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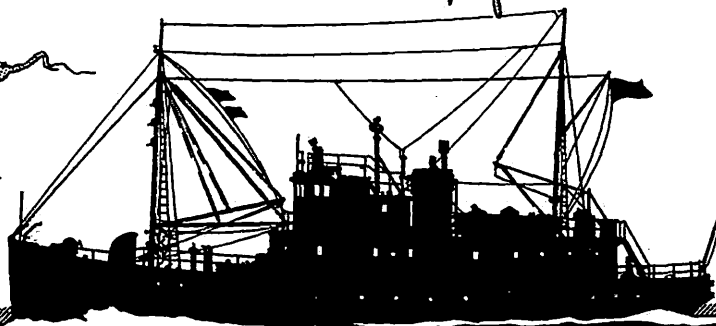
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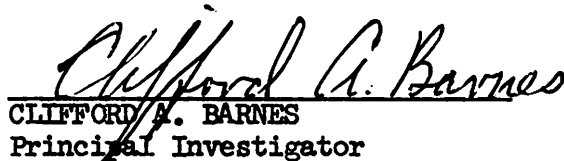
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THE UNION OF THE COLUMBIA RIVER AND THE PACIFIC OCEAN -- GENERAL FEATURES, by Alyn C. Duxbury. Pp. 914-922 in *Ocean Science and Ocean Engineering* 1965, vol. 2. Marine Technology Society, Washington D. C. 1965. (AEC: RLO -1725-5)

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TECHNICAL REPORT NO. 149
THE UNION OF THE COLUMBIA RIVER AND THE

PACIFIC OCEAN -- GENERAL FEATURES

Alyn C. Duxbury

ABSTRACT

The Columbia River is seasonal in its discharge, having both a winter and a summer peak. The winter peak is generally erratic and a function of the coastal precipitation, while the summer peak, produced by snow melt in the interior, is uniform. The effluent enters the Northeastern Pacific through a belt of near uniform surface coastal water (<32‰). In this region the Columbia is the largest single contributor of freshwater. During the summer peak discharge period the freshwater added by this one river represents approximately 95% of the area's coastal drainage. However, its influence on the dilution of the oceanic environment is reduced during the winter when other coastal rivers are also at peak flow.

In addition to the seasonal variation in river flow, there is a seasonal trend in the transport of the effluent once it has united with the sea. During the winter the prevailing winds hold the effluent close to the shore on the northern side of the river, producing a narrow band of relatively fresh water that is composed of effluent from several coastal sources. The summer brings persistent northerly winds which transport the river's discharge seaward to the southwest and create a zone of upwelling immediately adjacent to the coast on either side of the river. Since at this time of the year the freshwater in the oceanic environment adjacent to the river is nearly all Columbia River water, any modification of the distributions can be related to the Columbia River and the local transport processes.

INTRODUCTION

The Columbia River enters the Northeastern Pacific Ocean at the boundary of Washington and Oregon. This coastal area is one where many rivers and streams, fed by the coastal land precipitation, dilute the surface waters of the ocean to form a low salinity belt, <32‰, near the shore. It is in this environment that the Columbia discharges with sufficient volume to qualify as the largest single contributor of freshwater in the area. Yet during some periods of the year, primarily the wintertime, the effluent from the Columbia is not distinguishable from that of the other rivers once it becomes part of the marine environment.

FEATURES OF THE RIVER

The Columbia River is a difficult and complex river system to understand, let alone decipher its impact on the oceanic area it feeds. The river has been monitored for a considerable number of years to determine its average annual discharge of 7,300 m³ per sec. which represents approximately 14% of the total annual discharge from continental United States. Its drainage basin, Fig. 1, covers 670,000 km² with 85% of this area within the United States. The seasonal variations in the water supply from the different regions of this basin interact with each other to produce the irregular discharge pattern of the river. In general, the

