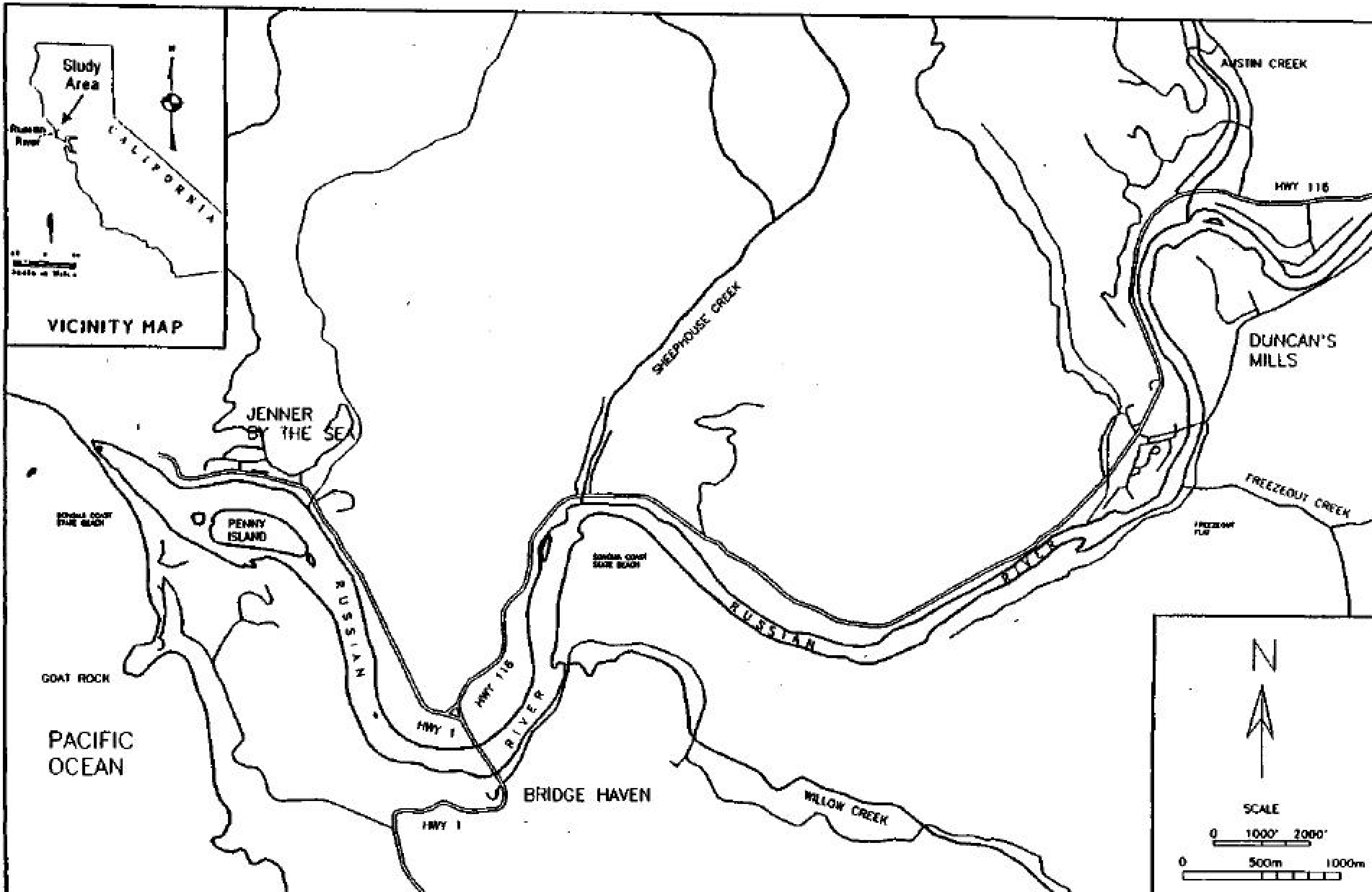
The Russian River Estuary is located approximately 60 miles northwest of San Francisco in Sonoma County (Figure 2.1). The Russian River Estuary is subject to frequent closure by the formation of a barrier beach across the mouth of the estuary. The closure of the estuary temporarily eliminates tidal exchange and creates ponding of the river, which results in a gradual increase of the water level in the estuary. This ponding effect results in the inundation of building foundation, residential yards, and agricultural lands. Damages to property have been limited by artificial breaching of the barrier beach, a practice which has been undertaken by Sonoma County Department of Roads at least since living memory (discussions in project public meeting, March 1, 1993; Schrad, 1992).

The barrier beach can also breach naturally if the water level in the estuary rises to levels which overtop the crest of the barrier beach. The natural or artificial breaching of the barrier beach lowers water levels, restores tidal circulation, and flushes pollutants, nutrients, fish, and other biological resources into the ocean.

During recent years, concerns have been raised regarding the adverse effects of artificial breaching on the estuarine ecology. The Department of Planning, Sonoma County, and the California State Coastal Conservancy initiated a study to identify any adverse impacts associated with artificial breaching and to develop a management plan for the Russian River Estuary.

A six month hydrological and biological field monitoring program has been undertaken to identify the physical processes associated with the inlet opening and closure, and identify the influence of these physical processes in the estuarine ecosystem. This monitoring program was later extended to twelve months to observe an annual variation in the characteristics of the estuary. The linkages between the physical and biological processes are then combined with a knowledge of the flood damage to property to develop a management plan for the Russian River Estuary.

The objective of the recommended management alternative is to manage the water levels, salinities, and water temperature in the estuary for the greatest benefit of the ecological resources. The adopted management alternative should also prevent flooding of property during periods of inlet channel closure.



Philip Williams & Associates, Ltd.
Pier 35, The Embarcadero
San Francisco, CA 94133
(415) 981-8363

Location Map for the Russian River Estuary

FIGURE 2.1

B. Limnology and Biology

The hydrologic analysis of the Russian River estuary undertaken by Phil Williams and Assoc. in parallel with this study covers existing and historic physical estuarine conditions. These data indicate long-term trends in the closure of the river mouth. The historic evidence presented in their report suggest natural conditions appropriate for a biological assemblage which has adapted to variable estuarine conditions over time, not unlike those present in the estuary today. Artificially breaching the mouth would tend to accelerate the temporal scale of any impacts due to natural breaching.

The limnological impacts of such an accelerated time scale appear beneficial to the aquatic community as a whole. The biological impacts of the accelerated time scale of artificial breaching, vary by species and time of year. The natural flow of euryhaline-marine fauna and the freshwater assemblage can be followed over time to document impact cycles critical to unique species. It is important to realize that all cause and effect relationships in dynamic systems such as estuaries have alternative structure and what might be a positive impact for one species will be negative for another. Some value as to the trade-offs in species must be considered when discussing the implications of breaching at different times and levels of flow.

The objective of this study was to look at the temporal variability of food and habitat in the estuary available to the species found in 1992-1993, and to suggest management alternatives directly related to the water level at the time of breaching (natural or artificial) which provide the least detrimental impacts to the biological community as a whole.

III. PHYSICAL CHARACTERISTICS OF THE RUSSIAN RIVER ESTUARY

A. General Comment

The earliest records of European settlement in the Russian River estuary date back to 1811, when a Russian colony was established near Fort Ross by Ivan A. Kuskof. The settlement raised livestock, hunted fur, and traded with Alaska (Department of Water Resources, 1964). Kuskof named the main river "Slavianka" which has been translated as Slav. The ranches and trade generated by the settlement proved to be unprofitable and were abandoned in 1841.

The earliest written reference to the Russian River appears in the Spanish land grant (the Bodega Grant) of July 19, 1843 which refers to *la boca del Rio Ruso* (Gudde, 1969). The Spanish claims were taken over by the US in 1846 and development of the watershed began on a large scale. The most significant impacts on the watershed of the Russian River have been logging, agriculture, cattle and sheep ranching, the construction of dams and water diversions, and the extraction of gravel from the bed of the Russian River.

B. Meteorologic and Oceanographic Processes

The estuarine portion of the Russian River Estuary is affected by both coastal and fluvial processes. These processes include general climate and precipitation, nearshore wave climate, tides, river discharge and sedimentation. The general climate of the region is dominated by the westerly flow of marine air from the Pacific (Rice, 1974). A wet, winter season exists from October to May, and dry, summer months extend from June through September. Over 90 percent of the annual precipitation occurs between October and May, usually in a few events of relatively short duration. A wind rose displaying the average windspeed and direction of wind observations collected at Point Reyes over a four-year period show that prevailing winds are from the northwest and west. The prevailing northwest and westerly winds occur most frequently during summer months, when temperature-induced pressure gradients form between high pressure areas over the Pacific Ocean and low pressure areas over the relatively warmer land mass. In the winter months, this pressure gradient is much less severe and bi-weekly low pressure systems travel out of the North Pacific with southwesterly to southerly winds. Waves generated during these cyclonic weather patterns can attack the shoreline from these same directions unimpeded by local topography.

Statistical wave hindcast methods were used to calculate specific wave statistics for several deep water wave stations along the California Coast from wind data collected for the years 1956-1958

(National Marine Consultants, 1960). Wave statistics presented included deep water wave height, wave direction, and wave period for both sea and swell. Seas are made up of waves of small wavelength created by local winds, while swell consists of waves of long wavelength that have been generated elsewhere and have traveled a significant distance from their place of origin. Average annual sea and swell data for hindcast station number 3 (nearest the Russian River) show that the predominant wave approach is from the north-northwest to southwest for swell and north-northwest to south-southeast for seas (Figure 3.1). More recently, actual wave gage measurements of significant wave height and spectral wave energy were collected at the Point Reyes buoy during the period April 1981 to May 1983 (Figure 3.2). Figure 3.2 displays the seasonal significant heights of sea and swell measured over this period, while Table 3.1 displays the joint distribution of significant wave heights and peak wave period. Significant wave heights for both sea and swell are highest during the winter months of November through January. During the summer months of July through August, seas have a relatively higher significant wave height, due to the local coastal winds generated during these months. From Table 3.1 it can be observed that wave heights of 151-180 cm and periods of 7 seconds have been most frequently observed over this two year record. In general, the coastline of Sonoma County is an area of relatively high wave energy and has been described by de Graca (1976) and Johnson (1956) (refer to Table 4.1).

C. Estuarine Morphometry

Existing Conditions

The earliest historic accounts of the Russian River estuary by the Russian settlers describe the need to drag boats across the barrier beach formed at the mouth, in order to gain access to the estuary. These accounts imply that the Russian River estuary was subject to periodic closure before major land use changes occurred in the watershed due to development. The Coastal Pilot (Davidson, 1869) also makes note that during the summer months, a dry bar forms completely across the mouth of the river, and remarks that after heavy rains help to break the bar, it often reforms after a few weeks of dry weather. The first topographic map prepared by the U.S. Coast and Geodetic Survey in 1876 (Figure 2.3) also depicts the estuary mouth as closed. Historical aerial photographs of the river mouth taken between 1942 and 1990 show the condition of the river mouth as both opened and closed at various points throughout time.

Several studies regarding the feasibility of a self-maintaining inlet at the mouth of the Russian River Estuary have been undertaken in the past for the purposes of establishing a navigable waterway between the river and the sea (Rice, 1974; Johnson, 1967; Sonoma Co. Planning Commission, 1957). Proposed commercial interests in support of such a plan have included the construction of a barge channel to transport gravel mined from the Russian River Valley, and the development of a small boat harbor inside the estuary. Rice (1974) provides a chronologic account of the events, plans and actions undertaken regarding these efforts.

The Jenner Jetty was originally proposed for the purpose of maintaining a navigable inlet to the Jenner Harbor in order to commercially extract gravel and sand deposits near the mouth of the river (Rice, 1974). It was also hypothesized that a permanently open inlet condition would be beneficial to the ingress and egress of anadromous fish, as well as maintaining tidal circulation and water quality. The south jetty, constructed between 1929 and 1941, was to be one of two hardened, rubble mound structures intended to maintain an open waterway at the river mouth. Remnants of the south jetty still exist along the spit that extends northward from the headland near Goat Rock.

Few bathymetric surveys of the estuary have been performed in the past. Bathymetric data from within the estuary is known only from the few hydrographic surveys conducted by the U.S. Coast and Geodetic Survey in 1876 (H1462b) and 1931 (H5098), the U.S. Army Corps of Engineers (COE) in 1960, privately funded surveys conducted during planning phases of jetty construction and harbor feasibility studies (Johnson, 1967; Sonoma County Planning Commission, 1957), and a few cross-section surveys conducted by Sonoma County Water District (1971-1993). Hydrographic surveys offshore of the river mouth were conducted in 1854 (H401, H421), 1862 (H806), and 1957 (H8354).

Aerial photographs which include the estuarine portion of the Russian River span the period between 1942 and 1990. A list of the date, scale, inlet condition, and general comments regarding morphologic character are presented in Table 3.2. Topographic maps with varying degrees of coverage of the area include U.S. Coast and Geodetic Survey maps from 1876 (T1430b), and 1930 (T4595). The entire study area is covered by the Duncans Mills and Arched Rock 7.5 U.S. Geological Survey topographic quadrangles (1943, 1977, and 1979).

In general, the estuarine portion of the Russian River extends approximately 6 to 7 miles upstream, from the mouth of the river between Duncans Mills and Austin Creek (Rice, 1974; COE, 1965). Tidal action has, on occasion occurred as far as 10 miles upstream at Monte Rio (California Dept. of Water Resources, 1964).

The coastline adjacent to the river mouth of the Russian River consists of rocky headlands both to the north and to the south, with sea cliffs ranging from 50 to 200 feet high (de Graca, 1976). Pocket beaches sometimes exist at the head of small coves which form between irregular projections along the coast. A tombolo connects Goat Rock to the mainland about 4,000 feet south of the river mouth. The sand spit that extends northward across the mouth of the Russian River, known as Goat Rock Beach, also begins in this area. Penny Island, a small elliptically shaped island exists approximately 3,000 feet upstream from the river mouth and has persisted in approximately the same position and general form on historic maps since at least 1876. Several rocky pinnacles exist within a mile radius offshore, to the west and northwest of the river mouth, and limit direct wave attack to WSW and SW.

Offshore of the study area, the continental shelf slopes uniformly from shore to its outer edge. The width of the continental shelf narrows from 20 miles west of Point Reyes, to approximately 5 miles offshore of Fort Ross. The 10-, 50-, 100- and 500-fathom contours exist 0.8, 6.8, 16.5 and 24.1 nautical miles, respectively, offshore of the Russian River mouth. No major features interrupt the uniform contours out to the shelf break, except for rocks near shore (de Graca, 1976). De Graca (1976) defines the boundaries of the littoral cell that includes the Russian River mouth as extending from the rocky headland just north of Fort Ross (approximately 5.5 miles north of the river mouth), to Bodega Head, 9.5 miles to the south of the river mouth. Johnson (1959) and de Graca (1976) have studied the offshore topography and sediment budget for the Russian River littoral cell and suggest that although net littoral transport along the northern California Coast is from the north to the south, they note that a reversal occurs in the area surrounding the Russian River mouth with south to north sediment transport occurring near shore. Both authors also note that wave energies, and hence littoral transport, are weakest in the vicinity directly surrounding the river mouth. The barrier spit that forms across the river mouth is created by the on-shore movement of sediment discharged from the river previously during peak precipitation and runoff events and transported landward by the long, low-energy waves that reach the shore during low precipitation, minimum runoff periods.

Many coastal lagoons or small-scale estuaries in California have been subject to accelerated deposition and loss of storage volume due to logging, agricultural practices, constriction of the inlets due to road and railroad embankments and fire (Goodwin and Williams, 1990). This loss of tidal volume and associated diminishing scour at the tidal inlet has led many systems that were once always open to tidal action to be subject to periodic closure (Section 3). However, a comparison of river cross-sections taken at the Highway One Bridge (River Mile 2.1) and Duncans Mills (River Mile 5.8) by the Sonoma County Water Agency shows there have been no long-term change in the bed between 1971 and 1992 at these structures. Studies to evaluate the feasibility of constructing a marina and a ship channel in the Russian River Estuary obtained limited bathymetric data in the vicinity of the barrier beach. However, both these limited sources of data imply that the massive sedimentation observed in other California coastal lagoons has not occurred in the Russian River, although the limited historic data is not conclusive.

1992 Bathymetric Survey

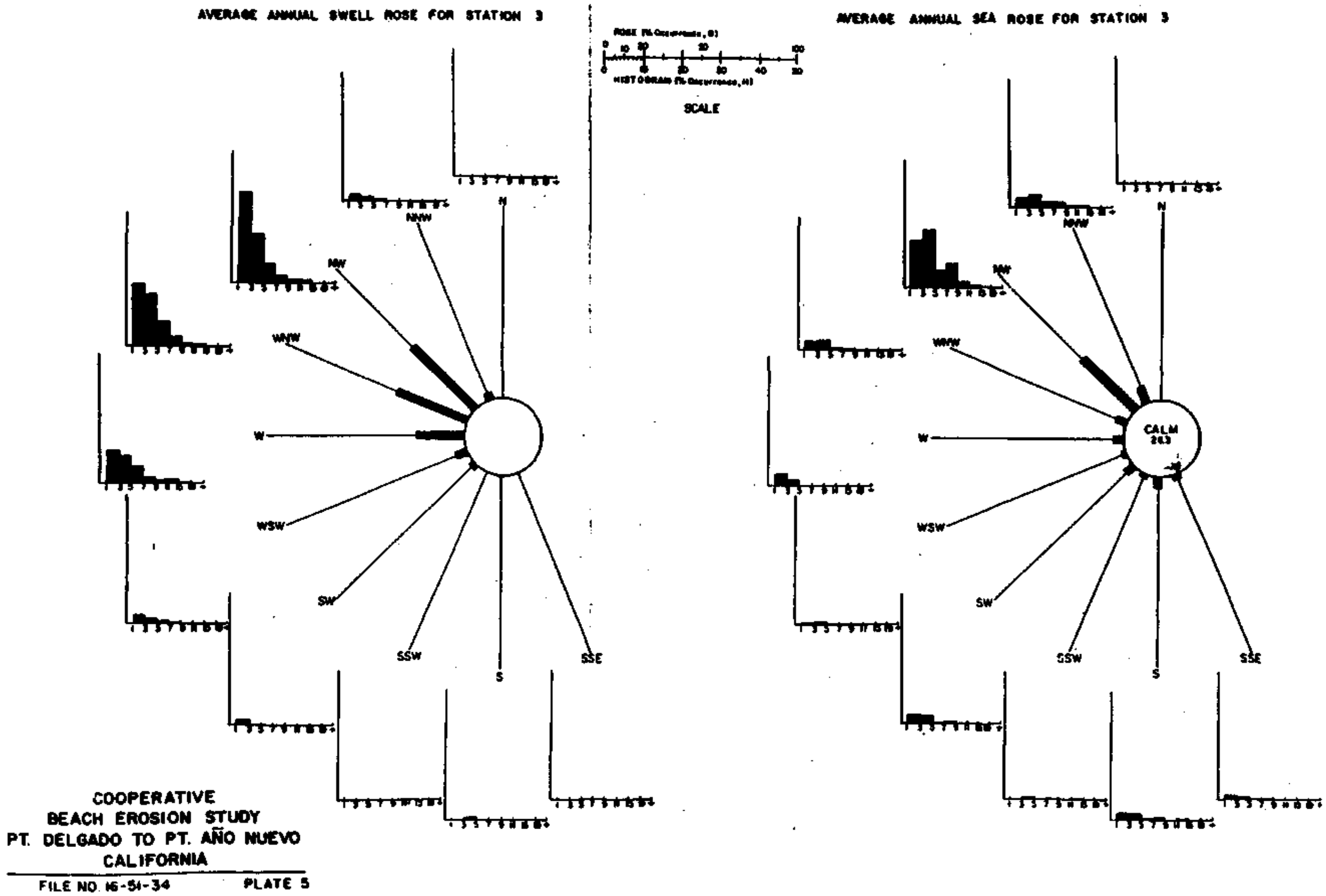
The bathymetry of the Russian River Estuary was surveyed during September, 1992. Thirty cross-sections of the estuary were surveyed from the barrier beach to the confluence with Austin Creek (Figure 3.4 and Appendix III). The location of cross-sections were selected to provide a realistic representation of the bathymetry for use in computer models. A bathymetric contour map was developed by creating a digital terrain model (DTM) of the riverbed from cross-section data point elevations. A DTM is an elevational approximation of a given terrain surface based on the construction of a triangulated irregular network (or TIN). The TIN enables the computation of contour lines by interpolating between points along each TIN face. Computer generated contours were further refined based on field observations and interpretations of aerial photographs (Figure 3.5). This data is compatible with the proposed County GIS system.

D. Beach Characteristics

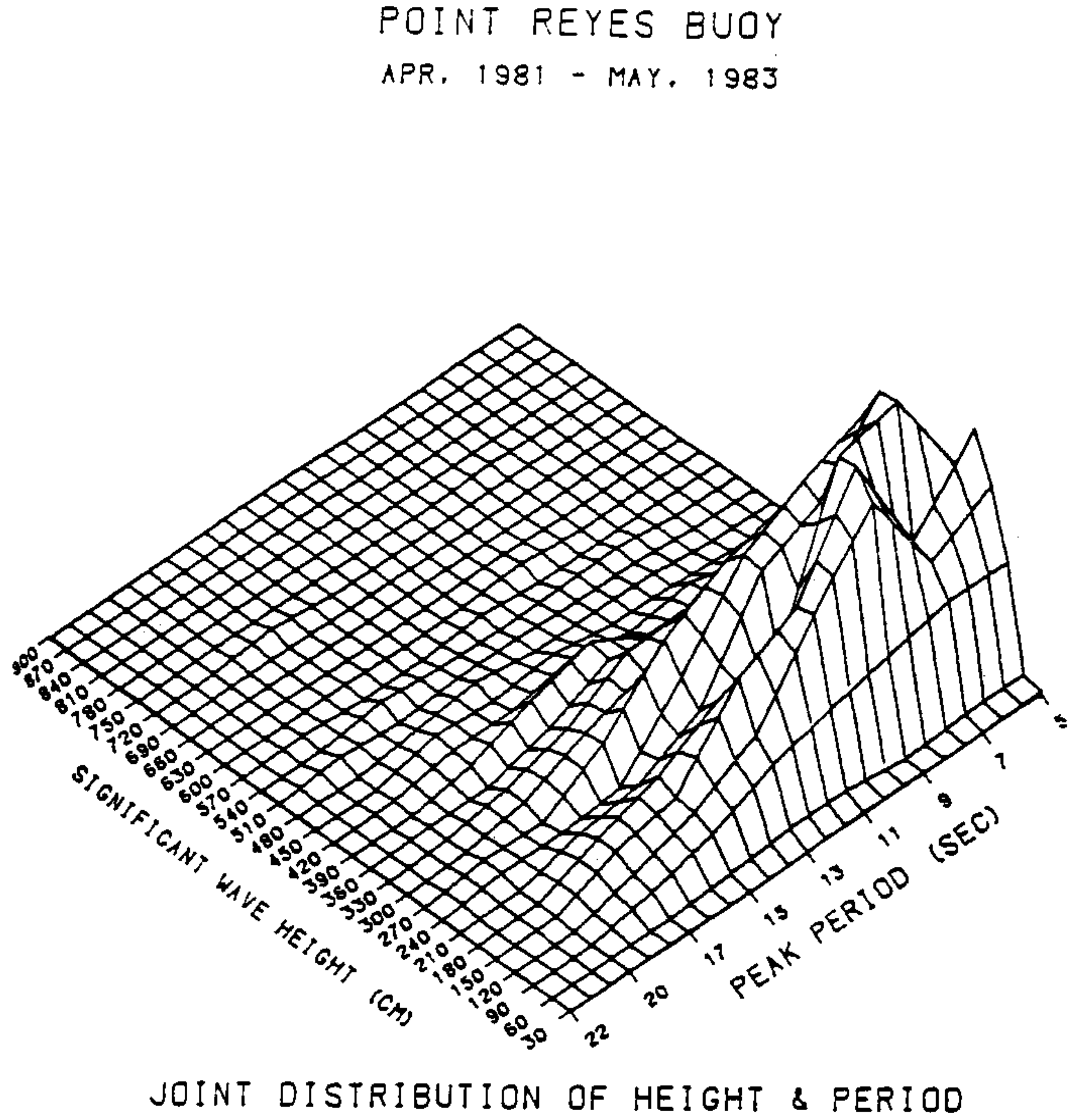
Existing Conditions

The beaches adjacent to the mouth of the Russian River have been studied previously for purposes of gaining insight into the coastal processes occurring in the area and the influence of the beaches on the morphologic aspect and physical sedimentary characteristics of the area. The COE performed beach surveys and sediment analyses from samples taken at Russian River in 1961, as part of a study of the coast of California between Point Delgado to Point Año Nuevo (COE, 1965). Two of the main purposes of this study, were to obtain data on shore processes, and to determine methods of maintaining stream outlets. Beach profile data from five summer and five winter profiles are shown in Appendix V. Twenty sediment samples were also taken to determine mineralogic composition and grain size characteristics of the sediments comprising the beaches at the river mouth.

In general, the beach material comprises medium grained, generally well sorted grey sand (COE, 965). The principal sources of beach material include 1) stream-borne sediments, 2) erosion of alluvial deposits, 3) influx of littoral sediments and 4) onshore transport of near-shore deposits. De



Philip Williams & Associates, Ltd. Consultants in Hydrology	Swell & Sea Rose Showing Direction of Wave Approach at Wave Hindcast, Station #3 Histograms show percent occurrence of differing wave heights. Data collected 1956-1958 Source: San Francisco District US Army Corps of Engineers, 1960	Figure 3.1



Philip Williams & Associates, Ltd. Consultants in Hydrology	Significant Wave Heights and Periods for the Point Reyes Buoy (1981-1983)	Figure 3.2

TABLE 3.1

JOINT DISTRIBUTION TABLE OF SIGNIFICANT WAVE HEIGHTS AND PEAK WAVE PERIODS

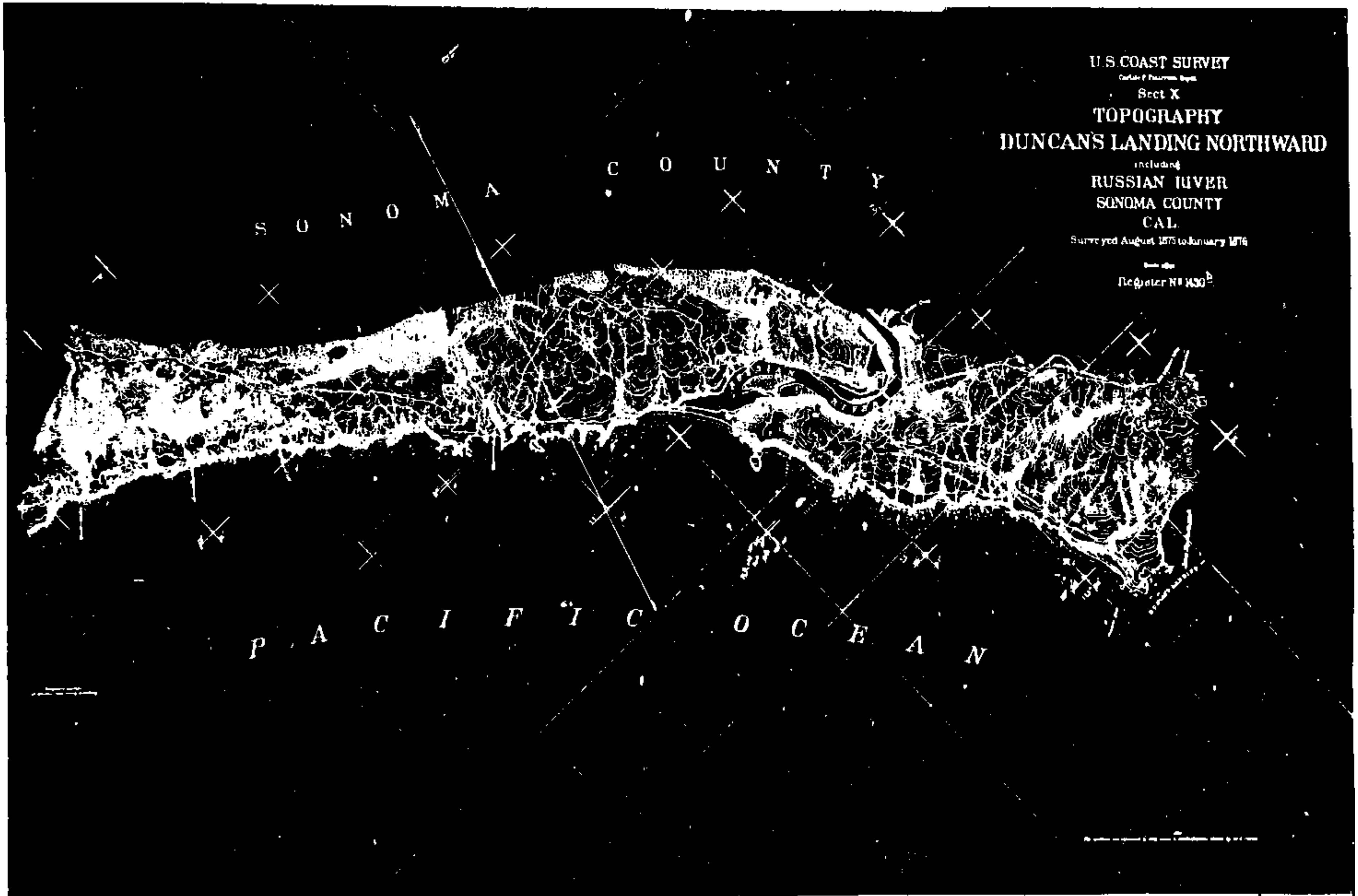
Source: Seymour *et al,* 1992. Point Reyes Buoy located at Latitude 37 56.3, Longitude 123 03.8 in 73 m depth.

APR, 1981 - MAY, 1983

JOINT DISTRIBUTION TABLE
TOTAL OBSERVATIONS =2618

SIGNIFICANT... WAVE HEIGHT (CM)	22+	20	17	15	13	11	9	7	5
871- 900									
841- 870									
811- 840									
781- 810									
751- 780									
721- 750							1		
691- 720			2						
661- 690									
631- 660									
601- 630						1			
571- 600			1			2			
541- 570		1			2				
511- 540			4	2	1	2	3		
481- 510		3	1	3	3	2	2		
451- 480			3	6	3	3	3		
421- 450			6	4	7	3	3	1	
391- 420		1	5	5	10	5	9	3	
361- 390			4	14	21	9	10	3	
331- 360		1	1	8	19	14	10	16	
301- 330		1	S	13	27	28	35	28	
271- 300		1	5	16	24	42	38	39	4
241- 270		3	2	17	41	56	63	72	3
211- 240		3	3	5	32	63	76	85	9
181- 210		1	8	11	24	62	73	100	26
151- 180		1	11	19	33	35	95	101	62
121- 150		1	11	16	46	58	96	53	81
91 -120			7	15	29	60	87	SO	64
61 -90			5	12	23	29	34	40	40
31 -60				2	4	3		2	2
1 -30									1

PEAK PERIOD (SEC)



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Consultants in Hydrology

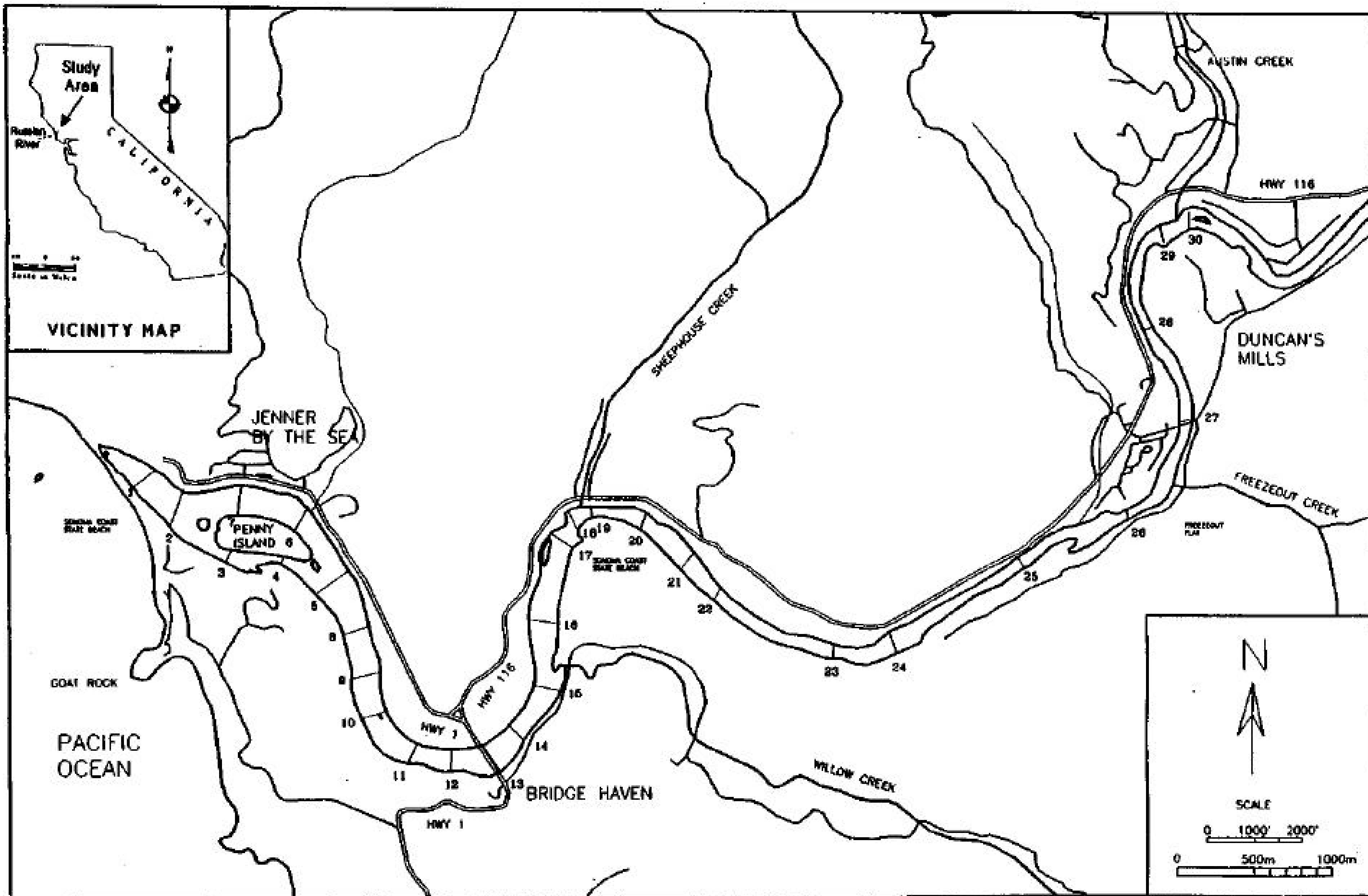
Russian River Estuary, 1876

Figure 3.3

TABLE 3.2

AERIAL PHOTOGRAPHS OF THE RUSSIAN RIVER ESTUARY

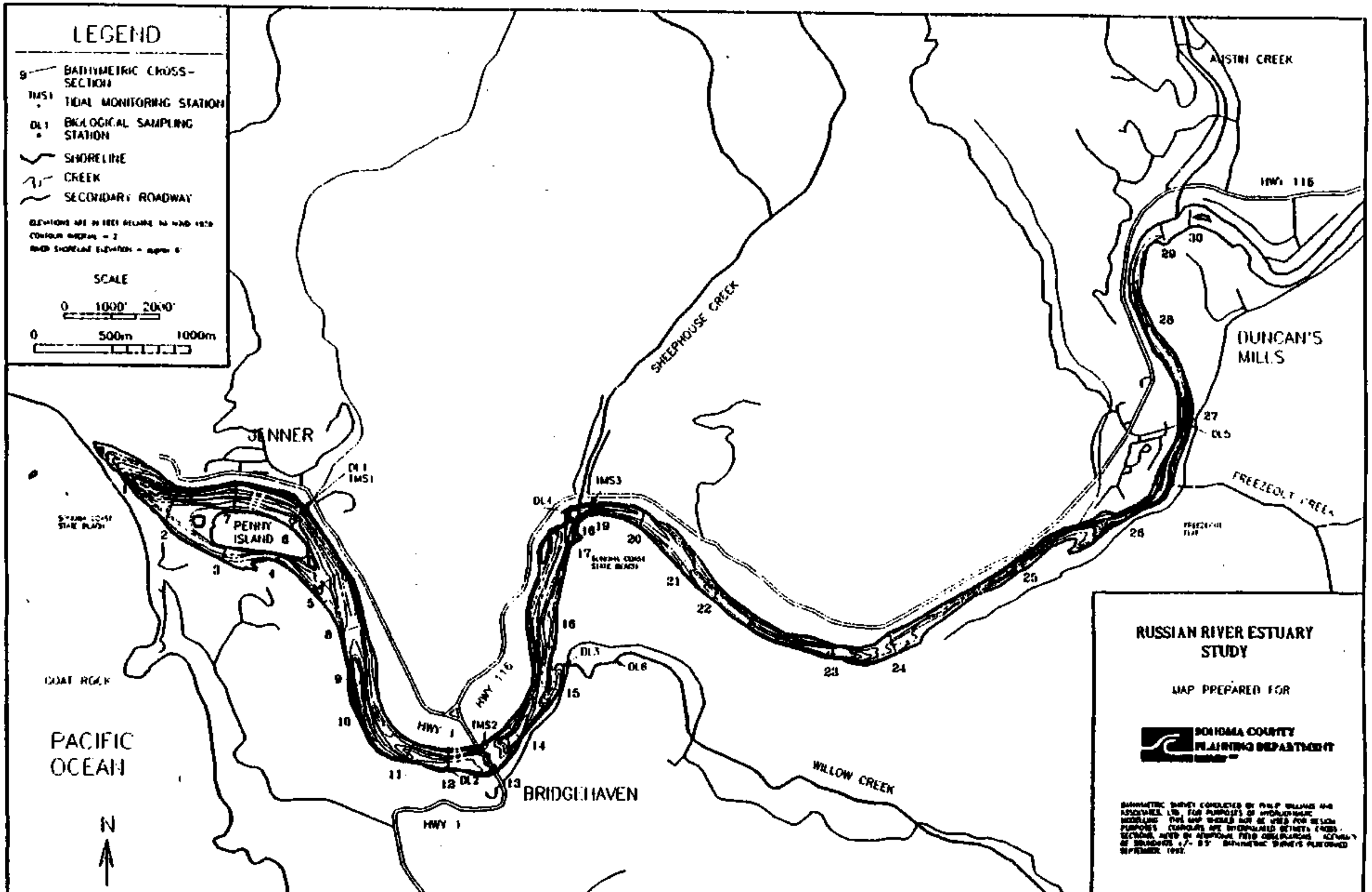
DATA SOURCES - HISTORICAL ANALYSIS					
DATE	TYPE OF DATA	SOURCE	SCALE	COVERAGE	CONDITION OF RIVER MOUTH
1876	TOPOGRAPHIC MAP	USC&GS	1:10,000	DUNCANS LANDING TO TIMBER GULCH	CLOSED
1030	TOPOGRAPHIC MAP	USC&GS	1:10,000	ROCKY POINT TO RUSSIAN GULCH	OPEN; JETTIED
1931	HYDROGRAPHIC CHART	USC&GS	1:10,000	ROCKY POINT TO RUSSIAN GULCH	OPEN; JETTIED
1942	B/W AERIAL PHOTOS	US ACOE		RIVER MOUTH	OPEN
1943	TOPOGRAPHIC MAP	USGS	1:24,000	DUNCAN MILLS QUADRANGLE	OPEN
1945	B/W AERIAL PHOTOS	US ACOE		JENNER TO HWY 1 BRIDGE	OPEN
1950	B/W AERIAL PHOTOS	US ACOE		GOAT ROCK TO JENNER	OPEN
1955	B/W OBLIQUE AERIALS	US ACOE		JENNER TO HWY 1 BRIDGE	OPEN; FLOODING
1956	B/W AERIAL PHOTOS	US ACOE	1:12,000	JENNER TO SHEEPHOUSE CREEK	OPEN
1958	B/W AERIAL PHOTOS	US ACOE	1:12,000	JENNER TO HWY 1 BRIDGE	N/A
1967	BLUE LINE AERIALS	SCWA	1:12,000	JENNER TO SHEEPHOUSE CREEK	OPEN
1979	BLUE LINE AERIALS	SCWA	1;12,000	JENNER TO SHEEPHOUSE CREEK	OPEN
1981	B/W AERIAL PHOTOS	US ACOE		JENNER TO SHEEPHOUSE CREEK	OPEN
1990	B/W AERIAL PHOTOS	SCDP	1:34,800	JENNER TO MONTE RIO	CLOSED; OPEN
1991	BATHYMETRIC CHART #18640	NOAA/NOS	1 :207,840	SAN FRANCISCO TO POINT ARENA	N/A



Philip Williams & Associates, Ltd.
Pier 35, The Embarcadero
San Francisco, CA 94133
(415) 981-8363

Location Map showing the Bathymetric Cross-Section Locations at the Russian River Estuary

3.4



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San Francisco, CA 94133

Contour Map of Channel Bathymetry – River Mouth to Austin Creek

Figure 3.5

Graca (1976) estimated that the total amount of beach materials discharged at the mouth of the Russian River, including both bedload and suspended load materials, to be approximately 267,000 tons per year. More recently, Simons, Li and Associates (1991) have estimated that the bed material load passing through the lower end of the middle Reach (Hacienda Bridge) is approximately 242,000 tons per year. For the period 1981-1991, this figure was revised to 110,000 tons per year (Philip Williams & Associates, Ltd., 1992). The sparse cross-sectional data for the Lower Reach between Hacienda Bridge and the Pacific Ocean does not exhibit significant aggradation or degradation, so that the estimated sediment delivery of approximately 100,000 tons per year seems a reasonable estimate. De Graca also remarked that the encroachment of dunes on the backshore and the accumulation of sand seaward of older erosional scarps indicate that little or no active alluvial erosion is occurring. Littoral transport in the immediate vicinity of the Russian River is also quite low. Investigations regarding near-shore sediment transport by Johnson (1959), Cherry (1964), and Minard (1971), conclude that there is an extremely low intensity of sediment movement in the littoral zone near the Russian River. Onshore movement of material discharged from the river and littoral drift deposits occurs during summer months when long period waves transport the sediment landward, rebuilding the beach that winter waves and river outflows removed.

The profile of a beach is described generally with reference to three zones: the backshore, foreshore and nearshore. Each of these zones are subject to different physical processes and hence possess different morphological characteristics. The backshore, extending landward from mean high-tide level, is sub-aerially exposed and affected by aeolian processes which have the potential to create dunes and revetment surfaces. The backshore commonly has a nearly horizontal to gently landward-sloping gradient whose seaward limit is marked by an abrupt change in slope. It is at this point, referred to as the bermcrest, that the steep, seaward slope of the beachface begins. The bermcrest is the maximum height of the barrier beach and is the maximum elevation of wave runup. The foreshore zone extends from the bermcrest to mean low tide and includes the beachface, the plunge step and ridge-and-runnel features (Figure 3.6). Along barrier beaches, such as at the Russian River, the backshore extends from the bermcrest landward toward the enclosed lagoon or semi-enclosed estuary.

The slope of the seaward beachface is dependent upon the composition of the foreshore and the physical processes affecting it: primarily wave energies, and tide levels. Bermcrest height is dependent upon incident wave energies and tidal range. The actual tidal range that can affect the beach is a composite of both astronomical (lunar) tides and meteorological tides (i.e., elevated tide levels due to onshore wind-wave set-up and storm surge). In general, steeply sloped beaches are built during summer months when the ratio of wave height to wave length (termed "wave steepness") is small. Prolonged periods of low wave steepness moves sediment onshore, allowing the bermcrest to grow and advance seaward, thus widening the beach. During winter months, the ratio of wave height to wave length increases due to high energy, winter storm events and the beachface gradient decreases. During high energy events, the bermcrest may be overtopped and eroded such that sediment is moved either further landward or offshore resulting in a flattened beach profile.

A semi-empirical criteria for determining whether the beach sand is moving onshore or offshore (Dean, 1973) is

$$\frac{H_O}{L_O} < \frac{pW}{0.6gT} \quad = \textit{ onshore transport of sand}$$

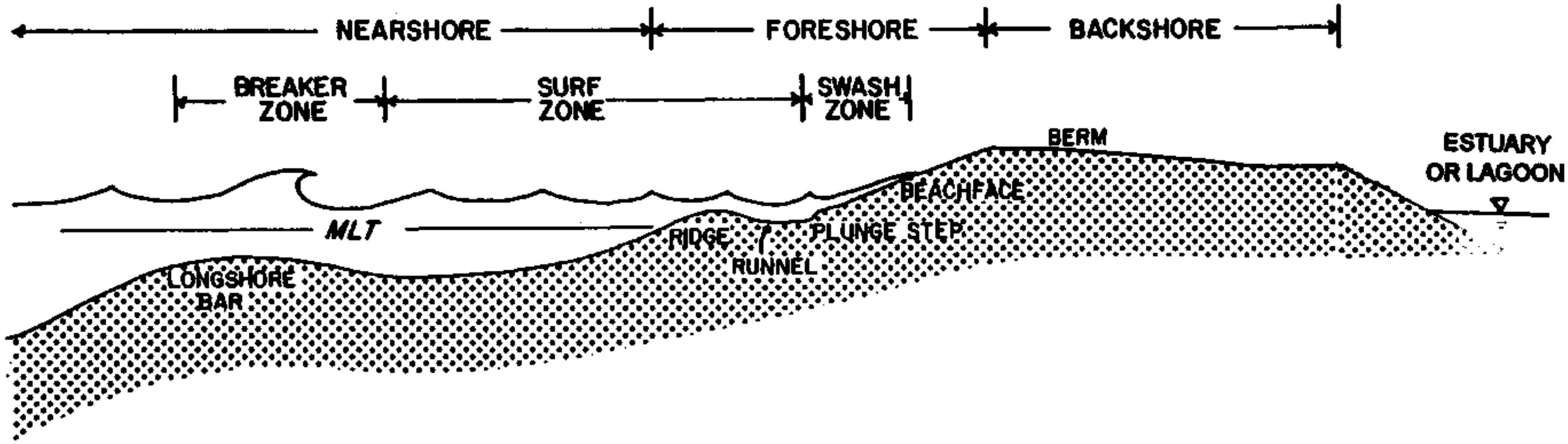
$$\frac{H_O}{L_O} > \frac{pW}{0.6gT} \quad = \textit{ offshore transport of sand}$$

where:	H_O	=	deep water wave height
	L_O	=	wave length
	W	=	fall velocity of the sand size
	T	=	wave period.

The beach profiles in Appendix V display the seasonal changes experienced by the foreshore over the summer and winter periods. Bermcrest heights of those profiles in the vicinity of the river mouth reach elevations of nearly .15 feet. Beach widths, as measured from historical maps and aerial photographs, are summarized in Table 3.3 and range from 80 to 670 feet at the narrowest point.

Beach Characteristics During the Monitoring Period

There was insufficient information from earlier beach transects to resurvey the same locations. However, transects were surveyed in November 1992 (Figures 3.7a and 3.7b). The beach foreshore has a slope of approximately 1 in 10, and the bermcrest (or maximum height of the barrier beach) was approximately 13.5 feet NGVD at the low point. This represents a period when the beach is transforming to winter conditions. In the five day period prior to the survey, the significant wave height and dominant period were 6.4 feet and 7.6 seconds respectively, resulting in Dean's criteria predicting a net offshore transport of sediment. The height of the barrier beach is determined by the wave runup associated with the wave climate since the previous breaching of the barrier beach. A record of significant wave heights at Bodega, the closest continuous wave monitoring recorder during the study period is summarized in Appendix VII.



Modified from Davis,1985

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Characteristics of a Natural Beach

Figure 3.6

E. River Inflows

General Comment

The Russian River drains an area of 1485 square miles in Mendocino and Sonoma Counties in Northern California. The River is approximately 110 miles in length and is the largest river on the California coast between Point Delgado and San Francisco Bay (COE, 1965) (Figure 3.8). Flows in the Russian River have been supplemented by diversions from the Eel River since 1929. The flows in the river are regulated partially by Coyote Dam in Mendocino County (completed in 1958) and Warm Springs Dam on Dry Creek, a major tributary of the Russian River in Sonoma County (completed in 1982). These two major reservoirs are operated for minimum fish flow releases during the dry summer months which has reduced the variability of the flows during the summer months. During winter flow conditions and significant storm events the flood peaks are reduced due to the operation of the reservoirs for flood control purposes.

Historic Data

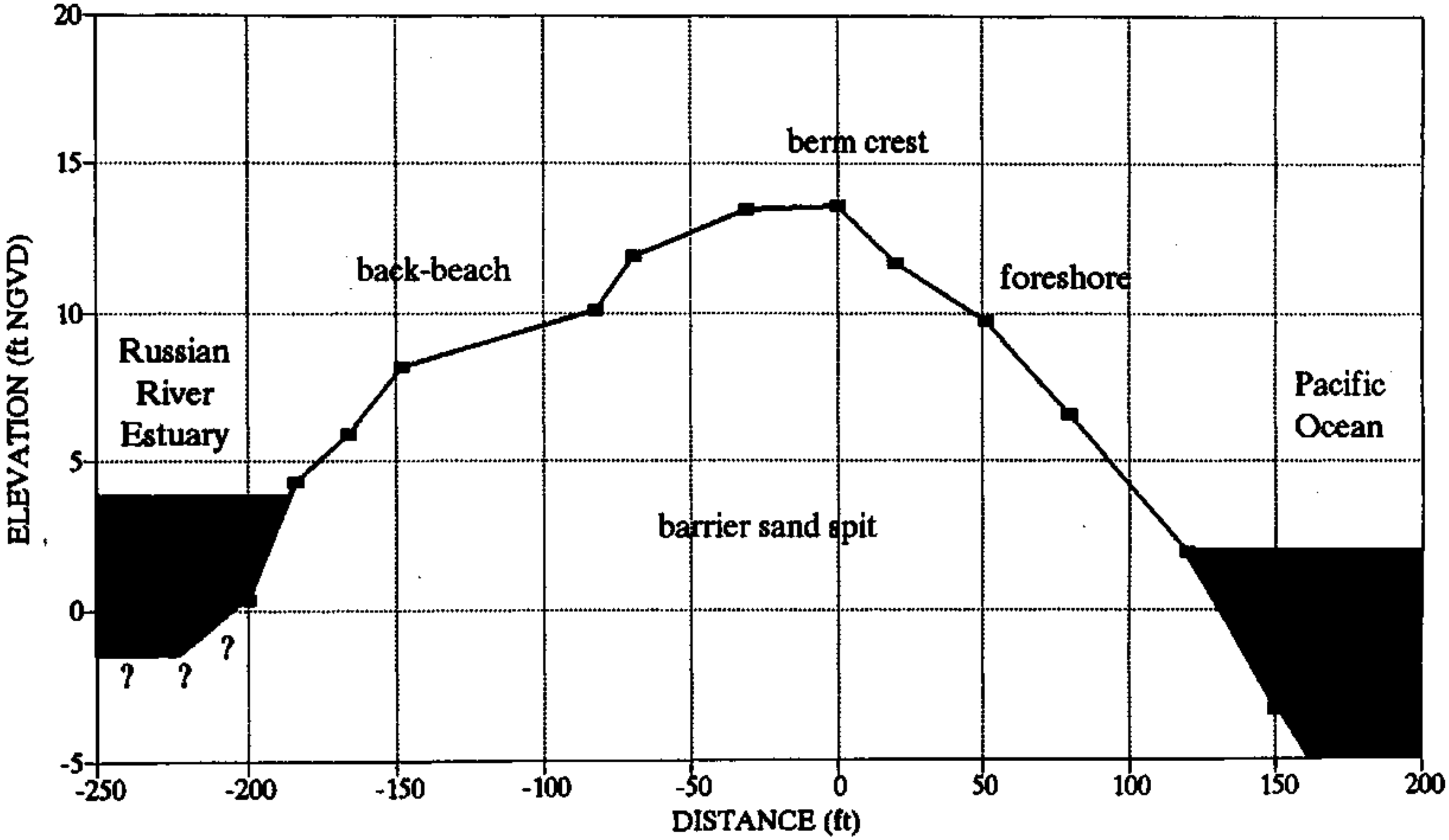
The most significant floods recorded by the USGS gage at Guerneville are 93,400 cfs in 1964 and 108,000 cfs in 1986. These flows can create significant geomorphic changes to the river system, but the mouth of the Russian River will be open during any significant flood discharges. The proposed management plan for the estuary is therefore more dependent on the dry season discharges since these flows govern the rate of rise of the water surface elevation and the depth and duration of flooding due to the closure of the barrier beach.

Figure 3.9 summarizes the mean monthly discharges for the period June through October since the installation of the gage near Guerneville in 1938. There is no data of low flows in the Russian River prior to the Eel River diversions in 1928. Some historical photographs indicate that the river bed could have been dry in the Alexander Valley (L Marcus, Coastal Conservancy, personal communication, 1993), although no narrative exists to say if this was the norm, or due to a temporary diversion.

The minimum discharge in the Russian River at Hacienda Bridge can differ depending on normal year, dry year or critical year flow requirements as established by the State Water Resource Control Board Decision 1610 (April 1986). During normal years, minimum flow requirement in the Russian River between Dry Creek and the river mouth are 125 cfs; during dry and critical years, minimum flow requirements between Dry Creek and the mouth are 85 cfs and 35 cfs, respectively (Appendix VIII).

Inflows During the Monitoring Program. April 1992 through March 1993

The flows at Hacienda Bridge near Guerneville are shown in Figure 3.10 and Appendix IV. The maximum flows (corresponding to an open entrance) were observed on December 11 (23,000), January 21 (62,000 cfs), and February 19 (28,999 cfs). Minimum flows were observed on May 20 (100 cfs) and October 22 (0 cfs) although the time sequence of discharges shown in Appendix IV indicate that these two flows were associated with stream gage malfunction. Daily flow records for the study period are given in Appendix IV.



RUSSNRVR/XSXNS/BCHPRFLS.WQ1/p1-112192/5-17-93

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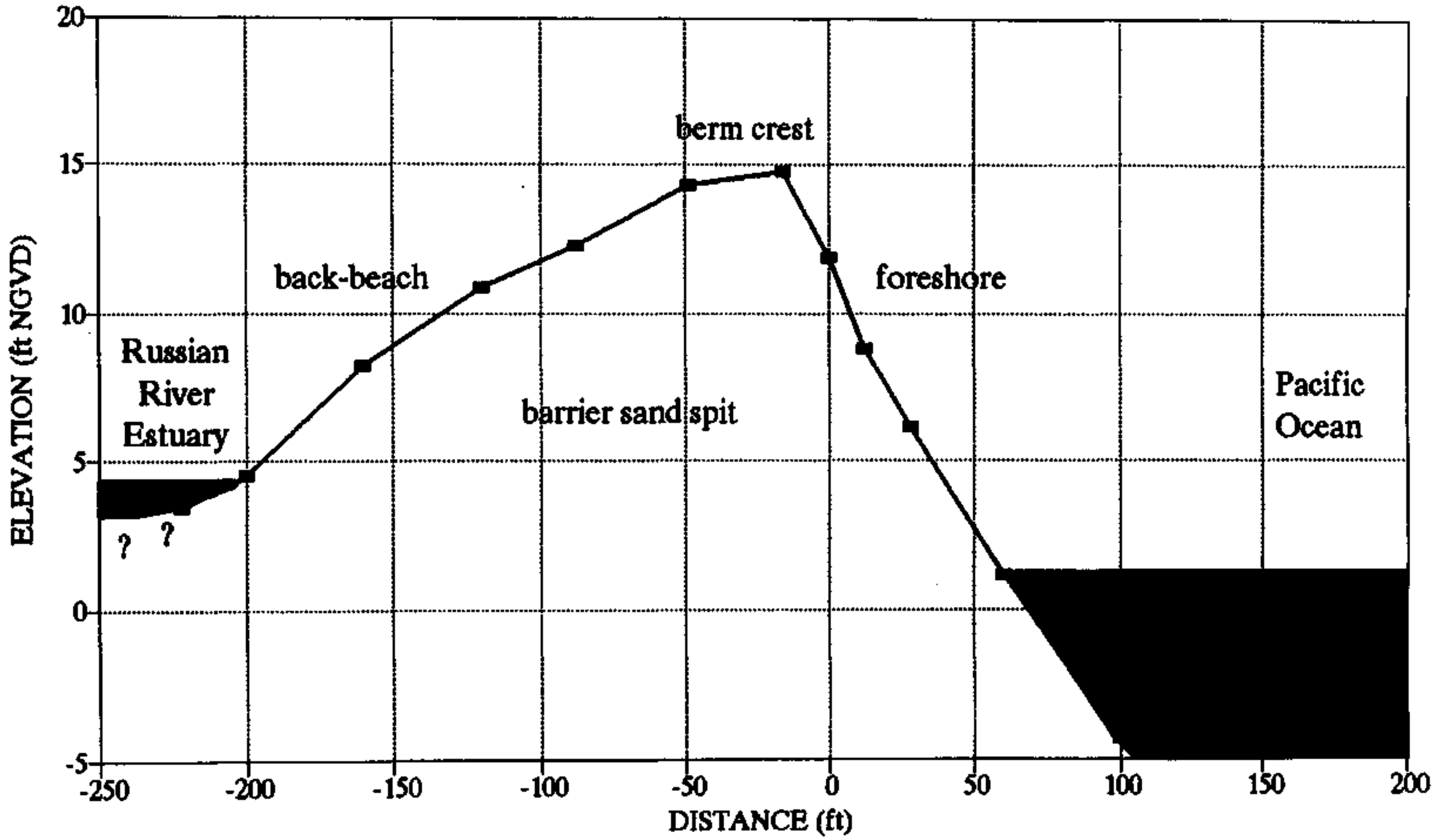
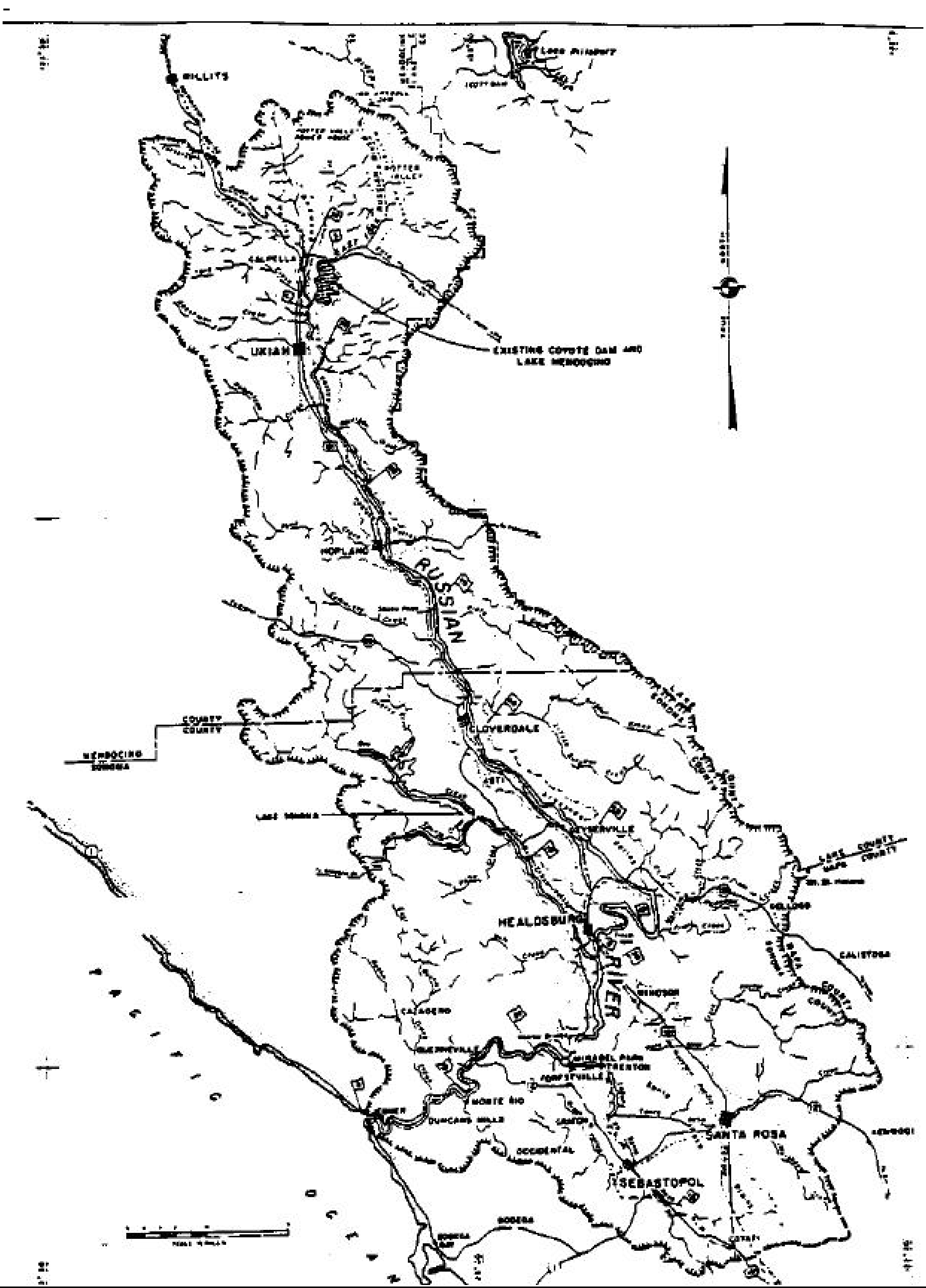
Russian River Estuary Project Beach Profiles - Profile P1, November 21, 1992

Figure 3.7a



CKC/RUSSNRVR/XSXNS/BCHPRFLS.WQl/P2-l12192/5-17-93

Philip Williams & Associates, Ltd. Consultants in Hydrology	**Russian River Estuary Project Beach Profiles - Profile P2, November 21, 1992**	Figure 3.7b



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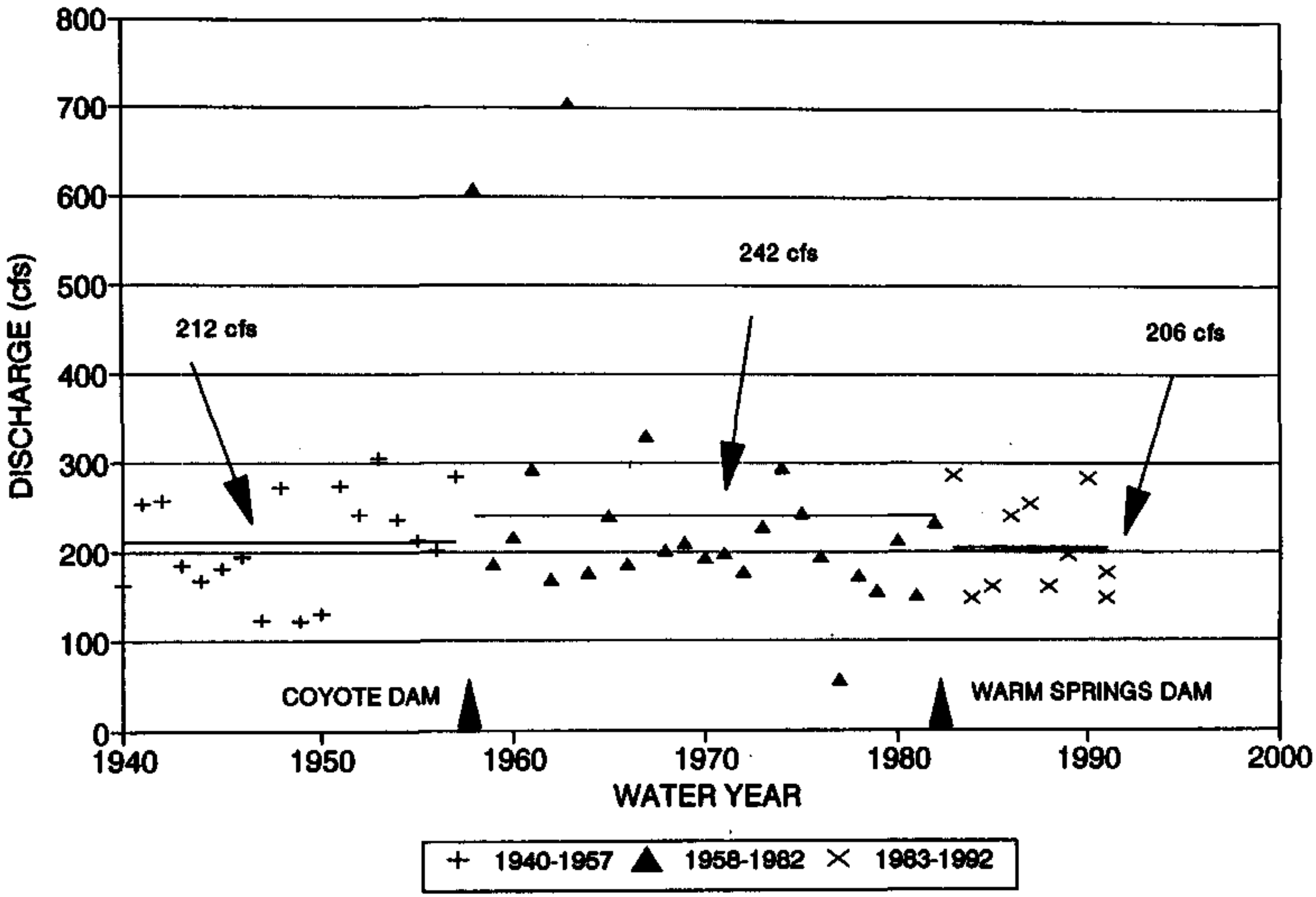
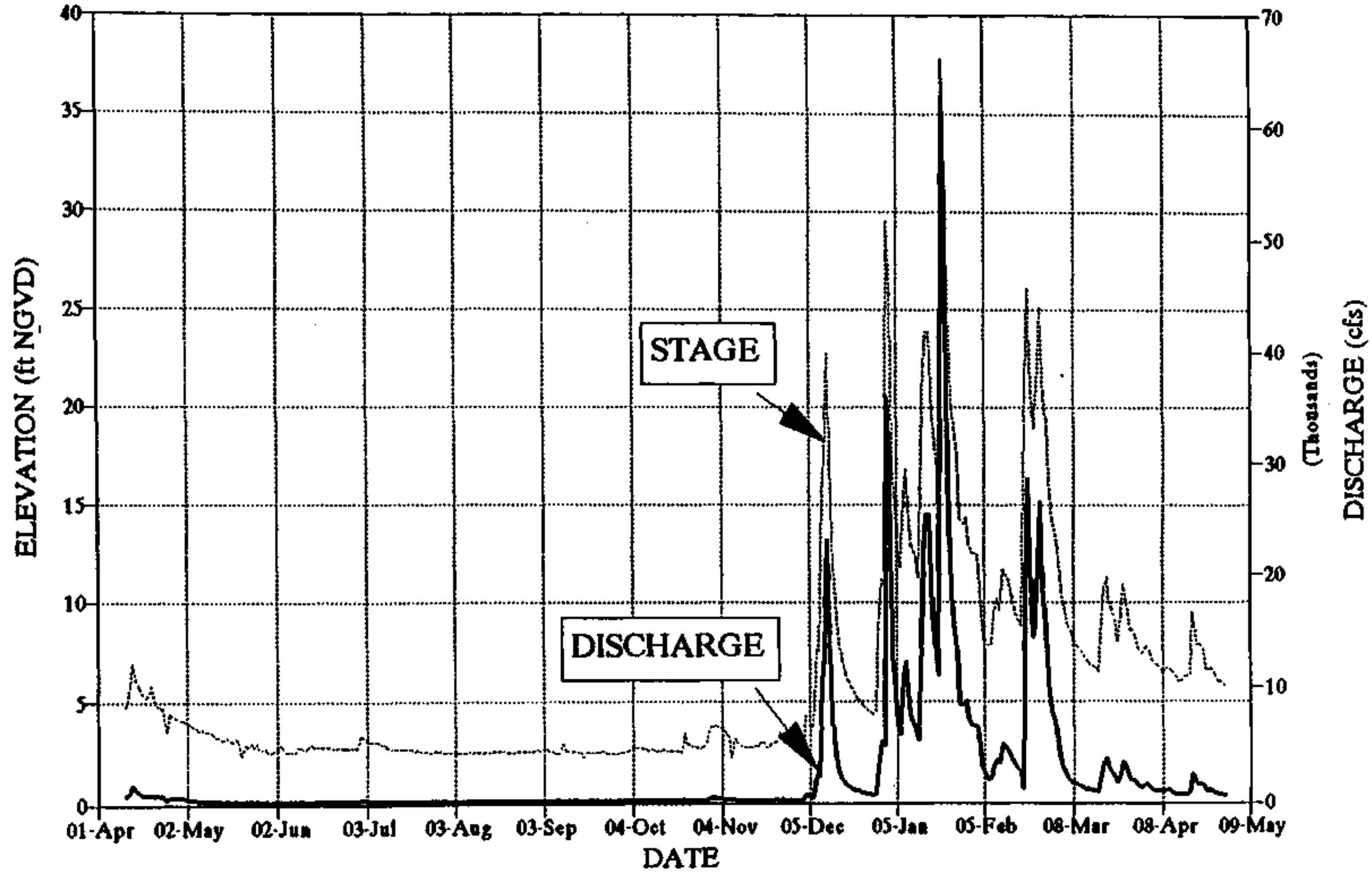
Watershed Map of the Russian River Estuary
Source: US Army Corps of Engineers, 1965

Figure 3.8

RUSSIAN RIVER NEAR GUERNEVILLE
AVERAGE DRY SEASON FLOW (O,J,J,A,S)



Philip Williams & Associates, Ltd. Consultants in Hydrology	**Mean Monthly Dry Season Discharges at Guerneville, 1939-92**	Figure 3.9



CKC/RUSSNRVR/FLOWDATA.WQl/STAGE.Q/3-14-93

Philip Williams & Associates, Ltd. Consultants in Hydrology	**Discharge and Stage in the Russian River, Hacienda Bridge for Flows Greater than 125 cfs, April 1992 through March 1993**	Figure 3.10

MINIMUM WIDTHS OF BARRIER BEACH

ESTIMATED FROM AERIAL PHOTOGRAPHS

DATE	MINIMUM WIDTH OF BARRIER BEACH (FT.)
September 23, 1945	192
September ‡, 1950	153
February 3, 1956	500
April 21, 1958	669
May 22, 1967	186
June 12, 1979	80
October 17, 1981	175
June 30, 1990	80
July 5, 1990	100

‡ Date not noted on aerial photograph

IV. INLET CHANNEL STABILITY

A. General Comment

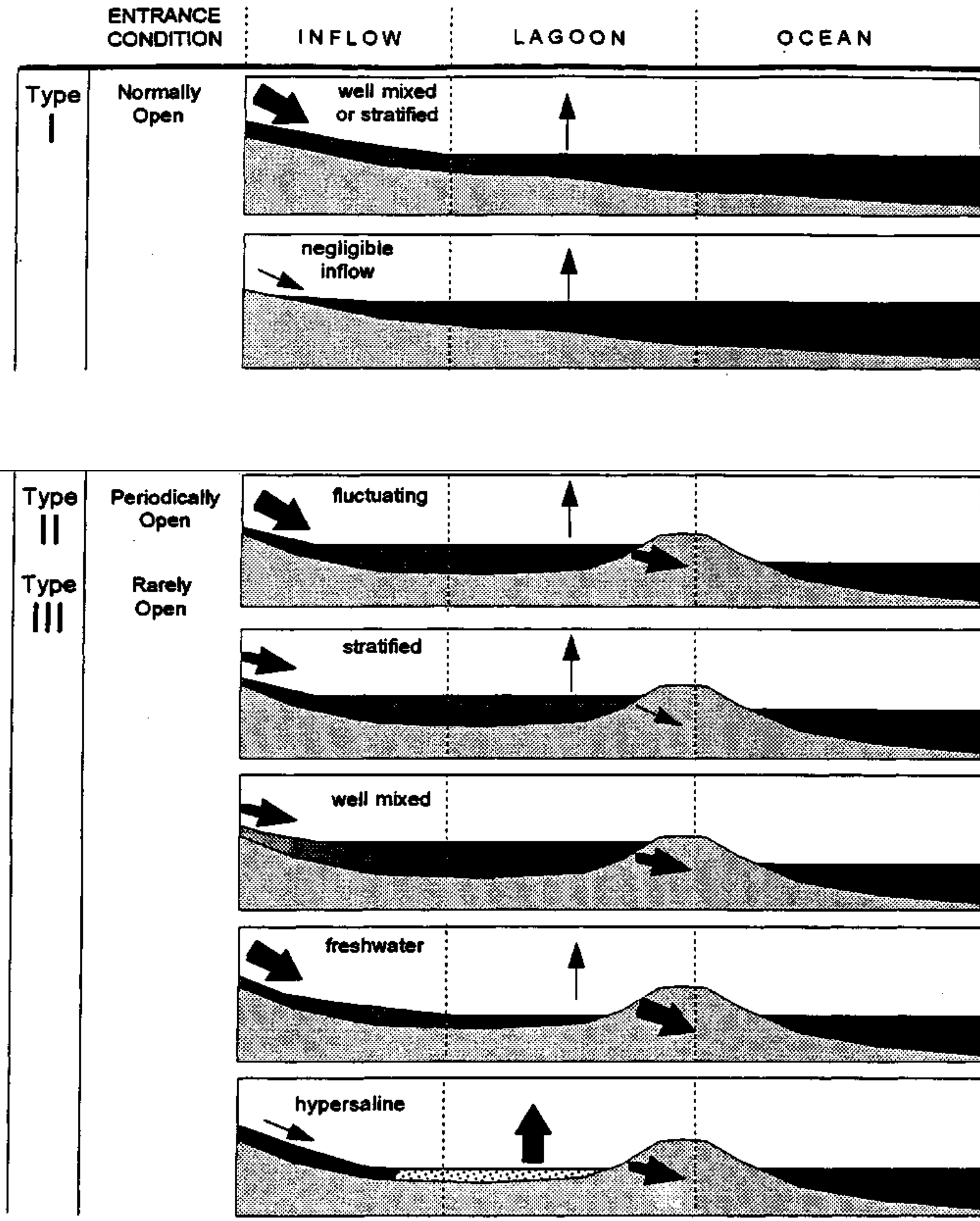
A lagoon is created in the lower reach of the Russian River when the mouth of the estuary is closed off by the barrier beach. There are several different types of coastal lagoons that can be formed along the California coast depending upon the freshwater inflow and either hydrologic conditions (Figure 4.1). The most important factor determining the type of lagoon is the nature of the inlet channel connecting the lagoon to the ocean. The inlet channel may be always open, never open or subject to periodic opening and governs the degree of tidal influence in the lagoon and adjacent marshes. The lagoon opening condition governs the depth, duration and frequency of inundation throughout the wetland. The salinity, period and frequency of inundation determine the distribution of habitat and therefore type of wildlife that will use the wetland.

The lagoon can be saline, brackish or fresh depending upon the lagoon opening condition, the freshwater inflows, seepage through the barrier beach and losses due to evapotranspiration. The salinity distribution in the lagoon and marshes depends on the mixing processes, including tidal trapping, tidal pumping, and the effects of wind.

High freshwater inflows and a very porous barrier beach usually result in predominantly freshwater conditions in the lagoon; for example, the Ventura River Estuary. Lesser quantities of freshwater inflow and limited mixing in a deep lagoon can result in stratified conditions throughout the lagoon; for example, Los Penasquitos Lagoon in California. Stratification can lead to elevated water temperatures in the salt water and anaerobic conditions at the lagoon bed. Fish kills and a stressed ecosystem have been observed to be associated with these conditions. If the lagoon inlet channel is closed and the freshwater inflows are small compared with the seepage losses and evapotranspiration, the lagoon can become hypersaline, with observed salinities exceeding 80 ppt. The Russian River Estuary is a Type II system with salinity stratification following closure of the barrier beach.

The hydrologic conditions within the lagoon can be predicted if the opening characteristics of the inlet channel, the tributary flows entering the lagoon, and the detailed bathymetry of the lagoon are known. Mathematical models are used to predict the flow and mixing processes in the system.

The inlet channel characteristics depend upon the balance between longshore sediment transport and wave action acting to close the inlet and the tidal prism (or volume of water stored between high and low



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Types of Coastal Lagoons in California
Source: Goodwin and Williams, 1992

Figure 4.1

tide) and freshwater inflows acting to scour the inlet channel. Local factors such as sediment characteristics, cobble bars, channel protection, and other geologic features also affect the configuration of the inlet channel.

There is no simple direct relationship between deep water wave energy and the energy associated with the tidal prism. Offshore waves are subject to refraction, diffraction and energy losses in the nearshore zone. The scouring potential of the tidal prism depends on the tidal range in the lagoon (which may be significantly less than the ocean) and the characteristics of the inlet channel. These difficulties may be overcome by a computer model describing the interaction between nearshore and lagoon processes. These kinds of model require extensive field data for validation and are still in the research phases of development.

An alternative approach is to utilize empirical or semi-empirical relationships developed during the past 50 years. The results of hydrodynamic computer models may be used to derive the parameters required for these semi-empirical methods.

The feasibility of maintaining the inlet channel of the Russian River Estuary open under normal conditions can be investigated by applying semi-empirical techniques that have been either developed for California coastal lagoons or which have been widely tested on Californian systems.

B. Comparison with Historical Conditions and other Lagoons in California

Under present conditions, the entrance of the Russian River remains open during the winter months when flows in the river are high and the barrier beach cannot form in the inlet. During periods of low river flows or intense wave action, the estuary entrance will close. An approximate estimate of the diurnal tidal prism is 1,750 acre-feet and for the mean tidal prism is 1,300 acre-feet (Table 4.1) in 1992. Historic records indicate that this tidal prism is approximately the same or less than conditions in 1876 which is insufficient to maintain the estuary open under all wave and flow conditions.

The possibility of maintaining the Russian River Estuary open to tidal action can be investigated by comparing the project site with other California lagoons. The tidal prism for other coastal lagoons in California are listed in Table 4.1. Each lagoon listed will have a different local wave climate, sediment particle size distribution, and watershed characteristics, but as a first approximation it appears that a substantial increase in the available tidal prism is required to maintain the Russian River Estuary always open to tidal action.

TABLE 4.1 TIDAL INLET CHARACTERISTICS FOR SOME CALIFORNIA COASTAL LAGOONS

SITE	LOCATION	POTENTIAL TIDAL PRISM ($10^6 ft^3$)		ANNUAL DEEP-WATER WAVE POWER (10^{11} FT-LB_F/FT/YR)	CLOSURE CONDITIONS
		DIURNAL	MEAN		
1	Smith River Estuary	35	24	303	(Infrequent)
2	Lake Earl	430	320	329	Frequent
3	Freshwater Lagoon	35	25	348	Always
4	Stone Lagoon	86	64	348	(Frequent)
5	Big Lagoon	240	180	348	(Frequent)
6	Eel River Delta	200	140	371	(Infrequent)
7	Estero Americano	22	15	(200)[a]	(Frequent)
8	Estero San Antonio	11	6.5	(200)	Frequent
9	Tomales Bay	1580	1070	209	Never
10	Abbotts Lagoon	17	11	307	Frequent
11	Drakes Estero	490	340	26	Never
12	Bolinas Lagoon	200	130[b]	117	Never
13	Pescadero	6.8	4.6	(200)	(Frequent)
14	Mugu, 1976	27	19	(100)	Frequent
15	Mugu, 1857	170	120	(100)	(Never)
16	Carpinteria	4.8[b]	1.5[b]	(50)	Infrequent
17	Agua Hedionda, 1976	80	55[b]	28	Never
18a	Batiquitos, 1985	20	13	(30)	Frequent
18b	Batiquitos, 1850	90	60	(30)	Never
19	San Dieguito, 1976	0.2	0.14	(30)	Frequent
20	San Dieguito, 1889	37	24	(30)	Never
21	Los Penasquitos, 1976	2	0.75	(30)	Frequent
22a	Tijuana, 1986	12.6[b]	4.8[b]	(100)	Infrequent
22b	Tijuana, 1977	14.8	8.3	(100)	Infrequent
22C	Tijuana, 1928	34.4	20.0	(100)	Never
22d	Tijuana, 1852	67.5	47.9	(100)	Never
23	Bolsas Bay, 1874	_	38	(30)	Never
24	Anaheim Bay	_	47	(30)	Never
25a	San Lorenzo River, c.	N/A	3.69	(200)	Frequent
25b	San Lorenzo River, est.	N/A	17.4	(200)	_
25	Bolsa Chica	113[b]	80[b]	29	_

[a] Parenthesis indicate an estimate of deep-water wave power.

[b] Indicates that tidal prism data based on a large-scale topographic map.

C. Maximum Velocity Criteria

For a tidal inlet to form and remain open the velocity of water moving out of the inlet must be sufficient to transport sediments deposited in the inlet by littoral drift and cross-shore transport driven by waves and wind. Thus a criteria of inlet stability is (Skou, 1990):

$$V_{MAX} > V_t \qquad (3.1)$$

where:

	V_{MAX}	=	maximum velocity in inlet
	V_t	=	critical threshold velocity (to move D_{50})
	D_{50}	=	mean sediment grain size

Byrne *et al.* (1980) discuss the results developed by various studies, producing a general approximation of conditions in oceanic inlets (Bruun, 1967; Jarrett, 1976) and an interesting observation is that for a stable inlet channel:

$$V_{MAX} \quad 1.0 \pm 15\% \ m/\text{sec} \ (3.28 \ ft/\text{sec}) \qquad (3.2)$$

This compares well with the theoretical value derived by O'Brien (1969).

Mean and maximum velocities that have been observed necessary for self-maintaining inlet channels summarized by Bruun (1978) are given in Table 4.2. For existing conditions, V_{MAX} can be measured but for any proposed lagoon configuration it is necessary to estimate V_{MAX} by computer simulations.

D. Escoffier Curve

Escoffier (1940) evaluated the stability of tidal inlets using the maximum inlet velocity, V_{MAX}, as a function of inlet channel cross sectional flow area, A_c. Escoffier (1940) derived an analytical solution for V_{MAX} based on equations presented by Brown (1928) and the following assumptions:

- Water entering and leaving the estuary through channels other than the inlet are negligible.
- There is a simple tidal variation in the ocean with a 24 hour period.
- Tidal variations in the ocean and estuary are sinusoidal.
- The flow area of the inlet channel (below MSL) is constant (prismatic) from ocean to bay.
- The surface of the estuary remains horizontal throughout the tidal cycle.
- The depth of the inlet channel is large compared with the range of the tide.
- The difference in head necessary to accelerate the mass of water in the inlet channel is neglected.

TABLE 4.2

MEAN AND MAXIMUM VELOCITY CRITERIA

Flow velocities required to maintain a lagoon entrance open to tidal exchange.

VELOCITIES (M/S)	ALL INLETS	SEMI-DIURNAL	DIURNAL
Vmean, max	1.00	0.99	1.03
Vmean (Keulegan, 1967)	0.75	0.71	0.81
Vmean	0.77	0.70	0.87

Source: Bruun, 1978.

- There is no surface runoff into the bay/lagoon.

$$V_{MAX} = c\left(\frac{A_c H}{2pL}\right)^{\frac{1}{2}} \left[\frac{(1+r^2)}{2} - r\right]^{\frac{1}{2}}$$

$$r = \left(\frac{12054c}{M}\right)^2 \frac{A_c^3}{2pHL}$$

where: V_{MAX} = mean velocity of peak tidal current (ft/sec)

c = Chezy's coefficient ($ft^{0.5}$/sec) = $R^{(1/6)}/n$

n = Manning's roughness coefficient

A_C = cross-sectional area of inlet channel (ft^2)

p = wetted perimeter of inlet channel cross-section (ft) $(2Ba)^{0.5}$

L = length of channel (ft)

H = mean tidal variation in the ocean (ft)

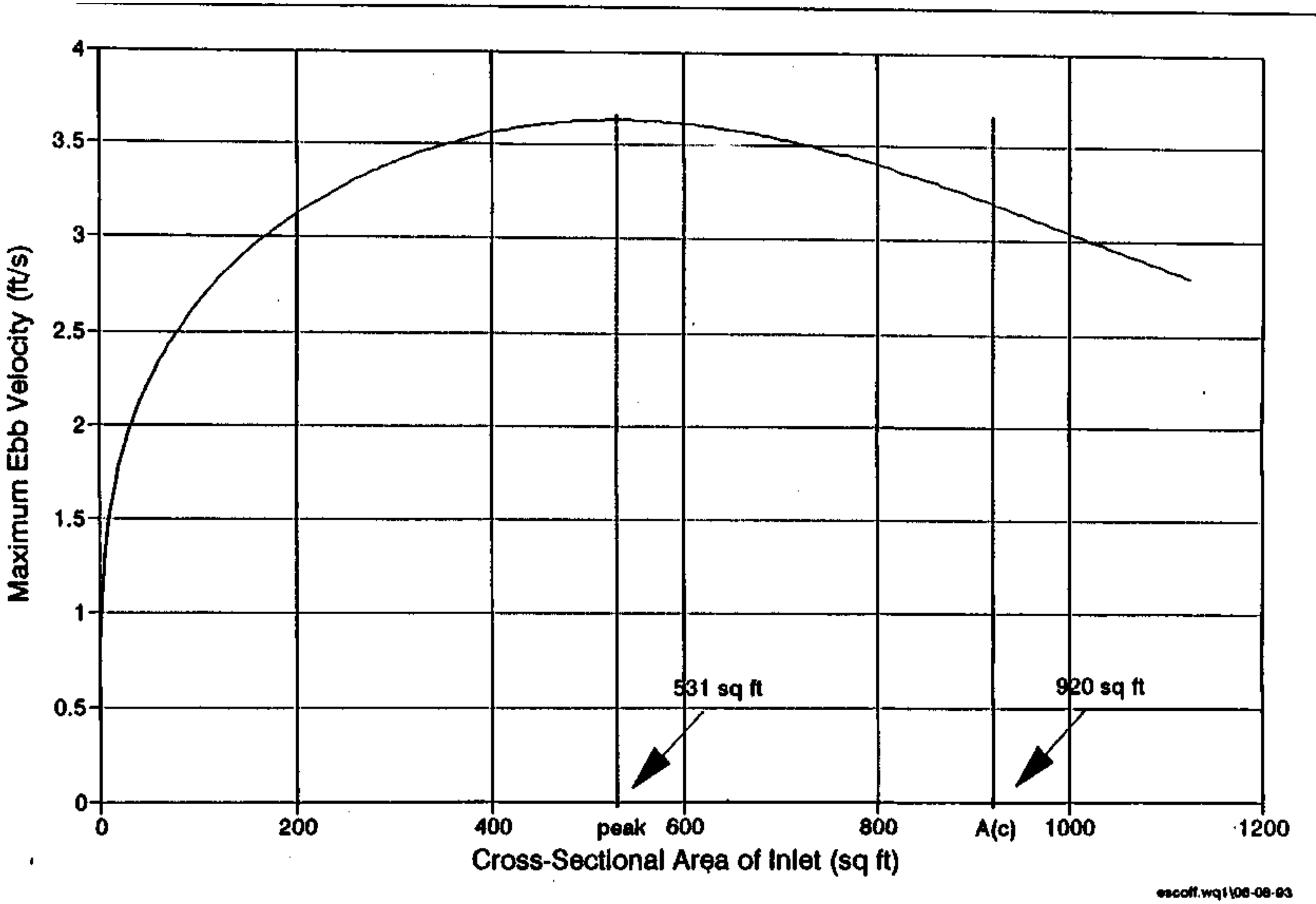
M = water surface are in bay/lagoon at MSL (ft^2)

Because V_{MAX} is a measure of sediment transport capacity, a small change in A_c will change the flow capacity of the inlet and lead to changes in erosion or deposition within the inlet (Skou, 1990).

The Escoffier Curve for the Russian River Estuary (Figure 4.2) shows that the maximum ebb velocity at the inlet is approximately 3.7 ft/s and occurs at a cross-sectional inlet area of approximately 530 ft^2.

The equilibrium cross-sectional area of the inlet channel using Jarrett (1976) equation is 920 ft^2.

The Escoffier Curve demonstrates that as the area of the inlet channel is reduced from 920 ft^2 by wave action to about 250 ft^2, the ebb velocity is increased. According to Escoffier's theory, the scouring action in the inlet channel is proportional to the maximum ebb velocity. Therefore, an increase in the ebb velocity will increase the scouring in the inlet channel and the cross-sectional area will increase and move back towards the equilibrium value of 920 ft^2. However, if a wave storm decreases the inlet to less than 250 ft^2, the maximum ebb velocity and scouring ability is reduced and the inlet area becomes smaller and smaller until closure occurs.



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Escoffier Curve for the Russian River Estuary

Figure 4.2

Under neap tide conditions, the peak ebb velocity is reduced from 3.2 ft/s to less than 3.0 ft/s or the critical velocity predicted by Bruun and O'Brien (Section 3.3).

E. Wave Power - Tidal Prism Relationship

The wave climate incident upon a tidal lagoon beach provides the energy to move sediments into the tidal inlet by littoral drift or cross-shore transport. Thus the greater the wave energy incident upon the beach relative to the tidal prism, the greater the potential instability of the system. Johnson (1973) presented the relationship (3.5) expressing an inlet closure parameter, C_w, based on the ratio of wave energy and tidal energy. The inlet will close at particular value of $C_w = C_{crit}$, giving the following stability criterion:

$$\frac{C_W}{C_{crit}} < 1 \qquad \textit{inlet remains open}$$

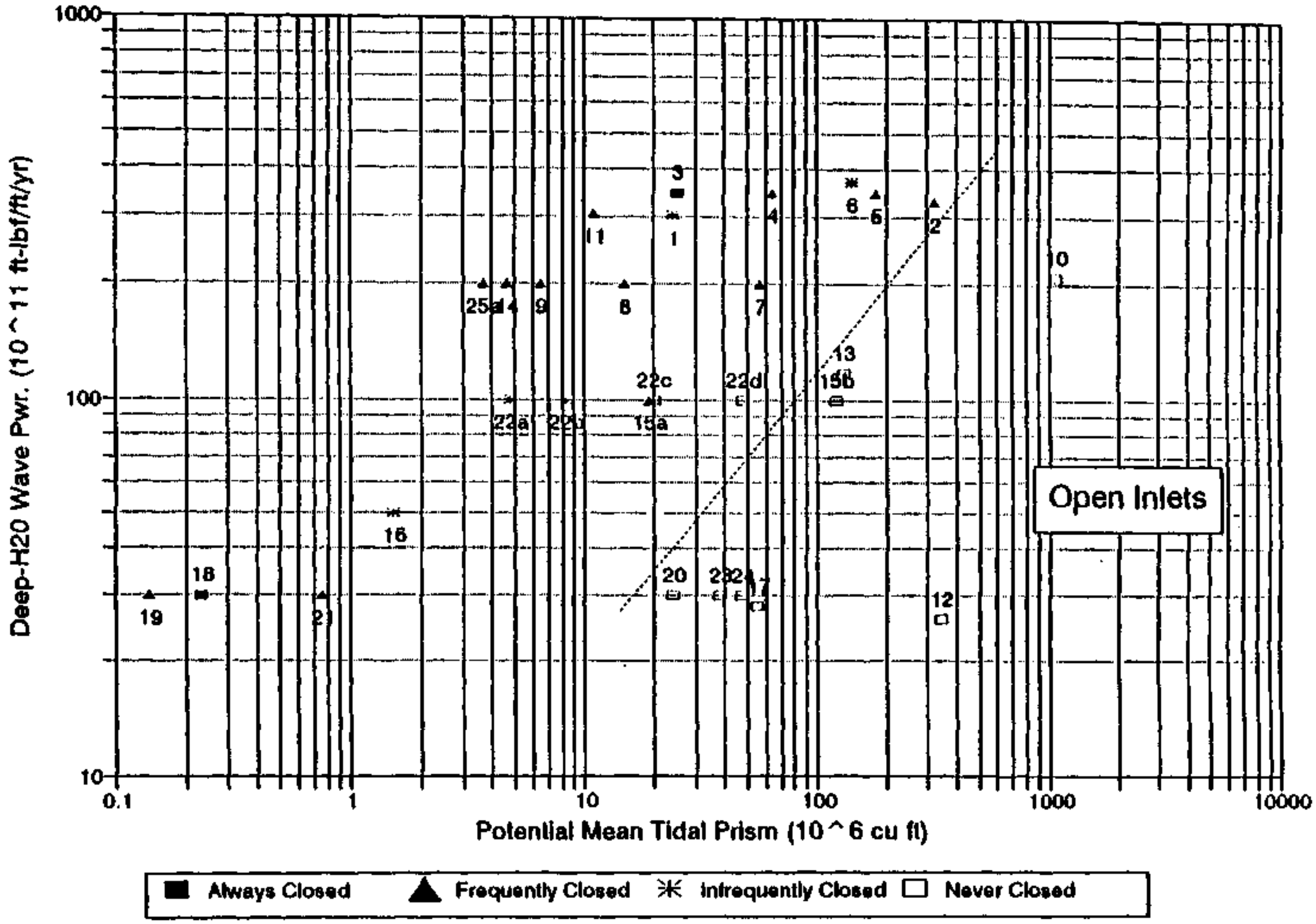
$$\frac{C_W}{C_{crit}} > 1 \qquad \textit{inlet will dose} \qquad (3.5)$$

$$C_W = \frac{E_S T_p W_C}{P(2ç_{o_S})p} \qquad (3.6)$$

where: C_w = closure criteria parameter
E_s, = wave energy in ft*lbs/ft
T_P = tidal period in seconds
W_c = width of entrance in feet
P = tidal prism in cubic feet
$^3{}_{o_S}$ = tidal amplitude in feet
p = unit weight of water in lbs/ft^3

Because of the difficulty defining the value of E_s, Johnson (1973) derived an alternative approach to Equation 3.5 using the annual deep water wave power (P_w). Johnson correlated P_w to potential tidal prism (P), finding that for a specific value of the P_w, there is a specific volume the P must exceed for the inlet to remain open.

These results are tabulated in Table 4.1 and illustrated in Figure 4.3. The identification numbers of symbols in Figure 4.3 correspond to sites listed in Table 4.1.



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Johnson Criteria for Closure of an Inlet: Annual Deep-Water Wave Power vs. Potential Mean Tidal Prism

Figure
4.3

The potential mean tidal prism for the Russian River Estuary is approximately 78 million cubic feet and the annual deep water wave power is approximately 200 x 10^{11} ft-lbf/ft/yr. Figure 4.3 shows that the Russian River Estuary is subject to closure and a substantial increase in tidal prism would be required to maintain the estuary open to tidal circulation at all times. The costs and environmental impacts of dredging the estuary prohibit this being a viable management alternative.

F. Littoral Drift - Tidal Prism Relationship

Bruun (1962, 1978) examined the actual quantity of sediment input into the tidal inlet system. Bruun's studies were empirical and examined inlet stability as a function of tidal prism (neap tide, ft^3), P_{NEAP} , and sediment input towards the inlet channel from the ocean side of the lagoon (during one tidal period in ft^3), Q_{LS}. Flows in the inlet channel must have the capacity to transport external sediment input (Q_{LS}) in addition to sediment being transported through the creeks and rivers tributary to the lagoon. This external sediment delivery to the channel is from littoral drift and bank erosion. Bruun (1962, 1978) established a stability criterion based upon the ratio of P_{NEAP} and Q_{LS} (Table 4.3):

Bruun also derived a relationship between cross-sectional area and littoral drift.

$$\frac{P}{Q_{LS}} = \frac{A_c V \frac{T_p}{2}}{Q_{LS}} \qquad (3.6)$$

where: Q_{LS} = drift of sediment during one tidal period towards the inlet (m^3)

P = neap tidal prism (m^3)

A_c = cross-sectional area (m^2)

T_p = tidal period in seconds

V = mean velocity through inlet (m/s)

The relationship between the littoral drift and inlet channel area is summarized in Table 4.4. Herein, longshore transport processes in major storms are assumed to be the dominant contributor of sediment from the ocean side of the lagoon. O'Brien (1972) has shown that under some conditions cross-shore transport may be significant.

Estimates for the monthly longshore transport rate have been determined by Johnson (1956) and de Graca (1976). The peak month for longshore transport is April, with an estimated monthly transport rate of 11.5 million ft^3 or 0.282 million ft^3/day. The potential neap tidal prism for the Russian River Estuary is

TABLE 4.3

RELATIONSHIP BETWEEN LONGSHORE TRANSPORT
TIDAL PRISM AND INLET CHANNEL STABILITY

BRUUN'S TIDAL INLET STABILITY RELATIONSHIPS	
$150 < (P_{NEAP}/Q_{LS})$	conditions are good, very good flushing and minor bar formation
$100 < (P_{NEAP}/Q_{LS}) < 150$	less good condition, an offshore bar formation is more pronounced
$50 < (P_{NEAP}/Q_{LS}) < 100$	rather large bar by entrance, but usually a channel through the bar
$20 < < (P_{NEAP}/Q_{LS}) < 50$	typical "bar-bypasser" Get flushed by the increased water discharge during storm and monsoons
$(P_{NEAP}/Q_{LS}) < 20$	very unstable inlets, mainly just overflow channels

TABLE 4.4

RELATIONSHIP BETWEEN SEDIMENT TRANSPORT,
INLET CHANNEL AREA, AND CHANNEL STABILITY

Bruun's Relationship between A_C and Q_{LS}

ASSUMPTIONS:

Mean maximum velocity set to 0.67 m/s
Most tidal inlets affected by semi-diurnal tide

0.0135	<	(A_C/Q_{LS})	good stability
0.00675	<	$(A_C/Q_{LS}) < 0.0135$	fair stability
(A_C/Q_{LS})	<	0.00675	poor stability

39 million ft^3. Bruun's ratio $\frac{P_{neap}}{Q_{LS}}$ is approximately 100, indicating the formation of a large bar at the inlet. The velocity in the inlet channel can be estimated under neap tide conditions from Equation 3.6 to be about 2.0 ft/s which is less than the critical value of 3.0 ft/s defined by Bruun.

Bruun's ratio of $\frac{A_c}{Q_{LS}}$ in metric units is 0.008 which indicates poor/fair stability of the inlet channel.

G. Summary of the Inlet Stability of the Russian River

A range of semi-empirical criteria for the closure of the Russian River Estuary has been examined. These criteria indicate that under the existing conditions, the Russian River Estuary will be subject to periodic closure. These predictions are consistent with recent and historic observations. These simple criteria also indicate that the inlet channel could be maintained open to tidal exchange under most hydrologic conditions only if the longshore or cross-shore transport rate was reduced, or if the tidal prism is increased. The rate of longshore transport can be reduced by the construction of jetties (refer to Section 6.3). A substantial increase in the tidal prism would require extensive dredging and is discussed in Section 6.5.

V. FREQUENCY OF INLET CLOSURE

A. The Physical Processes Associated with Lagoon Opening and Closures

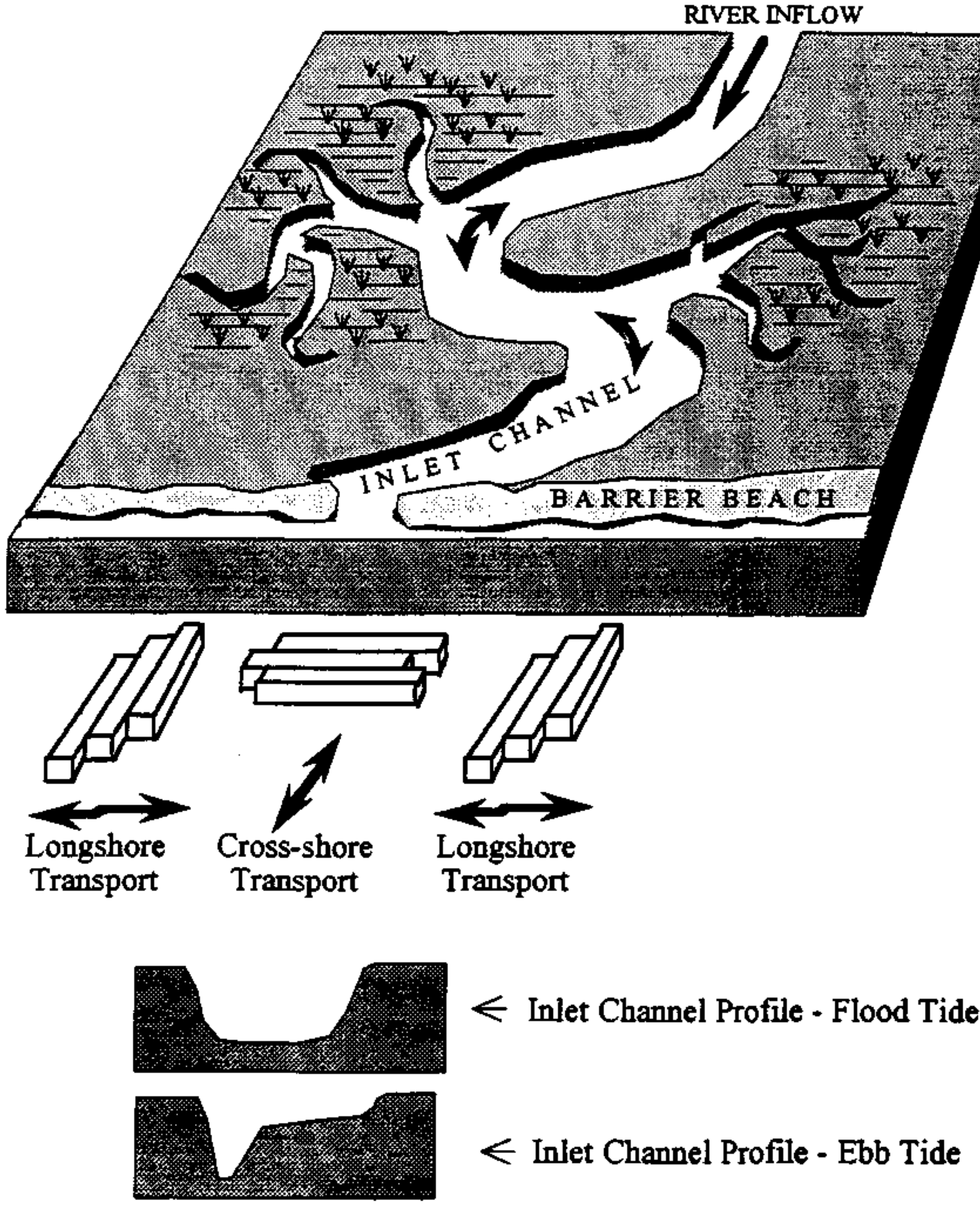
The mouth of the Russian River Estuary is subject to periodic closure (refer to Section 3). The dimensions of the mouth of the estuary are important factors affecting the tidal exchange between the ocean and estuary and are governed by the balance between nearshore sediment transport, and volume of water passing through the inlet during a tidal cycle. A conceptual representation of the balance between longshore and cross-shore sediment transport driven by ocean waves and the scouring of the inlet by flows is shown in Figure 5.1.

Historical accounts by local residents and records maintained by the County (Schrad, 1992) show that the estuary remains open during periods of low wave intensity and moderate to high freshwater inflows. If the scouring action of the tidal flows through the inlet is less than the rate of deposition of sand in the inlet due to longshore or cross-shore sand transport, the mouth of the estuary begins to close as the barrier beach extends across the inlet.
Closures usually occur during the spring, summer, and fall when the contributions of river flow are small. Appendix VI provides an incomplete record of lagoon openings and closures between 1930 and 1974 and a summary of County records on artificial breaches since 1988.

This summary demonstrates that most closures occur during the summer months and that artificial breaches have been undertaken at least since 1968. It is possible that prior to 1968, breaching was undertaken by local residents, although no records exist to document the frequency or criteria used to determine whether a breach was required.

Table 5.1 describes the cycle of inlet channel closures during the study period between April 17, 1992 and March 29, 1993. There were three artificial breaches completed by the County: one natural breach at a low elevation; and two breaches which may have been natural or artificially induced by individuals other than the County. The variation of water levels are shown in Appendix IV for the entire study period.

Figure 5.2 illustrates the tidal prism and sources of flows in the estuary when the inlet channel is open to tidal action, following a breach. Unless the wave intensity is small (the forcing mechanism for the beach transport) or the freshwater inflows increase significantly, the area of the inlet channel may decrease steadily and the inlet channel is frequently forced north as the estuary closes. The decrease in inlet area results in a reduction of tidal exchange and the tidal amplitude in the estuary is also



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Physical Processes within the Inlet Channel of an Estuary

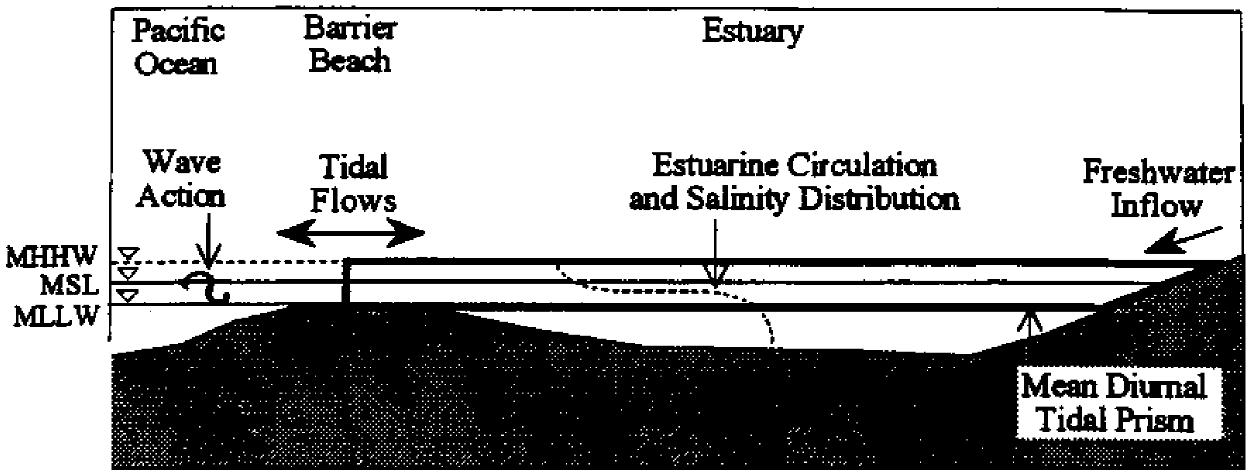
Figure 5.1

TABLE 5.1

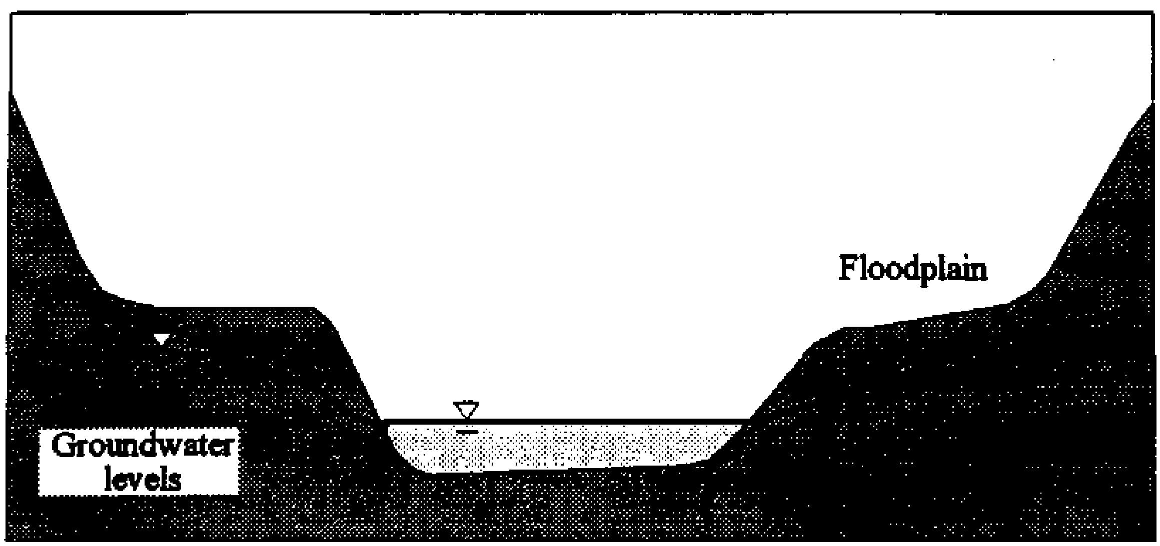
SUMMARY OF ESTUARY OPENINGS DURING THE STUDY PERIOD
APRIL 17, 1992 - MARCH 31, 1993

DATE	INLET CHANNEL CONDITION	WATER SURFACE ELEVATION ft (NGVD)	COMMENT
April 17-24, 1992	Open	Tidal	Tide Gage Installed at Jenner
April 24-May 1, 1992	Closed	4.20	
May 1-26, 1992	Open	Tidal	Natural breach
May 26-June 4, 1992	Closed	8.9	
June 4-July 8, 1992	Open	Tidal	Artificial breach by County
July 8-July 17,1992	Closed	6.5	
July 17-August 3, 1992	Open	Tidal	Natural or resident assisted breach
August 3-August 11, 1992	Closed	6.1	
August 11-September 21, 1992	Open	Tidal	Natural or resident assisted breach
September 21-0ctober 7, 1998	Closed	8.9	
October 7-November 23, 1992	Open	Tidal	Artificial breach by County
November 23-November 30, 1992	Closed	9.7	
November 30, 1992-March 29, 1993	Open	Tidal	Artificial breach by County
March 29, 1993			Tide gage removed, End of current study

Longitudinal Profile of Estuary



Cross-Section Through Estuary



Philip Williams & Associates, Ltd. Consultants in Hydrology	Conceptual Model for Predicting the Frequency of Breaching **(a) Inlet Channel Open**	Figure 5.2

reduced. This effect further reduces the scouring ability of the inlet channel and the estuary mouth gradually closes, creating a lagoon on the inland side of the barrier beach.