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annual mean discharge curve, Fig. 2, has two peaks of flow. The summer peak is fed by snow melt from the inland areas, while the winter peak is supplied by the heavy winter precipitation in the fraction of the drainage basin west of the Cascade Range. The magnitude of the supply of this latter small area is at times surprising, as witnessed by the Willamette River discharging more water than the Columbia upriver of The Dalles this last December. Although the mean annual discharge curve shown here appears to have a regular variation throughout its cycle, a typical curve for a single year is erratic, Fig. 2. The week-to-week changes in discharge during the winter can exceed the mean value by 100% and occur essentially at the whim of the Pacific Northwest weather. It should be understood that the extreme sharp peaks in the runoff curve that often appear in the winter have a limited effect on the time average discharge as they act for short periods of time and represent small volumes. The broader peaks acting over considerable time periods, however, are quite significant and may displace the yearly runoff curve from the mean.

SEASONAL VARIATION OF THE EFFLUENT DISTRIBUTION

The interaction between the movement of the coastal water and the prevailing surface winds through the coupling agent, wind stress, has been found to be quite important in the distribution of the Columbia River effluent at sea. An analysis of surface winds based on the 12 hourly U. S. Weather Bureau pressure charts for the years 1961-1963 shows that a seasonal migration of the mean wind direction occurs off the coasts of Washington and Oregon, Fig. 3. This change in orientation of the surface winds causes a change in the orientation of the wind-driven transport of the surface waters of the same area. The transport occurs approximately 90° to the right of the wind and carries the surface mixture of seawater and Columbia River effluent toward the shore and northward during the winter period. This mixture is then blended with waters having their sources in the harbors and streams north of the Columbia to form a belt of low salinity water that is not readily definable as a product of any one particular source, Fig. 4. The salinity has been used to distinguish the river effluent from the seawater exclusively, since it is readily measurable and the temperature contrast is usually very slight. Although the influence of the Columbia cannot be clearly defined within this winter distribution, it remains a major contributor of fresh water and has its waters held close along the Washington beaches, a situation not generally occurring during the rest of the year.

The summer's northerly winds cause the surface water to be transported to the southwest, offshore, Fig. 5. This transport carries the effluent away from the coast and creates a zone of surface divergence and upwelling immediately along the coast on either side of the river. This band of upwelled water acts as a buffer and prevents the River's effluent from maintaining prolonged contact with the shore areas near the mouth. Since during this summer period the Columbia River discharge represents approximately 95% of the fresh-water supplied to the sea locally, the influence of the fresh-water on the distributions in the area can be directly related to the River's supply.