The water level in the lagoon will rise gradually, if the total inflows exceed losses due to seepage through the barrier beach, groundwater recharge, and evaporation (Figure 5.3). The water level will rise to the lowest point on the barrier beach, when a natural breach would occur by overtopping (unless an artificial breach occurs at a lower elevation).

The height of the barrier beach is determined by the wave runup and is dependent on the local wave conditions following closure. During the current study, the height of the barrier beach varied between +4.2 feet to +15.0 feet NGVD during closure conditions. A water surface elevation of 15 feet NGVD in the lagoon would cause significant inundation of property (Section 5.2) and it is current practice to breach at an elevation of 8.0-10.0 feet NGVD.

When the barrier beach is overtopped, or breached artificially, the establishment of the inlet channel is not instantaneous, and sometimes more than one tidal cycle is required to drain the estuary. The development of the inlet channel takes several hours and is dependent upon the difference between the water level in the ocean and estuary and the width of the barrier beach. The development of the channel width was measured during the artificial breach on October 7, 1993 (Figure 5.4). The channel enlarged from the width of the bulldozer used for breaching (approximately 10 feet) to 225 feet in a period of 3 hours.

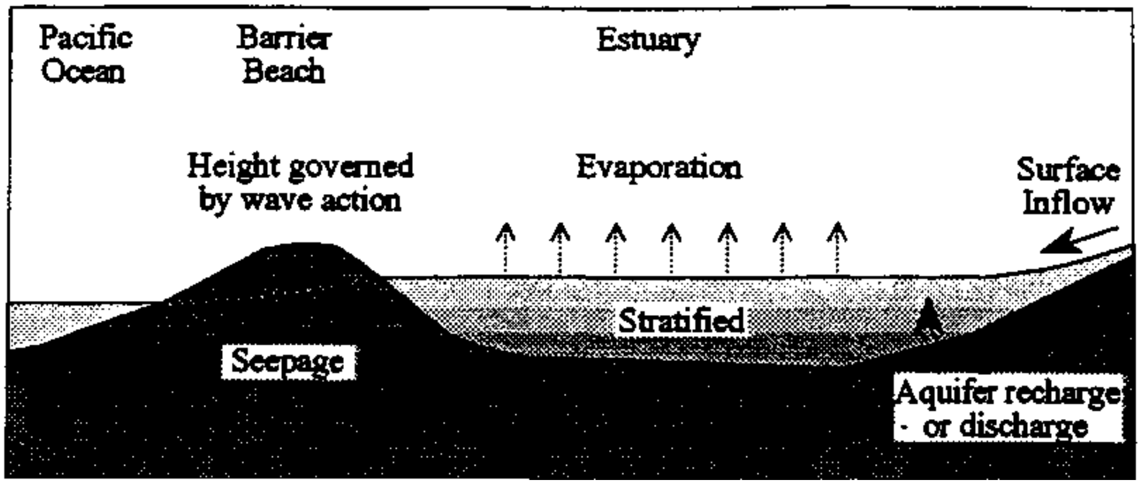
B. A Model of the Cycle of Inlet Openings

The frequency of natural breaching or artificial breaching following closure can be predicted by a simple mass balance model:

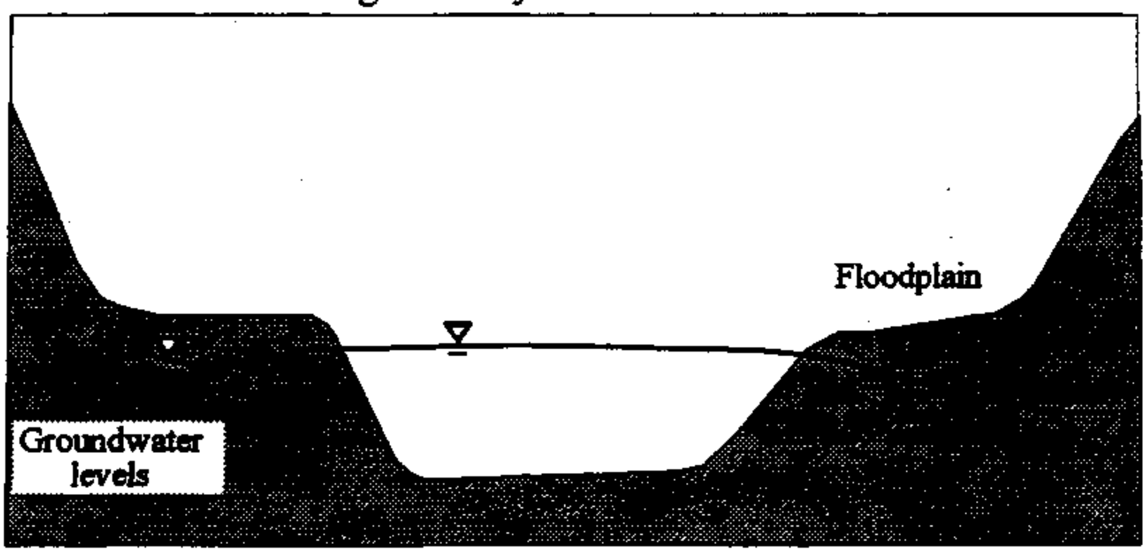
$$A\Delta Z = (Q - Ai_{evap} - Q_s - Q_{GW})\,\Delta t$$

where:	A	=	the surface area of the lagoon (ft^2)
	ÄZ	=	the change of water level in the lagoon (ft) during the time step *Ä*t(s)
	Q	=	the freshwater inflow to the lagoon from the Russian River and tributaries (ft^3/s)
	Q_S	=	the seepage loss through the barrier beach (ft^3/s)
	Q_{GW}	=	the loss or gain of water from the aquifer adjacent to the estuary (ft^3/s)
	i_{evap}	=	the rate of evaporation from the estuary (ft/s)

Longitudinal Profile of Estuary



Cross-Section Through Estuary



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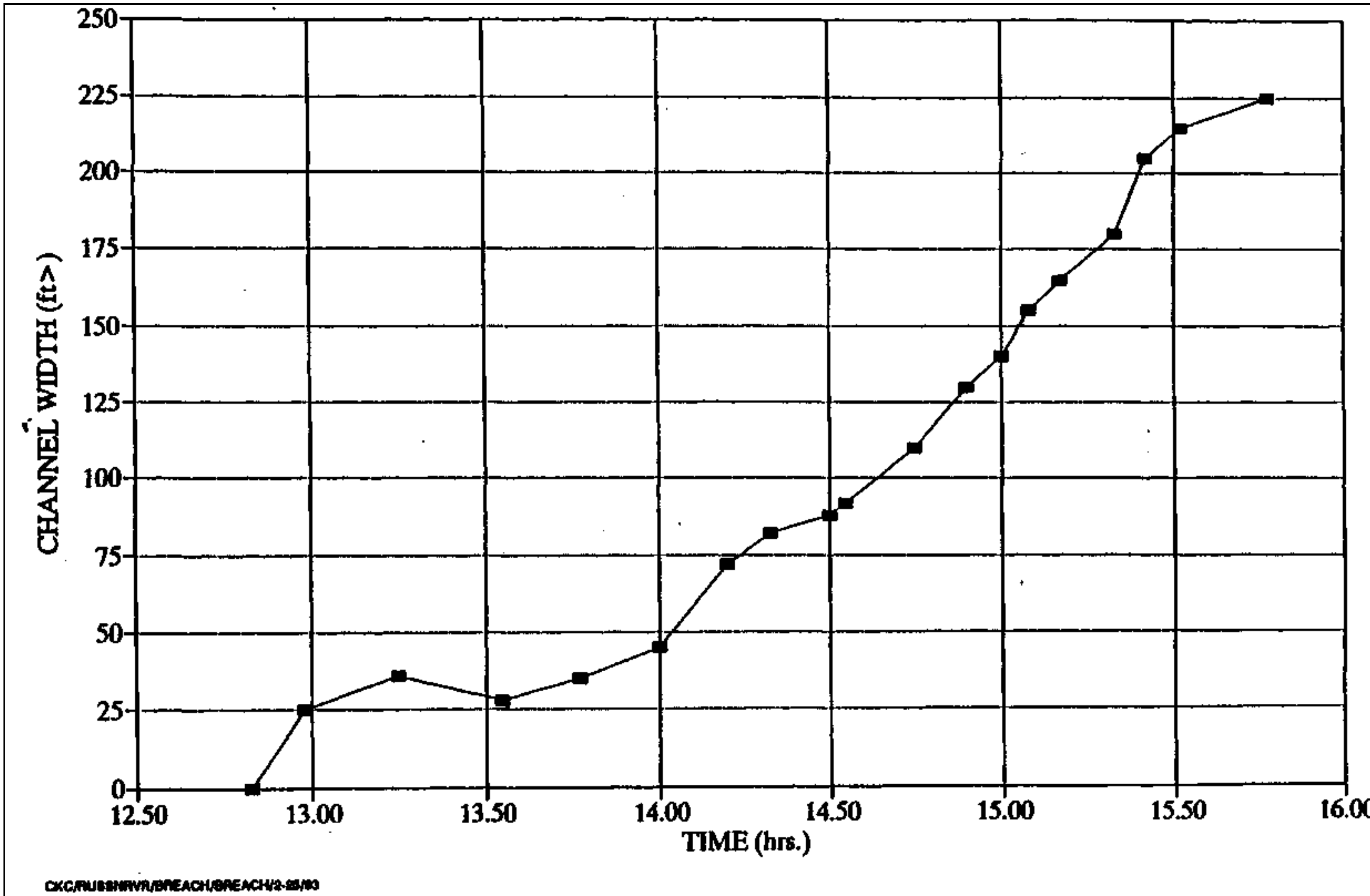
Conceptual Model for Predicting the Frequency of Breaching
(b) Inlet Channel Closed

Figure 5.3



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Width of Inlet following Artificial Breach, October 7, 1992

Figure 5.4

Q is obtained from the USGS gaging station at Hacienda Bridge. Q_{GVV} accounts for the losses between Hacienda Bridge and Monte Rio (the upstream limit of the model) and the interaction with the aquifer adjacent to the estuary. No detailed information is available for the aquifer groundwater elevations or extraction rates by wells. Therefore, Q_{GW} is a calibrated variable in the model. The rate of seepage through the barrier beach (Q_S) is estimated using the method of Valentine (1989). The stored volume of water in the estuary or the surface area of the lagoon, *A,* can be determined at any given elevation from the stage-storage curve (Figure 5.5) and the area-elevation relation (Figure 5.6). The rate of evaporation by month is estimated from values published by Goodridge (1979).

C. Calibration and Validation of the Model

The model was applied to the four periods of inlet channel closure during the study period for which there was a complete water surface record, namely: May 26 through June 4; July 8 through July 17; August 2 through August 12; and September 21 through October 8.

A comparison of observed and predicted water surface elevations are shown in Figures 5.7 to 5.10.

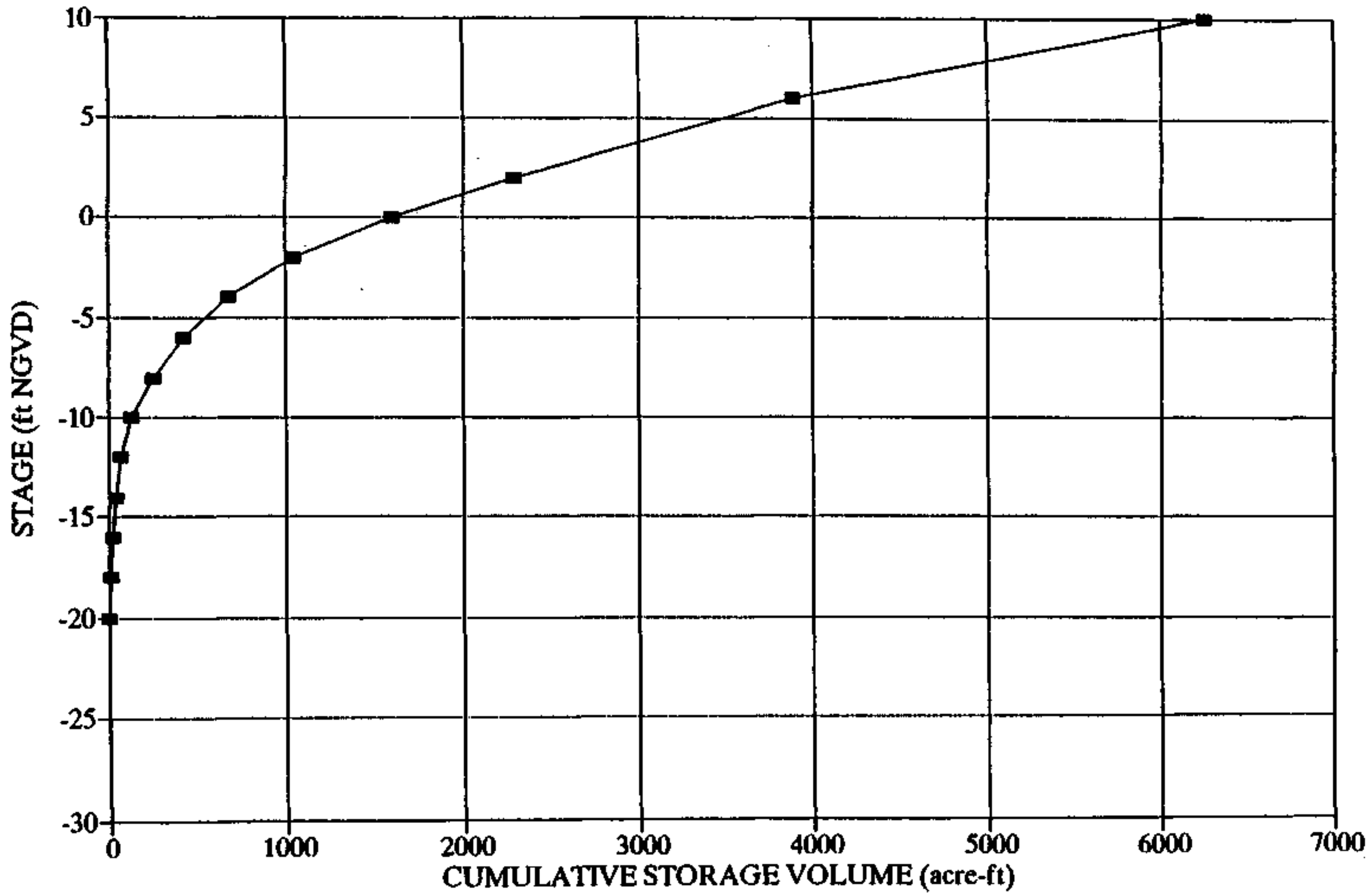
In these model predictions, the calibrated value of the losses between Guerneville and Monte Rio showed some variation, and the losses appear to be significant during the months of July, August, and September. If the model is to be used as a management tool, it is recommended that the predicted losses due to aquifer recharge and groundwater pumping be confirmed by a few stream discharge measurements at Monte Rio (or above the influence of tidal action). Preliminary predictions of these losses upstream of the estuary ranged from 0 percent of the flow in May to almost 40 percent in August. Despite this uncertainty, the model appears to give reasonable predictions of the rate of rise of water surface elevation in the estuary under closed inlet conditions.

D. Empirical Prediction of the Closure of the Entrance of the Estuary

The length of time that the estuary will be open to tidal exchange depends upon the following:

- *Intensity of Wave Energy.* The wave energy governs the longshore and cross-shore sediment transport rate which acts to close the inlet channel.

- *Sediment Availability.* There must be sufficient sediment available on the foreshore to fill the inlet channel.



CKC/RUSSNRVR/RRSTOR/CUMVOL/2-25-93

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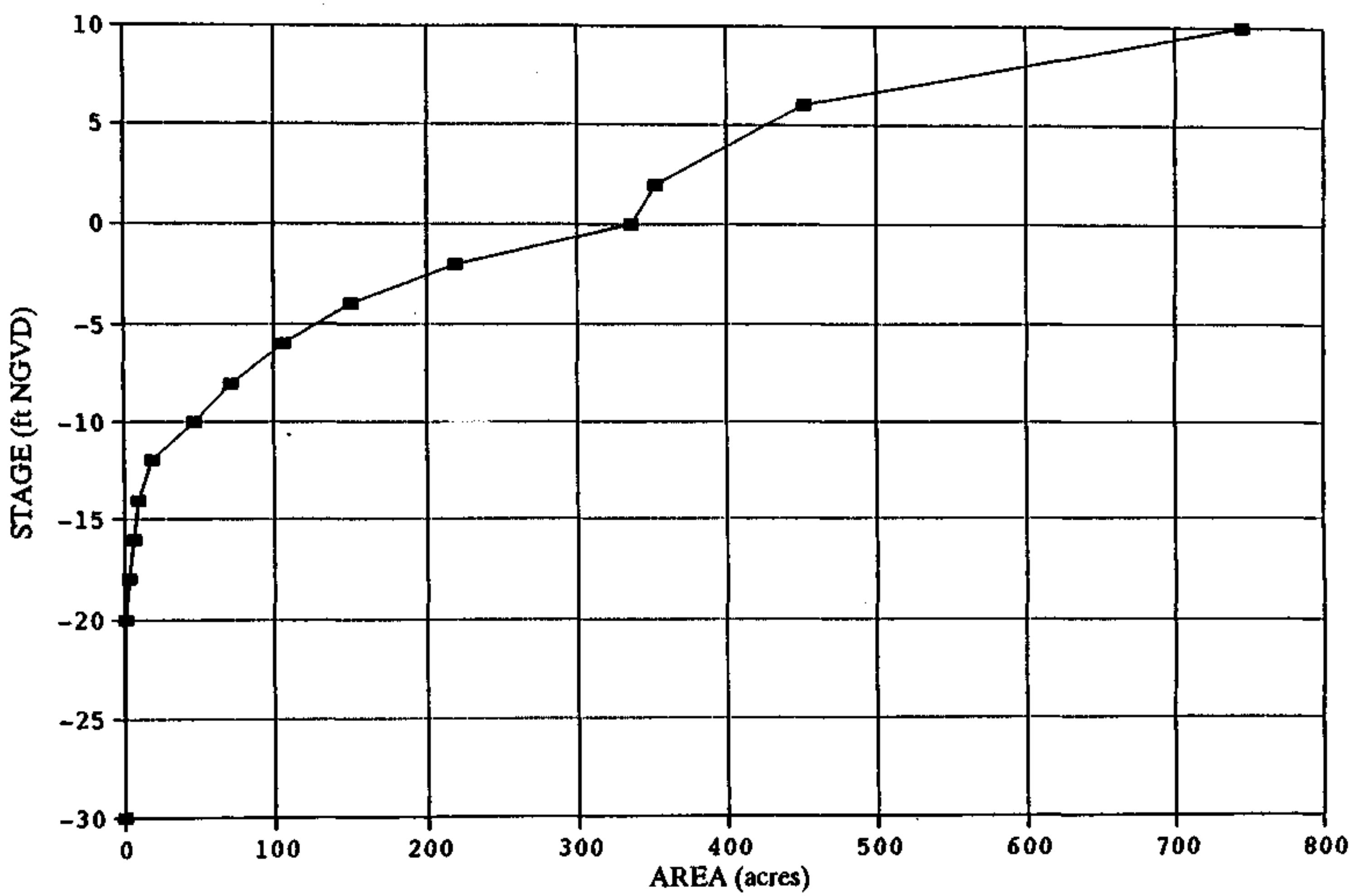
Cumulative Stage-Storage Curve for Russian River Estuary - River Mouth to Monte Rio

Figure 5.5



CKC/RUSSNRVR/RRSTOR.WQ1/AREA/2-25-93

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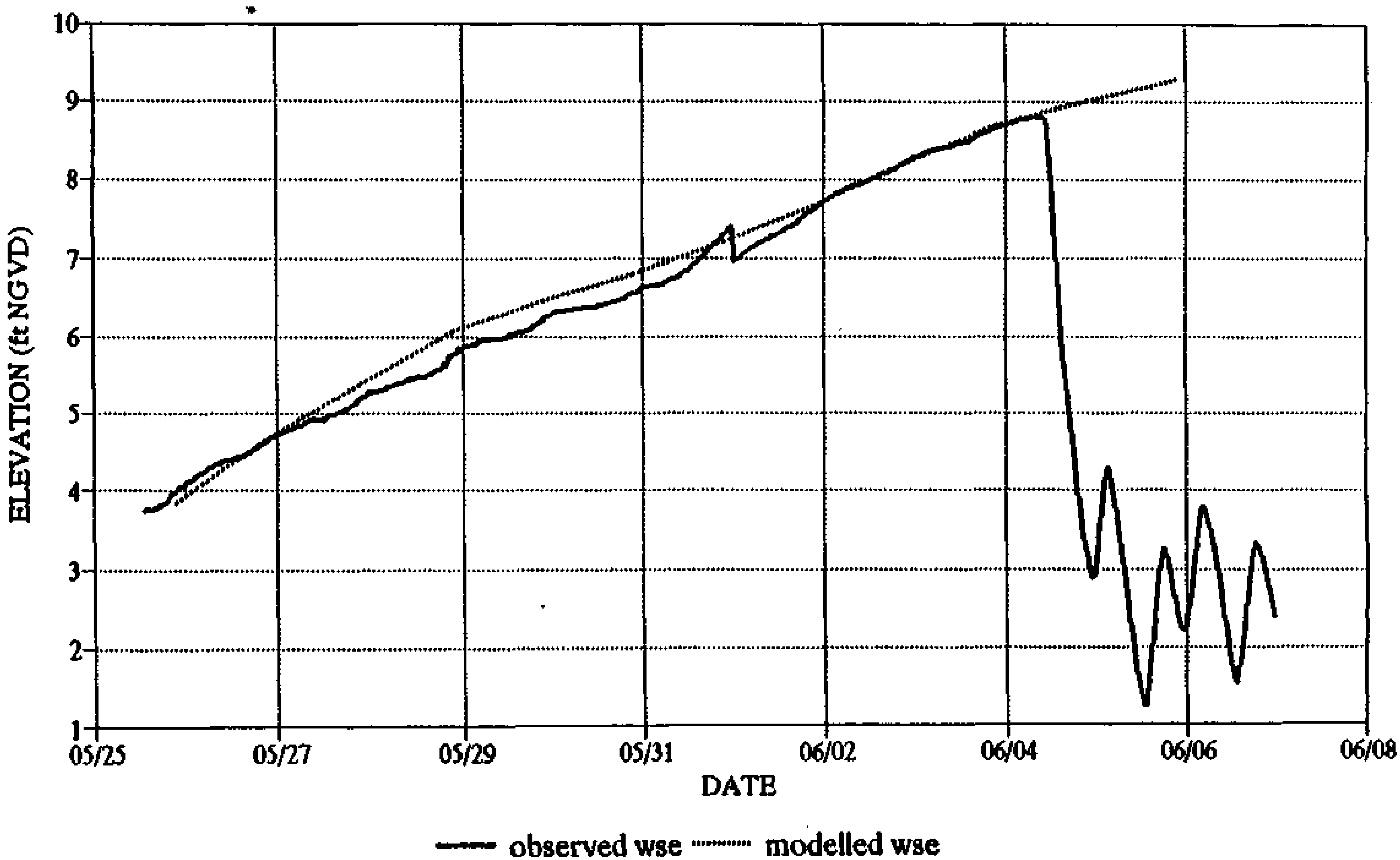
Stage-Area Curve for Russian River Estuary - River Mouth to Monte Rio

Figure 5.6



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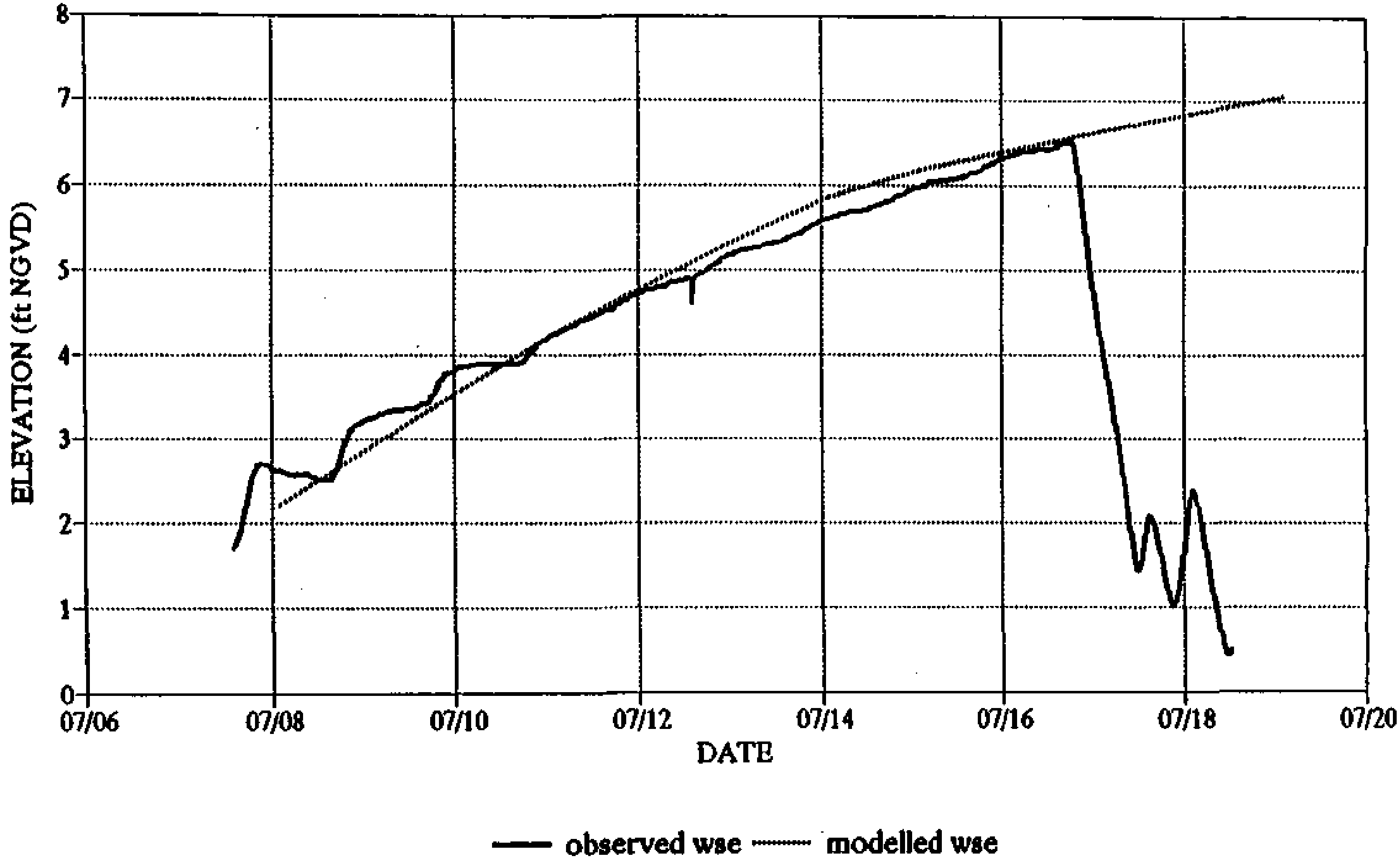
Simulation of Variation in Water Level in Estuary
May 26 - June 4, 1992

Figure 5.7



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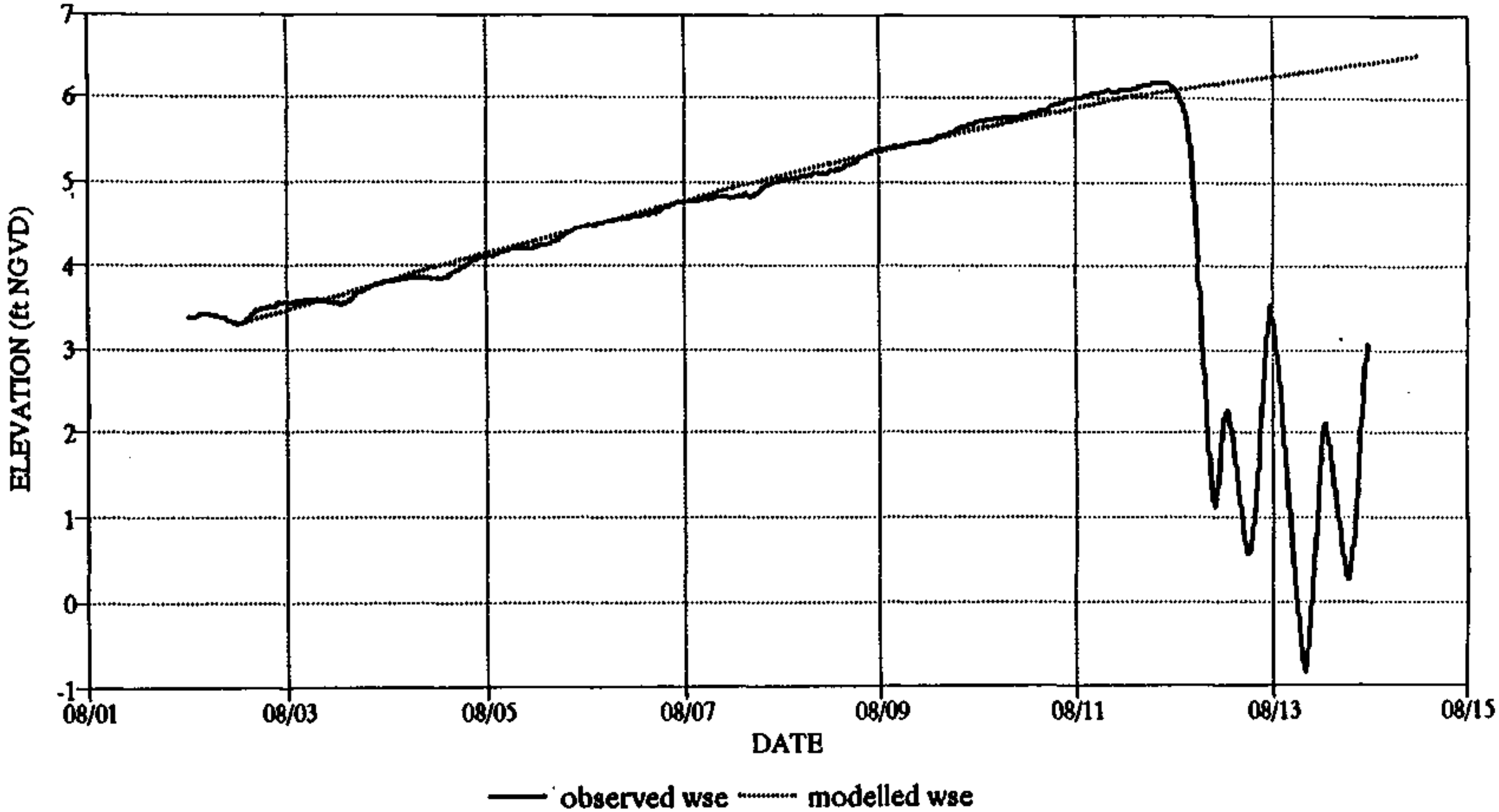
Simulation of Variation in Water Level in Estuary
July 8 - July 17, 1992

Figure
5.8



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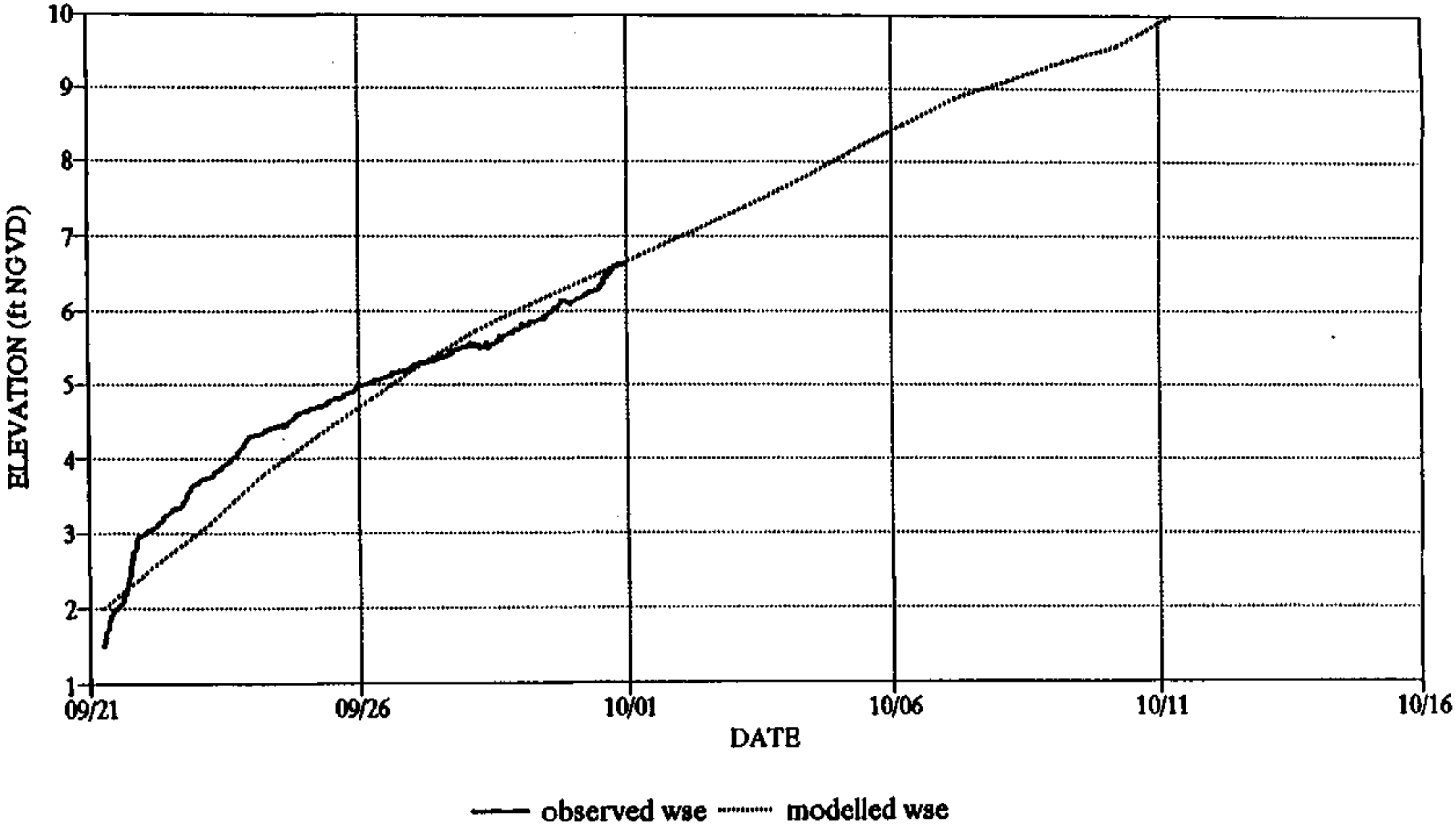
Simulation of Variation in Water Level in Estuary
August 2 - August 12, 1992

Figure
5.9



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Simulation of Variation in Water Level in Estuary
September 21 - October 8, 1992

Figure
5.10

- *Size of Sediments on Beach.* Large cobbles or coarse gravel are scoured less easily by tidal flows in the inlet channel. There may be seasonal variations in particle gradation.

- *Tidal Prism.* Volume of water which passes through the inlet channel in a tidal cycle.

- *Freshwater Inflows.* These river discharges supplement the tidal flows through the inlet channel and assist with scouring.

At the Russian River Estuary, the most important factors are wave energy, tidal prism, and freshwater inflows.

The significant deepwater wave height (H_S), diurnal tide range (H_r) and river discharge (Q) for the five days preceding closure of the inlet channel are summarized in Table 5.2 for the monitoring period April 1992 through March 1993. The significant wave height was obtained from the National Buoy Data Center for San Francisco. The Bodega Bay gage was not in operation for most of this study and was not therefore used. The wave energy shown in Table 5.2 can be considered an indication of ambient wave conditions only. The tide ranges are astronomical predictions for the ocean from NOAA. The river discharges are obtained from the USGS gaging station at Guerneville.

Several important observations can be made from Table 5.2:

- Closure of the estuary occurred during both spring and neap tides, although there was a greater tendency to closure during neap or intermediate tide ranges. The timing of closure is therefore dependent upon tidal prism, river inflows, and wave conditions.

- During the six observed closures in 1992, none occurred when the river discharges exceeded 700 ft^3/s. The lagoon does not close during the wet season months, implying that there is a critical river discharge above which the estuary will not close.

- Closure could occur during neap tides with low wave energy, or spring tides with high wave energy. Therefore, it is necessary to evaluate the relative roles of tidal prism, wave energy, and river discharges in causing closure.

The deepwater wave power was used due to the lack of inshore wave data and may be expressed as:

TABLE 5.2

SUMMARY OF SIGNIFICANT WAVE HEIGHT, DIURNAL TIDE RANGE, AND RIVER DISCHARGES PRIOR TO CLOSURES APRIL - NOVEMBER, 1992

DATE OF CLOSURE			DATE				
			04-21-92	04-22-92	04-23-92	04-24-92	04-25-92
04-25-92	H_S	(ft)	8.3	8.0	5.4	3.4	2.3
	H_r	(ft)	5.6	4.9	4.3	3.8	3.3
	Q	(ft^3/s)	923.0	783.0	747.0	369.0	649.0
			05-01-92	05-02-92	05-03-92	05-04-92	05-05-92
05-05-92	H_S	(ft)	6.9	4.8	4.1	4.3	5.4
	H_r	(ft)	6.0	6.5	6.9	7.1	7.1
	Q	(ft^3/s)	530.0	482.0	455.0	427.0	379.0
			07-04-92	07-05-92	07-06-92	07-07-92	07-08-92
07-08-92	H_S	(ft)	4.3	3.3	4.3	6.0	5.8
	H_r	(ft)	6.0	5.7	5.1	5.0	5.5
	Q	(ft^3/s)	249.0	246.0	245.0	218.0	212.0
			07-30-92	07-31-92	08-01-92	08-02-92	08-03-92
08-03-92	H_S	(ft)	4.0	3.5	4.2	4.9	5.6
	H_r	(ft)	7.6	7.3	6.4	5.6	5.1
	Q	(ft^3/s)	161.0	167.0	165.0	161.0	161.0
			09-17-92	09-18-92	09-19-92	09-20-92	09-21-92
09-21-92	H_S	(ft)	4.1	5.1	5.4	6.3	5.0
	H_r	(ft)	4.8	4.9	5.1	5.3	5.4
	Q	(ft^3/s)	179.0	177.0	182.0	179.0	172.0
			11-16-92	11-17-92	11-18-92	11-19-92	11-20-92
11-20-92*	H_S	(ft)	5.8	5.4	6.3	5.7	10.2
	H_r	(ft)	4.9	4.7	4.5	4.8	5.9
	Q	(ft^3/s)	218.0	258.0	255.0	218.0	234.0

* = Estimated date of closure

H_S = Significant Wave Height

H_r = Diurnal Tidal Range

Q = Discharge in the Russian River at Guerneville

$$\Phi_w = \frac{\rho_o\, g\, L_o\, H_s\, b}{16T}$$

where:	p_O	=	density of ocean water
	L_O	=	deepwater wave length
	H_S	=	deepwater significant wave height
	T	=	wave period of the significant wave
	b	=	characteristic width of the inlet channel.

The tidal power associated with the potential tidal prism may be defined as:

$$\Phi_p = gh_r\left[\rho_E \frac{P}{T_r} + \rho Q\right]$$

where:	p	=	density of river water
	p_E	=	density of water in estuary
	P	=	potential tidal prism
	T_r	=	diurnal tidal cycle
	Q	=	river inflow
	h_r	=	tide range.

Potential tidal prism is used, since the actual tidal prism is dependent upon the configuration of the inlet channel at any time, whereas the potential tidal prism can be predicted from astronomical tide tables and Figure 5.5.

The ratio of deepwater wave power to potential tidal power is summarized in Table 5.3. For the monitoring period, April 1992 to March 1992, the entrance to the estuary did not close provided the ratio $\frac{\Phi_P}{\Phi_W}$ exceeded 1 .5. This figure can be used as a first approximation to predict the type of wave, tide, and river flow conditions that will lead to closure.

TABLE 5.3

WAVE POWER AND TIDAL POWER
PRIOR TO OBSERVED CLOSURES
APRIL 1992 - MARCH 1993

DATE OF CLOSURE	WAVE POWER* Φ_W (kN-m/s)	TIDAL POWER* Φ_P (kN-m/s)	$\frac{\Phi_P}{\Phi_W}$
04-25-92	230	316	1.4
05-05-92	578	894	1.5
07-08-92	653	449	0.7
08-03-92	325	434	1.4
09-21-92	745	447	0.6
11-20-92	613	472	0.8

* Estimated for the 48 hour period prior to closure

VI. HYDROLOGICAL OPPORTUNITIES AND CONSTRAINTS FOR THE MANAGEMENT OF THE ESTUARY

A. Opportunities

There are a wide range of alternatives that can be adopted to enhance the ecological resources of the estuary.

Adaptive Management Plan

The adopted plan can be flexible, so that the results of future monitoring or data can be included into the operational guidelines for a greater benefit.

Tidal Circulation

Tidal circulation can be controlled by specifying one or a combination of the following factors as critical indicators:

- the frequency of breaching (important for staff time and cost);
- water temperature;
- critical degree of stratification;
- minimum salinities;
- dissolved oxygen (DO);
- other water quality parameters;
- ecological criteria.

The importance of each parameter can be assessed on its effect on the ecosystem.

Local Flooding

Local flooding, when the estuary is closed to the ocean, can be prevented by artificial breaching of the barrier beach or by establishing a structure which controls the water surface level in the lagoon.

Timing of Breaching

Artificial breaches determined by a specified water surface elevation, or a natural breach caused by overtopping the barrier beach, may occur during periods that are particularly sensitive to fisheries and the estuarine ecology. The ability to predict the rate or rise of the water surface elevation in the lagoon will enable artificial breaching to occur during periods which minimize adverse ecological impacts.

Freshwater Inflows

The Russian River and Dry Creek have reservoirs which allow some control of the river discharges entering the Russian River Estuary. Theoretically, it would be possible to reduce the low flow discharges provided the minimum fish releases were not jeopardized, or to increase the flows at critical periods if the water was available.

B. Constraints

There are several hydrologic constraints that must be considered in the recommended management alternative.

Flooding Caused by Closure of the Estuary

Closure of the inlet occurs during periods of low freshwater inflow, usually during the summer months. The height of the barrier beach governs the elevation that the water in the estuary would reach prior to natural breaching. Inundation of property will begin at approximately +10.0 feet NGVD, but the barrier beach can reach elevations in excess of 15 feet NGVD (Section 4). Inundation of property poses an upper limit on the desirable water level in the lagoon.

Water Quality

It was observed during this study that if the lagoon was breached at elevations close to +10.0 feet NGVD, there was a flushing of a high organic load from freshwater wetlands or tributaries with a high oxygen demand. The opening condition of the inlet channel affects the tidal flushing of the estuary which determines residence times of pollutants, the salinity structure of the estuary, levels of dissolved oxygen, temperature, and degree of stratification. Minimum standards of these parameters will provide constraints on the management alternatives.

Induced Flooding

During major flood events, the inlet channel will be open but the selected management alternative should not increase flood levels above existing flood levels.

Integrity of Structures

The management plan should not worsen scour problems at bridges, or other structures adjacent to the estuary.

Bank Stability

The selected management alternative should not accelerate bank erosion. Mechanisms for accelerating bank erosion are:

- seepage failures;
- reduction in resistance to erosion by creating fully saturated soil conditions for extended periods;
- increased velocities adjacent to the bank of the estuary.

Ecological Considerations

The estuary must be managed for the benefit of sensitive plant and animal species. These are discussed in detail by Nielsen (1993).

Public Safety

The natural or artificial breaching of the barrier beach can create standing waves in excess of 10 feet high and velocities in excess of 20 ft/s for short periods. The velocities are greater when the difference between the water level in the lagoon and ocean are large. The breaching of the barrier beach is a natural process, but it should be recognized in the management plan that the inlet channel poses a public safety issue.

Aesthetic Values

The Russian River Estuary is a relatively undeveloped estuary, noted for its outstanding vistas. The management plan should not impair the natural beauty of the site.

Significant Floods

Major floods can alter the geomorphology of the estuary, sediment load, bed composition, and cause damage to structures. The selected management plan should not worsen flooding caused by major flood events.

Implementation Costs

The annual costs of breaching the barrier beach and other implementation costs should be considered in the selection of the preferred alternative.

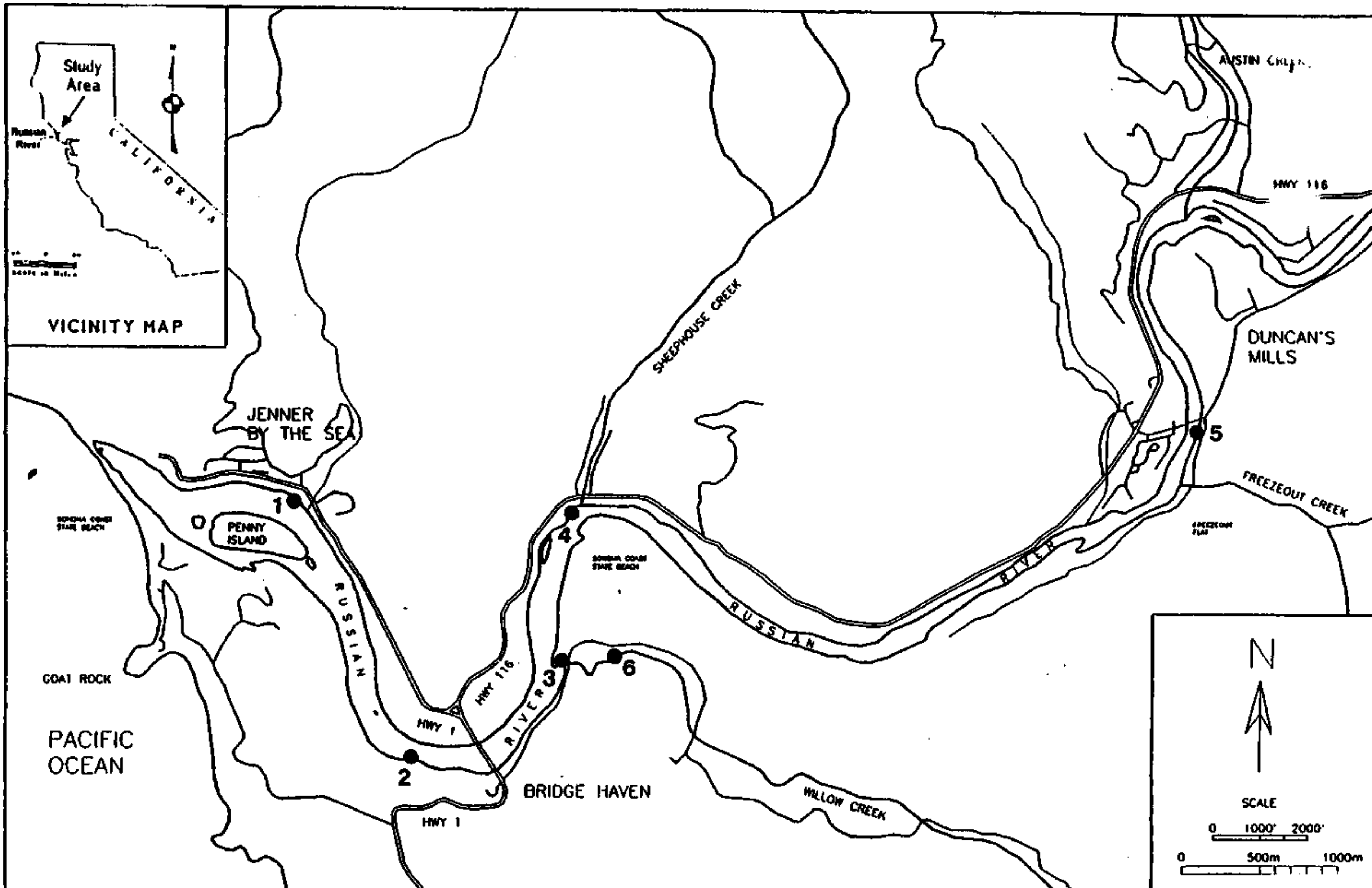
VII. LIMNOLOGICAL CONDITIONS OF THE ESTUARY

A, Russian River

Temperature and salinity values were collected continuously from April 1992 to May 1993, at four sites within the Russian River estuary (Table 7.1). An additional two site were instrumented with data loggers and low-level conductivity probes for in situ monitoring on Willow Creek marsh (Figure 7.1). In situ limnology sites were equipped with temperature data loggers designed and developed by R. Eads, USDA Redwood Sciences Laboratory, Arcata, CA, in conjunction with conductivity probes developed by MTI of Pocatello, ID. These loggers recorded individual temperature and conductivity values every 15 minutes and logged average records of these values onto computer chips every hour. The data recorded in situ was transferred weekly to portable lap-top computers in the field and returned to the laboratory for analysis, long-term storage and plotting. Temperature-compensated salinity values were derived from conversion algorithms (Perkins & Walker, 1972) and from calibration values derived in the laboratory (Perkins & Lewis, 1980) for each data logger and set of probes placed in the field. In situ data for temperature and salinity were checked for calibration in the field using a Hydrolab Scout 2 (Hydrolab Corporation, Austin, Texas). Field equipment found to be in error was replaced and returned to the lab for re-calibration. Data collected during such error intervals was not used in this analysis.

The four Russian River in situ sites plotted over time clearly demonstrated diurnal temperature flux, tidal intrusion of salt water into upstream pool habitats and variable impacts in salinity intrusion during periods of mouth closure (Figure 7.2). Salinity levels approaching or exceeding 30 ppt were recorded up to logger site *#4* at the old bridge footings. In all cases where salinity intrusion was documented, tidal flux was dampened during the closure of the river mouth and tidal salinity-surge was reinstated with breaching. Temperature values also showed steeper diurnal flux during periods when the mouth was open. This effect was not as pronounced in logger site #4.

Two in situ sites were lost to high flows during the winter of 1992-1993. Replacement equipment allowed continuous monitoring only at site #1 (visitor center) throughout the spring of 1993 (Figure 7.3). There were no recorded closures of the river mouth between Nov. 30, 1992 and the end of the study May 1, 1993. Freshwater discharge was sufficient during this period to sustain the mouth opening and to prevent saltwater intrusion at site #1, except during periods when tides exceeded 6 feet (1993 Tides & Current Tables, The Tidebook Company, San Francisco, CA).



In[illegible]u Limnology Sites

LOCATION MAP OF STUDY AREA FOR RUSSIAN RIVER ESTUARY

7.1

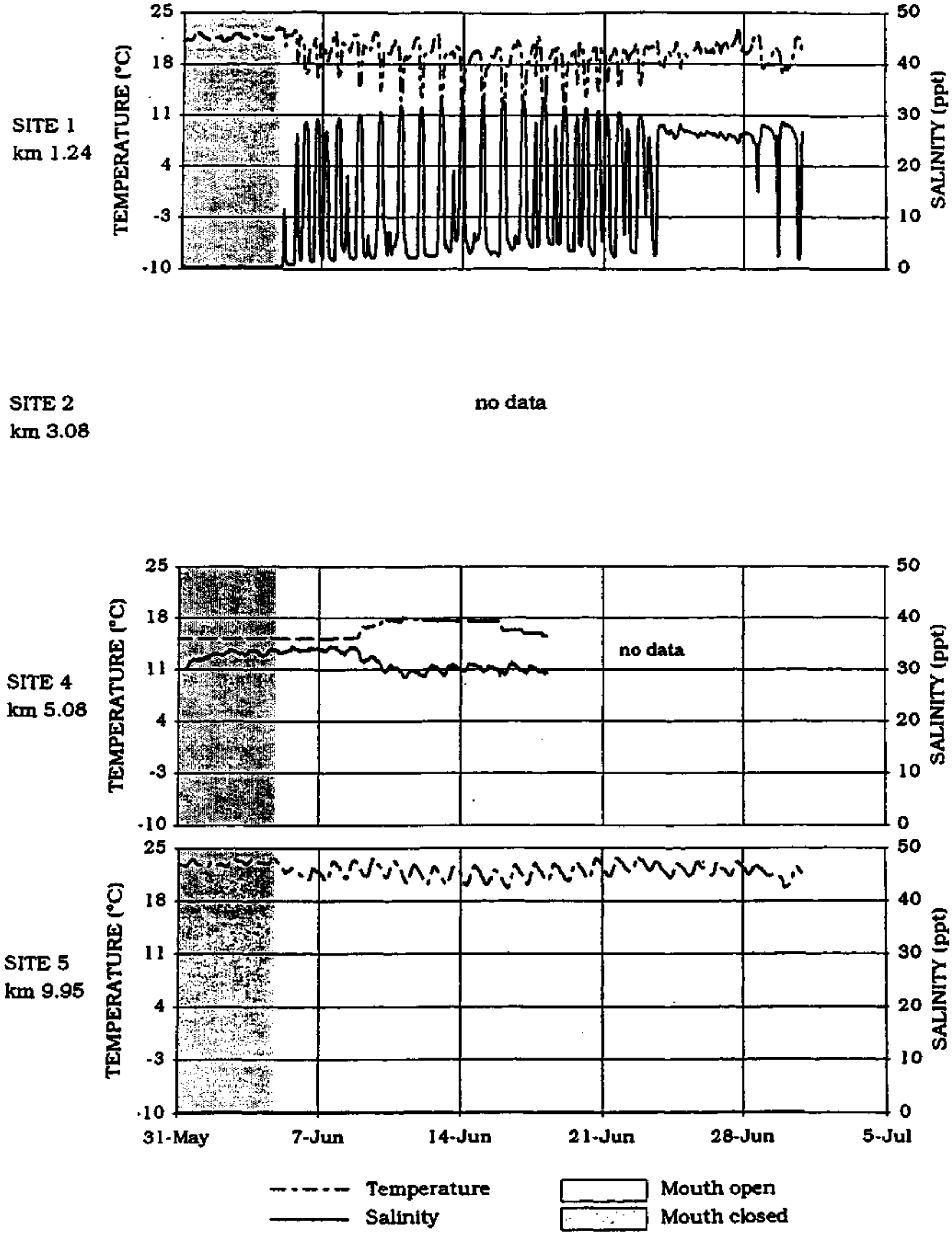
TABLE 7.1

RUSSIAN RIVER ESTUARY LOCATIONS AND LANDMARKS USED IN LIMNOLOGICAL AND BIOLOGICAL SURVEYS.

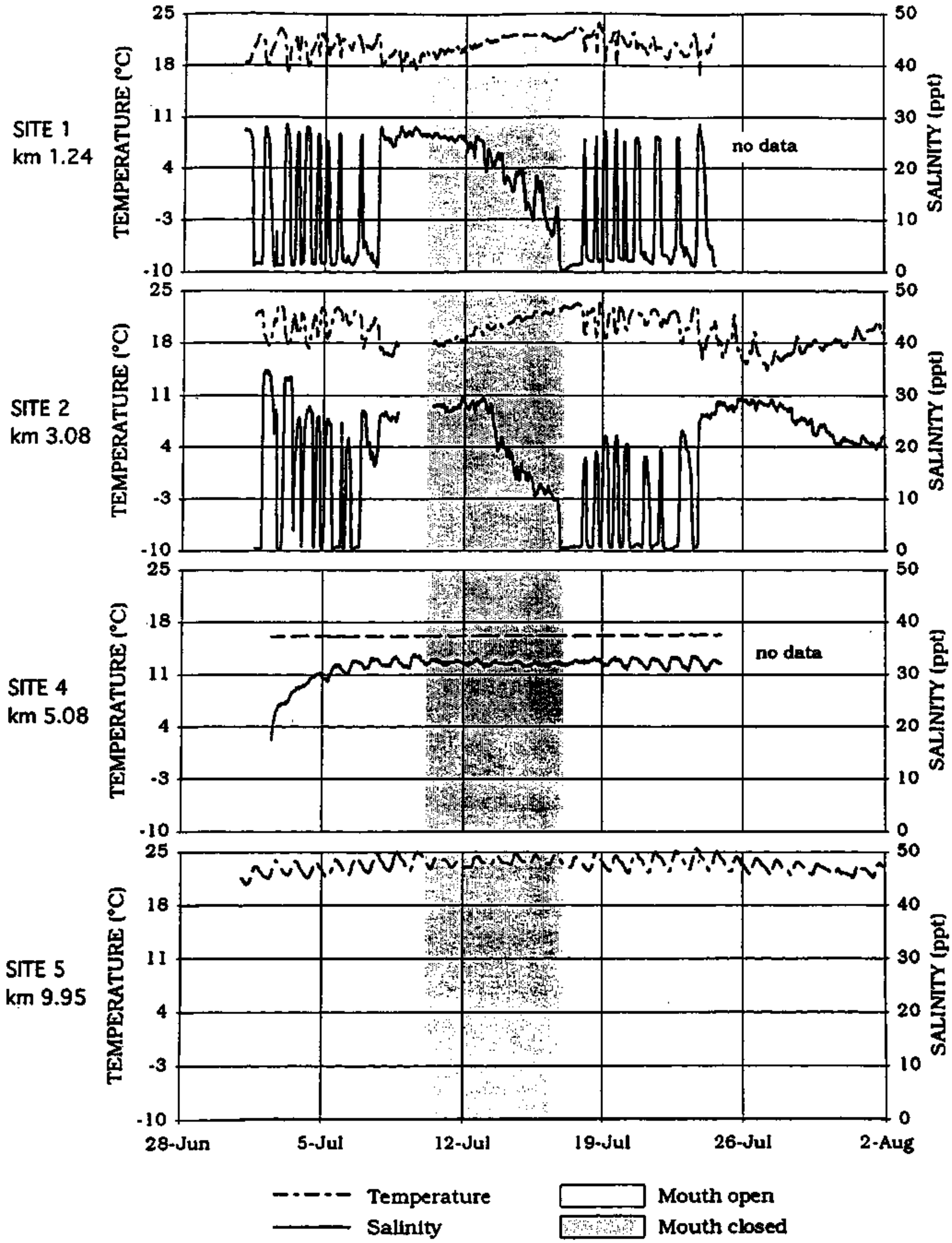
Stream km	Site Description
0.00	river mouth (location varies)
0.10	Transect #1 - old jetty
0.50	west tip Penny Island
0.80	right bank - white house
1.00	right bank - green house w/balcony
1.24	LOGGER 1 - Transect #2 - visitor center
1.40	telephone wires
1.50	east tip Penny Island
2.20	islets
3.08	LOGGER 2 - Transect #3 - bedrock shelf
3.40	Hwy. 1 bridge
4.10	Willow Creek mouth
4.22	LOGGER 3 - up Willow Cr. mouth
5.08	LOGGER 4 - Transect #4 - old bridge site
7.10	Transect #5 - left bank bedrock
8.50	Hwy. 1 curve - 35 mph sign
8.70	upper island - gravel bar
9.30	Freezeout flat pool
9.95	LOGGER 5 - Duncan Mills
10.00	Duncan Mills bridge
11.20	deep bedrock pool off Casini's ranch beach

Figure 7.2 - 7 pages

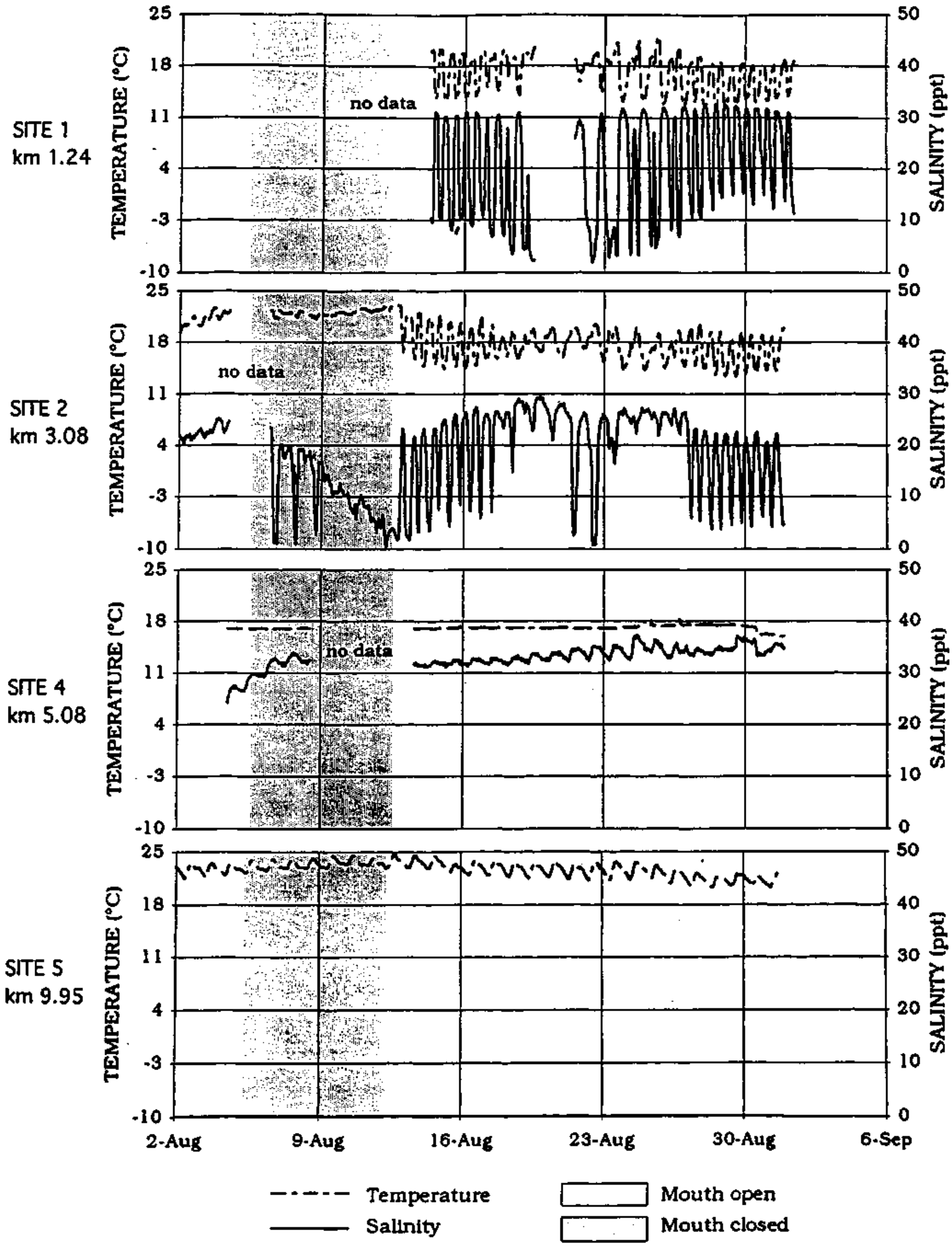
TEMPERATURE AND SALINITY--JUNE 1992



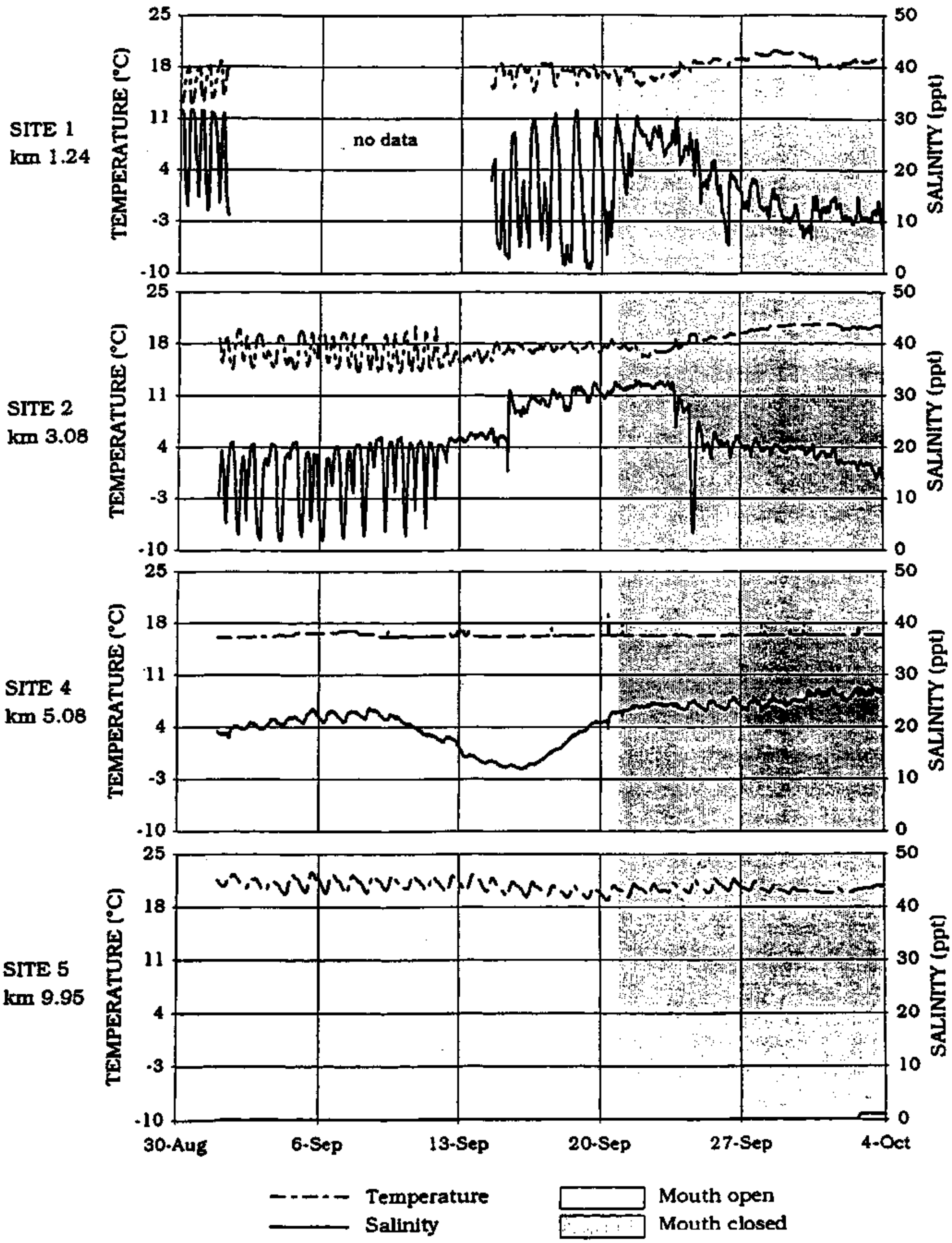
TEMPERATURE AND SALINITY--JULY 1992



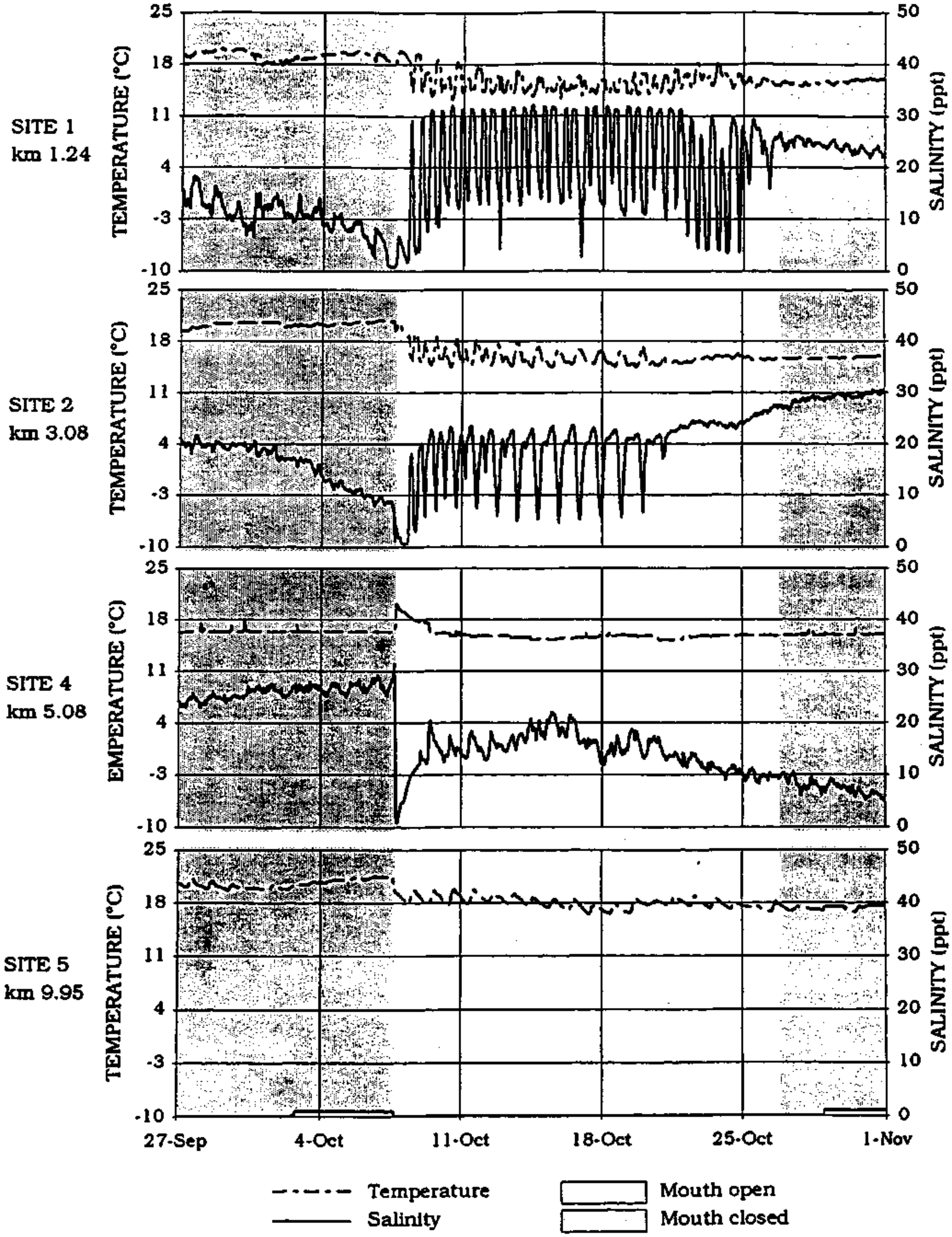
TEMPERATURE AND SALINITY--AUGUST 1992



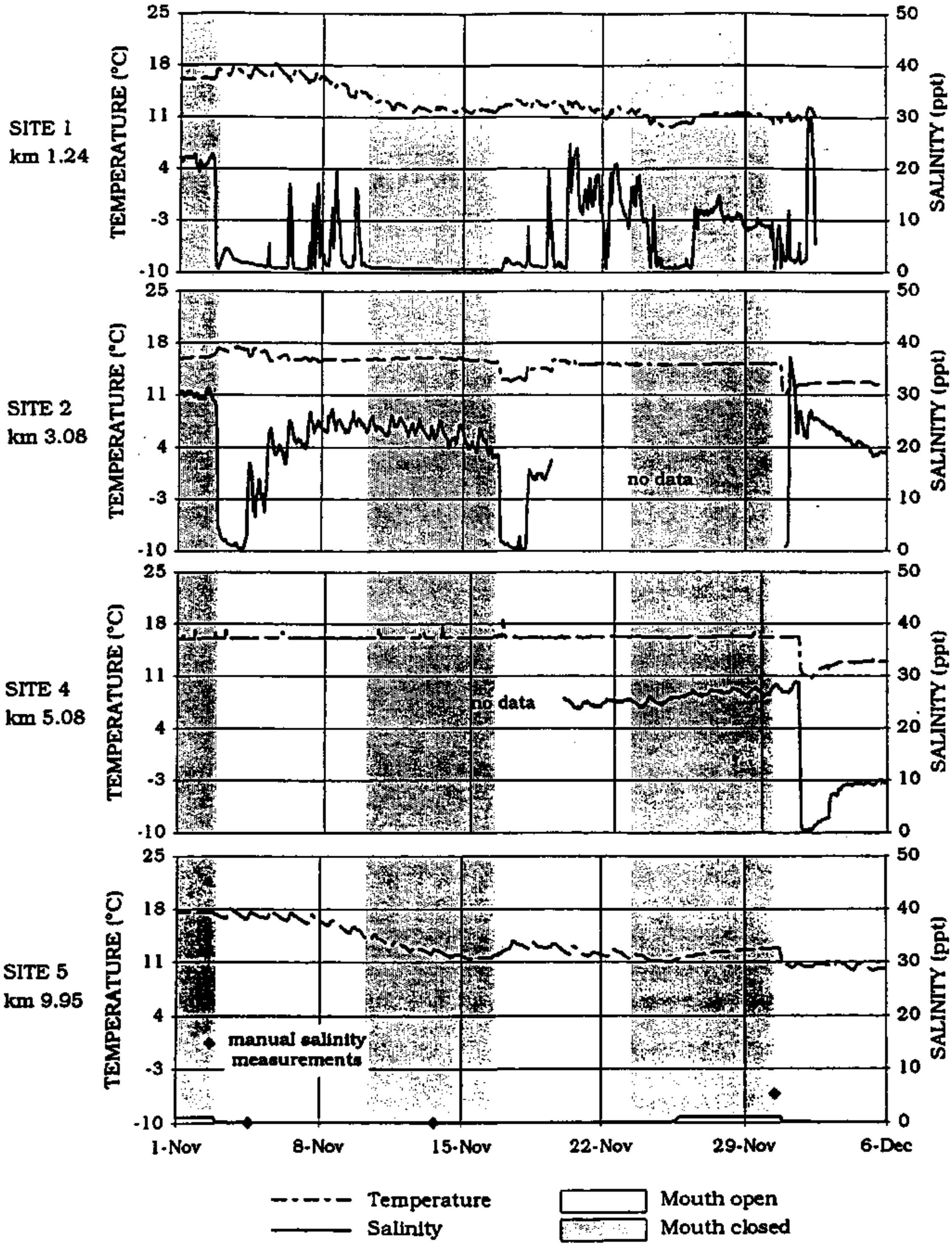
TEMPERATURE AND SALINITY--SEPTEMBER 1992



TEMPERATURE AND SALINITY--OCTOBER 1992



TEMPERATURE AND SALINITY--NOVEMBER 1992



TEMPERATURE AND SALINITY--DECEMBER 1992

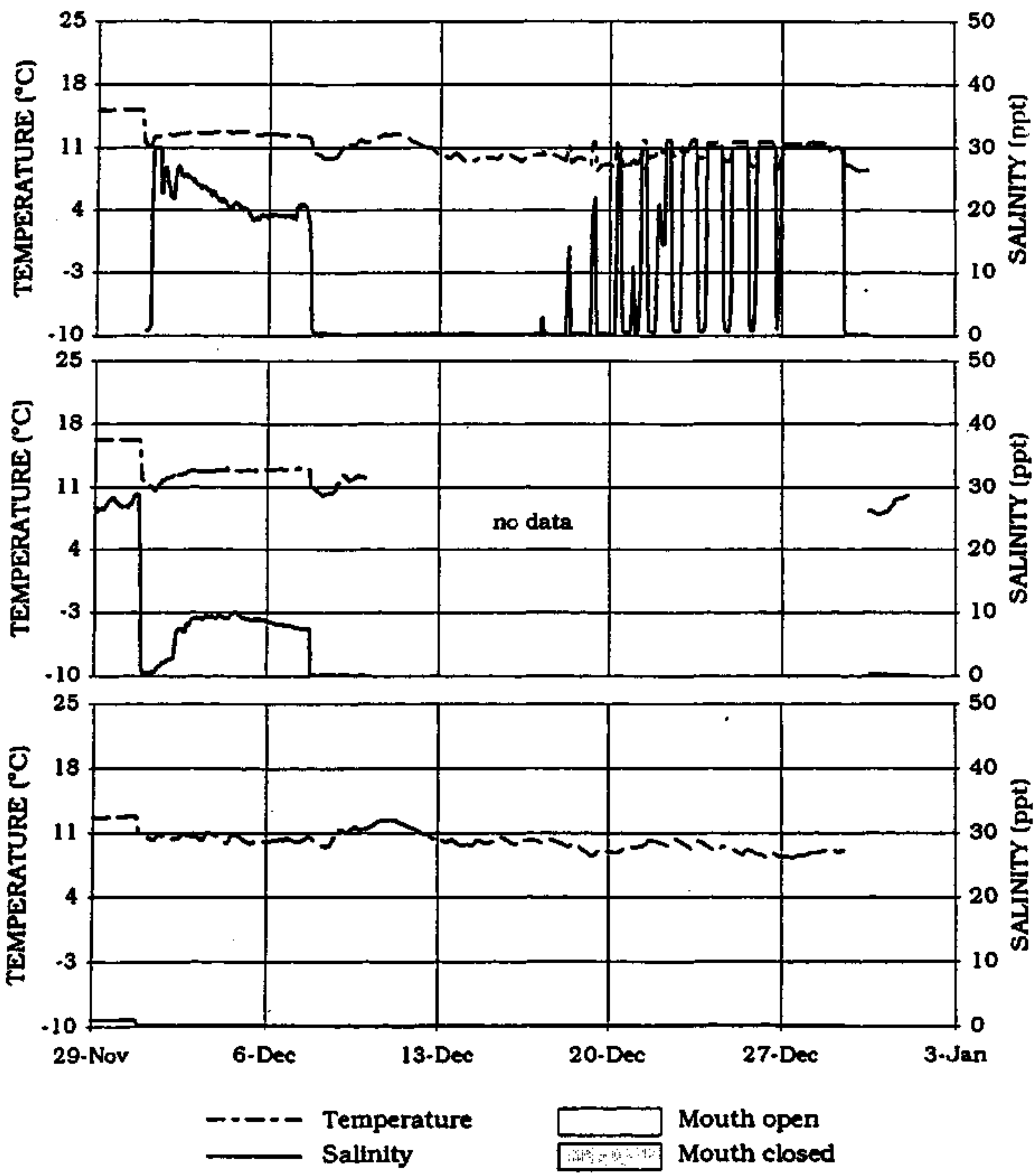
SITE 1
km 1.24

no data

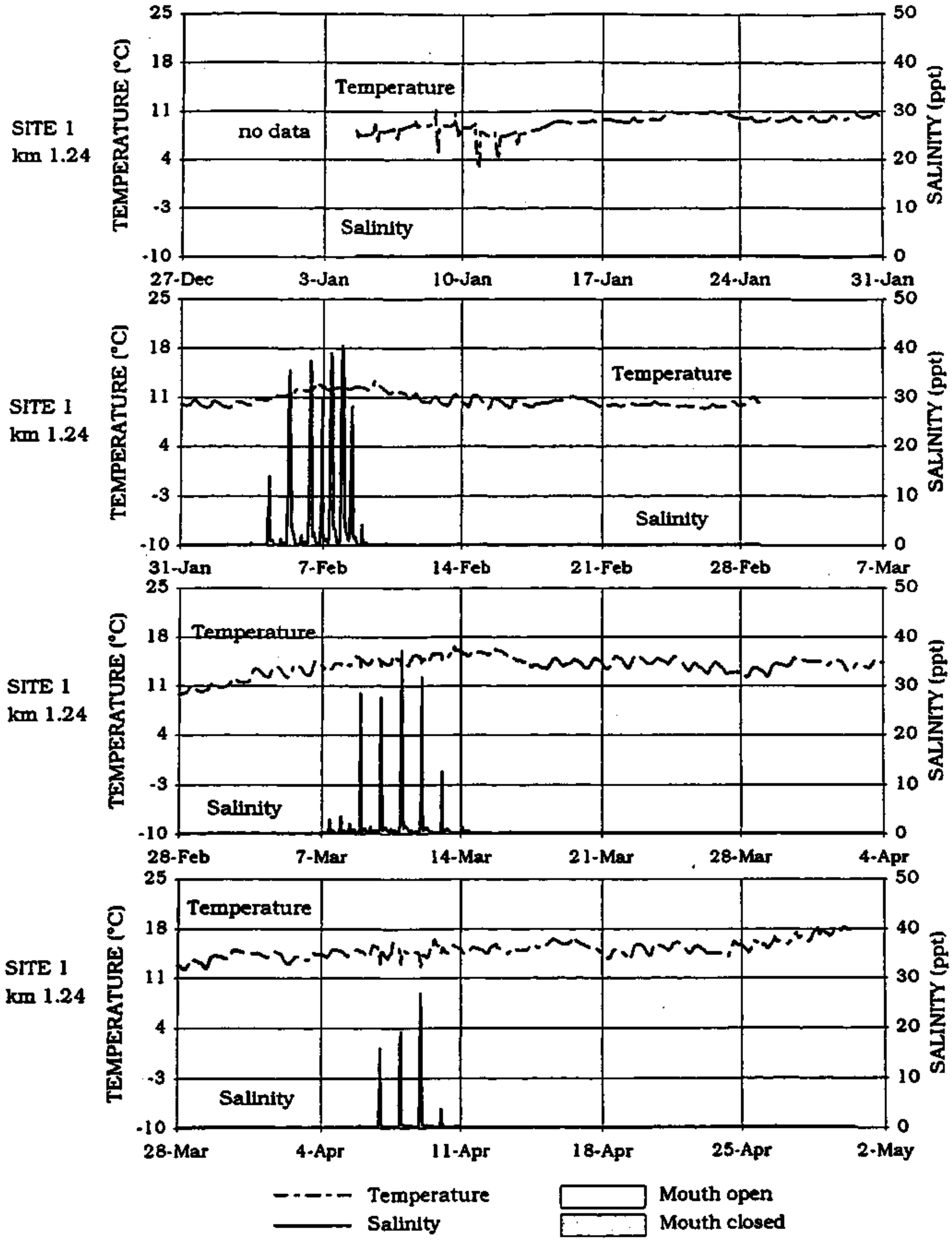
SITE 2
km 3.08

SITE 4
km 5.08

SITE 5
km 9.95



TEMPERATURE AND SALINITY--JANUARY-APRIL 1993



B. Hydrolab Data

In addition to in situ monitoring we conducted site specific hydrolab profiles to correlate the in situ values with measurements of temperature, dissolved oxygen (DO) and salinity taken throughout the water column (Figure 7.4). These water chemistry longitudinal profiles confirmed salinity stratification at depth and anoxic bottom conditions in deeper pools following periods of mouth closure. In June, stratification occurred between 2-4 meters of depth in the logger pools up to the old bridge site (#4). Sites measured upstream did not show saline stratification. In July, a steeper gradient of stratification was recorded from the visitor center to the mouth and the salt wedge intruded further upstream to stream km 7.1 where a deep pool stratified at 6 m of depth. In mid-July, deep pool bottom anoxic conditions were more extreme up to stream km 7.1.

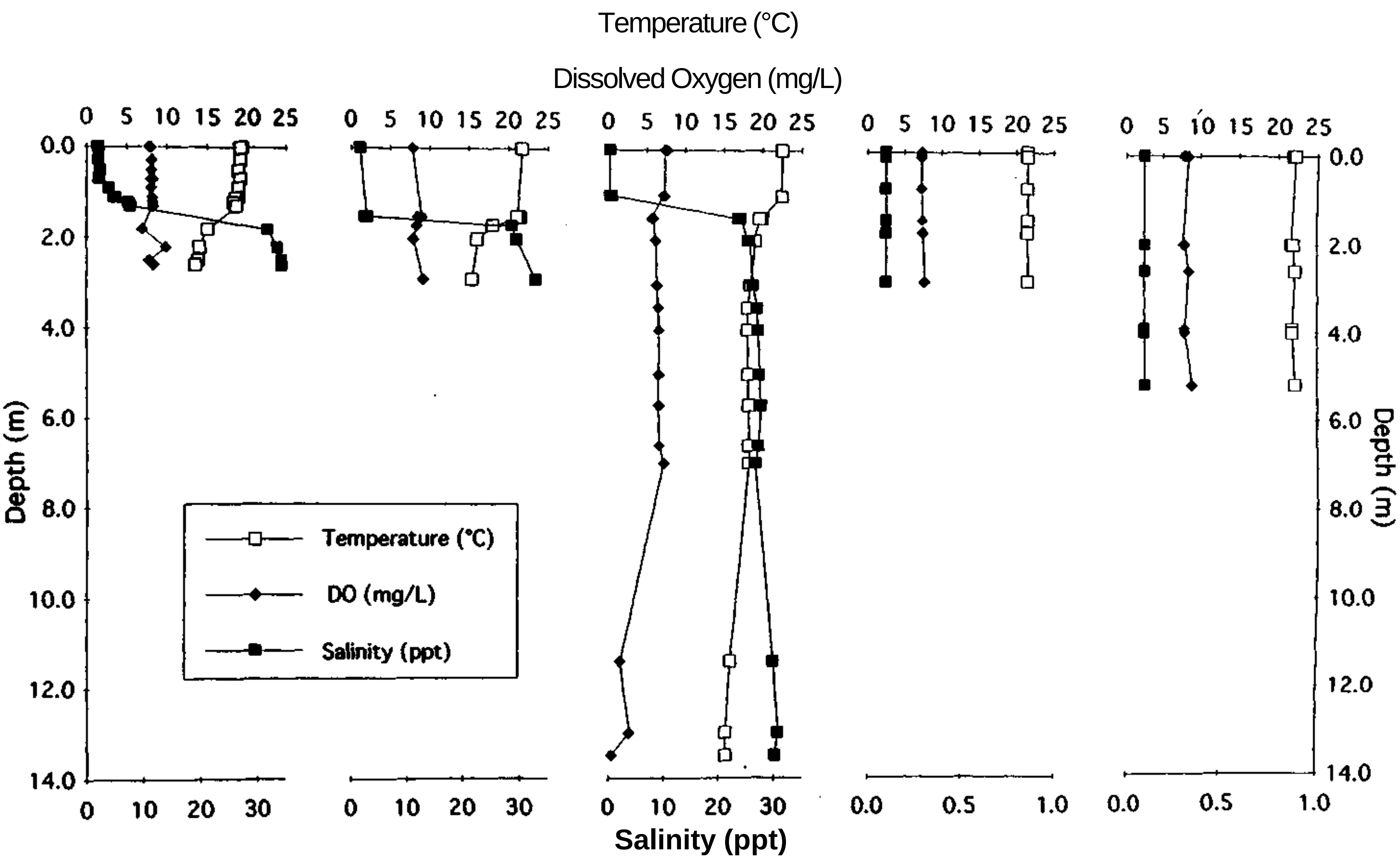
By September 15, 1992 stratification conditions downstream were less extreme at the downstream sites, but the deep pool at stream km 7.1 retained anoxic and hyper saline conditions at 5 m of depth. There appeared to be insufficient freshwater flows to flush this pool until the first storms of winter. Winter mixing limited stratification in most pools from Dec.- March. By April, 1993 pools in the lower basin began the process of saline stratification over again. Artificial breaching drew large quantities of freshwater from the estuary and accelerated mixing of the shallow areas of pools increasing the DO content of near surface waters. Salt water stored at depth, however, was not impacted by summer breach mixing (see July hydrolab data series).

Tidal flows traveling through the substrate caused changes in the salinity levels at maximum depths in deep pools reached by tidal upstream salt intrusion despite artificial summer freshwater discharge from dams on the Russian River. Significant winter storm flows were necessary to achieve complete mixing at depth in these deep stratified pools.

Hyper-saline and anoxic conditions at the bottom of pools leads to reduced benthic production and greater dependence on allochthonous material derived from adjacent tributaries to contribute to the food and energy of the estuary (Day et al. 1989). Salinity tends to outweigh temperature as a moderator of fish density patterns in estuaries (Kennish, 1992). Estuary pools where saline conditions were not stratified and salt water intrusion was not permanent, maintained dissolved oxygen conditions adequate for the most sensitive fish or invertebrate species at mid-depth (Figure 7.5).

Salinity cross sections were monitored within pools where salt water intrusion tended to stratify, to look at changes in the distribution of their saline content at depth over time (Figure 7.6). Stratification at depth occurred quickly, often within a 24 hour period after tidal deposition of marine waters. Riverine fresh water

Water Chemistry: Longitudinal Hydrolab Survey June 10-11, 1992

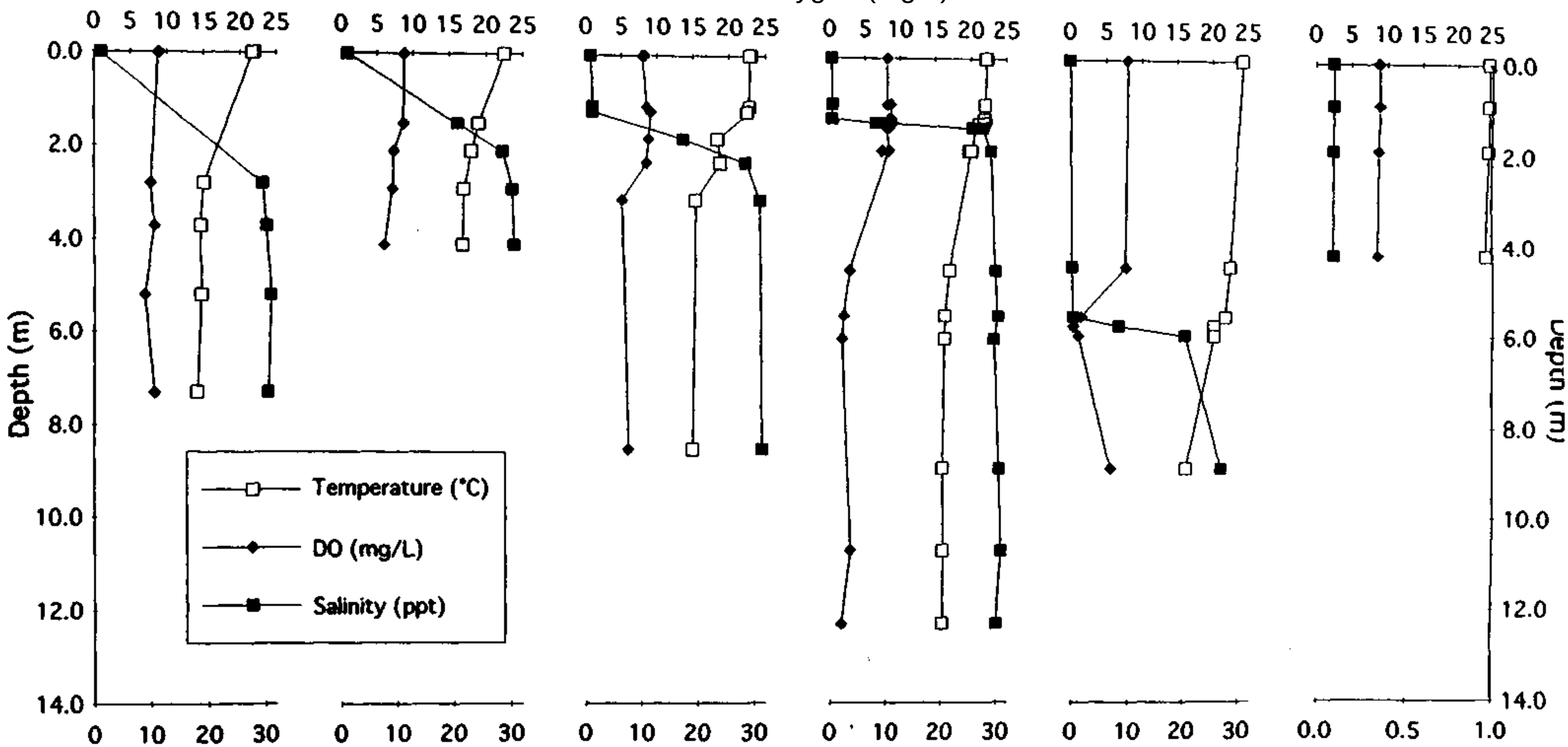


km 1.24	km 3.08	km 5.13	km 9.95	km 11.20
Logger 1 (Visitor Center)	Logger 2 (Highway One Bridge)	Logger 4 (Old bridge pool)	Logger 5 (Duncan's Mills)	Opposite Casini's

Water Chemistry: Longitudinal Hydrolab Survey July 2 & 7, 1992

Temperature (°C)

Dissolved Oxygen (mg/L)

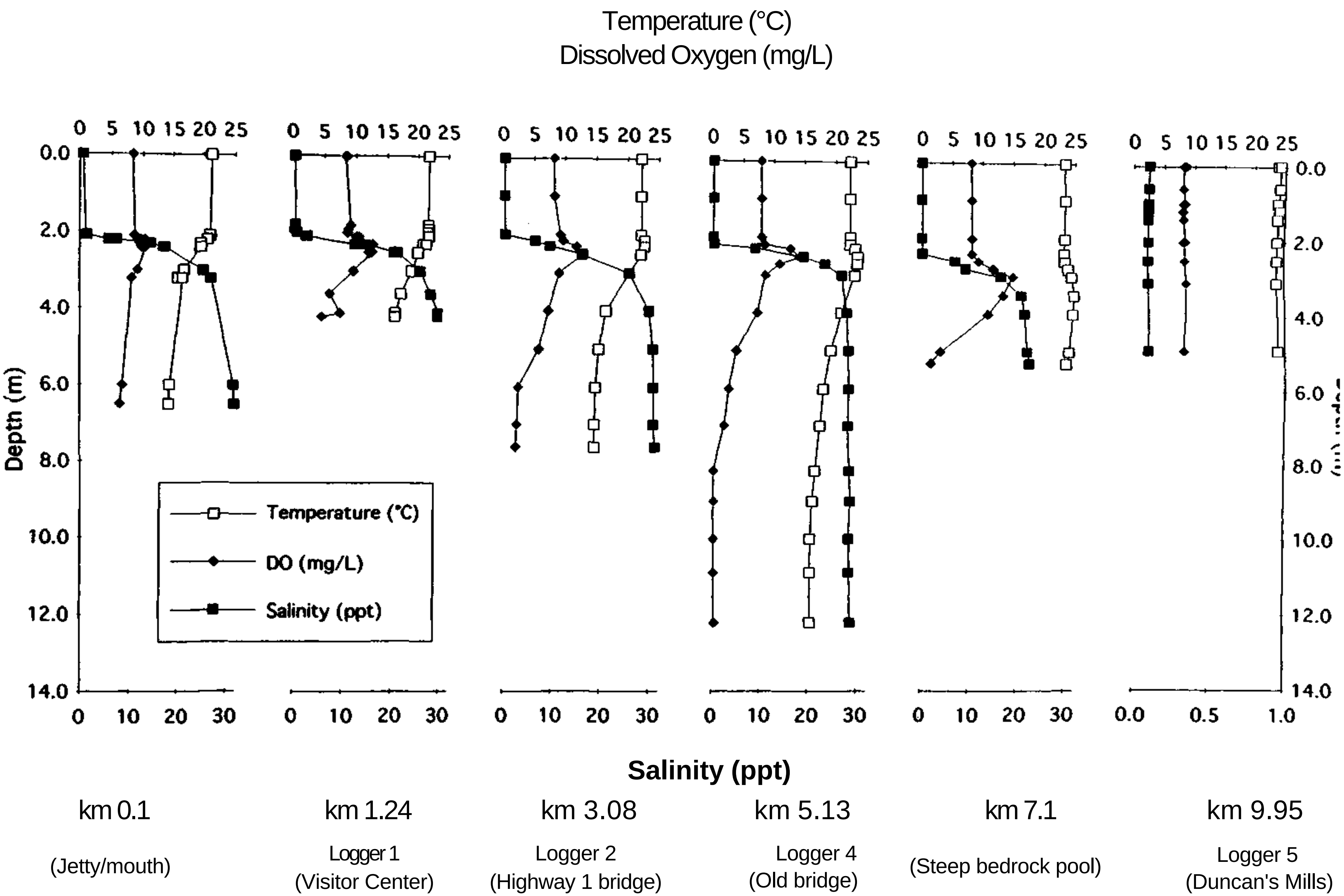


Salinity (ppt)

km 0.0-0.1	km 1.2-1.5	km 3.08	km 5.13	km 7.1	km 9.95
(Jetty/mouth)	Logger 1 (Visitor Center)	Logger 2 (Highway One Bridge)	Logger 4 (Old bridge pool)	(Steep bedrock pool)	Logger 5 (Duncan's Mills)

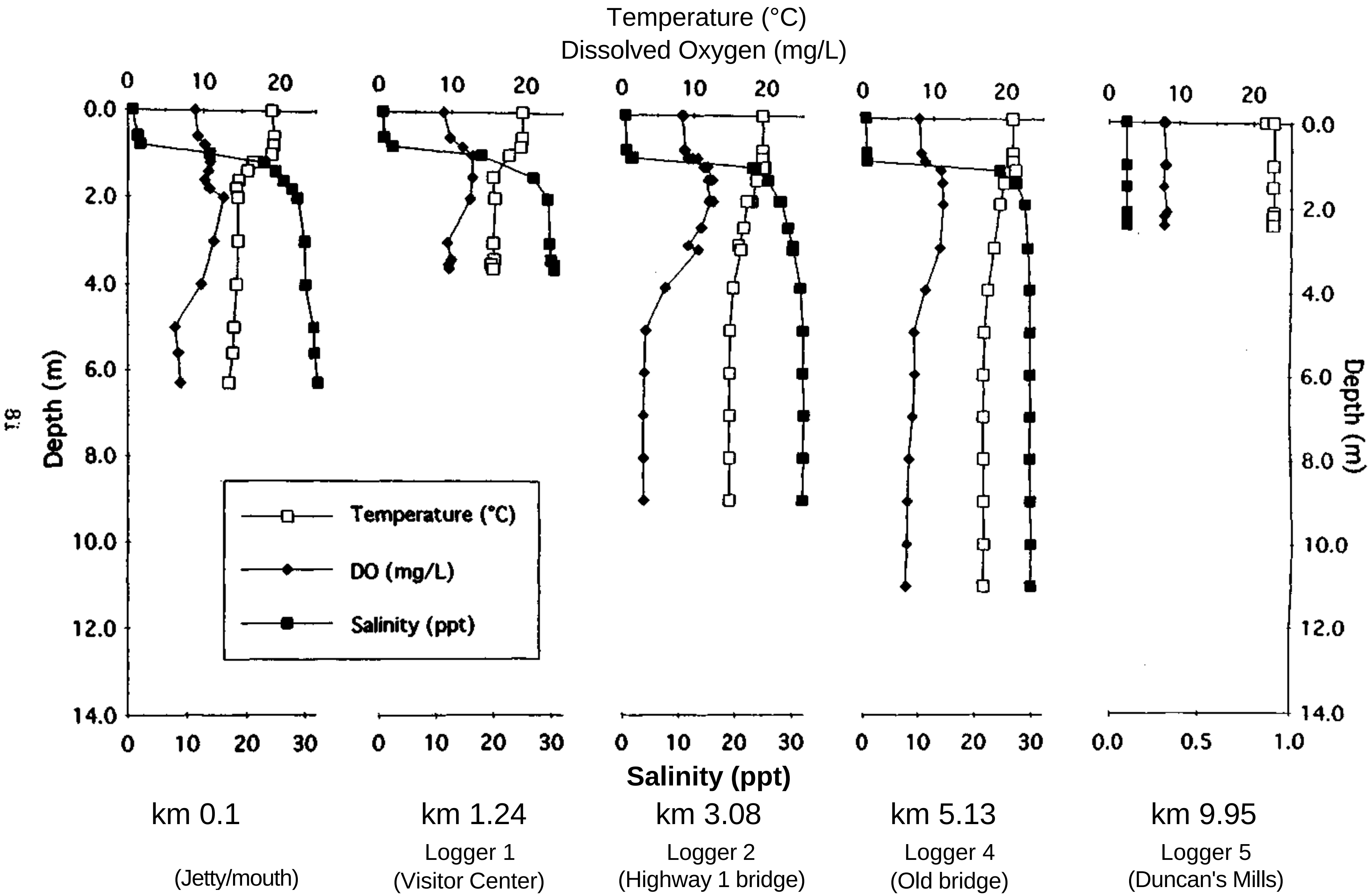
Water Chemistry: Longitudinal Hydrolab Survey July 15-16, 1992

Mouth closed



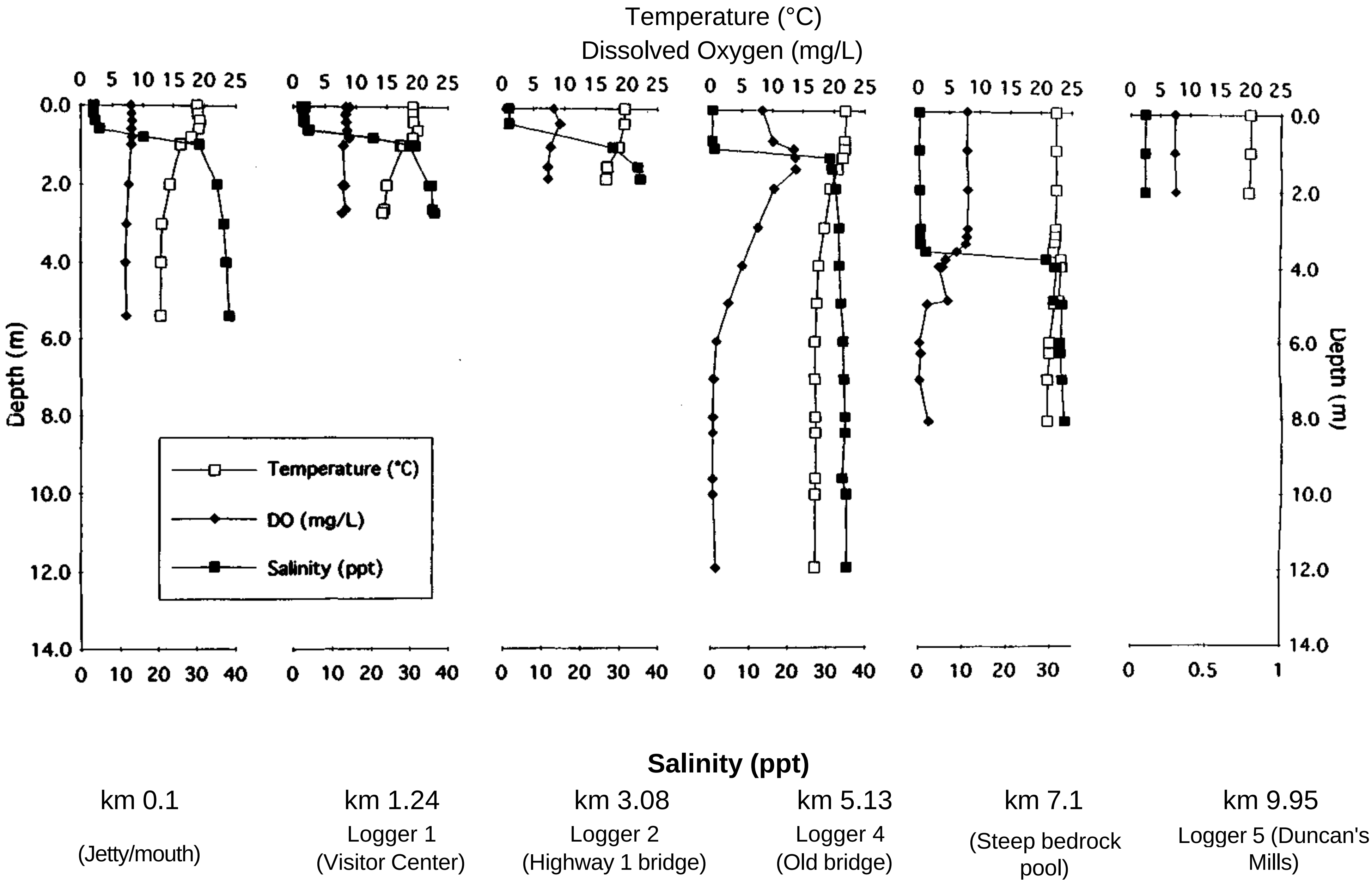
Water Chemistry: Longitudinal Hydrolab Survey July 30-31, 1992

Mouth open



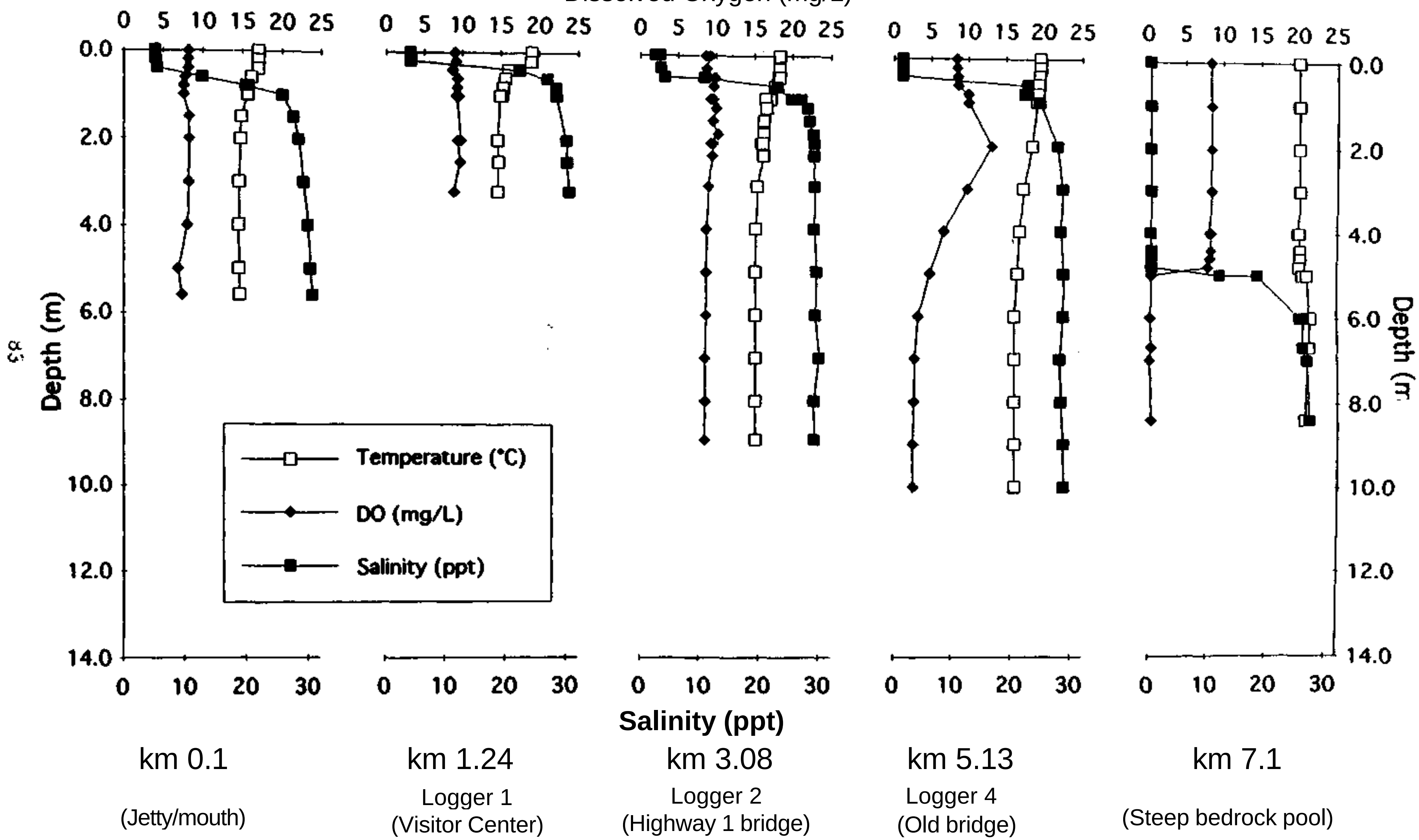
Water Chemistry: Longitudinal Hydrolab Survey August 20-21 1992