SHORT TERM VARIATIONS IN EFFLUENT DISTRIBUTION

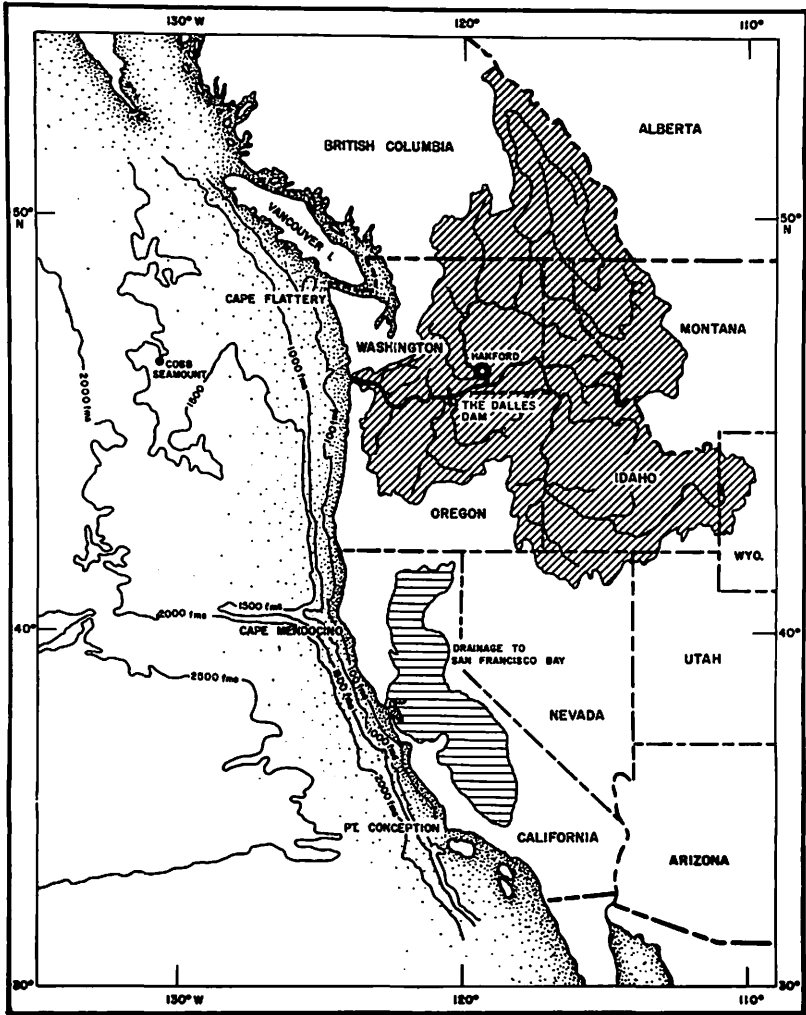
The seasonal trends in the distribution of effluent of the Columbia River are easy to obtain from the time averaged data. However, wind driven changes in the distributions can occur within extremely short time periods and nearly rival the magnitude of the seasonal shifts in distributions. In the immediate area of the mouth of the river, rapidly changing distributions governed by the periodic tidal discharge of the river, the hydraulic head and the offshore tidal currents as well as wind influence are expected. Further offshore the effect of these factors is considerably reduced and the rate of change of the distributions with time slowed. Wind shifts and their effects on the distributional patterns have been observed to occur at rates which nearly eliminate the possibility of gathering data that may be considered synoptic. Data collected by Oregon State University on the R. V. ACONA and the University of Washington on the R. V. BROWN BEAR during successive cruises show dramatically the redistribution of surface salinities in response to strong northerly winds, Fig. 6. As depicted here the bounding $32^{\circ}/\text{oo}$ isochaline migrated approximately 90 nm in less than 10 days, a time period well within the limits over which oceanic data is often considered synoptic.

SYNOPSIS OF PAST AND PRESENT STUDIES

The sphere of influence of the Columbia River water at sea has been intensively studied by the Department of Oceanography, University of Washington, since 1961. The initial phase of the investigation required large area surveys to develop a descriptive history of the environment. By 1963, sufficient information had been obtained to allow a change in emphasis toward a series of detailed studies in time and space. Despite the total effort expended in investigations of the effluent area, it is estimated that the present analyses are based on one sample of water for every cubic mile of seawater affected by the River; rather sparse information for such a dynamic area. Despite this seemingly low density of samples, considerable inroads into the understanding of the basic behavior of the system as a whole have been made and a sound working base has been established upon which more detailed and sophisticated studies can be built.

ACKNOWLEDGEMENTS

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Columbia River Drainage Basin and Adjacent Sea