Mouth open



Water Chemistry: Longitudinal Hydrolab Survey September 15-16, 1992

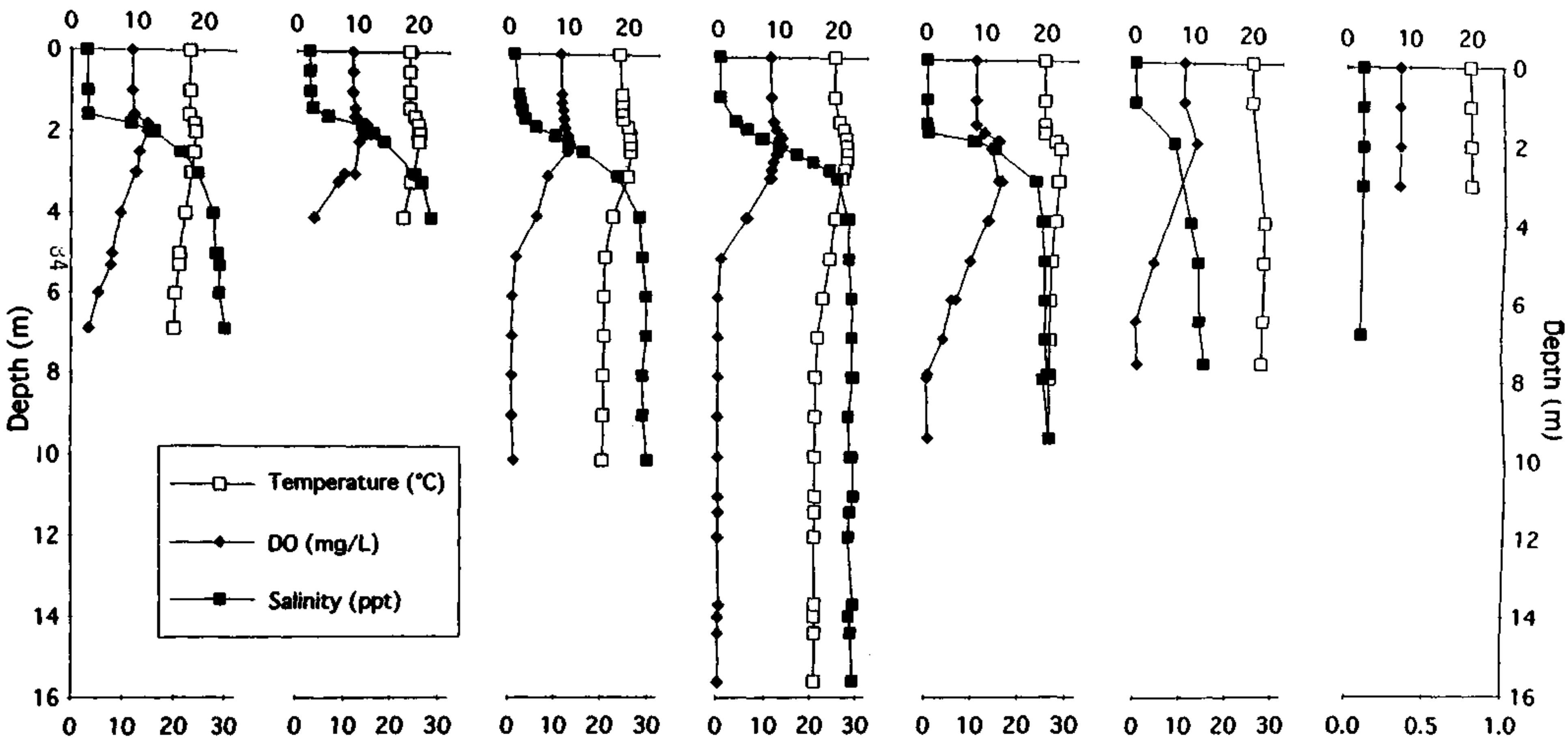
Mouth open



Water Chemistry: Longitudinal Hydrolab Survey September 28-30, 1992

Mouth closed

Temperature (°C)
Dissolved Oxygen (mg/L)

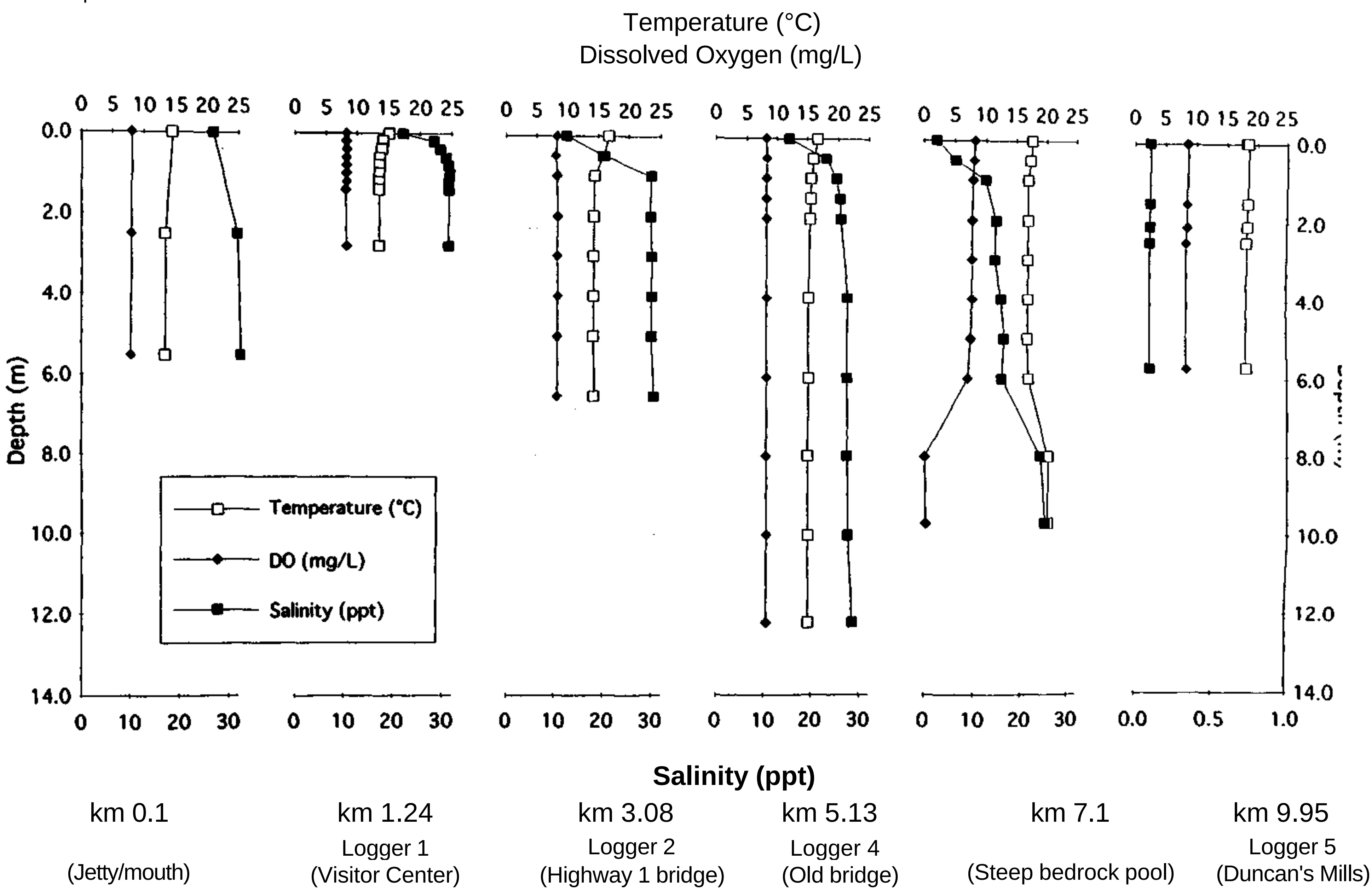


Salinity (ppt)

km 0.1	km 1.24	km 3.08	km 5.13	km 7.1	km 9.30	km 9.95
(Jetty/mouth)	Logger 1 (Visitor Center)	Logger 2 (Highway 1 bridge)	Logger 4 (Old bridge)	(Steep bedrock pool)	(Below Freezeout Flat)	Logger 5 (Duncan's Mills)

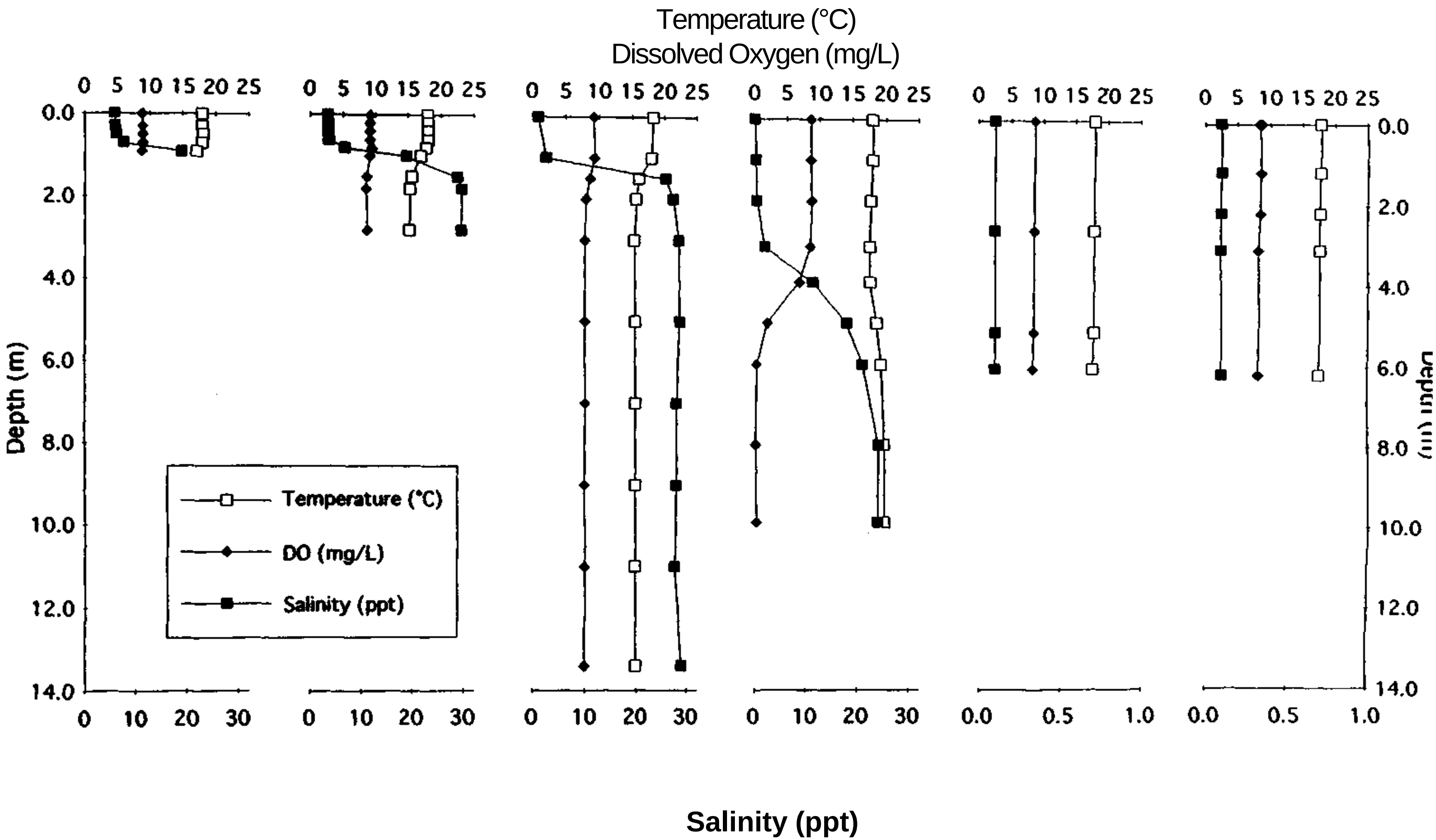
Water Chemistry: Longitudinal Hydrolab Survey October 14, 1992

Mouth open



Water Chemistry: Longitudinal Hydrolab Survey October 22, 1992

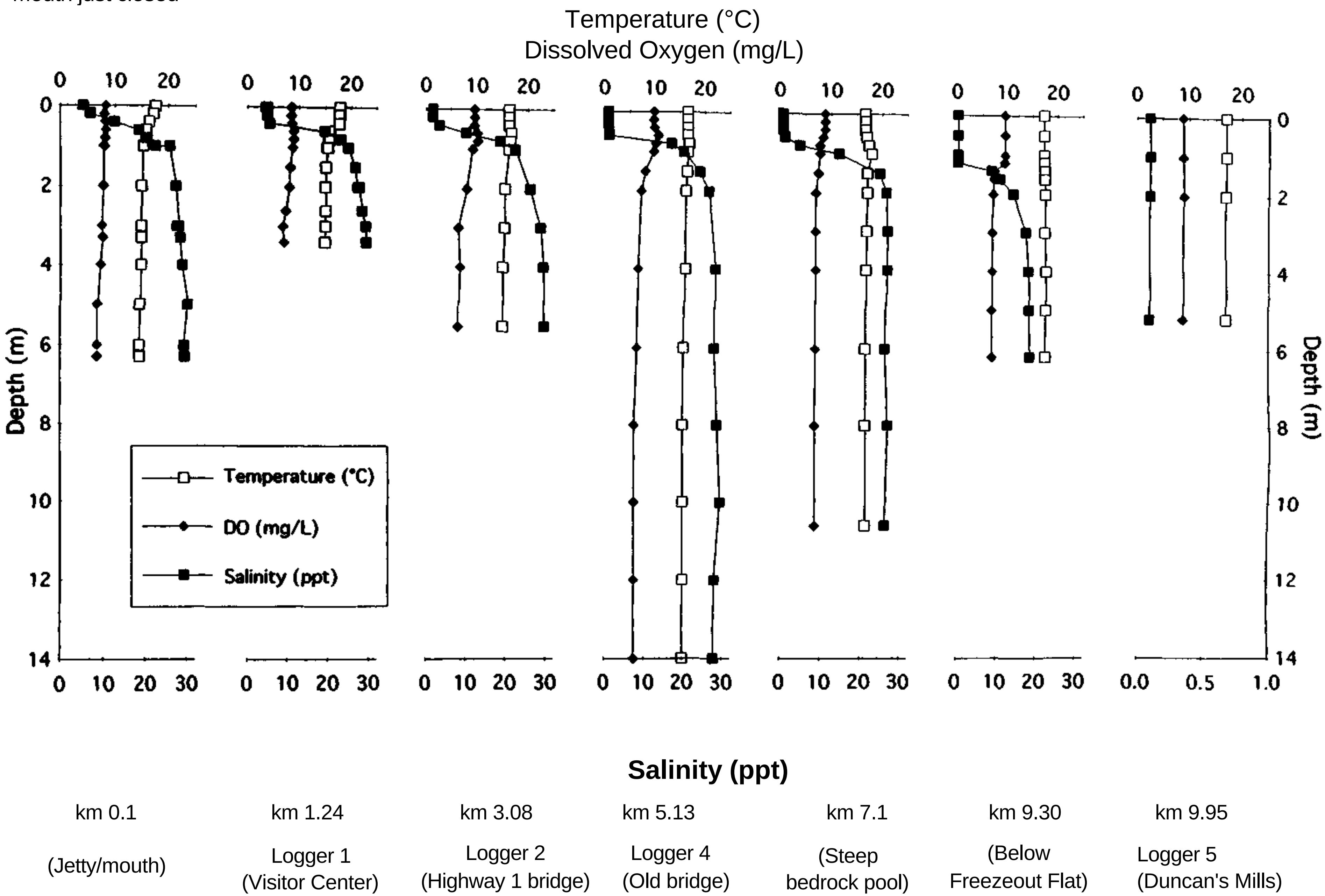
Mouth open



km 1.24	km 3.08	km 5.13	km 7.10	km 9.30	km 9.95
Logger 1 (Visitor Center)	Logger 2 (Highway 1 bridge)	Logger 4 (Old bridge)	(Steep bedrock pool)	(Below Freezeout Flat)	Logger 5 (Duncan's Mills)

Water Chemistry: Longitudinal Hydrolab Survey October 26-27, 1992

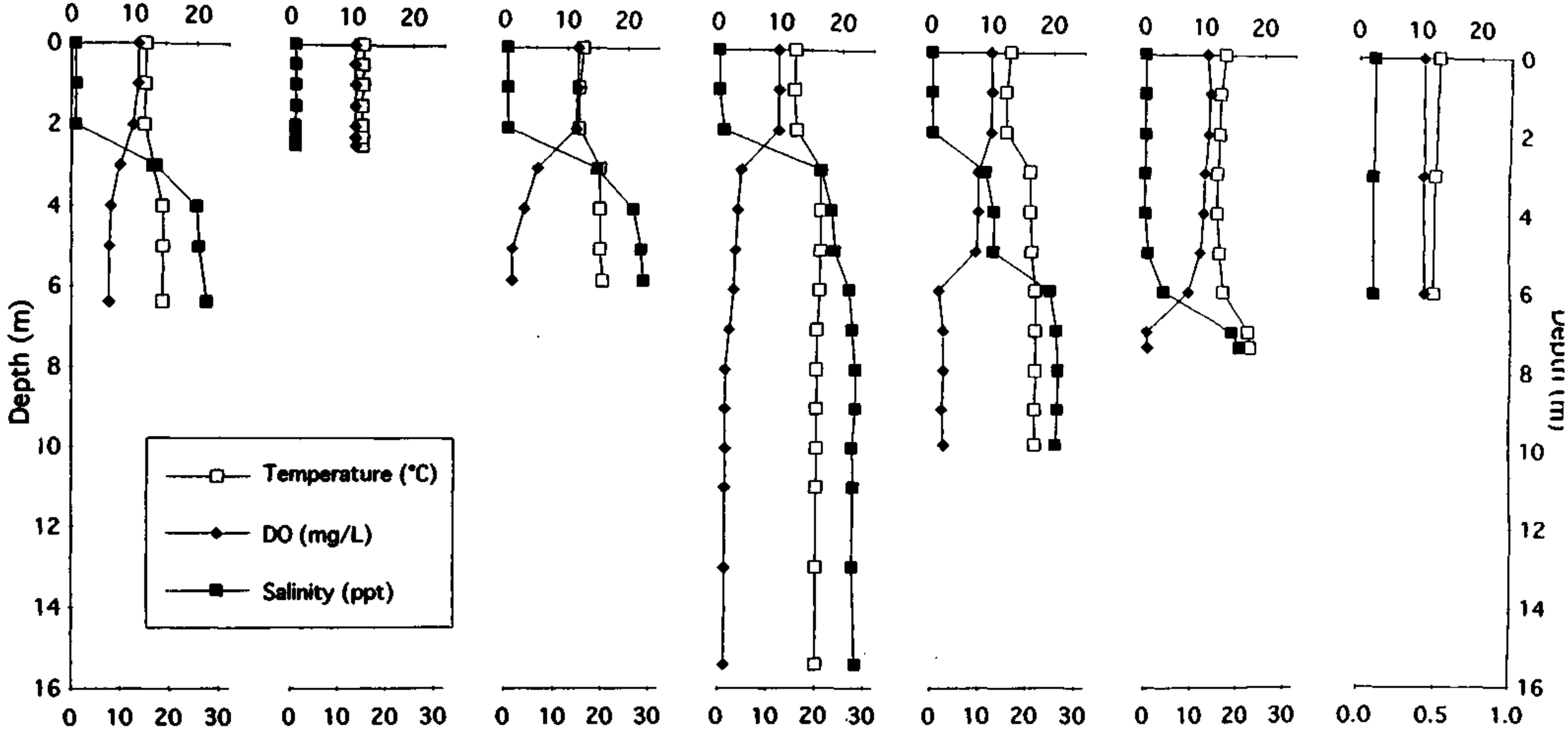
Mouth just closed



Water Chemistry: Longitudinal Hydrolab Survey November 13, 1992

Mouth closed

Temperature (°C)
Dissolved Oxygen (mg/L)

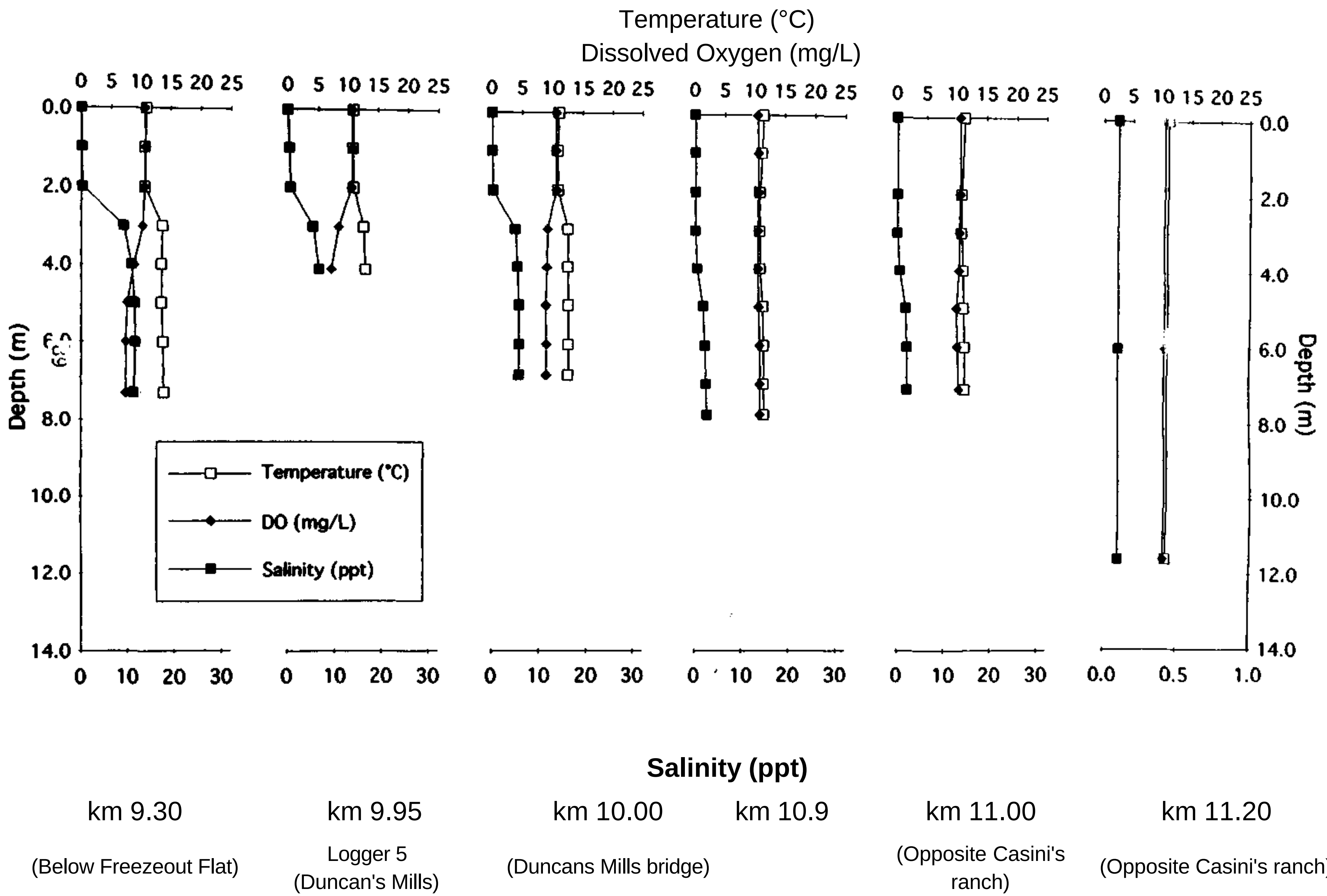


Salinity (ppt)

km 0.1	km 1.24	km 3.08	km 5.13	km 7.10	km 9.30	km 9.95
(Jetty/mouth)	Logger 1 (Visitor Center)	Logger 2 (Highway 1 bridge)	Logger 4 (Old bridge)	(Steep bedrock pool)	(Below Freezeout Flat)	Logger 5 (Duncan's Mills)

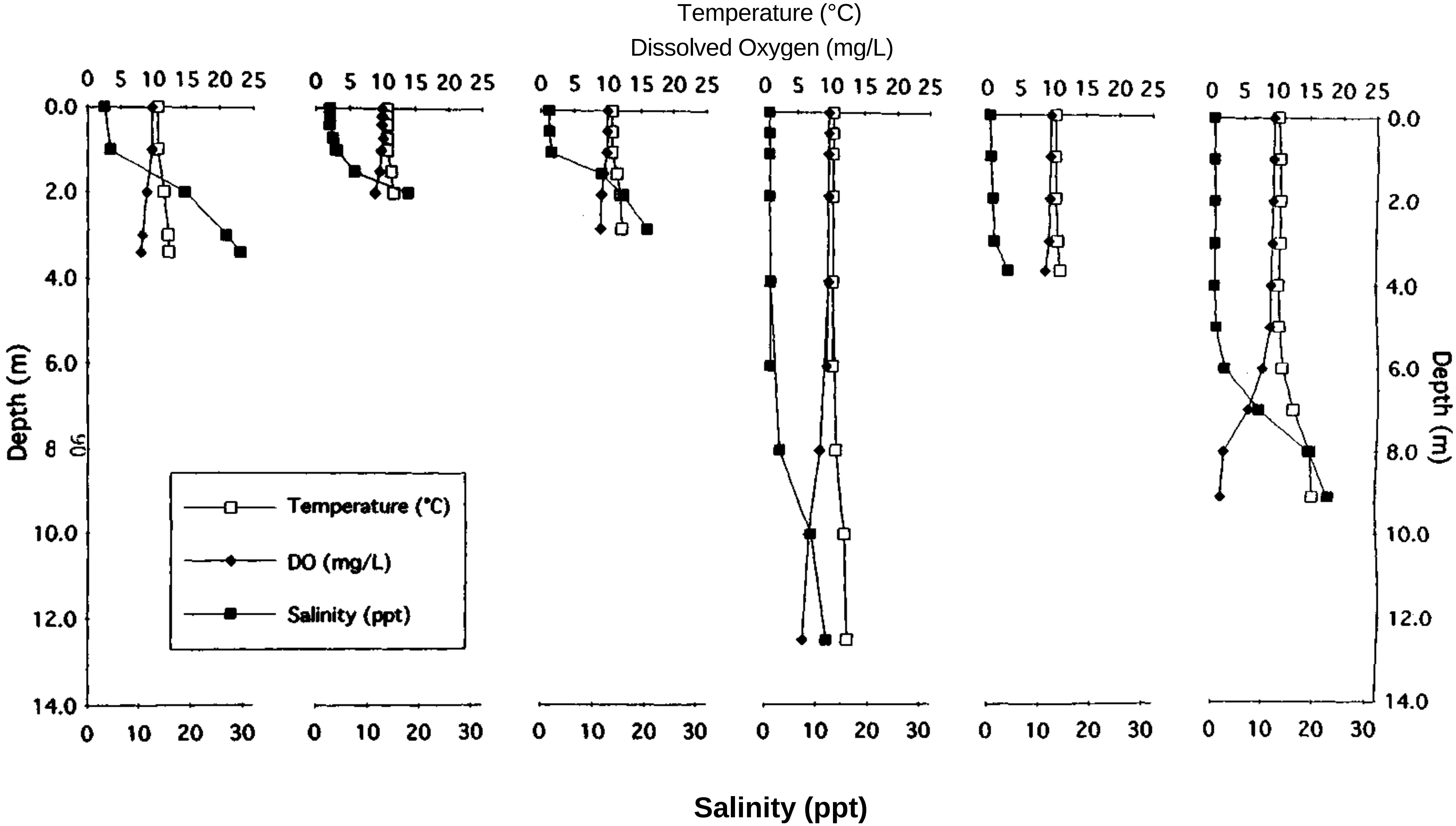
Water Chemistry: Longitudinal Hydrolab Survey November 30, 1992 (km 9.3-11.2)

Mouth closed



Water Chemistry: Longitudinal Hydrolab Survey December 1, 1992

Mouth open



km 0.1 (Jetty/mouth)

km 1.24 Logger 1 (Visitor Center)

km 3.08 Logger 2 (Highway 1 bridge)

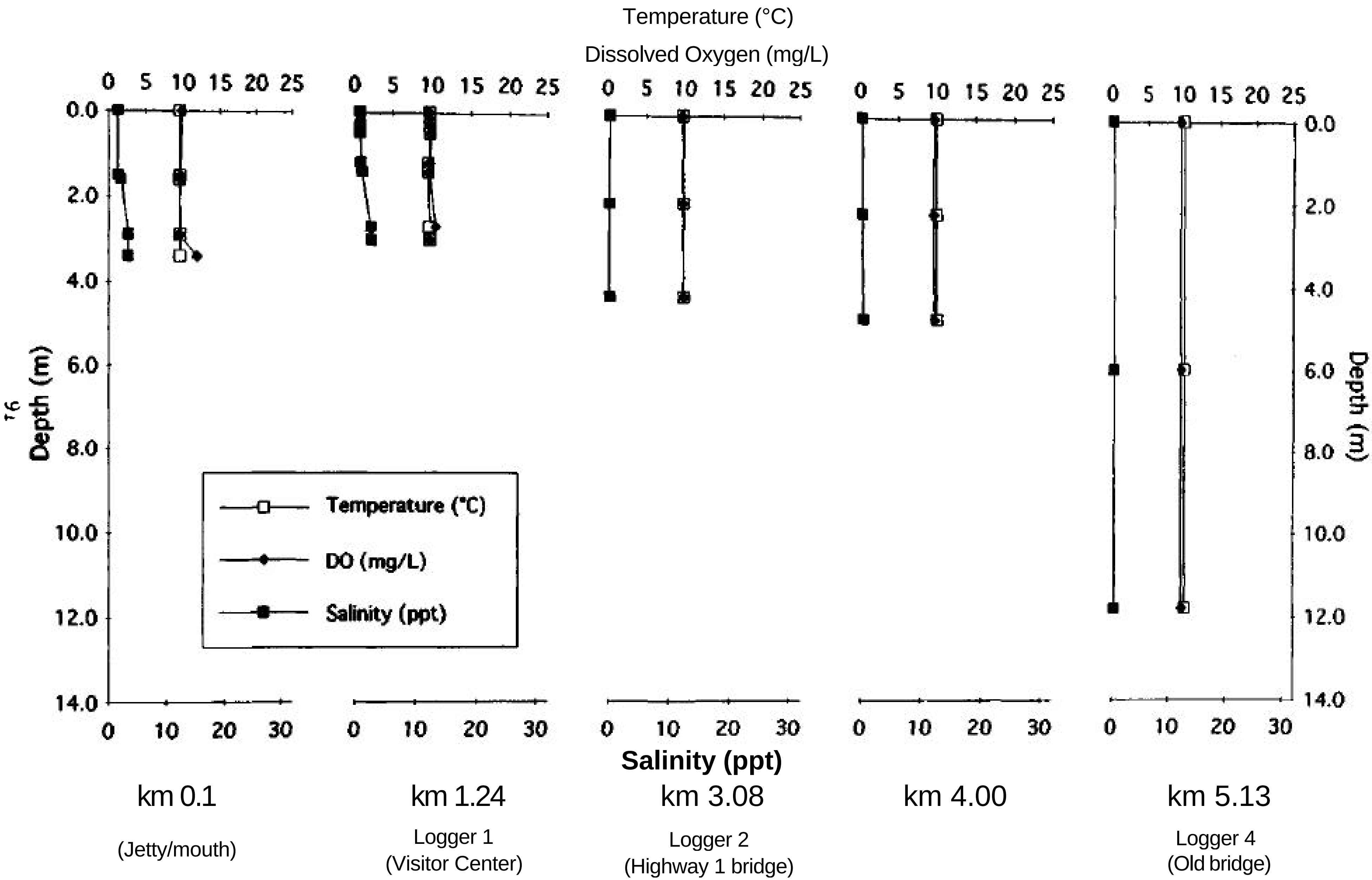
km 5.13 Logger 4 (Old bridge)

km 7.0 (Steep bedrock pool)

km 7.1 (Steep bedrock pool)

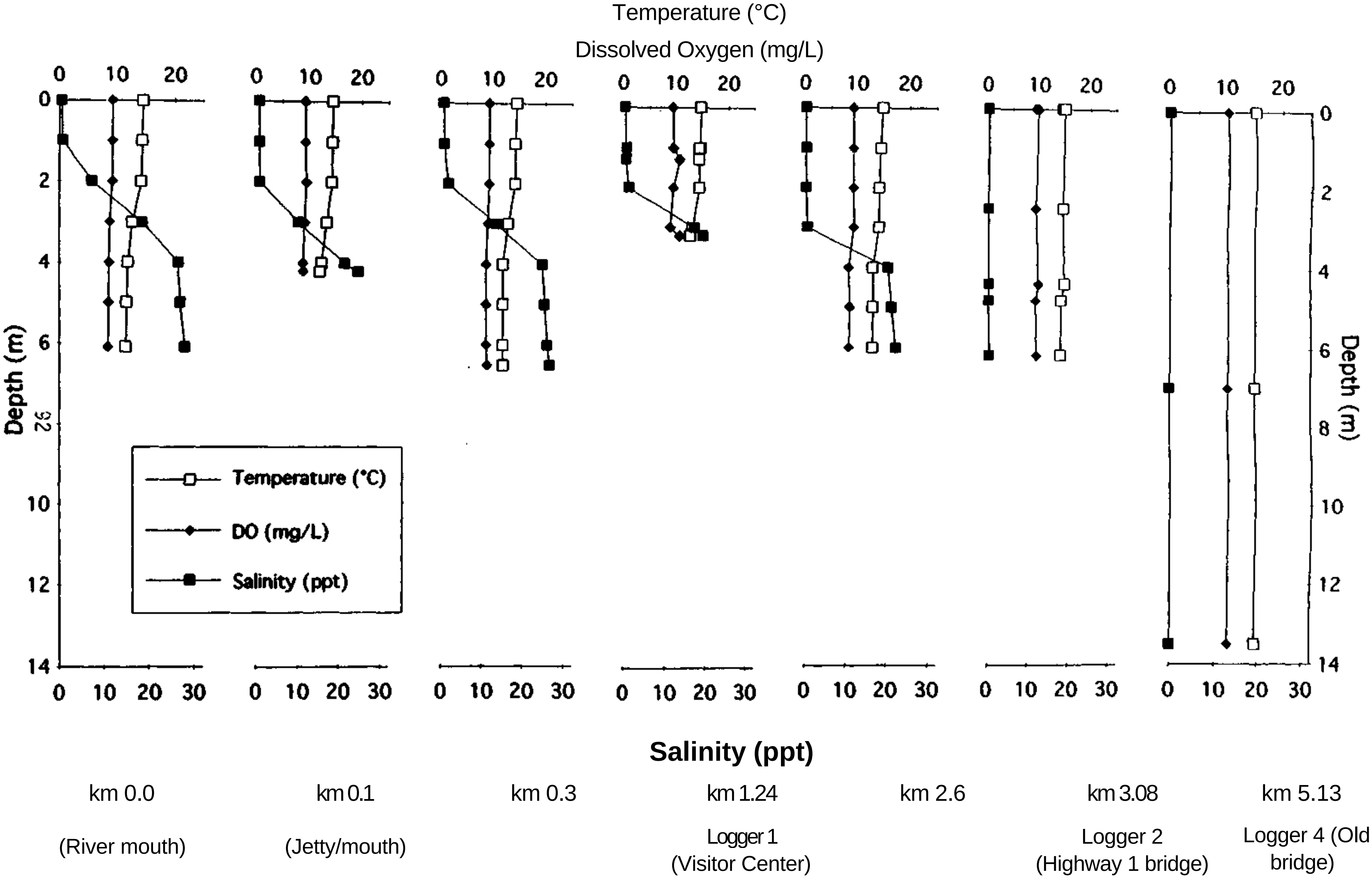
Water Chemistry: Longitudinal Hydrolab Survey December 16, 1992

Mouth open



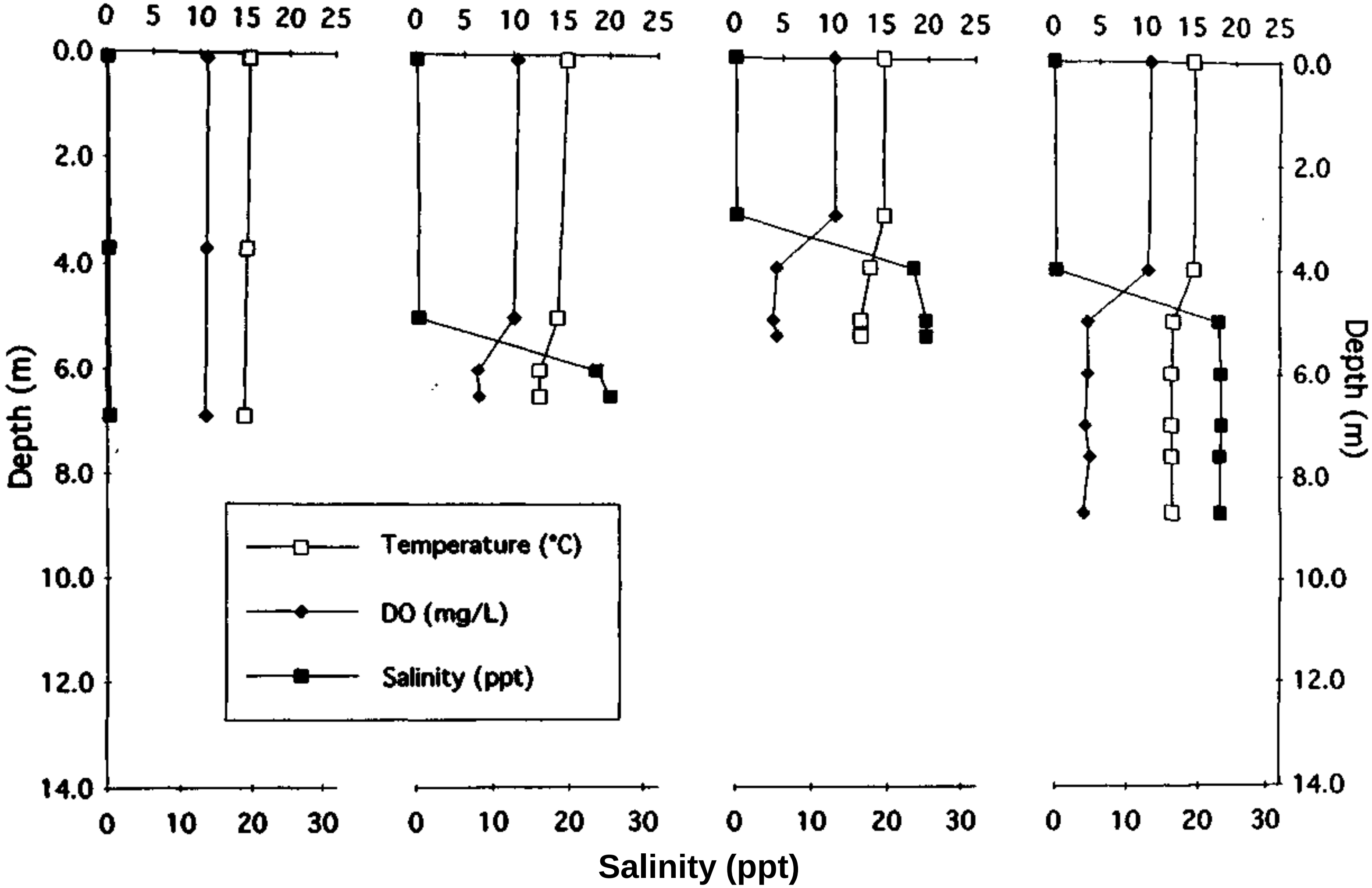
Water Chemistry: Longitudinal Hydrolab Survey April 6, 1993

Mouth open



Water Chemistry: Longitudinal Hydrolab Survey April 14, 1993

Mouth open



km 0.0 (River mouth)

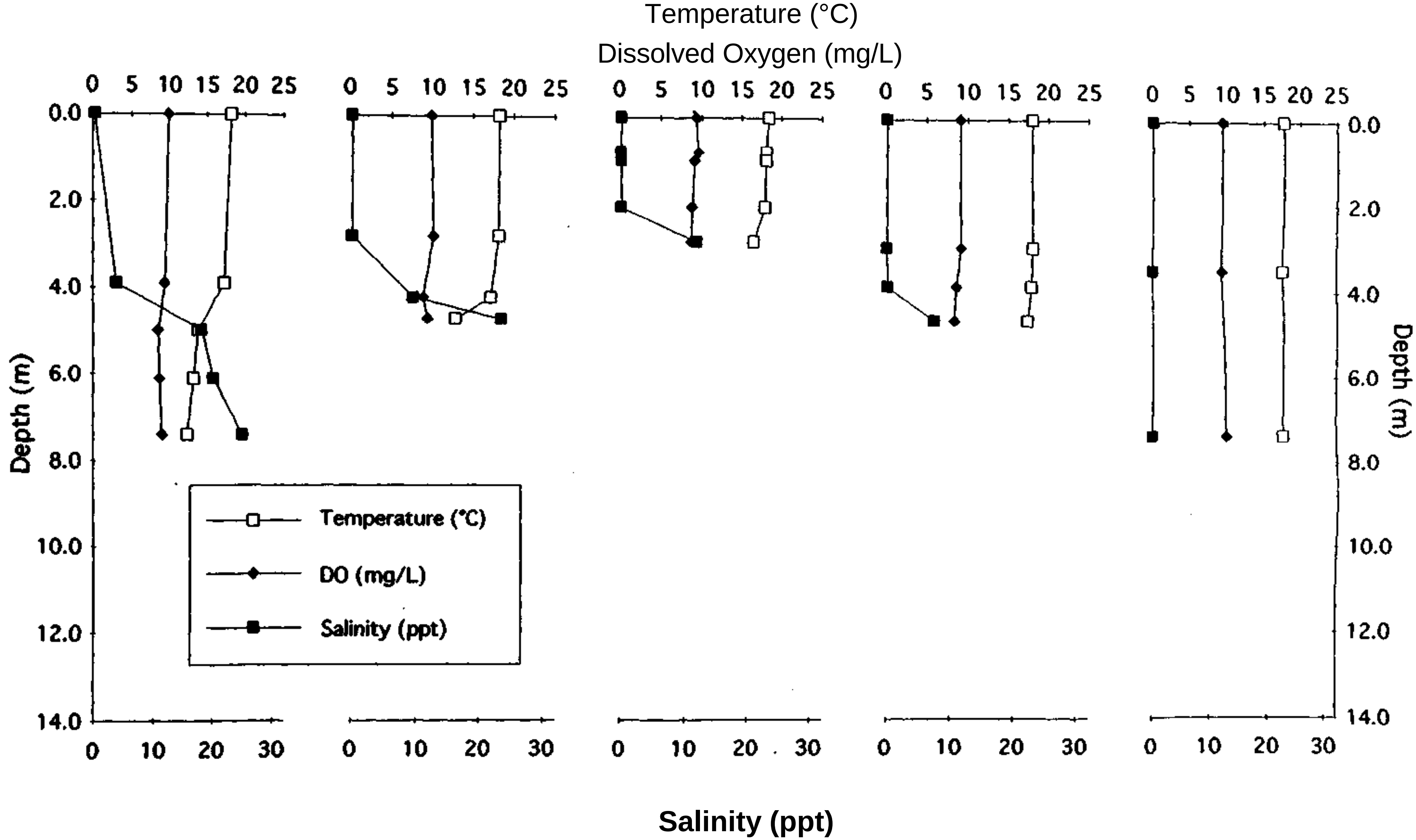
km 0.1 (Jetty/mouth)

km 2.50

km 3.08 Logger 2 (Highway 1 bridge)

Water Chemistry: Longitudinal Hydrolab Survey April 30, 1993

Mouth open



km 0.0 (River mouth)

km 0.1 (Jetty/mouth)

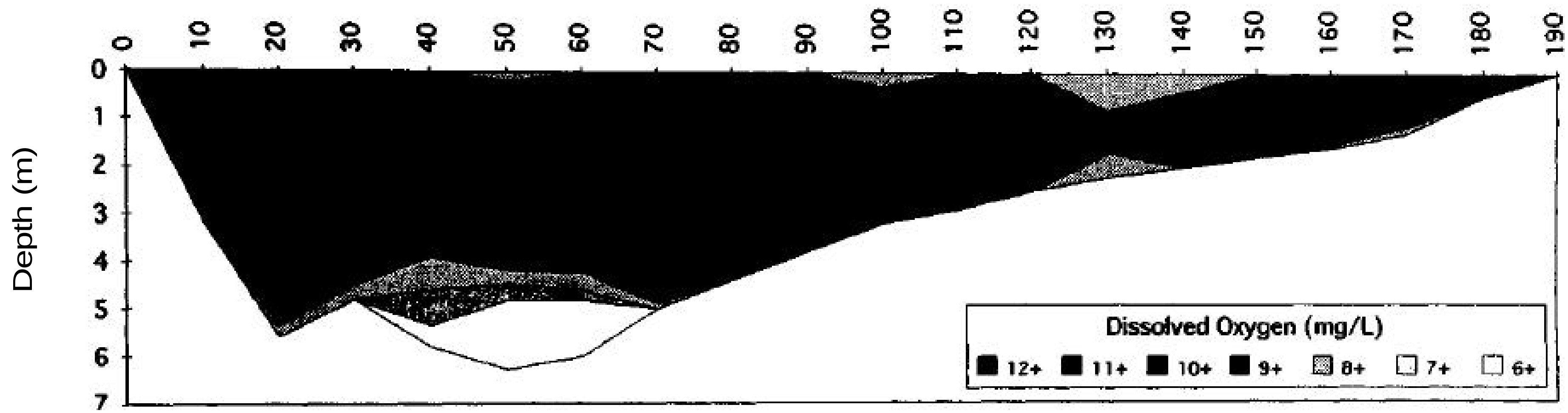
km 1.24 Logger 1 (Visitor Center)

km 2.50

km 3.08 Logger 2 (Highway 1 bridge)

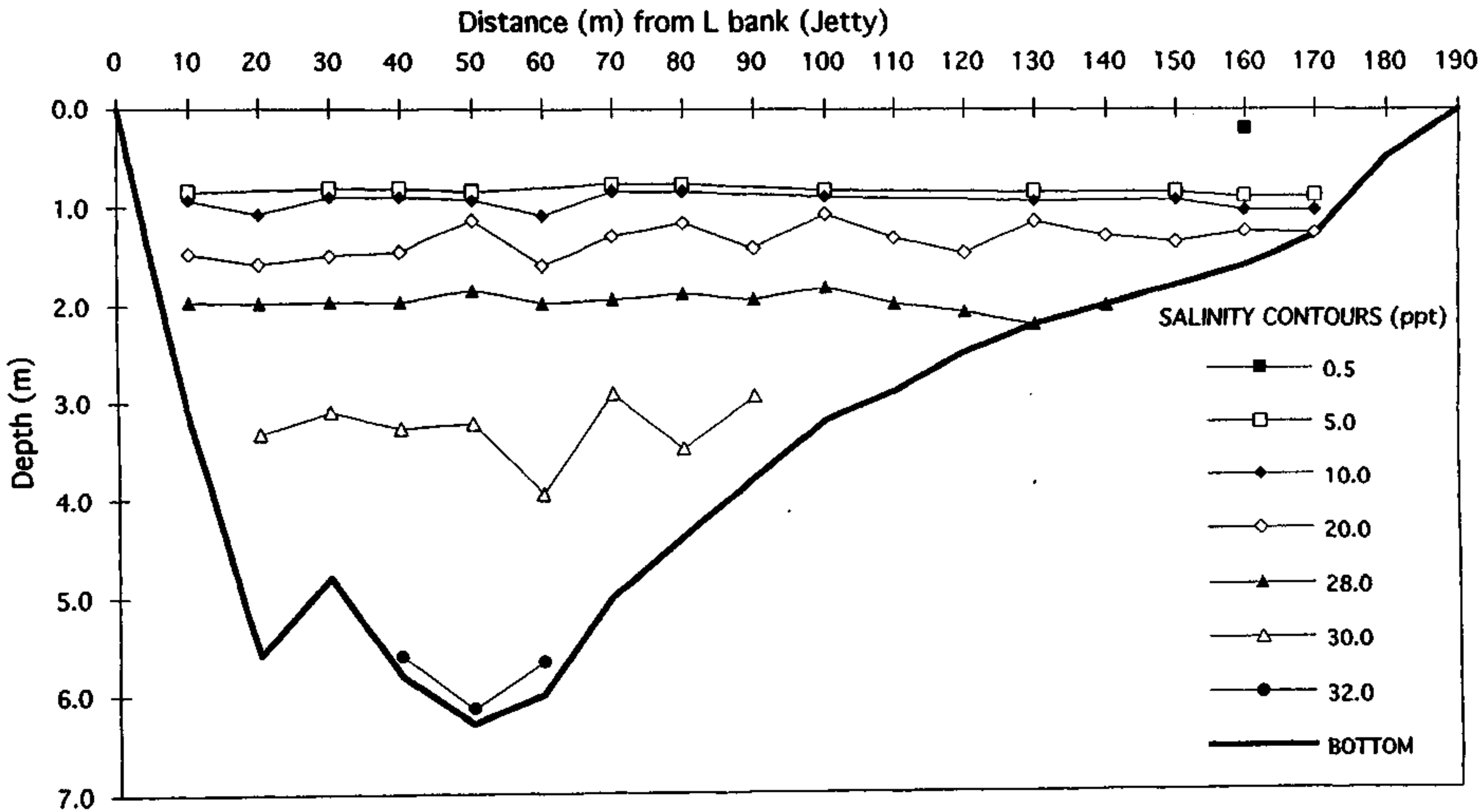
Fig 7.5

Distance from L bank (m)



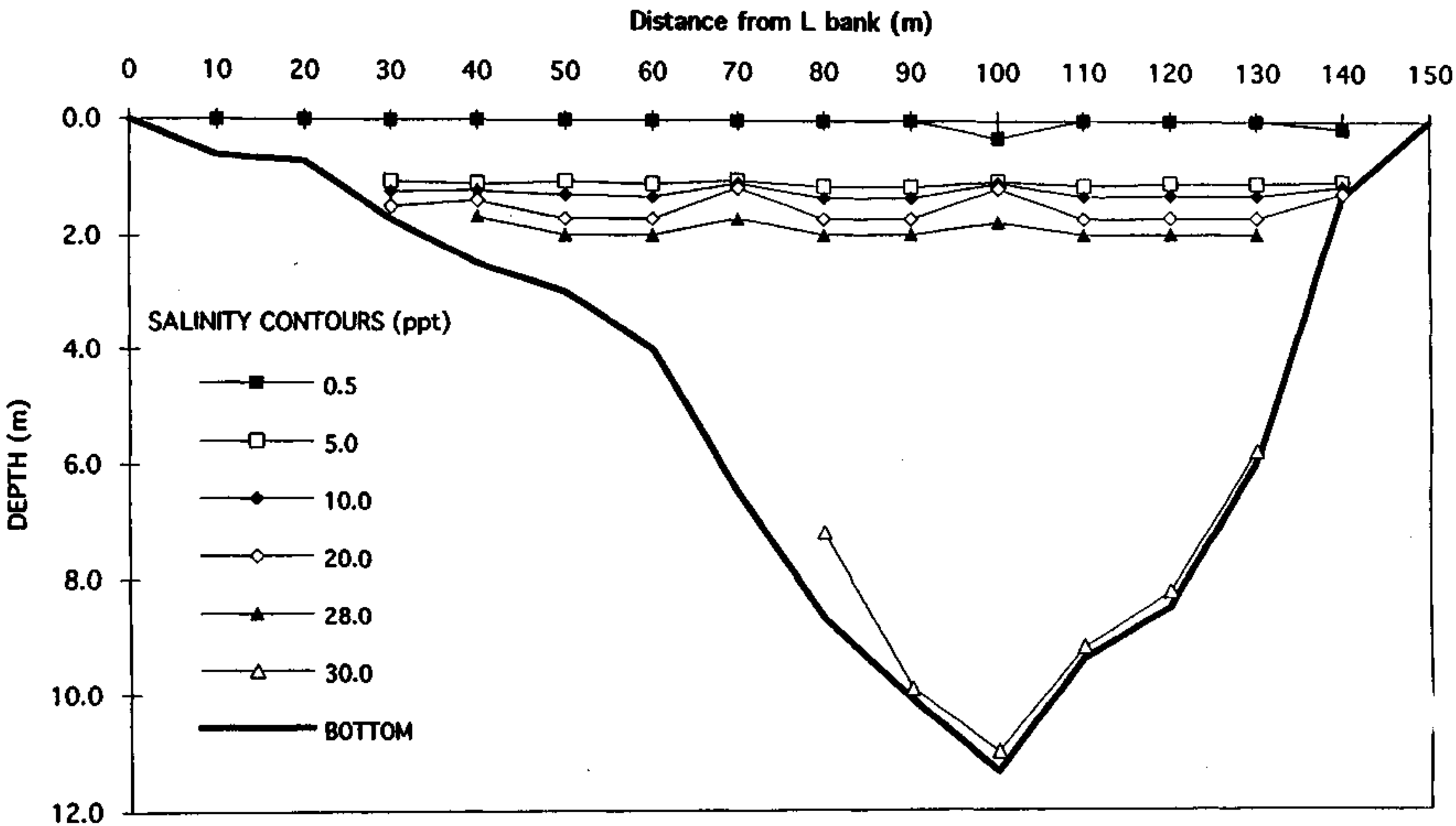
Russian River Estuary Study (USFS)
Fig. 7.6 - 2 pages

Salinity Cross-Section: RR km 0.1 (Jetty)
30-Jul-92



Salinity Cross-Section: RR km 5.13 (Old Bridge site)

31-Jul-92



flows floated over the surface of these dense salt pockets. Large portions of deep (> 10 m) riverine pools, often associated with bedrock formations along the river bank, retained salt water pockets throughout the summer. Anoxic bottom conditions formed over longer periods as the salt pockets were concentrated due to evaporation and substrate drainage. When the river mouth was open tidal activity allowed exchange of salt water with in the lower estuarine pools with fresh ocean waters, preventing the formation of anoxic conditions. When the mouth was closed during the summer of 1992, only one pool received sufficient wave wash over the sand bar to mix the salt pocket, maintain normal saline levels and prevent anoxic conditions. Since the estuary is used at different times of the year by fish and invertebrates which need clean, oxygen-rich saline waters, it is important to continuously monitor stratification at the mouth when considering the impacts of artificial breaching.

C. Willow Creek

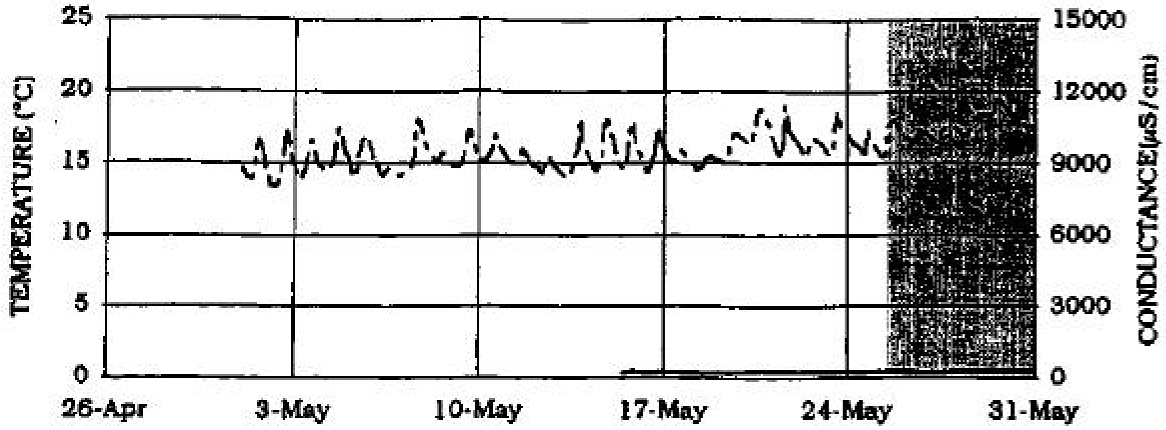
In situ monitoring sites were installed at two locations on Willow Creek (Sites #3 and #6; Figure 7.1). Conductivity probes installed at these sites were low tolerance probes designed to indicate presence/absence of saline waters with a conductance threshold of 2,000 S/cm. These probes were used to record low levels of saline intrusion more accurately than the high conductance probes used at the Russian River in situ sites. Due to the low threshold, upper salinity values were not recorded at these sites creating plateau plots of conductance when values exceeded 2,000 S/cm (Figure 7.7). Whenever possible manual values were recorded at both sites to indicate the ranges of upper saline values within the Willow Creek marsh. These manual records were plotted on the graphs in Figure 7.7.

On several occasions salt water did intrude up Willow Creek due to tidal activity without any direct relationship to the condition of the river mouth. The lower station at Willow Creek mouth remained partially saline from mid-August through November in 1992. The upper in situ site located in the deep channel at the head of the marsh maintained partial saline conditions from late August through October. Tidal activity obviously influenced the salt content of these sites during periods when the river mouth was open in the late fall. In hindsight we should have installed both types of conductance probes at these sights to properly monitor the seasonal flux of salt content in the marsh. Without consistent monitoring of the extreme seasonal range of values found at these sites, it is difficult to associate the influence of tidal activity and mouth condition in the marsh. Despite our limited data, it is clear that the Willow Creek marsh is limnologically influenced by conditions in the larger Russian River estuary and should be considered a vital part of the estuarine system.

WILLOW CREEK TEMPERATURE AND CONDUCTANCE -- MAY-JUNE 1992

SITE 3

km 0.1



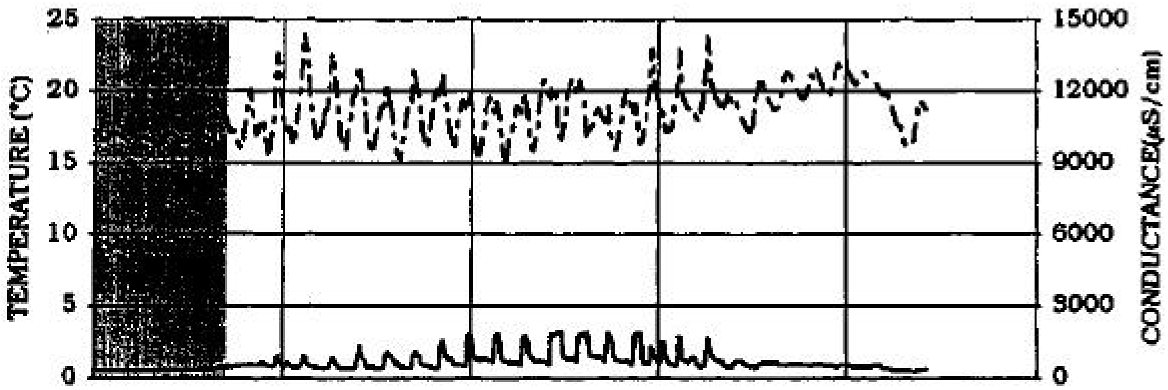
SITE 6

km 0.5

not installed

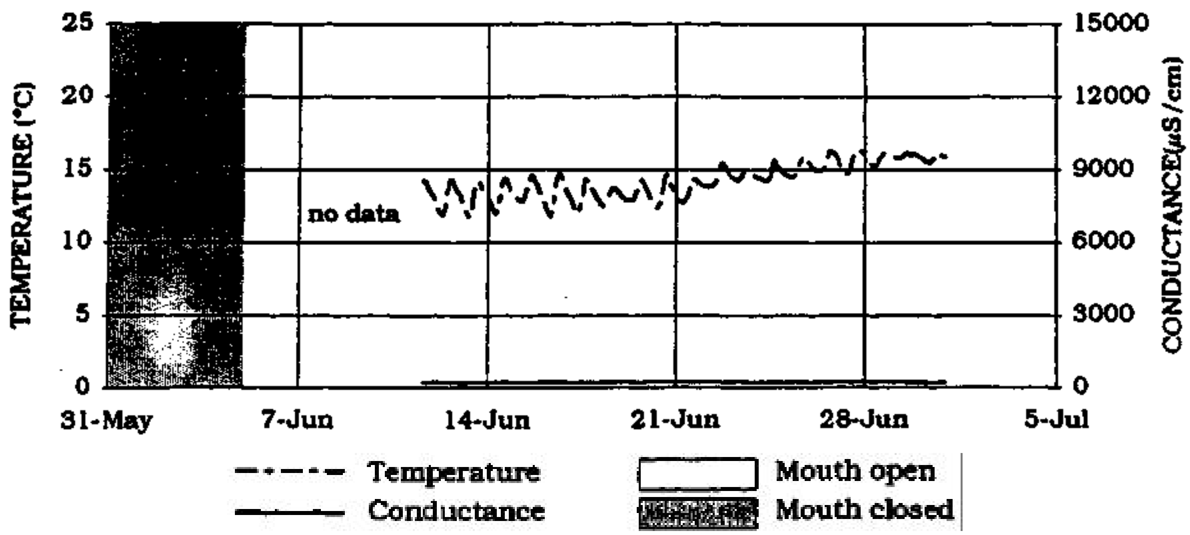
SITE 3

km 0.1

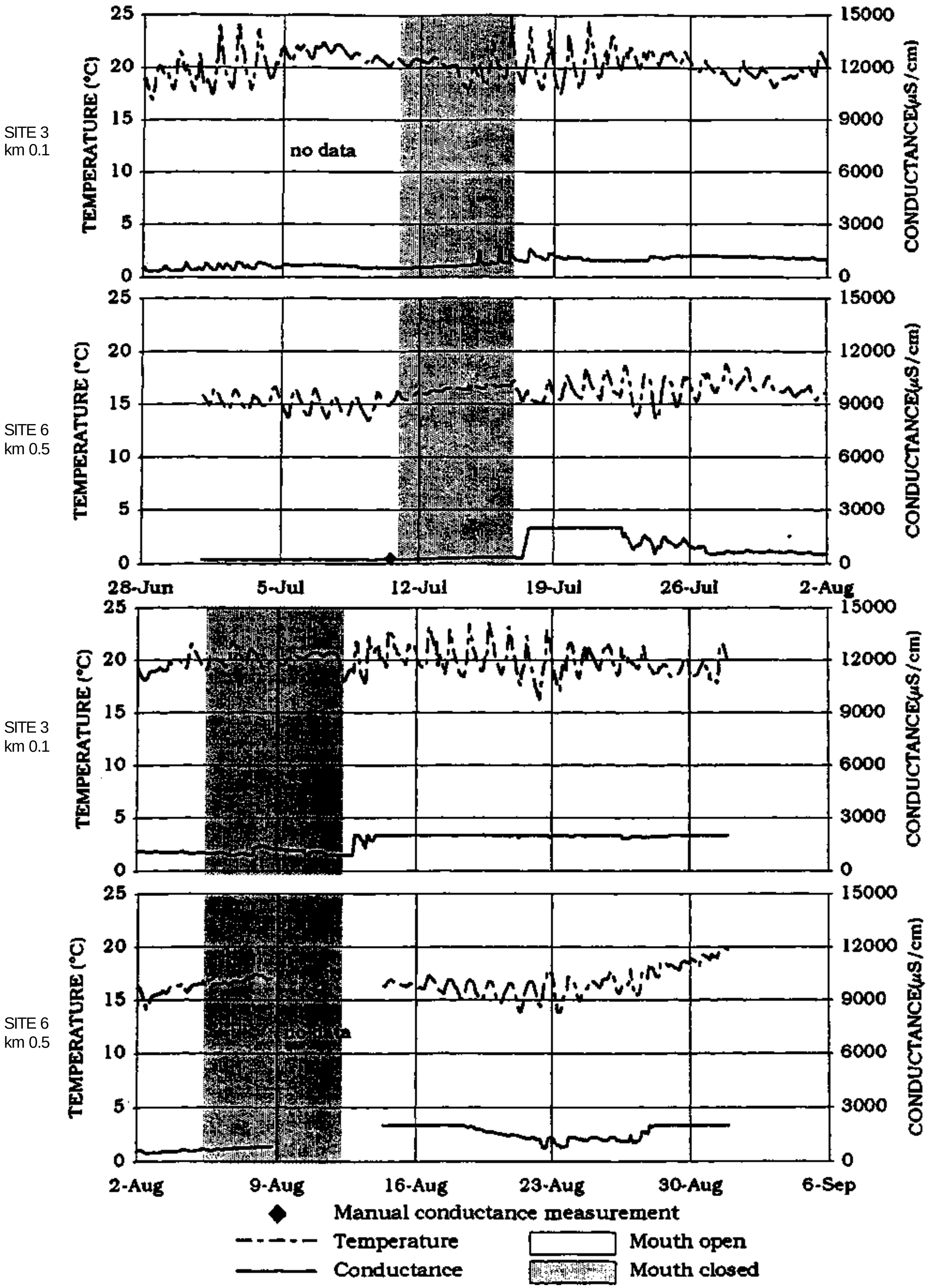


SITE 6

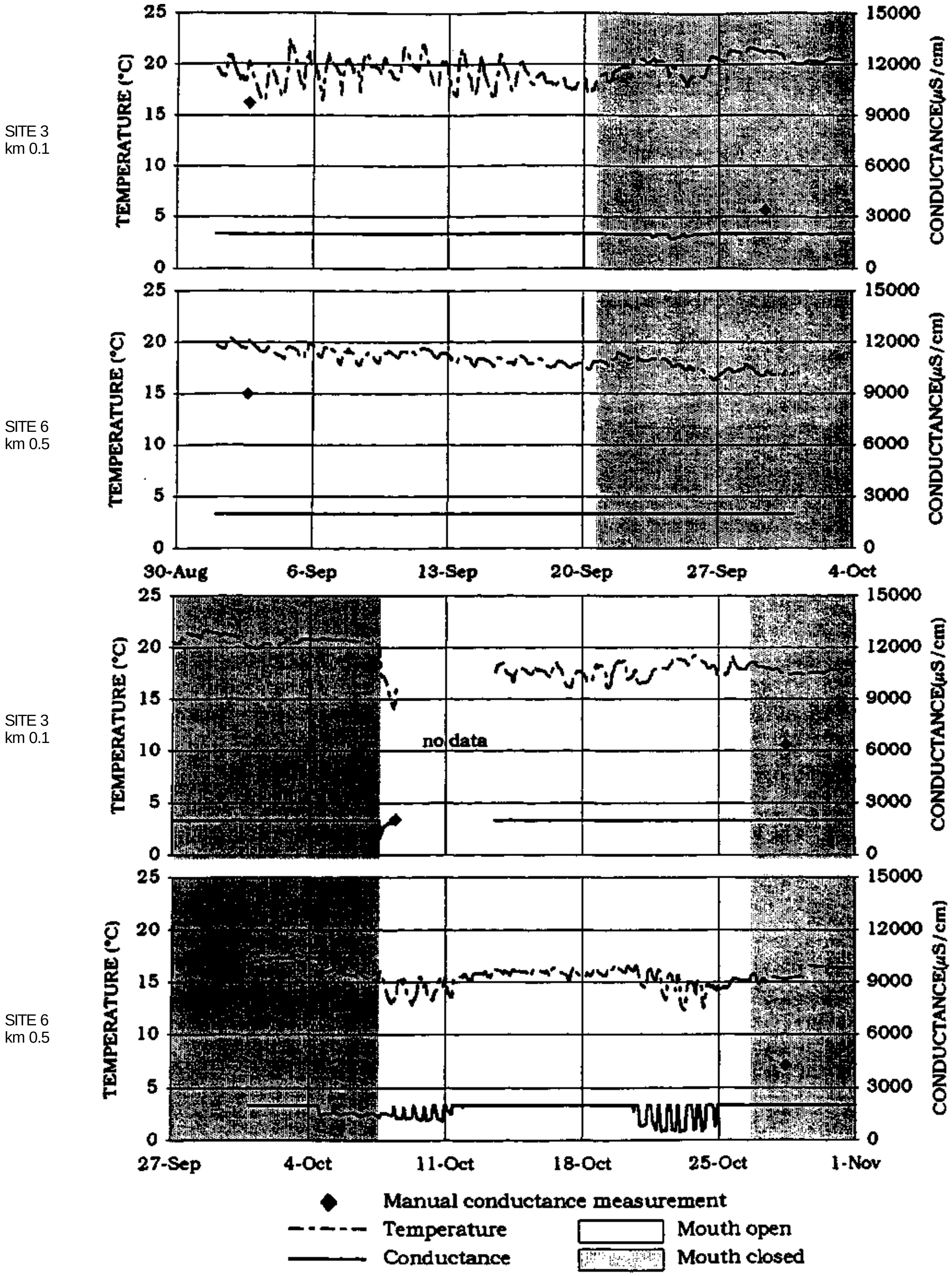
km 0.5



WILLOW CREEK TEMPERATURE AND CONDUCTANCE -- JULY-AUGUST 1992



WILLOW CREEK TEMPERATURE AND CONDUCTANCE -- SEPTEMBER-OCTOBER 1992



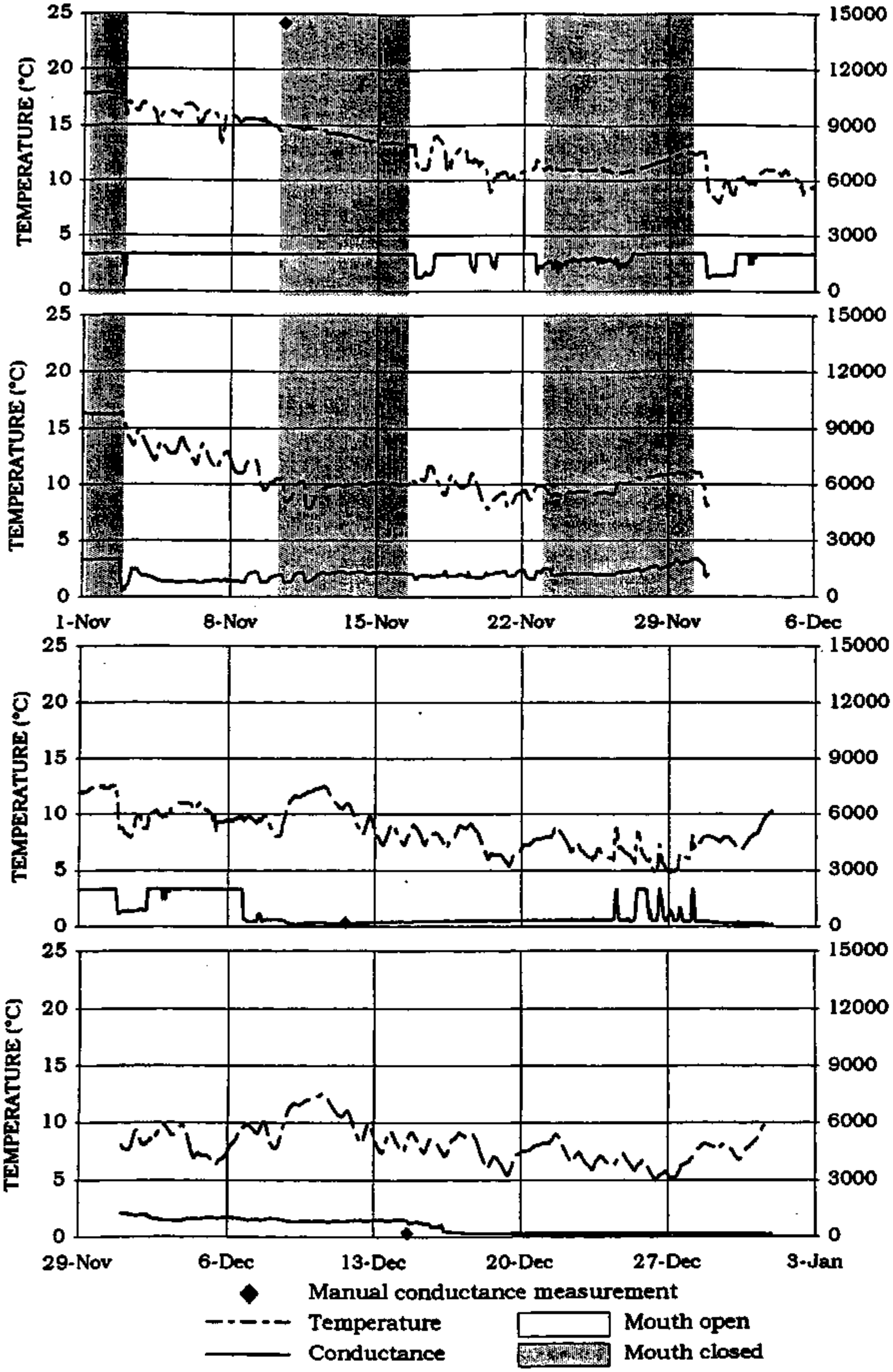
WILLOW CREEK TEMPERATURE AND CONDUCTANCE--NOVEMBER-DECEMBER 1992

SITE 3
km 0.1

SITE 6
km 0.5

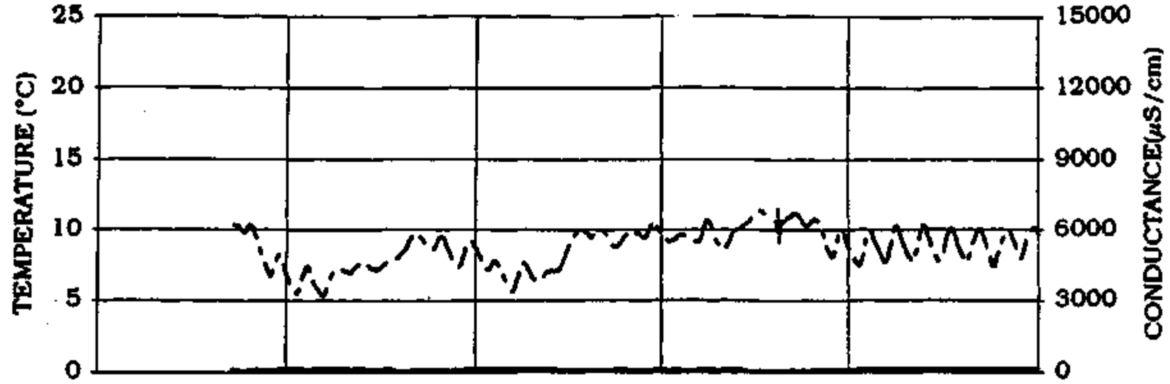
SITE 3
km 0.1

SITE 6
km 0.5

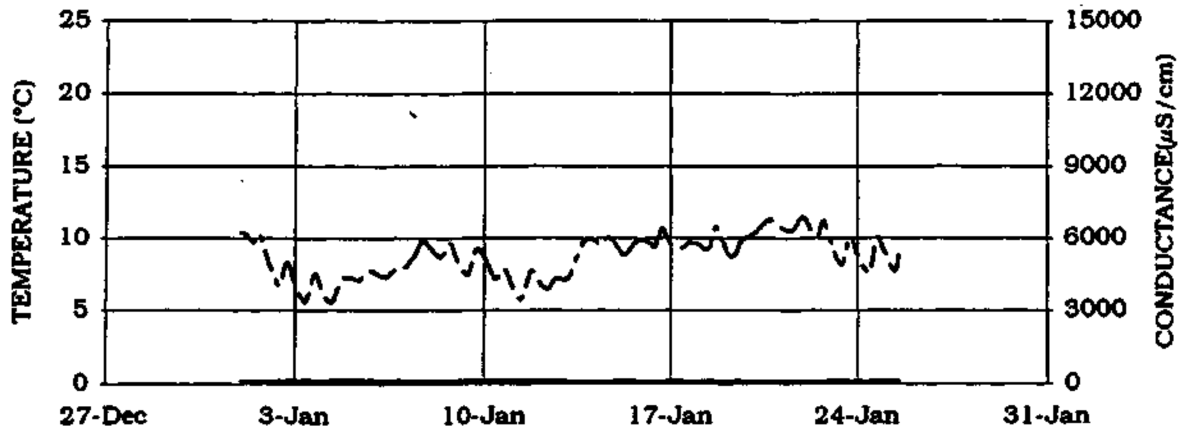


WILLOW CREEK TEMPERATURE AND CONDUCTANCE -- JANUARY-FEBRUARY 1993

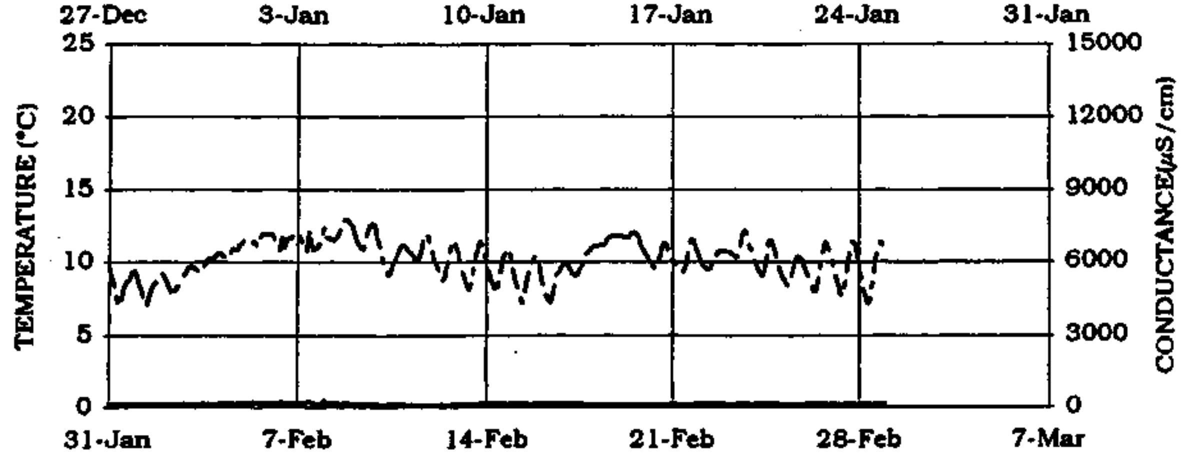
SITE 3
km 0.1



SITE 6
km 0.5

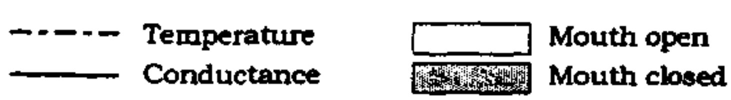


SITE 3
km 0.1



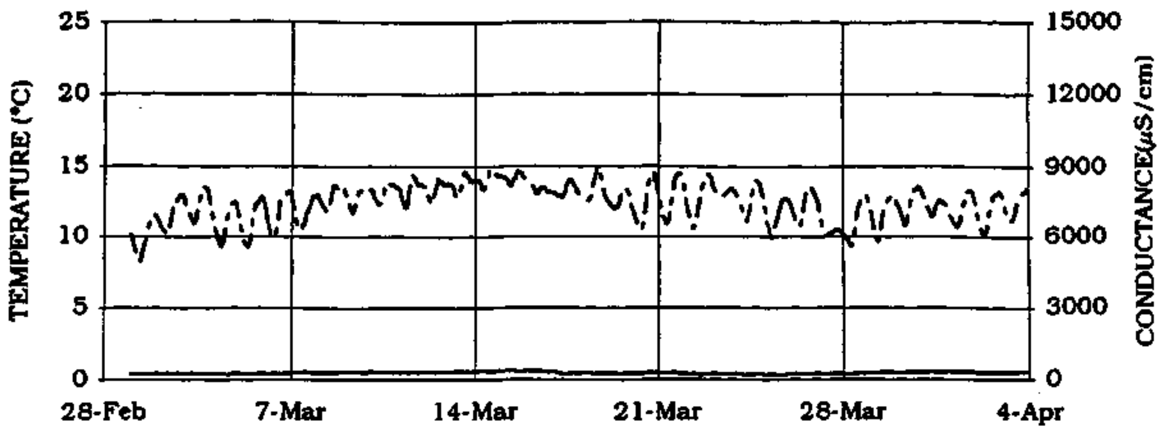
SITE 6
km 0.5

not installed



WILLOW CREEK TEMPERATURE AND CONDUCTANCE -- MARCH-APRIL 1993

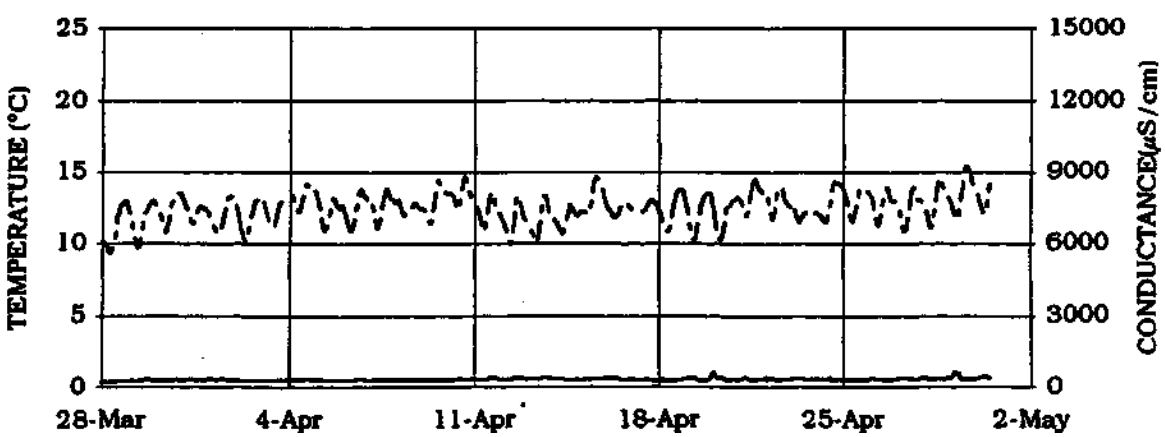
SITE 3
km 0.1



SITE 6
km 0.5

not installed

SITE 3
km 0.1



SITE 6
km 0.5

not installed

Temperature
Conductance
Mouth open
Mouth closed

The upper reaches of Willow Creek marsh (above the in situ site) became totally anoxic by mid-summer. Heavy sediment accumulation occurs in this area. Low fresh water inflows from Willow Creek are insufficient to provide mixing during summer runoff conditions. Stranded pools fed by limited subsurface flow from the creek, stratify and remain stagnant. The test breaching performed as part of this study, where the estuary water level was allowed to pass nine feet at the Jenner gage, caused inundation of these stagnant upper marsh areas. When the mouth was artificially breached, much of the anoxic waters from these pools also drained from the marsh. Turbulence during draining was not sufficient at Willow Creek mouth to break down the anoxic condition of these waters. Numerous fish were recorded escaping the anoxic wedge as it passed through the marsh. After stabilization of the water level in the estuary post-breaching, deep water anoxic conditions were found in estuarine pools 1.5 km downstream from the mouth of Willow Creek where none had been previously recorded.

Temperatures in the lower marsh reached upper incipient lethal levels for many fish during day time highs throughout the summer. This section of the marsh drained the main open marsh habitat where solar exposure contributed greatly to increased temperatures in mid-channel. The margin marsh habitat, however, was highly convoluted passing through many deep side channels and flowing under dense vegetation mats providing significant thermal refugia during periods of maximum solar exposure.

VIII. BIOLOGICAL CONDITIONS OF THE ESTUARY

A. Fish

Twenty-four species of fish were captured in the Russian River estuary (Table 8.1). Fish in the estuary were sampled by hand seine, beach seine, hook-and-line, deep-water otter trawl, benthic tube collections, backpack electrofishing and electrofishing by boat, from June 1992 to May 1993. The most common fish collected in the near-shore areas of the estuary throughout the year were Sacramento suckers, prickly sculpin, and three-spine sticklebacks. Starry flounder and English sole represented the most common deep bottom fish collected during the survey.

A left-facing starry flounder caught in August (Table 8.2), was originally thought to be a 'hybrid sole' as described in Miller and Lea (1972). Five samples of these fish were taken back to our laboratory at UC Berkeley for further morphological and genetic analysis. Based on genetic analysis of the cytochrome-B gene of the mitochondrial DNA of these flat fish and on morphological analysis based on H. Orcutt's (1949) criteria for dextral and sinistral forms of starry flounder, these fish appear to represent a group of sinistral forms of this species. This was not unexpected, according to Orcutt in 1949 54.6% of the starry flounder caught in the San Francisco Bay were the sinistral form. The sinistral fish were captured at the same time as right facing starry flounder and English sole were collected. Insufficient genetic information was available to determine if this form was reproductively isolated in the estuary.

Nine chinook salmon smolts were captured during deep water seines in the lower estuary during the mouth closure in early June, 1992. Fin clips from these salmon were taken to our laboratory at Berkeley for genetic analysis. Amplification of the control loop region of salmonid mtDNA using the polymerase chain reaction indicated that these chinook smolts were genetically distinct and different from the two chinook mtDNA lineages found in Warm Springs hatchery. It was suggested that these may be fish that escaped from a rearing pond operated in 1992, by Louisiana Pacific Company in Ukiah, at the headwaters of the Russian River. Further genetic analysis of fish remaining in the rearing pond in Ukiah showed these chinook to be closely related to one of the mtDNA lineages found at Warm Springs derived from University of Washington brood stock. They were not similar to the fish seined in June from the estuary.

This leaves open the question of natural chinook production in the Russian River. Documented records of natural spawning by chinook in the mainstem or larger tributaries of the Russian are lacking. The June capture date was late for chinook smolt out migration and may indicate an important aspect of the temporal planning needed for artificial breaching. The smolts appeared to be in good health despite the mouth closure at this time. We do not know how long they had been holding in the estuary prior to our

TABLE 8.1

RUSSIAN RIVER ESTUARY PROJECT

FISH SPECIES OBSERVED

FAMILY	SPECIES	COMMON NAME
Catostomidae	Catostomus occidentalis	Sacramento sucker
Cottidae	Cottus asper	Prickly sculpin
Cottidae	Leptocottus armatus	Staghorn sculpin
Gasterosteidae	Gasterosteus aculeatus	Three-spine stickleback
Poeciliidae	Gambusia affinis	Mosquitofish
Centrachidae	Lepomis cyanellus	Green sunfish
Cyprinidae	Cyprinus carpio	Carp
Cyprinidae	Hesperoleucus symmetricus	California roach
Cyprinidae	Mylopharodon concephalus	Hardhead
Clupeidae	Clupea harengus	Pacific herring
Embiotocidae	Cymatogaster aggregata	Shiner surfperch
Engraulididae	Engraulis mordax	Northern anchovy
Gobiesocidae	Gobiesox meandricus	Northern clingfish
Osmeridae	Hypomesus pretiosus	Surfsmelt
Bothidae	Citharichthys sordidus	Pacific sandab
Pleuronectidae	Inopsetta ischyra	Hybrid sole
Pleuronectidae	Parophrys vetulus	English sole
Pleuronectidae	Platichthys stellatus	Starry flounder
Pleuronectidae	Psettichthys melanostictus	Sand sole
Salmonidae	Oncorhynchus mykiss	Steelhead
Salmonidae	Oncorhynchus tshawytscha	Chinook salmon
Sciaenidae	Genyonemus lineatus	White croaker
Scorpaenidae	Sebastes sp.	Rockfish
Syngnathidae	Syngnathus leptorhynchus	Bay pipefish

RUSSIAN RIVER FISH
June 1992

DATE	3-Jun-92				4-Jun-92			
MOUTH	CLOSED				BREACHED 08:15			
METHOD	BOAT SEINE (5)				BEACH SEINE (3)			
LOCATION	RR mouth (km 0.0-1.0)				WC mouth (km 0.0-0.3)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker	110	22.0	37	22-56	178	59	27	21- 35
Prickly sculpin					32	11	66	46- 106
Staghorn sculpin								
Three-spine stickleback					47	16	27	11- 62
Mosquitofish								
Green sunfish								
Carp								
California roach								
Hardhead								
Pacific herring								
Shiner surfperch								
Northern anchovy								
Northern clingfish								
Surfsmelt								
Pacific sanddab								
Hybrid sole								
English sole								
Starry flounder (TL)	1	0.2	25					
Sand sole								
Steelhead					1-DEAD			
Chinook salmon (TL)	9	1.8	114	103- 134				
White croaker								
Rockfish								
Bay pipefish								

RUSSIAN RIVER FISH
July 1992

Russian River Estuary Study (USFS)

DATE	8-Jul-92				8-Jul-92				22-Jul-92			
MOUTH	OPEN				OPEN				OPEN			
METHOD	BEACH SEINE (5)				BEACH SEINE (4)				BEACH SEINE (9)			
LOCATION	RR mouth (km 0.5-0.8)				WC mouth (km 0.0-0.1)				RR (km 2.0-8.7)			
	CATCH		SL(mm)		CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker	32	6.4			96	24	33	20- 52	123	14	42	21- 74
Prickly sculpin	42	8.4			10	2.5	52	41- 66	20	2.2	52	28- 76
Staghorn sculpin	1	0.2										
Three-spine stickleback	12	2.4			68	17	34	15- 52	674	75	31	20-45
Mosquitofish												
Green sunfish												
Carp												
California roach												
Hardhead												
Pacific herring												
Shiner surfperch												
Northern anchovy												
Northern clingfish												
Surfsmelt												
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder									2	0.2	42	38-45
Sand sole												
Steelhead												
Chinook salmon												
White croaker												
Rockfish												
Bay Pipefish												

RUSSIAN RIVER FISH

August 1992

DATE	6-Aug-92				20-Aug-92			
MOUTH	CLOSED				OPEN			
METHOD	BEACH SEINE (4)				OTTER TRAWL (10)			
LOCATION	WC mouth (km 0.0-0.1)				RR (km 0.1 -3.2)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker	20	5.0	29	22- 36				
Prickly sculpin	1	0.3	54		28	2.8	36	22- 53
Staghorn sculpin					1	0.1	44	
Three-spine stickleback	107	26.8	34	19- 51	305	30.5	45	28-58
Mosquitofish					1	0.1		
Green sunfish								
Carp	1	0.2	93					
California roach								
Hardhead	1	0.2	70					
Pacific herring								
Shiner surfperch					5	0.5	67	33-99
Northern anchovy					1	0.1	33	
Northern clingfish					1	0.1	24	
Surfsmelt								
Pacific sanddab					4	0.4	75	56- 85
Hybrid sole					17	1.7	82	66-98
English sole					22	2.2	69	62-81
Starry flounder					7	0.7	76	52- 104
Sand sole								
Steelhead								
Chinook salmon								
White croaker					1	0.1	88	
Rockfish					1	0.1	47	
Bay pipefish					1	0.1	77	

RUSSIAN RIVER FISH
August 1992

DATE	26-Aug-92				26-Aug-92			
MOUTH	OPEN				OPEN			
METHOD	BEACH SEINE (9)				BEACH SEINE (4)			
LOCATION	RR (km 0.5-4.1)				WC MOUTH (km 0.0)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker	2	0.2			14	3.5		
Prickly sculpin	25	2.8			1	0.3		
Staghorn sculpin								
Three-spine stickleback	36	4			98	24.5		
Mosquitofish								
Green sunfish								
Carp								
California roach								
Hardhead								
Pacific herring								
Shiner surfperch								
Northern anchovy								
Northern clingfish								
Surfsmelt								
Pacific sanddab								
Hybrid sole								
English sole								
Starry flounder	7	0.8						
Sand sole								
Steelhead								
Chinook salmon								
White croaker								
Rockfish								
Bay pipefish								

DATE	5-Oct-92				5-Oct-92				7-Oct-92			
MOUTH	CLOSED				CLOSED				BREACH 12:00			
METHOD	ELECTROSHOCK				ELECTROSHOCK				SEINE, STATIONARY (20 MIN)			
LOCATION	WC marsh (km 0.2-0.3)				RR (km 4.1-5.3)				WC mouth (km 0.1)			
	CATCH		SL(mm)		CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU r	mean	range
Sacramento sucker	3	n/a	85	75- 101	7	n/a	51	47- 55				
Prickly sculpin	2	n/a	63	63- 63					8	8.0	45	22-70
Staghorn sculpin												
Three-spine stickleback					1	n/a	44		37	37	29	15- 46
Mosquitofish	12											
Green sunfish												
Carp												
California roach												
Hardhead												
Pacific herring												
Shiner surfperch												
Northern anchovy												
Northern clingfish												
Surfsmelt												
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder												
Sand sole												
Steelhead												
Chinook salmon												
White croaker												
Rockfish												
Bay pipefish												

DATE	8-Oct-92				19-Oct-92				19-Oct-92			
MOUTH	OPEN				OPEN				OPEN			
METHOD	SEINE, STATIONARY (20 MIN)				BEACH SEINE (10)				BEACH SEINE (3)			
LOCATION	WC mouth (km 0.1)				RR (km 0.4-5.2)				WC mouth (km 0.1)			
	CATCH		SL(mm)		CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker									1	0.3	52	
Prickly sculpin	15	15			42	4.2	31	27-37	2	0.7		
Staghorn sculpin					24	2.4	33	26- 51	5	1.7	67	
Three-spine stickleback	107	107			294	29.4			142	47.3	45	
Mosquitofish												
Green sunfish												
Carp												
California roach												
Hardhead												
Pacific herring												
Shiner surfperch												
Northern anchovy												
Northern clingfish												
Surf smelt												
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder												
Sand sole												
Steelhead												
Chinook salmon												
White croaker												
Rockfish												
Bay Pipefish												

October 1992

DATE	22-Oct-92				28-Oct-92				28-Oct-92			
MOUTH	OPEN				CLOSED				CLOSED			
METHOD	BEACH SEINE (6)				BEACH SEINE (3)				BEACH SEINE (6)			
LOCATION	RR (km 8.7)				WC mouth (km 0.0)				RR mouth (km 0.0)			
	CATCH		SL(mm)		CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker												
Prickly sculpin									1	0.2	40	
Staghorn sculpin									1	0.2	52	
Three-spine stickleback	9	1.5	22	11- 37	2	0.7	18	12- 24				
Mosquitofish												
Green sunfish												
Carp												
California roach												
Hardhead												
Pacific herring												
Shiner surfperch												
Northern anchovy												
Northern clingfish												
Surfsmelt												
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder												
Sand sole												
Steelhead												
Chinook salmon												
White croaker												
Rockfish												
Bay pipefish												

RUSSIAN RIVER FISH
November 1992

DATE	2-Nov-92				2-Nov-92				10-NOV-92			
MOUTH	CLOSED (PRE-BREACH)				BREACHED 12:00				CLOSED			
METHOD	BEACH SEINE (3)				10 MIN STATIONARY SEINE (3)				BEACH SEINE (14)			
LOCATION	RR mouth (km 0.0)				RR mouth (km 0.0)				RR (km 0.0-8.5)			
	CATCH SL (mm)				CATCH SL (mm)				CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker												
Prickly sculpin									2	0.1	53.0	46- 60
Staghorn sculpin	6	2.0	41.2	40- 42	5	1.7	39.8	36- 46	2	0.1	46.5	44-49
Three-spine stickleback									10	0.7	23.7	20- 32
Mosquitofish									2	0.1	17.5	15-20
Green sunfish												
Carp												
California roach												
Hardhead												
Pacific herring												
Shiner surfperch												
Northern anchovy												
Northern clingfish												
Surfsmelt					3	1.0	41.0	37- 48				
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder												
Sand sole												
Steelhead												
Chinook salmon												
White croaker												
Rockfish												
Bay Pipefish												

DATE	16-Nov-92				18-Nov-92			
MOUTH	BREACH 11:55				OPEN (11)			
METHOD	10 MIN STATIONARY SEINE (4)				OTTER TRAWL			
LOCATION	RR mouth (km 0.0)				RR (km 0.3-3.7)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker								
Prickly sculpin								
Staghorn sculpin					2	0.2	106.0	75- 137
Three-spine stickleback					12	1.1	42.6	35- 50
Mosquitofish								
Green sunfish								
Carp								
California roach								
Hardhead								
Pacific herring								
Shiner surfperch								
Northern anchovy					1	0.1	45	
Northern clingfish								
Surfsmelt	1	0.3	42.0		11	1.0	65.1	58- 73
Pacific sanddab								
Hybrid sole								
English sole					1	0.1	88	
Starry flounder					4	0.4	102.5	88- 121
Sand sole					80	7.3	56.19	35- 69
Steelhead								
Chinook salmon								
White croaker								
Rockfish								
Bay pipefish					1	0.1	155	

DATE	2-Nov-92				2-Nov-92				10-Nov-92			
MOUTH	CLOSED (PRE-BREACH)				BREACHED 12:00				CLOSED			
METHOD	BEACH SEINE (3)				10 MIN STATIONARY SEINE (3)				BEACH SEINE (14)			
LOCATION	RR mouth (km 0.0)				RR mouth (km 0.0)				RR (km 0.0-8.5)			
	CATCH		SL(mm)		CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker												
Prickly sculpin									2	0.1	53.0	46- 60
Staghorn sculpin	6	2.0	41.2	40- 42	5	1.7	39.8	36- 46	2	0.1	46.5	44- 49
Three-spine stickleback									10	0.7	23.7	20- 32
Mosquitofish									2	0.1	17.5	15- 20
Green sunfish												
Carp												
California roach												
Hardhead												
Pacific herring												
Shiner surfperch												
Northern anchovy												
Northern clingfish												
Surfsmelt					3	1.0	41.0	37- 48				
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder												
Sand sole												
Steelhead												
Chinook salmon												
White croaker												
Rockfish												
Bay Pipefish												

RUSSIAN RIVER FISH

November 1992

DATE	16-Nov-92				18-Nov-92			
MOUTH	BREACH 11:55				OPEN			
METHOD	10 MIN STATIONARY SEINE (4)				OTTER TRAWL (11)			
LOCATION	RR mouth (km 0.0)				RR (km 0.3-3.7)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker								
Prickly sculpin								
Staghorn sculpin					2	0.2	106.0	75- 137
Three-spine stickleback					12	1.1	42.6	35- 50
Mosquitofish								
Green sunfish								
Carp								
California roach								
Hardhead								
Pacific herring								
Shiner surfperch								
Northern anchovy					1	0.1	45	
Northern clingfish								
Surfsmelt	1	0.3	42.0		11	1.0	65.1	58- 73
Pacific sanddab								
Hybrid sole								
English sole					1	0.1	88	
Starry flounder					4	0.4	102.5	88- 121
Sand sole					80	7.3	56.19	35- 69
Steelhead								
Chinook salmon								
White croaker								
Rockfish								
Bay pipefish					1	0.1	155	

RUSSIAN RIVER FISH
March 1993

DATE	11-Mar-93				11-Mar-93			
MOUTH	OPEN				OPEN			
METHOD	OTTER TRAWL *(7)*				ELECTROSHOCK			
LOCATION	RR (km 0.1 -1.5)				RR (km 0.1 -5.2)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker					8	n/a	248	100- 385
Prickly sculpin	1	0.1	44					
Staghorn sculpin	1	0.1	56					
Three-spine stickleback	10	1.4	49	44- 54				
Mosquitofish								
Green sunfish								
Carp								
California roach					4	n/a	67	55- 86
Hardhead								
Pacific herring								
Shiner surfperch								
Northern anchovy								
Northern clingfish								
Surfsmelt					7	n/a	124	103- 131
Pacific sanddab								
Hybrid sole								
English sole								
Starry flounder	2	0.3	116	109- 122				
Sand sole								
Steelhead								
Chinook salmon								
White croaker								
Rockfish								
Bay pipefish								

DATE	14-Apr-93				22-Apr-93				22-Apr-93			
MOUTH	OPEN				OPEN				OPEN			
METHOD	OTTER TRAWL (10)				BEACH SEINE (6)				BEACH SEINE (4)			
LOCATION	RR (km 0.1 -3.5)				RR (km 4.1-5.2)				WC mouth (km 0.0-0.1)			
	CATCH		SL(mm)		CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker									1	0.3	70	
Prickly sculpin	4	0.4	75.5	63- 85					2	0.5	42	38- 47
Staghorn sculpin												
Three-spine stickleback	1	0.1	56		13	2.2	30.9	16- 49	22	5.5	36	14- 54
Mosquitofish												
Green sunfish									1	0.3	26	
Carp					1	0.2	20					
California roach												
Hardhead												
Pacific herring	4	0.4	182	175- 195	1	0.2	14					
Shiner surfperch	5	0.5	90.2	72- 108								
Northern anchovy												
Northern clingfish												
Surfsmelt												
Pacific sanddab												
Hybrid sole												
English sole												
Starry flounder	2	0.2	118	91- 145								
Sand sole												
Steelhead												
Chinook salmon					1	0.2	41					
White croaker												
Rockfish												
Bay pipefish												

RUSSIAN RIVER FISH
May 1993

DATE	10-May-93				10-May-93			
MOUTH	OPEN				OPEN			
METHOD	BEACH SEINE (8)				BEACH SEINE (3)			
LOCATION	RR (km 0.3-5.2)				WC mouth (km 0.0-0.1)			
	CATCH		SL(mm)		CATCH		SL(mm)	
SPECIES	total	CPU	mean	range	total	CPU	mean	range
Sacramento sucker								
Prickly sculpin					2	0.7	43	42- 43
Staghorn sculpin	4	0.5	58	39- 100				
Three-spine stickleback	8	1	36	19- 53	15	5	37	14- 52
Mosquitofish					3	1	23	21- 24
Green sunfish								
Carp								
California roach	2	0.25	38	37- 39				
Hardhead								
Pacific herring	652	81.5	20	15- 25	40	13		
Shiner surfperch								
Northern anchovy								
Northern clingfish								
Surfsmelt								
Pacific sanddab								
Hybrid sole								
English sole								
Starry flounder								
Sand sole								
Steelhead								
Chinook salmon					1	0.3	25	
White croaker								
Rockfish								
Bay pipefish								

capture. No chinook smolts were captured after the June 4th breach by the county. It is important to consider further genetic and distribution studies on chinook salmon in the Russian River to determine if these smolts represent a unique wild lineage endemic to the Russian River and if the timing of their migrations, both adult spawning and juvenile smolt, are impacted by the closure and/or breaching of the river mouth.

Various marine species were found to utilize the estuary at different times of the year. Juvenile staghorn sculpin were found in near shore habitats in the lower estuary from August-November. Pacific herring spawned in the estuary in March and young herring fry left in May. Northern anchovy were caught in August. Juvenile rockfish were found in the lower estuary in August when the mouth was open. Larval surfsmelt were seen during the November breach.

The distribution of marine fish captured during this study was limited to the lower estuary below Willow Creek mouth, with the most salt sensitive species found only in the bay directly adjacent to the mouth where tidal activity periodically renewed the salt water habitats. Upriver freshwater species, such as hardhead, California roach and mosquito fish, tended to move down into the estuary and the Willow Creek marsh during the summer and return to upstream habitats in the fall.

The assemblage within the estuary reflects most species common to the Sonoma coastal and river habitats. We sampled for tidewater gobies within the tidal flats around Penny Island and along the south shore of the estuary in habitats commonly used by these species (R. Swenson, Univ. CA, Berkeley, personal communications). Sampling was done by placing lined PVC tubes (1") in the substrate during low tide and leaving them for up to two weeks. Tidewater gobies commonly will select these tubes for as prime estuarine habitat for breeding nests and eggs casings can be seen attached to the lining after use. No tidewater gobies nor egg casings were found in 5 sampling sets of 25 tubes each in the Russian River. We can conclude from these samples taken throughout their salinity tolerance range that this species probably no longer exists in the Russian River estuary.

The only evidence of direct impact to the fish community during an artificial breach occurred during the 9' artificial breach on November 16, 1992. The standing wave at the mouth created by this breach carried freshwater from the estuary with tremendous force, taking with it hundreds of juvenile surfsmelt that had been swimming in the near shore estuary around the mouth for two weeks prior to the breach. Spawning of surfsmelt occurs at high tide (Sept. 20th was the last open-mouth high tide on the Russian River) and eggs tend to hatch in 10-11 days. Newly hatched larvae are about 3 mm long. Subsequent juvenile life history is not known (J. Hart, 1980). One Fish caught at the mouth during the November breach was 42 mm standard length (SL), but many smaller fish were seen in the outflow. After the artificial breach numerous smelt were seen and captured in the open estuary with an average size of 65 mm. Adult smelt reach sizes of 305 mm in coastal California waters. It may be important to consider the spawning movement of this fish within the estuary during breaching at this time of year. It is known that smelt tend to segregate by sexes and schools of fish dominated by males may enter spawn areas prior to females.

During the fall and winter of 1992-1993, the mouth of the Russian River remained open from late November through May, the time when most salmonid adults would be migrating upriver to spawn. Although no direct evidence can be drawn from our data, it is mandatory to consider these runs in the timing of artificial breaching in the fall in future years. One important implication of fall breaching is that critical river flows must be maintained along the migration route used by adult salmon. Pools deep enough to attract adult salmon may remain hyper saline at depth until the first large storm of the winter, providing no holding habitat for these fish in the estuary and lower river. Allowing the fish access to the freshwater system without migration holding pools with adequate water quality to sustain them is equivalent to a death warrant. The decision to breach the mouth in the fall and early winter period must include discussion of available upriver holding-pool habitat as well as access to spawning areas.

B. Crabs & Shrimp

Eight species of crab and five species of shrimp were collected during otter trawls on the Russian River estuary (Table 8.3; Figure 8.1). Of the crabs, *Cancer gracilis* was the most abundant in our surveys. This species mates in November. One gravid female (52.5 mm) was taken in November, 1992 (Figure 8.2). These crabs do not tolerate brackish or fresh water, and they were only found in salty bottom waters at the river mouth. Young crabs of this species are a major food of starry flounder found in trawls taken in the first 2 km of the estuary. The hairy crab was the next most abundant species in the estuary (Figure 8.3). This species is also considered an intertidal zone dweller and its natural history is poorly known (Morris et al. 1990).

Only three dungeness crabs were captured during the otter trawls. These crabs were once abundant from San Francisco Bay to Morro Bay including the Russian River (G. Casini, personal communications). The southern California dungeness crabs comprised three subpopulations, which showed little or no mixing. These areas now yield few crabs with most of the California production of this commercially valuable species occurring from Fort Bragg northward to the Oregon border. The size distribution captured in the Russian River estuary (Figure 8.3), suggests that despite its limited abundance, this species still spends long periods of time in the Russian River estuary and is not compromised directly by artificial breaching of the mouth.