Figure 1

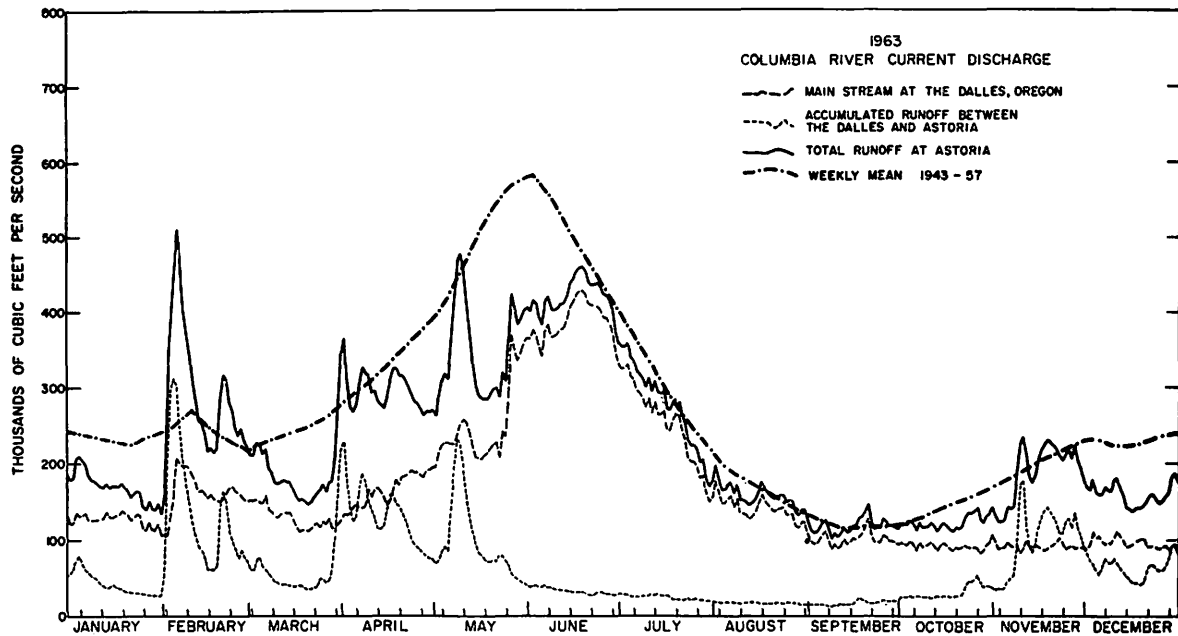


Figure 2

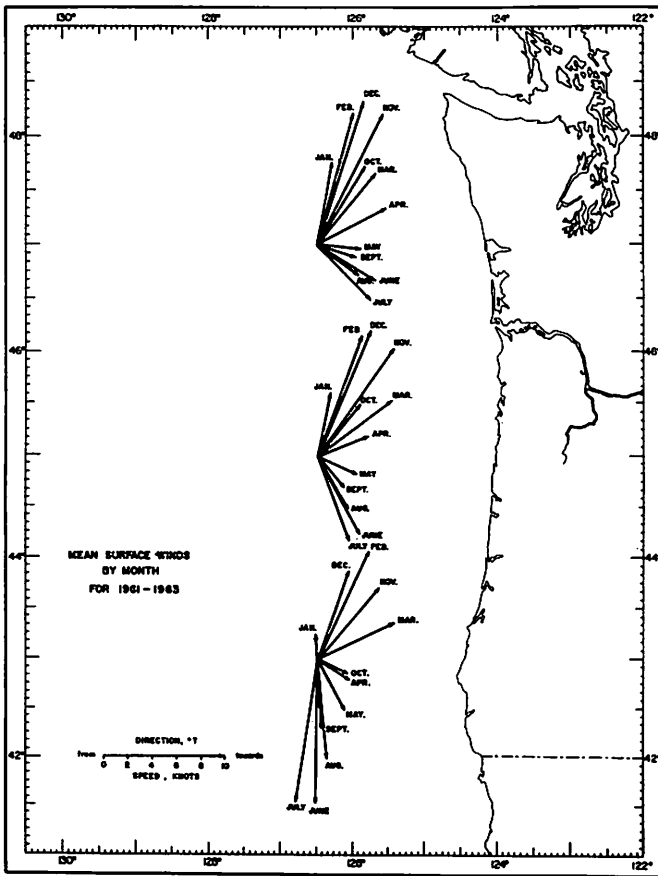


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