Shrimp species found in the Russian River estuary were common estuarine types and little is known about their biology. The Franciscan Bay shrimp was commonly caught by shrimp trawlers in San Francisco Bay and can

RUSSIAN RIVER INVERTEBRATES - CRABS AND SHRIMP

	FAMILY	SPECIES	COMMON NAME	Total collected	CPU (per tow)	SIZE (mm TL or min	max
						August 20, 1992	
CRABS			*CRABS*				
	Cancridae	*Cancer gracilis*	Slender crab *(Cancer gracilis)*	71	7.1	6.0	52.0
	Cancridae	*Cancer anthonyi*	Yellow crab *(Cancer anthonyi)*	1	0.1	18.0	18.0
	Cancridae	*Cancer jordani*	Hairy cancer crab *(Cancer jordani)*	12	1.2	7.0	19.0
	Cancridae	*Cancer magister*	Dungeness crab *(Cancer magister)*	1	0.1	88.0	88.0
	Cancridae	*Cancer productus*	Red crab *(Cancer productus)*	6	0.6	19.0	41.0
	Cancridae	*Cancer attenuaris*	Rock crab *(Cancer attenuaris)*	1	0.1	51.0	51.0
	Majidae	*Pugettia producta*	Kelp crab *(Pugettia producta)*	0	0.0		
	Grapsidae	*Hemigrapsus sp.*	Shore crab *(Hemigrapsus sp.)*	0	0.0		
SHRIMP			*SHRIMPS*				
	Crangonidae .	*Crangon sp.*	bay shrimp (spp.) *(Crangon sp.)*	1	0.1	41.0	41.0
	Crangonidae	*Crangon franciscorum*	Franciscan bay shrimp *(Crangon franciscorum)*	24	2.4	17.0	61.0
	Crangonidae	*Crangon nigromaculata*	Spotted bay shrimp *(Crangon nigromaculata)*	15	1.5	26.0	58.0
	Hippolytidae	*Lebbeus lagunae*	*Lebbeus lagunae*	3	0.3	14.0	15.0
	Palaemonidae	*Palaemon macrodactylus*	Oriental shrimp *(Palaemon macrodactylus)*	1	0.1	7.0	7.0

RUSSIAN RIVER INVERTEBRATES - CRABS AND SHRIMP

	November 18, 1992					OVERALL				
width)	Total	CPU	SIZE (mm TL or width)					SIZE (mm TL or width)		
mean	collected	(per tow)	min	max	mean	Total collected	CPU (per tow)	min	max	mean
18.1	14	1.3	34.0	60.5	50.8	85	2.30	6	60.5	24.33
18.0	0	0.0				1	0.03	18	18	18.00
13.9	0	0.0				12	0.32	7	19	13.92
88.0	2	0.2	31.9	133.0	82.5	3	0.08	31.9	133	84.30
27.3	0	0.0				6	0.16	19	41	27.33
51.0	0	0.0				1	0.03	51	51	51.00
	1	0.1	24.0	24.0	24.0	1	0.03	24	24	24.00
	2	0.2	12.0	16.0	14.0	2	0.05	12	16	14.00
41.0	0	0.0				1	0.03	41	41	41.00
26.5	32	2.9	39.0	67.0	51.3	56	1.51	17	67	40.63
33.4	0	0.0				15	0.41	26	58	33.40
14.7	0	0.0				3	0.08	14	15	14.67
7.0	0	0.0				1	0.03	7	7	7.00

Figure 8.1

Russian River Invertebrate Key

Phylum Mollusca / Class Gastropoda / Subclass Opisthobranchia Order Anaspidea / Family Aplysiidae

Aplysia vaccaria Winkler 1955
California Black Sea Hare

Phylum *Arthropoda / Class Crustacea / Subclass Malacostraca Superorder Eucarida / Order Decapoda / [Suborder Natantia] / Section Caridea Family Crangonidae*

Crangon stylirostris Holmes, 1900
(= Crago stylirostris) Bay Shrimp

Phylum *Arthropoda / Class Crustacea / Subclass Malacoslraca Superorder Eucarida / Order Decapoda / [Suborder Nalantia] / Section Caridea Family Palaemonidae*

Palaemon (Palaemon) macrodactylus Rathbun, 1902
Oriental Shrimp

Phylum *Arthropoda / Class Crustacea / Subclass Malacostraca Superorder Eucarida / Order Decapoda / Suborder Replantia Section Brachyura / Family Majidae*

Pugettia producta (Randall, 1839)
(= Eplaitus productus) Shield-Backed Kelp Crab, Kelp Crab

Phylum Arthropoda / Class Crustacea / Subclass Malacostraca Superorder Eucarida / Order Decapoda / Suborder Reptantia Section Brachyura / Family Cancridae

Cancer antennarlus Stimpson, 1856
Rock Crab

Phylum Arthropoda / Class Crustacea / Subclass Malacostraca /Superorder Eucarida / Order Decapoda / Suborder Reptantia /Section Brachyura / Family Cancridae

Cancer anthonyi Rathbun, 1897
Yellow Crab

Phylum Arthropoda / Class Crustacea / Subclass Malacostraca Superorder Eucarida / Order Decapoda / Suborder Reptantia Section Brachyura / Family Cancridae

Cancer gracilis Dana, 1852
Slender Crab, Graceful Crab

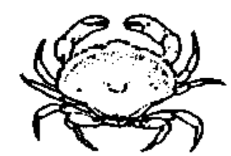
Phylum Arthropoda / Class Crustacea / Subclass Malacostraca /Superorder Eucarida / Order Decapoda / Suborder Reptantia /Section Brachyura / Family Cancridae

Cancer jordani Rathbun, 1900
Hairy Cancer Crab

Phylum Arthropoda / Class Crustacea / Subclass Malacostraca /Superorder Eucarida / Order Decapoda / Suborder Reptantia Section Brachyura / Family Cancridae

Cancer magister Dana, 1852
Dungeness Crab, Market Crab, Common Edible Crab

Phylum *Arthropoda / Class Crustacea / Subclass Malacostraca Superorder Eucarida / Order Decapoda / Suborder Reptantia Section Brachyura / Family Cancridae*



Cancer productus Randall, 1839
Red Crab

Figure 8.2

RUSSIAN RIVER INVERTEBRATES - CRABS AND SHRIMP

SIZE DISTRIBUTIONS - CRABS (mm carapace width)

1) *Cancer gracilis* Slender crab

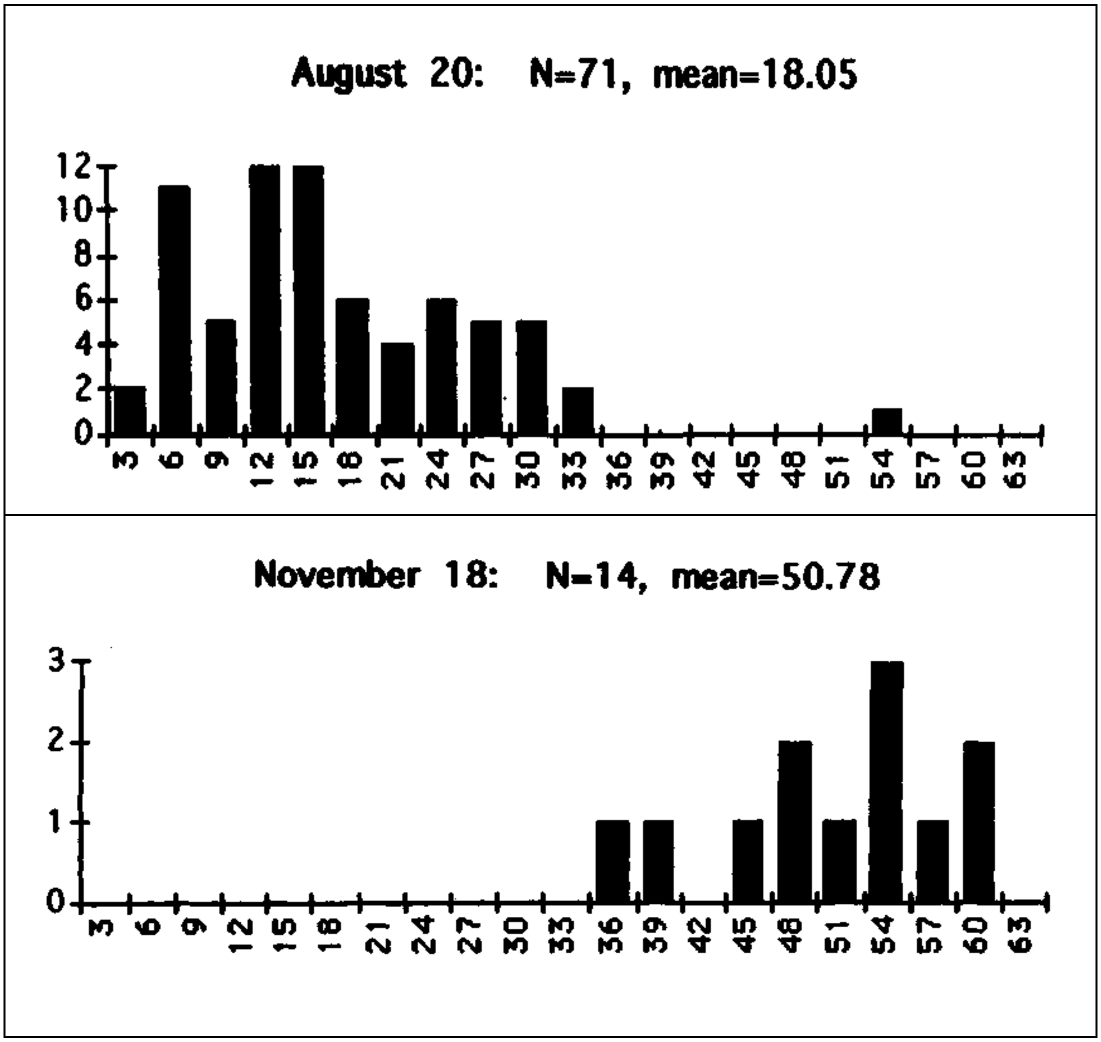
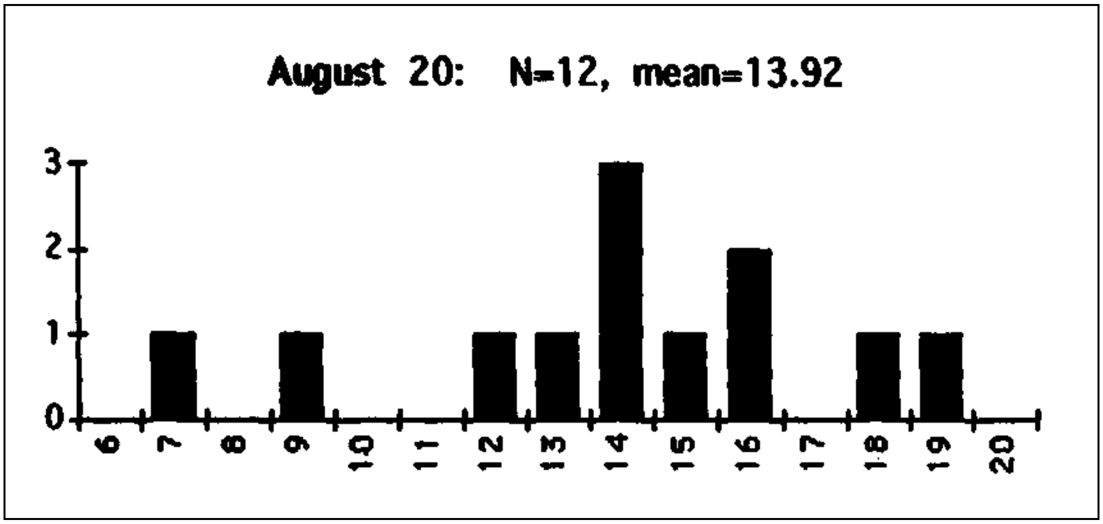


Figure 8.2

RUSSIAN RIVER INVERTEBRATES - CRABS AND SHRIMP

2) *Cancer jordani* Hairy cancer crab



3) Cancer *magister* Dungeness crab

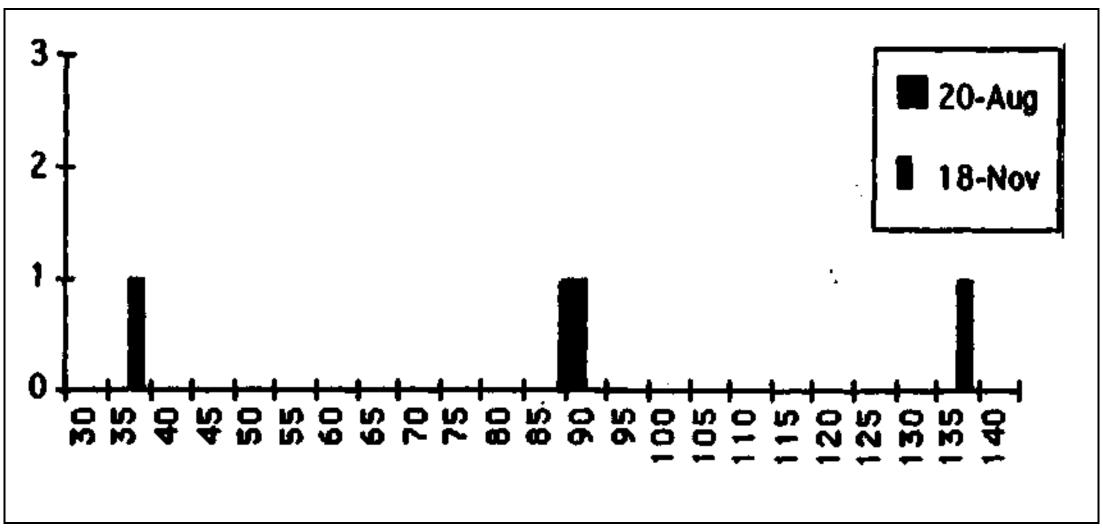
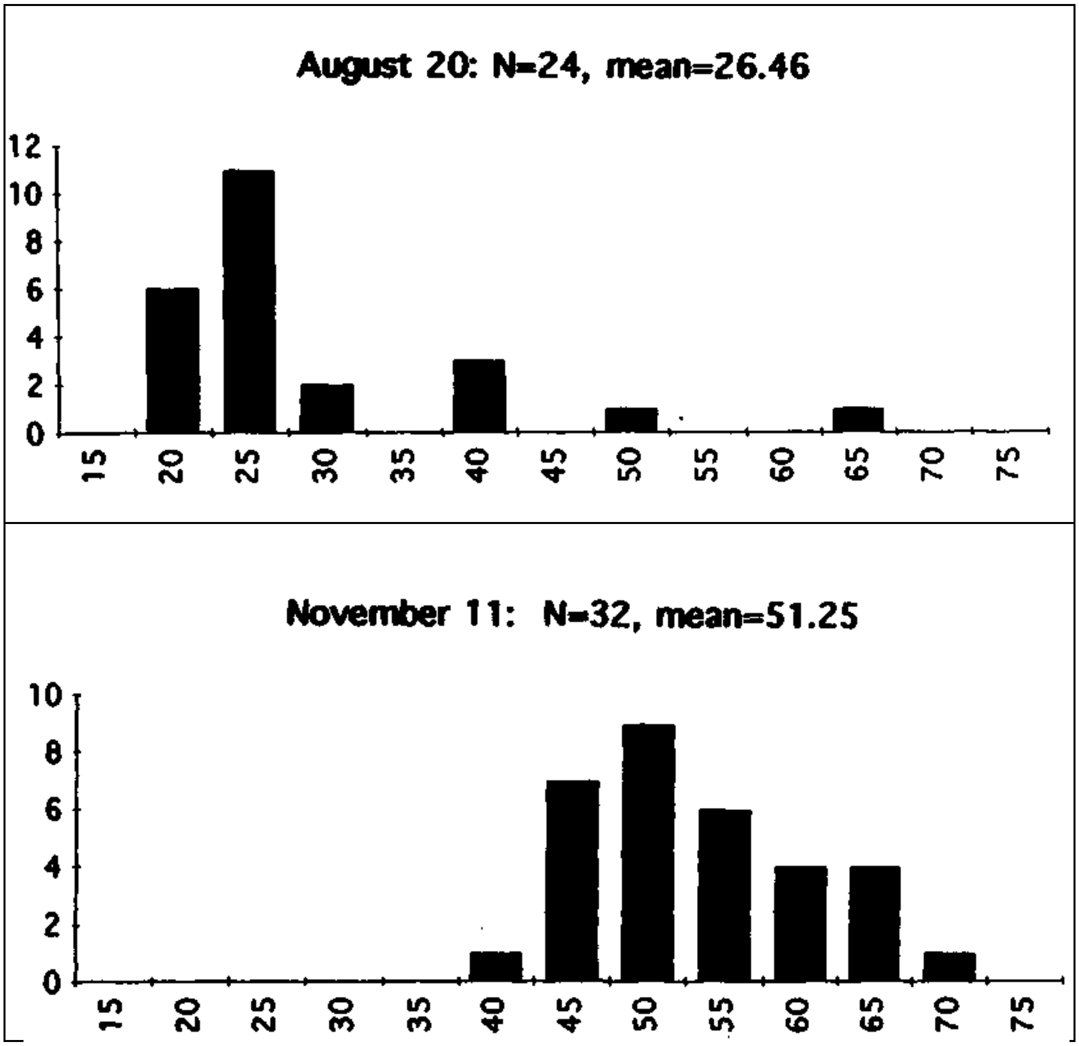


Figure 8.4

RUSSIAN RIVER INVERTEBRATES - CRABS AND SHRIMP

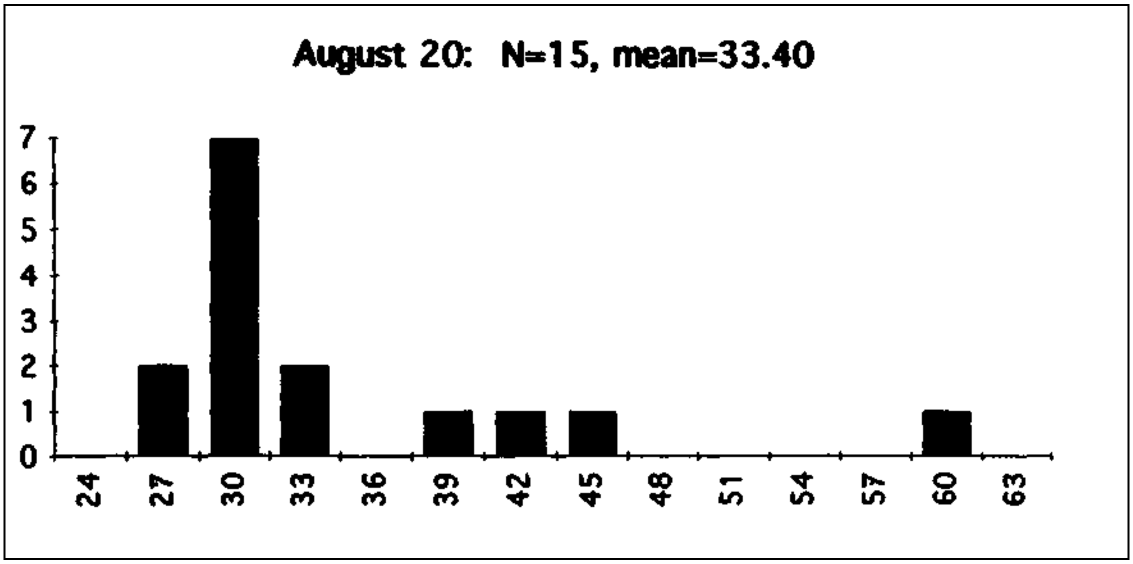
SIZE DISTRIBUTION - SHRIMP (mm total length)

1) *Crangon francisco* Franciscan bay shrimp



RUSSIAN RIVER INVERTEBRATES-CRABS AND SHRIMP

2) *Crangon nigromac* Spotted bay shrimp



tolerate broad temperature and saline tolerance ranges. All three species of *Crangonidae are* now fished mostly for bait. The variety of types of shrimp and the size distributions of the most abundant species (Figure 8.4) attest to the viability of this estuary. One species, the oriental shrimp, was accidentally introduced into San Francisco Bay around 1954, in ship bilge discharge. It has subsequently become abundant in many tidal creeks with brackish water conditions. These introduced shrimp mix with schools of native bay shrimp and may have been introduced into the Russian as fishing bait or in aquarium water where their larvae thrive. Reproduction of this species occurs from April to October.

In addition to crabs and shrimp, one macro invertebrate, a California black sea hare, was captured in an otter trawl above the Highway 1 bridge. This invertebrate is common in low intertidal zones, especially around kelp beds. This species appears to feed almost entirely on large brown kelp which occasionally washes into the Russian River estuary during increased tidal activity. The sea hare also deposits eggs intertidally or subtidally, but no other specimen of this species was ever found in the estuary.

C. Micro Invertebrates

Invertebrate samples were taken in the estuary using plankton tows from the boat, plankton tows from bridges and invertebrate drift samples, including one 24 hour sampling schedule in September, 1992. A total of 555.5 minutes of plankton tows were collected from June 4, 1992 to Nov. 16, 1992. Seventy five hours of drift sampling was done on Willow Creek from June 4, 1992 to September 22, 1992. Twenty five taxa were identified either to genus or family using Pennak (1989) and Merritt and Cummings (1984). Six additional zooplankton species were found but could not be identified with these keys.

The abundance and distribution of micro invertebrate taxa were compared for times when the river mouth was open and closed (Table 8.4 for plankton; Table 8.5 for drift). It is interesting to note from Table 8.4, that significantly more zooplankton was available in the river and in Willow Creek when the mouth was open. The reason for this is not clear from our samples made at several points along the river and not just in areas where stream velocity is significantly lower when the mouth is closed, i.e. at the mouth. The increase in planktonic abundance during open cycles may, however, be influenced by circulation of upstream flows within the estuary and/or by extended tidal activity throughout the lower estuary with the open beach barrier. Our sampling regime was not frequent enough to adequately test this hypothesis.

The drift in Willow Creek was not directly impacted by the river mouth opening in the Russian River. The mean invertebrate drift rate in Willow Creek upstream of the marsh was not significantly different when the mouth was closed (mean = $0.31/g/m^3/hr$) or open (mean = $0.27/g/m^3/hr$) during the summer low flow period of 1992. Table

8.5 identified those species whose abundance was significantly different during periods when the mouth was open or closed. From these data it appears that invertebrates associated with stream margin vegetation were more abundant when the mouth was open. This effect could be directly attributable to the dewatering of vegetation after flooding with the mouth closure. Invertebrates could be washed into the flows leaving Willow Creek as the water recedes from the shrubs and grasses surrounding the marsh. Drift samples were taken, however, above the impoundment area of the marsh at the second bridge with the same results. Different life stages of vegetation associated invertebrates may leave the upper stream reaches as additional vegetated habitat becomes available after the marsh is drained in a recolonization migration. How they know additional downstream habitat is available after breaching is a good question.

The only micro invertebrates which increased in abundance with mouth closure were large predatory aquatic bugs and copepods. Large predatory aquatic invertebrates are known to select microhabitats beneath rocks or at the bank margins during elevated flows. These bugs may reduce their forage range during periods when the mouth was open and not become as readily available as drift. Copepods are known to prefer lentic habitats such as the Willow Creek marsh during impoundment cycles. It was common to see an increase in their abundance in intermittent lentic habitats as long as seed populations survive the drainage periods.

One major impact from breaching recorded during this study was reflected in the drift and migrations out of Willow Creek marsh as the marsh drained. The change in invertebrate drift and fish movement from the marsh was dramatic for several species (Table 8.6). The impoundment in the marsh usually started to drain about three hours after the initial breach at the Russian River mouth. As this area drained, substantial quantities of mysid shrimp left or were drained from the marsh. During the 9'+ breach this species was so abundant they appeared like cream in the water. Fish in the marsh were also swept by the drainage velocity at the mouth of Willow Creek. Juvenile stickleback, Sacramento suckers and prickly sculpin appeared unable to swim against the outflow during the breach drainage. Larger sculpin were captured at the margins of the outflow channel, but it was not clear if they were following a food resource (i.e. small fish and shrimp) or if they too were forced out of the marsh by the flow. Only after the 9'+ breach, when anoxic waters surged from the marsh, were dead sculpin found along the bank of the outflow channel on Willow Creek.

TABLE 8.4

Plankton and invertebrates collected in plankton tows on the Russian River estuary and in Willow Creek during periods when the Russian River mouth was open or closed during the summer of 1992.

	Mouth	
Month (1992)	Open #/min.	Closed #/min.
June		
Russian River	47.22	14.64
Willow Creek	10.91	0.93
July		
Russian River	14.27	0.63
Willow Creek	1.32	0.21
August		
Russian River	17.56	0.03
Willow Creek	12.13	0.55
September		
Russian River	25.33	0.53
Willow Creek	27.63	12.63
October		
Russian River	11.21	0.72
Willow Creek	53.32	10.97
November		
Russian River	14.44	1.92
Willow Creek	2.35	0.54

TABLE 8.5

Drift taxa captured on Willow Creek during summer low-flow conditions.

Willow Creek Drift Taxa		Common Name	Open #/min	Closed #/min
Ephemeroptera		mayflies	0.1949	0.1227
Plecoptera		stoneflies	0.0165	0.1422*
Trichoptera	adult	Caddisflies	0.0004	0.0006
	larvae		0.0057	0.0537*
	pupae		0	0.0012
Hymenoptera		diving wasps	0.0135*	0.0059
Hemiptera		water bugs	0.0717*	0.0106
Coleoptera	adult	water beetles	0.0202*	0.0065
	larvae		0.0508	0.0814
Lepidoptera		aquatic caterpillers	0.0029	0
Homoptera		leafhoppers & aphids	0.0192*	0.0006
Diptera	adult	flies, mosquitoes & gnats	0.0588*	0.0006
	larvae		0.8003	0.8094
	pupae		0.0183	0.0171
Hydracarina		water mites	0.9022*	0.4726
Arachnida		spiders	0.0133	0
Collembola		springtails	0.0483*	0.0071
Ostracoda		seed shrimp	0.4319	0.5652
Amphipoda		scud	0.0512*	0.0018
Decapoda		crayfish & shrimp	0.0022	0
Copepoda		copepod	0.1804	0.2991*
Gastropoda		snails & limpets	0.0722*	0.0336
Pelecypoda		clams & mussels	0.0135	0
Planarians		fiat worms	0	0.0012
Odonata		damselflies & dragonflies	0.0063*	0.0018
Terrestrail	adults	ants & beetles	0.0089*	0.0012
Thysanoptera		thrips	0.0031	0.0035
Ptychopteridae		phantom crane flies	0.0264	0.0201
Oligochaeta		earth worms	0.0004	0.0006
Nematoda		aquatic worms	0	0.0012

* significant difference in temporal abundance for paired samples (T-test; $P<0.05$).

TABLE 8.6

Change in invertebrate drift and fish at the mouth of Willow Creek during draining of the marsh after artificial breach of the Russian River, October 7, 1992.

Species	Closed #/min	Open #/min
Ephemeroptera	1.43	0.34
Chironomidae	7.21	2.54
Hydracarina	0.39	0.24
Collembola	0.01	0.15
Ostracoda	0.99	1.51
Amphipoda	0	0.22
Mysidacea	0	17.07
Copepoda	1.57	26.93
Isopoda	0.08	1.22
Cladocera	0	0.88
Snails	0.79	0.19
Fish	0	11.59

D. Crayfish

We collected two species of crayfish in the Russian River system. Signal crayfish (Pacifastacus leniusculus) were trapped in the main river near Duncans Mills, and Louisiana red swamp crayfish (Procambarus clarkii) were collected by seine and trap near the mouth of Willow Creek. Both are freshwater species, though they may be found at the heads of estuaries (Smith & Carlton 1975). Neither species is native to this area: P. leniusculus was originally confined to the Pacific northwest (including California from the Klamath River north) and P. clarkii was introduced into California from the eastern U.S. Both species have been collected in the Russian River since at least 1959 (Riegel 1959) and are probably important parts of the ecology of the river. Crayfish remains were a major component of otter scat in many sites from Willow Creek to Duncans Mills.

TABLE 8.7

Summary of crayfish collections and trapping attempts in the Russian River and Willow Creek (TCL=total carapace length)

		LOCATION					SIZE -- TCL(mm)	
DATE	METHOD	system	km	SPECIES	#	SEX	mean	range
4-Jun-92	seine	WC	0.20	*P. clarki*	1	M	~35	
8-Mar-93	trap-4 day	WC	0.10	none				
8-Mar-93	trap-4 day	WC	0.30	none				
8-Mar-93	trap-4 day	WC	0.50	none				
8-Mar-93	trap-4 day	WC	0.60	none				
8-Mar-93	trap-4 day	WC	1.30	none				
18-Mar-93	trap-8 day	WC	0.10	none				
18-Mar-93	trap-8 day	WC	0.30	none				
18-Mar-93	trap-8 day	WC	0.50	none				
18-Mar-93	trap-8 day	RR	5.13	none				
18-Mar-93	trap-8 day	RR	9.95	*P. leniusculus*	2	M	53	47-58
30-Mar-93	trap-5 day	WC	0.30	none				
30-Mar-93	trap- 5 day	WC	0.50	none				
30-Mar-93	trap-5 day	RR	5.13	none				
30-Mar-93	trap-5 day	RR	9.95	*P. leniusculus*	1	F	43	
8-Apr-93	trap-8 day	WC	0.10	none				
8-Apr-93	trap-8 day	WC	0.15	*P. clarki*	1	F	67	
8-Apr-93	trap-8 day	RR	5.10	none				
8-Apr-93	trap-8 day	RR	9.90	*P. leniusculus*	6	F	47	42-57
				P. leniusculus	2	M	34	33-35
14-Apr-93	trap-6 day	WC	0.10	none				
14-Apr-93	trap-6 day	WC	0.10	none				
14-Apr-93	trap-6 day	WC	0.15	none				
14-Apr-93	trap-6 day	WC	0.15	none				

E. Amphibians

Amphibian surveys encompassing 16.8 hours of observation were conducted during the spring of 1993. These surveys were designed based on protocol in Corn and Bury (1990) and Bury and Corn (1991). One survey was done over night on April 4, 1993. Areas surveyed included bank riparian, isolated pools, sedge marsh habitat, log jam, grass marsh habitat and creek bottoms. Based on the literature, 13 species of salamanders and five species of frogs could occur in the lower estuary (Table 8.8). Only California slender salamanders (N=2), Pacific tree frogs (N=18) and bull frogs (N=3 tadpoles) were found, all within the Willow Creak marsh. One Pacific giant salamander was found in the guts of a large rainbow trout captured in Willow Creek on June 19, 1992. It is suspected that this fish captured the Pacific giant upstream of the estuary in Willow Creek. No sightings of this species were made during amphibian surveys or electrofishing in the Willow marsh.

The California slender salamander frequents grasslands with scattered trees such as those which surround Willow marsh. Eggs are laid in the fall and winter when breaching is atypical and the young emerge in winter and early spring (Stebbins, 1985). We do not feel that artificial breaching impacts this species in the Willow marsh. Pacific tree frogs are often found in association with chaparral and grassland habitats. This species breeds from November to July in marshes and ponds. Therefore, the marsh habitat of Willow Creek appears to be an important aspect of the life history of this frog. Based on their abundance throughout the marsh, the populations in Willow Creek appear adapted to periodic outflows due to breaching of the river mouth.

We have no explanation for the depauperate amphibian fauna within the marsh and estuary. More thorough sampling may be needed to find the actual diversity in this type of habitat. We are not aware of other estuarine associated amphibian surveys that have been done in Sonoma County, California to judge our findings by.

F. Birds

Observations of bird abundance, distribution and behavior were done over 164.4 hours from the mouth of the Russian River up to Duncan's Mills bridge (Table 8.9). The highest diversity of species abundance was found at Willow Creek marsh, however only 28% of the species observed were seen feeding within the marsh. There was no significant correlation without significant interactions between the number of birds observed and the status of the mouth of the Russian River (two-factor ANOVA with replication; $p>0.05$) for any species, with the exception of sandpipers ($p=0.01$) which were most abundant when the mouth was open. It is intuitively obvious that freshwater impoundment behind a closed sand bar would diminish the sandy, near shore habitat used by sandpipers for feeding within the lower estuary leading to this finding.

Table 8.8

AMPHIBIANS EXPECTED IN RUSSIAN RIVER AREA

FAMILY	SPECIES	SUBSPECIES	ABBR.	COMMON NAME	
SALAMANDERS			SALAMANDERS		
Ambystomatidae	*Ambystoma tigrinum*	*califomiense*	CTS	California Tiger salamander	
Ambystomatidae	*Ambystoma gracile*	*gracile*	NWS	Northwestern (brown) salamander	
Dicamptodontidae	*Dicamptodon ensatus*		PGS	Pacific giant salamander	
Dicamptodontidae	*Rhyacotriton olympicus*	*variegatus*	SOS	Southern Olympic salamander	??Southern limit Pt. Arena??
Salamandridae	*Taricha granulosa*		RSN	Rough-skinned newt	
Salamandridae	*Taricha torosa*	*torosa*	CRN	Coast range newt	
Salamandridae	*Taricha rivularis*		RBN	Red-bellied newt	Breeds in flowing rivers/creeks
Plethodontidae	*Ensatina eschscholtzii*	*xanthoptica*	YES(ENS)	Yellow-eyed salamander (Ensatina)	Two subspp may intergrade
Plethodontidae	*Ensatina eschscholtzii*	*oregonensis*	ORS(ENS)	Oregon salamander (Ensatina)	
Plethodontidae	*Aneides flavipunctatus*		BLS	Black salamander	
Plethodontidae	*Aneides ferrus*		CLS	Clouded salamander	
Plethodontidae	*Aneides lugubris*		ARS	Arboreal salamander	
Plethodontidae	*Batrachoseps* attenuatus		CSS	California slender salamander	
FROGS AND TOADS			FROGS AND TOADS		
Bufonidae	*Bufo boreas*	*halophilus*	WET	Western (California) toad	
Hylidae	*Hyla regilla*		PTF	Pacific treefrog	
Ranidae	*Rana aurora*	*draytonii*	RLF	California red-legged frog	
Ranidae	*Rana boylii*		YLF	Foothill yellow-legged frog	
Ranidae	*Rana catesbeiana*		BUL	Bullfrog	

Table 8.9 - 10 pages

RUSSIAN RIVER BIRD OBSERVATIONS

Site 1 : River Mouth (km 0)

	SITE 1 SUMMARY 32 SPECIES IDENTIFIED (22 observation hours)		
SPECIES	total obs	obs/20 min	% feeding
Common loon	15	0.23	53%
Eared grebe	3	0.05	100%
Western grebe	446	6.76	13%
Pied-billed grebe	52	0.79	46%
Grebe, unidentified	416	6.30	1%
Sooty shearwater	2	0.03	0%
Brown pelican	2391	36.23	3%
Double-crested cormorant	317	4.80	9%
Brandt's cormorant	45	0.68	40%
Pelagic cormorant	24	0.36	8%
Cormorant, unidentified	77	1.17	0%
Great blue heron	21	0.32	0%
Mallard	2	0.03	0%
Common goldeneye	4	0.06	100%
Surf scoter	12	0.18	0%
Common merganser	7	0.11	43%
Duck, unidentified	3	0.05	33%
Turkey vulture	14	0.21	0%
Red-tailed hawk	5	0.08	0%
Osprey	16	0.24	13%
American coot	2	0.03	0%
Killdeer	11	0.17	0%
Spotted sandpiper	23	0.35	0%
Western gull	1663	25.20	2%
Herring gull	5	0.08	0%
Heerman's gull	2423	36.71	0%
Gull, unidentified	8243	124.89	0%
Forester's tern	284	4.30	18%
Caspian tern	7	0.11	0%
Common murre	6	0.09	0%
Belted kingfisher	5	0.08	0%
Common raven	8	0.12	0%
Common crow	1	0.02	0%
Marsh wren	1	0.02	0%
Brewer's blackbird	6	0.09	0%
Song sparrow	2	0.03	0%
Unidentified passerine	1	0.02	0%

RUSSIAN RIVER BIRD OBSERVATIONS
SITE 2: MARSH SOUTH OF PENNY ISLAND (KM 0.9)

SPECIES	total sited	obs/20 min	% feeding
	SITE 2 SUMMARY 34 SPECIES IDENTIFIED (11.7 observation hours)		
Common loon	11	0.31	100.0%
Eared grebe	9	0.26	88.9%
Western grebe	7	0.20	85.7%
Pied-billed grebe	4	0.11	100.0%
Grebe, unidentified	5	0.14	20.0%
Brown pelican	11	0.31	0.0%
Double-crested cormorant	61	1.74	8.2%
Brandt's cormorant	9	0.26	0.0%
Cormorant, unidentified	2	0.06	0.0%
Great blue heron	8	0.23	0.0%
Black-crowned night heron	1	0.03	0.0%
Mallard	443	12.66	24.4%
American wigeon	6	0.17	50.0%
Rufflehead	15	0.43	0.0%
Common merganser	49	1.40	0.0%
Duck, unidentified	20	0.57	0.0%
Turkey vulture	62	1.77	0.0%
Red-shouldered hawk	1	0.03	0.0%
Osprey	6	0.17	0.0%
Merlin	1	0.03	0.0%
Virginia rail	1	0.03	0.0%
Killdeer	33	0.94	0.0%
Least sandpiper	10	0.29	50.0%
Sandpiper, unidentified	30	0.86	0.0%
Western gull	55	1.63	3.6%
Herring gull	6	0.17	0.0%
gull, unidentified	1246	35.60	0.0%
Forester's tern	21	0.60	0.0%
Tern, unidentified	1	0.03	100.0%
Great Homed Owl	1	0.03	0.0%
Allen's hummingbird	5	0.14	0.0%
Belted kingfisher	3	0.09	0.0%
Black phoebe	3	0.09	33.3%
Western flycatcher	1	0.03	0.0%
Common raven	5	0.14	0.0%
Marsh wren	1	0.03	0.0%
American robin	2	0.06	0.0%
Hermit thrush	1	0.03	0.0%
Red-winged blackbird	651	18.60	0.0%
Song Sparrow	18	0.51	0.0%
Unidentified passerine	1	0.03	0.0%

RUSSIAN RIVER BIRD OBSERVATIONS
SITE 3: RIVER AT MOUTH OF WILLOW CREEK (KM 4.1)

	SITE 3 SUMMARY 53 SPECIES IDENTIFIED (51 observation hours)		
SPECIES	total sited	obs/20 min	% feeding
Common loon	5	0.03	40.0%
Loon, unidentified	2	0.01	50.0%
Homed grebe	2	0.01	100.0%
Eared grebe	9	0.06	66.7%
Western grebe	76	0.50	28.9%
Pied-billed grebe	97	0.63	61.9%
Grebe, unidentified	23	0.15	47.8%
Brown pelican	1	0.01	0.0%
Double-crested cormorant	241	1.58	12.0%
Brandt's cormorant	70	0.46	2.9%
Cormorant, unidentified	18	0.12	22.2%
Great blue heron	?2	0.47	0.0%
Green-backed heron	1	0.01	0.0%
Great egret	19	0.12	5.3%
Snowy egret	11	0.07	18.2%
Domestic goose	281	1.84	0.0%
Canadian goose	7	0.05	0.0%
Brant	50	0.33	0.0%
Goose, unidentified	36	0.24	97.2%
Mallard	435	2.84	28.7%
Wood duck	4	0.03	25.0%
Common goldeneye	2	0.01	0.0%
Bufflehead	815	5.33	43.6%
Common merganser	162	1.06	27.2%
Duck, unidentified	2	0.01	100.0%
Turkey vulture	575	3.76	32.7%
Cooper's hawk	1	0.01	0.0%
Red-tailed hawk	16	0.10	0.0%
Red-shouldered hawk	4	0.03	25.0%
Northern harrier	2	0.01	0.0%
Osprey	41	0.27	2.4%
American kestral	5	0.03	0.0%
California quail	1	0.01	0.0%
American coot	264	1.73	33.0%
Killdeer	90	0.59	2.2%
Short-billed dowitcher	1	0.01	100.0%
Least sandpiper	35	0.23	100.0%

RUSSIAN RIVER BIRD OBSERVATIONS
SITE 3: RIVER AT MOUTH OF WILLOW CREEK (KM 4.1)

	SITE 3 SUMMARY 53 SPECIES IDENTIFIED (51 observation hours)		
SPECIES	total sited	obs/20 min	% feeding
Sandpiper, unidentified	41	0.27	0.0%
Western gull	201	1.31	0.0%
Herring gull	30	0.20	0.0%
Ring-billed gull	2	0.01	0.0%
Gull, unidentified	257	1.68	0.0%
Great Homed Owl	2	0.01	0.0%
Belted kingfisher	16	0.10	12.5%
Black phoebe	3	0.02	33.3%
Tree swallow	30	0.20	0.0%
Scrub jay	4	0.03	0.0%
Common raven	64	0.42	4.7%
Chestnut-backed chickadee	6	0.04	0.0%
Bushtit	4	0.03	0.0%
Marsh wren	1	0.01	0.0%
American robin	5	0.03	0.0%
Hermit thrush	1	0.01	0.0%
European starling	3	0.02	0.0%
Hutton's vireo	1	0.01	0.0%
Red-winged blackbird	239	1.56	12.6%
Brewer's blackbird	32	0.21	0.0%
Pine siskin	1	0.01	0.0%
Brown towhee	1	0.01	0.0%
White-crowned sparrow	53	0.35	7.5%
Unidentified passerine	27	0.18	0.0%

RUSSIAN RIVER BIRD OBSERVATIONS
SUE 4: HILL OVER BORROW PIT (WILLOW CREEK MOUTH)

	SITE 4 SUMMARY 50 SPECIES IDENTIFIED (29 observation hours)		
SPECIES	total sited	obs/30 min	% feeding
Homed grebe	5	0.07	0.0%
Eared grebe	10	0.14	50.0%
Western grebe	8	0.11	37.5%
Pied-billed grebe	45	0.64	53.3%
Grebe, unidentified	4	0.06	75.0%
Double-crested cormorant	104	1.47	6.7%
Brandt's cormorant	8	0.11	0.0%
Cormorant, unidentified	22	0.31	9.1%
Great blue heron	42	0.59	0.0%
Great egret	12	0.17	0.0%
Black-crowned night heron	2	0.03	0.0%
Canadian goose	9	0.13	0.0%
Mallard	516	7.30	42.6%
Wood duck	33	0.47	60.6%
Lesser scaup	3	0.04	33.3%
Bufflehead	289	4.09	31.1%
Ruddy duck	1	0.01	0.0%
Common merganser	5	0.07	40.0%
Duck, unidentified	3	0.04	0.0%
Turkey vulture	151	2.14	0.0%
Black-shouldered kite	1	0.01	100.0%
Sharp-shinned hawk	4	0.06	0.0%
Cooper's hawk	5	0.07	20.0%
Red-tailed hawk	54	0.76	5.6%
Red-shouldered hawk	2	0.03	0.0%
Ferruginous hawk	1	0.01	0.0%
Northern harrier	2	0.03	0.0%
Osprey	2	0.03	0.0%
American kestral	1	0.01	0.0%
California quail	7	0.10	0.0%
Virginia rail	1	0.01	0.0%
American coot	96	1.36	43.8%
Killdeer	28	0.40	3.6%
Sandpiper, unidentified	2	0.03	0.0%
Western gull	12	0.17	0.0%
Herring gull	1	0.01	0.0%
California gull	1	0.01	0.0%

RUSSIAN RIVER BIRD OBSERVATIONS
SITE 4: HILL OVER BORROW PIT (WILLOW CREEK MOUTH)

		SITE 4 SUMMARY 50 SPECIES IDENTIFIED (29 observation hours)	
SPECIES	total sited	obs/30 min	% feeding
Gull, unidentified	23	0.33	0.0%
Northern pygmy owl	1	0.01	0.0%
Great Horned Owl	1	0.01	0.0%
Allen's hummingbird	1	0.01	0.0%
Belted kingfisher	8	0.11	0.0%
Common flicker	2	0.03	0.0%
Red-shafted flicker	2	0.03	0.0%
Black phoebe	21	0.30	19.0%
Barn swallow	1	0.01	0.0%
Cliff swallow	1	0.01	0.0%
Scrub jay	9	0.13	0.0%
Common raven	27	0.38	0.0%
American robin	1	0.01	0.0%
European starling	3	0.04	0.0%
Red-winged blackbird	663	9.38	0.0%
Brewer's blackbird	15	0.21	0.0%
Blackbird, unidentified	40	0.57	0.0%
White-crowned sparrow	107	1.51	0.0%
Song sparrow	1	0.01	0.0%
Unidentified passerine	181	2.56	0.0%

RUSSIAN RIVER BIRD OBSERVATIONS
SUE 5: WILLOW CREEK MARSH

	STC 5 SUMMARY 55 SPECIES IDENTIFIED (27.7 observation hours)		
SPECIES	total sited	obs/20 min	% feeding
Pied-billed grebe	1	0.01	0.0%
Double-crested cormorant	3	0.04	0.0%
Brandt's cormorant	1	0.01	0.0%
Great blue heron	10	0.13	0.0%
Great egret	6	0.08	33.3%
Canadian goose	30	0.39	0.0%
Mallard	107	1.40	71.0%
Bufflehead	7	0.09	28.6%
Common merganser	33	0.43	0.0%
Turkey vulture	254	3.33	0.0%
Sharp-shinned hawk	1	0.01	0.0%
Cooper's hawk	7	0.09	42.9%
Red-tailed hawk	72	0.94	5.6%
Swaison's hawk	4	0.05	0.0%
Ferruginous hawk	1	0.01	0.0%
Golden eagle	5	0.07	0.0%
Northern harrier	6	0.08	0.0%
Osprey	1	0.01	0.0%
Peregrine falcon	1	0.01	0.0%
American kestral	4	0.05	0.0%
California quail	2	0.03	0.0%
Virginia rail	3	0.04	0.0%
Sora	4	0.05	0.0%
Killdeer	4	0.05	25.0%
Common snipe	8	0.10	0.0%
Western gull	15	0.20	0.0%
Gull, unidentified	142	1.86	0.0%
Great Horned Owl	1	0.01	0.0%
Belted kingfisher	5	0.07	0.0%
Common flicker	2	0.03	0.0%
Black phoebe	7	0.09	14.3%
Say's phoebe	2	0.03	50.0%
Western wood peewee	1	0.01	0.0%
Violet-green swallow	15	0.20	100.0%
Tree swallow	4	0.05	100.0%
Bam swallow	30	0.39	66.7%
Cliff swallow	2	0.03	100.0%

RUSSIAN RIVER BIRD OBSERVATIONS
SITE 5: WILLOW CREEK MARSH

	SITE 5 SUMMARY 55 SPECIES IDENTIFIED (27.7 observation hours)		
SPECIES	total sited	obs/20 min	% feeding
Stellar's jay	1	0.01	0.0%
Scrub jay	2	0.03	0.0%
Common raven	26	0.34	0.0%
Common crow	4	0.05	0.0%
Marsh wren	5	0.07	0.0%
American robin	1	0.01	0.0%
Wrentit	2	0.03	0.0%
Common yellowthroat	14	0.18	0.0%
Wilson's warbler	8	0.10	0.0%
House sparrow	3	0.04	0.0%
Red-winged blackbird	547	7.17	0.2%
Brewer's blackbird	8	0.10	0.0%
Blackbird, unidentified	25	0.33	0.0%
Brown-headed cowbird	5	0.07	0.0%
Purple finch	3	0.04	0.0%
American goldfinch	5	0.07	20.0%
Brown towhee	1	0.01	0.0%
White-crowned sparrow	440	5.76	0.0%
Golden-crowned sparrow	4	0.05	0.0%
Song sparrow	13	0.17	7.7%
Unidentified passerine	323	4.23	0.3%

RUSSIAN RIVER BIRD OBSERVATIONS
Site 7: Duncan's Mills Bridge (km 10)

	SITE 7 SUMMARY 28 SPECIES IDENTIFIED (16.5 observation hours)		
SPECIES	total sited	obs/20 min	% feeding
Western grebe	1	0.03	0%
Double-crested cormorant	74	2.24	5%
Brandt's cormorant	1	0.03	0%
Great blue heron	3	0.09	33%
Green-backed heron	1	0.03	0%
Mallard	15	0.45	73%
Wood duck	16	0.48	63%
Canvassback	1	0.03	0%
Lesser scaup	1	0.03	100%
Common merganser	174	5.27	56%
Turkey vulture	11	0.33	0%
Red-tailed hawk	3	0.09	0%
Osprey	13	0.39	0%
American kestral	2	0.06	0%
California quail	20	0.61	0%
American coot	8	0.24	0%
Killdeer	9	0.27	11%
Western gull	24	0.73	0%
Herring gull	1	0.03	0%
California gull	1	0.03	0%
Gull, unidentified	7	0.21	0%
Belted kingfisher	2	0.06	0%
Black phoebe	4	0.12	25%
Stellar's jay	3	0.09	0%
Scrub jay	1	0.03	0%
Common raven	3	0.09	0%
European starling	20	0.61	0%
Brown towhee	1	0.03	0%
Song sparrow	30	0.91	0%
Unidentified passerine	34	1.03	0%

RUSSIAN RIVER BIRD OBSERVATIONS
Site 8: Marsh at Hwy 1 116 (River km 3.3)

	SITE 8 SUMMARY 25 SPECIES IDENTIFIED (6.5 observation hours)		
SPECIES	total sited	obs/30 min	% feeding
Brown pelican	3	0.23	0%
Double-crested cormorant	10	0.77	0%
Brandt's cormorant	1	0.08	0%
Great blue heron	3	0.23	0%
Green-backed heron	1	0.08	0%
Great egret	5	0.38	0%
Mallard	15	1.15	67%
Common merganser	17	1.31	0%
Turkey vulture	7	0.54	0%
Cooper's hawk	1	0.08	0%
Red-tailed hawk	4	0.31	0%
American kestral	2	0.15	0%
California quail	6	0.46	0% .
Virginia rail	6	0.46	0%
Sora	6	0.46	0%
Common snipe	1	0.08	0%
Western gull	135	10.38	0%
Herring gull	1	0.08	0%
Gull, unidentified	79	6.08	0%
Great Homed Owl	3	0.23	0%
Black phoebe	6	0.46	33%
Common raven	3	0.23	0%
Common yellowthroat	5	0.38	0%
Wilson's warbler	1	0.08	0%
Red-winged blackbird	542	41.69	0%
Golden-crowned sparrow	11	0.85	0%
Unidentified passerine	35	2.69	0%

Observations were made of osprey feeding on adult and juvenile surfsmelt at the mouth of Willow Creek in the spring after the bird's return to the estuary. No observations were made of osprey feeding of spring salmonid smolt releases for Warm Springs hatchery within the estuary. An unusual sighting of a split-tailed fly catcher, endemic to Baha California was reported in Willow Creek marsh in 1992, but this bird was not observed during regular scheduled cycles and therefore is not included here.

G. Vegetation

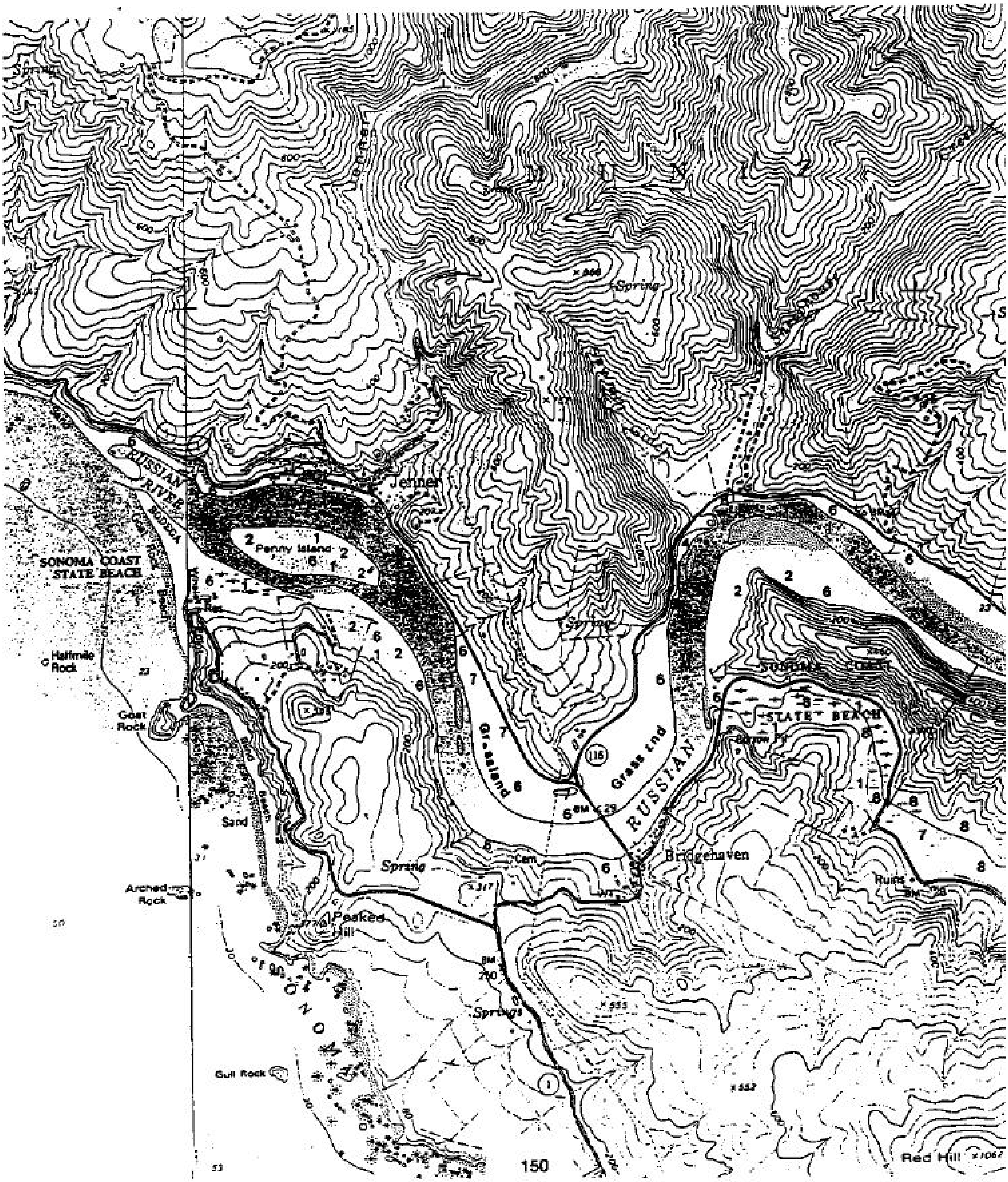
Surveys were made of the adjacent riparian vegetation surrounding the Russian River estuary and Willow Creek marsh in the spring of 1993. Eight general vegetation types based on Cheatham (1976) and Holland (1986) were used in this classification: 1-coastal and valley freshwater marsh; 2-coastal terrace prairie; 3-alluvial redwood forest; 4-upland redwood forest; 5-Douglas fir forest; 6-north coast riparian scrub; 7-freshwater seep; 8-red alder scrub (Figure 8.5). Total area of each vegetative type during the spring of 1993 with mouth-open conditions are given in Table 8.10. Freshwater seeps identified within the estuary riparian appeared to have flow sources independent of the main river and were not affected by mouth breaching.