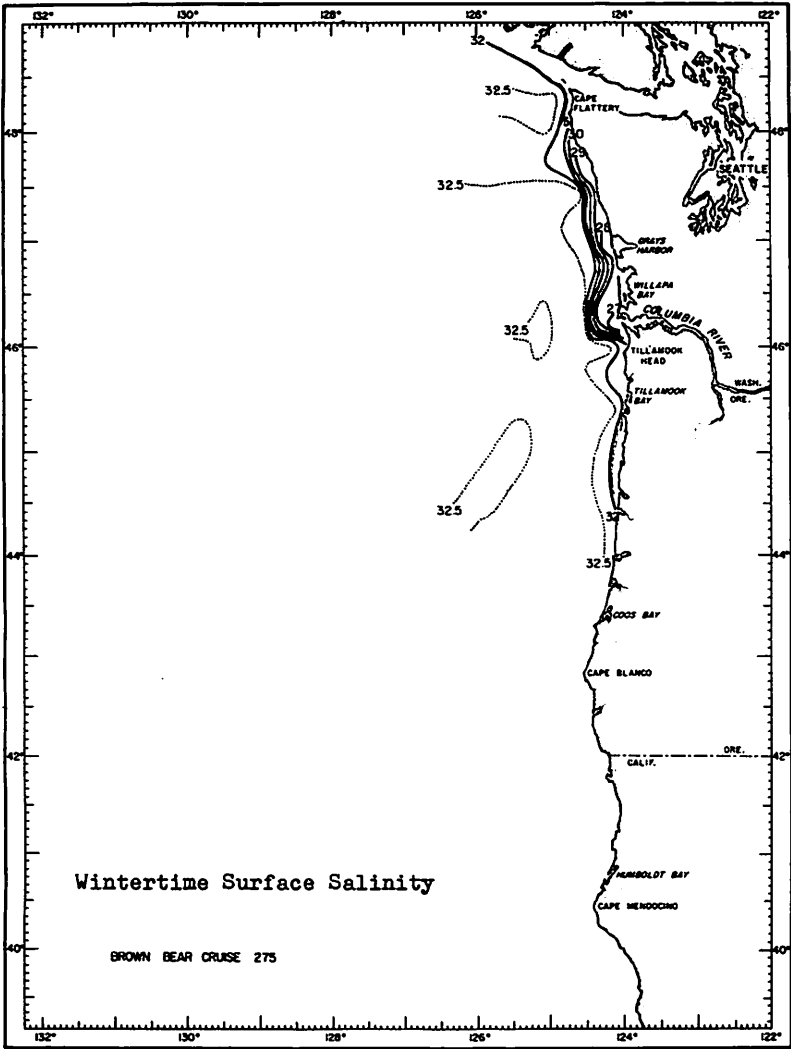


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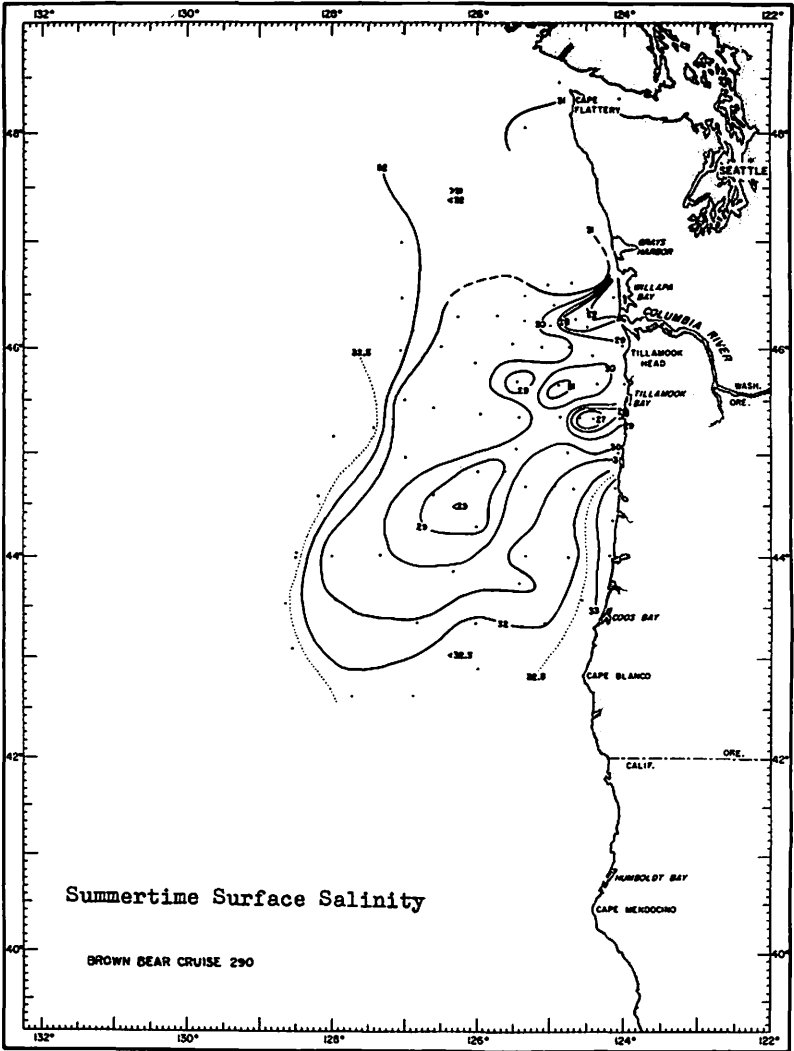