TABLE 8.10

Total area of vegetation habitat types found within estuarine riparian areas, April, 1993.

Vegetative Type	Total Area (km^2)
1) Coastal & Valley Freshwater Marsh	1.44
2) Coastal Terrace Prairie	1.27
3) Alluvial Redwood Forest	1.94
4) Upland Redwood Forest	0.08
5) Douglas Fir Forest	4.04
6) North Coast Riparian Scrub	37.71
7) Freshwater Seep	0.93
8) Red Alder Riparian Scrub	5.89

Figure 8.5. Distribution of terrestrial vegetation habitat types throughout the Russian River estuary and Willow Creek marsh. See Table 8.10 for key to the numbers representing individual habitat types.



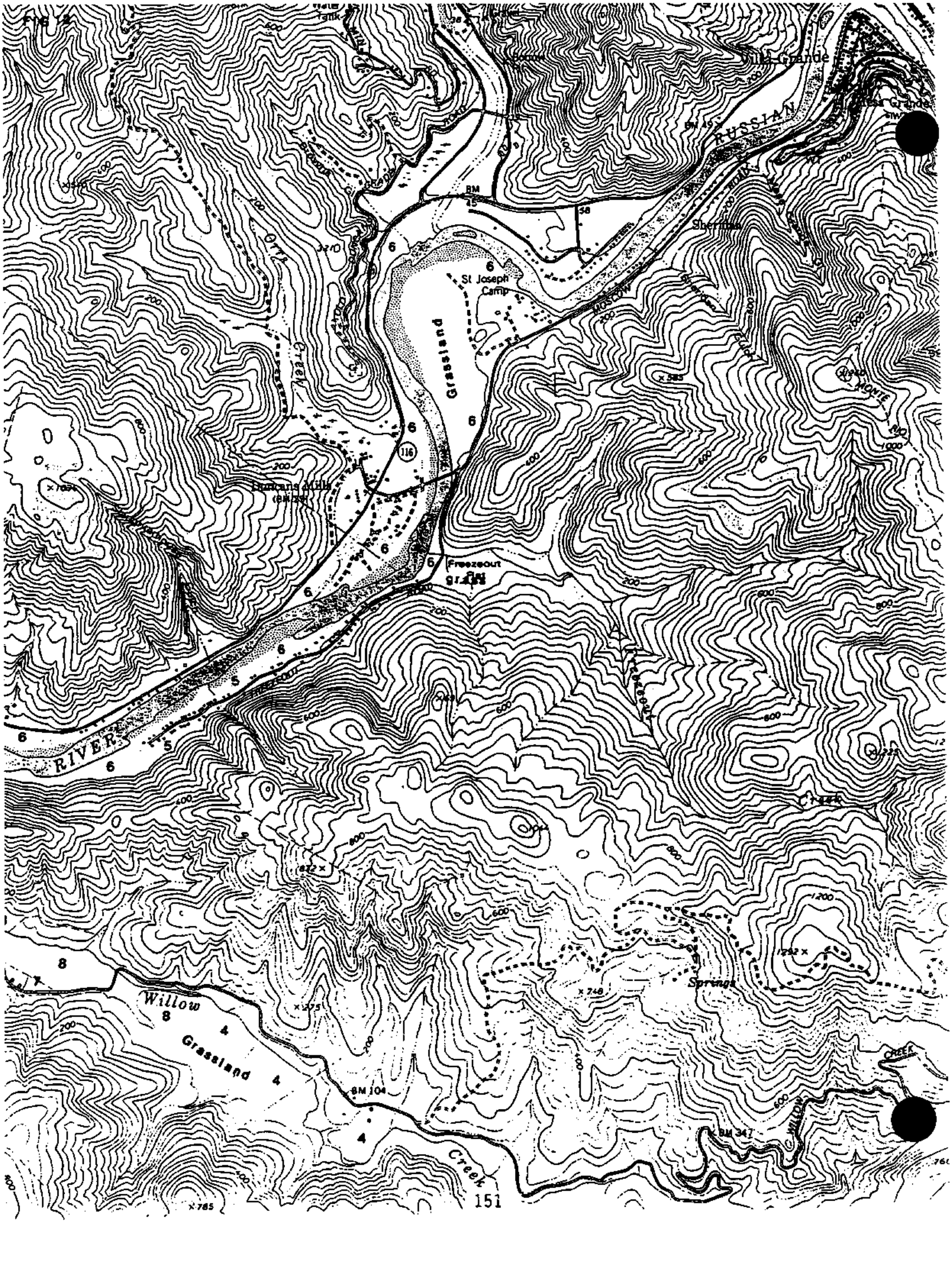


FIG 12
Villa Grande
RUSSIAN
RIVER
Sheridan
St Joseph Camp
Grassland
Duncans Mills
Freezeout
Creek
Willow
Grassland
Creek
Springs
BM 104
BM 347
MONTE
RIO

Transect surveys (N=14) were made during the spring of 1993, for sensitive plant species in the Willow Creek marsh based of a list provided by California State Parks: Sonoma Alopercus (*Alopercus aequalis* var. sonomensis; small spikerush *(Eleocharis parvula;* swamp harebell *(Campanula californica).* Plant identification in the field followed Munz, 1968. No sensitive plants were found the riparian area of the marsh impacted by water impoundment during mouth closure.

H. Russian River Estuary Study Pinniped Report

Submitted by Linda Hanson
Based on data collected by Linda Hanson,
Joe Mortenson, and Elinor Twohy
April 15, 1993

Two species of pinnipeds consistently use the area at the mouth of the Russian River. Harbor seals, sometimes numbering in the hundreds, are found at this site all year and use the sandspits on either side of the river mouth as haulout locations. Their preferred haulouts on the sandspits are located inside the estuary near the river mouth rather than on the outside adjacent to the open ocean. California sea lions can also be seen in the area from December through June each year. In contrast to the large resident harbor seal population, sea lion numbers are low, rarely more than five individuals, and they normally don't come ashore at this site. They forage, as do a small number of harbor seals, in the area near the river mouth. In the past year, juvenile elephant seals have occasionally been seen on the haulout. Their appearance is unusual since they haven't been previously reported using this site as a haulout location.

As part of a larger study, this investigation examines some of the long and short term effects of artificial breachings on pinnipeds at the mouth of the Russian River. The short term effects are based on observations made during three artificial breachings (Oct. 7, Nov. 2, and Nov. 16) occurring in the fall of 1992. Baseline data on site utilization and foraging behavior was gathered on the day before each opening and on the morning of the breaching process. The site was monitored for the entire period on the day of breaching and periodically for two days after the mouth was opened. Short term data was collected only for harbor seals at this site, since California sea lions had not yet arrived in the area. Elephant seals, so rarely seen at this site that no pattern of use has been established for them, were not included in this study.

The examination of long term effects of river closure on the use of this haulout site by harbor seals is based on census data independently collected from 1989 to 1992. Harbor seal scat samples, taken in 1989-1990, were used to determine differences in diet during periods when the river was open and closed. There is currently no data available for determining the dietary components of California sea lions at this site.

SHORT TERM EFFECTS OF BREACHING ON HAULOUT USE

Response of harbor seals hauled out at the mouth of the river to the equipment and disturbance of breaching.

Seals at the haulout were flushed into the water by the breaching activities on all three days of observation. However, the appearance and noise of the bulldozer did not necessarily cause the entire group to flush. Some seals remained on the beach for more than an hour and a half after the bulldozer had started to work on October 7 and November 16, and some seals remained through the entire breaching procedure on November 6. Moreover, several seals that left the haulout during the breaching process returned to rehaul despite the noise and presence of the bulldozer. Flushing responses that were observed during the breachings were initiated not only by the process itself, but by spectators, dogs, and boats. Birds, waves, and other undetermined sources also produced flushing reactions during the breachings.

Disturbance is the norm at this haulout, but the level of disturbance during breaching could easily be minimized if people not directly involved in the procedure were kept away from the area. Since the banks on both sides of the cut made by the bulldozer are unstable for a period of several hours after the breach, public safety, and liability concerns could be addressed at the same time the disturbance level is reduced.

Recovery time necessary for displaced harbor seals
to return to the haulout site after breaching.

The strong current flowing out through the river mouth after breaching made it difficult for seals to swim into the estuary to use the preferred haulout sites. Depending on the water flow it took from 30 minutes to 2 1/2 hours for the first seal to swim into the estuary after it began to empty.

Seals also attempted to move back to the haulout sites on all three breaching days by moving over the sandspits after the bulldozer left the beach. They were persistent in these attempts, but consistently turned back after encountering the spectators who had gathered along the cut margins and at the edge of the water.

Seals were easily able to reenter the estuary on the day of the breach after the water flow subsided. However, no seals rehauled during the daylight hours after the breach although the site was monitored for at least 5 hours after the river mouth was opened. On each occasion, seals were using the haulout by the next morning, which suggests that they rehauled within 18 hours of the breach.

Differences in haulout use at an up-river site
when the mouth is open or closed.

Access to another haulout site, located on logs upriver, is facilitated by opening the river mouth. When the estuary is closed, access to the river becomes more difficult since the seals must move overland to cross the sandbar. In addition, the dry upriver haulout site is lost as the water level rises in the closed estuary and the haulout logs become submerged. However, even when the estuary is closed, some seals persist is using the site as an underwater 'haulout' and can be counted as they surface to breathe. Seals (n=3) were observed surfacing on the day preceding one of the breaches, but none were observed in the area before the other two breaches. The logs were exposed and seals (n=6 to 8) were counted at the site within 24 hours of all three breaches.

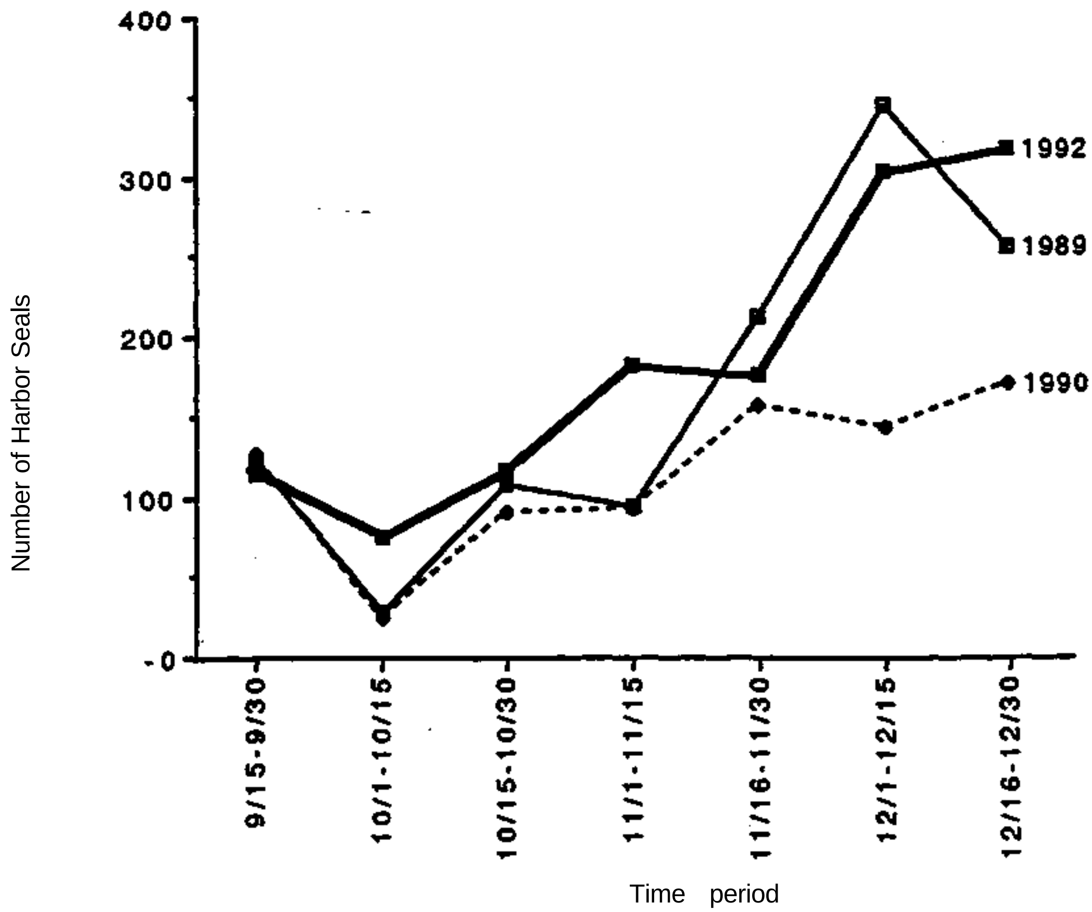
Breaching enhances the use of this haulout site by exposing the logs and allowing easy access through an open river mouth rather than across the sandbar.

LONG TERM EFFECTS OF BREACHING ON HAULOUT USE

Recovery time to "seasonal normal numbers" after breaching

Artificial breaching appears to have a minimal effect on the attendance patterns of harbor seals using the Russian River haulout on a long term basis. Comparison of haulout attendance (based on the maximum number of harbor seals counted in a two week period) in fall and winter of 1989, 1990, and 1992 shows an increase in attendance as fall progresses in all years (Figure 8.6). Breaching occurred in all the years, but varied as to type (natural or artificial), duration of closure, and number of closures during the time period. The increases seen in the months of November and December in 1989 and 1992 reflect changes in attendance patterns when artificial breachings occurred, while the change in 1990 reflects a period when the river opened naturally and the population was not disturbed by the artificial breaching process.

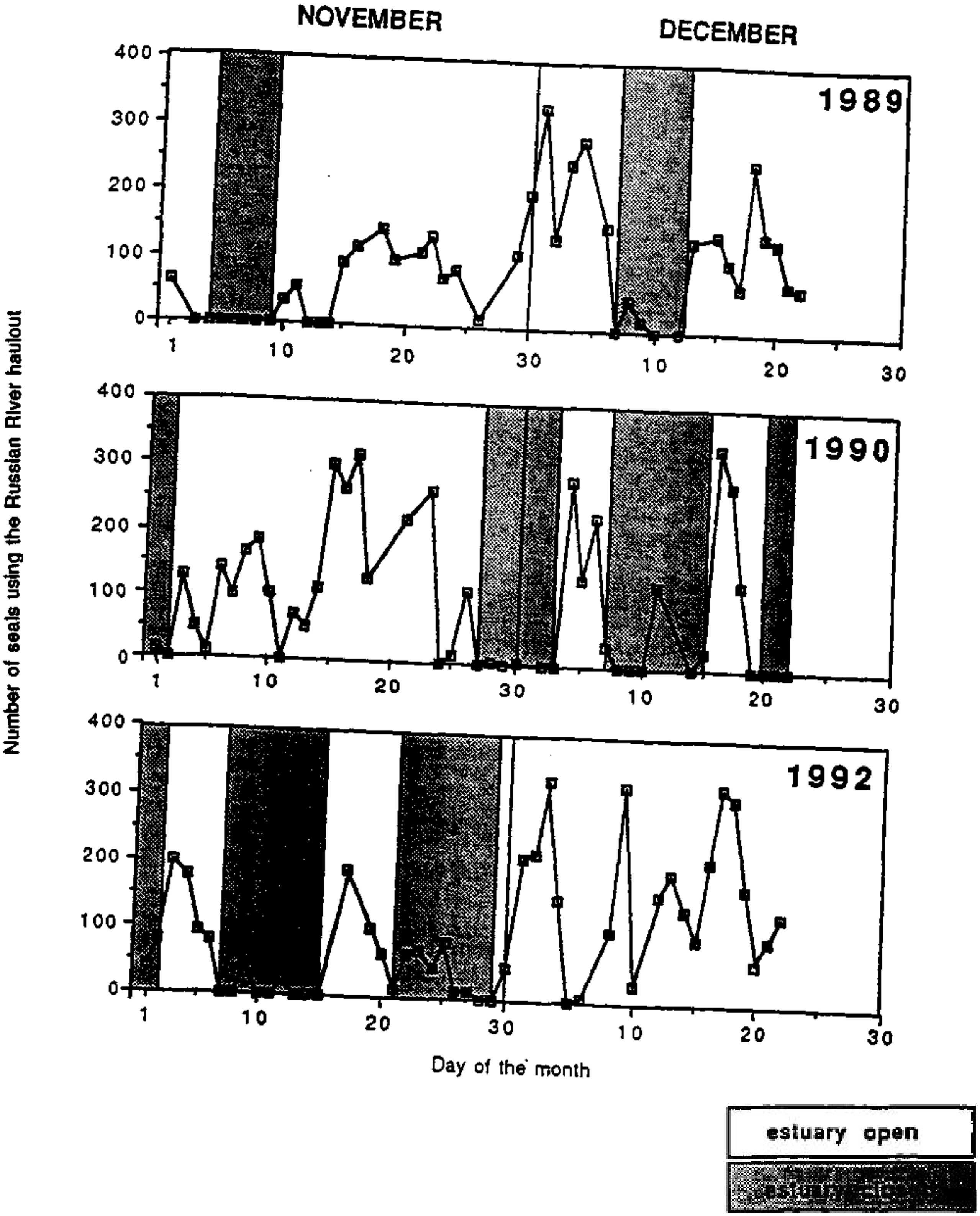
Figure 8.6 A comparison of the number of harbor seals at the Russian River haulout based on the maximum count in a two week period in September through December of 1989, 1990, and 1992.



Differences in haulout use by harbor seals when the estuary is open or closed

Daily census data collected in November and December of 1989, 1990, and 1992 show a reduced haulout attendance during periods of river closure as compared with periods when the estuary was open to the sea (Figure 8.7). The daily counts of harbor seals on the haulout can fluctuate widely from day to day when the estuary is open. These fluctuations are less extreme when the river mouth is closed since the number of seals using the haulout is likely to remain low for an extended period. The loss of easy access to the haulout and ready escape to the sea when the river mouth is closed may account for the lower number of harbor seals seen at that time. The decrease in use may also reflect the effects of an increased level of disturbance since the seals can be approached from two directions by people visiting the beach area when the sandbar forms across the river mouth.

Figure 8.7 Comparison of the number of harbor seals at the Russian River haulout during open and closed periods based on maximum daily counts in November and December of 1989, 1990, and 1992.



SHORT TERM EFFECTS OF BREACHING ON FORAGING BEHAVIOR

Observable shifts in harbor seal foraging patterns during the breaching period

Harbor seals were observed foraging in the surf zone during each breach. This type of foraging is commonly observed at this site and does not represent a shift in behavior due to breaching. Seals outside the river mouth were not observed foraging on prey flushed from the river system after breaching, although birds foraged extensively in the water plume leaving the river mouth.

Normal foraging patterns inside the estuary include searches, chases, and captures during the upriver salmonid and lamprey migrations. This type of foraging behavior was not observed during the October breach, but it was observed during both breaching periods in November. No foraging activity was observed on November 2, the day of the first November breach, but chases were observed inside the estuary two days later and a salmonid capture was recorded. During the second breach in November, foraging activity began as soon as harbor seals were able to enter the estuary on the day of the breach. No chases or fish captures were observed on that day, but foraging activity continued during the two remaining days the site was monitored and another salmonid capture was recorded. Based on salmonid return records from Warm Spring Hatchery, the probable prey taken during both of these breach periods would have been coho salmon.

Harbor seals are more successful at capturing fast moving salmonid prey if they can take advantage of trapped or stressed fish. The location of the breach and the amount of water impounded in the estuary may affect the salmonid capture rate for harbor seals at this site and should be considered as part of a breaching decision. The breach should provide a clear, wide opening into the estuary for migrating fish. If the breach does not open, the search time for predators is greatly reduced since their prey are forced to funnel through a shallow, narrow river mouth.

LONG TERM EFFECTS OF BREACHING ON FORAGING BEHAVIOR

Differences in the components of the harbor seal diet during periods when the estuary is open and closed

Harbor seal scat samples (n=109) collected in the winter of 1989 and the spring of 1990 were analyzed to determine the relative frequency of occurrence of prey items. Sixty-two samples were collected on 11 sampling days when the river mouth was open and 47 samples were collected on 4 sampling days when the estuary was closed. The percent frequency of occurrence of each prey item was determined by comparing the number of samples containing that particular prey item to the total number of samples collected (Table 8.11).

The scat samples contained a diverse set of prey items indicative of opportunistic feeding. Flatfish, octopus, and hake were the three most common prey items, appearing in at least 30% of the samples from all periods. The abundance of these prey types in the samples reflects prey abundance and foraging offshore rather than within the river system.

When the 109 winter/spring (December through May) samples were analyzed based on the condition of the estuary (open or closed), flatfish, octopus, and hake maintained their rank positions. However, a substantial shift occurred in the ranking order of several other species. Hagfish, midshipmen, cusk-eel, and salmonids were found more frequently in the closed period samples, while lamprey, smelt and skate were found more frequently in the samples collected when the estuary was open.

Four of these types (hagfish, midshipmen, cusk-eel and skate) are not found within this river system and their abundance in the diet should not be directly affected by the opening and closing of the river. The increase in the consumption of these prey items may have been due to a short peak in their availability coinciding with the particular sampling period or a shift in foraging to those items when other items in the open ocean became less available.

Although smelt are found in the estuary, the difference in its abundance between the closed and open periods was most likely due to the timing of the collections, rather than shifts in foraging between the two periods. Smelt remains were commonly found in all scat samples collected in February and March, but the estuary remained open during those months and no closed estuary samples could be collected.

The other two prey items, lamprey and salmonids, must migrate through the river mouth and thus an increase or decrease in their abundance may be directly related to the condition of the estuary. The marked increase in the frequency of occurrence of lamprey when the river mouth is open reflects the increased availability of these fish as they migrate through the estuary to spawn. Harbor seals can be observed feeding on lamprey in the beach areas near the river mouth and along the margins of the estuary as they move into the river system. When the mouth of the river is open, lamprey ranks as the fourth most frequently found item in the scats, but when the river mouth closes, this fish's access to the river system is blocked and it is seldom found in the samples. Based on these findings, it appears that harbor seals rarely forage on this fish in open water.

In contrast to lamprey predation which increased when the mouth of the river remained open, salmonid remains increased in frequency of occurrence when the river closed. Salmonid remains were found in 17% of the samples collected during the closed period as compared with a 5% frequency of occurrence in the open estuary collection period. This suggests a prey type leaving the estuary rather than one migrating upriver. The skeletal remains collected were predominantly smolt size fish (10 of 11 samples), which also indicates that predation was occurring on seaward migrating juvenile fish. Smolt size salmonids are released into the river system all year by Warm Springs Hatchery, although releases peak in the spring months.

If the higher abundance of smolt remains in the samples was only due to the estuary closing after the hatchery released smolt into the system, it would be expected that skeletal remains would be abundant on all closed period sampling days following hatchery plantings. This was not the case. Although the hatchery had released fish before each of the four sampling days in the closed period, salmonids remains were found in high frequency on only one of the days. It appears that other factors, in addition to river closure and smolt releases, are necessary for an increase in consumption of this prey type by the harbor seals. A series of three events proceeded the collection day with the high occurrence of salmonid prey. The hatchery released 36,000 smolt into the river system, it rained, and the estuary closed. This unusual sequence of events, which flushed a large release of smolt down the river and trapped it behind the sandbar, appeared to initiate heavy predation on smolt.

Based on the findings of the scat analysis, this population of harbor seals appears to feed outside the estuary on slow-moving or schooling prey with minimal anti-predator defenses. Lamprey increased in importance in the diet as they migrated through the estuary, but other up-river migrants, including adult salmonids, did not constitute an important part of the harbor seal diet. Predation on migrating salmonid smolt may increase when large numbers of these fish are flushed down river and trapped inside the estuary, but it appears that an unusual set of conditions is needed to initiate heavy predation on smolt. However, caution would dictate that the timing of smolt releases and artificial breaching be coordinated to avoid trapping released smolt behind the closed sandbar.

Table 8.11 Frequency of occurrence (express in %) and rank of prey items found in harbor seal scat samples collected at the Russian River haulout during the winter and spring months (December-May) of 1989 -1990.

Prey type	All Winter/Spring samples (n=109) % frequency (rank)		Open periods samples (n-62) % frequency (rank)		Closed period samples (n-47) % frequency (rank)	
Flatfish	64	(1)	63	(1)	66	(1)
Octopus	55	(2)	58	(2)	51	(2)
Hake	36	(3)	32	(3)	40	(3)
Hagfish	27	(4)	18	(7)	38	(4)
Smelt	26	<5)	32	(3)	17	(7)
Midshipman	25	(6)	16	(8)	36	(5)
Cusk eel	19	(7)	10	(10)	32	(6)
Herring	19	(8)	21	(6)	17	(7)
Skate	19	(8)	23	(5)	15	(8)
Lamprey	17	(9)	26	(4)	4	
Perch	16	(10)	16	(8)	15	(8)
Sculpin	12		11	(9)	13	(9)
Unknown fish (non-salmonid)	12		10	(10)	15	(8)
Salmonids	10		5		17	(7)
Rockfish	9		8		11	(10)
Cod	8		8		9	
Squid	7		7		9	
Cephalopods (unknown species)	6		2		13	(9)
Sablefish	5		2		9	
Unknown fish (non-salmonid)	4		0		7	
Shad	1		2		0	

SUMMARY AND RECOMMENDATIONS

The negative effects of breaching on haulout use by harbor seals appears to be minimal during the fall months since the number of seals using the haulout increases as the season progresses whether or not breaching occurs. Although breaching produces a high level of disturbance, this site is heavily disturbed on a regular basis even when breaching is not occurring.

Breaching may provide some benefits to the harbor seals by allowing easy access to the preferred haulout areas on the sandspit and upriver. However, it is important to note that the effects of breaching, and the disturbance surrounding it, may be quite different during other times of the year. Attempts to breach during the pupping period in April and May could produce unacceptable levels of disturbance that would endanger pups by causing mother-pup separation or pup abandonment.

Foraging by harbor seals at this site normally occurs outside the river system and is not affected by the closing or opening of the estuary because the major components of this population's diet are not found there. However, the frequency of occurrence of lamprey and salmonid smolt in the harbor seal scats can be linked to foraging within the river system. During the winter and spring months, lamprey remains occurred in the scat samples more frequently when the river system was kept open, while salmonid smolt remains occurred in higher frequencies when large numbers of these juvenile fish were trapped inside the closed estuary. It should be noted that an increase in the frequency of occurrence of salmonid smolt in the diet did not occur during all periods when the estuary was closed, and appeared to require a unique sequence of events.

Three recommendations to minimize the effect of the breaching procedure on both haulout use and foraging behavior during the fall season can be made based on the findings of this study:

1. Public access to the area should be curtailed on the day of breaching. This would lower the level of disturbance at the site and should allow the harbor seals to rehaul more quickly. Since breaching creates hazardous conditions for spectators at the river mouth, restricting access has the added benefit of increasing public safety, thereby reducing liability concerns.

2. The location of the breach and the amount of water impounded before it is done should be carefully considered to provide a wide, clear opening at the river mouth when salmonids are migrating upriver. Additional work would be necessary to determine if a relationship actually exists between the size and location of river opening and the salmonid capture rates for pinnipeds at this site. However, it would be

prudent to avoid creating a constricted opening, since pinnipeds are known to take advantage of obstacles and barriers to capture fast moving prey.

3. The timing of breaching and the release of smolt from Warm Springs Hatchery should be coordinated to avoid trapping released fish in the estuary. This requires that several variables be considered since the rate of downriver movement by released smolt is not consistent. However, the predation level by birds, particularly osprey, in the estuary can be used as an indicator of smolt arrival.

IX. DOCUMENTATION OF FLOODING IMPACTS

The Work Program called for the hydrological consultants to identify up to 15 of the most critical locations for damage if the Russian River mouth were to remain closed and the River allowed to rise. In addition, it was intended to develop a tabulation of flooding impacts depending upon various water elevations, as well as photodocument affected structures. This report and survey did not consider the impacts of storm induced river flooding.

Philip Williams and Associates Ltd. (PWA) presented the County with flooding data in two formats. First, assessor's parcel maps of the potential flooding areas were presented which focused on the parcels west of Highway One in Jenner and in the Bridgehaven area, primarily on the south side of the River. The maps identified the parcels in three categories: 1) residences with potential for flooding of structures at water surface elevations of 10 feet NGVD, 2) agricultural land with potential for minor flooding at water surface elevations of 10 feet NGVD (no structures affected - partial loss of land), 3) steep-walled riparian corridor or beach face relatively unaffected by flooding (i.e. no structures affected). Several parcel pages included notes about potential flooding as follows:

> Book 99, Page 15 (Jenner) - About three properties are situated at or below 10 feet NGVD. Residents in this area have complained of siltation and scour as being the biggest problems encountered.
>
> Book 99, Page 14 (Jenner) - About nine properties are situated at elevations at/or below 10 feet NGVD. Most properties with potential for flooding are between 8 and 10 feet NGVD. Potential flooding problems include flooding of basements and lower levels of homes; flooding of gardens and stairways to docks, possibility of floating docks or other objects being stuck submerged under fixed structures; heavy siltation due to deposition of fine grained suspended sediment; scour and erosion due to outrush of water during sudden breaching of mouth.
>
> Book 99, Page 12 (Jenner) - The Jenner Post Office and Deli/Gift Shop are located at approximately 10 to 11 feet NGVD.
>
> Book 99, Page 08 (Bridgehaven) - About three properties are situated at or below 10 feet NGVD. Mostly foundations of houses are above 10 feet NGVD but decks, docks and gardens have potential for flooding at six to eight feet NGVD.

The second source of data presented was a set of 46 photographs taken at critical locations in Jenner and Bridgehaven. The photographs were taken from a boat on five different dates and water surface elevations: 1) September 29, 1992 when the water surface elevation was 6.2 feet; 2) October 7, 1992 when the surface elevation was 9 feet; 3) November 21, 1992 when the water surface elevation was 4.1 feet; 4) November 22, 1992 when the water surface elevation was 6.9 feet; and 5) December 10, 1992 when the water surface elevation was 6 feet. The photos are labeled and the affected properties identified. Addresses and elevations when flooding would occur were included when possible. These photographs provide excellent documentation of potential flooding impacts were the River allowed to rise up to and beyond a water surface elevation of 10 feet.

In order to gain more information about flooding impacts, the County Task Force developed a survey form which was handed out at an area citizen's meeting and was mailed out to all owners of properties identified by PWA as potentially affected by flooding. The two-page survey asked a number of questions including whether their property is affected by flooding when the River mouth is closed; whether the property is residential, agricultural, or commercial; percentage of land affected; the height of the River when the structure becomes affected; and the use and square footage of the affected area of the structure or property. Additional comments were also solicited.

Survey forms from 20 property owners were returned; mostly in the Jenner/Bridgehaven areas, indicating varying degrees of flooding impacts. The most common complaint was erosion and undercutting of the River bank. Some noted loss of trees and other bank vegetation due to erosion. Some felt structures were threatened due to potential loss of banks under foundations. In addition many commented that yards and River access stairs and decks are affected by flooding. Respondents expressed concerns about flooding of residential structures if the River were allowed to reach heights in excess of 10 feet on the Jenner gauge, the highest the River has reached in recent times. Affected commercial parcels have lost use of parking areas due to inundation. The owner of agricultural property on the north side of the River indicated that 10 to 12 acres of pasture is affected by flooding when the mouth is closed. The owner indicated that this causes severe erosion on bank edges and drowns out desirable grasses and crops. It also makes access through their property difficult and spreads debris throughout the flooded area. The County has also received anecdotal accounts of flooding as far inland as Monte Rio. They include reports of beach inundation and erosion at the beach along Freezeout Road and Monte Rio Beach, loss of use of River access at the Bohemian Grove and impacts on instream gravel mining on Austin Creek. Probably the most significant potential threat to public health was identified by the owners of the Rancho Del Paradiso Water Company. This private water company serves 61 homes on Freezeout Road in Duncan's Mills. The water source is a gallery infiltration well in Freezeout Creek under the county bridge. When the mouth remains closed for an extended period, the brackish river water is backed up over the pump intake. The water then becomes non-potable.

In summary, recent River mouth management which has called for breaching between 7 and 9 feet has caused minimal to moderate problems in the Jenner and Bridgehaven area. These problems include potential increases in bank erosion, loss of vegetation, loss of use of parking areas, pastureland, stairs, decks, and beaches. These difficulties could be minimized by opening the River mouth at lower water elevations. If the River were opened less frequently at higher elevations, more severe flooding impacts would occur. These would include more severe erosion, inundation of commercial and residential structures, and potential failure of septic systems and water supply for 61 homes on Freezeout Road.

X. ECONOMIC IMPACTS

The Work Program called for exploration of all alternatives including the option of not opening the River mouth or opening the mouth on a less frequent basis. In order to fully explore these options, the Work Program called for an evaluation of the economic impact of allowing the River to flood including an estimated cost of damage that would be incurred and an estimate of acquiring all or some of the affected properties. This economic evaluation was not within the scope of work of the hydrologist. The County was to estimate these amounts through the input of the County Task Force including representatives from the County Assessor's Office and Risk Management.

Severe negative impacts to the ecology of the estuary were measured during the Study, when the estuary mouth was breached at elevations greater than ten feet. The economic impacts were not evaluated for breaching at higher elevations since there were no advantages identified.

XI. SAFETY ISSUES

Two main safety issues were raised as part of the Russian River Estuary Study.

The first issue relates to the height of the River when the artificial breach occurs. The higher the water elevation in the lagoon, the greater the risk both to the driver of the bulldozer that opens the mouth and to spectators or recreational beach users. The current operator has indicated that he would be unwilling to open the River at a water elevation in excess of 10 feet on the Jenner gauge. Since the hydrologist and biologist recommend that the mouth be opened at lower elevations, risk to the operator and the public would be reduced if implemented.

The second issue relates to accessibility of the breach area and operation to the public. The natural or artificial breaching of the barrier beach can create standing waves in excess of 10 feet high and velocities in excess of 15 feet per second for short periods. The velocities are greater when the difference between the water level in the lagoon and ocean are larger. It should be recognized in the management plan that the inlet channel poses a public safety issue. The preferred alternative proposed by the consultants includes a recommendation that the beach be closed to the public at a distance of at least 750 feet on either side of the breach for public safety reasons. This public access restriction may also allow pinnipeds to return to the beach during the breaching process.

XII. RECREATION

The major recreational opportunities along the Russian River within the project area are swimming, fishing, bird and pinniped observation, and boating. The Work Program called for a determination whether flooding has beneficial social effects, for example enhancement for recreational boating. Although a few local residents may enjoy boating in the estuary when the mouth is closed, there appears to be no significant recreational benefits of a closed and flooded estuary. County staff interviewed Tom Meldau, President of the Sequoia Canoe Club which is the major local organization providing coordinated canoeing and kayaking activities. He indicated that its members have no interest in the issue of River mouth closure. They have no organized field trips in this lower Russian River area. He said that this segment of the Russian River is of little interest to canoeists since the rest of the Russian River provides much greater recreational opportunities.

On the other hand, allowing the River mouth to remain closed has detrimental effects on recreation. Individual property owners, as well as the Monte Rio Park and Recreation District, complain about loss of use of beaches during inundation and permanent loss due to beach erosion following inundation. Property owners also lose River access opportunities when access stairs and docks are inundated. Recreational fishing opportunities are reduced when the mouth is closed for extended periods during spawning season when anadromous fish are unable to enter the River. The closed River mouth may prevent wild smolts and hatchery released fish from reaching the ocean.

According to the biologists, birds and pinnipeds are relatively unaffected by closure and opening of the River mouth. Observation of wildlife, therefore, does not appear to be affected by estuary management.

In summary, there appears to be no major beneficial effects from allowing the River to flood when the mouth is closed. Recreational opportunities are reduced when the mouth is closed due to inundation of beaches and River access opportunities. In addition, fisheries and fishing opportunities are detrimentally affected when migration is impeded due to mouth closure.

XIII. CITIZEN INPUT

Two citizen's meetings were held during the development of the Russian River Estuary Study. One additional meeting will be held to present the final report and its recommendations.

All citizen's meetings were held in Duncan's Mills at the Casini Ranch Family Campground, a location convenient for lower Russian River residents. Both meetings held to date were well attended, each with about 75-100 people. Meeting notices were mailed to all property owners along both sides of the Russian River between Monte Rio and the mouth of the Russian River. In addition, notices were placed in The Paper and the Bodega Bay Navigator.

The first citizen's meeting was held on May 11, 1992. At that meeting, Study goals and methodologies were outlined. The group seemed to be fairly evenly divided between those who felt the River should be opened on a regular basis and no further study was necessary and those who felt the Study was necessary and should be expanded upon. At that time field work had just begun and was anticipated to be completed in December of 1992. Many citizens concerned about adequate biological monitoring suggested that at least a full year of data be collected. Based on their suggestion and concurrence of the Inter-Agency Task Force, the length of field study was extended through April of 1993 to provide a full year of monitoring. Fortunately, the consultants agreed to continue monitoring without any additional costs to the County.

The second citizen's meeting was held on March 1, 1993 at which time both consultants made presentations detailing the type of data that had been collected and methodologies utilized. No conclusions were presented at that time. The citizens attending the second meeting seemed very interested in the consultants' reports and asked a number of technical questions.

It is anticipated that the final citizen's meeting will be held in December, 1993 to present the Study's recommended preferred alternative and obtain citizen input regarding the recommendations.

XIV. MANAGEMENT ALTERNATIVES

A. No Action Alternative

The no-action alternative would require no intervention at the mouth of the Russian River. Under this management alternative the height of the barrier beach would govern the maximum depth of property inundation adjacent to the estuary.

The height of the barrier beach is dependent upon the prevailing wave conditions and is typically in the range from +6.0 to +15.0 feet NGVD. The no-action alternative would be comparable to the earliest historic descriptions of the estuary, except for the changes to the river inflows. The construction of Warm Springs Dam and Lake Mendocino allows for some regulation of the river flows during dry periods and the establishment of minimum flows in the river for fish habitat.

There is no quantitative information on the summer flows in the Russian River prior to European settlement, but between the installation of the USGS gage near Guerneville (October, 1939) to the completion of Lake Mendocino in 1958 (supplemented by the effects of Lake Sonoma in October, 1983), the average monthly dry season river flow has shown little variation (Section 2.3), although the variability of low flows has been reduced.

The small increase in inflow during the summer months following dam completion in 1958 will result in more frequent lagoon breaching than would have occurred prior to the completion of the reservoirs. The regulated river inflows will exhibit less variation than the historic condition, and the frequency of breaching will also occur more regularly than may have been experienced prior to flow regulation.

The no-action alternative is close to the natural condition of the estuary, except for the alterations in the quality and quantity of river inflows, but there are several impacts associated with this management option.

Impact: <u>Flooding of Property</u>

Flooding of property starts at an elevation of approximately 10.0 feet NGVD. At these high elevations, incremental increase in volume seepage and evaporation losses are greater than at lower elevations, so that the expected rate of rise of the water level is less than 0.5 feet/day at normal low level flows. Therefore, property can be expected to be inundated for periods of at least 10 days before natural breaching occurs.

Impact: Bank Stability

The banks of the river through the estuary may be de-stabilized by seepage failures, if inundated for prolonged periods of time, and are then subjected to rapid drawdown.

Impact: Water Quality

Evidence was collected during the monitoring program completed for this study that high water levels in the estuary flush a high anaerobic organic load from wetlands in the tributaries such as Willow Creek. This load will deplete the dissolved oxygen (DO) in the estuary.

Impact: Scour in the Estuary

The ebb velocities in the estuary and scouring action on the banks and bed increases with the difference in water level between the ocean and estuary. Therefore, the loss of benthic organisms is increased and fish have less opportunity to move away from the main ebb currents during breaches associated with high estuary levels.

Impact: Public Safety

Natural breaches occur at a higher water surface elevation than an artificial breach, and although breaching is not an instantaneous process, there is the possibility of recreational users on the beach being cut off or being tempted to cross the inlet channel during breaching. Standing waves in excess of 10 feet high were observed in the artificial breach of where the water elevation was allowed to reach +9.6 feet NGVD.

Impact: Impacts to the Estuarine Ecology

See Chapters VII and VIII

B. Current Management Plan

The current management alternative is to breach the barrier beach whenever the water surface in the estuary reaches an elevation of approximately +7.5 to +9.0 feet NGVD (Schrad, 1992). This elevation has been selected as a compromise to minimize artificial intervention in the estuary, to minimize entrance dredging costs, to prevent inundation of property, and to facilitate concerns regarding fish migration.

The impacts associated with the current management alternative are described in Section XIV(A), although generally the impacts are less severe. The timing of artificial breaching and the appropriateness of +7.5 to +9.0 feet NGVD as the critical elevation is discussed in Sections XIV(D) and (E).

C. Structural Alternatives

General Comment

The coastline around the Russian River is subject to high wave energy (deSilva, 1973; Johnson, 1956) and intensive wave energy has destroyed previous jetties constructed in the inlet channel. In this hostile environment, any permanent structure would need to be a major construction project.

There are two types of structures that could be designed for the mouth of the Russian River.

Jetties

Jetties could be constructed to maintain a permanent inlet channel to the estuary. A permanent inlet channel would create several changes to the characteristics of the estuary. Pinnipeds, fish, and recreational boats could pass in and out of the estuary. The salinity structure would be changed and the estuary would be tidal at all times.

The cost of constructing jetties at the entrance to the Russian River would be several million dollars, and would have a negative aesthetic impact on one of the most pristine and undeveloped estuaries in California. The jetties would also create conditions that are very different from those observed during the past century or those described in the earliest historic records. For these reasons, jetties are not recommended and have not been considered further.

Water Surface Regulation Structure

The water surface elevation in the Russian River Estuary could be maintained within a prescribed range by a pump, siphon, or other structure located near the inlet.

A permanent weir or spillway structure has the same problems associated with a jetty structure. Pumps, siphons, and overflow pipes set throughout the barrier beach have the disadvantage of requiring an outlet close to or in the surf zone where it is subject to wave forces and clogging by beach sediments.

The pad for mounting pumps must be structurally sound, which would probably require mounting against the cliffs on the north side of the estuary. An adequate power supply must be provided for the pumps, which would probably be electric due to the noise and pollution risk associated with diesel generators. As an example of the required capacity of the pumps, assume that a water surface elevation of +6.0 feet NGVD corresponding to a surface area of 452.4 acres. If the water surface elevation is rising by 0.5 feet per day, the pump would need to discharge 114 cubic feet per second (cfs). This discharge would require a major pump station with the exposed parts constructed of stainless steel or other corrosion resistant materials. The costs of constructing and operating a pump station with this capacity will be very significant.

Gravity-driven water level control structures do not have the operating expenses associated with pumps or the difficulties of providing a power supply. An example of a permanent gravity driven structure used to control water levels in a coastal lagoon is at Capitola in Santa Cruz County. This structure has operated successfully for several years but is located in a sheltered area with a low wave energy climate. The scale of Capitola lagoon is much less than the Russian River with the outlet structure passing only a few cubic feet per second.

An alternative water level control structure has been proposed by the City of Santa Cruz for the San Lorenzo River Lagoon. A low cost pipe is buried in the barrier beach during the summer months and removed in the fall. A wooden intake structure provides control for the discharge and prevents fish from being drawn through the pipe. It is anticipated that the lower sections of the pipe may be damaged by wave action, but the cost of replacing the plastic pipe is significantly less than the cost of a reinforced concrete or steel permanent structure.

The design specifies a 300 foot length of 3 foot diameter pipe and is expected to discharge approximately 6 cfs. Therefore, approximately 20 of these pipes and inlet structures would be required for the Russian River. The intensity of wave action is greater at the Russian River and damage of the outlet sections of the pipe can also be anticipated.

If this alternative is selected as viable, the assessment of the field performance of the structure at Santa Cruz (due to be installed for the first time in 1993) is recommended.

The installation and removal of the temporary structures at the Russian River would be labor intensive. The cost of each pipe would be approximately $30,000.

This alternative would provide an effective means of controlling the water surface elevation, when there are ecological reasons for not breaching the barrier beach. It is also possible to design the inlet structure to draw water from different layers in the estuary, thereby controlling the temperature and salinity structure.

Public Safety

The outlet pipes would be located on a recreational beach, therefore there is the possibility of swimmers or walkers being knocked against the structure by waves. The inlet structures need to be designed carefully to prevent children from being held against the pipe by the velocity of the flow.

Aesthetic Concerns

The inlet structure would be visible from Jenner. In addition, during some wave conditions, it is possible that the pipes would be exposed.

D. Management for Alternative Maximum Water Surface Elevations

It is possible to manage the Russian River Estuary for a different maximum water surface elevation, or a different maximum water surface elevation during different months of the year.

Factors affecting the selection of a critical water level to initiate artificial breaching:

1. *Onset of flooding of property.* Structural damage is expected to occur at an elevation of +10.00 feet NGVD. Access to property or inundation of yards or pasture is affected at an elevation of +7.00 feet NGVD.

2. *Elevation of banks subject to active erosion.* Prolonged inundation of banks subject to erosion occurs at elevations of +2.0 feet NGVD.

3. *Frequency of Breaching.* The size of the channel formed across the barrier beach is a function of the volume of water released from the estuary. Breaching of the lagoon at a lower elevation will result in a smaller channel which will close in a shorter period. Therefore, breaching at a lower elevation will occur more frequently since there is a smaller volume in the estuary to be filled, and the barrier beach is reformed more quickly following breaching.

4. *Timing of Breaching.* The estuarine ecology is more sensitive to the effects of breaching at certain times of the years. The most critical periods have been defined by the USFS (Nielsen, 1993).

The model described in Section 4 can be used as a management tool to ensure that these critical periods are avoided to the extent possible.

5. *Assisted closures.* Current management of the estuary entrance allows the estuary to discharge the stored volume of water to the ocean, and remain open to tidal exchange until the inlet closes to longshore and cross-shore transport reforming the barrier beach.

   An alternative management strategy would be to induce a more rapid closure of the lagoon entrance by depositing material in the inlet channel during slack water when the level in the lagoon has lowered to an elevation within the tidal range. Assisted lagoon closure at Lower Low Water (LLW) would provide greater storage capacity and a longer period before breaching is required.

   Assisted lagoon closure at Higher High Water (HHW) or Lower High Water (LHW) would be more difficult to implement, but may result in less biota being flushed from the estuary by tidal exchanges.

   Assisted lagoon closures have been performed by the City of Santa Cruz on the smaller San Lorenzo River Estuary. It is recommended that the practical feasibility of this approach be attempted during the next artificial breaching at the Russian River.

6. *Salinity and Water Quality.* It is possible to manage the estuary for certain water quality parameters, for example: degree of stratification, minimum salinity, or minimum dissolved oxygen standards at specified monitoring stations in the estuary. This management alternative would require monitoring of the lagoon by County or Regulatory Agency Staff, or by establishing a remote sensor with automated transmission of data by telephone line to the County offices. The costs of this type of automated sensor is relatively small, but routine maintenance, protection against vandalism, and interpretation of data by County staff are required.

E. Tidal Prism Enhancement

The Russian River Estuary could be maintained open to tidal action under most hydrologic and wave conditions if the tidal prism was increased. As a first approximation, the Johnson Criteria (Section 3.5) would require an increase in the tidal prism of approximately 50 percent. The excavation required to create this tidal prism would be costly and create significant adverse environmental impacts during implementation. Further, this would create hydrological and ecological conditions that are very different from existing and historic conditions in the estuary. For these reasons, an alternative to enhancing the tidal prism has not been considered further.

F. Supplemental Inflows

The 1992-93 monitoring data demonstrated that the entrance of the estuary did not close, if the inflow exceeded 700 ft^3/s. The required inflow to maintain the estuary open will depend on the prevailing wave conditions, but if water was available to increase the minimum baseflows at certain times of the year, the periods of open conditions could be prolonged. If this is selected as a management strategy, visual or automated monitoring should be continued to determine the minimum inflows to maintain an open inlet channel.

XV. PREFERRED ALTERNATIVE

The results of the biological study indicate that the current management plan does facilitate a viable estuarine ecosystem. The ecosystem appears to be adapted to the shifts in salinity and water temperature. During the monitoring period, no serious effects to the biota were observed as a result of water quality problems.

These conclusions (Nielsen, 1993) are based on existing hydrological conditions of the estuary and the limited 12 month period of detailed monitoring. It should be noted that this period coincided with the end of an extended drought period and may not be representative of *normal* conditions in the estuary. However, the results of the monitoring study have shown in which ways management of the estuary can be refined.

<u>Elements Required for Implementation of Management Plan</u>

- *Breaching.* The barrier beach will continue to be breached by bulldozer. The modified criteria for breaching are described below (p. 179 and 180).

- *Tide Staff.* A tide staff should be installed next to the County Gage at Jenner, relative to NGVD. In the past, water surface elevations have been read from this gage and it is useful to maintain the original gage. The new gage should be clearly distinguishable from the old gage, for example it should be a different color and should be clearly marked in 10ths of a foot.

- *Automated Tide Recorder.* An automated tide recorder should be installed at the Jenner Gage. The water levels will be recorded on a personal computer (PC) located in the Visitors Center. The tide recorder and PC will be linked by telephone to the Department of Roads or other entity designated by the County. Current and recent water surface elevations in the estuary will be able to be displayed remotely in the County Offices. The simple mass balance model developed in this study can be used in projecting the rate of water level rise. This will reduce the number of trips required by County personnel when determining the most appropriate time to breach the barrier beach and will allow adequate preparation for scheduling breaching of the barrier.

  Calls from concerned local residents will still provide a safeguard in the event of tide recorder malfunction.

- *Use of Recorder as an Interpretative Tool.* As an option, the PC used to transmit data to the County could be developed as an interpretative exhibit. A brief animation describing the physical and biological characteristics of the estuary could be developed. This educational display might include: a graph of the recent water surface elevations of the past 24 hours, past week, and past month; scanned aerial photographs of the estuary; scanned historical photographs; presentation of the biological monitoring; description of the physical processes in the Russian River Estuary; and narrative text.

- *Monitoring.* Biological and hydrological monitoring will be undertaken to confirm the viability of the management plan and to facilitate future adaptations and refinements to the plan for the benefit of the ecosystem.

Critical Elevations

The maximum elevation was selected based on the following criteria:

- discharge of anoxic water from Willow Creek Marsh into the estuary;
- flooding of property;
- high flushing velocities caused by high water elevations in the estuary prior to breaching. High velocity flows associated with breaching remove aquatic invertebrates, particularly juvenile fish unable to cope with these currents;
- danger posed by the high velocity flows during and immediately following breaching to County personnel and recreational users of the beach.

Residents call the County when the County Gage reaches 7.0 feet (6.8 feet NGVD) and the County staff will normally breach within a few days This results in a current practice of breaching between 7.0 and 10.0 feet NGVD. At elevations exceeding 8.5 feet, the withdrawal of anoxic water from Willow Creek Marshes is observed. Therefore, to prevent this withdrawal from occurring and to limit the removal of aquatic invertebrates, it is recommended that the preferred maximum elevation in the management plan be set at 7.0 feet NGVD.

There is no preferred minimum elevation for breaching, although the development of an inlet channel at elevations less than 4.5 feet NGVD is limited and would require more frequent bulldozer activity.

The recommended range of water levels in the estuary during closure is therefore 4.5 - 7.0 feet NGVD.

In the event of intensive wave action on the beach, making breaching hazardous, the water level in the estuary may be allowed to reach 8.5 feet NGVD.

Timing of Breaching

Biological monitoring is recommended to provide further insight regarding the precise timing of breaching and to determine during a particular year when breaches should be undertaken to facilitate fish passage. The most significant time for biological considerations is spring and fall when fish and aquatic invertebrate passage is required. Monitoring during these broad time spans would aid in evaluating their extent.

The timing of some breaches where possible should be coordinated with the release of hatchery fish. The precise time of travel from Warm Springs hatchery to the estuary should be determined by the California Department of Fish and Game (refer to Monitoring Program below).

Monitoring Program

The monitoring program should be continued for 3-5 years following the implementation of the management plan to corroborate the recommendations of this twelve month study.

Hydrologic Monitoring

- The recommended automated tide recorder at the Visitor Center will allow continuous monitoring of the water surface elevations.

- If the model is to be used to project the rate of rise in the lagoon, additional calibration measurements of the river discharge just above the limit of tidal flows should be taken to establish a correlation between inflows to the estuary and the flows recorded at the gaging station at Guerneville.

- Periodic monitoring of water quality parameters should be undertaken to ensure that good water quality within the estuary is maintained.

Biologic Monitoring

- Seasonal (spring and fall) otter trawl sampling in the lower estuary to determine the distribution and abundance of fish and macro invertebrates.

- Seasonal (late spring and early summer) deep water beach seine samples, taken in the lower estuary to test for entrapment of salmonid smolts during closed estuary conditions.

- Behavioral observations (3) of pinniped activity during breaches under restricted public access to test the hypothesis that human activity deters pinniped landings on the beach post breaching.

- Plankton tows at the mouth of Willow Creek three hours post breaching (2/year) to monitor outflow levels of mysid shrimp and juvenile fishes.

<u>Other Considerations</u>

- Supplemental freshwater releases will prolong the opening of the estuary. Supplemental releases timed to coincide with hatchery releases or returning fish are worthy of consideration if additional water is determined to be available when drawing down the upstream reservoirs for flood control purposes.

- Assisted closures were not considered to be necessary in this plan.

- Pinnipeds did not appear to be affected adversely by the breaching process or by the presence of a bulldozer. However, people present on the beach while observing the breaching process prevented the pinnipeds from returning to the beach, which may affect their restive requirements.

- The beach should be closed a distance of at least 750 feet on either side of the breach for public safety reasons. This public access restriction may allow pinnipeds to return to the beach during the breaching process.

- Future and current studies on the flow releases from reservoirs and treated effluent discharges into the Russian River should consider the effect of breaching frequency, tidal exchange, and water quality within the estuary.

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