Figure 5

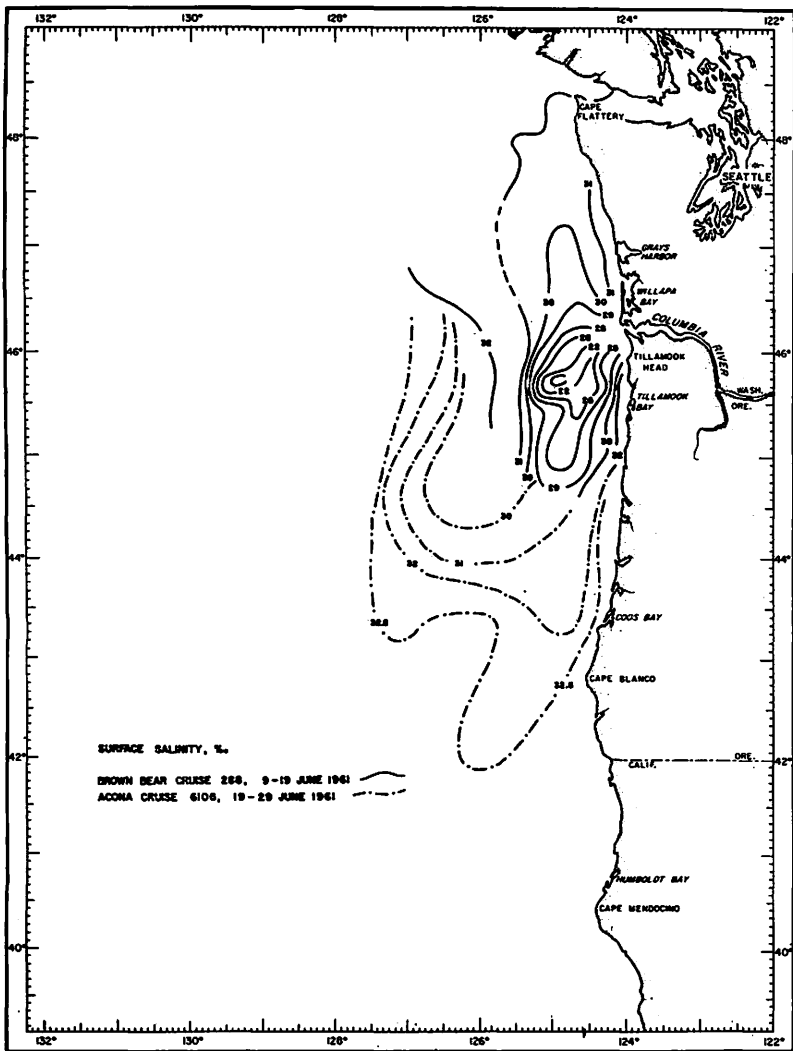


Figure 6

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